CALIFORNIA
Water Boards

EDMUND G. BROWN JR.
GOVERNOR

MATTHEW RODRIQUEZ
SECRETARY FOR
ENVIRONMENTAL PROTECTION

State Water Resources Control Board

RECEIVED
August 5, 2016
Commission on
State Mandates

August 5, 2016

VIA DROP BOX

Heather Halsey
Executive Director
Commission on State Mandates
980 Ninth Street, Suite 300
Sacramento, CA 95814

FILING OF ADMINSTRATIVE RECORD

Santa Ana Regional Water Permit, 09-TC-03
California Regional Water Quality Control Board, Santa Ana Region
Order No. R8-2009-0030
County of Orange, Orange County Flood Control District, Cities of Anaheim, Brea, Buena Park, Costa Mesa, Cypress, Fountain Valley, Fullerton, Huntington Beach, Irvine, Lake Forest, Newport Beach, Placentia, Seal Beach and Villa Park, Claimants

Dear Ms. Halsey:

By letter dated June 8, 2016, the Commission on State Mandates (Commission) requested the following additional information from the Santa Ana Regional Water Quality Control Board (Santa Ana Regional Board) and the State Water Resources Control Board (State Water Board):

(a) copy of the full administrative record of the California [Regional] Water Quality Control Board, Santa Ana Region permit order no. R8-2009-0030, National Pollutant Discharge Elimination System (NPDES) no. CAS618030; and

(b) copy of the full administrative record of the California State Water Resources Control Board permit order no. R8-2009-0030 (NPDES no. CAS618030).

By letter dated June 27, 2016, the Commission extended the compliance deadline to August 8, 2016.

The Santa Ana Regional Board has prepared the full administrative record for Order No. R8-2009-0030 (NPDES No. CAS618030) (Order) and it is attached to this letter. Regarding the State Water Board's administrative record for this matter, the State Water Board received petitions challenging the Santa Ana Regional Board's adoption of the Order from the County of Orange and the Orange County Flood Control District, the City of Lake Forest, the City of Brea, the City of Buena Park, the City of Seal Beach, the City of Huntington Beach, and the Natural

Resources Defense Council and Orange County Coastkeeper. The State Water Board has not exercised its jurisdiction over these petitions and no administrative record exists regarding any discretionary action taken by the State Water Board in this matter. I can provide copies of these petitions upon request.

Please do not hesitate to contact me with any questions at (916) 341-5182 or David.Rice@waterboards.ca.gov.

Very Truly Yours,

David Rice

David Rice
Senior Staff Counsel

cc: Mailing List **[via Commission Drop Box]**

[via email w/o attachment]
Kurt Berchtold, Executive Officer
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Administrative Record
Orange County MS4 Permit Order No. 2009-0030
Santa Ana Region

Administrative Record- Subjects

Item	Date	Subject	Begin Page No.	End Page No.
1	12/1/1983	US EPA Results of the Nationwide Urban Runoff Program, Vol. 1, Final Report. NTIS PB84- 185552	1	198
2	7/13/1990	Santa Ana Water Board Order 90-71: Waste Discharge Requirements for the County of Orange, the Orange County Flood Control District and the Incorporated Cities of Orange County Within the Santa Ana Region Areawide Urban Stormwater Runoff Orange County	199	242
3	6/1/1992	US EPA Environmental Impacts of Storm Water Discharges: A National Profile, EPA 841-R-92-001	243	287
4	3/8/1996	Santa Ana Water Board Order 96-31: Waste Discharge Requirements for the County of Orange, the Orange County Flood Control District and the Incorporated Cities of Orange County Within the Santa Ana Region Areawide Urban Stormwater Runoff Orange County	288	324
5	5/7/1996	Santa Monica Bay Resoration Project: An Epidemiological Study of Possible Adverse Health Effects of Swimming in Santa Monica Bay - Final Report	325	507
6	4/9/1999	Santa Ana Water Board Resolution 99-10: A Resolution Amending the Water Quality Control Plan for the Santa Ana R iver Basin to Establish a Total Maximum Daily Load for Fecal Coliform Bacteria in Newport Bay	508	525
7	11/1/1999	SCCWRP: Study of the Impact of Stormwater Discharge on Santa Monica Bay - Prepared for Los Angeles County Department of Public Works	526	545
8	2/28/2000	U.S. EPA Letter from Alexis Strauss to Walter Pettit	546	550
9	9/1/2000	OCPFRD: Management Guidelines for Use of Fertilizers and Pesticides	551	574
10	1/1/2001	Pew Oceans Commission: Marine Pollution in the United States	575	629
11	3/13/2001	SCAG County Population Forecasts for 2005	630	631
12	1/18/2002	Santa Ana Water Board Order R8-2002-0010: Waste Discharge Requirements for the County of Orange, the Orange County Flood Control District and the Incorporated Cities of Orange County Within the Santa Ana Region Areawide Urban Stormwater Runoff Orange County	632	712
13	2/1/2002	Model Urban Runoff Program - Prepared by the City of Monterey, California Coastal Commission, et. al.	713	1199
14	6/14/2002	Total Maximum Daily Loads For Toxic Pollutants San Diego Creek and Newport Bay, California, US EPA – Region 9, established June 14, 2002	1200	1288
15	6/14/2002	Total Maximum Daily Loads For Toxic Pollutants San Diego Creek and Newport Bay, California, US EPA – Region 9, established June 14, 2002 - Technical Support Documents (Relevent Maps)	1289	1299
16	6/14/2002	Total Maximum Daily Loads For Toxic Pollutants San Diego Creek and Newport Bay, California, US EPA – Region 9, established June 14, 2002 - Technical Support Documents (Freshwater Flow and Seasonal Variations)	1300	1305
17	6/14/2002	Total Maximum Daily Loads For Toxic Pollutants San Diego Creek and Newport Bay, California, US EPA – Region 9, established June 14, 2002 - Technical Support Documents (Organophosphate Pesticides)	1307	1327
18	6/14/2002	Total Maximum Daily Loads For Toxic Pollutants San Diego Creek and Newport Bay, California, US EPA – Region 9, established June 14, 2002 - Technical Support Documents (Selenium)	1328	1352
19	6/14/2002	Total Maximum Daily Loads For Toxic Pollutants San Diego Creek and Newport Bay, California, US EPA – Region 9, established June 14, 2002 - Technical Support Documents (Metals)	1353	1384
20	6/14/2002	Total Maximum Daily Loads For Toxic Pollutants San Diego Creek and Newport Bay, California, US EPA – Region 9, established June 14, 2002 - Technical Support Documents (Organochlorine Compounds)	1385	1404
21	6/14/2002	Total Maximum Daily Loads For Toxic Pollutants San Diego Creek and Newport Bay, California, US EPA – Region 9, established June 14, 2002 - Technical Support Documents (Chromium and Mercury)	1405	1415
22	6/14/2002	Total Maximum Daily Loads For Toxic Pollutants San Diego Creek and Newport Bay, California, US EPA – Region 9, established June 14, 2002 - Technical Support Documents (Decision Document)	1416	1452
23	6/14/2002	Total Maximum Daily Loads For Toxic Pollutants San Diego Creek and Newport Bay, California, US EPA – Region 9, established June 14, 2002 - Technical Support Documents (Responsiveness Summary)	1453	1502
24	11/22/2002	US EPA Memorandum: Establishing TMDL WLAs for Storm Water Sources and NPDES Permit Requirements based on Those WLAs	1503	1508
25	2004	Managing Mosquitoes in Stormwater Treatment Devices, Marco E. Metzger, University of California Davis, Division of Agriculture and Natural Resources, Publication 8125	1509	1520
26	1/2004	Evaluation of the Landscape Performance Certification Program - Prepared for Municipal Water District of Orange County, Metropolitan Water District of Southern California, and US Bureau of Reclamation, Southern California Area Office	1521	1610

27	7/2004	Residential Runoff Reduction Study, Municipal Water District of Orange County, Irvine Ranch Water District and Metropolitan Water District of Southern California	1611	1866
28	11/2005	National Management Measures to Control Nonpoint Source Pollution from Urban Areas. US EPA Publication No. EPA 841-B-05-004	1867	2384
29	2006	County of Orange Unified Annual Progress Report 2005-2006 Attachment C-11	2385	2390
30	2006	County of Orange Unified Annual Progress Report 2005-2006 C-11-31	2391	2662
31	7/21/2006	Excerpts from Orange County Drainage Area Management Plan (DAMP)	2663	2669
32	7/21/2006	Orange County Report of Waste Discharge (ROWD)	2670	2851
33	2/13/2008	ConTech Stormwater Solutions Comment Letter Re: First Draft of Tentative Order No. R8-2008-0030	2852	2853
34	4/10/2008	US EPA Letters from Alexis Strauss to Tam Doduc and Dorothy Rice	2854	2856
35	6/30/2008	Pesticide Runoff Management Plan - Newport Bay Watershed, Orange County, CA - Prepared by D. Haver and J. Kabashima (UCCE Cooperative Extension - OC)	2857	2872
36	8/7/2008	Washington Pollution Control Hearing Board Order	2873	2947
37	9/4/2008	US EPA Presentation: Hydromodification - A Regulatory Perspective by Dr. Cindy Lin	2948	2964
38	10/15/2008	National Research Council: National Academy of Sciences - Urban Stormwater Management in the United States Report	2965	3493
39	11/5/2008	Santa Cruz Sentinial Article "Measure E Looks Like a Win"	3494	3495
40	11/10/2008	Transmittal Letter of First Draft: Renewal of Waste Discharge Requirements for the County of Orange, Orange County Flood Control District and the Incorporated Cities of Orange County, Tentative Order No. R8-2008-0030, NPDES No. CAS618030, Areawide Urban Storm Water Runoff	3496	3496
41	11/10/2008	First Draft of Tentative Order R8-2008-0030	3497	3585
42	11/10/2008	Pronto Wash Comment Letter Re: First Draft of Tentative Order R8-2008-0030	3586	3586
43	11/21/2008	Agenda Announcement - Regional Board Meeting at City of Loma Linda, Item 11	3587	3590
44	11/21/2008	Addendum to Agenda Announcement -Regional Board Meeting at City of Loma Linda, Item 11	3591	3592
45	11/21/2008	Agenda Item 11: Fact Sheet for Tentative Order R8-2008-0030	3593	3618
46	11/21/2008	Agenda Item 11: Public Workshop Presentative for Tentative Order R8-2008-0030 by Mark Smythe	3619	3639
47	11/21/2008	Minutes from 11/21/08 Regional Board Meeting, Item 11	3640	3644
48	12/22/2008	Transmittal Letter of First Draft Comments Extension Notice Re: Tentative Order R8-2008-0030	3645	3645
49	2009	Critique of Certain Elements of Low Impact Development Metrics in Stormwater Permitting by Dr. Richard Horner	3646	3654
50	1/20/2009	City of Fullerton Comment Letter Re: First Draft of Tentative Order R8-2008-0030	3655	3658
51	1/22/2009	Transmittal Letter of First Draft Comments Second Extention Notice Re: Tentative Order R8-2008-0030	3659	3659
52	1/26/2009	City of Westminster Comment Letter Re: First Draft of Tentative Order R8-2008-0030	3660	3661
53	1/30/2009	City of Brea Comment Letter Re: First Draft Tentative Order R8-2008-0030	3662	3664
54	1/30/2009	City of Costa Mesa Comment Letter Re: First Draft Tentative Order R8-2008-0030	3665	3668
55	1/30/2009	City of Laguna Hills Comment Letter Re: First Draft Tentative Order R8-2008-0030	3669	3671
56	2/6/2009	City of Cypress Comment Letter Re: First Draft Tentative Order R8-2008-0030	3672	3684
57	2/10/2009	City of Orange Comment Letter Re: First Draft Tentative Order R8-2008-0030	3685	3705
58	2/11/2009	City of Yorba Linda Comment Letter Re: First Draft Tentative Order R8-2008-0030	3706	3708
59	2/12/2009	City of Lake Forest Comment Letter Re: First Draft Tentative Order R8-2008-0030	3709	3724
60	2/12/2009	San Bernardino County Stormwater Program Comment Letter Re: First Draft Tentative Order R8-2008-0030	3725	3730
61	2/13/2009	City of Anaheim Comment Letter Re: First Draft Tentative Order R8-2008-0030	3731	3738
62	2/13/2009	City of Huntington Beach Comment Letter Re: First Draft Tentative Order R8-2008-0030	3739	3740
63	2/13/2009	City of Irvine Comment Letter Re: First Draft Tentative Order R8-2008-0030	3741	3780
64	2/13/2009	NAIOP SoCal Chapter Comment Letter Re: First Draft Tentative Order R8-2008-0030	3781	3784
65	2/13/2009	NRDC Comment Letter Re: First Draft Tentative Order R8-2008-0030	3785	3801
66	2/13/2009	NRDC Comment Letter - Supporting Documents (Benefits of LID_00 Table of Contents)	3802	3802
67	2/13/2009	NRDC Comment Letter - Supporting Documents (Benefits of LID_01 Rain Gardens- Anacostia)	3803	3804
68	2/13/2009	NRDC Comment Letter - Supporting Documents (Benefits of LID_02 Hard Road Ahead- Blankenship)	3805	3807

69	2/13/2009	NRDC Comment Letter - Supporting Documents (Benefits of LID_03 Stormwater_1001_CWP [1])	3808	3817
70	2/13/2009	NRDC Comment Letter - Supporting Documents (Benefits of LID_04 Redevelopment Roundtable)	3818	3833
71	2/13/2009	NRDC Comment Letter - Supporting Documents (Benefits of LID_05 Model Post- Construction)	3834	3865
72	2/13/2009	NRDC Comment Letter - Supporting Documents (Benefits of LID_06 Cost Analysis Report)	3866	3963
73	2/13/2009	NRDC Comment Letter - Supporting Documents (Benefits of LID_07 lidtech)	3964	3982
74	2/13/2009	NRDC Comment Letter - Supporting Documents (Benefits of LID_08 lidsitedesign)	3983	3996
75	2/13/2009	NRDC Comment Letter - Supporting Documents (Benefits of LID_09 Jones_LID-1)	3997	4010
76	2/13/2009	NRDC Comment Letter - Supporting Documents (Benefits of LID_10 ahwanhee h2o_principles)	4011	4012
77	2/13/2009	NRDC Comment Letter - Supporting Documents (Benefits of LID_11 Urban Stormwater Management)	4013	4018
78	2/13/2009	NRDC Comment Letter - Supporting Documents (Benefits of LID_12 Wading in Waste)	4019	4026
79	2/13/2009	NRDC Comment Letter - Supporting Documents (Benefits of LID_13 Green from the Ground Up)	4027	4028
80	2/13/2009	NRDC Comment Letter - Supporting Documents (Benefits of LID_14 Stormwater Strategies)	4029	4029
81	2/13/2009	NRDC Comment Letter - Supporting Documents (Benefits of LID_15 rooftops to rivers)	4030	4083
82	2/13/2009	NRDC Comment Letter - Supporting Documents (Benefits of LID_16 LID-Factsheet)	4084	4087
83	2/13/2009	NRDC Comment Letter - Supporting Documents (Benefits of LID_17 LID_assistance)	4088	4090
84	2/13/2009	NRDC Comment Letter - Supporting Documents (Benefits of LID_18 lid_natural_approaches)	4091	4154
85	2/13/2009	NRDC Comment Letter - Supporting Documents (Benefits of LID_19 lid for bigbox retailers)	4155	4229
86	2/13/2009	NRDC Comment Letter - Supporting Documents (Benefits of LID_20 south_whidbey_record 102205)	4230	4232
87	2/13/2009	NRDC Comment Letter - Supporting Documents (Benefits of LID_21 Housing Density & Urban Land Use)	4233	4237
88	2/13/2009	NRDC Comment Letter - Supporting Documents (California-Specific Reports_00 Table of Contents-California-Specific)	4238	4238
89	2/13/2009	NRDC Comment Letter - Supporting Documents (California-Specific Reports_01 CA smart growth)	4239	4240
90	2/13/2009	NRDC Comment Letter - Supporting Documents (California-Specific Reports_02 LID-sustainable water mgmt)	4241	4241
91	2/13/2009	NRDC Comment Letter - Supporting Documents (California-Specific Reports_03 Infiltration of Urban Stormwater)	4242	4354
92	2/13/2009	NRDC Comment Letter - Supporting Documents (California-Specific Reports_04 alternative approaches_stormwater)	4355	4449
93	2/13/2009	NRDC Comment Letter - Supporting Documents (California-Specific Reports_05 Bldg Valuation Data)	4450	4451
94	2/13/2009	NRDC Comment Letter - Supporting Documents (California-Specific Reports_06 2007 rates & changes)	4452	4453
95	2/13/2009	NRDC Comment Letter - Supporting Documents (California-Specific Reports_07 water limited s ventura)	4454	4454
96	2/13/2009	NRDC Comment Letter - Supporting Documents (California-Specific Reports_08 water quest shifts course)	4455	4457
97	2/13/2009	NRDC Comment Letter - Supporting Documents (California-Specific Reports_09 Stormwater Treatment Options)	4458	4462
98	2/13/2009	NRDC Comment Letter - Supporting Documents (California-Specific Reports_10 Water Quality Regulatory Dynamics of)	4463	4471
99	2/13/2009	NRDC Comment Letter - Supporting Documents (California-Specific Reports_11 Role of Municipal Operators)	4472	4496
100	2/13/2009	NRDC Comment Letter - Supporting Documents (California-Specific Reports_12 water quality report-ventura)	4497	4502
101	2/13/2009	NRDC Comment Letter - Supporting Documents (Case Studies_01 Case Studies Part I)	4503	4651
102	2/13/2009	NRDC Comment Letter - Supporting Documents (Case Studies_ 02 Case Studies Part II)	4652	4860
103	2/13/2009	NRDC Comment Letter - Supporting Documents (Maryland Stormwater Design Manual_01 appendixb2)	4861	4865
104	2/13/2009	NRDC Comment Letter - Supporting Documents (Maryland Stormwater Design Manual_02 appendixb3)	4866	4877
105	2/13/2009	NRDC Comment Letter - Supporting Documents (Maryland Stormwater Design Manual_03 appendixc1)	4878	4898
106	2/13/2009	NRDC Comment Letter - Supporting Documents (Maryland Stormwater Design Manual_04 appendixc2)	4899	4929
107	2/13/2009	NRDC Comment Letter - Supporting Documents (Maryland Stormwater Design Manual_05 appendixd1)	4930	4936
108	2/13/2009	NRDC Comment Letter - Supporting Documents (Maryland Stormwater Design Manual_06 Appnd_A)	4937	4988
109	2/13/2009	NRDC Comment Letter - Supporting Documents (Maryland Stormwater Design Manual_07 Appnd_B1)	4989	5016
110	2/13/2009	NRDC Comment Letter - Supporting Documents (Maryland Stormwater Design Manual_ 08 Appnd_B1_1)	5017	5020
111	2/13/2009	NRDC Comment Letter - Supporting Documents (Maryland Stormwater Design Manual_09 Appnd_B1_2)	5021	5024
112	2/13/2009	NRDC Comment Letter - Supporting Documents (Maryland Stormwater Design Manual_10 Appnd_D2)	5025	5030

113	2/13/2009	NRDC Comment Letter - Supporting Documents (Maryland Stormwater Design Manual_11 Appnd_D3)	5031	5034
114	2/13/2009	NRDC Comment Letter - Supporting Documents (Maryland Stormwater Design Manual_ 12 Appnd_D4)	5035	5048
115	2/13/2009	NRDC Comment Letter - Supporting Documents (Maryland Stormwater Design Manual_ 13 Appnd_D5_	5049	5052
116	2/13/2009	NRDC Comment Letter - Supporting Documents (Maryland Stormwater Design Manual_ 14 Appnd_D6)	5053	5080
117	2/13/2009	NRDC Comment Letter - Supporting Documents (Maryland Stormwater Design Manual_ 15 Appnd_D7)	5081	5098
118	2/13/2009	NRDC Comment Letter - Supporting Documents (Maryland Stormwater Design Manual_ 16 Appnd_D8)	5099	5110
119	2/13/2009	NRDC Comment Letter - Supporting Documents (Maryland Stormwater Design Manual_ 17 Appnd_D9)	5111	5124
120	2/13/2009	NRDC Comment Letter - Supporting Documents (Maryland Stormwater Design Manual_ 18 Appnd_D10)	5125	5130
121	2/13/2009	NRDC Comment Letter - Supporting Documents (Maryland Stormwater Design Manual_ 19 Appnd_D11)	5131	5134
122	2/13/2009	NRDC Comment Letter - Supporting Documents (Maryland Stormwater Design Manual_ 20 Appnd_D12)	5135	5136
123	2/13/2009	NRDC Comment Letter - Supporting Documents (Maryland Stormwater Design Manual_ 21 Appnd_D13)	5137	5146
124	2/13/2009	NRDC Comment Letter - Supporting Documents (Maryland Stormwater Design Manual_ 22 Appnd_D14)	5147	5156
125	2/13/2009	NRDC Comment Letter - Supporting Documents (Maryland Stormwater Design Manual_ 23 Appnd_D15)	5157	5162
126	2/13/2009	NRDC Comment Letter - Supporting Documents (Maryland Stormwater Design Manual_ 24 Chapter1[1])	5163	5185
127	2/13/2009	NRDC Comment Letter - Supporting Documents (Maryland Stormwater Design Manual_ 25 chapter2)	5186	5228
128	2/13/2009	NRDC Comment Letter - Supporting Documents (Maryland Stormwater Design Manual_ 26 chapter 3)	5229	5276
129	2/13/2009	NRDC Comment Letter - Supporting Documents (Maryland Stormwater Design Manual_ 27 chapter 4)	5277	5294
130	2/13/2009	NRDC Comment Letter - Supporting Documents (Maryland Stormwater Design Manual_ 28 chapter5)	5295	5315
131	2/13/2009	NRDC Comment Letter - Supporting Documents (Maryland Stormwater Design Manual_ 29 errata)	5316	5393
132	2/13/2009	NRDC Comment Letter - Supporting Documents (Maryland Stormwater Design Manual_ 30 Glossary)	5394	5407
133	2/13/2009	NRDC Comment Letter - Supporting Documents (Maryland Stormwater Design Manual_ 31 Introduction[1])	5408	5419
134	2/13/2009	NRDC Comment Letter - Supporting Documents (Maryland Stormwater Design Manual_ 32 mancover[1])	5420	5420
135	2/13/2009	NRDC Comment Letter - Supporting Documents (Maryland Stormwater Design Manual_ 33 MD SW Dsgn Manual, V I & II)	5421	5422
136	2/13/2009	NRDC Comment Letter - Supporting Documents (Maryland Stormwater Design Manual_ 34 references)	5423	5426
137	2/13/2009	NRDC Comment Letter - Supporting Documents (Maryland Stormwater Design Manual_ 35 vol1 cover[1])	5427	5427
138	2/13/2009	NRDC Comment Letter - Supporting Documents (Maryland Stormwater Design Manual_ 36 vol2cover)	5428	5428
139	2/13/2009	NRDC Comment Letter - Supporting Documents (Government Sources_00 Table of Contents-Government Source)	5429	5429
140	2/13/2009	NRDC Comment Letter - Supporting Documents (Government Sources_01 buzzardsbay-Action Plan 2)	5430	5453
141	2/13/2009	NRDC Comment Letter - Supporting Documents (Government Sources_02 buzzardsbay-Action Plan3)	5454	5459
142	2/13/2009	NRDC Comment Letter - Supporting Documents (Government Sources_03 building livable, sustainable community)	5460	5486
143	2/13/2009	NRDC Comment Letter - Supporting Documents (Government Sources_04 Green Building &Landscaping Practices)	5487	5489
144	2/13/2009	NRDC Comment Letter - Supporting Documents (Government Sources_ 05 UFC-LID)	5490	5594
145	2/13/2009	NRDC Comment Letter - Supporting Documents (Government Sources_06 potential groundwater contamination)	5595	5602
146	2/13/2009	NRDC Comment Letter - Supporting Documents (Government Sources_07 preliminary data summary)	5603	5606
147	2/13/2009	NRDC Comment Letter - Supporting Documents (Government Sources_08 field eval of permeable pavements)	5607	5608
148	2/13/2009	NRDC Comment Letter - Supporting Documents (Government Sources_09 LID-literature review)	5609	5649
149	2/13/2009	NRDC Comment Letter - Supporting Documents (Government Sources_10 protect_water_higher_density[1])	5650	5695
150	2/13/2009	NRDC Comment Letter - Supporting Documents (Government Sources_11 LID pays off)	5696	5700
151	2/13/2009	NRDC Comment Letter - Supporting Documents (Government Sources_12 Many paths lead to adoption of LID)	5701	5732
152	2/13/2009	NRDC Comment Letter - Supporting Documents (Government Sources_13 sg_stormwater_BMP[1])	5733	5844
153	2/13/2009	NRDC Comment Letter - Supporting Documents (Government Sources_14 LID & Other Green Design Strats)	5845	5848
154	2/13/2009	NRDC Comment Letter - Supporting Documents (Government Sources_15 SWP Webcast Series)	5849	5849
155	2/13/2009	NRDC Comment Letter - Supporting Documents (Government Sources_16 bmp_refguide [1])	5850	5920

156	2/13/2009	NRDC Comment Letter - Supporting Documents (Government Sources_18 LID Design Strategies)	5921	6070
157	2/13/2009	NRDC Comment Letter - Supporting Documents (Government Sources_19 LID Design- A New Paradigm)	6071	6080
158	2/13/2009	NRDC Comment Letter - Supporting Documents (Government Sources_20 MA LID Toolkit)	6081	6082
159	2/13/2009	NRDC Comment Letter - Supporting Documents (Government Sources_21 Report of LID Findings)	6083	6108
160	2/13/2009	NRDC Comment Letter - Supporting Documents (Industry Sources_00 Table of Contents- Industry Sources)	6109	6109
161	2/13/2009	NRDC Comment Letter - Supporting Documents (Industry Sources_01 stormwater management)	6110	6110
162	2/13/2009	NRDC Comment Letter - Supporting Documents (Industry Sources_02 a low-impact approach to sw mgmt)	6111	6112
163	2/13/2009	NRD Comment Letter - Supporting Documents (Industry Sources_03 Buidling Green)	6113	6118
164	2/13/2009	NRDC Comment Letter - Supporting Documents (Industry Sources_04 Concrete Evidence)	6119	6122
165	2/13/2009	NRDC Comment Letter - Supporting Documents (Industry Sources_05 Carter & Burgess- LID)	6123	6128
166	2/13/2009	NRDC Comment Letter - Supporting Documents (Industry Sources_06 International SW BMP Database)	6129	6130
167	2/13/2009	NRDC Comment Letter - Supporting Documents (Industry Sources_07 Green Home Building Guidelines)	6131	6286
168	2/13/2009	NRDC Comment Letter - Supporting Documents (Industry Sources_08 Builder's Guide to LID)	6287	6288
169	2/13/2009	NRDC Comment Letter - Supporting Documents (Industry Sources_09 Guides to LID)	6289	6290
170	2/13/2009	NRDC Comment Letter - Supporting Documents (Industry Sources_10 LID Practices for SW Management)	6291	6297
171	2/13/2009	NRDC Comment Letter - Supporting Documents (Industry Sources_11 Municipal Guide to LID)	6298	6299
172	2/13/2009	NRDC Comment Letter - Supporting Documents (Industry Sources_12 the Practice of LID)	6300	6430
173	2/13/2009	NRDC Comment Letter - Supporting Documents (Industry Sources_13 Permeable Pavement)	6431	6435
174	2/13/2009	NRDC Comment Letter - Supporting Documents (Industry Sources_14 Enviro_Econ_Green[1])	6436	6548
175	2/13/2009	NRDC Comment Letter - Supporting Documents (Industry Sources_15 LID Offers Some Solns for Groundwater)	6549	6551
176	2/13/2009	NRDC Comment Letter - Supporting Documents (Industry Sources_16 residential storm water management)	6552	6614
177	2/13/2009	NRDC Comment Letter - Supporting Documents (Industry Sources_17 A Growing Trend in SW Mgmt)	6615	6617
178	2/13/2009	NRDC Comment Letter - Supporting Documents (Stormwater Regulations _00 Table of Contents-Storm Water Regulations)	6618	6618
179	2/13/2009	NRDC Comment Letter - Supporting Documents (Stormwater Regulations_01 susmp)	6619	6672
180	2/13/2009	NRDC Comment Letter - Supporting Documents (Stormwater Regulations _02 Santa Monica 7.10 Urban Runoff Pollution)	6673	6680
181	2/13/2009	NRDC Comment Letter - Supporting Documents (Stormwater Regulations _03 RWQCB LA- Order No 01-182)	6681	6752
182	2/13/2009	NRDC Comment Letter - Supporting Documents (Stormwater Regulations _04 Contra Costa Countrywide NPDES Municipal Stormwater Permit Amendment)	6753	6774
183	2/13/2009	NRDC Comment Letter - Supporting Documents (Stormwater Regulations _05 FL-Environmental Resource Permits)	6775	6804
184	2/13/2009	NRDC Comment Letter - Supporting Documents (Stormwater Regulations _06 general-ms4-permit_Illinois)	6805	6816
185	2/13/2009	NRDC Comment Letter - Supporting Documents (Stormwater Regulations _07 MD's Stormwater Management Program)	6817	6822
186	2/13/2009	NRDC Comment Letter - Supporting Documents (Stormwater Regulations _08 Explanation of MD's SWMP)	6823	6830
187	2/13/2009	NRDC Comment Letter - Supporting Documents (Stormwater Regulations _09 Maryland Model Stormwater Management Ordinance)	6831	6858
188	2/13/2009	NRDC Comment Letter - Supporting Documents (Stormwater Regulations _10 Maryland SW Mgmt Code 26.17.02.05)	6859	6861
189	2/13/2009	NRDC Comment Letter - Supporting Documents (Stormwater Regulations _ 11 Stormwater Management Ordinance-City of Chestertown)	6862	6877
190	2/13/2009	NRDC Comment Letter - Supporting Documents (Stormwater Regulations _12 Deparmtents-Drain_Commissioner-Soil_Erosion_Ordinance_9-9-03[1])	6878	6900
191	2/13/2009	NRDC Comment Letter - Supporting Documents (Stormwater Regulations _13 Missouri State Operating Permit)	6901	6922
192	2/13/2009	NRDC Comment Letter - Supporting Documents (Stormwater Regulations _14 NJ Stormwater Rules)	6923	6938
193	2/13/2009	NRDC Comment Letter - Supporting Documents (Stormwater Regulations _15 Annual Groundwater Recharge Analysis)	6939	6939
194	2/13/2009	NRDC Comment Letter - Supporting Documents (Stormwater Regulations _16 Tier A Municipal Stormwater NPDES Master General Permit)	6940	6972
195	2/13/2009	NRDC Comment Letter - Supporting Documents (Stormwater Regulations _17 nsps Computations)	6973	6977

196	2/13/2009	NRDC Comment Letter - Supporting Documents (Stormwater Regulations _18 nsps_userguidde2006013[1])	6978	6995
197	2/13/2009	NRDC Comment Letter - Supporting Documents (Stormwater Regulations _19 NJ SW bmp_manual)	6996	7333
198	2/13/2009	NRDC Comment Letter - Supporting Documents (Stormwater Regulations _20 Guidance for the Dev of Municipal Mitigation Plans)	7334	7342
199	2/13/2009	NRDC Comment Letter - Supporting Documents (Stormwater Regulations _21 Curve Number and Groundwater Recharge Credits for LID Facilites in NJ)	7343	7349
200	2/13/2009	NRDC Comment Letter - Supporting Documents (Stormwater Regulations _22 NY State SWM Design Manual)	7350	7708
201	2/13/2009	NRDC Comment Letter - Supporting Documents (Stormwater Regulations _23 Stormwater Management Manual-Portland Oregon)	7709	8286
202	2/13/2009	NRDC Comment Letter - Supporting Documents (Stormwater Regulations _24 Portland Title 33- Planning and zoning)	8287	8296
203	2/13/2009	NRDC Comment Letter - Supporting Documents (Stormwater Regulations _25 Municipal Code Chapter 21.5 SW Mgmt)	8297	8317
204	2/13/2009	NRDC Comment Letter - Supporting Documents (Stormwater Regulations _26 SWM in W A State Volume I)	8318	8447
205	2/13/2009	NRDC Comment Letter - Supporting Documents (Stormwater Regulations _27 Phase I Munivipal SW NPDES General Permit-Draft)	8448	8510
206	2/13/2009	NRDC Comment Letter - Supporting Documents (Stormwater Regulations _28 LID Strategy for Green Cove Basin)	8511	8527
207	2/13/2009	NRDC Comment Letter - Supporting Documents (Stormwater Regulations _29 City of Seattle Stormwater, Grading, and Drainage Control Code)	8528	8574
208	2/13/2009	NRDC Comment Letter - Supporting Documents (Stormwater Regulations _30 WV General NPDES WPC Permit)	8575	8588
209	2/13/2009	NRDC Comment Letter - Supporting Documents (Urban Storm Drainage Criteria Manual)	8589	8592
210	2/13/2009	NRDC Comment Letter - Supporting Documents (Technical Manuals: 13 Urban Storm Drainage Criteria Manual VOL I _Cover-Outside Spine Vol1)	8593	8593
211	2/13/2009	NRDC Comment Letter - Supporting Documents (Technical Manuals: 13 Urban Storm Drainage Criteria Manual VOL I _00 Cover Outside Vol1)	9594	8594
212	2/13/2009	NRDC Comment Letter - Supporting Documents (Technical Manuals: 13 Urban Storm Drainage Criteria Manual VOL I _00 Inside Cover Vol 1)	8595	8595
213	2/13/2009	NRDC Comment Letter - Supporting Documents (Technical Manuals: 13 Urban Storm Drainage Criteria Manual VOL I _00 Summary of Changes Vol 1 and DISCLAIMER)	8596	8599
214	2/13/2009	NRDC Comment Letter - Supporting Documents (Technical Manuals: 13 Urban Storm Drainage Criteria Manual VOL I _00 Toc Vol 1)	8600	8602
215	2/13/2009	NRDC Comment Letter - Supporting Documents (Technical Manuals: 13 Urban Storm Drainage Criteria Manual VOL I _01 Chapter 01 Drainage Policy)	8603	8637
216	2/13/2009	NRDC Comment Letter - Supporting Documents (Technical Manuals: 13 Urban Storm Drainage Criteria Manual VOL I _02 Chapter 02 Drainage Law)	8638	8674
217	2/13/2009	NRDC Comment Letter - Supporting Documents (Technical Manuals: 13 Urban Storm Drainage Criteria Manual VOL I _03 Chapter 03 Planning)	8675	8703
218	2/13/2009	NRDC Comment Letter - Supporting Documents (Technical Manuals: 13 Urban Storm Drainage Criteria Manual VOL I _04 Chapter 04 Rainfall)	8704	8732
219	2/13/2009	NRDC Comment Letter - Supporting Documents (Technical Manuals: 13 Urban Storm Drainage Criteria Manual VOL I _05 Chapter 05 Runoff 2006-08 Rev)	8733	8789
220	2/13/2009	NRDC Comment Letter - Supporting Documents (Technical Manuals: 13 Urban Storm Drainage Criteria Manual VOL I _06 Chapter 06 Streets Inlet Storm S ewers)	8790	8871
221	2/13/2009	NRDC Comment Letter - Supporting Documents (Technical Manuals: 13 Urban Storm Drainage Criteria Manual VOL I _07 Chapter 07 Major Drainage 2006-08 Rev)	8872	9000
222	2/13/2009	NRDC Comment Letter - Supporting Documents (Technical Manuals: 13 Urban Storm Drainage Criteria Manual VOL II_Cover-Outside Spine Vol2)	9001	9001
223	2/13/2009	NRDC Comment Letter - Supporting Documents (Technical Manuals: 13 Urban Storm Drainage Criteria Manual VOL II_00 Cover Outside Vol2)	9002	9002
224	2/13/2009	NRDC Comment Letter - Supporting Documents (Technical Manuals: 13 Urban Storm Drainage Criteria Manual VOL II_00 Inside Cover Vol 2)	9003	9003
225	2/13/2009	NRDC Comment Letter - Supporting Documents (Technical Manuals: 13 Urban Storm Drainage Criteria Manual VOL II_00 Summary of Changes Vol 2 and DISCLAIMER)	9004	9007
226	2/13/2009	NRDC Comment Letter - Supporting Documents (Technical Manuals: 13 Urban Storm Drainage Criteria Manual VOL II_00 Toc Vol 2)	9008	9009
227	2/13/2009	NRDC Comment Letter - Supporting Documents (Technical Manuals: 13 Urban Storm Drainage Criteria Manual VOL II_08 Chapter 08 Structure 2007 rev)	9010	9139

228	2/13/2009	NRDC Comment Letter - Supporting Documents (Technical Manuals: 13 Urban Storm Drainage Criteria Manual VOL II_09 Chapter 09 Culverts)	9140	9201
229	2/13/2009	NRDC Comment Letter - Supporting Documents (Technical Manuals: 13 Urban Storm Drainage Criteria Manual VOL II_10 Chapter Storage 2007-06 rev)	9202	9247
230	2/13/2009	NRDC Comment Letter - Supporting Documents (Technical Manuals: 13 Urban Storm Drainage Criteria Manual VOL II_11 Chapter 11 Flood Proofing)	9248	9275
231	2/13/2009	NRDC Comment Letter - Supporting Documents (Technical Manuals: 13 Urban Storm Drainage Criteria Manual VOL II_12 Chapter 12 Revegetation)	9276	9306
232	2/13/2009	NRDC Comment Letter - Supporting Documents (Technical Manuals: 13 Urban Storm Drainage Criteria Manual VOL II_Chapter 13 Design Examples part 1)	9307	9309
233	2/13/2009	NRDC Comment Letter - Supporting Documents (Technical Manuals: 13 Urban Storm Drainage Criteria Manual VOL II_Chapter 13 Design Examples part 2)	9310	9348
234	2/13/2009	NRDC Comment Letter - Supporting Documents (Technical Manuals: 13 Urban Storm Drainage Criteria Manual VOL II_Chapter 13 Design Examples part 3)	9349	9361
235	2/13/2009	NRDC Comment Letter - Supporting Documents (Technical Manuals: 13 Urban Storm Drainage Criteria Manual VOL II_Chapter 13 Design Examples part 4)	9362	9394
236	2/13/2009	NRDC Comment Letter - Supporting Documents (Technical Manuals: 13 Urban Storm Drainage Criteria Manual VOL II_Chapter 13 Design Examples part 5)	9395	9406
237	2/13/2009	NRDC Comment Letter - Supporting Documents (Technical Manuals: 13 Urban Storm Drainage Criteria Manual VOL II_Chapter 13 Design Examples part 6)	9407	9417
238	2/13/2009	NRDC Comment Letter - Supporting Documents (Technical Manuals: 13 Urban Storm Drainage Criteria Manual VOL II_Chapter 13 Design Examples part 7)	9418	9436
239	2/13/2009	NRDC Comment Letter - Supporting Documents (Technical Manuals: 13 Urban Storm Drainage Criteria Manual VOL II_Chapter 13 Design Examples part 8)	9437	9444
240	2/13/2009	NRDC Comment Letter - Supporting Documents (Technical Manuals_00 Table of Contents-Technical Manuals)	9445	9445
241	2/13/2009	NRDC Comment Letter - Supporting Documents (Technical Manuals_01 ACCWP Protecting Water Quality in Development Projects)	9446	9520
242	2/13/2009	NRDC Comment Letter - Supporting Documents (Technical Manuals_02 Start at the Source)	9521	9684
243	2/13/2009	NRDC Comment Letter - Supporting Documents (Technical Manuals_03 Using Site Design Techniques)	9685	9702
244	2/13/2009	NRDC Comment Letter - Supporting Documents (Technical Manuals_04 Caltrans- Stormwater Quality Handbook)	9703	10056
245	2/13/2009	NRDC Comment Letter - Supporting Documents (Technical Manuals_05 Green Technology)	10057	10173
246	2/13/2009	NRDC Comment Letter - Supporting Documents (Technical Manuals_06 NY State SWM Design Manual)	10174	10532
247	2/13/2009	NRDC Comment Letter - Supporting Documents (Technical Manuals_07 LID Hydrological Analysis)	10533	10577
248	2/13/2009	NRDC Comment Letter - Supporting Documents (Technical Manuals_08 LID_ Technical Guidance Manual for Puget Sound)	10578	10835
249	2/13/2009	NRDC Comment Letter - Supporting Documents (Technical Manuals_09 TechMemo1-Review of LID Techniques)	10836	10869
250	2/13/2009	NRDC Comment Letter - Supporting Documents (Technical Manuals_10 TechMemo2-Analysis and Reccommendations for Use of LID in Pugent Sound)	10870	10911
251	2/13/2009	NRDC Comment Letter - Supporting Documents (Technical Manuals_11 Tech Memo3-Suggested Adaptions)	10912	10931
252	2/13/2009	NRDC Comment Letter - Supporting Documents (Technical Manuals_12 The Texas Manual on Rainwater Harvesting)	10932	11019
253	2/13/2009	NRDC Comment Letter - Supporting Documents (Technical Manuals_14 Better Site Design)	11020	11053
254	2/13/2009	NRDC Comment Letter - Supporting Documents (Sources Cited in Letter_01 EPA reducingstormwatercosts)	11054	11090
255	2/13/2009	NRDC Comment Letter - Supporting Documents (Sources Cited in Letter_02 OPC LID Resolution May 15 2008)	11091	11094
256	2/13/2009	NRDC Comment Letter - Supporting Documents (Sources Cited in Letter_03 EPA Southern Oranage County Comments	11095	11096
257	2/13/2009	NRDC Comment Letter - Supporting Documents (Sources Cited in Letter_04 SWRCB LID Report Dec 2007)	11097	11123
258	2/13/2009	NRDC Comment Letter - Supporting Documents (Sources Cited in Letter_07 PA BMP Manual)	11124	11134
259	2/13/2009	NRDC Comment Letter - Supporting Documents (Sources Cited in Letter_09 WV FINAL DRAFT 2 MS4 permit 08)	11135	11169
260	2/13/2009	NRDC Comment Letter - Supporting Documents (Sources Cited in Letter_10 GA Stormwater Manual)	11170	11181
261	2/13/2009	NRDC Comment Letter - Supporting Documents (Sources Cited in Letter_11 Central Coast Phase II Letter)	11182	11188
262	2/13/2009	NRDC Comment Letter - Supporting Documents (Sources Cited in Letter_13 Horner LID Report for Ventura)	11189	11212
263	2/13/2009	NRDC Comment Letter - Supporting Documents (Sources Cited in Letter_13 Horner_initial_report_for SF_Bay)	11213	11236
264	2/13/2009	NRDC Comment Letter - Supporting Documents (Sources Cited in Letter_13 Horner_study_San Diego)	11237	11252

265	2/13/2009	NRDC Comment Letter - Supporting Documents (Sources Cited in Letter_13 Horner Supplementary_report for SF_Bay)	11253	11258
266	2/13/2009	NRDC Comment Letter - Supporting Documents (Sources Cited in Letter_14 Horner-Critique of Certain Elements Feb.2009)	11259	11267
267	2/13/2009	NRDC Comment Letter - Supporting Documents (Sources Cited in Letter_16 NRDC letter to C ARB re AB32)	11268	11296
268	2/13/2009	NRDC Comment Letter - Supporting Documents (Sources Cited in Letter_20 NRDC Energy_Down_ the Drain Report)	11297	11382
269	2/13/2009	NRDC Comment Letter - Supporting Documents (Sources Cited in Letter_21 Geosyntec New_Development_LID_Issue_Paper_Final)	11383	11462
270	2/13/2009	NRDC Comment Letter - Supporting Documents (Sources Cited in Letter_22 OPC State and Local Policies Jan. 2008)	11463	11558
271	2/13/2009	NRDC Comment Letter - Supporting Documents (Sources Cited in Letter_25 Great Lakes Water Institute Design Guidelines for Green Roofs)	11559	11580
272	2/13/2009	NRDC Comment Letter - Supporting Documents (NRDC_comment_letter_re_draft_North_OC-Permit_FINAL)	11581	11597
273	2/13/2009	NRDC Comment Letter - Supporting Documents (Richard Horner Critique Feb. 2009)	11598	11606
274	2/13/2009	OC Public Works Comment Letter Re: First Draft Tentative Order R8-2008-0030	11607	11645
275	2/13/2009	Orange County Vector Control District Comment Letter Re: First Draft Tentative Order R8-2008-0030	11646	11651
276	2/13/2009	Riverside County Flood Control and Water Conservation District Comment Letter Re: First Draft Tentative Order 8-2008-0030	11652	11675
277	2/13/2009	Southern California Gas Company Comment Letter Re: First Draft Tentative Order R8-2008-0030	11676	11678
278	2/13/2009	City of Villa Park Comment Letter Re: First Draft Tentative Order R8-2008-0030	11679	11683
279	2/13/2009	Construction Industry Coalition on Water Quality Comment Letter Re: First Draft Tentative Order R8-2008-0030	11684	11695
280	2/13/2009	City of Tustin Comment Letter Re: First Draft Tentative Order R8-2008-0030	11696	11698
281	2/13/2009	US EPA Region IX Comment Letter Re: First Draft Tentative Order R8-2008-0030	11699	11704
282	2/19/2009	SWRCB Comment Letter Re: First Draft Tentative Order R8-2008-0030	11705	11705
283	2/24/2009	City of Anaheim Comment Letter Re: First Draft Tentative Order R8-2008-0030	11706	11706
284	3/6/2009	City of Buena Park Comment Letter Re: First Draft Tentative Order R8-2008-0030	11707	11747
285	3/24/2009	Second Draft (markup) Tentative Order R8-2009-0030	11748	11846
286	3/24/2009	Second Draft (clean) Tentative Order R8-2009-0030	11847	11938
287	3/25/2009	Transmittal Letter of Second Draft: Renewal of Waste Discharge Requirements for the county of Orange, Orange County Flood Control District and the Incorporated Cities of Orange County, Tentative order No. R8-2009-0030, NPDES No. CAS618030, Areawide Urban Storm Water Runoff	11939	11940
288	4/8/2009	NRDC Comment Letter Re: Second Draft Tentative Order R8-2009-0030	11941	11958
289	4/9/2009	Building Industry Association of Southern California (BIA) Comment Letter Re: Second Draft Tentative Order No. R8-2009-0030	11959	11965
290	4/9/2009	Construction Industry Coalition on Water Quality (CICWQ) Comment Letter Re: Second Draft Tentative Order No. R8-2009-0030	11966	11971
291	4/9/2009	CICWQ Comment Letter Re: Second Draft Tentative Order R8-2009-0030 (Supporting Documents)	11972	12050
292	4/9/2009	ConTech Stormwater Solutions Comment Letter Re: Second Draft Tentative Order R8-2009-0030	12051	12053
293	4/9/2009	Golden State Water Company Comment Letter Re: Second Draft Tentative Order R8-2009-0030	12054	12056
294	4/9/2009	City of Huntington Beach Comment Letter Re: Second Draft Tentative Order R8-2009-0030	12057	12058
295	4/9/2009	City of Irvine Comment Letter Re: Second Draft Tentative Order R8-2009-0030	12059	12062
296	4/9/2009	City of Laguna Hills Comment Letter Re: Second Draft Tentative Order R8-2009-0030	12063	12065
297	4/9/2009	City of Lake Forest Comment Letter Re: Second Draft Tentative Order No. R8-2009-0030	12066	12069
298	4/9/2009	City of Lake Forest Comment Letter Re: Second Draft Tentative Order R8-2009-0030	12070	12073
299	4/9/2009	OC Public Works Comment Letter Re: Second Draft Tentative Order R8-2009-0030	12074	12090
300	4/9/2009	City of Orange Comment Letter Re: Second Draft Tentative Order R8-2009-0030	12091	12095
301	4/9/2009	Orange County Business District Comment Letter Re: Second Draft Tentative Order R8-2009-0030	12096	12097
302	4/9/2009	Orange County Water District Comment Letter Re: Second Draft Tentative Order R8-2009-0030	12098	12100

303	4/10/2009	Transmittal Letter of Third Draft: Renewal of Waste Discharge Requirements for the County of Orange, Orange County Flood Control District and the Incorporated Cities of Orange County, Tentative Order No. R8-2009-0030, NPDES No. CAS618030, Areawide Urban Storm Water Runoff	12101	12101
304	4/10/2009	Third Draft (markup) Tentative Order R8-2009-0030	12102	12196
305	4/10/2009	Third Draft (clean) Tentative Order R8-2009-0030	12197	12289
306	4/24/2009	Agenda Announcement - Regional Board Meeting at City of Santa Ana, Item 12	12290	12294
307	4/24/2009	Agenda Item 12: Errata Sheet	12295	12297
308	4/24/2009	Agenda Item 12: Fact Sheet for Tentative Order R8-2009-0030	12298	12327
309	4/24/2009	Agenda Item 12: Public Workshop Presentation for Tentative Order R8-2009-0030 by Mark Smythe	12328	12371
310	4/24/2009	Agenda Item 12: Public Workshop Presentation for Tentative Order R8-2009-0030 by Mark Smythe (Board Copy)	12372	12413
311	4/24/2009	Regional Board Meeting Transcript (Includes Agenda Item 12)	12414	12627
312	4/24/2009	Construction Industrial Coalition on Water Quality Presentation by Mark Grey	12628	12634
313	4/24/2009	Geosyntec Consultants Presentation by Eric Strecker	12635	12649
314	4/24/2009	Orange County Water District Presentation by Greg Woodsite	12650	12652
315	4/24/2009	NDRC and Orange County Coast Keeper Presentation by David Beckman, Bart Lounsburg, and Garry Brown	12653	12677
316	4/24/2009	Minutes from Regional Board Meeting, Item 12	12678	12682
317	5/1/2009	Fourth Draft (markup) Tentative Order R8-2009-0030	12683	12775
318	5/1/2009	Fourth Draft (clean) Tentative Order R8-2009-0030	12776	12868
319	5/7/2009	City of Irvine Comment Letter Re: Fourth Draft Tentative Order R8-2009-0030	12869	12869
320	5/8/2009	ConTech Stormwater Solutions Comment Letter Re: Fourth Draft Tentative Order R8-2009-0030	12870	12910
321	5/8/2009	City of Cypress Comment Letter Re: Fourth Draft Tentative Order R8-2009-0030	12911	12912
322	5/8/2009	City of Orange Comment Letter Re: Fourth Draft Tentative Order R8-2009-0030	12913	12915
323	5/8/2009	NRDC & Orange County Coastkeeper Comment Letter Re: Fourth Draft Tentative Order R8-2009-0030	12916	12944
324	5/8/2009	NRDC Comment Letter - Supporting Documents (01- EPA Results of National UR Program 1983)	12945	12955
325	5/8/2009	NRDC Comment Letter - Supporting Documents (02-EPA reducing stormwater costs)	12956	12992
326	5/8/2009	NRDC Comment Letter - Supporting Documents (03-CA OPC Resolution on LID)	12993	12996
327	5/8/2009	NRDC Comment Letter - Supporting Documents (04-EPA_comments_on_South_OC_Tentative Order)	12997	13607
328	5/8/2009	NRDC Comment Letter - Supporting Documents (05-Puget Sound)	13608	13680
329	5/8/2009	NRDC Comment Letter - Supporting Documents (06-NAS Urban Strmwater)	13681	14291
330	5/8/2009	NRDC Comment Letter - Supporting Documents (07-SWRCB Review of Low Impact Development Policies)	14292	14318
331	5/8/2009	NRDC Comment Letter - Supporting Documents (08-OPC Report-State and Local Policies Jan 2008)	14319	14414
332	5/8/2009	NRDC Comment Letter - Supporting Documents (09-EPAR9Bromley)	14415	14416
333	5/8/2009	NRDC Comment Letter - Supporting Documents (10 -Eberhardt EPA_R9)	14417	14422
334	5/8/2009	NRDC Comment Letter - Supporting Documents (11-Horner_initial_report_for_SF_Bay)	14423	14446
335	5/8/2009	NRDC Comment Letter - Supporting Documents (12-Horner_supplementary_report_for_SF_Bay)	14447	14452
336	5/8/2009	NRDC Comment Letter - Supporting Documents (13 -ECONorthwest study)	14453	14492
337	5/8/2009	NRDC Comment Letter - Supporting Documents (14-RWQCB Central Coast letter Feb 15 2008)	14493	14499
338	5/8/2009	NRDC Comment Letter - Supporting Documents (15 a-Philadelphia_stormwater_regulations)	14500	14511
339	5/8/2009	NRDC Comment Letter - Supporting Documents (16 -Pennslyvania_BMP_Manual)	14512	15196
340	5/8/2009	NRDC Comment Letter - Supporting Documents (17-Philadelphia_stormwater_manual)	15197	15588
341	5/8/2009	NRDC Comment Letter - Supporting Documents (18-West_Virginia_draft_permit_12.11.08)	15589	15623
342	5/8/2009	NRDC Comment Letter - Supporting Documents (19-West_Virginia_draft_permit_fact_sheet_12.11.08)	15624	15658
343	5/8/2009	NRDC Comment Letter - Supporting Documents (20 -Draft North OC Permit 3-24-09)	15659	15750
344	5/8/2009	NRDC Comment Letter - Supporting Documents (21-SWRCB wq2000_11)	15751	15781
345	5/8/2009	NRDC Comment Letter - Supporting Documents (22-EPAParkingSpaces06)	15782	15851
346	5/8/2009	NRDC Comment Letter - Supporting Documents (23a-2002-022_RB_BPA TMDL)	15852	15869

347	5/8/2009	NRDC Comment Letter - Supporting Documents (24 -r2_06_303d_reqtmdls)	15870	15900
348	5/8/2009	NRDC Comment Letter - Supporting Documents (25 -Fundamentals_of Urban_Runoff_full)manual)	15901	16227
349	5/8/2009	NRDC Comment Letter - Supporting Documents (26-CWP-Impacts_IC_Aq_Systems)	16228	16385
350	5/8/2009	NRDC Comment Letter - Supporting Documents (27-NRDC Stormwater Strategies Chap02)	16386	16401
351	5/8/2009	NRDC Comment Letter - Supporting Documents (28 a-SWRCB wq1999_05)	16402	16405
352	5/8/2009	NRDC Comment Letter - Supporting Documents (29 -Joint_Stormwater Agency Project_final_rpt)	16406	16495
353	5/8/2009	NRDC Comment Letter - Supporting Documents (30 -USGS-wrir-02-41-30)	16496	16501
354	5/8/2009	NRDC Comment Letter - Supporting Documents (31 Anacostia_environmental_standards)	16502	16523
355	5/8/2009	NRDC Comment Letter - Supporting Documents (32 Draft_Energy_Independence_Act_technical_guidance)	16524	16575
356	5/8/2009	NRDC Comment Letter - Supporting Documents (33 North Carolina Wildlife Fed)	16576	16599
357	5/8/2009	NRDC Comment Letter - Supporting Documents (34 TENTATIVE-Ventura-County-MS4-Permit_2009-02-24)	16600	16727
358	5/8/2009	NRDC Comment Letter - Supporting Documents (Supporting Docs for 2-29-08 Letter_01 brown_urban effects on stream)	16728	16728
359	5/8/2009	NRDC Comment Letter - Supporting Documents (Supporting Docs for 2-29-08 Letter_02 LA Co 1-10-08 letter)	16729	16797
360	5/8/2009	NRDC Comment Letter - Supporting Documents (EPA Prelim Data_ usw_a)	16798	16816
361	5/8/2009	NRDC Comment Letter - Supporting Documents (EPA Prelim Data_usw_b)	16817	16865
362	5/8/2009	NRDC Comment Letter - Supporting Documents (EPA Prelim Data_usw_c)	16866	16950
363	5/8/2009	NRDC Comment Letter - Supporting Documents (EPA Prelim Data_usw_d)	16951	16994
364	5/8/2009	NRDC Comment Letter - Supporting Documents (EPA Prelim Data_usw_e)	16995	17011
365	5/8/2009	OC Public Works Comment Letter Re: Fourth Draft Tentative Order R8-2009-0030	17012	17024
366	5/8/2009	Riverside County Flood Control and Water Conservation District Comment Letter Re: Fourth Draft Tentative Order R8-2009-0030	17025	17029
367	5/8/2009	San Bernardino County Stormwater Program Comment Letter Re: Fourth Draft Tentative Order R8-2009-0030	17030	17032
368	5/8/2009	US EPA Region IX Comment Letter Re: Fourth Draft Tentative Order R8-2009-0030	17033	17034
369	5/10/2009	Summary of Comments and Responses on the Orange County Municipal Storm Water Permit (Drafts 1-4)	17035	17095
370	5/13/2009	Reporter's Certificate Allison Swanson Certified Shorthand Reporter for the State of California	17096	17096
371	5/19/2009	City of La Palma Comment Letter Re: Fourth Draft Tentative Order R8-2009-0030	17097	17097
372	5/19/2009	City of Yorba Linda Comment Letter Re: Fourth Draft Tentative Order R8-2009-0030	17098	17098
373	5/21/2009	City of Brea Comment Letter Re: Fourth Draft Tentative Order R8-2009-0030	17099	17099
374	5/21/2009	City of Buena Park Comment Letter Re: Fourth Draft Tentative Order R8-2009-0030	17100	17100
375	5/21/2009	City of Cypress Comment Letter Re: Fourth Draft Tentative Order R8-2009-0030	17101	17106
376	5/21/2009	City of Fountain Valley Comment Letter Re: Fourth Draft Tentative Order R8-2009-0030	17107	17107
377	5/21/2009	City of Fullerton Comment Letter Re: Fourth Draft Tentative Order R8-2009-0030	17108	17108
378	5/21/2009	City of Garden Grove Comment Letter Re: Fourth Draft Tentative Order R8-2009-0030	17109	17109
379	5/21/2009	City of Huntington Beach Comment Letter Re: Fourth Draft Tentative Order R8-2009-0030	17110	17111
380	5/21/2009	City of Laguna Hills Comment Letter Re: Fourth Draft Tentative Order R8-2009-0030	17112	17112
381	5/21/2009	City of Lake Forest Comment Letter Re: Fourth Draft Tentative Order R8-2009-0030	17113	17114
382	5/21/2009	City of Newport Beach Comment Letter Re: Fourth Draft Tentative Order R8-2009-0030	17115	17115
383	5/21/2009	City of Placentia Comment Letter Re: Fourth Draft Tentative Order R8-2009-0030	17116	17116
384	5/21/2009	City of Seal Beach Comment Letter Re: Fourth Draft Tentative Order R8-2009-0030	17117	17117
385	5/21/2009	City of Villa Park Comment Letter Re: Fourth Draft Tentative Order R8-2009-0030	17118	17118
386	5/21/2009	City of Westminster Comment Letter Re: Fourth Draft Tentative Order R8-2009-0030	17119	17120
387	5/21/2009	Construction Industry Coalition on Water Quality (CICWQ) Comment Letter Re: Fourth Draft Tentative Order R8-2009-0030	17121	17143
388	5/22/2009	Agenda Announcement - Regional Board Meeting at City of Loma Linda, Item 12	17144	17150
389	5/22/2009	Agenda Item 12: Errata Sheet	17151	17153

390	5/22/2009	Agenda Item 12: R8 Low Impact Development (LID) Process Presentation Slide by Mark Smythe	17154	17154
391	5/22/2009	Regional Board Meeting Transcript (Includes Agenda Item 12)	17155	17262
392	5/22/2009	County of Orange Presentation by Richard Boon	17263	17265
393	5/22/2009	Larry Walker Associates Presentation by Mac Walker	17266	17270
394	5/22/2009	County of Orange Presentation By Mary Ann Skorpanich	17271	17272
395	5/22/2009	Geosyntec Consultants Presentation by Eric Strecker	17273	17276
396	5/22/2009	Minutes from 5/22/09 Regional Board Meeting, Item 12	17277	17280
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Results of the Nationwide Urban Runoff Program

Volume I - Final Report

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RESULTS

OF THE

NATIONWIDE URBAN RUNOFF PROGRAM

December, 1983

VOLUME I - FINAL REPORT

Water Planning Division

U.S. Environmental Protection Agency

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FOREWORD

The U.S. Environmental Protection Agency was created because of increasing public and government concern about environmental quality. The complexity of our environment and the interplay among its components require concentrated and integrated approaches to pollution problems.

The possible deleterious water quality effects of nonpoint sources in general, and urban runoff in particular, were recognized by the Water Pollution Control Act Amendments of 1972. Because of uncertainties about the true significance of urban runoff as a contributor to receiving water quality problems, Congress made treatment of separate stormwater discharges ineligible for Federal funding when it enacted the Clean Water Act in 1977. To obtain information that would help resolve these uncertainties, the Agency established the Nationwide Urban Runoff Program (NURP) in 1978. This five-year program was designed to examine such issues as:

- The quality characteristics of urban runoff, and similarities or differences at different urban locations;

- The extent to which urban runoff is a significant contributor to water quality problems across the nation; and

- The performance characteristics and the overall effectiveness and utility of management practices for the control of pollutant loads from urban runoff.

The interim NURP report, published in March 1982, presented preliminary findings of the program. This document is the final report covering the overall NURP program. Several specialized technical reports are published under separate cover.

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PREFACE

The Nationwide Urban Runoff Program (NURP) was conducted by the EPA and many cooperating federal, state, regional, and local agencies, distributed widely across the United States. The individual project studies, which were conducted over the past five years, were designed and overseen using a common technical team from EPA headquarters. This approach was taken to assure a desired level of commonality and consistency in the overall program, while allowing each individual project to specially tailor its effort to focus on local concerns.

The program has yielded a great deal of information which will be useful for a broad spectrum of planning activities for many years. Furthermore, it has fostered valuable cooperative relationships among planning and regulatory agencies. The most tangible products of the program are this report, the reports of various grantees (available under separate cover), and several technical reports which focus on specialized aspects of the program, its techniques, and its findings. In addition, a considerable number of individual articles drawing on information developed under the NURP program have already appeared in the technical literature and address specific technical or planning aspects of urban runoff.

At the time of publication of this Final Report, the main technical effort of the NURP program is complete; the field studies and the analysis of most of the resultant data are complete enough that the findings reported herein can be taken with confidence. However, there is still some work in progress to make certain details of the program available for future use. The products of this on-going work include:

- A summary database which is being compiled to make all technical information from the 28 projects available for review and use (DECEMBER 1985);

- A technical report which focuses on the program's studies and findings relative to detention and recharge devices (MAY 1984);

- A technical report on urban runoff effects on the water quality of rivers and streams (MARCH 1984); and

- A technical report on the effectiveness of street sweeping as a potential "best management practice" for water pollution control (MAY 1984).

This report and the supplementary technical documents identified above, supersedes the earlier NURP publication, "Preliminary Results of the Nationwide Urban Runoff Program," March 1982. Information presented there has been expanded, updated, and in some cases revised.

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ACKNOWLEDGEMENTS

The Nationwide Urban Runoff Program was unusual in its large scale, covering a broad spectrum of technical and planning issues at many geographic locations. Because the program placed such emphasis on tailoring the results to support the planning process, it involved many participants - some from EPA, some from other federal agencies, and many from state, regional, and local planning agencies and other consultants.

The program was developed, implemented, and managed by the Water Planning Division, Office of Water, at EPA Headquarters, Washington, D.C. Principal contributors were: Dennis N. Athayde, Program Manager; and Patrice M. Bubar, Norman A. Whalen, Stuart S. Tuller, and Phillip H. Graham, all of whom served as Project Officers. Additional contributions from EPA personnel came from Rod E. Frederick and Richard P. Healy (Monitoring and Data Support Division), Richard Field (Storm and Combined Sewer Section, EPA Office of Research and Development), and many project staff in the various EPA Regional Offices.

As described elsewhere, much of the field work, water quality analysis, and data analysis was performed by the U.S. Geological Survey (USGS), under a Memorandum of Agreement with EPA. Both District Offices and National Headquarters participated actively. The contributions of Messrs. Ernest Cobb and David Lystrom are especially acknowledged.

Members of the project team which provided essential strategic, technical, and management assistance to the EPA Water Planning Division through a contract with Woodward-Clyde Consultants were: Gail B. Boyd, David Gaboury, Peter Mangarella, and James D. Sartor (Woodward-Clyde Consultants); Eugene D. Driscoll (E. D. Driscoll and Associates); Philip E. Shelley (EG&G Washington Analytical Services Center, Inc.); John L. Mancini (Mancini and DiToro Consultants); Robert E. Pitt (private consultant); Alan Plummer (Alan Plummer and Associates); and James P. Heaney and Wayne C. Huber (University of Florida).

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CHAPTER 1
INTRODUCTION

Rain falling on an urban area results in both benefits and problems. The benefits range from watering vegetation to area cleansing. Many of the problems are associated with urban runoff, that portion of rainfall which drains from the urban surfaces and flows via natural or man-made drainage systems into receiving waters.

The historical concern with urban runoff has been focused primarily on flooding. Urban development has the general effect of reducing pervious land surface area and increasing the impervious area (such as roof tops, streets, and sidewalks) where water cannot infiltrate. In comparison with an undeveloped area (for a given storm event), an urban area will yield more runoff, and it will occur more quickly. Such increases in the rate of flow and total volume often have a decided effect on erosion rates and flooding. It is not surprising, therefore, that at the local level the quantity aspect continues to be a principal concern.

In recent years, however, concern with urban runoff as a contributor to receiving water quality problems has been expressed. Section 62 of the Water Quality Act of 1965 (P.L. 89-234) authorized the Federal government to make grants for the purpose of "assisting in the development of any project which will demonstrate a new or improved method of controlling the discharge into any water of untreated or inadequately treated sewage or other waste from sewerage which carry storm water or both storm water and sewage or other waste ..." The Federal Water Pollution Control Act Amendments of 1972 (P.L. 92-500) signaled a heightened national awareness of the degraded state of the nation's surface waters and a Congressional intent that national water quality goals be pursued. The scarcely two-year old Environmental Protection Agency built upon its predecessors' activities by taking up the challenge and implementing this far reaching legislation.

As a result of Section 208 of The Act, State and local water quality management agencies were designated to integrate water quality activities. As point source discharges were increasingly brought under control and funds for the construction and upgrading of municipal sewage treatment plants were granted, the awareness of nonpoint sources (including urban runoff) as potential contributors to water quality degradation was heightened. Uncertainties associated with the local nature and extent of urban runoff water quality problems, the effectiveness of possible management and control measures, and their affordability in terms of benefits to be derived mounted as water quality management plans were developed. The unknowns were so great and certain control cost estimates were so high that the Clean Water Act of 1977 (P.L. 95-217) deleted Federal funding for the treatment of separate stormwater discharges. The Congress stated that there was simply not enough

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known about urban runoff loads, impacts, and controls to warrant making major investments in physical control systems.

In 1978, EPA Headquarters reviewed the results of work on urban runoff by the technical community and t various 208 Areawide Agencies and determined that additional, consistent data were needed. The NURP program was implemented to build upon pertinent prior work and to provide practical information and insights to guide the planning process, including policy and program development and implementation. The NURP program included 28 projects, conducted separately at the local level, but centrally reviewed, coordinated, and guided. While these projects were separate and distinct, most share certain commonalities. All were involved with one or more of the following elements: characterizing pollutant types, loads, and effects on receiving water quality; determining the need for control; and evaluating various alternatives for the control of stormwater pollution. Their emphasis was on answering the basic questions underlying the NURP program and providing practical information needed for planning.

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CHAPTER 2
BACKGROUND

EARLY PERCEPTIONS

As noted earlier, drainage is perhaps the single most important factor of the urban hydrologic cycle. Nuisance flooding, more than anything else, gives Public Works directors concern, as complaints are received from unhappy motorists, residents, and business. Drainage has typically been considered a local responsibility, usually that of the City or County Public Works Department. Rarely does this responsibility go to the State or Federal level, except in cases of catastrophic flooding involving risk to human life and extensive property damage.

By 1964, the U.S. Public Health Service had begun to be concerned about identified pollutants in urban runoff and concluded that there may be significant water quality problems associated with stormwater runoff. In 1969, the Urban Water Resources Research Committee of the American Society of Civil Engineers (directed by M. B. McPherson and sponsored by the U.S. Geological Survey) recognized the potential threat of pollution from urban runoff and described a research program intended to obtain needed information to characterize urban stormwater quality.

In the late 1960's, the Federal Water Quality Administration (FWQA) conducted a study in an area of Tulsa, Oklahoma which was served by separate storm sewers. This first attempt at using regression analysis on urban runoff indicated that there was only a very poor correlation between stormwater runoff quantity and water quality constituents (except for suspended solids). Comparing the concentrations of various pollutants examined by this study (separate storm sewers) with previous data on combined sewer overflows indicated that storm runoff from areas having separate sewers had much lower values for BOD, fecal coliform, and most other pollutant concentrations. The study concluded that the largest portion of pollutants resulted from (1) washoff of material from impervious surfaces and (2) the erosion of drainage channels (caused by high volumes of runoff from the impervious surfaces). Control of urban runoff was recommended to reduce both runoff volume and rates.

Atlanta, Georgia is an example of a city that has both a combined sewer system and a separate system. In 1971, EPA conducted a study which compared the contribution of various sources of pollutants. It was concluded that, on an annual basis, 64 percent of the BOD load came from separate storm sewers, and 19 percent came from combined sewers, the balance coming from treatment plants.

In 1971, EPA also conducted a study in Oakland and Berkeley, California, to assess the infiltration of stormwater into sanitary sewers. While only four

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percent of the study area had combined sewerage and the remaining 96 percent separate, the study made it clear that infiltration can cause a separate system to function as though it were combined.

Studies in Sacramento, California, which has both combined and separate storm sewers, indicated that the stormwater was comparable to the average strength of domestic wastewater. However, the concentrations for BOD were found to be so unrealistically high, that contamination of the runoff by raw sanitary sewage was considered to be a distinct possibility.

In 1973, the Council on Environmental Quality published a report titled, "Total Urban Pollutant Loads: Sources and Abatement Strategies." The primary conclusion was that much pollution was coming from urban runoff and that, unless it was taken care of, the goals of the Act would not be met.

CONCLUSIONS FROM SECTION 208 EFFORTS

EPA guidance for conducting the early 208 planning efforts designated 17 topic areas (including urban runoff) that were to be addressed by all Water Quality Management agencies in developing their 208-funded plans. Although all topic areas were to be covered, the degree of emphasis to place on each was left to the individual agencies to decide. As a result, the amount of the 208 efforts spent in the area of urban runoff varied greatly (but was rarely a major portion).

Many of the 208 agencies began their studies with the assumption that urban runoff was an important cause of water quality problems. Although the studies developed much information on runoff and receiving waters, not enough basic information was known to assess urban runoff's role as a major cause of problems. This was partly because of interferences by other sources and complex relationships within the receiving waters. It was also due to the difficulties in deciding what constitutes a "problem." In some cases, "problems" were synonymous with criteria violations; in others, "problems" were synonymous with an impairment or denial of beneficial uses. In many cases, "problems" were concluded to exist, simply on the basis of the possible presence of certain contaminants in urban runoff, based solely on values taken from literature regarding studies conducted elsewhere. The practical implication of these differences (which were differences in viewpoints rather than differences in physical conditions, in many cases) was that local agencies were very reluctant to commit to implementing urban runoff controls in the absence of a clear problem definition.

Furthermore, in the early years of the 208 program, EPA's guidance on how to address urban runoff was vague. As a result, local agencies took a wait-and-see attitude on the stormwater portion of their plans. They simply did not know what EPA would eventually do on the issue of stormwater control.

Another major obstacle to implementation resulted from the uncertainties regarding the effectiveness of controls. Many of the measures proposed for controlling urban runoff are either new or special applications of conventional practices developed for other purposes. Little was known about how

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well they would work in urban runoff applications. Engineers, planners, public works personnel, and other decision makers have been understandably reluctant to invest large amounts of time and money in controls which may not perform as hoped.

Another obstacle to implementation of controls was a lack of basic data on sources, transport mechanisms, and receiving water characteristics (hydrologic and water quality aspects). Some of the more important topic areas where knowledge was lacking are summarized below:

- Sources - Not enough was known about where pollutants originate. Major sources certainly include vehicles, vegetation, erosion, fertilizer and pesticide application, litter, animals, and air pollution. However, a better understanding of source contributions could enhance control opportunities.

- Washoff/transport mechanisms - Not enough was known about how pollutants get from the sources to the receiving waters. Models could be better used for simulating runoff in problem definition and control evaluation, if they more accurately reflected washoff and transport mechanisms.

- Impacts - It was difficult to go beyond speculation in assigning urban runoff its proper share of responsibility for problems in cases where several pollutant sources contribute. In cases where other sources create obvious problems, it was difficult to determine the appropriate degree to which urban runoff should be controlled.

- Relative benefits - Planners had difficulty deciding whether the various benefits of controlling urban runoff quality justify the costs involved. There was considerable controversy over the present dry weather standards' relationship to beneficial uses, given the time and space scales of storm events and their intermittent nature. Many plans failed to be implemented because of uncertainties regarding: How much control is enough? Who benefits? Who should pay? Who should decide?

- Controls - Both cost and effectiveness data on full-scale control programs were lacking. Some of the control measures cited for typical 208 plans were plausible candidates, but their application for the purpose of urban runoff pollution control had not been studied quantitatively.

EPA'S ORD EFFORT

During the past 15 years, EPA's Office of Research and Development (ORD) has conducted over 250 studies on the characterization and control of stormwater discharges and combined sewer overflows, with particular emphasis on the latter due to their greater pollution potential. Consistent with overall Agency policies, ORD has deemphasized studies on receiving water impacts and effects (although it has done some such work). Rather, ORD has focussed principally on multi-purpose analyses and controls, because it is nearly

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impossible to segregate benefits and strategies of urban stormwater runoff pollution control from drainage, flood, and erosion control. Many significant results have been obtained by ORD's effort, which has dramatically increased the technical literature in the area.

Data from ORD studies indicate the high variability of pollutant concentrations in urban runoff. Based on loading projections, it is safe to conclude that urban stormwater can contribute significant pollutant loads to receiving waters, in many cases having pollutant concentrations on the order of secondary treatment plant effluent for some constituents. Nonetheless, in its efforts to find direct urban runoff generated receiving water impacts (using the conventional dissolved oxygen parameter as the indicator) ORD has been only partly successful. However, this was only one study and was not intended to be the final word. Nonetheless, based on the size of the load coming from urban runoff, a significant pollution potential is there for at least some types of receiving waters. For example, a small urban lake could receive nutrient loads sufficient to increase algal productivity and accelerate the eutrophication process. The existence of heavy metals and certain organics (mostly of petroleum origin) in urban runoff have also been documented by the ORD program.

In addition to studying urban runoff loads, the ORD program has investigated a number of management and control approaches. This effort has been very successful, and many innovative techniques have been proposed and tested. The results of such research, development, and demonstrations have been presented in reports which document many of these potential controls, thereby allowing the technology to be utilized in other programs and at other locations. Included have been such control measures as on-site (upstream) storage; porous pavement; the swirl concentrator, helical bend, tube settler, and fine mesh screens for grit and settleable solids removal; street sweeping; disinfection; and high rate filtration, dissolved air flotation, and microscreening for suspended solids and BOD removal. Most of these controls were developed principally to deal with combined sewer overflow problems. However, some may also have application in urban runoff control, once their effectiveness has been conclusively demonstrated and initial and operating cost data are available to allow the necessary trade-off studies to be made.

The ORD program's reports constitute an invaluable source of data and information that was used to design and guide the development of the emerging NURP program. Also, three of the NURP projects were joint efforts with ORD (i.e., West Roxbury, Massachusetts, Bellevue, Washington, and Lansing, Michigan).

OTHER PRIOR/ONGOING EFFORTS

The Clean Water Act requires EPA to provide Congress with a needs assessment every two years in the six categories of the construction grant funds program. In 1974, the Needs Survey for Separate Storm Sewer Discharges (Category VI) was done by each state. Using the goals of the Act as the criteria to be met, they identified a cost of about $235 billion (June 1973 dollars). One state alone identified $80 billion in needs to control separate storm sewer discharges. In 1976, the Needs Survey was conducted by the Agency, and it was found that Category VI would require $66 billion to meet the goals of

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the Act. This survey broke the goals into three categories or levels of pollution abatement; (1) aesthetics, (2) fish and wildlife, and (3) recreation. Costs to meet each category were determined.

As noted previously, the ASCE defined a program in 1969 to identify the causes and effects of urban stormwater pollution. The recommendations were not followed, so in 1974 at the Rindge, New Hampshire, Engineering Foundation Conference (jointly sponsored with ASCE's Urban Water Resources Research Council), a similar program was again recommended. A similar scenario occurred at the Easton, Maryland, conference of 1976 sponsored by the same group.

DISCUSSION

In the past (ca 1890), dilution was considered to be the appropriate way to control combined sewer overflows, since the primary concern was odor and related nuisances. Between 1890 and 1960 little concern was shown for stormwater pollution. Stormwater concerns were primarily related to drainage problems. As time progressed, water quality began to be considered, and workers began to characterize problems in terms of concentrations of certain pollutants and loads of these pollutants. In the 1970's, problems were being defined in terms of pounds of pollutants needing to be removed from overflows, in the interest of preventing pollution.

Past work, reported by EPA and published in professional journals, tended to focus on determining (a) the type and amount of pollutants involved and/or (b) methods to reduce the loads. However, such reports and articles did not consider either the level of improvement attainable or the need to improve quality of the receiving water body associated with the study. A conclusion common to all such reports was that not enough was known about stormwater to adequately understand cause and effect relationships. Also common to such reports were recommendations for further study and more data. A tangible result of the lack of belief and uncertain attitude in this area is the fact that stormwater controls for water quality have been implemented in so few places throughout the nation. Thus, there has been a critical need to objectively examine the situation.

Many factors led to the development of NURP, one being a legally-mandated necessity. As implementation of P.L. 92-500 moved into full swing, the lack of progress in the area of urban runoff was becoming apparent. In 1974 EPA lost a court case, which led to the decision that EPA should issue permits for separate storm sewer discharges. In 1976 EPA requested that the Areawide Waste Management Planning Program focus on the three or four most important of the 17 items required by the regulations. Many of the 208 Areawide Agencies cited urban runoff as an important item.

Two years later, EPA reviewed ninety-three 208 Areawide Agencies' work plans to assess their basis for having identified urban runoff as an element upon which they would focus. Review of these projects' methods and findings did not provide much to further our understanding of the pollution aspects of urban runoff. If one reason can be identified, it was the lack of site-specific data to define the local conditions.

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As mentioned earlier, the Rindge Conference recommended a candidate program for obtaining the data necessary to provide a good understanding of storm-water pollution (EFC/ASCE, 1974). It is not coincidental that the NURP program is quite similar in design to those recommendations.

THE NATIONWIDE URBAN RUNOFF PROGRAM

Program Design

NURP was not intended to be a research program, per se, and was not designed as such. Rather, the program was intended to be a support function which would provide information and methodologies for water quality planning efforts. Therefore, wherever possible, the projects selected were ones where the work undertaken would complete the urban runoff elements of formal water quality management plans and the results were likely to be incorporated in future plan updates and lead to implementation of management recommendations. Conduct of the program provided direction and assistance to 28 separate and distinct planning projects, whose locations are shown in Figure 2-1 and listed in Table 2-1, but the results will be of value to many other planning efforts. NURP also acted as a clearinghouse and, in that capacity, provided a common communication link to and among the 28 projects.

The NURP effort began with a careful review of what was known about urban runoff mechanisms, problems, and controls, and then built upon this base. The twin objectives of the program were to provide credible information on which Federal, State, and local decision makers could base future urban runoff management decisions and to support both planning and implementation efforts at the 28 project locations.

An early step in implementing the NURP program involved identifying a limited number of locations where intensive data gathering and study could be done. Candidate locations were assessed relative to three basic selection criteria:

- Meeting program objectives;
- Developing implementation plans for those areas; and
- Demonstrating transferability, so that solutions and knowledge gained in the study area could be applied in other areas, without need for intensive, duplicative data gathering efforts.

The program design used for NURP included providing a full range of technical and management assistance to each project as the needs arose. Several forums for the communication of experience and sharing of data were provided through semi-annual meetings involving participants from all projects. The roles and responsibilities of the various State, local, and regional agencies and participating Federal agencies were clearly defined and communicated at the outset. These were reviewed and revised where warranted as the projects progressed.

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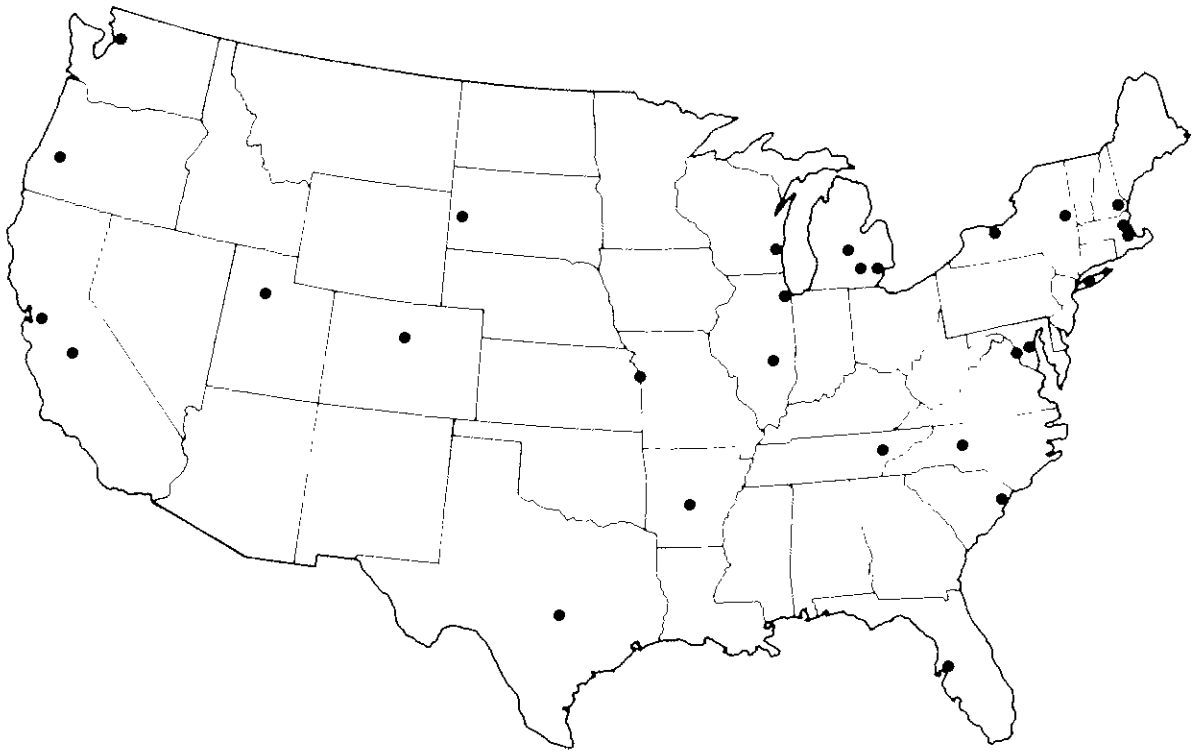

Figure 2-1. Locations of the 28 NURP Projects

TABLE 2-1. NURP PROJECT LOCATIONS

EPA Region	NURP Code	Project Name/Location	EPA Region	NURP Code	Project Name/Location
I	MA1	Lake Quinsigamond (Boston Area)	V	IL1	Champaign-Urbana, Illinois
	MA2	Upper Mystic (Boston Area)		IL2	Lake Ellyn (Chicago Area)
	NH1	Durham, New Hampshire		MI1	Lansing, Michigan
II	NY1	Long Island (Nassau and Suffolk Counties)		MI2	SEMCOG (Detroit Area)
	NY2	Lake George		MI3	Ann Arbor, Michigan
	NY3	Irondequoit Bay (Rochester Area)		WI1	Milwaukee, Wisconsin
III	DC1	WASHCOG (Washington, D.C. Metropolitan Area)	VI	AR1	Little Rock, Arkansas
	MD1	Baltimore, Maryland		TX1	Austin, Texas
IV	FL1	Tampa, Florida	VII	KS1	Kansas City
	NC1	Winston-Salem, North Carolina	VIII	CO1	Denver, Colorado
	SC1	Myrtle Beach, South Carolina		SD1	Rapid City, South Dakota
	TN1	Knoxville, Tennessee		UT1	Salt Lake City, Utah
			IX	CA1	Coyote Creek (San Francisco Area)
				CA2	Fresno, California
			X	OR1	Springfield-Eugene, Oregon
				WA1	Bellevue (Seattle Area)

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The 28 NURP projects were managed by designated State, county, city, or regional governmental associations. The U.S. Geological Survey (USGS) was involved with EPA as a cooperator, through an inter-agency agreement, on 11 of the NURP projects. The Tennessee Valley Authority was also involved in one project.

A major objective of the program was the acquisition of data. Because these data will be used for several years to characterize problems, evaluate receiving water impacts from urban runoff, and evaluate management practices, consistent methods of data collection had to be developed and rigorously employed.

Project Selection

Projects were selected from among the 93 Areawide Agencies that had identified urban runoff as one of their significant problems. The intention was to build upon what these agencies had already accomplished in their earlier programs. Also, projects that would be a part of this program were screened to be sure that they represented a broad range of certain characteristics (e.g., hydrologic regimes, land uses, populations, drainage system types). Actual selection of projects was a joint effort among the States, local governments, and Regional EPA offices. The five major criteria used to screen candidate projects were as follows:

1. Problem Identified. Had a problem relative to urban runoff actually been identified? Could that problem be directly related to separate storm sewer discharges? What pollutant or pollutants were thought to be causing the problem? Using the NURP problem identification categories, what was the "problem" (i.e., denying a beneficial use, violating a State water quality standard, or public concern)?

2. Type of Receiving Water. The effects of stormwater runoff on receiving water quality were the NURP program's ultimate concern. Because flowing streams, tidal rivers, estuaries, oceans, impoundments, and lakes all have different hydrologic and water quality responses, the types of receiving waters associated with each candidate project had to be examined to ensure that an appropriately representative mix was included in the overall NURP program.

3. Hydrologic Characteristics. The pattern of rainfall in the study area is perhaps the single most important factor in studying urban runoff phenomena, because it provides the means of conveyance of pollutants from their source to the receiving water. For this reason, projects in locations having in different hydrologic regimes were chosen for the program.

4. Urban Characteristics. Characteristics such as population density, age of community, and land use were considered as

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possible indicators of the waste loads and ultimately the rainfall-runoff water quality relationship. The type of sewerage system was another factor considered (e.g., whether it is combined, separate, or mixed; how severe the infiltration and inflow problems may be). Such factors have different effects on the quantity and quality of storm runoff, and were balanced as well as possible in selecting projects.

5. Beneficial Use of Receiving Water. Because this factor greatly affects the type of control measure that would be appropriate, attempts were made to include a wide range in selecting projects.

Although these were the primary criteria used to identify potential projects, other factors also had to be considered (e.g., the applicant agencies' willingness to participate, the State's acceptance of the project, the experience of the proposed project teams). Because the NURP program used planning grants (not research funds) a major consideration was the anticipated working relationships with local public agencies and the applicants' ability to raise local matching funds.

Program Assistance

Technical expertise and resources available for urban runoff planning varied among the various projects participating in NURP. Therefore, the program strategy called for providing a broad spectrum of technical assistance to each project as needed and for intercommunication of experiences and sharing of data in a timely manner.

Assistance was also provided to the applicants in developing their final work plans. This was done to ensure that there would be consistency among methods, especially in the collection of data. If there were to be differences in data from city to city, they must be due to the characteristics of each city and not a result of how the data were obtained.

Assistance with instrumentation was provided during the program in the form of information on available equipment, installation, calibration, etc. Because one of the more important elements of a data collection program is the "goodness" or quality of the data themselves, questionable data would be of little use. Accordingly, a quality assurance and quality control element was required in the plans for each project.

Periodic visits were made to each project site to ensure that the participants were provided opportunities to discuss any problems, technical or administrative. The visiting team typically included an EPA Regional Office representative, an EPA Headquarters representative, and one or two experienced consultants. All interested parties, including representatives from State or local governments, were requested to attend those visits.

As the projects moved farther into their planned activities and the time for data analysis approached, each project was required to describe how they were going to analyze their data. No single method was recommended for each project, because it was believed that a broad diversity of available methods

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would be suitable, if used properly. Guidance on proper use was provided as a part of technical assistance through project visits and special workshops for this purpose.

Communication

It was intended that the entire group of NURP participants function as a single team. Accordingly, a communication program was developed. National meetings were conducted semi-annually so that key personnel from the individual projects would have an opportunity to discuss their experiences and findings.

Reports were required of each project quarterly. EPA Headquarters also provided composite quarterly reports summarizing the status of each project and discussing problems encountered and solutions found.

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CHAPTER 3
URBAN RUNOFF PERSPECTIVES

In evaluating the impacts of urban runoff, one's perspective may be influenced by one's concerns and priorities - and what one defines to be a "problem". Recognizing this, the following discussion covers several such perspectives, including concerns over runoff quantity, water quality, and control possibilities.

RUNOFF QUANTITY

The following discussion covers a major cause and two major effects of runoff problems related to "quantity" (i.e., increased urbanization as a cause; flooding and erosion/sedimentation as effects).

Flooding Problems

As noted earlier, drainage has historically been the principal local-level concern regarding urban runoff. Concerns over quantity can be divided into two basic categories: nuisance flooding and major flooding. Nuisance flooding (e.g., temporary ponding of water on streets, road closings, minor basement flooding), although hardly tolerable to those immediately affected, rarely affects an entire urban populance. Nonetheless, the concerns of the (often vocal) minority of affected citizens commonly reach the point where local action is taken to minimize the recurrence of such events. Such mitigation activities are usually locally determined, funded, and implemented because both the affected public and government decision makers perceive and concur that such flooding constitutes a "problem".

Catastrophic flood events, on the other hand, have to be thought about differently for several reasons:

- They typically affect the majority of the urban populace.

- Mitigation measures often involve engineering improvements extending well beyond local jurisdictions.

- Mitigation measures often cost more than the local community could afford. Historically, the Federal government has become involved, in major flood control efforts through a number of related programs. In such cases, water quantity problems are relatively easy to define because the extent of flooding is readily observable, the degree of damage is easily determined, and the benefits of proposed flood control projects can be estimated. Thus, decision makers face a relatively low risk in prescribing courses of action and justifying the associated

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costs in light of benefits. As will be discussed later, decision making in the case of water quality concerns is less straightforward.

Erosion and Sedimentation Problems

Erosion results from rainfall and runoff when soil and other particles are removed from the land surface and transported into conveyance systems and water bodies. Since land surface erosion is the principle source of stream sediment, the type of soil, land cover, and hydrologic conditions are major factors in determining the severity and extent of sedimentation problems. Although erosion is a natural process, it is frequently exacerbated by the activities of man, in both urban and rural environments.

When addressing the broad spectrum of receiving water problems which result from sedimentation, it is convenient to divide cases into two categories; (1) those that respond to control measures directed at nuisance flood prevention, and (2) those that are not controlled by such measures. When natural loads are discharged into receiving waters, the effects are primarily physical and only secondarily chemical (because the mineral constituents which make up the primary sediment load are relatively benign in most cases). Among the physical problems imposed upon the receiving waters are:

- Excess turbidity reduces light penetration, thereby interfering with sight feeding and photosynthesis;

- Particulate matter clogs gills and filter systems in aquatic organisms, resulting, for example, in retarded growth, systemic disfunction, or asphyxiation in extreme cases; and

- Benthal deposition can bury bottom dwelling organisms, reduce habitat for juveniles, and interfere with egg deposition and hatching.

Although sedimentation is storm-event related, its resultant problems are not exclusively either "quantity" problems or water "quality" problems. Being hybrid problems, sedimentation control has received a mixed approach. The organizations involved range widely, from Federal agencies (e.g., the Army Corps of Engineers, the Soil Conservation Service) to local drainage and sedimentation control officials, frequently with involvement from State and county governmental agencies.

Urbanization as a Cause of Problems

Urbanization accelerates erosion through alteration of the land surface. Disturbing the land cover, altering natural drainage patterns, and increasing impervious area all increase the quantity and rate of runoff, thereby increasing both erosion and flooding potential. Also, the sedimentation products which result from urban activities are generally not as benign as the natural mineral sediments which result from soil erosion. Atmospheric deposition (associated with industrial, energy, and agricultural production activities) and added surface particulates (resulting from tire wear, auto

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exhaust, and road surface decomposition) fall in this latter category. Their effects on receiving waters tend to be more "chemical" than "physical". They may contain toxic substances and/or other compounds which can have adverse impacts upon receiving water quality and the associated ecological communities.

WATER QUALITY CONCERNS

The notion that urban runoff can be a significant contributor to the impairment or degradation of the quality of receiving waters has formed only recently and is not universally shared. It is the totality of receiving water characteristics (e.g., flow rate, size or volume, and physical and chemical characteristics) that determines its use, although some characteristics are more important than others (e.g., there must be present an appropriate rate of flow and/or volume in the receiving water to support the desired use).

In addressing the water quality needed to support a designated use, one must consider specific requisite characteristics. For example, in the case of swimming, total dissolved solids and dissolved oxygen levels are far less important than pathogenic organisms. For irrigation, the biochemical oxygen demand of the water is of little concern to the farmer, whereas the total dissolved solids level is of immense concern (to minimize salt buildup). Although high nutrient levels may be detrimental to the quality of impounded waters (by hastening eutrophication processes), a farmer may welcome nutrients in irrigation water.

It is also important to note that it is the concentration, rather than the mere presence of a water quality constituent, that affects use. The relationship between pollutant concentration and resultant impacts on receiving water use are quite non-linear, with plateau effects not uncommon. For example, consider dissolved oxygen and its effect upon fin fish. Down to a certain level below saturation, there are virtually no important effects (upon a given species). As dissolved oxygen levels fall below this threshold, the more sensitive members of the species begin to be affected. As levels continue to fall, the affected percentage of the population will increase until a level is reached at which the entire population can no longer survive. Obviously, any further reduction of dissolved oxygen level would have no further effect upon the community, since it no longer exists. It is important to keep this plateau effect in mind when considering the practical impacts of increased pollution and the practical value of remedial measures to restore beneficial uses, since limited removal of a polluting substance may do nothing to alleviate the problem. In the example given above, if one were to somehow reduce the input of oxygen demanding substances to the receiving water, the result might be that the dissolved oxygen level of the receiving water would rise from 1.0 mg/l to 3 mg/l. If the species of concern were trout, they still could not survive. Even though polluting substances were removed and money was spent, the desired benefit would not be achieved.

WATER QUANTITY AND QUALITY CONTROL

There is no question that excessive urban runoff causes problems. Remedial costs may be high, but the benefits are obvious. Currently, there is a growing national awareness that, if steps are taken during the planning phase

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of development, excessive stormwater discharges can be prevented, at least from typical events (large infrequent storms will always present a greater threat).

Past And Current Work

During the past two decades attention has been focused on reducing runoff rates and volumes and reducing flood damage. During the early 1970's, a manual of practices was prepared under grants from the Office of Water Research and Technology sponsored by the American Public Works Association stressing detention (Poertner, 1974). The University of Delaware also issued a manual of practices on methods to control rates and volumes of urban runoff (Toubier and Westmacott, 1974).

Work done by the ASCE Urban Water Resources Research Council during the sixties stressed the concept of natural easements for drainage, observing that there were two drainage ways; major routes for large events and minor routes for smaller more frequent events (Jones, 1968). It was claimed that money could be saved by using natural channels, swales, etc., thus reducing the need for more expensive concrete conveyances.

The idea of intentionally using natural runoff courses, green belts, and the like was new to engineers who had long been trying to control runoff through more artificial conveyances. In 1970, EPA's Office of Research and Development initiated work on a development known as the Woodlands project in Texas near Houston. Studies were conducted to determine how storm flows could be managed and water quality could be protected or improved by the use of natural drainage ways, detention facilities, porous pavements, increased infiltration rates, and a decrease in runoff rates (Characklis, 1979).

Federal Involvement

As part of its national effort to control erosion from agricultural lands, the Soil Conservation Service (SCS) (Department of Agriculture) provides technical assistance in developing erosion control plans. During the past decade or so, the methods they have developed have been applied much more widely than just to agricultural situations. SCS has become increasingly involved in erosion control in urban areas and has produced a useful document for assessing urban hydrology in small watersheds (SCS, 1975).

Other Federal agencies that have an interest in urban runoff and its control include the U.S. Geological Survey, the Federal Highway Administration, the Federal Housing Administration, the Tennessee Valley Authority, and others too numerous to mention.

State And Local Involvement

Although some 27 states have adopted floodplain management legislation to protect property, the control of urban drainage has traditionally been a local matter. Some states have some form of erosion control laws in force; however few states have runoff rate/quantity legislation. This situation has begun to change over the last decade, and Maryland is one example where the statewide legislation for stormwater management is implemented at the county level.

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The methods used tend to be preventive, wherein erosion is controlled by prescribing certain proven design practices and conventions. Many local agencies are developing control plans along these lines, so this report will not cover this aspect of control.

PROBLEM DEFINITION

As pointed out earlier, water quantity problems are relatively easy to identify and describe. Water quality problems, on the other hand, tend to be more elusive because their definition often involves some subjective considerations, including experiential aspects and expectations of the populace. They are not immediately obvious and are usually less dramatic than, for example, floods. They also tend to vary markedly with locality and geographic regions within the country. For example, a northwestern resident may want to upgrade stream quality to support some highly-prized species of game fish, while a northeastern resident contemplating the river flowing by the local factory might be grateful to see any game fish at all. Thus, a methodological approach to the determination of water quality problems is essential if one is to consider the relative role of urban runoff as a contributor. An important finding of the work conducted during this NURP program has been to learn to avoid the following simplistic logic train: (a) water quality problems are caused by pollutants, (b) there are pollutants in urban runoff, therefore, (c) urban runoff causes "problems". The unspoken implication is that a "problem" by definition requires action, and any type of "problem" warrants equally vigorous action. It becomes clear that a more fundamental and more precise definition of a water quality "problem" from urban runoff is necessary. For this purpose, the NURP has adopted the following three-level definition:

- Impairment or denial of beneficial uses;
- Water quality criterion violation; and
- Local public perception.

The first of these levels refers to cases of impairment or denial of a designated use. An example would be a case where a determination has been made that some specific beneficial use should be attained; however, present water quality characteristics are such that attainment of the use cannot be fully realized.

The second level of problem definition refers to violations of a designated water quality criterion. An example would be a case where some measure or measures of water quality characteristics have been found to violate recommended or mandatory levels for the receiving water classification. Some of the subtle distinctions between this and the preceding problem definition arise in the fact that receiving water classification may not be appropriate, the beneficial use may not be impaired or denied, and the water quality criteria associated with that classification may or may not be overly conservative or directly related to the desired use.

The third level of problem definition involves public perception. This may be expressed in a number of ways, such as telephone calls to public officials

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complaining about receiving water color, odor, or general aesthetic appearance. Public perception of receiving water body problems is highly variable also. Some people enjoy fishing for carp or gar, children will play in almost any creek, and so on. This level of problem definition can also include one concept of anti-degradation. Here the thought is that no polluting substances of any kind in any quantity should be discharged into the receiving water regardless of its natural assimilative capacity. This concern has its ultimate expression in the "zero discharge" concept. EPA's concept of anti-degradation, on the other hand, refers to degradation of use; a subtle but essential difference.

The foregoing levels of problem definition provide an essential framework within which to discuss water quality problems associated with urban runoff. However, it is important to understand that when one is dealing at a local level all three elements are typically present. Thus, it is up to the local decision makers, influenced by other levels of support and concern, to carefully weigh each, prior to making a final decision about the existence and extent of a problem and how it is to be defined. It follows that, if this step of problem definition is done carelessly, it will be difficult, if not impossible, to plan an effective control strategy and establish a means for assessing its effectiveness.

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CHAPTER 4
STORMWATER MANAGEMENT

INTRODUCTION

This chapter is included for those who wish to know more about how to plan and implement stormwater management programs. Most of the information contained herein was developed through several related programs that were proceeding in parallel with the NURP program.

- The Southeast Michigan Council of Governments (SEMCOG), a NURP grantee, was developing stormwater management procedures.

- The Midwest Research Institute (MRI) was collecting cost information on control practices from selected NURP projects.

- A related EPA Water Planning Division program, the Financial Management Assistance Program (FMAP), was developing financial and institutional planning procedures designed to be helpful in the implementation of stormwater management plans.

STORMWATER MANAGEMENT PLANNING[1]

Stormwater management planning develops policies, regulations, and programs for the control of runoff from the land. Stormwater management planning is normally directed toward either or both of two primary goals: the reduction of local flooding and/or the protection of water quality. However, stormwater management planning is also generally used to insure that stormwater programs and regulations provide multiple benefits to the affected communities and do so in a way that does not create additional problems.

Stormwater management planning need not involve expensive technical studies. Available data and maps, the experience of other communities, and advice from experts can be used to develop an effective planning program. Detailed technical studies can then be targeted toward specific issues and problems. Effective local planning can alleviate the need for costly remedial public works projects.

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[1] The material in this section of the chapter is largely from Technical Bulletin No. 1: Stormwater Management Planning: Cost-Saving Methods for Program Development, the first of a seven-part bulletin series on water quality management prepared by the Southeast Michigan Council of Governments and available from Information Service, SEMCOG, 8th Floor, Book Building, Detroit, Michigan 48226.

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The Need

Stormwater runoff cannot be ignored in developing communities. As urban development occurs, the volume of stormwater and its rate of discharge increase. These increases are caused when pavement and structures cover soils and destroy vegetation which otherwise would slow and absorb runoff. Pollutants, washed from the land surface and carried by runoff into lakes and streams, may add to existing water quality problems.

Figure 4-1 illustrates the effects of paved surfaces on stormwater runoff volumes. When natural ground cover is present over the entire site, normally less than 10 percent of the stormwater runs off the land into nearby creeks, rivers, and lakes. When paved surfaces cover 10 to 30 percent of the site area, approximately 20 percent of the stormwater can be expected to run off. As paved surfaces increase, both the volume and the rate of runoff increase. Furthermore, paved surfaces prevent natural infiltration of stormwater into the ground, and increased runoff volumes and rates increase soil erosion and pollutant runoff. Stormwater management planning can be used to develop programs to reduce adverse affects and even to provide community benefits.

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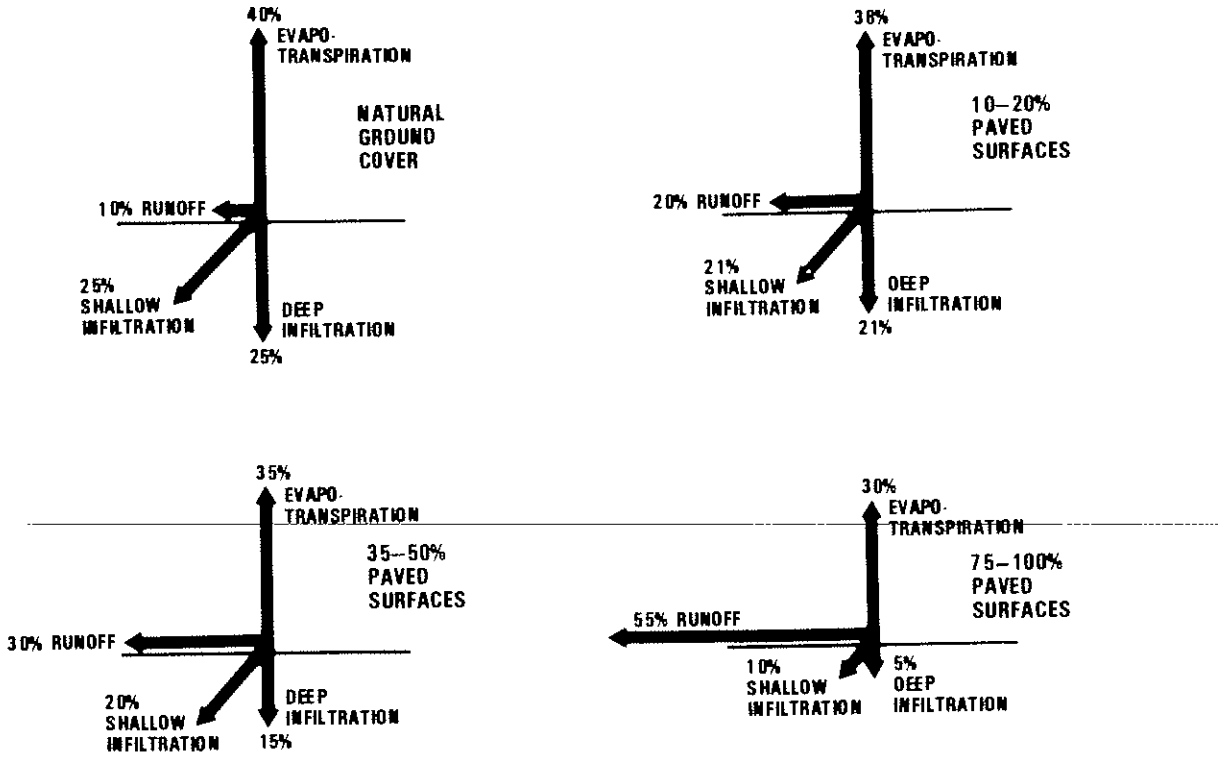

Source: J.T. Tourbier and R. Westmacott, *Water Resources Protection Technology: A Handbook of Measures to Protect Water Resources in Land Development*, p. 3.

Figure 4-1. Typical Changes in Runoff Flows Resulting from Paved Surfaces

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Stormwater management can and should be directed toward two goals: the control of runoff flows (i.e., volumes and rates) and the control of pollutants in stormwater. Control measures which emphasize the storage of runoff rather than the immediate conveyance from the site and from the community often provide benefits which meet both goals. Stormwater storage and conveyance measures, however, affect the community in a variety of ways. Through stormwater management planning the effects of alternative policies, programs, control measures, and financing schemes can be evaluated.

Stormwater management planning is directed toward basic policy questions, such as:

- What should be done with runoff from the land?
- Is the temporary (detention) or permanent (retention) storage of stormwater runoff desirable?
- Under the circumstances, should retention basins, detention basins, natural infiltration areas, or dished parking lots be used to store runoff?
- What requirements should be placed on new developments?
- Do stormwater runoff problems in developed areas warrant special attention?
- Should communal retention or detention facilities be provided by the local jurisdiction? If so, how can such areas be financed?
- Who should pay for retention and detention facilities on private property?
- Are the local jurisdictions already carrying out programs (such as parkland acquisition programs or wetlands regulation) which affect stormwater runoff? Can programs and/or regulations be coordinated to achieve multiple purposes?
- Should enclosed drains or natural channels be used to convey stormwater to and from storage areas?
- Can routing and storage be provided for major storms (e.g., 100-year frequency) as well as minor storms (e.g., 10-year frequency)?
- Who should be responsible for facility maintenance?

The specific questions to be addressed in a local government planning program will vary among local jurisdictions, reflecting varying problems and community objectives. The answers to these questions may take the form of policy statements, changes in regulations or engineering design standards, technical assistance materials for landowners or consulting engineers, revisions to existing programs, or a written plan document.

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Because stormwater management planning for quantity and quality control is relatively new, and because community stormwater concerns differ, there are no easy formulas for preparing stormwater management plans.

Stormwater Runoff as a Community Resource

Although, stormwater management programs are typically undertaken to avoid problems (e.g., flooding, pollution, lawsuits), effective planning can also be used to pursue potential community benefits. When effectively managed, stormwater can provide benefits such as:

- Recharge of groundwater supplies;
- Water quality enhancement;
- Recreational opportunities (e.g., use of large retention areas for boating, fishing, or nature study);
- Replenishment of wetlands which serve as wildlife habitats, absorb peak floods, and naturally break down certain pollutants;
- Maintenance of summertime lake levels and stream flows; and
- Enhancement of community appearance and image when facilities are attractively designed.

The Role of Local Governments

In some cases, the institutional systems for stormwater management may need to be complex, largely because State, county, and local agencies' policies, regulations, and procedures may all affect stormwater control within a particular development. For example, in Michigan, the following roles apply:

- County drain commissioners construct and manage county drains and also review subdivision plans to assure adequate drainage.
- County highway departments affect drainage in new developments by regulating connections to roadside drains and ditches.
- The State Department of Natural Resources regulates wetlands, dam construction, and floodplain alterations.
- The State Water Resource Commission issues permits for certain stormwater discharges when known water quality problems can be linked with a particular activity, (e.g., certain storm drains, animal feeding operations, industrial parking lots).
- Both the State Department of Public Health and county drain commissioners regulate drainage in proposed mobile home parks.
- County agencies and certain local governments issue erosion and sediment control permits for certain development sites.

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Furthermore, there has been increasing emphasis upon the consideration of environmental factors in land use decisions. Recent amendments to the City or Village Zoning Act and the Township Rural Zoning Act have clarified the legal authority of local governments to complete site plan reviews for environmental management purposes. Standards for the review of land uses must be included in local ordinances and take natural resource preservation into account. The Michigan Environmental Protection Act (MEPA) (Act 127, P.A. of 1970) places a duty on all government agencies to prevent or minimize water pollution and other environmental problems while carrying on regular activities. Section 5(2) of MEPA addresses the actions of local officials in the following terms:

> In any ... administrative, licensing or other proceedings, and in any judicial review thereof, any alleged pollution impairment or destruction of the air, water or other natural resources or the public trust therein, shall be determined, and no conduct shall be authorized or approved which does, or is likely to have such effect so long as there is a feasible and prudent alternative consistent with the reasonable requirements of the public health, safety and welfare.

Environmental aspects of stormwater runoff may be addressed by local officials in response to MEPA.

None of the above laws specifically require local governments to undertake stormwater management programs. Instead, local governments have a wide range of possible roles available to them. Stormwater management planning programs can be directed toward the review of existing State and county programs affecting stormwater runoff and toward the evaluation of alternative roles for the local government.

Possible roles for local governments in stormwater management include the following:

- Planning - The term "stormwater management planning" refers to the process of developing policies, programs, regulations, and other recommendations to chart the future course of the community in terms of stormwater management. Such planning can address existing problems or help to avoid future problems and community expenses.

- Regulations - Stormwater runoff control for each site plan and subdivision plan can be reviewed and approved by the local government.

- Design and Construction - Storm drainage facilities (e.g., pipes, basins, areas for retention) can be designed and constructed by the local government. Purchase of lands to serve as community stormwater retention areas may also be undertaken.

- Inspection and Maintenance - Requirements for regular inspection and maintenance of stormwater facilities, including drains and retention or detention basins, may be enforced by

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local governments. Requirements for easements are usually part of maintenance programs. Local governments may choose to undertake maintenance as a community service (such as a utility) or may require maintenance through contractual agreements with property owners.

The types of programs developed and the role assumed by a local government should, of course, reflect available financing options as well as program needs and management gaps.

FINANCIAL AND INSTITUTIONAL CONSIDERATIONS[2]

The traditional planning approach would ideally culminate in the successful implementation of a detailed design. In many cases, however, this objective is not accomplished due to financial and institutional constraints. Often a study team will fail to adequately consider such institutional and financial issues as who will manage the system and how will it be financed, thus creating a gap between technical planning and implementation. This omission is illustrated in Figure 4-2.

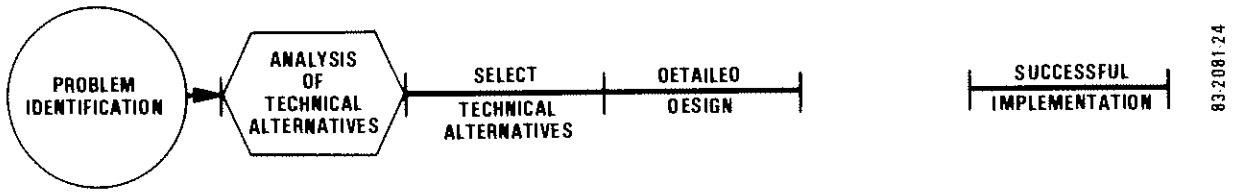

Figure 4-2. Incomplete Water Quality Planning

The implementation gap that results from the traditional planning approach has occurred all too often in attempts to control urban runoff.

As an illustration of the need to integrate financial and technical planning, consider the traditional process for developing a program to control construction runoff. A typical outcome of the process is a new ordinance. To reach this outcome, some of the issues that are normally considered from the technical perspective include:

- What are the technical construction requirements to be set out in the ordinance?
- What control measures will be required?
- How will compliance be monitored?

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[2] This material is largely from the draft document, Planning for Urban Runoff Control: Financial and Institutional Issues, December 1981, prepared for FMAP by the Government Finance Research Center of the Municipal Finance Officers Association, Washington, D.C.

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To balance the planning process, this technical analysis should be expanded to include financial and institutional issues such as:

- Does the city have legal authority to implement each requirement in an ordinance?

- How much will each cost, and who will pay for implementation of the control measures?

- Who will conduct compliance review, and who will pay for the reviews?

Numerous additional factors increase the need for financial and institutional analysis in all water quality management planning. Examples might include:

- Implementation of control programs occurs at the local level, and local budgets are being tightened as water quality expenditures compete with other local demands.

- Benefits from water quality projects are difficult to quantify and often accrue to people living downstream.

- It is becoming more difficult to obtain municipal funds through the bond market because of high interest rates.

- The cost of pollution controls is often sizable and difficult to allocate to specific polluters or beneficiaries.

These problems affect most areas of water quality management, but they are especially important in identifying and implementing solutions to urban runoff pollution.

Integrated Approach

An integrated planning approach helps water quality planners make the best control decisions in light of many complex issues. This approach takes the traditional planning process and adds to it financial and institutional elements at each step along the way. This integration is shown in Figure 4-3, with the traditional approach illustrated along the upper track and the financial and institutional elements added along the lower track.

During the early planning stages, financial and institutional issues are reviewed on a preliminary basis. This information becomes more detailed and refined as planning proceeds. Ultimately, the information forms the basis for a financial and institutional plan that supports the detailed design of a control alternative.

When very complex problems are being evaluated, it may be advisable to use a preliminary matrix early in the evaluation process for screening-out unacceptable alternatives. This approach permits a more detailed evaluation of issues surrounding the two or three best alternatives before a final selection is made. An example of a preliminary matrix is given in Figure 4-4.

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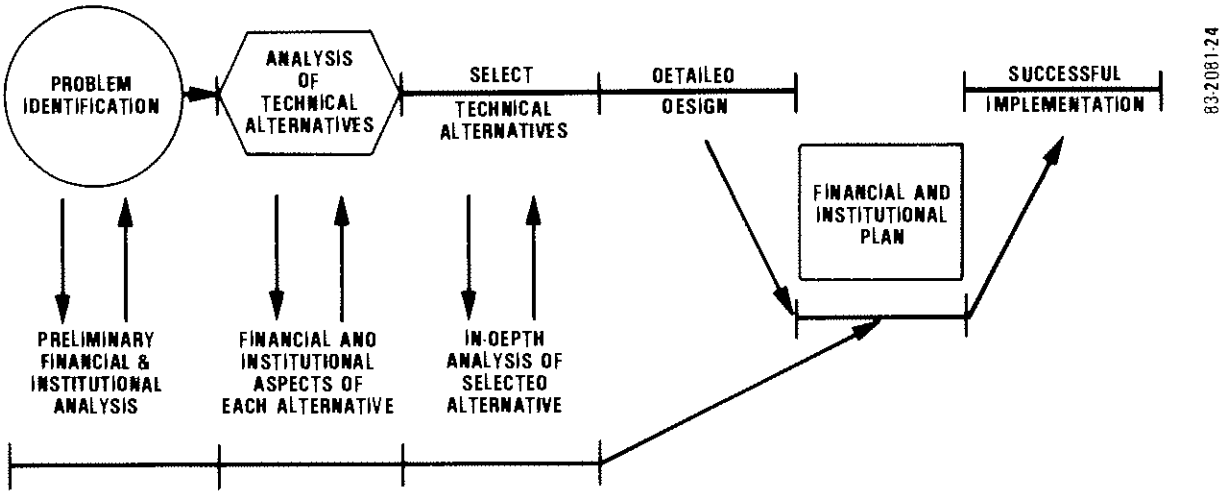

Figure 4-3. Integrated Water Quality Planning

CONTROL APPROACH	TECHNICAL DESCRIPTION	EFFECTIVENESS IN CONTROLLING POLLUTION	FINANCIAL ISSUES		INSTITUTIONAL ISSUES
			NET PRESENT VALUE	ABILITY TO PAY	
• SEPARATE SEWERS	CONSTRUCT NEW STORM SEWERS IN COMBINED AREAS	100% EFFECTIVE IN ELIMINATING CSOs	$1 BILLION	EXCEEDS CITY'S BONDING CAPACITY	EXISTING INSTITUTIONS COULD HANDLE THE PROJECT
• SELECTIVE EXPANSION OF UNDERSIZED TRUNK SEWERS	REMOVE BOTTLENECKS, REDUCE NUMBER OF OVERFLOW EVENTS	50% EFFECTIVE	$200 MILLION	IF STAGED OVER 10 YEARS, COULD BE FINANCED BUT WOULD RESTRICT OTHER PROGRAMS	EXISTING INSTITUTIONS COULD HANDLE THE PROJECT
• CONSTRUCTION OF DETENTION BASINS	CONSTRUCT 10 DETENTION BASINS SIZED TO HOLD THE FIRST FLUSH FROM A STORM	30% EFFECTIVE	$50 MILLION	IF STAGED OVER 5 YEARS, COULD BE FINANCED; COULD RESTRICT OTHER PROGRAMS	NEW ORGANIZATION MIGHT BE NEEDED TO MAINTAIN AND OPERATE BASINS

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Figure 4-4. Preliminary Matrix for Selection of a Control Approach (Combined Sewer Overflows)

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Once a control approach is selected, a detailed design and a financial and institutional plan can be prepared. Figure 4-5 illustrates the major features of a financial and institutional plan. Key features of the detailed analysis required to prepare this plan are discussed in the following section.

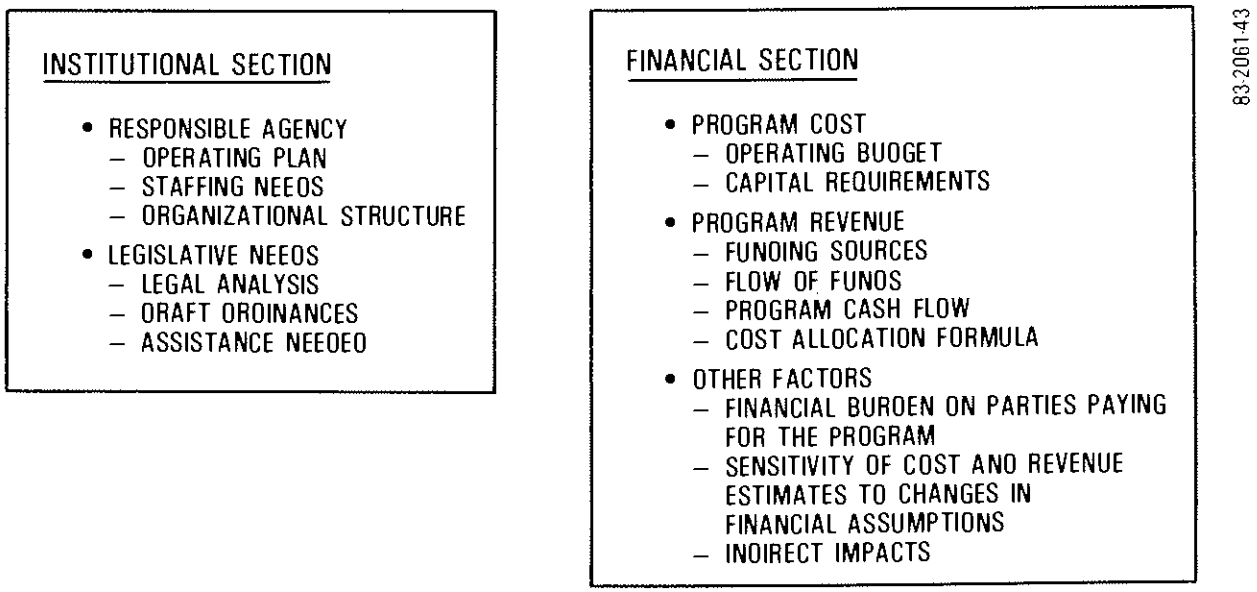

Figure 4-5. Major Components of a Financial and Institutional Plan

Key Financial and Institutional Elements

There are six essential elements[3] of financial and institutional analysis which provide a structure for the integrated planning process;

- institutional assessment,
- cost analysis,
- revenue analysis,
- ability-to-pay analysis,
- sensitivity analysis, and
- indirect impact analysis.

[3] These elements were first defined in Planning for Clean Water Programs: The Role of Financial Analysis, U.S. EPA's Financial Management Assistance Program by the Government Finance Research Center of the Municipal Finance Officers Association, September 1981.

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Each of these elements threads through the planning process and becomes more definitive as the process proceeds. The following discussion defines each element and identifies its major features.

Institutional Assessment

The institutional assessment identifies the organizations or participating agencies that would be affected or involved in implementing a particular control program. The role of each entity in a program is evaluated with respect to its interest in solving the problem and its planning, management, operating, and regulatory capabilities. If the study team identifies an urban runoff problem, a preliminary institutional analysis can provide insight into capabilities of agencies that may be asked to play a role in the implementation and can, in some cases, aid in determining the types of technical alternatives that are analyzed.

The key factors to consider in evaluating an agency's capabilities are its statutory authority and organizational ability. In order to control urban runoff, an agency must have or be able to obtain the authority to implement a control measure. The authority of an agency can be assessed by thoroughly reviewing applicable federal, state, and local legislation. This review helps to determine which agency can best manage a given problem and highlights areas where additional legislation or local ordinances are needed.

Cost Analysis[4]

A cost analysis is performed to identify the additional capital, operational, maintenance, and administrative costs of each activity that is part of a control program. These costs are estimated for each agency responsible for an activity. Cost estimates are prepared in uninflated dollars (using today's cost for all projections into the future) and brought back to their present value (or present worth) for comparison among alternatives. The interest rate to be used in the present value analysis is the agency's current interest rate for borrowing funds minus the expected rate of inflation.[5]

Cost analysis of control alternatives is included in increasing detail in each step of the planning process. It begins with "ball park" estimates in early stages which are refined as the process progresses and finalized in the detailed financial plan.

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[4] A substantial part of this material is from a report, Collection of Economic Data from Nationwide Urban Runoff Program Projects, prepared for EPA by the Midwest Research Institute, 425 Volker Boulevard, Kansas City, MO 64110.

[5] For a further discussion of present value analysis, see pp 36 to 42 of Facilities Planning 1981, U.S. Environmental Protection Agency, FRD-20, 1981.

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Cost estimates cannot be static. They are prepared on a preliminary basis when an alternative is first considered and detail is added as an alternative becomes more feasible. As the planning process progresses, estimates are updated on a regular basis to account for changing costs.

To update and improve available data on the costs of specific urban runoff BMPs, EPA conducted a program to guide, assist, and coordinate the efforts of selected NURP projects in gathering cost data on the BMPs and BMP systems which they were evaluating as part of the NURP national workplan. A report[6] was prepared to summarize the preliminary economic data submitted by the NURP projects. Economic data were submitted for street sweeping, detention basins, catch basin cleaning, ocean discharge control systems, and a public education/information program by nine projects. The data must be considered preliminary and subject to change, particularly annual operating cost data. Most of the capital cost data are well documented and represent the actual cost of the BMP control and will not change. The annual operating cost data, however, range from detailed analyses to estimates, and some of the data reported are incomplete. Since most of the projects were still in progress, incomplete operating cost data were to be expected.

The capital costs of street sweepers varied from $21,988 (in 1975) to $40,000 in 1981. The annual operating costs of street sweeping programs varied from $53,445 to $1,138,097. The unit cost varied from $16.80 to $45.45 per hour of operation, and from $5.95 to $23.36 per curb-mile swept. This wide range indicates that many variables affect the actual cost of operating a street sweeper.

The installed capital costs of recharge basins in Fresno, California, ranged from $933,750 to $5,587,000. BMP modifications to three detention basins in Oakland County, Michigan, cost $2,345 to $8,442. The installed capital cost of the modifications to the wet pond in the Lansing, Michigan project was $50,149. Construction of the wet pond in the Salt Lake County, Utah project cost $41,138; modifications to the dry pond included placing aluminum plates in an existing underdrain and installing a redwood outlet skimmer at a nominal cost of $371.

The annual operating costs of the Fresno, California, basins range from $1,625 to $7,975. The annual cost for the basin in Lansing, Michigan is incomplete and includes only the interest cost on a 7 percent, $38,500 bond used to help finance the project. The annual operating costs for the ponds in the Salt Lake County, Utah project were estimated at $560 for the wet pond and $200 for the dry pond.

The costs of the structural control alternatives to control discharge to the ocean in Myrtle Beach, South Carolina, were presented in detail and are valid estimates of the costs that will be incurred if one of them is constructed.

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[6] Collection of Economic Data From Nationwide Urban Runoff Program Projects - Final Report, April 7, 1982, EPA Contract No. 68-01-5052. Detailed cost data provided by the projects are included in the appendices of this Report to show how the various projects prepared the data for submission.

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The 1980 construction cost estimates ranged from $32,849,200 to $50,973,500, and the annual operating cost estimates ranged from $3,735,400 to $5,301,900. The cost of the public education program at Salt Lake County, Utah, was estimated at $1,550. The project will report the actual cost of the program upon its completion.

Revenue Analysis

The revenue analysis identifies the funding sources needed to match the estimated cost for control activities by participating agencies. This analysis is important because it ensures adequate funding to implement the technical solution to an urban runoff problem.

There are three categories of funding that are typically used to pay for runoff control: Federal and State funds, local public funds, and private funds. These sources include a variety of different financing mechanisms, each with advantages and disadvantages. The use of any or a combination of these sources requires consideration regarding:

- Revenue adequacy - Will funds be available in the long- and short-term?

- Equity - Are the beneficiaries of the control program paying their full share?

- Economic efficiency - Is the charge that is assessed equal to the social cost of the program?

- Administrative simplicity - Can the funds be managed and directed to the control program without significant administrative problems?

Ability-to-Pay Analysis

The ability-to-pay analysis evaluates the implementing agencies' and the individual user's ability to pay for the proposed program by determining how reasonable a proposed revenue program is in terms of its overall impact on the community as a whole as well as on individual residents.

For a given revenue source, the additional burden of the program is expressed as a percentage of the base costs. For example, if the proposed program is to be financed by property taxes and it adds $.50 to a $1,000 tax bill, the additional tax burden is .05 percent. In this instance, it would appear that the homeowner's ability to pay is quite high.

An important factor to remember is that programs to control urban runoff are not the only programs that are placing a burden on the people or institutions who must support them. Hence, the cost of a control program may not be excessive but cannot be imposed because ability to pay has already been exceeded due to other projects.

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Sensitivity Analysis

The sensitivity analysis identifies the extent to which local ability to pay varies with changes in the assumptions used to estimate costs and revenues. Major assumptions that influence costs and revenues are: phasing of capital improvement, anticipated local funding requirements, rate of inflation, growth rate, and local fee policies.

The first step in this analysis is to determine a range of values for key cost and revenue assumptions that could occur during the program. (For example, inflation may vary between 5 percent and 15 percent.) The ability-to-pay analysis is then repeated using the high and low values for these assumptions. The final step is to evaluate the changes in burden with "best-" and "worst-" case situations in comparison with burden under the "most likely" assumption.

The purpose of this analysis is to identify control programs that are least vulnerable to changing conditions. It also helps to make the planner aware of best- and worst-case scenarios so that contingency plans can be developed to cope with such events.

Indirect Impact Analysis

The indirect impact analysis is an assessment of the costs and benefits that are not directly attributable to a proposed program. These costs and benefits can be economic, social, and/or environmental. Quantifying the indirect impacts of a program is usually quite difficult, so the planner generally resorts to qualitative measurement.

An Example: Planning an Educational Program

To illustrate further the process of identifying and resolving the financial and institutional issues connected with implementation of an urban runoff control program, the following spells out the steps involved in evaluating one control approach applicable in already developed areas. The example chosen is an educational program to inform citizens, industry, and public agencies of the problems caused by runoff-borne lawn and garden chemicals, oil and chemical residuals from industrial yards, and pesticides, herbicides, and fertilizer from parks and golf courses.

In this example, the activities would include: development of an informational brochure, including printing and distribution, and maintenance of an information center. In Figure 4-6, the institutional characteristics needed to accomplish these activities are compared with the capabilities of existing agencies. The matrix shows that the County Department of Pollution Control could provide the technical input to the Public Information Center to write the brochure. The Council of Governments might coordinate the effort and assume overall responsibilities for getting the job done.

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INSTITUTIONAL CHARACTERISTICS NEEDED	AGENCIES					
	STATE	COUNCIL OF GOVERNMENTS	DEPARTMENT OF POLLUTION CONTROL	DEPARTMENT OF PLANNING	PUBLIC INFORMATION CENTER	CHAMBER OF COMMERCE
• COMMITMENT TO PROGRAM GOALS	*	*	*	*	*	*
• WORKING KNOWLEDGE OF EACH WASTE CONTRIBUTION TO THE RUNOFF PROBLEM	*	*	*	*		
• ABILITY TO WRITE CLEAR AND CONCISE INFORMATION FOR THE PUBLIC					*	
• ABILITY TO PRINT AND AND DISTRIBUTE BROCHURE				*		* DISTRIBUTE TO INDUSTRY
• STAFF TO RECEIVE FOLLOWUP CALLS		*				
• ABILITY TO ACCEPT FUNDS FROM SEVERAL AGENCIES TO PAY FOR THE PROGRAM		*				

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Figure 4-6. Institutional Assessment for Educational Program to Control Chemical Substances

Cost Analysis. Cost analysis determines the additional funds needed to implement a control alternative, including capital improvements and operation and maintenance. Additional administrative costs are less significant because most of these projects are undertaken by a public agency that is already performing the function to some extent.

Capital cost estimates are best prepared by the water quality planner with the assistance of the municipal engineer and in some cases his/her outside engineering advisor. These estimates identify all costs related to the purchase of a new facility or piece of equipment for a project and may require some research into vendor prices and bids on similar projects around the country. For programs which require changes to existing practices (street sweeping, etc.), the cost attributable to the water quality program is the incremental cost of the program.

Ultimately, the cost analysis is used to identify the least-cost method(s) for reducing pollution problems. It is important to remember that all costs associated with a given program must be considered. It is incorrect to assume that educational efforts, for example, are provided at no additional cost.

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As an example of a cost analysis, a possible budget sheet for the educational program for the current year is presented in Figure 4-7.

ACTIVITIES	AGENCIES					
	STATE	COUNCIL OF GOVERNMENTS	DEPARTMENT OF POLLUTION CONTROL	DEPARTMENT OF PLANNING	PUBLIC INFORMATION CENTER	TOTAL
1. DEVELOP BROCHURE					$13,000	$13,000
2. PRINT BROCHURE				$1,500		$ 1,500
3 DISTRIBUTE BROCHURE				$ 800		$ 800
4. CONDUCT INFORMATIONAL MEETINGS	$2,000	$ 5,500	$2,000			$ 9,500
5. STAFF FOLLOWUP FOR PROGRAM		$24,000				$24,000
TOTAL	$2,000	$29,500	$2,000	$2,300	$13,000	$48,800

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Figure 4-7. Cost Analysis for Educational Program to Control Chemical, Herbicide, Fertilizer and Pesticide Runoff

Revenue Analysis. After the program cost estimate is prepared, the potential sources of revenue are analyzed. There are several critical factors in analyzing revenue for urban runoff programs including:

- Cost/Revenue Balance - Will the revenues be sufficient to cover the costs on an annual basis?

- Equitable Allocation of Costs to Different Groups - Do those who contribute to the problem pay their fair share? Do those who benefit from the program pay their fair share?

- Revenue Agreement - Do groups understand their participation in a program and its revenue formula? Have written agreements which define the cost allocation procedure been prepared ?

Revenue analysis will vary with the type of control approach selected. The critical factor in the revenue analysis is the identification of each entity that will provide revenues and the development of an understanding by that entity of the problem, the control approach, and its share of the cost.

Ability-to-Pay Analysis. Most of the costs to control runoff from developed areas are imposed on the general public or the benefiting population as a new and additional governmental expense. The ability-to-pay analysis evaluates this increased burden on the local community as a percentage of property taxes, average income, property evaluation, or other appropriate measures.

Figure 4-8 illustrates an ability-to-pay analysis for the educational program example. The key parameters to determine homeowners' ability to pay in this case are the cost of the program per household, cost as a percentage of average annual household income, and cost as a percentage of property taxes.

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A. TOTAL PROGRAM COST (ONE-YEAR PROGRAM)	$48,000	
B. NUMBER OF HOUSEHOLDS AFFECTED	19,000	
C. COST PER HOUSEHOLD (A DIVIDED BY B)		$2.57
D. MEDIAN HOUSEHOLD INCOME	$14,700	
E. COST AS A % OF MEDIAN HOUSEHOLD INCOME (C DIVIDED BY D TIMES 100)		.02%
F. AVERAGE ANNUAL PROPERTY TAXES	$ 1,200	
G. COST AS A % OF PROPERTY TAXES (C DIVIDED BY F TIMES 100)		.21%

CONCLUSION: PROGRAM APPEARS TO NOT PLACE EXCESSIVE BURDEN ON LOCAL HOMEOWNERS

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Figure 4-8. Ability to Pay Analysis for Educational Program to Control Chemical, Herbicide, Fertilizer and Pesticide Runoff

Sensitivity Analysis. The sensitivity analysis will vary depending upon the revenue mechanism and program selected for implementing a proposed program. The most common revenue mechanisms for programs controlling runoff from developed areas are general funds and fees. Analyzing the sensitivity of general revenues requires a review of past collections relative to key parameters--inflation, housing starts, collection rates, capital improvements, and so on. Collections are then projected for worst and best case scenarios.

An additional consideration in the sensitivity analysis is revenue requirements. This relates to phasing a program, either handling capital improvements or starting a program on a limited basis with expansion to come in later years. For any one program, numerous options exist for staggering cash flows, and different scenarios should be developed to assess their impact on the program as part of the sensitivity analysis.

Indirect Impact. The indirect impact of a runoff control program for developed areas are extremely difficult to quantify. Educational programs will raise community awareness regarding the impacts of local activities on water pollution. Other indirect impacts from control programs may relate to recreational benefits, local improvements in quality of life, and increased tourism.

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RELATIONSHIP BETWEEN NURP AND WQM PLANS

Of the locations selected for projects under the NURP effort, some 80 percent had state-approved (i.e., certified by the Governor) water quality management (WQM) plans with elements which addressed urban runoff. For 5 of these locations, the NURP project constituted the urban runoff element of the plan. For the other locations, however, the original 208 effort was unable to develop the necessary information on either water quality effects or performance of best management practices (BMPs) to justify structuring formal implementation plans for urban runoff control. Consequently, the typical WQM plan elements dealing with urban runoff identified the need for further study, usually specifying problem assessment and BMP performance evaluation. These elements became the focal points of the activities funded by NURP.

The WQM plans for the remaining 20 percent of the locations which participated in the NURP program did not contain a specific urban runoff element. Presumably this was due to time and resource constraints in relation to other issues which were assigned higher priorities in planning efforts. In these cases, the NURP projects provided the opportunity to address a water quality issue not adequately addressed in the original 208 planning studies.

Over two-thirds of the NURP project locations reported that NURP findings and recommendations have or will be incorporated in the next annual update of their formal WQM plans. The remainder generally indicate that they expect the planning issues to be addressed at the local level or that NURP results will support planning and implementation activities, even though they do not anticipate formal incorporation in WQM plans at this time.

Over half of the NURP project locations report either active or planned implementation efforts based on the results of NURP. Thirty percent indicated that no implementation is being planned because the need for or value of urban runoff control was not demonstrated. The balance (20 percent) of the NURP locations suggest that while implementation activities are not currently planned, they expect NURP results to influence future deliberations on this issue.

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CHAPTER 5
METHODS OF ANALYSIS

INTRODUCTION

This chapter identifies and briefly discusses the methods adopted to assemble and analyze the large data base developed by the NURP projects and also provides the methods employed to develop and interpret results. The chapter is structured according to the three prime areas of program emphasis; (1) characteristics of pollutants in urban runoff, (2) water quality effects of urban runoff discharges including water quality criteria/standards violations and impairment or denial of beneficial uses of receiving water bodies, and (3) the effectiveness of control measures to reduce pollutant loads.

The procedures employed in this assessment were designed to provide generalized results and findings about urban runoff issues of interest for nationwide use. This national perspective, and the need to consider the fundamental variability of urban runoff processes, has prompted some significant advancements in the application of statistical methods and models. The basic methods used were, however, largely developed under different EPA efforts, many under the sponsorship of the Office of Research and Development, or other programs. In some cases, similar or equivalent procedures were applied in individual NURP projects; in other cases, methods adopted by individual projects in response to local needs and interests were different. Where possible, comparisons have been made between either detailed results, or conclusions drawn from such results, as derived from both local and national perspectives.

The descriptions provided in this chapter are brief and intended to communicate the technical framework upon which the results and conclusions are based. More detailed information on the methods and techniques are contained in other documents developed by NURP. Pertinent NURP reports cover, in separate volumes, probabilistic methods for analyzing water quality effects, detention and recharge basins for control of urban stormwater quality, and street sweeping for control of urban stormwater quality. The Data Management Procedures Manual, another of the project documents, is an additional source of information on details of the analysis methods utilized.

Because field measurements and sampling formed one of the most important information sources, it was essential that the monitoring and analysis programs produce consistent and sound data. Accordingly, NURP required that all projects adopt Quality Assurance/Quality Control elements as integral parts of their work plans. Key components of these plans include the following:

- Program Coordination. Projects were required to designate a QA/QC coordinator, responsible for the entire QA/QC effort.

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- Field Quality Assurance. Guidance was provided to the projects for all key aspects of the data collection process.

- Laboratory Quality Assurance. A manual prepared by EPA's Environmental Monitoring and Support Laboratory was provided to all projects and contained analytical quality control information.

- Data Management. A manual entitled "Data Management Procedures" was provided to all projects and covered such topics as data formatting, data reduction, and some analysis.

- Data Analysis. To encourage innovative approaches and responsiveness to local conditions, uniform methods of data analysis were not stressed. Technical guidance and mandatory review of analytical procedures were provided.

RUNOFF POLLUTANT CHARACTERISTICS

al

stantial component of the individual NURP projects was the acquisition subsequent analysis) of a data base for a number of storm events, con- ng of precipitation and the resulting quantity and quality of runoff a number of local urban catchments. One of the principal EPA objectives e analysis of these data has been to develop a concise summary of the cteristics of urban runoff. There are a number of questions concerning runoff characteristics which need to be addressed for water quality ing purposes, including what are the appropriate measures of the statis- characteristics of urban runoff (e.g., population distribution, central ncy, variability, etc.)? Do distinct subpopulations exist and what are characteristics? Are there significant differences in data sets ed according to locations around the county (geographic zones), land season, rainfall amount, etc.? How may these variations be recognized? s the most appropriate manner in which to extrapolate the existing data to locations for which there are no or limited measurements? Though questions cannot be fully answered given the current state of knowledge ning urban runoff, these are the types of issues addressed by the ls described in this chapter and the results presented in Chapter 6.

rincipal thrust of the individual NURP projects, and thus this nation- assessment report, was the characterization of what has been adopted as lard Pollutants" of primary concern in urban runoff. These include , oxygen consuming constituents, nutrients, and a number of the more ly encountered heavy metals. The methods used to characterize these rd pollutants are described under a separate heading below.

roximately two-thirds of the NURP projects the occurrence of compounds s list of "Priority Pollutants" was investigated. This program element so described under a separate heading below. A number of additional have also been addressed in the program. These are briefly discussed

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below because they relate closely to the general issue of pollutant characteristics. These include the following:

- Soluble vs Particulate Pollutant Forms. The distribution of soluble and particulate forms of a pollutant in urban runoff (particularly metals and nutrients) was examined in both the standard conventional pollutant and priority pollutant aspects of the study because certain beneficial use effects depend strongly on the form in which the contaminant is present. The priority pollutant program additionally determined "Total Recoverable" fractions, corresponding to contaminant forms used in EPA's published toxic criteria guidelines.

- Coliform Bacteria. Fecal coliform bacteria counts (and in some cases total coliform and fecal streptococcus as well) in urban runoff were monitored during a significant number of storms by seven of the NURP projects. Though the data base for bacteria is restricted, useful results are provided in Chapter 6.

- Wetfall/Dryfall. As part of program elements designed to examine sources of pollutants in urban runoff, a number of projects operated atmospheric monitoring stations for characterizing pollutant contributions from precipitation (wetfall) and from dry weather deposition (dryfall). Results of this work are reported in individual project reports and not included herein.

Standard Pollutants

The following constituents were adopted as standard pollutants characterizing urban runoff:

TSS - Total Suspended Solids
BOD - Biochemical Oxygen Demand
COD - Chemical Oxygen Demand
TP - Total Phosphorus (as P)
SP - Soluble Phosphorus (as P)
TKN - Total Kjeldahl Nitrogen (as N)
NO_{2+3}-N - Nitrite + Nitrate (as N)
Cu - Total Copper
Pb - Total Lead
Zn - Total Zinc

The list includes pollutants of general interest which are usually examined in both point and nonpoint source studies and includes representatives of important categories of pollutants--namely solids, oxygen consuming constituents, nutrients, and heavy metals.

The pollutant concentrations found in urban runoff vary considerably, both during a storm event, as well as from event to event at a given site and from site to site within a given city and across the country. This variability is the natural result of high variations in rainfall intensity and occurrence,

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geographic features that affect runoff quantity and quality, and so on. Considering this situation, a measure of the magnitude of the urban runoff pollution level and methods for characterizing its variability were needed. The event mean concentration (EMC), defined as the total constituent mass discharge divided by the total runoff volume, was chosen as the primary measure of the pollutant load. The rationale for adopting the EMC for characterizing urban runoff is discussed in the receiving water effects section of this chapter as well as in subsequent chapters. Event mean concentrations were calculated for each event at each site in the accessible data base. If a flow-weighted composite sample was taken, its concentration was used to represent the event mean concentration. Where sequential discrete samples were taken over the hydrograph, the event mean concentration was determined by calculating the area under the loadograph (the curve of concentration times discharge rate over time) and dividing it by the area under the hydrograph (the curve of runoff volume over time). Details of the calculation procedure have been described in the Data Management Procedures Manual. For the purpose of determining event mean concentrations, rainfall events were defined to be separate precipitation events when there was an intervening time period of at least six hours without rain.

A statistical approach was adopted for characterizing the properties of EMCs for standard pollutants. Standard statistical procedures were used to define the probability distribution, central tendency (a mean or median) and spread (standard deviation or coefficient of variation) of EMC data. EMC data for each pollutant from all storms and monitoring sites were complied in a central data base management system at the National Computer Center. The SAS computer statistical routines and other standard statistical methods were used to explore and characterize the data. The statistical methods used are, for the most part, not explained in this report since these are readily available in the literature. Nor are the operations of the SAS routines, which are available at most computer centers.

The underlying probability distribution of the EMC data was examined and tested by both visual and statistical methods. With relatively few isolated exceptions, the probability distribution of EMCs at individual sites can be characterized by lognormal distributions. Given this, concise characterization of the variable urban runoff characteristics at each of the sites is defined by only two values, the mean or median and the coefficient of variation (standard deviation divided by mean). Because the underlying distributions are lognormal, the appropriate statistic to employ for comparisons between individual sites or groups of sites is the median value, because it is less influenced by the small number of large values typical of lognormal distributions and, hence, is a more robust measure of central tendency. However, for comparisons with other published data which usually report average values and for certain computations and analyses (e.g., annual mass loads), the mean value is more appropriate.

Relationships among a number of statistical properties of interest are easily determined when distributions are lognormal. Figure 5-1 illustrates some relationships for lognormal distributions. In (a) the frequency distributions of two variable data sets which are log-normal and have the same median are shown. The log transforms of the data result in normal bell

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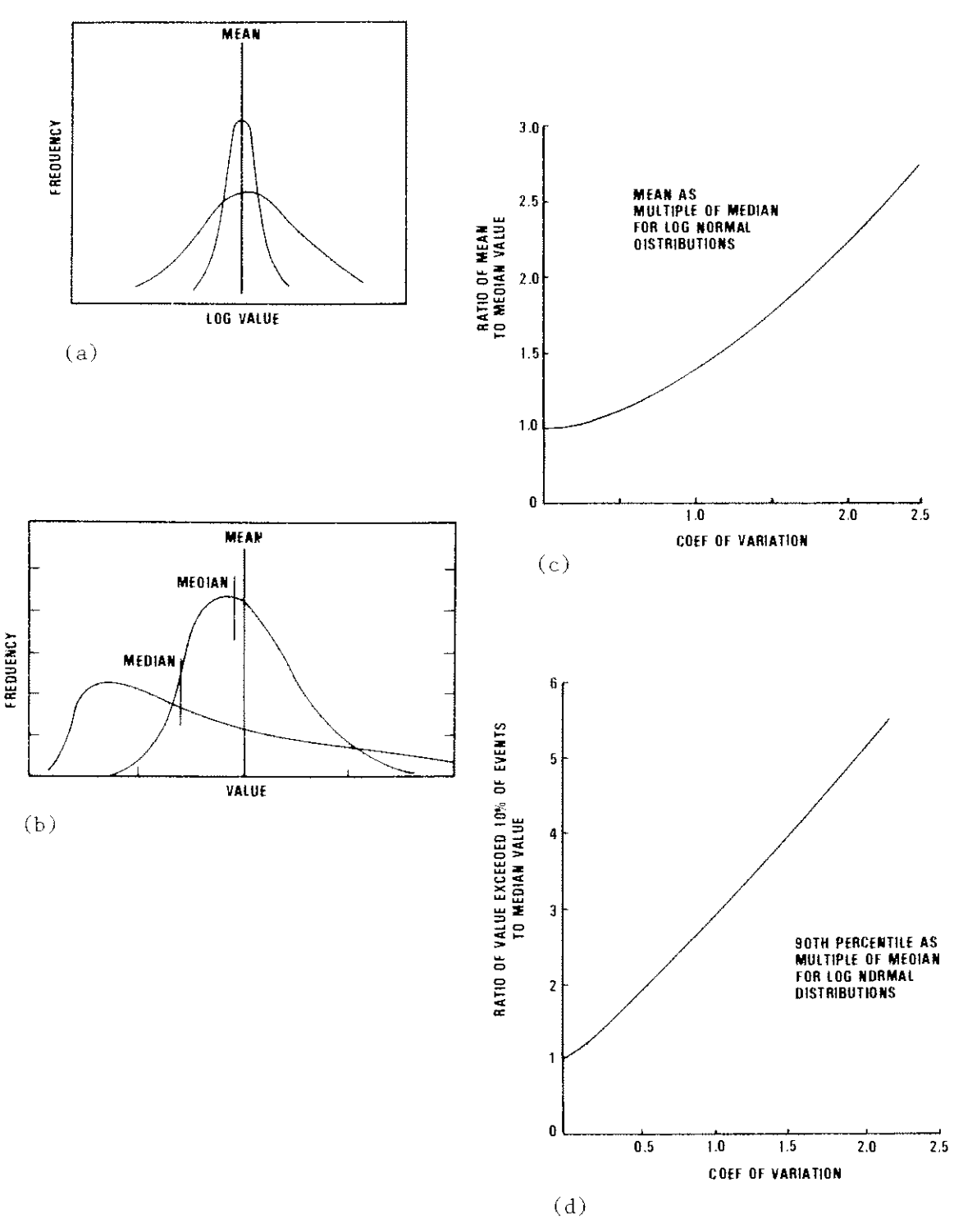

Figure 5-1. Lognormal Distribution Relationships

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shaped distributions; more variable data (higher coefficient of variation) result in a greater spread. Frequency histograms prepared using untransformed data values produce skewed distributions, as shown by (b) which illustrates two data sets which have the same arithmetic mean. The effect of coefficient of variation is shown as well as the relation between mean and median for lognormal distributions. An established relationship exists between median and mean, as shown by (c) and described by:

$$\frac{\text{Mean}}{\text{Median}} = \sqrt{1 + (\text{Coef Var})^2}$$

When a distribution is known to be lognormal the best estimate of the population mean is that derived from the lognormal relationships. For small samples it can be expected to be different than the result of a straight arithmetic averaging of sample data; the two estimates of the mean will give similar values when the number of samples is very large.

In addition, the expected value at any probability or frequency of occurrence (X_α) can be determined by:

$$X_\alpha = \exp\ (\mu_{lnx} + Z_\alpha\ \sigma_{lnx})$$

where:

Z_α = the standard normal probability

μ_{lnx} = mean of log-transformed data

σ_{lnx} = standard deviation of log-transformed data

X_α can be expressed as a ratio to the median value by the following equation which defines the ratio in terms of the coefficient of variation

$$\frac{X_\alpha}{\text{Median}} = \exp\ (Z_\alpha \sqrt{\ln\ (1 + (\text{Coef Var})^2)}).$$

This relationship is shown by (d) for 90th percentile values (10 percent exceedance, $Z_\alpha = 1.2817$).

The establishment of the fundamental distribution as lognormal, and the availability of a sufficiently large sample population of EMCs to provide reliable derived statistics, has a number of benefits:

- Concise summaries of highly variable data can be developed.
- Comparisons of results from different sites, events, etc., are convenient and are more easily understood.

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- Statements can be made concerning frequency of occurrence. One can express how often values will exceed various magnitudes of interest.

- A more useful method of reporting data than the use of ranges is provided; one which is less subject to misinterpretation.

- A framework is provided for examining "transferability" of data in a quantitative manner.

Priority Pollutants

In cooperation with EPA's Monitoring and Data Support Division (MDSD), a special study element was built into two-thirds of the NURP projects (20 of 28) to identify which of the compounds on EPA's list of "Priority Pollutants" are found in urban runoff, and the concentrations at which they occur. The base effort collected 121 samples of urban runoff which were analyzed for priority pollutants. A supplementary special metals study secured 147 samples. Methods utilized in this study element are described in the following report which covers this activity:

> "NURP Priority Pollutant Monitoring Project: Summary of Findings", December 1983; EPA Monitoring and Data Support Division, Office of Water Regulations and Standards, Washington, D.C.

In addition to the above special study, as previously mentioned, most NURP projects monitored selected heavy metals (principally total copper, total lead, and total zinc) in their routine monitoring programs. Summaries of these data are presented in Chapter 6.

Hydrometeorological Statistics

Consistent with the adoption of a storm "event" as the fundamental time scale used in the analysis of data and the interpretation of effects, rainfall data were analyzed to define "event" statistics for a significant number of locations throughout the country. The SYNOP program was employed for developing the statistical parameters of rainfall intensity, duration, volume, and interval between storm events. This program has been detailed in the NURP "Data Management Procedures Manual."

In addition to rainfall, rainfall-runoff relationships were characterized for monitored storm events. The runoff coefficient, defined as the ratio of runoff volume to rainfall volume, was computed, and effects of such catchment characteristics as land use and imperviousness were investigated. Long-term streamflow records for numerous stations across the country were also analyzed to characterize regional trends.

RECEIVING WATER QUALITY EFFECTS

General

A number of individual NURP projects examined the site-specific impacts of urban runoff on water quality for a variety of beneficial uses and receiving

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water types. These results provide important information on the extent to which urban runoff constitutes a "problem" as well as "ground truth" measurements against which more generalized techniques can be compared. Methodologies employed in these local studies vary and are described in the individual project reports. Relevant site-specific project results are cited in Chapter 9.

Receiving water impact analyses cannot be readily generalized because there is a high degree of site-specificity to the important factors. The type of beneficial use dictates the pollutants which are of principal concern; the type of water body (e.g., stream, lake, estuary) determines how receiving water quality responds to loads; and physical characteristics (e.g., size, geometry, flows) have a major influence on the magnitude of response to a particular load.

Despite the inherent limitations of a set of generalized receiving water impact analyses, a screening level analysis was considered a necessary element for a nationwide assessment of the general significance of urban runoff in terms of water quality problems, especially adverse effects on beneficial uses. Accordingly, a set of analysis methodologies were adopted and utilized as screening techniques for characterizing water quality effects of urban runoff loads on receiving water bodies. A key requirement was to delineate the severity of water quality problems by quantifying the magnitude, and in the case of intermittent loads, the frequency of occurrence of water quality impacts of significance. These procedures are identified and described briefly below. Significant technical aspects are detailed further in the supplementary NURP report which addresses the receiving water impact analysis methodology.

It was not possible to perform a "National Assessment" in the usual sense of the term. NURP has determined that it is not realistic (if the basis is effect on beneficial use of a water body) to estimate the total number of water quality problem situations in the nation which result from urban stormwater runoff or the cost of control which would ultimately result. The available analysis methods do permit an assessment of a different kind. NURP applied the analysis procedures as a screening type analysis to define the conditions under which problems of different types are likely or unlikely to occur. From the results of these screening analyses, NURP has drawn inferences and made general statements (Chapters 7 and 9) on the significance of urban runoff. Where it has been possible or practical to do so, these general screening analyses were applied to local situations which exist within certain of the individual NURP projects. Comparisons were made between specific water quality effects or broader conclusions relative to problems derived from both local analysis and general screening methods.

Time Scales of Water Quality Impacts

There are three types of water quality impacts associated with urban runoff. The first type is characterized by rapid, short-term changes in water quality during and shortly after storm events. Examples of this water quality impact include periodic dissolved oxygen depressions due to oxidation of contaminants, or short-term increases in the receiving water concentrations of one

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or more toxic contaminants. These short-term effects are believed to be an important concern and were the prime focus of the NURP analysis.

Long-term water quality impacts, on the other hand, may be caused by contaminants associated with suspended solids that settle in receiving waters and by nutrients which enter receiving water systems with long retention times. In both instances, long-term water quality impacts are caused by increased residence times of pollutants in receiving waters. Other examples of the long-term water quality impacts include depressed dissolved oxygen caused by the oxidation of organics in bottom sediments, biological accumulation of toxics as a result of up-take by organisms in the food chain, and increased lake entrophication as a result of the recycling of nutrients contributed by urban runoff discharges. The long-term water quality impacts of urban runoff are manifested during critical periods normally considered in point source pollution studies, such as summer, low stream flow conditions, and/or during sensitive life cycle stages of organisms. Since long-term water quality impacts occur during normal critical periods, it is necessary to distinguish between the relative contribution of urban runoff and the contribution from other sources, such as treatment plant discharges and other nonpoint sources. A site-specific analysis is required to determine the impact of various types of pollutants during critical periods, and this aspect of urban runoff effects was not addressed in detail in NURP.

A third type of receiving water impact is related to the quantity or physical aspects of flow and includes short-term water quality effects caused by scour and resuspension of pollutants previously deposited in the sediments. This category of impact was not addressed by NURP, in general, although one project provides some information.

As indicated previously, the first type of change in water quality associated with discharges from urban runoff is characterized by short-term degradation during and shortly after storm events. The rainfall process is highly variable in both time and space. The intensity of rainfall at a location can vary from minute to minute and from location to location. Phenomena which are driven by rainfall such as urban runoff and associated pollutant loadings are at least as variable. Short term measurements, on a time scale of minutes, to define rainfall, the runoff flow hydrograph, and concentrations of contaminants (pollutographs) feasibly can be taken at only a rather limited number of locations. These measurements have usually been employed in an attempt to refine or calibrate calculation procedures for estimating runoff flows and loads. Most urban areas contain a network of drainage systems which collect and discharge urban runoff into one or more receiving water bodies. Since the rainfall, runoff, and pollutant loads vary in both time and space, it is impossible to determine by calculation or measurement the very short time scale (minute-to-minute) changes in water quality of a receiving water and assign the changes to specific sources of runoff. Although very short duration exposures (on the order of minutes) to very high concentrations of toxics can produce environmental damage (mortality or sublethal effects) to aquatic organisms, it is likely that exposures on the order of hours have the highest possibility of causing adverse environmental impacts. This results, in part, from the smoothing obtained by mixing numerous sources which have high frequency (short-term) variability.

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In view of the above discussion, the time scale used by NURP for analysis of short-term receiving water impacts is the rainfall event time scale which is on the order of hours. To represent the average concentration of pollutants in urban runoff produced during such an event, NURP used the event mean concentration.

Criteria/Standards and Beneficial Use Effects

As discussed in previous chapters, three definitions have been adopted to assess receiving water problems associated with urban runoff; (1) impairment or denial of beneficial use, (2) violation of numerical criteria/standards, and (3) local perception of a problem. The procedures and methods employed in the NURP assessment focus on the first two problem definitions. A framework for identifying target receiving water concentrations associated with the criteria standards and beneficial use problems are provided below. The third problem type, local perception of a problem and degree of concern cannot be addressed by these quantitative procedures.

The analysis methods employed make it possible to project water quality effects caused by intermittent, short-term urban runoff discharges. Where appropriate, these effects are expressed in terms of the frequency at which a pollutant concentration in the water body is equalled or exceeded. However, if the basis for determining the significance of such water quality impacts (and hence the need for control) is taken to be the effect such receiving water concentrations have on the impairment or denial of a specific beneficial use, then it is necessary to go one step further. A basis is required for judging the degree to which a particular water quality impact constitutes an impairment of a beneficial use. With intermittent pollutant discharges, effects are variable and are best expressed in terms of a probability distribution from which estimates can be made of the frequency with which effects of various magnitude occur.

There is a rather broad consensus that existing water quality criteria, and water uses based on such criteria, are most relevant when considered in terms of continuous exposures (ambient conditions). Even where continuous discharges are involved, there has been discussion and debate as to whether a particular criterion should be interpreted as some appropriate "average" condition or a "never-to-exceed" limit. The basic issue is whether the more liberal interpretation will provide acceptable protection to the beneficial use for which the criterion in question has been developed. The only reason such distinctions become an issue is because the practical feasibility or relative economics, or both, are sufficiently different that one is encouraged to question whether the more restrictive interpretation is overly (or even excessively) conservative in terms of providing protection for the associated beneficial use.

The issue (i.e., whether traditional ambient criteria are excessively conservative measures of conditions which provide reasonable assurances of protection for a beneficial use when exceeded only intermittently) is particularly appropriate in the case of urban storm runoff. Analysis of rainfall records for a wide distribution of locations in the nation indicates that, even in the wetter parts of the country, urban runoff events occur only

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about 10 percent of the time. There are regional and seasonal differenc but typical values for annual average storm characteristics in the east half of the United States are:

	Average (Hours)	Median (Hours)	90th Percentile (Hours)
Storm Duration	6	4.5	15
Interval Between Storm Mid-Points	80	60	200

These estimates are based on results from an analysis of long-term rainfa records for 40 cities throughout the country. Median and 90th percenti values are derived from data mean and variance based on a gamma distributic which has been shown to characterize the underlying distribution of stc event parameters quite well.

In the semi-arid regions of the western half of the country, average stc durations tend to be comparable to the above, but average intervals betwe successive storms increase substantially (two to four fold) and are high seasonal. With urban storm runoff, therefore, one is dealing with polluta discharges which occur over a period of a few hours every several days more or after long dry periods. In advective rivers and streams, the wat mass influenced by urban runoff tends to move downstream in relatively di crete pulses. Because of the variability in the magnitude of the pollut loads from different storm events, only a small percentage of these puls have high pollutant concentrations.

There are currently no formal "wet weather" criteria and, thus, no general accepted way intermittent exposures having time scale characteristics typic of urban runoff can be related to use impairment. In the belief that would be inappropriate to ignore such considerations in a general evaluati of urban runoff, NURP has developed estimates for concentration levels whi result in adverse impacts on beneficial use when exposures occur intermi tently at intervals/durations typical of urban runoff. These "effec levels" were used to interpret the significance of the variable, intermitte water quality impacts of urban runoff. It should be understood that the effects levels do not represent any formal position taken by EPA, but a simply the most reasonable yardsticks available to meet the immediate nee of the evaluation of urban runoff. As used in the screening analysis proc dures, alternative values for "effects levels" may be readily substitut when either more accurate estimates can be made, or more (or less) conser tive approaches are indicated in view of the importance of a particular wat body or beneficial use.

Table 5-1 summarizes information on water quality criteria for a number contaminants routinely found in urban storm runoff. The data present include:

- Water quality criteria for substances on EPA's priority pollutant list (45 FR No. 79318, 11/28/80). These criteria provide

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TABLE 5-1. SUMMARY OF RECEIVING WATER TARGET CONCENTRATIONS USED IN SCREENING ANALYSIS - TOXIC SUBSTANCES (ALL CONCENTRATIONS IN MICROGRAMS/LITER, µg/ℓ)

Contaminant	Water Hardness mg/l (as Ca CO_3)	Freshwater Aquatic Life		Saltwater Aquatic Life		Human Ingestion	Estimated Effect Level For Intermittent Exposure	
		24 Hour	Max	24 Hour	Max	(1)	Thresh-hold	Significant Mortality
Copper	50	5.6	12	4.0	23	NP	20	50 - 90
	100	5.6	22	4.0	23		35	90 - 150
	200	5.6	42	4.0	23		80	120 - 350
	300	5.6	62	4.0	23		115	265 - 500
Zinc	50	47	180	58	170	NP	380	870 - 3,200
	100	47	321	58	170		680	1,550 - 4,500
	200	47	520	58	170		1,200	2,750 - 8,000
	300	47	800	58	170		1,700	3,850 - 11,000
Lead	50	0.75	74				150	350 - 3,200
	100	3.8	172	(25)	(670)	50.0	360	820 - 7,500
	200	12.5	400				850	1,950 - 17,850
	300	50.0	660	(C)	(A)		1,400	3,100 - 29,000
Chrome (+3)	50		2,200					
	100	(44)	4,700	N.P.	(10,300)	170.00	8,650	
	300	(C)	15,000		(A)			
Chrome (+6)	-	0.29	21.0	18	1260	50.0		
Cadmium	50	0.01	1.5				3	7 - 160
	100	0.02	3.0	4.5	59.0	10	6.6	15 - 350
	300	0.06	9.6				20	45 - 1,070
Nickel	50	56	1,090					
	100	96	1,800	7.1	140.0	13.4		
	300	220	4,250					

NOTES:

- NP = No criteria proposed.
- Some toxic criteria are related to Total Hardness of receiving water. Where this applies, several values are shown. Other values may be calculated from equations presented in EPA's Criteria Document (Federal Register, 45,231, November 28, 1980). Where a single value is shown, water hardness does not influence toxic criteria.
- Concentration values shown within parentheses ( ) are not formal criteria values. They reflect either chronic (C) or acute (A) toxicity concentrations which the EPA toxic criteria document indicated have been observed. Values of this type were reported where the data base was insufficient (according to the formally adopted guidelines which were used in developing the criteria) for EPA to develop 24 hour and Max values.
- Note (1): The "Human Ingestion" criteria developed by the EPA Toxic Criteria documents are indicated to relate to ambient receiving water quality. The Drinking Water Criteria relate to finished water quality at the point of delivery for consumption.
- Estimated Effects levels reflect estimates of the concentration levels which would impair beneficial uses under the kind of exposure conditions which would be produced by Urban Runoff. They are an estimate of the relationship between continuous exposure and intermittent, short duration exposures (several hours once every several days). Threshold concentrations are those estimated to cause mortality of the most sensitive individual of the most sensitive species.

  Significant Mortality concentrations are shown as a range which reflects 50 percent of the most sensitive species and mortality of the most sensitive individual of the 25th percentile species sensitivity.

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an extensive set of numerical values derived from bioassay studies.

- Estimates of "effects levels" which are suggested by NURP analysis to be relevant for the intermittent exposures characteristic of urban runoff.

By incorporating the numerical values for EPA's ambient water quality criteria and the concentration levels suggested by NURP for intermittent effects in the same table (or on the same graph in Chapter 7), a convenient, concise comparison is provided of the practical implications of applying one or the other as the yardstick for judging the protection or impairment of water use. The two sets of numerical values thus provide measures for two of the three options for defining a problem: violation of criteria or actual impairment of a beneficial use.

Comparison of the pollutant concentrations in urban runoff showing the frequency and magnitude of exceedance of ambient criteria and intermittent effects levels provides a qualitative sense of the control requirements (and implications regarding costs) attendant on the adoption of either problem definition as the operative one.

Rivers and Streams

The approach adopted to quantify the water quality effects of urban runoff for rivers and streams focuses on the inherent variability of the runoff process. What occurs during an individual storm event is considered secondary to the overall effect of a continuous spectrum of storms from very small to very large. Of basic concern is the probability of occurrence of water quality effects of some relevant magnitude.

To consider the intermittent and variable nature of urban runoff, a stochastic approach was adopted. The method involves a direct calculation of receiving water quality statistics using the statistical properties of the urban runoff quality and other relevant variables. The approach uses a relatively simple model of the physical behavior of the stream or river (as compared to many of the deterministic simulation models). The results are therefore an approximation, but appropriate as a screening tool.

The theoretical basis of the technique is quite powerful as it permits the stochastic nature of runoff process to be explicitly considered. Application is relatively straightforward, and the procedure is relevant to a wide variety of cases. These attributes are particularly advantageous given the national scope of the NURP assessment. The details of the stochastic method are summarized and presented below.

Figure 5-2 contains an idealized representation of urban runoff discharges entering a stream. The discharges usually enter the stream at several locations but are considered here to be adequately represented by an equivalent discharge flow which enters the system at a single point.

Receiving water concentration (CO) is the resulting concentration after complete mixing of the runoff and stream flows and is interpreted as the mean

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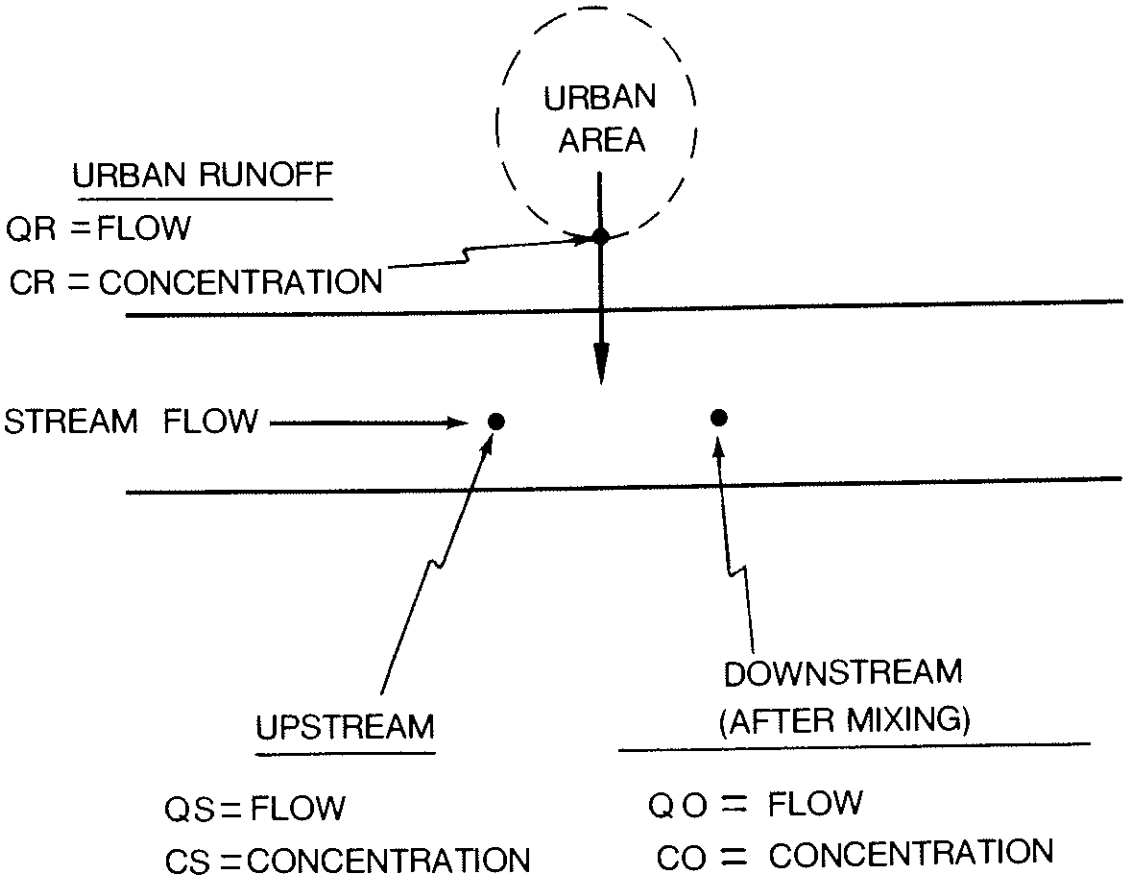

Figure 5-2. Idealized Representation of Urban Runoff Discharges Entering a Stream

stream concentration just downstream of all of the discharges as shown in Figure 5-2. The four input variables considered are:

- Urban runoff flow (QR)
- Urban runoff concentration (CR)
- Stream flow (QS)
- Stream concentration (CS)

Each is considered to be a stochastic random variable, which together combine to determine downstream flow and concentration. In addition, all variables are assumed to be independent, except urban runoff flow and streamflow where correlation effects can be incorporated as warranted.

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An essential condition of the current computational structure is that each of the four variables which contribute to downstream receiving water quality can be adequately represented by a lognormal probability distribution; from analysis of data or other estimating procedures, the statistical properties of each of the input parameter distributions are defined. Examination of a reasonably broad cross-section of data indicates that lognormal probability distributions can adequately represent discharges from the rainfall/runoff process, the concentration of contaminants in the discharge, and the daily flow record of many rivers and streams, particularly for a national scale screening approach. It should be noted, however, that modifications of the computation techniques could be made to accommodate the use of other distributions (e.g., gamma, exponential) for some or all of the parameters.

The analysis procedure is described in more detail in the supplementary NURP report cited earlier. It essentially operates as follows:

- Downstream Concentrations. Stream concentrations of a pollutant are considered to result from the combination of upstream flow at background concentration and runoff flow at its concentration. Variations in stream concentrations below the urban runoff discharge result from variations in each of these inputs; the most significant source of variation being whether or not an event is occurring (i.e., whether runoff flows and loads are present). Stream flows must be considered because of the major effect of dilution on the resulting concentrations. Upstream concentrations can, however, be set at zero for the calculations; in which case, the result obtained is the exclusive effect of urban runoff discharges, and not the overall expected stream concentration. Effects of urban runoff can be evaluated by considering only the periods during which runoff occurs.

- Parameter Estimates. Estimates for runoff flows and concentrations are developed from information derived from the NURP monitoring programs. Information on stream flow can be obtained from analysis of local stream gage records. Upstream concentrations tend to be very site-specific; for this reason, the screening analysis calculated only the effect of urban runoff discharges.

- Statistical Calculations. From the statistical properties (specifically, the means and standard deviations) of the flows and concentrations, properties of the dilution ratio can be defined, and the statistical properties of the resulting in-stream concentrations are calculated directly. The frequency with which any particular target concentration is exceeded during wet weather can be calculated from the statistical properties of stream concentration, using formulas or scaled directly from a standard plot of cumulative (lognormal) probability distributions.

  The frequency with which the target concentration is exceeded during all periods -- wet and dry -- is simply the product of

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the wet weather frequency and the probability (frequency) that it is raining. The probability that it is raining at any time is defined by the ratio of mean storm duration to mean inter-storm period, derived from the rainfall statistics.

$$\frac{D = \text{mean duration of storms}}{\Delta = \text{mean interval between storm midpoints}} = \text{fraction of time it is wet}$$

- Mean Recurrence Interval. In the presentation of results in Chapter 7, the probability distribution of event mean stream concentrations of an urban runoff pollutant during runoff periods is converted to a Mean Recurrence Interval (MRI) as a device to assist in the interpretation of results. The recurrence interval is defined as the reciprocal of probability. Because the basic calculation is based on storm events, this definition yields the overall average number of storms between specific event occurrences. Event recurrence is converted to what is believed to be a more meaningful time recurrence by dividing by the average number of storms per year, which is developed from analysis of rainfall records and defined as

$$\frac{\text{Hours/year} = 8760}{\text{Average interval between storm midpoints}} = \text{average \# storms per year}$$

As an example of the MRI calculations consider a stream concentration which has an exceedance probability of 1.0 percent (Pr = 0.01)

$$\text{Recurrence Interval} = 1/Pr = 1/0.01 = 100$$

The analysis is in terms of storm events, not time. Therefore this result is interpreted as one storm in every 100 events on average, will produce concentrations greater than the selected value. For an area where rainfall patterns produce an average of 100 storms per year, the average recurrence interval expressed in time units rather than events, is:

$$\text{Recurrence Interval (time)} = \frac{\text{event recurrence}}{\text{\# events/year}} = \frac{100 \text{ events}}{100 \text{ events/year}} = 1 \text{ year}$$

Currently, the primary use of the above procedure is as a screening tool in which approximate results and relative values are of interest. In this regard, NURP believes the Mean Recurrence Interval is a very useful definition. It should be interpreted as the long-term average interval between occurrences.

When results of this nature are interpreted, the following factors should be noted. The recurrence intervals of most interest relate to very low probabilities of occurrence. The tails of distributions may have appreciable uncertainty, and in the natural water systems, distributions may be lognormal

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over the bulk of the range but may deviate from the assigned distribution at the extremes. Computed stream concentrations at long recurrence intervals are likely to be conservative, that is, overstated because there are likely to be practical upper limits for runoff concentrations and lower limits to stream flow.

It also should be noted that serial correlations of streamflows or the tendency of wet and dry years to occur in clusters, though not a general behavior, may be significant in some cases. This situation would cause the average one year condition, for example, not to repeat itself every year but rather to occur several times per year, at intervals greater than one year.

Other Receiving Waters

Other receiving waters of general interest in assessing urban runoff effects include lakes, estuaries, embayments, and coastal zones. The methods adopted for lakes are briefly described below. The other receiving waters generally require site-specific and often complex analysis techniques (numerical methods, multi-dimensional modeling, etc.). Given this, a generalized screening-level assessment was not believed to be appropriate for this report. A number of the individual NURP projects consider these coastal water bodies and report on the specific methods adopted and results obtained.

For lake eutrophication problems, the time scale for analysis is considerably longer than the short (event scale) periods necessary for estuaries and rivers. For this case, annual average loads were used in a steady-state analysis performed using the type of empirical model advanced by Vollenweider and others. The EMC data developed from NURP monitoring programs can be readily converted to annual loads directly from annual flows or indirectly based on annual rainfall.

For total phosphorus, typically the limiting nutrient of concern, average concentrations are calculated using the following formula:

$$P = \frac{W'}{H/\tau \cdot \upsilon_s} \cdot 1000$$

The input values include pollutant mass loading (W'), lake physical characteristics of depth (H) and residence time (τ) and reaction rate coefficients (υ_s). The relative contribution of all load sources to lake total P concentrations can be defined by solving this equation for each of the sources. By comparing results in terms of lake concentrations for initial conditions (no control), and then modifying loads to reflect various levels of control, alternative control operations can be compared directly to effect on lake water quality.

Some judgement is involved in defining acceptable lake water quality concentrations, which depend in part on water use and on regional norms and expectations.

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EVALUATION OF CONTROLS

General

The evaluation of controls has two elements: (a) characterizing the controls' performance capabilities and (b) defining costs. For this report, only the characterization of performance is emphasized; cost relationships are addressed to a more limited extent. EPA's Economic Analyses Staff, Office of Analysis and Evaluation, has prepared the following report under contract:

> "Collection of Economic Data from Nationwide Urban Runoff Program Projects," EPA Office of Water Regulations and Standards, April 7, 1982.

This report, issued at an early stage in the NURP program, assembled and analyzed cost information on potential control measures. Useful cost information for detention basins was developed by the Washington, D.C. area NURP project and is discussed further in Chapter 8.

Detention Basins

There are a number of procedures which can be adopted for evaluation of detention basin control devices. Procedures adopted by individual NURP projects are described in project reports. The procedure adopted by NURP to generalize the analysis of detention basins, and provide a planning level basis for estimating capabilities and requirements, is detailed in a detention basin handbook being issued by NURP as a supplementary report.

Results presented in Chapter 8 provide a summary of observed performance characteristics of the detention devices monitored under the NURP program and a projection of long-term performance expected on the basis of basin size and regional rainfall characteristics. The latter result is based on the probabalistic analysis methodology described in the supplementary report. Planning level cost estimates for control of urban runoff using this technique are also presented.

Street Sweeping

A number of the individual NURP projects adopted street sweeping as a principal subject of investigation. Procedures and results are described in individual project reports and are consolidated and summarized in Chapter 8. The adopted procedure and detailed results are presented in the supplementary NURP report, which was cited earlier.

Recharge Devices

Recharge devices include impoundments or other structures such as pits, trenches, retention basins, percolating catch basins, in-line percolation chambers or perforated pipes, which function by intercepting some portion of storm runoff and allowing it to percolate into the ground.

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One of the basic questions which arises when controls of this type are considered is whether the percolation encouraged will produce undesirable degradation of groundwater quality. This aspect was examined by two NURP projects, and is discussed in Chapter 7 of this report.

Evaluation of percolating basins of any size is readily accomplished using the standard storage/treatment routines of stormwater models such as STORM or SWMM. In such cases the local soil permeability (the percolation rate) is applied as the treatment rate. In addition, statistical analysis procedures described in "A Statistical Method for the Assessment of Urban Stormwater" (EPA 440/3-79-023, May 1979) have been developed. A probabalistic analysis methodology adapted from the latter approach has been used by NURP to provide estimates of performance capabilities of recharge devices, which are presented in Chapter 8. A detailed discussion of the methodology is provided in the supplementary NURP report on detention/recharge devices cited earlier.

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CHAPTER 6
CHARACTERISTICS OF URBAN RUNOFF

INTRODUCTION

This chapter presents a condensed summary of data developed by the individual NURP projects together with analysis results and interpretations based on the aggregated data from all projects.

Both the format for the summaries and the evaluations performed were selected to best serve the NURP objective of developing a national perspective. The results presented do not exhaust the useful information and insights which can be derived from the extensive data base that has been assembled. Individual project reports and a substantial number of articles published in a variety of technical journals independently examine specific aspects of urban runoff, often from the perspective of local issues.

Comprehensive tabulations of NURP data have been assembled and will be made available to interested parties for use in local planning or continuing research or engineering activities. As noted below, only a portion of the entire data base generated by the 28 NURP projects has been made generally accessible at this time. Under an ongoing effort, the entire data base is being subjected to final quality assurance checks and placed into a separate file, copies of which will be made available to interested parties upon request. In addition, a summary of the event averaged data, used for the analyses presented in this chapter, is reproduced in a Data Appendix issued with this report.

Field monitoring was conducted to characterize urban runoff flows and pollutant concentrations and mass loadings. This was done for a variety of pollutants at a substantial number of sites distributed throughout the country. The resultant data represent a cross-section of regional climatology, land use types, slopes, and soil conditions and thereby provide a basis for identifying patterns of similarities or differences and testing for their significance. To meet the objective of maximizing the degree of transferability of urban runoff data, the NURP approach involved covering a spectrum of regional and land use characteristics, requiring consistent quality assurance programs among all projects, and encouraging each of the projects to obtain data for a statistically significant number of storm events at a site.

The portion of the NURP data base used in the characterization of urban runoff presented in this section excludes monitoring sites which are downstream of devices which modify runoff (e.g., detention basins). The data base of acceptable "loading sites" consists of 81 sites in 22 different cities, and includes more than 2300 separate storm events. The actual number of events

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for specific pollutants varies, and is somewhat smaller than the total number of storms monitored because all pollutants were not measured for all storms at all sites.

Data summaries and analyses were performed using storm event average values; within-event fluctuations are not considered. An event mean concentration (EMC) for pollutants of interest has been determined for each monitored storm. Preliminary results presented in an earlier NURP report were based on analysis of "pooled" EMCs which were available at the time regardless of site. This provided a useful start, a reference for individual NURP project activities, and established the order of magnitude of concentrations of various pollutants in urban runoff. With the substantially larger data set now available, a more useful approach is possible. For the analyses and comparisons presented in this chapter, the storm event average data were aggregated by site to describe site characteristics. Site mean values were then aggregated or compared.

Summaries, comparisons, and evaluations were restricted to concentrations and runoff-rainfall ratios. Although loading data (Kg/Ha) are also available for all monitored storms, they have not been used in comparisons for the following reason. Mass load is very strongly influenced by the size (volume) of the monitored storm event. Monitored events usually represent a very small sample of all storms for an area, are generally biased toward larger events, and are different from site to site. Therefore comparisons between sites or locations using loading data derived from monitored storms are quite likely to present a distorted picture.

Event mean concentrations, on the other hand, have been determined to be essentially uncorrelated with runoff volume, as discussed further later in this chapter. Site comparisons can be made with high confidence levels using concentration data, and the most meaningful load comparisons would be those developed by using concentrations, area rainfall volumes, and runoff-rainfall relationships.

Separate summaries of results are provided below for standard pollutants, coliform bacteria, pollutant loads, and priority pollutants.

LOGNORMALITY

As was pointed out in Chapter 5, the key to the mathematical tractability of the NURP methodologies is that the data can be well represented by a known probability density function (pdf). There are actually two issues involved; (1) the adequacy of the assumed pdf in terms of representing the essential characteristics of the data set in question, and (2) the estimation of the parameters of the population pdf that the observed data set is presumed to represent. These will be discussed in turn.

Adequacy of Representation

One can fit a polynomial of order (n-1) exactly to any data set of n numerical items, but its utility in predicting the probability of realizing a given value on a subsequent trial (either within or outside the original data set,

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i.e., the interpolation or extrapolation problem) is likely to be very limited. The number of parameters involved and the need to investigate its properties on an individual basis are further deterrents to such a practice. There is no dearth of pdf's that have been the subject of intensive investigation. However, the selection of a pdf is an objective choice that is best made based on professional knowledge of the processes deemed important to the desired probability model and the use to be made of it. For example, if the data are known to result from the product of many small effects, their logs will be the sum of the logs of these effects. By appeal to the central limit theorem, it is known that this sum is asymptotically normal and, therefore, that the data will be lognormally distributed. Based upon such natural expectations and prior experience (of a growing body of other workers in the field as well), the lognormal pdf was chosen. The fact that the variables of interest can assume only positive values with a finite mean and a finite nonzero lower bound (even in a standardized form) leads to the rejection of any pdf defined over the entire real domain, such as the normal distribution for instance.

There are a number of statistical procedures for evaluating the normality of a complete sample; at least nine can be found in the current literature. Some are origin and scale invariant (e.g., the Shapiro-Wilk, standard third moment, standard fourth moment, and studentized range) and thus are appropriate for testing the composite hypothesis of normality. Others require the complete specification of the null distribution (e.g., Kolmogorov-Smirnoff, Cramer-Von Mises, weighted Cramer-Von Mises, modified Kolmogorov-Smirnoff-D, and chi-squared), and typically, the mean and variance of the specified normal hypothesis are taken to be the known mean and variance of the complete sample. Some procedures (e.g., chi-squared) utilize the specified theoretical pdf, while others (e.g., the modified Kolmogorov-Smirnoff D-test) utilize the cumulative frequency distribution.

In testing for normality (in the logorithmic domain in our case), one specifies the level of significance (α), i.e., the probability of rejecting the null hypothesis when it is in fact true (Type I error). The choice of α requires tempered judgement, however. The power of a test (β) is the probability of rejecting the null hypothesis when it is in fact false. The probability of accepting the null hypothesis when it is in fact false (Type II error) is $1-\beta$. For a given sample size and test, fixing a value for α also determines a value for β (i.e., they are not independent). The smaller the α level, the less powerful the test. Thus one is forced to make a trade-off between the consequences of a Type I or II error when selecting an α value.

The median EMC values for each constituent at each site were calculated, and these sample sets were examined for lognormality using the Kolmogorov-Smirnoff D test. The α levels for TSS, Total P, TKN, Total Pb, and Total Zn were all greater than 0.15, indicating a high power level. In other words, these sample sets are extremely well represented by a lognormal distribution. For COD and nitrate + nitrite the α levels were 0.059 and 0.057 respectively, indicating a lower power level but suggesting that even for these constituents the lognormal distribution quite well describes the data. Because BOD, Soluble P, and Total Cu were measured at fewer than half of the project

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sites, the D-test could not meaningfully be used (i.e., n is too small). Stated another way, at the $\alpha = 0.05$ level, the hypothesis that the samples were drawn from a population with a lognormal distribution cannot be rejected for any of the constituents examined.

Turning to the individual sites, there were very few instances where n was large enough to support the meaningful use of the D-test, and so a different approach for examining the appropriateness of the lognormal distribution was used. Essentially it consisted of examining the cumulative frequency distributions (in log space) and third and fourth moment based statistics for adequacy of representation. Taking into account detection limit phenomenon, uncertainties associated with sampling and analytical determination errors (especially at low concentration levels), and an occasional outlier, well over 90 percent of the constituent distribution at all NURP sites were quite well represented by the lognormal distribution. For the few remaining data sets, the lognormal distribution, although not perfect, was adequate for our purposes.

Estimation of Parameters

As noted in Chapter 5, the lognormal distribution is completely specified by two parameters, the mean and the coefficient of variation. The values of these two parameters as calculated from the sample data set are the best estimates of the parameters of the underlying population in the maximum likelihood sense. For this reason, they were used in the NURP analysis. However, due to the existence of detection limit problems and sampling/analytical determination errors, the reasonableness of this decision was examined in general for all constituents and in great detail for Total Cu, the results of which will be described below.

For each of the 49 NURP sites where at least five Total Cu determinations were made, data were plotted (in logarithmic form) on probability paper. A line of best fit was drawn in, using professional judgement where detection limit or outlier problems existed, and the values of the median and standard deviation were read from the plot and converted into arithmetic space. These were then compared with those values calculated from the data themselves. One example is given in Figure 6-1 (the 116th and Claude Street site in Denver). Here the median and coefficient of variation from the plot (20 µg/l and 0.75) compare very well with those calculated directly from the data (22 µg/l and 0.74).

An example of an outlier plot is given in Figure 6-2 (the strip commercial site in Knoxville, TN). The one very low value (1 µg/l) is one-twentieth the typical detection limit (20 µg/l) and clearly does not belong to the same distribution that the other values do. Ignoring it, a very good fit exists and the parameters of the plot are 30 µg/l and 0.37 for the median and coefficient of variation as compared with the 25 µg/l and 1.35 values calculated from the data. The difference in medians is not too great, but the difference in coefficients of variation is quite large (over a factor of 3.5). This means that the upper end of the tail of the pdf is quite overestimated by the parameters estimated from the data and, consequently, that

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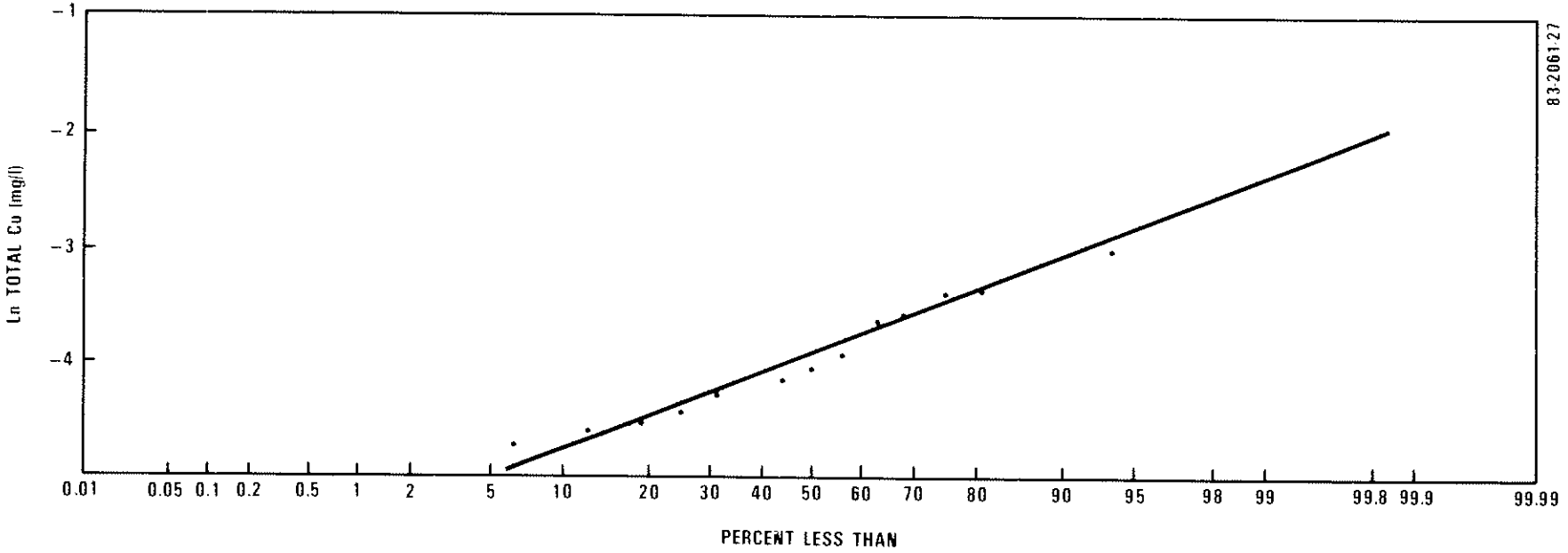

Figure 6-1. Cumulative Probability Distribution of Total Cu at CO1 116 and Claude Site

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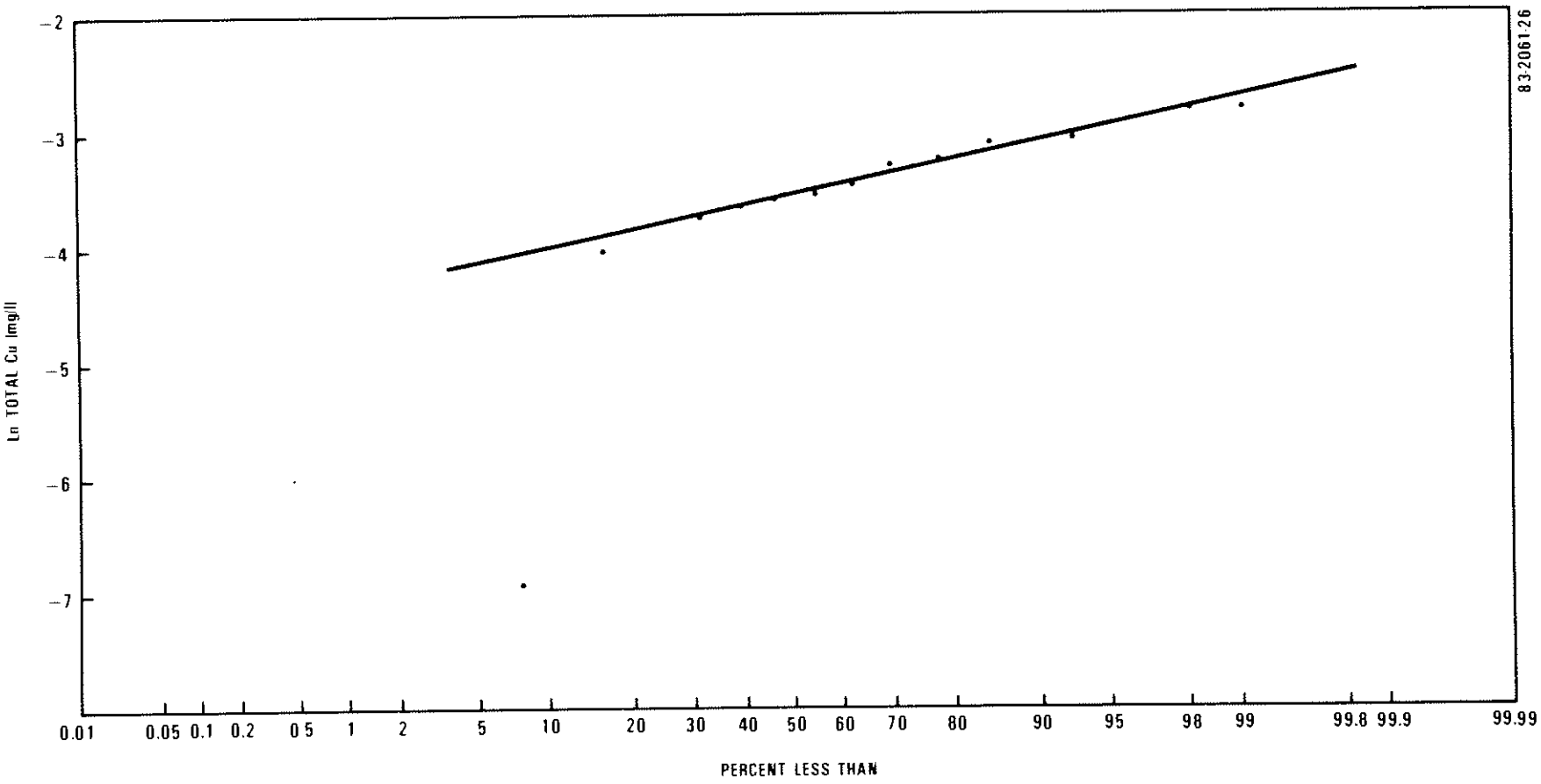

Figure 6-2. Cumulative Probability Distribution of Total Cu at TN1 SC Site

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subsequent analyses will be extremely conservative, i.e., higher values of copper concentrations will occur less often than predicted. In general, the effect of an outlier is to increase or decrease the estimate of the median, depending upon whether the outlier is high or low, and to increase the estimate of the coefficient of variation as compared to those obtained from the remainder of the data.

An example of a detection limit problem is given in Figure 6-3, the plot of copper data of the Durham, NH parking lot site. Although only four points appear on the plot, actually n = 31, meaning that 27 points are represented by the first plotting position (90.6 percent). These values (all reported at 100 ug/l) are presumably the detection limit of the analytical laboratory. Of course in reality not all 27 values are 100 ug/l; they are simply equal to or less than this value. Fitting a line to the remaining four data points merely assigns appropriate plotting positions to these "less than" values. The estimates of the median and coefficient of variation from the plot are 63 ug/l and 0.36 respectively, as compared to the estimates from the data of 103 ug/l and 0.13. In this case, the latter significantly overestimates the median and significantly underestimates the coefficient of variation, and this is the general effect when a detection limit problem is present. In terms of the effect on prediction of rare occurrences of high copper levels (the upper tail of the pdf) these effects are somewhat counterbalancing. To the extent that the increase in the coefficient of variation dominates, the results of subsequent analyses will not be conservative, since larger concentrations will occur somewhat more frequently than would be predicted.

When the results of this exercise are compared for all 49 sites, the median as estimated from the plot was found to be higher than that estimated from all the data at only six sites, was equal at five sites, and was less at 38 sites. However, at only three sites was the change greater than 10 ug/l. Considering the population of all copper sites, the average median is 47 ug/l and the coefficient of variation is 0.84 when the estimates are based on all the data. If the estimates are based upon the plots, the respective values are 42 ug/l and 0.24 respectively. The significant reduction in the coefficient of variation in this latter case deserves comment, because it suggests that much of the apparent variability from site to site is due to data artifacts such as detection limit phenomena, outliers, and/or sampling/analytical errors. Similar comparisons of the coefficients of variation for each site showed increases at 21 sites, 6 unchanged, and decreases at 22 sites. Considering all sites, the average coefficient of variation is essentially unchanged (0.61 vs 0.63) as is its variability (0.47 vs 0.49).

Based on the results of the analyses which have been performed, the NURP findings are as follows:

- Lognormal distributions adequately represent both the storm-to-storm variations in pollutant EMC's at an urban site, and site-to-site variations in the median EMC's which characterize individual sites.

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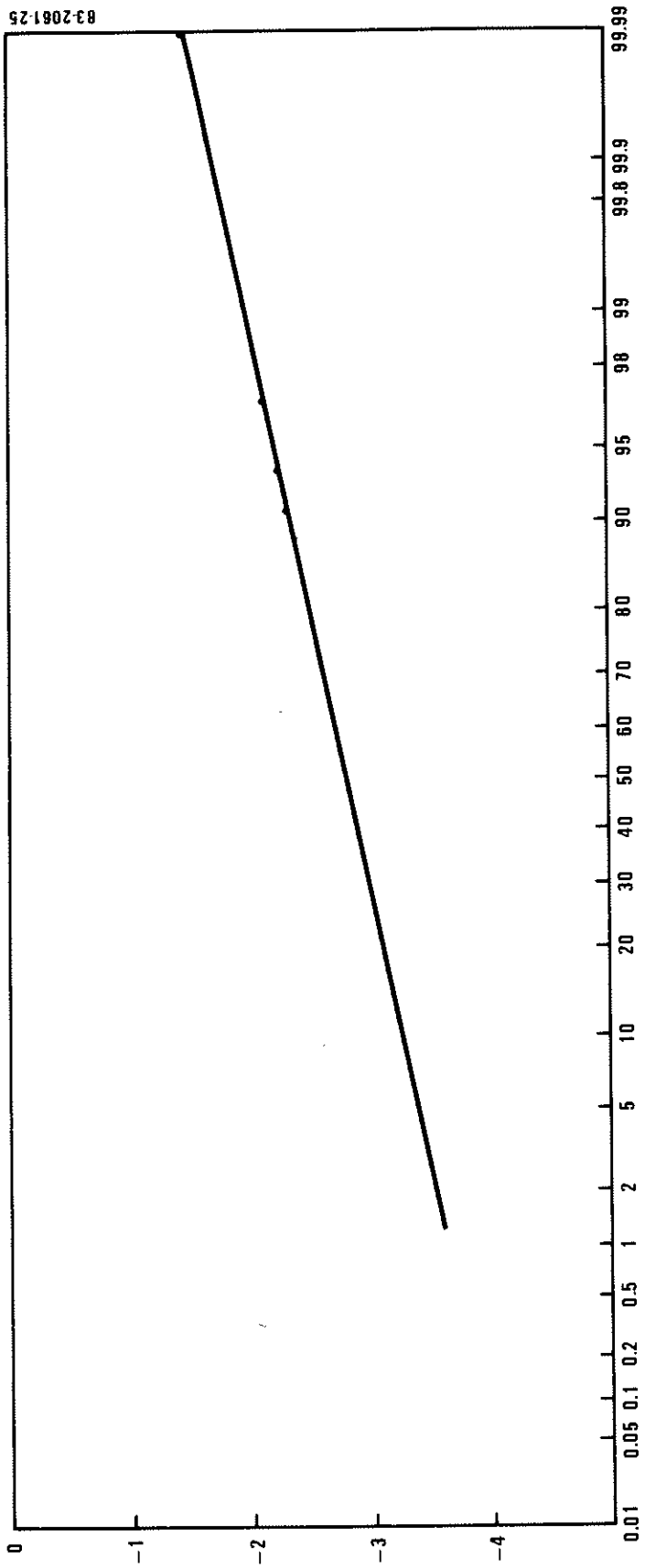

Figure 6-3. Cumulative Probability Distribution of Total Cu at NH1 Pkg. Site

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- More detailed analysis to compensate for sampling errors (e.g., outliers and detection limit problems) would result in some adjustments in the statistical parameters tabulated later on in this chapter. The data summaries presented are based on statistics computed directly from the log transforms of the data.

- Such adjustments would not have any significant effect on overall results nor on the general conclusions reached. However, at a small percentage of sites, the parameter estimates for some pollutants would change significantly.

- In general, estimates of the site median EMC would be least affected; estimates of variability more so. It is likely that the very high or very low values for coefficient of variation (storm-to-storm variability) would be adjusted to more central values.

STANDARD POLLUTANTS

This grouping includes the following pollutants:

TSS - Total Suspended Solids
BOD - Biochemical Oxygen Demand
COD - Chemical Oxygen Demand
TP - Total Phosphorus (as P)
SP - Soluble Phosphorus (as P)
TKN - Total Kjeldahl Nitrogen (as N)
NO_{2+3}-N - Nitrite + Nitrate (as N)
Cu - Total Copper
Pb - Total Lead
Zn - Total Zinc

It includes pollutants of general interest which are usually examined in other studies (both point and nonpoint sources) and includes representatives of important categories of pollutants, namely solids, oxygen consuming constituents, nutrients, and heavy metals.

Condensed Data Summary

Tables 6-1 through 6-10 summarize the NURP results for these pollutants. Monitoring sites are grouped in each of the tables according to dominant land use. Broad categories have been used; residential, commercial, industrial, urban open/nonurban (other), and mixed, this latter category being used for sites which had no predominant land use. It should be noted that the industrial category does not include heavy industry sites, but more typically reflects an industrial park type of use. As a result, most of these sites are more closely related to a commercial use than to the typical image called up by the term industrial site. For subsequent comparisons, the data shown in Tables 6-1 through 6-10 for the commercial and industrial sites, are combined and designated as commercial land use.

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TABLE 6-1. SITE MEAN TSS EMCs (mg/ℓ)

Residential

	Site	Land Use	Area (ac)	Pop. Den (#/ac)	% IMP.	No. of OBS	TSS Mean	TSS COV	TSS Median	TSS 90% Confidence Limits
1	CO1 Big Dry Cr	100	11	17	41	14	333	1.04	265	182-385
2	CO1 Chitty	100	57	24	18	14	160	.96	120	87-190
3	CO1 Elk Meadow	100	167	14	20	16	165	1.17	232	154-344
4	DC1 Dupont	100	13	-	-	8	66	2.02	39	51-74
5	DC1 Lovelidge	100	69	21	17	49	176	1.47	98	76-127
6	DC1 Stratton	100	8	-	-	11	64	1.01	36	30-44
7	IL1 Joes N	100	54	18	19	51	305	1.36	127	96-155
8	KS1 Overton	100	58	8	38	15	2216	1.47	1243	166-2837
9	MA2 Hemlock	100	59	5	18	5	78	2.49	29	8-111
10	MD1 Baltim Hill	100	14	10	51	18	74	1.32	45	30-68
11	MD1 Homeland	100	23	9	29	13	50	1.65	26	15-46
12	MD1 Mt Wash	100	17	12	29	20	96	1.17	62	84-89
13	MD1 Pos Hill	100	40	55	76	13	123	1.05	85	57-135
14	NY1 Farill's 9.	100	71	13	20	23	42	.85	32	25-47
15	NJ1 Hogue	100	-	-	-	8	65	.53	57	41-81
16	NJ1 Hamilton	100	160	5	22	30	114	1.15	98	52-150
17	NJ2 E. Rach.	100	346	14	18	7	294	1.12	195	101-380
18	IA1 Hollingwood	100	60	3	21	9	227	1.13	150	85-761
19	WA1 Spreey	100	95	9	29	113	111	.51	101	94-108
20	WI1 Durbank	100	61	15	50	45	266	.44	247	219-470
21	WI1 Hastings	100	13	17	51	33	170	.68	141	117-169
22	FL1 Wayne Apts	100	9	-	6	12	91	1.23	34	21-56
23	FL1 Mart	99	378	9	30	35	155	1.51	82	49-137
24	WI1 Lincoln	97	36	18	57	23	251	.89	206	165-358
25	TN1 R2	96	69	4	13	11	61	1.15	42	25-68
26	OC1 Nestleigh	93	41	7	21	41	75	1.45	43	33-57
27	CO1 IC - 92nd	92	62	-	27	11	156	.84	119	83-171
28	IL1 John S.	91	39	19	18	44	248	1.50	108	106-178
29	IN1 F1	91	109	21	33	11	611	.72	492	345-704
30	WA1 Lake Hills	91	102	12	37	126	127	.80	100	90-110
31	IL1 Maffly S.	90	28	22	13	59	111	1.08	71	174-256
32	FL1 Charter Hdq	89	42	-	16	12	31	1.76	16	9-10
33	OC1 Fairidge	88	19	-	14	47	25	1.55	14	18-18
34	CO1 Asbury	88	127	9	22	9	493	.62	380	344-593
35	IL1 Comb Inlets	88	538	8	17	27	250	.75	200	161-749
36	MA1 Locust	86	164	11	16	6	257	1.75	128	48-339
37	NC1 #1014	84	374	6	27	68	291	1.92	115	164-174
38	MA1 Jordon	79	110	10	21	9	79	1.74	39	19-81
39	DC1 Stedwick	78	27	15	34	47	94	1.02	38	11-43

Urban Open and Nonurban

	Site	Land Use % Open	Area (ac)	Pop. Den (#/A)	% IMP.	No. of OBS	TSS Mean	TSS COV	TSS Median	TSS 90% Confidence Limit
1	CA1 Seaview	100	632	-	-	11	238	.63	551	185-188
2	CO1 Mooney Gulch	100	405	0	3	7	411	.60	341	223-921
3	MA2 Thurnell	100	28,416	-	4	11	154	.92	111	74-113
4	MY2 English Br	98	5,748	-	1	29	17	2.45	6	4-10
5	NJ2 West Br	97	6,338	-	3	28	64	2.77	22	14-35
6	NY1 Thomas Cr	91	17,728	1	11	9	62	.74	51	14-77
7	MD3 Beaver Cr	90	2,103	-	6	5	13	.37	26	14-50
8	MD2 Sheffld Dact	80	562	-	7	32	178	2.36	149	09-224

Mixed

	Site	Land Use	Area (ac)	Pop. Den (#/A)	% IMP.	No. of OBS	TSS Mean	TSS COV	TSS Median	TSS 90% Confidence Limits
1	KS2 Nolaud	-	30	2	64	16	290	.91	208	145-297
2	MD3 Hardpdon	-	12	06	22	20	52	1.62	42	29-67
3	IL3 Hayli N	-	12	2	58	58	284	1.61	179	165-279
4	MI1 Waverly	-	10	11	68	15	85	1.38	62	39-69
5	IN1 SC	-	187	3	05	12	71	1.07	46	31-74
6	WI1 Wood Clr	-	45	12	51	37	363	.78	282	255-351
7	MA1 Rt 9	-	378	7	25	7	151	2.05	154	80-376
8	MA1 Convent	-	180	1	03	4	50	1.43	30	18-43
9	MI1 Grand R Gt	-	453	5	06	21	158	1.26	98	85-114
10	MI2 Pitt AA-S	-	2001	2	21	6	46	.17	43	37-45
11	NJ7 Cedar	-	76	-	5	27	293	1.92	139	99-202
12	MA1 Anna	-	601	9	12	6	150	2.95	61	19-166
13	MI1 Pitt AA-N	-	2871	2	26	6	68	.47	57	42-88
14	MI1 Grace M	-	164	5	25	23	172	.95	143	101-171
15	MI3 Swift Run	-	1707	2	4	5	60	.83	59	26-134
16	SO1 Meade	-	2035	-	-	15	3041	1.39	1804	1126-2897
17	CA1 Knox	-	1542	12	-	19	283	1.12	141	114-255
18	FL1 N. Jesuit	-	30	-	13	15	93	1.39	59	11-89
19	FL1 Wilder	-	194	-	97	19	53	.71	27	29-57
20	CO1 Knob Ave	-	69	9	50	32	402	.96	354	208-451

Commercial

	Site	Land Use & Coml	Area (A)	Pop. Den (#/A)	% IMP.	No. of OAS	TSS Mean	TSS COV	TSS Median	TSS 90% Confidence Limit
1	CO1 Villa Italia	100	74	0	91	27	266	1.89	122	61-183
2	NC1 1013 (C801	100	23	0	69	60	163	1.15	117	68-111
3	NJ3 Southgate	100	179	2	21	12	141	.76	119	79-160
4	WI1 Post Office	100	12	0	100	58	212	.90	161	131-197
5	NH1 Pkg Lot	100	1	0	91	12	74	1.68	18	27-64
6	IN1 CBD	100	26	0	09	15	121	.73	99	74-133
7	WI1 Rustler	100	12	0	100	42	202	.68	167	142-196
8	KS1 IC Metcalf	96	58	-	97	12	90	2.12	34	21-55
9	FL1 Nonna Pk	91	47	-	35	17	22	1.13	14	9-22
10	WI1 State Fair	74	29	10	77	29	412	.97	296	270-362

Industrial

	Site	Land Use %	Area (A)	Pop. Den (#/A)	% IMP.	No. of OBS	TSS Mean	TSS COV	TSS Median	TSS 90% Confidence Limits
1	MA2 Addition	100	19	0	69	5	48	.81	11	14-73
2	MI1 Indul Drain	100	63	0	64	18	90	.87	71	53-95
3	KS1 Lenexa	56	73	-	34	14	102	1.33	61	40-92
4	MI1 Grace S.	52	15	5	10	20	186	.94	137	101-186

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TABLE 6-2. SITE MEAN BOD EMCs (mg/ℓ)

Residential

	Site	Land Use	Area (Ac)	Pop. Den (#/Ac)	% IMP.	No. of OBS	BOD Mean	BOD COV	BOD Median	BOD 90% Confidence Limits
1	CO1 Big Dry Cr	100	31	19	41	8	-	-	-	-
2	CO1 Cherry	100	57	24	38	0	-	-	-	-
3	CO1 1162/Claude	100	167	14	24	0	-	-	-	-
4	DC1 Bullof	100	12	-	-	0	-	-	-	-
5	DE1 Lakeridge	100	6A	21	33	0	-	-	-	-
6	DC1 Littleton	100	8	-	-	4	-	-	-	-
7	IL1 John N	100	54	16	19	0	-	-	-	-
8	KS1 Overton	100	58	8	38	5	12	.59	11	6-18
9	MA2 Nemlock	100	50	5	16	0	-	-	-	-
10	MO1 Bojean Hill	100	14	10	53	0	-	-	-	-
11	MO1 Mooeland	100	23	9	29	0	-	-	-	-
13	MD1 Mt Wash	100	17	12	49	0	-	-	-	-
13	MA1 Res Hill	100	10	55	76	0	-	-	-	-
14	NJ1 Capitl P.	100	11	13	20	0	-	-	-	-
15	NJ1 Linqua	100	-	-	-	0	-	-	-	-
16	NJ3 Cranilon	100	106	5	22	0	-	-	-	-
17	NJ1 E. Poch.	100	146	18	38	0	-	-	-	-
18	IL1 Rollingwood	100	60	3	21	0	-	-	-	-
19	WA1 Surrey	100	96	9	29	0	-	-	-	-
20	WI1 Burbank	100	61	16	50	28	1	.64	0	5-1
21	WI1 Mastingl	100	15	17	51	20	9	.62	8	6-10
22	IL1 Young Acres	100	9	-	6	12	18	1.10	11	1-12
23	TX1 Mapl	99	378	0	40	4	-	-	-	-
24	WI1 Lincoln	91	16	18	67	11	18	1.21	17	7-20
25	IN1 R2	96	96	4	13	10	9	.66	7	5-10
26	DC1 Wellleigh	90	41	1	21	0	-	-	-	-
27	TX1 IC - 92nd	92	63	-	17	5	29	.60	23	11-41
28	IL1 John S.	92	39	18	18	0	-	-	-	-
29	IN1 R1	91	61	13	13	9	14	.87	11	7-19
30	WA1 Lake Hills	91	192	12	32	0	-	-	-	-
31	IL1 Wallis S.	90	16	19	31	0	-	-	-	-
32	IL1 Quarter Nou	89	42	-	16	12	11	1.24	6	5-13
33	OC1 Lakeridge	88	19	-	34	6	5	.64	4	2-7
34	CO1 Ashury	86	121	9	22	0	-	-	-	-
35	IL2 Cook Lakes	85	524	6	17	0	-	-	-	-
36	MA1 Locust	85	154	11	16	0	-	-	-	-
37	KS1 ATLP3	84	314	0	27	2	11	.13	10	6-35
38	MA1 Jordan	79	110	11	23	0	-	-	-	-
39	OC1 Speedwell	78	22	15	34	0	-	-	-	-

Mixed

	Site	Land Use %	Area (Ac)	Pop. Den (#/Ac)	% IMP.	No. of OBS	BOD Mean	BOD COV	BOD Median	BOD 90% Confidence Limits
1	KS1 Ngland	-	36	1	68	5	-	-	-	-
2	MD1 Nampden	-	11	40	12	0	-	-	-	-
3	IL1 Maillii N	-	17	3	58	0	-	-	-	-
4	MI1 Waverly	-	10	11	68	21	9	.64	7	6-9
5	TN1 SC	-	187	3	47	12	14	.47	11	7-15
6	WI1 Wood Ctr	-	45	12	51	11	14	.64	11	11-19
7	MA1 Al 9	-	139	1	21	0	-	-	-	-
8	MA1 Chevenl	-	100	1	13	9	-	-	-	-
9	MI1 Grand A Ot	-	453	5	18	15	8	.61	7	5-10
10	MI3 Pitt AA-S	-	2401	2	21	6	5	.49	5	3-7
11	NY2 Cedar	-	76	-	5	0	-	-	-	-
12	MA1 Anno	-	601	9	12	0	-	-	-	-
13	MI3 Pitt AA-N	-	2871	1	26	6	6	.70	5	3-9
14	MI1 Grace N	-	164	6	28	11	9	.78	7	5-14
15	MI3 Swift Run	-	1202	2	4	6	3	.41	3	2-4
16	SO1 Meade	-	2030	-	-	14	19	.75	15	11-24
17	CA1 Knox	-	1542	13	-	4	-	-	-	-
18	FL1 M. Jesull	-	30	-	13	15	16	.95	12	9-17
19	FL1 Wilder	-	194	-	97	15	15	1.18	14	9-19
20	CO1 North Ave	-	69	9	60	12	-	-	-	-

Commercial

	Site	Land Use Comm	Area (Ac)	Pop. Den (#/Ac)	% IMP.	No. of OBS	BOD Mean	BOD LDV	BOD Median	BOD 90% Confidence Limits
1	CO1 Villa Italia	100	34	0	93	9	-	-	-	-
2	MC1 1011 (CBD)	100	21	0	89	29	19	.80	13	10-27
3	NY1 Southgate	100	170	2	21	0	-	-	-	-
4	WI1 Post Office	100	12	0	100	35	41	.50	8	2-9
5	NN1 Pkg Lot	100	1	6	40	11	17	.80	11	10-16
6	IN1 CBD	100	26	6	99	11	11	.48	13	10-15
7	WI1 Austler	100	12	4	-	27	13	.39	10	8-13
8	KS1 IC Metcalf	96	58	-	92	13	8	.48	7	6-9
9	FL1 Norma St	91	47	-	45	12	12	.88	9	6-17
10	WI1 State Jour	14	29	10	73	15	19	.71	15	11-20

Urban Open and Nonurban

	Site	Land Use - Open	Area (Ac)	Pop. Den (#/Ac)	% IMP.	No. of OBS	BOD Mean	BOD COV	BOD Median	BOD 90% Confidence Limits
1	LA1 Seaview	100	213	-	-	0	-	-	-	-
2	CO1 Rumney Glade	100	405	0	1	8	-	-	-	-
3	NJ1 Thornell	100	28,414	-	4	0	-	-	-	-
4	MO1 English Br	99	5,249	-	1	0	-	-	-	-
5	MI1 Ansl Br	97	5,338	-	1	0	-	-	-	-
6	MI3 Indus Cr	91	17,718	1	11	9	-	-	-	-
7	MI3 Lower Cr	90	7,309	-	6	5	3	.41	2	-
8	NJ2 Thatch Duck	89	552	-	2	0	-	-	-	-

Industrial

	Site	Land Use %	Area (Ac)	Pop. Den (#/Ac)	% IMP.	No. of OBS	BOD Mean	BOD COV	BOD Median	BOD 90% Confidence Limits
1	MA1 Addison	100	18	0	65	0	-	-	-	-
2	MI1 Lupus Drain	100	61	0	64	9	10	.58	9	6-13
3	KS1 Lenexa	56	11	-	44	8	14	.77	11	7-17
4	MI1 Grace S.	51	15	5	39	9	5	.34	5	4-6

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Site	Land Use *	Area (Ac)	Pop. Den (/Ac)	* Imp.	Mul. at 085	COD Mean	COD COV	COD Median	90% Confidence Limits
1	1701 Big Dry Cr	33	19	41	16	129	.72	105	19-239
2	501 Cherry	658	14	38	18	122	.60	102	41-136
3	1501 Chittenden	600	14	24	15	117	.14	103	16-219
4	1101 Miller	109	-	-	7	64	.26	62	51-74
5	601 Lakeridge	600	13	13	44	60	.56	50	43-58
6	1101 Stanton	100	8	-	31	61	.55	45	39-53
7	1101 John M	1001	14	10	31	126	.80	94	79-122
8	501 Riverbluff	100	8	18	14	162	.67	135	101-184
9	1001 Shellblack	1001	50	6	11	-	-	-	-
10	1701 Woodland Hill	1100	14	30	61	218	1.34	128	85-193
11	801 Hempland	1101	93	9	29	177	.73	139	101-192
12	1701 Mill Wash	1001	17	12	29	164	.85	136	96-170
13	1401 Egg Hill	1001	104	55	76	127	.145	115	94-194
14	1401 Darlin's A.	1101	23	23	20	15	-	-	-
15	1101 Mead	1001	-	-	-	-	-	-	-
16	1401 Prairie Hill	1001	106	5	22	8	33	.43	24-41
17	1401 E. Wash	1001	346	10	36	7	86	.11	66-102
18	1401 Millingwood	1001	61	3	11	9	70	.05	64-84
19	1401 Shriver	1001	95	9	99	118	46	.54	39-46
20	1401 Fairfield	1001	63	15	50	27	39	.29	24-38
21	1401 Thistle	1001	33	12	51	21	41	.55	30-44
22	1401 Fielding Arch	1001	9	-	6	12	72	.96	34-79
23	1401 Pearl	1001	94	9	40	11	82	.83	49-94
24	1401 Hillfield	901	36	16	52	16	91	.95	46-94
25	1401 Dr	901	83	4	13	11	45	.39	34-51
26	001 Meadlangh	903	41	3	21	39	51	.41	41-52
27	1501 N. 92nd	902	67	-	37	11	174	.98	60-147
28	1401 John St.	901	19	14	19	29	111	.60	60-108
29	1401 Al	901	69	11	27	11	120	.96	66-135
30	1401 Hazl Hills	901	107	17	37	127	44	.54	18-41
31	1501 Heights S.	901	28	27	9	10	180	.71	119-179
32	1501 Shaeder Rds	1109	42	-	16	10	56	.64	47
33	1401 Hardscape	801	19	-	14	48	51	.46	42-52
34	001 Autumn	1101	127	9	31	9	234	1.12	156
35	1501 Oak Knolls	805	524	8	17	24	138	.90	102
36	901 Lisa L	805	154	11	15	6	104	.45	94
37	1401 Hills	804	104	4	31	34	91	.57	64
38	1401 Jordan	709	110	10	21	9	79	.53	70
39	001 Glenhill	708	27	11	34	45	45	.60	19

Site	Land Use *	Area (Ac)	Pop. Den (/Ac)	* Imp.	Mul. at 085	COD Mean	COD COV	COD Median	90% Confidence Limits
1	1501 Shawnee	1001	4631	-	-	14	.43	102	40-123
2	1501 Pioneer Trail	1001	4115	0	1	1	.03	64	64-67
3	1401 Pioneer	900	25,416	-	4	2	.16	21	38-64
4	1401 Pflumm Rd	904	6,248	-	1	1	-	-	-
5	1101 Mohawk Dr	907	5,138	-	1	0	-	-	-
6	1101 Mohawk Cir	901	17,728	1	11	2	.26	76	21-32
7	1401 Tower Dr	904	2,109	-	6	5	.16	25	15
8	1401 Shellhill Court	901	552	-	2	0	-	-	-

Site	Land Use *	Area (Ac)	Pop. Den (/Ac)	* Imp.	Mul. at 085	COD Mean	COD COV	COD Median	90% Confidence Limits
1	1401 Villa Stella	100	14	0	0	94	.14	93	84-103
2	1401 Mill Creek	100	21	0	0	69	.49	62	54-74
3	1401 Southgate	100	179	2	2	21	.0	21	21-21
4	1401 West Prince	100	12	0	0	105	.41	97	82-112
5	1401 Big Lot	100	3	0	0	96	.13	96	75-116
6	1401 Big	100	26	0	0	90	.15	90	75-106
7	1401 Hillside	100	13	0	0	-	.26	69	47-91
8	1501 N Metcalf	96	69	-	-	97	.26	75	42-108
9	1401 Normal Pl	91	97	-	-	45	.12	41	39-47
10	1401 State Fair	74	29	10	2	23	.21	113	84-142

Site	Land Use *	Area (Ac)	Pop. Den (/Ac)	* Imp.	Mul. at 085	COD Mean	COD COV	COD Median	90% Confidence Limits
1	1402 Addison	100	18	9	12	-	-	-	-
2	1401 Indus Health	100	53	13	64	42	.45	43	41-44
3	1501 Geneva	96	74	-	44	58	.60	51	39-64
4	1401 Ghoce S.	57	15	5	39	61	.71	47	33-64

TABLE 6-4. SITE MEAN TOTAL P EMCs (µg/ℓ)

Residential

	Site	Land Use * Res	Area (Ac)	Pop. Den (P/Ac)	% IMP.	No. of OBS	Total P Mean	COV	Median	90% Confidence Limits
1	C01 Big Oak Ln	100	31	19	41	16	693	.94	506	356-716
2	C02 Cherry	100	57	24	18	14	479	.54	392	293-479
3	C01 Elm Claude	100	107	14	24	18	630	.65	513	392-672
4	N02 Dupont	100	12	-	-	6	499	.32	435	353-640
5	W01 Lakeridge	100	68	21	10	48	321	.18	256	217-302
6	S01 Stratton	100	8	-	-	28	340	.54	300	256-351
7	N11 John N	100	54	18	19	13	750	.62	616	508-753
8	S01 Overton	100	58	8	7P	8	1636	.91	1207	737-2001
9	M02 Hemlock	100	50	6	16	6	314	1.05	236	95-491
10	M01 Bolton Hill	100	34	30	53	19	912	1.15	613	425-883
11	M01 Homeland	100	23	9	29	13	421	.20	345	263-471
12	M02 Mt Wash	100	11	12	29	20	456	.83	428	324-566
13	M01 Pen Mill	100	10	58	76	13	4090	1.05	2825	1845-4326
14	N11 Lamill's R.	100	73	13	20	24	221	.34	195	163-233
15	N11 Unqua	100	-	-	-	8	229	.61	196	134-285
16	N10 Longston	100	166	5	22	10	301	.54	265	206-340
17	N13 E. Poch.	100	346	1P	10	8	448	.47	405	300-646
18	T11 Rollingwood	100	60	3	21	9	268	.56	231	169-322
19	W01 Surrey	100	95	9	29	118	239	.83	184	164-205
20	W11 Burbank	100	63	16	10	45	229	.45	209	188-231
21	W11 Hastings	100	31	17	51	15	258	.51	230	203-264
22	T11 Young Apts	100	9	-	6	12	333	.65	279	205-380
23	T11 Hill	99	178	9	40	14	333	.80	260	189-349
24	W11 Lincoln	97	36	18	57	23	483	.69	373	298-466
25	TN1 RS	9N	P1	4	11	11	246	.41	222	185-287
26	W11 Westleigh	93	41	3	21	41	397	.75	319	268-380
27	K51 16 - 62nd	92	63	-	37	10	1791	1.11	782	441-1405
28	W11 John L.	91	33	18	38	32	532	.65	604	502-727
29	TN1 P1	93	69	11	33	11	705	.15	665	552-801
30	WA1 Pine Hills	91	102	12	37	127	264	.21	204	184-227
31	W11 Mallis S.	90	28	22	37	32	587	.69	483	401-582
32	F11 Charter Mdw	89	42	-	16	31	305	1.61	208	116-114
33	M01 Fairhdge	98	19	-	34	37	151	.13	254	242-334
34	C01 Pshony	66	122	9	23	9	1125	.71	P34	561-1239
35	N12 Comb Inlett	8P	524	8	12	26	506	.29	293	314-511
36	M11 Locust	85	154	31	16	6	1228	.29	961	545-1711
37	N01 11073	84	124	6	27	57	529	.99	175	117-444
38	M11 Jordan	79	110	10	21	9	448	.95	324	190-555
39	W11 Stedwick	71	21	15	34	44	388	.65	126	281-379

Mixed

	Site	Land Use *	Area (Ac)	Pop. Den (P/Ac)	% IMP.	No. of OBS	Total P Mean	COV	Median	90% Confidence Limits
1	L51 Noland	-	16	3	68	7	588	.34	526	413-671
2	M01 Hampden	-	67	40	72	20	750	1.41	426	243-1162
3	W11 Mallis N	-	12	3	58	26	998	.56	431	331-1003
4	M11 Waverly	-	30	11	68	15	196	.44	167	141-217
5	TN3 SC	-	187	3	43	13	352	.64	296	241-399
6	W11 Wong Lin	-	48	12	81	47	280	.59	240	218-294
7	MA1 Rt 9	-	339	7	23	8	1176	.65	996	513-1708
8	MA1 Convena	-	100	1	31	8	859	1.99	505	62-4411
9	M11 Grand R St	-	453	8	38	22	469	.35	384	319-477
10	M13 Pill AA-S	-	2001	2	21	6	103	.50	91	63-137
11	N12 Cedar	-	76	-	5	12	163	1.90	231	176-1011
12	MA1 Anna	-	601	9	10	5	534	.80	409	335-749
13	M13 Pitt 4A-N	-	2871	1	26	6	268	.47	243	181-351
14	M11 Grace N	-	184	5	38	23	394	.64	301	225-410
15	M13 Swill Run	-	1207	2	4	5	134	.56	117	91-193
16	S03 Meade	-	2030	-	-	15	1685	1.29	1153	743-1621
17	CP1 Knox	-	3542	12	-	19	418	.50	374	314-481
18	F11 N. Detroit	-	30	-	13	18	196	.71	151	120-214
19	F11 Wilder	-	194	-	97	18	729	.52	604	463-955
20	C01 North Ave	-	59	9	50	36	784	.69	671	470-795

Commercial

	Site	Land Use *	Area (Ac)	Pop. Den (P/Ac)	% IMP.	No. of OBS	Total P Mean	COV	Median	90% Confidence Limits
1	C01 Dille Plaza	100	24	0	91	27	704	1.25	436	316-601
2	N01 1513 (080)	100	13	0	69	51	395	.58	342	304-423
3	N13 Southgate	100	170	3	21	12	216	.26	209	193-239
4	W11 Post Office	100	12	0	100	10	118	.56	94	84-168
5	N51 Pkg Lot	100	1	0	46	27	173	1.21	114	107-208
6	TN1 C&B	100	26	0	99	15	212	.43	195	162-239
7	W11 Rustler	100	12	0	-	44	105	.29	89	89-98
8	K51 U. Metcalf	96	68	-	97	20	246	.99	176	128-341
9	F11 Numma Fk	91	47	-	46	12	151	.50	135	106-170
10	W11 State Farm	79	14	10	22	19	113	1.19	100	245-443

Urban Open and Nonurban

	Site	Land Use * Oppn	Area (Ac)	Pop. Den (P/Ac)	% IMP.	No. of OBS	Total P Mean	COV	Median	90% Confidence Limits
1	T01 Spencer	100	633	-	-	10	290	.82	255	219-249
2	L01 Bridge Golf	100	405	0	1	7	420	.41	390	224-528
3	N13 Thornell	100	28,416	-	4	33	191	.46	176	141-217
4	N12 English Dr	96	5,248	-	1	30	27	1.10	13	13-13
5	N12 West Dr	97	5,138	-	1	31	52	1.27	32	24-41
6	N13 Tremain Cr	91	17,228	1	11	16	195	.42	177	140-221
7	N11 Traver Ln	90	2,393	-	6	5	91	.26	85	58-121
8	N12 Sheilth Ccct	88	554	-	7	12	264	1.01	186	145-438

Industrial

	Site	Land Use * Ind	Area (Ac)	Pop. Den (P/Ac)	% IMP.	No. of OBS	Total P Mean	COV	Median	90% Confidence Limits
1	MA2 Adamson	100	18	3	69	5	114	.29	85	41-176
2	I11 Index Drainage	100	63	0	64	18	540	.59	472	376-589
3	K51 Lenexa	9N	72	-	44	16	691	.37	452	365-616
4	N51 Grape St.	62	26	5	19	37	436	.11	385	271-465

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Residential

	Site	Land Use % Res	Area (A)	Pop. Den (#/A)	% IMP.	No. of OBS	SOL P Mean	SOL P COV	SOL P Median	SOL P 90% Confidence Limits
1	CO1 Big Dry Cr	100	33	19	41	15	193	.64	163	125-213
2	CO1 Cherry	100	57	24	38	14	212	.47	192	155-237
3	CO1 116/Clau6e	100	167	14	24	16	196	.35	179	154-208
4	DC1 Dufief	100	12	-	-	6	448	.55	392	257-598
5	DC1 take#16ge	100	68	21	33	47	69	.62	59	51-68
6	OC1 5ration	100	8	-	-	27	251	.65	210	173-256
7	IL1 John N	100	54	18	19	0	-	-	-	-
8	t51 Overton	100	58	8	38	8	313	41	290	223-378
9	MA2 Nemloct	100	50	5	16	5	16[1]	.89	120	58-249
10	MD1 8nlton Nill	100	14	30	51	vi	-	-	-	-
11	MD1 Nome7an6	100	23	9	29	0	-	-	-	-
12	MD1 Mt Wasn	100	17	12	29	0	-	-	-	-
13	MD1 Pes Hill	100	10	56	76	0	-	-	-	-
14	NY1 Carll's R.	100	73	13	20	0	-	-	-	-
15	NT1 Unqua	100	-	-	-	0	-	-	-	-
16	NT3 Cranston	100	166	5	22	0	-	-	-	-
17	NV1 E. Roch.	100	346	18	38	0	-	-	-	-
18	TX1 Rollingwoo6	100	60	3	21	0	-	-	-	-
19	WA1 Surrey	100	95	9	29	0	-	-	-	-
20	W11 Burbant	100	63	15	50	0	-	-	-	-
21	W11 Haslings	100	33	17	51	0	-	-	-	-
22	FL1 Young Apls	100	9	-	6	0	-	-	-	-
23	TX1 Hart	99	578	9	40	0	-	-	-	-
24	W11 Lincoln	97	36	18	57	0	-	-	-	-
25	TN1 P2	96	89	4	13	11	132	.63	112	82-154
26	DC1 Westleigh	93	41	3	21	41	223	.71	182	154-215
27	K51 1C - 92n6	92	63	-	37	10	241	.62	205	147-285
28	I11 John S.	91	19	18	18	0	-	-	-	-
29	TN1 R1	91	69	11	33	11	136	.94	99	64-153
30	WA1 Late Hills	91	102	12	37	0	-	-	-	-
31	111 Mattis S.	90	28	22	37	0	-	-	-	-
32	F11 Charler M6g	89	42	-	16	0	-	-	-	-
33	DC1 Falridge	88	19	-	34	46	297	.87	224	186-270
34	CO1 Xsbury	86	127	9	22	9	212	.22	207	181-232
35	1L2 Comb 1rlels	85	524	8	17	24	98	1.21	63	95-88
36	N41 locust	85	154	11	16	6	184	.42*	169	121-235
37	NY1 #1123	84	374	6	22	0	-	-	-	-
38	MA1 Jordan	79	110	10	21	7	202	1.11	136	70-262
39	OC1 Stedwick	78	22	15	34	41	751	.70	206	174-243

Mixed

	Site	Land Use %	Area (A)	Pop. Den (#/A)	% IMP.	No. of OBS	SOL P Mean	SOL P COV	SOL P Median	SOL P 90% Confidence Limits
1	K51 Noland	-	36	3	68	8	165	.52	146	105-203
2	MD1 Hampden	-	17	40	72	0	-	-	-	-
3	111 Mattis N	-	17	3	58	0	-	-	-	-
4	M11 Waverly	-	30	11	68	32	43	.76	34	28-42
5	TM1 SC	-	187	3	43	13	192	1.17	128	81-203
6	W11 Wood Ctr	-	45	12	81	0	-	-	-	-
7	MA1 Rt 9	-	338	7	23	5	160	.38	150	106-213
8	MA1 Convent	-	100	1	33	6	106	1.83	51	19-138
9	M11 6man6 R Ot	-	453	5	38	20	68	.68	56	44-71
10	M13 Pitt AA-S	-	2001	2	21	6	13	.32	13	10-17
11	NY2 Cedar	-	76	-	5	26	49	1.16	32	23-44
12	MA1 Anna	-	601	9	12	4	-	-	-	-
13	M13 Pitt AA-N	-	2871	7	26	6	59	.88	44	24-82
14	M11 Grece M	-	164	5	28	21	47	.47	42	35-50
15	M13 Swilt Run	-	1207	2	4	5	39	.46	35	23-53
16	SD1 Meade	-	2030	-	-	14	87	.61	74	57-97
17	CA1 Knox	-	1542	12	-	18	169	.99	120	85-168
18	FL1 N. Jesuil	-	30	-	13	0	-	-	-	-
19	FL1 Hilder	-	194	-	97	0	-	-	-	-
20	CO1 Month Ave	-	69	9	50	30	228	.95	165	179-212

Commercial

	Site	Land Use % Coml	Area (A)	Pop. Den (#/A)	% IMP.	No. of OBS	SOL P Mean	SOL P COV	SOL P Median	SOL P 90% Confidence Limits
1	CO1 Villa Italia	100	24	0	91	26	293	1.09	198	147-266
2	NC1 1013 (CBD)	100	23	0	69	0	-	-	-	-
3	NY3 Southgate	100	179	2	21	0	-	-	-	-
4	W11 Post Office	100	12	0	100	0	-	-	-	-
5	NH1 Pkg Lot	100	1	0	90	0	-	-	-	-
6	TN1 CBD	100	26	0	99	15	46	.32	17	28-50
7	W11 Rustler	100	12	0	-	0	-	-	-	-
8	K51 1C Metcall	96	58	-	97	21	116	1.06	80	58-111
9	FL1 Norma Pt	91	47	-	45	0	-	-	-	-
10	W11 State Fair	74	29	10	77	31	-	-	-	-

Urban Open and Nonurban

	Site	Land Use % Open	Area (A)	Pop. Den (#/A)	% IMP.	No. of OBS	SOL P Mean	SOL P COV	SOL P Median	SOL P 90% Confidence Limits
1	CA1 Sraview	100	633	-	-	12	145	1.20	93	55-150
2	CO1 Paoney Gulch	100	405	0	1	7	137	.46	124	90-171
3	NY3 Thornell	100	28,416	-	4	0	-	-	-	-
4	NY2 English Br	98	5,248	-	1	18	5	.35	5	4-6
5	NY2 West Br	93	5,138	-	1	26	8	.56	7	6-8
6	NY1 Thomas Cr	91	17,728	1	11	0	-	-	-	-
7	M13 Travel Cr	90	2,301	-	6	5	31	.55	29	18-47
8	NY2 Sheriff Ditch	80	552	-	7	12	39	1.11	25	20-14

Industrial

	Site	Land Use % Ind	Area (A)	Pop. Den (#/A)	% IMP.	No. of OBS	SOL P Mean	SOL P COV	SOL P Median	SOL P 90% Confidence Limits
1	MA2 Addison	100	18	0	69	5	75	.92	55	26-116
2	M12 Indus Drain	100	63	0	64	14	127	.72	103	76-140
3	K51 Lenaxa	56	72	-	44	16	346	1.66	179	108-296
4	M11 Grace S.	52	75	5	39	16	59	1.74	37	24-56

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TABLE 6-6. SITE MEAN TKN EMCs (µg/ℓ)

Residential

	Site	Land Use	Area (A)	Pop. Den (#/A)	% IMP.	No. of OBS	TKN Mean	TKN COV	TKN Median	TKN 90% Confidence Limits
1	CO1 Btg Drg Cr	100	31	19	41	16	2,169	.58	2041	1617-2584
2	CO1 CHerry	100	57	24	38	14	2,609	.39	2430	2014-2904
3	CO1 116/Claude	100	167	14	24	19	2,891	.51	2501	2010-1112
4	OC1 Dufief	100	17	-	-	6	2,066	.11	2048	1841-2278
5	OE1 Lakeridge	100	68	21	33	48	1,774	.64	1450	1259-1670
6	OC1 Stratten	100	8	-	-	28	1,811	.34	1686	1494-1904
7	1t1 JoHn N	100	54	18	19	13	1,994	.81	1107	7520-3811
8	t51 Overton	100	58	8	38	5	-	-	-	-
9	MA2 Hemlock	100	50	5	16	5	1,679	.55	1217	1971-5252
10	MD1 Bolton Milt	100	14	30	51	18	6,067	.12	4815	1640-6170
11	MD1 Homeland	100	21	9	29	13	6,505	.40	6044	4996-7112
12	MD1 Mt Wash	100	17	12	29	20	6,915	.41	b40R	5502-7461
13	MD1 Res Hitl	100	10	55	76	13	10,803	.41	9915	9089-12154
14	Nb1 Carll's R.	100	71	11	20	24	1,487	.71	1201	955-1509
15	NY1 Unqua	100	-	-	-	8	1,408	.26	1161	1148-1618
16	Nb1 Cranston	100	166	5	27	11	1,492	.45	1358	1098-1679
17	NE3 E. PocN.	100	346	18	18	7	3,246	.90	7411	1369-4245
18	1t1 Potlingwood	100	60	1	21	9	5,004	2.37	1942	828-4554
19	MA1 Surrey	100	95	9	29	11R	1,007	.62	857	785-915
20	W11 Burbant	100	61	15	50		1,260	.50	1125	908-1195
21	W11 Hastings	100	13	17	51	15	1,102	.54	969	801-1173
22	FL1 Young Apts	100	9	-	6	12	1,139	.70	1097	791-1522
23	FX1 Mart	99	178	9	40	11	1,016	.75	2412	1674-3474
24	W11 Lincoln	37	16	18	52	1	-	-	-	-
25	TN1 P2	96	84	4	11	11	426	.11	452	379-519
26	OE1 WestleighN	93	41	3	21	41	1,901	.56	1660	1447-1904
27	KS1 IC - 47nd	92	61	-	12	8	4,182	.94	3051	1790-5200
28	1L1 JoHn S.	41	19	18	18	12	1,527	1.04	2441	1886-1155
29	FN1 Pi	91	69	11	11	11	1,131	.14	1071	894-1281
30	WP1 Lake Hills	91	102	12	37	127	1,056	.71	852	774-438
31	1L1 Mattis S.	90	28	22	37	37	1,440	.69	2825	2343-3406
32	FL1 CHarter Hdg	89	42	-	18	12	1,704	.83	1309	899-1905
33	OC1 Fairidge	88	19	-	34	46	2,712	.51	1958	1711-2215
34	CO1 Pebury	86	127	9	22	t	3,735	.56	3761	2774-4788
35	1L2 Comb Intets	85	524	6	17	0	-	-	-	-
36	MP1 Locust	85	154	11	16	6	2,695	.38	2522	1864-3412
37	NC1 #1021	84	324	F	23	67	1,498	.94	1086	921-1277
38	MA1 Jordan	79	110	10	21	9	1,191	.60	1194	845-1681
39	OC1 Stedwict	78	27	15	34	43	1,895	.57	1643	1435-1881

Mixed

	Site	Land Use %	Area (A)	Pop. Den (#/A)	% IMP.	No. of OBS	TKN Mean	TKN COV	TKN Median	TKN 90% Confidence Limits
1	KS1 Noland	-	36	3	68	0	-	-	-	-
2	MD1 HAmpden	-	17	40	72	19	6994	.55	6140	5004-7531
3	1L1 Mattis N	-	17	3	58	15	2872	.64	2172	7006-7805
4	W11 Waverly	-	10	11	68	15	1490	.51	1116	1142-1516
5	TN1 SC	-	187	1	41	11	623	.50	558	442-705
6	W11 Wood Ctr	-	45	12	81	16	1452	.35	1369	1180-1589
7	MA1 Rt 9	-	338	7	23	5	2446	.50	2188	1194-1412
8	MA1 Consent	-	100	1	33	8	1080	.64	910	615-1147
9	W11 Geaod R Ot	-	451	5	18	21	1631	.47	1506	1104-1740
10	W11 Pttt AA-5	-	7001	2	21	6	845	.29	811	647-1025
11	NY2 Cedar	-	76	-	5	21	1232	.81	951	724-1749
12	MA1 Anna	-	601	9	12	6	1888	.70	1547	920-2601
13	W13 Pttt AA-N	-	2891	7	26	6	1056	.22	1011	887-1215
14	W11 Grace N	-	164	5	28	21	1988	.47	1807	1536-2115
15	N13 Swift Run	-	1707	2	4	5	1116	.15	1104	968-1273
16	SO1 Meade	-	2010	-	-	11	4741	.50	1807	3010-4802
17	CA1 Knox	-	1542	17	-	20	2770	.75	1775	1171-2298
18	FL1 M. Jesutt	-	30	-	11	15	1388	.49	1244	1011-1542
19	FL1 Wilder	-	194	-	47	15	1107	.11	1056	970-1212
20	CO1 NorthN Aue	-	69	4	50	21	4196	.66	1522	2847-4166

Commercial

	Site	Land Use % Comm	Area (A)	Pop. Den (#/A)	% IMP.	No. of OBS	TKN Mean	TKN COV	TKN Median	TKN 90% Confidence Limits
1	CO1 Villa Italia	100	74	0	91	27	1657	.85	2785	2186-3548
2	NC1 1031 (CR01	100	21	0	64	61	1631	.10	1118	1152-1409
3	NY1 SouthGate	100	124	2	21	13	1256	.45	1144	975-1414
4	W11 Post Office	100	12	0	100	27	1021	.44	916	915-1035
5	NM1 Pkg Lot	100	1	0	42	18	7119	.66	1761	1116-2754
6	TN1 EBO	100	26	0	99	15	646	.41	597	499-714
7	W11 Rustler	100	12	0	-	25	1023	.61	916	754-1110
8	KS1 IC Metcalf	96	58	-	47	17	1176	.21	949	720-1352
9	FL1 Norma Pk	91	47	-	45	12	826	.84	633	437-925
10	W11 State Fatr	74	29	10	77	8	1656	.65	1189	913-2068

Urban Open and Nonurban

	Site	Land Use	Area (A)	Pop. Den (#/A)	% IMP.	No. of OBS	TKN Mean	TKN COV	TKN Median	TKN 90% Confidence Limits
1	FA1 Seaview	100	613	-	-	13	3674	.59	1159	7411-4139
2	CO1 Pooney GulcN	100	405	0	1	7	7954	.57	7615	1813-3768
3	NY1 JNornell	100	28,416	-	4	11	1099	.50	482	778-1240
4	NY2 EnglisN Br	98	5,248	-	1	15	340	.50	305	246-128
5	Nb2 West Br	97	5,338	-	1	24	392	.67	147	792-412
6	Nb1 ZNomas Er	91	17,728	1	11	10	1111	.16	1045	854-1279
7	N13 Fraser Cr	90	2,101	-	6	5	889	.11	883	796-981
8	NY2 SNeriff Dock	80	552	-	7	13	963	.76	765	628-937

Industrial

	Site	Land Use % Ind	Area (A)	Pop. Den (#/A)	% IMP.	No. of OBS	TKN Mean	TKN COV	TKN Median	TKN 90% Confidence Limits
1	MA2 Addison	100	18	0	69	5	2042	.49	1879	1227-2474
2	W11 Indus Drain	100	63	0	64	18	1274	.67	1107	891-1376
1	KS1 Lenaka	56	72	-	44	17	1385	.21	1117	796-1368
4	W11 Grace S.	52	25	5	39	18	1711	.56	1491	1205-1850

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TABLE 6-7. SITE MEAN NITRITE PLUS NITRATE EMCs (µg/ℓ)

Residential

	Site	Land Use % Res	Area (A)	Pop. Den (#/A)	% IMP.	No. of OBS	NO_{2+3}-N Mean	COV	Median	90% Confidence Limits
1	CO1 Stg Cry Cr	100	33	19	41	15	527	.34	499	429-580
2	CO2 Cherry	100	57	24	38	14	709	.40	667	542-288
3	CO1 116/Claude	100	167	14	24	16	670	.51	529	469-715
4	OC5 Dufief	100	12	-	-	8	420	.35	445	354-558
5	OC1 Lakeridge	100	68	21	33	49	246	.62	633	552-725
6	DC1 Stratton	100	8	-	-	33	418	.86	312	254-395
7	IL1 John K	100	54	18	14	-	-	-	-	-
8	K51 Overlon	100	58	8	38	-	-	-	-	-
9	MA2 Hemlock	100	50	5	16	4	-	-	-	-
10	MD1 Bollon Mill	100	14	10	52	19	9535	1.59	5073	3246-7930
11	MD1 Homeland	100	23	9	29	13	6343	4.56	1358	570-3234
12	MD1 Mt Wash	100	17	12	29	20	7822	1.56	4229	2253-6492
13	MD1 Res Mill	100	10	55	26	13	6938	1.08	4207	1048-2269
14	NY1 Carll's P.	100	73	13	20	24	230	1.38	442	31E-627
15	NY1 Pnqoa	100	-	-	-	8	1593	-	-	1020-1872
16	NY3 Cranston	100	166	5	22	0	-	-	-	-
12	NY3 E. Roch.	100	346	18	38	0	-	-	-	-
1P	TY1 Rollingwood	100	60	3	21	9	829	.51	283	581-1055
19	WA1 Surrey	100	95	9	79	0	-	-	-	-
20	W11 Burbank	100	63	15	50	18	275	.48	699	580-843
21	W11 Naslings	100	13	17	51	24	625	.39	582	510-664
22	f11 Young Apls	100	9	-	6	12	311	.64	262	193-355
23	TK1 Harl	99	328	9	40	10	1625	.54	1430	1062-1912
24	W51 Lincoln	97	36	18	57	3	-	-	-	-
25	IW1 R2	96	89	4	19	11	997	1.34	232	136-412
26	DC1 Wesleigh	93	41	9	71	41	202	.59	606	525-700
22	K51 IC - 92rd	92	63	-	37	0	-	-	-	-
28	311 Jnhn S.	91	39	18	18	0	-	-	-	-
29	IN1 R1	91	69	11	33	21	578	.72	458	315-665
30	WA1 Lake Hills	91	102	12	37	0	-	-	-	-
31	111 Malibs S.	90	28	22	37	0	-	-	-	-
32	f11 Charler Mdg	89	42	-	16	12	610	.77	483	339-688
33	DC1 Fairidge	88	19	-	34	48	927	.66	772	667-893
5a	C01 Asbury	86	122	9	22	9	881	.21	862	258-980
35	IL2 Comb Inlecs	85	524	8	12	21	296	.55	699	526-848
36	MA1 Locust	85	154	11	16	5	1705	.69	1406	726-2549
37	NC1 41023	84	324	6	27	67	716	.68	591	521-620
18	MA1 Jordnr	79	110	10	21	9	1747	.55	1094	795-1505
39	DC1 Sledwick	78	27	15	34	47	837	.70	686	588-800

Urban Open and Nonurban

	Site	Land Use % Open	Area (A)	Pop. Den #/A	% IMP.	No. of OBS	NO_{2+3}-N Mean	COV	Median	90% Confidence Limits
5	CA1 Seaview	100	611	-	-	12	1542	.49	1381	1087-1759
2	C11 Rooney Golcn	100	405	51	1	7	581	1.03	405	217-756
3	NY3 Thorbell	100	28,416	-	4	15	-	-	-	-
4	NY2 English Br	98	5,248	-	1	30	240	.60	206	173-245
5	NY2 West Br	97	5,338	-	1	11	862	.53	761	656-888
6	NY3 Thomas Cr	91	17,278	5	11	0	-	-	-	-
7	M13 Trayer Cr	90	2,303	-	6	5	1108	.17	1092	930-1283
8	NY2 Sheriff Docy	85	552	-	7	33	283	1.02	268	209-143

Mixed

	Site	Land Use %	Area (A)	Pop. Den (#/A)	% IMP.	No. of OBS	NO_{2+3}-N Mean	COV	Median	90% Confidence Limits
1	K51 Noland	-	36	3	68	0	-	-	-	-
2	MD1 Hampden	-	17	40	72	20	11,529	4.00	2293	1457-5355
1	IL1 Mallis N	-	17	3	58	0	-	-	-	-
4	W11 Waverly	-	30	11	68	35	725	.49	696	610-794
5	TW1 SC	-	187	3	43	13	582	1.49	327	192-558
6	W11 Wood Clr	-	45	12	81	17	251	.69	618	474-805
2	MA1 R1 9	-	338	7	23	5	1,789	.48	1613	1045-2490
8	MA1 Convent	-	100	1	13	6	960	.39	894	656-1218
9	M11 Grand R Ot	-	453	5	38	23	883	.44	807	694-938
10	W13 P111 AA-S	-	2001	2	21	6	284	.48	256	176-322
11	NY2 Cedar	-	26	-	5	32	248	.72	201	-
12	MA1 Anna	-	601	9	52	6	1,268	.60	1086	688-1214
13	W13 P111 AA-N	-	2821	7	26	5	469	.24	456	364-571
14	W11 Grace N	-	164	5	28	21	825	.43	803	693-931
15	W13 Swlfl Run	-	1202	7	4	5	1,033	.26	821	431-1563
16	S01 Meade	-	2030	-	-	15	616	.40	521	429-680
12	CA1 Knoa	-	1542	12	-	17	1,111	.36	1044	901-1210
18	fL1 W. Jasoll	-	30	-	13	14	126	.54	392	261-422
19	fL1 W11der	-	194	-	92	15	456	.42	412	336-505
20	C01 North Ave	-	69	9	50	32	1,744	.92	1286	1012-1626

Commercial

	Site	Land Use % Coml	Area (A)	Pop. Den (#/A)	% IMP.	No. of OBS	NO_{2+3}-N Mean	COV	Median	90% Confidence Limits
1	C01 Villa Italia	100	74	0	91	27	1180	.86	895	708-1143
2	NC1 1013 1C80)	100	23	0	69	61	1518	.55	980	878-1098
3	NY3 Southgate	100	129	2	21	0	-	-	-	-
4	W51 Post Office	100	12	0	100	28	708	.68	584	479-712
5	NH1 Pkg Lot	100	15	0	90	28	801	.84	615	486-778
6	TN1 T&D	100	26	0	99	15	662	.62	562	434-778
7	W11 Roslier	100	12	0	-	25	781	.69	642	527-791
8	K51 IC Melcolf	96	58	-	95	0	-	-	-	-
9	fL1 Norma Pk	91	42	-	45	12	356	.46	323	252-405
10	W11 Slate Fab	74	29	10	72	12	781	.50	702	540-897

Industrial

	Site	Land Use % Ind	Area (A)	Pop. Den (#/A)	% IMP.	No. of OBS	NO_{2+3}-N Mean	COV	Median	90% Confidence Limits
1	MA2 Addison	100	19	5	69	5	1355	.79	1301	997-1706
2	M11 Indus Oroln	100	63	0	64	18	686	.40	637	544-746
3	K51 Lenaaa	56	72	-	44	0	-	-	-	-
4	N11 Grace S.	52	75	5	39	12	742	.52	657	534-808

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TABLE 6-8. SITE MEAN TOTAL COPPER EMCs (µg/ℓ)

Residential

	Site	Land use % Res	Area (A)	Pop. Den (#/A)	% IMP.	No. of OBS	Total Copper Mean	COV	Median	90% Confidence Limits
1	CO1 Big Dry Cr	100	33	19	41	16	32	.82	25	18-34
2	CO1 Cherry	100	97	24	38	14	35	1.48	20	12-33
3	CO1 Hi/Clause	100	167	14	24	16	28	.74	22	16-29
4	OC1 Bufref	100	12	-	-	21	-	-	-	-
5	OC1 Laterldgr	100	68	21	33	14	18	.55	33	26-42
6	OE1 Stratton	100	8	-	-	10	28	.30	27	23-32
7	IL1 John N	100	54	18	19	36	80	.85	60	51-78
8	YS1 Overton	100	58	8	38	12	91	.50	81	93-101
9	MA1 Hemlock	100	60	5	16	0	-	-	-	-
10	MP1 Bolton Hill	100	14	10	51	19	107	.70	88	68-112
11	MO1 Hinkelbin	100	21	9	F9	13	312	.14	296	252-349
12	MO1 Mt Wash	100	12	12	29	20	26	.78	20	15-26
13	MA1 Yes Hill	100	10	64	76	13	42	.69	30	25-46
14	NH1 Carll s R.	100	71	11	20	0	-	-	-	-
15	NH1 Indus	100	-	-	-	0	-	-	-	-
16	NH3 Cranston	100	166	5	22	0	-	-	-	-
17	NH3 E. Avon.	100	246	18	38	0	-	-	-	-
18	TH1 Rollinswood	100	60	3	21	0	-	-	-	-
19	WA1 Surrey	100	95	9	29	0	-	-	-	-
20	WH1 Burbank	100	61	15	60	0	-	-	-	-
21	WH1 Mastimus	100	31	17	51	0	-	-	-	-
22	FL1 Young Apts	100	9	-	6	12	6	.36	6	5-7
23	TH1 Marl	99	378	9	40	0	-	-	-	-
24	WH1 Lincoln	97	16	18	50	0	-	-	-	-
25	TN1 P2	96	89	4	13	11	48	1.54	15	8-22
26	HO1 Westleigh	93	41	5	21	6	31	.43	34	28-40
27	KS1 IL - 96na	92	61	-	17	3	-	-	-	-
28	IL1 John S.	91	39	18	18	16	43	.84	33	26-40
29	TN1 P1	91	69	11	13	11	61	.60	52	38-70
30	WA1 Lake Mills	91	102	12	17	3	22	.34	21	15-29
31	IL1 Mallis S.	90	28	22	31	36	45	.76	36	30-44
32	KS1 Chester Ndg	89	42	-	16	12	10	.94	7	6-11
33	HO1 Fairridge	88	19	-	34	9	26	.39	25	19-31
34	CO1 Asbury	86	127	9	22	9	59	.84	45	29-71
35	IL2 Comb Inlets	85	124	8	17	26	49	.53	43	36-51
36	MA1 Locust	85	154	11	16	6	107	.21	104	80-135
37	NE1 #1061	84	144	6	27	66	39	.60	33	29-39
38	MA1 Jordin	79	110	10	31	8	24	.24	22	-
39	OC1 Steward	78	27	15	34	9	61	.15	25	23-26

Mixed

	Site	Land Use %	Area (A)	Pop. Den (#/A)	% IMP.	No. of OBS	Total Copper Mean	COV	Median	90% Confidence Limits
1	KS1 Naland	-	36	1	68	9	48	.38	45	36-57
2	MO1 Hampden	-	31	40	28	30	81	.46	61	45-92
3	IL1 Mattis N	-	17	3	58	17	48	.81	17	31-45
4	MI1 Waverly	-	30	11	69	16	15	.50	13	10-16
5	TN1 SC	-	181	3	41	13	42	1.15	25	14-41
6	WI1 Wood Cnr	-	45	12	81	11	-	-	-	-
7	MA1 Pi W	-	119	7	23	7	112	.49	100	71-141
8	MA1 Tenrrhi	-	180	1	31	7	205	.41	96	71-170
9	MO1 Grand & Ol	-	450	5	38	13	101	.53	76	20-35
10	MI3 Pitt AA-S	-	2003	2	45	0	-	-	-	-
11	NY2 Cedar	-	76	-	5	0	-	-	-	-
12	MA1 Anna	-	601	9	12	5	54	.51	46	30-71
13	MI3 Pitt AA-N	-	2811	7	26	0	-	-	-	-
14	MI1 Grand N	-	184	5	28	9	14	.31	12	11-15
15	MI3 Swift Run	-	1203	2	4	0	-	-	-	-
16	SO1 Meade	-	2030	-	-	0	-	-	-	-
17	OA1 Knox	-	1542	12	-	17	95	1.14	65	44-96
18	FL1 N. Jesuit	-	30	-	13	15	7	.61	5	5-9
19	FL1 Wilder	-	184	-	67	19	6	.84	5	4-7
20	CO1 North Ave	-	69	9	51	12	71	.83	54	47-74

Commercial

	Site	Land Use (Zoning)	Area (A)	Pop. Den (#/A)	% IMP.	No. of OBS	Total Copper Mean	COV	Median	90% Confidence Limits
1	CO1 Villa Italia	100	74	0	91	22	31	.87	25	20-32
2	NC1 TOll (CBD)	100	23	0	89	61	70	.54	61	54-69
3	NJ1 Suntogate	100	179	0	21	0	-	-	-	-
4	WI1 Post Office	100	12	2	100	0	-	-	-	-
5	NM1 Pkg Int	100	3	0	99	11	166	.13	161	-
6	TH1 CBD	100	26	0	99	15	42	.60	36	28-48
7	WI1 Rustler	100	12	0	-	0	-	-	-	-
8	KS1 Il Metcalf	96	98	-	97	6	81	.33	79	70-91
9	IL1 Norma 2k	93	AP	-	65	12	11	.32	10	8-13
10	WI1 State Fair	74	24	10	77	0	-	-	-	-

Urban Open and Nonurban

	Site	Land Use % Open	Area (A)	Pop. Den (#/A)	% IMP.	No. of OBS	Total Copper Mean	COV	Median	90% Confidence Limits
1	LA1 Seaview	100	633	-	-	12	59	.33	55	48-65
2	FO1 Bonney Gulch	100	405	0	1	6	37	1.09	25	17-48
3	NJ3 Thornell	100	28,416	-	4	0	-	-	-	-
4	UT1 Ingleish Cr	98	6,248	-	1	0	-	-	-	-
5	NY2 West Br	97	5,538	-	1	0	-	-	-	-
6	NY3 Indian Ck	91	17,726	1	11	0	-	-	-	-
7	NJ3 Teague Cr	90	7,303	-	6	0	-	-	-	-
8	NJ1 Summit Lk1	40	552	-	7	0	-	-	-	-

Industrial

	Site	Land Use - Ind	Area (A)	Pop. Den (#/A)	% IMP.	No. of OBS	Total Copper Mean	COV	Median	90% Confidence Limits
1	MA2 Mansso	100	18	0	49	0	-	-	-	-
2	MI1 Innus Drain	100	63	0	64	6	30	.55	27	21-43
3	KS1 Kenoma	96	72	-	44	5	28	.24	26	24-31
4	MI1 Grove St.	96	15	6	37	7	24	.16	21	18-27

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TABLE 6-9. SITE MEAN TOTAL LEAD EMCs (µg/ℓ)

Residential

	Site	Land Use % Res	Area (A)	Pop. Den (P/A)	% IMP.	No. of OBS	Total Lead Mean	COV	Median	90% Confidence Limits
1	ES1 Brq Dry Cr	100	13	19	41	16	183	.88	117	98-191
2	CO1 Cherry	100	51	24	18	14	194	.92	143	99-207
3	CO1 Elm/Chamb	100	167	14	24	16	292	.87	210	151-292
4	OC1 Dufref	101	12	-	-	1	-	-	-	-
5	OL1 Lakeridge	100	68	21	33	18	227	.54	201	164-245
6	OC1 Stratton	100	8	-	-	0	-	-	-	-
7	S11 John N	100	84	18	19	16	717	.71	191	158-211
8	HS1 Overton	100	58	8	16	11	118	.19	128	104-157
9	MA2 Hemlock	100	55	5	16	0	-	-	-	-
10	MD1 Dolling Hill	100	14	30	51	19	2745	4.53	592	295-1188
11	MI1 Moneland	100	21	9	29	10	76	.48	69	56-86
12	MD1 Mt Wash	100	17	12	29	20	86	.48	77	65-92
13	MD1 Res Mill	100	10	55	76	17	461	1.86	218	119-399
14	MA1 Carll's P	100	71	13	20	0	-	-	-	-
15	MY1 Penqua	111*	-	-	-	8	88	1.16	52	26-103
16	MA1 Cranston	100	166	5	22	31	34	.77	27	19-38
17	MY3 E. Rach.	100	146	18	38	8	191	.89	144	86-240
18	MS1 Rollingwood	108	60	3	21	0	-	-	-	-
19	MA1 Surrey	100	98	9	29	128	152	.51	136	126-146
20	MI1 Bimbank	101	63	15	51	44	95	.72	77	65-91
21	MI1 Hastings	100	33	17	51	15	108	.67	90	75-107
22	IL1 Young Apts	101	9	-	6	12	76	1.03	51	14-82
23	MS1 Mars	99	178	9	40	0	-	-	-	-
24	MI1 Lincoln	91	16	18	57	22	303	1.29	200	141-280
25	TM1 42	96	89	4	13	11	111	.41	101	99-151
26	OC1 Kesslyrgh	97	41	1	21	5	186	.37	184	157-216
27	HS1 IL - 82nd	92	61	-	37	1	-	-	-	-
28	IL1 John S.	91	39	18	28	13	217	.60	169	138-208
29	TM1 41	91	69	11	11	31	440	.61	376	277-511
30	MA1 Lake Mills	91	102	17	39	126	192	.67	159	140-174
31	IL1 Mallis S.	98	28	21	17	37	595	1.12	196	108-508
32	IL1 Charter Ridg	89	92	-	16	12	44	1.60	26	14-47
33	OC1 Fairridge	68	19	-	14	1	-	-	-	-
34	LB1 Asbury	86	127	9	28	9	431	.12	151	151-524
35	IL2 Sand Inlets	95	524	6	17	24	122	1.01	217	169-304
36	MA1 Locust	85	154	11	14	6	213	.67	225	116-171
37	MP1 #1023	84	129	6	27	66	254	.98	182	151-215
38	MA1 Jordan	79	110	10	21	9	168	.12	160	112-194
39	OC1 Shadwick	78	27	15	34	11	141	.41	110	105-161

Urban Open and Nonurban

	Site	Land Use % Open	Area (A)	Pop. Den (P/A)	% IMP.	No. of OBS	Total Lead Mean	COV	Median	90% Confidence Limits
1	FM1 Seymour	100	621	-	-	7	214	.59	159	91-279
2	LO1 Bonner Smith	100	355	1*	1	7	52	.41	39	22-69
3	MY3 Thornell	100	24,416	-	4	10	12	.42	11	9-14
4	MY2 Endrish Br	98	5,248	-	1	21	8	.69	8	6-10
5	HI* West Br	97	1,378	-	1	25	20	1.40	22	15-31
6	MI3 Thomas Cr	91	33,126	1	11	22	25	1.65	18	10-31
7	MI3 Prayer Cr	90	2,302	-	6	0	-	-	-	-
8	MY3 Sherriff Ducr	30	551	-	7	17	132	1.09	91	73-117

Mixed

	Site	Land Use 1	Area (A)	Pop. Den (P/A)	% IMP.	No. of OBS	Total Lead Mean	COV	Median	90% Confidence Limits
1	KS1 Noland	-	36	1	68	9	164	.49	147	110-196
2	MD1 Hampden	-	17	40	72	20	227	.82	176	131-242
3	LL1 Mattls M	-	17	3	58	41	554	1.06	180	103-478
4	MI1 Waverly	-	30	11	68	24	311	1.09	75	55-102
5	TM1 SC	-	187	1	43	13	237	.31	227	195-264
6	MI1 Wood Ctr	-	95	12	81	45	582	.94	424	348-517
7	MA1 Rt 9	-	338	7	11	7	419	1.02	167	165-471
8	MA1 Convent	-	100	1	13	7	196	.94	143	80-257
9	MI1 Grand R Ot	-	451	5	38	18	122	.90	91	66-126
10	MI3 Pitt AA-S	-	2001	2	21	6	21	1.63	11	4-28
11	MY2 Cedar	-	76	-	5	28	75	1.25	47	34-69
12	MA1 Anna	-	601	9	12	4	-	-	-	-
13	MI3 Pitt AA-M	-	2871	7	26	5	61	.71	50	27-97
14	MI1 Grace A	-	164	5	28	18	170	1.79	99	65-151
15	MI3 Swift Run	-	1207	2	6	4	-	-	-	-
16	SO1 Meade	-	2000	-	-	24	381	1.13	254	165-390
17	CA1 Knox	-	1542	12	-	22	495	.99	351	359-475
18	FL1 N. Jesuit	-	10	-	13	15	56	1.22	35	23-54
19	FL1 Wilder	-	194	-	97	15	86	.85	55	46-91
20	CO1 North Ave	-	69	9	50	11	158	.51	278	226-343

Commercial

	Site	Land Use % Coml	Area (A)	Pop. Den (P/A)	% IMP.	No. of OBS	Total Lead Mean	COV	Median	90% Confidence Limits
1	CO1 Villa Italia	100	74	0	91	27	262	1.21	187	172-224
2	MC1 1011 (CBD)	100	21	0	69	61	387	.81	296	254-349
3	MY3 Southgate	100	179	0	21	13	47	.50	42	31-53
4	MI1 Post Office	100	17	2	100	59	191	.90	145	126-173
5	MA1 Prg Lvl	100	1	0	90	11	208	.93	162	121-197
6	TM1 CBD	100	26	5	99	15	158	.52	140	112-175
7	MI1 Rustler	100	12	0	-	44	123	.70	98	83-116
8	RS1 IC Mercatl	96	58	-	97	7	-	-	-	-
9	FL1 Manna Pk	91	47	-	46	12	46	1.01	37	21-49
10	MI1 State Fair	74	29	10	37	27	409	.86	310	243-396

Industrial

	Site	Land Use % Ind	Area (A)	Pop. Den (P/A)	% IMP.	No. of OBS	Total Lead Mean	COV	Median	90% Confidence Limits
1	MA2 Addison	100	18	0	69	0	-	-	-	-
2	MI3 Lacus Sprgs	100	63	0	64	13	110	.77	93	65-129
3	KS1 Lenexa	96	72	-	44	6	-	-	-	-
4	MI1 Grace S.	52	15	5	39	13	114	.76	92	66-128

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TABLE 6-10. SITE MEAN TOTAL ZINC EMCs (µg/ℓ)

Residential

	Site	Land Use	Area (A)	Pop. Den (#/A)	% IMP.	No. of OBS	Total Zinc Mean	COV	Median	90% Confidence Limits
1	CO1 Fry Dry C.	RES	117	19	41	15	198	.80	151	110-208
2	CO1 Cherry	RES	57	24	38	19	195	.61	155	126-217
3	CO1 Elk Glayde	RES	167	14	24	11	195	.66	158	121-208
4	FL1 Duffiel	RES	22	-	-	8	156	.26	151	127-179
5	FL1 Lakeridge	RES	58	21	31	46	129	.70	106	91-171
6	DC1 Stratton	RES	8	-	-	28	84	.42	76	66-88
7	FL1 John M	RES	54	18	19	0	-	-	-	-
8	AL1 Sherine	RES	58	8	18	33	841	.97	596	399-891
9	MA2 Pemlaco	RES	56	5	16	0	-	-	-	-
10	MD1 Hollow Hill	RES	14	10	52	19	1388	2.21	573	112-971
11	MD1 Homeland	RES	31	6	29	33	120	.15	113	96-114
12	MD1 Mt Wash	RES	12	12	39	29	92	.56	91	67-98
13	MD1 Pen Hill	RES	10	55	76	11	521	1.20	140	211-542
14	MD1 Sherry C	RES	71	11	20	0	-	-	-	-
15	MA1 Unuus	RES	-	-	-	0	-	-	-	-
16	MA2 Cranberge	RES	160	5	22	9	415	.88	117	195-499
17	MA1 L. Rach	RES	346	18	38	8	988	1.10	127	180-594
18	FL1 Rollingwens	RES	60	1	21	0	-	-	-	-
19	WA1 Spicer	RES	91	9	29	118	164	.42	114	107-121
20	WA1 Garbank	RES	63	15	50	18	106	1.14	62	42-95
21	WA1 Hastings	RES	33	12	51	21	106	1.20	69	49-99
22	WA1 Young Apts	RES	9	-	6	12	60	.45	55	44-69
23	FL1 Hart	RES	376	0	40	8	-	-	-	-
24	WA1 Lincoln	RES	36	18	57	0	-	-	-	-
25	TN1 RZ	RES	89	4	32	11	91	.52	81	61-109
26	OC1 Wessleign	RES	41	1	21	14	67	.96	48	38-61
27	KS1 IC - 92nd	RES	63	-	17	3	-	-	-	-
28	IL1 John S.	RES	39	18	18	1	-	-	-	-
29	SM1 R1	RES	69	11	11	11	412	.59	754	261-427
30	WA1 Lake Mills	RES	102	32	17	126	120	.51	107	99-515
31	IL1 Mathis S.	RES	28	22	17	0	-	-	-	-
32	FL1 Charter Mag	RES	47	-	16	12	54	1.02	28	35-59
33	OC1 Fairidge	RES	19	-	10	44	86	.52	76	67-86
34	OC1 Asbury	RES	127	9	22	9	149	.61	295	206-427
35	LL2 Comb Inlets	RES	524	8	12	27	210	.69	189	154-212
36	MA1 Locust	RES	154	11	16	6	247	.11	216	184-301
37	NC2 #1063	RES	324	6	27	66	178	.81	118	139-160
38	MA1 Jurdan	RES	110	10	21	9	218	.28	210	177-249
39	OC1 Sledwick	RES	27	15	14	45	91	.70	75	64-86

Mixed

	Site	Land Use *	Area (A)	Pop. Den (#/A)	% IMP.	No. of OBS	Total Zinc Mean	COV	Median	90% Confidence Limits
1	FS1 Holland	-	35	3	60	9	910	2.10	525	242-940
2	MD1 Hampden	-	13	40	32	17	318	.95	112	206-440
3	IL1 Mathis N	-	17	3	96	0	-	-	-	-
4	MI1 Waverly	-	30	11	56	17	121	95	110	93-113
5	TN1 SC	-	197	3	60	12	144	40	134	114-167
6	WI1 Hogo Clr	-	45	17	61	27	476	1.21	305	222-474
7	MA1 Rl y	-	238	3	22	7	244	37	226	165-304
8	MA1 Convent	-	130	1	33	7	201	60	174	116-270
9	MI1 Grand R Ill	-	457	6	38	14	145	71	99	106-131
10	MI1 Pitt AA-S	-	2401	2	21	4	-	-	-	-
11	FS2 Cedac	-	76	-	6	0	-	-	-	-
12	MA1 Anna	-	601	9	13	5	176	1.50	99	45-214
13	MI3 Pitr AA-N	-	2831	2	26	4	-	-	-	-
14	MI1 Grale M	-	154	5	28	9	149	35	140	111-177
15	MI3 Swartz Bul	-	1207	2	4	7	-	-	-	-
16	SD1 Meade	-	2910	-	-	0	-	-	-	-
17	CA1 Knox	-	1542	12	-	21	203	.66	31	176-378
18	FL1 N. Jesuit	-	30	-	11	15	94	68	79	63-101
19	FL1 Wilder	-	194	-	97	15	51	.95	27	26-67
20	OC1 North Ave	-	69	9	50	13	541	.60	401	341-529

Commercial

	Site	Land Use * Comm	Area (A)	Pop. Den (#/A)	% IMP.	No. of OBS	Total Zinc Mean	COV	Median	90% Confidence Limits
1	CO1 Pello Llalla	COM	74	0	91	27	120	.92	397	148-113
2	NC1 1911 (CBD)	COM	21	0	109	60	521	.51	478	428-526
3	MA1 Soulmadle	COM	179	2	21	9	1438	1.56	517	218-1247
4	WI1 Prsl OFFice	COM	32	0	100	22	145	2.16	44	71-124
5	MA1 Plg Lal	COM	1	0	97	31	511	.65	410	361-517
6	TN1 CBD	COM	26	0	99	15	115	.41	289	240-349
7	WI1 Bushler	COM	12	0	-	19	156	.75	125	96-161
8	KS1 IC Melegle	COM	58	-	97	7	465	.79	168	272-811
9	FL1 Norma Pk	COM	47	-	85	12	17	.88	29	19-41
10	WI1 Llale Fare	COM	29	10	77	7	180	.66	234	150-163

Urban Open and Nonurban

	Site	Land use * Open	Area (A)	Pop. Den (#/A)	% IMP.	No. of OBS	Total Zinc Mean	COV	Median	90% Confidence Limits
1	LA1 Seaview	OPEN	613	-	-	17	190	.69	160	125-205
1	CO1 Rooney Gulch	OPEN	435	0	1	7	115	.56	91	61-136
2	NC1 Thornhill	OPEN	25,415	-	4	9	292	2.39	106	130-740
4	NC1 English Pr	OPEN	5,208	-	1	0	-	-	-	-
5	NC1 Best Br	OPEN	5,138	-	1	12	-	-	-	-
6	NC1 Thomas Cr	OPEN	17,724	1	11	9	1062	3.14	327	124-839
7	MI3 Prasee Cr	OPEN	2,767	-	6	2	-	-	-	-
9	MI2 Sheriff Cncl	OPEN	552	-	7	9	-	-	-	-

Industrial

	Site	Land Use * Ind	Area (A)	Pop. Den (#/A)	% IMP.	No. of OBS	Total Zinc Mean	COV	Median	90% Confidence Limits
1	MA2 Addison	IND	19	0	69	8	-	-	-	-
2	MI1 Ladus Ordin	IND	62	0	64	7	244	.42	225	167-203
3	IS1 Lenaxe	IND	22	-	84	6	2721	2.79	791	217-2854
4	MI1 Grace S.	IND	75	5	39	7	222	.54	196	135-264

* All observations below detection limit.

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These tables (one for each pollutant) list each of the appropriate sites in the data base, grouped according to general land use category. Some pertinent site characteristics are identified: drainage area, population density, and the percentage of the total area covered by impervious surfaces. The number of monitored storms at each site is tabulated. Urban runoff quality is summarized by the mean and median EMC for all storms monitored at the site, the storm-to-storm variability of EMC's (defined by the coefficient of variation), and the 90 percent confidence limits for the site median EMC.

Transferability of Data

The urban runoff loading site EMC data were carefully examined in an effort to determine whether specific groupings of results would suggest the presence of consistent patterns of similarities and/or differences that could be used to support estimates of urban runoff characteristics at unmonitored locations and sites.

Variability of EMCs at a Site. Inspection and analysis of the individual site coefficient of variation entries in Tables 6-1 through 6-10 shows that with very few exceptions (usually associated with constituents that were monitored in fewer than 10 storm events) the coefficients of variation fall in the range of 0.5 to 1.0. This applies to all constituents except TSS, for which the range in coefficients of variation is more like 1 to 2.

The frequency of occurrence of any EMC of interest can be estimated readily from the coefficient of variation by using the procedures outlined in Chapter 5. Thus, for TSS, 90 percent of the individual storm events at a given site will have EMCs that do not exceed a value of roughly 3 to 5 times the median EMC value for that site. For the other constituents, 90 percent of the individual storm events at a site will have EMCs less than about 2 to 3 times the median EMC value for that site. More refined estimates and values for other exceedance probabilities can be readily computed using the relationships presented in Chapter 5.

Effect of Geographic Location. Figures 6-4 through 6-13 indicate the range of median EMC's at individual sites, grouped by project. The land use category of the site is indicated by the letter R for residential, M for mixed, and C for commercial/industrial, and the plotting position is the median value as given by the data in Tables 6-1 through 6-10. The ends of the bars for each project are the highest and lowest 90 percent confidence limits for site median EMCs at the project for the constituent in question. Inspection of Figures 6-4 through 6-13 indicates that, for any given constituent, each project can be put into one of three rather general categories: (1) low EMCs and tightly grouped; (2) average characteristics; and (3) wide range and high EMCs. Using the numbers 1, 2, and 3 as shorthand, project categories for each constituent are summarized in Table 6-11. Although no site is category consistent for all constituents, WASHCOG (DC1), Tampa (FL1), Lansing (MI1), and Ann Arbor (MI3) tend to have lower and more tightly grouped EMCs than the others while Kansas City (KS1), Lake Quinsigamond (MA1), and Baltimore (MD1) tend to have a wider range and higher EMCs than the others. Thus we can conclude that some projects represented in the database appear, from the monitoring sites selected, to tend towards somewhat higher or lower EMC median values and ranges than the bulk of the projects. However, there are no distinct geographical patterns revealed.

SARB_000086

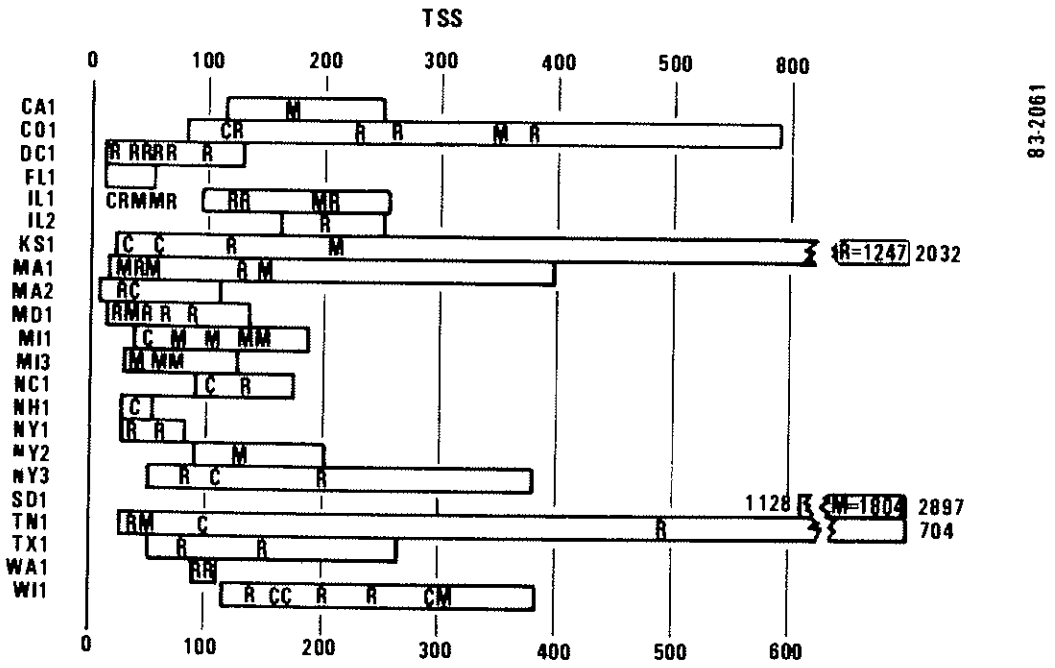


Figure 6-4. Range of TSS EMC Medians (mg/l) by Project

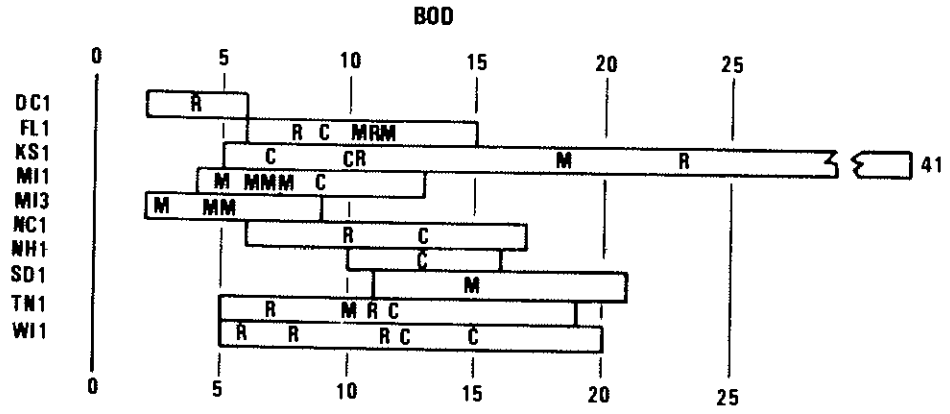


Figure 6-5. Range of BOD EMC Medians (mg/l) by Project

SARB_000087

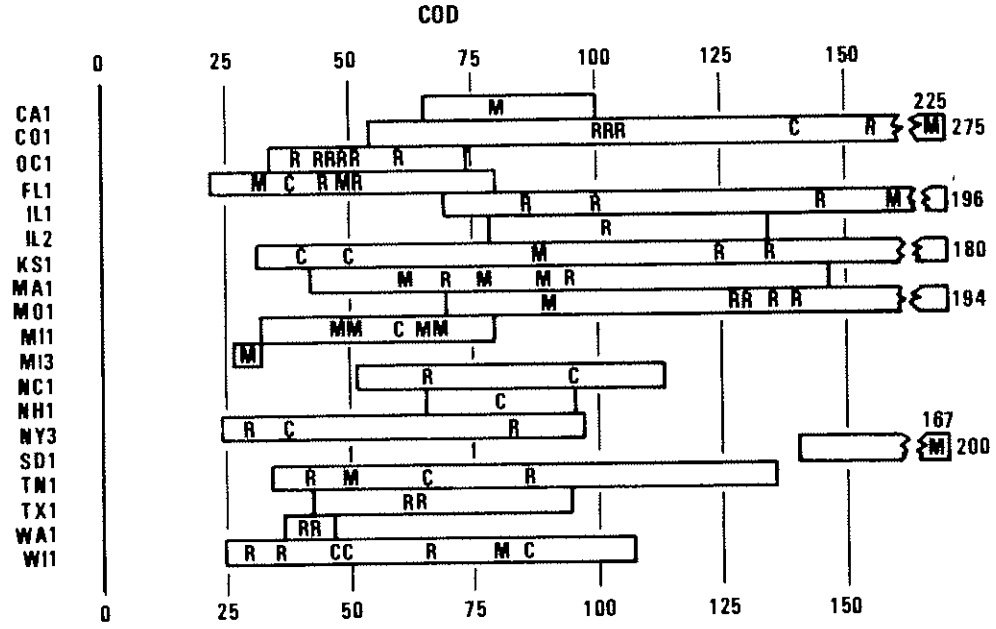


Figure 6-6. Range of COD EMC Medians (mg/l) by Project

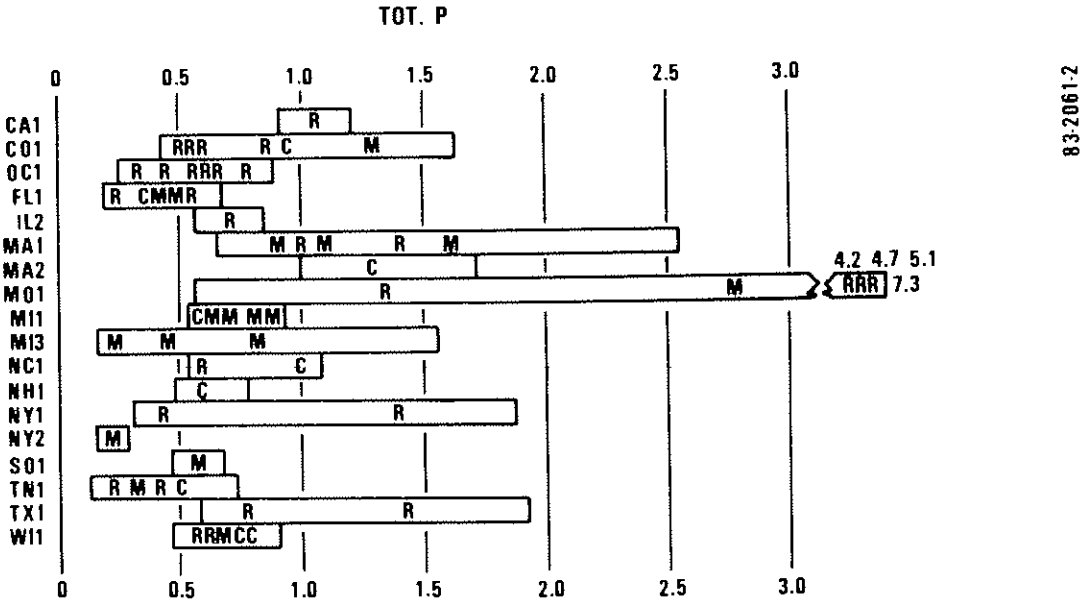


Figure 6-7. Range of Total P EMC Medians (mg/l) by Project

SARB_000088

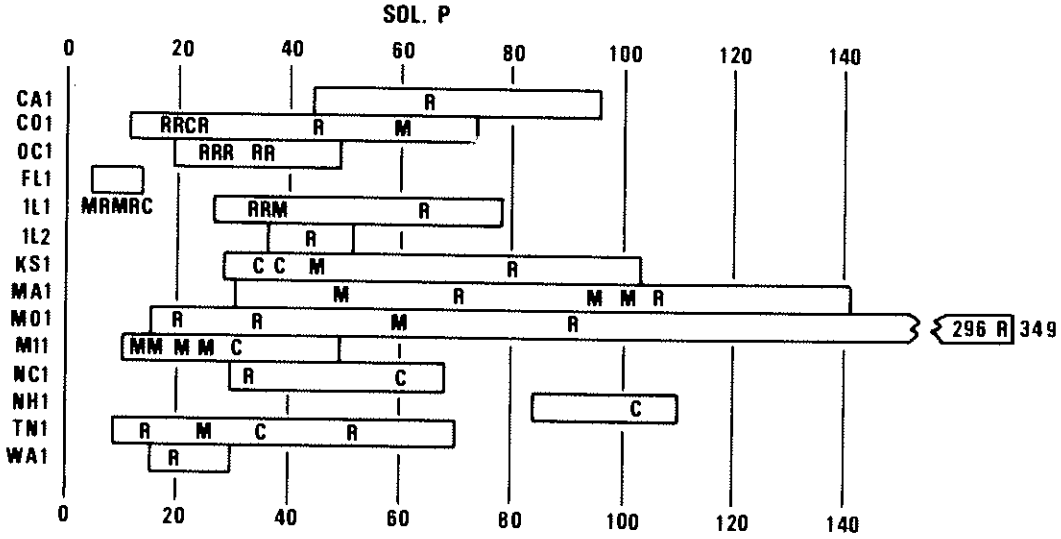


Figure 6-8. Range of Soluble P EMC Medians (mg/l) by Project

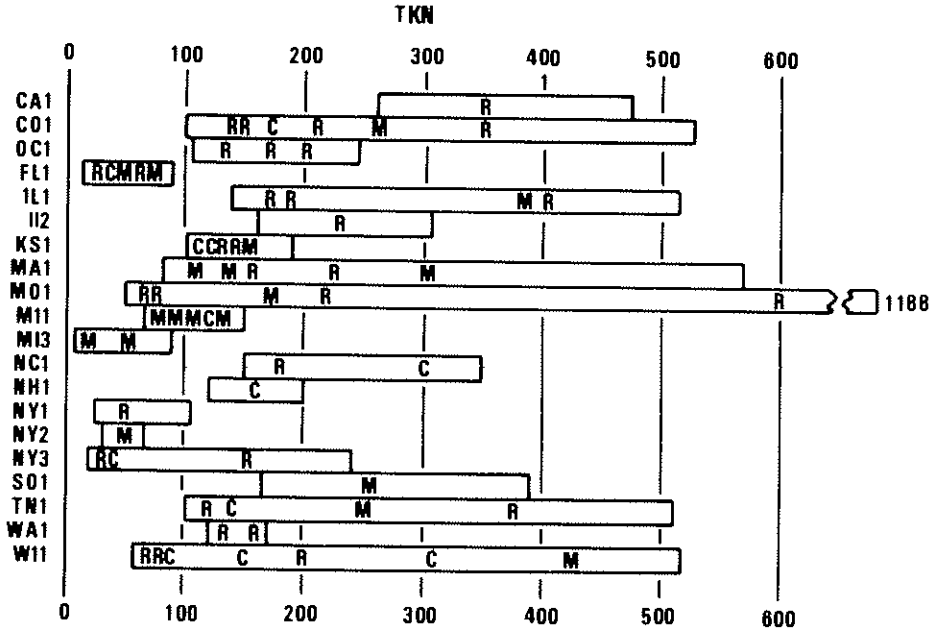


Figure 6-9. Range of TKN EMC Medians (mg/l) by Project

SARB_000089

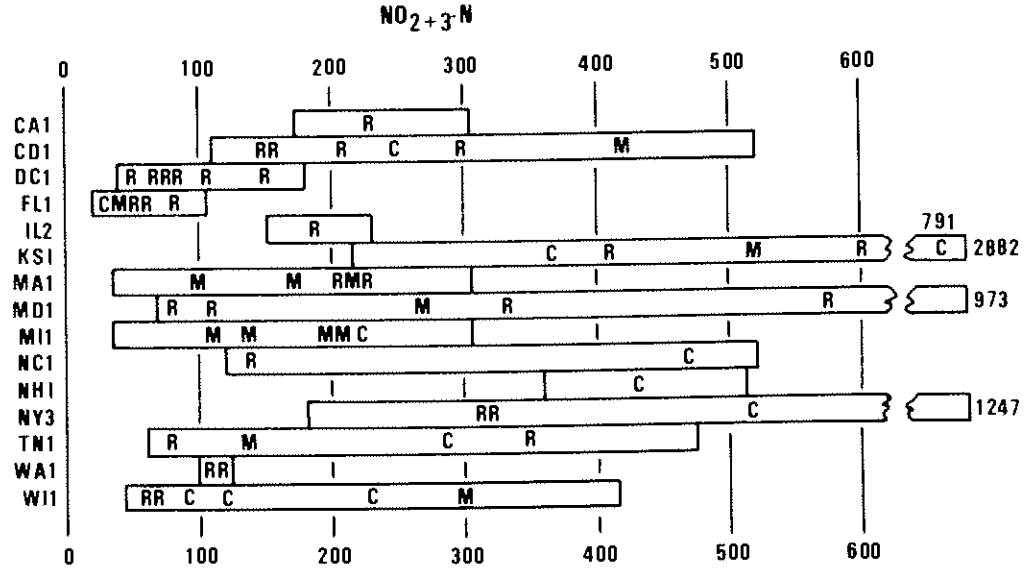


Figure 6-10. Range of NO_{2+3}-N EMC Medians (mg/l) by Project

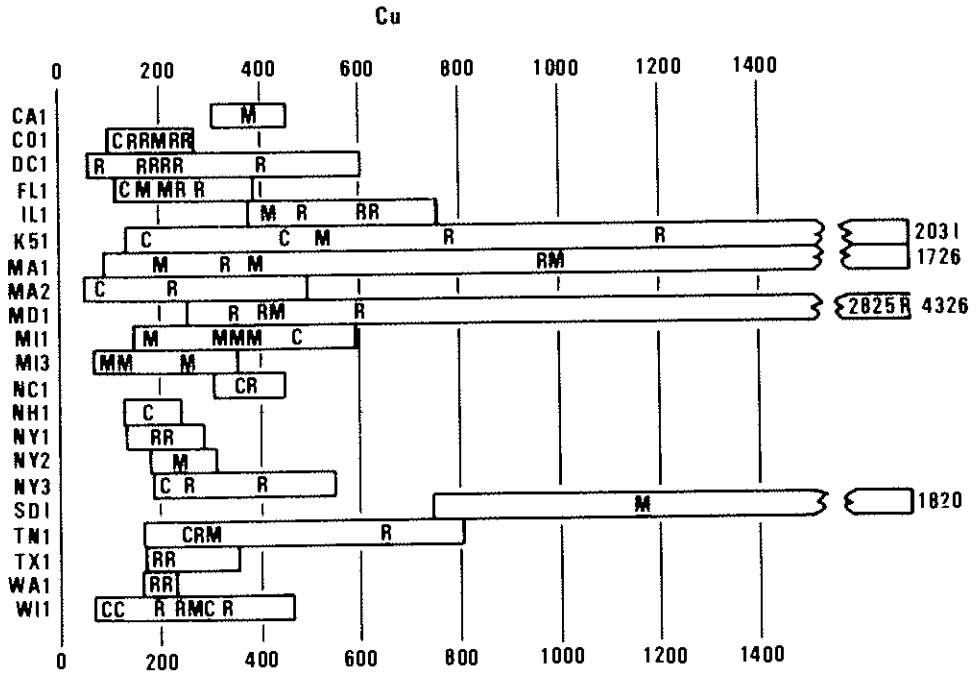


Figure 6-11. Range of Total Cu EMC Medians (µg/l) by Project

SARB_000090

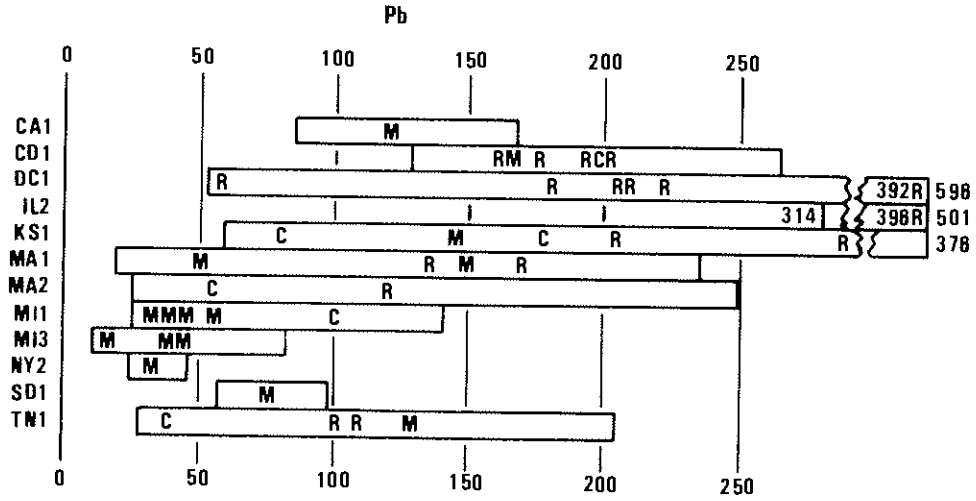


Figure 6-12. Range of Total Pb EMC Medians (µg/l) by Project

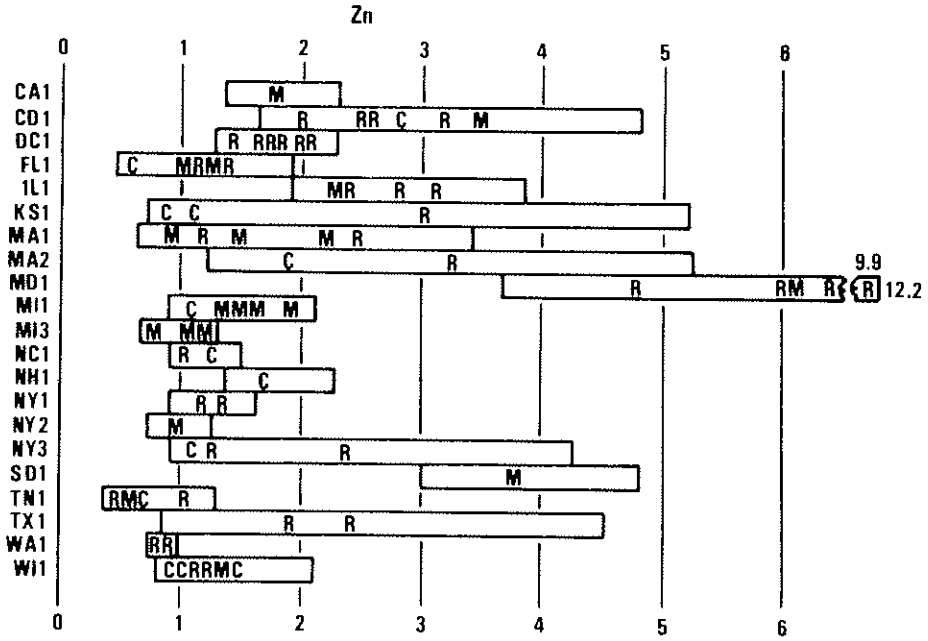


Figure 6-13. Range of Total Zn EMC Medians (µg/l) by Project

SARB_000091

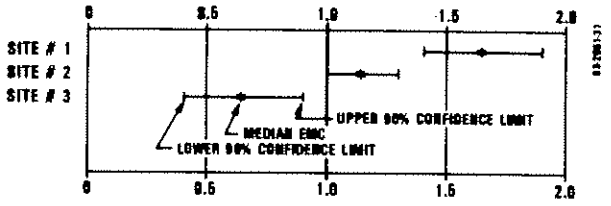
TABLE 6-11. PROJECT CATEGORY SUMMARIZED BY CONSTITUENT

	CO1	DC1	FL1	IL1	KS1	MA1	MD1	MI1	MI3	NY3	TN1	WI1
TSS	3	1	1	2	3	3	1	1	1	2	3	2
BOD	-	-	2	-	3	-	-	2	1	-	2	2
COD	3	1	1	3	3	2	3	1	-	1	2	2
Tot. P.	1	2	1	2	3	3	3	2	1	2	2	2
Sol. P.	2	3	-	-	3	2	-	2	1	-	2	-
TKN	2	1	1	2	2	2	3	1	1	2	1	1
NO_{2+3}-N	2	1	1	-	-	3	3	1	2	-	1	1
Tot. Cu	2	1	1	2	2	3	3	1	-	-	2	-
Tot. b	2	1	1	2	1	2	3	1	-	1	2	2
Tot. Zn	2	1	1	-	3	2	3	2	-	3	2	2

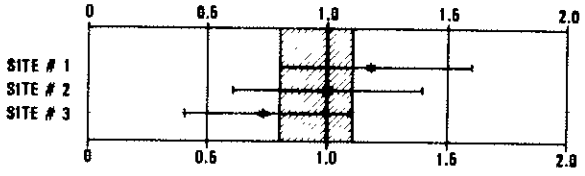
It must also be realized that had any particular project monitored other local sites (or additional sites) its categorization could well change. This can be seen qualitatively by perusing Figures 6-4 through 6-13 and mentally dropping the highest or lowest site from each grouping. Although some locations, such as Tampa, will undoubtably and appropriately be influenced by the relatively low EMCs and tight groupings found there in estimating probable values for other urban sites in the area, there is little to warrant attributing similar characteristics to other locations in the same geographical region. For the other locations it would appear that individual site differences eclipse any possible geographic ones.

Effect of Land Use Category. The data in Tables 6-1 through 6-10 were presented by land use category; residential, mixed, commercial, industrial, and open/non-urban. The question to be addressed here is the extent to which such site categorization can be used to assist in predicting EMC parameters for unmonitored sites. Two approaches were used. In the first, the site data for each project with more than three sites were normalized by dividing the site median and its upper and lower 90 percent confidence limits by the average project median value for the constituent in question. This procedure simply allows all constituents to be viewed on a common scale that is centered at unity. An example of the result is given in Figure 6-14. A legend is provided in Figure 6-14(a) showing the lower 90 percent confidence limit, the upper 90 percent confidence limit, and the location of the point estimate of the median within this confidence interval for a hypothetical constituent. Sites that fall to the right of the unity line have higher EMCs than average for this location, while sites that fall to the left of the unity line have lower EMCs than average. Thus, the interpretation is that for this location, Site #1 is the "dirtiest" (has the highest EMC value), Site #3 is the "cleanest", and Site #2 is in between, being somewhat "dirtier" than average. Since the 90 percent confidence limits for these three sites no not overlap, we know that this difference is statistically significant.

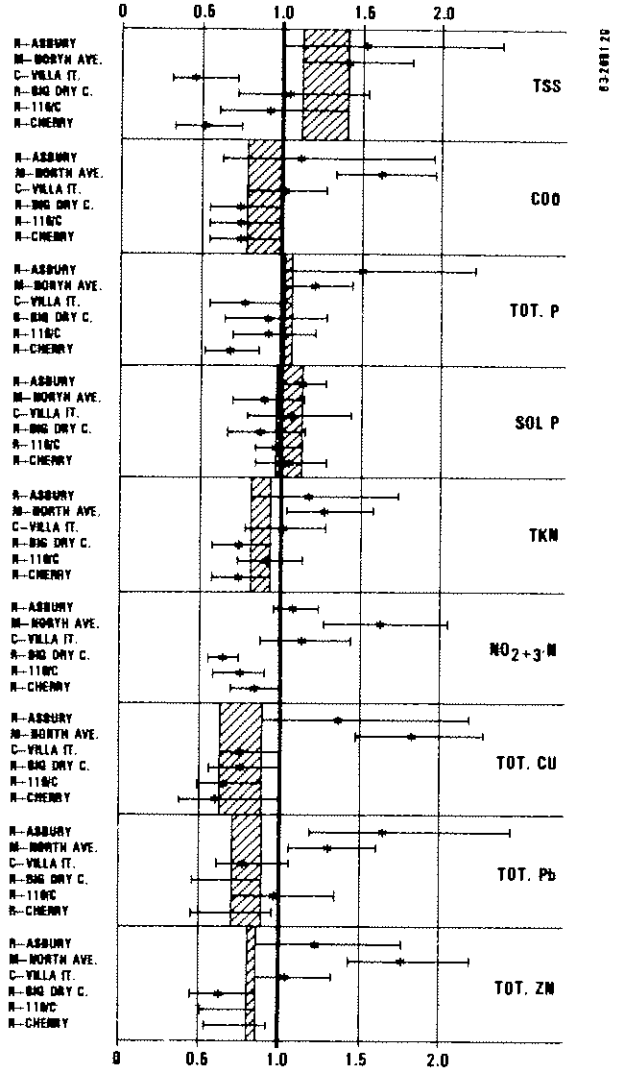
SARB_000092



(a) Significantly Different Sites



(b) Sites with No Significant Difference



(c) EMC Data from Denver (CO1)

Figure 6-14. Range of Normalized EMC Medians at Denver (CO1)

SARB_000093

The actual data for the Denver (CO1) project are presented in Figure 6-14(c). With the exception of nitrate + nitrite, there is little to no statistically significant difference among the majority of the sites for each constituent examined. The lack of consistency among the sites over the various constituents is apparent. One can observe that the Cherry site (residential) tends to plot at the lowest position for all constituents, suggesting that it is the "cleanest," the Asbury site (also residential) tends to plot at the highest position, suggesting that it is the "dirtiest." The Big Dry Cottonwood site, which is also residential, tends to fall between these two. Careful examination of other site data does not provide any evidence to explain this difference in response for sites in the same land use category at the same location. Thus, based on the information presented in Figure 6-14(c), one is forced to conclude that land use category does not provide a useful basis for predicting differences in site EMC values, at least for this project.

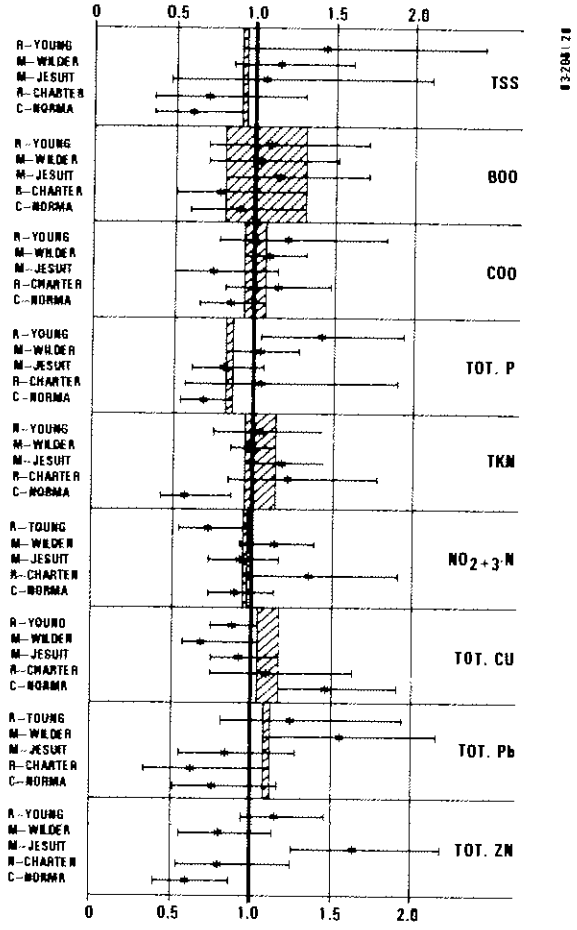
When the foregoing type of analysis was applied to the other applicable NURP projects, the results were the same. As another example, the range of normalized EMC medians at Tampa (FL1) and WASHCOG (DC1) are shown in Figure 6-15. These are essentially similar to the Denver results just discussed.

The WASHCOG data presented in Figure 6-15(b) suggest that there is little consistent difference among residential land use sites at that project. The data from Champaign/Urbana (IL1) presented in Figure 6-16 suggest just the opposite. As a part of this project's experimental design, two site pairs were selected. The sites of each pair were expected to respond in a similar fashion. That they do and that the responses of the two pairs are different from each other for most constituents is apparent in Figure 6-16. However, there is no consistency in the pair responses. For example, the Mattis pair has significantly higher EMC values for TSS, COD, and Total Pb, while the John Pair is higher in Total P. The residential land use category for these sites provides no explanation of these differences in response.

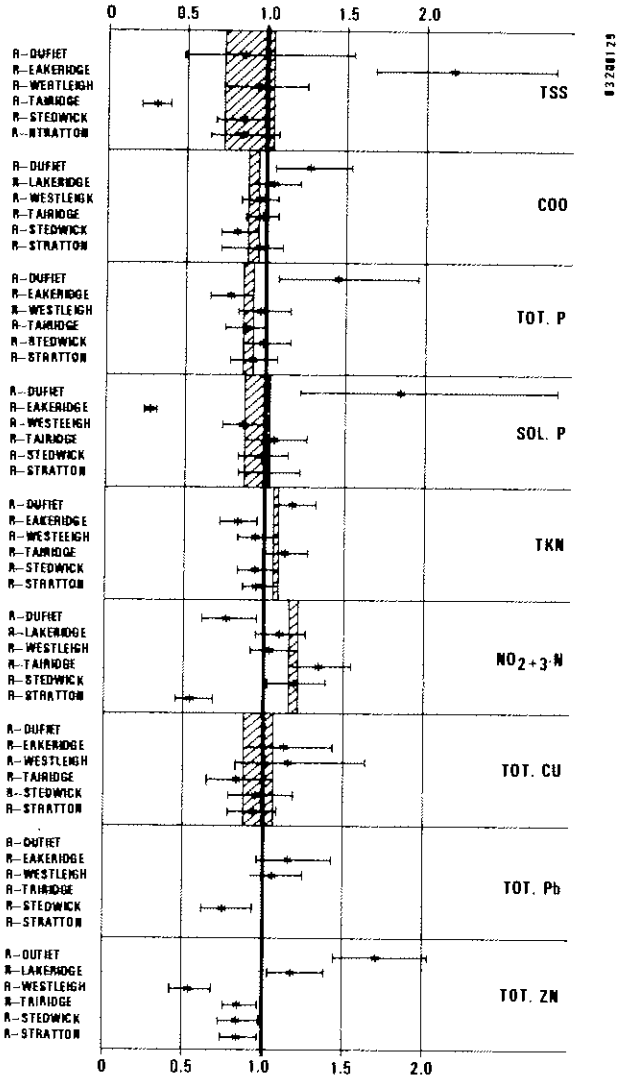
Based upon the foregoing approach, we can conclude that, while there can be differences in the responses of different sites at a given location, significant differences do not appear to be widespread, and where they occur, the site land use category is virtually useless in trying to understand or predict them.

The second approach to examining the effect of land use category on the EMC parameters of a site makes use of the observation, discussed earlier, that geographic location has no discernible effect on site response. Since site to site variability was shown to be very well represented by the lognormal distribution, analysis procedures similar to those described previously for characterizing an individual site were applied. Table 6-12 lists the median EMCs for all sites within each land use category. The coefficient of variation quantifies the variability of site characteristics within the land use category. To the extent that the sites included in this database provide a "representative" sample of the land use classifications, then the information summarized by Table 6-12 indicates the effect of land use on urban storm runoff pollutant discharges.

SARB_000094



(a) Tampa Sites



(b) WASHCOG Sites

Figure 6-15. Range of Normalized EMC Medians at FL1 and DC1

SARB_000095

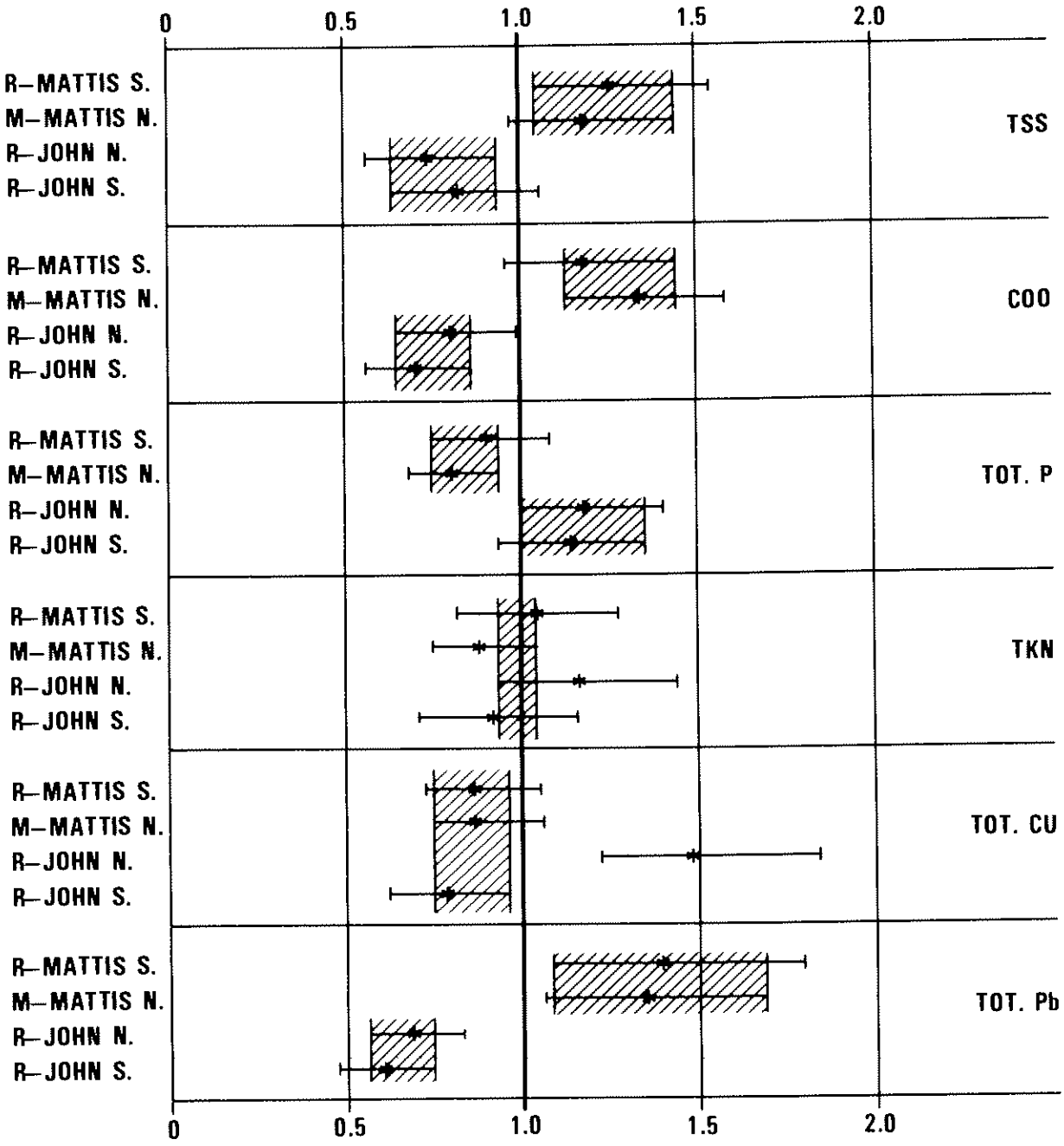


Figure 6-16. Range of Normalized EMC Medians at IL1

SARB_000096

TABLE 6-12. MEDIAN EMCs FOR ALL SITES
BY LAND USE CATEGORY

Pollutant		Residential		Mixed		Commercial		Open/Nonurban	
		Median	CV	Median	CV	Median	CV	Median	CV
BOD	mg/ℓ	10.0	0.41	7.8	0.52	9.3	0.31	-	-
COD	mg/ℓ	73	0.55	65	0.58	57	0.39	40	0.78
TSS	mg/ℓ	101	0.96	67	1.14	69	0.85	70	2.92
Total Lead	µg/ℓ	144	0.75	114	1.35	104	0.68	30	1.52
Total Copper	µg/ℓ	33	0.99	27	1.32	29	0.81	-	-
Total Zinc	µg/ℓ	135	0.84	154	0.78	226	1.07	195	0.66
Total Kjeldahl Nitrogen	µg/ℓ	1900	0.73	1288	0.50	1179	0.43	965	1.00
NO_2 -N + NO_3 -N	µg/ℓ	736	0.83	558	0.67	572	0.48	543	0.91
Total P	µg/ℓ	383	0.69	263	0.75	201	0.67	121	1.66
Soluble P	µg/ℓ	143	0.46	56	0.75	80	0.71	26	2.11

SARB_000097

Some caution in the interpretation of the information presented in Table 6-12 is in order since statistical confidence limits are not given. These are indicated in Figure 6-17 (a through k), which illustrates land use differences graphically, with additional statistical detail derived from the basic parameters listed in Table 6-11, to assist in interpretation and comparisons. The box plots which compare characteristics of all sites within a land use category identify the land use, median EMC, its 90 percent confidence limits, and the 10, 25, 75 and 90 percent quantities for the sites. Careful perusal of these box plots leads one to the conclusion that only the open/non-urban land use category appears to be significantly different overall. Responses of the other land use categories are varied and inconsistent among constituents. This may be seen in a somewhat different way by observing the plotting positions of the land use categories presented in Figures 6-4 through 6-13. Here also, there are no consistent tendencies. There are undeniably some trends. For example, in Figure 6-7 commercial sites occupy the lowest plotting position at each project for total phosphorus (MI1 and one WI1 site are exceptions), which certainly suggests that there might be a land use category difference for this constituent.

Review of Figure 6-17(j), however, suggests that while a trend to lower total phosphorus EMC values is apparent as one goes from residential, to mixed, to commercial land uses, the statistical significance may not be great. The actual site median total phosphorus EMC probability density functions for each land use are presented in Figure 6-18. Here it can be seen that although three different pdfs can be drawn for residential, mixed, and commercial land use categories, their degree of overlap is so great that there is little statistical significance to the apparent difference. Since this was the strongest tendency towards land use effect, we must conclude that using this approach there is again no truly discernible and consistent effect of land use on the quality of urban runoff.

The one exception is the open/non-urban category which, as its name suggests, includes atypical sites. The data in Table 6-12 and the box plots of Figure 6-12 suggest that the pdfs for this land use category are quite different from those of the other land use categories, and this is in fact the case. Figure 6-18 shows it dramatically for total phosphorus.

Thus, regardless of the analytical approach taken, we are forced to conclude that, if land use category effects are present, they are eclipsed by the storm to storm variabilities and that, therefore, land use category is of little general use to aid in predicting urban runoff quality at unmonitored sites or in explaining site to site differences where monitoring data exist.

Correlation Between EMCs and Runoff Volume. To examine the possible relationship between the event mean concentration of a particular constituent and the runoff volume, linear correlation coefficients (r) were calculated. The null hypothesis that the two variables are linearly unrelated was tested at both the 90 and 95 percent confidence levels. Since it is possible for correlation to be either positive or negative, the two-tailed test was used. Failure to reject the null hypothesis is interpreted as meaning that linear dependency between the two variables in the population has not been shown.

SARB_000098

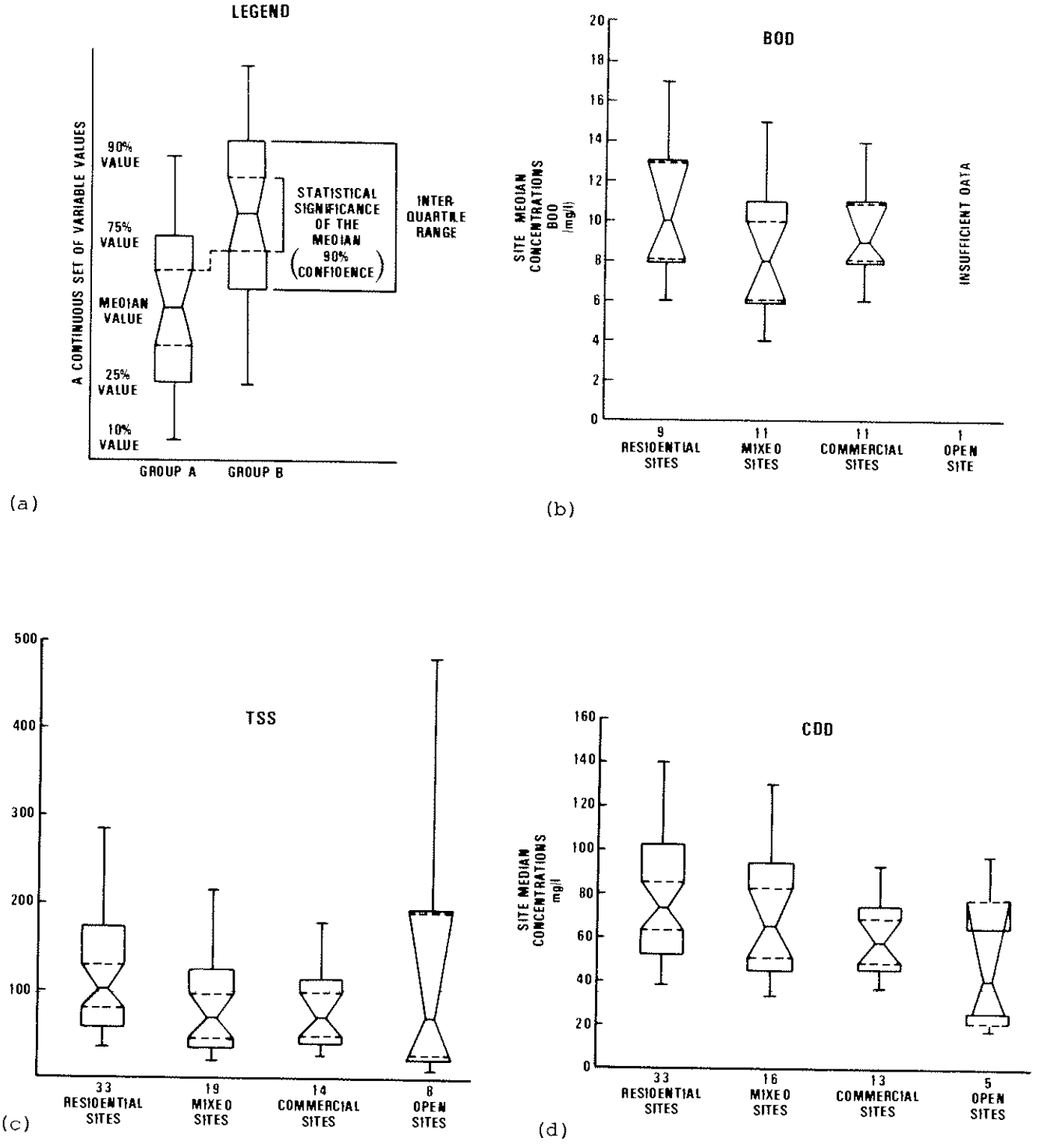


Figure 6-17. Box Plots of Pollutant EMCs for Different Land Uses

SARB_000099

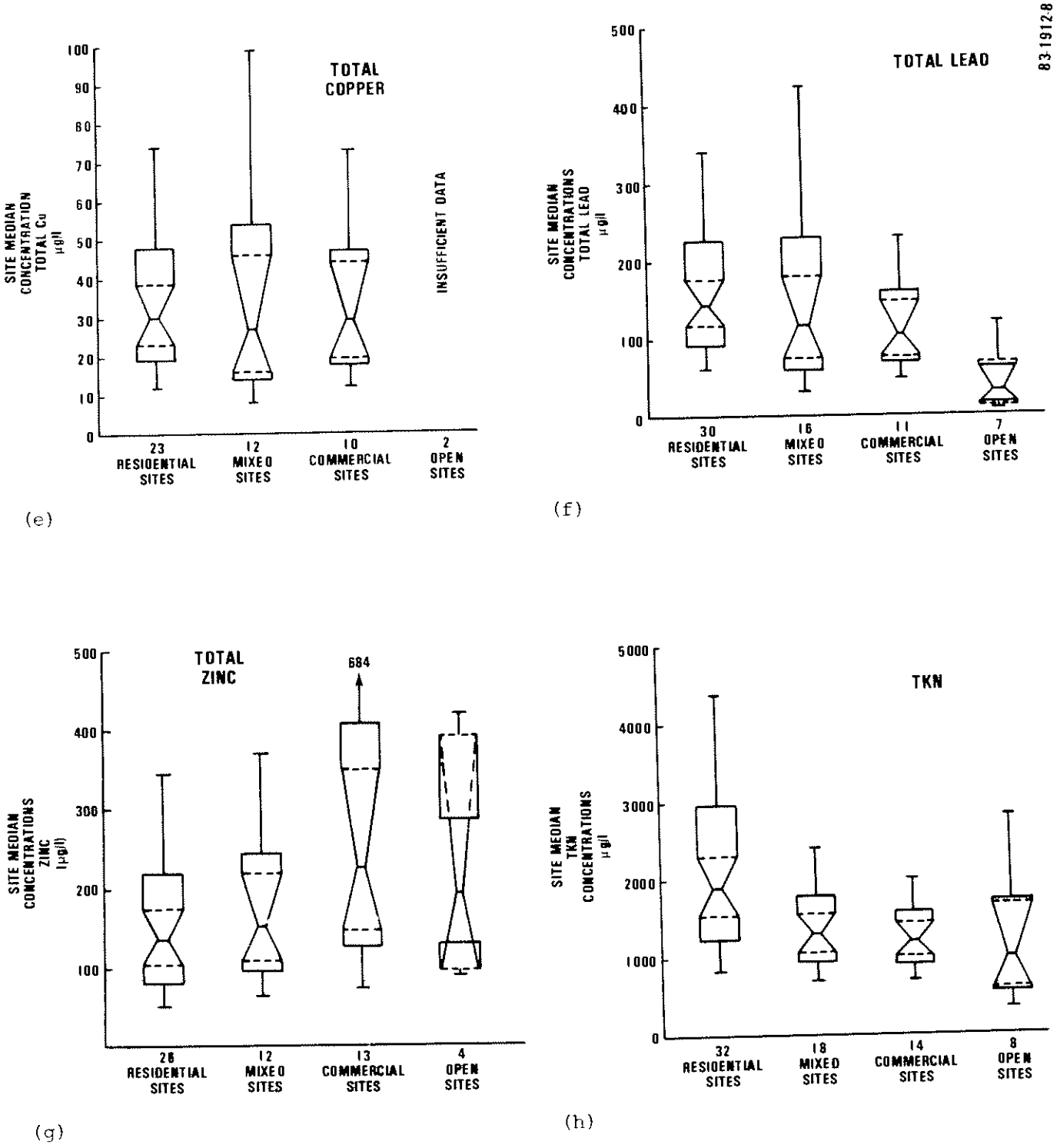
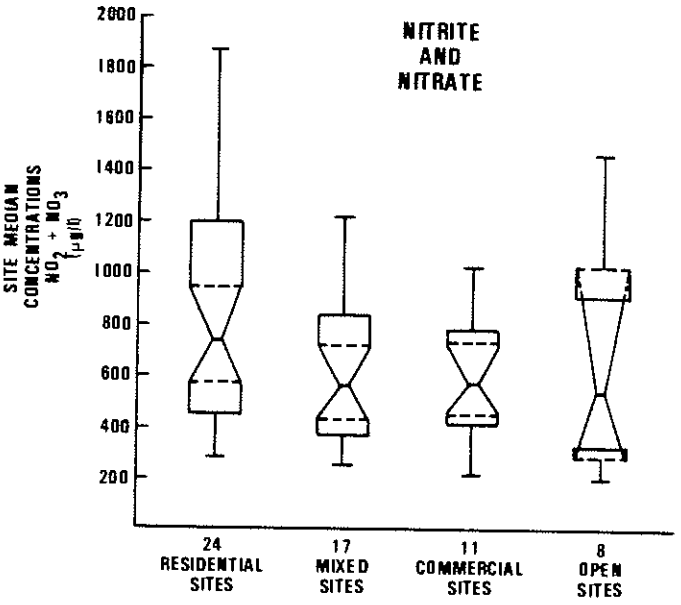
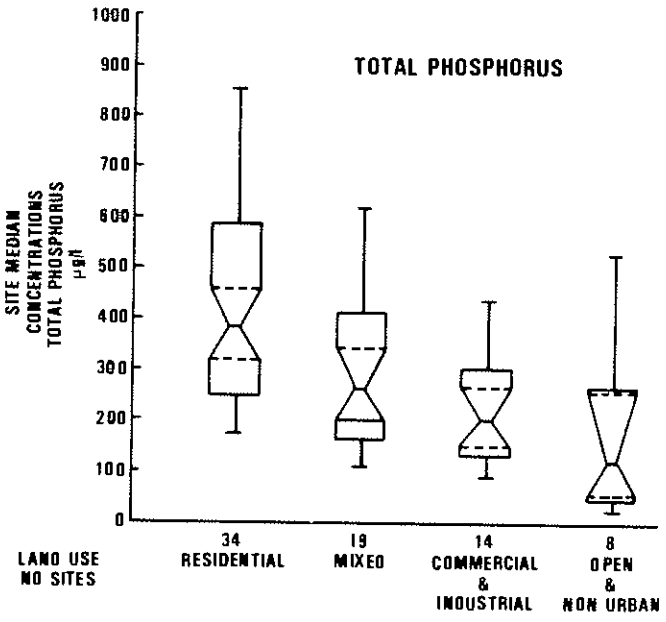


Figure 6-17. Box Plots of Pollutant EMCs for Different Land Uses (Cont'd)

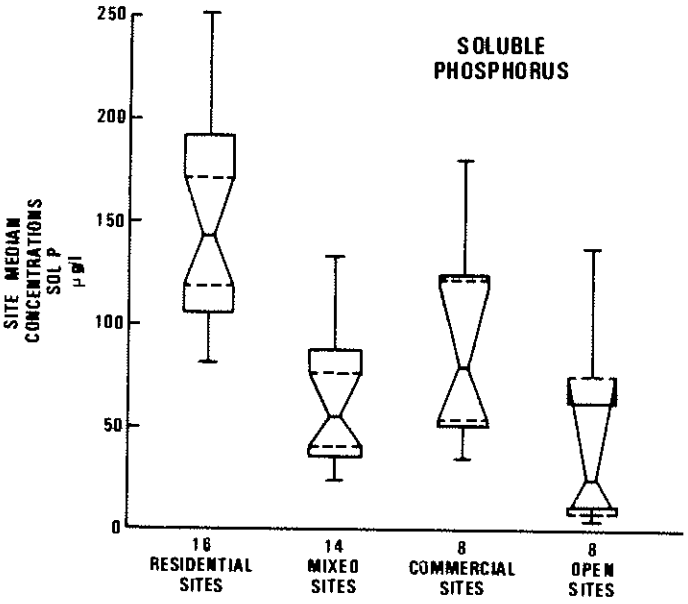
SARB_000100



(i)



(j)



(k)

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Figure 6-17. Box Plots of Pollutant EMCs for Different Land Uses (Cont'd)

SARB_000101

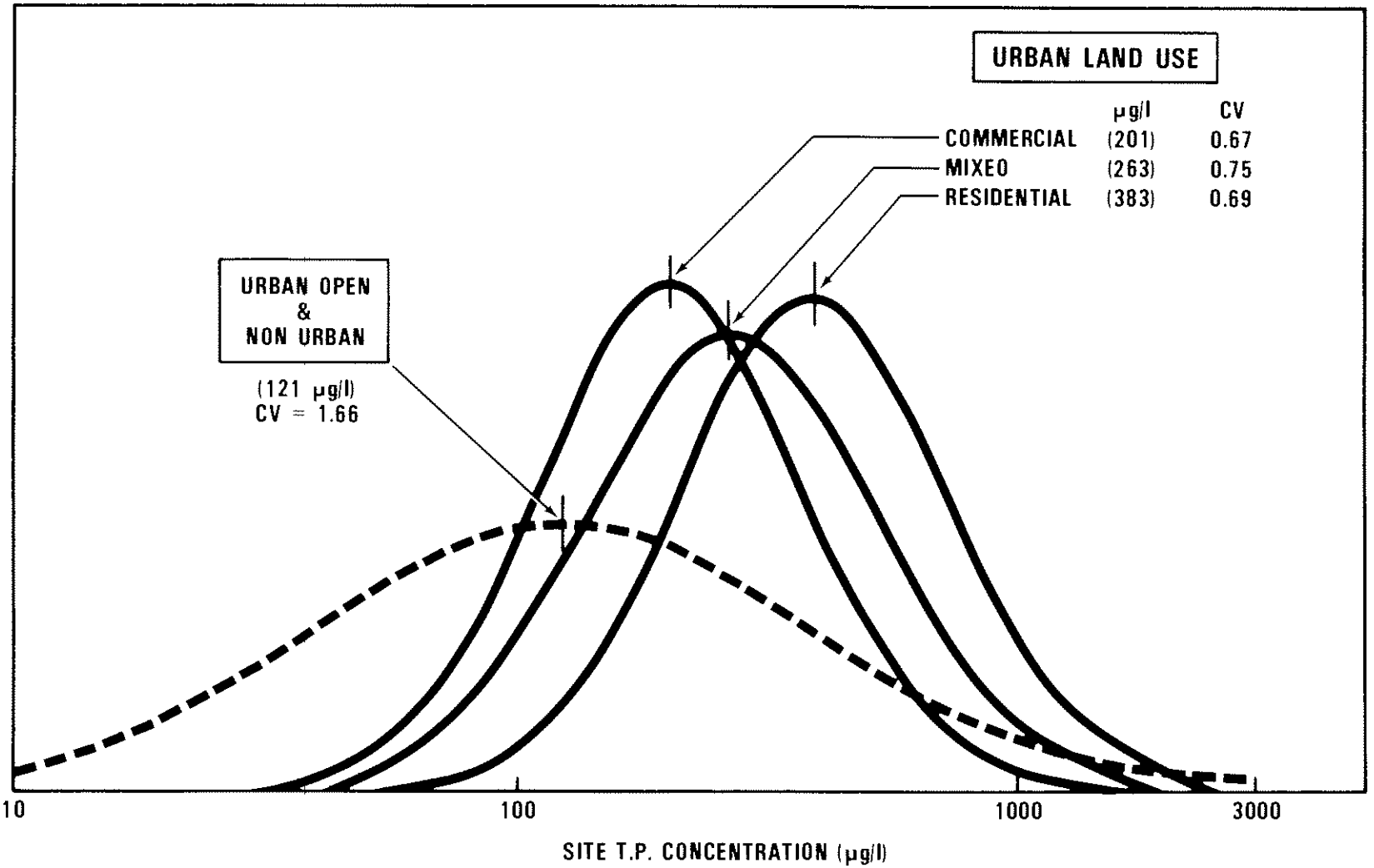

Figure 6-18. Site Median Total P EMC Probability Density Functions for Different Land Uses

SARB_000102

The rejection of the null hypothesis means that there is evidence of a linear dependency between the two variables in the population, but it does not mean that a cause-and-effect relationship has been established.

General guidelines for the use of this test suggest that it be used with caution for values of n less than ten due to the high uncertainties associated with estimates of population variance with small samples. Furthermore, when n is 2 a perfect correlation will result but is meaningless. To include as many sites as possible in this examination, all constituents for which n was 5 or greater were included. At the other extreme, when n is very large, say over 100, correlation coefficients are almost always significant but can be so weak that they are meaningless. For n = 100 the critical value of r at the 90 percent confidence level is 0.164, meaning that the correlation explains less than 3 percent of the concentration variability.

A total of 67 sites from 20 of the NURP projects were examined for possible correlation for nine constituents. Of the 517 linear correlation coefficients calculated (not all constituents were measured at all sites), 116 (22 percent) were significant at the 95 percent confidence level and 154 (30 percent) were significant at the 90 percent confidence level. Of the r values that were significant, 83 and 87 percent were negative at the 90 and 95 percent confidence levels respectively. When sites with fewer than 10 events were dropped, the foregoing was essentially unchanged. Greater detail in terms of the number of significant linear correlation by constituent is provided in Table 6-13. There it can be seen that the greatest tendency for positive values of r occurs with TSS, followed by soluble phosphorus. The correlation coefficients for the other 7 constituents all strongly tend to be negative.

When the results are examined by sites, however, a clearer picture emerges. Although it can be correctly argued that unless a correlation coefficient is statistically significant the number is meaningless, it also follows that in such a case they are as likely to be positive as negative. On the other hand, if all the correlation coefficients (whether significant or not) have the same sign, it suggests a tendency for that site. The sign of the correlation coefficient (if greater than 0.1) for each site and constituent examined is given in Table 6-14. Giving appropriate weight to significant r values but considering others as well, some 37 of the sites tend to have negative correlations, 13 tend to be positive, and the remaining 17 tend to be mixed. Perusal of Table 6-14 reveals that this tendency for sites to have either positive or negative correlation coefficients is quite strong, especially for sites with a large number of significant correlations. Sites where erosion, scour, system lag, and such are present could be expected to exhibit a tendency towards positive correlations. Sites lacking such effects could be expected to have negative correlation due to dilution associated with larger runoff events.

The magnitude of the correlation coefficients is indicated in Table 6-15. Two points stand out in particular. First, the r values are not very large, averaging around 0.55. This means that the correlation is only able to explain about 30 percent of the concentration variability. The few high values are always associated with very few observations ($n<10$) for which the

SARB_000103

TABLE 6-13. NUMBER OF SIGNIFICANT LINEAR CORRELATIONS BY CONSTITUENT

POLLUTANT	TOTAL # OF SITES	90% SIGNIFICANT CORRELATION			95% SIGNIFICANT CORRELATION		
		TOTAL #	# NEG.	# POS.	TOTAL #	# NEG.	# POS.
(a) ALL SITES							
TSS	67	13 (19%)	4	9	7 (10%)	3	4
COD	64	24 (38%)	23	1	19 (30%)	19	0
TOT. P	67	20 (30%)	16	4	15 (22%)	12	3
SOL. P	34	10 (29%)	6	4	7 (21%)	4	3
TKN	64	19 (30%)	18	1	14 (22%)	14	0
NO_{2+3}-N	57	17 (30%)	15	2	13 (23%)	11	2
TOT. Cu	49	17 (35%)	15	2	13 (27%)	12	1
TOT. Pb	59	15 (25%)	13	2	12 (20%)	11	1
TOT. Zn	56	19 (34%)	18	1	16 (29%)	15	1
TOTAL	517	154	128	26	116	101	15
PERCENT		30%	83%	17%	22%	87%	13%
(b) SITES WITH $n \geq 10$							
TSS	56	9 (16%)	4	5	7 (12%)	3	4
COD	52	21 (40%)	20	1	16 (31%)	16	0
TOT. P	53	17 (32%)	15	2	12 (23%)	11	1
SOL. P	23	8 (35%)	5	3	6 (26%)	4	2
TKN	50	17 (34%)	16	1	12 (24%)	12	0
NO_{2+3}-N	41	14 (34%)	12	2	12 (29%)	10	2
TOT. Cu	31	13 (42%)	12	1	12 (39%)	11	1
TOT. Pb	45	13 (29%)	12	1	11 (24%)	10	1
TOT. Zn	37	14 (38%)	13	1	11 (30%)	10	1
TOTAL	388	126	109	17	99	87	12
PERCENT		32%	87%	13%	26%	88%	12%

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SARB_000104

TABLE 6-14. SIGN OF CORRELATION COEFFICIENTS BY SITES

	TSS	COD	TOT. P	SOL. P	TKN	NO_{2+3}-N	TOT. CU	TOT. Pb	TOT. ZN
CA1 KNOX	+	−	+	⊕		⊕	−	−	
S. VIEW.	⊕	+			⊕		+	−	+
CO1 ASBURY	⊕	+	⊕	+	+	−	⊕	+	+
B. DRY C.		−	−	−	⊖	−	−		−
CHERRY			+	⊕		−	+		
N. AVE.		⊖	⊖	⊖	⊖	⊖	⊖	⊖	⊖
ROONEY	−	⊖	−	−	−	−	−	−	⊖
VILLA IT.	−	⊖	⊖	⊖	⊖	⊖	⊖	⊖	⊖
116/C	+	−	⊕			−	+		+
OC1 OUFIEF	−	⊖	+	−	−	−			−
FAIRIDGE		+	+	+	+				+
LAKERIDGE	+		+	⊕		⊖		−	⊖
STEOWICK		−		+		⊖	+	−	⊖
STRATTON	+	−			+		−		−
WESTLEIGH		⊖			−	⊖	⊖	−	⊖
FL1 CHARTER/H	−	⊖	⊖		⊖	−	⊖	⊖	⊖
YOUNG		−	−			−	+		
NORMA P.	+	+				+			−
IL1 JOHN N.	+	⊖	⊖		⊖		−	−	
JOHN S.	+	⊖	⊖		−		−		
MATTIS N.		⊖	⊖		⊖		⊖	⊖	
MATTIS S.	−	⊖	⊖		⊖		⊖	⊖	
KS1 92nd	−	+	−	+	+				

	TSS	COD	TOT P.	SOL P	TKN	NO_{2+3}-N	TOT. CU	TOT. Pb	TOT. ZN
KS1 LENAXA	+	⊖	⊖	−	−		⊖		
METCALF		−	−	−	−		−		−
NOLAND		⊖	−	⊖			+	−	−
OVERTON	+		+				−	−	⊖
MA1 ANNA	+		+		+	−		−	+
CONVENT	−	+		+	−	−	+		+
JORDAN			+	+	−	⊖	−		⊖
LOCUST	⊕	+	⊕	+	+	⊖	+	⊕	
RT. 9	+			+	−	⊖	+	+	
MA2 ADDISON	⊕		−	−	+	−			
HEMLOCK	⊕		+	⊕	+	−			
MD1 BOLTON	⊕	−	+		−	−	⊖	+	−
HAMPDEN		−	⊖				⊖		−
HOMELAND	+	+	+		−	+	−	+	+
MT. WASH.	⊕	−	−		−	−	+	−	−
RES. HILL	+	⊖			⊖		⊖	−	−
MI1 GRACE S.	+	−	−		−	−	⊖	−	−
GRACE N.	+	−		+					⊖
GRAND		−	−		−		−	−	⊖
IND. DR.	+		+	+		−	−	−	−
WAVERLY		−	−	−	−	−	−		−
NC1 1013		⊖	⊖		⊖	⊖	⊖	⊖	⊖
1023	⊕		+			−	+		
NH1 PKG.	−	⊖	−		⊖	⊖	⊖	⊖	⊖

	TSS	COD	TOT. P	SOL. P	TKN	NO_{2+3}-N	TOT. CU	TOT. Pb	TOT. ZN
NY1 CARLL R.	+					⊖			
NY2 CEDAR				+		⊕		+	
NY3 CRANSTON	+	+	+		−			−	−
E. ROCH.	−	⊖	⊖		⊖			⊖	⊖
SOUTHGATE	+	−	+	−					−
TN1 CBD	⊖	−	⊖	⊖	⊖	−	⊖	⊖	⊖
R1	⊕	+	+	⊖	+	−	⊕	⊕	⊕
R2	+	−	−	−	⊖	−			−
SC	+		−	⊖	−	⊖		+	
TX1 HART	+	⊕			+	+			
R'WOOD.	−	+			⊖				
WA1 LAKE H.	−	⊖	−		⊖		+	⊖	⊖
SURREY D.	−	⊖	⊖		⊖			⊖	⊖
WI1 BURBANK		−	⊕						+
HASTINGS		⊖	−		+	+		⊖	−
LINCOLN		−	−			−		+	
POST D.	⊖	⊖	⊖		⊖	⊖		⊖	−
RUSTLER	⊖	⊖	−		⊖	⊖			−
STATE F.	⊖	⊖	⊖		−	⊖		−	+
WOOD C.					−	−			+

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+ INDICATES A POSITIVE R VALUE
− INDICATES A NEGATIVE R VALUE
◯ INDICATES A SIGNIFICANT R VALUE
BLANK INDICATES EITHER R LESS THAN 0.1 OR NO DATA

SARB_000105

TABLE 6-15. CORRELATION COEFFICIENT VALUES BY SITE

		TSS	COD	TOT. P	SOL. P	TKN	NO_{2+3}-N	TOT. CU	TOT. Pb	TOT. ZN
CA1	KNOX				.43		(.70)			
	S. VIEW.	(.57)				.49				
CO1	ASBURY	.58		(.84)				.58		
	B. ORY C.					.47				
	CHERRY				(.10)					
	N. AVE.		(.58)	(.47)	(.42)	.72	(.52)	(.47)	(.42)	(.41)
	ROONEY		(.78)							(.75)
	VILLA IT.		(.70)	(.58)	(.67)	(.69)	(.44)	(.46)	(.55)	(.61)
	I16/C			(.85)						
OC1	OUFIEF		(.76)							
	FAIRIDGE									
	LAKERIDGE				(.42)		(.28)			(.41)
	STEOWICK						.28			.26
	STRATTON				-.2					
	WESTLEIGH		(.32)				.38	(.84)		(.44)
FL1	CHARTER/H		(.82)	.54	U	(.68)		.54	(.67)	.58
	YOUNG				U					
	NORMA P.				U					
IL1	JOHN N.		.31	(.39)	U	.29	U			U
	JOHN S.		.36	(.42)	U		U			U
	MATTIS N.		(.84)	(.58)	U	(.48)	U	(.40)	(.46)	U
	MATTIS S.		(.81)	(.56)	U	(.53)	U	(.34)	(.46)	U
KS1	92nd				U		U			

		TSS	COD	TOT P.	SOL P	TKN	NO_{2+3}-N	TOT. CU	TOT. Pb	TOT. ZN
KS1	LENAXA		(.70)	(.51)	U		U	.80		
	METCALF		.40	.40	U		U			
	NOLAND		(.77)		(.82)	U	U			
	OVERTON					U	U			(.57)
MA1	ANNA									
	CONVENT									
	JORDAN						(.68)			(.74)
	LOCUST	.80		(.91)			.82		.78	
	RT. 9						.87			
MA2	ADDISON	.83	U							
	HEMLOCK	.85	U		(.94)					
MO1	BOLTON	(.50)			U			(.47)		
	HAMPDEN			.42	U			(.61)		
	HOMELAND				U					
	MT. WASH.	.42			U					
	RES. HILL		(.79)		U	(.58)		(.55)		
MI1	GRACE S.							.70		
	GRACE N.									(.80)
	GRAND									.51
	IND. DR.									
	WAVERLY									
NC1	1013		(.58)	(.49)	U	(.57)	(.67)	(.32)	(.29)	(.64)
	1023	(.32)			U					
NH1	PKG.		(.58)		U	(.48)	(.46)	(.50)	(.41)	(.58)

		TSS	COD	TOT. P	SOL. P	TKN	NO_{2+3}-N	TOT. CU	TOT. Pb	TOT. ZN
NY1	CARLL R.		U		U		(.70)	U		
NY2	CEDAR		U				(.42)	U		
NY3	CRANSTON				U		U	U		
	E. ROCH.		(.79)	(.84)	U	.70	U	U	(.72)	(.72)
	SOUTHGATE				U		U	U		
TN1	CBO	.48		(.82)	-.47	(.56)		(.51)	(.51)	(.85)
	RI	(.82)			(.62)			(.72)	(.85)	(.82)
	R2					(.81)				
	SC				(.49)		(.85)			
TX1	HART		.57		U			U		
	R'WOOD.				U	(.77)		U		
WA1	LAKE H.		(.33)		U	(.34)			(.29)	(.37)
	SURREY D.		(.38)	(.30)	U	(.21)		U	(.18)	(.23)
WI1	BURBANK			.26	U			U		
	HASTINGS		(.49)		U			U	(.32)	
	LINCOLN				U	U		U		U
	POST O.	(.39)	(.28)	.24	U	(.48)	(.53)	U	.23	
	RUSTLER	(.37)	(.55)		U	.39	.37	U		
	STATE F.	(.47)	(.48)	(.47)	U		(.72)	U		
	WOOD C.				U			U		

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(.) INDICATES 95% LEVEL OF SIGNIFICANCE, OTHERS ARE AT THE 90% LEVEL
U INDICATES AN UNMEASURED CONSTITUENT
BLANK INDICATES NO SIGNIFICANT CORRELATION

SARB_000106

test is suspect since one or two events may dominate the correlation or otherwise cause it to be overstated due to uncertainties in parameter estimation. Second, only 25 percent of the sites account for over two-thirds of the significant correlations. In fact, 33 of the 67 sites had at most one significant correlation, 16 had 2 or 3, and 18 had 4 or more significant r values.

Data for the sites with many significant correlations are presented in Table 6-16. It can be noted that the r values for all constituents are around 0.55. Thus, there is no overall tendency to have strong correlations for some constituents and weak correlations for others. On a site by site basis, the strength of the apparent correlation varies inversely with n as does the significance requirement. Discounting the sites with very low or high values of n, however, the r values for the remainder are again around 0.55, which is the average for all 19 of these sites. Turning to land use, it is significant that half of the sites with many significant correlations have a large commercial/industrial component. Discounting sites with a small number of observations ($n \leq 12$), the sites in Table 6-16 are smaller (average size is 41 acres vs 126 acres for all sites), more impervious (average of 65 percent vs 40 percent for all sites), and have higher runoff coefficients (0.5 vs 0.3 for all sites). Thus, one could conjecture that their responses might tend to be somewhat less random and more ameanable to deterministic analysis (i.e., with conventional modeling approaches). Since they represent only around 25 percent of the total number of sites, however, and the correlations are rather weak, any effect of EMC correlation with runoff volume can be ignored without serious overall error.

This finding of no significant linear correlation between EMCs and runoff volumes is important for several reasons. First, in stormwater monitoring programs there is a natural and appropriate bias that favors emphasizing resource allocation to larger storm events. This was generally the case with the NURP projects as well. However, because of differences in local meteorological conditions, degree of site imperviousness, and other factors, there are appreciable differences in the average sizes of storms monitored by site in the NURP database. Since no significant linear correlation was found, such biases and differences are not expected to influence EMC comparisons to any appreciable extent.

Secondly, the probabilistic methodologies for examining receiving water impacts identified in Chapter 5 assume, as they are now structured, that concentration and runoff volume are independent (i.e., that there is no significant correlation). Although the methods can be modified to account for such correlations if they exist, the finding of no significant correlation indicates that such refinement is not warranted at this time.

Other Factors. We have not exhaustively analyzed all potential effects of other factors that might influence and hence modify our interpretations and conclusions regarding site differences. Factors such as slope, population density, soil type, seasonal bias in monitored events, and precipitation characteristics (average rainfall intensity, peak rainfall intensity, rainfall duration, time since last storm event, etc.) all have a potential

SARB_000107

TABLE 6-16. SITES WITH MANY SIGNIFICANT CORRELATIONS

		TSS	COD	TOT. P	SOL. P	TKN	NO_2+3-N	Cu	Pb	Zn	AVG r^2	AVG r	$\bar{n}$	LAND USE	% IMPERVIOUS	RUNOFF COEFFICIENT
CO1	NORTH AVE.	–	–.58	–.47	–.42	–.72	–.52	–.47	–.42	–.46	.28	.52	32	30%C	50%	.239
	VILLA IT.	–	–.70	–.58	–.67	–.69	–.44	–.46	–.55	–.65	.35	.59	27	100%C	91%	.927
OC1	WESTLEIGH	–	–.32	–	–	–	–.39	–.84	–	–.44	.29	.54	35	93%R	21%	.119
FL1	CHARTER/H	–	–.62	–.54	U	–.68	–	–.54	–.67	–.56	.37	.60	12	89%R	16%	.153
IL1	MATTIS N.	–	–.64	–.59	U	–.48	U	–.40	–.46	U	.27	.52	35	50%C	58%	.639
	MATTIS S.	–	–.61	–.55	U	–.53	U	–.34	–.46	U	.26	.51	33	90%R	37%	.330
KS1	LENAXA	–	–.70	–.51	U	–	U	–.80	–	–	.46	.68	16	50%I	44%	.540
MA 1	LOCUST	.80	–	.91	–	–	–.82	–	.78	–	.69	.83	6	85%R	16%	.209
MO 1	RES. HILL	–	–.79	–	U	–.58	–	–.55	–	–	.42	.65	13	100%R	76%	.486
NC1	1013 (CBO)	–	–.58	–.46	U	–.57	–.67	–.32	–.29	–.54	.26	.51	61	100%C	69%	.791
NH1	PKG.	–	–.58	–	U	–.49	–.46	–.50	–.41	–.58	.26	.51	33	100%C	90%	.658
NY3	E. ROCHESTER	–	–.79	–.84	U	–.70	U	U	–.72	–.72	.57	.76	8	100%R	38%	.195
TN1	CBO	–.48	–	–.62	–.47	–.56	–	–.51	–.51	–.65	.30	.55	15	100%C	99%	.206
	R1	.82	–	–	–.62	–	–	.72	.85	.82	.57	.77	11	91%R	33%	.032
WA 1	LAKE H.	–	–.33	–	U	–.34	U	U	–.29	–.37	.11	.33	126	91%R	37%	.199
	SURREY O.	–	–.34	–.30	U	–.21	U	U	–.18	–.23	.07	.26	118	100%R	29%	.177
WI1	P.O.	–.39	–.28	–.24	U	–.46	–.53	U	–.23	–	.14	.37	40	100%C	95%	.899
	RUSTLER	–.37	–.55	–	U	–.39	–.37	U	–	–	.18	.43	20	100%C	95%	.793
	STATE FAIR	–.47	–.48	–.47	U	–	–.72	U	–	–	.30	.55	25	74%C	77%	.622
	AVERAGE r^2	.34	.33	.29	.31	.30	.30	.31	.28	.32						
	AVERAGE r	.58	.58	.53	.55	.55	.55	.56	.53	.57						

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influence on the median and variability of pollutant concentrations at a site.

On the basis of limited screening, however, we have concluded that such factors do not appear to have any real consistent significance in explaining observed similarities or differences among individual sites. Therefore, although more detailed and rigorous analysis and evaluation of the NURP database may well provide additional useful insight and understanding of the influence of such other factors, we do not believe that the basic findings and conclusions presented in this report will be significantly altered by the results of such efforts. Furthermore, the value of any such insights as may be developed are likely to have limited influence on general decisions on control of urban runoff. For example, the finding of a strong seasonal effect on EMC values would have little influence on a decision to require detention basins in all newly developing urban areas, nor would it be likely to influence their design.

Urban Runoff Characteristics

Having determined, as discussed in the preceding section, that geographic location, land use category, or other factors appear to be of little utility in explaining overall site-to-site variability or predicting the characteristics of unmonitored sites, the best general characterization of urban runoff can be obtained by pooling the site data for all sites (other than the open/non-urban ones). This approach is appropriate, given the need for a nationwide assessment and the general planning thrust of this report. Recognizing that there tend to be exceptions to any generalization, however realistic and appropriate, in the absence of better information the data given in Table 6-17 are recommended for planning level purposes as the best description of the characteristics of urban runoff.

TABLE 6-17. WATER QUALITY CHARACTERISTICS OF URBAN RUNOFF

Constituent	Event to Event Variability in EMC's (Coef Var)	Site Median EMC	
		For Median Urban Site	For 90th Percentile Urban Site
TSS (mg/l)	1-2	100	300
BOD (mg/l)	0.5-1.0	9	15
COD (mg/l)	0.5-1.0	65	140
Tot. P (mg/l)	0.5-1.0	0.33	0.70
Sol. P (mg/l)	0.5-1.0	0.12	0.21
TKN (mg/l)	0.5-1.0	1.50	3.30
NO_{2+3}-N (mg/l)	0.5-1.0	0.68	1.75
Tot. Cu (µg/l)	0.5-1.0	34	93
Tot. Pb (µg/l)	0.5-1.0	144	350
Tot. Zn (µg/l)	0.5-1.0	160	500

SARB_000109

Coliform Bacteria

Coliform bacteria counts in urban runoff were monitored for a significant number of storm events by seven of the NURP projects at 17 different sites. Data were collected at twelve of these sites for more than five and up to 20 storm events. Data on either Fecal Coliform or both Fecal and Total Coliform counts are available for a total of 156 separate storm events. Although the data base for bacteria is thus considerably more restricted than for other pollutants, useful results have been obtained.

Table 6-18 summarizes the results of an analysis of these data. Some variability exists from site to site, and data are too limited to identify any land use distinctions. However, results from the different sites and projects are consistent in showing a very dramatic seasonal effect. Coliform counts in urban runoff during the warmer periods of the year are approximately 20 times greater than those in urban runoff that occurs during colder periods.

The substantial seasonal differences which are observed do not correspond with comparable variations in urban activities. This suggests that seasonal temperature effects and sources of coliform unrelated to those traditionally associated with human health risk may be significant.

In addition to the summarized data presented here, special study reports prepared by the Long Island and Baltimore projects address the issue of animal and other sources of coliform bacteria using information derived from field monitoring and the technical literature. The Baltimore NURP project also conducted small scale site studies which simulated washoff by storms and identified that quite substantial differences in coliform levels can result from the general cleanliness of an area, which they associate with the socio-economic strata of the neighborhood. A special study by the Long Island NURP project examined salmonella counts in urban runoff and in an adjacent shellfish area influenced by urban runoff. The Knoxville, TN project also conducted a special study on Salmonella. These project reports may be obtained through NTIS.

Other issues related to bacteria as a health risk were raised and warrant further investigation. A better understanding is needed of the contribution of domestic animals or such wildlife as may be expected in urban areas to observed coliform levels.

Though high levels of indicator microorganisms were found in urban runoff, the analysis as well as current literature suggests that indicators such as fecal coliform may not be useful in identifying health risks from urban runoff pollutions.

PRIORITY POLLUTANTS

'ackground

he NURP priority pollutant monitoring project was conducted to evaluate the resence, concentration, and potential water quality impacts of priority pollutants in urban runoff. A total of 121 urban runoff samples were collected

SARB_000110

TABLE 6-18. FECAL COLIFORM CONCENTRATIONS IN URBAN RUNOFF

Project and Site		Warm Weather			Cold Weather		
		Site No. Obs	Median EMC (1000/ 100 ml)	C.V.	Site No. Obs	Median EMC (1000/ 100 ml)	C.V.
DC1	Burke	1	4.6	-	1	0.02	-
	Westleigh	1	46	-	2	0.35	-
	Stedwick	2	10	-	1	0.2	-
MD1	Homeland	7	11	1.8	-	-	-
	Mt Wash	1	130	-	1	3.3	-
	Res Hill	1	281	-	1	330	-
NC1	(CBD) 1013	11	15	1.6	8	1.0	0.6
	Res 1023	2	23	-	4	2.6	1.1
NH1	Pkg Lot	20	0.3	0.5	-	-	-
NY1	Carll	12	24	0.9	15	1.4	1.5
	Unqua	7	11	1.6	4	0.9	14
SD1	Meade	9	57	0.7	-	-	-
TN1	CBD	7	54	1.5	7	1.0	1.4
	R1	6	56	2.0	4	1.6	1.9
	R2	6	19	6.2	4	0.5	2.4
	SC	7	12	2.8	4	0.9	1.7
		76 Events			52 Events		
All Sites*		11	21	0.8	9	1	0.7

Notes:

* For general characterization of urban runoff, exclude the following sites:

- NH1 - A small (0.9A) Parking Lot; concentrations low and atypical.
- Four sites with only one observation for season; variability is too high for any confidence in representativeness of a single value.

SARB_000111

at 61 sites (two storm events per site) in 20 of the NURP projects that participated in this phase of the program. These sites were predominantly in the residential, mixed, or commercial land use areas as defined earlier. Thus, the results of this effort cannot be attributed to runoff from industrial facilities or complexes. Furthermore, an especially exhaustive quality control component, over and above the standard NURP QA/QC effort, was imposed on the priority pollutant portion of the program, resulting in the rejection of nearly 14 percent of the data. Therefore, there is a high level of confidence in the results of this project.

Since only two samples were collected at each site, no meaningful site statistic could be calculated. Therefore the data were pooled for analysis. In view of the discussion in the preceding section, however, this approach seems to be justified.

A detailed compilation of NURP priority pollutant analytical results including city and site where the sample was collected, date of collection; discrete or composite sample, pH, and pollutant concentration can be found in the final report on the NURP Priority Pollutant Monitoring Program soon to be issued by the Monitoring and Data Support Division of the agency. A summary of the findings taken from the December 5, 1983 draft of that report follows.

Pollutants Not Included in NURP. Asbestos and dioxin were excluded from the NURP program. However, standard laboratory methods will reveal the presence of dioxin at concentrations of 1 to 10 µg/l, and most laboratories did scan their chromatograms for the possible presence of this pollutant. All such scans were negative, and on this basis dioxin is included as "not detected".

Results Not Valid. The NURP results for seven priority pollutants cannot be considered valid. Recent EPA investigation has revealed that standard methods are not appropriate for the measurement of hexachlorocyclopentadiene, dimethyl nitrosamine, diphenyl nitrosamine, benzidine, and 1,2-diphenylhydrazine. Two other pollutants, acrolein and acrylonitrile, must be analyzed within three days of sample collection. Such a time constraint was an impractical one for the NURP program.

Pollutants Detected in Runoff

Seventy-seven priority pollutants were detected in the NURP urban runoff samples. This group includes 14 inorganic and 63 organic pollutants (Table 6-19).

Inorganic Pollutants. As a group, the toxic metals are by far the most prevalent priority pollutant constituents of urban runoff. All 14 inorganics (13 metals, plus cyanides; asbestos excluded) were detected, and all but three at frequencies of detection greater than 10 percent. Most often detected among the metals were copper, lead, and zinc, all of which were found in at least 91 percent of the samples. Their concentrations were also among the highest for any pollutant, and reached a maximum of 100, 460, and 2,400 µg/l, respectively. Other frequently detected inorganics included arsenic, chromium, cadmium, nickel, and cyanide (Table 6-20). Twelve of the thirteen toxic metals (antimony excluded) were also sampled in the special

SARB_000112

TABLE 6-19. SUMMARY OF ANALYTICAL CHEMISTRY FINDINGS FROM NURP PRIORITY POLLUTANT SAMPLES[1]

(Includes information received through September 30, 1983)

Pollutant	Cities Where Detected[2]	Frequency of Detection[3]	Range of Detected Concentrations (µg/ℓ)[4]
I. PESTICIDES			
1. Acrolein	Holding times exceeded		
2. Aldrin	4,7,26	6	0.002T-0.1M
3. α-Hexachlorocyclohexane (α-BHC) (Alpha)	7,8,22,26	20	0.002?-0.1M
4. β-Hexachlnrocyclohexane (β-BHC) (Beta)	7,8	5	0.018-0.1M
5. γ-Hexachlorocyclohexane (γ-BHC) (Gamma) (Lindane)	7,8,22,26	15	0.007-0.1M
6. δ-Hexachlorncyclohexane (δ-BHC) (Delta)	7,26	6	0.004-0.1M
7. Chlordane	2,8,21,26	17	0.01[illegible]-10
8. DDD	Not detected		
9. DDE	26	6	0.007-0.027
10. DDT	7	1	0.1M
11. Dieldrin	26,27	6	0.00?-0.1
12. α-Endosulfan (Alpha)	7,26,27	19	0.008-0.2
13. β-Endosulfan (Beta)	Nnt detected		
14. Endosulfan sulfate	Nnt detected		
15. Endrin	Not detected		
16. Endrin aldehyde	Not detected		
17. Heptachlnr	7,8,27	6	0.01-0.1M
18. Heptachlor epoxide	7,26	2	0.003T-0.1M
19. Isophorone	7	3	10M
20. TCDD (2,3,7,8-tetrachlorodibenzo-p-dinxin)	Not included in NURP program		
21. Toxaphene	Nnt detected		
II. METALS AND INORGANICS			
22. Antimnny	7,24,26	13	2.6-23A
23. Arsenic	2,3,7,12,19,20,21,22,26,27	52	1-50.5
24. Asbestos	Not included in NURP prngram		
25. Beryllium	7,12,20,21	12	1-49
26. Cadmium	1,2,3,7,12,20,21,27	48	0.1M-14
27. Chromium	1,2,7,8,12,17,19,20,21,22,26, 27,28	58	1-190
28. Copper	1,2,3,4,7,8,12,17,19,20,21,22, 23,26,27,28	91	3L-100
29. Cyanides	4,8,19,22,26,27	22	2-300
30. Lead	1,2,3,4,7,8,12,17,19,20,21,22, 26,28	94	6-460
31. Mercury	7,20,28	9	0.6-1.2
32. Nickel	2,3,7,12,20,21,26,27	43	1-182
33. Selenium	7,19,23	11	2-77
34. Silver	3,17,27	7	0.2M-0.8
35. Thallium	7	6	1-14
36. Zinc	1,2,3,7,12,17,19,20,21,22, 23,27,28	94	10-2400
III. PCBs AND RELATED COMPOUNDS			
37. PCB-1016 (Aroclor 1016)	Nnt detected		
38. PCB-1221 (Aroclor 1221)	Not detected		
39. PCB-1232 (Aroclor 1232)	Not detected		
40. PCB-1242 (Aroclor 1242)	Not detected		
41. PCB-1248 (Aroclnr 1248)	Not detected		
42. PCB-1254 (Aroclor 1254)	Not detected		
43. PCB-1260 (Aroclor 1260)	2	1	0.03
44. 2-Chloronaphthalene	Not detected		

SARB_000113

TABLE 6-19. SUMMARY OF ANALYTICAL CHEMISTRY FINDINGS FROM NURP PRIORITY POLLUTANT SAMPLES[1] (Cont'd)

(Includes information received through September 30, 1983)

Pollutant	Cities Where Detected	Frequency of Detection	Range of Detected Concentrations (ug/L)
IV. HALOGENATED ALIPHATICS			
45. Methane, bromo- (methyl bromide)	Not detected		
46. Methane, chloro- (methyl chloride)	Not detected		
47. Methane, dichloro- (methylene chloride)	4,17,22	11	5-14.4A
48. Methane, chlorodibromo-	28	1	2
49. Methane, dichlorobromo-	28	1	2
50. Methane, tribromo - (bromoform)	28	1	1
51. Methane, trichloro- (chloroform)	4,17,20,22,23,27,28	9	0.2T-12
52. Methane, tetrachloro- (carbon tetrachloride)	4,28	3	1-2
53. Methane, trichlorofluoro-[4]	2,4,24,28	5	0.61-27
54. Methane, dichlorodifluoro- (Freon-12)[5]	Not detected		
55. Ethane, chloro-	Not detected		
56. Ethane, 1,1-dichloro-	4,28	3	1.5A-3
57. Ethane, 1,2-dichloro-	28	1	4
58. Ethane, 1,1,1-trichloro-	4,2,7,22,24	6	1.6-30A
59. Ethane, 1,1,2-trichloro-	28	2	2-3
60. Ethane, 1,1,2,2-tetrachloro-	4	2	2A-3
61. Ethane, hexachloro-	Not detected		
62. Ethene, chloro- (vinyl chloride)	Not detected		
63. Ethene, 1,1-dichloro-	28	2	1.5-4
64. Ethene, 1,2-trans-dichloro-	20,28	4	1-3
65. Ethene, trichloro-	2,4,8,24,28	6	0.3T-12
66. Ethene, tetrachloro-	8,17,22,28	5	14-43
67. Propane, 1,2-dichloro-	28	1	3
68. Propene, 1,3-dichloro-	28	2	1-2
69. Butadiene, hexachloro-	Not detected		
70. Cyclopentadiene, hexachloro-	Standard methods inappropriate		
V. ETHERS			
71. Ether, bis(chloromethyl)[3]	Not detected		
72. Ether, bis(2-chloroethyl)	Not detected		
73. Ether, bis(2-chloroisopropyl)	Not detected		
74. Ether, 2-chloroethyl vinyl	Not detected		
75. Ether, 4-bromophenyl phenyl	Not detected		
76. Ether, 4-chlorophenyl phenyl	Not detected		
77. Bis(2-chloroethoxy) methane	Not detected		
VI. MONOCYCLIC AROMATICS (EXCLUDING PHENOLS, CRESOLS, PHTHALATES)			
78. Benzene	4,17,27	5	1-13
79. Benzene, chloro-	7,20,26,28	5	1A-1AM
80. Benzene, 1,2-dichloro-	Not detected		
81. Benzene, 1,3-dichloro-	Not detected		
82. Benzene, 1,4-dichloro-	Not detected		
83. Benzene, 1,2,4-trichloro-	Not detected		
84. Benzene, hexachloro-	Not detected		
85. Benzene, ethyl-	4,8,17,20,26,28	6	1-7
86. Benzene, nitro-	Not detected		
87. Toluene	4,17	2	2-9
88. Toluene, 2,4-dinitro-	Not detected		
89. Toluene, 2,6-dinitro	Not detected		

SARB_000114

TABLE 6-19. SUMMARY OF ANALYTICAL CHEMISTRY FINDINGS FROM NURP PRIORITY POLLUTANT SAMPLES[1] (Cont'd)

(Includes information received through September 30, 1983)

Pollutant	Cities Where Detected[4]	Frequency of Detection[3]	Range of Detected Concentrations (µg/L)[5]
VII. PHENOLS AND CRESOLS			
90. Phenol	4,7,26	14	1J-15T
91. Phenol, 2-chloro-	28	1	2
92. Phenol, 2,4-dichloro-	Not detected		
93. Phenol, 2,4,6-trichloro-	Not detected		
94. Phenol, pentachloro-	4,8,19,20,26,27,28	19	1T-115
95. Phenol, 2-nitro-	8	1	1M
96. Phenol, 4-nitro-	4,7,8,20,26,28	16	1T-37
97. Phenol, 2,4-dinitro-	Not detected		
98. Phenol, 2,4-dimethyl-	4,7,8,26	8	1T-10M
99. m-Cresol, p-chloro-	4	1	1.5A
100. o-Cresol 4,6-dinitro-	Not detected		
VIII. PHTHALATE ESTERS			
101. Phthalate, dimethyl	8	1	1L
102. Phthalate, diethyl	3,4,17,28,21	6	1-10M
103. Phthalate, di-n-butyl	4,22,24	6	0.5T-11
104. Phthalate, di-n-octyl	8,20,26,27,28	6	0.4T-26
105. Phthalate, bis(2-ethylhexyl)	4,12,14,22,21,24	22	47-62
106. Phthalate, butyl benzyl	2,8,26	6	1-10M
IX. POLYCYCLIC AROMATIC HYDROCARBONS			
107. Acenaphthene	Not detected		
108. Acenaphthylene	Not detected		
109. Anthracene	2,17,20,21,26,28	7	1-10M
110. Benzo (a) anthracene	2,21,27	4	1-10M
111. Benzo (b) fluoranthene	26,27	5	1-5
112. Benzo (k) fluoranthene	2,21,27	5	4-14
113. Benzo (g,h,i) perylene	21	1	5
114. Benzo (a) pyrene	2,21,26,27	6	1-10M
115. Chrysene	2,7,17,21,26,27	10	0.6T-10M
116. Dibenzo (a,h) anthracene	21	1	1T
117. Fluoranthene	2,8,12,17,21,26,27,28	16	0.3T-21
118. Fluorene	28	1	1
119. Indeno (1,2,3-c,d) pyrene	21	1	4
120. Naphthalene	4,24,26,28	9	0.8T-2.3
121. Phenanthrene	2,8,17,20,21,26,27,28	12	0.3T-10M
122. Pyrene	2,3,8,12,17,21,26,27,28	15	0.3T-16

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TABLE 6-19. SUMMARY OF ANALYTICAL CHEMISTRY FINDINGS FROM NURP PRIORITY POLLUTANT SAMPLES[1] (Cont'd)

(Includes information received through September 30, 1983)

Pollutant	Cities Where Detected[2]	Frequency of Detection[3]	Range of Detected Concentrations (µg/ℓ)[4]
X. NITROSAMINES AND OTHER NITROGEN-CONTAINING COMPOUNDS			
123. Nitrosamine, dimethyl (DMN)	Standard methods inappropriate		
124. Nitrosamine, diphenyl	Standard methods inappropriate		
125. Nitrosamine, di-n-propyl	Not detected		
126. Benzidine	Standard methods inappropriate		
127. Benzidine, 3,3'-dichloro-	Not detected		
128. Hydrazine, 1,2-diphenyl-	Standard methods inappropriate		
129. Acrylonitrile	Holding times exceeded		

[1] Based on 121 sample results received as of 9/30/83, adjusted for quality control review.

[2] Cities from which data are available:

1. Durham, NH
2. Lake Quinsigamond, MA
3. Mystic River, MA
4. Long Island, NY
7. Washington, DC
8. Baltimore, MD
12. Knoxville, TN
17. Glen Ellyn, IL
19. Austin, TX
20. Little Rock, AR
21. Kansas City, KS
22. Denver, CO
23. Salt Lake City, UT
24. Rapid City, SD
26. Fresno, CA
27. Bellevue, WA
28. Eugene, OR

Numbering of cities conforms to NURP convention.

[3] Percentages rounded to nearest whole number.

[4] Some reported concentrations are qualified by STORET quality control remark codes, to wit: A = Value reported is the mean of two or more determinations; G = Value reported is the maximum of two or more determinations; L = Actual value is known to be greater than value given; M = Presence of material verified but not quantified; T = Value reported is less than criteria of detection. One value in this column indicates one positive observation or that all observations were equal.

[5] No longer included as a priority pollutant.

SARB_000116

TABLE 6-20. MOST FREQUENTLY DETECTED PRIORITY POLLUTANTS IN NURP URBAN RUNOFF SAMPLES[1]

Priority Pollutants Detected in 75 Percent or More of the NURP Samples

Inorganics	Organics
30. Lead (94%)	None
36. Zinc (94%)	
28. Copper (91%)	

Priority Pollutants Detected in 50 percent to 74 percent of the NURP Samples

Inorganics	Organics
27. Chrominum (58%)	None
23. Arsenic (52%)	

Priority Pollutants Detected in 20 percent to 49 percent of the NURP Samples

Inorganics	Organics
26. Cadmium (48%)	105. Bis(2-ethylhexyl) phthalate (22%)
32. Nickel (43%)	3. α-Hexachlorocyclohexane (20%)
29. Cyanides (23%)	

Priority Pollutants Detected in 10 percent to 19 percent of the NURP Samples

Inorganics	Organics
22. Antimony (13%)	12. α-Endosulfan (19%)
25. Beryllium (12%)	94. Pentachlorophenol (19%)
33. Selenium (11%)	7. Chlordane (17%)
	5. γ-Hexachlorocyclohexane (Lindane) (15%)
	122. Pyrene (15%)
	90. Phenol (14%)
	121. Phenanthrene (12%)
	47. Dichloromethane (methylene chloride) (11%)
	96. 4-Nitrophenol (10%)
	115. Chrysene (10%)
	117. Fluoranthene (16%)

[1] Based on 121 sample results received as of September 30, 1983, adjusted for quality control review. Does not include special metals samples.

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metals project in order to determine the relationships among dissolved, total, and total recoverable concentrations. The discussion and result of this separate effort are in a subsequent section of this chapter.

A comparison of individual urban runoff sample concentrations undiluted by stream flow (i.e., end of pipe concentrations) with EPA water quality criteria and drinking water standards reveals numerous exceedances of these levels, as shown in Table 6-21. Freshwater acute criteria were exceeded by copper concentrations in 47 percent of the samples and by lead in 23 percent. Freshwater chronic exceedances were common for lead (94 percent), copper (82 percent), zinc (77 percent), and cadmium (48 percent). One organ oleptic (taste and odor) criteria exceedance was observed. Regarding human toxicity, the most significant pollutant was lead. Lead concentrations violated drinking water criteria in 73 percent of the observations.

Whenever an exceedance is noted above, it does not necessarily imply that an actual violation of criteria did or will take place in receiving waters. Rather, the enumeration of exceedances is used as a screening procedure to make a preliminary identification of those pollutants for which their presence in urban runoff requires highest priority for further evaluation. Exceedances of freshwater chronic criteria levels may not persist for a full 24-hour period, for example. However, many small urban streams probably carry only slightly diluted runoff following storms, and acute criteria or other exceedances may in fact be real in such circumstances.

Among the inorganics, the most frequently detected pollutants are also those which are found at the highest concentrations, which most frequently exceed water quality criteria and which are the most geographically well-distributed. One additional observation can be made concerning the samples from Washington, D.C. These samples accounted for a preponderance of the detections of many of the less frequently detected inorganics, including antimony, beryllium, mercury, nickel, selenium, and thallium. No sampling or analytical irregularities have been identified which explain this result.

Organic Pollutants. In general, the organic pollutants were detected less frequently and at lower concentrations than the inorganic pollutants. Sixty-three of a possible 106 organics were detected. The most commonly found organic was the plasticizer bis (2-ethylhexyl) phthalate (22 percent) followed by the pesticide α-hexachlorocyclohexane (α-BHC) (20 percent). An additional 11 organic pollutants were reported with detection frequencies between 10 and 20 percent; 3 pesticides, 3 phenols, 4 polycyclic aromatics, and a single haloginated aliphatic (Table 6-20).

Criteria exceedances were less frequently observed among the organics than the inorganics. One unusually high pentachlorophenol concentration of 115 µg/l resulted in the only exceedance of the organoleptic criteria (Table 6-21). This observation and one for the chlordane exceeded the freshwater acute criteria. Freshwater chronic criteria exceedances were observed for pentochlorophenol, bis (2-ethylhexyl) phthalate, γ-hexachlorocyclohexane (Lindane), α-endosulfan, and chlordane. All other organic exceedances were in the human carcinogen category and were most serious for α-hexachlorocyclohexane (α-BHC), γ-hexachlorocyclohexane (γ-BHC or Lindane), chlordane, phenanthrene, pyrene, and chrysene.

SARB_000118

TABLE 6-21. SUMMARY OF WATER QUALITY CRITERIA EXCEEDANCES FOR POLLUTANTS DETECTED IN AT LEAST 10 PERCENT OF NURP SAMPLES: PERCENTAGE OF SAMPLES IN WHICH POLLUTANT CONCENTRATIONS EXCEED CRITERIA[1]

Pollutant	Frequency of Detection (%)	Detections/ Samples[2]	Criteria Exceedances [3,4]						
			None	FA	FC	/|	HH	HF[5]	DW
I. PESTICIDES									
3. a-Hexachlorocyclohexane	20	21/106						8,18,20	
5. γ-Hexachlorocyclohexane (Lindane)	15	15/100			8			0,16,16	
7. Chlordane	17	7/42		2	17			17,17,17	
12. α-Endosulfan	19	9/49			10				
II. METALS AND INORGANICS									
22. Antimony	13	14/106	X						
23. Arsenic	52	45/87						52,52,52	1
25. Beryllium	12	11/94			6*			12,12,12	
26. Cadmium[5]	48	44/91		R	48		1		1
27. Chromium[5,6]	58	47/81			1*				1
28. Copper[5]	91	79/87		47	82				
29. Cyanides	23	16/71		3	22		4		
30. Lead[5]	94	75/80		23	94		23		73
32. Nickel[5]	43	39/91			5		22		
33. Selenium	11	10/88			5		10		10
36. Zinc[5]	94	88/94		14	77				
IV. HALOGENATED ALIPHATICS									
47. Methane, dichloro-	11	3/28						0,0,11	
VII. PHENOLS AND CRESOLS									
90. Phenol	14	13/91	X						
94. Phenol, pentachloro-	19	21/111		1*	11*	1			
96. Phenol, 4-nitro-	10	11/107	X						
VIII. PHTHALATE ESTERS									
105. Phthalate, bis(2-ethylhexyl)	22	15/69			22*				
IX. POLYCYCLIC AROMATIC HYDROCARBONS									
115. Chrysene	10	11/109						10,10,10	
117. Fluoranthene	16	17/109	X						
121. Phenanthrene	12	13/110						12,12,12	
122. Pyrene	15	16/110						15,15,15	

* Indicates FTA or FTC value substituted where FA or FC criterion not available (see below).

[1] Based on 121 sample results received as of September 30, 1983, adjusted for quality control review.

[2] Number of times detected/number of acceptable samples.

[3] FA = Freshwater ambient 24-hour instantaneous maximum criterion ("acute" criterion).
FC = Freshwater ambient 24-hour average criterion ("chronic" criterion).
FTA = Lowest reported freshwater acute toxic concentration. (Used only when FA is not available.)
FTC = Lowest reported freshwater chronic toxic concentration. (Used only when FC is not available.)
/\ = Taste and odor (organoleptic) criterion.
HH = Non-Carcinogenic human health criterion for ingestion of contaminated water and organisms.
HF = Protection of human health from carcinogenic effects for ingestion of contaminated water and organisms.
DW = Primary drinking water criterion.

[4] Entries in this column indicate exceedances of the human carcinogen value at the 10^{-5}, 10^{-6}, and 10^{-7} risk level, respectively. The numbers are cumulative, i.e., all 10^{-5} exceedances are included in 10^{-6} exceedances, and all 10^{-6} exceedances are included in 10^{-7} exceedances.

[5] Where hardness dependent, hardness of 100 mg/l $CaCO_3$ equivalent assumed.

[6] Different criteria are written for the trivalent and hexavalent forms of chromium. For purposes of this analysis, all chromium is assumed to be in the less toxic trivalent form.

SARB_000119

An additional 50 organic pollutants were found in one to nine percent of the samples. These frequencies of detection are low, and the pollutant is noted in Table 6-22.

Among the PCB group, there was only a single detection of one PCB type among all the samples. Approximately two-thirds of the halogenated aliphatic compounds were detected. Among those cities reporting these compounds, the city of Eugene, Oregon, figured prominently. For example, eight pollutants from this group were found in Eugene only. None of the pollutants in the ethers group were detected.

Monocyclic aromatics were rarely detected in the samples. However, many reported detections of benzene and toluene, two commonly reported pollutants, had to be withdrawn due to contamination problems.

Of the 11 phenolics, four have not been reported in urban runoff, while three have been observed only once. The remaining four have been found fairly frequently but at low concentrations. Exceedances of criteria were noted only for pentachlorophenol.

All the phthalate esters were detected at least once in the NURP program, with bis (2-ethylhexyl) found most frequently. Several times the reported concentration exceeded the lowest observed freshwater acute toxic concentration for this pollutant. Given the significant blank contamination problems with the phthalates, however, these findings must be interpreted with caution.

Only two of the polycyclic aromatic hydrocarbons were not detected in at least one sample. Crysene, phenanthrene, pyrene, and fluoranthene were each found at least 10 percent of the time. All the observed concentrations for the first three of these pollutants exceeded the criteria for the protection of human health from carcinogenic effects (there are no such criteria for fluoranthene). Results for the polycyclic aromatics were generally free from quality control problems.

There were no detections of nitrosamines or other nitrogen-containing compounds. Due to methodological and holding time problems, however, results for only two compounds can be used. Moreover, for one of these compounds, 3,3-dichlorobenzidine, performance evaluation results were unacceptable in several cases.

Pollutants Not Detected In Urban Runoff

Some 43 priority pollutants were not detected in any acceptable runoff samples (Table 6-22). All of these pollutants are organics. This group of substances should be considered to pose a minimal threat to the quality of surface waters from runoff contamination.

While the priority pollutants which were not detected are of less immediate concern than those pollutants found often, they cannot safely be eliminated from all future consideration. Many of these pollutants have associated water quality criteria which are below the limits of detection of routine

SARB_000120

TABLE 6-22. INFREQUENTLY DETECTED ORGANIC PRIORITY POLLUTANTS IN NURP URBAN RUNOFF SAMPLES[1]

Priority Pollutants Detected in 1 percent to 9 percent of the NURP Samples

51. Trichloromethane (9%)
120. Naphthalene (9%)
98. 2,4-Dimethyl phenol (8%)
109. Anthracene (7%)
2. Aldrin (6%)
6. δ-Hexachlorocyclohexane (6%)
9. DDE (6%)
11. Dieldrin (6%)
17. Heptachlor (6%)
58. 1,1,1-Trichloroethane (6%)
65. Trichloroethene (6%)
85. Ethylbenzene (6%)
102. Diethyl phthalate (6%)
103. Di-n-butyl phthalate (6%)
104. Di-n-octyl phthalate (6%)
106. Butyl benzyl phthalate (6%)*
114. Benzo(a)pyrene (6%)
4. β-Hexachlorocyclohexane (5%)
53. Trichlorofluoromethane (5%)[2]
66. Tetrachloroethene (5%)
78. Benzene (5%)
79. Chlorobenzene (5%)
111. Benzo(b)fluoranthene (5%)*
64. 1,2-trans-dichloroethene (4%)
110. Benzo(a)anthracene (4%)
19. Isophorone (3%)
52. Tetrachloromethane (carbon tetrachloride) (3%)
56. 1,1-Dichloroethane (3%)
87. Toluene (3%)
112. Benzo(k)fluoranthene (3%)
18. Heptachlor epoxide (2%)*
59. 1,1,2-Trichloroethane (2%)*
60. 1,1,2,2-Tetrachloroethane (2%)*
63. 1,1-Dichloroethene (2%)
68. 1,3-Dichloropropene (2%)*
113. Benzo(g,h,i)perylene (2%)
10. DDT (1%)*
43. PCB-1260 (1%)*
48. Chlorodibromomethane (1%)*
49. Dichlorobromomethane (1%)*
50. Tribromomethane (bromoform) (1%)*
57. 1,2-Dichloroethane (1%)*
67. 1,2-Dichloropropane (1%)*
91. 2-Chlorophenol (1%)*
95. 2-Nitrophenol (1%)*
99. p-Chloro-m-creosol (1%)*
101. Dimethyl phthalate (1%)*
116. Dibenzo(a,h)anthracene (1%)*
118. Fluorene (1%)*
119. Indeno(1,2,3-cd)pyrene (1%)*

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TABLE 6-22. INFREQUENTLY DETECTED ORGANIC PRIORITY POLLUTANTS IN NURP URBAN RUNOFF SAMPLES[1] (Cont'd)

Priority Pollutants Not Detected in NURP Samples

8. DDD
13. β-Endosulfan
14. Endosulfan sulfate
15. Endrin
16. Endrin aldehyde
21. Toxaphene
37. PCB-1016
38. PCB-1221
39. PCP-1232
40. PCB-1242
41. PCB-1248
42. PCB-1254
44. 2-Chloronaphthalene
45. Bromomethane (methyl bromide)
46. Chloromethane (methyl chloride)
54. Dichlorodifluoromethane (Freon-12)[2]
55. Chloroethane
61. Hexachloroethane
62. Chloroethene (vinyl chloride)
69. Hexachlorobutadiene
71. Bis(chloromethyl) ether[2]
72. Bis(chloroethyl) ether
73. Bis(chloroisopropyl) ether
74. 2-Chloroethyl vinyl ether
75. 4-Bromophenyl phenyl ether
76. 4-Chlorophenyl phenyl ether
77. Bis(2-chloroethoxy) methane
80. 1,2-Dichlorobenzene
81. 1,3-Dichlorobenzene
82. 1,4-Dichlorobenzene
83. 1,2,4-Trichlorobenzene
84. Hexachlorobenzene
86. Nitrobenzene
88. 2,4-Dinitrotoluene
89. 2,6-Dinitrotoluene
92. 2,4-Dichlorophenol
93. 2,4,6-Trichlorophenol
97. 2,4-Dinitrophenol
100. 4,6-Dinitro-o-cresol
107. Acenaphthene
108. Acenaphthylene
125. Di-n-propyl nitrosamine
127. 3,3'-Dichlorobenzidine

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TABLE 6-22. INFREQUENTLY DETECTED ORGANIC PRIORITY POLLUTANTS IN NURP URBAN RUNOFF SAMPLES[1] (Cont'd)

Priority Pollutants Not Analyzed for or Withdrawn for Methodological Reasons or Holding Time Violations

1. Acrolein
20. TCDD (Dioxin)
24. Asbestos
70. Hexachlorocyclopentadiene
123. Dimethyl nitrosamine (DMN)
124. Diphenyl nitrosamine
126. Benzidine
128. 1,2-Diphenyl hydrazine
129. Acrylonitrile

* Detected in only one or two samples.

[1] Based on 121 sample results received as of September 30, 1983, adjusted for quality control review.

[2] No longer on the priority pollutant list.

analytical methods. Some of these substances may in fact have been present in the NURP samples. Four priority pollutants not detected in runoff were found in street dust sweepings from Bellevue, Washington, suggesting that further urban runoff samplings can be expected to detect more priority pollutants. More sensitive analytical methodologies must be used and dilution effects considered before it can be said with assurance that these pollutants are not found in urban stormwater runoff at levels which, without dilution, pose a threat to human health or aquatic life.

DDD, chloromethane, 1,2-dichlorobenzene, and 2,4-dichlorophenol were detected in runoff samples at least once, but these observations had to be withdrawn for quality control reasons. Therefore, among the not detected pollutants, these four can be considered to have a slightly elevated possibility of actually being present in the runoff samples.

RUNOFF-RAINFALL RELATIONSHIPS

A runoff coefficient (Rv), defined as the ratio of runoff volume to rainfall volume, has been determined for each of the monitored storm events. As with the EMCs, the runoff coefficient values at a particular site are, with relatively few exceptions, well characterized by a lognormal distribution. Table 6-23 summarizes the statistical properties of Rv's at the loading sites in the data base.

Figure 6-19 illustrates the relationship between percent impervious area and the median runoff coefficient for the site. Sites which monitored fewer than 5 storms are excluded. The upper plot (a) groups the results from 16 of the

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TABLE 6-23. RUNOFF COEFFICIENTS FOR LAND USE SITES

Residential

	Site	Land Use Type	No. of Events	Drainage Area (Acs)	Population Density (Pers/Acre)	Imperv.	Runoff Coef (Rv)	
							Median	Coef Var
1	CA1 Big Bear	RES	16	33	10	3%	.35	.37
2	CA1 Cherry	RES	15	65	24	3%	.35	.65
3	ID1 Glendale	RES	24	167	28	4%	.6	.8
4	CO1 Gilbert	RES	63	17	9	19	.4	.47
5	OR1 Lutheridge	RES	84	86	3	2%	.13	.43
6	OR1 Stratton	RES	31	2	2	3%	.3	.37
7	FL1 Ponte Vedra	RES	17	3	-	-	.4	.45
8	FL1 Tahiti N	RES	43	63	14	19	.13	.37
9	IS1 Riverside	RES	11	54	9	18	.28	.11
10	MA2 Sheldon	RES	6	50	5	2%	.15	.16
11	NM1 Bonanza Apts	RES	15	14	30	11	.44	.37
12	NC1 Homestead	RES	15	20	9	29	.4	.26
13	NC1 Mt Wash	RES	20	17	12	29	.14	1.25
14	MD1 Pet Mill	RES	11	10	55	2%	.41	.54
15	NJ1 Carll's Ml	RES	20	23	13	20	.21	.41
16	NJ1 Crinston	RES	11	16	5	27	.16	.15
17	NJ1 Ft Lee	RES	9	14	14	38	.38	.43
18	CA1 Rollingwood	RES	9	60	3	17	.02	.29
19	WA1 Surrey	RES	134	95	9	29	14	.56
20	NJ1 Ridgeb	RES	44	11	15	50	.17	.37
21	NJ1 Washings	RES	33	33	17	51	.27	.37
22	IL1 Park	RES	24	175	4	40	.09	.36
23	NJ1 Lincoln	RES	19	16	10	57	.21	.55
24	TN1 I2	RES	21	89	4	13	.01	.67
25	CA1 Wellington	RES	14	41	3	21	.12	1.15
26	KS1 El - Bend	RES	14	61	-	22	.25	1.08
27	IL1 John C.	RES	29	39	12	12	.17	.54
28	TN1 P1	RES	9	69	11	52	.01	.38
29	WA1 Lake Hills	RES	1,1	102	12	17	.20	.51
30	FL1 Martin S	RES	20	26	22	20	.13	.16
31	FL1 Chapter M.	RES	11	42	-	36	.5	4.66
32	GL1 Talmadge	RES	14	13	-	30	.35	1.32
33	CO1 Ashley	RES	16	127	9	7	.19	.92
34	IL1 Cobb Toilets	RES	29	574	8	51	.17	.48
35	MO1 Locust	RES	6	150	11	26	.01	.33
36	NC1 #3022	RES	63	3x4	1.	2%	5%	6%
37	MA1 Jordan	RES	9	1111	10	21	1	.05
38	OC1 Shadwell	RES	45	77	15	14	.20	1.07

Mixed

	Site	Land Use Type	No. of Events	Drainage Area (Acs)	Population Density (Pers/Acre)	Imperv.	Runoff Coef (Rv)	
							Median	Coef Var
1	MA1 Whitfield	-	25	34	3	16	.09	1.04
2	MA1 Hampden	-	22	7	4%	22	.29	.51
3	IL1 Marcy N	-	24	17	2	56	6A	.52
4	MA1 Waverly	-	35	32	11	6A	.06	.25
5	TN1 I1	-	12	167	3	43	14	.46
6	WI1 Lake Flr	-	44	45	12	51	.26	.42
7	MA1 Wall	-	7	35c	7	11	.20	.99
8	MA1 Concord	-	8	100	1	27	.50	.36
9	MI1 Grand R Dr	-	22	453	9	36	.31	.50
10	IL1 Wilmer	-	15	194	-	-	.41	1.12
11	MI1 Polk &A-S	-	8	2001	2	31	.29	.41
12	NJ1 Cedar	-	12	76	-	6	.06	1.05
13	IL1 Jesbit	-	15	30	-	12	.32	1.03
14	MA1 Alma	-	8	661	9	12	.17	1.6A
15	MI1 IL1 &A-N	-	6	2671	7	26	.10	.43
16	MI1 Brook h	-	24	1A4	5	25	.11	.41
17	IL1 Swell Lur	-	5	1107	1	0	21	.18
18	SD1 Meade	-	16	2000	-	-	10	.57
19	CA1 Kobe	-	42	1690	12	-	.20	.71
20	CO1 Ninth Ave	-	33	19	7	90	.24	.59

Commercial

	Site	Land Use & Cond	No. of Events	Drainage Area (Acs)	Population Density (Pers/Acre)	Imperv	Runoff Coef (Rv)	
							Median	Coef Var
1	IN1 Wills Trailer	IND	23	14	0	91	.93	.45
2	NC1 1012 (CBD)	IND	112	21	6	69	.79	.49
3	NJ1 Southgate	IND	13	179	2	21	.20	.28
4	WI1 Lake Office	IND	50	12	0	2M	.90	.19
5	MI1 Rustler	IND	99	12	0	2M	.79	.19
6	NM1 Dealer	IND	14	1	1	90	.6h	.50
7	TN1 CBD	IND	14	31	0	99	.33	.41
8	IS1 SC Height	MIX	21	60	-	47	.46	.55
9	CL1 Normal Park	RES	17	47	-	44	.48	.86
10	WI1 State Fair	COM	21	29	10	77	.62	.20

Undeveloped and Mountain

	Site	Land Use Type	No. of Events	Drainage Area (Acs)	Population Density (Pers/Acre)	Imperv.	Runoff Coef (Rv)	
							Median	Coef Var
	TN1 Swanson	UND	20	653	-	1	.03	5.56
	CO1 Power Switch	UND		1,05	-	1	.14	2.04
	NC1 Upper??	UND	13	2,430	-	3	0%	0%
1	NJ1 Sno'l Sr	UND	9	1,45	-	3	0%	1.73
	NJ1 Bear Br	UND	10	6,346	-	1	0%	1%
4	SD1 Indian Cr	UND	12	17,2?6	1	2%	0%	5%
	NC1 Tributary	UND	-	1,13		2	1	1.7
	NC1 Cove Cr	UND	1	150			1%	1.7%

Industrial

	Site	Land Use Type	No. of Events	Drainage Area (Acs)	Population Density (Pers/Acre)	Imperv	Runoff Coef (Rv)	
							Median	Coef Var
1	MD1 Albrison	IND	6	18	0	69	5%	.53
2	NJ1 Indus Estate	IND	18	61	1	64	.1%	.71
3	AZ1 Central	IND	19	32	-	44	.54	.27
4	NJ1 Bruce 1	IND	20	5	5	69	.12	.43

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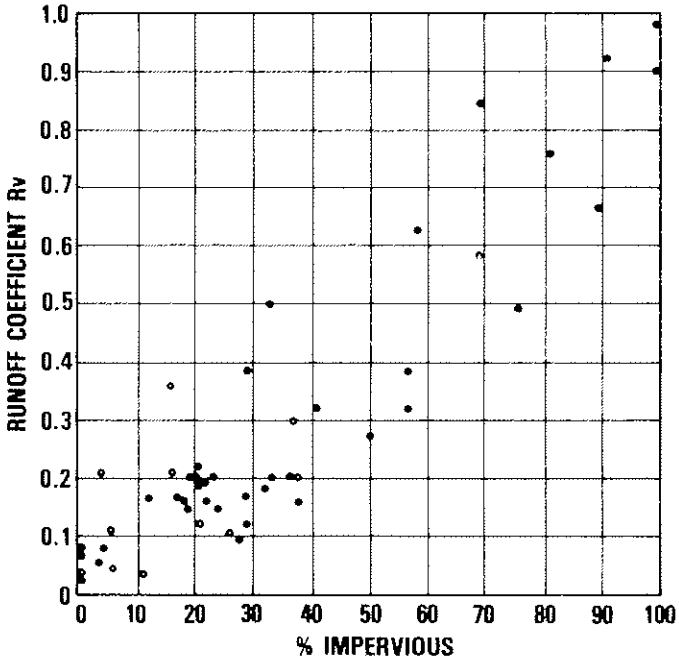
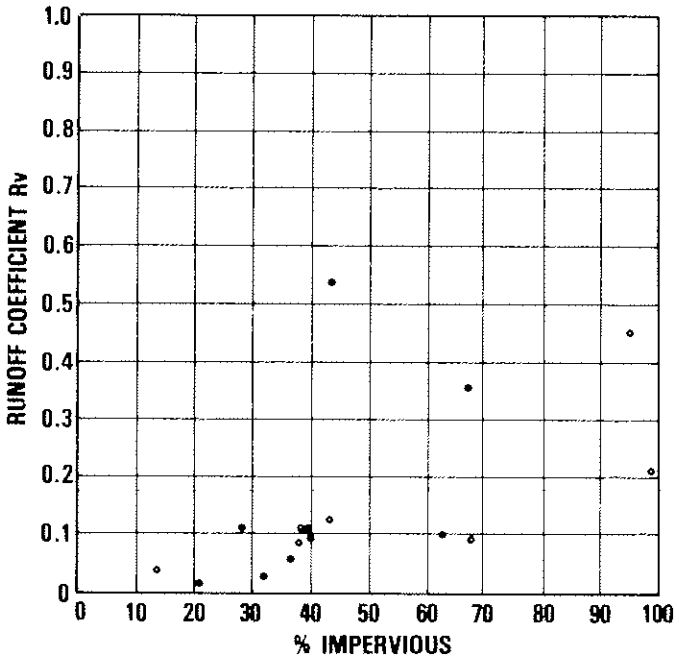


(a) 16 Projects



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(b) 4 Projects (KS1, MI1, TN1, TX1)

Figure 6-19. Relationship Between Percent Impervious Area and Median Runoff Coefficient

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20 projects investigated. The lower plot (b) groups results from the remaining four projects (KS1, MI1, TN1, TX1). The reason for the difference is unexplained. However, the separate grouping is based on the fact that the relationship for these sites is internally consistent and significantly different than the bulk of the project results.

Figure 6-20 illustrates the same impervious area/runoff coefficient relationship, but shows the 90 percent confidence limits for median Rv's.

POLLUTANT LOADS

Although the EMC median concentration values are appropriate for many applications (e.g., assessing water quality impacts in rivers and streams), when cumulative effects such as water quality impacts in lakes and comparisons with other sources on a long-term basis (e.g., annual or seasonal loads) are to be examined, the EMC mean concentration values should be used. Taking the EMC median and coefficient of variation values given in Table 6-17, we have converted them into mean values using the relationship given in Chapter 5. These EMC mean concentrations and the values used in the load comparison to follow are listed in Table 6-24.

The range shown for site mean concentrations for both the median and 90th percentile urban sites reflects the difference in means depending on whether the higher or lower value of coefficient of variation listed in Table 6-17 is used to describe event-to-event variability of EMC's at urban sites. The range in values shown for use in the load comparisons below reflects the median and 90th percentile site mean concentrations, using the average of the range caused by coefficient of variation effects.

TABLE 6-24. EMC MEAN VALUES USED IN LOAD COMPARISON

Constituent	Site Mean EMC		
	Median Urban Site	90th Percentile Urban Site	Values Used in Load Comparison
TSS (mg/l)	141 - 224	424 - 671	180 - 548
BOD (mg/l)	10 - 13	17 - 21	12 - 19
COD (mg/l)	73 - 92	157 - 198	82 - 178
Tot. P (mg/l)	0.37 - 0.47	0.78 - 0.99	0.42 - 0.88
Sol. P (mg/l)	0.13 - 0.17	0.23 - 0.30	0.15 - 0.28
TKN (mg/l)	1.68 - 2.12	3.69 - 4.67	1.90 - 4.18
NO_{2+3}-N (mg/l)	0.76 - 0.96	1.96 - 2.47	0.86 - 2.21
Tot. Cu (ug/l)	38 - 48	104 - 132	43 - 118
Tot. Pb (ug/l)	161 - 204	391 - 495	182 - 443
Tot. Zn (ug/l)	179 - 226	559 - 707	202 - 633

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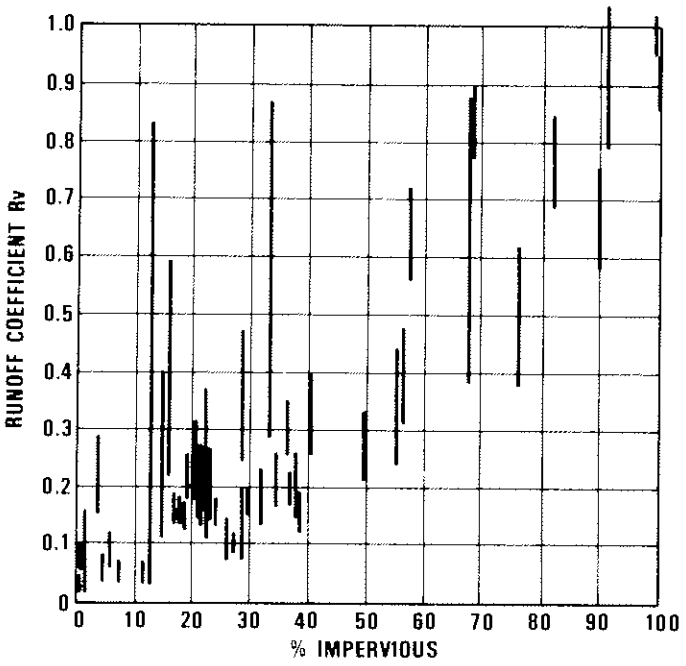

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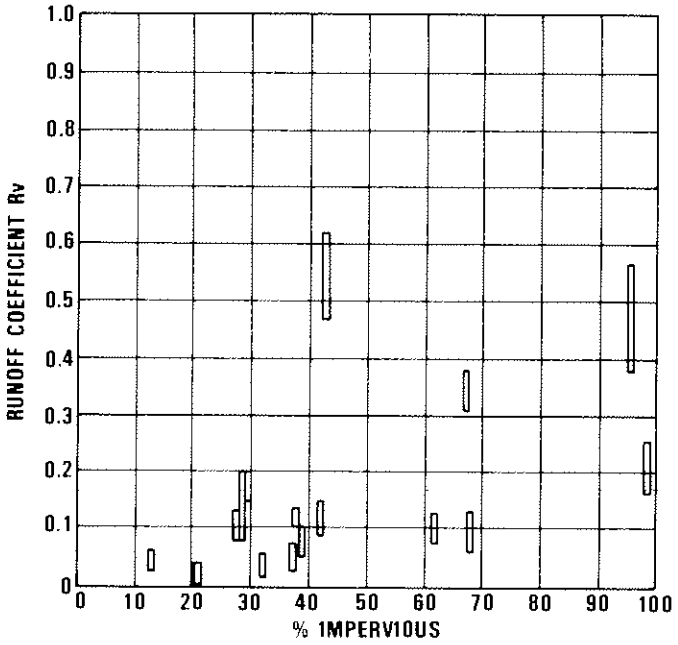
(a) 16 Projects



(b) 4 Projects (KS1, MI1, TN1, TK1)

Figure 6-20. 90 Percent Confidence Limits for Median Runoff Coefficients

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It is a straightforward procedure to calculate mean annual load estimates for urban runoff constituents on a Kg/Ha basis by assigning appropriate rainfall and runoff coefficient values and selecting EMC mean concentration values from Table 6-24. In and of themselves, however, such estimates seem to be of little utility. Therefore, it was decided to do a comparison of the mean annual loads from urban runoff with those of a "well run" secondary treatment plant. We chose to use TSS = 25 mg/l, BOD = 15 mg/l, and Tot. P = 8 mg/l for the effluents from such plants for the purposes of this order of magnitude comparison. For a meaningful comparison for a specific situation, locally appropriate values should be used. Based upon Table 6-24, the corresponding urban runoff mean concentrations used were TSS = 180 mg/l, BOD = 12 mg/l, and Total P = 0.4 mg/l as typical and TSS = 548 ug/l, BOD = 19 mg/l, and Tot. P = 0.88 mg/l as a "worst case" for comparison purposes.

The value of 0.35 was selected as a typical mean runoff coefficient. It is the median of the NURP mean runoff coefficient database for the twenty projects discussed earlier; their average is 0.42, but we believe that this number is overly weighted by the disproportionate number of highly impervious sites in the database. Assuming an average population density of 10 persons per acre (the average of the NURP sites) and a mean annual rainfall of 40 inches per year, urban runoff averages 104 gallons per day per capita. This is also a reasonable estimate of sewage generation in an urban area. Therefore, as a first cut, the ratio of mean pollutant concentrations of urban runoff and POTW effluents will also be the ratio of their annual loads. Thus, we have;

$$\text{TSS} = \frac{180}{25} \approx 7 \; ; \; \text{BOD} = \frac{12}{15} \approx 0.8 \; ; \; \text{Tot. P} = \frac{0.4}{8} \approx 0.05$$

using typical urban runoff values, and;

$$\text{TSS} = \frac{548}{25} \approx 22 \; ; \; \text{BOD} = \frac{19}{15} \approx 1.3 \; ; \; \text{Tot. P} = \frac{0.88}{8} \approx 0.1$$

using the "worst case" values. These numbers suggest that annual loads from urban runoff are approximately one order of magnitude higher than those from a well run secondary treatment plant for TSS, the same order of magnitude for BOD, and an order of magnitude less for Tot. P.

If the hypothetical urban area just described were to go to advanced waste treatment and achieve an effluent quality of TSS = 10 mg/l, BOD = 5 mg/l, and Total P = 1 mg/l and no urban runoff controls were instituted, the mean annual load reductions to the receiving water would be:

$$\text{TSS} = \frac{25 - 10}{180 + 25} \approx 7\% \; ; \; \text{BOD} = \frac{15 - 5}{12 + 15} \approx 37\% \; ; \; \text{Tot. P} = \frac{8 - 1}{0.4 + 8} \approx 83\%$$

for our typical case, and;

$$\text{TSS} = \frac{25 - 10}{548 + 25} \approx 3\% \; ; \; \text{BOD} = \frac{15 - 5}{19 + 15} \approx 29\% \; ; \; \text{Tot. P} = \frac{8 - 1}{0.88 + 8} \approx 79\%$$

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for our "worst case." On the other hand, if urban runoff controls that reduced TSS by 90 percent, BOD by 60 percent, and Total P by 50 percent were instituted, (typical results from a well-designed detention basin), the mean annual load reductions to the receiving water would be:

$$\text{TSS} = \frac{180 - 18}{180 + 25} \approx 79\% \; ; \; \text{BOD} = \frac{12 - 7}{12 + 15} \approx 19\% \; ; \; \text{Total P} = \frac{0.4 - 0.2}{0.4 + 8} \approx 2\%$$

for our typical case, and;

$$\text{TSS} = \frac{548 - 55}{548 + 25} \approx 86\% \; ; \; \text{BOD} = \frac{19 - 8}{19 + 15} \approx 32\% \; ; \; \text{Total P} = \frac{0.88 - 0.44}{0.58 + 8} \approx 5\%$$

Thus, if these pollutants are causing receiving water quality problems, consideration of urban runoff control appears warranted for TSS, both urban runoff control and AWT might be considered for BOD, and only AWT would be effective for Total P.

The foregoing should be viewed as illustrative of a preliminary screening for trade-off studies that can be performed using appropriate values for a specific urban area, rather than as description of any particular real-world case. They are, however, believed useful in providing order of magnitude comparisons. Local values for annual rainfall, runoff coefficient, or point source characteristics that are different than those used in the illustration will of course change the results shown; although in most cases the changes would not be expected to cause a significant change in the general relationship.

As a final perspective on urban runoff loads, Table 6-25 presents an estimate of annual urban runoff loads, expressed as Kg/Ha/year, for comparison with other data summaries of nonpoint source loads which state results in this manner. Load computations are based on site mean pollutant concentrations for the median urban site and on the specified values for annual rainfall and runoff coefficient. Typical values for mean runoff coefficient (based on NURP data) have been assigned for residential land use (Rv = 0.3), commercial land use (Rv = 0.8), and for an aggregate urban area which is assumed to have representative fractions of the total area in residential, commercial, and open uses (Rv = 0.35).

Several useful observations can be made. The annual load estimates which results are comparable to values and ranges reported in the literature. Although the findings presented earlier in this chapter indicated that the land use category does not have a significant influence on site concentrations of pollutants, on a unit area basis total pollutant loads are significantly higher for commercial areas because of the higher degree of imperviousness typical of such areas. For broad urban areas, however, the relatively small fraction of land with this use considerably mitigates such an effect.

Finally, the annual loads shown by Table 6-25 have been computed on the basis of a 40 inch annual rainfall volume. For urban areas in regions with higher

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TABLE 6-25. ANNUAL URBAN RUNOFF LOADS KG/HA/YEAR

Constituent	Site Mean Con.mg/l	Residential	Commercial	All Urban
Assumed Rv		0.3	0.8	0.35
TSS	180	550	1460	640
BOD	12	36	98	43
COD	82	250	666	292
Total P	0.42	1.3	3.4	1.5
Sol. P	0.15	0.5	1.2	0.5
TKN	1.90	5.8	15.4	6.6
NO_{2+3}-N	0.86	2.6	7.0	3.6
Tot. Cu	0.043	0.13	0.35	0.15
Tot. Pb	0.182	0.55	1.48	0.65
Tot. Zn	0.202	0.62	1.64	0.72

NOTE. Assumes 40 inches/year rainfall as a long-term average.

or lower rainfall, these load estimates must be adjusted. The results presented earlier suggest that pollutant concentrations are not sensitive to runoff volume; however, total loads (the product of concentration and volume) are strongly influenced by the volume of runoff. For estimates using equivalent site conditions (Rv), loads for areas with other rainfall amounts are obtained by factoring by the ratio of local rainfall volume to the 40 inch volume used for the table. Planners who believe that the average annual runoff coefficients in their local areas are substantially different from those used in the table can make similar adjustments.

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CHAPTER 7
RECEIVING WATER QUALITY EFFECTS OF URBAN RUNOFF

INTRODUCTION

The effects of urban runoff on receiving water quality are very site specific. They depend on the type, size, and hydrology of the water body, the designated beneficial use and the pollutants which affect that use, the urban runoff (URO) quality characteristics, and the amounts of URO dictated by local rainfall patterns and land use.

A number of the NURP projects examined receiving water impacts in some detail, others less rigorously. Because of the uniqueness of URO water quality impacts, individual project results are considered best used for confirmation and support, rather than as a basis for broad generalizations.

Accordingly, this chapter is structured to address each of the principal categories of receiving water bodies separately; streams and rivers, lakes, estuaries and embayments, and groundwater aquifers. Some can be addressed more thoroughly than others at this time. The approach taken to develop a general, national scale screening assessment of the significance of URO pollutant discharges is to compute anticipated effects using analysis methodologies identified in Chapter 5, where these are appropriate and to compare anticipated effects indicated by such generalizations to specific experiences and conclusions drawn by relevant individual NURP projects.

As with any generalization, there will be exceptions. Specific local situations can be expected which are either more or less favorable than the general case. The results presented herein should therefore be interpreted as representative estimates of a substantial percentage of urban runoff sites, but not all of them.

Receiving waters have distinctive general characteristics which depend on the water body type (e.g., stream, lake, estuary) and relatively unique individual characteristics which depend on geometry and hydrology. Given a minimum acceptable amount of data on water bodies and their setting, it appears possible to make useful generalizations regarding the quantitative effects of urban runoff on concentrations of various pollutants in the receiving waters and to draw inferences concerning the influence urban runoff may have on the beneficial uses of the water bodies. However extending the results of such an analysis to an assessment of the prevalence of urban runoff induced "problems" on a national scale cannot be accomplished in a way would provide an acceptable level of confidence in any conclusions drawn therefrom. In addition to the importance of local hydrology, meteorology, and urban characteristics, the emphasis placed on each of the three elements that influence problem definition;

(1) Denial or serious impairment of beneficial use;

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(2) Violation of ambient water quality standards; and

(3) Local perception;

will result in a high degree of site-specificity to the determination of the existence of a problem.

RIVERS AND STREAMS

General

Flowing streams carry pollutant discharges downstream with the stream flow. For intermittent stormwater discharges, a specific stream location and the biota associated with it are exposed to a sequence of discrete pulses contaminated by the pollutants which enter with urban runoff. Because of the inherent variability of urban runoff (URO), the average concentrations in such pulses vary, as do their duration and the interval between successive pulses. Table 7-1 summarizes average values for storm duration and intervals between storm events for selected locations in the U.S., based on analysis of long term rainfall records using a methodology (SYNOP) presented in an earlier NURP document (the NURP Data Management Procedures Manual). The information presented provides a sense of the temporal aspects of such intermittent pulses and, by inference, the intermittent exposure patterns to which stream biota are subjected. For many locations, storm pulses are produced for about six hours every three days or more, on average.

A probabalistic methodology has been used to examine the concentration characteristics of the storm pulses produced in streams, given the variability of the relevant processes which are directly involved. Stream flow rates, runoff flow rates, and concentrations vary and result in variable stream concentrations. For streams, it is not the runoff volume per se that is important. The combination of stream and runoff flow rates (together with runoff concentration) determine the pollutant concentration in the stream pulse. The duration of the runoff event and the stream velocity dictate the spatial extent of the storm pulse in the stream. The analysis presented in this section addresses the frequency and magnitude of pollutant concentrations in the instream storm pulses which are produced.

Runoff and Stream Flow Rates

The local combination of stream and runoff flow rates for an urban location are, as indicated, important determinants of the stream concentrations which will result. For long-range projections, the most appropriate data sources for characterizing these parameters are long-term stream flow gauging records (USGS) and long-term rainfall records (USWS).

Figure 7-1(a) illustrates the regional variation of average daily stream flows expressed as cfs/sq mile of drainage area, based on long-term (50 years or more) gauging records at over 1000 stations. Figure 7-1(b) presents a somewhat simplified regional pattern for average rainfall intensity. The data base for this plot is considerably smaller, consisting of rainfall records (usually 10 to 30 years of record) for approximately 40 cities. Localized peturbations exist, but are smoothed out by contours presented.

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TABLE 7-1. AVERAGE STORM AND TIME BETWEEN STORMS FOR SELECTED LOCATIONS IN THE UNITED STATES

Location	Average Annual Values in Hours	
	Storm Duration	Time Between Storm Midpoints
Atlanta, GA	8.0	94
Birmingham, AL	7.2	85
Boston, MA	6.1	68
Caribou, ME	5.8	55
Champaign-Urbana, IL	6.1	80
Chicago, IL	5.7	72
Columbia, SC	4.5	68
Davenport, IA	6.6	98
Detroit, MI	4.4	57
Gainesville, FL	7.6	106
Greensboro, SC	5.0	70
Kingston, NY	7.0	80
Louisville, KY	6.7	76
Memphis, TN	6.9	89
Mineola, NY	5.8	89
Minneapolis, MN	6.0	87
New Orleans, LA	6.9	89
New York City, NY	6.7	77
Steubenville, OH	7.0	79
Tampa, FL	3.6	93
Toledo, OH	5.0	62
Washington, DC	5.9	80
Zanesville, OH	6.1	77
Mean	6.1	81
Denver, CO	9.1	144
Oakland, CA	4.3	320
Phoenix, AZ	3.2	286
Rapid City, SD	8.0	127
Salt Lake City, UT	7.8	133
Mean	6.5	202
Portland, OR	15.5	83
Seattle, WA	21.5	101
Mean	18.5	92

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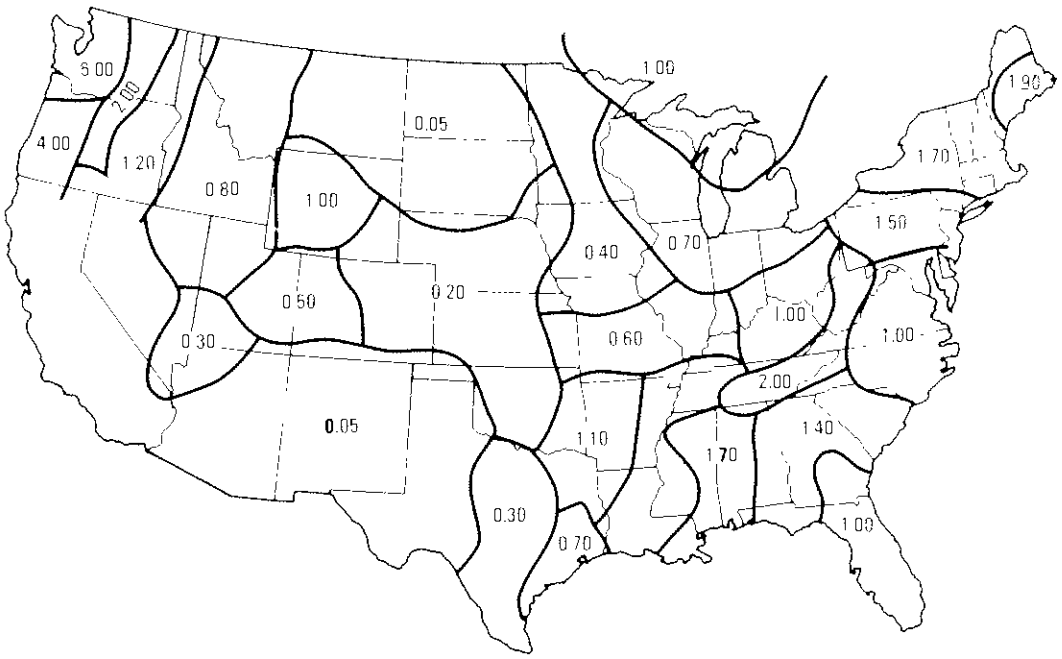

Figure 7-1(a). Regional Value of Average Annual Streamflow (cfs/sq mi)

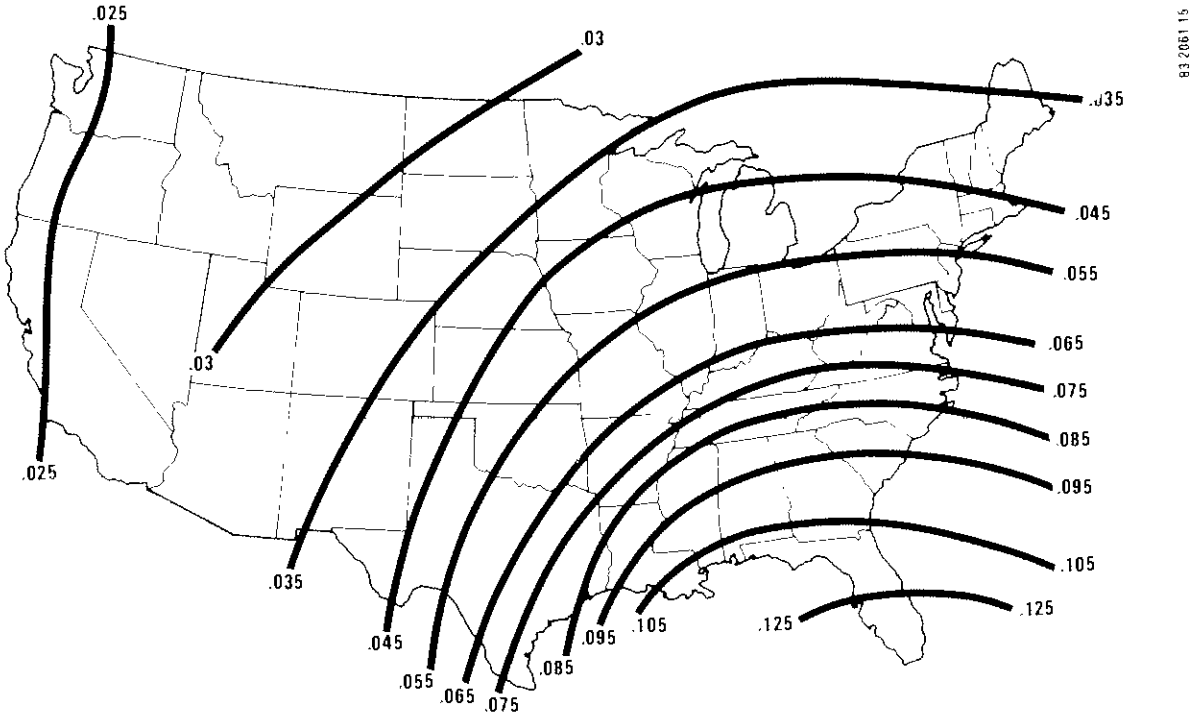

Figure 7-1(b). Regional Value of Average Storm Event Intensity (inch/hr)

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Variability of daily stream flows was determined for a smaller sample (about 150 sites) of the stream sites. Variability of storm event average intensities was determined for all of the rain gauge locations in the current data base. These results are summarized in Table 7-2.

Total Hardness of Receiving Streams

Where the beneficial use of principal concern is the protection of aquatic life, the URO pollutants of major concern appear to be heavy metals, particularly copper, lead and zinc. The potential toxicity of these pollutants are strongly influenced by total hardness, as indicated by Table 5-1 in Chapter 5. Other beneficial uses deal with pollutants and effects that are not influenced by total hardness or (as with drinking water supplies) do not modify the assigned significance of heavy metal concentrations on the basis of total hardness.

As with stream flow and precipitation, distinct regional patterns also exist for receiving water total hardness concentrations. Figure 7-2 delineates the national pattern of regional differences. These patterns impose an additional regional influence on the potential of urban runoff to create problem conditions in streams and rivers.

Technical Approach To Screening Analysis

The magnitude and frequency of occurrence of intermittent stream concentrations of pollutants of interest, that result from urban runoff, has been computed using the probabilistic methodology discussed in Chapter 5.

The input data required for application of the methodology includes representative values for the mean and variability of stream flow, runoff flow, and runoff pollutant concentrations. The material presented earlier in this chapter provides the basis for assigning values for the flows; the results summarized in Chapter 6 provide the basis for specifying pollutant concentration inputs. In order to translate the probability distribution of stream concentrations (which is the basic output of the analysis methodology) to an average recurrence interval, which is considered to provide a more understandable basis for comparisons, the average number of storms per year is also required. This is estimated directly from the average interval between storm midpoints generated by the statistical analysis of hourly rainfall records.

For a general screening on a national scale, an estimate of typical values for a selected geographic location must be made. This has been done, and the set of input values considered to be typical of geographical location are described and summarized below. The values used should be considered reasonably representative of the majority of sites in the area, but it should be recognized that not all potential sites will have conditions either as favorable or unfavorable as those listed.

We have worked with a limited sample in assigning typical values. A greater data base on rainfall and stream flow would permit greater spatial definition

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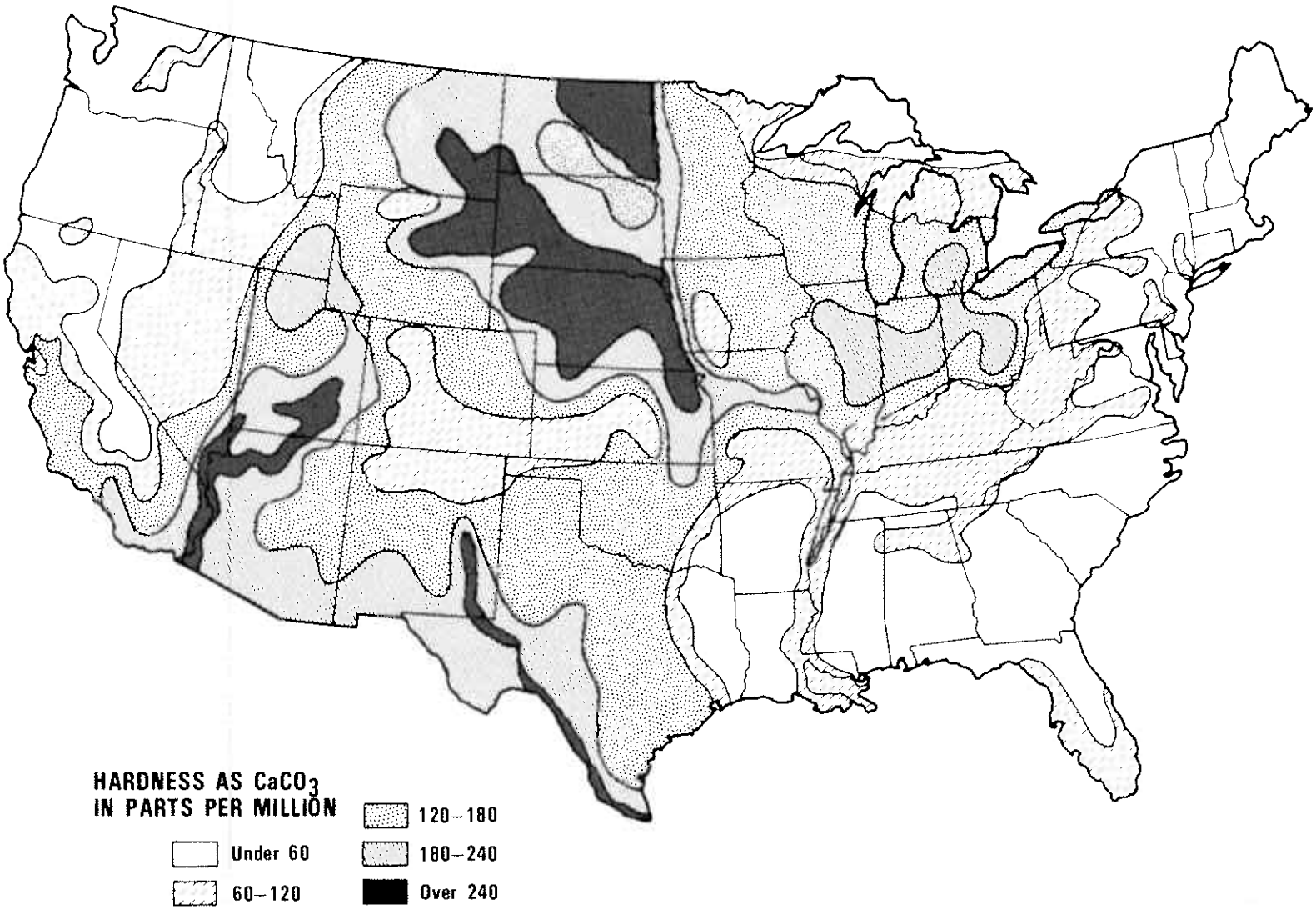

Figure 7-2. Regional Values for Surface Water Hardness

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than shown in the results. Specific regions or states could, with development of a more detailed spatial definition of stream flows and rainfall, extend the analysis presented to provide a considerably more comprehensive assessment of problem potential for local areas. This would involve the development of input parameters (rainfall and streamflow) readily derived from available long term USGS stream flow records and USWS rainfall records and their use in the methodology with quality parameters based either on the NURP analysis presented in Chapter 6, or on local monitoring activities.

The analysis methodology presently available permits computation of the probability distribution of instream concentrations, incorporating the effect of upstream (background) concentrations of the pollutant of interest. The results presented here assume upstream concentrations of zero, principally because of our inability at present to make reliable estimates of typical values for the magnitude and variability for pollutants of interest, especially on the broad national scale being examined. As a result, the summaries will show the effects of urban runoff contributions only. In cases where the background is small relative to the URO contribution, the summaries will represent actual conditions quite closely. However, where background is high and has appreciable variability, the implications of the URO contribution will be overstated, particularly the inferred improvement which could result from control of URO.

In order to perform a national screening of regional influences on urban runoff impacts, eight geographical regions illustrated by Figure 7-3 have been delineated. Using the information summarized by Figures 7-1 and 7-2, typical values for the pertinent rainfall/runoff and stream parameters have been assigned for each of the regions. Table 7-2 summarizes the values for these parameters which are used in the screening analysis.

TABLE 7-2. TYPICAL REGIONAL VALUES

Area	Event Average Rainfall Intensity		Average Number of Events/year	Average Runoff Flow Rate		Stream Flow Rate (Daily Avg Flows)		Stream Total Hardness (mg/l)
	Mean (in/hr)	c.v.		Mean Event (cfs/sq mi)	c.v.	Mean (cfs/sq mi)	c.v.	
1	0.04	1.00	110	5	0.85	1.75	1.25	50
2	0.10	1.35	100	12	1.15	1.25	1.25	50
3	0.08	1.35	90	10	1.15	1.00	1.25	50
4	0.055	1.25	110	7	1.05	0.75	1.25	200
5	0.04	1.10	63	5	0.95	0.35	1.25	200
6	0.03	1.10	70	4	0.95	0.05	1.25	300
7	0.045	1.20	30	5	1.00	0.05	1.25	200
8	0.025	0.85	80	3	0.75	4.50	1.25	50

Average stream flow and rainfall intensity were taken from the plots, which are based on sources previously described. The estimate for variability of daily stream flows (coefficient of variation) is based on computed values for a sample of about 150 perennial streams. Results for a number of regional

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Figure 7-3. Geographic Regions Selected for Screening Analysis

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groupings indicated median values for coefficient of variation to fall between approximately 1 and 1.5. Since there were no clear regional patterns apparent, a uniform value for coefficient of variation of stream flows of 1.25 was assigned.

The coefficient of variation of rainfall intensities was taken directly from the statistical analysis of the rainfall records examined. This was reduced by 15 percent to provide estimates of the coefficient of variation of runoff flow rates, based on a recent published report, "Comparison of Basin Performance Modeling Techniques", Goforth, Heaney and Huber, ASCE JEED, November 1983, using the SWMM model on a long-term rainfall record.

The quality characteristics of urban runoff used in the screening analysis are listed in Table 7-3, and are based on the results summarized in Chapter 6. The analysis results have been rounded in the selection of representative site median EMCs and are interpreted as being representative of an array of urban sites discharging into the receiving stream being analyzed.

Average site conditions are based on the 50th percentile of all urban sites. Since the data analysis indicated that sites at some locations tend to cluster at either the higher or lower ends of the range for all sites, high range and low range site conditions were also selected for use in the screening analysis. High range site conditions are nominally based on the 90th percentile of all site median concentrations; the low range on the 10th percentile site. The variability of EMCs from storm to storm at any site is based on the median of the coefficients of variation of EMCs at sites monitored by NURP. This value was used for the low range and average site condition and was increased nominally for the high range site condition.

TABLE 7-3. URBAN RUNOFF QUALITY CHARACTERISTICS
USED IN STREAM IMPACT ANALYSIS
(Concentrations in µg/l)

	COPPER		LEAD		ZINC	
	Site Median EMC	Coef Var	Site Median EMC	Coef Var	Site Median EMC	Coef Var
Low Range of Site Conditions	15	0.6	50	0.75	75	0.7
Average Site Conditions	35	0.6	135	0.75	165	0.7
High Range of Site Conditions	90	0.7	350	0.85	450	0.8

An illustrative example of a site-specific application of the probabilistic analysis methodology employed is presented in order to:

1. Illustrate the nature of the computational results produced;

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2. Assist in the interpretation of the tabulations presented later which summarize results of the national scale screening analysis;

3. Indicate how magnitude/frequency of instream concentrations may be interpreted for inferences concerning the absence or presence of a "problem" and where a problem is concluded to exist, its degree of severity; and

4. Demonstrate how alternative URO control options may be evaluated in terms of their expected impact on water quality and potential effect on problem severity.

From selected representative values for mean and variability of stream and runoff conditions, the probability distribution of resulting instream concentrations during storm events can be computed. Figure 7-4 illustrates a plot of such an output. Uncertainty in estimates for specific inputs can be accommodated by sensitivity analyses which incorporate upper and lower bounds for specific parameter values. Results are then presented as a band rather than a specific projection. The probabilities which are the basic output of the analysis may be converted to average recurrence intervals to provide what is believed to be a more understandable basis for interpreting and evaluating results.

Figure 7-5 presents results converted to the average recurrence interval at which specific stream concentrations will be produced during storm runoff periods.

The significance of a particular magnitude/frequency pattern of stream concentrations caused by urban runoff can be evaluated by comparing them with concentrations which are significant for the beneficial use of the water body. In the example presented, we have excluded comparisons with drinking water criteria on the basis that urban streams are not generally used as domestic water sources, and in any event, the criteria relate to finished water, and surface water supplies almost invariably receive treatment.

Protection of aquatic life is selected for the screening analysis of the impact of urban runoff because it is believed to be the predominant potential beneficial use for urban streams on a national scale. The concentrations which result from urban runoff are compared with stream target concentrations associated with different degrees of adverse impact, as discussed and tabulated in Chapter 5.

In the site specific situation illustrated, the stream concentrations of copper caused by untreated urban runoff discharges exceed the "EPA Maximum" criterion more than ten times per year on average. The concentration level suggested by the NURP analysis to be the Threshold level of adverse biological impacts is exceeded an average of five times per year (recurrence interval 0.2 year), and significant mortality of more sensitive biological species occurs about once every three years on average. Although this stress level may not be great enough to result in a total denial of the use, there are many who would argue that it represents an unacceptably severe degree of impairment of this beneficial use.

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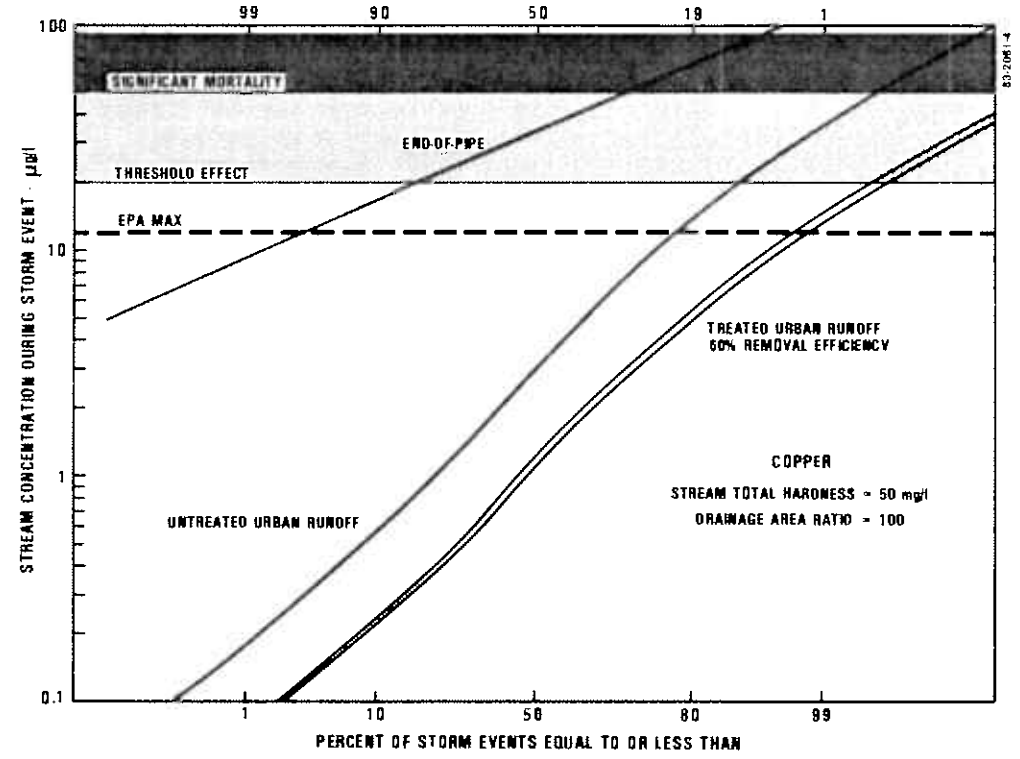

Figure 7-4. Probability Distributions of Pollutant Concentrations During Storm Runoff Periods

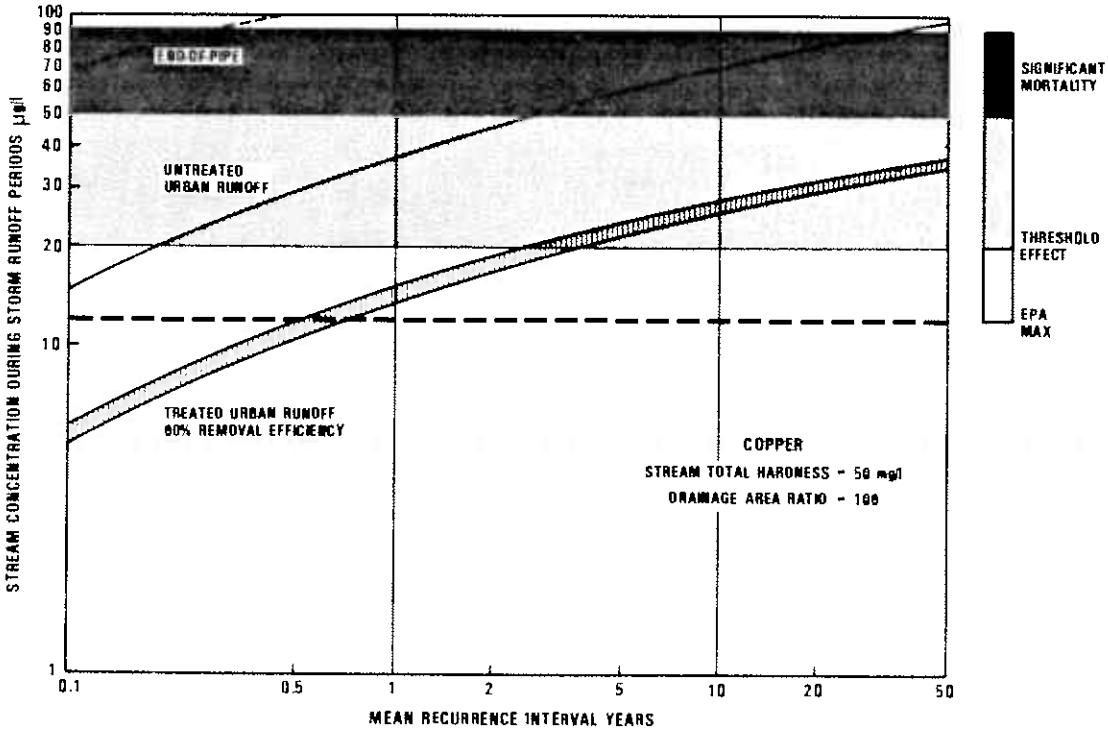

Figure 7-5. Recurrence Intervals for Pollutant Concentrations

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The projection labeled "treated urban runoff" may be taken to represent the in-stream result for either the originally considered discharge following the application of controls which effect a 60 percent reduction, or of an uncontrolled urban runoff site with lower levels of copper in the runoff. In this case, threshold levels are reached only once every 3 or 4 years on average, and significant mortality levels are virtually never reached. Even though the ambient "EPA MAX" criterion is exceeded once or twice a year on average, one might conclude that the implied degree of stress is tolerable and is not interpreted to represent a significant degree of impairment of the use.

The Threshold and Significant Mortality levels are estimates, which have been explained earlier. In addition, the "acceptable" frequency at which specific adverse effects can be tolerated is subjective at this time, since there are no formal guidelines. However, an approach of this nature must be taken in any evaluation of the significance of urban runoff and the importance of applying control measures. There are two reasons why this is necessary. First, because of the stochastic nature of the system we are dealing with, virtually any target concentration we elect to specify will be exceeded at some frequency, however rare. Secondly, from a practical point of view, there are limits to the capabilities of controls, however rigorously applied. In the illustration presented, the untreated urban runoff site assigned urban runoff copper concentrations equivalent to the average urban site. Since NURP analysis data indicate that the copper in urban runoff has a soluble fraction of about 40 percent, the level of removal used in the example reflects a control efficiency approaching the practical limit. Receiving water impacts are significantly reduced, but not totally eliminated.

Results of Screening Analysis

A projection of stream water quality responses has been made for each of the eight geographical areas shown by Figure 7-3. The rainfall, runoff, and stream flow estimates used in the computations are those summarized in Table 7-2. The urban runoff quality characteristics used are those presented in Table 7-3.

To consolidate screening analysis results for easier comparison, results are not presented as continuous concentration/frequency curves as used in the illustrative example presented above. Instead, the comparison plots which follow show only the recurrence interval at which specified biological effects levels are exceeded. The concentrations which correspond with these effects are strongly influenced by stream total hardness, and hence vary regionally. Table 7-4, based on information presented in Chapter 5, summarizes the stream target concentrations used in the screening analysis summary.

Analysis results are presented for Copper (Figure 7-6), Lead (Figure 7-7) and Zinc (Figure 7-8). Each individual bar represents a different geographical region, and the analysis is performed for two drainage area ratios. Since regional stream flow differences are based on unit flows (cfs/sq mile of drainage area), actual flow in a receiving stream at a particular location is

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TABLE 7-4. REGIONAL DIFFERENCES IN TOXIC CONCENTRATION LEVELS
(Concentrations in µg/l)

Pollutant	Stream Total Hardness µg/l	Geo-graphic Regions	EPA MAX	Suggested Values For		
				Threshold Effects[1]	Significant Mortality[2] (a)	(b)
Copper	50	1,2,3,8	12	20	50	90
	200	4,5,7	42	80	180	350
	300	6	62	115	265	500
Lead	50	1,2,3,8	74	150	350	3200
	200	4,5,7	400	850	1950	17,850
	300	6	660	1400	3100	29,000
Zinc	50	1,2,3,8	180	380	870	3200
	200	4,5,7	570	1200	2750	8000
	300	6	800	1700	3850	11,000

[1] Threshold Effects - mortality of the most sensitive individual of the most sensitive species.

[2] Significant Mortality

Level (a) - mortality of 50 percent of the most sensitive species.

Level (b) - mortality of the most sensitive individual of 25th percentile sensitive species.

a function of both the unit flow rate and the size of the contributing drainage area. The "drainage area ratio" (DAR) used in the analysis is

$$DAR = \frac{\text{Urban Area Contributing Runoff}}{\text{Stream Drainage Area Upstream of Urban Input}}$$

It is a measure of the location of the urban area relative to the headwaters of the receiving stream.

The shading scheme used on the bars duplicates that used earlier in the illustrative example (Figure 7-5), and identifies the recurrence interval for each of the target concentrations. For example, instream copper concentrations during storm runoff periods in geographic region 1, with average site conditions for copper concentrations in urban runoff, and a DAR = 10, are projected to be as follows (middle plot, Figure 7-6).

- EPA MAX - ambient criterion is exceeded at a frequency of 0.02 year (= 50 times/year) or about every other storm event on average.

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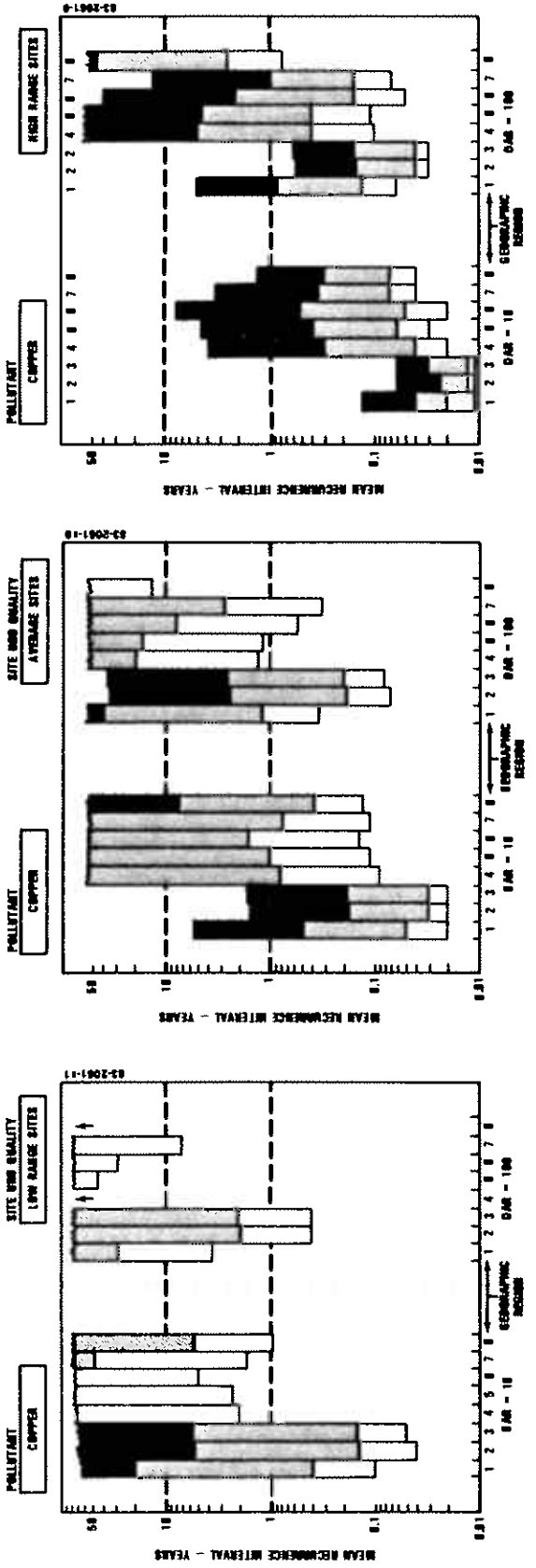

Figure 7-6. Exceedance Frequency for Stream Target Concentration
COPPER

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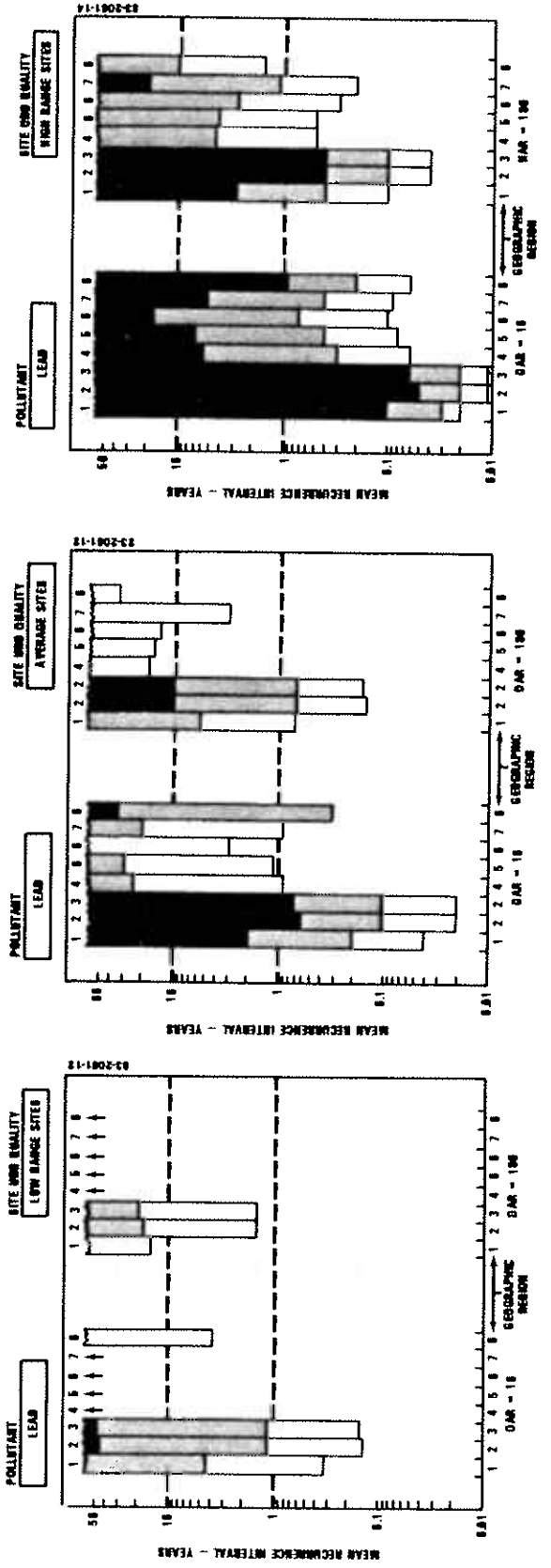

Figure 7-7. Exceedance Frequency for Stream Target Concentration
LEAD

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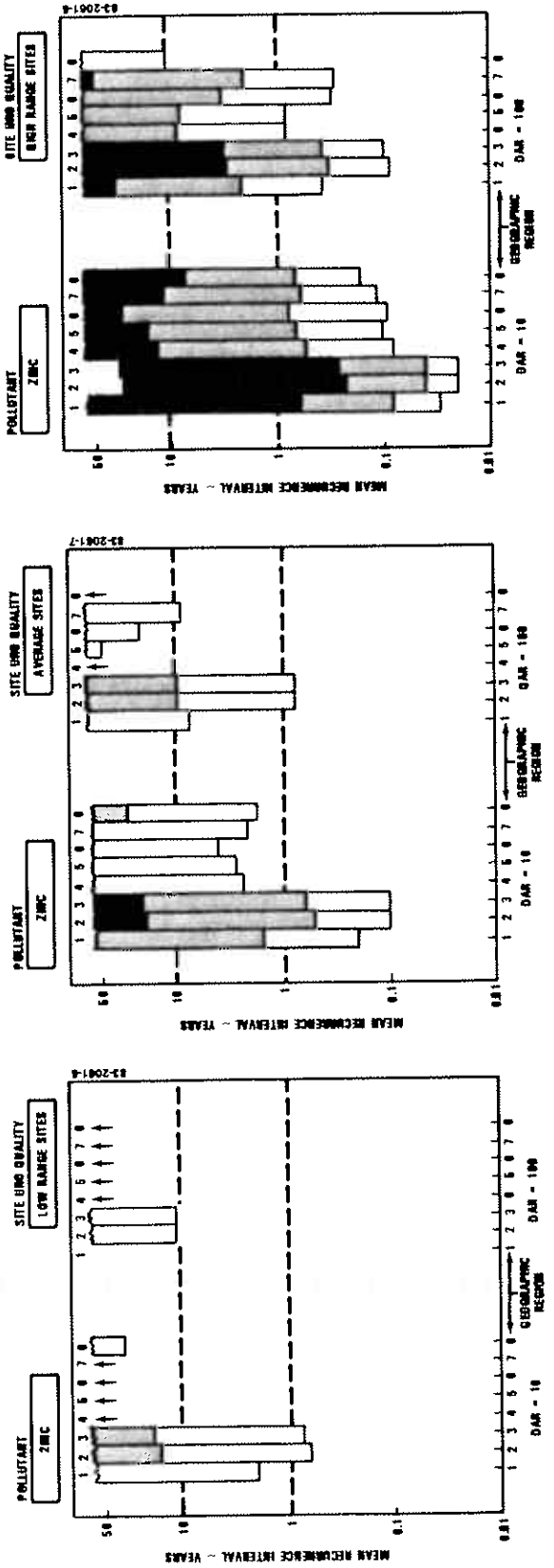

Figure 7-8. Exceedance Frequency for Stream Target Concentration
ZINC

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- Threshold concentration levels at which adverse biological stress for short duration exposures is projected to occur have a recurrence interval of about 0.05 years (20 times/year).

- Significant mortality levels are exceeded at intervals of about 0.5 year (twice/year) for the less severe effect, to about once in 5.5 year for the more severe impact specified.

The plot is terminated at an upper level for recurrence interval of 50 years. Although the analysis procedure computes specific recurrence intervals in excess of this value, a realistic interpretation suggests that such conditions are for practical purposes quite unlikely to ever be reached or exceeded. At computed recurrence intervals of about 10 years or more estimates are not considered to be reliable and are very probably conservative. Therefore, indicated mean recurrence intervals in excess of 10 years probably (and 50 years certainly) should be interpreted as "unlikely" or "highly unlikely".

Discussion

An inspection of the screening analysis results (Figures 7-6 through 7-8) indicates the reason why it is unrealistic to attempt a broad generalization on whether urban runoff is, or is not a "problem" in rivers and streams. Water quality impacts can vary widely, depending on regional rainfall and stream hydrology, urban site quality characteristics, drainage area ratio (reflecting the size of the receiving stream relative to the urban area), and the total hardness of the receiving stream. While the screening analysis results provide an informative and useful perspective on the issue, it should be recognized that any specific site may differ considerably from the typical conditions used to characterize rainfall and stream flow for the area, and further, that local variations in runoff quality characteristics within the range defined by the NURP data can also have significant influence. The dominant indication of the analysis is that the problem potential for urban runoff is highly site-specific. Nevertheless some useful generalizations can be made.

Perhaps the major factor which dictates whether urban runoff discharges of copper, lead, or zinc will adversely impact aquatic life is the natural hardness of the receiving streams. As a result, the southeast and gulf coast areas are consistently indicated to be more sensitive than other areas of the country. Of the remaining soft water areas, the northeast is somewhat less sensitive; the Pacific northwest markedly less. This is attributed to significantly lower storm intensities in these areas, coupled in the northwest with appreciably higher stream flows.

Drainage area ratios have an important effect, reflecting as they do the magnitude of stream flow at the urban location. The effect is much greater for geographical regions with high unit flow (cfs/sq mile) than for lower stream flow regions.

Finally, the quality characteristics of the urban sites have a significant influence. Stream concentrations differ markedly depending on whether the local urban sites tend to cluster toward the lower or higher end of the range of site median concentrations indicated by the NURP data base.

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A comparison of the relative position of the bars on Figures 7-6, 7-7 and 7-8, is sufficient to indicate the comparative sensitivity to urban runoff pollutant discharges. However, it is also desirable to decide whether a given stream effect constitutes a serious degree of impairment of an aquatic life beneficial use. There are no formal guidelines, and interpretations that are either more liberal or more restrictive than those suggested below may be preferred by others dealing with specific stream segments. For the interpretation of the national scale screening analysis, the following decision basis has been used to identify the situations in which urban runoff is likely to result in a water use "problem", (i.e., cause an unacceptable degree of use impairment):

- Threshold effects - (mortality of the most sensitive individual of the most sensitive species) occur more often than about once a year on average.

- Significant mortality - using the lower of the two levels (i.e., 50 percent mortality of the most sensitive species), occurs more often than about once every 10 years on average.

Using these guidelines for assessing the occurrence of problem situations, copper is shown to be the most significant of the three heavy metals consistently found in urban runoff at elevated concentration levels. Where site concentrations are at the high range of observed urban site conditions, problems are expected in all geographic regions at a DAR = 10, and in all geographic regions except region 8 at DARs as high as 100. When site concentrations are in the average range of observed conditions, problem situations are restricted to geographic regions 2 and 3 (plus region 1 at DAR = 10). When site copper concentrations are in the lower range of observed site conditions, problem situations are restricted to geographic regions 2 and 3 at low DARs. They are marginal (significant mortality once every 5 years) but remain a problem according to the definition adopted. The "marginal" attribution is used here, because the more severe degree of significant mortality (most sensitive individual of 25th percentile sensitive species) is indicated by the analysis virtually never to occur.

Thus, copper discharges in urban runoff are indicated to represent a significant threat to aquatic life use in regions 2 and 3 (southeast and Gulf Coast) under almost all possibilities for urban site runoff quality. In region 1 (northeast), problems would be expected at all but the lower range of site concentrations. In the hard water areas (regions 4, 5, 6, 7) problems are expected only where site runoff quality is in the high end of the range of observed site median concentrations.

It should be noted that the analysis has been based on <u>total</u> copper concentrations in urban runoff. Toxic effects are usually considered to be exerted by the soluble form of the metal, and EPA defines an "active" fraction based on a mild digestion which converts some of the inactive particulates to soluble forms, to account for transformations which may occur in the natural water systems. Copper in urban runoff has a typical soluble fraction of about 50 percent, and the active fraction would therefore fall somewhere between 50 and 100 percent of the total concentration used in the analysis. The analysis has been performed using the total fraction, since adequate

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information is not available at present to reliably adjust these values. However, although the problem assessment presented above may be somewhat conservative, further refinement along these lines would not change the inferences drawn from the screening analysis results.

Zinc, like copper, has an indicated soluble fraction in the order of 50 percent, and the screening analysis indications will also be unaffected by this consideration. It is indicated to be unlikely to pose a significant threat to aquatic life in most urban runoff situations. Exceptions are restricted to soft water areas in the east and south, lower DARs, and sites with high zinc concentrations in urban runoff.

Lead results must be viewed with greater caution, because soluble fractions in urban runoff are indicated to be quite low (less than 10 percent). Problem indications are therefore likely to be reasonably conservative, i.e., overstate the problem potential. Problem situations may be expected to be restricted to soft water areas in the east and Gulf areas when urban sites have average site concentrations and DARs are low, and even at high DARs when site concentrations are in the high range. Lead is not indicated to be a threat to aquatic life in the hard water areas of the country or in the Pacific northwest, except for the combination of low DAR and high site concentration.

In performing the screening analysis, upstream concentrations were assumed to be zero; that is, the receiving stream had only a diluting effect on the urban runoff pollution. In actual cases background concentrations will be greater than zero, and in some instances upstream contributions (e.g., agricultural runoff, another city) could be significant and result in more severe conditions than those identified in the screening analysis.

On the basis of the foregoing, it appears appropriate to identify copper as the key toxic pollutant in urban runoff, for the following reasons:

- Problem situations anticipated for lead and zinc do not occur under any conditions for which copper does not show up as a problem as well - and with more severe impacts. On the other hand, copper is indicated to be a problem in situations where lead or zinc are not.

- Based on the ratios between concentrations producing increasingly severe effects, copper is suggested to be a more generic toxicant. It has an effect on a broad range of species. This is in contrast to lead and zinc for which a substantially greater degree of species selectivity is indicated. Some species are sensitive, others relatively insensitive to lead and zinc.

- From the NURP data, locations which tend to have site median concentrations in the low, average, or high end of the range have generally consistent patterns for each of the three heavy metals.

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- Control measures which produce reductions in copper discharges to receiving waters could be expected to result in equivalent reductions in zinc, and greater reductions in lead, by virtue of its significantly greater particulate fraction.

Copper is accordingly suggested to be an effective indicator for all heavy metals in urban runoff relative to aquatic life. It might be used as the focus for control evaluations, site specific bioassays, monitoring activities, and the like.

It should be noted that while immediate water column impacts of lead are not as significant as those for copper, the high particulate fraction of lead would tend to result in greater accumulations in the stream bed. This aspect has not been addressed by the NURP program in sufficient detail to warrant any comment on its potential significance.

The results of the screening analysis summarized by Figures 7-6 through 7-8 are approximate, because they are influenced by the suitability of the typical values for stream and runoff flows which were assigned. This however can be refined by the use of appropriate values which can be developed from readily available data bases, and thus adjusted for local variations which are to be expected. A second issue relative to the reliability of the projections is the validity of the computations, given that the input parameters are representative. This has been confirmed by a number of validation tests, discussed in the NURP supporting document referenced earlier, which addresses the stream analysis methodology.

The remaining issue for evaluating the reliability of the indications of problem potential produced by the screening analysis is the reasonableness of the intermittent exposure concentration levels, which have been associated with various biological effects levels, and the guidelines adopted for this discussion, which determine whether or not a problem is expected. While rather tenuous at this time, the information available does provide support.

Two of the NURP projects examined aquatic life effects in streams receiving runoff from monitored sites.

- Bellevue, WA concluded that whatever adverse effects were observed were attributable to habitat impacts (stream bed scour and deposition) as opposed to chemical toxicity. For this project, heavy metal concentrations in the monitored urban runoff sites were typical of the average for all urban sites. The screening analysis results under these conditions do not indicate the expectation of a problem.

- Tampa, FL conducted extensive bioassay tests but failed to show any adverse effect of water column concentrations of pollutants in urban runoff. The screening analysis results presented in Figure 7-6 indicate marginal problem conditions at low DAR for this geographic region. At this project however, all monitored sites show heavy metal concentrations significantly lower than the low range conditions used in the screening analysis. When

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the screening analysis is repeated using site concentrations representative of Tampa monitoring results, a problem situation is not predicted, even at DARs lower than is probably the case for this location.

LAKES

Because lakes provide extended residence times for pollutants, the significant time scale for evaluating urban runoff impacts is at least seasonal, and usually annual or longer, rather than the storm event scale used for streams. The screening methodology identified in Chapter 5, uses annual nutrient loads to assess the tendency for development of undesirable eutrophication effects.

Figure 7-9 illustrates the effect of urban runoff on average lake phosphorus concentration. The very significant influence of area ratio is evident. The larger the urban area which drains into a lake of a given size, the greater the annual loading, and the higher will be the lake phosphorus concentration and the eutrophication effects produced.

The phosphorus concentrations characteristic of the urban sites surrounding a particular lake are also seen to be significant. The three bands shown reflect the range of possibilities, based on the NURP data. The same basis is used to estimate the phosphorus loads from average urban sites and those at the higher and lower ends of site conditions, as was described for heavy metals in the previous section. In this case, because it is annual mass loads which are of interest, site median concentrations have been converted to site mean values for use in the computations.

Lake phosphorus concentrations are also influenced by the annual runoff volume (annual precipitation and runoff coefficient). The results illustrated are based on an annual rainfall of 30 inches and an overall average runoff coefficient of 0.2. Plotted results may be scaled up or down in proportion to the ratio between local values for these parameters and those used in the illustration.

Finally, the lake morphology and hydrology influence the outcome; specifically depth (H) and residence time (τ). This is reflected by the width of each of the bands, which are based on a range of values for H/τ (1 to 10) estimated to be fairly typical for lakes in urban settings.

If an average lake phosphorus concentration of 20 µg/l is used as a reference concentration to assess the tendency for producing undesirable levels of biostimulation, it is apparent that only lakes with rather small area ratios are likely to be unaffected by urban runoff nutrient discharges. Since the three bands represent different concentration levels of phosphorus in urban runoff, qualitative inferences may be drawn concerning the beneficial use impacts of control activities. More detailed estimates may of course be made by use of the methodology with site specific parameters.

The salient feature of the situation, as generalized by the analysis summarized by Figure 7-9, is that the problem potential of urban runoff for lakes is quite site specific. The illustration considers only urban runoff loads; in an actual situation, all nutrient sources (point and nonpoint)

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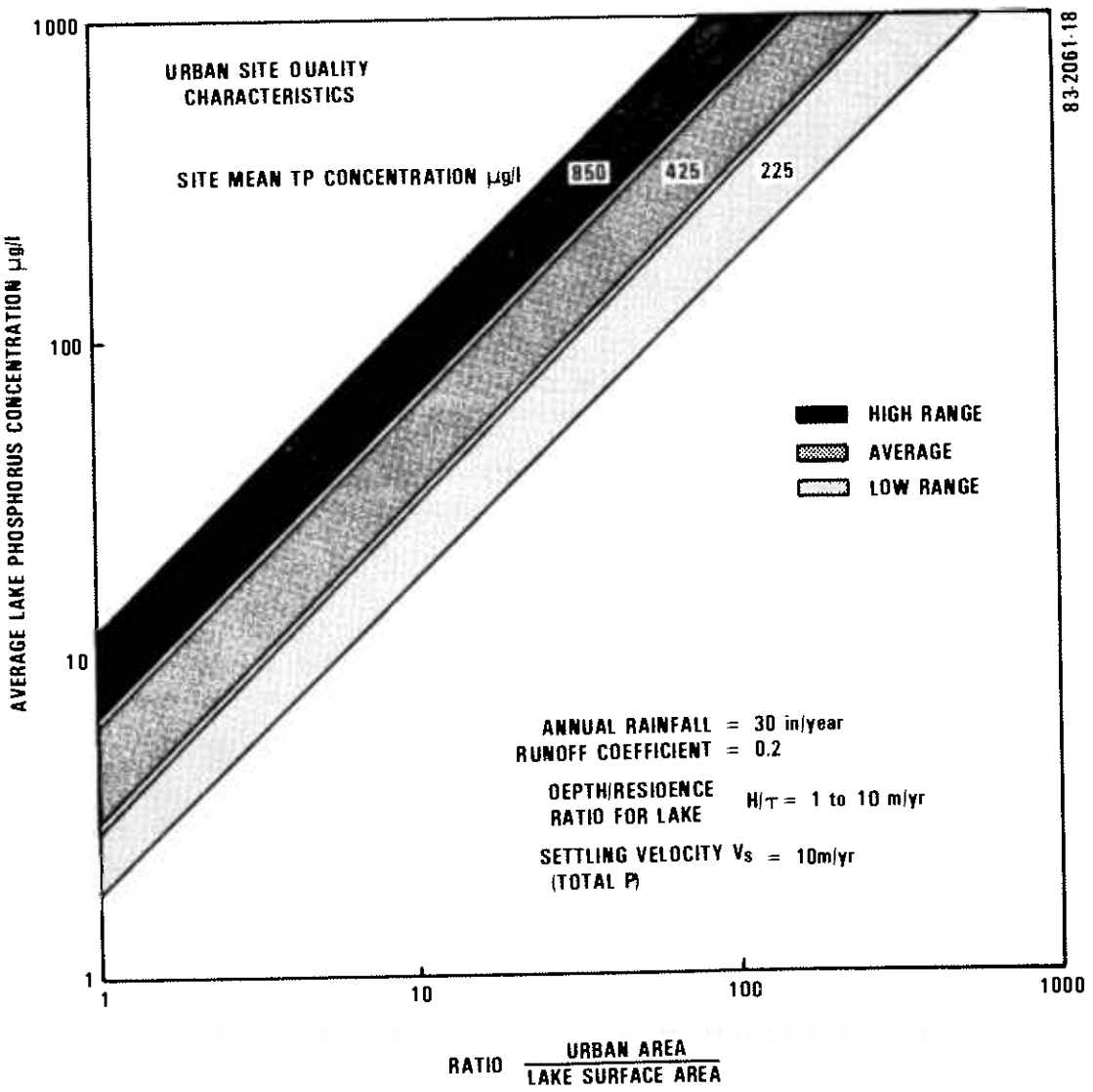

Figure 7-9. Effect of Urban Runoff on Lake Phosphorus Concentrations

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would be considered, and this would tend to modify the relative significance of urban runoff on lake conditions.

Several of the NURP projects addressed impacts on lake quality in some depth. These projects include the following:

- Irondequoit Bay, NY - Lake has been highly eutrophic, due to point and nonpoint discharges. Sewage treatment plant and combined sewer overflow discharges have been removed, so that residual sources are recycle from lake sediments and nonpoint sources, including urban runoff, from the contributing drainage area. Further reductions are considered necessary to meet targets. (Area ratio is high at this location.)

- Lake George, NY - Lake is oligotrophic; the study addressed the concern that urban runoff from present and potential future development would unacceptably accelerate degradation of existing water quality. (Area ratio is low at this location.)

- Lake Quinsigamond, MA - Urban runoff was determined to be one of a number of sources preventing water quality objectives from being met. Some control of urban runoff phosphorus loads was recommended as one of the elements of an overall management plan.

Each of the above situations is sufficiently unique, and the mix of urban runoff and other load sources is sufficiently different to suggest that it is inappropriate to attempt a broad generalization. The interested reader may refer to the individual project documents which are available through NTIS for more information.

ESTUARIES AND EMBAYMENTS

These water bodies are normally of sufficient size and complexity that simple screening analyses have not been considered to be sufficiently useful or effective to justify their use.

The Long Island, NY NURP project examined and confirmed that urban runoff sources of coliform bacteria are the principal contributors to the water column concentrations that result in closure of shellfish beds in a number of embayments (principally the Great South Bay). Estimates of control activities that would allow the opening of presently closed areas were also made. The reader is referred to the project documents for further information.

The significance of urban runoff and other nonpoint source loads on eutrophic levels in the Potomac estuary is being investigated under a study which is not associated with the NURP program. However, among other objectives of the WASHCOG NURP project, estimates of urban nonpoint source loads have been developed to support this study.

Although specific situations where urban runoff is significant have been identified, no general assessment for water bodies of this type can be made at this time.

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GROUNDWATER AQUIFERS

Much of the precipitation which falls on an area either percolates directly into the ground, or does so after relatively short overland flow distances. This condition is essentially uncontrollable and distinctly different from the case where urban runoff from impervious areas is deliberately collected and routed to a recharge device which causes it to percolate to groundwaters.

This type of control approach is a practical and effective technique for reducing pollutant loads which would otherwise reach surface waters as discussed in Chapter 8. The concern addressed here is with the extent to which groundwater aquifers may be contaminated by this practice.

The Long Island, NY and Fresno, CA NURP projects examined this issue through extensive tests utilizing recharge basins ranging from recent installations to others which have been in service in excess of 20 years. A somewhat simplified consolidation of the salient findings of these two projects is presented below. The interested reader is referred to the individual project report documents, available through NTIS, for the important details and qualifications.

- Most pollutants of importance in urban runoff are intercepted during the process of infiltration and quite effectively prevented from reaching the groundwater aquifers underlying recharge basins. The pollutants tested and found to behave in this manner include the heavy metals, an appreciable number of the organic priority pollutants and pesticides, and coliform bacteria.

- Chlorides, which are sometimes present in urban runoff at elevated concentrations due to road deicing practices, are not attenuated during recharge.

- Pollutants accumulate in the upper soil layers. The concentrations found are a function of the length of time a basin has been in service. Effective retention of pollutants takes place with all soil types tested, ranging from clays to sands. The depth of pollutant penetration is affected by soil type; however in no case did contaminant enrichment of soil exceed several meters depth, and highest concentrations were found near the surface.

- The limit of the ability of the soil to retain the pollutants of interest is unknown. Additional study of this aspect is appropriate. However given the long service periods of a number of the recharge basins studied, this does not appear to represent an imminent concern.

- At both of these NURP locations, groundwater surfaces were at least 20 feet, and often appreciably more, below the base of the recharge device. The indicated findings may not be applicable at locations with shallow depths to groundwater.

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- No significant differences in interception/retention of pollutants is apparent for basins with bare versus vegetated recharge surfaces. However vegetation does apparently help to maintain infiltration rates normal for the soil type.

- Surface soil accumulations of priority pollutants in dual purpose installations used for both recharge and recreational use warrants further investigation to determine whether such practice creates unacceptable health risks or requires appropriately designed and conducted maintenance procedures.

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CHAPTER 8
URBAN RUNOFF CONTROLS

INTRODUCTION

This chapter summarizes the information developed by the individual NURP project studies relating to performance characteristics of selected techniques for the control of urban runoff quality. The number of control practices addressed here is considerably smaller than the array of best management practices suggested in prior studies and publications. This is not intended to exclude consideration of other approaches. However, the techniques discussed in this chapter may be taken as an expression of controls considered by the agencies involved to be potentially attractive and practicable at localized planning levels. They represent the practices for which performance data were obtained under the NURP program and which can be analyzed and evaluated in this report.

Most of the NURP projects provide in their project reports a detailed analysis and evaluation of the controls that were studied. These reports are available through NTIS. In addition to this information source, an analysis was performed by EPAs NURP headquarters team, using results available from all project studies. The objective was to provide an overview and a generic description of performance characteristics in a format considered to be useful for planning activities. Thus, in addition to providing a consolidated summary of project results, this chapter presents a summary of the results of applying analysis methodologies developed under the NURP program. Further detail on the former can be obtained by reference to relevant project report documents; a more comprehensive development of the latter is provided in separate NURP documents ("Detention and Recharge Basins for Control of Urban Runoff Quality", and "Street Sweeping for Control or Urban Runoff Quality").

The types of control techniques which received attention (to a greater or lesser degree) in the NURP program can be grouped into four general categories.

- Detention Devices - These include normally dry detention basins typically designed for runoff quantity control, normally wet detention basins, dual purpose basins, over-sized drain pipes, and catchbasins.

- Recharge Devices - These include infiltration pits, trenches, and ponds; open-bottom galleries and catchbasins; and porous pavements.

- Housekeeping Practices - These are principally street sweeping, but also include sidewalk cleaning, litter containers, catchbasin cleaning, etc.

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- Other - These include the so-called "living filter" approaches, grassed swales, wetlands, etc.

DETENTION DEVICES

General

Detention basins proved to be one of the most popular approaches to urban runoff quality control selected at the local level, based on the number of individual projects which elected to study them and the number of detention devices tested in the study. It is perhaps instructive to note that nearly all the detention facilities studied were either already in place, or required only modifications of outlet structures before initiation of the NURP-supported studies. In general, detention devices proved to provide a highly effective approach to control of urban runoff quality, although the design concept has a significant bearing on performance characteristics.

Table 8-1 lists the NURP projects that included detention devices as elements of their study program. Both the number of devices, and the number of storms analyzed vary considerably, as indicated in Table 8-1, depending on project priorities and other relevant activities. As a result, not all of the sites are incorporated in the summary presented below. The Washington Area Council of Governments (WASHCOG) conducted a particularly thorough and comprehensive investigation of control techniques, particularly detention basins. They have prepared several useful and informative analyses of performance results on these devices.

Dry Basins

This is a type of detention basin which is currently in fairly extensive service in various parts of the country. The performance objective of such basins is commonly called "peak shaving", that is, to limit the maximum rate of runoff to some preselected magnitude, usually a maximum pre-development rate. The purpose is to control flooding and erosion potential in areas downstream of new development. Such basins employ a bottom outlet having a hydraulic capacity restricted to the maximum allowable flow. Runoff from smaller storms flows along the bottom of the basin and is discharged without restriction. Flows in excess of design are backed up in the basin temporarily and ponding occurs only during larger storms and for relatively short periods of time. This class of retention basin is thus normally dry.

Performance of such basins, from a pollutant removal aspect, range from insignificant to quite poor. Accordingly, the limited data available are not discussed in this chapter.

Wet Basins

This designation covers detention basins which maintain a permanent pool of water. They may vary considerably in appearance, ranging from natural ponds or small lakes dedicated urban runoff control to enlarged sections in

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TABLE 8-1. DETENTION BASINS MONITORED BY NURP STUDIES

Project	Site	Design Type	No. Events in/out
CO1 Denver	North Ave	Dry Basin	39/21
DC1 Washington, D.C.	Burke	Wet Basin	60/35
	Lakeridge	Dry Basin	49/41
	Stedwick	Dual-Purpose	48/34
	Westleigh	Wet Basin	41/45
IL2 N. Illinois	Lake Ellyn	Wet Basin	29/23
MI1 Lansing	Dryer Farms	Dry Basin	2/8
	Grace St. N*	Wet Basin	23/21
	Grace St. S*	Wet Basin	20/22
	Waverly Hills	Wet Basin	35/30
MI3 Ann Arbor	Pitt-AA	Wet Basin	6/6
	Traver	Wet Basin	5/5
	Swift Run	Wet Basin	5/5
NY1 Long Island	Unqua Pond	Wet Basin	8/8

* These are oversized storm drains installed below street level. Inverts of control sections are below the general grade line, so a permanent pool is maintained.

constructed drainage systems. Runoff from an individual storm displaces all or part of the prior volume, and the residual is retained until the next storm event. This pattern may or may not be modified by natural base inflows during dry weather depending on the local situation.

Detention basins utilizing this design concept have been shown by the NURP studies to be capable of highly effective performance in urban runoff applications, as summarized below. Although performance characteristics of individual basins ranged from poor to excellent, analysis shows these differences to be attributable to the size of the basin relative to the connected urban area and local storm characteristics. Performance data also indicate that in addition to removal of particulate forms or pollutants by sedimentation, some basins exhibit substantial reductions in soluble nutrients (soluble phosphorus, nitrate + nitrite nitrogen). This is attributed to biological processes which are permitted to proceed in the permanent water pool.

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There are a number of ways to characterize detention basin performance. The primary basis selected by NURP for doing so is to define performance efficiency on the basis of the total pollutant mass removed over all storms. This provides a meaningful general measure for comparison, is relevant for water quality effects associated with extended time scales (e.g., nutrient load impacts on lakes), and conforms with the capabilities of the NURP analysis methodology developed to provide a planning-level basis for estimating cost/benefit differences in size or application density of this type control.

Table 8-2 tabulates performance in terms of reduction in pollutant mass loads over all monitored storm events. The analysis methodology developed under the NURP program activities suggests that performance should be expected to improve as the overflow rate (QR/A = mean runoff rate ÷ basin surface area) decreases and as the volume ratio (VB/VR = basin volume ÷ mean runoff volume) increases. The NURP basins used in the analysis are listed in increasing order of expected performance capabilities.

The wide range of relative basin sizes provided by this data base is apparent, and performance is seen to generally correspond with expectations. The poorest performance occurs in a basin with an average overflow rate during the mean storm of about six times the median settling velocity (1.5 ft/hr) of particles in urban runoff. In addition, less than 5 percent of the mean storm runoff volume remains in this basin following the event, to be susceptible to additional removal by quiescent settling during the interval between storms. The basins which exhibit high removal efficiencies, at the other end of the scale, have size relationships which result in the mean storm displacing only about 10 percent of the available volume, and producing overflow rates which are only a small fraction of the median particle settling velocity.

This rationale is described more completely in the supporting NURP document on detention basins identified earlier. The testing of the methodology against the NURP monitoring data is presented, and the basis for the performance projections illustrated below is documented.

Figure 8-1 presents a projection of removal efficiency of urban runoff detention devices as a function of basin size relative to the contributing catchment area and regional differences in typical rainfall patterns. The removal rates apply for TSS, which are all settleable, and must be factored by the particulate/soluble fraction of other pollutants which have significant soluble fractions in urban runoff. It applies for the specific basin average depth and area runoff coefficient indicated (which are fairly typical based on NURP data). However performance relationships could be different than indicated based on relevant local values for the controlling parameters.

An alternate approach for characterizing performance of detention basins concentrates on the variable characteristics of individual storm events and how these are modified by the detention device. A comparison of the mean and coefficient of variation of basin inflow and discharge concentrations provides another measure of performance of an urban runoff detention device.

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TABLE 8-2. OBSERVED PERFORMANCE OF WET DETENTION BASINS
REDUCTION IN PERCENT OVERALL MASS LOAD

Project and Site	No. of Storms	Size Ratios		Average Mass Removals - All Monitored Storms (Percent)									
		QR/A	VB/VR	TSS	BOD	COD	TP	Sol.P	TKN	NO_{2+3}	T.Cu	T.Pb	T.Zn
Lansing Grace St. N.	18	8.75	0.05	(-)	14	(-)	(-)	(-)	(-)	(-)	(-)	9	(-)
Lansing Grace St. S.	18	2.37	0.17	32	3	(-)	12	23	7	1	(-)	26	(-)
Ann Arbor Pitt-AA	6	1.86	0.52	32	21	23	18	(-)	14	7	•	62	13
Ann Arbor Traver	5	0.30	1.16	5	(-)	15	34	56	20	27	•	•	5
Ann Arbor Swift Run	5	0.20	1.02	85	4	2	3	29	19	80	•	82	(-)
Long Island Unqua	8	0.08	3.07	60	(TOC=7)		45	•	(-)	(-)	•	80	•
Washington, D.C. Westleigh	32	0.05	5.31	81	•	35	54	71	27	•	•	•	26
Lansing Waverly Hills	29	0.04	7.57	91	69	69	79	70	60	66	57	95	71
NIPC Lake Ellyn	23	0.10	10.70	84	•	•	34	•	•	•	71	78	71

Notes: (-) Indicates apparent negative removals.

• Indicates pollutant was not monitored.

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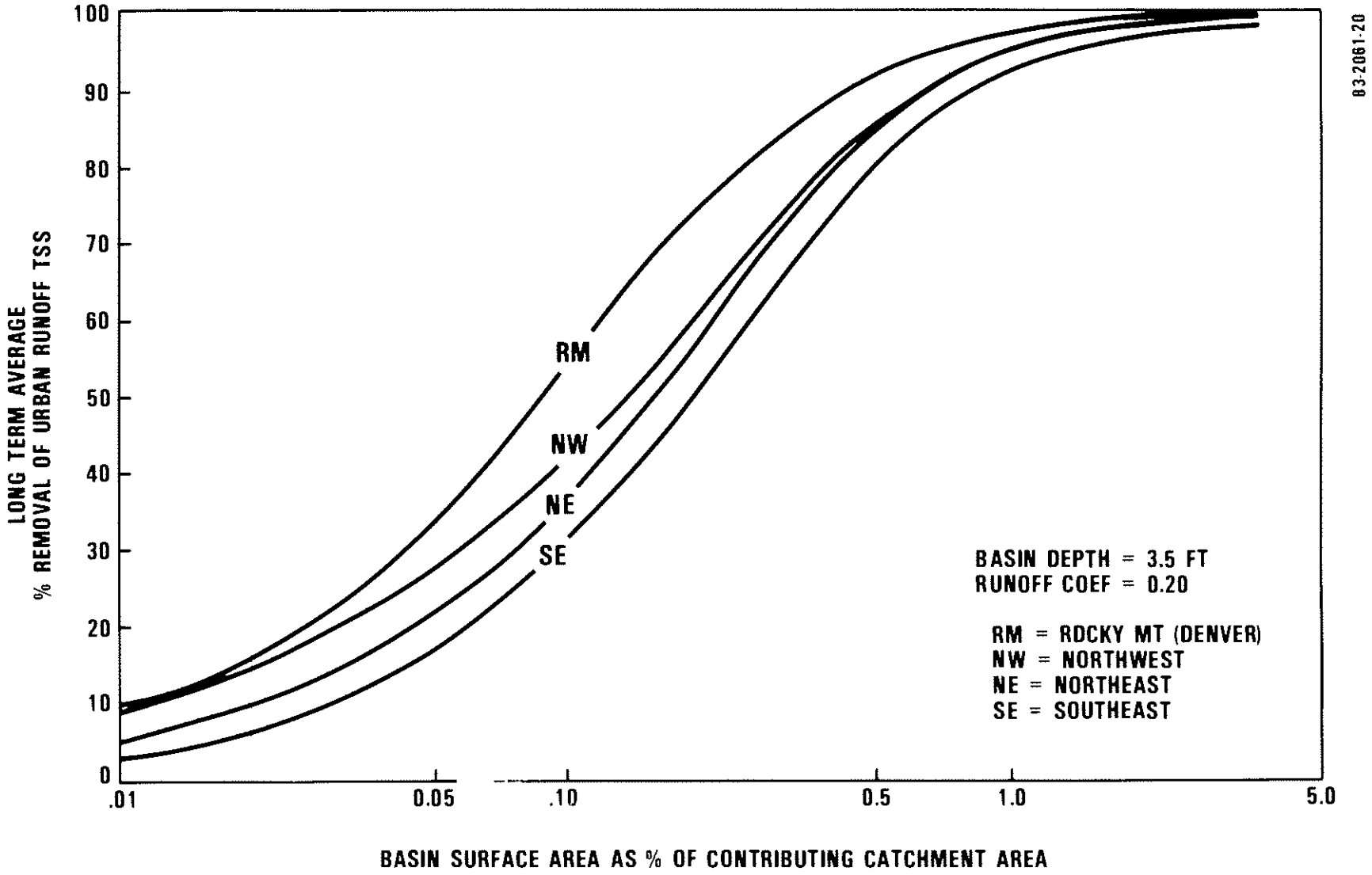

Figure 8-1. Regional Differences in Detention Basin Performance

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This approach provides more useful information for subsequently evaluating the effect of controls on water quality impacts on rivers and streams. As evident from the discussion in Chapter 6, reductions in the mean and variability of runoff concentrations (and the inferred reduction in mean and variability of runoff rates) will have a significant beneficial effect on the severity of impacts on flowing streams.

Table 8-3 summarizes detention basin performance when assessed in this manner. It should be noted that in most cases more inlet storm events were monitored than discharge events, and that some inlet events do not have a matching discharge event and vice-versa. Further, for the larger basins where storm inflow displaces only a fraction of the basin volume, it is unlikely that influent and effluent for a specific event represent the same volume of water. The tacit assumption in this analysis is that the inflow events which were monitored provide a representative sample of the total population of all influent event mean concentrations (EMCs). Similarly, the monitored effluent events are assumed to be a representative sample of all basin discharge EMCs. The appropriateness of this assumption is obviously more uncertain where the number of individual storm events monitored is small.

For each basin influent and effluent, the arithmetic mean and variance were computed based on the relationships for lognormal distributions. The percent reduction in the mean concentration and the coefficient of variation are tabulated (Table 8-3). Note that where the number of monitored events shown in this table differ from those listed in Table 8-2, it is because the mass removal computations were restricted to synoptic storms (i.e., matching influent and effluent results were available for an event).

Performance characteristics are generally consistent using either approach, even though each displays a different type of information. Performance improves with detention basin size relative to catchment size and hence the magnitude of the runoff processed. Giving greater weight to the sites monitoring large numbers of storms, indications are that for most pollutants wet ponds also generally result in a considerable reduction in the variability of pollutant concentrations.

A significant exception to this tendency to reduce variability is shown for the soluble nitrogen forms (NO_2 + NO_3). The positive removal efficiency indicated by reduction of mean concentrations must be attributed to biological processes rather than sedimentation. A substantial increase in variability is consistently indicated by the data. Among the heavy metals, lead which is nearly all in particulate form shows significant reductions in variability. Copper and zinc which have high (40 to 60 percent) soluble fractions show an ambiguous pattern with regard to changes in variability.

In a few of the cases where atypical results are indicated, unique local conditions suggest plausible explanations. For example, at the Ann Arbor (Traver) site, erosion from an unstabilized bank at the outlet of this newly constructed basin is attributed to the poor suspended solids removal observed. The poor removal characteristics at the Unqua site for TKN and nitrate may be associated with the significant wildfowl population at this site.

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TABLE 8-3. OBSERVED PERFORMANCE OF WET DETENTION BASINS
(PERCENT REDUCTION IN POLLUTANT CONCENTRATIONS)

(a) Mean EMC

Project and Site	No. of Storms (1)	Percent Reduction in Mean EMC									
		TSS	BOD	COD	TP	Sol.P	TKN	NO_{2+3}	T.Cu	T.Pb	T.Zn
Lansing Grace St. N.	23/20	(6)	(26)	15	(10)	(26)	11	(1)	(9)	39	(9)
Lansing Grace St. S.	18/17	22	4	(3)	6	0	(5)	(20)	25	14	7
Ann Arbor Pitt-AA	6/6	38	17	23	28	(2)	11	8	·	59	22
Ann Arbor Traver	5/5	0	(66)	12	37	63	19	28	·	·	19
Ann Arbor Swift Run	5/5	83	11	(3)	(38)	21	25	77	·	86	·
Long Island Unqua	8/8	34	(TOC=26)		38	·	(31)	(10)	·	78	·
Washington, D.C. Westleigh	40/40	83	·	33	59	70	19	28	10	·	10
Lansing Waverly Hills	35/30	87	52	52	69	56	30	54	53	93	58
NIPC Lake Ellyn	25/20	92	·	64	61	62	·	82	88	91	87

(b) Coefficient of Variation of EMCs

Project and Site	No. of Storms (1)	Percent Reduction in Coef of Variation of EMCs									
		TSS	BOD	COD	TP	Sol.P	TKN	NO_{2+3}	T.Cu	T.Pb	T.Zn
Lansing Grace St. N.	23/20	14	49	35	(7)	(13)	30	0	0	45	(31)
Lansing Grace St. S.	18/17	(7)	(59)	39	13	0	20	21	17	18	15
Ann Arbor Pitt-AA	6/6	17	(6)	10	28	(84)	37	0	·	53	(5)
Ann Arbor Traver	5/5	14	(109)	58	(3)	42	(150)	(82)	·	·	0
Ann Arbor Swift Run	5/5	(5)	39	50	(150)	0	20	(150)	·	26	·
Long Island Unqua	8/8	(87)	(TOC=66)		47	·	19	(66)	·	65	·
Washington, D.C. Westleigh	40/40	46	·	(26)	15	20	41	(280)	0	·	(14)
Lansing Waverly Hills	35/30	38	5	69	34	26	(8)	(198)	(22)	34	(36)
NIPC Lake Ellyn	25/20	44	·	41	71	48	·	(115)	60	19	41

Notes: (1) In/Out; numbers are approximate, and vary with pollutant. Removals in parentheses indicate negative removal.

Dot (·) indicates pollutant either not monitored or number of observations is too small for reliable estimate of percent reduction.

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The ability of detention basins to reduce coliform bacteria concentrations is also of considerable interest because of the significant impact these urban runoff contaminants exert on recreational or shellfish harvesting beneficial uses. Other than at the Unqua site of the Long Island NURP project, the number of observations made for indicator bacteria were too few to support a reliable assessment of the ability of detention basins to effect quality improvements. However, extensive data of this nature were secured on detention basin influent and effluent during all monitored storms at the Unqua site.

Since coliform bacteria have a high rate of die-off in natural waters, performance characteristics based on total mass reductions are not particularly meaningful. The Unqua site data were analyzed to evaluate performance in terms of reductions in concentration levels. Over eight monitored storms at this site, covering a wide range in storm size, the mean EMC (MPN/100 ml) was reduced by 94 percent for total coliform, 91 percent for fecal coliform, and 95 percent for fecal streptococcus bacteria. Variability of bacteria concentrations in the pond outlet increased, with effluent coefficients of variation ranging from about 10 to 100 percent greater than influents. Accordingly, detention basins employing permanent pools (wet ponds) are indicated to be capable of substantial reductions in indicator bacteria.

Dual Purpose Basins

In the absence of a well defined terminology, we have adopted this designation to define basins that are normally dry, and hence retain their full potential for flood control, but which have outlet designs that result in a slow release rate for detained storm flows. Detention time is extended considerably compared with that provided by dry basins employing conventional outlet designs.

One of the detention basins examined by the WASHCOG NURP project, was of this type. This project designates such designs as "Extended Detention Dry Ponds." The pond was converted from a conventional dry pond by replacing the outlet pipe with a perforated riser enclosed in a gravel jacket. The modification was designed to detain stormwater runoff for up to 24 hours, instead of the 1 to 2 hours typically observed in conventional dry ponds.

For undetermined reasons, average detention periods during the study were in the order of 4 to 8 hours, and hence considerably shorter than the design objective. Nevertheless, based on monitoring of more than 30 storm events, the removal of particulate forms of urban pollutants was typically high and comparable to the performance efficiency of wet ponds.

Observed removals for this site (Stedwick) are summarized by Table 8-4, showing percent reductions in both mass and concentration distributions. The principal differences in performance of dual purpose basins compared with wet basins are suggested by the available data to consist of the following:

- Soluble pollutants (e.g., soluble P and Nitrate/Nitrite) are not effectively reduced because of the absence of a permanent pool within which biological reactions have an opportunity to occur in addition to sedimentation.

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- The variability of pollutant EMC's does not appear to be modified to the extent that this occurs in wet ponds.

TABLE 8-4. PERFORMANCE CHARACTERISTICS OF A DUAL-PURPOSE DETENTION DEVICE

(Stedwick Site - Washington Area NURP Project)

Pollutant	Percent Reduction In		
	Pollutant Mass Load Over All Monitored Storms	Pollutant EMC's Mean	Coef Var
TSS	64	63	(31)
COD	30	41	17
Total P	< 15	11	0
Sol P	1	(4)	(13)
TKN	•	8	(11)
Organic N	30	•	•
NO_{2+3}	10	13	6
T. Cu	•	•	•
T. Pb	84	•	•
T. Zn	57	43	33

Although the performance characteristics of basins of this type are indicated to be somewhat inferior to the potential offered by wet ponds, there are a number of considerations which make dual purpose basins highly attractive candidates for quality control of urban runoff. These include the fact that flood control requirements are likely to be more economically obtained than with wet basins and that many existing stormwater management basins may be readily modified to significantly enhance their capability for improving the quality of urban runoff. In areas where ordinances requiring conventional stormwater management ponds are already in existence, the only changes required would be an alternate specification of the outlet design.

Costs

The information presented here is intended to provide an order of magnitude estimate of the cost of providing different levels of control of urban runoff pollutant discharges, when wet detention devices are used as the best management practice (BMP). The summary is based on the size versus performance relationship presented earlier in Figure 8-1 and on the size versus cost relationships presented below.

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The analysis is based on cost information developed by the WASHCOG NURP project and discussed in detail in one of their project reports produced for the NURP effort. Construction cost estimates as a function of basin volume are shown by Figure 8-2, adopted from this source. This estimate compares quite favorably with a similar cost/size relationship developed previously by the Soil Conservation Service (SCS).

The cost relationship shown by this figure applies to "dry pond" designs and relates only to expected cost of construction activities. For specific cost estimates, the results derived from Figure 8-2 should be modified as appropriate, in accordance with the following:

- The highly variable capital cost of land acquisition is not included in the construction costs.

- Outlet modifications to provide a dual purpose basin design will increase construction costs by about 10 to 12 percent.

- Pond designs which meet the peak shaving requirements of conventional (dry) pond designs, but also provide a permanent pool of water may have costs up to 40 percent greater than indicated by the cost relationship shown by Figure 8-2.

- An additional allowance equal to 25 percent of construction costs is suggested to allow for planning, design, administration, and construction related contingencies.

- Operation and maintenance costs are estimated to involve an annual expenditure of approximately 3 to 5 percent of base construction cost, that is, before application of the 25 percent factor for design, planning, and administration. The total is composed of two elements: 2 to 3 percent of construction cost estimates the annual cost of routine maintenance and upkeep; an additional 1 to 2 percent of construction cost estimates the annualized cost of sediment removal operations for a 10 year clean-out cycle.

Planning agencies often distinquish between "on-site" controls, which are applied to relatively small urban catchments, often installed by the developer of an urban property, and "off-site" controls, which involve larger basins and serve substantially larger urban drainage areas. Because of the appreciable economy of scale inherent in the cost relationship defined by Figure 8-2, this factor must be taken into account in developing cost/performance summaries for urban runoff quality control using detention basins. Accordingly, the control costs presented below for wet basin designs indicate the differences based on the size of the urban catchment the basin is designed to serve.

Figure 8-3 presents a planning level approximation of both present value and annual cost of wet detention basins. Amoritization of costs is based on a 20 year basin life and an interest rate of 10 percent.

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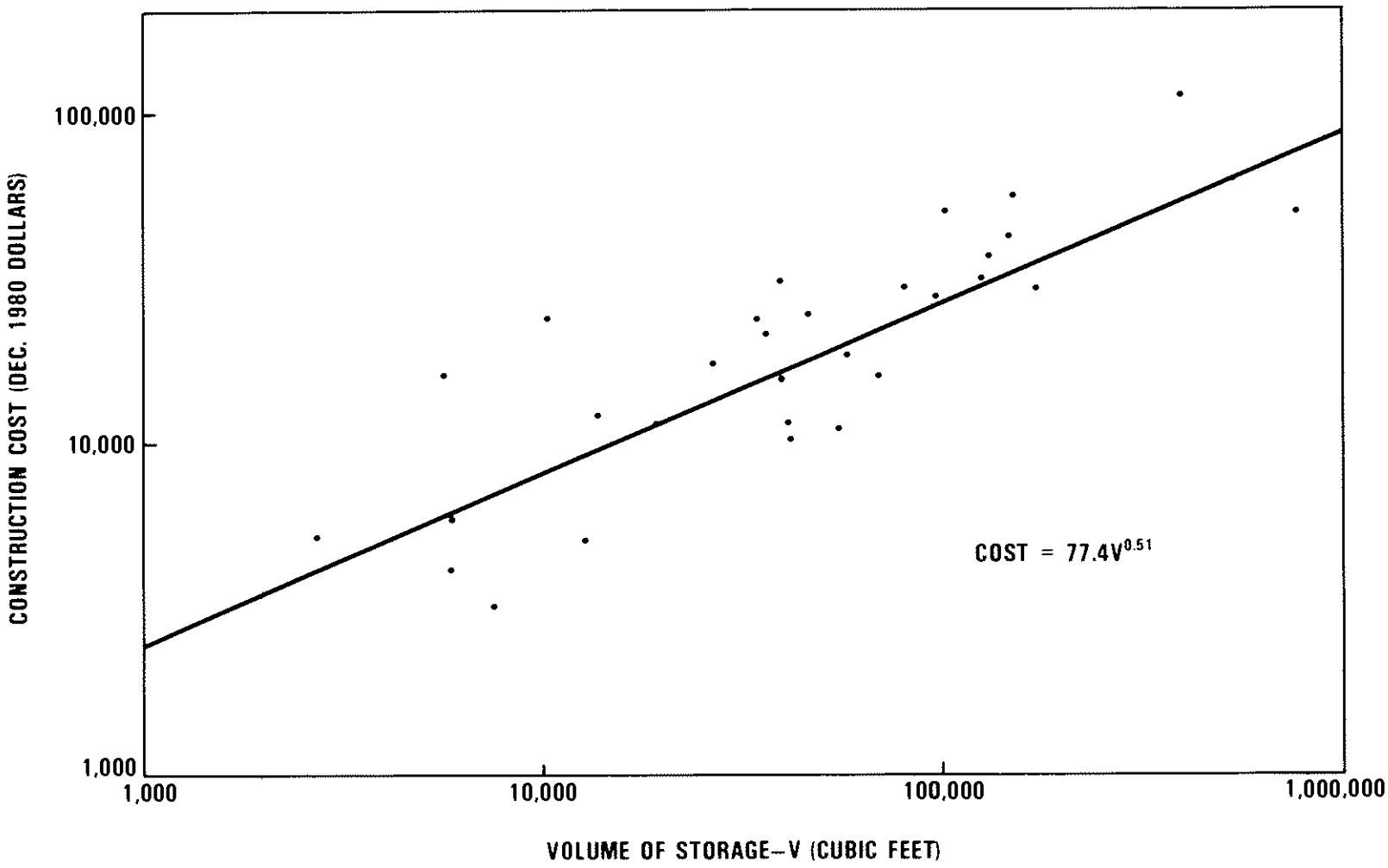

Figure 8-2. Average Stormwater Management (Dry) Pond Construction Cost Estimates Vs. Volume of Storage

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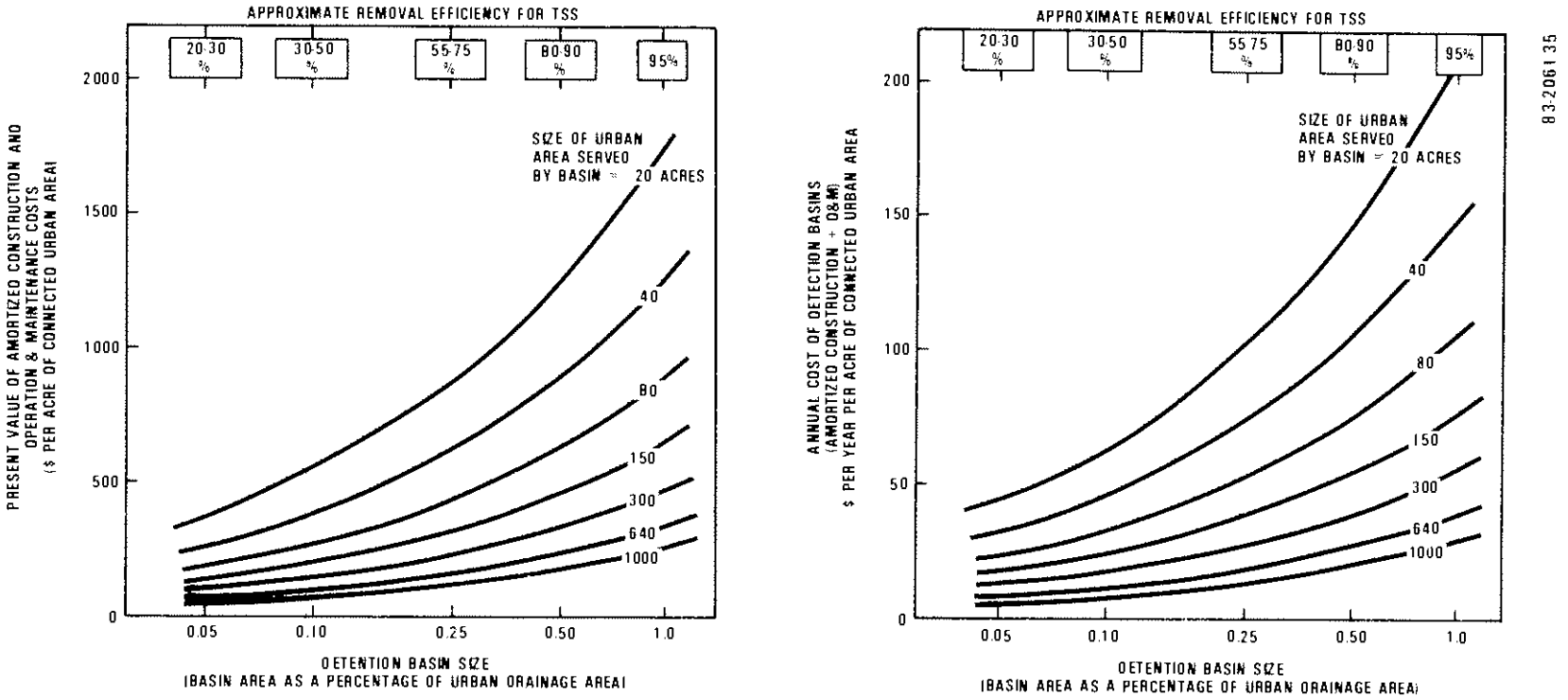

BASIS WET BASINS--CONSTRUCTION COSTS 48% GREATER THAN FIGURE B 2
ANNUAL O&M COST-5% OF BASE CONSTRUCTION COST
BASIN AVG DEPTH 3.5 FEET
INTEREST RATE 10%
BASIN LIFE 20 YEARS

Figure 8-3. Cost of Urban Runoff Control Using Wet Detention Basins

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The performance levels associated with a particular basin size are shown at the top of the plots as a range for long-term average removal efficiencies for TSS. The range associated with a particular size reflects the regional differences in performance which can be expected (Figure 8-1) as a result of regional differences in storm characteristics. Approximate removal efficiencies for pollutants other than TSS can be estimated by factoring the indicated TSS removal by the particulate fraction of the pollutant of interest. The supplementary NURP document dealing with detention basins provides information to permit further refinement. A more concise local summary of cost/performance relationships can be developed using the NURP data and analysis methods, if local rainfall and land use characteristics, and design and planning preferences are utilized.

The generalized relationships shown by Figure 8-3 can be summarized as follows, if an urban catchment size of 20 to 40 acres is taken to represent a typical "on-site" control application, and an "off-site" application is reflected by detention basins serving 640 to 1000 acres.

Control Application	Approximate Level of Control (% TSS Reduction)	Cost Per Acre of Urban Area (Approximate)	
		Present Value	Annual Cost
On-site	50	$500 - $700	$60 - $80
	90	$1000 - $1500	$125 - $175
Off-site	50	$100	$10
	90	$250	$25

RECHARGE DEVICES

Control measures which enhance the infiltration of urban runoff are indicated by the NURP studies to be techniques which are practical to apply and capable of effective reductions in urban runoff quantity and quality. This finding is based on project reports and on the results of a screening analysis using a probabilistic methodology described in a supplementary NURP document on detention basins.

The issue of the potential contamination of groundwater aquifers due to enhanced infiltration of urban storm runoff has been discussed in the previous chapter dealing with receiving water impacts. The favorable findings support further consideration of this technique. At the same time, it must be emphasized that specific local conditions may make recharge inappropriate. Such conditions can include steep slopes, soil conditions, depth to groundwater, and the proximity of water supply wells. Sound planning and engineering judgement must be applied to determine the acceptability of this control approach in a local situation.

However, where local conditions premit, a wide variety of design concepts are available for use. These range from off-site applications consisting of

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large retention basins, to small individual on-site units which include infiltration pits and trenches, percolating catch basins, and porous pavement. The operating principle is the same regardless of size or design concept. The important elements are the surface area provided for sub-surface percolation and the storage volume of the device. Overall performance will be related to the size of the recharge device relative to the urban catchment it serves and the permeability (infiltration rate) of the soil.

The context in which the performance capabilities of recharge devices are evaluated is the extent to which urban runoff is "captured" and prevented from discharging directly to surface waters. Pollutant removals are reduced in direct proportion to the runoff volume which is intercepted and recharged. Load reductions will be further enhanced if quality improvements occur in the portion of the runoff which is not captured. The combination of soil infiltration rate and percolating area provided determines the "treatment rate" of a specific recharge device. When storm runoff is applied to the device at rates of flow equal to or less than this rate, 100 percent of the runoff is captured during that event. At higher applied rates, the fraction of the runoff flow in excess of the treatment rate will escape and discharge to surface waters.

Most recharge devices other than porous pavement also provide storage volume. This improves performance capability because portions of the excess runoff can be retained for subsequent percolation when applied rates subside. Overflow to surface water occurs only when the available storage is exceeded.

The Long Island and Metropolitan Washington, D.C. (WASHCOG) NURP projects examined the performance of on-site recharge devices. An interconnected system of percolating catch basins in Long Island was estimated to reduce surface water discharges of storm runoff by more than 99 percent. The WASHCOG project found that a porous pavement site produced pollutant load reductions on the order of 85 to 95 percent depending on the specific pollutant considered. An infiltration trench studied by this project produced reductions in the order of 50 percent.

The NURP analysis methodology was employed in a screening analysis to assist planning evaluations by establishing the relationship between performance level and device size and soil percolation rates. Figure 8-4 presents a planning level estimate of the influence of size, soil characteristics, and regional rainfall differences on the performance of recharge devices.

The upper plot illustrates the significant effect regional differences in rainfall characteristics can have on the performance of identical recharge devices. Basin depth, soil percolation rate, and runoff coefficient for the urban catchment are the same for each case. The performance differences result from differences in the intensity and volume of the average storms in each region. Basin size is represented on the horizontal axis by expressing the percolation area that is provided as a percentage of the area of the contributing urban catchment. For example, a recharge device with a percolating surface area equal to 0.10 percent of an urban catchment represents a design which provides (43,560 sq ft/acre x 0.10/100% =) 43.5 square feet of

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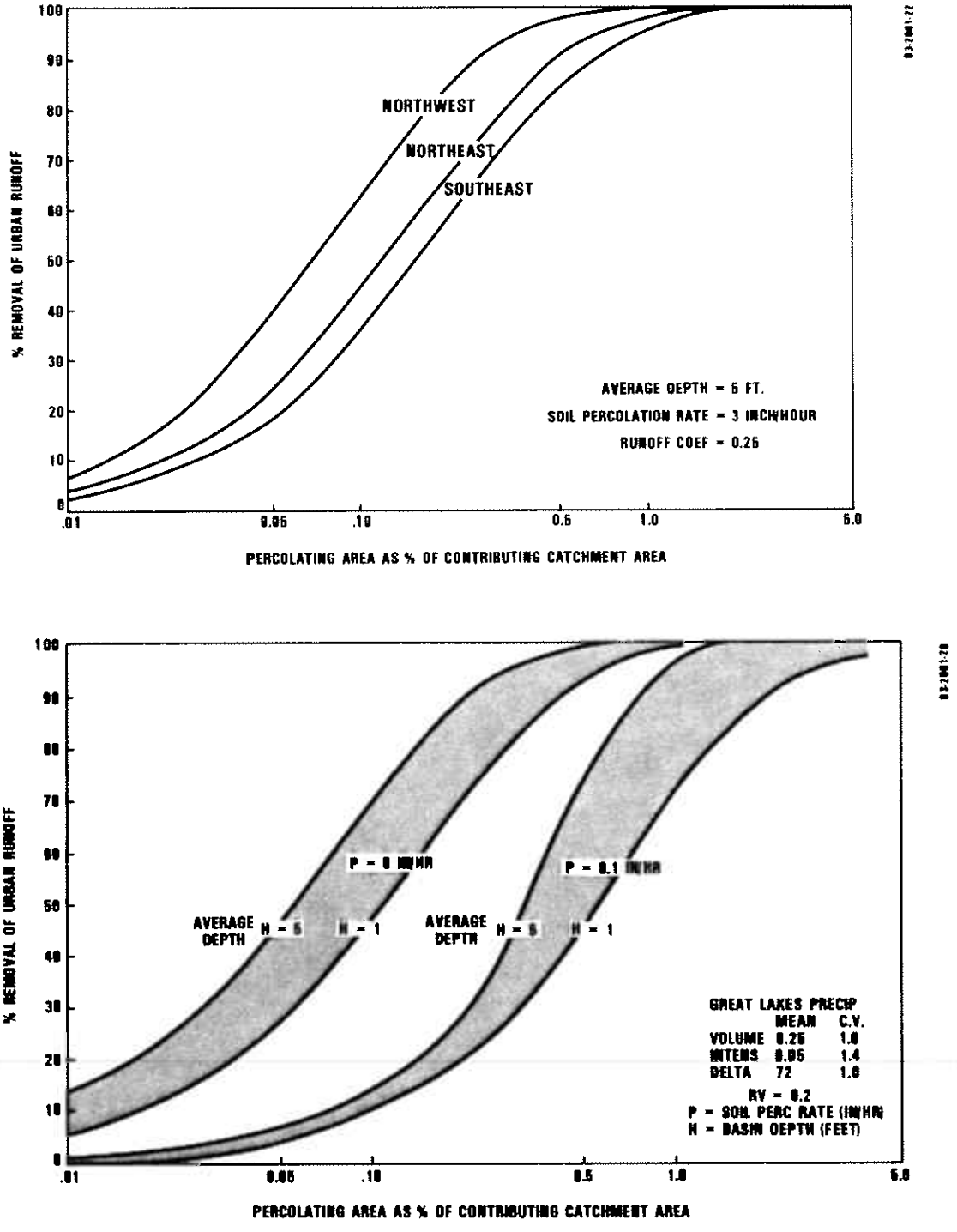

Figure 8-4. Long Term Average Performance of Recharge Devices

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percolating surface area for each acre of urban catchment it serves. The long-term average reductions in urban runoff volume and pollutant load which can be expected will be approximately 35 percent in the southeast, 45 percent in the northeast and 65 percent in the Pacific northwest.

The lower plot illustrates the much more significant influence of the amount of storage volume provided (incidated by basin average depth), and the permeability of the soil through which the storm runoff must percolate. The rainfall characteristics used in this analysis are typical of the Great Lakes region of the United States and are roughly comparable to those in the northeastern part of the country. As might be expected, the permeability of the soil in which the recharge device is constructed has a dominant influence on performance capability. However significant compensation for low percolation rates can be achieved by increases in percolation area and storage volume.

When the screening analysis results are considered along with the favorable results from the NURP studies, the NURP findings indicate that with a reasonable degree of design flexibility to compensate for soils with lower percolation rates, recharge devices provide a very effective method for control of urban runoff.

STREET SWEEPING

End-of-pipe urban runoff pollutant concentrations have been commonly viewed as being a function of two prime factors -- accumulation of contaminants on street surfaces and rainfall/runoff washoff. The postulated beneficial effect of street sweeping was to reduce contaminant accumulation. Prior to NURP, emphasis of street sweeping investigations was placed on street surface mechanisms (e.g., accumulation and washoff) and sweeper equipment performance in removing street dirt. While these studies provided valuable insights into the possible benefits of street sweeping, measurements of end-of-pipe concentrations are the only direct measures of street sweeping effectiveness in water quality terms.

Recognizing this, NURP was designed to provide a large data base of urban runoff water quality concentrations for both swept and unswept conditions. In addition, the NURP street sweeping projects gathered and evaluated data on atmospheric deposition (i.e., wetfall and dryfall), street surface accumulation and washoff, and street sweeper removal rates and costs. The individual project reports look at these other issues, and the results are not repeated herein. Of prime interest and provided below is the effectiveness of street sweeping in reducing end-of-pipe urban runoff pollutant concentrations (and ultimately receiving water impacts). The findings presented below are based upon the analyses performed by the individual projects, as well as other statistical techniques, and are generally consistent with the projects' conclusions.

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Five of the 28 NURP prototype projects had the evaluation of street sweeping as a central element of their work plans. These projects were as follows:

Project	Number of Sites
Castro Valley, CA	1
Milwaukee, WI	8
Champaign-Urbana, IL	4
Winston-Salem, NC	2
Bellevue, WA	2

Long Island, NY and Baltimore, MD also collected limited street sweeping data. The experimental designs of the projects varied in detail, but essentially followed either a paired basin or serial basin approach to gather test and control data, with some projects using both approaches. The general concept was that during a test period street sweeping would be more intensive (up to daily) and thorough (e.g., with operator training, parking bans, etc.) than during control periods when the streets were to be swept as usual or not at all.

In the paired basin approach, two adjacent or close-by basins were operated in a "control" or unswept mode for certain periods of time to establish a baseline comparison, and then street sweeping was performed in a "test" basin while the other remained as a control. The data provided an overall comparison between basins as well as a series of synoptic events for both basins. In the serial approach, a basin was periodically operated in either a control or test mode, with the periods adjusted so that all seasons of the year were represented in each mode. Here, rather than synoptic data pairs, one has data strings for both "swept" and "unswept" conditions.

There are no well established or prescribed procedures for evaluating the possible reduction in runoff concentrations due to street sweeping. Issues of concern include storm size and intensity effects, time since last rain, ability to select truly paired basins, seasonal effects, etc. In an attempt to sort out these issues, an exploratory data analysis was performed, and the following findings were established:

- Street sweeping has not been found to change the basic probability distribution of event mean concentrations. That is, the fundamental assumption of random, lognormal behavior is valid during sweeping operations.

- The runoff quality characteristics of a basin during swept or unswept conditions is best measured by the maximum likelihood estimator of the median EMC, with the uncertainty indicated by the 90 percent confidence interval of the median.

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- There is in most cases no significant correlation (and in a few cases a weak negative correlation) between EMCs and storm runoff volume. EMCs and storm runoff intensities are also generally uncorrelated (but in isolated cases exhibit a weak positive correlation). The implication of these findings is that differences in concentrations between swept and unswept conditions will be largely unaffected by the size of the storms during the monitoring periods. Because of this independence between concentration and volume, effects of sweeping on EMCs will also indicate effects on mass pollutant loads.

- EMCs for synoptic events on paired basins are, in general, not significantly correlated or in some cases are weakly correlated; however, over the longer term (e.g., mean, frequency distribution, etc.), there are no significant differences between the distribution of EMCs of paired basins. These results show that basins are independent from storm to storm, and thus, comparisons between basins should not be attempted using synoptic events, but the basins do have similar statistical properties and thus can be considered paired.

To evaluate the effectiveness of street sweeping, a series of bivariate plots were constructed for projects using the serial basin approach. The site median EMCs for swept and unswept conditions form the data pairs of the plots. Bivariate plots are presented in Figure 8-5 for TSS, COD, TP, TKN, and Pb concentrations, respectively. Each plot contains swept or unswept conditions for multiple project sites. The assumption of the analysis is that a large enough data base was collected to negate any temporal effects such as seasonal, land use conditions, parking patterns, and other possible factors (as noted earlier, storm volume and intensity effects are not believed to be significant). Examining the bivariate plots, it is observed that, for the NURP data, the median concentrations are as likely to be increased as decreased by street sweeping. Further, street sweeping never produced a dramatic (e.g., >50 percent) reduction in concentrations (or loads).

Street sweeping performance, as measured by the percent change in the site median EMC, for selected NURP sites is graphically displayed in Figure 8-6. The results are for five constituents (TSS, COD, TP, TKN, and Pb) at 10 sites nationwide). For each site, the median EMC is based on data from between 10 and 60 events, with 30 events typical. Based on Figure 8-6 a number of important observations are evident.

- Performance as measured by change in site median EMC is highly variable.

- Where reductions occur, they generally occur for all constituents.

- Reductions never exceed 50 percent.

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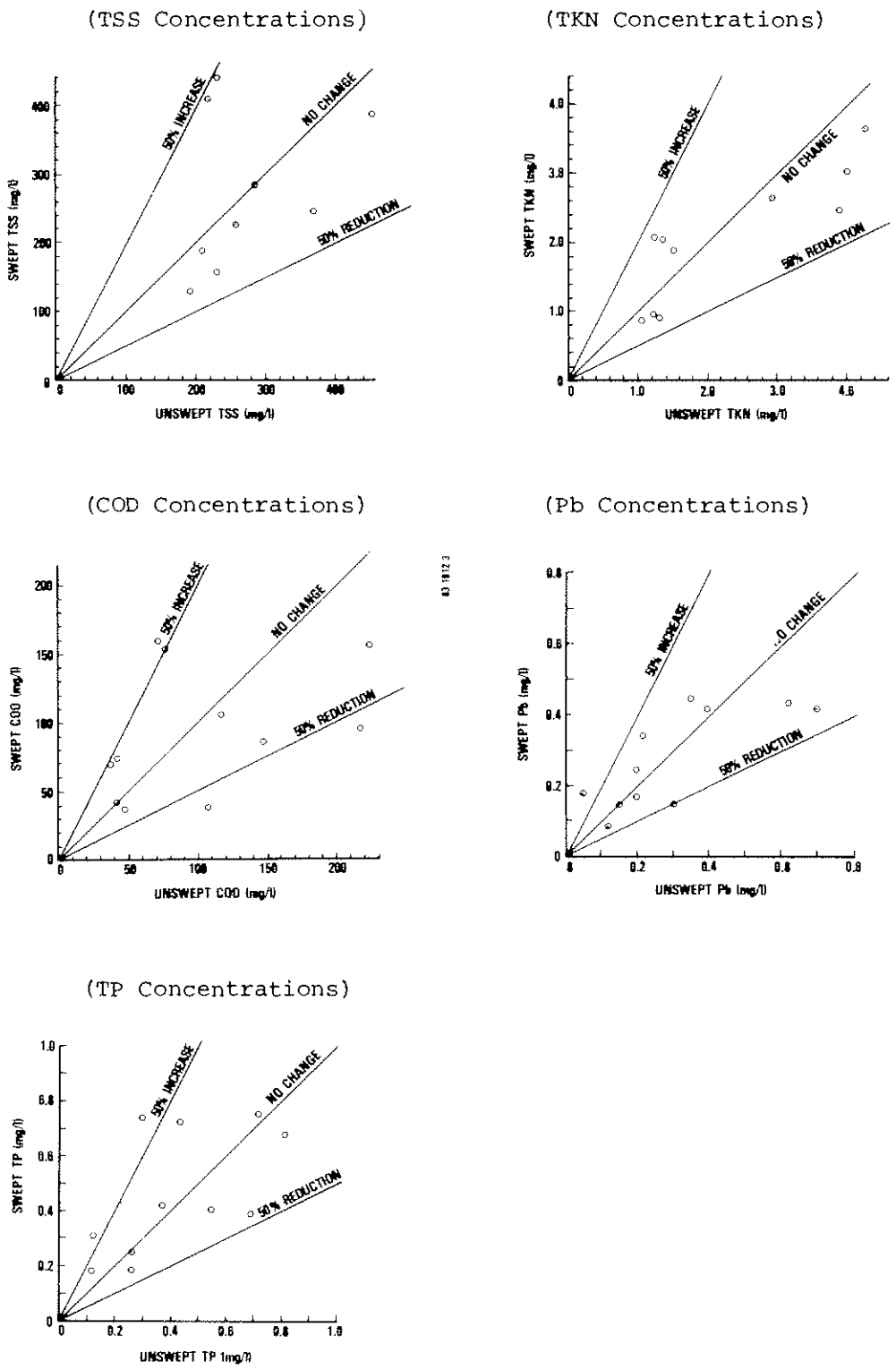

Figure 8-5. Bivariate Plots of Median EMCs for Swept and Unswept Conditions

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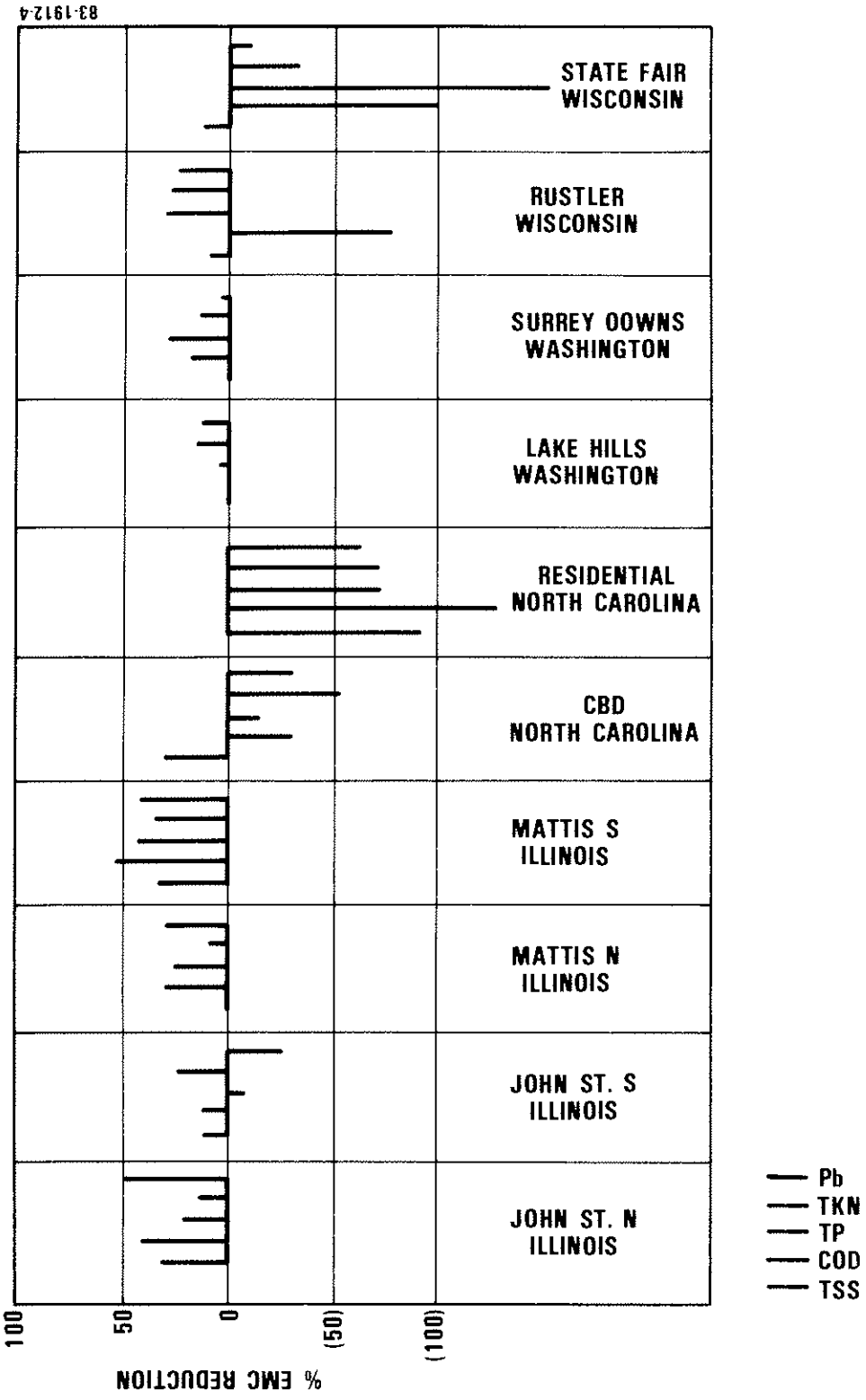

Figure 8-6. Street Sweeping Performance

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In evaluating the results, it is critical that the uncertainty in the estimate of median EMCs based on limited observed data, and thus the uncertainty in performance estimates, be assessed. This is especially true for the cases of apparent increases in concentrations indicated by Figure 8-6.

For each of the 10 sites considered, the 90 percent confidence intervals of the site median EMCs were computed as indicated in Figure 8-7. This analysis indicates that there is generally no significant difference between median EMCs for swept and unswept conditions. The implications of this analysis of uncertainty are as follows:

- Based on statistical testing, no significant reductions in EMCs are realized by street sweeping.

- The indicated changes in site median EMCs (increases or decreases) are much more likely due to random sampling than actual effects of sweeping operations.

- Benefits of street sweeping (if any) are masked by the large variability of the EMCs, therefore the benefit is certainly not large (e.g., >50 percent), and an even larger site data base is required to further identify the possible effect.

- In the above context, the hypothesis that street sweeping increases EMCs is generally not shown by the data, though it could occur in isolated, site specific cases.

Urban runoff loads are the product of long term (e.g., annual) runoff volume and event mean concentration. Under this definition, statements concerning EMCs also hold for loads.

OTHER CONTROL APPROACHES

Several best management practices (BMPs) in addition to those discussed above should be identified on the basis that local planning efforts determined them to be practical to apply and to have the potential to provide significant improvements in the quality characteristics of urban runoff. They are grouped together in this section and discussed only briefly, principally because, for one reason or another, sufficient data to characterize their performance capabilities was not developed during the NURP program.

Grass Swales

Three grass swales were monitored by the Washington, D.C. area NURP project. No significant improvement is urban runoff quality was indicated for pollutants analyzed. Increases in zinc concentration which were observed were attributed to mobilization of zinc from the galvanized culverts which carried runoff under the driveways at the monitored residential sites. However the project study report concluded that modifications which would increase residence of runoff in the swales and enhance infiltration capability could make this BMP effective for control of urban runoff.

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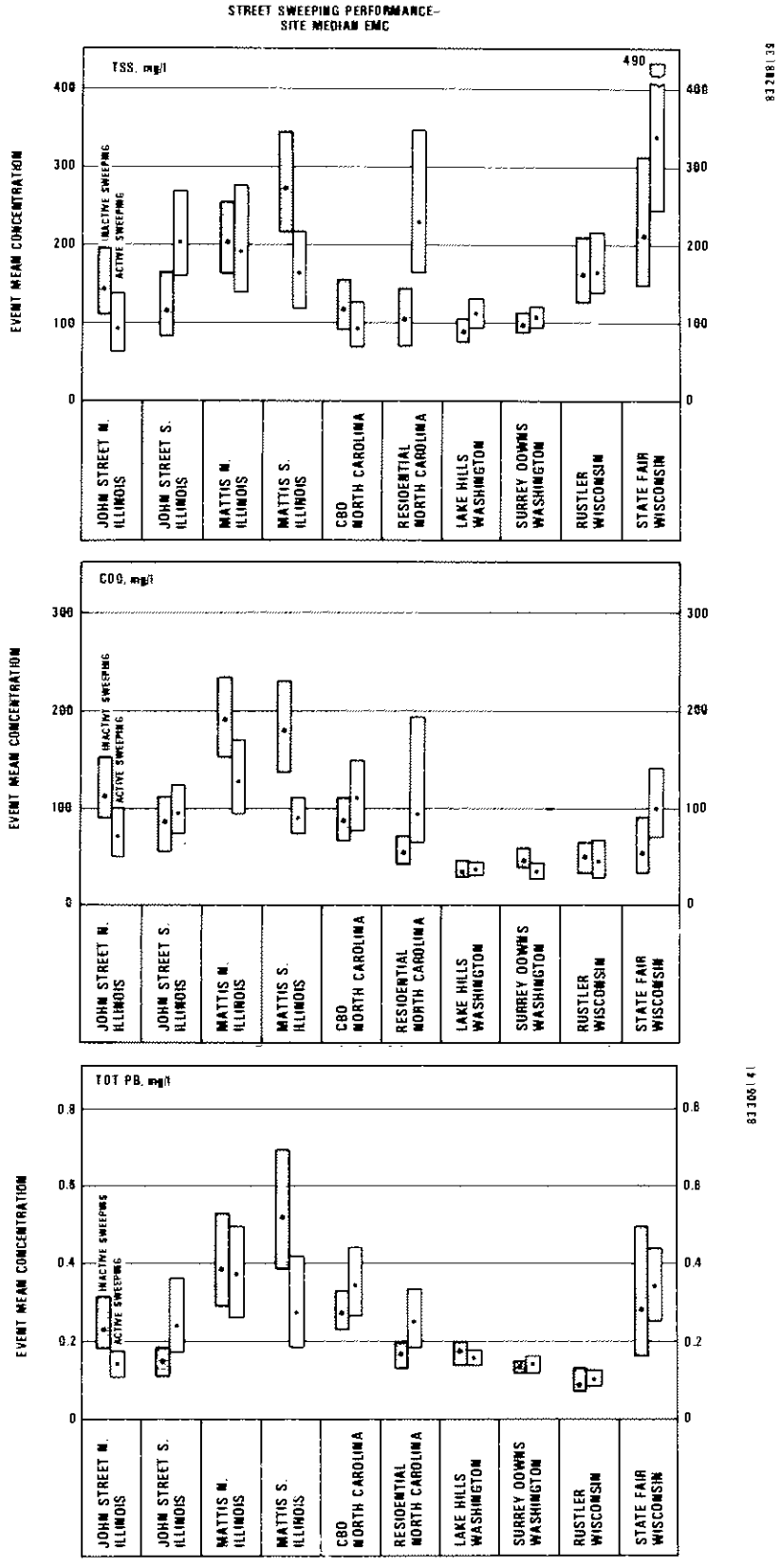

Figure 8-7. Effect of Street Sweeping on Site Median EMC Values

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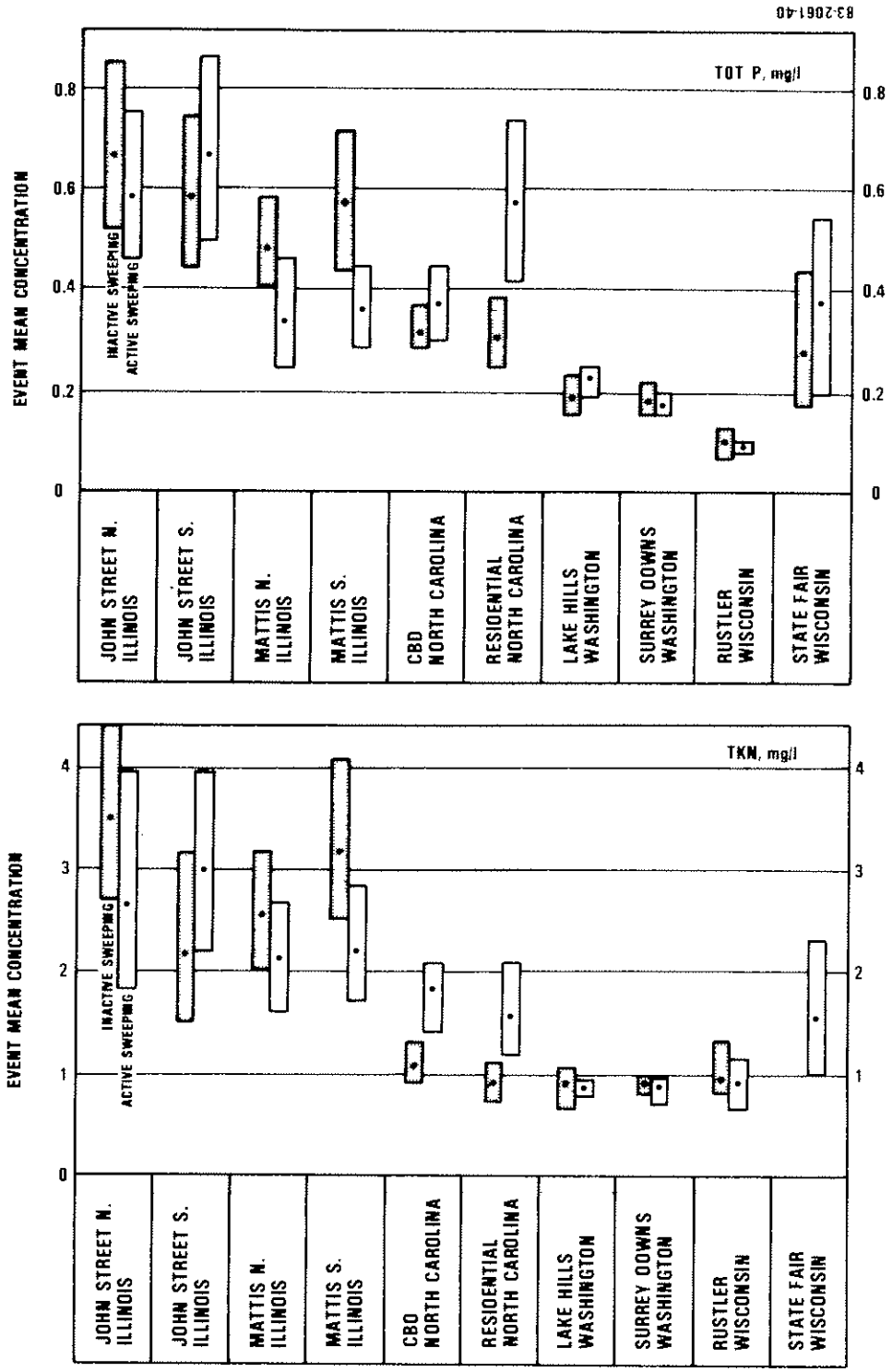

Figure 8-7. Effect of Street Sweeping on Site Median EMC Values (Cont'd)

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The Durham, New Hampshire NURP project monitored performance of a carefully designed artificial swale which received runoff from a commercial parking lot. Over 11 monitored storms, both soluble and particulate fractions of heavy metals (Cu, Pb, Zn, and Cd) were reduced by approximately 50 percent. Reductions in COD, nitrate, and ammonia were on the order of 25 percent. The swale did not prove to be effective in reducing concentrations or organic nitrogen, phosphorus, or bacterial species. It should be noted that the performance capabilities indicated are based only on the concentration changes produced in the stormwater which passes completely through the swale. To the extent that infiltration of a portion of the runoff is effected by a swale, load reductions would be increased in proportion.

The NURP results suggest that grass swales represent a practical and potentially effective technique for control of urban runoff quality; that design conditions are of major significance; and that additional study is necessary to establish such parameters.

Wetlands

The potential of either natural or artificially created wetland areas to effect favorable modification of urban runoff pollutant loads (particularly sediment, nutrients, and heavy metals) has been widely suggested. The NURP experience reinforces this expectation, but has not developed the detailed performance data to permit either characterizing general performance capabilities or identifying general design principles and parameters. Additional study will be required to develop such information.

Miscellaneous

This category encompasses a variety of BMPs which were identified at the local level as techniques of quality control which appeared to be relevant for the circumstances which were operative. They are grouped under this category because (a) their applicability tends to be site-specific rather than general, and (b) while their effectiveness as a BMP may be substantial on a relatively small spatial scale, the broad-scale effect on urban runoff loads has not been possible to document.

BMPs in this category include erosion control practices and urban housekeeping practices. As an example of the former, the Little Rock, Arkansas NURP project widened and stabilized (with rip rap) a segment of an urban stream to reduce erosion potential. The Baltimore NURP project data clearly indicated the substantial difference in urban runoff quality that can result from the general level of cleanliness maintained in an urban neighborhood.

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CHAPTER 9
CONCLUSIONS

INTRODUCTION

The Nationwide Urban Runoff Program has addressed such issues as quantifying the characteristic of urban runoff, assessing the water quality effects on receiving water bodies attributable to urban runoff discharges, and examining the effectiveness of control practices in removing the pollutants found in urban runoff. This chapter summarizes NURP's conclusion relating to these issues and is based on the results presented in Chapters 6, 7, and 8 of this report. Conclusions reached by the individual NURP projects are also presented to further support the results of the national level analysis.

URBAN RUNOFF CHARACTERISTICS

General

Field monitoring was conducted to characterize urban runoff flows and pollutant concentrations. This was done for a variety of pollutants at a substantial number of sites distributed throughout the country. The resultant data represent a cross-section of regional climatology, land use types, slopes, and soil conditions and thereby provide a basis for identifying patterns of similarities or differences and testing their significance.

Urban runoff flows and concentrations of contaminants are quite variable. Experience shows that substantial variations occur within a particular event and from one event to the next at a particular site. Due to the high variability of urban runoff, a large number of sites and storm events were monitored, and a statistical approach was used to analyze the data. Procedures are available for characterizing variable data without requiring knowledge of or existence of any underlying probability distribution (nonparametric statistical procedures). However, where a specific type of probability distribution is known to exist, the information content and efficiency of statistical analysis is enhanced. Standard statistical procedures allowed probability distributions or frequency of occurrence to be examined and tested. Since the underlying distributions were determined to be adequately represented by the lognormal distribution, the log (base e) transforms of all urban runoff data were used in developing the statistical characterizations.

The event mean concentration (EMC), defined as the total constituent mass discharge divided by the total runoff volume, was chosen as the primary water quality statistic. Event mean concentrations were based on flow weighted composite samples for each event at each site in the accessible data base. EMCs were chosen as the primary water quality characteristic subjected to detailed analysis, even though it is recognized that mass loading characteristics of urban runoff (e.g., pounds/acre for a specified time interval) is

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ultimately the relevant factor in many situations. The reason is that, unlike EMCs, mass loadings are very strongly influenced by the amount of precipitation and runoff, and estimates of typical annual mass loads will be biased by the size of monitored storm events. The most reliable basis for characterizing annual or seasonal mass loads is on the basis of EMC and site-specific rainfall/runoff characteristics.

Establishing the fundamental distribution as lognormal and the availability of a sufficiently large population of EMCs to provide reliability to the statistics derived has yielded a number of benefits, including the ability to provide:

- Concise summaries of highly variable data
- Meaningful comparisons of results from different sites, events, etc.
- Statements concerning frequency of occurrence. One can express how often values will be expected to exceed various magnitudes of interest.
- A more useful method of reporting data than the use of ranges; one which is less subject to misinterpretation
- A framework for examining "transferability" of data in a quantitative manner

Conclusions

1. Heavy metals (especially copper, lead and zinc) are by far the most prevalent priority pollutant constituents found in urban runoff. End-of-pipe concentrations exceed EPA ambient water quality criteria and drinking water standards in many instances. Some of the metals are present often enough and in high enough concentrations to be potential threats to beneficial uses.

   All 13 metals on EPA's priority pollutant list were detected in urban runoff samples, and all but three at frequencies of detection greater than 10 percent. Most often detected among the metals were copper, lead, and zinc, all of which were found in at least 91 percent of the samples.

   Metal concentrations in end-of-pipe urban runoff samples (i.e., before dilution by receiving water) exceeded EPA's water quality criteria and drinking water standards numerous times. For example, freshwater acute criteria were exceeded by copper concentrations in 47 percent of the samples and by lead in 23 percent. Freshwater chronic exceedances were common for lead (94 percent), copper (82 percent), zinc (77 percent), and cadmium (48 percent). Regarding human toxicity, the most significant pollutants were lead and nickel, and for human carcinogenesis, arsenic and beryllium. Lead concentrations violated drinking water criteria in 73 percent of the samples.

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It should be stressed that the exceedances noted above do not necessarily imply that an actual violation of standards will exist in the receiving water body in question. Rather, the enumeration of exceedances serves a screening function to identify those heavy metals whose presence in urban runoff warrants high priority for further evaluation.

Based upon the much more extensive NURP data set for total copper, lead, and zinc, the site median EMC values for the median urban site are: Cu = 34 µg/l, Pb = 144 µg/l, and Zn = 160 µg/l. For the 90th percentile urban site the values are: Cu = 93 µg/l, Pb = 350 µg/l, and Zn = 500 µg/l. These values are suggested to be appropriate for planning level screening analyses where data are not available.

Some individual NURP project sites (e.g., at DC1, MD1, NH1) found unusually high concentrations of certain heavy metals (especially copper and zinc) in urban runoff. This was attributed by the projects to the effect of acid rain on materials used for gutters, culverts, etc.

2. The organic priority pollutants were detected less frequently and at lower concentrations than the heavy metals.

Sixty-three of a possible 106 organics were detected in urban runoff samples. The most commonly found organic was the plasticizer bis (2-ethylhexl) phthalate (22 percent), followed by the pesticide α-hexachlorocyclohexane (α-BHC) (20 percent). An additional 11 organic pollutants were reported at frequencies between 10 and 20 percent; 3 pesticides, 3 phenols, 4 polycyclic aromatics, and a single halogenated aliphatic.

Criteria exceedances were less frequently observed among the organics than the heavy metals. One unusually high pentachlorophenol concentration of 115 µg/l resulted in exceedances of the freshwater acute and organoleptic criteria. This observation and one for chlordane also exceeded the freshwater acute criteria. Freshwater chronic criteria exceedances were observed for pentachlorophenol, bis (2-ethylhexyl) phthalate, gamma-BHC, chlordane, and alpha-endosulfan. All other organic exceedances were in the human carcinogen category and were most serious for alpha-hexachlorocyclohexane (alpha-BHC), gamma-hexachlorocyclohexane (gamma-BHC or Lindane), chlordane, phenanthrene, pyrene, and chrysene.

The fact that the NURP priority pollutant monitoring effort was limited to two samples at each site leaves us unable to make many generalizations about those organic pollutants which occurred only rarely. We can speculate that their occurrences tend to be very site specific as opposed to being a generally widespread phenomena, but much more data would be required to conclusively prove this point.

3. Coliform bacteria are present at high levels in urban runoff and can be expected to exceed EPA water quality criteria during and immediately after storm events in many surface waters, even those providing high degrees of dilution.

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Fecal coliform counts in urban runoff are typically in the tens to hundreds of thousand per 100 ml during warm weather conditions, with the median for all sites being around 21,000/100 ml. During cold weather, fecal coliform counts are more typically in the 1,000/100 ml range, which is the median for all sites. Thus, violations of fecal coliform standards were reported by a number of NURP projects. High fecal coliform counts may not cause actual use impairments, in some instances, due to the location of the urban runoff discharges relative to swimming areas or shellfish beds and the degree of dilution/dispersal and rate of die off. The same is true of total coliform counts, which were found to exceed EPA water quality criteria in undiluted urban runoff at virtually every site every time it rained.

The substantial seasonal differences noted above do not correspond with comparable variations in urban activities. The NURP analyses as well as current literature suggest that fecal coliform may not be the most appropriate indicator organism for identifying potential health risks when the source is stormwater runoff.

4. Nutrients are generally present in urban runoff, but with a few individual site exceptions, concentrations do not appear to be high in comparison with other possible discharges to receiving water bodies.

   NURP data for total phosphorus, soluble phosphorus, total kjeldahl nitrogen, and nitrate plus nitrite as nitrogen were carefully examined. Median site EMC median concentrations in urban runoff were TP = 0.33 mg/l, SP = 0.12 mg/l, TKN = 1.5 mg/l, and NO2+3 - N = 0.68 mg/l. On an annual load basis, comparison with typical monitoring data, literature values, and design objectives for discharges from a well run secondary treatment plant suggests that mean annual nutrient loads from urban runoff are around an order of magnitude less than those from a POTW.

5. Oxygen demanding substances are present in urban runoff at concentrations approximating those in secondary treatment plant discharges. If dissolved oxygen problems are present in receiving waters of interest, consideration of urban runoff controls as well as advanced waste treatment appears to be warranted.

   Urban runoff median site EMC median concentrations of 9 mg/l BOD5 and 65 mg/l COD are reflected in the NURP data, with 90th percentile site EMC median values being 15 mg/l BOD5 and 140 mg/l COD. These concentrations suggest that, on an annual load basis, urban runoff is comparable in magnitude to secondary treatment plant discharges.

   It can be argued that urban runoff is typically well oxygenated and provides increased stream flow and, hence, in view of relatively long travel times to the critical point, that dissolved oxygen problems attributable solely to urban runoff should not be widespread occurrences. No NURP project specifically identified a low DO condition resulting from

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urban runoff. Nonetheless, there will be some situations where consideration of urban runoff controls for oxygen demanding substances in an overall water quality management strategy would seem appropriate.

6. Total suspended solids concentrations in urban runoff are fairly high in comparison with treatment plant discharges. Urban runoff control is strongly indicated where water quality problems associated with TSS, including build-up of contaminated sediments, exist.

   There are no formal water quality criteria for TSS relating to either human health or aquatic life. The nature of the suspended solids in urban runoff is different from those in treatment plant discharges, being higher in mineral and man-made products (e.g., tire and street surface wear particles) and somewhat lower in organic particulates. Also, the solids in urban runoff are more likely to have other contaminants adsorbed onto them. Thus, they cannot be simply considered as benign, nor do they only pose an aesthetic issue. NURP did not examine the problem of contaminated sediment build-up due to urban runoff, but it undeniably exists, at least at some locations.

   The suspended solids in urban runoff can also exert deleterious physical effects by sedimenting over egg deposition sites, smothering juveniles, and altering benthic communities.

   On an annual load basis, suspended solids contributions from urban runoff are around an order of magnitude or more greater than those from secondary treatment plants. Control of urban runoff, as opposed to advanced waste treatment, should be considered where TSS-associated water quality problems exist.

7. A summary characterization of urban runoff has been developed and is believed to be appropriate for use in estimating urban runoff pollutant discharges from sites where monitoring data are scant or lacking, at least for planning level purposes.

   As a result of extensive examination, it was concluded that geographic location, land use category (residential, commercial, industrial park, or mixed), or other factors (e.g., slope, population density, precipitation characteristics) appear to be of little utility in consistently explaining overall site-to-site variability in urban runoff EMCs or predicting the characteristics of urban runoff discharges from unmonitored sites. Uncertainty in site urban runoff characteristics caused by high event-to-event variability at most sites eclipsed any site-to-site variability that might have been present. The finding that EMC values are essentially not correlated with storm runoff volumes facilitates the transfer of urban runoff characteristics to unmonitored sites. Although there tend to be exceptions to any generalization, the suggested summary urban runoff characteristics given in Table 6-17 of the report are recommended for planning level purposes as the best estimates, lacking local information to the contrary.

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RECEIVING WATER EFFECTS

General

The effects of urban runoff on receiving water quality are highly site-specific. They depend on the type, size, and hydrology of the water body; the urban runoff quantity and quality characteristics; the designated beneficial use; and the concentration levels of the specific pollutants that affect that use.

The conclusions which follow are based on screening analyses performed by NURP, observations and conclusions drawn by individual NURP projects that examined receiving water effects in differing levels of detail and rigor, and NURP's three levels of problem definition. Conclusions are organized on the basis of water body type: rivers and streams, lakes, estuaries and embayments, and groundwater aquifers. Site-specific exceptions should be expected, but the statements presented are believed to provide an accurate perspective on the general tendency of urban runoff to contribute significantly to water quality problems.

Rivers and Streams

1. Frequent exceedances of heavy metals ambient water quality criteria for freshwater aquatic life are produced by urban runoff.

   The Denver NURP project found that in-stream concentrations of copper, lead, zinc, and cadmium exceeded State ambient water quality standards for the South Platte River during essentially all storm events.

   NURP screening analyses suggest that frequent exceedances of both EPA 24-hour and maximum water quality criteria for heavy metals should be expected on a relatively general basis.

2. Although a significant number of problem situations could result from heavy metals in urban runoff, levels of freshwater aquatic life use impairment suggested by the magnitude and frequency of ambient criteria exceedances were not observed.

   Based upon the magnitude and frequency of freshwater aquatic life ambient criteria exceedances, one would expect to observe impairment of this beneficial use in most streams that receive urban runoff discharges. However, those NURP project studies which examined this issue did not report significant use impairment problems associated with urban runoff.

   The Bellevue, Washington NURP project concluded that toxic effects of urban runoff pollutants did not appear to be a significant factor.

   The Tampa, Florida NURP project conducted biological studies of the impact of stormwater runoff upon the biological community of the Hillsborough River. They conducted animal bioassay experiments on five sensitive species in two samples of urban runoff from the Arctic Street drainage basin. Thirty-two bioassay experiments were completed including 22 acute tests and 10 chronic tests. Neither sample of stormwater was acutely toxic to test organisms. Long-term chronic experiments were

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undertaken with two species and resulted in no significant effects attributable to stormwater exposure.

NURP screening analyses suggest that the potential of urban runoff to seriously impair this beneficial use will be strongly influenced by local conditions and the frequency of occurrence of concentration levels which produce toxic effects under the intermittent, short duration exposures typically produced by urban runoff.

While the application of the screening analysis to the Bellevue and Tampa situations supports the absence of a problem situation in these cases, it also suggests that a significant number of problem situations should be expected. Therefore, although not the general, ubiquitous problem situation that criteria exceedances would suggest, there are site-specific situations in which urban runoff could be expected to cause significant impairment of freshwater aquatic life uses.

Because of the inconsistency between criteria exceedances and observed use impairments due to urban runoff, adaptation of current ambient quality criteria to better reflect use impacts where pollutant exposures are intermittent and short duration appears to be a useful area for further investigation.

3. Copper, lead and zinc appear to pose a significant threat to aquatic life uses in some areas of the country. Copper is suggested to be the most significant of the three.

Regional differences in surface water hardness, which has a strong influence on toxicity, in conjunction with regional variations in stream flow and rainfall result in significant differences in susceptibility to adverse impacts around the nation.

The southern and southeastern regions of the country are the most susceptible to aquatic life effects due to heavy metals, with the northeast also a sensitive area, although somewhat less so.

Copper is the major toxic metal in urban runoff, with lead and zinc also prevalent but a problem in more restricted cases. Copper discharges in urban runoff are, in all but the most favorable cases, a significant threat to aquatic life uses in the southeast and southern regions of the country. In the northeast, problems would be expected only in rather unfavorable conditions (large urban area contribution and high site concentrations). In the remainder of the country (and for the other metals) problems would only be expected under quite unfavorable site conditions. These statements are based on total metal concentrations.

4. Organic priority pollutants in urban runoff do not appear to pose a general threat to freshwater aquatic life.

This conclusion is based on limited data on the frequency with which organics are found in urban runoff discharges and measured end-of-pipe concentrations relative to published toxic criteria. One unusually high pentachlorophenol concentration of 115 µg/l resulted in the only exceedance of the organoleptic criteria. This observation and one for

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chlordane exceeded the freshwater acute criteria. Freshwater chronic criteria exceedances were observed for pentochlorophenol, bis (2-ethylhexyl) phlhalate, γ-hexachlorocyclohexane (lindane), α-endosulfan, and chlordane.

5. The physical aspects of urban runoff, e.g., erosion and scour, can be a significant cause of habitat disruption and can affect the type of fishery present. However, this area was studied only incidentally by several of the projects under the NURP program and more concentrated study is necessary.

   The Metropolitan Washington Council of Governments (MWCOG) NURP project did an analysis of fish diversity in the Seneca Creek Watershed, 20 miles northwest of Washington, D.C. In this study, specific changes in fishery diversity were identified due to urbanization in some of the sub-watersheds. Specifically, the number of fish species present are reduced and the types of species present changed dramatically, e.g., environmentally sensitive species were replaced with more tolerant species. For example, the Blacknose Dace replaced the Mottled Sculpin. MWCOG concluded that the changes in fish diversity were due to habitat deterioration caused by the physical aspects of urban runoff.

   The Bellevue, Washington NURP project concluded that habitat changes (streambed scour and sedimentation) had a more significant effect than pollutant concentrations, for the changes produced by urbanization.

6. Several projects identified possible problems in the sediments because of the build-up of priority pollutants contributed wholly or in part by urban runoff. However, the NURP studies in this area were few in number and limited in scope, and the findings must be considered only indicative of the need for further study, particularly as to long-term impacts.

   The Denver NURP project found significant quantities of copper, lead, zinc, and cadmium in river sediments. The Denver Regional Council of Governments is concerned that during periods of continuous low flow, lead may reach levels capable of adversely affecting fish.

   The Milwaukee NURP project reported the observation of elevated levels of heavy metals, particularly lead, in the sediments of a river receiving urban runoff.

7. Coliform bacteria are present at high levels in urban runoff and can be expected to exceed EPA water quality criteria during and immediately after storm events in most rivers and streams.

   Violations of the fecal coliform standard were reported by a number of NURP projects. In some instances, high fecal coliform counts may not cause actual use impairments due to the location of the urban runoff discharge relative to swimming areas and the degree of dilution or dispersal and rate of die off.

   Coliform bacteria are generally accepted to be a useful indicator of the possible presence of human pathogens when the source of contamination is sanitary sewage. However, no such relationship has been demonstrated for

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urban runoff. Therefore, the use of coliforms as an indicator of human health risk when the sole source of contamination is urban runoff, warrants further investigation.

8. Domestic water supply systems with intakes located on streams in close proximity to urban runoff discharges are encouraged to check for priority pollutants which have been detected in urban runoff, particularly those in the organic category.

   Sixty-three of a possible 106 organics were detected in urban runoff samples. The most commonly found organic was the plasticizer bis (2-ethylhexl) phthalate (22 percent), followed by the pesticide α-hexachlorocyclohexane (α-BHC) (20 percent). An additional 11 organic pollutants were reported at frequencies between 10 and 20 percent; 3 pesticides, 3 phenols, 4 polycyclic aromatics, and a single halogenated aliphatic.

Lakes

1. Nutrients in urban runoff may accelerate eutrophication problems and severely limit recreational uses, especially in lakes. However, NURP's lake projects indicate that the degree of beneficial use impairment varies widely, as does the significance of the urban runoff component.

   The Lake Quinsigamond NURP project in Massachusetts identified eutrophication as a major problem in the lake, with urban runoff being a prime contributor of the critical nutrient phosphorus. Point source discharges to the lake have been eliminated almost entirely. However, in spite of the abatement of point sources, survey data indicate that the lake has shown little improvement over the abatement period. In particular, the trophic status of the lake has shown no change, i.e., it is still classified as late mesotrophic-early eutrophic. Substantial growth is projected in the basin, and there is concern that Lake Quinsigamond will become more eutrophic. A proposed water quality management plan for the lake includes the objective of reducing urban runoff pollutant loads.

   The Lake George NURP project in New York State also identified increasing eutrophication as a potential problem if current development trends continue. Lake George is not classified as eutrophic, but from 1974 to 1978 algae production in the lake increased logarithmically. Lake George is a very long lake, and the limnological differences between the north and south basins provide evidence of human impact. The more developed, southern portion of the lake exhibits lower transparencies, lower hypolimnetic dissolved oxygen concentrations, higher phosphorus and chlorophyll a concentrations, and a trend toward seasonal blooms of blue-green algae. These differences in water quality indicators are associated with higher levels of cultural activities (e.g., increased sources of phosphorus) in the southern portion of the lake's watershed, and continued development will tend to accentuate the differences.

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The Lake George NURP project estimated that urban runoff from developed areas currently accounts for only 13.6 percent of the annual phosphorus loadings to Lake George as a whole. In contrast, developed areas contribute 28.9 percent of the annual phosphorus load to the NURP study areas at the south end of the Lake. Since there are no point source discharges, this phosphorus loading is due solely to urban runoff. These data illustrate the significant impact of urbanization on phosphorus loads.

The NURP screening analysis suggests that lakes for which the contributions of urban runoff are significant in relation to other nonpoint sources (even in the absence of point source discharges) are indicated to be highly susceptible to eutrophication and that urban runoff control may be warranted in such situations.

2. Coliform bacteria discharges in urban runoff have a significant negative impact on the recreational uses of lakes.

As was the case with rivers and streams, coliform bacteria in urban runoff can cause violations of criteria for the recreational use of lakes. When unusually high fecal coliform counts are observed, they may be partially attributable to sanitary sewage contamination, in which case significant health risks may be involved.

The Lake Quinsigamond NURP project in Massachusetts found that bacterial pollution was widespread throughout the drainage basin. In all cases where samples were taken, fecal coliforms were in excess of 10,000 counts per 100 ml, with conditions worse in the Belmont street storm drains. This project concluded that the very high fecal coliform counts in their stormwater are at least partially due to sewage contamination apparently entering the stormwater system throughout the local catchment.

The sources of sewage contamination are leaking septic tanks, infiltration from sanitary sewers into storm sewers, and leakage at manholes. In the northern basin, the high fecal coliform counts are attributed to known sewage contamination sources on Poor Farm Brook. The data from the project suggest that it would be unwise to permit body contact recreation in the northern basin of the lake during or immediately following significant storm events. The project concluded that disinfection at selected storm drains should be considered in the future, especially if the sewage contamination cannot be eliminated.

The Mystic River NURP project in Massachusetts found various areas where fecal coliform counts were extremely high in urban stormwater. Fecal coliform levels of up to one million with an average of 178,000/100 ml were recorded in Sweetwater Brook, a tributary to Mystic River, during wet weather. These high fecal coliform levels were specifically attributed to surcharging in their sanitary sewers, which caused sanitary sewage to overflow into their storm drains via the combined manholes present in this catchment. Fecal coliform levels above the class B fecal coliform standard of 200 per 100 ml were found in approximately one-third of the samples tested in the upper and lower forebays of the Upper Mystic Lake and occasionally near the lake's outlet. In addition, Sandy Beach, a public swimming area on Upper Mystic Lake, exceeded the State fecal

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coliform criteria in July of 1982, and warnings that swimming may be hazardous to public health were posted for several days. It is important to note that sewage contamination of surface waters is a major problem in the watershed. The project concluded that urban runoff contributes to the bacteria load during wet weather but, comparatively, is much less significant than the sanitary sources.

Estuaries and Embayments

1. Adverse effects of urban runoff in marine waters will be a highly specific local situation. Though estuaries and embayments were studied to a very limited extent in NURP, they are not believed to be generally threatened by urban runoff, though specific instances where use is impaired or denied can be of significant local and even regional importance. Coliform bacteria present in urban runoff is the primary pollutant of concern, causing direct impacts on shellfish harvesting and beach closures.

   The significant impact of urban runoff on shellfish harvesting has been well documented by the Long Island, New York NURP project. In this project, stormwater runoff was identified as the major source of bacterial loading to marine waters and, thus, the indirect cause of the denial of certification by the New York State Department of Conservation for about one-fourth of the shellfishing area. Much of this area is along the south shore, where the annual commercial shellfish harvest is valued at approximately $17.5 million.

   The Myrtle Beach, South Carolina NURP project found that stormwater discharges from the City of Myrtle Beach directly onto the beach showed high bacterial counts for short durations immediately after storm events. In many instances these counts violated EPA water quality criteria for aquatic life and contact recreation. The high bacteria counts, however, were associated with standing pools formed at the end of collectors for brief periods following the cessation of rainfall and before the runoff percolated into the sand. Consequently, the threat to public health was not considered great enough to warrant closure of the beach.

Groundwater Aquifers

1. Groundwater aquifers that receive deliberate recharge of urban runoff do not appear to be imminently threatened by this practice at the two locations where it was investigated.

   Two NURP projects (Long Island and Fresno) are situated over sole source acquifers. They have been practicing recharge with urban runoff for two decades or more at some sites, and extensively investigated the impact of this practice on the quality of their groundwater. They both found that soil processes are efficient in retaining urban runoff pollutants quite close to the land surface, and concluded that no change in the use of recharge basins is warranted.

   Despite the fact that some of these basins have been in service for relatively long periods of time and pollutant breakthrough of the upper soil

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layers has not occurred, the ability of the soil to continue to retain pollutants is unknown. Further attention to this issue is recommended.

CONTROL EFFECTIVENESS

General

A limited number of techniques for the control of urban runoff quality were evaluated by the NURP program. The set is considerably smaller than previously published lists of potential management practices. Since the control approaches that were investigated were selected at the local level, the choices may be taken as an initial indication of local perceptions regarding practicality and feasibility from the standpoint of implementation.

Conclusions

1. There is a strong preference for detention devices, street sweeping, and recharge devices as reflected by the control measures selected at the local level for detailed investigation. Interest was also shown in grass swales and wetlands.

   Six NURP projects monitored the performance of a total of 14 detention devices. Five separate projects conducted in-depth studies of the effectiveness of street sweeping on the control of urban runoff quality. A total of 17 separate study catchments were involved in this effort. Three NURP projects examined either the potential of recharge devices to reduce discharges of urban runoff to surface waters or the potential of the practice to contaminate groundwaters. A total of 12 separate sites were covered by this effort.

   Grass swales were studied by two NURP projects. Two swales in existing residential areas, and one experimental swale constructed to serve a commercial parking lot were studied.

   A number of NURP projects indicated interest in wetlands for improving urban runoff quality at early stages of the program. Only one allocated monitoring activity to this control measure, however.

   Various other management practices were identified as having local interest by individual NURP projects, but none of them was allocated the necessary resources to be pursued to a point which allowed an evaluation of their ability to control pollution from urban runoff. Management practices in this category included urban housekeeping (e.g., litter programs, catch basin cleaning, pet ordinances) and public information programs.

2. Detention basins are capable of providing very effective removal of pollutants in urban runoff. Both the design concept and the size of the basin in relation to the urban area served have a critical influence on performance capability.

   Wet basins (designs which maintain a permanent water pool) have the greatest performance capabilities. Observed pollutant reductions varied from excellent to very poor in the basins which were monitored. However,

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when basins are adequately sized, particulate removals in excess of 90 percent (TSS, lead) can be obtained. Pollutants with significant soluble fractions in urban runoff show lower reductions; on the order of 65 percent for total P and approximately 50 percent for BOD, COD, TKN, Copper, and Zinc. Results indicate that biological processes which are operative in the permanent pool produce significant reductions (50 percent or more) in soluble nutrients, nitrate and soluble phosphorus. These performance characteristics are indicated by both the NURP analysis results and conclusions reached by individual projects.

Dry basins, (conventional stormwater management basins), which are designed to attenuate peak runoff rates and hence only very briefly detain portions of flow from the larger storms, are indicated by NURP data to be essentially ineffective for reducing pollutant loads.

Dual-purpose basins (conventional dry basins with modified outlet structures which significantly extend detention time) are suggested by limited NURP data to provide effective reductions in urban runoff loads. Performance may approach that of wet ponds; however, the additional processes which reduce soluble nutrient forms do not appear to be operative in these basins. This design concept is particularly promising because it represents a cost effective approach to combining flood control and runoff quality control and because of the potential for converting existing conventional stormwater management ponds.

Approximate costs of wet pond designs are estimated to be in the order of $500 to $1500 per acre of urban area served, for on-site applications serving relatively small urban areas, and about $100 to $250 per acre of urban area for off-site applications serving relatively large urban areas. The costs reflect present value amounts which include both capital and operating costs. The difference is due to an economy of scale associated with large basin volumes. The range reflects differences in size required to produce particulate removals in the order of 50 percent or 90 percent. Annual costs per acre of urban area served are estimated at $60 to $175, and $10 to $25 respectively.

3. Recharge Devices are capable of providing very effective control of urban runoff pollutant discharges to surface waters. Although continued attention is warranted, present evidence does not indicate that significant groundwater contamination will result from this practice.

Both individual project results and NURP screening analyses indicate that adequately sized recharge devices are capable of providing high levels of reduction in direct discharges of urban runoff to surface waters. The level of performance will depend on both the size of the unit and the soil permeability.

Application will be restricted to areas where conditions are favorable. Soil type, depth to groundwater, land slopes, and proximity of water supply wells will all influence the appropriateness of this control technique.

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Surface accumulations which result from the high efficiency of soils to retain pollutants, suggest further attention in applications where dual purpose recharge areas also serve as recreational fields or playground areas.

4. Street sweeping is generally ineffective as a technique for improving the quality of urban runoff.

Five NURP projects evaluated street sweeping as a management practice to control pollutants in urban runoff. Four of these projects concluded that street sweeping was not effective for this purpose. The fifth, which had pronounced wet and dry seasons, believed that sweeping just prior to the rainy season could produce some benefit in terms of reduced pollution in urban runoff.

A large data base on the quality of urban runoff from street sweeping test sites was obtained. At 10 study sites selected for detailed analysis, a total of 381 storm events were monitored under control conditions, and an additional 277 events during periods when street sweeping operations were in effect. Analysis of these data indicated that no significant reductions in pollutant concentrations in urban runoff were produced by street sweeping.

There may be special cases in which street cleaning applied at restricted locations or times of year could provide improvements in urban runoff quality. Some examples that have been suggested, though not demonstrated by the NURP program, include periods following snow melt or leaf fall, or urban neighborhoods where the general level of cleanliness could be significantly improved.

5. Grass swales can provide moderate improvements in urban runoff quality. Design conditions are important. Additional study could significantly enhance the performance capabilities of swales.

Concentration reductions of about 50 percent for heavy metals, and 25 percent for COD, nitrate, and ammonia were observed in one of the swales studied. However the swale was ineffective in reducing concentrations of organic nitrogen, phosphorus, or bacterial species. Two other swales studied failed to demonstrate any quality improvements in the urban runoff passing through them.

Evaluations by the NURP projects involved concluded, however, that this was an attractive control technique whose performance could be improved substantially by application of appropriate design considerations. Additional study to develop such information was recommended.

Design considerations cited included slope, vegetation type and maintenance, control of flow velocity and residence time, and enhancement of infiltration. The latter factor could produce load reductions greater than those inferred from concentration changes and effect reductions in those pollutant species which are not attenuated by flow through the swale.

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6. Wetlands are considered to be a promising technique for control of urban runoff quality. However, neither performance characteristics nor design characteristics in relation to performance were developed by NURP.

   Although a number of projects indicated interest, only one assigned NURP monitoring activity to a wetland. This was a natural wetland, and flows passing though it were uncontrolled. Results suggest its potential to improve quality, but the investigation was not adequate to associate necessary design factors to performance capability. Additional attention to this control technique would be useful, and should include factors such as the need for maintenance harvesting to prevent constituent recycling.

ISSUES

A number of issues with respect to managing and controlling urban runoff emerge from the conclusions summarized above. In some instances they represent the need for additional data/information or for further study. In others they point to the need for follow-up activity by EPA, State, or local officials to assemble and disseminate what is already known regarding water quality problems caused by urban runoff and solutions.

Sediments

The nature and scope of the potential long-term threat posed by nutrient and toxic pollutant accumulation in the sediments of urban lakes and streams requires further study. A related issue is the safe and environmentally sound disposal of sediments collected in detention basins used to control urban runoff.

Priority Pollutants

NURP clearly demonstrated that many priority pollutants can be found in urban runoff and noted that a serious human health risk could exist when water supply intakes are in close proximity to urban stormwater discharges. However, questions related to the sources, fate, and transport mechanisms of priority pollutants borne by urban runoff and their frequencies of occurrence will require further study.

Rainfall pH Effects

The relationship between pH and heavy metal values in urban runoff has not been established and needs further study. Several NURP projects (mostly in the northeastern states) attributed high heavy metals concentrations in urban runoff to the effects of acid rain. Although it is quite plausible that acid rain increases the level of pollutants in urban runoff and may transform them to more toxic and more easily assimilated forms, further study is required to support this speculation.

Industrial Runoff

No truly industrial sites (as opposed to industrial parks) were included in any of the NURP projects. A very limited body of data suggests, however, that runoff from industrial sites may have significantly higher contaminant

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levels than runoff from other urban land use sites, and this issue should be investigated further.

Central Business Districts

Data on the characteristics of urban runoff from central business districts are quite limited as opposed to other land use categories investigated by NURP. The data do suggest, however, that some sites may produce pollutant concentrations in runoff that are significantly higher than those from other sites in a given urban area. When combined with their typically high degrees of imperviousness, the pollutant loads from central business districts can be quite high indeed. The opportunities for control in central business districts are quite limited, however.

Physical Effects

Several projects concluded that the physical impacts of urban runoff upon receiving waters have received too little attention and, in some cases, are more important determinants of beneficial use attainment than chemical pollutants. This contention requires much more detailed documentation.

Synergy

NURP did not evaluate the synergistic effects that might result from pollutant concentrations experienced in stormwater runoff, in association with pH and temperature ranges that occur in the receiving waters. This type of investigation might reveal that control of a specific parameter, such as pH, would adequately reduce an adverse synergistic effect caused by the presence of other pollutants in combination and be the most cost effective solution. Further investigations should include this issue.

Opportunities for Control

Based upon the results of NURP's evaluation of the performance of urban runoff controls, opportunities for significant control of urban runoff quality are much greater for newly developing areas. Institutional considerations and availability of space are the key factors. Guidance on this issue in a form useful to States and urban planning authorities should be prepared and issued.

Wet Weather Water Quality Standards

The NURP experience suggests that EPA should evaluate the possible need to develop "wet weather" standards, criteria, or modifications to ambient criteria to reflect differences in impact due to the intermittent, short duration exposures characteristic of urban runoff and other nonpoint source discharges.

Coliform Bacteria

The appropriateness of using coliform bacteria as indicator organisms for human health risk where the source is exclusively urban runoff warrants further investigation.

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Wetlands

The use of wetlands as a control measure is of great interest in many areas, but the necessary information on design performance relationships required before cost effective applications can be considered has not been adequately documented. The environmental impacts of such use upon wetlands is a critical issue which, at present, has been addressed marginally, if at all.

Swales

The use of grass swales was suggested by two NURP projects to represent a very promising control opportunity. However, their performance is very dependent upon design features about which information is lacking. Further work to address this deficiency and appropriate maintenance practices appears warranted.

Illicit Connections

A number of the NURP projects identified what appeared to be illicit connections of sanitary discharges to stormwater sewer systems, resulting in high bacterial counts and dangers to public health. The costs and complications of locating and eliminating such connections may pose a substantial problem in urban areas, but the opportunities for dramatic improvement in the quality of urban stormwater discharges certainly exist where this can be accomplished. Although not emphasized in the NURP effort, other than to assure that the selected monitoring sites were free from sanitary sewage contamination, this BMP is clearly a desirable one to pursue.

Erosion Controls

NURP did not consider conventional erosion control measures because the information base concerning them was considered to be adequate. They are effective, and their use should be encouraged.

Combined Sewer Overflows

In order to address urban runoff from separate storm sewers, NURP avoided any sites where combined sewers existed. However, in view of their relative levels of contamination, priority should be given to control of combined sewer overflows.

Implementation Guidance

The NURP studies have greatly increased our knowledge of the characteristics of urban runoff, its effects upon designated uses, and of the performance efficiencies of selected control measures. They have also confirmed earlier impressions that some States and local communities have actually begun to develop and implement stormwater management programs incorporating water quality objectives. However, such management initiatives are, at present, scattered and localized. The experience gained from such efforts is both needed and sought after by many other States and localities. Documentation,

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evaluation, refinement and transfer of management and financing mechanisms/ arrangements, of simple and reliable problem assessment methodologies, and of implementation guidance which can be used by planners and officials at the State and local level are urgently needed as is a forum for the sharing of experiences by those already involved, both among themselves and with those who are about to address nonpoint source issues.

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California Regional Water Quality Control Board
Santa Ana Region

ORDER NO. 90-71

NPDES No. CA 8000180

Waste Discharge Requirements
for
the County of Orange, the Orange County Flood Control District
and
the Incorporated Cities of Orange County Within the Santa Ana Region
Areawide Urban Stormwater Runoff
Orange County

The California Regional Water Quality Control Board, Santa Ana Region (hereinafter Regional Board), finds that:

1. On March 15, 1990, the County of Orange and the Orange County Flood Control District (OCFCD), in cooperation with the cities of Anaheim, Brea, Buena Park, Costa Mesa, Cypress, Fountain Valley, Fullerton, Garden Grove, Huntington Beach, Irvine, La Habra, La Palma, Los Alamitos, Newport Beach, Orange, Placentia, Santa Ana, Seal Beach, Stanton, Tustin, Villa Park, Westminster, and Yorba Linda (hereinafter collectively referred to as dischargers), submitted NPDES Application No. CA 8000180 for an areawide stormwater discharge permit under the National Pollutant Discharge Elimination System (NPDES).

2. The 1972 Clean Water Act (CWA) recognized the need to prohibit the discharge of pollutants to surface water bodies from point sources such as industrial facilities and municipal sewage treatment plants. The discharges of pollutants from point sources are regulated by the NPDES permit system, which required technology-based controls for treatment of wastewater. Stormwater point source discharges were exempt from the NPDES permitting requirements unless these discharges were contaminated by industrial/commercial activity. The Regional Board recognized the water quality problems associated with stormwater discharges from industrial facilities and has issued a number of stormwater permits for such facilities in accordance with the EPA regulations.

3. In 1976, the United States Environmental Protection Agency (EPA) issued new regulations establishing a comprehensive permitting program for all stormwater discharges except for rural runoff uncontaminated by industrial/commercial activity. Channelized stormwater runoff from rural areas continued to be defined as nonpoint source unless designated otherwise by the permitting authority.

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4. Since 1976, EPA has issued several revisions to the stormwater regulations. Section 405 of the Water Quality Act (WQA) of 1987 added Section 402(p) to the CWA. Pursuant to Section 402(p)(4) of the CWA, EPA is required to promulgate regulations for stormwater permit applications for stormwater discharges associated with industrial activities and municipal separate storm drain systems serving a population of 100,000 or more. Section 402 (p)(4) of the CWA also requires dischargers of stormwater associated with industrial activities and municipal separate storm drain systems serving a population of 250,000 or more to file stormwater permit applications by February 4, 1990.

5. On December 7, 1988, EPA published its proposed regulations in the Federal Register to solicit public comments. Final regulations are tentatively scheduled to be promulgated on July 20, 1990 and to be published in the Federal Register on August 4, 1990. In the absence of final stormwater regulations, a permit governing municipal stormwater discharges should meet both the statutory requirements of Section 402 (p)(3)(B) and all requirements applicable to a NPDES permit issued under the issuing authority's discretionary authority in accordance with Section 402 (a)(1)(B) of the CWA.

6. Studies in urban areas have shown that urban runoff typically contains significant quantities of pollutants. There are a number of water quality segments in the Orange County drainage areas which could be adversely impacted by stormwater discharges and urban runoff. In some areas, such as Newport Bay, the beneficial uses have been impaired due to pollutant discharges. A comprehensive stormwater and urban runoff management and regulatory program is essential for the protection of the water resources of the Region. The County of Orange, the cities in Orange County, and the Regional Board have recognized this fact, and as a first step towards protecting water quality in the area, a comprehensive management program is being developed. This order outlines the existing programs and specifies additional requirements to achieve water quality objectives for the Orange County drainage areas. The intent of this permit is to regulate pollutant discharges and improve water quality in the Region in a timely manner.

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7. Within the Santa Ana Region, the OCFCD serves a population of approximately 2.0 million, occupying an area of approximately 511 square miles (approximately 128 square miles of unincorporated areas and 383 square miles of incorporated areas). The District's systems include an estimated 400 miles of storm drain systems. A major portion of the urbanized areas of Orange County drains into water bodies within this Regional Board's jurisdiction. The project area is shown on Attachment "A". The major storm drain systems and drainage areas in Orange County which are within this Region are shown on Attachment "B". A portion of the Orange County drainage area is within the jurisdiction of the San Diego Regional Board and is regulated under Order No. 90-38, NPDES No. CA 0108740, issued by the San Diego Regional Board.

8. The discharges consist of surface runoff generated from various land uses in all the hydrologic drainage areas which discharge into water bodies in Orange County. The quality of these discharges varies considerably and is affected by land use activities, basin hydrology and geology, season, the frequency and duration of storm events, and the presence of illegal disposal practices/illicit connections. The constituents of concern and significance in these discharges are: total and fecal coliform, enterococcus, total suspended solids, biochemical oxygen demand (BOD), chemical oxygen demand (COD), total organic carbon (TOC), oil and grease, heavy metals, nutrients, base/neutral and acid extractibles, pesticides, herbicides, petroleum hydrocarbon components, and pH.

9. There are several entities whose land/facilities drain into the Orange County storm drain systems. The County of Orange has control over a large portion of the storm drain systems and has agreed to be the major responsible party in implementing the provisions of this order. The incorporated cities within the county have also agreed to cooperate with the county in controlling and improving the quality of urban runoff from their respective areas. The County of Orange has been named as the "principal permittee" and the OCFCD and the incorporated cities have been named as "co-permittees". Attachment "C" lists the incorporated cities with their 1990 estimated populations. Of the 23 cities listed, there are seven cities with an estimated 1990 population of over 100,000.

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10. Due to the enormous variability in stormwater quality and the complexity of the urban runoff management program, this areawide stormwater permit is categorized as a major NPDES permit. This areawide stormwater permit requires all entities discharging stormwater/urban runoff into the storm drain systems or any surface water bodies to have appropriate controls for proper management of stormwater runoff. The Regional Board has the discretion and authority to require non-cooperating entities to participate in this areawide permit or obtain individual stormwater discharge permits, pursuant to 40 CFR 122.26(a). The entities listed in Attachment "D" are considered as potential dischargers of stormwater to the Orange County drainage areas. It is expected that these entities will also work cooperatively with the County of Orange to manage urban stormwater runoff.

11. The County of Orange, as the "principal permittee", will obtain the cooperation of all entities in implementing the provisions of this order. The dischargers have agreed upon the responsibilities as outlined in the draft May 16, 1990 Implementation Agreement. In general, the County of Orange, the "principal permittee", will be responsible for preparing operating budgets, preparing and monitoring the implementation programs, and coordinating and submitting reports to the Regional Board. The OCFCD and the incorporated cities, the "co-permittees", will develop site-specific compliance requirements, perform compliance monitoring and inspections, submit storm drain maps and compliance reports to the County of Orange, and exercise enforcement authority for achieving compliance.

12. The County of Orange obtains its authority to control pollutants in stormwater discharges, to prohibit illegal discharges/illicit connections, to control spills, and to require compliance and carry out inspections of the storm drain systems in the County of Orange from the Orange County Flood Control Act, Orange County Water Pollution Ordinance, and various county ordinances which address industrial wastes and waste discharges within the unincorporated areas of Orange County and contract cities. The "Co-Permittees" have various forms of legal authority in place, such as charters, State Code provisions for General Law cities, city ordinances, and applicable portions of municipal codes and the State Water Code, to regulate stormwater/urban runoff discharges.

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13. A Water Quality Control Plan was adopted by the Regional Board on May 13, 1983. The Plan contains water quality objectives and beneficial uses of waters in the Santa Ana Region. On July 14, 1989, the Regional Board adopted a Basin Plan amendment, incorporating revised beneficial use designations for the ground and surface waters of the Region.

14. The State Water Resources Control Board (State Board) adopted a Water Quality Control Policy for the Enclosed Bays and Estuaries of California on May 16, 1974. The policy provides that the discharge of industrial process waters to enclosed bays and estuaries shall be prohibited. Stormwater and urban runoff are not considered industrial process waters for the purpose of that policy.

15. The 1988 California Ocean Plan, as amended on March 22, 1990, contains revised water quality objectives for California ocean waters in accordance with Section 303(c)(I) of the Clean Water Act and Section 13170.2(b) of the California Water Code.

16. The requirements contained in this order are necessary to implement the Ocean Plan and the Water Quality Control Plan.

17. An attempt has been made to incorporate all of the essential elements of the proposed federal stormwater regulations in this permit.

18. Stormwater discharges to the storm drain systems in Orange County are tributary to various water bodies of the state. The identified water bodies are as follows:

Inland Surface Streams

a. Santa Ana River[1], Reaches 1 and 2,

b. Silverado Creek,

c. Santiago Creek, Reaches 1, 2, 3, and 4,

d. San Diego Creek, Reaches 1 and 2,

e. San Joaquin Freshwater Marsh,

[1] Stormwater/urban runoff discharged from the storm drain systems operated by the Counties of San Bernardino and Riverside drain into the Santa Ana River at Reaches 3, 4, 5, and 6.

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18. (cont'd)

f. All other tributaries to these Creeks: Bonita Creek, Serrano Creek, Peters Canyon Wash, Hicks Canyon Wash, Bee Canyon Wash, Borrego Canyon Wash, Agua Chinon Wash, Laguna Canyon Wash, Rattlesnake Canyon Wash, Sand Canyon Wash

Bay, Estuaries, and Tidal Prisms

g. Anaheim Bay,

h. Sunset Bay,

i. Bolsa Bay,

j. Lower and Upper Newport Bay,

k. Tidal Prism of Santa Ana River (to within 1000 feet of Victoria Street) and Newport Slough,

l. Tidal Prism of San Gabriel River (River Mouth to Marina Drive),

m. Tidal Prisms of Flood Control Channels Discharging to Coastal or Bay Waters (e.g. Huntington Harbour)

Ocean Waters

Nearshore Zone

n. San Gabriel River to Poppy Street in Corona Del Mar,

o. Poppy Street to Southeast Regional Boundary,

Offshore Zone

p. Waters between Nearshore Zone and Limit of State Waters,

Lakes and Reservoirs

q. Anaheim Lake,

r. Irvine Lake (Santiago Reservoir)

s. Laguna, Lambert, Peters Canyon, Rattlesnake, Sand Canyon, and Siphon Reservoirs.

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18. (cont'd)

The beneficial uses of these water bodies include municipal and domestic supply (MUN), agricultural supply (AGR), industrial service supply (IND), groundwater recharge, navigation (NAV), water contact recreation (REC-1), non-contact water recreation (REC-2), ocean commercial and nonfreshwater sportfishing (COMM), warm freshwater habitat (WARM), cold freshwater habitat (COLD), preservation of areas of biological significance (BIOL), wildlife habitat (WILD), preservation of rare and endangered species (RARE), marine habitat (MAR), and shellfish harvesting (SHELL). The beneficial uses of individual water bodies are shown on Attachment "E".

19. Numeric and narrative water quality standards exist for these water bodies. Currently, this permit does not contain numeric limitations for any constituents because the impact of stormwater discharges on the water quality of the above named receiving waters has not been fully determined. Extensive water quality monitoring and analysis of the data are essential to make that determination. This order requires the dischargers to continue to monitor the stormwater discharges or begin monitoring as necessary, and to analyze the data. Additionally, the order also requires development and implementation of best management practices[2] (BMPs) in accordance with the WQA of 1987. It is anticipated that with the implementation of BMPs by the dischargers, the pollutants in the stormwater runoff will be reduced and the quality of the receiving waters will be improved. The ultimate goal of the urban stormwater runoff management program is to attain water quality consistent with the water quality objectives for the receiving waters to protect the beneficial uses.

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[2] Best Management Practices (BMPs) are water quality management practices that are maximized in efficiency for the control of stormwater runoff pollution.

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20. The County of Orange has an active surface water quality monitoring program in the permit area. Dry weather sampling is performed bimonthly and wet weather sampling is performed during significant storm events (>0.5 inches of rainfall). Stormwater runoff samples collected are analyzed for nutrients, trace metals, specific conductance, dissolved oxygen, temperature, and pH. Sediment samples are also collected and analyzed for radiochemical constituents (only at Huntington Harbour), organics, and trace metals on a semi-annual basis. This monitoring program includes 21 water quality monitoring stations, 17 water level stations (12 of which are stream gaging stations), and 31 precipitation stations. Most of the water quality monitoring stations are located at storm drain systems associated with drainage areas in which land use activities have been identified to significantly impact the beneficial uses of waters in Orange County. These drainage areas, characterized as agricultural, commercial, and industrial, are mainly located upstream of Newport Bay. Those pollutants that have been identified to cause significant threat to the water quality of Newport Bay include nutrients (especially nitrates), pesticides, herbicides, and suspended solids.

21. With respect to industrial activities, the Regional Board currently regulates discharges of point source process wastewater and non-process wastewater and stormwater to storm drain systems through NPDES permits. The Regional Board is proposing to regulate three major nurseries discharging irrigation tail water to San Diego Creek by issuing waste discharge requirements. Point source discharges including stormwater will continue to be regulated by the Regional Board. Industrial stormwater dischargers are required to cooperate with the County of Orange to control the discharge of pollutants in the stormwater runoff from individual facilities or to obtain individual industrial stormwater discharge permits from the Regional Board.

22. Recognizing the need for public involvement and participation in the development and implementation of an effective stormwater/urban runoff management program, the Regional Board will conduct at least one workshop each year during the term of this permit. The purposes of the workshops will be to solicit comments and to inform the public of the progress of the program. Written comments submitted will be forwarded to the State Board, EPA, and the County of Orange for their review and comments.

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23. In accordance with California Water Code Section 13389, the issuance of waste discharge requirements for this discharge is exempt from those provisions of the California Environmental Quality Act contained in Chapter 3 (commencing with Section 21100), Division 13 of the Public Resources Code.

24. The Regional Board has considered an antidegradation analysis, pursuant to 40 CFR 131.12 and State Board Resolution No. 68-16, for this discharge. The Regional Board finds that the stormwater discharges are consistent with the federal and state antidegradation requirements and a complete antidegradation analysis is not necessary.

25. The Regional Board has notified the dischargers and interested agencies and persons of its intent to issue waste discharge requirements for this discharge and has provided them with an opportunity to submit their written views and recommendations.

26. The Regional Board, in a public hearing, heard and considered all comments pertaining to the discharge and to the tentative requirements.

IT IS HEREBY ORDERED that the dischargers, in order to meet the provisions contained in Division 7 of the California Water Code and regulations adopted thereunder, and the provisions of the Clean Water Act, as amended, and regulations and guidelines adopted thereunder, shall comply with the following:

I. RESPONSIBILITIES OF PRINCIPAL PERMITTEE

The principal permittee shall be responsible for the overall program management, including the following:

1. Administer the Orange County Water Pollution Ordinance.

2. Conduct water quality and hydrographic monitoring of the storm drain system outfalls as agreed upon by the Executive Officer.

3. Develop uniform criteria for storm drain system inspections.

4. Conduct inspections of the storm drain systems within its jurisdiction.

5. Implement management programs, monitoring programs, and implementation plans within its jurisdiction as required by this order.

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I. RESPONSIBILITIES OF PRINCIPAL PERMITTEE - CONT'D

6. Prepare and submit to the Regional Board all the reports, plans, and programs as required in this order.

7. Monitor the implementation of the plans and programs and determine their effectiveness in attaining water quality objectives.

8. Coordinate all the activities with the Regional Board.

9. Enact legislation and ordinances as necessary to establish legal authority.

10. Obtain public input[3] for any proposed management and implementation plans.

11. Pursue enforcement actions as necessary to ensure compliance with stormwater management programs and implementation plans.

12. Respond to emergency situations such as accidental spills, leaks, illegal discharges/illicit connections etc. to prevent or reduce the discharge of pollutants to storm drain systems and waters of the United States.

II. RESPONSIBILITIES OF THE CO-PERMITTEES

The co-permittees shall be responsible for the management of storm drain systems within their jurisdictions, including the following:

1. Conduct storm drain system inspections in accordance with the uniform criteria developed by the principal permittee.

2. Conduct and coordinate with the principal permittee any surveys and characterizations needed to identify the pollutant sources and drainage areas.

3. Review and approve management programs, monitoring programs, and implementation plans.

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[3] Public input is demonstrated by: (1) disseminating the notice of availability of plans for review and comment to the public at large, environmental groups, federal, state and local agencies and other interested parties; and, (2) addressing concerns expressed by the public.

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II. RESPONSIBILITIES OF THE CO-PERMITTEES - CONT'D

4. Implement management programs, monitoring programs, and implementation plans within each respective jurisdiction as required by this order.

5. Submit storm drain system maps with periodic revisions as necessary.

6. Prepare and submit all reports to the principal permittee in a timely manner.

7. Enact legislation and ordinances as necessary to establish legal authority.

8. Pursue enforcement actions as necessary to ensure compliance with the stormwater management programs and the implementation plans.

9. Respond to emergency situations such as accidental spills, leaks, illegal discharges/illicit connections, etc. to prevent or reduce the discharge of pollutants to storm drain systems and waters of the United States.

III. GENERAL REQUIREMENTS

1. The dischargers shall prohibit illegal discharges from entering into the municipal storm drain systems. Discharges conditionally allowed to enter storm drain systems are specified in Item V.6.

2. The dischargers shall develop and implement best management practices (BMPs) to control discharge of pollutants to the maximum extent practicable[4] to waters of the United States. The BMPs so developed, along with a time schedule for implementation, shall be submitted for the approval of and/or modification by the Executive Officer of the Regional Board. In developing the best management practices, the dischargers shall consider the water quality objectives of all the receiving water bodies.

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[4] Maximum Extent Practicable (MEP) means to the maximum extent possible, taking into account equitable considerations of synergistic, additive, and competing factors, including but not limited to, gravity of the problem, fiscal feasibility, public health risks, societal concern, and social benefits.

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IV. COMPILATION AND SUBMITTAL OF EXISTING DATA

1. Runoff Quality/Quantity

The dischargers shall collectively submit all quantitative information, generated since 1980 or earlier where better information exists, on stormwater discharges to the storm drain systems. This information will be used to facilitate the identification of sources of pollutants present in the stormwater discharges and to develop an effective discharge monitoring program for this order. Information to be submitted shall include the following:

a. Any historical averages and extremes data for stormwater discharges;

b. Analytical and flow data for stormwater samples collected from the storm drain system outfalls, and within any waters of the United States;

c. Precipitation data from the precipitation stations and the duration of the storm events (if available);

d. Discharge data from the storm drain systems as determined from the gaging stations;

e. Analysis of the data and the major pollutants identified in the stormwater discharges from each drainage area to each receiving water body and a determination whether the identified pollutants came from non-point source or point-source discharges.

2. System/Drainage Area Characterization

The dischargers shall submit information to the Regional Board for identification and characterization of the sources of pollutants in the stormwater discharges. The following information shall be provided:

a. An identification of all land use activities in each drainage area and a map showing various land use activities and storm drain systems in each drainage area.

b. An identification of the drainage areas, more than 50 acres in size, that discharge stormwater to the storm drain systems and of those drainage areas that discharge to storm drain systems with pipe diameters greater than 36 inches.

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IV. COMPILATION AND SUBMITTAL OF EXISTING DATA - CONT'D

c. The sizes of these drainage areas (acreage) and the sizes (pipe diameters or approximate dimensions of the storm drain systems) and physical characteristics of the storm drain systems. These physical characteristics shall include, but not be limited to, whether the storm drain system is lined or unlined and whether it has intermittent or continuous flow;

d. The names, locations, and Standard Industrial Codes (SIC) of specific industrial sources and principal land use activities in each drainage area, identified in IV.2.a., above, discharging to the storm drain systems. An estimate of the runoff coefficients for these drainage areas shall also be provided;

e. The locations of present storm drain outfalls discharging to waters of the United States. The name of each receiving water body shall be reported and the location of each outfall shall be indicated on a map;

f. The locations of major structural controls for stormwater discharge (e.g. retention basins, detention basins, etc).

3. Illegal Discharges/Illicit Connections

a. The dischargers shall provide a list of dischargers (permitted and unpermitted) known to exist currently who discharge process or non-process wastewater to the storm drain systems. The dischargers shall also provide any existing procedures used for detecting illegal discharges/illicit connections to the storm drain systems, the rationale for the procedures, and the drainage areas (or cities) in which these programs are practiced; and

b. A description of the present and historic use of ordinances or other controls to prohibit the illegal discharges/illicit connections to storm drain systems;

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IV. COMPILATION AND SUBMITTAL OF EXISTING DATA - CONT'D

4. Stormwater Management Program

A description of the existing stormwater/urban runoff management programs and structural and non-structural BMPs implemented by the dischargers.

5. Stormwater/Urban Runoff Monitoring Program

A description of the existing monitoring programs and the rationale for their selection.

6. Pollutant Information

The dischargers shall provide information regarding the discharge of any pollutant required under 40 CFR 122.21(g)(7)(iii) and (iv).

7. Other Pertinent Existing Information

The dischargers shall provide to the Regional Board any other existing information that is pertinent to this permit. For example, a description of drainage area hydrologic parameters.

V. RECONNAISSANCE SURVEY

1. The dischargers shall submit information from a reconnaissance survey to be conducted at the storm drain systems. The purpose of the survey is to identify illegal discharges/illicit connections to the storm drain systems. The reconnaissance survey field manual and implementation plan for prosecuting violators and eliminating illegal discharges so developed, along with time schedules for implementation, shall be submitted for the approval of and/or modification by the Executive Officer of the Regional Board.

2. By January 31, 1991, a proposed reconnaissance survey field manual, including a time schedule, shall be submitted for approval and/or modification by the Executive Officer of the Regional Board.

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V. RECONNAISSANCE SURVEY - CONT'D

3. The discharger shall implement the reconnaissance survey field manual after consideration of public comments and approval/modification of the manual by the Executive Officer of the Regional Board. By January 31, 1992 and every year thereafter, until the completion of the survey, a progress report containing the following information shall be submitted:

   a. Results of the reconnaissance survey, including an analysis of the results.

   b. Additional information that would lead to isolating and identifying sources of illegal discharges/illicit connections to the storm drain systems. Such information should include, but is not limited to, visual observations (e.g. color, turbidity, odor, etc), major land use activities in the surrounding drainage areas, seasonal change of flow, the surrounding hydrogeologic formation, etc.

   c. A listing of any identified or suspected illegal dischargers including the names, locations, and types of the facilities and the names of the storm drain systems and receiving waters the illegal discharges are discharged to.

   d. A listing of large industrial facilities (with more than 100 employees) where hazardous/toxic substances are stored and/or used, landfills, hazardous waste disposal, treatment, and/or recovery facilities, and any known spills, leaks or other problems in the area.

   e. A discussion on all activities, related to the survey, conducted for the past 12 months.

4. By January 31, 1992, the dischargers shall submit a proposed implementation plan, including a tentative time schedule, to prosecute violators and eliminate such discharges to the storm drain systems. The proposed plan shall also include a description of the legal authorities for prosecuting violators and eliminate or control illicit disposal practices/illegal discharges to the storm drain systems, and a proposed time schedule for obtaining such legal authorities, if necessary.

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V. RECONNAISSANCE SURVEY - CONT'D

5. The dischargers shall implement the program for prosecuting violators and eliminate illegal discharges to the storm drain systems after consideration of public comments and approval/modification of the program by the Executive Officer of the Regional Board. By January 31, 1993 and every year thereafter, the discharger shall submit a progress report evaluating the effectiveness of the plan in detecting and eliminating illegal discharges/illicit connections to the storm drain systems.

6. The permittees shall effectively eliminate all identified illegal discharges/illicit connections in the shortest time practicable, and in no case later than July 1, 1995. Those illegal discharges/illicit connections identified after July 1, 1995 shall be eliminated in the shortest time practicable. The following discharges shall not be considered illegal discharges provided the discharges do not cause or contribute to violations of water quality standards and are not significant contributors of pollutants to waters of the United States: discharges composed entirely of stormwater, discharges covered under NPDES permits or waivers/clearances, discharges to storm drain systems form potable water line flushing, fire fighting, landscape irrigation, diverted stream flows, rising groundwaters (not including active dewatering systems), groundwater infiltration as defined at 40 CFR 35.2005(20), discharges from potable water sources, passive foundation drains (not including active groundwater dewatering), air conditioning condensation, irrigation water, water from crawl space pumps, passive footing drains (not including active groundwater dewatering systems), lawn watering, individual residential vehicle washing, flows from riparian habitats and wetlands, dechlorinated swimming pool discharges, street wash waters related to cleaning and maintenance by permittees, or waters not otherwise containing wastes as defined in California Water Code Section 13050 (d). If it is determined that any of the preceding discharges cause or contribute to violations of water quality standards or are significant contributors of pollutants to waters of the United States, the permittees shall prohibit these discharges from entering storm drain systems.

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VI. DRAINAGE AREA MANAGEMENT PROGRAM

1. The dischargers shall develop and implement best management practices (BMPs) to control the discharge of pollutants to waters of the United States. The discharger shall submit information pertaining to the proposed stormwater system management programs for approval of and/or modification by the Executive Officer of the Regional Board. The information shall include, but need not be limited to, the following:

   a. A brief description of the existing BMPs and other stormwater system management programs.

   b. Proposed modifications to the existing BMPs and other stormwater system management program to reduce pollutants in the stormwater discharges from industrial, commercial, and residential areas to the maximum extent practicable. At a minimum, the following shall be considered in developing the BMPs:

      Structural Controls

      i. For the permitted area, wherever appriopriate, structural controls such as first flush diversion, detention/retention basins, infiltration trenches/basins, porous pavement, oil/grease separators, grass swales, wire concentrators, etc.

      Non-Structural Controls

      ii. Education programs to educate the public on proper disposal of hazardous/toxic wastes. These may include public workshops, meetings, notifications by mail, collection programs for household hazardous wastes, etc.

      iii. Management practices such as street sweeping, proper maintenance of streambanks, erosion control structures, etc.

      iv. Regulatory approaches such as county and local ordinances, permitting of construction sites, etc.

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VI. DRAINAGE AREA MANAGEMENT PROGRAM - CONT'D

v. Enforcement programs, established by the county and cities, including response to emergency incidents, field inspections, **and identification and elimination of illegal discharges/illicit connections to the storm drain systems.**

c. An implementation plan for site-specific BMPs which are required to reduce pollutants in the stormwater discharges from residential, commercial and industrial areas, and construction sites. Requirements for the implementation of BMPs at these sites are described below:

i. New Construction Sites

Runoff from construction sites has the potential to adversely impact the quality of waters of the United States. A full range of structural and non-structural BMPs shall be required at new construction sites. All industrial/commercial construction operations that result in a disturbance of one acre or more of total land area (or a smaller parcel of land which is a part of a larger common development) and residential construction sites that result in a disturbance of five acres or more of total land area (or a smaller parcel of land which is a part of a larger common development) shall be required to develop and implement BMPs, **including a long term funding mechanism and commitment to support required maintenance of the BMPs,** to control erosion/siltation and contaminated runoff from the construction sites.

ii. Residential and Commercial/Industrial Sites

Numerous studies have shown that runoff from residential and commercial/industrial areas has contributed a number of pollutants into waters of the United States. As development progresses, the percentage of paved surface increases, the rate of runoff increases, and the amount of pollutants in the runoff also increases. To prevent the increase of pollutants in the stormwater discharges, all new developments and existing facilities with

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VI. DRAINAGE AREA MANAGEMENT PROGRAM - CONT'D

ii. Residential and Commercial/Industrial Sites - (cont'd)

significant redevelopment, irrespective of their size, must develop individual comprehensive, long-term, post construction stormwater management plans, incorporating the structural and non-structural BMPs. These management plans shall include a long term funding mechanism and commitment to support required maintenance of the BMPs.

d. A description of the legal authorities for implementing the programs, and a proposed time schedule for obtaining such legal authorities, if necessary.

e. A description of staff, equipment, and funds available to implement the programs.

2. By July 31, 1991, the BMPs and other stormwater system management program so developed, along with a time schedule for implementation, shall be submitted for the approval of and/or modification by the Executive Officer of the Regional Board.

3. The dischargers shall implement the BMPs and other stormwater management programs after consideration of public comments and approval/modification of the programs by the Executive Officer of the Regional Board. By July 31, 1992 and every year thereafter, the dischargers shall submit a progress report assessing the reduction of pollutants discharged to waters of the United States and to evaluate the effectiveness of the BMPs developed for the stormwater discharges. The dischargers shall also include recommended BMP modifications, with a time schedule for implementation, needed to achieve compliance with any water quality objectives not attained.

VII. STORMWATER SYSTEM MONITORING PROGRAM

1. The discharger shall submit a stormwater system monitoring program for approval of and/or modification by the Executive Officer. The objectives of the stormwater system monitoring program are:

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VII. STORMWATER SYSTEM MONITORING PROGRAM - CONT'D

a. To define the type, magnitude (concentration and mass load), and sources of pollutants in the stormwater system discharges within each permittee's respective jurisdiction so that appropriate pollution prevention and correction measures can be identified;

b. To evaluate the effectiveness of pollution prevention and correction measures; and

c. To evaluate the compliance with water quality objectives established for the stormwater system or its components.

2. At a minimum, the stormwater system monitoring program shall include the following:

a. A brief description of the existing monitoring programs.

b. For both storm and non-storm conditions, sampling of the stormwater system discharges at major and representative outfalls discharging to waters of the United States to determine the pollutant loading rates to each receiving water body listed in Attachment "E".

c. For both storm and non-storm conditions, a description of the number of monitoring stations, the locations of these monitoring stations, and the rationale for their selection.

d. For both storm and non-storm conditions, a description of the physical, chemical, and biological parameters selected for analysis, the method of analysis, the type of sampling, and the sampling frequency proposed. The rationale for each of these selections shall be provided.

e. Monitoring of the stormwater system discharges to identify illicit connections shall be conducted.

f. Quality assurance and quality control plans for the stormwater system monitoring program shall be submitted.

g. A data base that consolidates all monitoring information shall be maintained.

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VII. STORMWATER SYSTEM MONITORING PROGRAM - CONT'D

h. A description of the staff, equipment, and funds available to implement the monitoring program shall be provided.

i. A description of the legal authorities for implementing the program, and a proposed time schedule for obtaining such legal authorities (if necessary) shall be provided.

3. By November 30, 1990, the stormwater system monitoring program so developed, along with a time schedule for implementation, shall be submitted for the approval of and modification by the Executive Officer of the Regional Board.

4. The dischargers shall implement the stormwater system monitoring program after consideration of public comments and approval/modification of the program by the Executive Officer of the Regional Board. By November 30, 1991 and every year thereafter, the dischargers shall submit a report on progress towards implementation of the approved stormwater monitoring program.

VIII. RECEIVING WATER MONITORING PROGRAM

1. The discharger shall develop a receiving water monitoring program to assess the effects of pollutants from the stormwater system discharges on receiving water bodies, and to evaluate compliance with water quality objectives of the receiving water bodies. All the water bodies listed in Attachment "E" shall be addressed. The receiving water monitoring program shall be coordinated with the stormwater system monitoring program required under Section VII such that the aforestated objectives of the receiving water monitoring program will be achieved.

2. At a minimum, the receiving water monitoring program shall include the following:

a. A brief description of the existing monitoring programs.

b. A description of the number of monitoring stations, the location of these monitoring stations, and the rationale for their selection.

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VIII. RECEIVING WATER MONITORING PROGRAM - CONT'D

c. A description of the physical, chemical and biological selected for analysis, the type of sampling, and the sampling frequency proposed. The rationale for each of these selections shall be provided.

d. Quality assurance and quality control plans for the receiving water monitoring program.

e. Maintenance of a data base that consolidates all monitoring information. This data base shall be coordinated with the data base required for the stormwater system monitoring program (VII.2.g.).

3. By November 30, 1990, the discharger shall submit a proposed receiving water monitoring program, including a time schedule for implementation, for the approval of and modification by the Executive Officer of the Regional Board.

4. The dischargers shall implement the receiving water monitoring program after consideration of public comments and approval/modification of the program by the Executive Officer of the Regional Board. By November 30, 1991 and every year thereafter, the discharger shall submit a report on progress towards implementation of the approved receiving water monitoring program.

IX. FISCAL ANALYSIS

1. By July 31, 1991 and every year thereafter, a fiscal analysis of the capital and operation and maintenance expenditures necessary to accomplish the activities of the proposed plans and programs shall be performed.

2. By August 31, 1991 and every year thereafter, a fiscal analysis of the capital and operation and maintenance expenditures shall be submitted for review by EPA and the Regional Board.

X. DATA ANALYSIS

1. For the stormwater system monitoring program, the results of the chemical analysis and quantitative data (such as flow, precipitation, and discharge data) shall be compiled for each drainage area, each storm event, and for different times during the same storm event. The mass loading rates for the pollutants of concern shall be calculated.

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X. DATA ANALYSIS - CONT'D

2. An evaluation shall be performed for the calculated mass loading rates from the stormwater system monitoring program and the receiving water monitoring program. Any impact of the discharges from the stormwater systems on the receiving waters shall be discussed, starting with the most significantly impacted receiving water bodies. The evaluation shall be concluded with recommendations and the corrective actions proposed for any resulting discrepancies.

3. By January 31, 1992 and every year thereafter, the analysis of all the above data shall be submitted.

XI. PROGRAM ANALYSIS

1. In January of every year, the principal permittee shall conduct an analysis of the effectiveness of the overall stormwater management program. If the water quality objectives of the receiving waters are violated as a result of stormwater/urban runoff discharges, the principal permittee shall identify proposed programs which will result in the attainment of the water quality objectives, and a time schedule to implement the new programs.

2. By March 31, 1992 and every year thereafter, the analysis of the overall program and any proposed programs, to achieve compliance with water quality objectives of water bodies that have not been attained, shall be submitted.

XII. REPORTING

1. All reports shall be signed by a responsible officer or duly authorized representative of the discharger and shall be submitted to EPA and the Regional Board under penalty of perjury.

2. A signed copy of the Implementation Agreement between the County of Orange, the OCFCD, and the cities shall be submitted by January 31, 1991. Any revisions to the Implementation Agreement shall be forwarded to the Executive Officer within 30 days of approval by all the dischargers.

3. Other reports and information required to be submitted to the Regional Board under the requirements specified above shall be reported in accordance with the following schedule:

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XII. REPORTING - CONT'D.

TASK		COMPLIANCE REPORT DUE
a.	Existing reports and programs IV.1.-IV.7.	01/31/91
b.	Proposed Reconnaissance Survey Field Manual - V.2	01/31/91
c.	Proposed Implementation Plan for Prosecuting Illegal Discharges - V.4.	01/31/92
d.	Management Programs (BMPs) and Implementation Plan - VI.1 & VI.2.	07/31/91
e.	Stormwater System Monitoring Program VII.1. - VII.3.	11/30/90
f.	Receiving Water Monitoring Program VIII.1. - VIII.3.	11/30/90
g.	Progress Reports after Plan Implementation	
	i. Reconnaissance Survey - V.3.	01/31 of every year[5]
	ii. Illegal Discharges - V.5.	01/31 of every year[6]
	iii. Management Programs - VI.3.	07/31 of every year[7]
	iv. Stormwater System Monitoring Program VII.4.	11/30 of every year[8]
	v. Receiving Water Monitoring Program VIII.4.	11/30 of every year[9]
h.	Compliance - Illegal Discharges	See Item V.6.

[5] The first progress report is due on January 31, 1992.

[6] The first progress report is due on January 31, 1993.

[7] The first progress report is due on July 31, 1992.

[8] The first progress report is due on November 30, 1991.

[9] The first progress report is due on November 30, 1991.

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XII. REPORTING - CONT'D

TASK		COMPLIANCE REPORT DUE
i.	Fiscal Analysis - IX.	08/31 of every year[10]
j.	Data Analysis - X.	01/31 of every year[11]
k.	Program Analysis - XI.	03/31 of every year[12]

XIII. EXPIRATION AND RENEWAL

1. This Order expires on July 1, 1995 and the discharger must file a Report of Waste Discharge in accordance with outlaw 23, Chapter 3, Subchapter 9 of the California Code of Regulations not later than 180 days in advance of such expiration date as application for issuance of new waste discharge requirements. This report of waste discharge shall include, but is not limited to, the following:

   a. Summary of the results of the monitoring program.

   b. Summary of BMPs implemented and evaluations of their effectiveness.

   c. Summary of procedures implemented to detect, identify, and eliminate illegal discharges and illicit disposal practices and an evaluation of their effectiveness.

   d. Summary of enforcement procedures and actions taken to require stormwater dischargers to comply with the approved stormwater management programs.

   e. Summary of measures implemented to control pollutants in surface runoff from construction sites and an evaluation of their effectiveness.

   f. Evaluation of the need for additional BMPs, source control, and/or structural control measures.

   g. Proposed plan of stormwater/urban runoff quality management activities that will be undertaken during the term of the next permit.

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[10] The first annual fiscal analysis is due on August 31, 1991.

[11] The first data analysis is due on January 31, 1992.

[12] The first program analysis is due on March 31, 19

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XIII. EXPIRATION AND RENEWAL - CONT'D

h. Any significant changes to the storm drain systems, outfall locations, detention/retention basins, and structural/non-structural controls.

2. This order shall serve as a National Pollutant Discharge Elimination System permit pursuant to Section 402 of the Clean Water Act, or amendments thereto, and shall become effective 10 days after date of its adoption, provided that the Regional Administrator of the Environmental Protection Agency has no objection. If the Regional Administrator objects to its issuance, the permit shall not become effective until such objection is withdrawn.

I, Gerard J. Thibeault, Executive Officer, do hereby certify that the foregoing is a full, true, and correct copy of an order adopted by the California Regional Water Quality Control Board, Santa Ana Region, on July 13, 1990.

Gerard J. Thibeault
Executive Officer

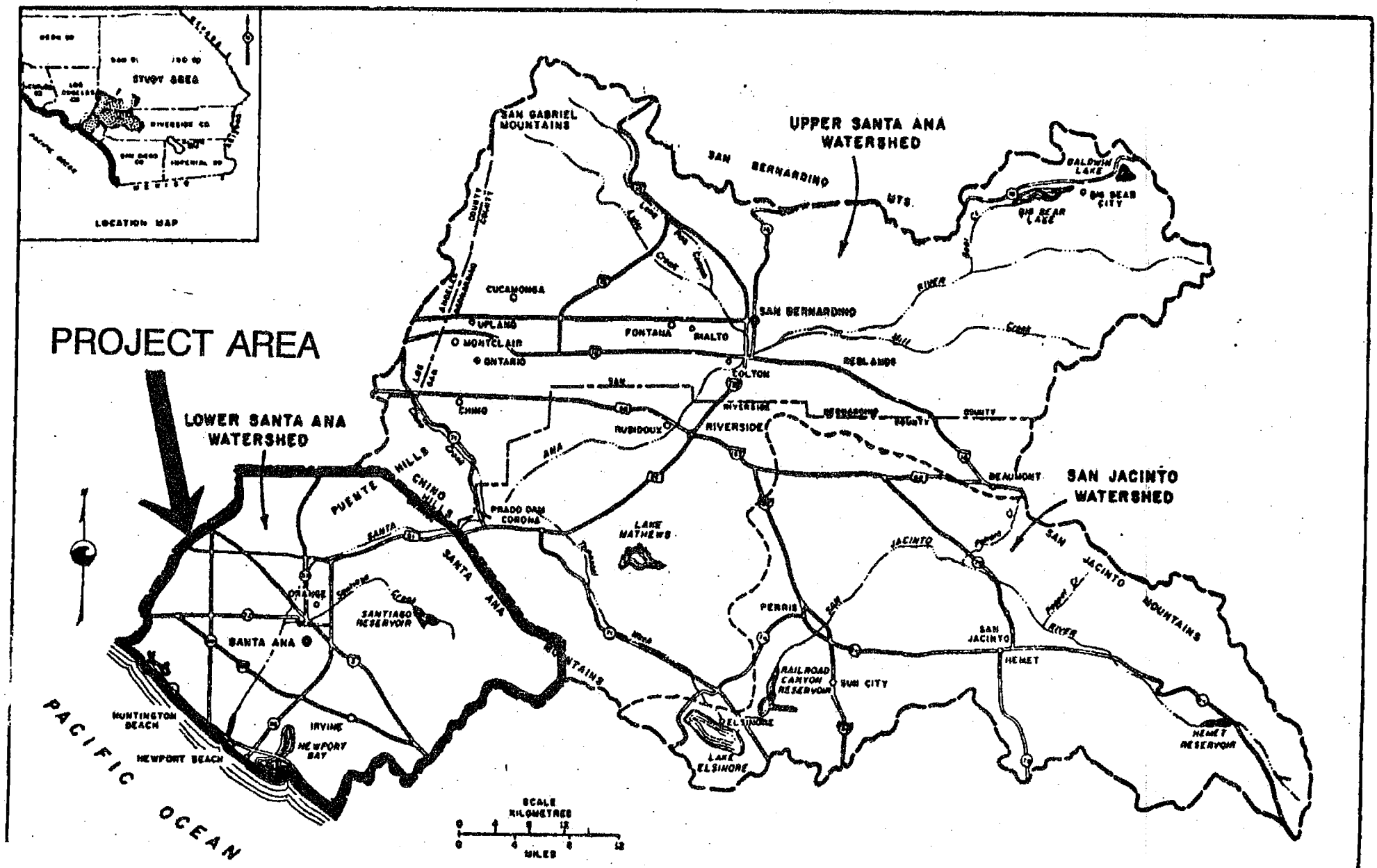

FIGURE 1 - SANTA ANA PLANNING AREA

NT OF WATER RESOURCES, SOUTHERN DISTRICT, 1982

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RBSA_28504

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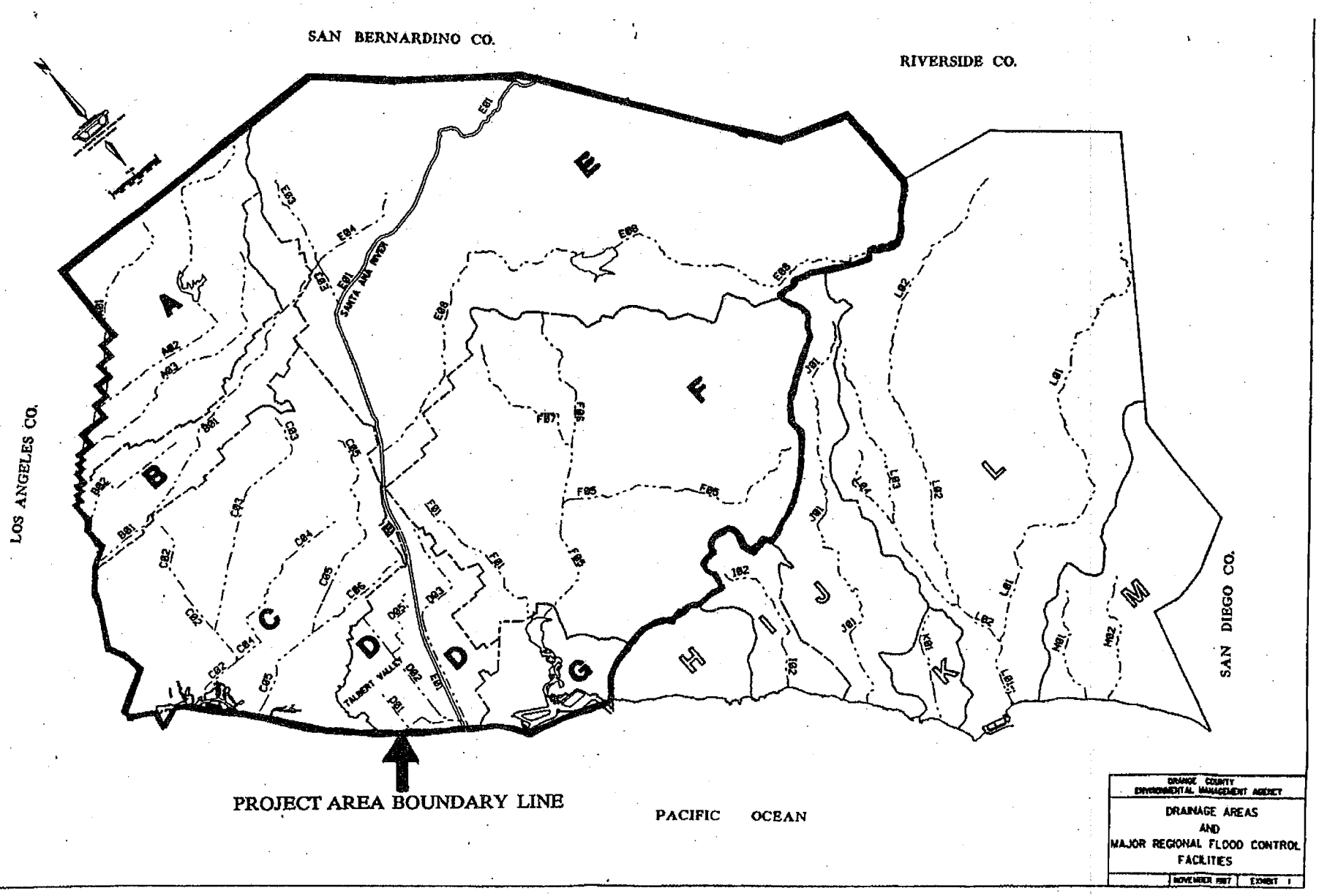

LEGEND

A,B - San Gabriel River Drainage Area
C - Huntington Harbour & Bolsa Bay Drainage Area
D - Greenville-Banning Channel Drainage Area
E - Santa Ana River Drainage Area
F,G - Newport Bay Drainage Area

Order No. 90-71
NPDES No. CA 8000180
Attachment "B"

SARB 090226 RBSA 28505

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ATTACHMENT "C"

Incorporated Cities of Orange County and 1990 Population Estimate, Santa Ana Region

Anaheim	249556
Brea	33698
Buena Park	66090
Costa Mesa	96094
Cypress	44323
Fountain Valley	55780
Fullerton	109972
Garden Grove	137632
Huntington Beach	187782
Irvine	105311
La Habra	48964
La Palma	16291
Los Alamitos	12561
Newport Beach	70091
Orange	108144
Placentia	43775
Santa Ana	233782
Seal Beach	27110
Stanton	28796
Tustin	53030
Villa Park	7022
Westminster	72413
Yorba Linda	49479

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ATTACHMENT "D"

POTENTIAL POLLUTANT DISCHARGE ENTITIES IN ORANGE COUNTY

Caltrans
Universities and Colleges
  University of California, Irvine
  University of California, Riverside
  California State University, Fullerton
  Coastline College
  Cypress College
  Fullerton College
  Irvine Valley College
  Golden West College
  Orange Coast College
  Rancho Santiago College
Metropolitan Water District
Department of Defense
  Naval Weapons Station, Seal Beach Naval Reserve Center, Los Alamitos
School Districts
  Lowell
  La Habra
  Brea-Olinda
  Buena Park
  Fullerton
  Yorba Linda
  Placentia
  Cypress
  Centralia
  Savanna
  Magnolia
  Anaheim
  Orange
  Los Alamitos
  Garden Grove
  Santa Ana
  Tustin
  Westminster
  Ocean View
  Fountain Valley
  Huntington Beach
  Newport-Mesa
  Irvine
  Saddleback
  Laguna Beach
Hospitals
  Fairview Hospital, Costa Mesa
  U.C. Irvine Medical Center
Orange County Sanitary District
Orange County Water District
Southern Pacific Railroad
ATSF Railroad

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ATTACHMENT "D" (CONT'D)

Army Corps of Engineers
- Carbon Canyon Dam
- Brea Dam
- Fullerton Dam
- Prado Dam

National Forest Service

State Parks
- Chino Hills State Park
- Crystal Cove State Park
- San Clemente State Park

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TABLE 2-1
BENEFICIAL USES

Water Body	Beneficial Use																	
	MUN	AGR	IND	PROC	GWR	NAV	POW	REC1	REC2	COMM	WARM	COLD	BIOL	WILD	RARE	SPWN	MAR	SHEL
OCEAN WATERS																		
NEARSHORE ZONE*																		
San Gabriel River to Poppy Street in Corona del Mar	+		X			X		X	X	X							X	X
Poppy Street to Southeast Regional Boundary	+					X		X	X	X			X				X	X
OFFSHORE ZONE																		
Waters Between Nearshore Zone and Limit of State Waters	+					X		X	X	X							X	
BAYS, ESTUARIES, AND TIDAL PRISMS																		
Anaheim Bay - Outer Bay	+					X		X	X				X	X	X		X	
Anaheim Bay - National Wildlife Refuge Portion	+							X[1]	X				X	X	X		X	
Sunset Bay - Huntington Harbour	+					X		X	X	X				X			X	
Bolsa Bay	+							X	X	X			X	X	X		X	X
Lower Newport Bay	+					X		X	X	X							X	X
Upper Newport Bay	+							X	X	X			X	X	X		X	X
Tidal Prism of Santa Ana River (to within 1000' of Victoria Street) and Newport Slough	+							X	X	X				X	X		X	
Tidal Prism of San Gabriel River - River Mouth to Marina Drive	+							X	X	X				X			X	X
Tidal Prisms of Flood Control Channels Discharging to Coastal or Bay Waters	+							X	X	X				X			X	

X= Present or Potential Beneficial Use
I= Intermittent Beneficial Use

*Defined by Ocean Plan Chapter II A.1.: "Within a zone bounded by shoreline and a distance of 1000 feet from shoreline or the 30-foot depth contour, whichever is further from shoreline..."

+ Excepted from MUN by Reg. Bd. Res. 89-42

1 No access per agency with jurisdiction (U.S. Navy)

Order No. 90-71
NPDES No. CA 8000180
Attachment "E"

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TABLE 2-1
BENEFICIAL USES

Water Body	Beneficial Use																	
	MUN	AGR	IND	PROC	GWR	NAV	POW	REC1	REC2	COMM	WARM	COLD	BIOL	WILD	RARE	SPWN	MAR	SHEL
INLAND SURFACE STREAMS																		
LOWER SANTA ANA RIVER BASIN																		
Santa Ana River																		
Reach 1- Tidal Prism to 17th St in Santa Ana	+							X[2]	I		I			I				
Reach 2- 17th Street in Santa Ana to Prado Dam	+	X			X			X	X		X			X				
Santiago Drainage																		
Silverado Creek	X				X			X	X			X		X				
Santiago Creek:																		
Reach 1- below Irvine Lake	X				X			X[2]	X			X		X				
Reach 2- Irvine Lake (see Lakes, p. 2-13)																		
Reach 3- Irvine Lake to Modjeska Canyon	I				I			I	I		I			I				
Reach 4- in Modjeska Canyon	X				X			X	X			X		X				
San Diego Creek Drainage																		
San Diego Creek:																		
Reach 1- below Jeffrey Road	+							X[2]	X		X			X				
Reach 2- above Jeffrey Road to Headwaters	+				I			I	I		I			I				
San Joaquin Freshwater Marsh	+							X	X		X			X	X			
All Other Tributaries to these Creeks: Bonita Creek, Serrano Cr., Peters Canyon Wash, Hicks Canyon Wash, Bee Canyon Wash, Borrego Canyon Wash, Agua Chinon Wash, Laguna Canyon Wash, Rattlesnake Canyon Wash, Sand Canyon Wash	+				I			I	I		I			I				

\+ Excepted from MUN by Reg. Bd. Res. 89-42
2 Access prohibited in all or part by Orange County Environmental Management Agency (OCEMA)

X= Present or Potential Beneficial Use
I= Intermittent Beneficial Use

Order No. 90-7
NPDES No. CA
Attachment "E"

SARB_000231
RBSA_28510

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TABLE 2-1
BENEFICIAL USES

Water Body	Beneficial Use																	
	MUN	AGR	IND	PROC	GWR	NAV	POW	REC1	REC2	COMM	WARM	COLD	BIOL	WILD	RARE	SPWN	MAR	SHEL
LAKES AND RESERVOIRS																		
UPPER SANTA ANA RIVER BASIN																		
Baldwin Lake	+							I	I		I	I		I				
Big Bear Lake	X	X			X			X	X		X	X		X				
Evans Lake	+							X	X		X	X		X				
Jenks Lake	X	X			X			X	X			X		X				
Lee Lake	+	X	X		X			X	X		X			X				
Mathews, Lake	X	X	X	X	X			X[4]	X		X			X	X			
Mockingbird Reservoir	+	X						X[5]	X		X			X				
Norconian, Lake	+							X	X		X			X				
LOWER SANTA ANA RIVER BASIN																		
Anaheim lake	+				X			X	X		X			X				
Irvine lake (Santiago Reservoir)	X	X						X	X		X	X		X				
Laguna, Lambert, Peters Canyon, Rattlesnake, Sand Canyon and Siphon Reservoirs	+	X						X[6]	X		X			X				
SAN JACINTO RIVER BASIN																		
Canyon Lake (Railroad Canyon Reservoir)	X	X			X			X	X		X			X				
Elsinore, Lake	+							X	X		X			X				
Fulmor, Lake	X	X						X	X		X	X		X				
Hemet, Lake	X	X			X			X	X		X	X		X		X		
Perris, Lake	X	X	X	X	X			X	X		X	X		X				

\+ Excepted from MUN by Reg. Bd. Res. 89-42
4 Access prohibited by the Metropolitan Water District
5 Access prohibited by the Gage Canal Company (owner-operator)
6 Access prohibited by Irvine Ranch Company (owner)

X= Present or Potential Beneficial Use
I= Intermittent Beneficial Use

Order No. 90-71
NPDES No. CA 8000180
Attachment "E"

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California Regional Water Quality Control Board
Santa Ana Region

July 13, 1990

ITEM: 10

SUBJECT: Waste Discharge Requirements for the County of Orange, Orange County Flood Control District, and the Incorporated Cities of Orange County Within the Santa Ana Region, Stormwater Runoff Management Program, Orange County, Order No. 90-71 (NPDES No. CA 8000180)

DISCUSSION:

See attached Fact Sheet.

RECOMMENDATION:

Adopt Order No. 90-71, NPDES No. CA 8000180, as presented.

In addition to the dischargers, comments were solicited from the following agencies and/or persons:

U. S. Environmental Protection Agency - Robert Wills, Pretreatment, Sludge, and Stormwater Section
U.S. Army District, Los Angeles, Corps of Engineers - Permits Section
NOAA, National Marine Fisheries Service
U.S. Fish and Wildlife Service
State Water Resources Control Board - Ted Cobb, Office of the Chief Counsel
State Water Resources Control Board - Archie Matthews, Division of Water Quality
State Department of Water Resources - Los Angeles
California Regional Water Quality Control Board, San Francisco Bay Region (2) - Tom Mumley
California Regional Water Quality Control Board, Los Angeles Region (4) - Catherine Tyrell
California Regional Water Quality Control Board, Central Valley Region (5) - Wayne Pierson
California Regional Water Quality Control Board, San Diego Region (9) - Bruce Posthumus
State Department of Fish and Game - Marine Resources Region
State Department of Health Services - Santa Ana
State Department of Health Services - San Diego
State Department of Health Services - San Bernardino
State Department of Parks and Recreation - Henry R. Agonia
Orange County Health Care Agency - Robert Merryman

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San Bernardino County Department of Health Services - Paul Ryan
San Bernardino County Flood Control District - Chuck Laird
Riverside County Health Department - John Fleming
Riverside County Flood Control & Water Conservation District - Frank Peairs
South Coast Air Quality Management District, El Monte
Caltrans, District 8 - Santa Ana
Southern Pacific Railroad
Atchison, Topeka & Santa Fe Railway Company
Seal Beach Naval Weapons Station
Seal Beach Naval Reserve Center, Los Alamitos
U. S. Marine Corps Air Station, El Toro
U. S. Army Corps of Engineers
National Forest Service
Brown & Caldwell - Jack Baylis
Uribe And Associates - Geoff Brosseau
Bill Dendy & Associates - Bill Dendy
Irvine Company - Sat Tamaribuchi
Building Industry Association - Governmental Affairs Council

Universities and Colleges

University of California, Irvine
University of California, Riverside
California State University, Fullerton
Chapman College
Coastline College
Cypress College
Fullerton College
Irvine Valley College
Golden West College
Orange Coast College
Rancho Santiago College
California State Polytechnic University, Pomona, Department of Geography & Social Sciences - Dr. Crane Miller

School Districts

Anaheim Elementary School District
Anaheim Union High School District
Brea-Olinda Unified School District
Buena Park Joint Union High School District
Centralia Elementary School District
Cypress Elementary School District
Fountain Valley Union High School District
Fullerton Elementary School District
Fullerton Joint Union High School District
Garden Grove Unified School District
Huntington Beach Elementary School District
Huntington Beach Union High School District
Irvine Unified Union High School District
La Habra Joint Union High School District
Los Alamitos Unified School District
Lowell Joint Union High School District
Magnolia Elementary School District

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School Districts - cont'd
Newport-Mesa Unified School District
Ocean View Union High School District
Orange Unified School District
Placentia Unified School District
Santa Ana Unified School District
Savanna Union High School District
Tustin Unified School District
Westminster Union High School District
Yorba Linda Joint Union High School District

Hospitals
Fairview Hospital, Costa Mesa
U.C. Irvine Medical Center

Environmental Organizations
Sierra Club, Orange County Chapter
Sierra Club, Los Angeles Chapter - Dick Hingson
Natural Resources Defense Council (NRDC)
Cousteau Society
Amigos De Bolsa Chica
Audobon Sea & Sage Chapter
Huntington Beach Wetlands Conservancy
Surfrider Foundation

Newspapers
Orange County Register
Los Angeles Times
Press Enterprise

Major Water/Wastewater Agencies
Santa Ana Watershed Project Authority - Neil Cline
Irvine Ranch Water District - John Morris
Los Alisos Water District - Kenneth Peterson
El Toro Water District - Robert Hill
L.A. County Department of Public Works - John Mitchell
County Sanitation Districts of Orange County - Wayne Sylvester
Orange County Water District - Bill Mills
Metropolitan Water District - Kevin Wattier

Other Cities in the Region with population >100,000
City of Ontario - City Manager/Director of Public Works
City of San Bernardino - City Manager/Director of Public Works
City of Fontana - City Manager/Director of Public Works
City of Rancho Cucamonga - City Manager/Director of Public Works
City of Riverside - City Manager/Director of Public Works
City of Moreno Valley - City Manager/Director of Public Works

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California Regional Water Quality Control Board
Santa Ana Region
6809 Indiana Avenue, Suite 200
Riverside, CA 92506-4298

FACT SHEET

PROJECT

The attached pages contain information concerning an application for waste discharge requirements and a National Pollutant Discharge Elimination System (NPDES) permit. Order No. 90-71, NPDES No. CA 8000180, prescribes waste discharge requirements for urban stormwater runoff from the cities and the unincorporated areas in Orange County within the jurisdiction of the Santa Ana Regional Board. On March 15, 1990, the County of Orange and the Orange County Flood Control District (OCFCD), in cooperation with the cities of Anaheim, Brea, Buena Park, Costa Mesa, Cypress, Fountain Valley, Fullerton, Garden Grove, Huntington Beach, Irvine, La Habra, La Palma, Los Alamitos, Newport Beach, Orange, Placentia, Santa Ana, Seal Beach, Stanton, Tustin, Villa Park, Westminster, and Yorba Linda (hereinafter collectively referred to as the dischargers), submitted NPDES Application No. CA 8000180 for an areawide stormwater discharge permit under the National Pollutant Discharge Elimination System (NPDES). As part of the permit application, a topographic map, a storm drain system map, listings of cities and entities participating in this program, and copies of ordinances relevant to the urban stormwater runoff of various cities were submitted.

PROJECT AREA

The permitted area is delineated by the Los Angeles County-Orange County boundary line on the northwest, the San Bernardino-Orange County boundary line on the north and northeast, the Riverside County-Orange County boundary line on the east, the Santa Ana Regional Board-San Diego Regional Board boundary line on the southeast, and the Pacific Ocean on the southwest (see Attachment "B").

CLEAN WATER ACT REQUIREMENTS

The Federal Clean Water Act (CWA) allows the U. S. Environmental Protection Agency (EPA) to delegate its NPDES permitting authority to states with an approved environmental regulatory program. The State of California is one of the delegated states. The Porter-Cologne Act (California Water Code) authorizes the State Board, through its Regional Boards, to regulate and control the discharge of pollutants into waters of the state and tributaries thereto.

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CLEAN WATER ACT REQUIREMENTS - CONT'D

Section 405 of the Water Quality Act (WQA) of 1987 added Section 402(p) to the CWA. Pursuant to Section 402(p)(4) of the CWA, the EPA is required to promulgate regulations for stormwater permit applications for stormwater discharges associated with industrial activities and municipal separate storm drain systems serving a population of 100,000 or more. Section 402 (p)(4) of the CWA also requires dischargers of stormwater associated with industrial activities and municipal separate storm drain systems serving a population of 250,000 or more to file stormwater permit applications by February 4, 1990.

On December 7, 1988, EPA published its proposed regulations in the Federal Register to solicit public comments. Final regulations are tentatively scheduled to be promulgated on July 20, 1990 **and to be published in the Federal Register on August 4, 1990.** In the absence of final stormwater regulations, a permit governing municipal stormwater discharges should meet both the statutory requirements of Section 402 (p)(3)(B) and all requirements applicable to a NPDES permit issued under the issuing authority's discretionary authority in accordance with Section 402 (a)(1)(B) of the CWA.

AREAWIDE STORMWATER PERMIT

To regulate and control stormwater discharges from the Orange County area to the Orange County storm drain systems, an areawide approach is essential. The entire storm drain system is not controlled by a single entity; the County of Orange, the OCFCD, and several cities manage the system. In addition to the cities and the county, there are a number of other significant contributors of urban stormwater runoff to these storm drain systems. These include: large institutions such as the State University system, schools, hospitals etc.; state agencies such as Caltrans; public utilities such as Orange County Water District, Metropolitan Water District etc.; national defense installations such as Seal Beach Naval Weapons Station, El Toro Marine Base, etc.; National Forest Service; state parks; and entertainment centers such as Disneyland. Some of these storm drain systems discharge into storm drain systems controlled by other entities, such as the Los Angeles County Flood Control District, which is under the Los Angeles Regional Board's jurisdiction. The Los Angeles area storm drain systems are regulated under a separate permit, NPDES No. CA 0061654, issued by the Los Angeles Regional Board. Stormwater runoff draining into the storm drain systems in Orange County under the San Diego Regional Board's jurisdiction is regulated by Order No. 90-38, NPDES No. CA 0108740, issued by the San Diego Regional Board. Some of the storm drain systems controlled by the Counties and Cities of San Bernardino and Riverside discharge into storm drain systems of the County and Cities of Orange.

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AREAWIDE STORMWATER PERMIT - CONT'D

The management and control of the entire flood control system cannot be effectively carried out without the cooperation and efforts of all these entities. Also, it would not be meaningful to issue a separate stormwater permit to each of the entities within the permitted area whose land/facilities drain into the county storm drain systems. The Regional Board and a majority of the cities and the county have concluded that the best management option for the Orange County area is to issue an areawide stormwater permit.

COORDINATION WITH OTHER REGIONAL AGENCIES

In developing best management practices and monitoring programs, consultation/coordination with other flood control districts and other regional boards are essential. Regional Board staff will coordinate the program with other regional boards and other flood control districts/cities on an "as needed" basis.

EXISTING FACILITIES AND PROGRAMS

Within the Santa Ana Region, Orange County Flood Control District, operated by the County of Orange, serves a population of approximately 2.0 million, occupying an area of approximately 511 square miles **(approximately 128 square miles of unincorporated areas and 383 square miles of incorporated areas)**. The District's system includes an estimated 400 miles of drainage facilities. A major portion of the urbanized areas of Orange County drains into water bodies within this Regional Board's jurisdiction. Stormwater discharges from these urbanized areas consist mainly of surface runoff from various land use activities such as residential, commercial, industrial, and agricultural. The constituents of concern and significance in these discharges are: total and fecal coliform, **enterococcus**, total suspended solids, biochemical oxygen demand, chemical oxygen demand, total organic carbon (TOC), oil and grease, heavy metals, nutrients, base/neutral and acid extractibles, pesticides, herbicides, and petroleum hydrocarbon components.

The County of Orange has an active surface water quality monitoring program in the permitted area. Dry weather sampling is performed bimonthly and wet weather sampling is performed only during significant storm events (>0.5 inches of rainfall). Stormwater runoff samples collected are analyzed for nutrients, trace metals, total coliform, oil and grease, specific conductance, dissolved oxygen, temperature, and pH. Sediment samples are also collected and analyzed for radiochemical constituents (only at Huntington Harbour), organics, and metals on a semi-annual basis. This monitoring program includes 21 water quality monitoring stations, 17 water level stations (12 of which are stream gaging stations),

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EXISTING FACILITIES AND PROGRAMS - CONT'D

and 31 precipitation stations. Most of the water quality monitoring stations are located at storm drain systems associated with drainage areas in which land use activities have been identified to significantly impact the beneficial uses of waters in Orange County. These drainage areas, characterized as residential, agricultural, commercial, and industrial, are mainly located upstream of Newport Bay. Those pollutants that have been identified to cause significant impairment to the beneficial uses of Newport Bay include nutrients (especially nitrates), pesticides, herbicides, and suspended solids. The sources of these pollutants are not fully identified. To protect the beneficial uses of waters of the state, the pollutants from all sources need to be controlled. Recognizing this, and the fact that stormwater discharges contain significant amounts of pollutants, the County of Orange, the incorporated cities of Orange County, and the Regional Board have all agreed that an areawide stormwater permit is the most effective way to develop and implement a comprehensive stormwater management program in a timely manner. This areawide stormwater permit will contain requirements with time schedules that will allow the County of Orange and the cities to address water quality problems caused by stormwater/urban runoff and to develop and implement management programs to reduce pollutants in stormwater system discharges and improve the water quality of the receiving waters.

PERMIT REQUIREMENTS

In accordance with Section 402(p)(3), as part of a program to reduce the pollutants in stormwater system discharges to the maximum extent practicable, the dischargers are required to submit existing management plans and programs being implemented in the localities, and information that could lead to successful identification of illegal discharges and sources of pollutants in stormwater system discharges. In addition, the dischargers will be required to adopt and implement effective management programs and control measures in accordance with time schedules approved by the Executive Officer of the Regional Board.

If existing management programs are not effective in controlling pollutant loading and achieving the water quality objectives of the receiving waters, additional programs shall be developed and implemented.

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PERMIT REQUIREMENTS - CONT'D

The permit also requires development and implementation of management programs (best management practices[1]) during the life of the permit such that the quality of stormwater discharged can be improved and the water quality objectives of the receiving waters can be met ultimately. It is also expected that the beneficial uses of the receiving waters will be protected through implementation of best management practices.

Currently, the County of Orange has 21 monitoring stations throughout the system. **The proposed order requires the dischargers to submit a stormwater system monitoring program that will meet the objectives, as outlined in Item VII.1., of the program.**

BENEFICIAL USES

Stormwater flows which are discharged to storm drain systems in Orange County are tributary to various water bodies (inland surface streams, bays and tidal prisms, ocean waters, and lakes and reservoirs) of the state. The beneficial uses of these water bodies include municipal and domestic supply, agricultural supply, industrial service supply, groundwater recharge, navigation, water contact recreation, non-contact water recreation, ocean commercial and nonfreshwater sportfishing, warm freshwater habitat, cold freshwater habitat, preservation of areas of biological significance, wildlife habitat, preservation of rare and endangered species, marine habitat, and shellfish harvesting. The ultimate goal of this stormwater management program is to protect the beneficial uses of the receiving waters.

ANTIDEGRADATION ANALYSIS

The Regional Board has considered whether a complete antidegradation analysis, pursuant to 40 CFR 131.12 and State Board Resolution No. 68-16, is required for the stormwater discharges. The Regional Board strongly believes that the pollutant loading rates to the receiving waters will be reduced with the implementation of the requirements in this order. As a result, the

ANTIDEGRADATION ANALYSIS

quality of stormwater discharges and receiving waters will be improved, thereby protecting the beneficial uses of waters of the United States. This discharge is consistent with the federal and state antidegradation requirements and a complete antidegradation analysis is not necessary.

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[1] Best Management Practices (BMPs) are water quality management practices that are maximized in efficienc control of stormwater runoff pollution.

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ANTIDEGRADATION ANALYSIS

quality of stormwater discharges and receiving waters will be improved, thereby protecting the beneficial uses of waters of the United States. This discharge is consistent with the federal and state antidegradation requirements and a complete antidegradation analysis is not necessary.

PUBLIC WORKSHOP

The Regional Board recognizes the significance of Orange County's Stormwater/Urban Runoff Management Program and will conduct a workshop to provide for public involvement and participation in the development and implementation of the tentative waste discharge requirements. The purpose of the workshop is solely to solicit comments. The workshop will be held on Friday, June 8, 1990, at 9:30 a.m. at Hofert Hall, 39707 Big Bear Boulevard in Big Bear Lake. Public comments received at the workshop and during the comment period will be incorporated into the proposed waste discharge requirements, which will be considered for adoption at a subsequent Board meeting.

The Regional Board will conduct at least one workshop every year during the term of this permit to discuss the progress of the stormwater management program. The details of the annual workshop will be published in local newspapers and mailed to interested parties. Persons wishing to be included in the mailing list for any of the items related to this permit may register their name, mailing address and phone number with the Regional Board office at the address given below.

PUBLIC HEARING

The Regional Board will hold a public hearing regarding the proposed waste discharge requirements. The public hearing is scheduled to be held on Friday, July 13, 1990, at 9:00 p.m. at the City Council Chambers in Riverside. Further information regarding the conduct and nature of the public hearing concerning these waste discharge requirements may be obtained by writing or visiting the Santa Ana Regional Board office, 6809 Indiana Avenue, Suite 200, Riverside.

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WRITTEN COMMENTS

Interested persons are invited to submit written comments on the proposed waste discharge requirements and the Executive Officer's proposed determinations. Comments should be submitted by June 22, 1990, either in person or by mail to:

Joanne Lee
California Regional Water Quality Control Board
Santa Ana Region
6809 Indiana Avenue, Suite 200
Riverside, CA 92506-4298

INFORMATION AND COPYING

Persons wishing further information may write to the above address or call Joanne Lee at (714)782-4130. Copies of the application, proposed waste discharge requirements, and other documents (other than those which the Executive Officer maintains as confidential) are available at the Regional Board office for inspection and copying by appointment scheduled between the hours of 10:00 a.m. and 4:00 p.m., Monday through Thursday (excluding holidays).

REGISTER OF INTERESTED PERSONS

Any person interested in a particular application or group of applications may leave his name, address, and phone number as part of the file for an application. Copies of tentative waste discharge requirements will be mailed to all interested parties.

United States
Environmental Protection
Agency

Office of Water
Washington, DC 20460

EPA 841-R-92-001
June 1992

EPA ENVIRONMENTAL IMPACTS OF STORMWATER DISCHARGES

A National Profile

SARB_000243

CONTENTS

- Environmental Impacts of Stormwater Discharges [2]
  - Introduction
- Stormwater Pollution - A National Concern [3]
  - Defining the Problem
  - A National Ranking
  - Regulating the Risk
  - Stormwater and the Urbanization Process
- Pollutants in Stormwater and Examples of Associated Impacts [21]
  - Sediment/Habitat Alteration
  - Oxygen Demanding Substances
  - Nutrients
  - Toxic Substances
  - Bacteria
  - Floatables
- Examples of Successful Stormwater Controls [28]
  - Control Practices
  - Land Disturbance/Activity
  - Additional Examples of Successful Urban and Industrial Stormwater Control Practices
- References [41]

Jim Platt, Environmental Improvement Division
Planning Section, Surface Water Quality Bureau

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Environmental Impacts Of Stormwater Discharges

Introduction

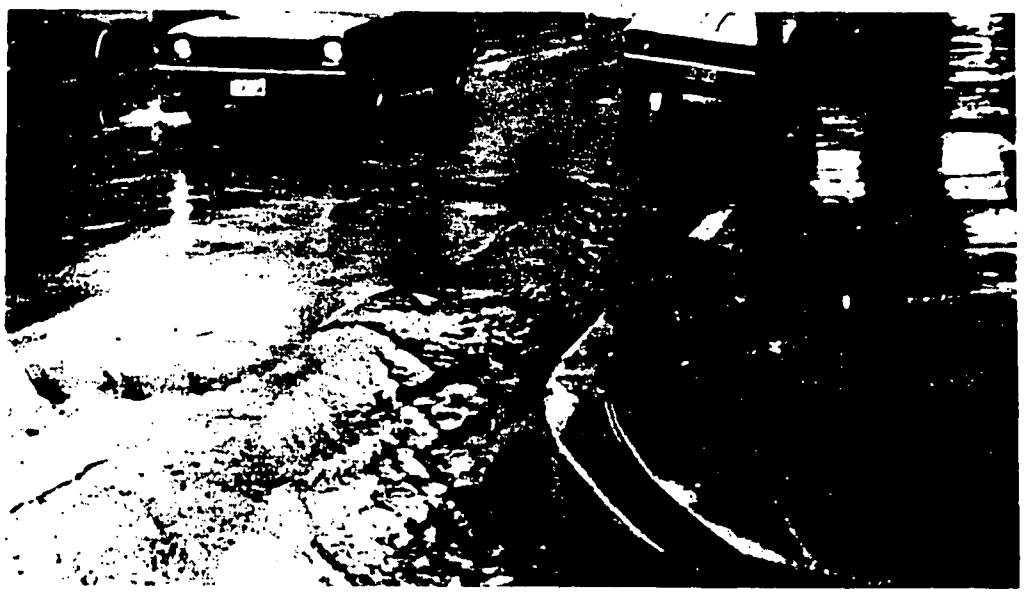
What constitutes stormwater discharges? What pollutants are associated with stormwater and why? In comparison to other pollution sources, how does stormwater affect the Nation's rivers, lakes, and estuaries? What sources of stormwater pollution are not currently regulated under the NPDES program and what are their impacts? What have we learned in our efforts to control and manage sources of stormwater pollution?

These questions and others face local, state, and federal water quality managers as they struggle to implement cost effective control strategies which target stormwater and other pollutant discharges in areas where the greatest risks to water quality impairment exist. This booklet was prepared based on the best available current information, to assist managers in answering the above questions. It is intended as a capsule summary of national level information on water quality drawn from various EPA program reports (i.e., the Section 305(b) National Water Quality Inventory, the Section 319 Nonpoint Source Program, and the Nationwide Urban Runoff Program – NURP), as well as from more site-specific information and data generated by local agencies and researchers over the last decade.

The remainder of this booklet is in three parts. In the first part, we define the general nature of and impacts from stormwater discharges and compare, on a national scale, stormwater pollution to other point and nonpoint pollution sources. A differentiation is made between stormwater discharges that are currently regulated versus not regulated under the NPDES program. A discussion of the relationship between land use/land disturbance and the magnitude of stormwater pollution is provided.

In the second part we examine in more detail, the pollutant characteristics and impacts of stormwater runoff. This is presented by a series of site specific examples where environmental impacts caused by various types of stormwater sources have been observed and documented.

In the third and last part, we examine lessons learned from recently implemented stormwater control strategies which have shown promise in effectively minimizing impacts in areas of greatest risk.



Chesapeake Bay Foundation

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STORMWATER POLLUTION - A NATIONAL CONCERN

Defining the Problem

As human activities alter the watershed landscape, adverse impacts to receiving waters may result from changes in the quantity and quality of stormwater runoff. Rain (and snow) falling onto the surface of unmanaged urbanizing watersheds results in a predictable increase in the quantity of runoff (and snowmelt) volume flowing to receiving waters. If left unmanaged, the hydraulic impacts (e.g., flooding, erosion, channelization) associated with the increased water volumes may be several orders of magnitude higher than that of the undisturbed watershed. In addition to causing runoff volume impacts, stormwater can also be a major nonpoint pollution source in many watersheds, which is the focus of the remainder of this booklet.

Table 1. Examples of Pollutant Characteristics Found in Stormwater Runoff from Various Land Uses in the Great Lakes Region[a]

Land Use	Suspended Sediment (kg/ha-yr)	Total Nitrogen (kg/ha-yr)	Total Phosphorus (kg/ha-yr)	Lead (kg/ha-yr)
General Agriculture	5-8000	0.8-75	0.1-9	0.003-0.09
Cropland	30-7500	6-60	0.3-7	0.006-0.007
Improved Pasture	50-90	5-15	0.1-0.6	0.005-0.02
Forested/Wooded	2-900	1-8	0.03-0.7	0.01-0.05
Idle/perennial	9-900	0.6-7	0.03-0.7	0.01-0.05
General Urban	300-2500	8-10	0.5-4	0.2-0.6
Residential	900-4000	6-9	0.6-1	0.08[b]
Commercial	75-1000	3-12	0.09-0.9	0.3-1.0
Industrial	750-2000	3-13	0.9-6	-[c]
Developing Urban	>10,000[b]	90[b]	>10[b]	3.0-7.0

[a] *Source: Novotny and Chesters, 1981*
[b] *Only one value reported.*
[c] *Not assumed.*

There are six primary nonpoint source activities associated with stormwater runoff pollution. They are (in no particular order):

- Agriculture,
- Silviculture,
- Mining,
- Construction,
- Urban activities, (including storm sewers, industrial and commercial operations, urban growth, land disposal[a], and hydromodification[a]), and
- Atmospheric deposition.

The first five are the traditional nonpoint sources; the sixth, atmospheric deposition, has also been recognized as a major contributor of nitrogen, sulfates, and trace metals to stormwater runoff in highly urbanized areas (Halverson, et al., 1984).

The types and amounts of pollutants carried by stormwater runoff, commonly resulting in nonpoint source pollution of receiving waters, are highly variable (USEPA, 1983a). The pollutant characteristics of stormwater runoff are largely based on land use characteristics (as illustrated in Table 1) and vary with the duration and the intensity of rainfall events (Metropolitan Washington Council of Governments, 1980). Table 1 illustrates the high variability of pollutant loads associated with stormwater runoff. For example, Table 1 shows loads of suspended sediment vary considerably within a land use and among land uses. Pollutant characteristics from stormwater runoff also vary regionally.

Recent regulatory efforts have focused almost exclusively on point sources (e.g., municipal and industrial wastewater discharges). In the early 1970s, however, it was recognized that nonpoint sources, including pollutants originating from agri-

[a] *An undefined portion of land disposal and hydromodification activities occurs in rural areas.*

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Table 2(a). Degree of Designated Use Support in the Nation's Assessed Waters[a]

	River Miles	Lake Acres*	Estuary Square Miles
Do not Support Uses	9.5% (62,218)	21% (3,940,277)	8% (2,064)
Partially Support Uses	21% (134,472)	19% (3,471,633)	25% (6,573)
Threatened	6.5% (43,214)	16% (2,902,809)	11% (3,052)
Fully Support Uses	63% (407,162)	44% (8,173,917)	56% (15,004)
Assessed	647,066	18,488,636	26,693
Total in U.S.**	1,800,000	39,400,000	35,624

*Not including Great Lakes

**Total waters based on State-reported Information in America's Clean Water: The States' Nonpoint Source Assessment, ASIWPCA, 1985. Total U.S. estuarine square miles based on 1990 State reported 305(b) data and excludes Alaska, New Jersey, Pennsylvania, and Island Territories.

[a]*Source: National Water Quality Inventory: 1990 Report to Congress*

culture, mining, and land disposal activities, as well as stormwater from diffuse urban sources such as construction sites, impervious surfaces, and unsewered residential areas, were contributing significantly to the impairment of the Nation's surface and groundwaters.

A National Ranking

Based in part on national assessments conducted by the U.S. Environmental Protection Agency (EPA) it is now recognized that nonpoint sources and certain diffuse point sources[a] (e.g., stormwater discharges) are responsible for between one-third to two-thirds of existing and threatened impairments of the Nation's waters (USEPA, 1991a). Under Sections 305(b) and 319(a) of the Clean Water Act, states report to the EPA on the quality of their rivers, streams, lakes, estuaries, coastal waters, wetlands, and groundwater. EPA, in turn, prepares summary reports to Congress called the National Water Quality Inventory [for 305(b)], and Managing Nonpoint Source Pollution [for 319(a)]. These reports contain national statistics on the degree of impairment of assessed waters [see Table 2(a)]. Impairment is measured according to the level at which the designated uses of the waterbody are attained or supported [see Table 2(b)]. For example, as shown in Table 2(a), of the waters assessed by the States under 305(b) (approximately one-third of

Table 2(b). Designated uses and support levels

Wildlife	Fish & wildlife
Fishery	Warm water fishery Cold water fishery
Shellfishery	Shellfish protection
Drinking	Domestic water supply
Agriculture	Agriculture Irrigation Livestock watering
Industry	Industrial
Recreation	Recreation Primary contact Secondary contact Noncontact
Navigation	Navigation
High Quality	High Quality/ Nondegradation
Supported	= all uses supported
Partial Support	= one use *not* supported
Non-support	= 2 or more uses not supported
Threatened	= all uses supported but one or more uses threatened

Pollution Source Categories Considered
(legend to Figure 1)

	305(b)	319
Agriculture	✓	✓
Silviculture	✓	✓
Mining	✓	✓
Construction	✓	✓
Urban Runoff[a]	✓	✓
Combined Sewers	✓	
Land Disposal	✓	✓
Hydromodification	✓	✓
Municipal Pt.Source	✓	
Industrial Pt.Source	✓	
Other[b]		✓
Unknown		✓

[a]*Urban runoff includes sewered and unsewered urban areas including industrial and commercial; under 319 also includes combined sewers.*

[b]*Other includes atmospheric deposition, storage/tank leaks, highway runoff, spills, in-place, natural, recreational and urban growth.*

Pollutant Categories Considered
(legend to Figure 1)

	305(b)	319
unknown toxicity		✓
pesticides	✓	✓
priority organics		✓
nonpriority organics		✓
metals	✓	✓
ammonia		✓
chlorine		✓
other inorganics		✓
nutrients	✓	✓
pH	✓	✓
siltation	✓	✓
organic enrichment/DO	✓	✓
salinity	✓	✓
thermal modification	✓	✓
flow alteration	✓	✓
other habitat alterations	✓	✓
pathogens	✓	✓
radiation		✓
oil and grease		✓
not reported		✓
suspended solids	✓	

[a]*In this report, point sources are pollutant loads discharged at a specific location from pipes, outfalls, and conveyance channels (ditches, grass swales) from either municipal/industrial wastewater treatment facilities or from urban, suburban, or industrial/commercial stormwater drainage systems.*

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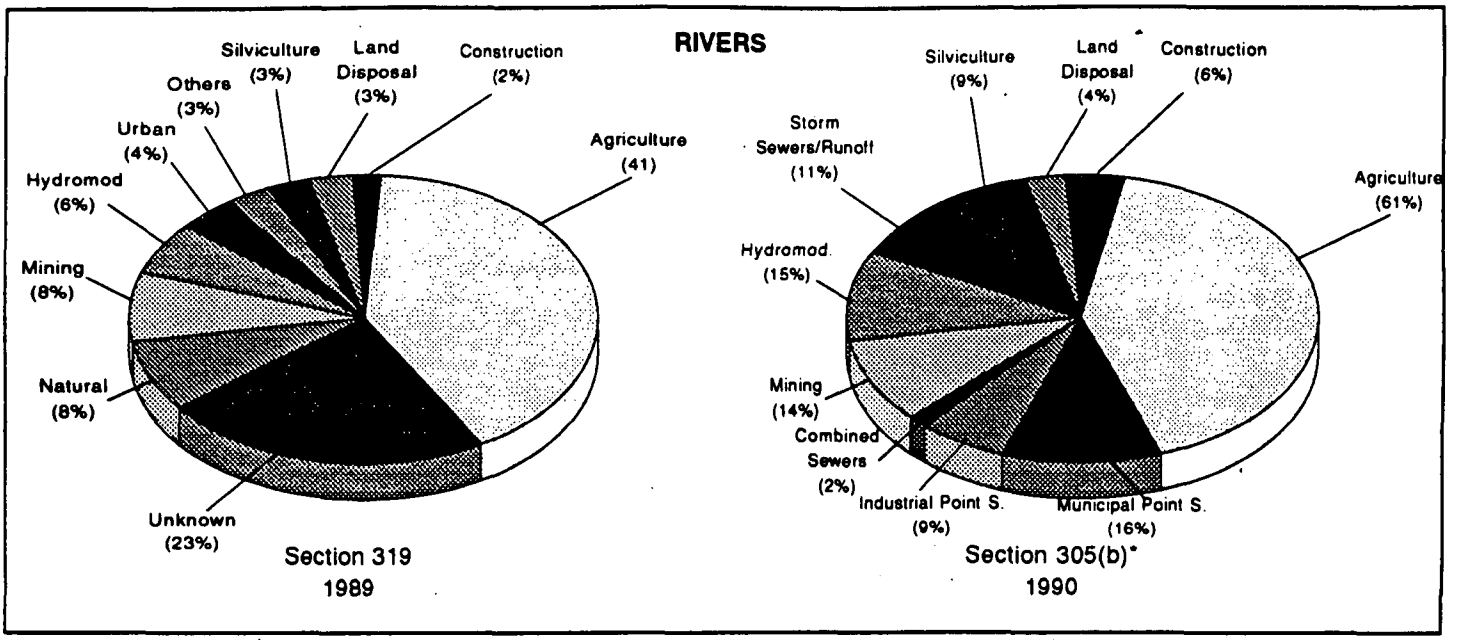

Figure 1(a). Comparison of sources impacting use support in rivers. (see inset previous page for pollution source categories)

**305(b) sources may overlap as cause of impairment for a given waterbody, accounting for total pie percentage of 147%*

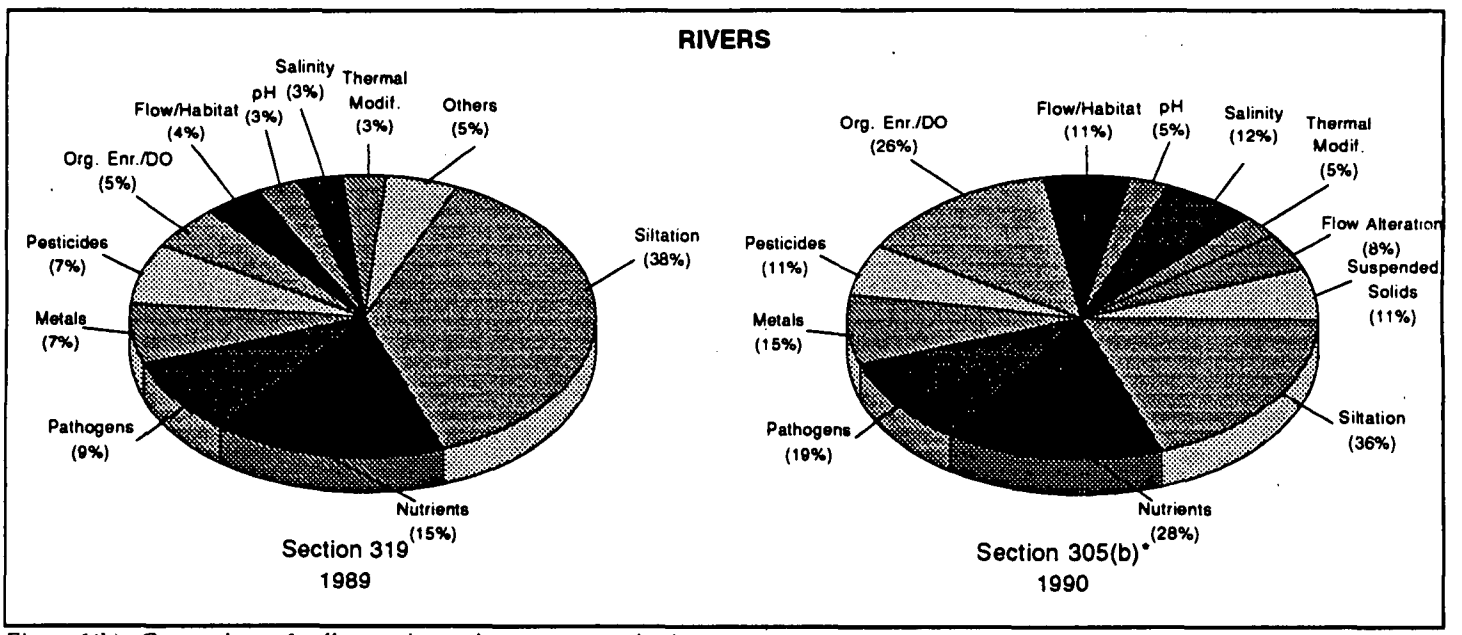

Figure 1(b). Comparison of pollutants impacting use support in rivers. (see inset previous page for pollutant categories)

**305(b) pollutants may overlap as cause of impairment for a given waterbody, accounting for total pie percentage of 187%.*

river miles, one-half of lake acres and three-quarters of estuarine waters), roughly 50 to 60 percent are fully supporting the uses for which they are designated.

Although methodologies used by the states to report and analyze data differ between the 319 and 305(b) reports according to the different requirements of the Clean Water Act, their general conclusions are nonetheless comparable. Both methods, for instance, use similar pollution source categories and pollutant categories (see insets previous page) to track the relative causes of use impairment. Figure 1 compares, for example, the reported pollution sources and pollutants impacting use support in rivers for the two methods. Note that, **for rivers, both the 319 and 305(b) methods show agriculture to be the primary source contributing to use impairment; siltation/suspended solids and nutrients are the pri-**

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mary pollutants causing riverine impacts, followed by pathogens, metals, and pesticides. Other nonpoint pollution sources contributing to use impairment in rivers and whose individual levels of contribution are similar for both 305(b) and 319 are construction, land disposal, silviculture, urban runoff/storm sewers, hydromodification, and mining. A major uncertainty is the

Table 3. Pollution Sources - Regulating the Risk (a comparison of pollution sources contributing to the Nation's surface water impairment)

Pollution Source Category[a]	% Impairment[b] Rivers 305(b)	Rivers 319	Lakes 305(b)	Lakes 319	Estuaries 305(b)	Estuaries 319	Currently Regulated Under NPDES	Currently Not Regulated Under NPDES
Rural Nonpoint Sources:								
Agriculture[c]	61	41	57	23	18	7	only large feed lots	all other including ag. storm and return flows
Mining	14	8	9	7	2	5	only sites > 2 ha (5 ac)	all sites < 2ha (5 ac)
Silviculture	9	3	3	—	2	1		✓
Subtotal	[84][f]	[52][f]	69	30	22	13		
Urban Nonpont Sources:								
Storm Sewers/Urban Runoff	11	4	28	6	30	11	industrial sites and cities and counties with pop. ≥ 100,000	all cities and counties with pop. < 100,000
Combined Sewers	2	—	0	—	6	—	✓	
Hydro/Habitat Modification[d]	15	6	40	6	5	—		✓
Land Disposal[d]	4	3	24	4	19	8	all but septic tanks	septic tanks
Construction	6	2	3	2	11	—	only sites > 2ha (5ac)	all sites < 2ha (5ac)
Others[e]	—	3	—	16	—	43		✓
Subtotal	38	18	[95][f]	[34][f]	[71][f]	[62][f]		
Point Sources:								
Municipal Point Sources	16	—	17	—	35	—	✓	
Industrial Point Sources	9	—	9	—	10	—	✓	
Subtotal	25	—	26	—	45	—		
Other Sources:								
Unknown	—	23	—	21	—	4	?	?
Natural[e]	—	8	—	10	—	5		✓
In-place[e]	—	—	—	3	—	16		✓
Total Percent	147	100	190	100	138	100		

[a] *See explanation of pollution sources on next page.*
[b] *Percent of impaired river miles, lake acres, and estuary square miles affected by each pollution source.*
[c] *See 319 agriculture breakdown on next page.*
[d] *An undefined portion of use impairment from hydro/habitat modification and land disposal is attributable to rural areas resulting in an overestimation of urban contribution to impairment.*
[e] *others include, in addition to natural and in-place ,atmospheric deposition, waste storage/storage tank leaks, highway maintenance and runoff, spills, recreational activities, and urban growth.*
[f] *Box indicates largest contributor to use impairment by category group (i.e., rural nonpoint, urban nonpoint, point, or other).*

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Agriculture Subcategories Under 319[a] (legend to Table 3)

	% Impairment		
	Rivers (miles)	Lakes (acres)	Estuaries (Sq. miles)
Nonirrigated crops	5.7	2.3	0.3
Irrigated crops	1.9	3.8	0.0
Specialty crops	0.1	0.4	0.0
Pastureland	1.4	0.9	0.6
Rangeland	2.1	0.5	0.8
Feedlots—all types	2.4	0.7	0.1
Aquaculture	0.0	0.0	0.0
Animal Holding areas	1.4	0.7	0.4
Streambank erosion	0.7	0.1	0.0
Unspecified/odd	25.2	13.7	4.8
Total	41.0	23.0	7.0

[a]*Source: Managing Nonpoint Source Pollution: 1991 Report to Congress*

23% unknown sources identified in the 319 program for rivers.

Table 3 extends the comparison between 319 and 305(b) methods for pollution sources causing impairment of assessed river miles, lake acres (excluding Great Lakes) and estuary square miles, as reported in the most recent 305(b) document (USEPA, 1992), and 319 document (USEPA, 1991a). Pollution source categories are grouped into rural nonpoint sources, urban nonpoint sources, point sources, and other sources. As seen in Table 3, the level of contribution to reported impairment caused by a given 319 or 305(b) source category varies between waterbody types, however, the general trend is similar for both methods. For example, for rivers, rural nonpoint sources represent the largest contribution to impairment under both 319 and 305(b) methods, followed by urban nonpoint sources. **For lakes and estuaries, however, the largest contributors to use impairment are reported to be urban nonpoint sources, regardless of which method is used.**

Stormwater runoff from agriculture and from urban areas are the two present leading causes of surface water quality impairment nationwide, except for estuaries (where point sources are shown to be the second largest contributor to impairment behind urban nonpoint sources)

Furthermore, while urban population areas (greater than 2500 inhabitants as defined by the Bureau of Census) take up only about 2.5% of the total land surface of the country, stormwater pollution from these urban areas and associated urban activities (i.e., storm sewers/urban runoff, combined sewers, hydromodification, land disposal, construction, urban growth, etc.) accounts for a proportionately high degree of water quality impairment (i.e., 18% of impaired river miles, 34% of impaired lake acres, and 62% of impaired estuary square miles reported under 319) when compared to that (see Table 3) from rural activities (i.e., agriculture, silviculture, and mining) which take up approximately 53% of the total land surface (USDA, 1992).

Explanation of 305(b)/319 Pollution Sources (legend to Table 3)

Agriculture:	Runoff from crop production, pastures, rangeland, feedlots, and irrigated return flows
Silviculture:	Runoff from forest management, harvesting, and road construction
Mining:	Runoff and process fluids from mining, petroleum drilling, and mine tailing sites
Construction:	Runoff from highway building and land development
Urban Runoff:	Runoff from sewered and unsewered urban areas, including industrial and commercial activities; under 319 also includes combined sewers
Combined Sewers:	Storm and sanitary sewers combined, which may discharge untreated wastes during storms
Land Disposal:	Runoff and leachate from landfills, septic tanks, and hazardous waste disposal sites
Hydromodification:	Channelization, dredging, dam construction, and streambank modification
Municipal Point Source:	Discharge from POTW (publicly owned treatment works)
Industrial Point Source:	Discharge from industrial processes
Other:	Includes atmospheric deposition, waste storage/tank leaks, highway runoff, spills, in-place contaminants, natural, and recreational and urban growth
Unknown:	Unknown

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This indicates the importance of focusing efforts on the management and control of stormwater discharges from urban areas and associated urban activities (i.e., storm sewers/urban runoff, combined sewers, hydromodification, land disposal, construction, urban growth, etc.) since the potential for future urban growth and cumulative impacts from increased stormwater discharges from expanding urban activities is relatively great.

The above analysis, although an approximation, indicates the relative importance of urban stormwater discharges as a major contributor to the impairment of the Nation's waters. This is consistent with the National Oceanic and Atmospheric Administration (NOAA) findings that urban runoff is a leading cause of impairment to shellfish growing waters (NOAA; 1988; 1989; 1990). This qualitative analysis does not allow, however, for a detailed ranking of all subcategories of stormwater discharges, including industrial and commercial activities occurring in urban areas. Certain source categories included under 319 and 305(b) that do correlate well with industrial activities are land disposal, mining, and construction and these are shown to be important contributors to water quality impairment (see Table 3).

It is not readily apparent as to what degree stormwater discharges are currently regulated in relation to the level of impairment reported. For example, although agriculture is a major nonpoint source contributor to water quality impairment, currently only the largest animal feedlots require stormwater discharge permits. Table 3 shows the status of National Pollutant Discharge Elimination System (NPDES) permit requirements for each pollution source category and we discuss this status in more detail below.

Regulating the Risk

The 1987 amendments to the Clean Water Act require EPA to develop NPDES permit application requirements for the following "Phase I" classes of stormwater discharges:

- discharges from large municipal separate storm sewer systems (systems serving a population of 250,000 or more) and medium municipal separate storm sewer systems (systems serving a population of 100,000 or more, but less than 250,000);
- stormwater discharges associated with industrial activity [identified by Standard Industrial Classification (SIC) codes]; and
- discharges which are designated by EPA or an NPDES approved State as needing an NPDES permit because the discharge contributes to a violation of a water quality standard or is a significant contributor of pollutants to waters of the United States.

Statutorily excluded from the NPDES requirements under the Clean Water Act are general agricultural stormwater, irrigation return flows, and uncontaminated runoff from oil and gas or mining operations.

The CWA creates a temporary moratorium on the general requirement of the CWA that point source discharges of pollutants to waters of the United States must be authorized by an NPDES permit. Under the moratorium, EPA is prohibited from issuing NPDES permits for non-Phase I discharges composed entirely of stormwater prior to October 1, 1992. EPA is required to issue regulations by no later than October 1, 1992 which designate additional "Phase II" stormwater discharges to be regulated to protect water quality and establish a comprehensive program to regulate such designated sources. The program must, at a minimum:

(A) establish priorities,

(B) establish requirements for State stormwater management programs, and

(C) establish expeditious deadlines.

The program may include performance standards, guidelines, guidance, and management practices and treatment requirements, as appropriate.

Phase I Stormwater Discharges. On November 16, 1990, EPA published regulations specifying permit application requirements for industrial activities and large/medium municipal separate storm sewer systems, the two major classes of Phase I stormwater sources (see inset next page).

Municipal - The November 16, 1990 regulations defined a municipal separate storm sewer system serving a population of 100,000 or more to include municipal separate storm sewers within the boundaries of 173 incorporated cities, and within unincorporated portions of 47 counties that were identified as

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Defining Stormwater Discharges

As "Phase I" Discharges:

Municipal:

- Separate storm sewers[a] in incorporated (city) and unincorporated (county) urban areas with population of 100,000 or more
- Combined sewer overflows (subject to NPDES permit requirements prior to Phase I)

Industrial:

- Heavy manufacturing facilities
- Medium manufacturing facilities with materials exposed to rainfall
- Priority oil and gas facilities
- Active and inactive mines
- Construction sites greater than 2ha(5ac)
- Landfills, storage or disposal facilities handling industrial/hazardous wastes
- Scrapyards/salvage yards
- Runoff from sewage treatment plants
- Selected transportation facilities
- Steam electric power plants
- Large animal feedlots (subject to NPDES permit requirements prior to Phase I)

Statutorily Excluded:

- Agricultural stormwater
- Irrigation return flows
- "Uncontaminated" runoff from oil and gas or mining operations

[a]*Separate storm sewers include pipe conveyance as well as ditches, and grass swales in suburban areas*

having populations of 100,000 or more in unincorporated, urbanized portions of the county. In addition, the regulations allowed for additional municipal separate storm sewers to be designated by the Director of the NPDES program as being part of a large or medium municipal system. **The inclusion of these 173 cities and 47 urban counties in the Phase I program recognizes that stormwater runoff from high density urbanized areas has a significant potential to impact receiving waters** due to the greater concentration of commercial and industrial activities; the existence of leaks, cross connections and illicit discharges into sewer systems; and the large impervious areas which normally exist.

Industrial - The November 16, 1990 regulations also defined the term "storm water discharges associated with industrial activity" broadly to include 11 categories of industrial facilities (see Phase I inset). EPA estimates that over 100,000 industrial facilities are addressed by this definition. Many of the Phase I industrial facilities (e.g., mining, landfills, construction, etc.) have previously been addressed by the NPDES program as traditional sources.

For example, stormwater discharges from mining sites have long been recognized as having significant impacts on receiving water quality, and national effluent guideline limitations under NPDES have been developed for most types of mining activities to control surface drainage (but not groundwater seepage). A wide variety of waste materials can be exposed to stormwater at waste disposal sites and scrap yards, which now require NPDES permits. Under RCRA Subtitle D, States reported that of the 1,100 municipal solid waste landfills which monitored discharges to surface water, 660 were cited for surface water impacts. Older landfills are of most concern because they may have received large volumes of hazardous waste and, in general, their use of design controls was very limited. Runoff generated from construction activities has the potential for serious water quality impacts from sediments and other land related pollutants. Annually, about 1.6 million acres of land are disturbed by construction activities nationwide. Only construction sites larger than 5 acres are currently required to be permitted under NPDES.

Pollutant concentrations in runoff from industrial facilities located in urban areas can be significantly higher than from residential or commercial areas due to the increased presence and amounts of toxic materials (Roesner, 1978). In general, the level of pollutants from industrial facilities is related to the type of activities occurring at the site, and the degree to which these activities are exposed to precipitation. Illicit connections, cross connections, improper waste disposal, and spills may also contribute sanitary or industrial waste waters directly to municipal storm sewer systems, leading to high metal, nutrient, or bacterial concentrations. A high priority has been set under the Phase I NPDES stormwater permit program to identify and bring these "non-storm" water pollution discharges under control.

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Phase I Implementation - The Phase I stormwater program takes two very different approaches to defining the roles of EPA and authorized NPDES States in controlling pollutants in stormwater discharges. With respect to permits for large and medium municipal systems, the efforts of the NPDES permitting authority (EPA or an authorized NPDES State) are directed to ensuring that municipalities develop and implement stormwater management programs to control pollutants to the maximum extent practicable. Municipal programs address ways to reduce pollutants in stormwater from privately-owned lands (e.g., commercial operations, houses) that discharge to a municipal system, as well as modifying municipal activities (e.g., road deicing and maintenance, flood control efforts, maintenance of municipal lands, etc.) to address stormwater quality concerns. NPDES permit activities can define the role of municipalities under this program in a flexible manner that allows local governments to assist in identifying individual priority pollutant sources (e.g., industrial sources, illicit connections, spills, etc.) within the municipality and to develop and implement appropriate controls for such discharges.

With respect to permits for stormwater discharges associated with specific Phase I industries identified in the November 1990 regulations, the NPDES permitting authority has a more direct role in regulating these facilities. In addition, NPDES permits for discharges from large and medium municipal separate storm sewer systems will establish municipal responsibilities for assisting EPA and authorized NPDES States in implementing controls to reduce pollutants in stormwater discharges associated with Phase I industrial activities which discharge through municipal systems.

Phase II Stormwater Discharges. EPA is currently evaluating a number of options for identifying Phase II stormwater discharges to be regulated to protect water quality. **Of the options being considered, perhaps the most difficult to address is whether to expand the categories of individual facilities (such as commercial or light industrial facilities) requiring permits, or rather to include these within an expansion of municipal separate storm sewer systems requiring permits.** Addressing additional municipal separate storm sewer systems would result in requiring the selected municipalities to:

(A) identify individual priority pollutant sources within the municipality (e.g., industrial sources, illicit connections, spills, etc.), and

(B) develop and implement appropriate controls for such discharges.

On the other hand, individual facilities specifically identified as new categories under Phase II of the NPDES stormwater permit program would primarily be regulated directly through requirements in NPDES permits. These two classes of Phase II sources (i.e., individual and municipal) are discussed in more detail below.

For **individual facilities under Phase II**, EPA could specify new categories of stormwater discharges (in addition to the existing 11 categories) to be regulated separately or under Phase II municipal separate storm sewer systems. Among the discharges that EPA could include for Phase II requirements are the 13 categories of stormwater sources identified in the inset above. The number of individual facilities within these new categories under consideration is currently unknown.

Defining Stormwater Discharges

As "Phase II" Discharges:

Municipal:

- **Separate storm sewers[a] in incorporated (city) and unincorporated (county) urban areas with populations less than 100,000**

Individual facilities:

- **Industrial facilities owned or operated by municipalities with a population less than 100,000**
- **Light industrial facilities**
- **Medium industrial facilities without materials exposed to rainfall**
- **Gas stations and automobile related facilities**
- **Tank farms**
- **Abandoned mine sites**
- **Construction sites less than 2ha(5ac)**
- **Runoff from construction projects for roads used for silviculture**
- **Municipal landfills that do not receive industrial waste**
- **Large parking lots (shopping centers, stadiums, etc)**
- **Military bases**
- **Research centers**
- **Animal feedlots not currently subject to NPDES permit requirements**

[a]*Separate storm sewers include pipe conveyance as well as ditches, and grass swale in suburban areas*

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For **municipal separate storm sewer systems under Phase II,** EPA is considering expanding NPDES requirements to urban areas having populations less than 100,000. Under Phase I, EPA defined municipal separate storm sewer systems on the basis of political boundaries, including 173 incorporated cities (having a population of 100,000 or more) and 47 of 500 counties having an unincorporated urban population of 100,000 or more. The counties that were addressed by the 11/16/90 regulation were in a handful of States, primarily MD, VA, FL, and CA. **While the current regulations indirectly address suburban growth in these States, in most parts of the country, the regulations only address core cities and exclude suburban or "urban fringe" development.** This is typified in Figure 2 for the Milwaukee, Wisconsin area, where only the incorporated city of Milwaukee and none of the urban fringe area within Washington, Waukesha, Ozaukee, Milwaukee, and Racine Counties is required to apply for a stormwater permit. The 1990 population for the Milwaukee urbanized area is about twice that of Milwaukee City and population densities are similar.

The Bureau of Census has defined 396 "urbanized areas" (UAs) based on the 1990 Census to define large metropolitan population patterns. UAs are comprised of a central "core" city (or cities) with a surrounding closely settled area. The population of the entire urbanized area must be greater than 50,000 people, and the closely settled area outside the city, the urban fringe, must have a population density generally greater than 1,000 persons per square mile (just over 1.5 persons per acre) to be included. **These 396 UAs contain over 158 million people, or over 63% of the Nation's total population. However, UAs only occupy about 1.5-2% of the Nation's land area.** Urban fringe areas surrounding core cities are typically divided into numerous local governments, as defined in Table 4 based on 1990 Census data.

Table 4. Municipalities Associated With Urbanized Areas (UAs)[a]

Size of UA	Number of UAs	Number of Incorporated Places[b]	Number of Minor Civil Divisions[c]	Number of County Equivalents[d]
250,000 or more	172	3,874	880	470
100,000-250,000	121	930	362	200
50,000-100,000	103	829	315	258

[a]Based on 1990 Census data
[b]Incorporated places include incorporated cities, towns, villages , and boroughs
[c]Minor civil divisions include unincorporated towns and townships in 20 States
[d]County equivalents include counties, parishes in LA, and boroughs in Alaska. Some double counting of counties occurred as portions of several UAs may be in one county (for example, the portions of the Washington UA, Baltimore UA, and Annapolis UA are in Anne Arundel County, MD)

The 220 Phase I NPDES municipalities have a combined urban population of 78 million. The remaining 80 million people located in urbanized areas are outside of Phase I municipalities. **Most urban growth occurs in the urban fringe areas outside of core cities.** For example, between 1970 and 1980, the population of incorporated cities with a population of 100,000 or more (Phase I cities) increased by only 0.6 million, with the population of many of these cities decreasing. Between 1970 and 1980, the population of urbanized areas outside of cities with a population of 100,000 or more increased 30 times more (an increase of 18.9 million) than the population of these core cities. This is important from a stormwater perspective as numerous studies (e.g., NURP) have shown that **it is much more cost effective to develop measures to prevent or reduce pollutants in stormwater during new development than it is to correct these problems later on.**

Addressing new development is generally considered to be institutionally feasible as many municipalities already have some form of approval or permit program in place that can be modified to address stormwater concerns. In addition, the economic achievability of implementing stormwater controls is expected to be greater for new development versus established core cities since: (1) structural controls and therefore costs can be minimized; (2) new development often absorbs a significant portion of infrastructure capital costs; and (3) the tax base on a per capita basis in urban fringe areas is likely to be

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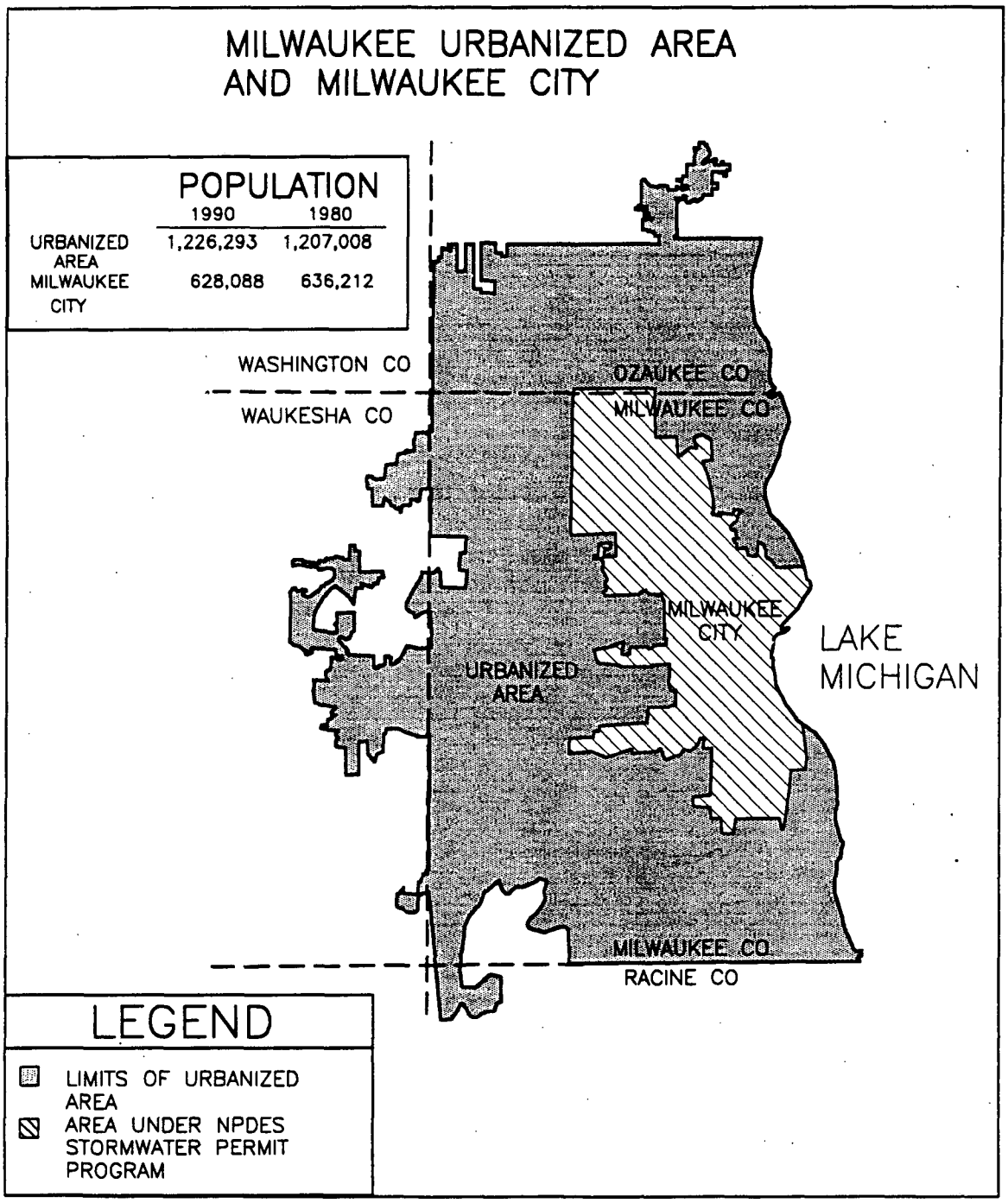

Figure 2. Jurisdiction of Phase I NPDES Stormwater Permit Program in Milwaukee, Wisconsin

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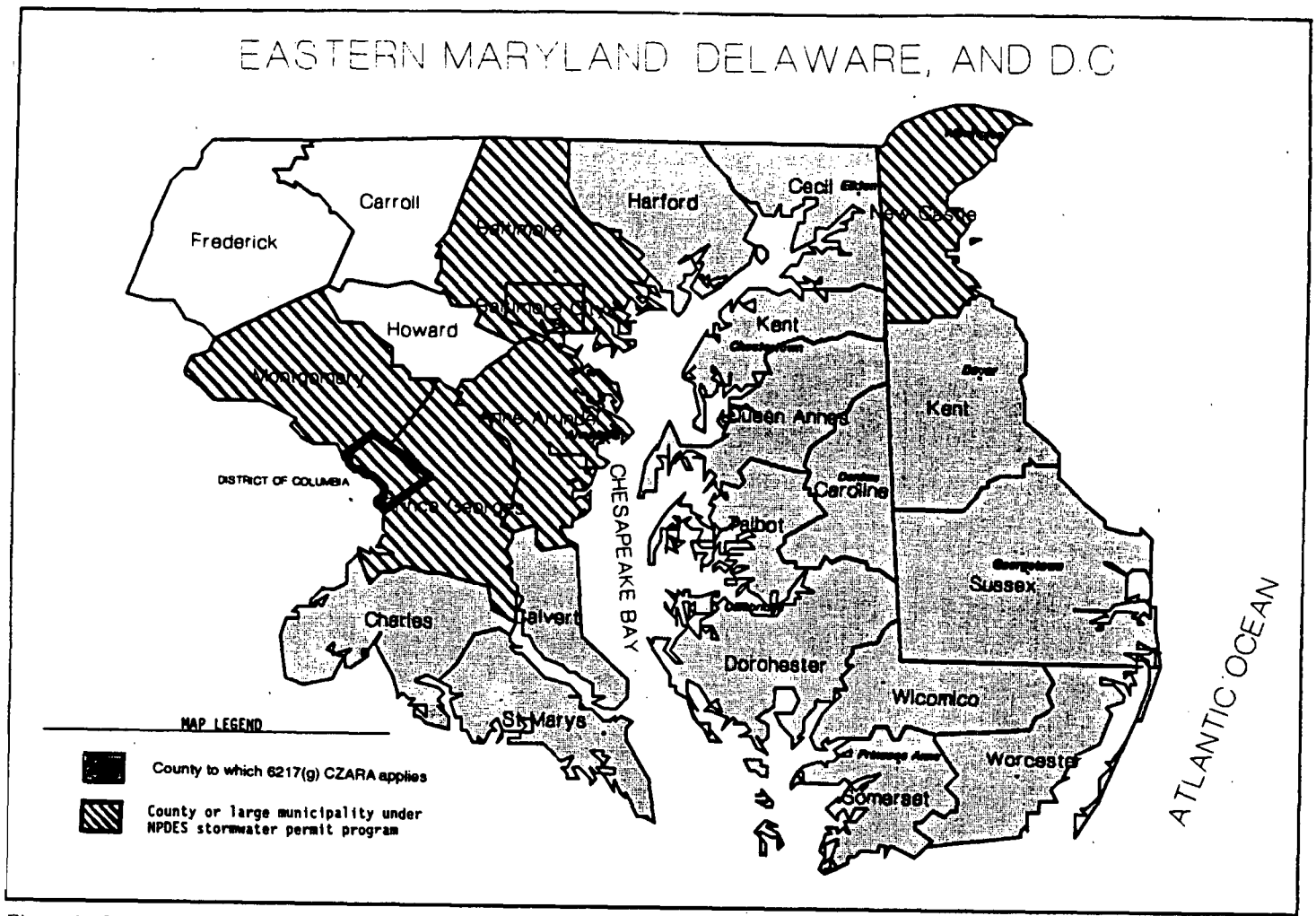

Figure 3. Jursidiction of Phase I NPDES Stormwater and CZARA Programs in Maryland, Delaware, and Washington, DC

greater (National League of Cities, 1991).

Relationship of NPDES to Other Programs. Figure 3 illustrates the current jurisdiction of the Phase I NPDES stormwater discharge permit program and the Coastal Nonpoint Pollution Control Program under Section 6217(g) of the Coastal Zone Act Reauthorization Amendments of 1990 (CZARA), respectively, in Maryland, Delaware, and Washington, DC. Although not a permit program, the CZARA program is intended to foster the development and implementation of management measures for nonpoint source pollution control to restore and protect coastal waters in conformance with guidance developed by EPA (USEPA, 1991c). "Management measures" are defined under CZARA as economically achievable measures to control the addition of pollutants to coastal waters, which reflect the greatest degree of pollutant reduction achievable through the application of the best available nonpoint pollution control practices, technologies, processes, siting criteria, operating methods, or other alternatives. CZARA management measures include a mix of non-structural and structural control practices in order to optimize costs and pollutant removal effectiveness over a range of land uses and activities.

For the example presented in Figure 3, two cities in close proximity (Washington, DC and Baltimore, MD) and the urbanized counties which surround these cities are addressed by the Phase I NPDES program. **However, incorporated towns or cities with populations less than 100,000 within the NPDES counties are exempt from the NPDES program,** such as the city of Annapolis, MD, as well as 43 other incorporated towns in Anne Arundel, Prince Georges, and Montgomery Counties (MD). Since Maryland is an approved

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coastal zone State[a], the areas within the coastal zone that are exempt from NPDES requirements will be included in the State's approved Coastal Nonpoint Pollution Control Program under CZARA. Counties and municipalities landward of the coastal zone with populations less than 100,000 are currently not addressed by either the Phase I NPDES or CZARA programs and fall under the jurisdiction of other nonpoint source management programs including Section 319 of the Clean Water Act and US Department of Agriculture conservation programs.

[a] *There are 29 federally approved State and Territorial coastal zone programs, including states bordering the Great Lakes (e.g., Wisconsin). The definition of the approved coastal zone boundary varies substantially by State.*

Stormwater and the Urbanization Process

As pointed out by Novotny (1992), the extent and nature of **stormwater pollution is characterized not only by meteorologic conditions, type of land surface, and its inherent difficulty to measure or quantify, but perhaps most importantly by its relationship to the level and type of activity, or disturbance, occurring on the land surface in question.**

In the EPA Nationwide Urban Runoff Program (NURP), significant differences in measured pollutant concentrations, reported as event mean concentrations (EMCs), were not detected among the three major urban land use categories (i.e., residential, commercial, and mixed urban). Only open/non-urban lands were significantly different from the previous three land use types (USEPA, 1983b). The NURP data point out the existence of high variability in urban stormwater runoff quality and the need to characterize urban runoff for individual urban areas when conducting site-specific designs for stormwater controls. Data on pollutant loadings given in Table 1 also demonstrate the wide variations in loads associated with traditional land use categories.

In contrast to land use, land disturbance through urbanization, (i.e., construction, deforestation, wetland drainage, channelization) is perhaps more directly correlated to the level of pollutant loadings and impacts caused by stormwater runoff. **Urbanization alters the natural vegetation and natural infiltration characteristics of the watershed, causing runoff from an urban area to have a much higher surface flow, a much smaller interflow, and a somewhat reduced baseflow (see Figure 4).** Urbanization also can create water quality impacts by increasing the amount of sediment, nutrients, metals, and other pollutants associated with land disturbance and alteration activities, as well as with the permanent increase in the impervious urban surfaces created . Thus urbanization tends to increase both runoff volumes and pollutant loadings to the receiving waterbody.

Effects of Urbanization-Developing Areas. The change of land use from natural or agricultural to

Phases of Urbanization

Suburban/Urban Area Development -
Land conversion through deforestation and drainage/filling creates extensive erosion and changes the hydrologic balance of the watershed. Soil loss from uncontrolled construction can reach a magnitude of over 100 ton/ha.yr. Shifts from the natural watershed flow and stream channel conditions greatly reduce the habitat value of the stream.

Suburban/Urban Areas - Post Development-
Once stabilized, pollutants accumulate on impervious surfaces and are washed off. Primary pollutant sources are atmospheric deposition, urban surfaces (roofs, autos on streets), and miscellaneous activities (animals, litter, spills, fertilizer application, street salting, septic system failures, etc.). Loading rates of pollutants are generally correlated with degree of imperviousness, land area size, and type of drainage system.

Fully Developed (Core)Urban Areas -
Sewered watersheds are characterized by extensive impervious areas, large runoff volumes during storms, and increased loadings of pollutants from similar sources (see above). Older urban areas commonly are served by combined sewers which often overflow during wet weather releasing pathogens and industrial toxicants. Increased industrial and commercial activities (land disposal, storage piles, vehicle maintenance, spills, etc.) create opportunities for release of toxic substances into separate and combined sewer systems.

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urban occurs in several steps (see inset previous page) that range from developing suburban/urban areas to fully developed cities serviced by extensive sewer networks and transportation corridors.

During the construction phase of suburban/urban land development, the hydrology of a stream changes in response to initial site clearing and grading. Trees that had interrupted rainfall are felled (see Figure 4a). Natural depressions that temporarily ponded water are graded to a uniform slope. The thick humus layer of the forest floor that had absorbed rainfall is scraped off or eroded away. **Having lost much of its natural storage capacity, the cleared and graded construction site can no longer prevent rainfall from being rapidly converted to runoff** (Schueler, 1987).

Pollutant export increases dramatically both during and after development. **Unless adequate erosion controls are installed and maintained at the site, enormous quantities of sediment are delivered to the stream channel, along with attached soil nutrients and organic matter.** Uncontrolled construction site sediment loads have been reported to be on the order of 35 to 45 tons/acre/year (Novotny and Chesters, 1981; Wolman and Schick, 1967; Yorke and Herb, 1976, 1978).

After construction is completed, roof tops, roads, parking lots, sidewalks, and driveways make much of the site impervious to rainfall. Unable to percolate through the soil, rainfall is converted to runoff. The excess runoff becomes too great for the existing drainage system to handle. As a result, the drainage network must be improved to direct and convey the runoff away from the site (Schueler, 1987). **Downstream of the land development activity, impacts in the form of streambank erosion, channelization, and elimination/alteration of habitat occur due to increases in streamflow volumes, flooding frequency, peak flows, and movement of sediment.** The effect of development on stream hydrology in a typical, moderately developed watershed is shown in Figure 4b,c and summarized in the inset (next page) by Schueler (1987).

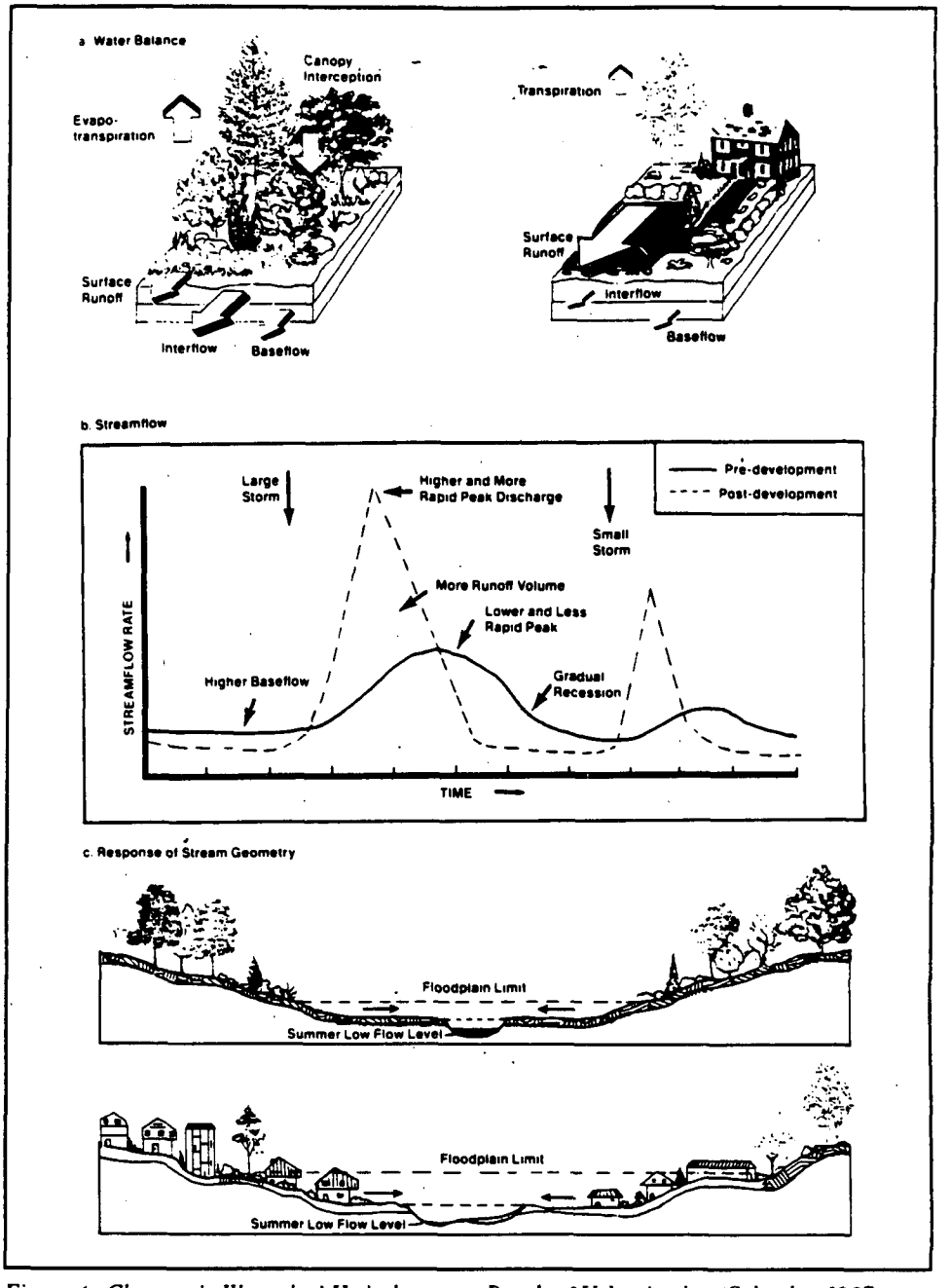

Figure 4. Changes in Watershed Hydrology as a Result of Urbanization (Schueler, 1987)

Construction activities are temporary, but the permanent change

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Changes in Stream Hydrology from Urbanization[a]

- Increased peak discharges compared to predevelopment levels (Leopold, 1968; Anderson, 1970);
- Increased volume of storm runoff produced by each storm in comparison to predevelopment conditions;
- Decreased time needed for runoff to reach the stream (Leopold, 1968), particularly if extensive drainage improvements are made;
- Increased frequency and severity of flooding;
- Reduced streamflow during prolonged periods of dry weather due to the reduced level of infiltration in the watershed; and
- Greater runoff velocity during storms, due to the combined effect of higher peak discharges, rapid time of concentration and the smoother hydraulic surfaces that occur as a result of development.

[a] *Schueler (1987)*

Table 5. Average Annual Atmospheric Deposition Rates for the Washington, D.C. Area[a]

Pollutant	Rural (a)	Suburban (b) (lbs/acre/year)	Urban (c)
Total Solids	99	155	245
Chemical Oxygen Demand	199	133	210
Total Nitrogen	19.9	12.8	17.0
Nitrate-N	9.4	5.6	6.8
Ammonia-N	5.5	1.1	1.0
Total Kjeldahl-N	10.5	7.2	10.2
Total Phosphorus	0.71	0.50	0.84
Ortho-phosphorus	0.28	0.26	0.35
Trace Metals			
Cadmium	ND	0.09	0.003
Copper	ND	0.21	0.61
Lead	0.06	0.44	0.53
Iron	ND	1.57	5.60
Zinc	0.67	1.35	0.65

[a] *MWCOG (1983a). Note: ND = no data*

in land use and the hydraulic and pollutant characteristics associated with the transformed urban landscape produce lasting effects. Most of these impacts are caused by the net increase in impervious surfaces. In developed suburban/urban areas, pollutants accumulate rapidly on impervious surfaces and are easily washed off. Measured rates of atmospheric deposition of pollutants in the Washington D.C. area are summarized in Table 5. Halverson et al. (1984) reported that the contribution of precipitation to runoff pollution from paved surfaces was 100% for ammonia and nitrate nitrogen. They also reported values of 28 percent for sulfate and 13 percent for phosphorus. They suggested that nitrogen, sulfate and phosphorus should be considered when assessing urban runoff quality. **The type of surfaces in the urban landscape are also an important source of pollutants in runoff.** Trace metals, for example, are a common component of surfaces such as roofing materials, downspouts, galvanized pipes, metal plating, paints, wood preservatives, catalytic converters, brake linings, and tires. Over time, these surfaces corrode, decay, or leach out, releasing metals into the runoff (Schueler, 1987). **Other sources of pollutants that accumulate and subsequently wash off impervious surfaces include pet droppings, lawn fertilizer and pesticides,organic matter, litter, used motor oil, and road salt (see Table 6).**

Gwinnett County, Georgia, An Urban Fringe Area. Stormwater runoff characteristics also vary with the age of the development and the rate at which natural and agricultural lands are converted to urban areas. This rate of change depends on the land location and its proximity to other urban areas and core cities. **Urban fringe areas are experiencing the largest land use changes due to rapid growth in population resulting in an excessive net increase in pollution loadings. Many of these fringe areas are not currently covered under the Phase I NPDES stormwater program.** A typical rapidly growing fringe area not initially regulated under the NPDES program, Gwinnett County, GA

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Table 6. Sources of Urban Runoff Pollutants

Source	Pollutant of Concern
Erosion	Sediment and attached soil nutrients, organic matter, and other adsorbed pollutants.
Atmospheric Deposition	Hydrocarbons emitted from automobiles, dust, aromatic hydrocarbons, metals, and other chemicals released from industrial and commercial activities.
Construction Materials	Metals from flashing and shingles, gutters and downspouts, galvanized pipes and metal plating, paint, and wood preservatives.
Manufactured Products	Heavy metals; halogenated aliphatics; phthalate esthers; PAHs; other volatiles; phenols and oil from automobile use, zinc and cadmium from tire wear, and pesticides and phenols from other uses including industrial.
Landscape Maintenance	Fertilizer and pesticides. Generally as impervious area increases, nutrients build up on surfaces and runoff transport capacities also rise resulting in high loads. Exceptions include intensively landscaped areas (e.g., golf courses, cemeteries).
Plants and Animals	Plant debris, animal excrement.
Septic Tanks	Coliform bacteria, nitrogen/NO_3
Non-stormwater Connections	Inadvertent or deliberate discharges of sanitary sewage and industrial wastewater to storm drainage systems, including illicit connections, leaking sanitary collection systems, spills, industrial and commercial activities, construction activities, infiltration of contaminated groundwater, and improper disposal.
Accidental Spills	Pollutants of concern depend on the nature of the spill.

[a] *Based in part on Woodward-Clyde Consultants, 1990.*

(see Figure 5) has experienced an increase in population from about 72,000 to 275,000 during the 1975 to 1986 period, and significant conversion of forest and agricultural lands to urban areas. Urban areas increased from about 50,000 acres in 1975 to over 100,000 acres in 1990 (Atlanta Regional Commission land use database - unpublished). This urban fringe growth rate, although high, was not significantly different from that of all urban areas in the entire country during this same time period, according to Bureau of Census data (USDA, 1992). Based on analysis of Census data, the projected population of Gwinnett County is expected to exceed 700,000 by year 2012 (also county estimate). Consequently, the corresponding increase in urban areas may be expected to exceed 170,000 acres or about 300% of the 1975 values.

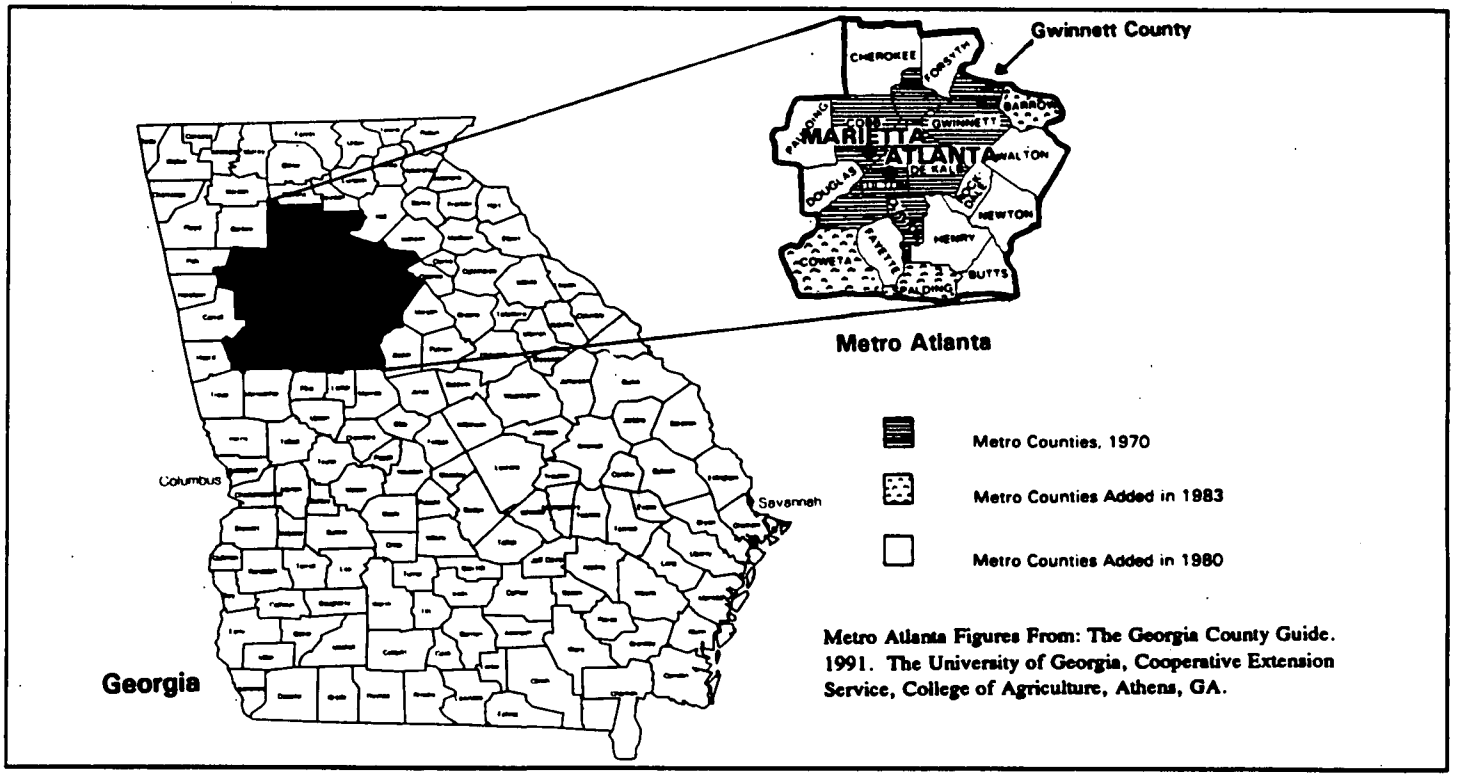

Figure 5. Location of Gwinnett County, Georgia

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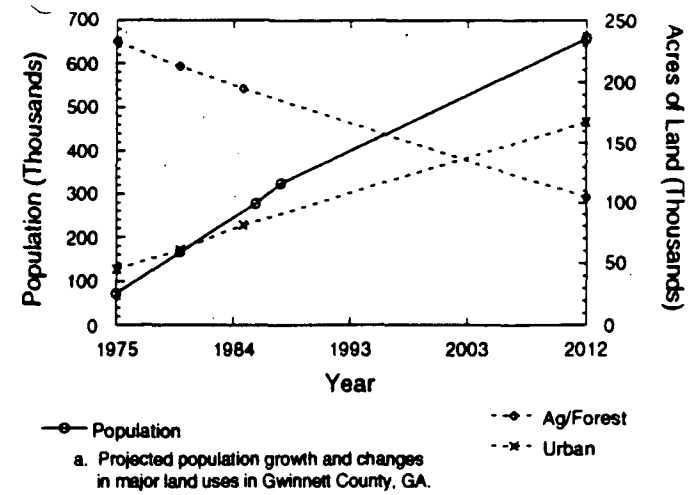
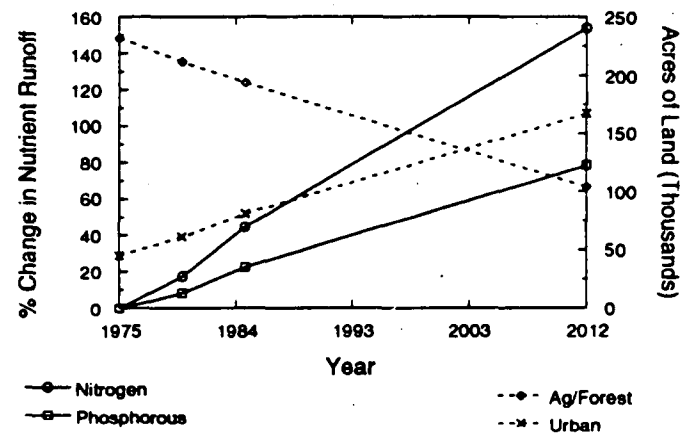
Figure 6a illustrates the observed (1975-85) and expected (1985-2012) rate of change in land use distribution as the population increases.

In the absence of a comprehensive urban planning program addressing stormwater runoff in particular, such rapid land conversion and associated land disturbances due to construction activities will yield high sediment and pollutant loadings. Furthermore, the permanent change in land use activities will result in dramatic changes in hydrologic and pollutant characteristics. Current NPDES regulations address construction activities (>5 acres) but do not address the longer term cumulative effects of urbanization.

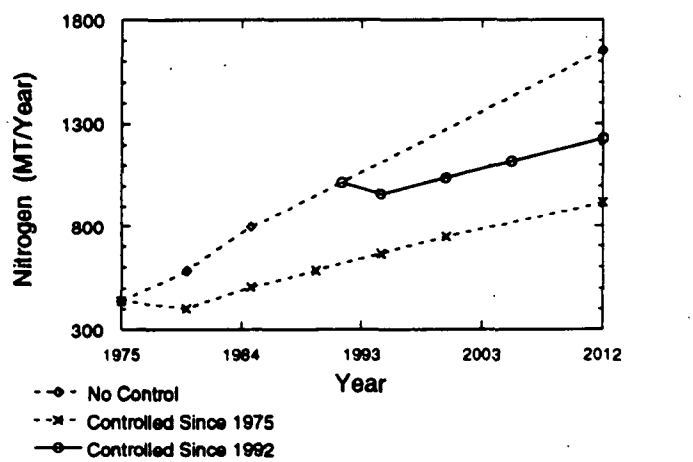
The long-term rates of change of nutrient loadings in Gwinnett county were roughly estimated using a generalized loading function model and existing information from the Census and National Resource Inventory files. Nutrient load estimates were derived for the years 1975, 1980, and 1985 based on existing land use and population data, and for the year 2012 based on projected land use distribution (Figure 6b). Projected population and land use distributions for 2012 were estimated based on the mean annual rate of change during the 1975-1985 period. Temporary sediment and nutrient loadings due to construction activities were not considered in these estimates. Currently, construction activities are regulated under Federal or State approved NPDES programs. The 2012 nutrient loading projections indicate a relative increase in nitro-



a. Projected population growth and changes in major land uses in Gwinnett County, GA.



b. Projected increase in total runoff nutrient loadings and changes in land use in Gwinnett County, GA.



c. Long term trends in stormwater nitrogen loads in urban areas of Gwinnett County, GA, for 3 control scenarios.

Figure 6. Comparison of population, land use, and pollutant loadings for Gwinnett County, Georgia

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Table 7. Ranges in Pollutant Concentrations Found in Runoff[a] From Commercial and Residential Areas

Constituent	Mean Concentration in Runoff		
	10th Percentile Urban Site	Median Urban Site	90th Percentile Urban Site
Total suspended solids (mg/L)	35	125	390
BOD (mg/L)	6.5	12	20
COD (mg/L	40	80	175
Total Phosphorus (mg/L)	0.18	0.41	0.93
Soluable Phosphorus (mg/L)	0.10	0.15	0.25
Total Kjeldahl nitrogen (mg/L)	0.95	2.00	4.45
Nitrate-nitrogen (mg/L	0.40	0.90	2.20
Total Copper (µg/L)	15	40	120
Total Lead (µg/L)	60	165	465
Total Zinc (µg/L)	80	210	540

[a] *Source: Woodward-Clyde Consultants, 1990.*

gen of about 154% and phosphorous of about 79% above the 1975 levels.

The importance of addressing stormwater runoff in the early stages of urban land development is illustrated by the temporal increase in nitrogen load from urban areas under three control scenarios: no control, control beginning in 1975, and control beginning in 1992 (Figure 6c). The nitrogen loadings under the no control condition were derived based on urban development trends in Gwinnett county. The control conditions for each of the treatment scenarios consisted of a 50% reduction goal in nitrogen loading from all new development and 10 to 25% reduction goals from existing and retrofit urban areas. The projection of annual nitrogen loads to year 2012, for controls beginning in 1975 and controls beginning in 1992, shows an overall annual reduction of 734 and 420 tons of nitrogen respectively, corresponding to 45% and 25% of the projected value for the uncontrolled condition. A comparison of the two control programs shows that **if implementation of stormwater controls is delayed, achieving lower levels of nitrogen loadings may require implementation of a retrofit program with limited control options consisting primarily of costly structural practices.**

As discussed earlier, the recent and projected rapid growth rate of the urban fringe area of Gwinnett County is expected to parallel a similar rapid growth rate of urban fringe areas nationwide. **A basic principle of stormwater controls for urban development is that it is much more cost effective and institutionally feasible to develop controls for new development than it is to retrofit old development.** At the time the 319 status on water quality impairment was last reported (1991), stormwater runoff from urban and land development activities representing only about 2% of the Nation's land surface was responsible for 18% to 62% of the reported impairment to surface water bodies (see Table 3). The growth rate of urban land areas for the last 4 decades (based on Bureau of Census data) has been about 20% per decade creating the potential for rapidly increasing impacts if stormwater discharges from new urban fringe growth is not adequately managed.

Fully Developed Core Urban Areas. In fully developed urban areas, the amount of impervious land is extensive, providing further opportunity for pollutants to wash off urban surfaces in even larger amounts. Original stormwater systems were typically constructed for flood control purposes. Water quality programs probably did not address stormwater quality concerns and runoff is typically directed to surface water. Older, more established urban areas are also characterized by greater commercial and industrial activities; the existence of leaks, cross connections and illicit discharges into sewer systems; and often the existence of combined sewer systems. These create opportunities for the release of toxic pollutants and large amounts of pathogens during wet weather overflows of the combined sewers.

Pollutant concentrations in urban runoff vary considerably, both during the course of a storm event and from event to event at a given site, from site to site within a given urban area, and from one urban area to another across the country. This variability is the result of variations in rainfall characteristics, differing watershed features that affect runoff quantity and quality, and variability in urban activities (Woodward-Clyde, 1990). Table 7 presents ranges of urban runoff pollutant concentrations based on results of

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Table 8. Strength of Point and Nonpoint Urban Sources[a]

Wastewater type	BOD_5, mg/L	SS, mg/L	Total N, mg/L	Total P, mg/L	Lead, mg/L	Total coliforms, MPN/100 mL
Urban stormwater	10 to 250	3 to 11,000	3 to 10	0.2 to 1.7	0.03 to 3.1	10^3 to 10^8
Construction site	not available	10,000 to 40,000	not available	not availble	not available	not available
CSOs	60 to 200	100 to 1,100	3 to 24	1 to 11	0.4 (mean)	10^5 to 10^7
Light industrial	8 to 12	45 to 375	0.2 to 1.1	not available	0.02 to 1.1	10
Roof runoff	3 to 8	12 to 216	0.5 to 4	not available	0.005 to 0.03	10^2
Untreated sewage	160 (mean)	235 (mean)	35 (mean)	10 (mean)	not available	10^7 to 10^9
POTW effluent	20 (mean)	20 (mean)	30 (mean)	10 (mean)	not available	10^4 to 10^6

[a]*Source: Ellis (1986) as reported by Novotny (1992)*

the Nationwide Urban Runoff Program (NURP). Values represent the mean of event mean concentration (EMC) pollutant values for the median, 10th percentile, and 90th percentile sites in the NURP data. Although statistically significant differences in EMCs were not detected amount the three major urban land use categories (i.e., residential, commercial, and mixed urban), or among geographical locations or between runoff events (volumes), nevertheless these data are perhaps the best available for planning purposes in describing the general quality of urban runoff. The NURP data base does not, however, represent pollutant contributions from illicit connections, spills, industrial activities, or dumping, as these sources were not evaluated at the time NURP was conducted.

A comparison of the pollutant strength (i.e., concentrations) of typical point and nonpoint urban sources is presented in Table 8. **The pollution potential of urban runoff carried by separate storm sewers is similar to treated municipal wastewater, while that of combined sewer overflows (CSOs) is greater than treated and less than untreated municipal wastewater (Novotny, 1992). Although the pollution strength of CSOs is somewhat less than that of raw wastewater, an overflow from a large storm may shock the receiving waterbody many times greater than a normal effluent load.** Floatable debris in CSOs and separate storm sewers can further degrade receiving water. This debris represents both an aesthetic problem and a threat to aquatic life.

Impacts on Aquatic Ecosystems. The aquatic ecosystems in urban headwater streams (i.e., streams whose upper reaches lie within urbanizing areas) are particularly susceptible to the impacts of urbanization (Schueler, 1987). The massive shift from natural flow and channel conditions reduce the habitat value of the stream. As reported by Schueler (1987), studies of fish diversity and abundance over time in urbanizing streams [Dietemann (1975), Ragan and Dietemann (1976), Klein (1979) and MWCOG (1982)] have shown that **fish communities become less diverse and are composed of more tolerant species after the surrounding watershed is developed. Sensitive fish species either disappear or occur rarely. The total number of fish in urbanizing streams also usually declines.**

Similar trends have been noted among aquatic insects which are a major food resource for some species of fish (Schueler, 1987). These species cling to rocks (or other aquatic substrates) and rely on the passing flow of leaf litter and organic matter for sustenance. Higher post-development sediment and trace metals can interfere in their efforts to gather food. Changes in water temperature, oxygen levels, and substrate composition can further reduce the species diversity and abundance of the aquatic insect community.

No single factor is responsible for the progressive degradation of urban stream ecosystems. Rather, it is probably the cumulative impacts of many individual factors such as sedimentation, scouring, increased flooding, lower summer flows, higher water temperatures, and increased pollutants. A more detailed discussion of the impacts of urban stormwater pollution on receiving waters is presented in the next chapter of this booklet.

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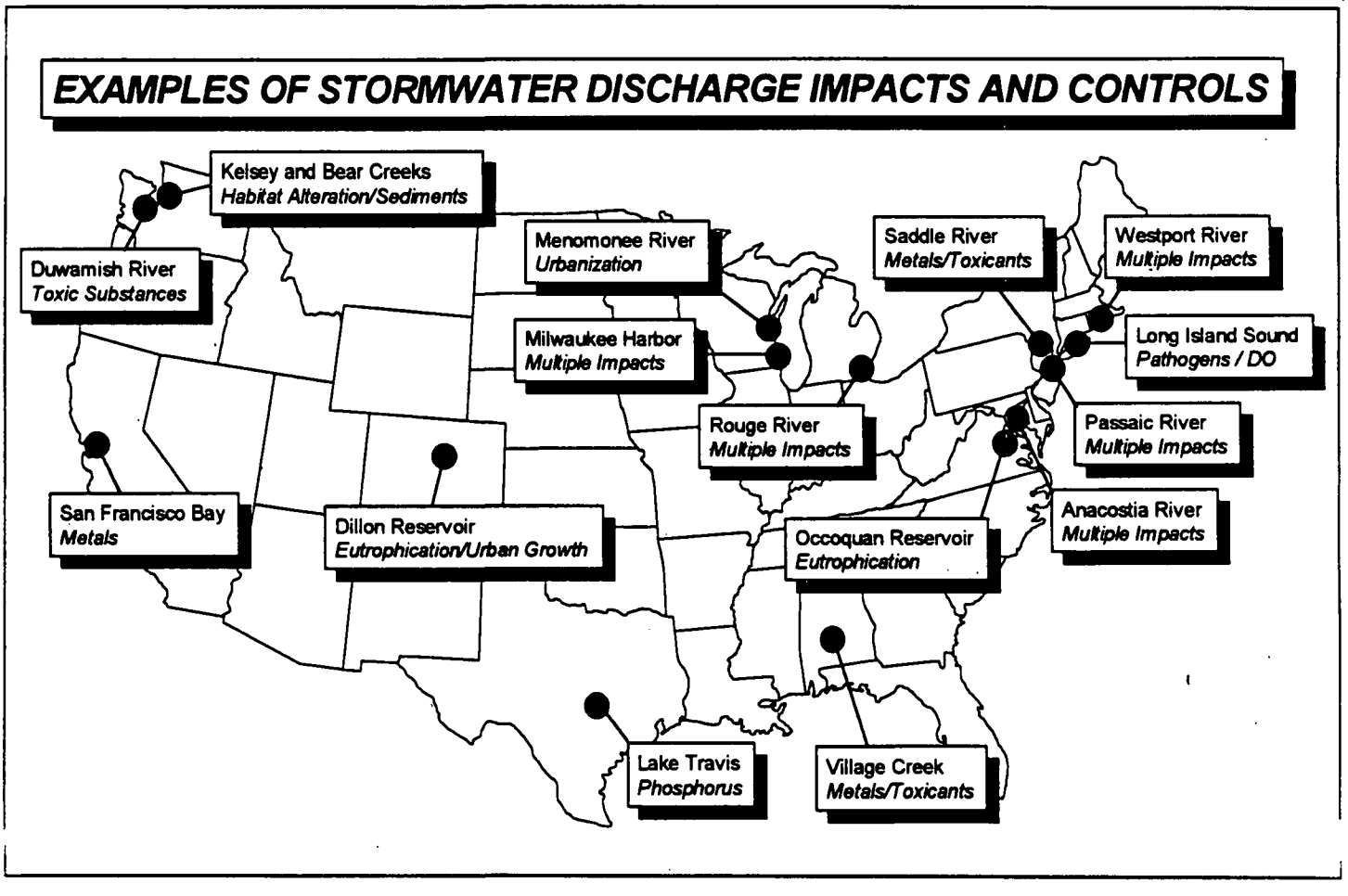
POLLUTANTS IN STORMWATER AND EXAMPLES OF ASSOCIATED IMPACTS

The net effect of urbanization is to increase pollutant export by several orders of magnitude over pre-development levels. The impact of the higher export is felt not only on adjacent streams, but also on downstream receiving waters such as lakes, rivers, and estuaries. The nature of the impacts associated with specific urban stormwater pollutants are reviewed in this chapter. Examples of documented impacts covering the range of pollutants and source types are also presented. The land activities that are likely to result in the most severe receiving water impacts are also identified (after Schueler, 1987). The following principal types of pollutants found in urban runoff are addressed:

- **Sediment/habitat alteration;**
- **Oxygen-demanding substances** (organic matter);
- **Nutrients**
  - phosphorus
  - nitrogen;
- **Toxic substances**
  - heavy metals
  - oil and grease
  - others;
- **Bacteria;**
- **Floatables;** and

the multiple impacts of several of these pollutants acting in concert.

The locations of the fifteen case examples of documented receiving water impacts caused by stormwater pollution are shown on the map below. Examples which address stormwater control practices are also presented in the last chapter of this booklet.



Sediment/Habitat Alteration

High concentrations of suspended sediment in streams can cause multiple impacts including increased turbidity, reduced light penetration, reduced prey capture for sight feeding predators, clogging of gills/filters of fish and aquatic invertebrates, reduced spawning and juvenile fish survival, and reduced angling success. Additional impacts result after sediment is deposited in slower moving receiving waters, such as smothering of the benthic community, changes in the composition of the bottom substrate, more rapid filling of small impoundments which create the need for costly dredging, and reduction in aesthetic values. Sediment having a high organic or clay content is also an efficient carrier of toxicants and trace metals. Once deposited, pollutants in these enriched sediments can be remobilized under suitable environmental conditions to pose an additional risk to benthic and other aquatic life. A study of Kelsey Creek in Seattle, WA, revealed the impacts of stormwater flows and sedimentation on fish populations (Kelsey and Bear Creeks).

The greatest sediment loads are exported during the construction phase of any development activity. Furthermore, in intensively developed watersheds, increased streamflow can result in channel degradation requiring streambank erosion controls.

Kelsey and Bear Creeks, Seattle, Washington (Habitat Alteration/Sediments)

A comparison of urban Kelsey Creek to rural Bear Creek near Bellevue, Washington (Pitt and Bissonette, 1984); indicated significant interrelationships among the physical, biological, and chemical characteristics. The urban creek, although not grossly polluted, contained a limited and unhealthy salmon fishery where many fish suffered from respiratory anomalies. The most significant impact resulting from the urban area is high flood flows which alter the stream channel, and carry priority pollutants, organics and metals through the stream system. Low dissolved oxygen in the stream bed results in low embryo survival rates.

Monitoring conducted by the City of Bellevue, the U.S. Geological Survey, and the Municipality of Metropolitan Seattle revealed that concentrations of metal and organic priority pollutants are higher near the source areas than in the stream itself. Heavy metals were observed to originate primarily from street dirt.

Evaluations of control practices indicated that detention basins in a residential area did not significantly improve runoff quality although peak flows were reduced by approximately 60%. A specialized street sweeper was needed to obtain effective removal of small dirt normally washed off by rain as regular street cleaning removed only a maximum of 10% of pollutants. Bi-yearly catchbasin cleaning resulted in a maximum effectiveness of 25%.

Urbanization has led to rapid stormwater conveyance to streams. However, these increased flows result in the transport of metals and toxic pollutants through the stream system with little deposition in the stream bed. If the flows are reduced, increased amounts of toxic materials are expected to settle in the stream bed with increased negative effects on aquatic life. However, reducing the flows would allow the retainment of many smaller fish and organisms which are currently washed from the system. The monitoring and stormwater control management of Kelsey Creek demonstrates the importance of balancing the benefits obtainable from reduced flows with the potential impacts resulting from increased deposition of toxic pollutants and organics.

Oxygen Demanding Substances

Decomposition of organic matter by microorganisms depletes dissolved oxygen (DO) levels in receiving waters, especially slower moving streams and lakes and estuaries. There are several measures of the degree of potential DO depletion, the most common of which are the Biochemical Oxygen Demand (BOD) test and the Chemical Oxygen Demand (COD) test. Both of these tests have problems associated with their use in urban runoff, but it has been demonstrated (e.g., Rouge River, Western Long Island Sound—see insets) that urban run-

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off can severely depress DO levels after large storms, and that BOD solids can accumulate in bottom sediment causing impacts during periods of dry weather. BOD levels can exceed 10 to 20 mg/l during storm events which can lead to anoxic conditions (zero oxygen) in shallow, slow-moving or poorly-flushed receiving waters. The problem is particularly acute in some older urban areas, where storm runoff BOD mixes with overflows from combined or sanitary sewers.

The greatest export of BOD typically occurs from older highly impervious, highly populated urban areas with outdated combined storm sewers. In contrast, only moderate BOD export has been reported from newer, low density suburban residential development. A study of the Rouge River, Michigan, included an examination of BOD loadings from a highly developed basin, and is presented at right (Rouge River).

Rouge River, Michigan
(Multiple Impacts)

The Rouge Basin, located in Southeast Michigan in the Detroit metropolitan area, is a fan shaped basin with four river branches draining 438 square miles. In addition to the four major river branches, the Basin's surface water system includes numerous tributary streams and over 400 lakes and ponds. The Basin contains all or part of 48 municipalities with a population of 1.5 million people. More than 50 percent of the land in the Basin is developed for residential, commercial or industrial uses with portions intensely urbanized (Newport and Davenport, 1988). The City of Detroit and the older cities adjacent to Detroit have combined sewers. Though the Rouge has been designated as a *warm water fishery and suitable for recreational and agricultural* use, applicable water quality standards, including dissolved oxyten, are not being met. The Rouge has been designated as an Area of Concern by the International Commission overseeing the Great Lakes, as it contributes some of the greatest pollutant loadings to the Great Lakes. Annual stormwater loadings in 1985 to the Rouge Basin were estimated to be 6,360,000 lb/yr BOD_5 (45% of the total BOD_5 load), 154,000,000 lbs/yr TSS (88% of the total TSS load), and 1,110,000 lb/yr nitrogen (about twice the nitrogen load from CSOs). CSOs contribute 5,489,000 lbs/yr BOD_5 (40%) of the total load), 13,100,000 lbs/yr suspended solids (8%) and 567,000 lbs/yr nitrogen. Loadings are impairing the uses of the Basin.

In July 1985, the Michigan Water Resources Commission passed a resolution requesting the department of Natural Resources to develop a Remedial Action Plan (RAP) addressing the water quality in the Rouge Basin. Of particular concern were the adverse impacts from CSOs, illicit connections to storm drains and storm water runoff. The RAP, published in 1989, recommends a 20 year program of nearly $1 billion to eliminate CSOs, improve separate sanitary sewers, upgrade treatment facilities and fund local stormwater programs.

Nutrients

The levels of phosphorus and nitrogen in urban runoff can lead to accelerated eutrophication in downstream receiving waters. Generally, phosphorus is the controlling nutrient in freshwater systems. The greatest risk of eutrophication is in urban lakes and impoundments with long detention times (two weeks or greater). Surface algal scums, water discoloration, strong odors, depressed oxygen levels (as the bloom decomposes), release of toxins, and reduced palatability to aquatic consumers are among the problems encountered. High nutrient levels can also promote the growth of dense mats of green algae that attach to rocks and cobbles in shallow, unshaded headwater streams. High nutrient loads from urban runoff, in combination with other sources, can contribute to eutrophication in both fresh and tidal waters.

As a general rule of thumb, as impervious area increases, nutrients build-up on surfaces and runoff transport capacities rise as well, leading to high pollution loads. Exceptions include land under development, and land activities that receive unusually high fertilizer inputs, such as golf courses, cemeteries, and other intensively landscaped areas.

Examples of eutrophication caused by nonpoint sources of nutrients include the Dillon Reservoir in Colorado and the Occoquan Reservoir

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in Virginia. These are discussed in the following chapter on control practices.

Toxic Substances

Toxic substances are all defined as materials capable of producing an adverse response or effect in a biological system. A large number of potentially toxic compounds are routinely detected in urban stormwater. These include trace metals (lead, zinc, copper, and cadmium) pesticides and herbicides, hydrocarbons (derived from oil and grease, and gasoline runoff). These toxic chemicals tend to accumulate in benthic sediments of urban streams, lakes, and estuaries. Both the San Francisco Bay, and the Duwamish River, Washington have received significant loadings of toxic substances and heavy metals from stormwater runoff, and are presented at right (San Francisco Bay, Duwamish River).

Heavy Metals - Heavy metals are of concern because of their toxic effects on aquatic life and their potential to contaminate drinking water supplies. The heavy metals having the highest concentrations in urban runoff are copper, lead, and zinc with cadmium a distant fourth. However, when inappropriate connections between sanitary and storm sewers are present, other heavy metals such as arsenic, beryllium, chromium, mercury, nickel, selenium, and thallium can be found. A large fraction of the heavy metals in urban runoff are adsorbed to particulates and thus are not readily available for biological uptake and subsequent bioaccumulation. Also, the typical periods of exposure are those of urban runoff

San Francisco Bay (Metals)

Southern San Francisco Bay is a highly urbanized estuary in the Santa Clara watershed which encompasses the Silicon Valley (Mulmey, 1988). The Bay is a major navigable waterway for the U.S. Navy and commerce, a valuable fishery for salmon and herring and a recreational resource. Despite significant advances on controlling municipal and industrial point source pollution over the last two decades, water quality impairment due to toxic pollution from urban runoff continues in the southern bay segment. The California Regional Water Quality Control Board adopted water quality standards for copper, lead, nickel and zinc to protect the beneficial uses of the Bay and , with local municipalities, developed a water-quality/technology based program for reducing urban runoff pollutants. Sources of pollution include urban runoff, illicit connections, illegal dumping and construction/development sites.

Duwamish River, Washington (Toxic Substances)

The Duwamish River is vital to Washington State's commerce as a primary navigational route, a major contributor to the State's salmon and steelhead trout industry and a recreational resource (USEPA, 1990). The lower six miles of the river flow through a heavily industrialized area of Seattle including airplane factories, shipyards, metal scrap yards, oil tank farms and port facilities. Though water quality improvements were observed through control of point sources, metals and organic toxicants from industrial and urban nonpoint sources continued to degrade water quality in the river. In the early 1980's copper concentrations in the river water exceeded the USEPA's acute freshwater criterion (18 ug/l), and lead concentrations exceeded the EPA chronic freshwater criterion (3.2 ug/l). The highest concentrations of metals (lead, copper, zinc, mercury and cadmium) were found unevenly distributed in the sediments of the river, suggesting that contaminants came from localized sources (such as storm drains) where zinc concentrations were as high as 3,000 ppm and lead as high as 18,000 ppm. Sediments inside a storm drain near a lead smelter were found to contain 350,000 ppm (or 35%) lead. These sediments were removed and handled as hazardous waste. Sources of pollutants along the river included illegal dumping in storm drains, mismanagement of industrial chemicals and wastes, industrial activities, and storm drain sediments. Storm drain sediments contained significant concentrations of copper, lead, arsenic, zinc, mercury, PCBs and cadmium from historic activities.

The Municipality of Metropolitan Seattle (Metro) received a Clean Water Act Section 205 grant for sampling storm drain sediments to track pollutants and locate sources. Eventually, the sediments themselves were considered a significant source. Removal of sediments from storm drain systems and reductions in contaminant inputs from industrial facilities eliminated major sources of contamination to the Duwamish River. In 1989, sediments in a storm drain line near a lead smelter contained 85 to 97 percent less lead than 1984 levels. Remedial actions at smelter and electric transformer recycling facilities resulted in reduced PCB, copper and lead concentrations in the stormwater. Reduced activity at shipyards (due to economic factors) and implementation of voluntary and mandatory BMPs in salvage yards reduced zinc loadings by 90 percent from 194 lb/day to 15 lb/day.

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events (typically under 8 hours), which are much shorter than the exposure periods used in bioassay tests (typically 24 to 96 hours for toxicity testing). Nonetheless, it is likely that the heavy metals in urban runoff are toxic to aquatic life in certain situations, particularly for the more soluble metals such as copper and zinc. Additionally, resuspension of bottom deposits from high flow events may impact on downstream benthic invertebrates. Compared to risks to aquatic life, human health risks appear to be more remote.

Oil and Grease - Oil and grease contain a wide variety of hydrocarbon compounds, some of which (e.g., polynuclear aromatic hydrocarbons) are known to be toxic to aquatic life at low concentrations. Hydrocarbons are often initially found as a rainbow colored film or sheen on the water's surface. Other hydrocarbons, especially weathered crankcase oil, appear in solution or in emulsion and have no sheen. However, hydrocarbons have a strong affinity for sediment, and much of the hydrocarbon load eventually adsorbs to particles and settles out. Hydrocarbons tend to accumulate rapidly in the bottom sediments of lakes and estuaries, where they may persist for long periods of time and exert adverse impacts on benthic organisms. The precise impacts of hydrocarbons on the aquatic environment are not well understood. Bioassay data which do exist are largely confined to laboratory exposure tests for specific hydrocarbon compounds. Remarkably few toxicity tests have been performed to examine the effect of urban runoff hydrocarbon loads on aquatic communities under the typical exposure conditions found in urban streams.

Other Pollutants - Other toxic compounds that have been detected in urban runoff include pesticides, herbicides, and synthetic organic compounds. Concentrations of these toxic substances in runoff from residential and commercial areas rarely exceed current water quality criteria. However, it should be noted that there has been relatively little sampling of runoff reported from industrial areas, where toxic compounds might be expected to be more prevalent (e.g., Duwamish River).

Examples of Impacts from Toxic Substances. In-stream monitoring of Village Creek in Birmingham, Alabama (Water Quality Engineers, 1981—not an inset) provides a classic example of stream degradation due to intense urban development. At the stream's origin at Roebuck Springs, the creek had excellent physical and chemical characteristics, supporting watercress and other vegetation. By the time the stream passed through the city, it turned grey-green and had an oily sheen and contained significant debris. Further downstream at the western limits of Birmingham, the creek was dark green, had a putrid odor and contained considerable oil and grease. At this point the creek was often anaerobic and contained no fish or other biological life. This study found that, on an annual basis, more than 90 percent of the copper loadings, more than 75 percent of the chromium and zinc loadings, and about 40 percent of the lead loadings originated from urban runoff.

A study (Dong et al., 1979, and Southeastern Wisconsin Planning Commission, 1976—not an inset) of the Menomonee River near Milwaukee, Wisconsin indicated that the upper, more rural reaches of the river had an average of 40 times more fish than the lower, urbanized reach. The urban segments of the river supported a significantly reduced and scattered fish population and some segments were virtually devoid of even highly pollution tolerant species. These conditions are the combined result of higher concentrations of toxic pollutants and poorer habitat conditions resulting from increased flow velocities and channelization. Further, the watershed benthic community is in poor condition in the urban area. The Menomonee study concluded that a relatively small degree of urbanization, less than 20 percent, was sufficient to cause significant receiving water degradation.

Studies at other locations have produced results similar to those cited above. Interestingly, toxic pollutants or long-term oxygen depletion has been found to cause more serious receiving water problems than short-term, event-related oxygen depletion or other concentration excursions. The long-term affects due to accumulation of toxic compounds in sediments and their subsequent movement through the food chain is especially pronounced in urban receiving waters. Studies on the Saddle River near Lodi, New Jersey (Wilbur and Hunter, 1980) found significant enrichment of heavy metals (two to seven times) in lower Saddle River sediments (affected by urbanization) as compared to upper rural reaches (see also Saddle River case

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study at right) Similar results were found in a stream near Champaign-Urbana, Illinois (Rolfe and Reinhold, 1977—not an inset), where the upper two inches of sediment in an urban stream reach had much higher lead concentrations (almost 400 ug/g) than sediments in the rural stream reaches. Species diversity of plants and animals were found to be lower in urban streams as compared to streams in rural areas. This impact is likely to be influenced by habitat and temperature changes, as well as pollutant levels.

Bacteria

Bacterial levels in undiluted urban runoff usually will exceed federal public health standards for water contact recreation and shellfish harvesting. Because bacteria multiply faster during warm weather, it is not uncommon to find a twenty-fold difference in bacterial levels between summer and winter. The substantial seasonal differences often found do not correspond with comparable variations in urban activities. This suggests that in addition to temperature effects, many sources of coliform unrelated to those traditionally associated with human health risk (e.g., animal excrement, illicit connections, leaking sanitary collection systems), may be significant. Thus, despite the high numbers of coliforms found in urban runoff, in the absence of contamination from sanitary sewage, the health implications are unclear. The current literature suggests that fecal coliform may not be consistently reliable in identifying human health risks from urban runoff pollution (Moffa, 1990). The impact of bacterial pollution in coastal waters is illustrated in the Western Long Island Sound and Westport River, Massachusetts case studies (see insets next page).

Studies conducted by the National Oceanic and Atmospheric Administration (NOAA, 1988, 1989, and 1990) indicate that urban runoff is a major pollutant source which adversely affects shellfish growing waters. The NOAA studies identified urban runoff as affecting over 578,000 acres of shellfish growing waters on the East Coast (39 percent of harvest-limited area); 2,000,000 acres of shellfish growing waters in the Gulf of Mexico (59% of the harvest-limited area); and 130,000 acres of shellfish growing waters on the West Coast (52% of harvest-limited areas).

Although nearly every urban and suburban land use can export bacteria at levels which will violate health standards, older and more intensively developed urban areas typically produce the greatest export. The problem is especially significant in urban areas that experience combined or sanitary sewer overflows that export bacteria derived from human wastes.

Saddle River, New Jersey (Metals/Toxicants)

Saddle River drains an area of 59 mi^2 extending from the headwaters in Southern Rockland County, NY to Garfield, NJ where it intercepts the Passaic River. The study was centered around the lower reaches of the Saddle River and encompasses the borough of Lodi, NJ. The area is heavily urbanized with 60% of the area as single-family housing, 6% multi-family residential, 11 % industrial, 12% commercial, 10 % open and 2 % public and municipal (Wilber and Hunter, 1980). Because municipal and industrial wastewater is dispatched to Passaic Valley Sewerage Authority via trunk sewers, the only pollution from Lodi is from nonpoint sources. Eleven individual storm hydrographs were monitored at the storm sewer outfalls during the project period. Samples were collected manually at 5 to 10 minute intervals over the complete hydrograph. Water samples were analyzed for lead, zinc, copper, nickel, and chromium. The major contributors of heavy metals in stormwater were lead and zinc. They accounted for 89% of the total metals observed. Copper, nickel and chromium were usually found in smaller quantities.

Rainfall as a source of metals to the Saddle River was investigated by collection of rainwater samples by local residents. The concentration in precipitation was between 4 and 10 percent of the concentration in runoff. Peak concentrations of heavy metals in runoff were observed within the first half hour after the initiation of runoff, thus giving a first flush effect. In general, metal loadings were correlated with increased percentages of commercial and industrial land-use. An average of 66 percent of the total solids for the three storms studied were removed after four hours of settling. The majority of the lead and zinc were found in the non-settleable solids fractions. Copper was found primarily *in the soluble plus colloidal fractions.*

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Floatables

Floatable debris in stormwater runoff commonly includes plastic and paper products, garden refuse, tires, and metal and glass containers. These pollutants degrade the aesthetic quality of both receiving waters and river banks and shorelines. Vegetation and wildlife may also be impacted. In the tidal Anacostia River, Maryland, floating debris has impaired restoration efforts by hindering the establishment of emergent vegetation (USACOE, 1990). Fish and aquatic wildlife mortality may also be attributed to debris, due to either ingestion or entanglement in the slowly decomposing materials.

Western Long Island Sound (Pathogens/DO)

Long Island Sound is a major marine resource for the state of Connecticut as well as a source of recreation to more than ten million New Yorkers. Water quality of Western Long Island Sound has been degraded by both point and nonpoint discharges which have resulted in low DO concentrations, toxic contamination, and closure of beaches and commercial shellfish beds due to high fecal coliform concentrations. Combined sewer overflows and urban stormwater runoff are two significant pollution sources to Long Island Sound. It is estimated that up to 85% of the sewer lines in New York City are combined. Urban runoff is the largest identified nonpoint pollution source, based on the number of estuaries along the Connecticut shoreline impacted. Stormwater runoff pollution from New York City has been implicated in a New York Harbor Water Quality Survey because of the increase in coliforms and reduction in DO observed after rainstorms. Increases in coliform levels between 3 and 8 times were observed after rainfall events for Jamaica Bay, Upper Harlem River, Gowanns Canal, Hudson River, Lower East River, and Western Long Island Sound. These increases were due to urban stormwater runoff and CSOs (City of New York, 1987).

Westport River, Massachusetts (Multiple Impacts)

Analysis of pollution sources to Buzzards Bay is typified by loads to the Westport River and includes pollution from surface runoff, boat discharges, storm sewers, septic systems, feedlot and pasture runoff. Nonpoint source pollution has been implicated based on the high concentrations of coliform bacteria observed after rainfall events. Bacteria, nutrients, and solids contamination from nonpoint sources has impacted water quality of the East Branch of the Westport River (EBWR), one of the most productive shellfisheries on the south shore of Massachusetts. Violations of Class SA (for tidal, salt water suitable for primary contact recreation) water quality criteria for coliform bacteria have forced the closure of 960 acres of shellfish beds (over 75% of the shellfish producing area) in 1979, including soft-shell clams, quahog and oyster beds. Since between 1983 and 1985, 555 acres of the 960 acres permanently closed in 1979 have been reclassified to allow periodic harvesting. The area between Gunning Island and Cadman's Neck was closed for a minimum of eight days following a rainfall of one inch or more. These standards were not sufficient for the area north of Cadman's Neck (200 areas), which in 1985 showed bacterial levels in excess of the standard for at least 10 to 16 days after rainfall; this area remains permanently closed. It has been estimated that annual losses in commercial shellfishing exceed 1$ million not including losses to recreational diggers.

Westport is primarily a rural community that has experienced a population growth of 25% between 1970 and 1975. Most of the land in the drainage basin is undeveloped, consisting predominantly of forested land with smaller areas of wetlands and lakes. Agricultural land, primarily cropland with some pastureland, is the second largest land use within the region. Residential, commercial and industrial land comprise less than 10 percent of the total watershed. In the past 35 years, significant land use changes have occurred within the southeastern Massachusetts area. From 1951 to 1971, developed land within Westport increased by 96%, while open, forested, and agricultural land decreased by 19%. The conversion of undeveloped land continued with residential land use increasing by 1,500 acres and commercial land increasing by 110 acres between 1971 and 1981. Land use data developed by the Soil Conservation Service and the Environmental Protection Agency showed that between 1983 and 1988 combined residential and urban land use increased by 13%. Agricultural, forested, and open land use decreased by 8% during this same period (Metcalf & Eddy, 1989).

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EXAMPLES OF SUCCESSFUL STORMWATER CONTROLS

In this last chapter we examine general stormwater control practices and present examples of successful stormwater programs implemented at various stages of urban development. **A basic principle of stormwater controls for urban development is that it is much more cost effective and institutionally feasible to develop controls for new development than it is to retrofit old development.** Structural practices for stormwater pollution control require not only capital but operation and maintenance costs, and are often constrained by spatial and financial limitations in core urban areas. In addition, some structural controls can destroy the resource it is designed to protect due to disruption of the hydrologic cycle. In contrast, non-structural practices may be included in the development process, for which municipalities usually have pre-existing permitting programs. Combining both types of controls into an integrated stormwater management program can result in effective water quality protection at minimal cost. Before presenting representative case studies, the practices for control of stormwater are first defined.

Examples of Non-structural Stormwater Practices

- Zoning Ordinances
- Subdivision Regulations
- Capital Improvement Plans
- Site Plan Reviews
- Planned Unit Development Reviews
- Restrictive Covenants
- Environmental Impact Assessment/Statements
- Public Education Programs
- Growth Management
- Buffers and Setbacks
- Environmental Permitting
- Pollution Prevention for All Sources
- Spill Control Programs
- Road Maintenance Programs

Control Practices

Non-Structural Practices. Non-structural practices are those not requiring construction or maintenance. These differ from structural practices in that they are preventative in nature, and have the potential to be more cost effective especially if implemented early in the site planning stages. They include such practices as: regional comprehensive stormwater management programs; planning future development to minimize stormwater runoff; limiting the amount of impervious surface in new and retrofitted development; instituting fertilizer and pesticide management programs; requiring setbacks from surface water and wetlands to protect their environmental integrity; siting infrastructure so as not to encourage development in environmentally sensitive areas that are critical to maintaining water quality; requiring the use of best management practices through land development regulations and site plan approval; and inspecting stormwater management systems and erosion control structures to ensure they are functioning properly.

Examples of Structural Stormwater Practices

Developing Areas

- Extended Detention Ponds
- Stormwater Wetlands
- Multiple Pond Systems
- Infiltration Trenches
- Infiltration Basins
- Filter Strips

Core Urban Areas

- Illicit Connection Controls
- Porous Pavements
- Stormwater Detention/Wetland Retrofits
- Sand Filters

Non-structural practices for controlling stormwater pollution have typically centered around preventing land use disruptions on areas critical to maintaining water quality and reducing the source of pollution.

Structural Practices. Structural management practices are defined as those designed and constructed to mitigate the adverse impact of stormwater runoff. The selection and use of individual practices has typically been based on land use activities, existing structures, hydrology and climate, soil type and other site specific conditions.

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In addition to installation costs, structural practices usually require continuing operation and maintenance efforts. Table 9 summarizes the site-specific and maintenance burdens of several selected structural practices.

The lack of adequate maintenance and upkeep may dramatically reduce their effectiveness in removing pollutants from stormwater runoff. For example, a sand filter system in Maryland that had not been maintained for several years appeared to be clogged with sediment and grease to the point that the operation of the system may have been impaired (Shaver, 1991).

Separate storm sewers may also receive materials other than stormwater (e.g., illicit connections from industrial and commercial facilities). Controlling these sources may involve structural practices such as conventional wastewater treatment units, or repairing/retrofitting connections to the storm sewer system.

Integrated Management Programs. The stormwater management practices presented above may be used in conjunction with one another, taking an integrated approach to minimizing stormwater impacts. Structural practices could be targeted at areas already built up, while developing areas utilize a more non-structural approach.

Strategies have been shown to be successful when targeted to land disturbance, not necessarily land use, and should reflect land use/activity changes. Guiding development to areas capable of sustaining growth without excessive impacts to the natural environment, and encouraging the implementation of stormwater practices as development proceeds, can minimize the need for future stormwater control efforts. Many local governments have adopted integrated stormwater management programs to regulate development activities within their jurisdictions. Several states, including Oregon, New Jersey, Delaware, and Florida, have adopted comprehensive plans involving guidance of future growth and avoidance of water quality and quantity impacts associated with uncontrolled development.

Land Disburbance/Activity

The extent of stormwater pollution problems is dependent upon the land disturbance/activity which in turn is a function of the stage of the urbanization process. The range of stormwater management options applied has been based to a certain extent on the stage of land development, each stage representing a unique set of challenges and opportunities. Three land development stages that have been addressed by states and municipalities while developing stormwater management programs are defined below. Within each of these stages a brief description of relevant case studies illustrating different stormwater control approaches is presented.

Undeveloped Areas. Undeveloped areas consist of relatively unurbanized land with low population densities. Although the land use is primarily rural, the proximity and location of these lands presents the potential for eventual development into urban and suburban settings. Stormwater runoff from these areas currently results primarily from agricultural, forestry, and resource extraction activities.

Table 9. Regional, Site Specific, and Maintenance Considerations for Structural Practices to Control Sediments in Stormwater Runoff

BMP Option	Size of Drainage Area	Site Requirement	Regional Restrictions	Maintenance Burdens	Longevity
Infiltration basins	moderate to large	deep permeable soils	arid and cold regions	high	low
Vegetated filter strips	small	low density areas with low slopes	arid and cold regions	low	low if poorly maintained
Filtration basins and sand filters	widely applicable	widely applicable	arid and cold regions	moderate	low to moderate
Extended detention ponds	moderate to large	deep soils	few restrictions	dry ponds have relatively high burdens	high
Wet ponds	moderate to large	deep soils	arid regions	low	high
Constructed stormwater wetlands	moderate to large	poorly drained soils, space may be limiting	arid regions	annual harvesting of vegetation	high

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In undeveloped areas stormwater management programs may be integrated with local planning and regulatory programs at an early stage of development. These management programs, relying primarily on nonstructural practices, have been aimed at minimizing future degradation of water quality.

Depending on the expected degree and rate of development, integrated management programs have been tailored to address pollution generating activities associated with the various phases of urbanization. Many local governments, aware of the consequences of uncontrolled urbanization, have adopted planning programs in which stormwater pollution considerations were major decision criteria. Two case studies in which stormwater pollution control practices were addressed at an early phase of development are presented. These case studies are the Occoquan Reservoir, Virginia (see inset) which utilized zoning ordinances to achieve stormwater management goals, and Lake Travis, Texas in which point and nonpoint pollution concerns were integrated into a single management program, discussed below.

Occoquan Reservoir, Virginia (Eutrophication)

The Occoquan Reservoir is the major water supply for 600,000 people in the Virginia suburbs of Washington, DC. The 9.8 billion gallon reservoir is located at the mouth of a 580 square mile watershed in Northern Virginia. Between 1976 and 1978 a special planning study carried out by the Northern Virginia Planning District Commission concluded that nonpoint sources of pollution were a significant contributor to water quality problems in the Occoquan Reservoir, and were much higher than originally thought (NVPDC, 1987, NVPDC, 1990). The primary concern for the reservoir was eutrophication resulting from nitrogen and phosphorus loadings.

In response to this study, the Occoquan Basin Nonpoint Pollution Management Program was initiated in February, 1982 to address nonpoint source pollution (NPS) in the Occoquan watershed.

This program is designed to manage nonpoint source pollution loadings from each of the watershed's jurisdictions, with each developing its own NPS program. Most of these local programs utilize Best Management Practices compiled in a BMP Handbook for the Occoquan Watershed. BMPs included in the Handbook include extended detention ponds, dry ponds, infiltration trenches and non-structural practices such as fertilizer application controls, street sweeping, and zoning changes.

The Program maintains a water quality model of the watershed to analyze the effects of land use changes on water quality. In 1982 Fairfax County "downzoned" approximately 27,000 acres in the Occoquan watershed to reduce the future nonpoint source pollution loads entering the reservoir, based on results from the model. Downzoning, the process of reclassifying existing zoning regulations (in this case to lower density residential), is used to reduce development impacts. The validity of basing land use decisions designed to protect water quality on modelling results was recently upheld in Fairfax County Circuit Court.

Lake Travis, Texas Phosphorus

The Highland Lakes, a chain of reservoirs in Central Texas, provide hydroelectric power, flood control, and recreational opportunities. Sedimentation, eutrophication, and toxic contamination problems caused by stormwater runoff to these lakes prompted the Lower Colorado River Association (LCRA) to develop the Water Quality Leadership Policy (WQLP) in 1988 (Hartigan and Wilwerding, 1991). Analysis of the monitoring data of the Highland Lakes showed that over 90% of the pollution was from nonpoint sources. LCRA estimates that the NPS loads to the Lake Travis basin could increase by 200 to 600 percent in the future, largely due to the conversion of rangeland into urban and suburban development. The WQLP initiated public education efforts along with a regulatory program to control nonpoint source pollution in its ten county district. The Lake Travis Nonpoint Source Pollution Control Ordinance was adopted by the LCRA Board of Directors in December 1989 and went into effect on February 1, 1990. The ordinance targets new urban and suburban development in the 250 square mile area of western Travis County.

The Lake Travis Ordinance establishes a set of performance standards that require new developments to remove a specified amount of the annual NPS pollution load, depending on the site's proximity to the shoreline and the slope of the property. Sites within 500 feet of the lake and/or those on steep slopes require a higher level of runoff treatment than those inland or on flatter ground. In general, the more intensively a site is developed, the more pollution must be removed. This approach recognizes the link between land use and NPS pollution; however, there are

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no land use control stipulations in the ordinance.

The Ordinance requires all land owners proposing to develop land within the Lake Travis watershed to submit an application for review and plans on how the surface runoff from the site will be treated. The plan must include temporary erosion and sediment control plans including a restoration program for all disturbed areas, description of the design and location of structural practices used to meet the performance standards, and establishment of a maintenance organization to ensure that the structural practices are adequately maintained. An ongoing program conducted jointly by LCRA, the US EPA Region 6 and the U.S. Geological Survey will evaluate the Ordinance on a periodic basis to determine whether the standards are adequate to protect the water quality of Lake Travis and whether or not the structural best management practices are adequate to meet the standards of onsite pollutant removal.

Developing Urban Areas. Developing urban areas are those lands currently experiencing new development or redevelopment resulting in significant changes to the landscape. These areas include suburban cities and urban fringes located adjacent to urban areas.

Many of these areas are experiencing a dramatic rise in population compared to well established urban areas. For instance, between the 1970 and the 1980 period, the population of urbanized areas increased 30 times more (an increase of 18.9 million) than core cities with a population exceeding 100,000. One activity affecting stormwater quality in developing areas is land disturbance in and around construction sites where exposed soils results in increased sedimentation, erosion, and nutrient transport. Land disturbance in these areas may result in severe stormwater pollution if adequate control programs are not incorporated into the development process. Yet these areas, where the majority of new growth and land disturbance and conversion are occurring, are not necessarily covered under the Phase I NPDES stormwater program. Moreover, an important characteristic of these areas resulting from land conversion consists of permanent changes to land use patterns. These changes induce a significant disruption to the hydrologic cycle and modification of runoff water quality (modification of natural vegetation and infiltration rates, increase storm peak discharges and transport capacities, and decrease of low flow especially during prolonged dry periods).

Stormwater management efforts have been directed primarily toward controlling construction site stormwater runoff. Stormwater pollution control efforts have been minimized by retaining and treating stormwater onsite rather than by addressing impacts occurring offsite. To address impacts originating from developing areas, several state and local agencies have developed comprehensive programs incorporating both structural and nonstructural practices. Typical comprehensive studies include the Anacostia River study (see inset next page) that involves a sediment control program designed to control stormwater pollution from construction sites, and the Dillon Reservoir study in Colorado, discussed below, which addresses both stormwater and point source discharges.

Dillon Reservoir, Colorado Eutrophication/Urban Growth

Dillon Reservoir is a large (2970 acre) impoundment of the Blue River in Colorado. The Reservoir supplies drinking water to the Denver metropolitan area and is used for recreation, fish habitat and agriculture. Water quality degradation, primarily eutrophication and sedimentation, has occurred since the Reservoir's construction over 20 years ago. At higher elevations the watershed is primarily undeveloped, while the lower elevations contain three major municipalities, four major treatment plants, housing developments and a large molybdenum mine. A study completed in 1983, supported by the EPA through the Clean Lakes Program of the Clean Water Act, identified phosphorus as the primary contributor to the Reservoir's eutrophication. According to the Clean Lakes study, which evaluated 1982 Reservoir phosphorus levels, human activities were found to account for about 1/2 of the total phosphorus load, and of this, between 1/2 and 2/3 was attributed to urban nonpoint sources including runoff from parking lots, golf courses, and construction sites, as well as leakage from septic tanks.

The Northwest Colorado Council of Governments, cooperating with local and state agencies, developed a strategy for phosphorus control by holding the phosphorus loadings to existing (1982) waste load allocation levels (4609 kg/yr) and allowing no further water quality degradation (USEPA, 1991b). To meet the

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phosphorus loading while allowing for future growth in the basin, nonpoint source controls were encouraged by allowing point/nonpoint source trading at a ratio of 2:1. For every 2 kg of nonpoint source phosphorus removed, 1 kg of phosphorus credit is added to the point source limit. This system provided for maintenance of existing phosphorus levels in the Reservoir, while accounting for increased loading from growth. In addition to providing environmental benefits, this program provides economic benefits and incentives for nonpoint source reduction. The 2:1 ratio provides a margin of safety in the source trading program, and if further phosphorus reduction in the Reservoir is desired, the ratio can be adjusted.

To date, only one point/nonpoint source trade has been completed. The low volume of trade has caused the program to operate differently than was first envisioned. The low volume of trade occurred because the POTWs were able to achieve some of the highest phosphorus removal efficiencies in the nation using expensive advanced treatment technology. Consequently, point/nonpoint source trading has played only a minor role in the overall basinwide phosphorus mitigation strategy. The major constraint to future development is a limit on nonpoint source phosphorus loading.

Although total phosphorus loading was only 5,559 pounds in 1989, i.e., 54 percent of the total phosphorus allowed, additional reductions in phosphorus loadings must result from reductions in nonpoint sources. Nonpoint/nonpoint trades

Anacostia River Case Study, Metropolitan Washington, DC (Mutiple Impacts)

The Anacostia River watershed covers approximately 170 square miles of the metropolitan Washington, DC area. Roughly 145 square miles of the basin are in Maryland with the remaining 25 square miles within the District of Columbia. Nonpoint source pollution associated with storm runoff from construction sites were analyzed based on data collected from 9 subbasins in a 32 square mile area north of Washington, DC in Montgomery County, MD (Yorke and Herb, 1978).

From 1963 to 1974 the study area experienced extensive urbanization, a process that continued beyond the period of the study. Urban land use increased from 3 to 11% from 1966 to 1974 and suburban land increased from 6 to 23% of the total drainage area, resulting in significant increases in impervious areas. Impacts resulting from urbanization during this time included the loss of aquatic habitat and consequent decline in the biological community, increased sediment transport and bank erosion, widening of the stream channel, and increased flooding. Fish species in the Anacostia River declined from an average of 7.2 species per station in 1948 to 3.6 species per station in 1972. The decline of fish species was attributed to loss of habitat and increased stream sedimentation.

Changes in stream sediment yield were correlated to land development which averaged 3% of the basin during the study period. Regression analysis of this relationship indicated that 40% of the changes in sediment yield were due to construction activities. From this analysis sediment yield from construction sites was estimated to range from 7 to 100 tons per acre per year, with an average of 32.7.

In 1971 an existing sedimentation control program from construction/developing areas was enforced, requiring developers to incorporate and maintain control practices at their construction sites. The most commonly used measures were: 1) mulch and/or temporary vegetation to protect exposed slopes; 2) interceptor dikes to reduce erosion on rights of way by temporarily diverting storm runoff to where the water can be transported with minimal erosion; 3) grassed waterways, level spreaders, and grade stabilization structures to convey storm runoff through the construction site without erosion, 4) diversion berms to divert storm runoff from areas with critical slopes, 5) sediment basins to trap and store sediment from construction sites before it can enter the stream system. The program also included a number of non-structural practices, such as keeping the smallest practical area of land exposed for the shortest period of time, and fitting the development plan to the topography and soils so as to create the least erosion possible.

This program resulted in the implementation of control practices in up to 60% of construction sites in four subbasins. The enforcement of these practices resulted in an estimated reduction in suspended sediments from construction sites of 60 to 80%. It was estimated that the suspended sediment load in the Anacostia River basin between 1962 and 1974 would have been reduced by 50% if strictly enforced sediment control had been used throughout the period. At the time of the study, the cost of sediment control practices on 1,900 acres was estimated to be $1,030/acre corresponding to $19 for each ton of sediment control. This study indicated that costs could be reduced if construction were limited to areas with slopes less than 10% and sites immediately adjacent to stream channels were avoided. Those non-structural control practices would have the effect of preventing the problem before it occurred.

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are beginning to be used to offset nonpoint sources from new development through the control of existing nonpoint sources. For example, the Frisco Sanitation District built a series of concrete vaults (man holes) to control runoff. Filtering the runoff through perforated pipes resulted in removal efficiencies of 50 to 70 percent for total phosphorus and the alleviation of drainage problems. Encouraged by the results of the first project, the district expanded its program to another section of town with the help of federal funds administered through the Clean Water Act's nonpoint source management program. Since the Frisco Sanitation District did not need all the phosphorus credits it earned, the credits were set aside for the construction of a new town golf course. The result was a nonpoint/nonpoint source trade. The removal capabilities of this project will be monitored to determine the actual phosphorus credits applied to the new golf course.

The county-owned Snake River treatment plant is also involved in a nonpoint source control trading project. The project will offset increased contributions of phosphorus to Dillon Reservoir resulting from a stream diversion plan by reducing loads from another stream that is currently responsible for the highest phosphorus load entering the Reservoir. The diverted stream is expected to load an additional 200 pounds of phosphorus into the Reservoir. The phosphorus reduction will occur on Soda Creek where the treatment plant has constructed a discharge control structure using an existing road causeway over the Reservoir to intercept and filter the stream flow. When Reservoir levels are low, phosphorus removal efficiencies of 50%, or 75 pounds, are expected. After modelling studies assess the actual removal achieved by the dam, phosphorus discharge credits will be shared equally by the Snake River Plant and the Denver Water Board.

The Dillon experience illustrates the importance of a comprehensive basin-wide management approach which does not focus on isolated point sources. Modelling studies considered the contributions from point, nonpoint, and background sources of phosphorus to determine the maximum loadings from these categories that would maintain the in-lake phosphorus standard of 0.0074 mg/L. As a result of Dillon's projective planning, 1989 phosphorus loads to the Reservoir totaled only 53 percent of the critical load. Modelling is an essential component of this water quality-based approach to evaluate current control strategies and predict the impact of future development.

Core Urban Areas. Existing urban areas, with typical population densities greater than 100,000, are communities with limited potential for new development. These existing, incorporated urban areas with typical populations greater than 100,000 are currently subject to Phase I NPDES stormwater permit requirements. The Phase I NPDES stormwater program also applies to some highly populated counties.

Original stormwater systems in established urban areas were typically constructed for flood control purposes. Water quality programs probably did not address stormwater quality concerns and runoff is typically directed to surface water.

These urban areas are characterized by high percentages of impervious surfaces, which contribute to increased storm water discharges and pollutant transport capacities. Reduction of infiltration rates and groundwater recharge also results in lower baseflows and higher pollutant concentrations in receiving waters, especially during prolonged dry periods. Other stormwater impacts include increases in temperature and concentrations of toxic chemicals, nutrients, heavy metals, oil, grease, and pesticides.

Core urban areas may also experience stormwater pollution problems resulting from illicit connections, leaking sanitary sewage systems, or ground water infiltration. Illicit connections can often be traced to the initial development of the storm sewer system, or arise during redevelopment where storm sewers are either mistaken for sanitary sewers or intentionally used for wastewater conveyance. In industrial facilities, floor drains or other discharge points which are connected to the separate storm sewer system may receive spills, rinse waters, or process wastewaters that should be sent to a treatment plant. Illicit connection programs are directed at identifying such problems for corrective action.

Stormwater control practices in established urban areas have typically included retrofits of detention ponds and controls on combined sewer systems as well as the construction of wetlands and sand filters. As development proceeds, the range of available non-structural options decreases. The following representa-

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tive case studies highlight a number of stormwater control programs. The Kelsey/Bear Creeks, Washington, case study below examines stormwater impacts from developed areas, and the effects of street sweeping, catchbasin cleaning, and detention ponds on runoff quality and quantity. Various stormwater control practices in the Milwaukee metropolitan area were evaluated using a computer simulation model (see inset next page). The Anacostia Watershed Retrofit Project (see inset below) illustrates a basin-wide approach to storm sewer retrofitting. Additional examples from core urban areas are also included.

Kelsey/Bear Creeks, Washington Habitat Alteration/Sediments

Kelsey Creek (see page 22 inset) is located in a highly urbanized suburb of Seattle, Washington. The watershed is 90% developed with residential units and commercial/light industry uses (Pitt and Bissonnettee, 1984). Kelsey Creek, a natural water channel, was developed to convey stormwater from the City of Bellevue to Lake Washington, a major water body in the Puget Sound area. The creek serves as a recreational resource and has a productive, but limited, salmon fishery. Increased peak flows from urban development dramatically altered the stream channel causing severe streambed erosion. The number and diversity of aquatic organisms declined as bed scouring and the resultant deposition of suspended sediment destroyed stream habitat. Reduced dissolved oxygen in the sediments depressed salmon embryo survival. The fish population adapted to the degrading environment by shifting species composition from coho salmon to less sensitive cutthroat trout.

Urban stormwater was monitored for six metals and suspended solids. Dry weight concentrations of pollutants from various nonpoint sources, including atmospheric deposition, street dirt accumulation, and catchbasin and detention basin sediment, were measured. Impervious sources (streets, sidewalks, driveways, parking lots and rooftops) were found to contribute more than 60% of the total runoff flow when precipitation exceeded 0.1 inch. Street surfaces contributed 25% of the total flow in the monitored sites. Most of the total solids in urban runoff originated from residential yards. Nutrients were primarily detected in street dirt samples, originating from vehicle emissions. Only a small fraction of the total particulate loadings on the impervious surfaces were removed by rain (15%). Large particles were not effectively removed, while about one-half of the smallest particles (less than 50 microns) were washed off during rains. These small particles were not very abundant, but contained high heavy metal and nutrient concentrations. Most of the settled particulate material in the storm drainage inlets and sewerage pipes was not removed during observed storms.

Several control practices were instituted as pilot projects to determine their effectiveness: street sweeping, catchbasin cleaning and detention ponds. Intensive street sweeping (3 times per week) resulted in rapid and significant decreases in street surface suspended solids loadings, from 110 g/curb-meter down to 55 g/curb-meter. This 50% reduction in suspended solids loadings resulted in a maximum 10% decrease in metal loadings. The median particle size also decreased signifi-

Anacostia Watershed Retrofit Project, Metropolitan Washington, DC (Multiple Impacts)

Opportunities for urban retrofitting are limited in developed watersheds, but they can be implemented after extensive onsite evaluations. In the 179 square mile Anacostia watershed in Montgomery County, MD, over 125 sites were identified as candidates for retrofitting between 1989 and 1991 (Schueler et al., 1991). Retrofit operations included source reduction, extended detention (ED) marsh ponds or ED ponds to handle the first flush, additional storage capacity in the open channel, routing of stormwater runoff away from sensitive channels, diversion of the first flush to sand-peat filters, and installation of oil/grit separators in the drain network itself. The most commonly used technique in the Anacostia watershed is the retrofit of existing dry stormwater detention or flood control structures to improve their runoff storage and treatment capacity. Existing detention ponds are maintained by excavation, adding to the elevation of the embankment, or by construction of low-flow orifices. The newly created storage is used to provide a permanent pool, extended detention storage, or shallow wetland. Nearly 20 such retrofits are in some stage of design or construction in the Anacostia watershed.

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cantly with intensive street cleaning. A regenerative air street cleaner showed substantially higher performance in removing the finer street particles. **It appears that conventional street sweeping removes the larger particles and rain removes the smaller particles; however, street sweeping did not reduce loadings of toxic compounds by more than 10%. Cleaning of storm drainage inlets and catch basin sumps twice per year reduced the lead and total solids runoff concentrations by between 10 to 25%. COD, nutrients and zinc were reduced by between five and ten percent.** After an initial cleaning, it appeared that almost a full year was required for sediment to reach a 'stable volume' in the storm drain inlet structures. Only 60% of the total available sump volumes in the inlet structures and catchbasins were used for detention of particulates at the 'stable volume.' Small detention basins (detention times of 30 minutes or less) did not have any significant effect on urban runoff quality but did reduce peak flow rates by up to 60 percent. Detention basins should be carefully located so increased flow rates do not disturb critical habitat areas. The final recommendation states that if intensive street sweeping was implemented along with semi-annual catchbasin sediment removal, urban runoff discharges for most pollutants would be reduced by as much as 25%. Though these reductions are small, they may be important in reducing the accumulation of contaminated sediments in smaller creek systems.

Milwaukee Harbor, Wisconsin (Multiple Impacts)

Milwaukee Harbor is a freshwater reservoir-embayment of Lake Michigan. The Milwaukee River is productive, and typically oversaturated with oxygen, as it moves through the agricultural and mixed land uses of the upper two-thirds of the watershed (Pitt, 1986). Upon reaching the deeper and slower moving, impounded lower one-third of the watershed which includes the suburban and urban areas of the city of Milwaukee, dissolved oxygen levels plummet 5 to 6 mg/L resulting in periodic septic conditions. Point source sewage treatment plant discharges are not important for this watershed because only 10% of the city's population is served by sewage treatment plants that discharge into the river. Water quality and quantity are monitored at 6 sampling stations along the river by the Milwaukee Sewerage District and the U.S. Geological Survey.

The Ontario Ministry of the Environment, in cooperation with the Wisconsin Department of Natural Resources, funded the application of the Source Loading and Management Model (SLAMM) which was used to predict the effectiveness of various stormwater runoff source area, sewerage, and outfall controls for urban runoff in the Milwaukee metropolitan area. Performance data on control practices for reducing runoff flow volumes and lead discharges were obtained from two study areas in Toronto, including a mixed residential/commercial and a light/medium industrial area. The data from the Toronto study were augmented with extensive literature information on the effectiveness of source area and outfall urban controls. Control options analyzed using SLAMM included: increased street cleaning, catchbasin cleaning, wet detention basins, infiltration of runoff from half of the residential roofs currently draining to pavement, and combinations of these practices. Cost effectiveness of the retrofits was analyzed by examination of the cost per unit removal for suspended solids, phosphorus, fecal coliform bacteria, and lead for each of the control options.

Three cost-effective programs for stormwater runoff particulate control were identified: 1) detention basins and detention basins plus street sweeping at a cost of $2 to $3 per kg with a potential maximum control of 26%; 2) partial infiltration plus large wet basins at $6 per kg with a maximum control potential of 44%; and 3) all practices combined including increased street cleaning and catchbasin cleaning, partial infiltration, and large wet detention basins at $9 per kg with a maximum control level of 47%.

The most highly recommended program combined infiltration and wet detention ponds. However, control program performance varied for different land uses. The modeling effort further revealed that the age of development as well as land use should be considered in the evaluation of water quality and effectiveness of controls.

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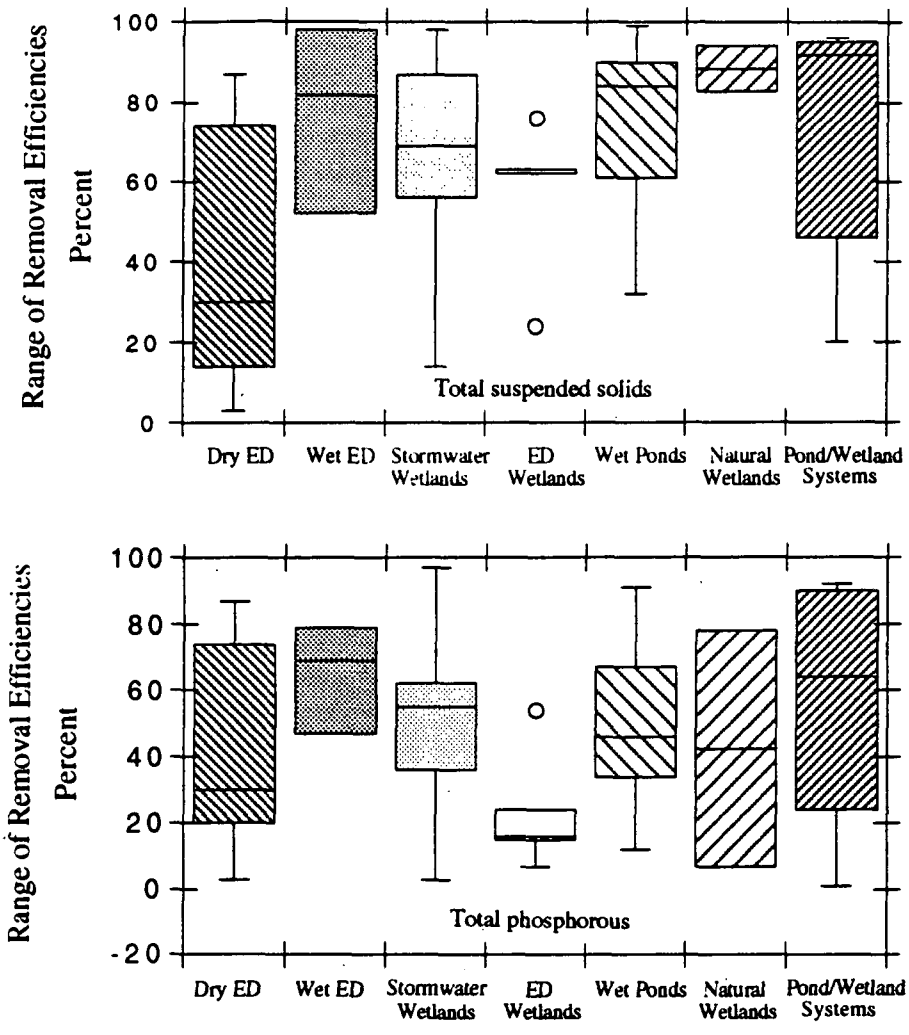

Legend

Reported removal efficiencies for each management practice are variable. To account for this variability the box and whiskers representation was used to display the range of the reported values and to characterize the distribution by indicating various percentiles. It should be noted that because of the limited data points, no advanced statistical tests were used to evaluate the significance of the reported data. The box encloses 50% of the reported values, with the lower and upper sides of the box representing the 25th and 75th percentiles respectively. The line inside the box represents the median value of the distribution. The horizontal whiskers above and below the box, if any, indicate the 90th and 10th percentiles, respectively. Extreme values, also called outliers, if any, (higher than the 90th or lower than the 10th percentiles) are represented by circles.

Total Suspended Solids and Phosphorus Removal Capabilities of Structural Stormwater Management Practices (MWCOG,1992)

Additional Examples of Successful Urban and Industrial Stormwater Control Practices

Metropolitan Washington Council of Governments

This study, prepared as a part of the Technical Guidance to implement Section 6217(g) of the Coastal Zone Act Reauthorization Amendments, provides a comparative assessment of various structural stormwater quality control practices (MWCOG, 1992). It analyzes the capabilities and limitations of eleven practices. The study thoroughly reviewed the existing literature, consulted with numerous local and state experts around the country, and analyzed data from ongoing projects. The results of the literature survey concerning the effectiveness of eleven stormwater management practices in removing total suspended sediment and total phosphorus presented in this study are illustrated in the Figures above.

Although a wide range of removal efficiencies for each practice was observed, high removal rates were achieved in a number of cases. The maximum removal rates for total suspended sediments ranged from 70% to more than 95%. The highest reported removals were achieved by wet ponds, wet extended detention ponds, natural wetlands, and ponds/wetland systems.

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Wet Detention Ponds, Charlotte, NC

The performance of existing urban wet detention ponds in the City of Charlotte within the piedmont region of North Carolina, was evaluated based on a comprehensive data collection program (Wu, Holman, and Dorney, 1988). The hydrologic and water quality responses of three wet ponds were characterized during storm water events. The three ponds studied control a combined area of 437 acres. Although initially designed and built for storm runoff control, the results of this study indicate wet ponds have significant capacity to improve water quality.

Differences in removal efficiencies among the three ponds were attributed in part to surface area ratios calculated based on pond surface and subarea acreage. Observed removal of total suspended solids was consistently high (82-100%) for the pond with the highest area ratio. The two heavy metals monitored in this study, zinc and iron, were also consistently removed with an efficiency rate of about 80% in pond A (high surface area ratio), and 42% in pond B (low surface area ratio). For total phosphorous and nitrogen the removal efficiencies were inconsistent, attributable to the variable input from waterfowl droppings in the ponds. Average removal efficiencies for two of the ponds are shown in the Table below.

Removal Efficiency Achieved by Wet Detention Ponds

Constituent	% Removal Pond 1	Pond 2
TSS	91	54
Nutrients	6-23	20-24
Metals	79-82	42-45

High removal efficiencies for total phosphorus were also observed. Apart from the extended wetlands for which fewer data were obtained from the literature survey, the highest removal efficiencies achieved exceeded 60% for the other ten practices. The highest removals were achieved with wet extended detention ponds, natural wetlands, and pond/wetland systems. The performance of existing urban wet detention ponds was also examined in a case study from Charlotte, North Carolina (see inset above).

Illicit Connection Controls, Michigan

Recent studies in Michigan have recognized that development occurring while undersized waste water treatment plants are operating can create wide-spread illicit connection problems. For example, the Huron River Pollution Abatement Program in Wastenaw County, Michigan, inspected 660 businesses, homes, and other buildings discharging stormwater to the Allen Creek drain. Of the buildings inspected, 14% were found to have improper storm drain connections, with the highest percentage (60%) for automobile related businesses. Although some of the problems discovered in this study resulted from improper plumbing or illegal connections, the majority were approved connections at the time they were built. Efforts are underway to correct those illicit connections identified during the inspection program (40 CFR parts 122, 123, and 124).

Combined Sewer Pollution Control: Structural Practices. Structural practices for controlling combined sewer overflow pollution usually parallel conventional wastewater treatment practices. They are designed to handle intermittent and random flows which vary in magnitude and quality. These practices include in-line storage, off-line storage, storage sedimentation, swirl concentrators, screens, dissolved air floatation, high rate filtration, treatment lagoons, contact stabilization, rotating biological contactors, and high rate trickling filters. They all differ in costs, efficiencies, suitability, and operation and maintenance. Two case studies concerning in-line storage and an integrated approach follow.

In-line Storage Control, Seattle

In-line storage control is a low capital cost method that uses existing facilities. It is easily integrated with dry-weather collection, treatment, and disposal activities, and is adaptable to future expansion. Metropolitan Seattle implemented an on-line storage control system to mitigate Combined Sewer Overflows (CSO) impacts to receiving waters (Finnemore, 1982). The system performance was evaluated in

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terms of the reduction of overflow volume, overflow frequency, and annual reduction of pollutant loads.

The system was estimated to reduce overflow volume by 74%. The resulting reductions in pollution loads were estimated to be 493,000kg/year of suspended solids, and 136,000kg/year of BOD. The total costs for this system are summarized as follows:

In-line Storage Control Costs

Regulators	$9,762,000
Computer facilities	$5,717,000
Engineering	$924,000
O&M cost (per year)	$440,000

Integrated Approach, Saginaw, MI

Saginaw, Michigan uses a combination of storage and treatment processes to take advantage of the capabilities of exisiting systems (Finnemore, 1982). This integrated approach reduces the volume of overflows to receiving waters and treats overflows that do occur to near primary treatment levels. This integrated system at the Hancock Street facilities, includes: (1) in-line storage; (2) using existing interceptor capacity controlled by modified regulator stations; (3) a flood protection pumping station, an off-line storage-treatment basin capable of treating and disinfecting all overflows; and (4) a capability to treat all flows retained in storage at the local dry-weather treatment plant. Together this system supports a city-wide plan to eliminate uncontrolled combined sewer discharge to the Saginaw River.

The performance of the Hancock Street storage/treatment facility was characterized using data from the 1978 summer monitoring program. Eleven storms occurred during the monitoring period and an estimated 52,000,000 gallons were pumped to the storage/treatment basin. Forty percent of this volume overflowed, after treatment, during three storms. The overflow frequency was reduced by 73%, and the effectiveness of the basin in treating the overflows ranged between 35% and 75% reduction in concentrations of eight different pollutants.

The total construction cost of the Hancock Street CSO control facilities was $7,280,000, including modifications to the in-line storage system (regulators) and the storage/treatment facilities. Estimated annual operating and maintenance cost for the storage/treatment system is about $50,000/yr.

Detention Ponds and Retention Basins. The ability of wet detention ponds and retention basins to remove pollutants from stormwater has been extensively studied. Numerous case studies have shown that reductions in suspended sediments, nutrients, and heavy metals are possible through the use of either retrofitted stormwater basins or detention ponds designed specifically for water quality improvements. The following case study reported variable reductions in total suspended solids, metals, and nutrients.

Urban Retention Ponds, Orlando, FL

A three pond stormwater retention system receiving stormwater from a highway interchange in Orlando, Florida, was investigated (Youssef, Wanielista, and Harper, 1986). The three ponds were interconnected by way of a large culvert to allow overflow to other ponds when storm runoff exceeds the design level. The first receiving pond has an approximate surface area of 1.3 ha (3.2 acres), an average depth of 1.5m (4.9 feet), and a total drainage area of 10.8 ha (26.7 acres). The ponds maintained a large standing crop of filamentous algae virtually year-round.

Field investigations conducted during 1982-1984 were designed to assess 1) the quantity of pollutants entering the pond, 2) the average water quality parameters in the basin water, 3) the accumulation of nutrients and heavy metals in the sediment of the pond, and 4) the leaching of heavy metals to the groundwater beneath the retention ponds.

The removal efficiencies of particulate metals were found to range from 77% for copper to over 95% for lead and zinc, while the removal of the dissolved fraction was only about 50% for lead and copper and 88% for zinc. The removal of particulate phosphorus and organic nitrogen was, on the other hand, poor and did not exceed 12%. The removal of the dissolved fraction of nutrient loadings ranged from 81.6% for ammonia to 90% for phosphorus.

Accumulation of phosphorus in the bottom sediment of the pond was evaluated at 99% of the total input during a 7 year period. However, 85-90% removal of the total nitrogen load was attributed to nitrification-denitrification processes. The removal of particulate heavy metals from the pond water was also attributed to settling and accumulation in

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Constructed Wetlands for Wastewater Treatment
DUST Marsh Trap Efficiencies (percent)

Constituents	System A	System B	System C[a]	Overall[b]
TDS	-9	-20	-50	-49
TSS	42	24	45	64
BOD_5	-26	-22	-8	-35
NH_3-N	-22	27	12	10
NO_3-N	9	5	8	15
TKN	7	-32	-17	-28
Orthophosphate	53	19	28	56
Total phosphate	17	-44	51	48
Chromium (Cr)	40	20	53	68
Copper (Cu)	5	-10	32	31
Lead (Pb)	30	27	83	88
Manganese (Mn)	-22	-1	-86	-111
Nickel (Ni)	34	-30	12	20
Zinc (Zn)	6	-22	51	33

[a]*System C inflow = composite of System A and B outflows.*
[b]*Overall trap efficiencies may be greater than cumulative reductions by individual systems because System C provides secondary treatment for System A and B discharges*

the bottom sediment within a relatively short distance from the stormwater inlet.

One common concern of using retention basins is the potential for groundwater contamination. However, monthly groundwater samples revealed no conclusive evidence of heavy metals migration from the pond.

Stormwater Wetlands, Fremont, CA

This study summarizes the results from the Demonstration Urban Stormwater Treatment (DUST) marsh project at Coyote Hills in Fremont, California (Meiorin, 1986). The study analyzes the applicability of artificial wetlands as a means for improving urban stormwater quality. The wetland system and control structures consist of a series of detention basins designed to simulate a secondary wastewater treatment plant, including pretreatment, clarifier, and biological processes. The basins were built in 1983 to receive water from approximately 4.6 square miles including residential, commercial, and open areas as well as urban roads.

A monitoring program during the wet seasons of 1984 and 1985 documented the marsh development and treatment effectiveness. Samples from eleven storms collected from each basin outflow were analyzed and the results, expressed in terms of trap efficiency, are listed in the table above.

The overall trap efficiency for heavy metals (chromium, copper, nickel, lead, and zinc) ranged from 20-88%, due in part to settling of heavy suspended particles. Nitrogen is transported into the marsh primarily as ammonia and organic nitrogen and was moderately trapped due to plant uptake and adsorption into the sediment. However, a higher trap efficiency was seen for phosphorus (orthophosphate and total phosphate).

Heavy metal concentrations in vegetation generally followed a pattern of greatest relative uptake occurring in plant roots with decreasing levels in the leaf and seed tissues. Generally soil-root concentrations were less than half of those found in the surface soil, leaf and seed concentration were one-half to one-fourth of the root amount. Bioaccumulation of chromium, copper, lead and zinc in fish tissue exceeded the 85% Elevated Data Level (EDL[a]) in all the basins; however, bioaccumulation of cadmium, nickel and selenium was not significant. Further research was recommended to determine the long-term build-up of heavy metals and toxic hydrocarbons in the foodchain.

It should be noted that the results of this study were collected from a relatively new wetland system, and the uptake of nutrients and heavy metals could vary as the system matures.

Sand Filters, Delaware

The State of Delaware developed a design approach for implementation of stormwater management water quality control practices targeting urban areas having little or no pervious area (Shaver, 1991). The controls were adopted under the urban stormwater runoff component of the NPDES program. The State of Delaware enacted an urban stormwater control program focussing on new construction. After July 1, 1991 all new development activities require reviews for water quality impacts prior to their approval. The program requires that pre-development peak discharges

[a]*Statistical values developed by the California Fish and Game from the 1984 Toxic Substances Monitoring program indicating percent of exceedance of a toxic substance in observed fish tissues.*

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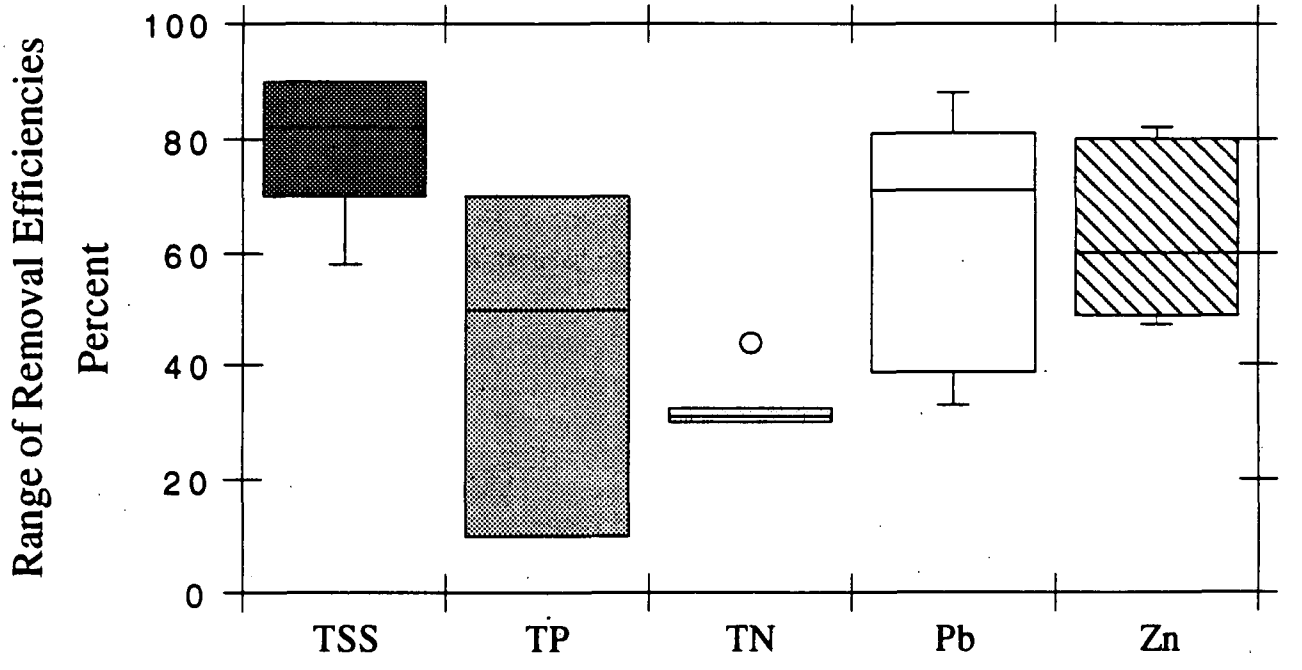
are not exceeded and water quality is protected by vegetative and structural control strategies designed to remove 80% of the inflow's suspended solids. Shallow stormwater management ponds that encourage plant growth are preferred because nutrients are a significant source of water quality degradation in Delaware. Often spatial or other engineering considerations limit the use of ponds in urban areas. In heavily urbanized areas, sand filters may be appropriate for both new development and retrofits as they do not limit land usage. The sand filters will be designed to treat runoff from frequent storm events, i.e., the first inch of rainfall. The design procedures for the sand filters are based on equations developed by the City of Austin as well as structural design previously used for a project in the State of Maryland.

Filter efficiency is related to the distribution of pollutants in the various particle size classes. Most of urban particulate matter is of a coarser size fraction; however, most of the other pollutants (except for metals which tend to be more evenly distributed across the size classes) are associated with the smaller particle sizes. For example, approximately 6% of urban particulate matter is in the silt and clay soil size range; but silts and clays contain more than 50% of the phosphorus. The sedimentation chamber of the filtration system is designed to remove the sand and gravel components and the sand filter is designed to remove the finer silt and clay particles. The detention chamber provides a detention time sufficient to remove sand and coarse particles based on their calculated settling velocities. The filter drains the first inch of runoff within a 24 hour period by assuming an average filtration rate of 0.04 gal/min/ft^2 for the sand. The design drainage area, typically a parking lot, must be less than 5 acres. Predicted removal efficiencies are 70% removal of total suspended solids, 33% removal of total phosphorus, 21% removal of total nitrogen, and 45% removal of the metals lead and zinc. Actual removals contained in the Austin report are somewhat higher than expected. Removal efficiencies reported in several sources (Woodward-Clyde, 1991) are illustrated in the following Figure. For example, the 25th and 75th percentile of TSS removal by filtration systems were about 70 and 90 percent, respectively. The median value is about 82 percent.



Removal efficiencies for total suspended solids, total phosphorous, total nitrogen, lead, and zinc by sandfilter basins.

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California Regional Water Quality Control Board
Santa Ana Region

ORDER NO. 96-31
NPDES No. CAS618030

Waste Discharge Requirements
for
the County of Orange, Orange County Flood Control District
and
The Incorporated Cities of Orange County Within the Santa Ana Region
Areawide Urban Storm Water Run-off
Orange County

The California Regional Water Quality Control Board, Santa Ana Region (hereinafter Regional Board), finds that:

1. On December 30, 1994, the County of Orange and the Orange County Flood Control District (OCFCD), in cooperation with the cities of Anaheim, Brea, Buena Park, Costa Mesa, Cypress, Fountain Valley, Fullerton, Garden Grove, Huntington Beach, Irvine, La Habra, La Palma, Lake Forest, Los Alamitos, Newport Beach, Orange, Placentia, Santa Ana, Seal Beach, Stanton, Tustin, Villa Park, Westminster, and Yorba Linda (hereinafter collectively referred to as permittees), submitted National Pollutant Discharge Elimination System (NPDES) Application No. CA 8000180 and a Report of Waste Discharge for reissuance of their areawide storm water NPDES permit.

2. Section 402(p) of the federal Clean Water Act (CWA), as amended by the Water Quality Act of 1987, requires NPDES permits for storm water discharges from separate municipal storm drain systems, storm water discharges associated with industrial activity (including construction activities), and designated storm water discharges which are considered significant contributors of pollutants to waters of the United States (U.S.). On November 16, 1990, the United States Environmental Protection Agency (hereinafter US EPA) published regulations (40 CFR Parts 122, 123 and 124) which describe permit application requirements for storm water discharges pursuant to Section 402(p) of the CWA. Prior to EPA's promulgation of the final storm water regulations, the three counties (Orange, Riverside, and San Bernardino) and the incorporated cities within the jurisdiction of the Santa Ana Region requested areawide NPDES permits for urban storm water run-off.

3. On July 13, 1990, the Regional Board adopted Order No. 90-71 for urban storm water run-off from urban areas in Orange County within the Santa Ana Region. The County of Orange was named as the principal permittee and the Orange County Flood Control District (OCFCD) and the incorporated cities were named as the co-permittees. In order to more effectively carry out the requirements of this order, the permittees have agreed that the County of Orange will continue as principal permittee and the OCFCD and the incorporated cities will continue as co-permittees. Order 90-71 expired on July 1, 1995.

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4. Order No. 90-71 required the permittees to develop and implement a drainage area management plan (DAMP) and a storm water and receiving water monitoring plan, to eliminate illegal and illicit discharges to the storm drain systems and to enact the necessary legal authority to effectively prohibit such discharges. The overall goal of these requirements was to reduce pollutant loadings to surface waters from urban run-off to the maximum extent practicable (MEP)[1].

5. This order outlines the next step toward an effective program and specifies requirements to protect the beneficial uses of the waters of the U. S. The intent of this permit is to regulate pollutant discharges, identify and focus on those areas which threaten the beneficial uses and improve water quality in the Region in a timely manner. This order regulates urban storm water run-off[2] from areas under the jurisdiction of the permittees.

6. The Report of Waste Discharge (the permit renewal application) included the following major components:

   a. Summary of status of current Storm Water Management Program
   b. Proposed Plan of Storm Water Quality Management Activities for 1995-2000
   c. The Drainage Area Management Plan
   d. A Model Water Quality Ordinance
   e. An Enforcement Consistency Guide
   f. A Reconnaissance Survey Field Inspection and Documentation Manual

7. The permittees serve a population of approximately 2.6 million, occupying an area of approximately 511 square miles (including both unincorporated areas and the limits of 31 cities). The permittees have jurisdiction over and /or maintenance responsibility for storm water conveyance systems within Orange County. The County's systems include an estimated 400 miles of storm drain systems. A major portion of the urbanized areas of Orange County drains into water bodies within this Regional Board's jurisdiction. The project area is shown on Attachment A. The major storm drain systems and drainage areas in Orange County which are within this Region are shown on Attachment B. A portion of the Orange County drainage area is within the jurisdiction of the San Diego Regional Board and is currently regulated under an order issued by that Board.

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[1] Maximum Extent Practicable (MEP) means to the maximum extent possible, taking into account equitable considerations of synergistic, additive, and competing factors, including but not limited to, gravity of the problem, fiscal feasibility, public health risks, societal concerns, and social benefits.

[2] Urban storm water run-off includes those discharges from residential, commercial, industrial and construction areas within the permitted area and excludes discharges from feedlots, dairies and farms.

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8. The permittees may lack legal jurisdiction over storm water discharges into their systems from some of the State and federal facilities, utilities and special districts, Native American tribal lands, waste water management agencies and other point and non-point source discharges otherwise permitted by the Regional Board. The Regional Board recognizes that the permittees should not be held responsible for such facilities and/or discharges.

9. Storm water discharges consist of surface run-off generated from various land uses in all the hydrologic drainage areas which discharge into the water bodies of the U. S. The quality of these discharges varies considerably and is affected by land use activities, basin hydrology and geology, season, the frequency and duration of storm events, and the presence of illegal disposal practices/illicit connections. Nationwide studies in urban areas have shown that urban run-off typically contains significant quantities of pollutants. Preliminary results from urban storm water monitoring programs within the permitted area indicate that the major pollutants of concern are certain heavy metals, sediment, chemical oxygen demand (COD), pesticides, herbicides, and nutrients.

   The 1989, 1991, and 1994 Water Quality Assessments by the Regional Board identified impairment of a number of water bodies within the permitted area. The beneficial uses of these water bodies have been found to be threatened or impaired due to point and non-point source discharges.

10. Certain activities that generate pollutants present in storm water runoff are beyond the ability of the permittees to eliminate. Examples of these include operation of internal combustion engines, atmospheric deposition, brake pad wear, tire wear and leaching of naturally-occurring minerals from local geography.

11. Storm water discharges to the storm drain systems in Orange County are tributary to various water bodies of the Region. The permitted area can be subdivided into five tributary watersheds: the San Gabriel River drainage area, the Huntington Harbor and Bolsa Bay drainage area, the Greenville-Banning Channel drainage area, the Santa Ana River drainage area, and the Newport Bay drainage area (see Attachment B). These watersheds are tributary to the Pacific Ocean. The surface water bodies in Orange County include:

    Inland Surface Streams

    a. Santa Ana River, Reaches 1 and 2,

    b. Silverado Creek (tributary to Santiago Creek),

    c. Santiago Creek, Reaches 1, 2, 3, and 4 (tributary to the Santa Ana River),

    d. San Diego Creek, Reaches 1 and 2 (tributary to Newport Bay),

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e. San Joaquin Freshwater Marsh (tributary to San Diego Creek),

f. All other tributaries to these Creeks: Bonita Creek, Serrano Creek, Peters Canyon Wash, Hicks Canyon Wash, Bee Canyon Wash, Borrego Canyon Wash, Agua Chinon Wash, Laguna Canyon Wash, Rattlesnake Canyon Wash, Sand Canyon Wash, Black Star Creek, Carbon Canyon Creek, Coyote Creek and other tributaries to these washes,

Bays, Estuaries, and Tidal Prisms

g. Anaheim Bay,

h. Sunset Bay,

i. Bolsa Bay and Bolsa Chica Ecological Reserve,

j. Lower and Upper Newport Bay,

k. Tidal Prism of Santa Ana River (to within 1000 feet of Victoria Street) and Newport Slough, Santa Ana Salt Marsh,

l. Tidal Prism of San Gabriel River (River Mouth to Marina Drive),

m. Tidal Prisms of Flood Control Channels Discharging to Coastal or Bay Waters (e.g. Huntington Harbor),

Ocean Waters

Nearshore Zone

n. San Gabriel River to Poppy Street in Corona Del Mar,

o. Poppy Street to Southeast Regional Boundary,

Offshore Zone

p. Waters between Nearshore Zone and Limit of State Waters,

Lakes and Reservoirs

q. Irvine Lake (Santiago Reservoir), and

r. Laguna, Peters Canyon, and Rattlesnake Reservoirs.

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11. (cont'd)
The beneficial uses of these water bodies include: municipal and domestic supply, agricultural supply, industrial service supply, groundwater recharge, navigation, hydropower generation, water contact recreation, non-contact water recreation, commercial and sportfishing, warm freshwater habitat, cold freshwater habitat, preservation of biological habitats of special significance, wildlife habitat, preservation of rare, threatened or endangered species, marine habitat, shellfish harvesting, spawning, reproduction and development of aquatic habitats, and estuarine habitat . The ultimate goal of this storm water management program is to protect the beneficial uses of the receiving waters.

12. The Santa Ana River Basin is the major watershed within the jurisdiction of the Regional Board. The lower Santa Ana River Basin (downstream from Prado Basin) includes the Orange County drainage areas and the Upper Santa Ana River Basin includes the San Bernardino and the Riverside drainage areas. Within the Region, generally the San Bernardino County drainage areas drain to the Riverside County drainage areas, and Riverside County drainage areas discharge to Orange County.

13. Within the Region, run-off from the San Bernardino County areas is generally conveyed to the Riverside County areas through the Santa Ana River or other drainage channels tributary to the Santa Ana River. These flows are then discharged to Reach 2 of the Santa Ana River through Prado Basin (Reach 3 of the Santa Ana River). Most of the flow in Reach 2 is recharged in Orange County. During wet weather, some of the flow is discharged to the Pacific Ocean through Reach 1 of the Santa Ana River.

14. The three county areas within this Region are regulated under three areawide permits for urban storm water run-off. These areawide NPDES permits are:

a. Orange County, NPDES No. CAS618030;
b. Riverside County, NPDES No. CAS618033; and
c. San Bernardino County, NPDES No. CAS618036.

15. Studies conducted by the EPA, the states, flood control districts and other entities indicate the following major sources for urban storm water pollution nationwide:

a. Industrial sites where appropriate pollution control and best management practices (BMPs)[3] are not implemented;

b. Construction sites where erosion and siltation controls and BMPs are not implemented; and

c. Urban run-off where the drainage area is not properly managed.

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[3] Best Management Practices (BMPs) are water quality management practices that are maximized in efficiency for the control of storm water run-off pollution.

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16. To address the industrial and construction sites, the State Board issued two statewide general NPDES permits: one for storm water run-off from industrial sites (NPDES No. CAS000001, General Industrial Activities Storm Water Permit) and the second one for storm water run-off from construction sites (NPDES No. CAS000002, General Construction Activity Storm Water Permit). In addition, the Regional Board adopted Order No. 94-005, NPDES NO. CA 8000279, for storm water run-off from facilities owned and/or operated by Caltrans, which includes freeways and highways, and Order 94-7, NPDES No. CA 8000336 for concentrated animal feeding operations, including dairies. The Regional Board issued and continues to issue individual storm water permits for certain industrial facilities within the Region.

17. One of the major components of these statewide permits and the Caltrans permit is the development and implementation of a storm water pollution prevention plan (SWPPP).

18. Most industrial activities (some light industrial activities are exempt) and construction sites on five acres or more are required to get coverage under these statewide general permits.

19. The Regional Board administers compliance with the State's General Industrial Activities Storm Water Permit and the General Construction Activity Storm Water Permit. However, in most cases, the industries and construction sites discharge into storm drains and/or flood control facilities owned and operated by the permittees. These industries and developers are also regulated under local laws and regulations. Therefore, a coordinated effort of the permittees and the Regional Board staff is critical to avoid duplicative and overlapping storm water regulatory activities. A memorandum of understanding between the permittees and the Regional Board may be appropriate to efficiently implement the storm water regulations for industries and construction sites at the local level.

20. The permittees have agreed to continue to notify Regional Board staff when conditions are observed during their routine activities which result in a threat or potential threat to water quality. This also includes failure to obtain coverage under the general storm water permits.

21. The permittees have developed project conditions of approval for new developments to be implemented at the time of grading or building permit issuance for individual sites on five acres or more, with the intent to comply with the General Construction Activity Storm Water Permit.

22. The permittees own/operate facilities where industrial or related activities take place that may have an impact on storm water quality. Some of the permittees also enter into contracts with outside parties to carry out municipal related activities that may also have an impact on storm water quality. These facilities and related activities include, but are not limited to, street sweeping, catch basin cleaning, maintenance yards, vehicle and equipment maintenance areas, waste transfer stations, corporation and storage yards, parks and recreational facilities, landscape and swimming pool maintenance activities, storm

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drain system maintenance activities and the application of herbicides, algaecides and pesticides. As part of this order, the permittees will prepare an environmental performance report for appropriate public facilities under their jurisdiction, and develop and implement best management practices for those activities found to require pollution prevention measures. Non-storm water discharges from these facilities and/or activities could also affect water quality. This order prohibits non-storm water discharges from public facilities unless the discharges are exempt under Section III, Discharge Limitations, 3 & 5 of this order or are permitted by the Regional Board under an individual NPDES permit.

23. Successful implementation of the provisions and limitations in this order will require the cooperation of all the public agency organizations within Orange County having programs/activities that have an impact on storm water quality. A list of these organizations is included in Attachment C. As such, these organizations are expected to actively participate in implementing the Orange County NPDES Storm Water Program. The Regional Board has the discretion and authority to require non-cooperating entities to participate in this areawide permit or obtain individual storm water discharge permits, pursuant to 40 CFR 122.26(a).

24. The major focus of storm water pollution prevention is the development and implementation of appropriate drainage area management plan (DAMP) including best management practices (BMPs). The ultimate goal of the urban storm water management program is to support attainment of water quality consistent with the water quality objectives for the receiving waters in order to protect beneficial uses through the implementation of the DAMP. The permittees developed and submitted a DAMP for approval, which was approved on May 3, 1994.

25. The DAMP is a dynamic document and the permittees have implemented, or are in the process of implementing, the various elements of the DAMP. This order requires the permittees to continue to implement the BMPs listed in the DAMP and to effectively prohibit illegal and illicit discharges to the storm drain system.

26. Urban run-off contains pollutants from privately owned and operated facilities such as residences, businesses, private and/or public institutions, and commercial establishments. Therefore, a successful storm water management plan should include the participation and cooperation of the public, businesses, the permittees and the regulators. The DAMP has a strong emphasis on public education.

27. The Orange County DAMP defined a management structure for the permittees' compliance effort, a formal agreement to underpin cooperation, and detailed municipal efforts to develop, implement, and evaluate various BMPs or control programs in the areas of public agency activities, public information, new development and construction, public works construction, industrial discharger identification, and illicit discharger/connection identification and elimination. The DAMP also defined an extensive surface water quality and sediment monitoring program.

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28. In order to characterize storm water discharges, to identify problem areas, to determine the impact of urban run-off on receiving waters, and to determine the effectiveness of the various BMPs, an effective monitoring program is critical. From 1990 through 1995, the principal permittee administered the monitoring program for the permittees which included storm water monitoring, receiving water monitoring, dry weather monitoring and sediment monitoring. The permit application included a summary of monitoring data collected during 1991-1994. The monitoring program did not identify any specific pollutant sources which could be targeted for special pollutant control programs. The monitoring data indicated spatial differences in water quality between Orange County's major watersheds. Some of the monitoring data collected to date may be used to develop baseline water quality data for future evaluation of program effectiveness.

29. The Strategic Plan and Initiatives (June 22, 1995) for the State Water Resources Control Board and the Regional Water Quality Control Boards recognizes the importance of an integrated watershed management approach. The Regional Board also recognizes that a watershed management program should integrate all related programs, including the storm water programs. Consistent with this approach, an integrated monitoring program could be developed with the cooperation of all the stakeholders, including the permittees in the three counties, and the Regional Board. The Regional Board will coordinate the activities within the watershed and seek participation of the permittees.

30. Any illegal dumping and illicit/illegal connections and discharges[4] to the storm drains could contribute to storm water and other surface water contamination. A reconnaissance survey of the municipal storm drain systems (open channels and underground storm drains) is being conducted by the permittees. The permittees are required to detect, identify and eliminate illicit/illegal discharges. Additionally, the permittees are also required to develop a program to prohibit illegal/illicit connections to their storm drains and flood control facilities.

31. The County of Orange obtains its authority to control pollutants in storm water discharges, to prohibit illegal discharges/illicit connections, to control spills, and to require compliance and carry out inspections of the storm drain systems in the County of Orange from the Orange County Flood Control Act, Orange County Water Pollution Ordinance, and various county ordinances which address industrial wastes and waste discharges within the unincorporated areas of Orange County and contract cities. The permittees have various forms of legal authority in place, such as charters, State Code provisions for General Law cities, city ordinances, and applicable portions of municipal codes and the State Water Code, to regulate storm water/urban run-off discharges.

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[4] Illegal discharge means any discharge (or seepage) to the municipal separate storm sewer that is not composed entirely of storm water except for the authorized discharges listed in Section III of this permit. Illegal discharges include the improper disposal of wastes into the storm sewer system.

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In order to insure countywide consistency and to provide a legal underpinning to the entire Orange County Storm Water Program, a model water quality ordinance was completed on August 15, 1994 and is available to the permittees for adoption.

32. Early identification of potential storm water impacts and mitigation measures can significantly reduce storm water pollution problems. The permittees should consider these impacts and appropriate mitigation measures in the planning procedures and in the California Environmental Quality Act (CEQA) review process for specific projects, Master Plans, etc. The County of Orange already requires a Water Quality Management Plan which addresses permanent post-construction BMPs, in addition to the SWPPP required by the statewide general permit for construction activity.

33. Successful implementation of the provisions and limitations in this order will require the cooperation of all the public agency organizations within Orange County having programs/activities that have an impact on storm water quality (e.g. Fire Department, Building and Safety, Code enforcement, etc.). As such, these organizations are expected to actively participate in implementing this areawide storm water program.

34. In accordance with the Clean Water Act and its implementing regulations, this order requires the permittees to develop and implement programs and policies necessary to control the discharge of pollutants in urban run-off to waters of the U. S. to the maximum extent practicable.

35. The legislative history and the preamble to the federal storm water regulations indicate that the Congress and the U.S. EPA were aware of the difficulties in regulating urban storm water run-off solely through traditional end-of-pipe treatment. However, it is the Regional Board's intent that this order shall achieve attainment and protection of the beneficial uses of receiving waters. This order, therefore, includes Receiving Water Limitations required to implement water quality objectives and to prevent nuisance and water quality impairment in receiving waters. In accordance with Section 402 (p) of the Clean Water Act, this order requires the permittees to implement control measures in accordance with the approved DAMP that will reduce pollutants in storm water discharges to the maximum extent practicable. The Receiving Water Limitations require the implementation of control measures that are technically and economically feasible as necessary to protect beneficial uses and attain water quality objectives of the receiving waters.

36. The Regional Board finds that the unique aspects of the regulation of storm water discharges through municipal storm sewer systems, including intermittent discharges, difficulties in monitoring and limited physical control over the discharge, will require adequate time to implement and evaluate the effectiveness of best management practices and to determine whether they will adequately protect receiving waters. Therefore, the permit includes a procedure for determining whether storm water discharges are causing

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continuing and recurring exceedances of receiving water limitations and for evaluating whether the DAMP must be revised. The permittees will be in compliance with the Receiving Water Limitations so long as it complies with that procedure.

37. A revised Water Quality Control Plan (Basin Plan) was adopted by the Regional Board and became effective on January 24, 1995. The Basin Plan contains water quality objectives and beneficial uses for water bodies in the Santa Ana Region. The Basin Plan also incorporates by reference all State Board water quality control plans and policies including the 1990 Water Quality Control Plan for Ocean Waters of California (Ocean Plan) and the 1974 Water Quality Control Policy for Enclosed Bays and Estuaries of California (Enclosed Bays and Estuaries Plan).

38. The requirements contained in this order are necessary to implement the plans and policies described in Finding 36, above. These plans and policies contain numeric and narrative water quality standards for the water bodies in this Region. This order does not contain numeric effluent limitations for any constituents because the impact of the storm water discharges on the water quality of the receiving waters has not yet been fully determined. Continuation of water quality/biota monitoring and analysis of the data are essential to make that determination.

39. The permittees may petition the Regional Board to issue a separate NPDES permit to any discharger of non-storm water into storm drain systems that they own or operate.

40. The permittees have developed a Storm Water Implementation Agreement between the County, its cities and the Orange County Flood Control District as required under Order No. 90-71.

41. The storm water regulations require public participation in the storm water management program development and implementation. As such the permittees are required to solicit and consider all comments received from the public and submit copies of the comments to the Executive Officer of the Regional Board. In considering the public comments, the permittees may modify reports, plans, or schedules prior to submittal to the Executive Officer.

42. In accordance with California Water Code Section 13389, the issuance of waste discharge requirements for this discharge is exempt from those provisions of the California Environmental Quality Act contained in Chapter 3 (commencing with Section 21100), Division 13 of the Public Resources Code.

43. The Regional Board has considered anti-degradation requirements, pursuant to 40 CFR 131.12 and State Board Resolution 68-16, for this discharge. The Regional Board finds that the storm water discharges are consistent with the federal and state anti-degradation requirements and a complete anti-degradation analysis is not necessary.

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44. The Regional Board has notified the permittees and interested parties of its intent to issue waste discharge requirements for this discharge and has provided them with an opportunity to submit their written views and recommendations.

45. The Regional Board, in a public hearing, heard and considered all comments pertaining to the discharge and to the tentative requirements.

IT IS HEREBY ORDERED that the permittees, in order to meet the provisions contained in Division 7 of the California Water Code and regulations adopted thereunder, and the provisions of the Clean Water Act, as amended, and regulations and guidelines adopted thereunder, shall comply with the following:

I. RESPONSIBILITIES OF PRINCIPAL PERMITTEE

The principal permittee shall be responsible for the overall program management and shall:

1. Conduct chemical and biological water quality monitoring of the storm drain system outfalls as agreed upon by the Executive Officer of the Regional Board.

2. Develop criteria for inspections of the municipal separate storm drain systems.

3. Conduct inspections of the storm drain systems within its jurisdiction.

4. Implement management programs (within its jurisdiction), monitoring programs, and related plans as required by this order.

5. Enact and revise policies/ordinances necessary to establish legal authority as required by the Federal Storm Water Regulations.

6. Respond and/arrange for responding to emergency situations such as accidental spills, leaks, illegal discharges/illicit connections, etc. to prevent or reduce the discharge of pollutants to storm drain systems and waters of the U.S.

7. Prepare and submit to the Executive Officer of the Regional Board unified reports, plans, and programs as required by this order.

The activities of the principal permittee should include, but not be limited to, the following:

8. Coordinate permit activities and participate in any subcommittees formed as necessary, to coordinate compliance activities with this order.

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9. Provide technical and administrative support and inform the co-permittees of the progress of other pertinent municipal programs, pilot projects, research studies, etc.

10. Coordinate the implementation of areawide storm water quality management activities such as public education, pollution prevention, household hazardous waste collection, etc.

11. Develop and implement mechanisms, performance standards, etc., to promote uniform and consistent implementation of BMPs among the permittees.

12. Pursue enforcement actions as necessary within its jurisdiction to ensure compliance with storm water management programs, ordinances and implementation plans including physical elimination of undocumented connections and illicit discharges.

13. In conjunction with the other permittees, implement the BMPs listed in the approved DAMP.

14. Monitor the implementation of the plans and programs required by this order and determine their effectiveness in protecting beneficial uses.

15. Coordinate all the activities with the Regional Board including the submittal of all reports, plans, and programs as required under this order.

16. Obtain public input for any proposed management and implementation plans where applicable.

17. Cooperate in watershed management programs and regional and/or statewide monitoring programs.

II. RESPONSIBILITIES OF THE CO-PERMITTEES

The co-permittees shall be responsible for the management of storm drain systems within their jurisdictions and shall:

1. Implement management programs, monitoring programs, implementation plans and all BMPs outlined in the DAMP within each respective jurisdiction as required by Order No. 96-31.

2. Adopt the Orange County Water Quality Ordinance or the equivalent legislation necessary to establish and maintain adequate legal authority as required by the Federal Storm Water Regulations.

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3. Conduct storm drain system inspections in accordance with the criteria developed by the principal permittee.

The co-permittees' activities should include , but not be limited to, the following:

4. Participate in committees or subcommittees formed by the principal permittee to address storm water related issues to comply with this order.

5. Review, approve, implement, and comment on all plans, strategies, management programs, monitoring programs, as developed by the principal permittee or any subcommittee to comply with this order.

6. Pursue enforcement actions as necessary to ensure compliance with the storm water management programs, ordinances and the implementation plans including physical elimination of undocumented connections and illicit discharges.

7. Conduct and coordinate with the principal permittee any surveys and characterizations needed to identify the pollutant sources and drainage areas.

8. Submit storm drain system maps with periodic revisions as necessary.

9. Respond to emergency situations such as accidental spills, leaks, illegal discharges/illicit connections, etc. to prevent or reduce the discharge of pollutants to storm drain systems and waters of the U.S.

10. Prepare and submit all reports to the principal permittee in a timely manner.

III. DISCHARGE LIMITATIONS

1. The permittees shall prohibit illicit/illegal discharges from entering into the municipal separate storm sewer systems (municipal storm drain systems) and require controls to reduce the discharge of pollutants to the maximum extent practicable.

2. The discharge of storm water from permittees' municipal storm drain systems to waters of the United States containing pollutants which have not been reduced to the maximum extent practicable is prohibited.

3. The following discharges need not be prohibited by the permittees unless identified by the permittees as a source of pollutants to the receiving waters.

   a. discharges composed entirely of storm water,

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b. covered by NPDES permits or written clearances issued by the Regional or State Board
c. from potable water line flushing and other potable water sources,
d. fire hydrant testing and flushing,
e. air conditioning condensation,
f. landscape irrigation, lawn garden watering and other irrigation waters,
g. passive foundation drains,
h. passive footing drains,
i. water from crawl space pumps,
j. dechlorinated swimming pool discharges,
k. non-commercial vehicle washing,
l. diverted stream flows,
m. rising ground waters and natural springs,
n. ground water infiltration as defined in 40 CFR 35.2005 (20) and uncontaminated pumped groundwater,
o. flows from riparian habitats and wetlands,
p. street wash water and run-off from fire fighting (program descriptions shall address discharges or flows from fire fighting only where such discharges are identified as significant sources of pollutants to waters of the United States),
q. waters not otherwise containing wastes as defined in California Water Code Section 13050 (d), and
r. other types of discharges identified and recommended by the permittees and approved by the Regional Board.

For purposes of this order, a discharge may include storm water and other types of discharges as indicated above.

4. If it is determined by the permittees that any of the preceding discharges cause or contribute to violations of water quality standards or are significant contributors of pollutants to waters of the U.S., the permittees shall prohibit these discharges from entering the storm drain system.

5. Non-storm water discharges from public agency activities into waters of the U.S. are prohibited unless the non-storm water discharges are permitted by an NPDES permit or are included in Item 3., above. If permitting or immediate elimination of the non-storm water discharges is impractical, the permittees shall include in the Environmental Performance Report, required under Section V., Provision 18., of this order, a proposed plan to eliminate the non-storm water discharges in a timely manner.

6. The permittees shall reduce the discharge of pollutants to the storm water conveyance systems to the maximum extent practicable.

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IV. RECEIVING WATER LIMITATIONS

1. Receiving water limitations have been established based on beneficial uses, water quality objectives, and water quality standards contained in the Basin Plan, and amendments thereto, and on ambient water quality. They are intended to protect the beneficial uses and attain the water quality objectives contained in the Basin Plan. The discharge of urban storm water, or non-storm water, from a municipal storm sewer system for which the permittees are responsible under the terms of this permit shall not cause continuing or recurring impairment of beneficial uses or exceedances of water quality objectives. The permittees will not be in violation of this provision so long as they are in compliance with the requirements set forth in 1.a.

   a. If the Executive Officer determines that a continuing or recurring impairment of beneficial uses or exceedances of water quality objectives has been caused by urban storm water discharges from the municipal storm sewer system, the following steps shall be taken:

      i. The Executive Officer will evaluate the adequacy of the permittees' implementation of the approved DAMP based on the permittees' submitted reports and other relevant information. The Executive Officer will determine if implementation of the approved DAMP has a reasonable likelihood of preventing future continuing or recurring impairment of beneficial uses or exceedances of water quality objectives resulting from urban storm water discharges. If the Executive Officer makes this determination, the permittees are required to continue implementing the approved DAMP.

      ii. If the Executive Officer determines that implementation of the approved DAMP will not have a reasonable likelihood of preventing future impairment of beneficial uses or exceedances of water quality objectives, the permittees shall, upon notice from the Executive Officer, do the following:

         A. Submit a report that includes an evaluation of the relative contribution of the urban storm water discharges to the impairment of beneficial uses or the exceedances of water quality objectives. The report shall address the persistence, the significance, and to the extent feasible, the causes of the impairment or exceedance, and the technical and economic feasibility of control actions available to the permittees to reduce or eliminate the impairment or exceedance.

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B. Submit a report reviewing the approved DAMP to determine whether it should be revised so that there will be a reasonable likelihood of preventing future continuing or recurring beneficial use impairment or exceedances of water quality objectives, or whether revisions to achieve protection of beneficial uses or attainment of water quality objectives are technically or economically infeasible. If the report recommends revision of the approved DAMP, the report shall include a work plan to revise the plan so that it will have a reasonable likelihood of preventing future continuing or recurring beneficial use impairment or exceedance or water quality objectives. If the report concludes that no revisions are necessary to achieve protection of beneficial uses or attainment of water quality objectives, the report shall explain how implementation of the approved DAMP will achieve compliance. If the report determines that revisions to achieve protection of beneficial uses or attainment of water quality objectives are technically or economically infeasible, the permittees shall continue to comply with the DAMP, shall fully document this determination and shall make recommendations for actions to achieve compliance.

C. The permittees shall implement the work plan and the revised DAMP as approved by the Executive Officer.

2. The Executive Officer shall review and approve or disapprove the reports required under Receiving Water Limitation 1. The reports may be submitted as part of the next Annual Report, or at some other time designated by the Executive Officer. So long as the permittees have complied with the procedures set forth in Receiving Water Limitation 1, they do not have to repeat the procedure for continuing or recurring exceedances of the same receiving water limitations. As appropriate, any determinations under this part or revisions to the approved DAMP may be considered by the Regional Board in a public meeting.

V. PROVISIONS

GENERAL

1. Permittees shall demonstrate compliance with all the requirements in this order and specifically with Section III. Discharge Limitations and Section IV. Receiving Water Limitations, through timely implementation of their approved Drainage Area Management Plan (DAMP) and any approved modifications, revisions, or amendments developed pursuant to this order. The approved DAMP, as included in the Report of Waste Discharge, including any approved amendments thereto, is hereby made an enforceable component of this order.

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2. The permittees shall implement all elements of the approved DAMP. Where the dates are different than those of the order, the dates in the order shall prevail. Any proposed revisions to the DAMP shall be submitted with the Annual Report to the Executive Officer of the Regional Board for review and approval. All approved revisions to the DAMP shall be implemented in a timely manner.

3. The permittees shall comply with Monitoring and Reporting Program No. 96-31 which is hereby made a part of this order and any revisions thereto. The Executive Officer is authorized to revise the Monitoring and Reporting Program and also to allow the permittees to participate in regional, statewide, national or other monitoring programs in lieu of Monitoring and Reporting Program No. 96-31.

4. Upon approval by the Executive Officer of the Regional Board, all plans, reports and subsequent amendments as required by this order shall be implemented and shall become an enforceable part of this order. Prior to approval by the Executive Officer, these plans, reports and amendments shall not be considered as an enforceable part of this order.

5. The permittees shall report to the Executive Officer of the Regional Board:

   a. Any enforcement actions and discharges of storm or wastewaters, known to the permittees, which may have an impact on human health or the environment,

   b. Any suspected or reported activities on federal, state, or other entity's land or facilities, where the permittees do not have any jurisdiction, and where the suspected or reported activities may be contributing pollutants to waters of the U.S.

6. The permittees shall not issue any grading permit for construction activities which will disturb five acres or more (or less than five acres, if it is part of a larger common plan of development or sale which is five acres or more) until proof of coverage with the State's General Construction Activity Storm Water Permit is verified. The proof of coverage may include a letter from the Regional Board office, a copy of the Notice of Intent, Waste Discharger Identification number, etc.

7. The permittees shall identify all illegal and or illicit connections by February 1, 1997 and submit a report of the findings by February 28, 1997 including a schedule for elimination of any identified illicit connection and for periodic inspections of the storm drain facilities.

8. Permit application and special NPDES program requirements contained in 40 CFR 122.21 (a), (b), (d)(2), (f), (p); 122.41 (a), (b), (c), (d), (e), (f), (g), (h), (i), (j), (k), (l); and 122.42 (c) are incorporated into this order by reference.

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IMPLEMENTATION AGREEMENT

9. No later than May 31, 1996, the permittees shall submit to the Executive Officer of the Regional Board a copy of the existing Storm Water Program Implementation Agreement with authorized signatures of each of the permittees. Any further revisions to the implementation agreement shall be forwarded to the Executive Officer of the Regional Board within 30 days of approval by the permittees.

LEGAL AUTHORITY

10. The permittees shall adopt the proposed Water Quality Ordinance, or its equivalent. The permittees shall review their existing grading and erosion control ordinances and determine the need for any revision. Upon adoption of the ordinances, but no later than July 31, 1997 each permittee shall certify to the Regional Board that it has adequate legal authority to control the discharges of pollutants into the municipal storm drain system and that it has satisfied the requirements of 40 CFR Section 122.26(d)(2)(i)(A-F). The certification may be submitted jointly by all permittees.

ENFORCEMENT/COMPLIANCE STRATEGY

11. The Permittees shall implement the Enforcement Consistency Guide, dated 8/15/94, or an equivalent enforcement strategy, in order to enforce the Water Quality Ordinance. Upon implementation, but no later than July 31, 1997, each permittee shall certify to the Regional Board that the guide or similar policies are in place for their enforcement staff. Before implementation, this guide and its equivalent must include the following:

    a. A mechanism to determine compliance of industrial facilities, commercial facilities, and construction sites with storm water ordinances and concerns;

    b. A program to monitor and control the pollutants in storm water discharges to the municipal system from industrial facilities that the permittees determines are contributing to a substantial pollutant loading to the municipal storm drain system. The program shall identify priorities and procedures for inspections and establishing and implementing control measures.

12. The permittees shall develop a training program and offer it to the staff of existing industrial and construction inspection programs, to raise concerns with regard to storm water requirements.

13. The permittees will continue to provide notification to the Regional Board regarding storm water related information gathered during site inspections of industrial and construction sites regulated by the Statewide General Storm Water Permits.

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PUBLIC EDUCATION AND OUTREACH

14. The permittees will continue to implement the public education efforts already underway and shall implement all of the proposed efforts contained in the permit application. Any proposed changes shall be reported in the Annual Report.

15. When feasible, the permittees shall participate in joint outreach with other programs including, but not limited to, other municipal storm water programs to ensure that a consistent message on storm water pollution prevention is brought to the public.

16. The permittees shall develop public education materials to encourage the public to report illegal dumping from residential, industrial, construction and commercial sites into public streets, storm drains and other water bodies.

17. The permittees shall develop BMP guidance for the control of those potentially polluting activities not otherwise regulated by any agency.

MUNICIPAL FACILITIES

18. The permittees shall prepare an Environmental Performance Report, as stated in the amended DAMP, to address public agency facilities and activities not currently required to obtain coverage under the State's general storm water permits. This report may include a pollution prevention strategy to ensure that the public agency facilities and/or activities that are currently not required to obtain coverage under the State's general storm water permits are not sources of pollutants into the waters of the U.S. A report shall be submitted to the Executive Officer of the Regional Board by July 31, 1997, identifying the extent of the investigation and all findings of the Environmental Performance Report as it pertains to storm water quality. Thereafter, the permittees shall include in the annual report for each year the actions taken by the permittees to eliminate discharges of pollutants to waters of the U.S., identified by the permittees, at public agency facilities.

MUNICIPAL CONSTRUCTION PROJECTS/ACTIVITIES

19. This order authorizes the discharge of storm water run-off from construction projects that may result in land disturbance of five (5) acres or more (or less than five acres, if it is part of a larger common plan of development or sale which is five acres or more) that are under ownership and/or direct responsibility of any of the permittees.

20. Prior to commencement of construction activities, the permittees shall notify the Executive Officer of the Regional Board of the proposed construction project. Upon completion of the construction project, the Executive Officer shall be notified of the completion of the project.

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21. The permittees shall develop and implement a storm water pollution prevention plan (SWPPP) and a monitoring program that is specific for the construction project prior to the commencement of any of the construction activities. The SWPPP shall be kept at the construction site and released to the public and/or Regional Board staff upon request.

22. The SWPPP and the monitoring program for the construction projects shall be consistent with the requirements of the latest version of the State's General Construction Activity Storm Water Permit.

23. The permittees shall give advance notice to the Executive Officer of the Regional Board of any planned changes in the construction activity which may result in non-compliance with the latest version of the State's General Construction Activity Storm Water Permit.

24. All other terms and conditions of the latest version of the State's General Construction Activity Storm Water Permit shall be applicable.

NEW DEVELOPMENT (INCLUDING RE-DEVELOPMENT)

25. Within 90 days of the issuance of this order, the permittees shall begin implementation of the new development BMPs (DAMP, Appendix G, dated September 1993) and BMPs for public works construction (DAMP, Appendix H) that were developed under Order 90-71. Each permittee shall certify to the Regional Board by November 15, 1996, that these guidelines or the equivalent are being implemented and enforced.

26. Within 120 days of the issuance of this order, the permittees shall review their planning procedures and CEQA document preparation processes to insure that storm water-related issues are properly considered. If necessary, these processes shall be revised to include storm water requirements for evaluation of appropriate mitigation measures.

27. The permittees shall, through conditions of approval, insure proper maintenance and operation of any permanent flood control structures installed in new developments. The parties responsible for the maintenance and operation of the facilities shall be identified.

FISCAL RESOURCES

28. The permittees shall prepare and submit a unified fiscal analyses to the Executive Officer of the Regional Board. The fiscal analysis shall be submitted with the Annual Report document no later than November 15th of each year and shall, at a minimum, include the following:

    a. Each permittee's expenditures for the previous fiscal year,
    b. Each permittee's budget for the current fiscal year,
    c. A description of the source of funds, and
    d. Each permittee's estimated budget for the next fiscal year.

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PERMIT EXPIRATION AND RENEWAL

29. This order expires on March 1, 2001 and the permittees must file a Report of Waste Discharge (permit application) no later than 180 days in advance of such expiration date as application for issuance of new waste discharge requirements. The Report of Waste Discharge shall, at a minimum, include the following:

    a. Any revisions to the Drainage Area Management Plan including, but not limited to, all the activities the permittees propose to undertake during the next permit term, goals and objectives of such activities, an evaluation of the need for additional source control and/or structural BMPs, any proposed pilot studies, etc.;

    b. Changes in land use and/or population including map updates; and

    c. Any significant changes to the storm drain systems, outfalls, detention or retention basins or dams, and other controls including map updates of the storm drain systems.

    d. To incorporate new or revised program elements and compliance schedule(s) necessary to comply with Section IV of this order.

30. This Order may be modified, revoked or reissued prior to its expiration date for the following reasons:

    a. To address significant changes in conditions identified in the technical reports required by the Regional Board which were unknown at the time of the issuance of this order;

    b. To incorporate applicable requirements of statewide water quality control plans adopted by the State Water Resources Control Board or any amendments to the Basin Plan approved by the Regional Board, the State Board, and, if necessary, by the Office of Administrative Law; or

    c. To comply with any applicable requirements, guidelines, or regulations issued or approved under the Clean Water Act, if the requirements, guidelines, or regulations contain different conditions or additional requirements than those included in this order.

31. This order shall serve as a National Pollutant Discharge Elimination System (NPDES) Permit pursuant to Section 402 (p) of the Clean Water Act, or amendments thereto, and shall become effective ten days after the date of its adoption provided the Regional Administrator of the U. S. EPA has no objections. If the Regional Administrator objects to its issuance, the permit shall not become effective until such objection is withdrawn.

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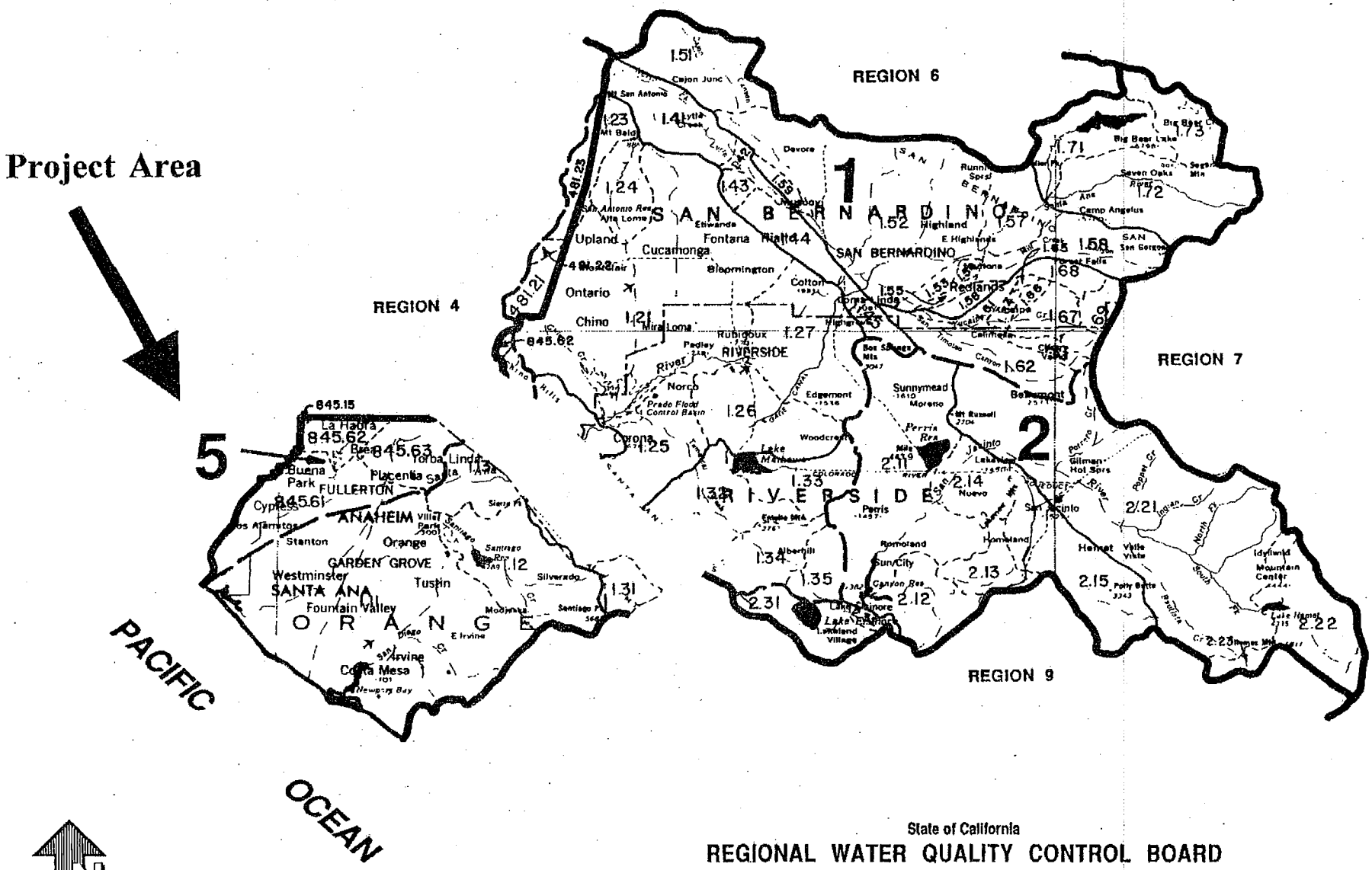
32. Order No. 90-71 is hereby rescinded.

I, Gerard Thibeault, Executive Officer, do hereby certify that the foregoing is a full, true, and correct copy of an order adopted by the California Regional Water Quality Control Board, Santa Ana Region, on March 8, 1996.

Gerard J. Thibeault
Executive Officer



April 1973
Revised: July 1976
Revised: August 1986

State of California
REGIONAL WATER QUALITY CONTROL BOARD

Santa Ana Region (8)

SANTA ANA HYDROLOGIC BASIN PLANNING AREA (SA)

Scale in miles
8 0 8 16 24 32
Scale 1:500,000

RBSA_370958

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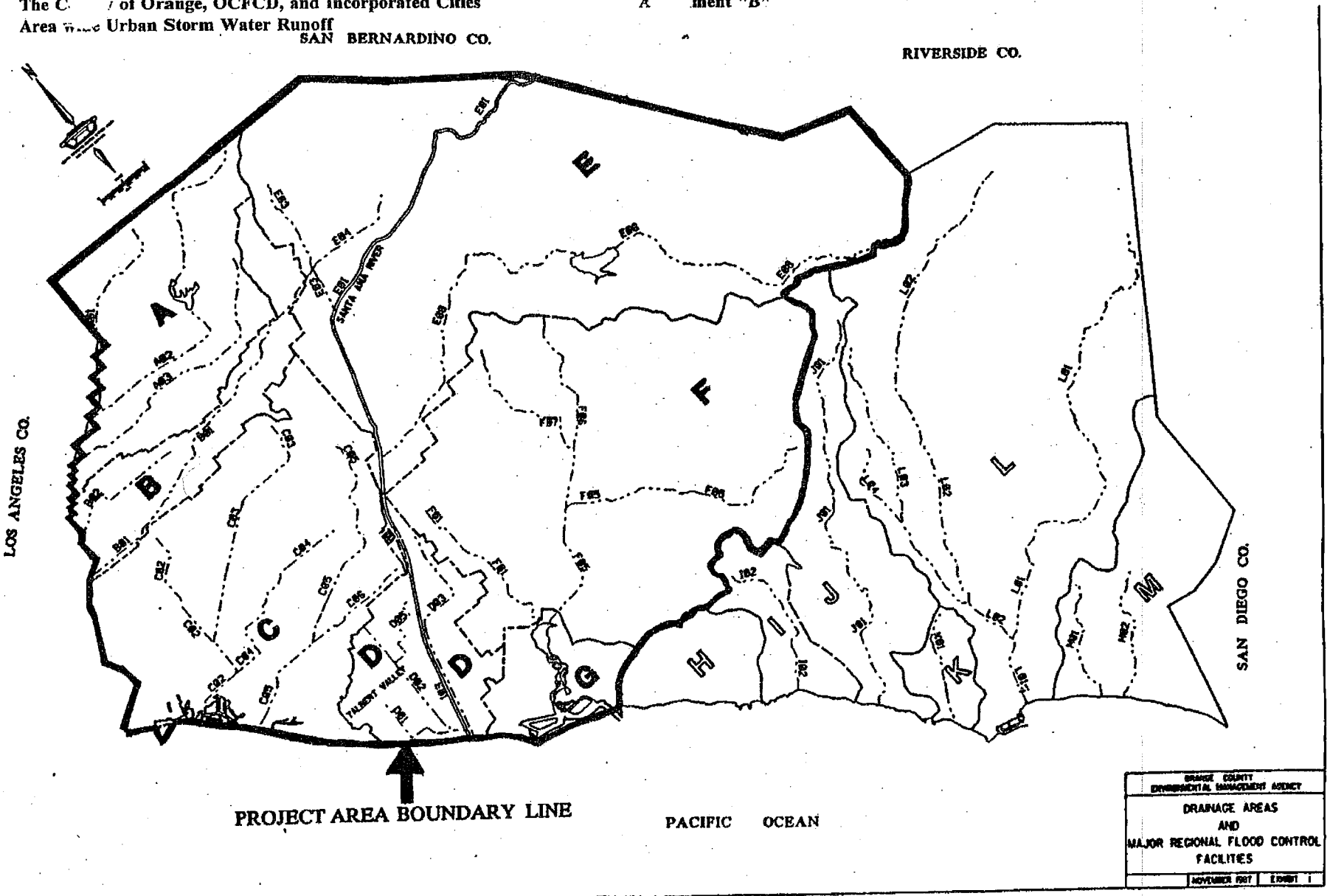

LEGEND

A,B - San Gabriel River Drainage Area
C - Huntington Harbour & Bolsa Bay Drainage Area
D - Greenville-Banning Channel Drainage Area
E - Santa Ana River Drainage Area
F,G - Newport Bay Drainage Area

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SARB_00317

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Order No. 96-31
Attachment "C"

LIST OF OTHER ENTITIES WITH THE POTENTIAL TO DISCHARGE POLLUTANTS TO THE ORANGE COUNTY STORM WATER SYSTEM

California Department of Transportation (Caltrans), District 12
Southern Pacific Railroad
Atchison, Topeka & Santa Fe Railway Company
Seal Beach Naval Weapons Station
Seal Beach Naval Reserve Center, Los Alamitos
U. S. Marine Corps Air Station, El Toro
National Forest Service

Universities and Colleges

University of California, Irvine
California State University, Fullerton
Chapman College
Coastline College
Cypress College
Fullerton College
Irvine Valley College
Golden West College
Orange Coast College
Rancho Santiago College

School Districts

Anaheim Elementary School District
Anaheim Union High School District
Brea-Olinda Unified School District
Buena Park Joint Union High School District
Centralia Elementary School District
Cypress Elementary School District
Fountain Valley Union High School District
Fullerton Joint Union High School District
Garden Grove Unified School District
Huntington Beach Elementary School District
Huntington Beach Union High School District
Irvine Unified Union High School District
La Habra Joint Union High School District
Los Alamitos Unified School District
Lowell Joint Union High School District
Magnolia Elementary School District
Newport-Mesa Unified School District
Ocean View Union High School District
Orange Unified School District

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Order No. 96-31
Attachment "C" (cont'd)

Placentia Unified School District
Santa Ana Unified School District
Savanna Union High School District
Tustin Unified School District
Westminster Union High School District
Yorba Linda Joint Union High School District

Hospitals

Anaheim General Hospital
Brea Community Hospital
Chapman General Hospital
Children's Hospital of Orange County, Orange
Coastal Communities Hospital, Santa Ana
Fairview Hospital
FHP Hospital, Fountain Valley
Fountain Valley Regional Hospital and Medical Center
Hoag Hospital, Newport Beach
Kaiser Foundation Hospital, Anaheim
Orange County Community Hospital, Buena Park
Pacifica Community Hospital, Huntington Beach
Placentia Linda Community Hospital
Santa Ana Hospital and Medical Center
St. Joseph's Hospital, Orange
U.C. Irvine Medical Center
Vencor Hospital of Orange County, Westminster
Whittier Hospital and Medical Center, Buena Park

Water/Wastewater Agencies

Santa Ana Watershed Project Authority
Irvine Ranch Water District
Los Aliso Water District
El Toro Water District
San Bernardino County Flood Control District
Riverside County Flood Control & Water Conservation District
L.A. County Department of Public Works
County Sanitation Districts of Orange County
Orange County Water District
Metropolitan Water District

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California Regional Water Quality Control Board
Santa Ana Region

Monitoring and Reporting Program No. 96-31
NPDES No. CAS618030

for
the County of Orange, Orange County Flood Control District,
and
Incorporated Cities of Orange County Within the Santa Ana Region
Areawide Urban Storm Water Run-off

I. GENERAL

1. Revisions of the monitoring and reporting program are appropriate to ensure that the permittees are in compliance with requirements and provisions contained in this order. Revisions may be made under the direction of the Executive Officer at any time during the term, and my include a reduction or increase in the number of parameters to be monitored, the frequency of monitoring, or the number and size of samples collected.

2. The Executive Officer is authorized to allow the permittees to participate in statewide, national, or other monitoring programs in lieu of this monitoring program.

3. All sample collection, handling, storage, and analysis shall be in accordance with 40 CFR Part 136 or other methods approved by the Executive Officer.

4. The permittees are authorized to complement their monitoring data with other monitoring sources provided the monitoring conditions and sources are similar to those in the Santa Ana Watershed.

5. The permittees shall implement the Orange County Water Quality Monitoring Program (submitted as part of the permit application) until development and implementation of other acceptable monitoring programs.

II. OBJECTIVES

The overall goal of this monitoring program is to develop and support an effective watershed management program. The following are the major objectives:

1. To develop and support an effective municipal non-point source control program.

2. To define water quality status, trends, and pollutants of concern associated with municipal storm water discharges.

3. To characterize pollutants associated with municipal storm water discharges and to assess the influence of urban land uses on water quality and the beneficial uses of receiving waters.

4. To identify significant water quality problems related to urban storm water discharges.

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SARB_000314

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5. To identify other sources of pollutants in storm water run-off to the maximum extent possible (e.g., atmospheric deposition, contaminated sediments, other non-point sources, etc.).

6. To identify and prohibit illicit discharges.

7. To identify those waters, which without additional action to control pollution from urban storm water discharges cannot reasonably be expected to attain or maintain applicable water quality standards required to sustain the beneficial uses in the Basin Plan.

8. To evaluate the effectiveness of existing municipal storm water quality management programs, including an estimate of pollutant reductions achieved by the structural and nonstructural BMPs implemented by the permittees.

9. To evaluate costs and benefits of proposed municipal storm water quality control programs to the stakeholders including the public.

The Regional Board recognizes that these objectives may not be attainable during this permit period and authorizes the Executive Officer to evaluate and to determine adequate progress toward meeting each objective.

III. MONITORING PROGRAM REQUIREMENTS

The permittees shall develop and submit for approval of the Executive Officer an integrated watershed monitoring program geared towards achieving the above stated goals. This program may be developed in cooperation with the permittees from the San Bernardino and Riverside counties. The Executive Officer or his/her designated representative(s) shall facilitate the coordination meetings or subcommittees formed to achieve this goal. The development and implementation of the monitoring program shall be in accordance with the time schedules prescribed by the Executive Officer. At a minimum, the program shall include the following:

1. Uniform guidelines for quality control, quality assurance, data collection and data analysis.

2. A mechanism for the collection, analysis and interpretation of existing data from local, regional or national monitoring programs. These data sources may be utilized to characterize different storm water sources; to determine pollutant generation, transport and fate; to develop a relationship between land use, development size, storm size and the event mean concentration of pollutants; to determine spatial and temporal variances in storm water quality and seasonal and other bias in the collected data; and to identify any unique features of the Santa Ana Watershed. The permittees are encouraged to use data from similar studies, if available.

3. A description of the monitoring program including:

   a. The number of monitoring stations;

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b. Monitoring locations within flood control channels, bays and estuaries, coastal areas, major outfalls, and other receiving waters;

c. Environmental indicators (e.g., ecosystem, biological, habitat, chemical, sediment, stream health, etc.) chosen for monitoring;

d. Parameters selected for field screening and for laboratory work; and

e. Total number of samples to be collected from each station, frequency of sampling during wet and dry weather, short duration or long duration storm events, type of samples (grab, 24-hour composite, etc.), and the type of sampling equipment.

4. A mechanism for analyzing the collected data and interpreting the results including an evaluation of the effectiveness of the management practices, and need for any refinement of the management practices.

5. A description of the responsibilities of all the participants in this program including cost sharing.

IV. REPORTING

1. All progress reports and proposed strategies and plans required by this order shall be signed by the principal permittee and copies shall be submitted to the Executive Officer of the Regional Board under penalty of perjury.

2. The permittees shall submit an **ANNUAL PROGRESS REPORT** to the Executive Officer of the Regional Board and to the Regional Administrator of the U.S. EPA, Region 9, no later than November 15th, of each year. This progress report may be submitted in a mutually agreeable electronic format. At a minimum, annual progress report shall include the following:

a. A review of the status of program implementation and compliance (or non-compliance) with the schedules contained in this order;

b. An assessment of the effectiveness of control measures established under the illicit discharge elimination program and the Drainage Area Management Plan. The effectiveness may be measured in terms of how successful the program has been in eliminating illicit/illegal discharges and reducing pollutant loads in storm water discharges;

c. An assessment of any storm water management program modifications made to comply with Clean Water Act requirements to reduce the discharge of pollutants to the maximum extent practicable;

d. A summary and analysis of monitoring results from the previous year and any changes to the monitoring program for the following year;

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e. A fiscal analysis progress report as described in Section V., Provision, 25., of this order;

f. A draft workplan which describes the proposed implementation of the DAMP for next fiscal year. The workplan shall include clearly defined tasks, responsibilities, and schedules for implementation of the storm water program and each permittee's actions for the next fiscal year; and

g. Major changes in any previously submitted plan/policies.

3. The permittees shall be responsible for the submittal of all required information/materials needed to comply with this order in a timely manner to the principal permittee. All such submittals shall be signed by a duly authorized representative of the permittee under penalty of perjury.

V. REPORTING SCHEDULE

All reports required by this order shall be submitted to the Executive Officer of the Regional Board in accordance with the following schedule:

ITEM	DUE DATE
Report on Illicit/Illegal Discharges & Storm Water Program Implementation Agreement	February 28, 1997
Legal Authority & Enforcement Strategy Certification	July 31, 1997
Environmental Performance Report	July 31, 1997
New Development BMP Certification	November 15, 1996
Proposed Monitoring Program	July 31, 1997
Annual Report/Fiscal Analysis	November 15th of each year

Ordered by _____
Gerard J. Thibeault
Executive Officer
March 8, 1996

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California Regional Water Quality Control Board
Santa Ana Region
2010 Iowa Avenue, Suite 100
Riverside, CA 92507-2409

FACT SHEET

March 8, 1996

ITEM: 12

SUBJECT: Waste Discharge Requirements for the County of Orange, Orange County Flood Control District, and the Incorporated Cities of Orange County within the Santa Ana Region, Storm Water Runoff Management Program, Orange County, Order No. 96-31 (NPDES No. CAS 618030)

PROJECT

The attached pages contain information concerning an application for renewal of waste discharge requirements and a National Pollutant Discharge Elimination System (NPDES) permit, which prescribes waste discharge requirements for urban storm water runoff from the cities and the unincorporated areas in Orange County within the jurisdiction of the Santa Ana Regional Board. On December 30, 1994, the County of Orange and the Orange County Flood Control District (OCFCD), in cooperation with the cities of Anaheim, Brea, Buena Park, Costa Mesa, Cypress, Fountain Valley, Fullerton, Garden Grove, Huntington Beach, Irvine, La Habra, La Palma, Lake Forest, Los Alamitos, Newport Beach, Orange, Placentia, Santa Ana, Seal Beach, Stanton, Tustin, Villa Park, Westminster, and Yorba Linda (hereinafter collectively referred to as permittees), submitted National Pollutant Discharge Elimination System (NPDES) Application No. CAS 618030 (Report of Waste Discharge) for reissuance of their areawide storm water NPDES permit. The permit application was submitted in accordance with the previous NPDES permit (Order No. 90-71, NPDES No. CA 8000180) which expired on July 1, 1995. Additionally, the permit application follows guidance provided by staff of the State Water Resources Control Board (State Board) and the Regional Water Quality Control Boards (Regional Boards).

CLEAN WATER ACT REQUIREMENTS

The 1987 amendments to the Clean Water act (CWA) required municipal separate storm drain systems and industrial facilities to obtain NPDES permits for storm water runoff from their facilities. On November 16, 1990, the United States Environmental Protection Agency (EPA) promulgated the final storm water regulations. Prior to EPA's promulgation of the final storm water regulations, the counties of Orange, Riverside and San Bernardino requested for areawide NPDES permits for storm water runoff. On July 13, 1990, the Regional Board issued Order No. 90-71 to the permittees. This areawide NPDES permit is being considered for renewal by the Regional Board in accordance with Section 402 (p) of the CWA and all requirements applicable to an NPDES permit issued under the issuing authority's discretionary authority. The storm water regulations are contained in 40 CFR Parts 122, 123 and 124.

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CARB_000318

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PROJECT AREA

The permitted area is delineated by the Los Angeles County-Orange County Boundary line on the northwest, the San Bernardino-Orange County boundary line on the north and northeast, the Riverside County-Orange County boundary line on the east, the Santa Ana Regional Board-San Diego Regional Board boundary line on the southeast, and the Pacific Ocean on the southwest (see Attachment A of the order). The permittees serve a population of approximately 2.6 million, occupying an area of approximately 511 square miles (including both unincorporated areas and the limits of 31 cities). The permittees have jurisdiction over and /or maintenance responsibility for storm water conveyance systems within Orange County. The County's systems include an estimated 400 miles of storm drain systems. A major portion of the urbanized areas of Orange County drains into water bodies within this Regional Board's jurisdiction. Storm water discharges from urbanized areas consist mainly of surface runoff from residential, commercial, and industrial developments. In addition, there are storm water discharges from agricultural land uses, including farming and animal operations. However, the CWA specifically excludes agricultural discharges from regulation under this program. Other areas of the County not addressed or which are excluded by the storm water regulations and areas not under the jurisdiction of the permittees are excluded from the area requested for coverage under this permit application. This includes the following areas and activities:

- Federal lands and state properties, including, but not limited to, military bases, national forests, hospitals, schools, colleges, universities, and highways;
- Native American tribal lands; and
- Utilities and special district properties.

WATERSHED MANAGEMENT

To efficiently manage the water resources of the Region, it is critical to have a holistic approach. The entire storm drain system in Orange County is not controlled by a single entity; the County of Orange, the OCFCD, several cities, Caltrans, U.S. Army Corps of Engineers and a number of other entities own, operate and/or manage the storm drain systems. In addition to the cities, the County and the OCFCD, there are a number of other significant contributors of storm water runoff to these storm drain systems. These include: large institutions such as the State University facilities, schools, hospitals, etc.; federal facilities such as Department of Defense facilities; State agencies such as Caltrans, water and wastewater management agencies such as Orange County Water District, Metropolitan Water District etc.; the National Forest Service; state parks; and entertainment centers such as Disneyland. The quality and quantity of storm water runoff into and out of Orange County also depends upon runoff from San Bernardino and Riverside County areas which are tributary to Orange County. Some of the runoff from Orange county enters systems controlled by other entities, such as the Los Angeles County Flood Control District, which is under the Los Angeles Regional Board's jurisdiction.

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Some of these facilities such as U.S. Marine Corps, Tustin and El Toro Air Stations, Disneyland and Caltrans are already under individual permits for storm water runoff. The Los Angeles and San Diego Regional Boards have also issued areawide storm water permits for areas within their jurisdiction.

Cooperation and coordination among all the stakeholders are essential for efficient and economical management of the watershed. Regional Board staff will facilitate coordination of monitoring and management programs among the various stakeholders.

EXISTING PROGRAMS AND FUTURE DIRECTION

As required under Order No. 90-71, the permittees developed a Drainage Area Management Plan (DAMP) which was approved by the Executive Officer of the Regional Board on April 29, 1994. The DAMP includes a number of best management practices and a very extensive public education program. The monitoring program includes 89 monitoring stations within streams and flood control channels and 21 stations within the bays, estuaries and the ocean. The findings and conclusions from these monitoring stations and monitoring programs of other municipal permittees (Riverside and San Bernardino Counties) may be used to identify problem areas and to evaluate the effectiveness of the DAMPs. The future direction of some of these program elements will depend upon the results of the ongoing studies and holistic approach to watershed management.

Other elements of the storm water management program include identification and elimination of illegal/illicit discharges and establishment of adequate legal authority to control pollutants in storm water discharges. Most of the cities and the County of Orange have completed a survey of their storm drain systems to identify illegal/illicit connections and have adopted appropriate ordinances to establish legal authority. The remaining permittees are in the process of complying with these requirements.

It appears that coordination among the municipal permittees in Orange, Riverside and San Bernardino Counties and a watershed approach to managing storm water are the essential factors in mapping the future course of the storm water program.

BENEFICIAL USES

Storm water flows which are discharged to municipal storm drain systems in Orange County are tributary to various water bodies (inland surface streams, bays and tidal prisms, ocean waters, and lakes and reservoirs) of the state. The beneficial uses of these water bodies include municipal and domestic supply, agricultural supply, industrial service supply, groundwater recharge, navigation, hydropower generation, water contact recreation, non-contact water recreation, commercial and sportfishing, warm freshwater habitat, cold freshwater habitat, preservation of biological habitats of special significance, wildlife habitat, preservation of rare, threatened or endangered species, marine habitat, shellfish harvesting, spawning, reproduction and development of aquatic habitats, and estuarine habitat. The ultimate goal of this storm water management program is to protect the beneficial uses of the receiving waters.

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ANTIDEGRADATION ANALYSIS

The Regional Board has considered whether a complete antidegradation analysis, pursuant to 40 CFR 131.12 and State Board Resolution No. 68-16, is required for these storm water discharges. The Regional Board finds that the pollutant loading rates to the receiving waters will be reduced with the implementation of the requirements in this order. As a result, the quality of storm water discharges and receiving waters will be improved, thereby protecting the beneficial uses of waters of the United States. This is consistent with the federal and state antidegradation requirements and a complete antidegradation analysis is not necessary.

PUBLIC WORKSHOP

The Regional Board recognizes the significance of Orange County's Storm Water/Urban Runoff Management Program and will conduct, participate, and/or assist with any workshop during the term of this permit to promote and discuss the progress of the storm water management program. The details of the workshop will be published in local newspapers and mailed to interested parties. Persons wishing to be included in the mailing list for any of the items related to this permit may register their name, mailing address and phone number with the Regional Board office at the address given below.

PUBLIC HEARING

The Regional Board will hold a public hearing regarding the proposed waste discharge requirements. The public hearing is scheduled to be held on Friday, March 8, 1996 at 9:30 a.m. at the Newport Beach City Council Chambers, 3300 Newport Boulevard, Newport Beach, CA. Further information regarding the conduct and nature of the public hearing concerning these waste discharge requirements may be obtained by writing or visiting the Santa Ana Regional Board office, 3737 Main Street, Suite 500, Riverside, CA 92501-3339.

INFORMATION AND COPYING

Persons wishing further information may write to the above address or call Laurie Taul at (909) 782-4906. Copies of the application, proposed waste discharge requirements, and other documents (other than those which the Executive Officer maintains as confidential) are available at the Regional Board office for inspection and copying by appointment scheduled between the hours of 10:00 a.m. and 4:00 p.m., Monday through Thursday (excluding holidays).

REGISTER OF INTERESTED PERSONS

Any person interested in a particular application or group for applications may leave his name, address and phone number as part of the file for an application. Copies of tentative waste discharge requirements will be mailed to all interested parties.

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RECOMMENDATION

Adopt Order 96-31, NPDES No. CAS 618030, as presented.

In addition to the permittees, comments were solicited from the following agencies and/or persons:

U. S. Environmental Protection Agency - Robert Wills / Eugene Bromley, Pretreatment, Sludge, and Storm Water Section
U.S. Army District, Los Angeles, Corps of Engineers - Permits Section
NOAA, National Marine Fisheries Service
U.S. Fish and Wildlife Service - Carlsbad
State Water Resources Control Board - Ted Cobb, Office of the Chief Counsel
State Water Resources Control Board - Archie Matthews / Bruce Fujimoto, Division of Water Quality
State Department of Water Resources - Glendale
California Regional Water Quality Control Board, North Coast Region (1) - Nathan Quarles
California Regional Water Quality Control Board, San Francisco Bay Region (2) - Tom Mumley
California Regional Water Quality Control Board, Central Coast Region (3) - Adam White
California Regional Water Quality Control Board, Los Angeles Region (4) - Mark Pumford
California Regional Water Quality Control Board, Central Valley Region (5) - Wayne Pierson / Pamela Barksdale
California Regional Water Quality Control Board, Central Valley Region (5R), Redding - Carole Crowe
California Regional Water Quality Control Board, Central Valley Region (5F), Fresno - Darrel Everson
California Regional Water Quality Control Board, Lahontan Region (6SLT), South Lake Tahoe - John Short
California Regional Water Quality Control Board, Lahontan Region (6V), Victorville - Tom Rheiner
California Regional Water Quality Control Board, Colorado River Basin Region (7) - Orlando Gonzales
California Regional Water Quality Control Board, San Diego Region (9) - Deborah Jayne
State Department of Fish and Game - Long Beach
State Department of Health Services - Santa Ana
State Department of Parks and Recreation - Henry R. Agonia
Orange County Health Care Agency - Robert Merryman
South Coast Air Quality Management District, Diamond Bar - James Lents
Caltrans, District 12, Santa Ana - Praveen Gupta
Southern Pacific Railroad
Atchison, Topeka & Santa Fe Railway Company
Seal Beach Naval Weapons Station
Seal Beach Naval Reserve Center, Los Alamitos
U. S. Marine Corps Air Station, El Toro - Lt. Col. Bevis
National Forest Service

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Uribe And Associates - Pete Uribe
Bill Dendy & Associates - Bill Dendy
Woodward-Clyde - Bob Collacott
The Irvine Company - Sat Tamaribuchi
Building Industry Association - Governmental Affairs Council
Southern California Association of Governments, Los Angeles - Tabi Hiwot

Universities and Colleges (Chancellor)
University of California, Irvine
California State University, Fullerton
Chapman College
Coastline College
Cypress College
Fullerton College
Irvine Valley College
Golden West College
Orange Coast College
Rancho Santiago College

School Districts (Superintendent)
Anaheim Elementary School District
Anaheim Union High School District
Brea-Olinda Unified School District
Buena Park Joint Union High School District
Centralia Elementary School District
Cypress Elementary School District
Fountain Valley Union High School District
Fullerton Elementary School District
Fullerton Joint Union High School District
Garden Grove Unified School District
Huntington Beach Elementary School District
Huntington Beach Union High School District
Irvine Unified Union High School District
La Habra Joint Union High School District
Los Alamitos Unified School District
Lowell Joint Union High School District
Magnolia Elementary School District
Newport-Mesa Unified School District
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Santa Ana Unified School District
Savanna Union High School District
Tustin Unified School District
Westminster Union High School District
Yorba Linda Joint Union High School District

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Hospitals (Administrator)
Anaheim General Hospital
Brea Community Hospital
Chapman General Hospital, Orange
Children's Hospital of Orange County. Orange
Coastal Communities Hospital, Santa Ana
Fairview Hospital
FHP Hospital, Fountain Valley
Fountain Valley Regional Hospital and Medical Center
Hoag Hospital, Newport Beach
Kaiser Foundation Hospital, Anaheim
Orange County Community Hospital, Buena Park
Pacifica Community Hospital, Huntington Beach
Placentia Linda Community Hospital
Santa Ana Hospital and Medical Center
St. Joseph's Hospital, Orange
U.C. Irvine Medical Center
Vencor Hospital of Orange County, Westminster
Whittier Hospital and Medical Center, Buena Park

Environmental Organizations
Sierra Club, Orange County Chapter
Sierra Club, Los Angeles Chapter - Dick Hingson
Natural Resources Defense Council (NRDC)
Cousteau Society
Amigos De Bolsa Chica
Audobon Sea & Sage Chapter
Huntington Beach Wetlands Conservancy
Surfrider Foundation

Newspapers
Orange County Register
Los Angeles Times
Press Enterprise

Major Water/Wastewater Agencies
Santa Ana Watershed Project Authority - Neil Cline
Irvine Ranch Water District - General Manager
Los Alisos Water District - General Manager
El Toro Water District - General Manager
San Bernardino County Flood Control District - Naresh Varma
Riverside County Flood Control & Water Conservation District - Jason Christie
L.A. County Department of Public Works - Gary Hildebrand
County Sanitation Districts of Orange County - Blake Anderson
Orange County Water District - Bill Mills
Metropolitan Water District - Ed Means

AN EPIDEMIOLOGICAL STUDY OF POSSIBLE ADVERSE HEALTH EFFECTS OF SWIMMING IN SANTA MONICA BAY

Final Report

May 7, 1996

Santa Monica BAY Restoration PROJECT

101 Centre Plaza Drive
Monterey Park, CA 91754
213 266 7516
Fax 213 266 7600

A Partnership To
Restore And Protect
Santa Monica Bay

Funded by US EPA
and the State Water Resources
Control Board in cooperation
with the public, local agencies,
and industry.

A Health Effects Study of Swimmers in Santa Monica Bay[1]

Summary

In the summer of 1995, the Santa Monica Bay Restoration Project (SMBRP) conducted the first large-scale epidemiologic study in the nation to investigate possible adverse health effects associated with swimming in ocean waters contaminated by urban runoff. The overall objective of this study was to answer the public's most frequently asked question, *"How safe is it to swim in Santa Monica Bay?"* by investigating swimmers' reports of illness and determining whether the risks of contracting these illnesses were associated with exposure to pathogens in urban runoff.

BACKGROUND

Since the genesis of the Santa Monica Bay Restoration Project (SMBRP), a primary focus of energy has been to find the answer to a fundamental human health question: *"How safe is it to swim in Santa Monica Bay?"* Nearly fifty million tourists and local residents come to Santa Monica Bay's public beaches each year to enjoy its recreational resources, but there has been wide public perception and some scientific evidence that there may be health risks associated with swimming in beach areas contaminated by runoff.

In previous investigations conducted by the SMBRP, human pathogens were detected in summer runoff, an unexpected result since sewer and storm drain systems in Los Angeles are completely separate. Possible sources of pathogen contamination into the storm drain system include illegal sewer connections, leaking sewer lines, malfunctioning septic systems, illegal dumping from recreational vehicles, or direct human sources such as campers or transients. Other potential sources of human pathogens in near shore areas include sewage spills into storm drains, small boat waste discharges and swimmers themselves.

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[1] "An Epidemiological Study of Possible Adverse Health Effects of Swimming in Santa Monica Bay."

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The members of the SMBRP therefore decided that the definitive step necessary to answer this question of swimming-related health risks was an epidemiological study. Through this study, we would finally know if risks exist and whether they differ according to where one swims, and we would have the basis for revising recreational water quality standards and monitoring programs so that they are based on risks to human health.

STUDY OVERVIEW

During the course of the study (June to September 1995), 15,492 beachgoers who swam at three Santa Monica Bay beaches located near flowing storm drain outlets (Santa Monica Beach near Ashland Avenue, Will Rogers Beach at Santa Monica Canyon, and Surfrider Beach near Malibu Creek), were interviewed. Nine to 14 days after the beach interviews, 13,278 follow-up telephone interviews were conducted to ascertain the occurrence of symptoms--fever, chills, eye discharge, earache, ear discharge, skin rash, infected cut, nausea, vomiting, diarrhea, diarrhea with blood, stomach pain, coughing, coughing with phlegm, nasal congestion, sore throat and a group of symptoms indicative of "highly credible gastrointestinal illness" (HCGI)[2] and "significant respiratory disease" (SRD)[3].

Water samples were collected daily in ankle depth water at various distances from the drains (0, 100 yards north and south, and at 400 yards) (Figure 1) and analyzed for total and

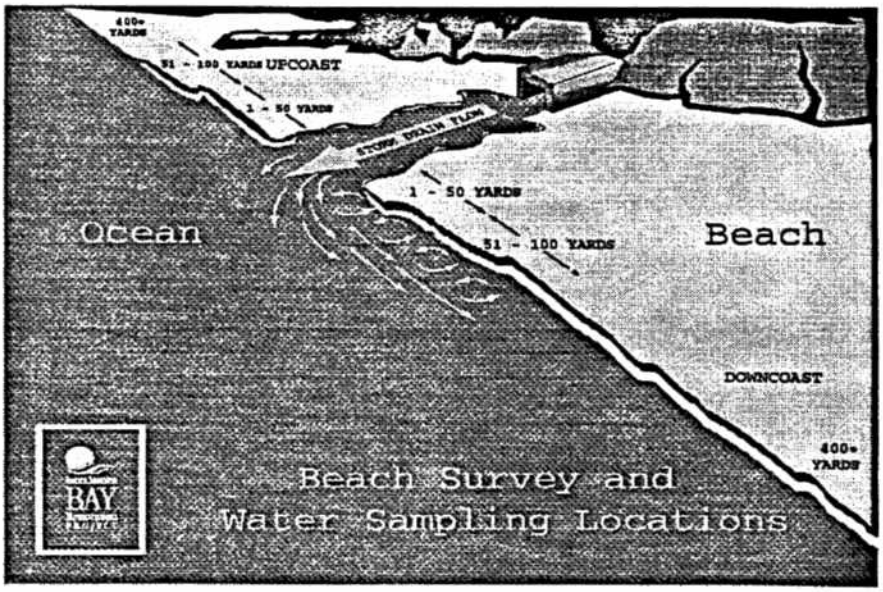

Figure 1. Beach survey and water sampling locations.

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[2] Two definitions of HCGI were used in this study and grouped as HCGI-1 (vomiting, diarrhea and fever, stomach pain and fever) or HCGI-2 (vomiting and fever).

[3] Symptoms including fever and nasal congestion, fever and sore throat, and cough with sputum.

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fecal coliforms, enterococci, and *E. coli*. In addition, water samples were collected at storm drain sites every Friday, Saturday and Sunday and analyzed for enteric viruses.

SUMMARY OF FINDINGS

The analyses conducted in this study addressed two questions: a) What are the risks of illness relative to the distance one swims from a flowing storm drain?; and b) Are the risks of illness associated with measures of water quality? The major findings resulting from these analyses are as follows:

1. **There is an increased risk of illness associated with swimming near flowing storm drain outlets in Santa Monica Bay.** Statistically significant increases in risks for a broad range of adverse health effects (fever, chills, ear discharge, vomiting, coughing with phlegm, HCGI-2[4] and SRD) were found for subjects that swam in front of storm drains (at 0 yards) in comparison to those who swam over 400 yards away[5] (Table 1). For example, there was a 57 percent greater incidence of fever for swimmers at the drain than at 400 yards away. These increases in risk appeared to be limited to the 0 yards distance, as a significant drop-off in effects were observed at other distances upcoast or downcoast from the drain (Figure 2).

Table 1. Comparative health outcomes for swimming in front of drains versus 400+ yards away.

Health Outcome	Relative Risk (0 vs. 400+ Yds.)	Estimated No. of Excess Cases per 10,000 Persons
Fever	57%	259
Chills	58%	138
Ear Discharge	127%	88
Vomiting	61%	115
Coughing with phlegm	59%	175
Any of the above symptoms	44%	373
HCGI-2	111%	95
SRD	66%	303
HCGI-2 or SRD	53%	314

[4] See footnote 2.

[5] Indicator bacteria levels at 400 yards are low, therefore comparisons could be made between rates of illness in swimmers at this distance and at 0 yards.

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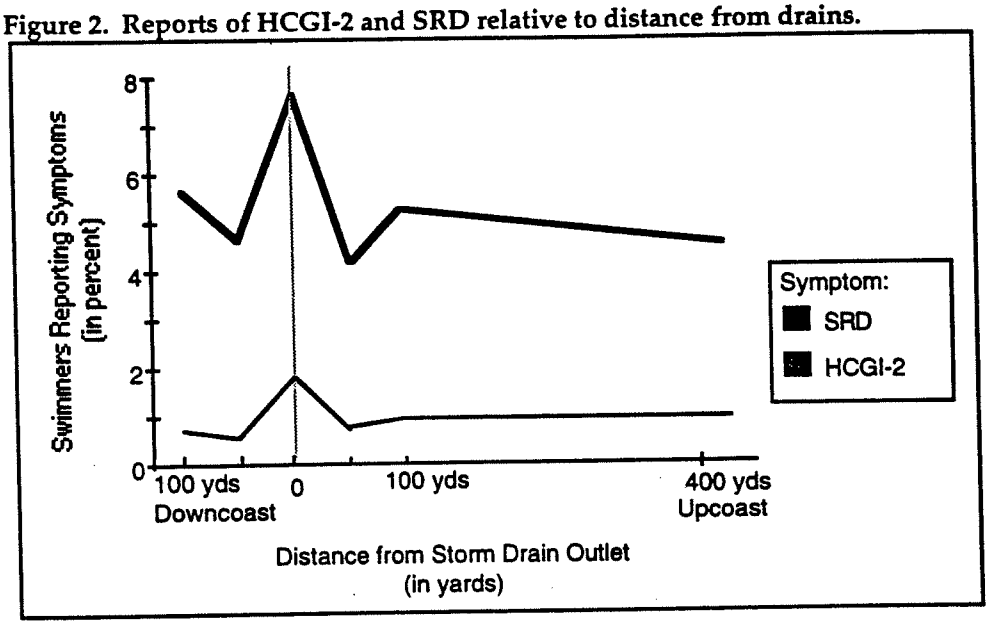
The estimated number of excess cases of illness attributable to swimming at the drain reached into the 100's per 10,000 exposed subjects (greater than 1 percent) suggesting that significant numbers of beachgoers swimming near storm drain outlets are subject to increased health risks.

Figure 2. Reports of HCGI-2 and SRD relative to distance from drains.



The results did not change when adjusted for age, beach, gender, race, California versus out-of-state resident, socioeconomic status, or worry about potential health hazards at the beach. Distance results also did not change substantially when controlled for each bacterial indicator.

2. **There is an increased risk of illness associated with swimming in areas with high densities of bacterial indicators.** Researchers used "cutoff points" to determine whether there were differences in the incidence of illness for those who swam in waters with bacterial densities "greater than" versus "less than" certain cutoff levels. Symptoms were found to be associated with swimming in areas where bacterial indicator counts were "greater than" the cutoff points that are used as part of federal and state water quality standards. (Cutoffs vary by type of bacterial indicator.)

Table 2 shows the various outcomes that were found to be associated with these high densities of indicator bacteria. For *E. coli*, associations were seen for earache and nasal congestion. Only skin rash was associated with total coliforms and fecal coliforms. For enterococci, effects were noted for diarrhea with blood and HCGI-1.

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Table 2. **Health outcomes associated with swimming in areas with high bacterial indicator counts.**

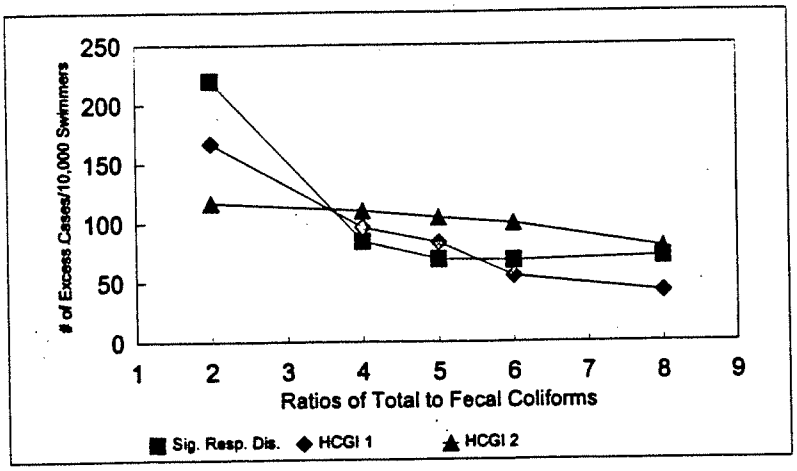
Indicator (cutoff)	Health Outcomes	Increased Risk	Excess Cases per 10,000 Persons
E. coli (> 320 cfu*)	Earache	46%	149
	Nasal Congestion	24%	211
Enterococcus (>106 cfu)	Diarrhea w/ blood	323%	27
	HCGI-1	44%	130
Total coliform (>10,000 cfu)	Skin rash	200%	165
Fecal coliform (>400 cfu)	Skin rash	88%	74

*colony forming units

3. **The total coliform to fecal coliform ratio was found to be one of the better indicators for predicting health risks.** In addition to investigating single bacterial indicators, associations between adverse health effects and the ratio of total to fecal coliforms were investigated. Significant associations were observed, with incidence of illness generally increasing as the ratio of densities of total coliforms to fecal coliforms decreased (Figure 3). When analyses were restricted to times when total coliforms exceeded 1,000 cfu, the strongest effects were generally observed when the ratio of 2:1 was used for comparison.

None of the bacterial results changed when adjusted for age, beach, gender, race, California vs. out-of-state resident, socioeconomic status or worry about potential health hazards at the beach.

Figure 3. Relationship of excess cases of illness and total-to-fecal coliform ratios.



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4. **Illnesses were reported more often on days when the samples were positive for enteric viruses.** Seventeen water samples (taken in the storm drain) were positive for enteric viruses. Although based on small numbers, a comparison of subjects who were swimming within 50 yards of the drain on days when samples were tested for viruses indicates that a number of outcomes were reported more often on days when the samples were positive for viruses versus days when samples were negative. Symptoms for which increased risks were noted include: fever (53 percent increase), vomiting (89 percent increase), HCGI-1 (74 percent increase) and HCGI-2 (126 percent increase). Results remained essentially unchanged when adjusted for covariates or for each bacterial indicator. Research with gene probes is ongoing and will be presented in a future addendum to this report.

5. **High densities of bacterial indicators were measured on a significant number of survey days, particularly in front of drains.** A great deal of day-to-day variability in bacterial indicator counts was recorded, however high bacterial densities in water samples were detected most frequently directly in front of drains (at 0 yards) (see Table 4). High densities of *E. coli*, fecal coliforms, and enterococcus occurred on over 25 percent of survey days. Total coliform levels were exceeded less frequently (8.6 percent of days). Total-to-fecal coliform ratios of less than 5 occurred on 12 percent of survey days.

Table 4. **Percentage of survey days when bacterial indicator cutoff levels were exceeded in Santa Monica Bay.**

Bacterial Indicator (cutoffs)	Percent of Survey Days Bacterial Cutoffs Exceeded			
	Distance from Drain Outlets			
	0 yards	1-100 yards upcoast	1-100 yards downcoast	400+ yards upcoast
E. coli (>320 cfu)	25.0%	3.5%	6.7%	0.6%
Total coliforms (>10,000 cfu)	8.6%	0.4%	0.9%	0.0%
Fecal coliforms (>400 cfu)	29.7%	3.0%	8.6%	0.9%
Enterococcus (>106 cfu)	28.7%	6.0%	9.6%	1.3%
Total/fecal ratio ≤5 (total coliforms>1000 cfu)	12.0%	0.5%	3.9%	0.4%

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High counts were recorded more frequently downcoast (versus upcoast) from storm drain outlets due to the general pattern of water flow along the Bay's shoreline. At 400 yards away, high counts occurred on generally less than one percent of days.

5. **Characteristics of the survey population.** Persons who bathed and immersed their heads in the ocean water were potential subjects for this study. There were no restrictions based on age, sex or race. Persons who had bathed at the study beaches within seven days of the survey date (before and after) were excluded, as were subjects who bathed on multiple days. Since a primary research question was whether the risk of illness was associated with levels of particular indicator organisms in the water, it would have been impossible to link subjects' experiences with specific counts on a given day if they were in the water on numerous days.

   Fifty-five percent of the subjects surveyed were male, 45 percent female. Forty-eight percent of the subjects were children (under 12 years of age); 13-to-25 year-olds comprised 26 percent of the survey population and the remaining 26 percent were aged 26 and over. The ethnicity of the survey population was 45 percent white, 43 percent Latino, 3 percent black, 3 percent Asian, 3 percent multi-ethnic, and 2 percent "other." Children and Latino subjects tended to swim closer to the drain. Sixty-three percent of subjects swimming at the drain were children under 12. Eighty-eight percent of the surveyed subjects were residents of California.

THE EPI STUDY ACTION AGENDA

The results of this health risk investigation provide both good new and cause for concern. *The good news is that, of the Bay's 50-plus mile coastline, less than 2 miles are problematic.* However, the study has also confirmed that there is some risk of illness associated with swimming immediately adjacent to flowing storm drains. Although it is not yet known what specific pathogens cause illness, the study confirms that the bacterial indicators that are being monitored *do help* to predict risk. In addition, a new tool, the total-to-fecal coliform ratio, has been found to be a useful predictor of illness. With the scientific findings now documented through this study, we have laid the foundation to develop new policies and actions that will improve our ability to protect the public's health.

As a first step, the members of the Santa Monica Bay Restoration Project have identified an "Epi Study Action Agenda" to respond to the findings of this study and because of the need to "act now." Some of these actions have already begun, but many more steps are yet to be

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taken. Like the broader issue of urban runoff and storm water pollution, however, prevention and elimination of pathogen contamination in recreational waters requires a long-term, comprehensive approach. There is, however, much that can begin immediately.

Educating and advising the public about the health risks of swimming near storm drain outlets, ensuring that pathogen sources are identified and controlled, and preventing contamination of runoff into the drainage system are among the governmental actions that have been initiated. The general public also has a role to play -- taking action to prevent urban runoff pollution at home, at the work site and at play.

(This "Action Agenda" will be refined and considered for adoption by the SMBRP Watershed Council at its June meeting.)

EDUCATE AND ADVISE THE PUBLIC

1. **Improve warnings to swimmers by posting new signs and flags near flowing storm drains.** The Los Angeles County Department of Health Services (LACDHS) will revise the Beach Regulatory Protocol to ensure that beaches are well posted and/or closed as necessary. These revisions include:

   a. Strengthen the wording on warning signs posted near flowing storm drain outlets to read as follows: "WARNING! STORM DRAIN WATER MAY CAUSE ILLNESS. NO SWIMMING." This warning will be posted in both English and Spanish.

   b. Post warning signs on both sides of all flowing storm drains in Los Angeles County and place crossed flags adjacent to the signs.

   The remaining procedures contained in the Protocol (regarding incidents such as beach closure requirements in cases of sewage spills, etc.) will continue to be implemented as appropriate.

2. **Warn swimmers to stay away from storm drain outlets.** Los Angeles County Lifeguards will advise beachgoers to stay away from areas directly in front of storm drain outlets when swimming.

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3. **Integrate messages about human health risks associated with contaminated urban runoff into storm water education campaigns.**

IMPLEMENT SOURCE CONTROL MEASURES

4. **Prevent and control sources of pathogens to urban runoff.** Controlling pathogen sources is but one part of a comprehensive strategy to address the problem of urban runoff pollution. The Los Angeles County Department of Public Works (LAC-DPW) and the cities in the Santa Monica Bay watershed will therefore continue to implement urban runoff source control measures (including Best Management Practices such as storm drain stenciling, street sweeping, and used oil recycling programs), and where needed, will expand or accelerate these programs.

5. **Divert dry-weather flows from problem storm drains.** The LAC-DPW and cities will continue to work with municipal wastewater agencies and the Los Angeles Regional Water Quality Control Board (LARWQCB) to complete the assessments of projects to divert dry-weather flows from problem storm drains to sewage treatment facilities. Projects that are feasible and cost-effective will be implemented in a timely manner.

6. **Construct a pilot dry-weather flow treatment facility at the Pico-Kenter drain.** The cities of Los Angeles and Santa Monica have been investigating construction of a pilot ozonation facility to treat dry-weather flows from the Pico-Kenter drainage area.

7. **Investigate and correct malfunctioning septic systems.** Cities and the Los Angeles County Department of Health Services will enhance programs to investigate and correct malfunctioning septic systems, especially in the watersheds along the northern Santa Monica Bay coastline;

8. **Maximize the ability to respond to and control sewage spills.** Municipal wastewater treatment facility operators will review sewage spill reporting and response procedures and develop/modify procedures where necessary to block, capture and re-direct spills to storm drains back into the sewer system.

IDENTIFY AND PREVENT PATHOGEN SOURCES

9. **Identify and eliminate illicit connections and illicit discharges to the storm drain system.** The municipal storm water/urban runoff pollution control permit issued by Los Angeles Regional Water Quality Control Board (LARWQCB) requires

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implementation of programs to identify and eliminate illicit connections and discharges to the storm drain system. To accelerate the implementation of these programs, the LAC-DPW will develop a model program which includes standardized storm drain inspection procedures, illicit connection and discharge identification and elimination procedures, and enforcement procedures to terminate illicit connections and discharges.

10. **Investigate adverse impacts of street and sidewalk washing and develop methods to eliminate or minimize impacts.** The City of Los Angeles will, in the next year, investigate the impact of street and sidewalk washing on pathogen loadings to storm drain systems and will develop appropriate Best Management Practices to minimize the adverse impacts.

11. **Develop standardized procedures for locating sources of pathogens.** The LAC-DPW will lead efforts to develop a standardized sanitary survey protocol (procedures) for locating sources of pathogens and based in the results of this study, develop criteria for initiation of a sanitary survey;

INCORPORATE FINDINGS INTO STANDARDS AND MONITORING PROGRAMS

12. **Provide periodic reports to the public on beach water quality.** Shoreline bacterial monitoring programs are currently conducted by the City of Los Angeles, the County Sanitation Districts of Los Angeles County and the Los Angeles County Department of Health Services. These programs currently report individual bacterial indicator counts and it is recommended that the total-to-fecal coliform ratio also be added and incorporated into the regional water quality data base maintained by the LARWQCB. Both the individual indicator counts and total/fecal ratio should be used as the basis for development of periodic reports to the public on beach water quality prepared by the LARWQCB, SMBRP, Heal the Bay or other organizations.

13. **Review and revise recreational water quality standards or criteria.** Recreational use of coastal waters occurs near urbanized regions throughout California and the U.S. Current standards/criteria for bacterial indicators are not based on epidemiological studies of swimmers in marine waters contaminated by urban runoff. Given the results of this study, it is recommended that the U.S. Environmental Protection Agency, the California State Department of Health Services and the State Water

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Resources Control Board review existing recreational water quality standards/criteria for marine waters and revise them as appropriate.

14. **Review water quality data trends in Santa Monica Bay.** The SMBRP will spearhead a team to review existing water quality data utilizing analytical methodologies identified through this study, so that additional results can be incorporated into modifications of the beach warning protocol and water quality monitoring and reporting activities.

15. **Support additional research projects that help answer additional questions about potential health risks.** Examples of such studies may include an assessment of health risks to persons who frequently swim in the Bay (e.g. surfers and lifeguards) or research efforts necessary to improve our ability to more quickly detect human pathogens in urban runoff.

FINANCE SOURCE CONTROL MEASURES

16. **Seek financing at local, state and federal levels for implementation of source control measures.** The members of the SMBRP will investigate financing mechanisms to support implementation of local efforts to control storm water and urban runoff pollution.

ACTIONS THE PUBLIC CAN TAKE

In addition to governmental action, the general public can take steps to help reduce urban runoff pollution. Urban runoff pollution includes bacteria, trash and chemicals which are washed into the storm drain system from streets, neighborhoods, business locations, parking lots, construction sites, etc. This type of pollution is a problem because, unlike the sewer system, which includes treatment plants, the storm drain system carries water and whever else is put into it--without treatment--to our streams and the ocean. Urban runoff pollution can be minimized by following these suggestions:

1. **Practice "good housekeeping " in and around the home.**
   - Clean up after your pet. Dispose of wastes in trash cans.
   - Make sure that septic tanks are properly maintained.
   - Properly dispose of disposable diapers.
   - Use a broom rather than a hose to clean up garden clippings. Deposit leaves and grass clippings in a trash can or start a compost pile.

- Take leftover household hazardous materials to a Countywide Household Hazardous Waste collection event or other local collection program.
- Take used motor oil and antifreeze to a participating gas station or other recycling center.
- Have your car inspected and maintained regularly to reduce leakage of oil, antifreeze and other fluids.
- Recycle reuseable materials.

2. **Practice "good housekeeping" at your worksite and where you play.**
   - Clean up spills of materials such as vehicle fluids, paints and solvents properly.
   - Control runoff and prevent erosion at construction sites.
   - Cover and maintain dumpsters.
   - Properly dispose of kitchen wastes. Wash down floor mats in areas that drain to the sewer system.
   - Compost or haul away manure from horses or other livestock.
   - Use pumpout and dump stations to dispose of sewage from boats and recreational vehicles.

3. **Promote pollution prevention and awareness in your community.**
   - Participate in programs such as storm drain stenciling and Coastal Cleanup Day.
   - Support your municipality by reporting any dumping of inappropriate materials into storm drains (such as oil and antifreeze) to 1-800-303-0003.

STUDY PARTICIPANTS

A unique team was assembled to carry out the various elements of this study. Dr. Robert Haile, USC School of Medicine, Department of Preventive Medicine, served as Principal Investigator. Dr. Haile led the research team that conducted the beach and follow-up telephone interviews and conducted the health risk analyses utilizing water quality and survey data. The City of Los Angeles Environmental Monitoring Division (LA-EMD) analyzed daily water samples for total coliform, fecal coliform and enterococcus. Heal the Bay volunteers collected the daily bacterial indicator samples and their Executive Director, Dr. Mark Gold served as a principal study advisor. The County Sanitation District of Orange County (CSDOC) collected and analyzed water samples for enteric viruses. The University of Southern California, Department of Biology conducted enteric virus analysis utilizing polymerase chain reaction (PCR)/gene probe technique. The Santa Monica Bay Restoration Project and Foundation served as principal project organizer and was responsible for project

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management, coordination of financing and contracts, and for providing technical and policy oversight.

FUNDING FOR THIS STUDY

The financial and human resources for this study were provided by many public and private entities. The Santa Monica Bay Restoration Project and Foundation thanks the following organizations for their support and commitment to this important scientific undertaking: the State Water Resources Control Board, City of Los Angeles, Beach Cities Health District, City of Santa Monica, Los Angeles County Department of Public Works, Los Angeles Regional Water Quality Control Board, Chevron Companies, Las Virgenes Municipal Water District, Milken Families Foundation, Heal the Bay, and the U.S. Environmental Protection Agency.

ABOUT THE SANTA MONICA BAY RESTORATION PROJECT AND FOUNDATION

The Santa Monica Bay Restoration Project (SMBRP) is a coalition of government, environmentalists, scientists, industry and the public charged with finding solutions to the Bay's problems. The SMBRP, established in 1988 as part of the Clean Water Act National Estuary Program, completed a comprehensive "Bay Restoration Plan" in 1994 that outlines a wide range of actions necessary to restore and protect the Bay. Implementing this health effects study was one of the Plan's highest priorities.

The Santa Monica Bay Restoration Foundation is a non-profit, 501(c)(3) community foundation of the SMBRP. The Foundation is an independent fundraising vehicle created to attract research, planning and implementation funds for activities, such as this epidemiological study, that lead to the restoration and enhancement of Santa Monica Bay.

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AN EPIDEMIOLOGICAL STUDY OF POSSIBLE ADVERSE HEALTH EFFECTS OF SWIMMING IN SANTA MONICA BAY

Final Report

Submitted by: Robert W. Haile and, in alphabetical order, James Alamillo, Kevin Barrett, Ron Cressey, John Dermond, Carolyn Ervin, Alice Glasser, Nina Harawa, Patricia Harmon, Janice Harper, Charles McGee, Robert C. Millikan, Mitchell Nides, John S. Witte

May 7, 1996

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GLOSSARY

Bacterial Indicator Counts - one way of estimating the amount of untreated sewage in contaminated water is to test it for bacteria that are commonly found in human waste. The amount of these bacteria found can then "indicate" the amount of contamination even if they themselves are not pathogenic.

Bathing (or swimming) - by bathing, subjects had to immerse their faces in the water; incidental splashing of the face would not qualify as "bathing" for purposes of this study.

"Cabelli-type" -refers to the Victor Cabelli's classic studies comparing health outcomes in swimmers versus non-swimmers while monitoring marine water quality. His studies were sponsored by the Environmental Protection Agency in the late seventies and early eighties.

Cohort - the study group being followed over a defined period of time.

Colony forming units (cfu) - the unit of measure used to evaluate the bacterial indicator counts. It refers to the density of the bacterial colonies grown per 100mL of water sampled.

Confounder - an independent risk for the outcome of interest that is also associated with the exposure of interest so it can distort its apparent effect on disease outcome.

Cytopathic Effect (CPE) - microscopic observations of changes in the morphology and/or growth rate of a cell culture assay system resulting from infection of the cells by virus.

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Downcoast - in this study refers to the area south of the storm drain of interest.

Enteric Viruses - refers to a group of viruses transmitted through human waste. Can cause a variety of adverse health effects.

Enterococcus - (formerly known as Streptococcus faecalis). A bacteria that is part of the normal flora found in human and animal waste. Commonly used as a bacterial indicator.

E. coli - another bacteria normally found in human waste. Is sometimes used as a bacterial indicator.

Fecal Coliforms - a group of bacteria from the intestinal tract of humans, mammals and birds, commonly found in urban run-off. Commonly used as a bacterial indicator of the presence of sewage.

HCGI1 - (highly credible gastroenteritis one) - defined for this study as a person having either 1) vomiting 2) diarrhea and fever 3) stomach pain and fever. This is the standard definition for this symptom complex as defined by the EPA and used by many previous studies.

HCGI 2 - (highly credible gastroenteritis two) - defined for this study as a person having vomiting and fever.

Indicator Counts-refers to bacterial indicator counts as defined above.

Odds Ratio - it approximates the risk ratio in this study. (See Risk Ratio below).

Pathogenic - refers to organisms that cause disease.

PEPS - Population Estimation and Projection System from LA County 1993.

Plaque Forming Unit (PFU) - macroscopic hole(s) in the monolayer of a cell culture assay system resulting from localized lysis of the cells in the monolayer that initially

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began with infection of one cell by an infectious unit of virus. In the PFU assay technique, agar is incorporated into the medium so that cell lysis resulting in release of additional infectious virus restricts the infection of new cells to only the adjacent healthy cells. Multiple cycles results in a hole in the monolayer.

Plume - refers to the quantity and direction the run-off from the storm drain takes when it enters the ocean. Due to ocean currents, it is generally believed that plumes from the storm drains considered in this study usually go downcoast, but this may not always be the case.

RR (Risk Ratio) - a measure of relative effect comparing the symptom risk of exposed subjects to subjects in a different exposure category.

SRD (significant respiratory disease) - in our study defined as a complex of symptoms that include; 1) fever and nasal congestion; 2) fever and sore throat and 3) cough with sputum.

Study Area 1 - defined as the area within 100 yards upcoast and downcoast of the storm drain of interest, the "exposed area".

Study Area 2 - defined as the area 400+ yards upcoast and downcoast of the storm drain of interest, the "control area".

Total Coliforms - bacteria that can originate from soil, plants, human and animal waste. Commonly used as a bacterial indicator.

Total Coliform/Fecal Coliform Ratio - a ratio used by bacteriologists as an additional bacterial indicator. For those wishing to know more, the baseline ratio is derived from the cut-off points of total and fecal coliforms, 1000(total)/200(fecal)=5. When one is

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exposed to sewage contaminated water the fecal coliforms increase thus decreasing the ratio to <5.

Upcoast-refers to the area north of the storm drain of interest.

Water Sampling-In this study refers to taking samples of ocean water in front of the storm drain and at 100 and 400 yards away in order to test for the following indicators, total and fecal coliforms, enterococus, E. coli and enteric viruses.

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participate were then interviewed about basic demographic data and about their bathing, including type of bathing activity (particularly immersion of the head into ocean water). Distance from the storm drain, gender, age, and race of the subject were noted by the interviewer.

On the same days that subjects were recruited, morning water samples were collected at ankle depth at 0, 100 yards north and south of the storm drain, and 400 yards north or south (depending on which area was used as a "control" area). Samples were analyzed for total and fecal coliforms, enterococci, and *E. coli*. In addition, one sample each Friday, Saturday, and Sunday of the study was taken in the storm drain (0 yards) at each study beach and analyzed for enteric viruses.

Nine to fourteen days after the interview date, subjects were interviewed by telephone to ascertain the occurrence(s) of fever, chills, eye discharge, earache, ear discharge, skin rash, infected cut, nausea, vomiting, diarrhea, diarrhea with blood, stomach pain, coughing, coughing with phlegm, nasal congestion, sore throat, and a group of symptoms indicative of highly credible gastrointestinal illness (HCGI) and significant respiratory disease (SRD). Of the 15,492 subjects interviewed on the beach, we were able to contact and interview 13,278 (86% follow-up). Of these 13,278, 1,485 were found to be ineligible because they bathed (and immersed their heads) at a study beach between the day of the beach interview and the telephone follow-up. This left 11,793 eligible subjects who provided data that were analyzed for this study. Of these, 107 were excluded because they reported not immersing their faces in the ocean water, leaving 11,686 subjects for analysis.

Analyses addressed the following two questions: 1) What are the relative risks of specific adverse health outcomes in subjects bathing at 0, 1-50, and 51-100 yards from a storm drain compared to subjects bathing at the same beach, but beyond 400 yards from a storm drain? 2) Are risks of specific outcomes (e.g. highly credible gastrointestinal illness; ear, eye and sinus infections; upper respiratory infections; skin rashes and lesions) among subjects associated with levels of the bacterial indicators (or viruses) mentioned above.

EXECUTIVE SUMMARY

A cohort study was conducted to investigate the possible adverse health effects of bathing in Santa Monica Bay and whether the risks of ill health outcomes were associated with urban runoff from storm drains. Exposures of primary interest were pathogens that produced acute illnesses (for reasons discussed in our original proposal, chronic health effects were not studied).

Three beaches with a wide range of indicator counts and high density of bathers were studied. The beaches were Santa Monica Beach (near the Ashland Avenue storm drain), Will Rogers Beach (Santa Monica Canyon Channel or storm drain) and Surfrider Beach (near Malibu Creek).

Persons who bathed and immersed their heads in the ocean water were potential subjects for this study. There were no restrictions based on age, sex, or race. Persons who had bathed at the study beaches, Mothers' Beach in Marina del Rey or near the Santa Monica Pier within seven days of the study date were excluded, as were subjects who bathed at the study beaches (or Mothers Beach or near the Santa Monica Pier) between the date of the beach interview and the telephone follow-up. Subjects who bathed on multiple days had to be excluded since one of our primary research questions was whether risk of health outcomes was associated with levels of specific indicator organisms on the day a subject entered the water. Given the range of incubation periods for the outcomes of interest and that the counts were quite variable from day to day, it would have been impossible to link subjects' experiences with specific counts on a given day if they were in the water on numerous days. Persons bathing within 100 yards upcoast or downcoast of the storm drain and persons bathing greater than 400 yards beyond a storm drain were targeted for this study.

For this study, 22,085 subjects were interviewed on the beach to ascertain eligibility and willingness to participate. Of these, 17,253 subjects were found to be eligible and able to participate (had a telephone and were able to speak English or Spanish). Of these, 15,492 agreed to participate. Eligible subjects who agreed to

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respectively. Diarrhea with blood RR=4.23 (1.12-15.91) and HCGI 1 RR=1.44 (1.03-2.03) were associated with enterococci, using the higher cutpoint of 106 cfu.

It is conceivable that real increases in risk might have been missed with these cutpoints, particularly since they were not based on data that were generated by previous studies of Santa Monica Bay, so we also calculated odds ratios from categorical models using quintiles (of bacterial indicator levels) and from continuous models. For the continuous linear (on logistic scale) models, the odds ratios correspond to a unit increase equal to the difference between the 90th and 10th percentiles (i.e. the difference between the midpoints of the fifth and first quintiles). In general, results from the categorical models resembled results using the cutpoints (to define dichotomies) described above. The continuous models yielded a number of positive associations. For *E. coli*, small but statistically significant associations were seen for skin rash and stomach pain. Only skin rash was associated with total coliforms. Fever, skin rash, and HCGI 1 and 2 were associated with fecal coliforms. For enterococci, significant positive associations were noted for fever, skin rash, nausea, diarrhea, stomach pain, coughing, runny nose, HCGI 1, HCGI 2, and SRD.

In addition to investigating single bacterial indicators, associations between adverse health effects and the ratio of total to fecal coliforms, and the ratio of total coliforms to enterococci were investigated. For the total to fecal ratio, we initially used a cutpoint of 5.0, assuming the risk may be higher when the ratio is smaller. For the entire data set, significant associations were observed for diarrhea RR=1.28 (1.08-1.51) and HCGI 2 RR=1.87 (1.20-2.90). We then estimated effects of this ratio restricted to subjects in water where the total coliforms exceeded 1,000 cfu. Significant effects were observed for nausea RR=1.48 (1.08-2.04), diarrhea RR=1.40 (1.07-1.85), and HCGI2 RR=3.12 (1.60-6.07). We also conducted a similar analysis restricted to subjects in water where the total coliforms exceeded 5,000 cfu. Significant effects were observed for fever, eye discharge, skin rash, nausea, diarrhea, stomach pain, nasal congestion, HCGI 1, and SRD. Risk ratios ranged from 2-7. We then conducted a similar analysis restricted to subjects in water where the total coliforms exceeded 10,000 cfu. Here we observed significant

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As a measure of strength of association, we relied initially on the risk ratio (RR), which expresses the risk (proportion of subjects who report a given symptom) among subjects who bathed, for example, in front of the drain (0 yards) versus the risk among subjects who bathed 400+ yards from the drain. Comparing subjects who swam at 0 versus 400+ yards from the drain for all three beach sites combined, statistically significant increases in risk were observed for fever, where the RR=1.57 (95% C.L. = 1.17-2.10), chills RR=1.58 (1.04-2.39), ear discharge RR=2.27 (1.14-4.51), vomiting RR=1.61 (1.01-2.56), coughing with phlegm RR=1.59 (1.10-2.29), a group of symptoms we labeled highly credible gastrointestinal illness (HCGI 2) RR=2.11 (1.12-3.97), and a group of symptoms indicative of significant respiratory disease (SRD) RR=1.66 (1.25-2.21). These increases in risk were observed predominantly at the distance of 0 yards.

A second set of analyses was completed, restricted to days when the total coliforms to fecal coliforms ratio was greater than 5 for the water samples taken at 400 yards. The rationale was to exclude days when the plume from the drain or some other source of high counts apparently reached the 400 yard area, making this less than an ideal "control" zone. The relative risks for the seven outcomes cited above all increased. In addition, some significant increases in risk were observed for adverse health effects at distances of 1-50 and 51-100 yards from the drain, compared to 400+ yards from the drain.

The results for distance did not change when adjusted for age, beach, gender, race, California versus out-of-state resident, socioeconomic status, and worry about potential health hazards at the beach. Distance results also did not change substantially when controlled for each bacterial indicator.

A number of approaches to analyzing the effects of bacterial indicators were taken. We first calculated risk ratios for the lower and higher cutpoints described in the text (e.g. 200 and 400 colony forming units, or cfu, for fecal coliforms). Very few associations were observed when these cutpoints were used. None were detected for *E. coli* at lower cutpoints (35 or 70 cfu). Earache RR= 1.46(1.06-2.00) and runny nose RR=1.24(1.00-1.53) were associated with *E. coli* at the highest cutpoint of 320 cfu. Only skin rash was associated with total and fecal coliforms using the cutpoints of 10,000 and 400 cfu,

indicator) of interest. For a number of outcomes, the attributable number ranged into the 100's of new cases per 10,000 exposed subjects (complete results are presented in Tables 65-70).

In summary, both sets of results (the positive associations between adverse health effects and a) distance from the drain and b) bacterial indicators and presence of enteric viruses) taken together strongly suggest that there is an increased risk of a relatively broad range of symptoms caused by swimming in ocean water at the beach sites included in this study, particularly close to the drains and when indicator densities increase or ratios between selected indicators decrease.

associations with eye discharge, ear discharge, skin rash, nausea, diarrhea, stomach pain, nasal congestion, HCGI 1, and HCGI 2. The significant RR's ranged from 2-39. All the effects noted above became consistently stronger as the analyses were increasingly restricted to occasions with higher counts of total coliforms. Since this ratio appeared to be informative, a range of cutpoints (2, 4, 6, 8) was subsequently investigated. There was a consistent pattern of stronger risk ratios as the cutpoint became lower (when the analyses were restricted to times when total coliforms exceeded 1,000 or 5000 cfu), with the strongest effects generally observed when the cutpoint of 2 was used. The consistency of the results suggests the observed associations are real.

None of the bacterial results changed when adjusted for age, beach, gender, race, California versus out-of-state resident, socioeconomic status, and worry about potential health hazards at the beach. They also did not change when we adjusted the bacterial results for distance from the drain.

The analysis of samples for enteric viruses yielded seventeen samples (taken in the storm drain) that were positive for enteric viruses. This number of positive samples did not enable us to conduct many analyses; however, we were able to compare the frequency of outcomes reported by subjects who were swimming within 50 yards of the drain on days when samples were tested for viruses and found to be negative versus days when the samples were positive for viruses. Results are presented in Table 73. Although based on small numbers, a number of outcomes were reported more often on days when the samples were positive for viruses, including fever (RR=1.53, 95% CI 0.97-2.42, p=value 0.07); vomiting (RR=1.89, 0.94-3.78), HCGI-1 (RR=1.74, 0.99-3.06) and HCGI-2 (RR=2.26, 0.91-5.60). Results remained essentially unchanged when adjusted for covariates or for each bacterial indicator. Research with gene probes is ongoing and will be presented in an addendum at a later date.

The attributable number for noteworthy distance and bacterial indicator results was also calculated. This attributable number is an estimate of the number of new cases of a specific adverse health outcome that is attributable to the exposure (distance or bacterial indicator) of interest. For a number of outcomes, the attributable number ranged into the

Beaches in Santa Monica Bay are heavily used during the summer months. It is estimated that 50-60 million persons visit Santa Monica Bay beaches annually. Concern about adverse health effects due to swimming in the bay has been raised by interested parties (SMBRP, 1995), citing numerous anecdotal reports of illnesses that were perceived to be caused by swimming in the bay. "Is it safe to swim in Santa Monica Bay?" appeared to be a prevalent concern.

These circumstances (high volume of urban runoff in storm drains, numerous days with high levels of bacterial indicators, isolation of pathogenic human enteric viruses even when water quality indicator densities were low, heavily populated beaches, and concern about adverse health effects) provided the motivation to study the possible health effects of swimming in the bay. It was decided by the Technical Committee and the Management Committee of the Santa Monica Bay Restoration Project (SMBRP) that an epidemiological study of bathers in Santa Monica Bay was the most direct and relevant means of addressing the question, "Is it safe to swim in Santa Monica Bay?" A pilot study was conducted in the summer of 1994 to assess the feasibility of a large-scale study. The protocol for the large scale study was revised as a result of this pilot study and was subsequently approved by SMBRP.

II. MATERIALS AND METHODS

Overview:

A cohort study was conducted to investigate the possible adverse health effects of bathing in Santa Monica Bay and whether the risks of ill health outcomes were associated with urban runoff from storm drains. Exposures of primary interest were pathogens that produced acute illnesses (for reasons discussed in our original proposal, chronic health effects were not studied).

Three beaches with a wide range of indicator counts and high density of bathers were studied. The beaches were Santa Monica Beach (near the Ashland Avenue storm drain), Will Rogers Beach (Santa Monica Canyon Channel or storm drain) and Surfrider Beach (near Malibu Creek). Maps indicating beach sites are included in Appendix E.

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I. INTRODUCTION

At the time this study began, there had never been an epidemiologic study of persons who swam in marine waters contaminated by heavy urban runoff. Waters adjacent to the County of Los Angeles receive runoff from a system of storm drains year round. Even in the dry months of the summer, an average of 10-25 million gallons of runoff (or non-storm water discharge) per day enter Santa Monica Bay from the storm drain system (this includes, of course, substantial flows from permitted discharges beyond the control of the owner/operator at the facility). These drains are separated completely from the municipal sewage system of pipes and treatment plants; waters collected by the storm drain system are not subject to treatment and are discharged directly into the ocean at a number of sites. Years of monitoring by public agencies and recent surveys by the Santa Monica Bay Restoration Project have demonstrated that total and fecal coliforms as well as enterococci are sometimes elevated in surfzones adjacent to storm drain outlets; pathogenic human enteric viruses have been isolated from storm drain effluents, even when levels of all indicators, including F2 male-specific bacteriophage, were low (SMBRP, 1991). Sewage spills and hydraulic overload following rainstorms occur intermittently and may lead to discharge of primary-treated sewage and floatables such as tampon applicators into storm drains (NRDC, 1991); leaky sewer lines, illegal sewer connections, blocked sewer overflows, leaky septic tanks and local direct human sources (such as the transient population and illegal dumping of recreational vehicles) may also contribute human waste to storm drains emptying into the bay (SMBRP, 1990, 1992). At least 338 beach closures/advisories (many due to high bacteria levels attributable to storm drain runoff) occurred in Los Angeles and San Diego Counties in 1990 (NRDC, 1991). Water sampling at varying depths and distances from storm drains has established that a gradient of water quality (as measured by bacterial indicator densities) exists at Santa Monica Bay beaches receiving storm drain effluent (SMBRP, 1991).

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Nine to fourteen days after the interview date, subjects were interviewed by telephone to ascertain the occurrence(s) of fever, chills, eye discharge, earache, ear discharge, skin rash, infected cut, nausea, vomiting, diarrhea, diarrhea with blood, stomach pain, coughing, coughing with phlegm, nasal congestion, sore throat, and a group of symptoms indicative of highly credible gastrointestinal illness (HCGI) and significant respiratory disease (SRD). Of the 15,492 subjects interviewed on the beach, we were able to contact and interview 13,278 (86% follow-up). Of these 13,278, 1,485 were found to be ineligible because they swam (and immersed their heads) at a study beach between the day of the beach interview and the telephone follow-up. This left 11,793 eligible subjects who provided data for this study. We excluded 107 of these subjects because they reported not immersing their faces in ocean water, leaving 11,686 subjects for analysis.

Analyses addressed the following two questions: 1) What are the relative risks of specific outcomes in subjects bathing at 0, 1-50, and 51-100 yards of a storm drain compared to subjects bathing at the same beach, but beyond 400 yards of a storm drain? 2) Are risks of specific outcomes (e.g. highly credible gastrointestinal illness; ear, eye and sinus infections; upper respiratory infections; skin rashes and lesions) among subjects associated with levels of the bacterial indicators (or viruses) mentioned above. Given this design of the study, we are not able to address the effects of repeated exposures or chemical contamination or special at risk populations.

A detailed description of the study follows, including sections on study preparation, data collection (beach and telephone interviews), collection of water samples, laboratory analyses of water samples, and statistical analyses of the data.

Study Preparation:

Staff Recruitment and Selection:

The project coordinating team of the Santa Monica Bay Beach Study consisted of a multi-ethnic group of researchers with extensive experience in the design and conduct of epidemiologic studies. Included in this team were the study's principal investigator, the principal project coordinator, the study physician, and several professionals with

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Persons who bathed and immersed their heads in the ocean water were potential subjects for this study. There were no restrictions based on age, sex, or race. Persons who bathed at the study beaches, Mothers' Beach in Marina del Rey or near the Santa Monica Pier within seven days of the study date were excluded, as were subjects who bathed at the study beaches (or Mothers Beach or near Santa Monica Pier) between the date of the beach interview and the telephone follow-up. Subjects who swam on multiple days had to be excluded since one of our primary research questions was whether risk of health outcomes was associated with levels of specific indicator organisms on the day a subject entered the water. Given the range of incubation periods for the outcomes of interest and that the counts were quite variable from day to day, it would have been impossible to link subjects' experiences with specific counts on a given day if they were in the water on numerous days. Persons bathing within 100 yards upcoast or downcoast of the storm drain and persons bathing greater than 400 yards beyond a storm drain were targeted for this study.

For this study, 22,085 subjects were interviewed on the beach to ascertain eligibility and willingness to participate. Of these, 17,253 subjects were found to be eligible and able to participate (had a telephone and were able to speak English or Spanish). Of these, 15,492 agreed to participate. Eligible subjects who agreed to participate were then interviewed about basic demographic data and about their bathing, including type of bathing activity (particularly immersion of the head into ocean water). Distance from the storm drain, gender, age, and race of the subject were noted by the interviewer.

On the same days that subjects were recruited, morning water samples were collected at ankle depth at 0, 100 yards north and south of the storm drain, and 400 yards north or south (depending on which area was used as a "control" area). Samples were analyzed for total and fecal coliforms, enterococci, and *E. coli*. In addition, one sample each Friday, Saturday, and Sunday of the study was taken in the storm drain (0 yards) at each study beach and analyzed for enteric viruses.

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interview. Interviewing instructions contained in the original version of the beach questionnaire were eliminated after a few days of field-testing, streamlining it from two sheets (3-sides) to one double-sided sheet that could be folded up while remaining attached to a clipboard. Interviewers were able to write down respondents' phone numbers and useful comments on the flip side of the beach questionnaire (field sheet) without worrying about it being lifted and carried away by a sudden gust of wind.

The telephone questionnaire was finalized after consultation with the study physician, the Chief of Infectious Disease at Olive View/UCLA Medical Center, and the California State Department of Health Services. Previous studies have suggested that acute infectious diseases including gastroenteritis, ear and respiratory infections, conjunctivitis, and skin rashes can be transmitted through polluted salt or brackish water. Therefore, sixteen questions representative of easily recognizable symptoms of these illnesses were asked during the telephone interview. The instrument was designed with space available for comments. In addition, the questionnaire contained sections for recording demographic information obtainable from the field sheet or the telephone interview. At the end of the telephone interview, respondents were queried about their levels of concern regarding health hazards at the beach. Interviewers used probing techniques to elicit better information whenever respondents experienced difficulty in answering questions clearly. Questions concerning types and durations of water activities were not included because participants in our pilot study found them annoying and too difficult to answer.

The symptoms and corresponding probes are listed below:

1. **Fever** - defined as a temperature equal to or greater than 100° F or 38° C. If the temperature was not taken, a subjective answer was considered positive if the respondent either volunteered or answered positive to the probes of feeling warm, achy and/or having chills.
2. **Chills** - substantiated by probing for uncontrollable shaking. Not considered "yes" when fever was "no."

diverse research backgrounds and practical expertise in data collection, management and analysis.

Other staff were recruited from several sources (mainly UCLA and Santa Monica City College) by fliers and adds in the UCLA newspaper. Ideal candidates were those who could be trained to interview both at the beach and on the telephone. First, a project coordinator screened each applicant for experience and telephone demeanor, then explained the job requirements. Next, applicants were interviewed by three to four project coordinators. Staff members who had worked on the pilot study two years earlier were contacted and offered positions as experienced interviewers and/or mid-level supervisors.

The mid-level supervisory and interviewing/office staffs were comprised of individuals representing various ethnicities and educational backgrounds. Twenty-four interviewers were undergraduate students, 17 were college graduates and 9 had worked toward or achieved graduate degrees. Thirteen telephone and beach interviewers were bilingual in English and Spanish and several students, although not completely bilingual, could manage the beach interview in Spanish. Other interviewers' language skills allowed for the conduct of interviews in Japanese, French and German. Fifty staff members worked the majority of the summer -- 24 mainly full-time, 26 part-time.

Questionnaire Development:

The beach questionnaire and the follow-up telephone questionnaire were developed by the project coordinating team during a series of meetings. The beach questionnaire was photocopied on colored paper in order to distinguish among the three beaches (Santa Monica/Ashland: yellow; Surfrider/Malibu:pink; Will Rogers/Santa Monica Canyon Channel: blue). The telephone questionnaire was formatted to be scanned by an optical mark reader. Both questionnaires were fully translated into Spanish, with special attention paid to the diversity of Latino/a subgroups living around and within the Los Angeles area. Appendix A contains a copy of each questionnaire.

The coordinating team designed the beach questionnaire to serve as an instrument on which to record subjects' names, telephone numbers and swimming locations, plus as an aid in determining subject eligibility and accessibility for the follow-up telephone

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Orientation and Training:

All office and interviewing personnel were introduced to general interviewing techniques, the study background and protocol, and participated in role-playing exercises during an 8-hour orientation and training session. Pertinent information and materials were provided in a "Santa Monica Bay Beach Study Training Manual" (See Appendix D). During the following week, the supervisory staff underwent a day of practice training on the beach, and then worked during the following four days one-on-one practice training with the rest of the beach interviewers. At the beginning of data collection staff meetings were held each day to discuss experiences on the beach and to address questions and problems. Emphasis was placed on ways to observe and approach potential subjects and strategies were standardized for handling answers to their questions. As a result of these early meetings, the field sheet was streamlined and the method of assigning interviewers to designated areas on the beach was developed.

New beach interviewers who joined the project after the onset of the study first trained in the office with experienced interview supervisors, and then were taken to the beaches and allowed to practice the interview by interacting with beach patrons in non-study areas. This protocol was used for training beach interviewers throughout the summer.

A separate 8-hour training session was later held for telephone interviewers in which telephone interviewing techniques and the telephone questionnaire were emphasized. Interviewers were instructed on the use of standardized probes to clarify symptom events and to document answers to probes as well as comments voluntarily offered by subjects.

Telephone interviewers continued their training by conducting interviews under the direction and observation of a trained supervisor. These interviewers and their supervisors became adept at handling numerous scenarios by sharing experiences during the first few days of telephone interviews. Phone supervisors provided suggestions to beach interviewers about the types of comments on the field sheet (i.e., respondent's demeanor, swimming behavior, etc.) most useful in expediting the phone interview. The

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3. **Redness and discharge from eyes** - used to evaluate the diagnosis of conjunctivitis. Both redness and discharge were documented because BOTH had to be positive for a "yes" answer. Standard probes to "don't know" responses were "Did you have pink eye?...Did you have yellow discharge?" This was done to exclude irritation from salt water, smog and other sources.
4. **Earache** - To substantiate a positive response, the respondent was also asked if he/she had an ear infection.
5. **Discharge/draining from ear** - used to assess swimmer's ear.
6. **Skin rash** - The respondent was asked the location of the rash. Only rashes covering the body (as opposed to small patches, for example, on the foot or arm) were marked positive on the questionnaire. This was done to increase the chances that the observed rash was a generalized viral exanthem or contact rash that was more likely to be caused by immersion in polluted ocean water.
7. **Cuts or scrapes that became infected** - several probes were used to delineate a positive answer including more redness, swelling, pus and red streaks around the cut.
8. **Nausea** (not related to pregnancy) - The two probes that were used were, "Did you feel like throwing up?" or "...feel so sick that you couldn't eat?".
9. **Vomiting** - self-explanatory.
10. **Diarrhea** - self-explanatory.
11. **Diarrhea with blood** - would narrow condition down to certain diseases that present with this symptom, like Shigellosis or *E. coli* 0157.
12. **Stomach pain or cramps** - menstrual cramps were excluded. Interviewers were instructed to circle which symptom was experienced if not both.
13. **Coughing** - a probe for allergies and smoking was used.
14. **Coughing with phlegm** - self-explanatory.
15. **Nasal congestion/runny nose** - allergies/smoking probe used.
16. **Sore throat** - interviewers probed by asking if one had trouble with swallowing or eating (e.g, "Was it difficult to swallow food?").

water. Appendix B contains pamphlets and forms used on the beach. (The field sheet is in Appendix A.)

The number of staff members required at the beach sites ranged from 3 to 12 depending on the expected size of the crowd that day. Anticipating the crowd size depended primarily on weather prediction, and the number of interviews collected from a particular day of the week during previous weeks. For example, unless unusual weather was predicted, Sundays and holidays were consistently the days with the largest crowds at all three beach sites. Generally numbers increased at all the sites as the week progressed from Monday to Friday. Sometimes, uncertainty in the weather resulted in office staff being sent to the beach when beach crowds were unexpectedly large.

The average work day at the beach usually began around 11:00 A.M. Monday through Thursday; 10:00 - 10:30 A.M. Friday through Sunday. Beach interviewers could be easily identified by blue T-shirts bearing the "Santa Monica Bay Beach Study" logo. Upon arrival, the first item of business for the beach supervisor was to measure the areas within 50 and 100 yards on both sides of the selected storm drain. This was usually done by pacing off steps and was done daily because the outlets shifted for two of the three storm drains. The storm drain at Ashland was fixed (concrete), whereas those at Will Rogers and Malibu were often dredged by bulldozers or temporarily maintained by dry weather flows. They were occasionally reforming, straying, multiplying or disappearing.

The area boundaries (at 50, 100, and 400 yards) were marked with visible objects such as trash cans or beach umbrellas, although these markers were not used when the area happened to be bordered by a life guard station. In either case, survey areas could be easily delineated without arousing suspicion by beachgoers as to why these areas were important to the study.

Beach interviewers were responsible for determining and recording the locations of eligible participants. On the field sheet (see Appendix A) the storm drain was designated as point **0** (as indicated by the diagram on the next page, subjects did not have to be in the middle of the drain to be coded as point 0; they had to be in the water within a range of distance (usually a matter of 2-20 yards) where the flow from the drain entered

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methods for training telephone interviewers were maintained throughout the summer as new staff members were enlisted.

Data Collection:

Personnel Structure:

The scope of data collection and management required the availability of workers seven days a week from 9 A.M. to 9:30 or 10 P.M. Each task accomplished at the beach and at the study office was managed by a mid-level supervisor. The study employed three telephone room supervisors and seven beach supervisors. Although specialists were developed for each task, the success of the study depended on staff flexibility. In essence, each full-time staff member had a main job (e.g. beach interviewer) and an alternative job (e.g. data editor or telephone interviewer.) Most workers were skilled in multiple tasks and clerical tasks were shared. Staff members generally settled into the roles where they felt most comfortable, resulting in maximum productivity.

Project coordinators organized and supervised mid-level supervisory personnel and at times assumed some of their responsibilities. Beach and telephone supervisors, along with at least two project coordinators, attended weekly meetings during which schedules were planned and employee performances were discussed. Supervisors staggered beach interviewers' schedules to insure adequate crews on the beach during the afternoons when beaches tended to be busier. Basically, flexibility was encouraged so that beach interviewers, phoners and data editors could switch tasks depending on weather conditions and beach attendance on a particular day.

Beach Interviews:

Staff assigned to recruit subjects at the beach sites gathered each morning one half hour before leaving the office in carpools. The selected supervisor of each beach site was responsible for insuring that the crew assigned to her/his beach was transported and had the appropriate supplies. Supplies included pencils and clipboards, field sheets, forms on which to tally non-participants and ineligibles, forms on which to tally completed interviews and monitor interviewers, information pamphlets in English and Spanish, gifts for respondents (frisbees, visors and buckets), umbrellas, beach towels, ice chests, and

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the bay); the two zones spanning up to 50 yards on either side of point **0** were designated **4** and **5**; zones **3** and **6** spanned from 50 to 100 yards in either direction; and zones **1** (downcoast) and **8** (upcoast) were 400 yards and beyond in either direction. All zones except for **1** and **8,** i.e., up to 100 yards on either side of the storm drain, were considered exposure zones and were referred to as **Study Area 1**. Zones **1** and **8,** i.e., 400 yards and beyond, were considered control zones and were referred to as **Study Area 2**. Mostly zones 1 and 8 served as Study Area 2 at Malibu and Ashland beaches, respectively. The sampling strategy required that one subject be recruited from Study Area 2 for every 3 subjects in Study Area 1. It was extremely rare that a subject either swam across zones or entered the water in different zones. When this occurred, the subject was coded in the zone closest to the drain.

Generally one or more interviewers covered each zone, but this depended on the number of interviewers working that day and on the number of beachgoers occupying each zone. Bilingual interviewers were often placed strategically, either in heavily populated areas, one on each side of the drain, or were encouraged to traverse zones -- often being called out of assigned zones to assist in an interview. Covering small areas of the beach insured that surveyors could recognize those in their area who were newly arrived, those who had already been approached, and those who did not need to be approached since they had not immersed their heads in the water. Having individuals responsible for small areas provided the best opportunity for contacting every eligible participant. This system also insured that beachgoers were not disturbed by repeated approaches about the survey.

On a typical weekday during the earliest phase of the study, the majority of time was spent recruiting participants from Study Area 1 (exposure). Recruitment from Study Area 2 (control) was usually left until later in the day when the beach crew had an idea of the number of people needed from that area. For instance, if by 2:00 p.m. 30 interviews had been completed in Study Area 1, the supervisor would send a team to Study Area 2 until the necessary number of interviews was accumulated, say 10 or more. As the study progressed, the supervisors became more familiar with the beaches and knew how to

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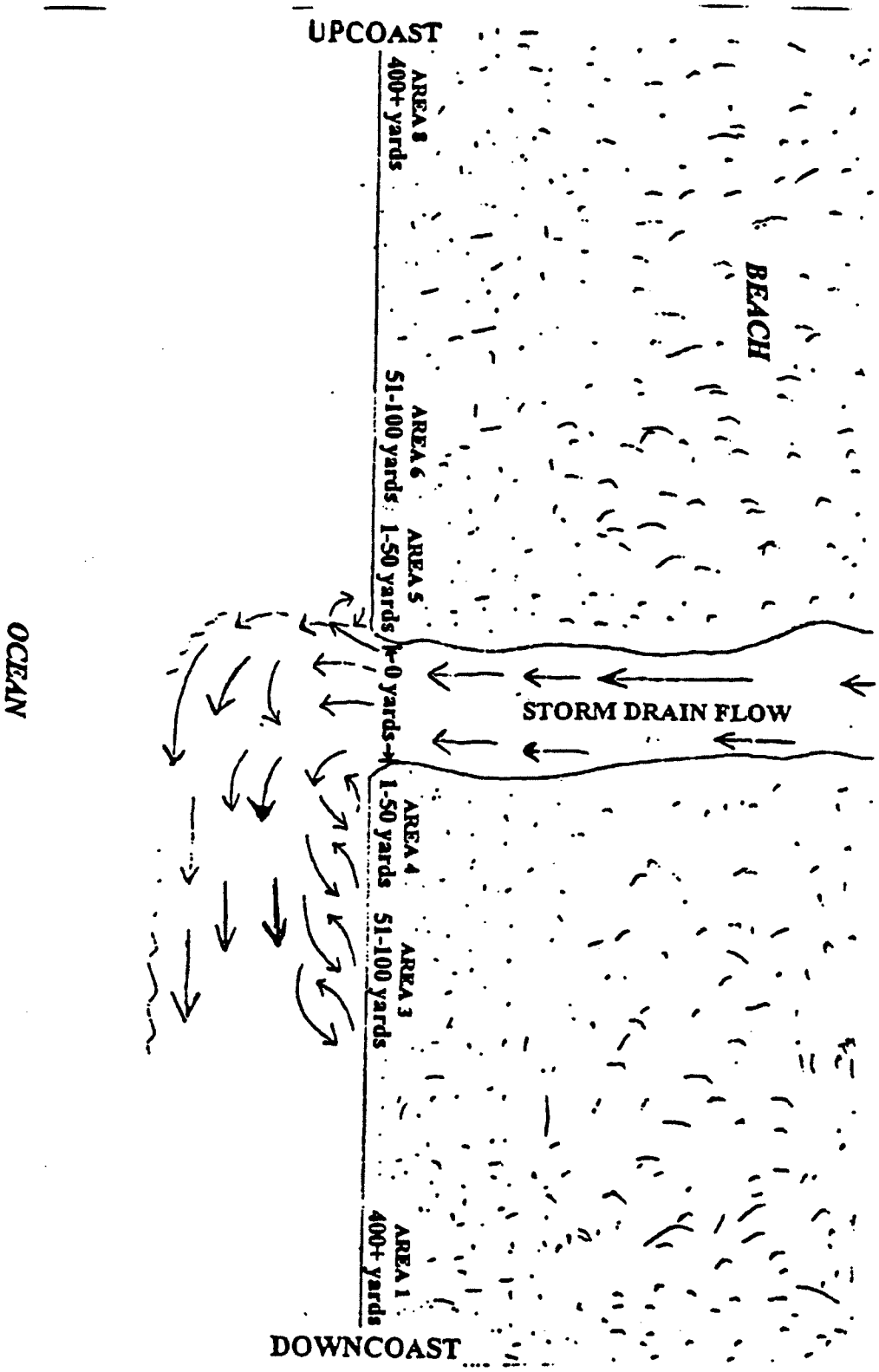
DIAGRAM ILLUSTRATING ZONES



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Participants were told that someone from the beach study office would phone them in 9 days and asked the number and time of day at which they could most easily be contacted. All respondents received an information pamphlet that described the study, provided the study office telephone number, and served as a reminder of the follow-up telephone interview. This pamphlet was printed in English as well as Spanish. Participants were encouraged to call the study office to be interviewed if they happened to be inaccessible on the scheduled phone interview date. Information about all members of a particular household was recorded on the same field sheet.

Unsuccessful interviews were tallied on a "Log of Non-Participants" sheet by race, gender and reason for non-participation (Appendix B). Only individuals who could be approached directly were tallied, as it was not feasible to determine the identity and number of accompanying children under 12.

Most essential to data quality was the careful observation of the bathing/swimming behaviors of the respondents approached for interview. Different techniques were used to approach potential subjects. Sometimes an interviewer waited until a group came back from the water to their towels, let them rest for a few minutes, and then approached. An alternative approach involved waiting until several unassociated groups had gone in and come out of the water. The interviewer then made "rounds" of 4-8 groups at a time. Many of the written parts of the interview were completed later at the encampment where beach interviewers were situated.

Since the beach contact laid the groundwork for the follow-up telephone interview, the interviewers spent as much time as each individual or family needed to establish rapport and convey a sense of professional interest in their swimming behavior. A level of trust had to be established in order to obtain phone numbers. In the early stages of the study, telephone interviewers were faced with a significant percentage of calling attempts resulting in wrong telephone numbers. Some of these were undoubtedly due to people's reluctance to give out their correct numbers. However, the percentage of wrong numbers decreased considerably when it became policy for beach recruiters to repeat the number aloud and verify it as written with the person being interviewed.

dispatch interviewers to Study Area 2 earlier in the day. On crowded days, such as weekends, interviewers were automatically assigned to Study Area 2 for the entire day, and supervisors provided them with regular notice as to the numbers needed from their area. Similarly, interviewers provided supervisors with regular reports on the quantity of their interviews.

Interviewers approached every potentially eligible beach visitor in their assigned zones. During the first few weeks of data collection, eligibility for adults and children was determined differently. Adults were eligible only if their heads or faces had been submerged in the ocean water (subjects with only incidental wetting of their faces, e.g. from splashing, were not recruited). Early on, children 12 years and younger were eligible if they had had any contact with the water, preferably hands and face (we assumed a lower standard of sanitary practices might place them at risk of exposure); however, once it seemed as though the projected sample size would easily be achieved, project coordinators decided to have children recruited under the same criteria as adults. Members of the same family were allowed to be subjects in this study because a) we judged that it would have been very difficult to identify and recruit only one member per family and b) it would have been impossible to achieve our sample size since we had to approach every potentially eligible subject throughout the study period to achieve our sample size.

A single adult or any adult member of a family could serve as the source of information on him-/herself or other family members. That adult was also often the source of information on children who were not part of the family but had come to the beach under his/her supervision. Children 12 years or older could be questioned directly if the interviewer had obtained consent from an accompanying adult. Teenagers who were not accompanied by adults were recruited and told to inform their parents about the follow-up telephone interview. Finally, in theory, a person could have been recruited into the study more than once, if they met the eligibility criteria each time. In reality, only a handful (perhaps 5) of subjects participated in the study twice.

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temporarily affected by algal blooms that made swimming unpleasant. One of the study zones at Ashland within Study Area 2 is approximately 250 yards from the Pico-Kenter storm drain -- a drain with a history of high indicator counts, usually diverted during previous summers.

Telephone Interviews:

The majority of telephone interviews were conducted from the beach study office, although occasionally an interviewer called from home if an interview could not be completed during regular office hours. Interviewers were scheduled to begin calling at 8 A.M. and interviewing generally continued until 9 or 10 P.M. Study participants were telephoned 9 to 14 days after their interviews at the beach. Interviews were conducted in English and Spanish.

In order to conduct telephone interviews, callers needed the field sheet in hand so that they could review the household size, names and ages of potential study eligibles, and read useful comments regarding eligibility and approachability. For this reason, a "calling queue" system was established in which field sheets were organized by scheduled call date, preferred call time (i.e., morning, afternoon, evening), and whether or not they were Spanish-only or out-of-area calls. Often phone numbers had to be obtained for participants that were interviewed as part of a group at the beach but lived in a different household.

Usually the contact person for the telephone interview was the respondent who had provided information at the beach interview; however, other options were utilized. A spouse could answer questions about the other's health when knowledgeable and comfortable with the idea; otherwise, the interview was conducted with each spouse separately. Interviewers were instructed not to allow participants existing in non-marital relationships to answer for partners, since they were considered more likely to be in a "honeymoon" phase wherein confidences about health problems might not be shared.

Adults were generally required to answer for children under 12, but could do so for any of their children if preferred. Often interviews were conducted with the parent asking the child questions. A divorced or separated parent could respond for a child only

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Interviewers carrying toys experienced enhanced success upon approaching households with children. In such cases, it was advantageous to have two interviewers approach the group, one with toys and the other with paperwork. The interviewer with the toys was able to keep the children occupied, relieving the parent's concern or need to watch them while participating in the interview, probably offsetting a fair number of refusals. An example of a typical beach interview is included in Appendix C.

Beach interviewers usually left the beach to return to the study office around 4:30 P.M. on weekdays and 5:30 P.M. on weekends. Supervisors collected the field sheets and non-participation log sheets, edited them for accuracy and completeness, and tallied the day's interviews on the "Beach Interview: Daily Tally Sheet" (Appendix B). One of the office staff was responsible for reviewing the field sheets on a daily basis and contacting beach interviewers, if necessary, to obtain missing information.

Several conditions at the study beaches resulted in logistical dilemmas for the survey. At study onset, the creek outlet at Malibu was close to the pier and most of the interviews were conducted on its south side where the people were swimming. In addition, no-flow days were common, i.e., there was no visible outlet from the creek to the ocean. Moreover, lifeguards often placed flags designating surfing-only areas such that Study Area 1 was off-limits to families and swimmers. When strictly enforced, swimmers were made to leave the area before they became eligible for the study. It was also not uncommon for lifeguards to approach people playing directly in the area of the storm drain and tell them to move to a "safer" area before they could become eligible to be interviewed. This happened at Ashland and Will Rogers as well.

Malibu's creek outlet was eventually moved upcoast for the summer in order to create greater accessibility to the more popular beach area during peak season. The noise and fumes emitted by bulldozers disrupted several days of interviewing, especially since it took several park service outings to get the outlet to stay upcoast. The outlet at Will Rogers beach also shifted positions so that it was subjected to bulldozings in order to create more usable beach. When the outlet was dredged, parts of the beach, especially within Study Area 1, were not available to beachgoers. Ashland and Will Rogers were

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following the beach interview (the first calling day), the field sheets were placed in a "call-back" compartment to receive priority attention during the next 5 days. All "call-backs" were attempted at least 3 times a day. Generally, interviews were completed within the 9- to 14-day window period, but there were exceptions. For a few days beyond the 5th calling day, field sheets were kept in a compartment for special priority calls. If these participants were accessed after the 5th day, interviewers made sure that the reported symptoms had occurred within the study window period. Families with small children were not called after 9 P.M., while the success rate among young singles was enhanced when calling hours were extended to 10 P.M. on some nights. At least one bilingual (English/Spanish) interviewer telephoned from the study office. Unattainable phone interviews were tracked on the "Log of Weekly Loss-To-Follow-Up" sheet (Appendix B).

The interviewing staff became very skilled at developing immediate rapport with the respondents over the phone. The interview proceeded smoothly once the interviewer introduced her/himself, the purpose for the call, and established eligibility. The telephone questionnaire was relatively easy to administer, as there were no open-ended questions. Interviewers sometimes linked questions about symptoms that regularly occur together, improving the flow of the interview without de-emphasizing the importance of each symptom. Information regarding swimming location was generally bubbled after the interview was completed, and interviewers were always blinded as to any preliminary analyses relating locations to health outcomes. The average interview took about 3 minutes per respondent. Appendix C contains a typical example.

When attempted calls were answered by an answering machine or someone other than a designated contact person or eligible participant, the interviewer left a message asking that the contact person return the call by phoning the study office and asking to speak to "Toni" -- a unisex name which none of the interviewers normally used. Afterwards, the corresponding field sheet was placed in the appropriate "Toni" folder according to beach, so as to be easily retrievable upon call-back. In this way, anyone answering the telephone could interview a caller asking for "Toni", having been trained

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if he/she was the custodian since the beach interview. With older children, interviews were facilitated once the interviewer had introduced her/himself and the study to a parent or guardian. Only rarely, when a language difficulty was otherwise unresolvable, would a capable child be allowed to interpret for an adult or another child. Nannies or babysitters who were daily care-givers could answer for charges.

Beach participants were eligible to respond to the follow-up telephone interview if they had not been back in the water at any of the 3 study beaches or at Mothers' Beach in Marina del Rey and the area around Santa Monica Pier since the day of the beach interview (subjects in the water at Mother's Beach or around the Santa Monica Pier were excluded because these areas are associated with high bacterial counts and swimming there may have caused symptoms such as the ones under investigation in this study). Very few subjects visited beaches other than the study beaches. Ineligible participants were tallied on a "Log of Weekly Loss-To-Follow-Up" sheet (Appendix B) according to ethnicity, age group (younger than 12, 12 and older), gender and map code. The telephone interviewer also verified that the participant had gotten her/his face wet in ocean water on the beach interview day. If both these criteria were met, the participant was deemed study eligible. A telephone interview form was dedicated to each participant who was then assigned a unique identifier.

The identifier consisted of a letter corresponding to the visited beach, a number designating the household, and a letter specific to a participating household member. Telephone interview forms were preprinted with sequential household identifying numbers and grids premarked with those numbers. At the time of the phone interview, an interviewer reviewed the field sheet to determine the number of forms required. The interviewer bubbled (i.e. darkened in pencil the circle indicating the correct data item) in the beach letter, the household number, and the participant letter in the provided section on the telephone interview form. The same identifier(s) was recorded on the field sheet.

The first attempt at calling the contact person was determined by the preferred time indicated on the field sheet. Respondents who said they could be called "anytime" were first called in the morning. If calling attempts were unsuccessful on the 9th day

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to the beach visit, the interviewer asked for a description of how often the symptom was experienced. This was done to decide whether the symptom was associated with an ongoing condition such as an allergy or smoker's cough, etc. In the majority of cases, if the symptom was already present at the time of the beach visit, it was not considered an event. A "don't know" (DK) was also not considered an event.

Phone interviewers were encouraged to write comments on the questionnaire form. Comments volunteered by the respondent were written on the left side of the page to differentiate them from answers to standard probes that were written on the right side. These comments were used in symptom ascertainment, especially when the respondent reported having had the symptom prior to the beach visit. The study physician reviewed these comments, and if the information was unclear, would question the interviewer for a better understanding. Sometimes, the study physician would re-phone the respondent to clarify the response. There were a few rare cases where an existent symptom worsened so dramatically after the beach visit that it was considered an event. In these cases, the study physician darkened the extra bubble associated with each symptom on the far right of the questionnaire form.

Data Editing:

Each completed telephone questionnaire underwent at least four reviews before it was scanned. Interviewers reviewed each questionnaire upon completion, although on busy telephoning shifts this step might have been bypassed. Telephone supervisors reviewed each interview and addressed any immediately apparent inconsistencies or omissions prior to the form's subsequent examination by a project coordinator. The study physician verified all ambiguous symptom events. Finally the forms were subjected to the final edit step.

In the final edit step, one staff person reviewed the field sheet while another reviewed the accompanying telephone form(s). The editor with the telephone form read aloud all the information which appeared on the top, i.e., identifier, beach and phone dates, interviewer numbers, age category, gender, map code, and whether or not respondent had gotten his/her face wet. The editor with the field sheet would check this

in advance to recognize a "Toni call." On average, 10 to 15 interviews were conducted in this fashion on a daily basis.

Interviewers kept track of their calls on the "Telephone Tally Sheet" (Appendix B), an instrument designed to keep account of the telephone activity of each work shift, i.e., 9 A.M. - 3 P.M.; 3 P.M. - 9:30 P.M. Calls were tallied within the following categories: completed interview, answering machine, "Toni call", busy signal, later appointment, no answer, disconnected, and wrong number. Also tallied were the number of households and individuals, and the number of attempts to complete these interviews. These tally sheets were helpful in allocating staff to the most productive hours.

The close supervision of telephone interviews allowed for optimum quality control. Telephone interviews were always monitored by a supervisor to insure that probes were used uniformly and answers to respondents' questions were addressed in an accurate and unbiased manner. Supervisors reviewed each questionnaire for content soon after the interview took place so that interviewers were directed as to how to unravel inconsistencies and recall or obtain missing information, even calling the respondent back if necessary. There were occasions when supervisors made these calls in order to validate information. All interviews were also reviewed by a project coordinator within 24 hours after completion.

Office Operations (Other Than Telephoning):

Symptom Evaluation:

For our purposes, determining that a participant experienced a specific health outcome depended on the self-report of having one or more representative symptoms. Each of the 16 symptoms listed in the phone questionnaire was associated with 3 possible questions. For each symptom, the first question was asked, "Did you or your child have (symptom) at any time since your visit to the beach?" When the response was negative, the interviewer moved on to the next symptom. If the response was positive, the interviewer continued by asking, "Was this a problem you had before going to the beach?" If the answer was "no", this was considered a symptom event, and the interviewer moved on. However, if the respondent reported having had the symptom prior

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A similar method was used for the detection and correction of logical errors, for example, inadherence to skip patterns. Records containing logical errors were listed and corrections were entered into a computer file that was merged with the original data set.

Other aspects of data management involved the creation of new variables like symptom groups, and the merging of bacterial indicator counts and household income estimates with the questionnaire data. Bi-weekly progress reports describing the numbers of completed interviews as well as respondent characteristic were generated using Excel 5.0. Excel was also used to enter and report daily beach interviews, daily non-participation and weekly loss-to-follow-up counts.

Collection of Water Samples

Samples were collected daily from mid-June to September at three locations; Santa Monica Beach near the Ashland Avenue storm drain (Ashland), Will Rogers Beach near the Santa Monica Canyon storm drain (Will Rogers), and Surfrider Beach near Malibu Creek (Malibu). Four samples were taken at each location. Three of the sampling points at each location (0 yards, 100 yards upcoast and downcoast of the storm drain flows) represented a grid presumably covering the most elevated indicator bacteria counts in the surf-zone. The fourth sample (400 yards upcoast or downcoast) represented a control site that was presumably unaffected by high indicator densities from storm drain flows. For quality assurance purposes, one duplicate per beach site was collected on each sampling day. Discharge flow rates at the time of sampling were not made.

All samples were collected at ankle depth with sampling poles and one liter, high-density, sterile polypropylene bottles. Samples were taken at ankle depth because 1) all shoreline monitoring is done with ankle depth samples; 2) children were presumed to be at higher risk and are exposed mostly to water at ankle depth; 3) previous studies (SMBRP, 1990) demonstrated that bacterial densities at chest depth were at least an order of magnitude lower than ankle depth samples; 4) additional samples would increase the costs and demands on the lab to unacceptable levels. The samples were collected from the incoming surf as the surf foam reached the sample bottle at the height of the sampler's ankle. The sample bottles were immediately sealed and placed on ice. All samples were

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vocalized information against that on the field sheet. Any necessary corrections were made on the telephone form and the entire telephone form was inspected for dark and thorough marking (bubbling.) Unresolvable inconsistencies were referred to the telephone interviewer and corrected. Once edited in this manner, the telephone forms were set into a pile separate from the field sheets, ready for scanning. The field sheets were stamped "Completed", initialed by the editor, and filed in sequential identifier order for later reunification with the telephone form.

Data Management:

The telephone interview forms were scanned on a NCS OPSCAN 5 optical mark reader. Edit checks were conducted to locate and correct miscoded identifiers, inappropriately missing responses to variables, and logical response errors. In most cases, missing data were the result of the scanner having failed to pick up marked responses.

Miscoded identifiers and missing data for selected variables, i.e., beach and phone interview dates, gender, age, interviewer numbers, and map code, were initially manually edited in the data set if the information was written on the form but not coded or lightly bubbled. At this point, the forms were reunited with the field sheets and filed.

Most data management tasks were performed using Dbase IV. The data manager printed a list of identifiers and values from the telephone forms that could be verified with the field sheets. This list was used as a final check for data consistency between the two interview forms. Corrections were made to the telephone forms along with brief notations describing the corrections, and photocopies of the forms were given to the data manager to perform manual edits.

The data manager next produced a hard-copy list and computer file on which to enter the remaining missing responses. Office staff examined the field sheet and telephone interview and either entered the correct responses or confirmed the nonexistence of data. The missing data were entered into the computer file and merged with the original data set.

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(52 grams per 1 liter, with the addition of 10 mL of 1% of Bacto rosolic acid in 0.2N NaOH) was used for fecal coliforms. Difco mE Agar (7.12 grams per 100 mL with the addition of 0.024 grams nalidixic acid and 1.5 mL of 1% triphenyl tetrazolium chloride) was used for the initial isolation of enterococci. BBL Esculin Iron Agar (16.5 grams per 1 liter) was used for the substrate test for enterococci. Each batch of agar media was tested for pH and sterility. Positive and negative control cultures were also inoculated onto representative portions of the prepared plates. Only media that passed all QA checks were used.

E. coli was analyzed using Hach m-ColiBlue24 Broth, which is commercially prepared and packaged in PourRite ampules. The ampules were refrigerated until the day of use when the tops were broken and the liquid broth aseptically poured onto a sterile absorbent pad in a sterile 47mm petri dish with a tight-fitting lid. All ampules were used before their expiration dates.

Sterile phosphate buffered water was used as the diluent for all dilutions and also as a rinse water during membrane filtration. The phosphate buffer was made according to Standard Methods for the Examination of Water and Wastewater (American Public Health Association, 1992) Section 9050C1. The buffer was prepared with 1.25 mL stock phosphate buffer solution (34 grams potassium dihydrogen phosphate in 1 liter deionized water) and 5 mL stock magnesium chloride solution (81.1 grams magnesium chloride per 1 liter deionized water) per 1 liter deionized water. Buffer was dispensed into either 1 liter screw-capped flasks (for rinse water) or into screw-capped test tubes (9 mL per tube) for dilution blanks. The buffer was autoclaved, cooled, and then tested for pH and sterility. Buffer was stored at room temperature until used. The holding time for the prepared buffer was three months.

Membrane Filtration Procedure

Water samples were analyzed by the membrane filtration procedure according to Standard Methods. Total coliform densities by membrane filtration were determined as recommended in Standard Methods Section 9222B and fecal coliform densities were determined according to Section 9222D. Enterococci densities were analyzed according

SARB_000382

collected between 8:00 A.M. and 11:00 A.M. in the following order; Malibu, Will Rogers, and Ashland. After all samples were collected, they were transferred to the Los Angeles Bureau of Sanitation's Environmental Monitoring Division's microbiology laboratory at the Hyperion Treatment Plant by noon for analysis. Samples were taken in the morning because a) it was not feasible to collect samples later in the day and have them analyzed given the daily schedule in the lab and b) it was not advisable to have staff obviously collecting water samples at specific locations relative to the drain at the same time subjects were being interviewed on the beach.

Laboratory Determination of Bacterial Indicators (Total and Fecal Coliforms, *E. coli*, Enterococcus)

All laboratory work was conducted by the City of Los Angeles, Environmental Monitoring Division, Biology Section - Microbiology Unit.

Samples

All samples were collected using clean, sterile 1 liter polypropylene sample bottles, leaving ample air space in the bottle to facilitate mixing by shaking. After collection, samples were transported to the lab in an iced cooler to maintain sample temperature below 10°C. Samples were received within six hours of sample collection and analyses started within two hours of arrival to the lab.

Media

Agar used for the culturing of the indicator bacteria total coliforms, fecal coliforms, and enterococci were prepared according to the manufacturers' directions using a New Brunswick Scientific Co., Inc. AgarMatic benchtop sterilizer. Each agar was cooled to approximately 45°C and aseptically dispensed via a pump and sterile tubing into sterile, disposable 60mm petri dishes for total coliforms and enterococci. Agar for fecal coliforms was dispensed into 47mm sterile petri dishes with tight-fitting lids. Prepared plates were placed in covered containers and refrigerated until used. The maximum holding time for the prepared plates was two weeks.

Difco mEndo Agar LES (51 grams of dehydrated media to 1 liter of deionized water containing 20 mL of 95% ethanol) was used for total coliforms. Difco mFC Agar

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10. The walls of the funnel are rinsed down three times with approximately 30 mL of sterile, buffered rinse water. When the rinse water has drained through, the vacuum is turned off.

11. The funnel is lifted off and the filter is aseptically removed using a sterile forceps. The filter is aseptically placed, using a rolling motion, grid side up onto the surface of the appropriately labeled petri dish containing agar or a broth-saturated pad. Care is taken to avoid trapping air between the agar or pad surface and the filter.

12. Steps 6-11 are repeated for each sample volume or dilution required for the sample. The smallest sample volume is filtered first, followed by increasing sample volumes.

13. If dilutions are required, 1:10 serial dilutions are made, using sterile 9 mL dilution blanks and 1 mL of sample. The most dilute sample aliquot is filtered first, followed by increasing sample concentration dilutions.

14. When all the sample volumes or dilutions have been filtered for the sample, the plates are placed into the appropriate incubators.

    a. Total coliform mEndo LES agar plates are incubated for 24 ± 2 hours at 35.0 ± 0.5°C.

    b. Fecal coliform mFC agar plates are incubated for 24 ± 2 hours at 44.5 ± 0.2°C. These plates are incubated within 20 minutes of filtration to ensure heat-shock of the non-fecal bacteria. The plates are placed in either dry heat-sink incubators or sealed in water-proof bags and placed in a 44.5 ± 0.2°C water bath.

    c. Enterococcus mE agar plates are incubated for 48 ± 2 hours at 41.0 ± 0.5°C.

    d. *E. coli* broth plates are incubated for 24 ± 4 hours at 35.0 ± 0.5°C.

15. All sample collection, filtering, and incubation times are recorded in the sample log book.

B. Colony Morphology

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to Section 9230C. *E. coli* densities by membrane filtration were determined as recommended by Hach Method 10029 for m-ColiBlue24 Broth.

A. Filtration/Incubation

Millipore's Microfil System, consisting of disposable 100 mL polypropylene "push-fit" sterile funnels and HA 0.45 μm sterile membrane filters, were used for filtering each sample. Samples were filtered under partial vacuum provided by a vacuum pump. The filtration procedure used is as follows:

1. Using an alcohol flamed-sterilized forceps, a new sterile membrane filter is aseptically placed, grid side up, onto the sterile filter support base.
2. The Microfil sterile, disposable funnel is aseptically placed on the support and pushed down to fix it firmly in place.
3. The funnel is rinsed with approximately 20-30 mL of sterile, buffered water. This is the sample QA blank to ensure that the equipment and the buffered rinse water were sterile.
4. The vacuum is applied and the buffered rinse water is allowed to drain through the filter. The vacuum is turned off.
5. The funnel is lifted off and the filter is aseptically removed using a sterile forceps. The filter is aseptically placed, using a rolling motion, grid side up, onto the surface of the appropriately labeled petri dish containing agar. Care is taken to avoid trapping air between the agar surface and the filter.
6. A new sterile filter is aseptically placed onto the filter support base.
7. The membrane filter is wet with approximately 20-30 mL of sterile, buffered rinse water before the sample aliquot is added, using sterile disposable pipets or sterile graduated cylinders.
8. The sample is swirled in the filter funnel by moving the funnel in a gentle circular motion to evenly distribute bacterial cells on the filter surface.
9. The vacuum is applied and the buffer and sample is allowed to drain through the filter.

adding the counts of all the sample volumes filtered and multiplying by 100 and then dividing by the sum of all the volumes (mL) filtered.

Quality Assurance

Quality assurance and quality control tests were performed to verify the validity of the analytical data collected. All areas that influence the reported data were subjected to established microbiological quality control procedures in accordance with Standard Methods. These areas included sample storage and holding, lab facilities, personnel, equipment, supplies, media, and analytical test procedures. In addition, duplicate analyses were performed on ten percent of all samples. When quality control results were not within acceptable limits, corrective action was initiated. The laboratory also participated in performance evaluation samples sent by the State Department of Health Services. The quality assurance program helped ensure the production of uniformly high quality and defensible data. The Hyperion microbiology laboratory has been certified by the California State Department of Health Services.

Virus Sampling and Assay for Enteric Viruses

All laboratory work was conducted at the Environmental Sciences Laboratory of the County Sanitation District of Orange County.

Sampling Design and Frequency

Method 9510 C g of Standard Methods for the Examination of Water and Wastewater, 18th edition was used in all virus sampling. The sampling was performed at three storm drain sites on Friday, Saturday and Sunday from June 23 to September 24, 1995. Sampling days and duration of the project reflected heaviest beach usage during the 1995 swimming year. Water samples as large as 100 gallons were filtered through electropositive filters at ambient pH. Flow rate through the adsorption filter was kept below 5 gpm. Adsorption filters were eluted in the field with one liter of sterile 3% beef extract adjusted to pH 9.0 with sodium hydroxide.

Field eluates were returned to the laboratory where they were reconcentrated using an organic flocculation procedure described by Katezenelson et al., 1976. In this method, the eluate was adjusted to pH 3.5 by dropwise addition of 1N HCI while mixing

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A stereoscopic microscope with a fluorescent lamp is used to aid in identifying and counting colonies after the appropriate incubation times. All colony counts, counting times, and any other notable information is recorded on the sample data worksheet.

1. Total coliforms: typical colonies have a pink to dark-red color with a shiny, greenish-gold, metallic surface sheen. The sheen may appear only in the central area or on the periphery.
2. Fecal coliforms: any colony exhibiting any light or dark blue color, whether covering the entire colony or only in or on part of the colony.
3. Enterococcus: after 48 ± 2 hours incubation, mE filters with growth on them are transferred to room temperature EIA plates. These EIA plates are incubated for 20 minutes at 41.0 ± 0.5 °C. Enterococci are pink to red-brown colonies with black or reddish-brown precipitate or halos on the underside of the filter when place on EIA agar.
4. *E. coli*: all blue to purple colored colonies (total coliforms are all red plus blue/purple colored colonies).

C. Calculations

Due to the possible adverse effect of colony crowding on sheen or color development on the membrane filter, and to be assured of a statistically valid colony count, minimum and maximum levels are adhered to for each of the indicator organisms. The minimum and maximum ranges are as follows:

1. Total bacteria: <200 total colonies (background and indicator bacteria)
2. Total coliform: 20 - 80 coliform colonies
3. Fecal coliform: 20 - 60 fecal coliform colonies
4. Enterococcus: 20 - 60 enterococcus colonies
5. *E. coli*: 50 coliform colonies

Indicator bacteria are expressed as bacterial density - colony forming units (CFU) per 100 mL of sample. Counts within the statistical range for the bacterial indicator are calculated by multiplying the colony count by 100 and dividing by the volume (mL) of sample filtered. If no counts fall within the ideal range, the density is calculated by

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final concentrate that could be quantified. The remaining concentrate volume was split in half and analyzed using the liquid overlay technique known as the cytopathic effect assay (CPE). The CPE assay is generally considered to detect a greater number of viruses, but it is not quantitative. All flasks of BGMK cells used in the CPE method were frozen after a maximum of 10 days. The flasks were then thawed and a portion of the original flask was transferred to a fresh flask of BGMK cells. Flasks that did not exhibit CPE in the initial CPE assay or the subsequent passage to fresh cells were considered to be negative for detectable infectious viruses. Any flask exhibiting CPE in either initial or subsequent passages was further examined by the plaque forming unit method to confirm the presence of infectious viruses.

Statistical Analyses

From the initial data set of 11,793 subjects who were successfully contacted and eligible, 107 were excluded due to reporting that they (or their child) did not get their face wet when swimming, leaving a total of 11,686 subjects included here. When looking at the bacteriological exposures, subjects with missing values (for the bacterial densities) were excluded (subject counts for each of these exposures are given in the tables). Socioeconomic status (SES) was estimated from census data (based on median values for each subject's zip code); missing SES values (for 1,546 subjects) were imputed as the median value among all subjects.

To assess the health effects of swimming near storm drains and high bacteriological levels, we first used simple descriptive statistics, such as histograms, tabular comparisons, and stratified analyses. We then calculated odds ratios (ORs) and 95% confidence intervals (CIs) from logistic regression models. These models provided approximate relative risks while allowing for control of potential confounding. We fit models for the two primary exposures (i.e., distance of swimming from the storm drain and measures of bacteriological exposure) for each of the outcomes of interest. We present results from modeling the exposure categorically and continuously. For the continuous models, we either present ORs and 95% CIs, or P values for trend; note that one can assess the trend P from the continuous 95% CIs.

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continuously on a magnetic mixer. After reaching pH 3.5, mixing continued for an additional 30 minutes in order to maximize the potential for virus particles to adsorb to the organic floc. The entire eluate was then centrifuged at 3000 X g for 10 minutes in order to recover the floc. The pelletized floc was then resuspended in 0.45N Na_2HPO_4. In most cases, the final concentrate was in the 10 to 15 mL range.

Analyses of initial samples on tissue culture indicated that some of the final concentrates were toxic to host cells. Because of this toxicity, all final concentrates were detoxified prior to assay using the procedure described by Glass et al, 1978.

Additional parameters measured by the field team was ambient pH, temperature, conductivity and Total Dissolved Solids.

Seed Studies

Seed studies were performed at the laboratory using water collected from each sample location. Six studies were performed in water collected from Santa Monica Canyon, seven in water from Malibu and seven in water from Ashland. These studies were done to measure the effectiveness (i.e., percent recovery) of the virus adsorption, elution and reconcentration procedures in actual storm drain effluent.

Two 35 gallon containers were filled with water from each location. The water was trucked to the L.A. County Sanitation Districts Laboratory where a known amount of vaccine strain poliovirus was added to the water. Three grab samples were taken from the 35 gallon containers at the beginning and end of each experiment. These grab samples were diluted 1:10 in Hank's Balanced Salt Solution (HBSS) to minimize any toxic effect to the virus by the water itself. Percent recovery was measured by comparing the concentration of virus as measured in the grab samples to the concentration measured in the final sample concentrates.

Enteric Virus Assay

All samples were analyzed for infectious human enteric viruses on Buffalo green monkey kidney cells (BGMK). Ten percent of the final concentrate volume was initially analyzed by the plaque forming unit (PFU) technique. The reason for this initial screening was to determine whether there were viruses present in a small portion of the

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participants at the beach, ineligible, lost to follow-up, or from whom we obtained completed interviews did not differ by beach site (Figure 2). Reasons for non-participation are listed in Table 2. The major reason for non-participation was that the subject was ineligible because of a prior visit to a study beach (usually the same beach) or Mothers' Beach in the prior seven days (17% of beach contacts). Of the 22,085 persons approached on the beach, only 1761 (8%) refused to participate. Whites were slightly more likely to be non-participants than other racial ethnic groups (usually because they were ineligible). There were no major differences in the ethnicity or gender of non-participants across beaches (Figure 3). Reasons for "non-actualized" telephone interviews, meaning the attempt did not result in a completed interview from a subject interviewed at the beach, are presented in Table 3. The major reason was that subjects were found to be ineligible because they had returned to a study beach and immersed their heads in the water subsequent to the day of the beach interview (10% of beach interviews). The major reason for losses to follow-up was an apparently wrong or disconnected number (8% of beach interviews), which occurred predominantly early in the study. The proportions of "non-actualized" telephone interviews did not differ substantially by ethnicity, gender, or age (Figure 4) (although there was a slight tendency for whites and older subjects to fall into this category).

Table 4 presents characteristics of the 11,793 subjects who remained eligible throughout the study and completed the beach and telephone interviews. An objective was to have a ratio of 3:1 for subjects 0-100 versus greater than 400 yards from the storm drain. We achieved a ratio of 2.9:1. The majority of subjects (78%) came from family units where we included more than one subject per family. Only ten percent of subjects had residences in zip codes where the median household income was less than $25,000. This percentage was slightly higher at Ashland (13%). Eighty-eight percent of subjects were residents of California and there were no differences in this percentage by beach. We compared the study subjects with residents of Los Angeles County using the Population Estimation And Projection System (PEPS) for 1993 provided to us by the Toxics Epidemiology Program of the Department of Health Services of Los Angeles

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Potential confounders adjusted for include: age, beach, race, gender, SES, California versus out-of-state residence and worry about potential environmental hazards due to swimming in the Santa Monica Bay. In addition, we adjusted the distance results for each of the bacteriological exposures and we adjusted the bacteriological results for distance. We also performed subgroup analyses by age and beach for the exposures/outcomes of interest. Interactions between distance from the drains and bacteriological exposures were assessed (with logistic regression) as well. Finally, for the significant results, we estimated the number of cases attributable to the corresponding exposure. The list of variables available for analysis is presented after the narrative portion of the Results and Discussion sections.

III. RESULTS

For clarity of presentation, we will describe all major results in this narrative section, followed by the Discussion Section. All of the tables and figures are provided after the References Section (before the Appendices). Results will be described in four sections: descriptive data from the beach and telephone interviews, descriptive data from the laboratory determinations of bacterial indicators, associations between risk of health outcomes and distance from the storm drain, and associations between bacterial indicators and risk of health outcomes. At the end of the last section, we present results of multivariate modeling where we included both distance from the drain and the bacterial indicators in the same model. After the section on multivariate modeling, we present an analysis of the virus data. Final results for all associations we examined are included here.

Descriptive Data (from the beach and telephone interviews)

Table 1 presents a calendar with the number of completed interviews by day. As expected, more interviews were completed on weekends. Also, more interviews were completed in July than other months. As stated earlier, we were able to successfully complete telephone follow-up interviews for 84% of the eligible subjects who were interviewed on the beach (Figure 1). The proportions of subjects who were non-

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be due to swimming in the ocean making it more difficult to detect any excess risk due to swimming). This decision was made prior to seeing what risk ratios were associated with this variable.

With respect to proportions of subjects reporting symptoms, there were no differences by gender. There were no substantial differences by age, although the proportion of children 0-12 with fever and vomiting was slightly higher than among older subjects and the proportion of children 0-12 with cuts that became infected was slightly lower than among older subjects. There were generally no differences by ethnicity, socioeconomic status (SES), or residence in California versus outside of California, with the following minor exceptions. Latino/a subjects reported less diarrhea, stomach pain or cramps, and nasal congestion. Based on the opinion of many of our bilingual staff, we suspect this may reflect some underreporting of these symptoms, rather than a real difference in outcomes. Persons who lived in zip codes where the median household income was less than $25,000 reported higher rates of fever, while subjects who lived in zip codes with median household incomes greater than $25,000 reported higher rates of diarrhea, but generally there were no striking differences by this ecological measure of SES. Overall, there was a tendency for California residents to report more symptoms than non-residents, but these differences were small.

Finally, Table 11 also presents results for the variable regarding level of concern about environmental hazards at the beach. As level of concern increases, the proportion of subjects reporting symptoms increases. This question was asked only at the end of the telephone interview because we did not want to bias responses to the list of symptoms by asking before then and we did not want to ask it at the beach because we wanted a streamlined questionnaire and we did not want to raise concerns about the beach for subjects who participated in this study. The manner in which it was asked does not enable us to distinguish between two possibilities: people with a high degree of concern overreported their symptoms relative to the other subjects or, more plausibly, those who subsequently experienced symptoms after the beach interview had their level of concern raised (after the fact). In either event, this variable was not strongly associated with

County (Table 5). As expected, the study subjects were younger (e.g. 48% were under 12 years of age versus 22% from PEPS). This reflects the fact that beachgoers who enter the water tend to be younger, which allowed us to examine possible differences in effects by age. The proportion of male study subjects was slightly higher in the study than in Los Angeles County (55% vs 50%). For White and Latino/a subjects, there were no substantial differences between study subjects and their proportions in L.A. County.

Table 6 presents subject age by map area (distance from the drain) for each beach. Table 7 presents similar data by gender for each beach and Table 8 presents these data by ethnicity. A summary for all beaches combined is presented in Table 9. Children 0-12 years of age tended to swim at the drain more than older subjects (63% of subjects swimming at the drain were children 0-12, whereas children 0-12 represented only 48% of all subjects). There were no differences by gender (e.g. 53% of subjects swimming at the drain were males and they constituted 55% of all study subjects). There was a tendency for Latino/a subjects to swim at the drain more so than Whites (59% of subjects swimming at the drain were Latino/a, whereas they comprised 43% of the total study subjects).

Table 10 presents counts of each symptom ascertained from the telephone interview. Table 11 presents rates for each symptom by various categories. The most commonly reported single symptoms were: nasal congestion (reported by 9.1% of respondents), coughing (7.1%), sore throat (6.8%), stomach pain or cramps (6.2%), diarrhea (5.3%), and fever (4.8%). The most commonly reported composite variable was significant respiratory disease or SRD (5%), which is defined as all those reporting any one or more of the following symptom groups: 1) fever and nasal congestion or 2) fever and sore throat or 3) cough with phlegm. The other composite variables were HCGI 1 (3%) and HCGI 2 (0.9%). HCGI 1 included all those experiencing any one or more of the following symptom groups: 1) vomiting or 2) diarrhea and fever or 3) stomach ache and fever. HCGI 2 includes all those reporting both vomiting and fever (we decided to exclude diarrhea in this second composite since diarrhea was reported relatively commonly by study subjects and much of it may represent background rates that may not

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Avenue for each indicator, Figures 6A-D present the counts for Malibu, and Figures 7A-D for Will Rogers.

From the tables and figures, four major points are evident: 1) the counts were highly variable from day to day; 2) for a substantial proportion of days, the counts exceeded the established cutoffs; 3) the counts were generally higher in front of the drain and then dropped off with increasing distance from the drain; 4) the water samples taken at 400 yards were not always "clean" with respect to the bacterial indicators (i.e. counts occasionally exceeded the established cutoffs). Also, in general, the water quality (as judged by these indicators) was relatively poor compared to previous years.

Associations Between Distance from the Drain and Health Outcomes

As a measure of the strength of association, we rely predominantly on the risk ratio (labeled RR in the tables). This ratio expresses the risk (proportion of subjects who report a given symptom) among subjects who swam, for example, in front of the drain (designated 0 yards) versus the risk among subjects who swam 400+ yards from the drain. For the sake of brevity, subjects who swam 400+ yards from the drain are referred to as "controls" since they served as the reference group for all calculations in this section. Ninety-five percent confidence intervals are presented for each RR. For example, in Table 17, the RR for fever is 1.57, suggesting that the risk of fever for subjects swimming at 0 yards (in front of the drain) is 57% higher than the corresponding risk for subjects who swam at 400+ yards from the drain. The interval estimate is 1.17-2.10, which is narrow and the lower bound is above 1.0, indicating the result is informative and statistically significant at alpha = .05. For interested readers, we also present the absolute number of subjects in each comparison group who reported a symptom and the absolute risk in each group, facilitating calculations of excess risk and attributable numbers.

Since the predominant direction of the plumes traveling from the storm drains into the ocean was downcoast, we distinguished distance from the drain by designating upcoast and downcoast distances. Tables 17-21 present risks and RR's for subjects swimming at 0 versus 400+yards, 1-50 yards upcoast versus 400+yards, 51-100 yards

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upcoast vs. 400+ yards, 1-50 yards downcoast vs. 400+ yards, and 51-100 yards downcoast vs. 400+ yards, respectively. The effects for 0 yards and the downcoast distances are also summarized in Table 22, and the 0 yards and upcoast distances are summarized in Table 23. Comparing subjects who swam at 0 versus 400+ yards from the drain, we observed statistically significant increases in risk for fever, where the RR=1.57 (95% C.L. = 1.17-2.10), chills RR=1.58 (1.04-2.39), ear discharge RR=2.27 (1.14-4.51), vomiting RR=1.61 (1.01-2.56), coughing with phlegm RR=1.59 (1.10-2.29), HCGI 2 RR=2.11 (1.12-3.97), and SRD RR=1.66 (1.25-2.21). These increases in risk appeared to be limited to the 0 yards distance, since we observed very few significant effects at other distances upcoast or downcoast from the drain, and no significant trends with increasing distance from the drain (data not shown).

As we noted earlier, there were a number of days when the bacterial indicators at 400 yards exceeded the cutoff points, suggesting that this distance was not always a "clean control" area. As we describe in the next section, one of the better indicators for predicting health risks is the total coliforms to fecal coliforms ratio. We conducted a second set of analyses restricted to the days when the total to fecal ratio was greater than 5 for the water samples taken at 400 yards for a given beach (we noted that the enterococci count was always less than 106 during these times). The rationale was to exclude days when the plume from the drain (or some other source of higher counts, such as septic tanks) apparently reached the 400 yard point, making this point less than an ideal "control" zone. The prior expectation was that health risks associated with distance should increase since we "cleaned up" the control area. Results are presented in Tables 24-30. The relative risk point estimates for the seven outcomes found significant above (fever, chills, ear discharge, vomiting, coughing with phlegm, HCGI 2, and SRD) all increased for the 0 yards versus 400+ yards comparison (see Table 24). The interval estimates were wider since the results were based on fewer numbers of subjects. It was also of interest to see if health effects were observed for the other distances of 1-50 and 51-100 yards versus 400+ yards from the drain. A number of higher RR's were observed for the effect of swimming 1-50 yards upcoast, but none reached statistical significance

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(Table 25). For subjects at 51-100 yards upcoast versus 400+ yards, significant increases in risk were observed for sore throat RR=1.45 (1.01-2.09) and SRD RR=1.91 (1.16-3.16) (Table 26). Similarly, for swimmers 1-50 yards downcoast, we observed a number of higher risks (Table 27); only the effect of SRD was statistically significant RR=1.77 (1.07-2.95). At 51-100 yards downcoast, significant increases in risk were observed for coughing, coughing with phlegm, nasal congestion, and SRD. Results are summarized in Tables 29 (downcoast) and 30 (upcoast).

Distance Effects Adjusted For Potential Confounders: We then used logistic regression to adjust for potential confounders. The resulting odds ratios provide close approximations to risk ratios and using logistic regression allows for more efficient and complex modeling of associations. Results are presented in Table 31. Adjusting for beach, age, race, gender, SES, California versus out-of-state residents, and worry about potential health hazards at the beach did not change the essential findings, although the associations for vomiting and HCGI 2 were slightly attenuated and no longer significant. It is possible, but, in our opinion, highly unlikely that we have missed a major confounder of the distance effects.

Possible Heterogeneity By Beach and By Age: We hesitate providing results for subgroups since the study was never designed to have sufficient power to detect subgroup differences. With this caveat, we explored possible differences in effects by beach and by age. Results for each beach separately are presented in Tables 32-34. There appear to be some differences in effects by beach, but it is difficult to judge what is real versus what is due to random variation with smaller numbers; the only noteworthy result from a test of heterogeneity was for earache ($p<0.01$). Results for three age categories (0-12, 13-25, 26+) are presented in Tables 35-37. It appears that children and young adults have higher risks associated with distance than older adults for a number of outcomes. In fact, the highest risks were usually noted for subjects aged 13-25 years of age. A heterogeneity test was significant only for SRD ($p=0.05$)

Associations Between Bacterial Indicators and Health Outcomes

We took a number of approaches to analyzing the effects of bacterial indicators. For each indicator, we calculated risk ratios using the higher and lower cutpoints described earlier (e.g. 200 and 400 cfu for fecal coliforms). This ratio expresses the risk of a given outcome among subjects who swam in water where the bacterial indicator was higher than the cutpoint (presumably higher risk) compared to the risk of the same outcome among subjects who swam in water where the same bacterial indicator was below the cutpoint. It was conceivable that we might have failed to detect a real increase in risk with these cutpoints, particularly since they were not based on prior data that were obtained for Santa Monica Bay, so we also calculated odds ratios from categorical models using quintiles (instead of dichotomies, as above), and from continuous models. For the categorical models, the quintile medians, total number of subjects in each quintile, and the number reporting a given symptom in each quintile are provided in the tables. For the continuous linear (on logistic scale) models, odds ratios correspond to a unit increase equal to the difference between the 90th and 10th percentiles (i.e. the difference between the midpoints of the fifth and first quintiles). Results for each bacterial indicator are presented below.

E. coli. Results are presented in Tables 38-42. We observed no effects on risk using the cutpoints of 35 or 70 cfu for any symptom (Tables 38 and 39). We also investigated effects associated with cutpoints of 160 and 320 (Table 40). At the highest cutpoint of 320, associations were observed for earache RR=1.46(1.06-2.00) and nasal congestion RR=1.24(1.00-1.53). Results for the categorical and continuous models are presented in Table 41. No effects were observed for the categorical model (quintiles). With the continuous model, small but significant effects were noted for skin rash, nausea, and stomach pain. These associations were slightly stronger for skin rash and no longer statistically significant for nausea and stomach pain after adjustment for covariates (Table 42).

Enterococcus. Results are presented in Tables 43-46. No increases in risk were detected when 35 cfu was used as the cutpoint (Table 44). When 106 cfu was used as the

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cutpoint, significant effects were noted for diarrhea with blood RR=4.23 (1.12-15.91) and HCGI 1 RR=1.44 (1.03-2.03) (Tables 43 and 44). Results from the categorical model suggest positive associations for diarrhea and stomach pain, where the odds ratios for the fifth versus first quintile were 1.31 (1.00-1.72) and 1.31 (1.02-1.68) respectively. In the continuous model, positive associations were noted for fever, skin rash, nausea, diarrhea, stomach pain, coughing, runny nose, and HCGI 1 (Table 45). The categorical findings were substantially weakened, while the continuous results were essentially unchanged after adjustment for covariates (Table 46).

Total Coliforms. Results are presented in Tables 47-50. No significant effects were seen when the cutpoint of 1,000 cfu was used (Table 48). When 10,000 cfu was used as the cutpoint, only skin rash exhibited a positive association RR=3.00 (1.86-4.83) (Tables 47 and 48). Similarly, the categorical model only showed an association with skin rash and the continuous model did not yield any associations (Table 49). Results did not materially change after adjustment for covariates (Table 50).

Fecal Coliforms. Results are presented in Tables 51-54. No significant effects were seen when 200 cfu was used as the cutpoint (Table 52). When 400 cfu was used, only an association with skin rash was evident RR=1.88 (1.21-2.94) (Tables 51 and 52). A similar effect was observed in the categorical model, where the odds ratio for skin rash comparing the fifth to the first quintile was 2.04 (1.09-3.81). In the continuous model, significant effects were observed for fever, skin rash, and HCGI 1. Adjusting for the potential confounders did not change the results except, with the continuous model, nasal congestion was now positively associated with fecal coliforms.

In addition to investigating effects for single indicators, as above, we also assessed the effects of the total coliforms to fecal coliforms ratio and the ratio of total coliforms to enterococcus. Results are summarized below.

Total coliforms to fecal coliforms ratio. As initially suggested by Jack Petralia (Los Angeles County Department of Health Services) we initially used a ratio of 5.0 for the cutpoint, assuming that the risk may be higher when the ratio is smaller than 5.0. When the effects of this ratio were estimated for the entire data set, significant effects

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were noted for diarrhea RR=1.28 (1.08--1.51) and HCGI 2 RR=1.87 (1.20-2.90) (Table 55). We then estimated effects of this ratio restricted to subjects in water where the total coliform levels were greater than 5,000 cfu. Significant effects were observed for fever, eye discharge, skin rash, nausea, diarrhea, stomach pain, nasal congestion, HCGI 1, and SRD (Table 56). The significant RR's ranged from 2-7. We then conducted a similar analysis restricted to subjects in water where the total coliform level exceeded 10,000 cfu. Here we observed significant increases in risk for eye discharge, ear discharge, skin rash, nausea, diarrhea, stomach pain, nasal congestion, HCGI 1, and HCGI 2 (Table 57). The significant RR's ranged from 2-39. Results for all three analyses (the entire data set, counts > 5,000 cfu, counts > 10,000 cfu) are summarized in Table 58. It is noteworthy that all the effects noted above became consistently stronger as the analyses were increasingly restricted to occasions with higher total counts.

Since this ratio appeared to be informative (using 5.0 as a cutpoint), we decided to explore a range of cutpoints (2, 4, 6, 8) to see which cutpoint yielded the strongest associations (Table 59a for all the data, 59b restricted to times when the total coliforms exceeded 1,000 cfu and Table 59c for occasions when the total coliforms were greater than 5,000. When the ratio cutpoints were analyzed for all days, diarrhea and diarrhea with blood were associated with the ratio at some cutpoints but no consistent patterns across cutpoints was evident. In contrast, when analysis was restricted to times when the total coliforms exceeded 5,000 cfu, there was a strong and consistent pattern of increasing RR's as the ratio decreased, with the strongest effects observed using a cutpoint of 2.0. When the analysis was restricted to times when the total coliforms exceeded 1,000 cfu, the pattern was not as strong or consistent, although most effects were again strongest using the cutpoint of 2.0.

Results for the categorical and continuous models are presented in Table 60 (note: this analysis included the entire data set). The categorical model indicated a positive association with diarrhea, coughing and coughing with phlegm and the continuous model yielded associations with diarrhea, stomach pain, cough, coughing with phlegm, and sore throat. Results were, in general, slightly weaker when adjusted for covariates (Table 61)

and statistical significance remained only for cough and cough with phlegm; nevertheless, for the associations with diarrhea, stomach pain, and sore throat from the continuous model, adjusting for covariates only shifted the lower 95% C.I. bound from 1.00 to 0.98 or 0.97.

Total coliforms to enterococci ratio. Accepted cutpoints are not available for this ratio, so the analysis explored a range of cutpoints (4, 7, 10, 13), in addition to categorical and continuous models. Results for the range of cutpoints are presented in Table 62. Diarrhea was associated with this ratio at all cutpoints with an odds ratio of 1.4-1.5. In general, the highest cutpoint of 13 yielded the greatest number of significant associations (fever, nausea, diarrhea, and stomach pain were associated with this ratio when 13 was used as the cutpoint). In the categorical model, the ratio was associated with increases in risk for nausea, diarrhea, and HCGI 1 (Table 63). In the continuous model, no effects were noted. Results were slightly weaker for nausea and HCGI-2 and essentially unchanged for diarrhea and HCGI-1 after adjustment for covariates (Table 64).

Results of Multivariate Modeling With Both Distance and Bacterial Indicators

To further assess the associations for distance and bacterial indicators, these exposures were simultaneously included in logistic regression models. Hence, in these models, distance was adjusted for the bacterial indicator and vice-versa. When modeling the potential associations with distance from the drain, including *E. coli*, enterococcus, total coliform, or fecal coliform one-at-a-time as covariates generally did not alter the findings presented here; the only differences were that earache now appeared positively associated with enterococcus (adjusted OR=1.51, 95% CI=1.0-2.28) and with fecal coliform (adjusted OR=1.61, 95% CI=1.06-2.44) comparing the highest to lowest quintile and that the total coliform-skin rash association was slightly weakened. A model that included both distance and all indicators together did not materially alter our general findings.

To investigate further the potential associations for distance and bacterial measures, we modeled the interactions between these exposures using logistic regression. In particular, we looked at the interaction between swimming (at zero or four-hundred yards from the drain) and swimming when the bacterial level was above or below the highest cutpoints used here. For example, for fecal coliform, we compared the risk for those swimming at the storm drain when fecal coliform > 400 cfu versus the risk for those swimming at 400+ yards when fecal coliform <= 400 cfu (i.e., the referent group). In addition, we compared the risk from swimming at 400+ yards when fecal coliform > 400 cfu and the risk from swimming at the storm drain when fecal coliform <= 400 cfu to the risk for those swimming at 400+ yards when fecal coliform <= 400 cfu. This type of modeling helps distinguish whether a combination of exposures (e.g., swimming at the storm drain and swimming on high count days) increases one's risk over the exposures alone. Based on these models, we observed the following noteworthy results (i.e. a pattern of increased risk associated with both high bacterial counts and distance in front of the drain). In comparison with swimming at 400+ yards when *E. coli* <= 70 cfu, the relative risk of vomiting for swimming at 400+ yards when *E. coli* > 70 cfu was 0.63 (95% CI=0.19-2.05), for swimming at the storm drain when *E. coli* <= 70 cfu was 1.26 (95% CI-0.65-2.47), and for swimming at the storm drain when *E. coli* >70 cfu was 2.11 (95% CI=1.14-3.89). The relative risk of HCGI 2 for swimming at 400+ yards when *E. coli* > 70 cfu was 0.74 (95% CI=0.38-1.44), for swimming at the storm drain when *E. coli* <= 70 cfu was 1.65 (95% CI=0.70-3.90), and for swimming at the storm drain when *E. coli* > 70 cfu was 2.45 (95% CI1.08-5.57), again in comparison with swimming at 400+ yards when *E. coli* <= 70 cfu. Finally, the relative risk of HCGI 2 for swimming at 400+ yards when enterococcus > 106 cfu was 6.34 (95% CI=0.81-49.36), for swimming at the storm drain when enterococcus <= 106 cfu was 1.71 (95% CI=0.76-3.87), and for swimming at the storm drain when enterococcus > 106 cfu was 4.68 (95% CI=1.97-11.10), in comparison with swimming at 400+ yards when enterococci <=106 cfu. Note that the interaction model for distance and total coliform did not converge.

Summary of Bacteriological Results

Tables 65-70 summarize the noteworthy distance and bacterial indicator results presented above. For each association, the relative risk and attributable number are presented. The attributable number is an estimate of the number of new occurrences of the specified outcome that are attributable to the exposure of interest. For example, based on the results from this study, the first row of table 65 indicates that approximately 259 new cases of fever will occur for every 10,000 people who swim at the drain instead of 400 yards (or more) away from the drain. These values are estimated as:

$$\text{Attributable number} = A * (RR-1) / RR,$$

where A = the number of exposed and diseased subjects, and RR = the risk ratio. The attributable numbers have an important public health interpretation: they provide an estimate of the maximum number of potential cases that could be prevented (based on the specific point estimate and assuming a causal effect) if the exposure was completely eliminated. The attributable numbers per 10,000 subjects exposed ranged into the 100's for a number of exposures. At meetings organized by the SMBRP prior to the start of the study (and attended by senior scientists who were to direct the study, SMBRP staff and technical advisors, and public health practitioners from the L.A. County Department of Health Services), an excess risk of 1 case per 100 exposed subjects was identified by verbal consensus as a "noteworthy" risk. The attributable number corresponds to this excess risk and any number above 100/10,000 represents an excess risk greater than 1/100. For bathing at the drain versus 400+ yards, attributable numbers for fever (259), chills (138), vomiting (115), coughing with phlegm (175) and SRD (303) all exceeded 100 cases/10,000 exposed. For bacterial indicators, when the entire data set was analyzed (Table 66), attributable numbers exceeded 100 cases/10,000 exposed for HCGI1 (130 for enterococcus), skin rash (165 for total coliforms), diarrhea (277 for the total to fecal ratio), nausea (147 for the total to enterococcus ratio), diarrhea (262 for the total to enterococcus ratio, and HCGI1 (111 for the total to enterococcus ratio). The attributable numbers from the continuous models were much smaller because the odds ratios from these models were relatively weak (Table 67). Table 68 presents attributable numbers for

the range of cutpoints (2, 3, 4, 5, 8) for the ratio of total to fecal coliforms for the entire data set. Diarrhea was most often associated with higher attributable numbers, but there was no consistent pattern across the range of cutpoints. When a similar analysis was done, but restricted to occasions when the total coliforms exceeded 1,000 cfu (Table 69B), the highest attributable numbers were generally associated with the cutpoint of 2.0. Many of these numbers were in the range of 100-400 cases per 10,000 exposed subjects. When this analysis was restricted to days when the total coliforms were greater than 5,000 cfu, there was a consistent pattern of higher attributable numbers associated with lower cutpoints. At the cutpoint of 2, attributable numbers ranged into the mid- and high 100's of cases per 10,000 exposed subjects for a number of outcomes. Finally, Table 70 presents a similar analysis for a range of cutpoints for the ratios of total coliforms to enterococcus. Diarrhea had the higher attributable numbers across all cutpoints (around 200 cases/10,000 exposed). Higher attributable numbers were associated with the highest cutpoint of 13.

Results of Virus Sampling Procedures

Results of the virus sampling procedures are presented in Tables 71 and 72. The percentage recovery from the seed experiments was quite high. Enteric viruses were detected on 8/11, 8/26, 9/3, 9/9, 9/10, 9/16 for Ashland; 7/21, 7/28, 8/25, 8/26, 9/9, 9/10, and 9/16 for Malibu, and 7/7, 7/18, 7/28, and 8/4 for Santa Monica Canyon. This number of positive samples did not enable us to conduct many analyses; however, we were able to compare the frequency of outcomes reported by subjects who were swimming within 50 yards of the drain on days when samples were tested for viruses and found to be negative versus days when the samples were positive for viruses. Results are presented in Table 73. Although based on small numbers, a number of outcomes were reported more often on days when the samples were positive for viruses, including fever (RR=1.53, 95% CI 0.97-2.42, p-value 0.07); vomiting (RR=1.89, 0.94-3.78), HCGI-1 (RR=1.74, 0.99-3.06) and HCGI-2 (RR=2.26, 0.91-5.60).

In Table 74, we present results for the virus analysis, adjusted for covariates. Results remained essentially unchanged. Finally, we also adjusted these results further

by including the bacterial indicators, one at a time, into the model (results not shown). These last series of adjustments made essentially no difference in the results (e.g. for fever, the crude RR=1.53 p=0.07, adjusted for covariates RR=1.56 p=0.06, adjusted for covariates plus fecal coliforms RR=1.57 p=0.06, covariates plus *E. coli* RR=1.58 p=0.06, covariates plus total coliforms RR=1.56 p=0.06, and covariates plus enterococcus RR=1.57 p=0.06).

Research with gene probes is ongoing and will be presented in an addendum to this report sometime in the near future (the lab conducting this work hopes to complete the assays by Spring, 1996).

IV. DISCUSSION

The following circumstances provided the motivation to conduct an epidemiological study of the possible acute health effects of swimming in Santa Monica Bay: A) the beaches are heavily populated in the summer months, B) there is a measurable volume of discharge into the bay from storm drains even in the summer months when there is little rainfall, C) there are numerous days with high levels of bacterial indicators, D) pathogenic human enteric viruses have been isolated from storm drain effluent even when bacterial indicator counts are low, and, E) anecdotal reports raised concern about adverse health effects of swimming in the bay. Based on numerous meetings and extensive peer review, the Santa Monica Bay Restoration Project decided that an epidemiological study of subjects swimming at selected beaches in Santa Monica Bay was the most direct and relevant means of addressing the question of possible adverse health effects.

The initial goal, as stated in the approved protocol, was to recruit 9000 subjects. Through refining our office and field techniques, we were able to complete interviews on 11,793 subjects who remained eligible throughout the follow-up phase of the study while completing the study at least $100,000 below the projected budget. Of the 22,085 subjects approached on the beach, only 1761 refused to participate, for a response rate on initial contact of 92%. Also, of the 15,492 eligible subjects interviewed on the beach, we

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were able to contact by telephone and interview 13,278 (86% follow-up). The potential for selection biases would seem to be minimal, given the high response rates. It is also worth noting that the proportions and reasons for ineligibility or loss to follow-up were similar by beach.

The three beach sites where the study was conducted, Surfrider/Malibu, Will Rogers/Santa Monica Canyon, and Santa Monica/Ashland Avenue, were selected because prior data indicated they were heavily populated and experienced a wide range of indicator counts in the past. Throughout the summer, we encountered the size of crowds we expected at Malibu and Ashland Avenue. Work at Will Rogers by the Los Angeles County Department of Public Works throughout much of the summer substantially diminished the crowds at this beach. Our prior expectation of a wide range of indicator counts was realized throughout the summer of this study. We also observed a high degree of variability from day to day, and a substantial proportion of days when levels exceeded generally established cutpoints, particularly for samples taken at the drain. Malibu and Will Rogers exceeded cutpoints more often than Ashland Avenue; in fact, the lower standard cutpoints were exceeded the majority of the time for most of the bacterial indicators at Malibu and Will Rogers. Counts were generally highest at the drain and then diminished as distance from the drain increased. Of note, however, is that the counts for water samples taken at 400 yards sometimes exceeded cutpoints at all three beaches, suggesting this distance did not always represent a "clean control area".

We operationalized the issue of health effects from swimming in Santa Monica Bay into two research questions. 1) What are the relative risks of specific health outcomes among subjects bathing at 0, 1-50, and 51-100 yards of a storm drain compared to subjects bathing at the same beach but beyond 400 yards from a drain? We reasoned that if pathogens were coming from a storm drain and causing symptoms in swimmers, the risk of these specific symptoms should be higher in subjects who swim closer to the drain. 2) Are the risks of specific outcomes associated with levels of indicator organisms (as they are commonly monitored by departments of public health). This second question is motivated primarily by policy considerations, so we wanted to test the predictive value

of feasible, common monitoring practices. Results addressing each question are discussed below.

Associations between distance and health outcomes.

We observed differences in risk when we compared subjects swimming at 0 yards (meaning where the drain enters the bay) versus subjects swimming at 400+ yards. Significant increases in risk were noted for the single symptoms of fever, chills, ear discharge, vomiting, and coughing with phlegm, and the composite variables of HCGI 2 and SRD. Most of the risk ratios ranged from 1.5-2.0, suggesting a 50-100% increase in risk. The strongest effects were for ear discharge and HCGI 2. Very few increases in risk were observed for subjects swimming at 1-50 or 51-100 yards from the drain compared to subjects swimming at 400+ yards. This was an unexpected result. We are aware of at least two alternative explanations. One is that the risk is actually limited to subjects swimming in front of the drain, possibly because the level of pathogens at greater distances from the drain was quickly diluted below an infectious dose. This seems implausible since the plume clearly traveled beyond this point and high bacterial counts were noted at 1-50 and 51-100 yards (and some of these bacterial indicators were associated with increased risk of disease). Another explanation is that the risk is highest at 0 yards, but there may also be an elevated but smaller risk at 1-50 or 51-100 yards, which we were unable to detect because the reference group (subjects at 400+ yards) was occasionally exposed to water with high bacterial counts. To address this possibility, we analyzed a subset of the data restricted to days and beaches where the total:fecal ratio for the water sample taken at 400 yards was greater than 5.0. We chose this ratio because it was associated with adverse health effects (see below). This reanalysis yielded stronger relative risks when comparing subjects at 0 versus 400+ yards (compared to the original analysis of the entire unrestricted data set) and we also observed some increases in risk at 1-50 and 51-100 yards. This suggests that risk may not be limited to the 0 yards distance, and argues against a standard that discourages swimming only at the mouth of the drain (although the risks are clearly higher there).

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The results regarding distance were not changed when we controlled for potential confounders, and are very unlikely to be due to confounding. The concern with confounding has been raised previously (Saliba 1990, Fleischer 1993, Kay 1994,), but it dealt with a different study design, sometimes referred to as the "Cabelli-type" study. In this design, risks in swimmers are compared to risks in non-swimmers. The problem with that design is that swimmers and non-swimmers are self-selected and may differ with respect to background risks since there are presumably many other exposures/pathways that can produce the symptoms under investigation. Some of these are unknown or difficult to quantify, so doubt remains, even after adjustment for the known and measured potential confounders, that the swimmers and non-swimmers are actually comparable. We implemented a design that should have substantially reduced the potential for confounding by restricting it entirely to swimmers (who immersed their heads in the water) and making comparisons between groups of swimmers (defined, for example, by distance from the drain) to estimate risk ratios. A priori, we believed that the background risk of subjects swimming closer to a drain should not be materially different from the background risk of subjects swimming farther away (they are all self-selected swimmers). When we compared a number of characteristics between subjects at different distances, the only variables that were differentially distributed by distance were age and ethnicity. Younger subjects and Latino/a subjects tended to swim closer to the drains. These variables, however, were not independent risk factors for the outcomes. When we controlled for these, as well as other covariates, there was no evidence of confounding.

We limited analyses of subgroups for three reasons: 1) the study was never designed to detect subgroup differences with reasonable power; 2) there were few reasons, a priori, to expect differences in effects between subgroups defined by most variables (e.g. gender, California resident, ethnicity, etc); and 3) policies that may emerge from this work would most likely have to apply to the "general population" and not to specific subgroups (it would seem implausible to establish one policy for one subgroup of the population defined, for example, by age, race, gender, and SES, and other policies for other subgroups). Based on discussions with interested parties, we agreed to explore

differences by beach and by age of the subjects. There appeared to be some differences when we stratified by beach; however, it is difficult to judge whether these are real differences or simply the result of random variation with smaller sample sizes per subgroup. When we stratified by age into three categories (0-12, 13-25, >25), the increased health risks observed earlier appeared to be stronger for children and adults less than 25. In fact, the strongest associations were usually evident in the 13-25 year age group. We presume this is due mostly to their increased activity (and hence exposure) in the water, which we did not attempt to quantify, and less so to any increased susceptibility for a given dose of exposure.

We decided not to restrict recruitment to one subject per family for two reasons. 1) It would have been impossible to achieve the sample size we needed. As it was, we approached every single potentially eligible subject throughout the study period to achieve our sample size. 2) We believed it would have been very difficult to only select and recruit one subject per family and explain this to the satisfaction of the family. Given the strong reasons for accepting other family members, we decided to proceed with this plan since we believe the effects on our results and conclusions are trivial. When we consider the effects of possible intra-familial transmission, the following distinction is helpful. If a case of illness was caused by swimming at a study beach and that case infects other family members and results in illness, all of these cases are rightly attributed to the swimming related exposure. On the other hand, if a case of illness was caused by some other exposure and this case transmitted the infection to other cases in the family during the follow-up period for that family, these cases should not be (and are not) attributed to the swimming exposure. Families such as these should be distributed similarly by distance from the drain and by levels of indicator counts and are reflected in the background rates. To the extent this happened, it would reduce our power only. Nevertheless, to further address this issue, we included a family variable as a covariate (controlling for it in the logistic models did not change any of the results) and stratified the results by this variable to look for heterogeneity (and similar effects were noted in the stratum comprised of single subjects and the stratum comprised of subjects from families

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where more than one subject per family was included). We have added results and text to the Results and Discussion sections to address this issue.

Associations between bacterial indicators and health outcomes.

In general, when we estimated risk ratios using the established cutpoints, there were very few positive associations with any single indicator. There were none for *E. coli* at the lower cutpoints of 35 and 70 cfu. At the highest cutpoint of 320 cfu, earache and nasal congestion were weakly associated with *E. coli*. Only skin rash was associated with total and fecal coliforms at the higher cutpoints of 10,000 cfu and 400 cfu, respectively. Enterococci were positively associated with diarrhea with blood and HCGI 1 at the higher cutpoint of 106 cfu. The risk of diarrhea with blood was four times higher, but this estimate was based on very few cases. There was about a 40-50% increase in risk of HCGI, consistent with previous results by Cabelli (1982) and Genthe (preprint).

We recognize that these cutpoints do not have a strong scientific basis, particularly when applied to West Coast beaches with heavy urban runoff such as Santa Monica Bay, so we also investigated possible effects of the bacterial indicators with the use of categorical models (where quintiles were assessed) and continuous models. For the most part, the categorical models yielded results similar to the dichotomous results described above. The continuous models generally yielded more positive associations, particularly for enterococci. No additional associations were detected for total coliforms; fever, skin rash, and HCGI 1 were associated with fecal coliforms; skin rash, nausea, and stomach pain were associated with *E. coli*. Continuous results for enterococci indicate positive associations with fever, skin rash, nausea, diarrhea, stomach pain, coughing, runny nose, and HCGI 1.

In addition to evaluating single indicators, associations with the total coliform to fecal coliform ratio and the total coliform to enterococci ratio were investigated. For the total:entero ratio, the categorical model indicated inverse associations with nausea, diarrhea, and HCGI 1. This ratio was not more predictive of health risks than the continuous model for enterococci alone. In contrast, the ratio of total to fecal coliforms proved to be quite informative. There were two components to the rationale for this

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analysis. First, as the level of fecal coliforms increased relative to total coliforms (i.e. the ratio was low), concern increased that there was substantial fecal contamination of the storm drain, possibly increasing risk of adverse health effects. Second, the effect of this lower ratio should be stronger when there was a higher degree of contamination, indicated by total coliform counts in excess of 1,000, 5,000 or 10,000 cfu. The results were consistent with this rationale. Using a ratio of 5.0 as the cutpoint, diarrhea and HCGI 2 were associated with a lower ratio when all the data were analyzed, regardless of the absolute level of total coliforms. When this analysis was restricted to subjects in water where the total coliforms exceeded 5,000 cfu, significantly higher risks were detected for nine different outcomes. Further, when this analysis was restricted to subjects in water where the total coliforms exceeded 10,000 cfu, the risk ratios for these nine outcomes all increased again (with the absolute risk in the exposed group reaching 14-19% for each symptom). Although the number of subjects became small in some subgroups, the strong consistency of the results across the increasing levels of total coliforms is persuasive that the associations are probably real. Which cutpoint (for the ratio) is associated most consistently with risk is an important question. When a range of cutpoints (2, 3, 4, 5, 6, 8) was analyzed using the entire data set, no consistent pattern emerged. This is not entirely surprising since an analysis of all data points treats all ratios of similar numerical value equally, even though a ratio of 5 when the total coliforms are very low may not increase risk (although the same ratio of 5 may be associated with increased risks when the density of total coliforms is high (say, above 1,000 or 5,000 cfu). When this type of analysis was restricted to days when the total coliform densities were high (above 1,000 cfu and particularly above 5,000) a consistent pattern emerged, with higher risks and attributable numbers associated with low ratios.

For reasons developed in the previous section on distance effects, it is very unlikely that the bacterial indicator associations observed in this study are confounded to any substantial degree. It is highly unlikely that the background risks are different for subjects exposed to higher or lower levels of a given indicator level, which were unknown to the subjects, particularly if one stratifies by distance.

It is worth considering which bacterial indicators are the most useful. This will depend, of course, on criteria used to define "usefulness". It would seem that the magnitude of the attributable numbers and the frequency that selected cutpoints are exceeded may be useful components of any set of criteria. From Tables 66 and 67, when all data are considered together no single indicator (or ratio of indicators) stood out as having the highest attributable numbers. Enterococci (at levels above 106 cfu) were associated with an attributable number of 130 cases of HCGI 1 per 10,000 exposed subjects; total coliforms (at levels above 10,000 cfu) were associated with an attributable number of 165 cases of skin rash; the ratio of total to fecal coliforms had an attributable number of 277 cases of diarrhea; and the ratio of total coliforms to enterococci had attributable numbers of 147 and 262 for nausea and diarrhea, respectively. From the continuous models, enterococci had the greater number of associations but the effects (estimated by odds ratios) and the attributable numbers were small. The largest attributable numbers were observed for the total to fecal coliforms ratio when the analyses were restricted to subjects in water where the total coliforms exceeded 5,000 cfu. The attributable numbers increased very consistently as the ratio decreased from 8 to 6 to 5 to 4 to 2. However, these stronger effects would be limited to a smaller proportion of the beach going population (those swimming in water where the total coliforms exceeded 5,000 cfu). It is also worth noting (from Table 65) that the effect of swimming at the drain (0 yards) versus 400+ yards from the drain was associated with relatively large attributable numbers (e.g. 303/10,000 exposed subjects for SRD, 115 for vomiting, 175 coughing with phlegm).

We very briefly review results of other studies to lend a broader context to our results, although we point out that results of other studies may not be relevant to the situation in Santa Monica Bay and different designs were employed in these other studies.

The question of whether acute infectious disease can be acquired through bathing in marine water contaminated with sewage has been the subject of several large epidemiological studies conducted throughout the world. The most consistent finding of

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these studies is that bathers, defined as those that immerse their heads in water while swimming, are at a higher risk of contracting gastrointestinal (GI) disease than those who do not immerse their heads, the non-bathers. However, this has not always been observed. Another aspect of these studies has been to investigate whether elevated counts of certain bacterial indicators commonly found in sewage contaminated water are predictive of disease, even though the bacteria themselves may not be pathogenic. To date, the reported results trying to associate elevated indicator counts with health outcomes have been inconsistent.

Cabelli (1979) was the first investigator to demonstrate an association between water quality at ocean beaches and health outcomes. He conducted a large, prospective cohort study of 8,000 subjects sponsored by the EPA that has subsequently become a classic study of health outcomes and marine water quality. The study compared symptom rates among bathers and non-bathers at two beaches that had been classified as relatively unspoiled (RU) and barely acceptable (BA) using coliform counts as the indicators to make this determination. Family groups were interviewed on the beach to document bathing behavior and again by phone 8-10 days later to assess the development of GI and respiratory symptoms. Water sampling for bacterial indicators (total and fecal coliforms, *E. coli*, Enterobacter, Enterococcus, Klebsiella and P. aeruginosa) was done concurrently at the two beaches. The BA beach not only reported higher symptom rates than the RU beach but also mean levels of the bacterial indicators were significantly higher than at the RU beach. A noteworthy result of this study was that measurable health effects occurred at both marine beaches within guidelines (total and fecal coliforms standards) developed for fresh water beaches.

Cabelli (1982) next used the results of a large prospective cohort study to develop a linear regression model for the relationship between mean enterococci density and gastroenteritis among bathers. Almost 26,000 subjects were identified on weekends over a six year period in three locations: two ocean beaches (New York and Boston), and one brackish/fresh water lake (Louisiana). Exposure status (bathers were defined in Cabelli's study as having the head immersed underwater, non-bathers included waders and those

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who stayed out of the water) was determined by interview on each study day. Individuals who swam immediately prior to or after the weekend under study were excluded from the analysis. Incidence of gastroenteritis was obtained by telephone interview 8-10 days later; subjects did not make use of a toll-free number or local clinic for medical advice/diagnosis. Enterococci densities were determined for each study day. Based upon the results of the regression analysis, the authors concluded that bathing in water containing as little as 10 enterococci/100 ml of sample represented an absolute risk of GI illness of 10 per 1000 bathers and a relative risk of 2.0 comparing bathers and non-bathers.

Current EPA criteria concerning the sanitary quality of marine waters are based upon these results (Cabelli, 1984; Cabelli, 1989). Several criticisms have been leveled against the 1982 study (Fleisher, 1991): (1) Results were pooled for marine and estuarine water locations, despite the fact that survival of pathogenic organisms may be inversely correlated with salinity (Dufour, 1984); (2) Results from several beach locations were combined without considering local differences in marine flora, sewage outflow, immunity/demographic characteristics of subjects, beach contour and sediment/turbidity characteristics. Fleisher's analysis of Cabelli's data showed significant variation in the mathematical relationship between indicator levels and disease outcome among the beaches studied: in addition, a surprisingly poor fit for HCGI relative to total GI symptoms in the linear regression model led Fleisher to fit an alternative (logistic) model to the data -- one with more "biological support" -- choosing covariates "not based solely on statistical considerations but rather on hypotheses generated by previous epidemiologic studies" (Fleisher, 1991, p. 262). From this reanalysis, Fleisher concluded that "not only the magnitude...but the existence of any relationship between enterococci density and gastroenteritis may be site specific" (Fleisher, 1991, p. 263). (3) Cabelli had speculated earlier (1979) that the primary disease outcome -- an acute, relatively mild gastroenteritis which had a short incubation period and duration -- was most compatible with exposure to human rotaviruses or Norwalk-like viruses, so that estimates of water

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quality based upon proxy measures might be subject to considerable error (further discussed below).

The Cabelli-EPA study design has been endorsed by the World Health Organization and the United Nations environment program. "Cabelli-style" ocean studies have been carried out at a number of locations throughout the world. Most report higher morbidity among bathers (head immersed in water) as compared to non-bathers for gastrointestinal illness, eye and ear infections. Correlations with indicator organisms however are inconsistent (for review, see Saliba 1990). In Hong Kong (Cheung, 1990), Staphylococci levels were correlated with ear, respiratory, and total illness, while *E. coli* was found to be the best predictor of gastroenteritis. In South Africa (von Schirnding, 1992), bathers and non-bathers were compared for incidence of gastro-intestinal, respiratory, and skin symptoms at two beaches, one with high levels of indicators (enterococcus and coliforms) and the other relatively clean: symptom rates were higher for swimmers at the polluted beach, but "were not statistically significant." In the United Kingdom (Balarajan, 1991), enterococcus and coliform levels "varied appreciably" and could not be correlated with illness; overall, a relative risk of 1.31 (95% confidence interval 1.04 to 1.64) was obtained for occurrence of at least one symptom (GI, respiratory, other) in bathers compared to non-bathers after controlling for age and sex. Genthe (19..) reported that enterococcus was the most predictive of gastroenteritis, although fecal coliforms were also significantly associated with risk. Staphylococcus was not associated with risk. Several investigators have recently suggested that these studies may underestimate the true risk: (1) Non-differential measurement error in estimated organism densities could result in a 30 to 57% underestimate of true risk (Fleisher, 1990). Both the MPN and MF methods of enumerating coliforms are imprecise; Fleisher points out that none of the studies cited above made use of replicate determinations on individual samples, nor did they consider diurnal and other variations which may occur in bacterial indicator levels, particularly at marine locations. (2) Bacterial indicators do not reflect the occurrence of enteroviruses in marine waters, which are likely to be the true pathogen of interest (Gerba, 1979), nor do they reflect levels of Vibrio spp., marine

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pathogens recently linked to a variety of human health outcomes including necrotizing wound infections (Howard, 1988) (3) These studies attempted to gain power by including subjects from a variety of locations without accounting for variations between beaches. Smaller studies focussing on subgroups (such as snorkelers, windsurfers, and bathers) within a given location have reported a more pronounced effect (Dewailly, 1986; Philipp, 1985; Deitmer, 1990); for example, Dewailly reported a relative risk of 5.5 for symptoms of gastroenteritis among windsurfers at a specific estuarine location.

Using a Cabelli-like approach the New Jersey Department of Health commissioned a large prospective cohort study in the late 1980's to investigate water quality and health outcomes after swimming in fresh and ocean water in that state. 16,089 subjects were recruited from nine ocean and two lake beaches. Again, bathers and non-bathers were identified, interviewed on the beach and telephoned up to 10 days later to ascertain the development of symptoms. Water sampling for bacterial indicators, total and fecal coliforms, enterococcus, C. Perfringens as well as F2 male-specific bacteriophage (developed by Cabelli et al to estimate levels of viral pathogens) was concurrently done. Bathers at all beaches had higher symptom rates than non-bathers (an excess of 12.1 cases per 1000 subjects was reported) even though illness could not be correlated with any elevation of any of the bacterial indicators. However, these findings are not surprising since none of the beaches were located near any areas of heavy urban run-off. The water tested was "generally of high quality"[3] leading the authors to conclude that the observed health effects were "the natural consequences of bathing, not the result of contaminated water".

A number of concerns have been raised about the New Jersey study. (See our original proposal for a detailed description - available from the Santa Monica Bay Restoration Project). Some of the concerns were: (1) The study had little power to detect an association between health effects and sewage contamination. None of the beaches studied were located near heavy urban runoff areas, so that the water tested was "generally of high quality" at all beaches. Little variability in indicator levels was observed between sampling sites, so that the effect of a range of indicators (either within

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or across beaches) was not assessed. Water samples were collected only at chest depth and not ankle depth; children (at increased risk for symptoms in most studies when compared with adults) wade, play and swim in the near shore areas where their activities and wave action may disturb sediments, releasing absorbed bacteria and virus into the water. (2) The conclusions rely heavily on p-values. Measures of effect, such as risk ratios with confidence intervals, were not calculated. (3) The issue of residual confounding was not addressed; confounding may be due to lack of comparability of exposed and unexposed groups.

Finally, it should be noted that Cabelli-like studies are not the only kind that have been used to investigate health outcomes after immersion in marine water contaminated by sewage. Fleisher, (1993) using a randomized intervention and follow-up design, conducted the first epidemiological study that related indicator organism density to an individual bather. In 1989 and 1990, he recruited 484 subjects from various locations in the United Kingdom. Subjects were given an interview, a physical exam to exclude ongoing illness and then randomly assigned to a bather or non-bather group. On the day of the trial non-bathers were assigned to a roped off beach area while bathers were carefully monitored. Water sampling for elevated bacterial indicators, total and fecal Coliforms as well as enterococcus (in his papers, Fleisher uses the older nomenclature for enterococcus, Streptococcus faecalis) was done at the actual time bathers were in the water. Food consumption habits at the time of the trial were also monitored in order to exclude food-borne illness as a confounder. After the trial, follow-up for GI disease was done through either an interview or a mailed questionnaire. Results showed that only enterococcus cultured from water samples taken from the surface at chest depth was predictive for development of GI symptoms. Fleisher continued the randomized intervention and follow-up studies with more detailed follow-up exams after bathing (1993), the results of which still support enterococcus as the best predictor of GI disease.

As was mentioned, the study design employed here is different in fundamental ways from the study designs commonly employed by other investigators. The major difference between the design used here and the Cabelli-type study design is that all of

our analyses were between different groups of swimmers whereas studies employing the Cabelli-type design compare risks between swimmers and non-swimmers. A major challenge with the Cabelli-type design is to ensure comparability between swimmers and non-swimmers. For example, in one of Cabelli's studies, there was an anomalous finding among children of a significantly higher rate of gastrointestinal symptoms for nonbathers relative to bathers at the unpolluted beach, suggesting that the two groups were not comparable. Perhaps parents tended to keep children out of the water who were feeling ill or incubating gastrointestinal illnesses. Differences between persons who choose to bathe and those who do not are difficult to measure and account for in the analysis of such studies (Saliba, 1990). The Cabelli-type design is similar to the one used here in that it is an observational cohort study and it relies on measurements of bacterial indicators that are feasible on a large scale and are similar to those that are commonly practiced by various health agencies. Fleischer (1993) and Kay (1994) have raised additional concerns with this type of study. The major concern deals with measurement errors and misclassification of exposure status due to "failure to control for the substantial amount of temporal and spatial variation in indicator organism densities shown to occur within just a few hours at marine water bathing locations" and the fact that "the microbiological quality of water was not assigned to each bather at the time and place of bathing".

To address the concerns with confounding and misclassification of exposure status, Fleischer and Kay used a very different design. Instead of an observational study, they used a randomized trial wherein subjects were randomly assigned to bathing and non-bathing groups and numerous water samples were taken every half-hour over the exposure period every 20 meters and at three depths (at surf, mid, and chest depths). In principle, if the trial is large enough, randomization should generate a balance between comparison groups ("exposed" and "unexposed") with respect to the distribution of other risk factors for the health outcomes under study. Also, as they argue, the water testing protocol should reduce misclassification of exposure status for individual subjects.

As we see it, with respect to measurement of bacterial indicators, the two approaches are addressing slightly different questions and may be seen, at some level, as complementing each other. The approach taken by Fleischer aims at estimating a more accurate dose-response relationship for indicator counts as they pertain to individuals by reducing misclassification of exposure for individual subjects as it pertains to this objective. This generates interesting, useful data and may detect associations missed by a Cabelli-type approach, but it is also a step further removed from helping to set policy based on bacterial indicators. Given a predictive result generated from this more intense sampling scheme, the policy implication for where, when, and what to monitor for is not obvious, given limited resources of the agencies responsible for monitoring. For example, Kay (1994) suggests that, based on their results, enterococci should replace coliforms as the basis for setting standards and that adverse health effects were identified when concentrations exceeded 32 per 100 ml. It is not so obvious where and when one should monitor for enterococci. Clearly the intense protocol used in the trial is not feasible. If one does less (read less accurate in terms of assessing exposure for a given subject) monitoring, the nature of the dose-response curve probably changes since "dose" is being measured differently. A level of 32 per 100 ml may no longer be associated with the same risk as in the trial. The approach taken by Cabelli addresses more directly the question of whether bacterial indicators, as they are commonly measured by health departments, do in fact predict risk of adverse health effects. If the results of such a study are negative, as they have been in a number of studies with respect to specific indicators, the only appropriate conclusion is that these indicators, **as measured**, do not predict risk. Left unanswered is whether different, perhaps more intense, sampling and measurement protocols would yield different results. If the results are positive, the connection to a monitoring policy is more obvious since the sampling scheme employed in the study is close to the usual monitoring protocol.

Since there is no perfect design for all scientific and policy purposes, we settled on an observational design that would minimize the potential for confounding, which we viewed as a major lingering concern with previous studies. We had doubts about the

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feasibility and ethics of trying to conduct a randomized trial given the "charged" nature of the debate regarding Santa Monica Bay. Given the observational design, we chose to focus on two questions (Is distance associated with risk of adverse health outcomes? Do bacterial indicators, as they are commonly monitored, predict risk of adverse health outcomes?) that were primarily motivated by policy considerations.

Aside from the emphasis on distance and bacterial indicators, this is the first large scale study of which we are aware that also included measurements of viruses. The standard method, which appeared to be running very well, as judged in part by the excellent recovery rates, detected virus on a number of occasions. Only limited statistical analysis was possible. It was of interest that a number of adverse health effects were reported more often on days when the samples were positive, suggesting assays for viruses may be informative for predicting risk. The research involving gene probes is ongoing. We hope to include the results as an addendum to this report. Cabelli (1982) and Kay (1994) both mention that Norwalk-like viruses are a plausible cause of gastroenteritis. Enteroviruses, the commonest viruses in sewage effluent, can cause respiratory symptoms. As pointed out by Walker (1992), testing for viruses is potentially important. Not only are viruses potentially responsible for many of the symptoms associated with swimming in ocean water but they decay at a slower rate in sea water than bacteria and they can cause infection at a much lower dose.

In summary, we believe that the results of this study are valid for the purposes of addressing the two research questions we posed in the beginning. Distance from the storm drain, particularly swimming in front of the storm drains that we studied, is associated with an increased risk for a relatively broad range of adverse health effects, including HCGI and significant respiratory disease. A number of bacterial indicators, particularly the total coliforms to fecal coliforms ratio and enterococcus, measured in a manner similar to routine monitoring, are also associated with increased risk of adverse health effects. Both sets of results suggest that there is an increased risk of a relatively broad range of symptoms caused by swimming adjacent to the drains at the beach sites included in this study. The estimated attributable numbers, which reached into the 100's

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per 10,000 exposed subjects, suggest these risks are not trivial when we consider the millions of persons who visit the beaches in Santa Monica Bay. In numerous discussions organized by the SMBRP, prior to the start of this study, an excess risk of 1 case per 100 exposed was generally considered a noteworthy health risk, so the study was designed to detect this level of risk (of course, the relative magnitude of these risks compared to other health risks will be a matter of judgement by interested parties). It is also probable that the risk is higher than we observed in this study since both distance and bacterial indicators are proxy measures of the actual pathogens causing these adverse health effects. It is worth recalling here that we excluded subjects who frequently entered the water at these beaches. We did this so we could link reported outcomes with a specific set of bacterial indicators for the one day and place a subject was in the water, which we needed to address the second research question we posed. If there is a dose-response relationship such that increasing exposure is associated with increasing risk, which seems plausible, then one may conclude that surfers, lifeguards, and other subjects who frequently enter the water and immerse their heads may be at an increased risk of adverse health outcomes (perhaps substantially so) than the relatively infrequent recreational swimmers included in this study. A counter-argument that has been raised is that frequent swimmers may develop an immunity to the pathogens and thereby have a lower risk. This would seem to be an important issue that warrants further study. Surfers would seem to be an appropriate group to study since there are not enough lifeguards at a given beach to achieve the statistical power one needs. The study design would have to be different than the one used here to address the issue of frequent use. Interested readers are referred to the original proposal for this study, where an adjunct study of surfers was presented. We consider the policy implications of the present study to be beyond the scope of this final report. They will be the subject of a separate report issued by the Santa Monica Bay Restoration Project.

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LIST OF VARIABLES

ITEM	RANGE	CODES
BEACH ID	A,M;W	A=ASHLAND,M=MALIBU,W=WILL ROGERS
PARTICIPANT #	1-12500	
RELATION	A,B,C,D,E,F,G,H,I,J	
PRE PRINTED #	1-12500	
BEACH INT MONTH	06-10	06=JUNE,07=JULY,08=AUG,09=SEPT,10=OCT
BEACH INT DAY	1-31	
PHONE INT MONTH	06-10	06=JUNE,07=JULY,08=AUG,09=SEPT,10=OCT
PHONE INT DAY	1-31	
WATER CLEAN?	1-2	1=NO,2=YES
GENDER	1-2	1=FEMALE,2=MALE
AGE	1-9	1=0-12,2=13-18,3=19-25,4=26-35,5=36-45,6=46-55,7=56-65,8=66-75,9=>75
EXACT AGE FOR UNDER 12	1-12	
MAP CODE	1-8	
BEACH INTR #	0-999	
PHONE INTR #	0-999	
Q1 FACE WET	1-2	1=NO FACE NOT WET,2 YES FACE GOT WET
Q2	1-3	1=NO CHILD DID NOT GET FACE WET,2=YES GOT FACE WET,3=DON'T KNOW/REMEBER
Q3.1.A FEVER	1-3	1=NOT HAVE SYMPTON SINCE VISIT,2=YES HAD SYMPTON SINCE VISIT, 3=DK
Q3.1.C FEVER	2	2=EVENT DUE TO BEACH VISIT
Q3.2.A CHILLS	1-3	1=NOT HAVE SYMPTON SINCE VISIT,2=YES HAD SYMPTON SINCE VISIT, 3=DK
Q3.2.C CHILLS	2	2=EVENT DUE TO BEACH VISIT
Q3.3.A EYE DISCHARGE	1-3	1=NOT HAVE SYMPTON SINCE VISIT,2=YES HAD SYMPTON SINCE VISIT, 3=DK
Q3.3.B EYE DISCHARGE	1-3	1=NOT HAD SYMPTON BEFORE VISIT,2=YES HAD SYMPTOM BFORE VISIT, 3=DK
Q3.3.C EYE DISCHARGE	2	2=EVENT DUE TO BEACH VISIT
Q3.4.A EARACHE	1-3	1=NOT HAVE SYMPTON SINCE VISIT,2=YES HAD SYMPTON SINCE VISIT, 3=DK
Q3.4.B EARACHE	1-3	1=NOT HAD SYMPTON BEFORE VISIT,2=YES HAD SYMPTOM BFORE VISIT, 3=DK
Q3.4.C EARACHE	2	2=EVENT DUE TO BEACH VISIT
Q3.5.A EAR DISCHARGE	1-3	1=NOT HAVE SYMPTON SINCE VISIT,2=YES HAD SYMPTON SINCE VISIT, 3=DK
Q3.5.B EAR DISCHARGE	1-3	1=NOT HAD SYMPTON BEFORE VISIT,2=YES HAD SYMPTOM BFORE VISIT, 3=DK
Q3.5.C EAR DISHCARGE	2	2=EVENT DUE TO BEACH VISIT
Q3.6.A SKIN RASH	1-3	1=NOT HAVE SYMPTON SINCE VISIT,2=YES HAD SYMPTON SINCE VISIT, 3=DK
Q3.6.B SKIN RASH	1-3	1=NOT HAD SYMPTON BEFORE VISIT,2=YES HAD SYMPTOM BFORE VISIT, 3=DK
Q3.6.C SKIN RASH	2	2=EVENT DUE TO BEACH VISIT
Q3.7.A INFECTED CUT	1-3	1=NOT HAVE SYMPTON SINCE VISIT,2=YES HAD SYMPTON SINCE VISIT, 3=DK
Q3.7.B INFECTED CUT	1-3	1=NOT HAD SYMPTON BEFORE VISIT,2=YES HAD SYMPTOM BFORE VISIT, 3=DK
Q3.7.C INFECTED CUT	2	2=EVENT DUE TO BEACH VISIT

SARB_000423

Q3.8.A NAUSEA	1-3	1=NOT HAVE SYMPTON SINCE VISIT,2=YES HAD SYMPTON SINCE VISIT, 3=DK
Q3.8.B NAUSEA	1-3	1=NOT HAD SYMPTON BEFORE VISIT,2=YES HAD SYMPTOM BFORE VISIT, 3=DK
Q3.8.C NAUSEA	2	2=EVENT DUE TO BEACH VISIT
Q3.9.A VOMITING	1-3	1=NOT HAVE SYMPTON SINCE VISIT,2=YES HAD SYMPTON SINCE VISIT, 3=DK
Q3.9.B VOMITING	1-3	1=NOT HAD SYMPTON BEFORE VISIT,2=YES HAD SYMPTOM BFORE VISIT, 3=DK
Q3.9.C VOMITING	2	2=EVENT DUE TO BEACH VISIT
Q3.10.A DIARRHEA	1-3	1=NOT HAVE SYMPTON SINCE VISIT,2=YES HAD SYMPTON SINCE VISIT, 3=DK
Q3.10.B DIARRHEA	1-3	1=NOT HAD SYMPTON BEFORE VISIT,2=YES HAD SYMPTOM BFORE VISIT, 3=DK
Q3.10.C DIARRHEA	2	2=EVENT DUE TO BEACH VISIT
Q3.11.A DIARRHEA W/ BLOOD	1-3	1=NOT HAVE SYMPTON SINCE VISIT,2=YES HAD SYMPTON SINCE VISIT, 3=DK
Q3.11.B DIARRHEA W/ BLOOD	1-3	1=NOT HAD SYMPTON BEFORE VISIT,2=YES HAD SYMPTOM BFORE VISIT, 3=DK
Q3.11.C DIARRHEA W/ BLOOD	2	2=EVENT DUE TO BEACH VISIT
Q3.12.A STOMACH PAIN	1-3	1=NOT HAVE SYMPTON SINCE VISIT,2=YES HAD SYMPTON SINCE VISIT, 3=DK
Q3.12.B STOMACH PAIN	1-3	1=NOT HAD SYMPTON BEFORE VISIT,2=YES HAD SYMPTOM BFORE VISIT, 3=DK
Q3.12.C STOMACH PAIN	2	2=EVENT DUE TO BEACH VISIT
Q3.13.A COUGHING	1-3	1=NOT HAVE SYMPTON SINCE VISIT,2=YES HAD SYMPTON SINCE VISIT, 3=DK
Q3.13.B COUGHING	1-3	1=NOT HAD SYMPTON BEFORE VISIT,2=YES HAD SYMPTOM BFORE VISIT, 3=DK
Q3.13.C COUGHING	2	2=EVENT DUE TO BEACH VISIT
Q3.14.A COUGH W/ PHLEGM	1-3	1=NOT HAVE SYMPTON SINCE VISIT,2=YES HAD SYMPTON SINCE VISIT, 3=DK
Q3.14.B COUGH W/ PHLEGM	1-3	1=NOT HAD SYMPTON BEFORE VISIT,2=YES HAD SYMPTOM BFORE VISIT, 3=DK
Q3.14.C COUGH W/ PHLEGM	2	2=EVENT DUE TO BEACH VISIT
Q3.15.A RUNNY NOSE/CONGES	1-3	1=NOT HAVE SYMPTON SINCE VISIT,2=YES HAD SYMPTON SINCE VISIT, 3=DK
Q3.15.B RUNNY NOSE/CONGES	1-3	1=NOT HAD SYMPTON BEFORE VISIT,2=YES HAD SYMPTOM BFORE VISIT, 3=DK
Q3.15.C RUNNY NOSE/CONGES	2	2=EVENT DUE TO BEACH VISIT
Q3.16.A SORE THROAT	1-3	1=NOT HAVE SYMPTON SINCE VISIT,2=YES HAD SYMPTON SINCE VISIT, 3=DK
Q3.16.B SORE THROAT	1-3	1=NOT HAD SYMPTON BEFORE VISIT,2=YES HAD SYMPTOM BFORE VISIT, 3=DK
Q3.16.C SORE THROAT	2	2=EVENT DUE TO BEACH VISIT
Q4 WORRIED ABOUT HAZARD	1-4	1=NOT AT ALL WORRIED,2=SOMEWHAT WORRIED,3=A LITTLE WORRIED,4=VERY WORRIED
Q5 ETHNIC BACKGROUND	1-6	1=WHITE,2=BLACK,3=LATINO,4=ASIAN,5=MULTI-ETHNIC,6=OTHER
Q6 ZIP CODE	0-99999	
MEDIAN INCOME FOR ZIP		MEDIAN HOUSEHOLD INCOME FOR RESPONDENTS ZIP CODE
RECODED AGE	1-2	1=0-12,2=>12
RECODED MAP AREA	1-2	1=DIRTY (AREAS 0/3/4/5/6),2=CLEAN (AREAS 1/8)
E COLI FROM SAMPLE AREA1		
E COLI FROM SAMPLE AREA2		
E COLI FROM SAMPLE AREA3		
E COLI FROM SAMPLE AREA4		

SARB_000424

LIST OF VARIABLES

E COLI FROM SAMPLE AREA5		
ENTEROCOCCUS AREA1		
ENTEROCOCCUS AREA2		
ENTEROCOCCUS AREA3		
ENTEROCOCCUS AREA4		
ENTEROCOCCUS AREA5		
FECAL COLIFORMS AREA1		
FECAL COLIFORMS AREA2		
FECAL COLIFORMS AREA3		
FECAL COLIFORMS AREA4		
FECAL COLIFORMS AREA5		
TOTAL COLIFORMS AREA1		
TOTAL COLIFORMS AREA2		
TOTAL COLIFORMS AREA3		
TOTAL COLIFORMS AREA4		
TOTAL COLIFORMS AREA5		
FLOW		
FAMILY SIZE		1=INDIVIDUAL,2-9=FAMILY SIZE
HCGI_1		
HCGI_2		
SRD		

SARD_000425

Table 1. Completed Interviews by Beach Interview Date

JUNE

	22	23	24	25	26	27	28	29	30	total
Ashland	15	4	61	103	16	19	22	34	20	294
Malibu	3	5	39	36	2	28	13	20	15	161
W Rogers	8	0	13	17	5	11	2	9	13	78
total	26	9	113	156	23	58	37	63	48	533

JULY

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	monthly total
Ashland	114	159	108	133	20	31	52	72	238	43	75	45	46	50	115	41	42	31	39	21	54	181	338	32	29	55	69	51	265	244	31	2824
Malibu	32	70	15	31	21	18	23	37	66	39	22	39	62	40	81	61	43	29	49	32	61	62	139	41	31	38	58	38	196	135	37	1614
W Rogers	38	43	39	31	10	10	21	18	34	34	37	27	37	30	69	26	13	2	20	28	26	45	84	57	13	9	8	30	58	138	18	1053
total	184	272	162	195	51	59	96	127	338	116	134	111	145	120	265	128	98	62	108	81	141	288	561	130	73	102	135	119	519	517	86	5523

AUGUST

BEACH	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	monthly total
Ashland	17	13	29	20	72	203	16	29	12	47	40	166	287	24	22	11	17	21	121	99	18	16	25	18	32	116	151	49	18	37	8	1754
Malibu	51	21	19	18	57	117	20	52	77	35	74	139	101	43	25	19	32	60	117	71	26	21	31	56	21	66	134	30	31	2	45	1611
W Rogers	3		5	7	70	25	29	26	9	32	41	56	56	8	7	2	1	21	10	16	4	0	1	7	8	33	36	3	7	12	6	541
total	71	34	53	45	199	345	65	107	98	114	155	361	444	75	54	32	50	102	248	186	48	37	57	81	61	215	321	82	56	51	59	3906

SEPTEMBER

BEACH	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	monthly total
Ashland	38	118	346	357					21	77						29	20						23	19								1048
Malibu	13	126	150	245					21	30						26	24							15								650
W Rogers	16	28	62	27																												133
total	67	272	558	629	0	0	0	0	42	107	0	0	0	0	0	55	44	0	0	0	0	0	23	34	0	0	0	0	0	0	0	1831
																																11793

SARB_000426

Figure 1. Study Eligibles

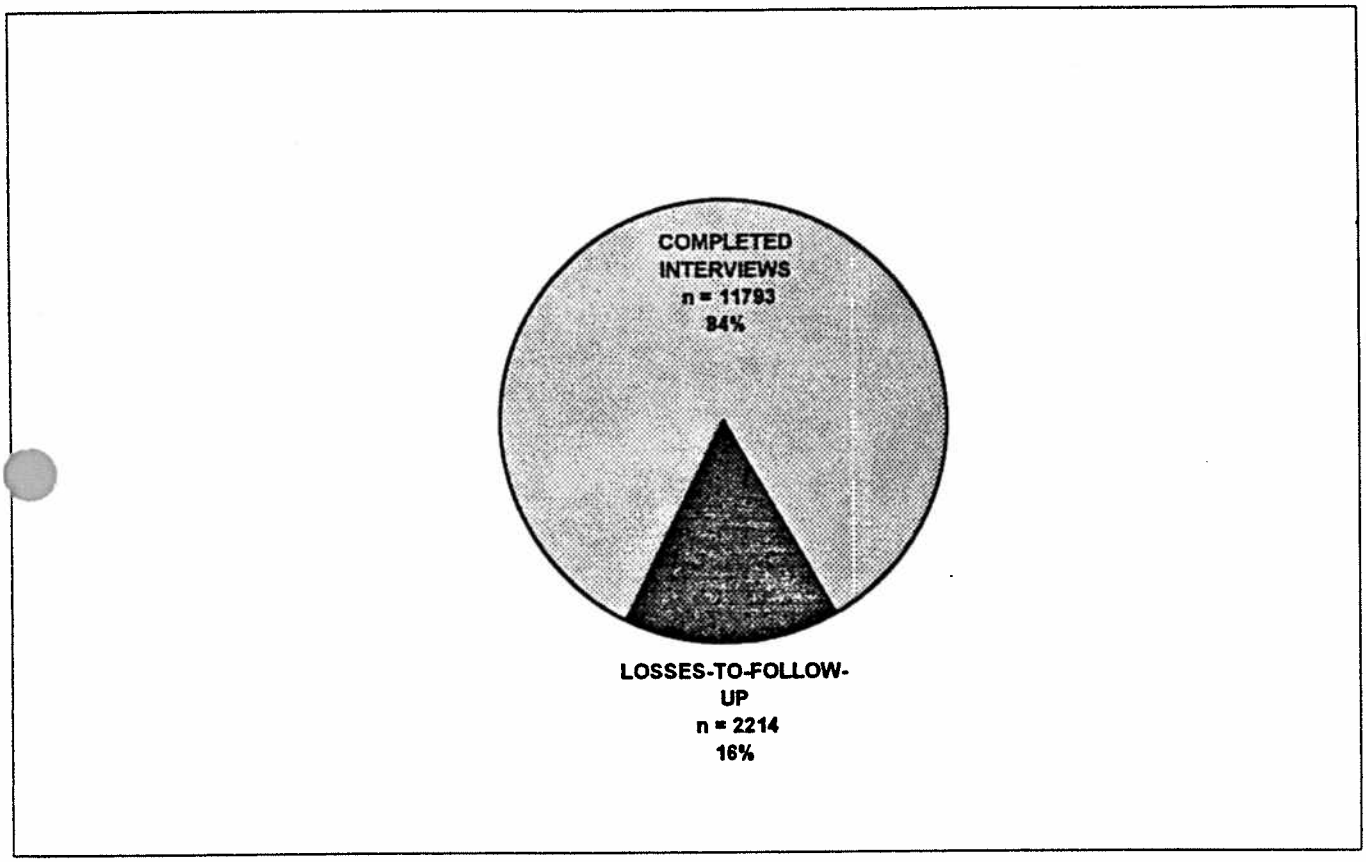
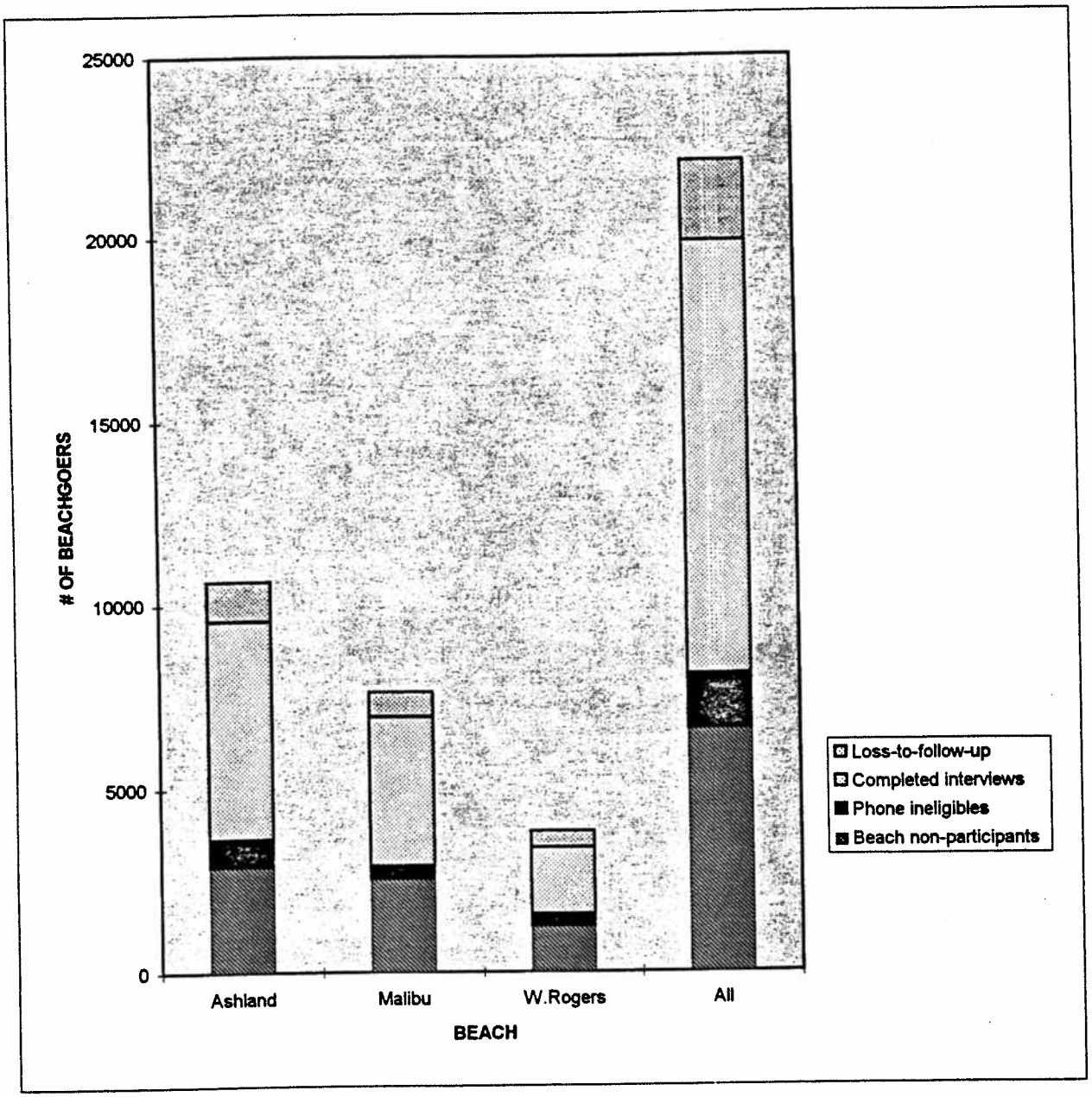


Figure 2. Beach Encounters by Beach



	Ashland	Malibu	W.Rogers	All
Beach non-participants (incl. ineligibles)	2862 (27%)	2508 (33%)	1223 (32%)	6593 (30%)
Phone ineligibles (back to beach)	766 (7%)	380 (5%)	339 (9%)	1485 (7%)
Completed interviews	5920 (56%)	4067 (53%)	1806 (47%)	11793 (53%)
Losses-to-follow-up	1078 (10%)	681 (9%)	455 (12%)	2214 (10%)
	10626	7636	3823	22085

Table 2. Reasons for Non-Participation at the Beach (All Beaches)

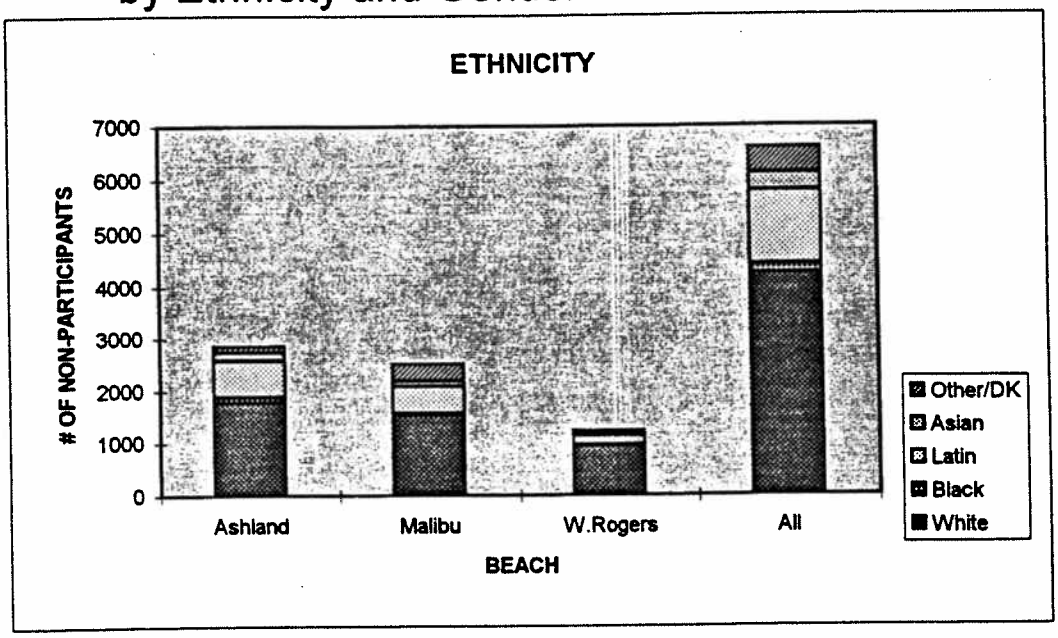
		%	*% of all beach encounters*
Ineligible (been to beach)	3681	56	*17*
Refusal	1761	27	*8*
Language difficulty	648	10	*3*
No telephone	503	8	*2*
	6593	101*	*30*

Table 3. Reasons for Non-Actualized Telephone Interviews (All Beaches)

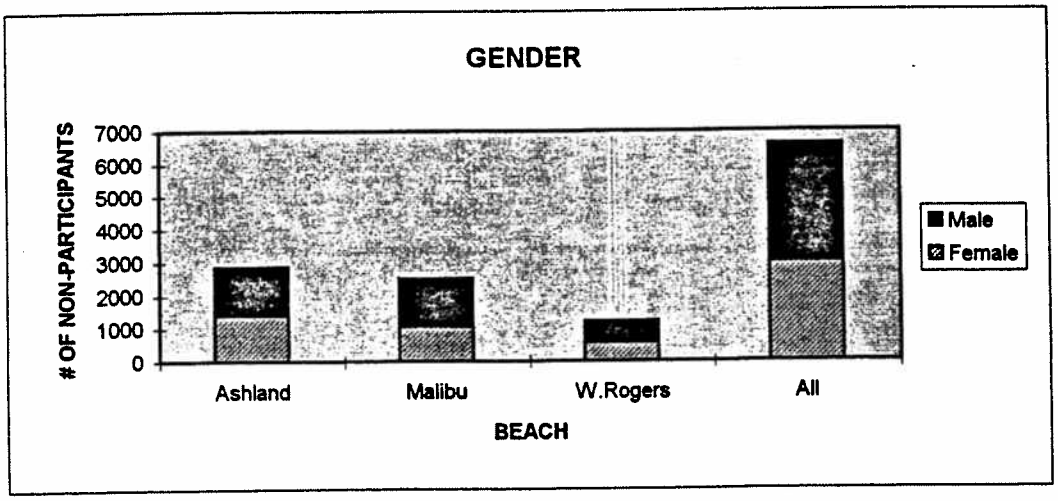
		%	*% of all beach interviews*
Ineligible (back to beach)	1485	40	*10*
Wrong number/disconnect	1170	32	*8*
Answering machine	504	14	*3*
No answer	283	8	*2*
Other reason (moved, etc.)	235	6	*1*
Refusal	22	1	*0*
	3699	101*	*24*

* Does not add to 100% due to rounding.

Figure 3. Non-Participation (Including Ineligibles) at 3 Beaches by Ethnicity and Gender*



	Ashland	Malibu	W.Rogers	All
White	1768 (62%)	1530 (61%)	930 (76%)	4228 (64%)
Black	123 (4%)	31 (1%)	28 (2%)	182 (3%)
Latin	691 (24%)	509 (20%)	172 (14%)	1372 (21%)
Asian	151 (5%)	113 (5%)	55 (4%)	319 (5%)
Other/DK	129 (4%)	325 (13%)	38 (3%)	492 (7%)

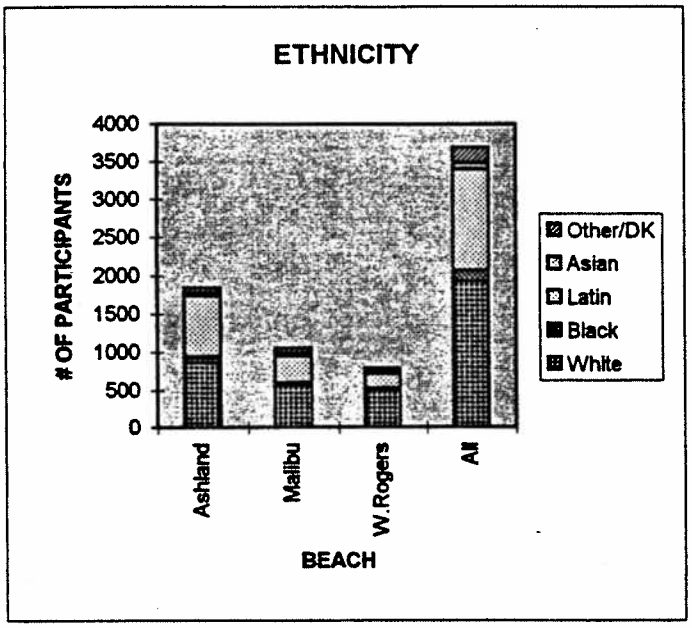


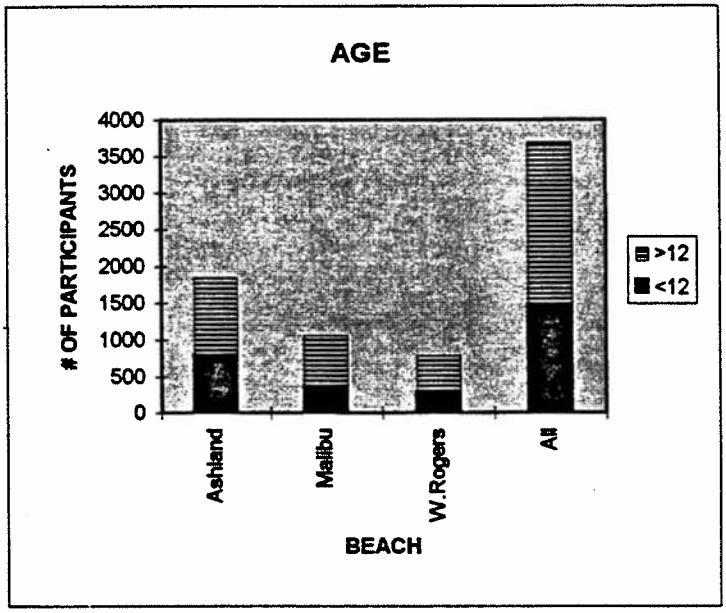
	Ashland	Malibu	W.Rogers	All
Female	1384 (48%)	1057 (42%)	559 (46%)	3000 (46%)
Male	1478 (52%)	1451 (58%)	664 (54%)	3593 (54%)

* Children younger than 12 were not tallied.

SARB_000430

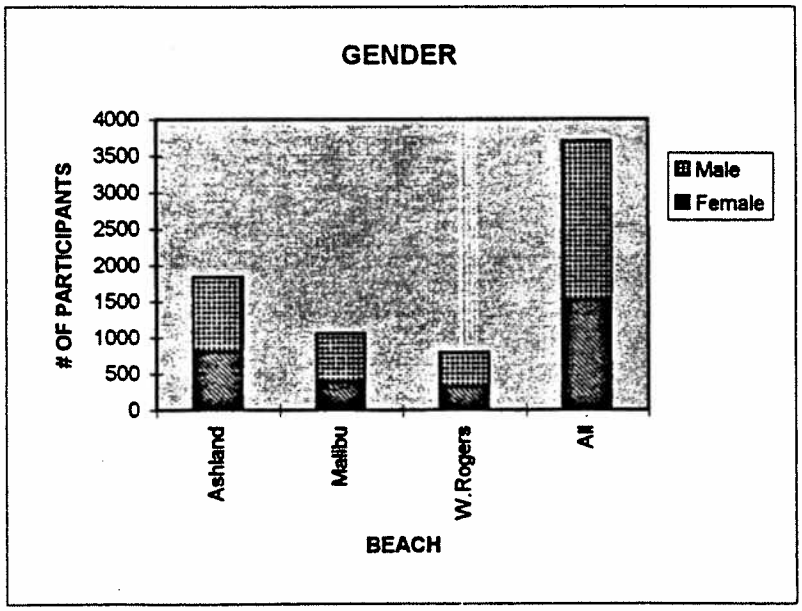
Figure 4. Non-Actualized Telephone Interviews from 3 Beaches by Ethnicity, Age and Gender





	Ashland	Malibu	W.Rogers	All
White	856 (46%)	569 (54%)	505 (64%)	1930 (52%)
B	88 (5%)	29 (3%)	17 (2%)	134 (4%)
Latin	87 (43%)	353 (33%)	194 (24%)	1334 (36%)
Asian	38 (2%)	31 (3%)	19 (2%)	88 (2%)
Other/DK	75 (4%)	79 (7%)	59 (7%)	213 (6%)

	Ashland	Malibu	W.Rogers	All
≤12	812 (44%)	381 (36%)	299 (38%)	1492(40%)
>12	1032 (56%	680 (64%)	495 (62%)	2207(60%)



	Ashland	Malibu	W.Rogers	All
Female	803 (44%)	392 (37%)	316 (40%)	1511 (41%)
Male	1041(56%)	669 (63%)	478 (60%)	2188 (59%)

Table 4. Beach Study Respondent Characteristics

Proximity to Drain

BEACH	0-100 Yds	> 400 Yds	RATIO
Ashland	4388	1532	2.9:1
Malibu	3034	1033	2.9:1
W Rogers	1310	496	2.6:1
	8732	3061	2.9:1

Family Size

BEACH	individuals			family members			totals		
Ashland	1115	(19%)	{43%}	4805	(81%)	{52%}	5920	(100%)	{50%}
Malibu	920	(23%)	{36%}	3147	(77%)	{34%}	4067	(100%)	{34%}
W Rogers	547	(30%)	{21%}	1259	(70%)	{14%}	1806	(100%)	{15%}
	2582	(22%)	{100%}	9211	(78%)	{100%}	11793	(100%) *	{100%} †

SES based on zip code (California only)

BEACH	<=25000			>25000			totals		
Ashland	655	(13%)	{64%}	4583	(87%)	{50%}	5238	(100%)	{51%}
Malibu	238	(7%)	{23%}	3142	(93%)	{34%}	3380	(100%)	{33%}
W Rogers	128	(8%)	{13%}	1464	(92%)	{16%}	1592	(100%)	{16%}
	1021	(10%)	{100%}	9189	(90%)	{100%}	10210	(100%)	{100%}

Residency based on zip code

BEACH	CA resident			Outside CA			totals		
Ashland	5341	(90%)	{51%}	579	(10%)	{42%}	5920	(100%)	{50%}
Malibu	3472	(85%)	{33%}	595	(15%)	{43%}	4067	(100%)	{34%}
W Rogers	1612	(89%)	{15%}	194	(11%)	{14%}	1806	(100%)	{15%}
	10425	(88%)	{100%}	1368	(12%)	{100%}	11793	(100%)	{100%}

* ( ) row percentages

† { } column percentages

SARB_000432

Table 5. Beach Study Respondent Characteristics vs. PEPS

Beach Study Respondents

AGE		
0-12	5,718	48%
13-18	1,772	15%
19-25	1,213	10%
26-35	1,688	14%
36-45	994	8%
46-55	314	3%
56-65	61	1%
66-75	30	0%
>75	3	0%
	11,793	

PEPS*

AGE		
0-14	2,074,678	22%
14-19	539,427	6%
20-24	653,813	7%
25-34	1,746,236	19%
35-44	1,583,407	17%
45-54	1,043,714	11%
55-64	668,540	7%
65-74	538,028	6%
>75	392,559	4%
	9,240,402	

Beach Study Respondents

AGE		
<=12	5,718	48%
13-25	2,985	25%
>=26	3,090	26%

PEPS

AGE		
>=14	2,074,678	22%
15-24	1,193,240	13%
>=25	5,972,484	65%

*Population Estimation and Projection System (Los Angeles County, 1993)

SARB_000433

Table 5, cont. Beach Study Respondent Characteristics vs. PEPS

Beach Study Respondents

GENDER		
female	5,319	45%
male	6,474	55%

PEPS*

GENDER		
female	4,726,498	50%
male	4,713,953	50%

Beach Study Respondents

ETHNICITY		
White	5,295	45%
Black	367	3%
Latino	5,103	43%
Asian/other	1,028	9%

PEPS

ETHNICITY		
White	3,414,147	36%
Black	938,202	10%
Latino	3,871,909	41%
Asian/other	1,216,192	13%

*Population Estimation and Projection System (Los Angeles County, 1993)

Table 6. Respondent Age by Map Area for Each Beach

Ashland									
Map Area*	0-12		13-25			>=26		totals	
drain	91	(59%) {3%}	23	(15%) {2%}		40	(26%) {3%}	154	(100%) {3%}
1-50 down	656	(54%) {21%}	234	(19%) {17%}		318	(26%) {11%}	1208	(100%) {20%}
1-50 up	688	(51%) {22%}	353	(26%) {25%}		309	(23%) {12%}	1350	(100%) {23%}
51-100 down	216	(48%) {7%}	122	(27%) {9%}		114	(25%) {5%}	452	(100%) {8%}
51-100 up	588	(48%) {19%}	321	(26%) {23%}		315	(26%) {15%}	1224	(100%) {21%}
400+ down	105	(57%) {3%}	44	(24%) {3%}		36	(19%) {2%}	185	(100%) {3%}
400+ up	714	(53%) {23%}	309	(23%) {22%}		324	(24%) {17%}	1347	(100%) {23%}
	3058	(52%) {100%}	1406	(24%) {100%}		1456	(25%) {100%}	5920	(100%) † {100%} ‡

Malibu								
Map Area	0-12		13-25		>=26		totals	
drain	390	(65%) {21%}	119	(20%) {11%}	94	(16%) {9%}	603	(100%) {15%}
1-50 down	124	(35%) {7%}	117	(33%) {11%}	111	(32%) {5%}	352	(100%) {9%}
1-50 up	412	(39%) {22%}	337	(32%) {31%}	310	(29%) {16%}	1059	(100%) {26%}
51-100 down	85	(39%) {5%}	75	(35%) {7%}	57	(26%) {3%}	217	(100%) {5%}
51-100 up	362	(45%) {19%}	196	(24%) {18%}	245	(31%) {15%}	803	(100%) {20%}
400+ down	457	(48%) {24%}	237	(25%) {21%}	252	(27%) {19%}	946	(100%) {23%}
400+ up	49	(56%) {3%}	22	(25%) {2%}	16	(18%) {1%}	87	(100%) {2%}
	1879	(46%) {100%}	1103	(27%) {100%}	1085	(27%) {100%}	4067	(100%) {100%}

Will Rogers								
Map Area	0-12		13-25		>=26		totals	
drain	50	(57%) {6%}	22	(25%) {5%}	16	(18%) {3%}	88	(100%) {5%}
1-50 down	155	(40%) {20%}	102	(27%) {21%}	127	(33%) {23%}	384	(100%) {21%}
1-50 up	80	(40%) {10%}	46	(23%) {10%}	76	(38%) {14%}	202	(100%) {11%}
51-100 down	182	(39%) {23%}	138	(30%) {29%}	145	(31%) {26%}	465	(100%) {26%}
51-100 up	57	(33%) {7%}	41	(24%) {9%}	73	(43%) {13%}	171	(100%) {9%}
400+ down	234	(52%) {30%}	115	(26%) {24%}	99	(22%) {18%}	448	(100%) {25%}
400+ up	23	(48%) {3%}	12	(25%) {3%}	13	(27%) {2%}	48	(100%) {3%}
	781	(43%) {100%}	476	(26%) {100%}	549	(30%) {100%}	1806	(100%) {100%}

* down = downcoast; up = upcoast

( ) row percentages

{ } column percentages

SARB_000435

Table 7. Respondent Gender by Map Area for Each Beach

	Ashland					
Map Area*	female			male		totals
drain	87	(56%)	{3%}	67	(44%)	{2%}	154 (100%) {3%}
1-50 down	553	(46%)	{20%}	655	(54%)	{21%}	1208 (100%) {20%}
1-50 up	642	(48%)	{23%}	708	(52%)	{22%}	1350 (100%) {23%}
51-100 down	212	(47%)	{8%}	240	(53%)	{8%}	452 (100%) {8%}
51-100 up	548	(45%)	{20%}	676	(55%)	{21%}	1224 (100%) {21%}
400+ down	75	(41%)	{3%}	110	(59%)	{3%}	185 (100%) {3%}
400+ up	629	(47%)	{23%}	718	(53%)	{23%}	1347 (100%) {23%}
	2746	(46%)	{100%}	3174	(54%)	{100%}	5920 (100%) † {100%} ‡

	Malibu					
Map Area	female			male		totals
drain	271	(45%)	{15%}	332	(55%)	{15%}	603 (100%) {15%}
1-50 down	124	(35%)	{7%}	228	(65%)	{10%}	352 (100%) {9%}
1-50 up	457	(43%)	{25%}	602	(57%)	{26%}	1059 (100%) {26%}
51-100 down	86	(40%)	{5%}	131	(60%)	{6%}	217 (100%) {5%}
51-100 up	366	(46%)	{20%}	437	(54%)	{19%}	803 (100%) {20%}
400+ down	452	(48%)	{25%}	494	(52%)	{22%}	946 (100%) {23%}
400+ up	38	(44%)	{2%}	49	(56%)	{2%}	87 (100%) {2%}
	1794	(44%)	{100%}	2273	(56%)	{100%}	4067 (100%) {100%}

	Will Rogers					
Map Area	female			male		totals
drain	42	(48%)	{5%}	46	(52%)	{4%}	88 (100%) {5%}
1-50 down	164	(43%)	{21%}	220	(57%)	{21%}	384 (100%) {21%}
1-50 up	85	(42%)	{11%}	117	(58%)	{11%}	202 (100%) {11%}
51-100 down	186	(40%)	{24%}	279	(60%)	{27%}	465 (100%) {26%}
51-100 up	85	(50%)	{11%}	86	(50%)	{8%}	171 (100%) {9%}
400+ down	202	(45%)	{26%}	246	(55%)	{24%}	448 (100%) {25%}
400+ up	15	(31%)	{2%}	33	(69%)	{3%}	48 (100%) {3%}
	779	(43%)	{100%}	1027	(57%)	{100%}	1806 (100%) {100%}

* down = downcoast; up = upcoast

† ( ) row percentages

‡ { } column percentages

SARB_000436

Table 8. Respondent Ethnicity by Map Area for Each Beach

Ashland

Map Area*	White			Black			Latino			Asian			multi			other			totals		
drain	28	(18%)	{1%}	8	(5%)	{3%}	108	(70%)	{4%}	4	(3%)	{2%}	4	(3%)	{2%}	2	(1%)	{2%}	154	(100%)	{3%}
1-50 down	464	(38%)	{21%}	52	(4%)	{19%}	558	(46%)	{20%}	65	(5%)	{31%}	39	(3%)	{21%}	30	(2%)	{23%}	1208	(100%)	{20%}
1-50 up	457	(34%)	{20%}	60	(4%)	{22%}	725	(54%)	{25%}	35	(3%)	{17%}	49	(4%)	{26%}	24	(2%)	{18%}	1350	(100%)	{23%}
51-100 down	207	(46%)	{9%}	20	(4%)	{7%}	186	(41%)	{7%}	21	(5%)	{10%}	8	(2%)	{4%}	10	(2%)	{8%}	452	(100%)	{8%}
51-100 up	471	(38%)	{21%}	55	(4%)	{20%}	590	(48%)	{21%}	38	(3%)	{18%}	46	(4%)	{24%}	24	(2%)	{18%}	1224	(100%)	{21%}
400+ down	71	(38%)	{3%}	12	(6%)	{4%}	82	(44%)	{3%}	1	(1%)	{0%}	13	(7%)	{7%}	6	(3%)	{5%}	185	(100%)	{3%}
400+ up	564	(42%)	{25%}	64	(5%)	{24%}	609	(45%)	{21%}	45	(3%)	{22%}	31	(2%)	{16%}	34	(3%)	{26%}	1347	(100%)	{23%}
	2262	(38%)	{100%}	271	(5%)	{100%}	2858	(48%)	{100%}	209	(4%)	{100%}	190	(3%)	{100%}	130	(2%)	{100%}	5920	(100%) †	{100%} ‡

Malibu

Map Area	White			Black			Latino			Asian			multi			other			totals		
drain	231	(38%)	{11%}	5	(1%)	{10%}	337	(56%)	{21%}	13	(2%)	{10%}	11	(2%)	{10%}	5	(1%)	{5%}	602	(100%)	{15%}
1-50 down	161	(46%)	{8%}	3	(1%)	{6%}	157	(45%)	{10%}	7	(2%)	{6%}	11	(3%)	{10%}	13	(4%)	{14%}	352	(100%)	{9%}
1-50 up	499	(47%)	{24%}	24	(2%)	{49%}	459	(43%)	{28%}	25	(2%)	{20%}	22	(2%)	{20%}	27	(3%)	{29%}	1056	(100%)	{26%}
51-100 down	132	(61%)	{6%}	0	(0%)	{0%}	67	(31%)	{4%}	4	(2%)	{3%}	7	(3%)	{6%}	7	(3%)	{8%}	217	(100%)	{5%}
51-100 up	450	(56%)	{22%}	2	(0%)	{4%}	271	(34%)	{17%}	50	(6%)	{40%}	11	(1%)	{10%}	19	(2%)	{20%}	803	(100%)	{20%}
400+ down	535	(57%)	{26%}	15	(2%)	{31%}	300	(32%)	{18%}	25	(3%)	{20%}	49	(5%)	{44%}	22	(2%)	{24%}	946	(100%)	{23%}
400+ up	36	(41%)	{2%}	0	(0%)	{0%}	50	(57%)	{3%}	1	(1%)	{1%}	0	(0%)	{0%}	0	(0%)	{0%}	87	(100%)	{2%}
	2044	(50%)	{100%}	49	(1%)	{100%}	1641	(40%)	{100%}	125	(3%)	{100%}	111	(3%)	{100%}	93	(2%)	{100%}	4063	(100%)	{100%}

Will Rogers

Map Area	White			Black			Latino			Asian			multi			other			totals		
drain	22	(25%)	{2%}	3	(3%)	{6%}	57	(65%)	{9%}	4	(5%)	{7%}	2	(2%)	{3%}	0	(0%)	{0%}	88	(100%)	{5%}
1-50 down	173	(45%)	{17%}	6	(2%)	{13%}	171	(45%)	{28%}	13	(3%)	{22%}	16	(4%)	{27%}	5	(1%)	{10%}	384	(100%)	{21%}
1-50 up	107	(53%)	{11%}	13	(6%)	{28%}	66	(33%)	{11%}	5	(2%)	{9%}	7	(3%)	{12%}	4	(2%)	{8%}	202	(100%)	{11%}
51-100 down	277	(60%)	{28%}	13	(3%)	{28%}	119	(26%)	{20%}	18	(4%)	{31%}	19	(4%)	{32%}	19	(4%)	{39%}	465	(100%)	{26%}
51-100 up	105	(61%)	{11%}	0	(0%)	{0%}	47	(27%)	{8%}	10	(6%)	{17%}	4	(2%)	{7%}	5	(3%)	{10%}	171	(100%)	{9%}
400+ down	277	(62%)	{28%}	11	(2%)	{23%}	127	(28%)	{21%}	7	(2%)	{12%}	10	(2%)	{17%}	16	(4%)	{33%}	448	(100%)	{25%}
400+ up	28	(58%)	{3%}	1	(2%)	{2%}	17	(35%)	{3%}	1	(2%)	{2%}	1	(2%)	{2%}	0	(0%)	{0%}	48	(100%)	{3%}
	989	(55%)	{100%}	47	(3%)	{100%}	604	(33%)	{100%}	58	(3%)	{100%}	59	(3%)	{100%}	49	(3%)	{100%}	1806	(100%)	{100%}

* down = downcoast; up = upcoast

† ( ) row percentages

‡ { } column percentages

SARB_000437

Table 9. Age, Gender and Ethnicity by Map Area For All Beaches

	beach										
Map Area*	Ashland			Malibu			Will Rogers			totals		
drain	154	(18%)	{3%}	603	(71%)	{15%}	88	(10%)	{5%}	845	(100%)	{7%}
1-50 down	1208	(62%)	{20%}	352	(18%)	{9%}	384	(20%)	{21%}	1944	(100%)	{16%}
1-50 up	1350	(52%)	{23%}	1059	(41%)	{26%}	202	(8%)	{11%}	2611	(100%)	{22%}
51-100 down	452	(40%)	{8%}	217	(19%)	{5%}	465	(41%)	{26%}	1134	(100%)	{10%}
51-100 up	1224	(56%)	{21%}	803	(37%)	{20%}	171	(8%)	{9%}	2198	(100%)	{19%}
400+ down	185	(12%)	{3%}	946	(60%)	{23%}	448	(28%)	{25%}	1579	(100%)	{13%}
400+ up	1347	(91%)	{23%}	87	(6%)	{2%}	48	(3%)	{3%}	1482	(100%)	{13%}
	5920	(50%)	{100%}	4067	(34%)	{100%}	1806	(15%)	{100%}	11793	(100%) †	{100%} ‡

	age										
Map Area	0-12			13-25			>=26			totals		
drain	531	(63%)	{9%}	164	(19%)	{5%}	150	(18%)	{5%}	845	(100%)	{7%}
1-50 down	935	(48%)	{16%}	453	(23%)	{15%}	556	(29%)	{18%}	1944	(100%)	{16%}
1-50 up	1180	(45%)	{21%}	736	(28%)	{25%}	695	(27%)	{22%}	2611	(100%)	{22%}
51-100 down	483	(43%)	{8%}	335	(30%)	{11%}	316	(28%)	{10%}	1134	(100%)	{10%}
51-100 up	1007	(46%)	{18%}	558	(25%)	{19%}	633	(29%)	{20%}	2198	(100%)	{19%}
400+ down	796	(50%)	{14%}	396	(25%)	{13%}	387	(25%)	{13%}	1579	(100%)	{13%}
400+ up	786	(53%)	{14%}	343	(23%)	{11%}	353	(24%)	{11%}	1482	(100%)	{13%}
	5718	(48%)	{100%}	2985	(25%)	{100%}	3090	(26%)	{100%}	11793	(100%)	{100%}

	gender								
Map Area	female			male			totals		
drain	400	(47%)	{8%}	445	(53%)	{7%}	845	(100%)	{7%}
1-50 down	841	(43%)	{16%}	1103	(57%)	{17%}	1944	(100%)	{16%}
1-50 up	1184	(45%)	{22%}	1427	(55%)	{22%}	2611	(100%)	{22%}
51-100 down	484	(43%)	{9%}	650	(57%)	{10%}	1134	(100%)	{10%}
51-100 up	999	(45%)	{19%}	1199	(55%)	{19%}	2198	(100%)	{19%}
400+ down	729	(46%)	{14%}	850	(54%)	{13%}	1579	(100%)	{13%}
400+ up	682	(46%)	{13%}	800	(54%)	{12%}	1482	(100%)	{13%}
	5319	(45%)	{100%}	6474	(55%)	{100%}	11793	(100%)	{100%}

* down = downcoast; up = upcoast

† ( ) row percentages

‡ { } column percentages

SARB_000438

Table 9, cont. Age, Gender and Ethnicity by Map Area For All Beaches

	ethnicity																									
Map Area*	White				Black				Latino				Asian				multi				other				totals			
drain	281	(33%)	{5%}		16	(2%)	{4%}		502	(59%)	{10%}		21	(2%)	{5%}		17	(2%)	{5%}		7	(1%)	{3%}		844	(100%)		{7%}
1-50 down	798	(41%)	{15%}		61	(3%)	{17%}		886	(46%)	{17%}		85	(4%)	{22%}		66	(3%)	{18%}		48	(2%)	{18%}		1944	(100%)		{16%}
1-50 up	1063	(41%)	{20%}		97	(4%)	{26%}		1250	(48%)	{24%}		65	(2%)	{17%}		78	(3%)	{22%}		55	(2%)	{20%}		2608	(100%)		{22%}
51-100 down	616	(54%)	{12%}		33	(3%)	{9%}		372	(33%)	{7%}		43	(4%)	{11%}		34	(3%)	{9%}		36	(3%)	{13%}		1134	(100%)		{10%}
51-100 up	1026	(47%)	{19%}		57	(3%)	{16%}		908	(41%)	{18%}		98	(4%)	{25%}		61	(3%)	{17%}		48	(2%)	{18%}		2198	(100%)		{19%}
400+ down	883	(56%)	{17%}		38	(2%)	{10%}		509	(32%)	{10%}		33	(2%)	{8%}		72	(5%)	{20%}		44	(3%)	{16%}		1579	(100%)		{13%}
400+ up	628	(42%)	{12%}		65	(4%)	{18%}		676	(46%)	{13%}		47	(3%)	{12%}		32	(2%)	{9%}		34	(2%)	{13%}		1482	(100%)		{13%}
	5295	(45%)	{100%}		367	(3%)	{100%}		5103	(43%)	{100%}		392	(3%)	{100%}		360	(3%)	{100%}		272	(2%)	{100%}		11789	(100%)	†	{100%} ‡

* down = downcoast; up = upcoast

† ( ) row percentages

‡ { } column percentages

Table 10. Subgroup Specific Symptom Counts

	TOTAL	A) gender		B) age groups			C) ethnicity					
Symptom		Female	Male	<=12	13-25	>=26	White	Black	Latino	Asian	multi	other
Fever	567	257	310	323	121	123	259	21	231	18	27	11
Chills	296	140	156	139	70	87	150	8	114	7	11	6
Redness/discharge from eyes	212	108	104	118	39	55	72	8	112	2	12	6
Earache	407	192	215	185	119	103	212	15	152	6	9	12
Discharge/draining from ears	79	41	38	29	27	23	33	1	41	0	3	1
Skin rash	110	56	54	55	21	34	35	2	65	1	3	4
Cuts becoming infected	76	29	47	21	31	24	46	1	24	2	2	1
Nausea	432	219	213	206	106	119	223	16	155	10	18	10
Vomiting	204	91	113	144	33	27	80	7	98	5	11	3
Diarrhea	627	286	341	307	130	190	365	23	174	15	30	20
Diarrhea with blood	14	7	7	7	4	3	5	0	8	0	1	0
Stomach pain or cramps	736	351	385	370	194	171	387	28	250	23	30	18
Coughing	834	372	462	454	214	166	389	34	333	28	35	14
Coughing with phlegm	390	156	234	195	111	84	176	10	177	8	14	4
Nasal congestion or runny nose	1079	477	602	504	307	268	588	32	361	31	43	23
Sore throat	802	386	416	350	233	219	422	25	291	14	28	21
hcgi_1	355	166	189	223	65	67	164	16	141	9	20	5
hcgi_2	101	39	62	76	15	10	43	2	48	2	5	1
srd	589	264	325	307	158	124	276	20	241	14	26	11

SARB_000440

Table 10, cont. Subgroup Specific Symptom Counts

	D) SES		E) residency		F) concern about hazards			
Symptom	<=$25,000	>$25,000	CA resident	non CA	not at all worried	somewhat worried	a little worried	very worried
Fever	64	447	526	40	46	68	122	227
Chills	30	236	272	24	20	39	59	140
Redness/discharge from eyes	15	176	194	16	23	26	46	77
Earache	22	336	363	39	28	56	83	172
Discharge/draining from ears	3	71	75	3	7	5	20	38
Skin rash	22	79	104	6	14	12	25	44
Cuts becoming infected	3	62	67	8	6	14	13	33
Nausea	32	347	387	39	18	55	82	195
Vomiting	12	172	187	13	11	20	47	83
Diarrhea	22	497	532	90	34	98	119	273
Diarrhea with blood	2	10	13	1	1	2	4	5
Stomach pain or cramps	41	598	652	78	53	98	151	295
Coughing	75	663	764	66	85	117	164	324
Coughing with phlegm	30	314	363	24	48	57	71	152
Nasal congestion or runny nose	72	863	964	103	93	171	238	424
Sore throat	61	634	721	75	73	134	178	301
hcgi_1	27	288	322	29	22	36	72	150
hcgi_2	6	89	97	3	5	10	21	47
srd	49	473	547	39	60	87	118	220

SARB_000441

Table 11. Subgroup Specific Symptom Rates per 100 Persons

SYMPTOM	TOTALS	A) gender		B) age			C) ethnicity					
		female	male	0-12	13-25	>=26	White	Black	Latino	Asian	multi	other
1 Fever	4.8	4.8	4.8	5.6	4.1	4.0	4.9	5.7	4.5	4.6	7.5	4.0
2 Chills	2.5	2.6	2.4	2.4	2.3	2.8	2.8	2.2	2.2	1.8	3.1	2.2
3 Redness/discharge from eyes	1.8	2.0	1.6	2.1	1.3	1.8	1.4	2.2	2.2	0.5	3.3	2.2
4 Earache	3.5	3.6	3.3	3.2	4.0	3.3	4.0	4.1	3.0	1.5	2.5	4.3
5 Discharge/draining from ears	0.7	0.8	0.6	0.5	0.9	0.7	0.6	0.3	0.8	0.0	0.8	0.4
6 Skin rash	0.9	1.1	0.8	1.0	0.7	1.1	0.7	0.5	1.3	0.3	0.8	1.4
7 Cuts becoming infected	0.6	0.5	0.7	0.4	1.0	0.8	0.9	0.3	0.5	0.5	0.6	0.4
8 Nausea	3.7	4.1	3.3	3.6	3.6	3.9	4.2	4.4	3.0	2.6	5.0	3.6
9 Vomiting	1.7	1.7	1.7	2.5	1.1	0.9	1.5	1.9	1.9	1.3	3.1	1.1
10 Diarrhea	5.3	5.4	5.3	5.4	4.4	6.1	6.9	6.3	3.4	3.8	8.3	7.2
11 Diarrhea with blood	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.0	0.2	0.0	0.3	0.0
12 Stomach pain or cramps	6.2	6.6	5.9	6.5	6.5	5.5	7.3	7.6	4.9	5.9	8.3	6.5
13 Coughing	7.1	7.0	7.1	7.9	7.2	5.4	7.3	9.3	6.5	7.1	9.7	5.1
14 Coughing with phlegm	3.3	2.9	3.6	3.4	3.7	2.7	3.3	2.7	3.5	2.0	3.9	1.4
15 Nasal congestion or runny nose	9.1	9.0	9.3	8.8	10.3	8.7	11.1	8.7	7.1	7.9	11.9	8.3
16 Sore throat	6.8	7.3	6.4	6.1	7.8	7.1	8.0	6.8	5.7	3.6	7.8	7.6
HCGI_1	3.0	3.1	2.9	3.9	2.2	2.2	3.1	4.4	2.8	2.3	5.6	1.8
HCGI_2	0.9	0.7	1.0	1.3	0.5	0.3	0.8	0.5	0.9	0.5	1.4	0.4
SRD	5.0	5.0	5.0	5.4	5.3	4.0	5.2	5.4	4.7	3.6	7.2	4.0

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Table 11, cont. Subgroup Specific Symptom Rates per 100 Persons

SYMPTOM	D) SES		E) residency		F) concern about environmental hazards at beach			
	<=25,000	>25,000	CA resident	outside CA	not at all worried	somewhat worried	a little worried	very worried
1 Fever	6.3	4.9	5.0	3.1	3.0	3.3	4.9	6.6
2 Chills	2.9	2.6	2.6	1.9	1.3	1.9	2.4	4.1
3 Redness/discharge from eyes	1.5	1.9	1.9	1.2	1.5	1.3	1.9	2.2
4 Earache	2.2	3.7	3.5	3.0	1.8	2.7	3.3	5.0
5 Discharge/draining from ears	0.3	0.8	0.7	0.2	0.5	0.2	0.8	1.1
6 Skin rash	2.2	0.9	1.0	0.5	0.9	0.6	1.0	1.3
7 Cuts becoming infected	0.3	0.7	0.6	0.6	0.4	0.7	0.5	1.0
8 Nausea	3.1	3.8	3.7	3.0	1.2	2.6	3.3	5.7
9 Vomiting	1.2	1.9	1.8	1.0	0.7	1.0	1.9	2.4
10 Diarrhea	2.2	5.4	5.1	7.0	2.2	4.7	4.8	7.9
11 Diarrhea with blood	0.2	0.1	0.1	0.1	0.1	0.1	0.2	0.1
12 Stomach pain or cramps	4.0	6.5	6.3	6.0	3.4	4.7	6.1	8.5
13 Coughing	7.3	7.2	7.3	5.1	5.5	5.6	6.6	9.4
14 Coughing with phlegm	2.9	3.4	3.5	1.9	3.1	2.7	2.9	4.4
15 Nasal congestion or runny nose	7.1	9.4	9.2	8.0	6.0	8.2	9.6	12.3
16 Sore throat	6.0	6.9	6.9	5.8	4.7	6.4	7.2	8.7
HCGI_1	2.6	3.1	3.1	2.2	1.4	1.7	2.9	4.3
HCGI_2	0.6	1.0	0.9	0.2	0.3	0.5	0.8	1.4
SRD	4.8	5.1	5.2	3.0	3.9	4.2	4.8	6.4

SARS_000443

Table 12. Percentage of Days in which Bacterial Indicators Exceeded the Standard Cutoff Levels

A. ASHLAND

	AREA				
Bacterial Indicator	Storm Drain 0 Yards (%)	1-100 Yards Upcoast (%)	1-100 Yards Downcoast (%)	400 + Yards Upcoast (%)	Cutoff **cfu**
E. coli	30.8	7.8	9.1	11.7	35
E. coli	19.2	5.2	2.6	3.9	70
Entercoccus	19.0	6.3	5.1	5.1	35
Fecal Coliforms	11.4	3.8	3.8	1.3	200
Total Coliforms	44.3	12.7	12.8	3.8	1000

B. MALIBU

	AREA				
Bacterial Indicator	Storm Drain 0 Yards (%)	1-100 Yards Upcoast (%)	1-100 Yards Downcoast (%)	400 + Yards Downcoast (%)	Cutoff **cfu**
E. coli	60.3	24.4	66.7	52.6	35
E. coli	55.1	15.4	53.8	25.6	70
Entercoccus	51.3	19.2	48.7	21.8	35
Fecal Coliforms	52.6	10.3	43.6	11.5	200
Total Coliforms	23.1	3.8	14.1	6.4	1000

C. WILL ROGERS

	AREA				
Bacterial Indicator	Storm Drain 0 Yards (%)	1-100 Yards Upcoast (%)	1-100 Yards Downcoast (%)	400 + Yards Downcoast (%)	Cutoff **cfu**
E. coli	74.0	21.9	45.2	15.1	35
E. coli	58.9	13.7	17.8	1.4	70
Entercoccus	79.5	23.3	42.5	9.6	35
Fecal Coliforms	56.2	6.8	8.2	1.4	200
Total Coliforms	46.6	5.5	5.5	0.0	1000

Note: Samples collected once daily between 8 am and 11 am.

cfu = colony forming units

SARB_000444

Table 13. Percentage of Days in which Bacterial Indicators Exceeded the Higher Cutoff Levels

A. ASHLAND

	AREA				
Bacterial Indicator	Storm Drain 0 Yards (%)	1-100 Yards Upcoast (%)	1-100 Yards Downcoast (%)	400 + Yards Upcoast (%)	Cutoff **cfu**
E. coli	9.0	1.3	0.0	0.0	160
E. coli	6.4	1.3	0.0	0.0	320
Entercoccus	6.3	0.0	1.3	0.0	106
Fecal Coliforms	10.1	1.3	1.3	0.0	400
Total Coliforms	25.3	1.3	3.8	0.0	5,000
Total Coliforms	15.2	0.0	1.3	0.0	10,000

B. MALIBU

	AREA				
Bacterial Indicator	Storm Drain 0 Yards (%)	1-100 Yards Upcoast (%)	1-100 Yards Downcoast (%)	400 + Yards Downcoast (%)	Cutoff **cfu**
E. coli	47.4	10.3	33.3	7.7	160
E. coli	39.7	7.7	19.2	1.3	320
Entercoccus	34.6	5.1	17.9	2.6	106
Fecal Coliforms	46.2	6.4	21.8	2.6	400
Total Coliforms	5.1	2.6	1.3	0.0	5,000
Total Coliforms	3.8	1.3	0.0	0.0	10,000

C. WILL ROGERS

	AREA				
Bacterial Indicator	Storm Drain 0 Yards (%)	1-100 Yards Upcoast (%)	1-100 Yards Downcoast (%)	400 + Yards Downcoast (%)	Cutoff **cfu**
E. coli	42.5	5.5	8.2	0.0	160
E. coli	28.8	1.4	1.4	0.0	320
Entercoccus	45.2	6.8	9.6	1.4	106
Fecal Coliforms	32.9	1.4	2.7	0.0	400
Total Coliforms	16.4	1.4	2.7	0.0	5,000
Total Coliforms	6.8	0.0	1.4	0.0	10,000

Note: Samples collected once daily between 8 am and 11 am.

cfu = colony forming units

SARB_000445

Table 14. Total Coliforms/Enterococcus Within Specified Ranges

A. ASHLAND

	AREA			
Total Coliforms/Enterococcus	Storm Drain 0 Yards (% of days)	1-100 Yards Upcoast (% of days)	1-100 Yards Downcoast (% of days)	400 + Yards Upcoast (% of days)
<=7	2.5	21.5	25.6	21.8
<=10	11.4	27.9	26.9	29.5
<=13	15.2	30.4	30.8	42.3

B. MALIBU

	AREA			
Total Coliforms/Enterococcus	Storm Drain 0 Yards (% of days)	1-100 Yards Upcoast (% of days)	1-100 Yards Downcoast (% of days)	400 + Yards Downcoast (% of days)
<=7	44.9	66.7	50.0	51.3
<=10	59.0	78.2	74.4	74.4
<=13	68.0	84.6	80.8	83.3

C. WILL ROGERS

	AREA			
Total Coliforms/Enterococcus	Storm Drain 0 Yards (% of days)	1-100 Yards Upcoast (% of days)	1-100 Yards Downcoast (% of days)	400 + Yards Downcoast (% of days)
<=7	46.6	65.8	69.9	83.6
<=10	60.3	78.1	79.5	91.8
<=13	69.9	82.2	89.0	95.9

Note: Samples collected once daily between 8 am and 11 am.

SARB_000446

Table 15. Total Coliforms/Fecal Coliforms Within Specified Ranges

A. ASHLAND

	AREA			
Total Coliforms/Fecal Coliforms	Storm Drain 0 Yards (% of days)	1-100 Yards Upcoast (% of days)	1-100 Yards Downcoast (% of days)	400 + Yards Upcoast (% of days)
<=5	17.7	34.2	30.8	48.7
<=4	17.7	29.1	26.9	41.0
<=2	7.6	20.3	14.1	24.4

B. MALIBU

	AREA			
Total Coliforms/Fecal Coliforms	Storm Drain 0 Yards (% of days)	1-100 Yards Upcoast (% of days)	1-100 Yards Downcoast (% of days)	400 + Yards Downcoast (% of days)
<=5	82.1	85.9	88.5	89.7
<=4	80.8	82.1	82.1	84.6
<=2	51.3	68.0	55.1	60.3

C. WILL ROGERS

	AREA			
Total Coliforms/Fecal Coliforms	Storm Drain 0 Yards (% of days)	1-100 Yards Upcoast (% of days)	1-100 Yards Downcoast (% of days)	400 + Yards Downcoast (% of days)
<=5	52.1	76.7	75.3	84.9
<=4	41.1	72.6	63.0	75.3
<=2	13.7	27.4	24.7	30.1

Note: Samples collected once daily between 8 am and 11 am.

SARB_000447

Table 16. Total Coliforms/Fecal Coliforms Within Specified Ranges On Days When Total Coliforms > 1000 and > 5000

A. ASHLAND

> 1000	AREA			
Total Coliforms/Fecal Coliforms	Storm Drain 0 Yards (% of days)	1-100 Yards Upcoast (% of days)	1-100 Yards Downcoast (% of days)	400 + Yards Upcoast (% of days)
<=5	0.0	0.0	0.0	0.0
<=4	0.0	0.0	0.0	0.0
<=2	0.0	0.0	0.0	0.0

> 5000

Total Coliforms/Fecal Coliforms				
<=5	0.0	0.0	0.0	-
<=4	0.0	0.0	0.0	-
<=2	0.0	0.0	0.0	-

B. MALIBU

> 1000	AREA			
Total Coliforms/Fecal Coliforms	Storm Drain 0 Yards (% of days)	1-100 Yards Upcoast (% of days)	1-100 Yards Downcoast (% of days)	400 + Yards Downcoast (% of days)
<=5	55.6	0.0	54.6	20.0
<=4	55.6	0.0	36.4	0.0
<=2	16.7	0.0	18.2	0.0

> 5000

Total Coliforms/Fecal Coliforms				
<=5	25.0	0.0	0.0	-
<=4	25.0	0.0	0.0	-
<=2	0.0	0.0	0.0	-

Note: Samples collected once daily between 8 am and 11 am.

SARB_000448

Table 16 Continued. Total Coliforms/Fecal Coliforms Within Specified Ranges On Days When Total Coliforms > 1000 and > 5000

C. WILL ROGERS

> 1000

Total Coliforms/Fecal Coliforms	AREA: Storm Drain 0 Yards (% of days)	1-100 Yards Upcoast (% of days)	1-100 Yards Downcoast (% of days)	400 + Yards Downcoast (% of days)
<=5	50.0	25.0	75.0	-
<=4	41.2	25.0	75.0	-
<=2	14.7	0.0	0.0	-

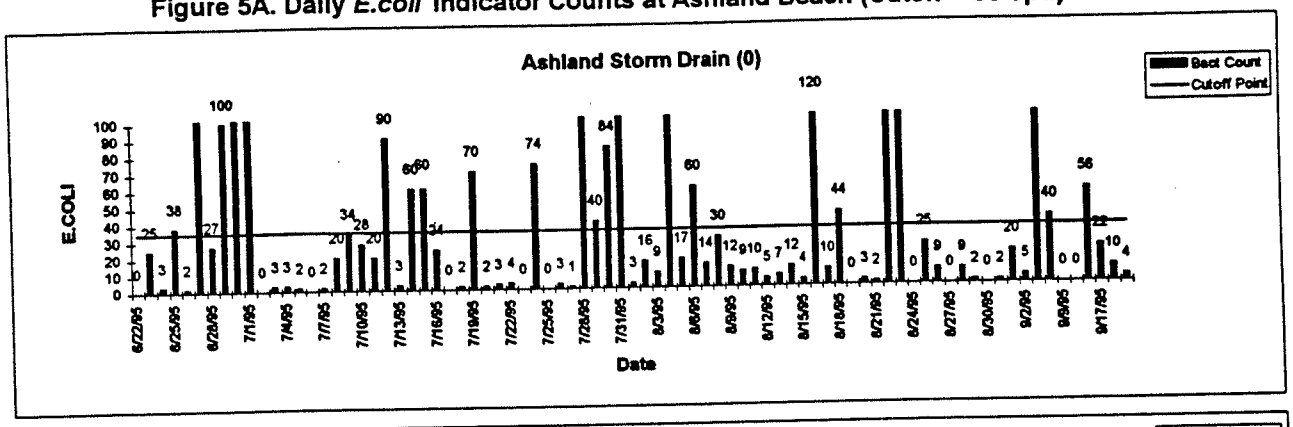
> 5000

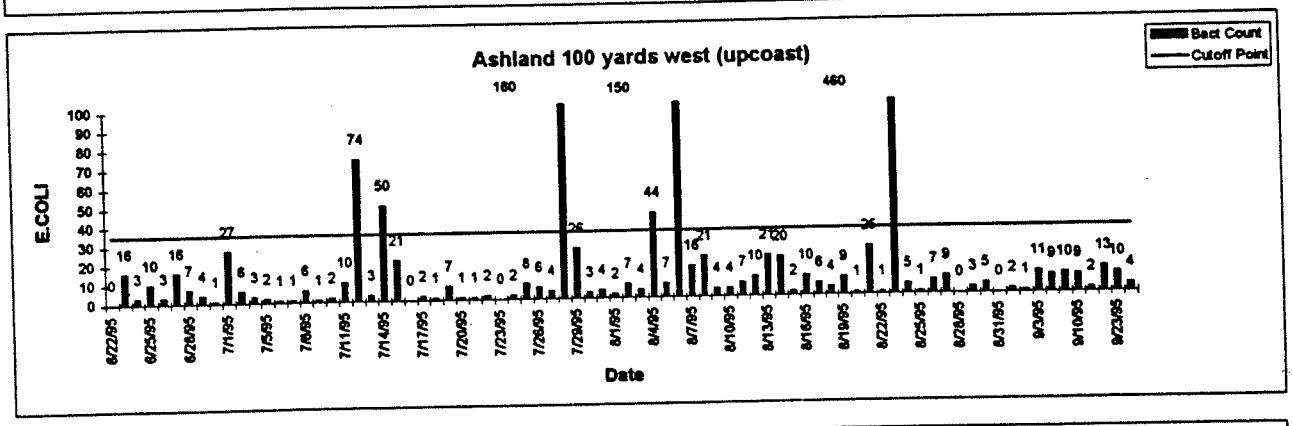
Total Coliforms/Fecal Coliforms				
<=5	33.3	0.0	50.0	-
<=4	33.3	0.0	50.0	-
<=2	16.7	0.0	0.0	-

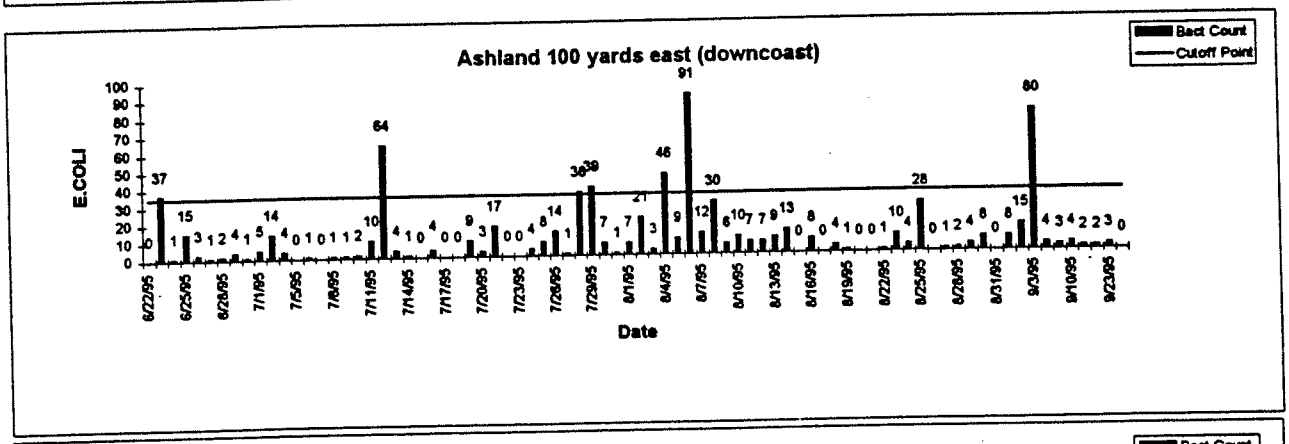
Note: Samples collected once daily between 8 am and 11 am.

SARB_000449

Figure 5A. Daily *E.coli* Indicator Counts at Ashland Beach (Cutoff = 35 cpu)







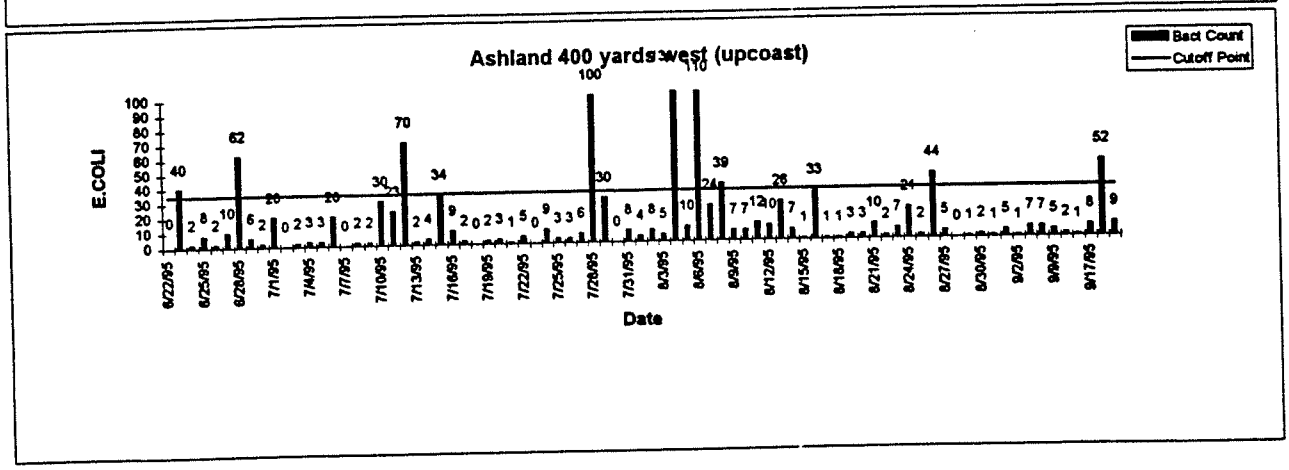


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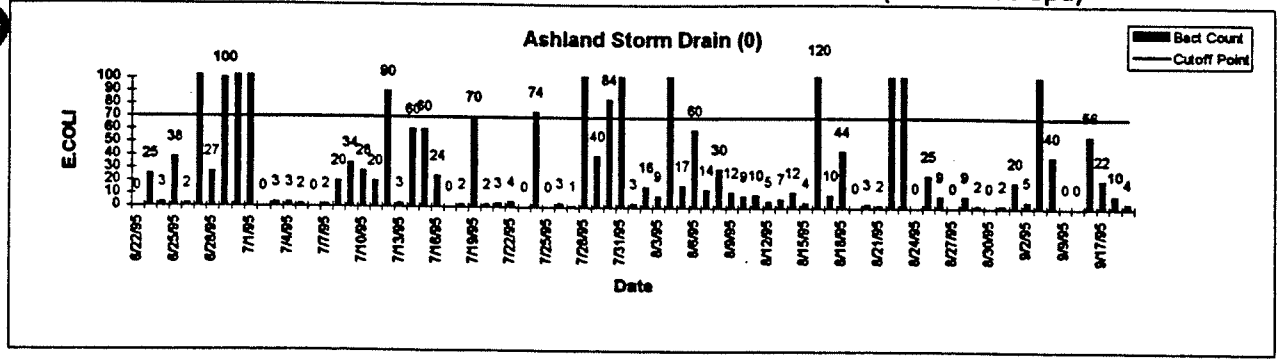
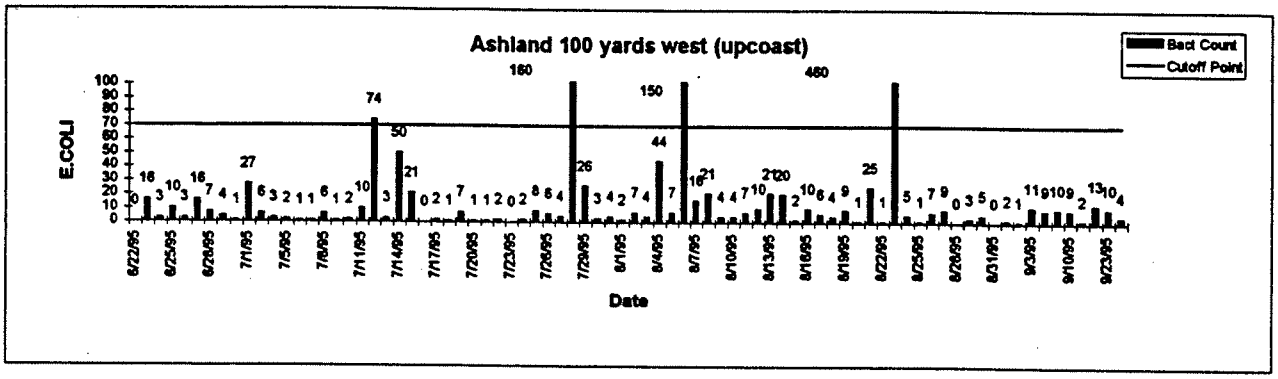
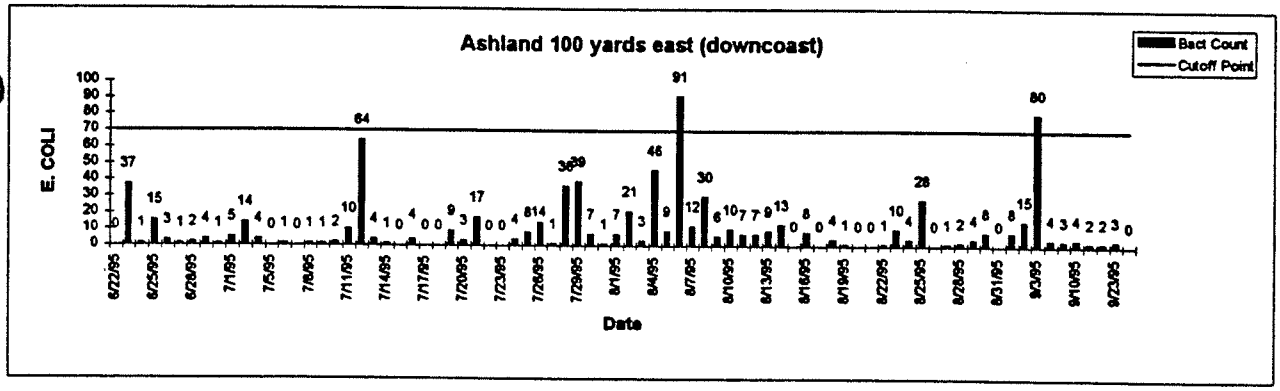
Figure 5A, cont. Daily *E.coli* Indicator Counts at Ashland Beach (Cutoff = 70 cpu)







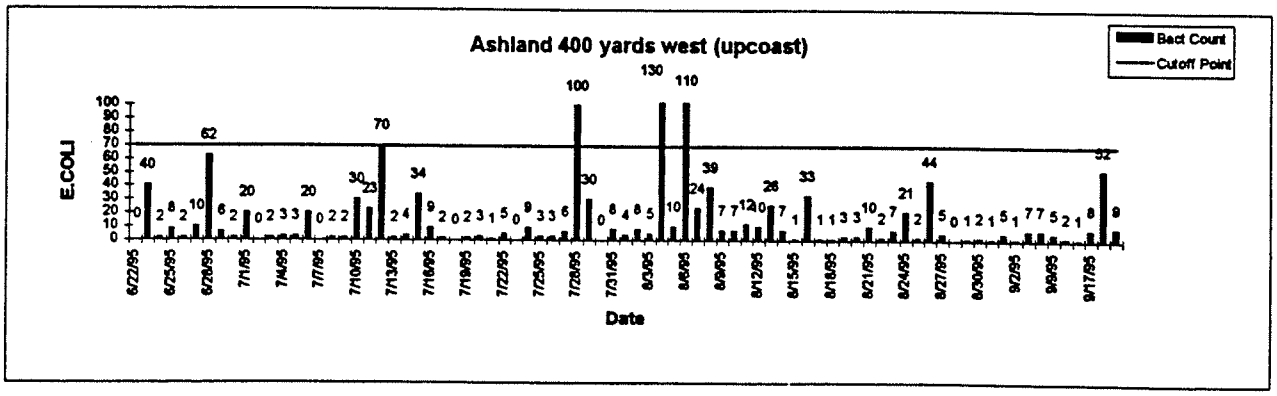
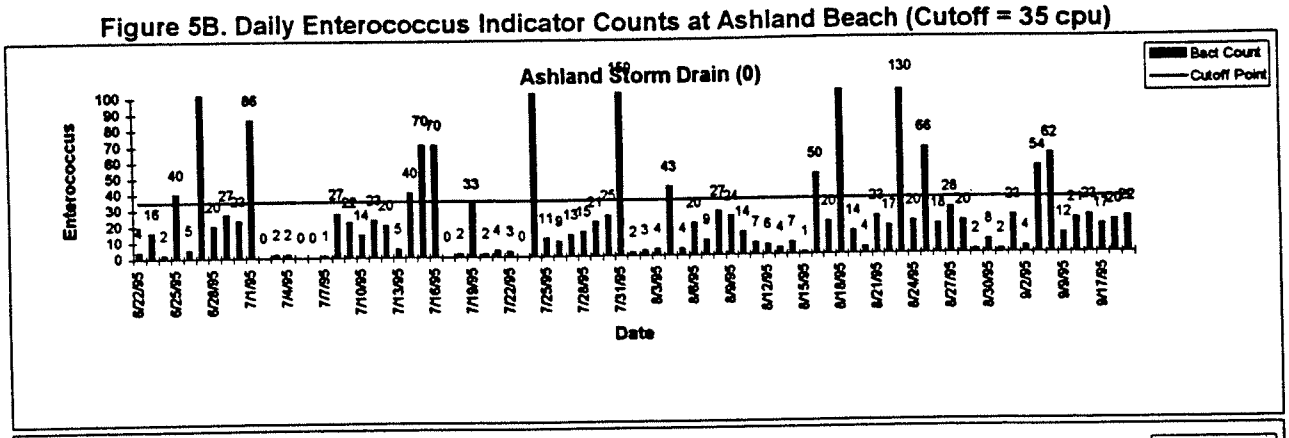
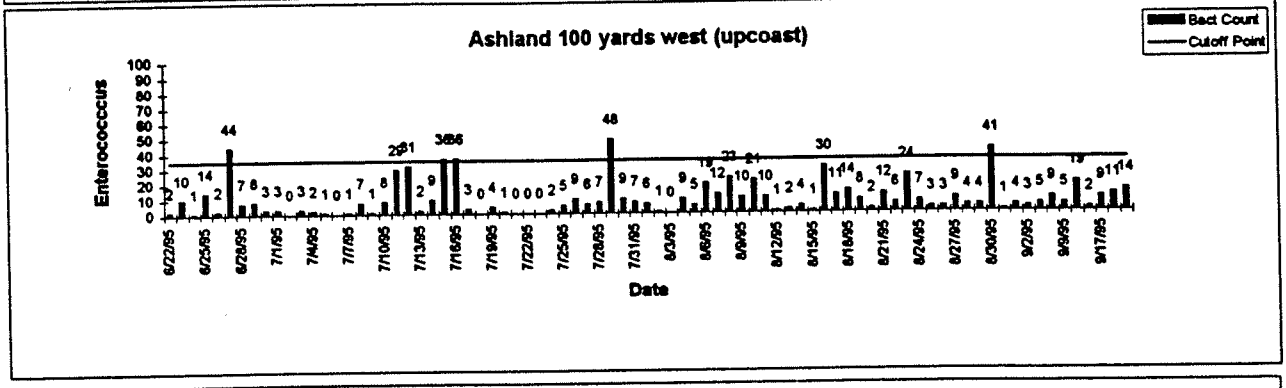
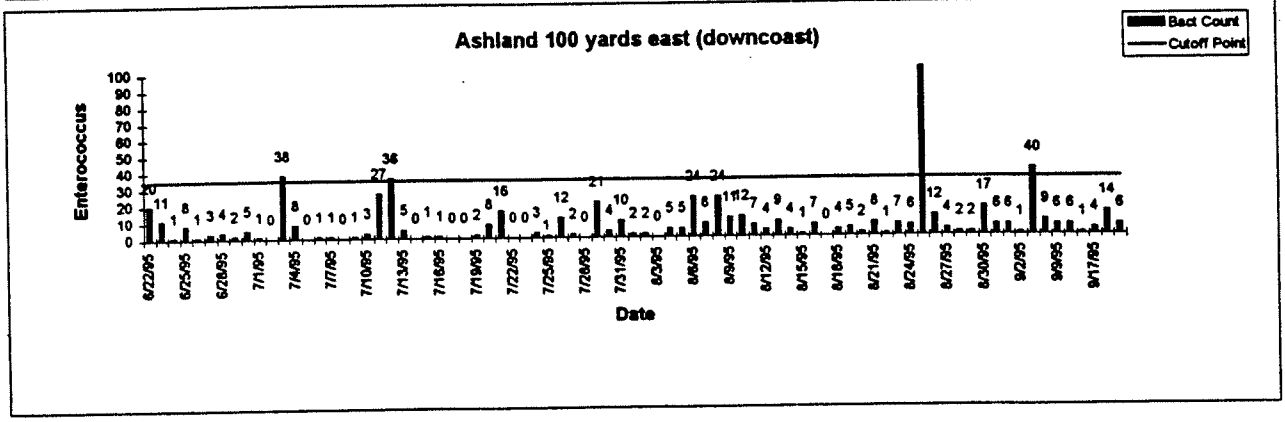


Figure 5B. Daily Enterococcus Indicator Counts at Ashland Beach (Cutoff = 35 cpu)







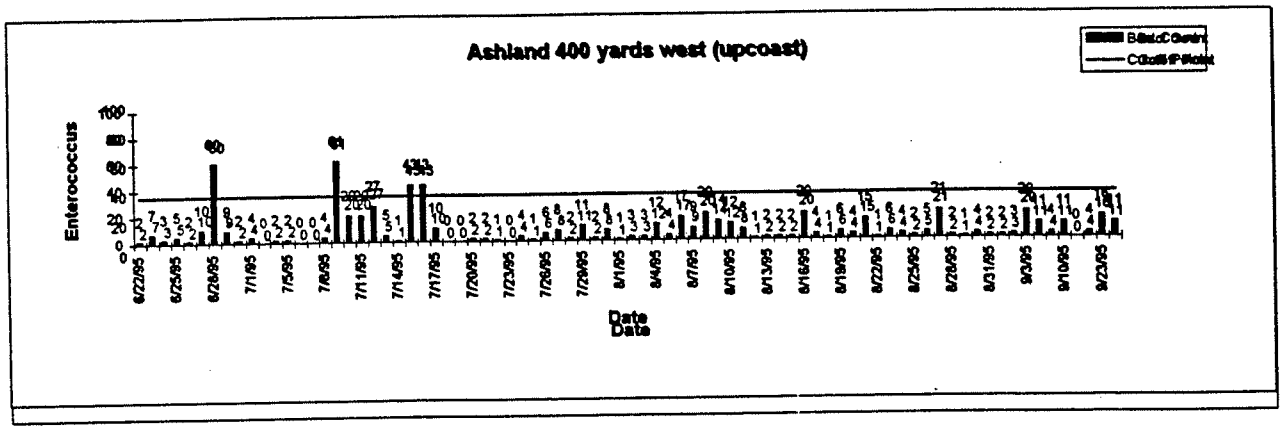


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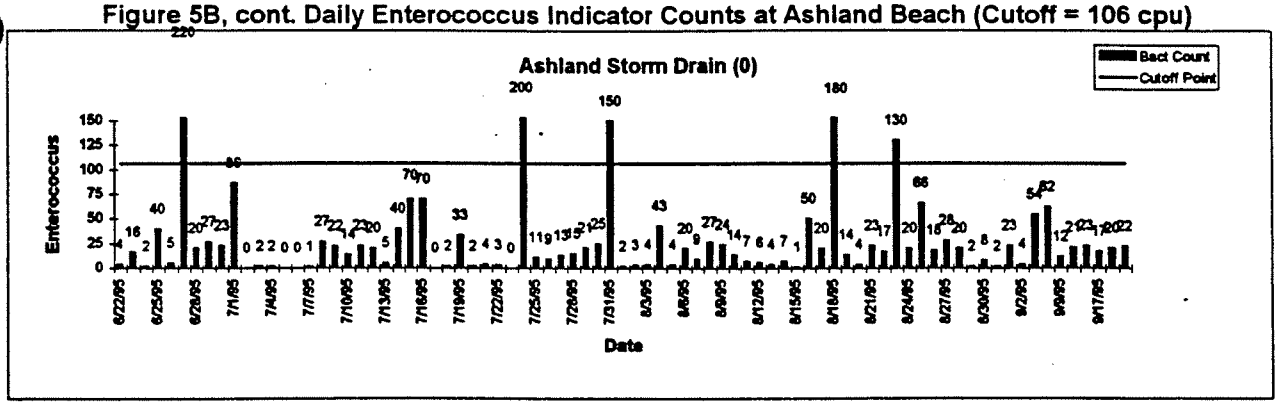
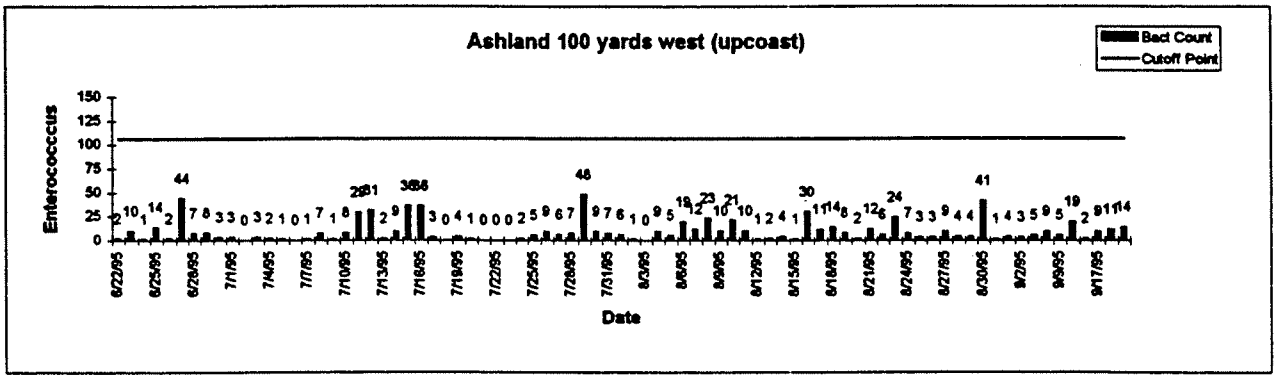
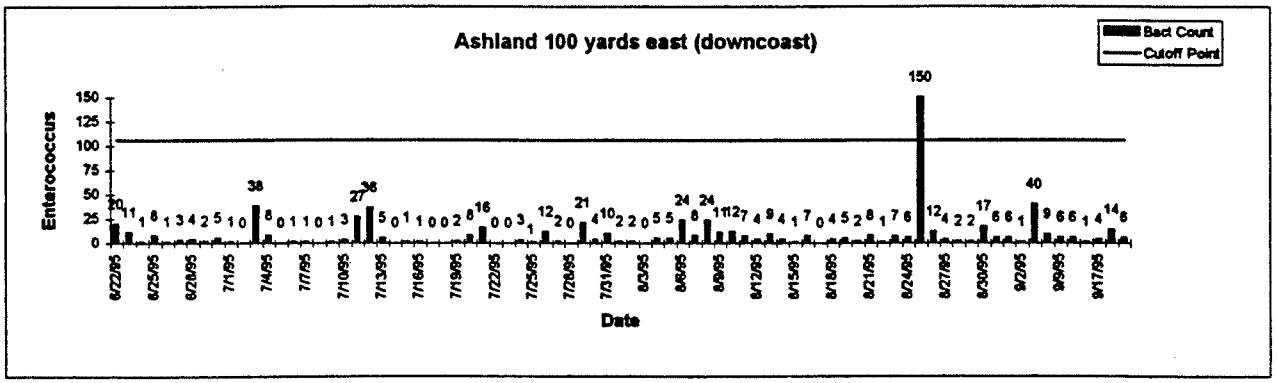
Figure 5B, cont. Daily Enterococcus Indicator Counts at Ashland Beach (Cutoff = 106 cpu)







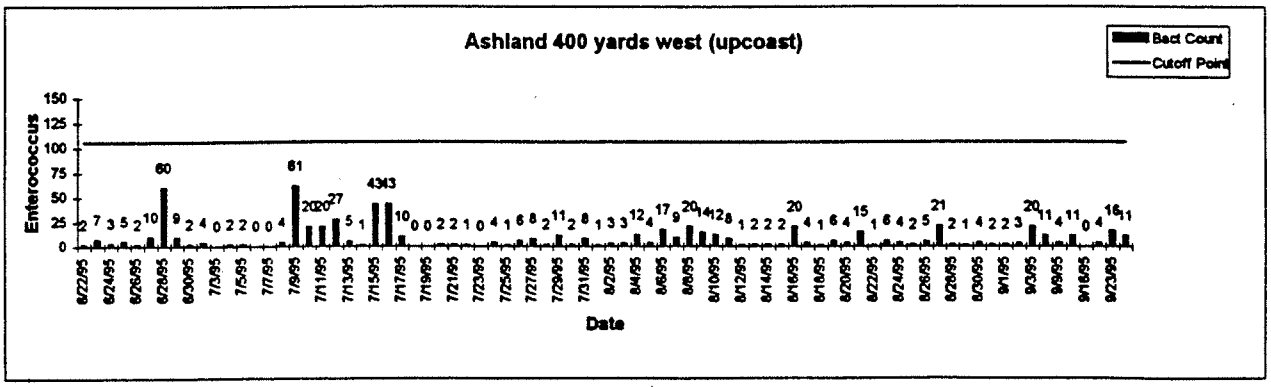
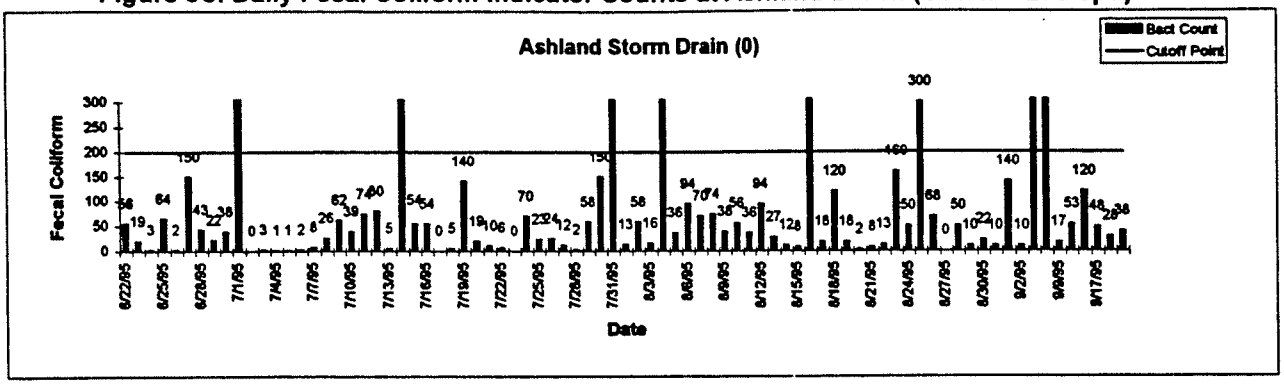
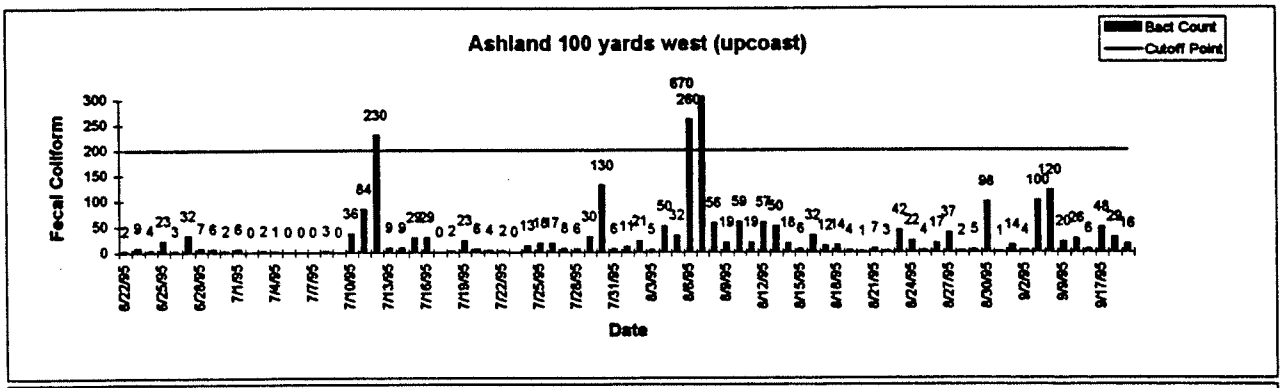
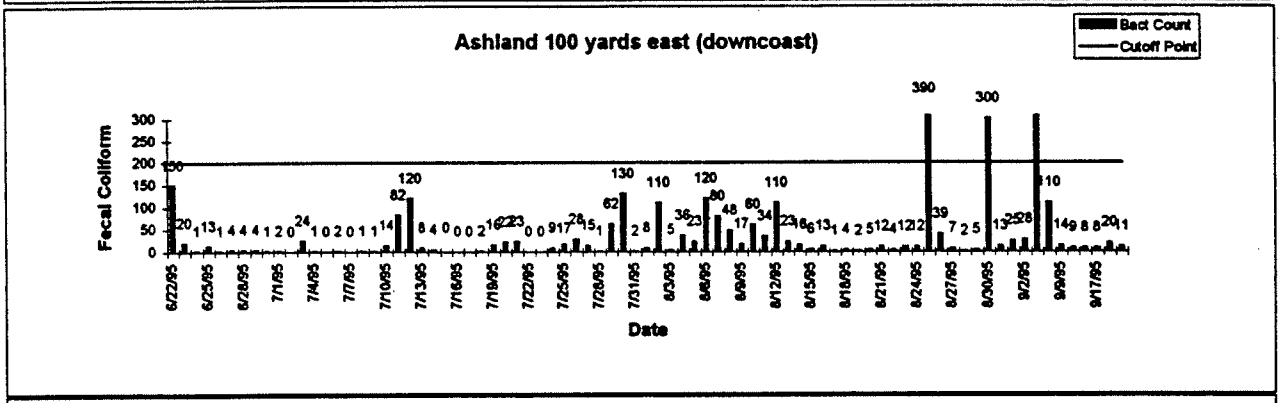


Figure 5C. Daily Fecal Coliform Indicator Counts at Ashland Beach (Cutoff = 200 cpu)







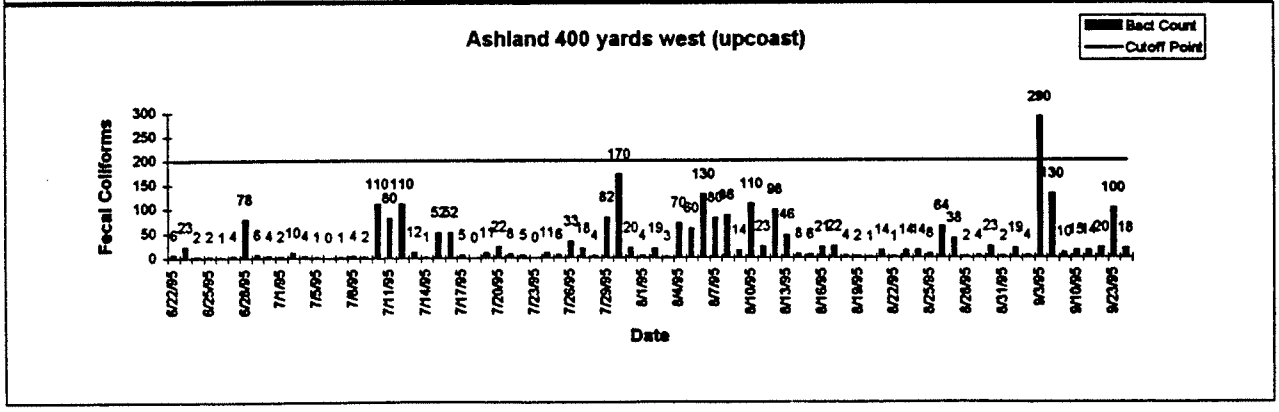
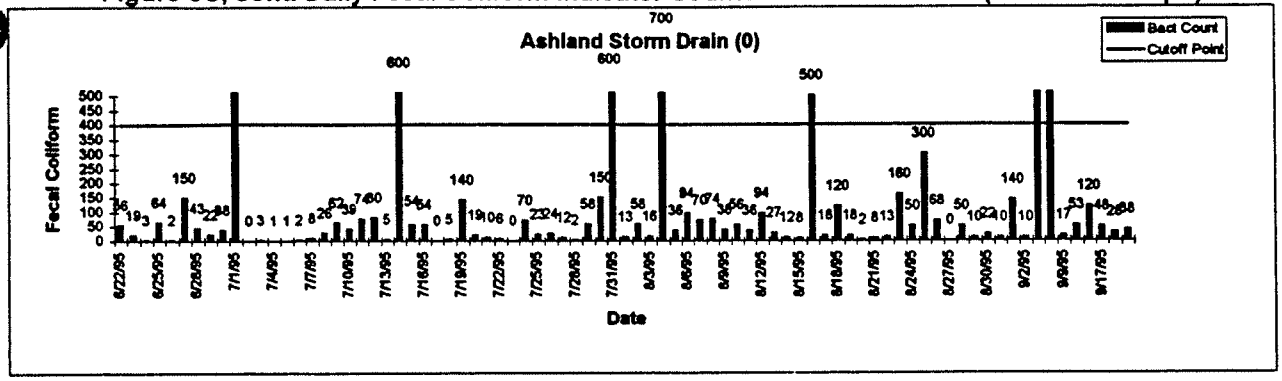
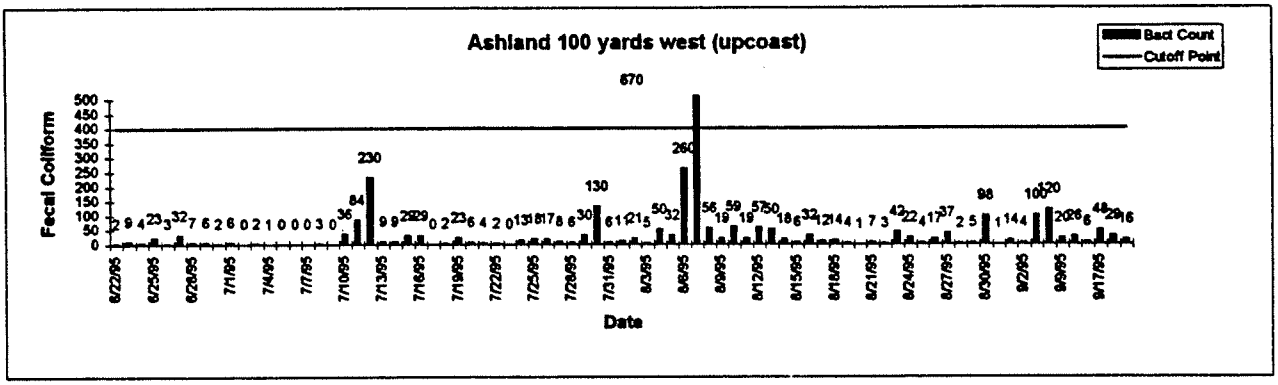
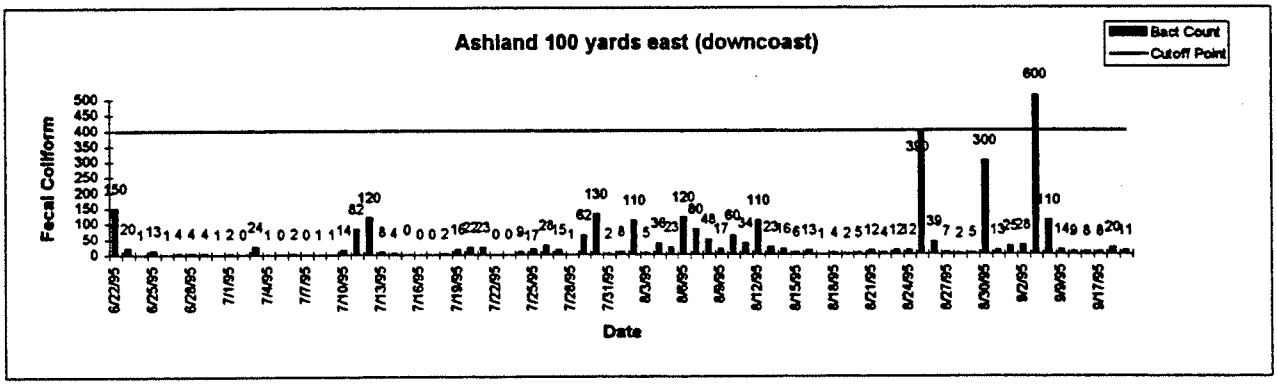


Figure 5C, cont. Daily Fecal Coliform Indicator Counts at Ashland Beach (Cutoff = 400 cpu)







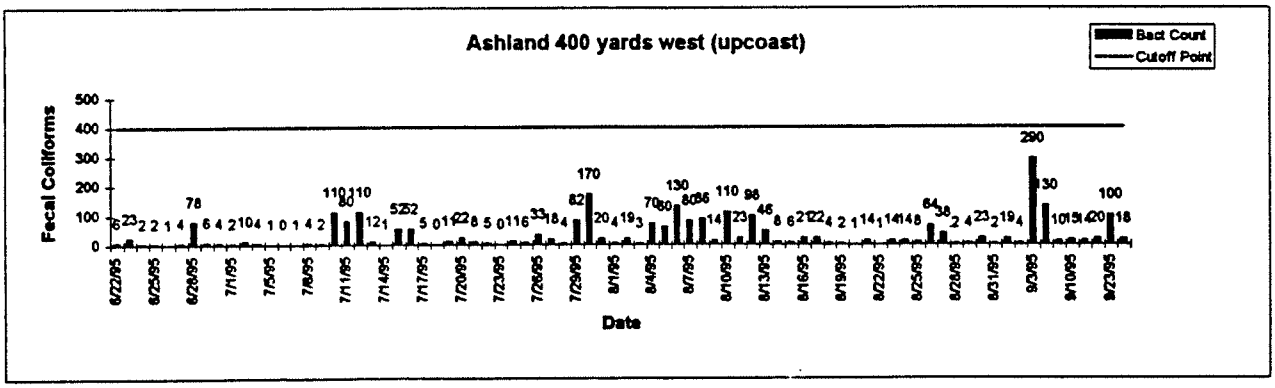
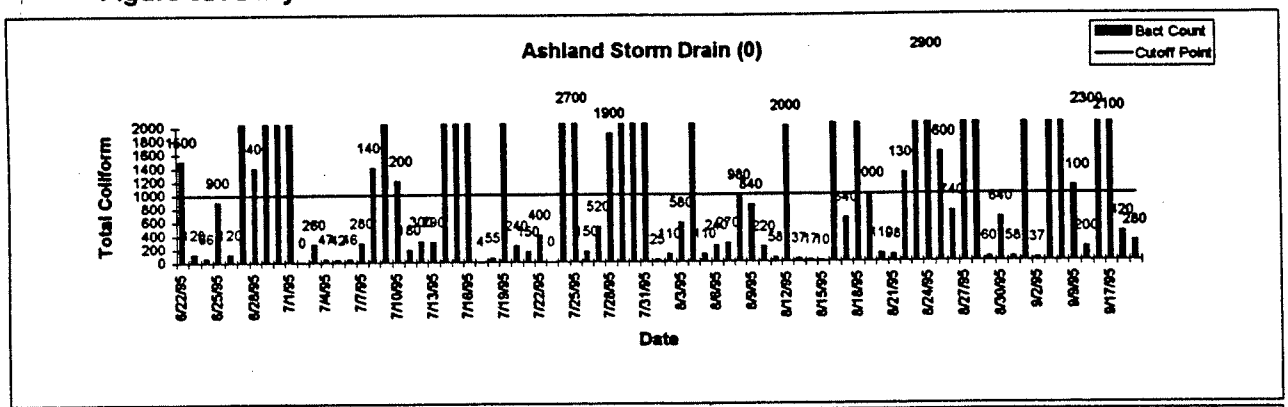
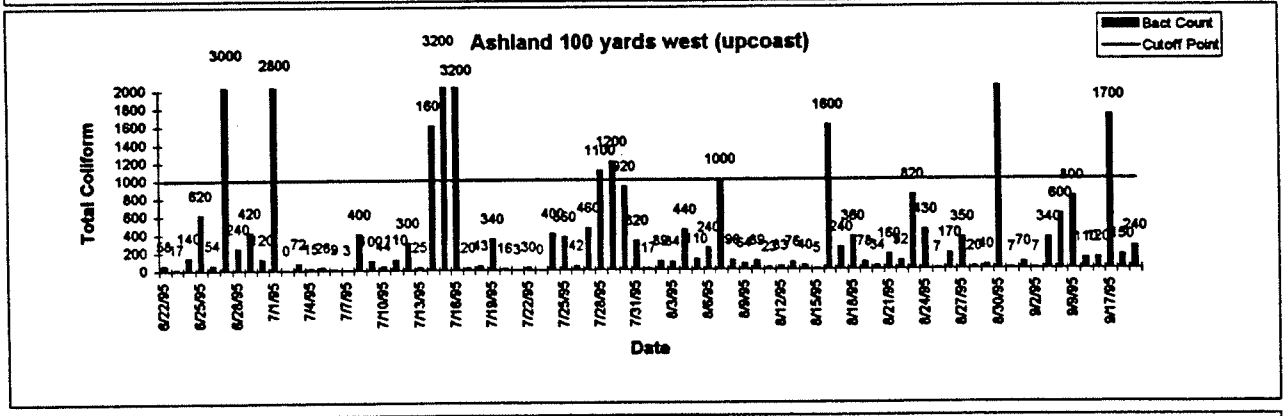
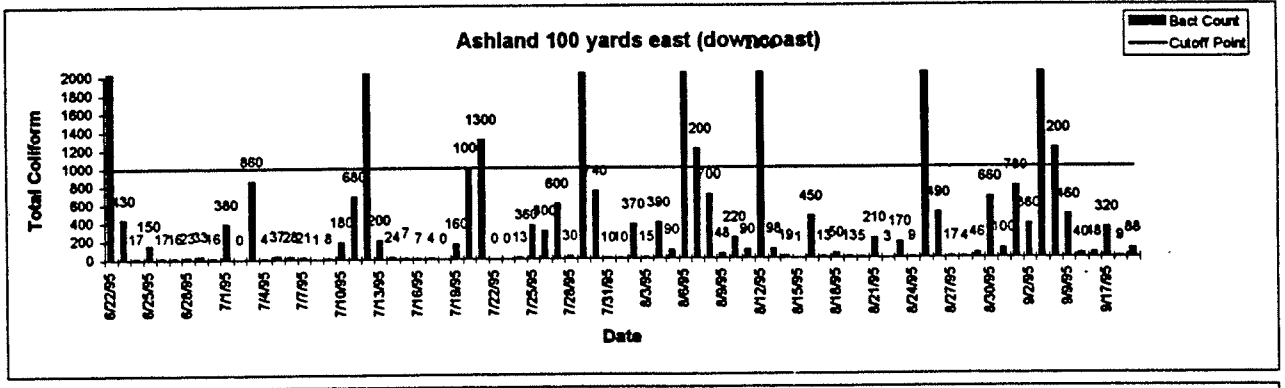
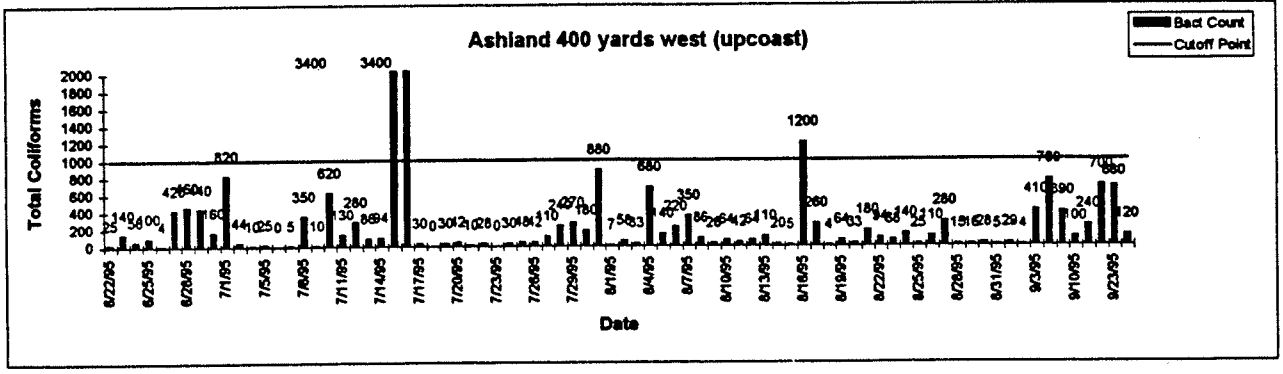


Figure 5D. Daily Total Coliform Indicator Counts at Ashland Beach (Cutoff = 1000 cpu)



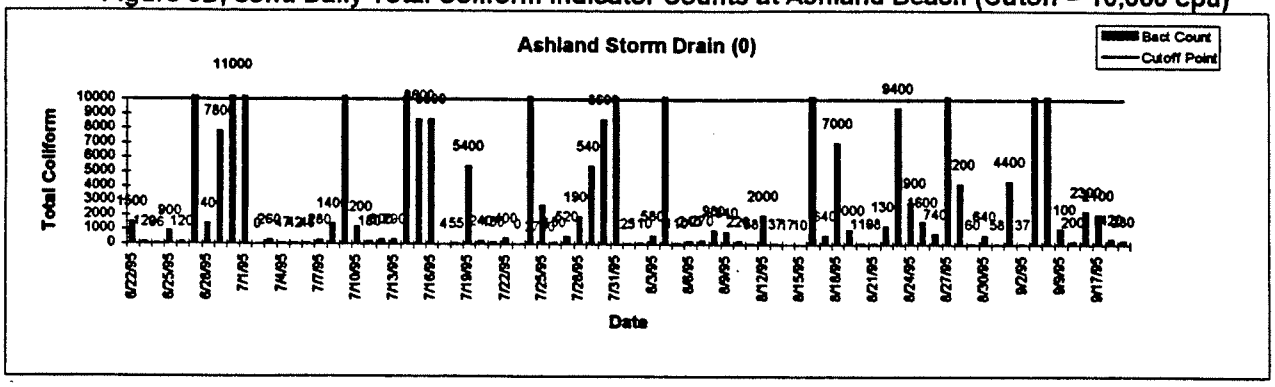


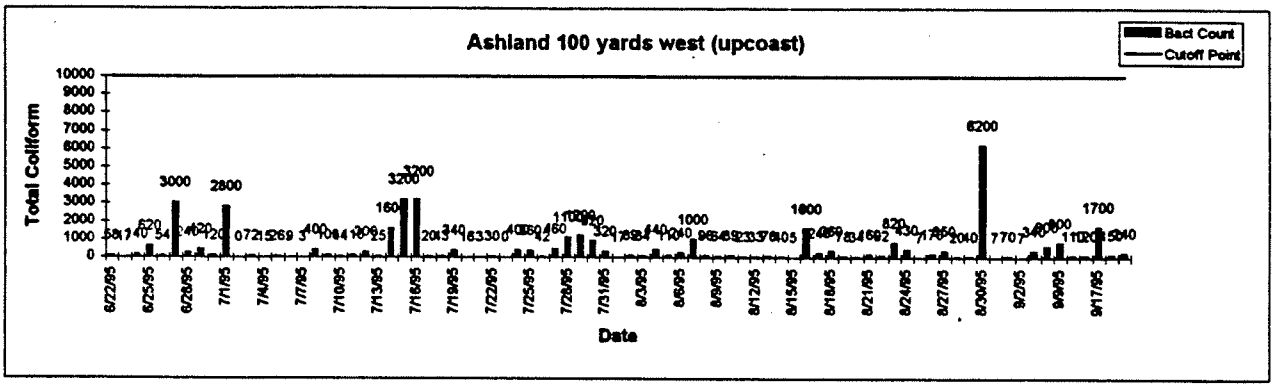


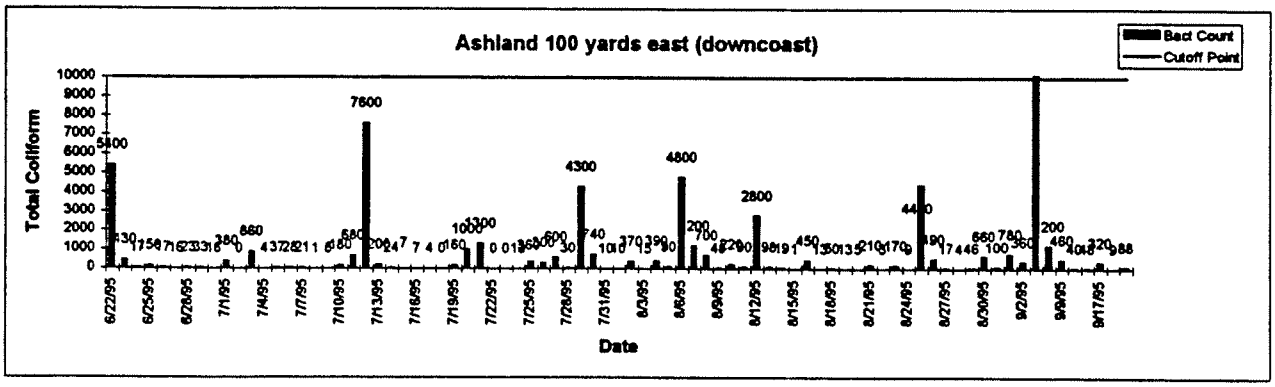


SARB_000456

Figure 5D, cont. Daily Total Coliform Indicator Counts at Ashland Beach (Cutoff = 10,000 cpu)







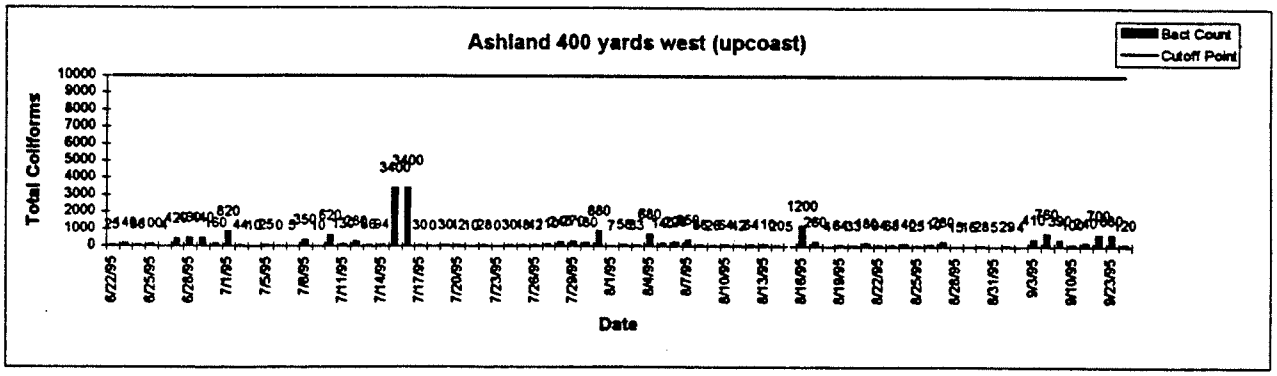
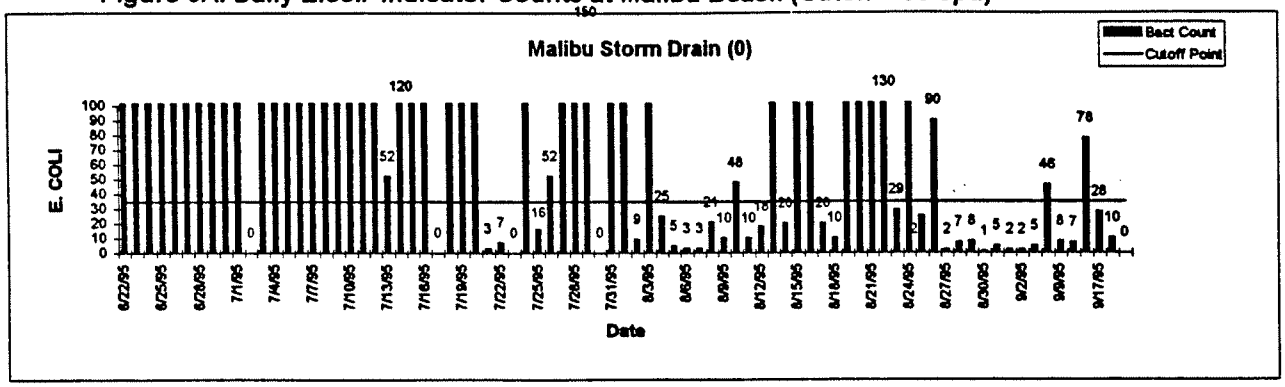
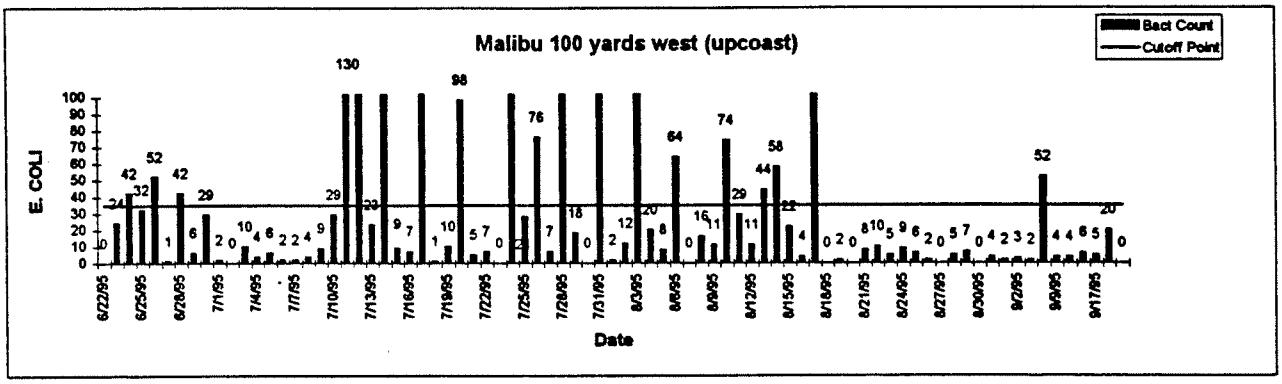
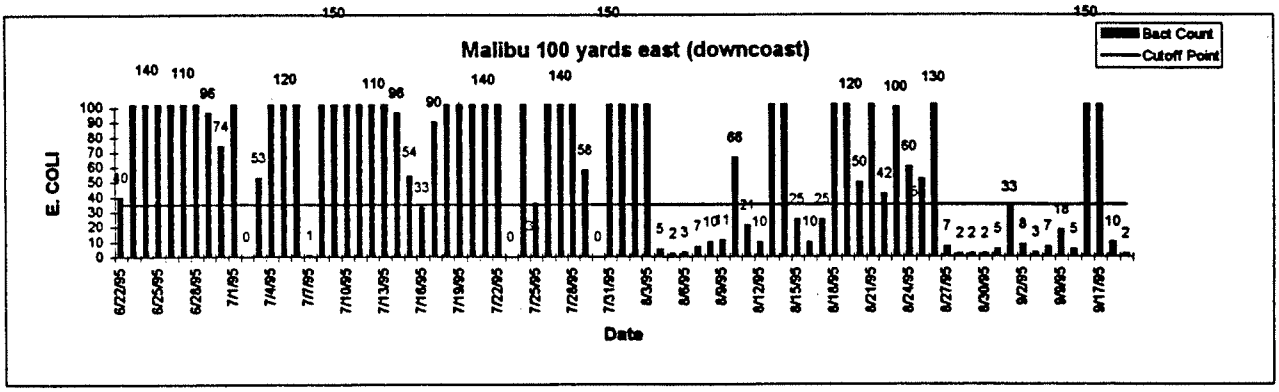


Figure 6A. Daily *E.coli* Indicator Counts at Malibu Beach (Cutoff = 35 cpu)







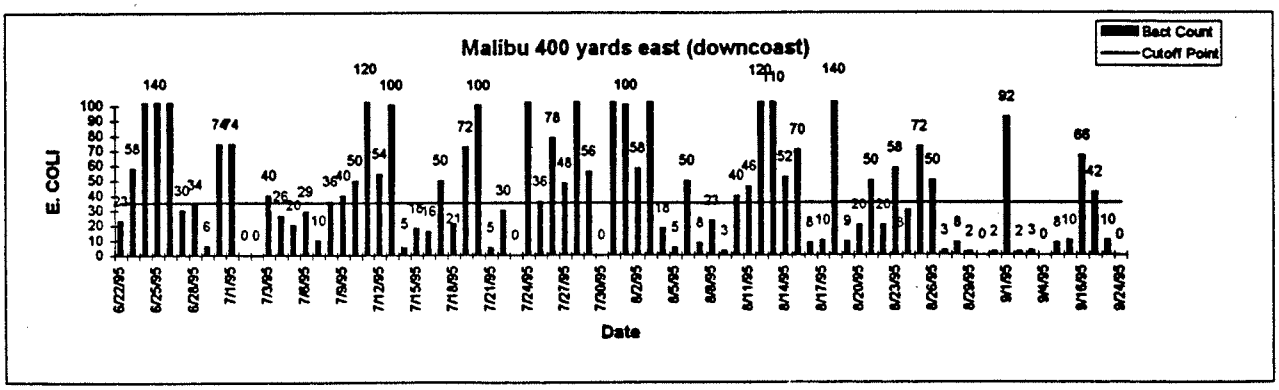


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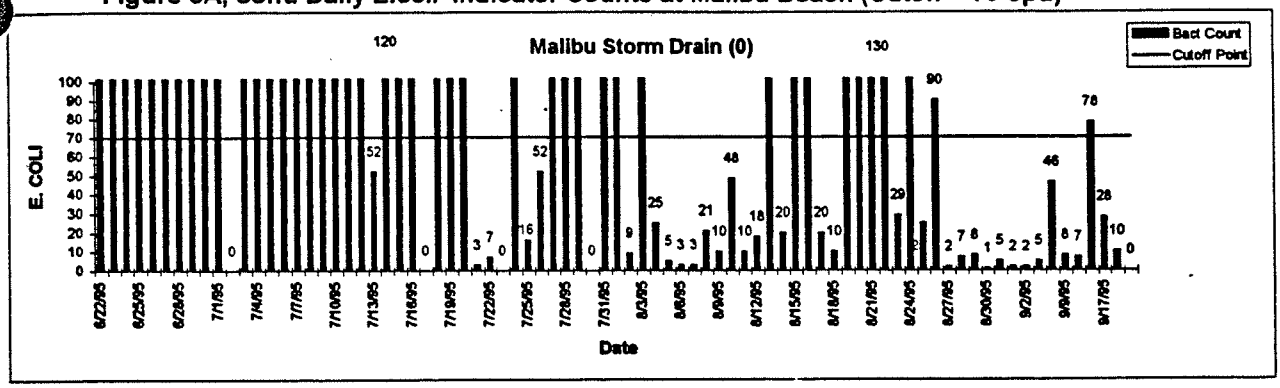
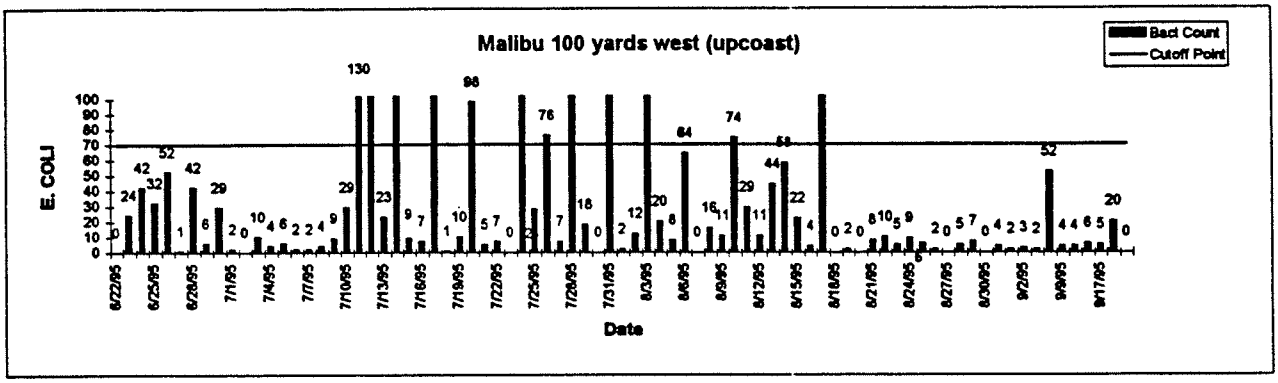
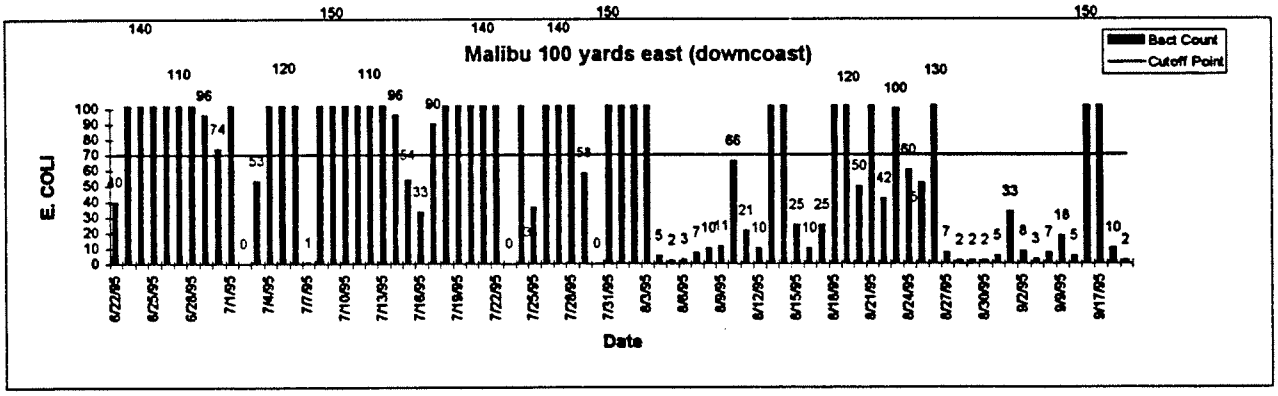
Figure 6A, cont. Daily *E.coli* Indicator Counts at Malibu Beach (Cutoff = 70 cpu)







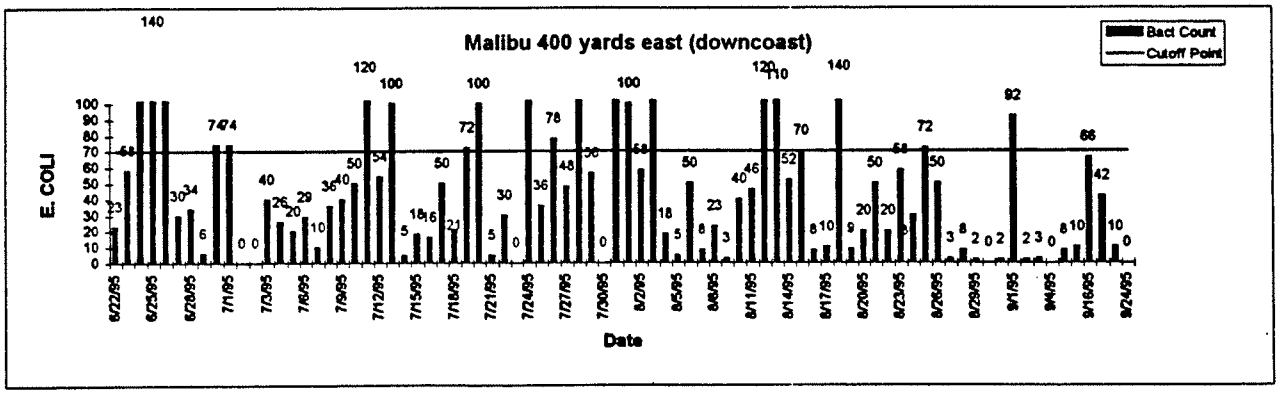


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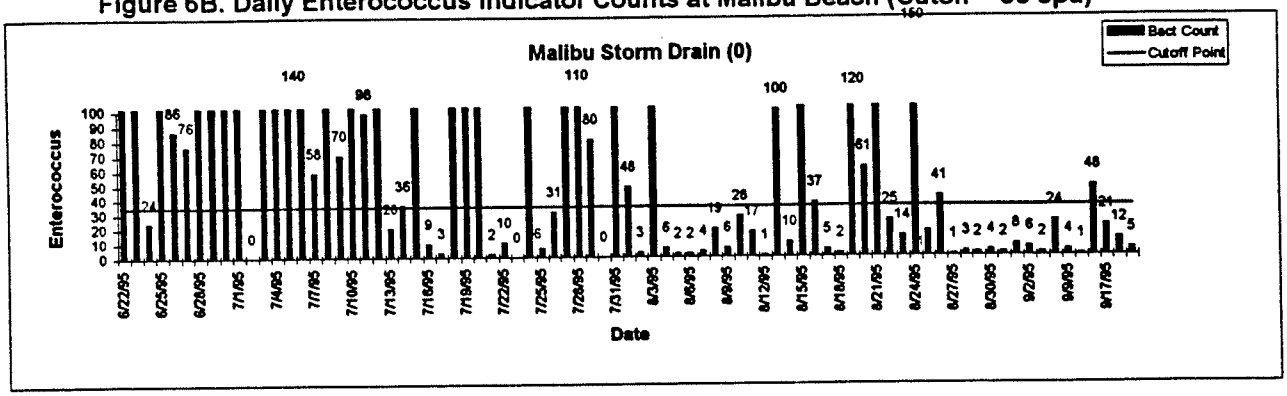
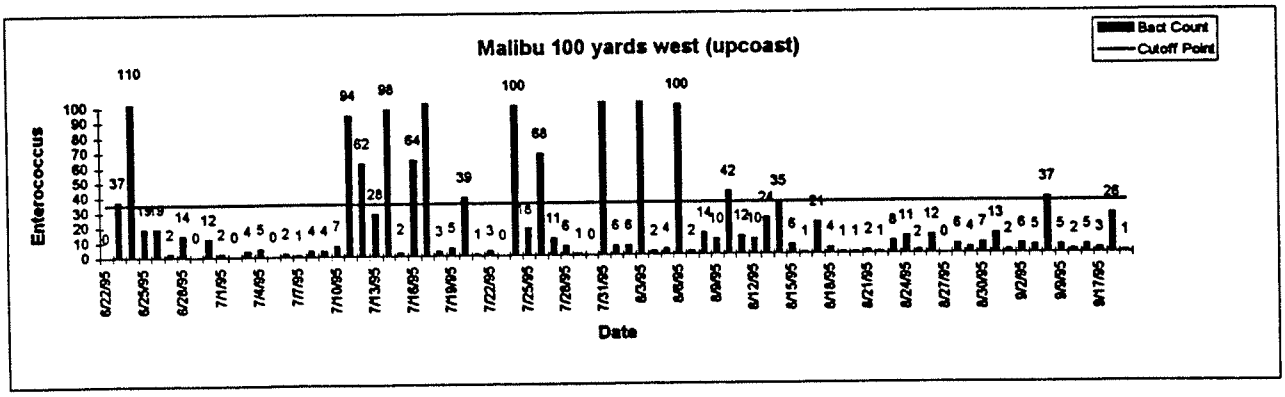
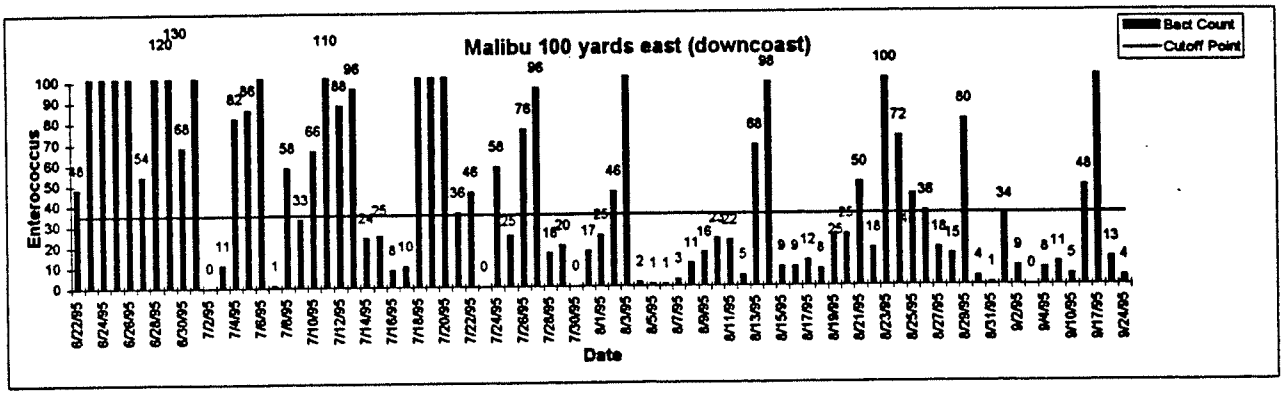
Figure 6B. Daily Enterococcus Indicator Counts at Malibu Beach (Cutoff = 35 cpu)







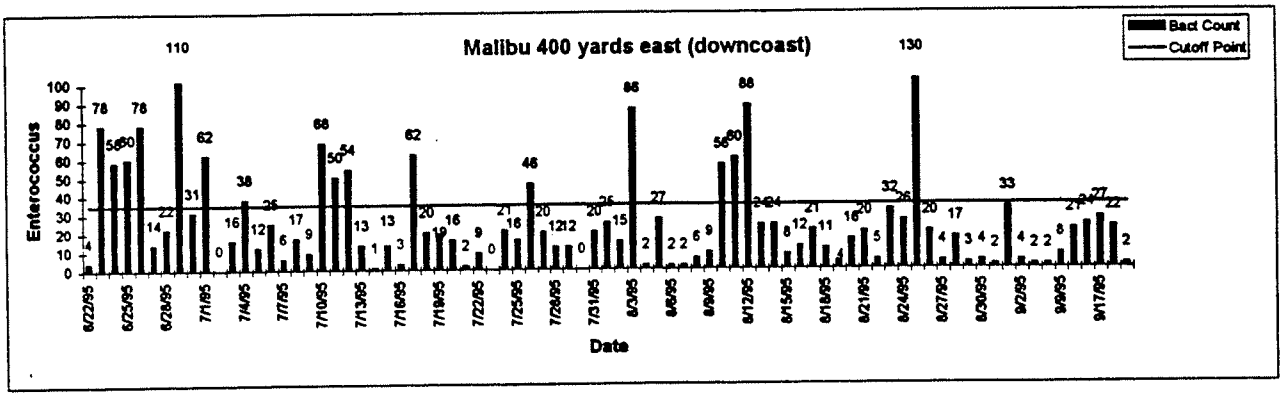
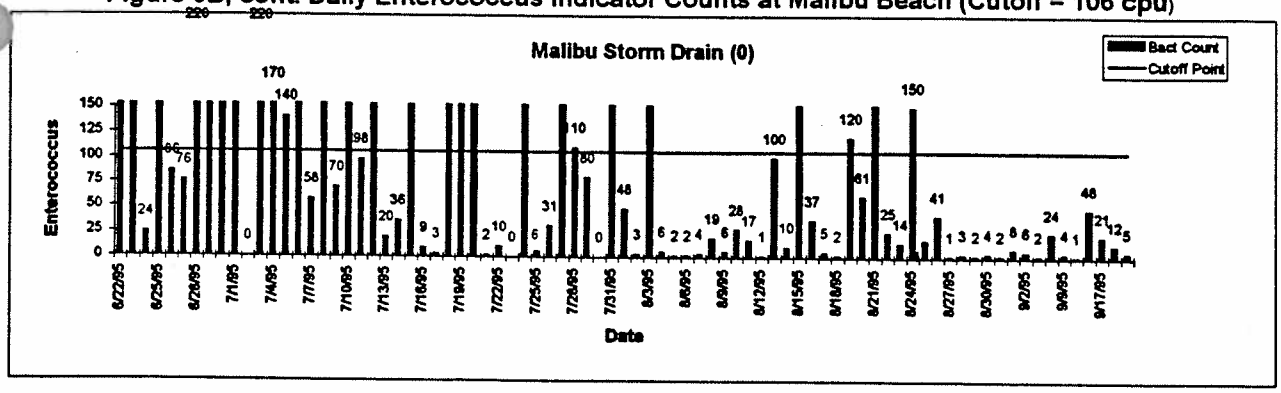
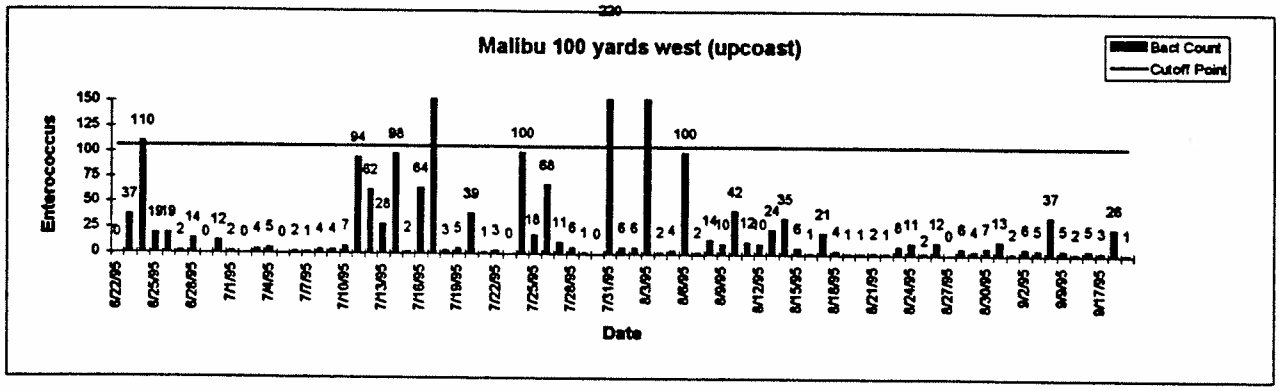
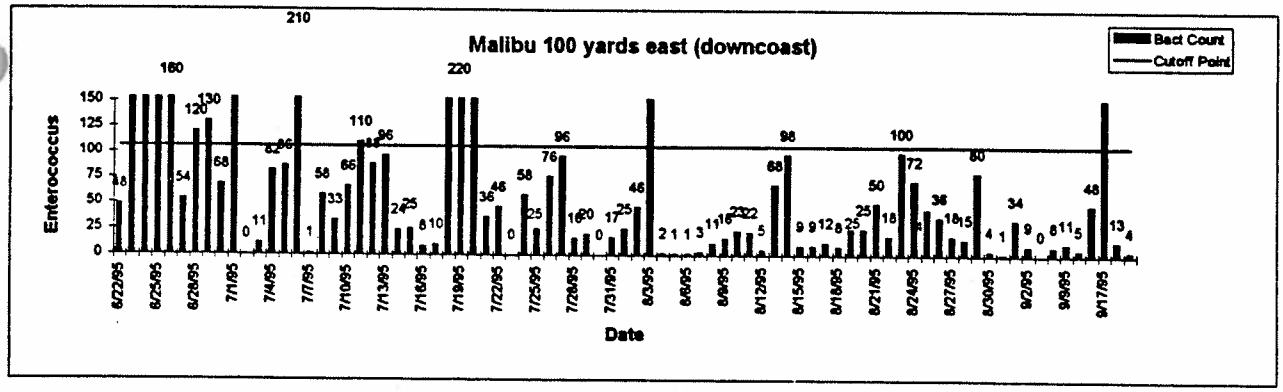


Figure 6B, cont. Daily Enterococcus Indicator Counts at Malibu Beach (Cutoff = 106 cpu)







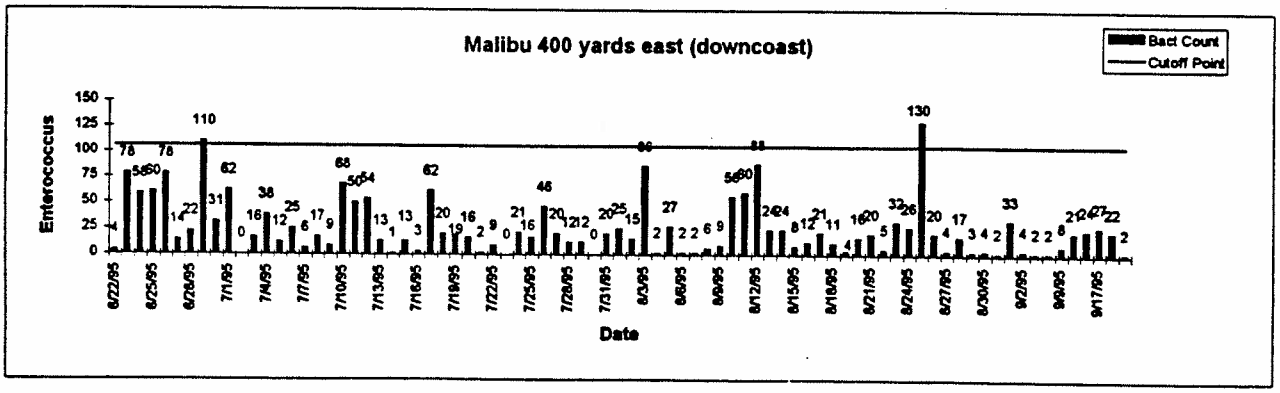
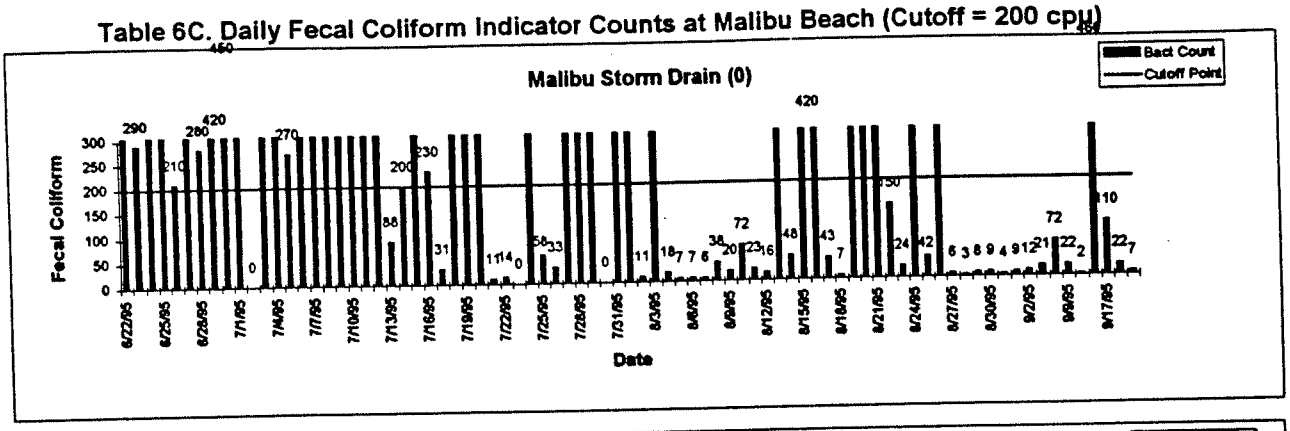
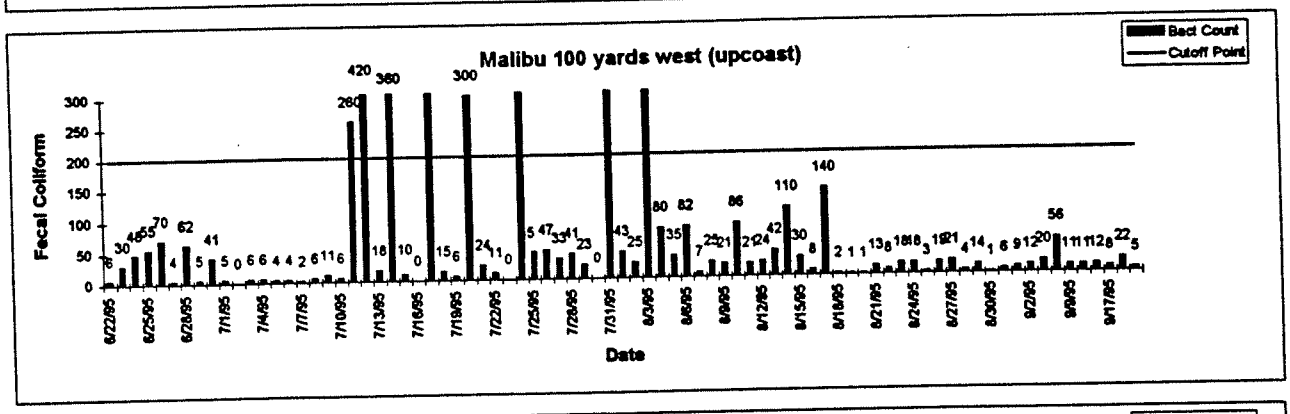
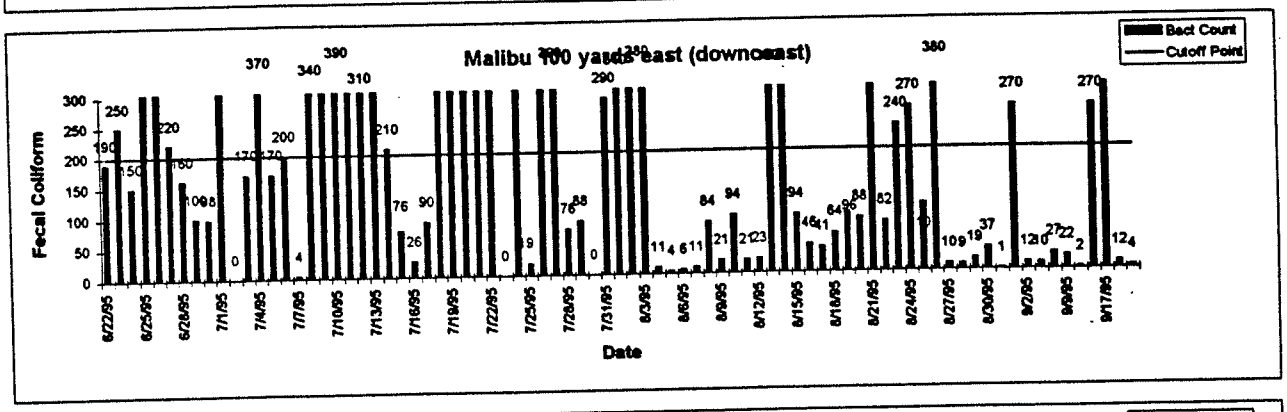


Table 6C. Daily Fecal Coliform Indicator Counts at Malibu Beach (Cutoff = 200 cpu)







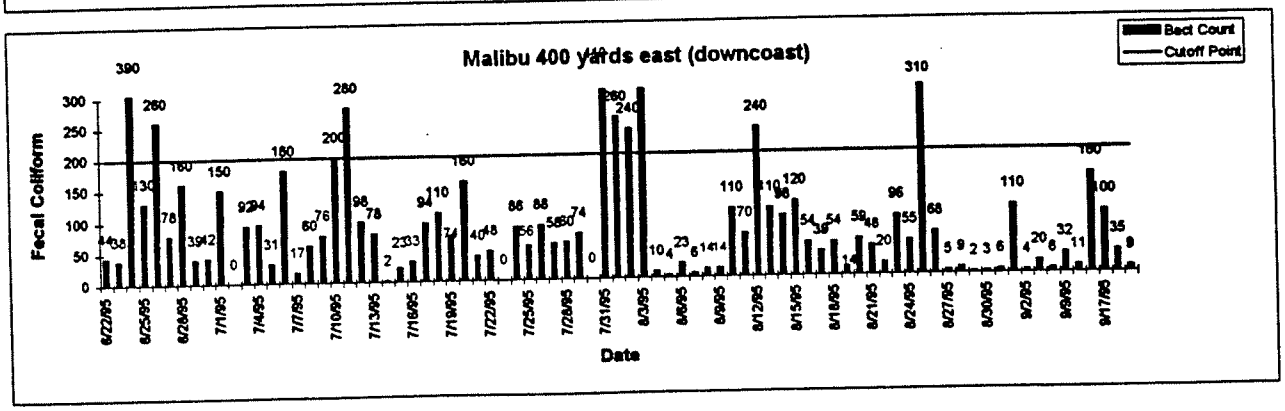
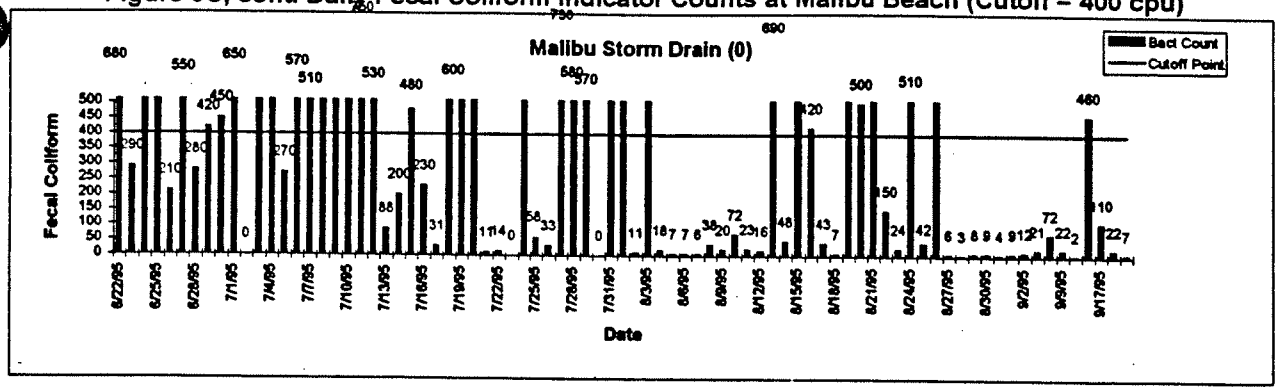
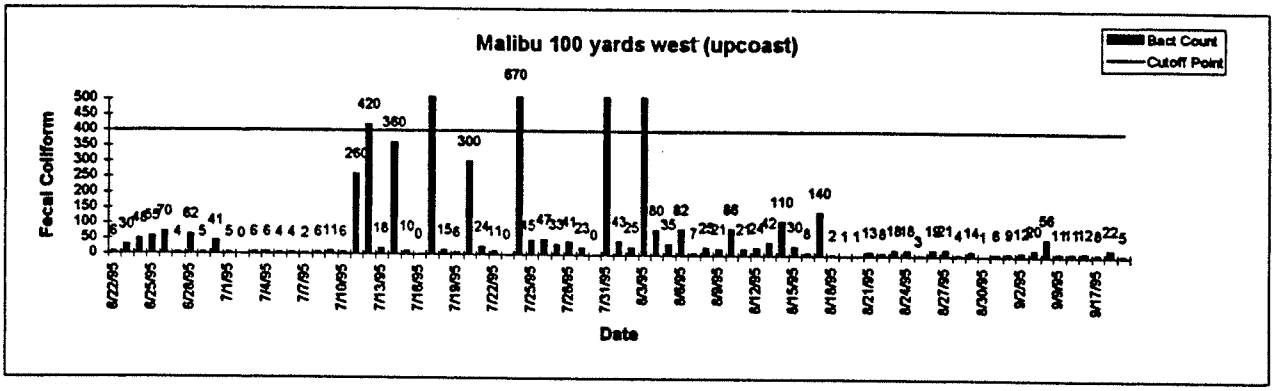
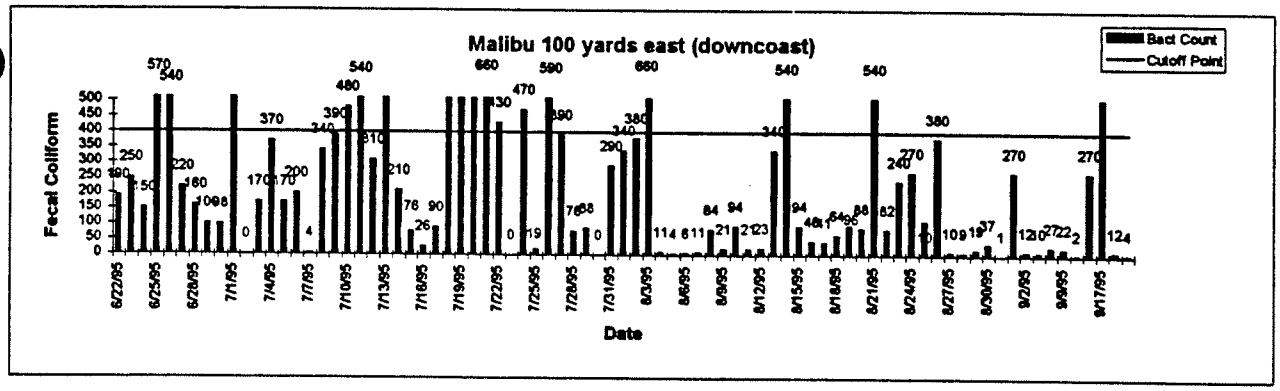


Figure 6C, cont. Daily Fecal Coliform Indicator Counts at Malibu Beach (Cutoff = 400 cpu)







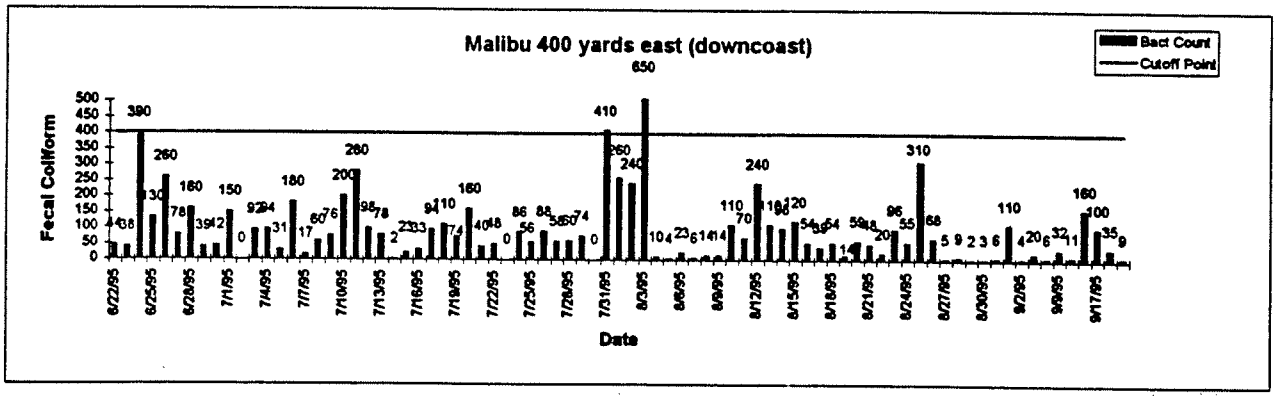
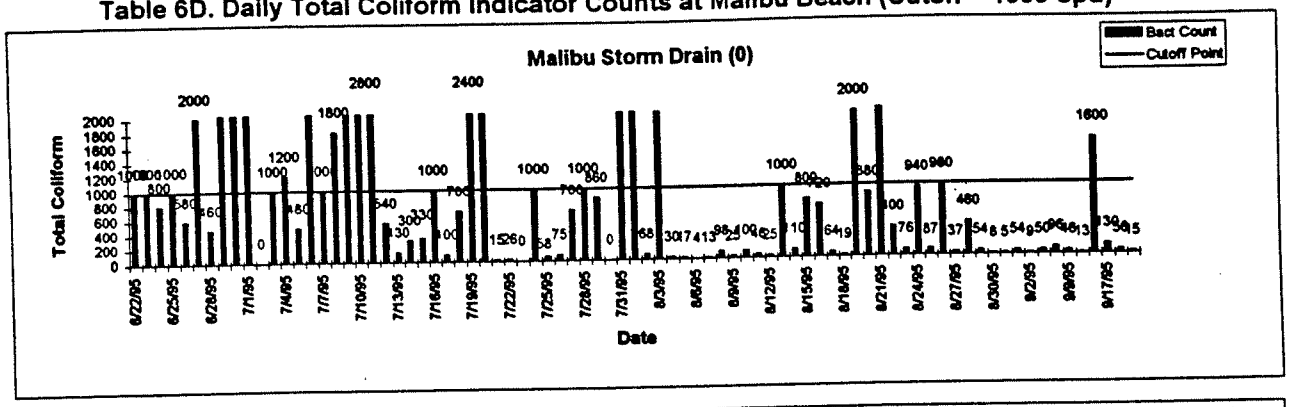
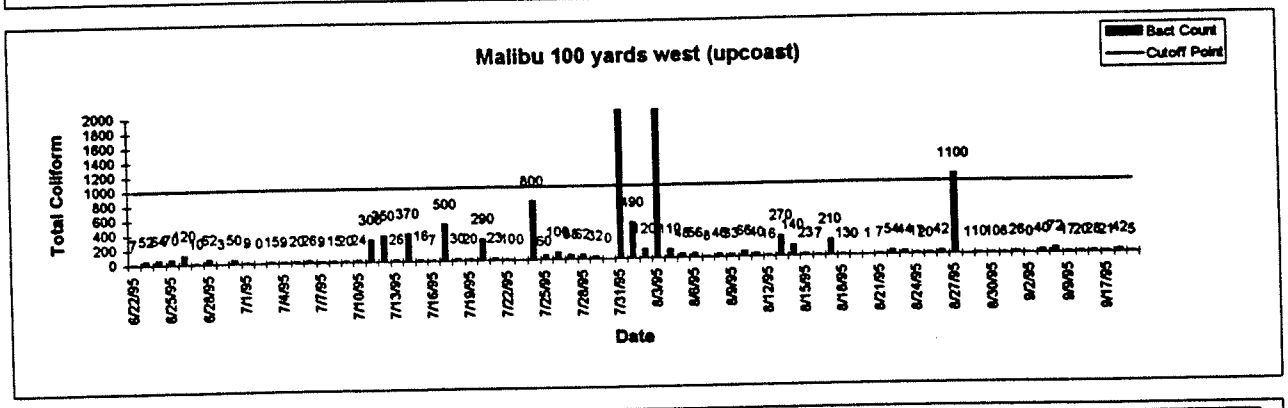
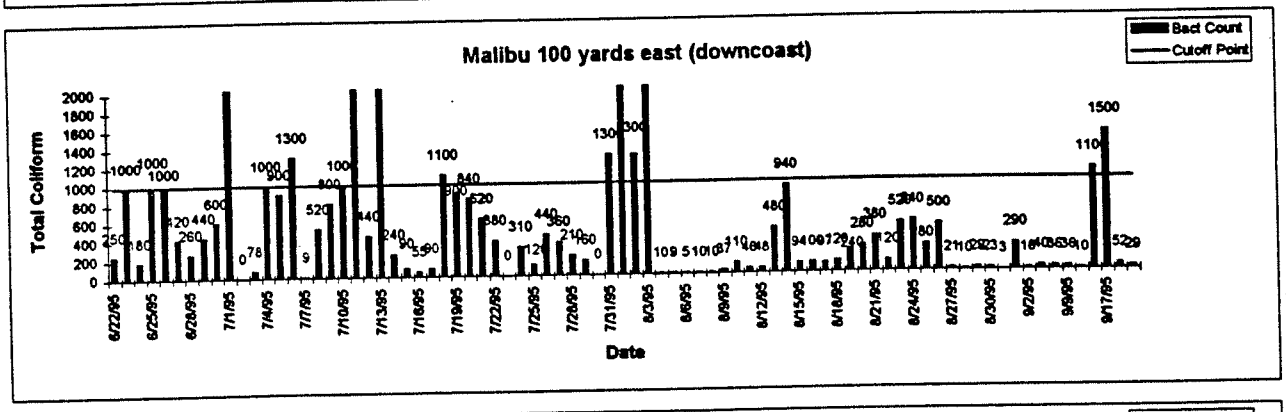


Table 6D. Daily Total Coliform Indicator Counts at Malibu Beach (Cutoff = 1000 cpu)







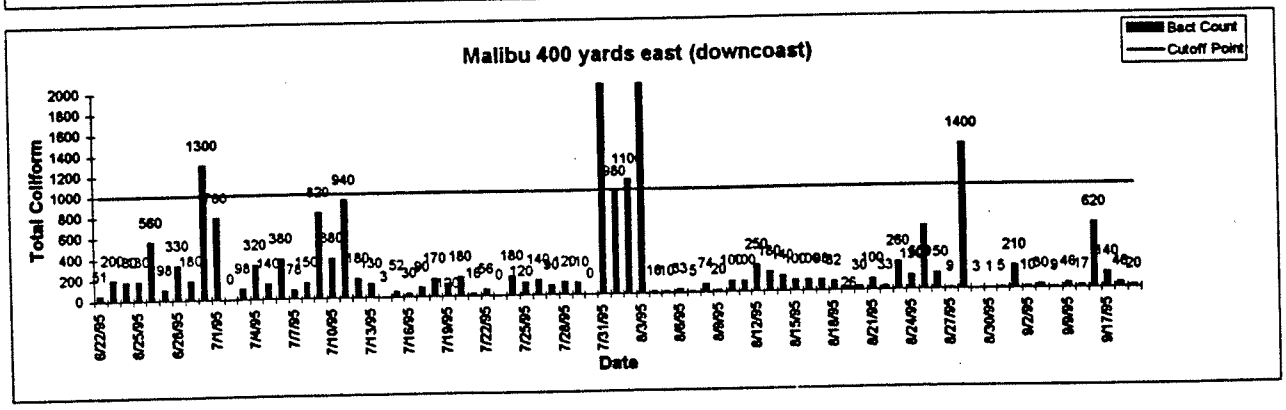


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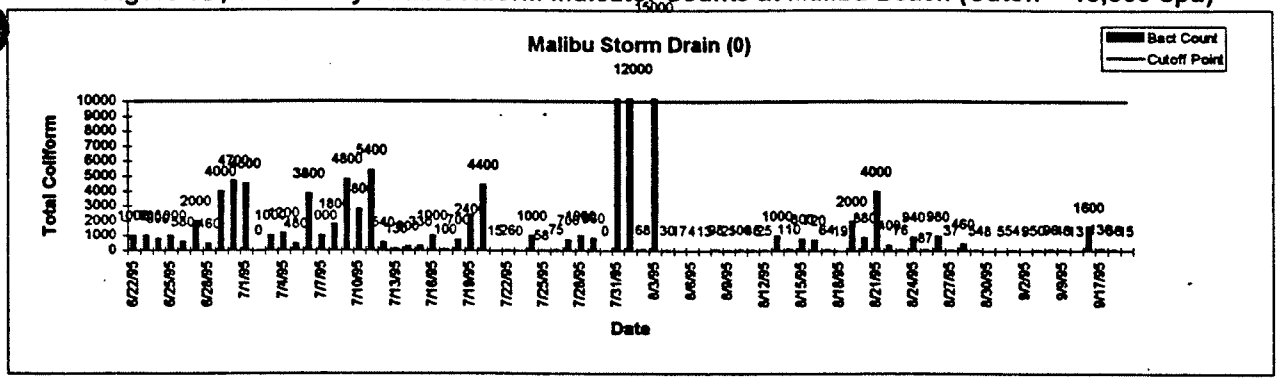
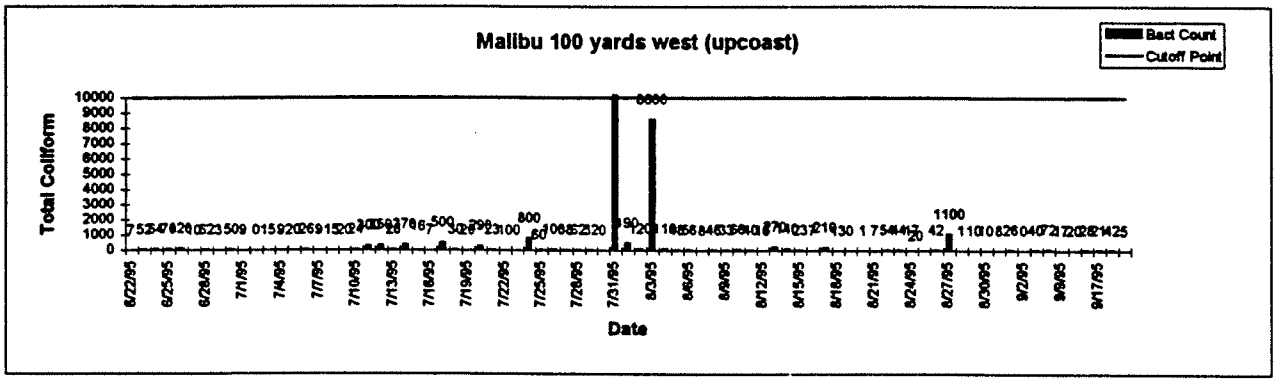
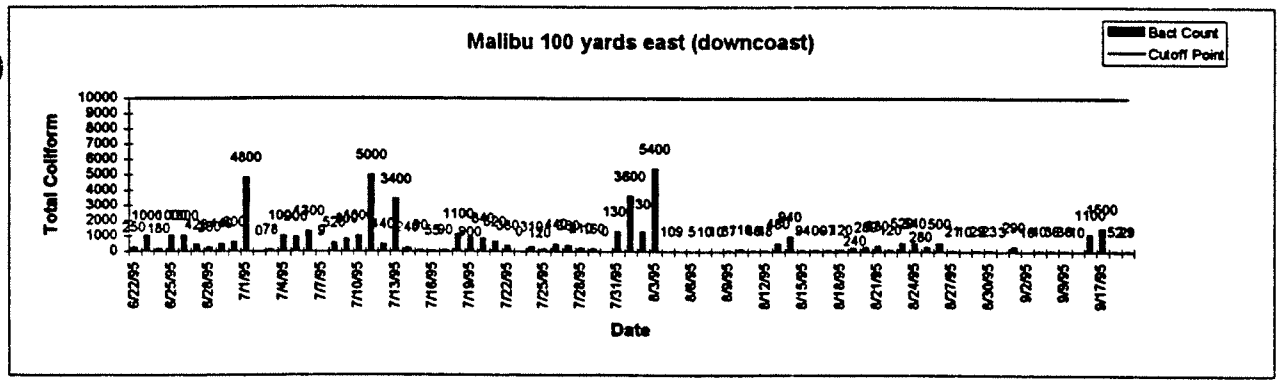
Figure 6D, cont. Daily Total Coliform Indicator Counts at Malibu Beach (Cutoff = 10,000 cpu)







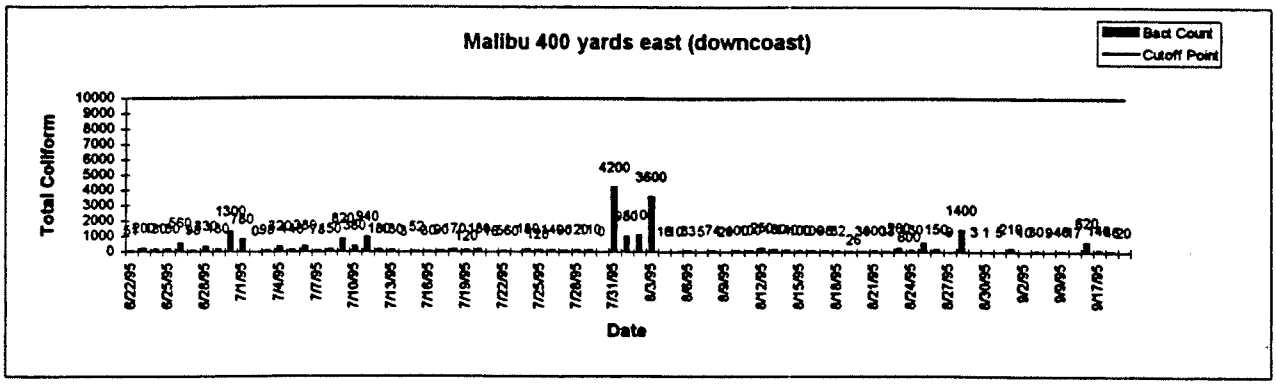
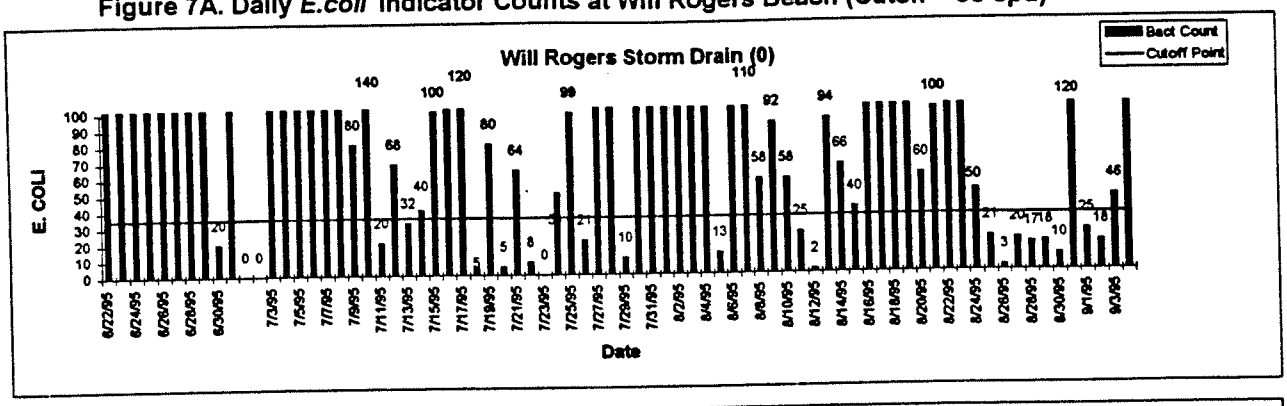
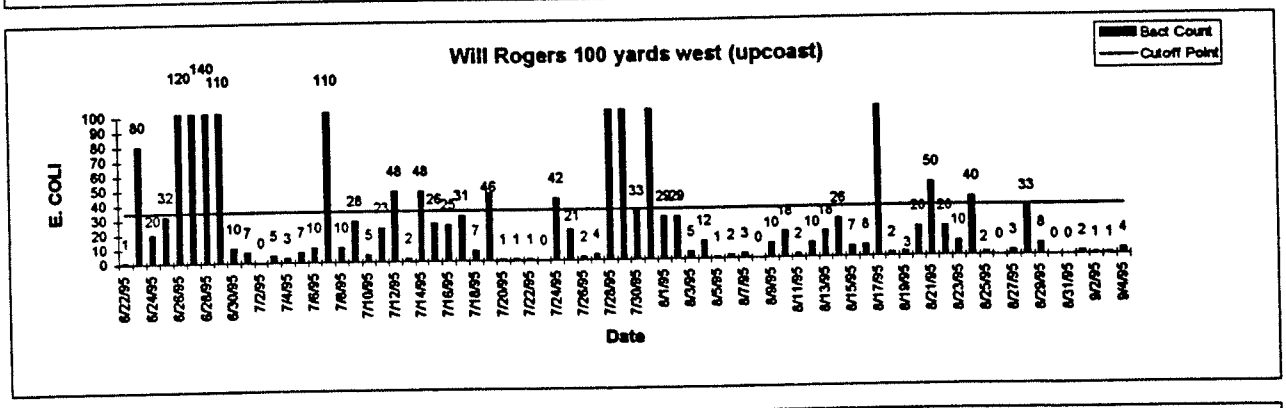
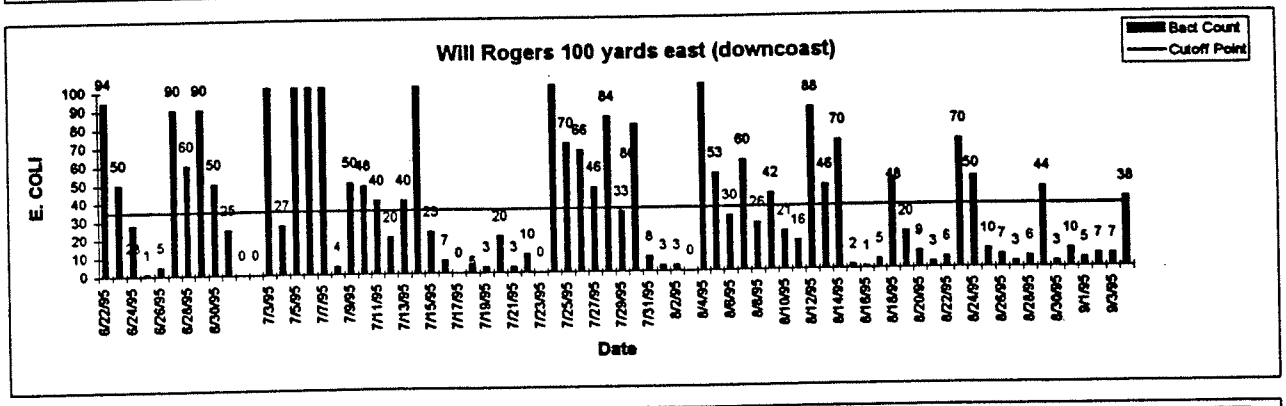


Figure 7A. Daily *E.coli* Indicator Counts at Will Rogers Beach (Cutoff = 35 cpu)







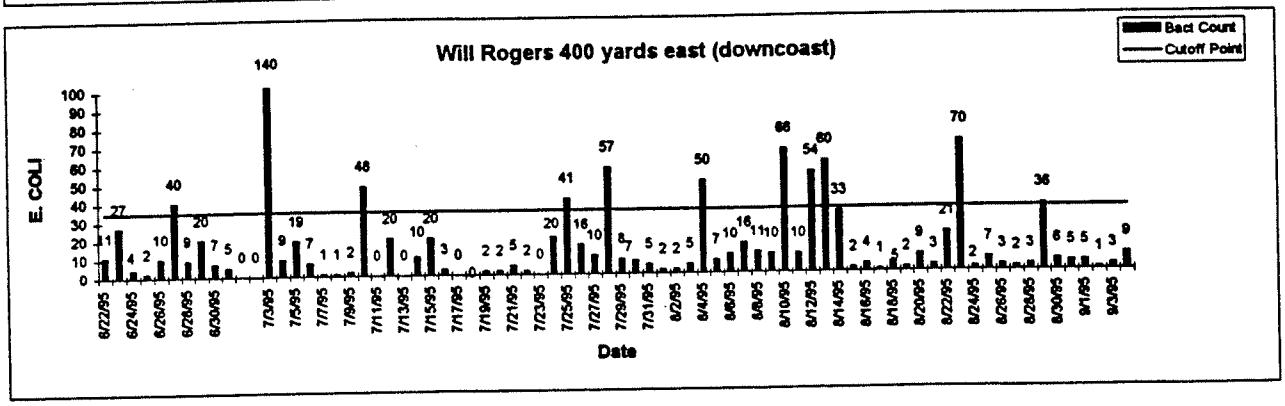
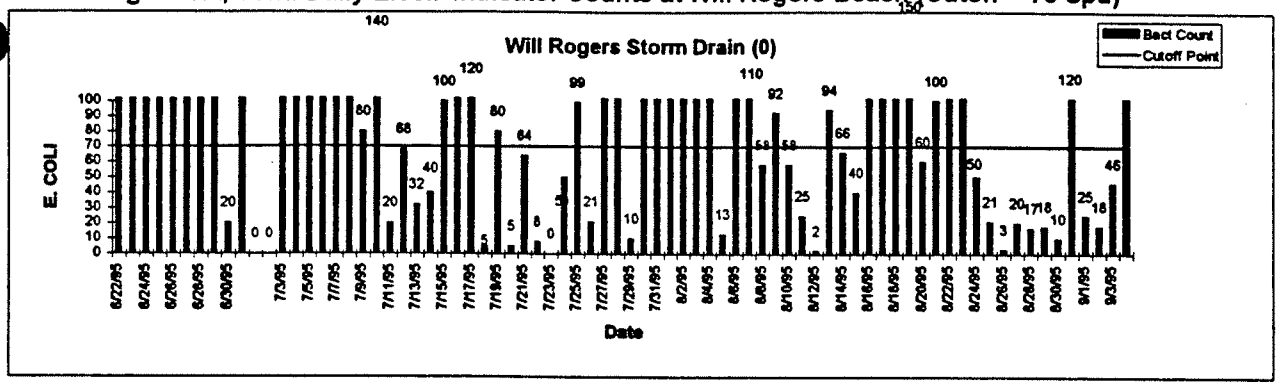
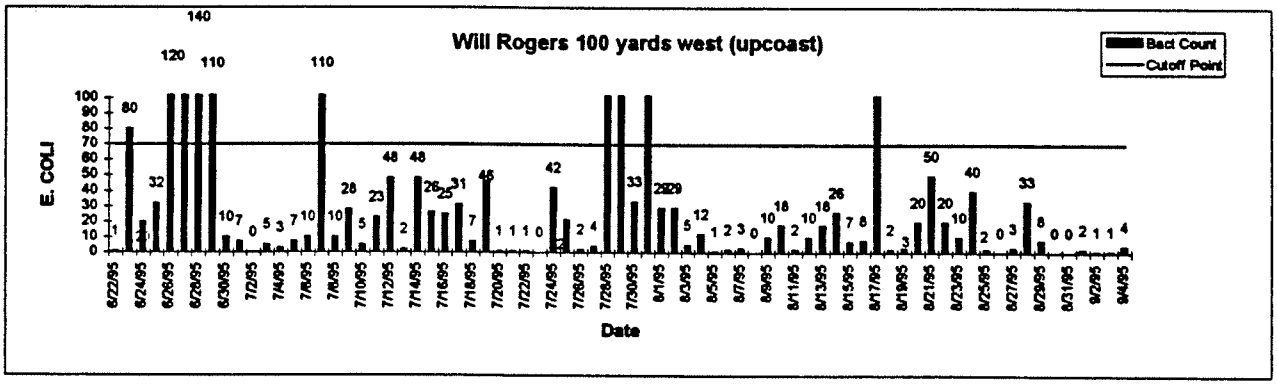
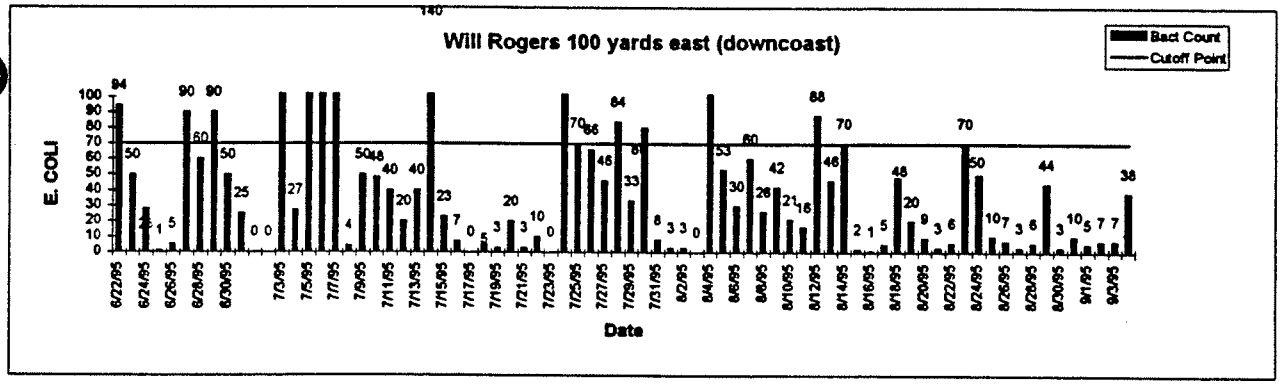


Figure 7A, cont. Daily *E.coli* Indicator Counts at Will Rogers Beach (Cutoff = 70 cpu)







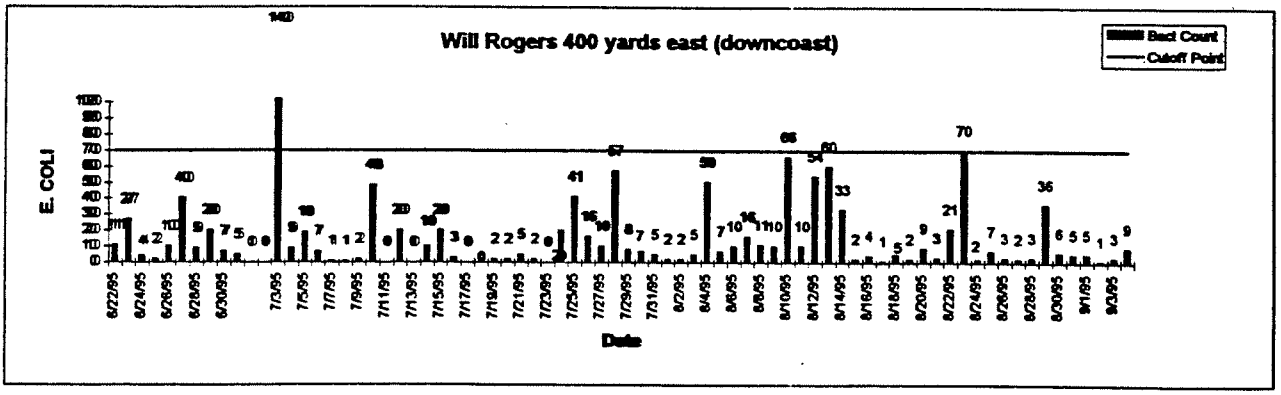
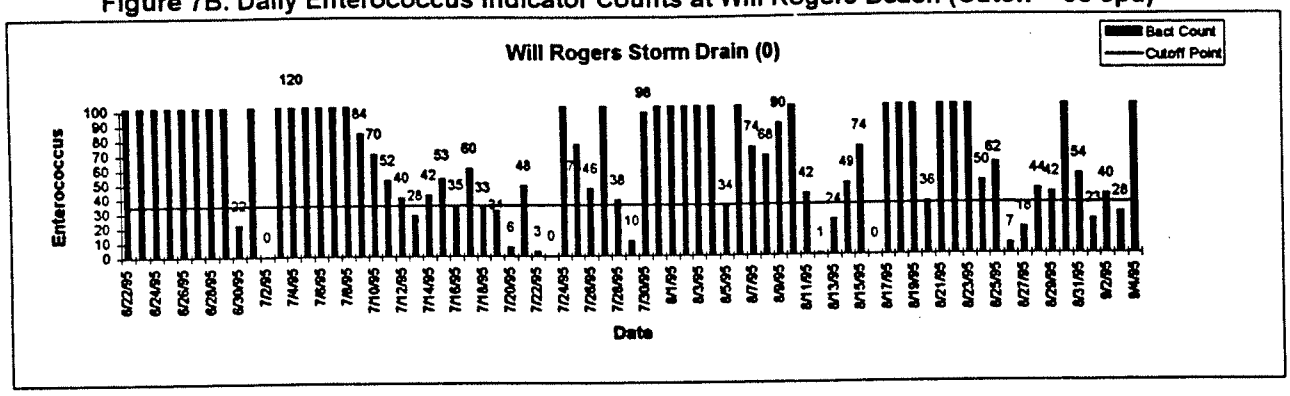
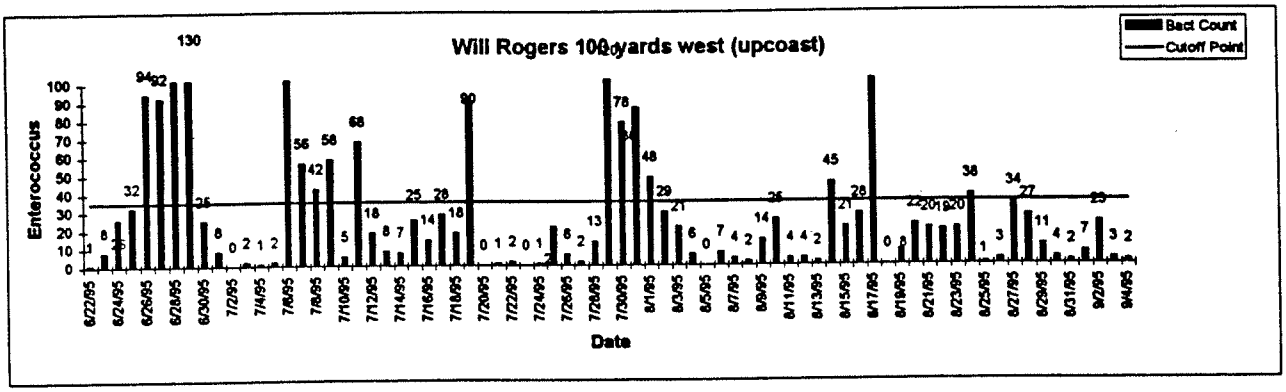
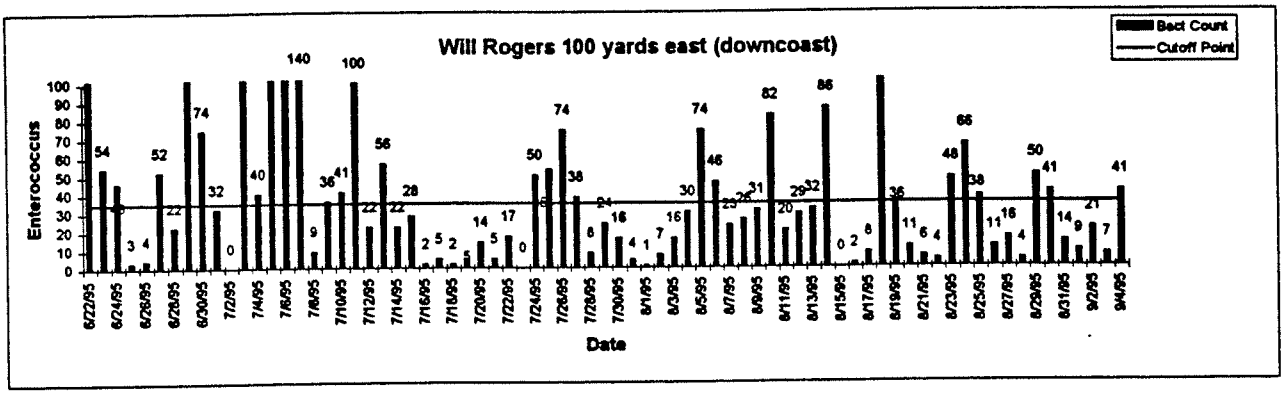


Figure 7B. Daily Enterococcus Indicator Counts at Will Rogers Beach (Cutoff = 35 cpu)







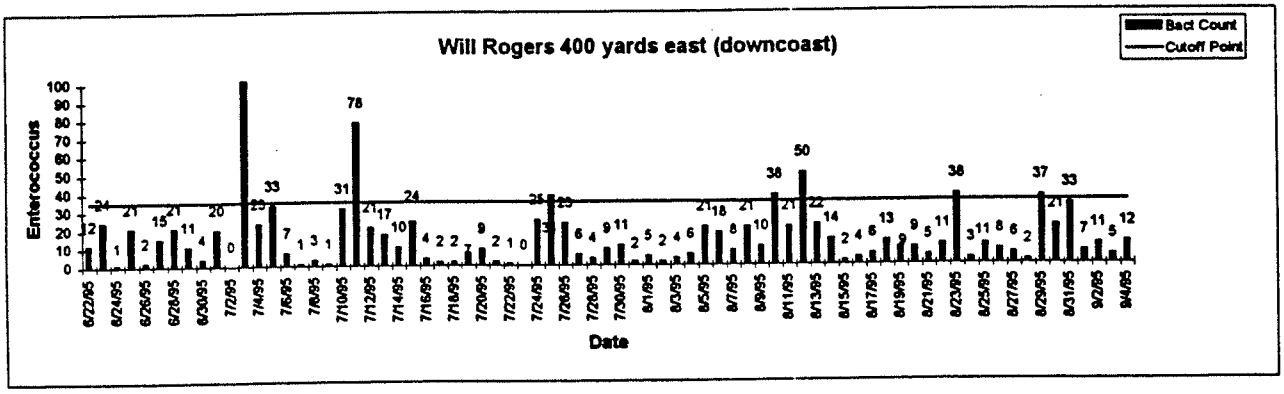
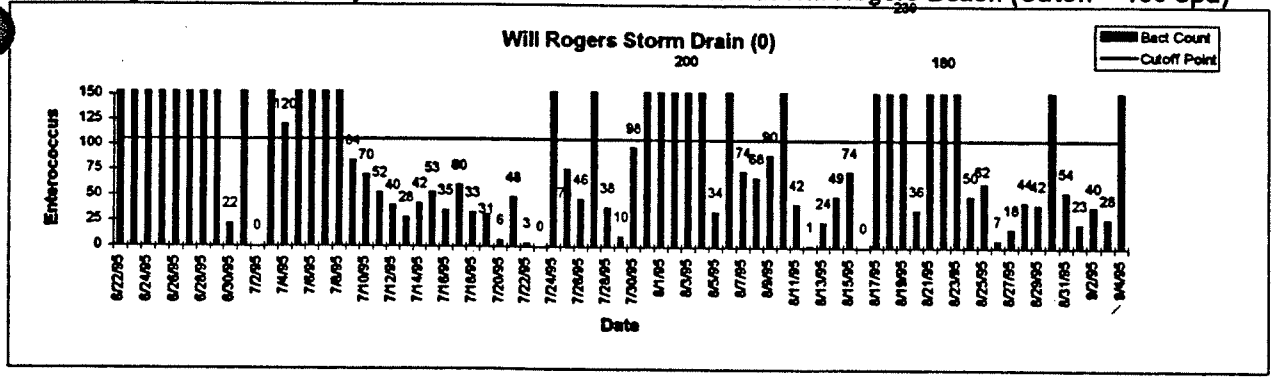
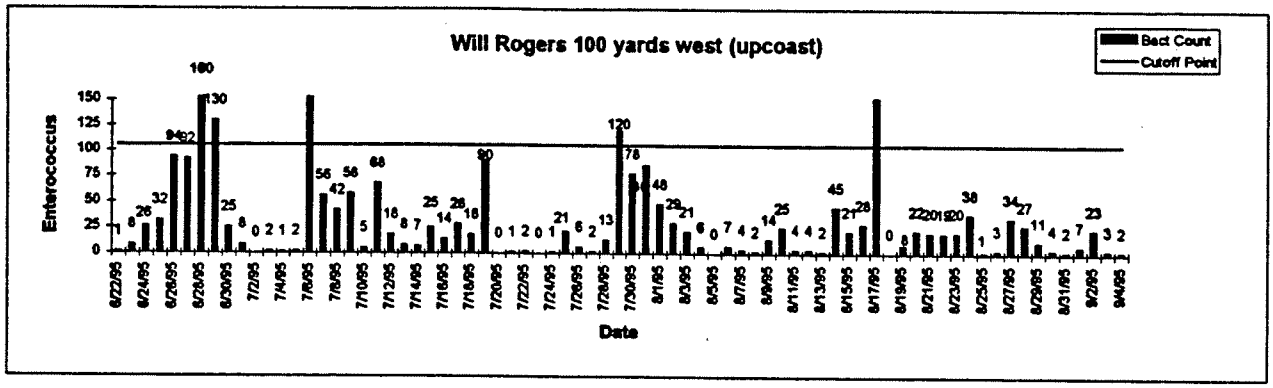
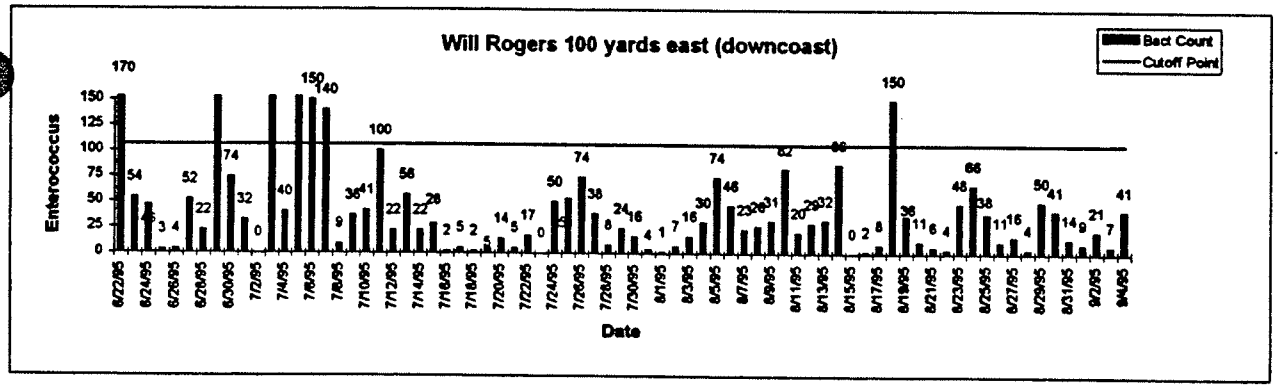


Figure 7B, cont. Daily Enterococcus Indicator Counts at Will Rogers Beach (Cutoff = 106 cpu)







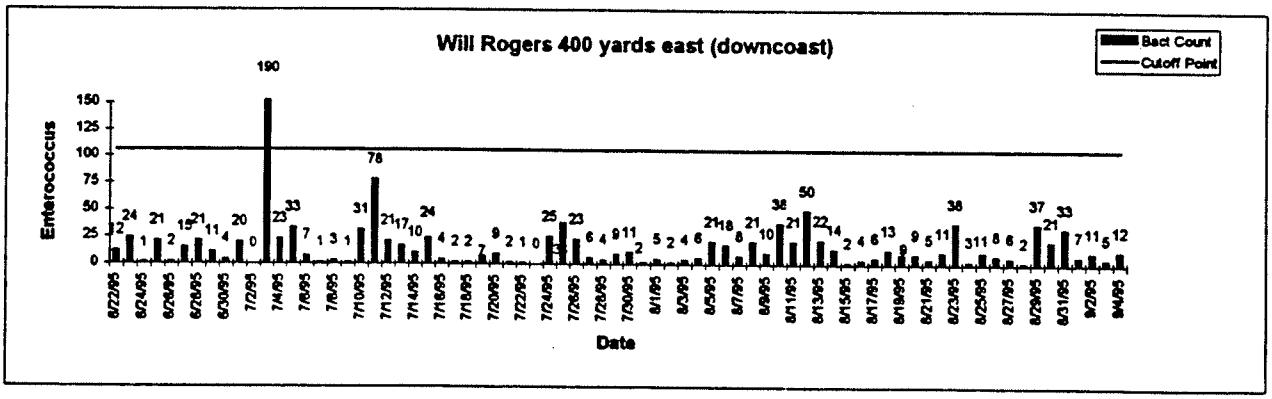
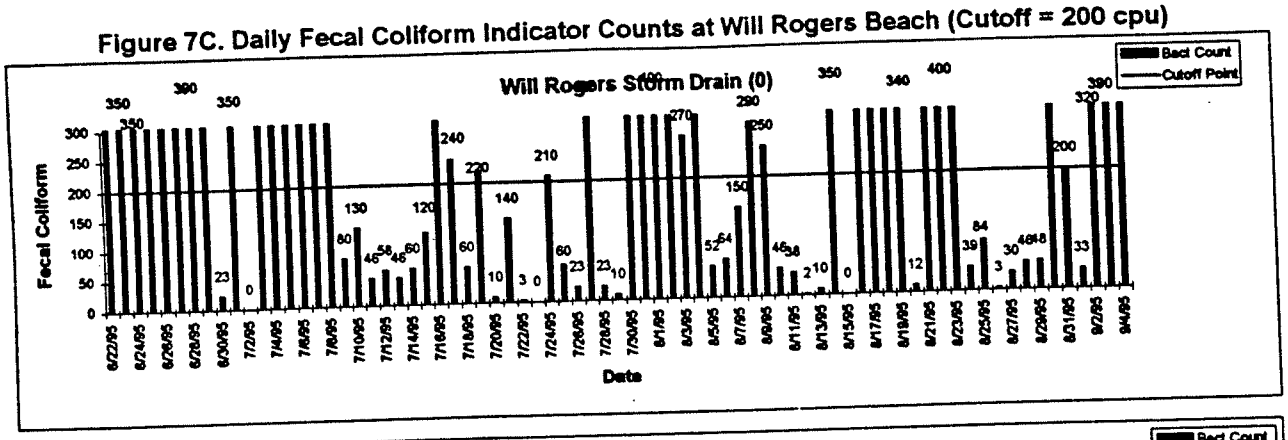
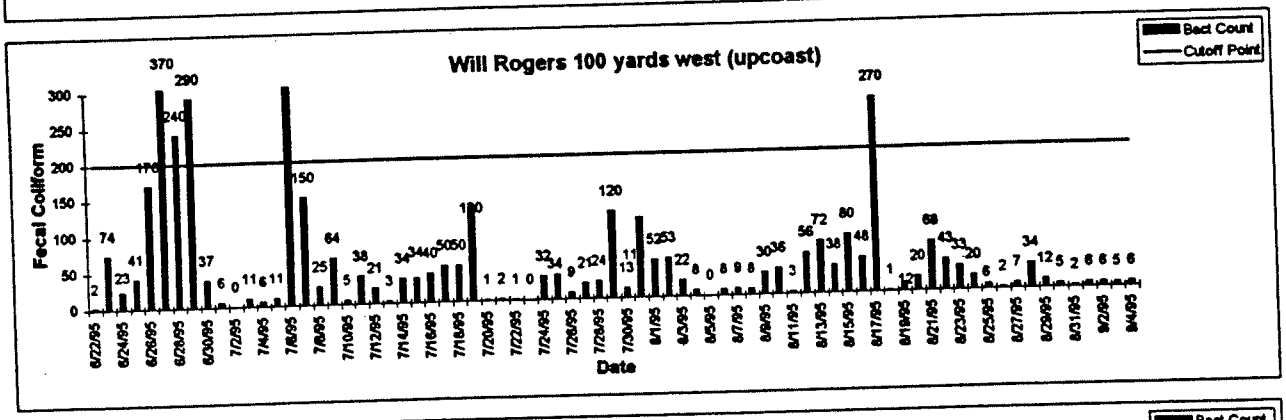
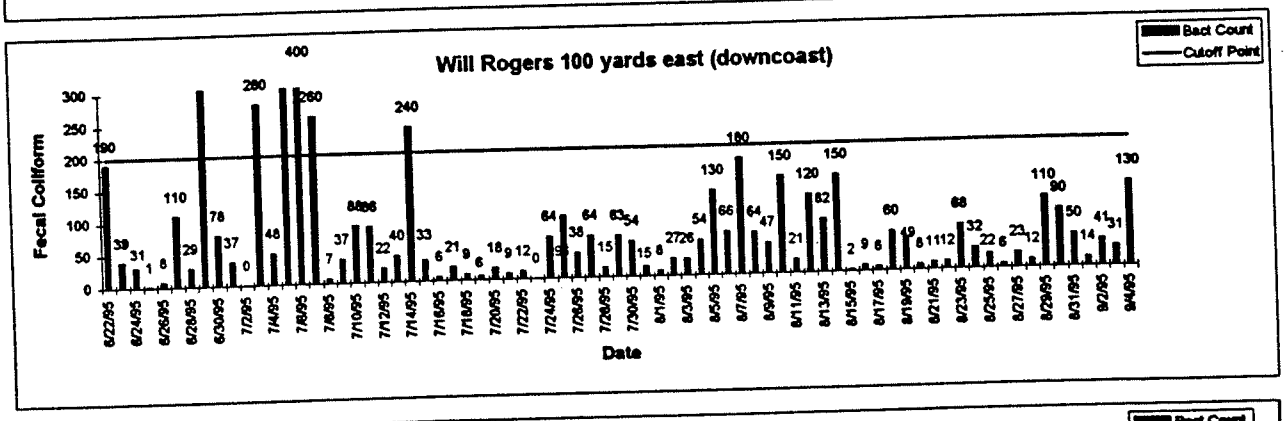


Figure 7C. Daily Fecal Coliform Indicator Counts at Will Rogers Beach (Cutoff = 200 cpu)







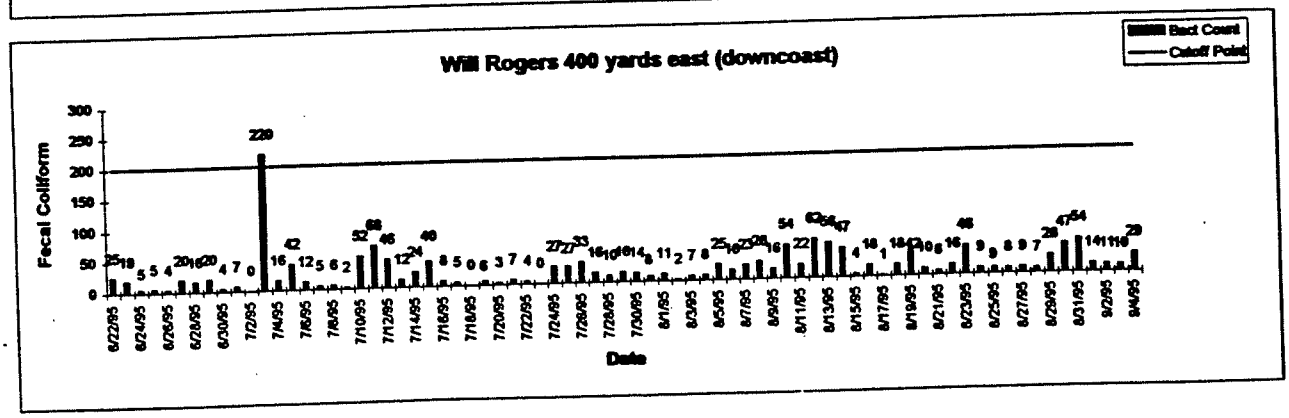
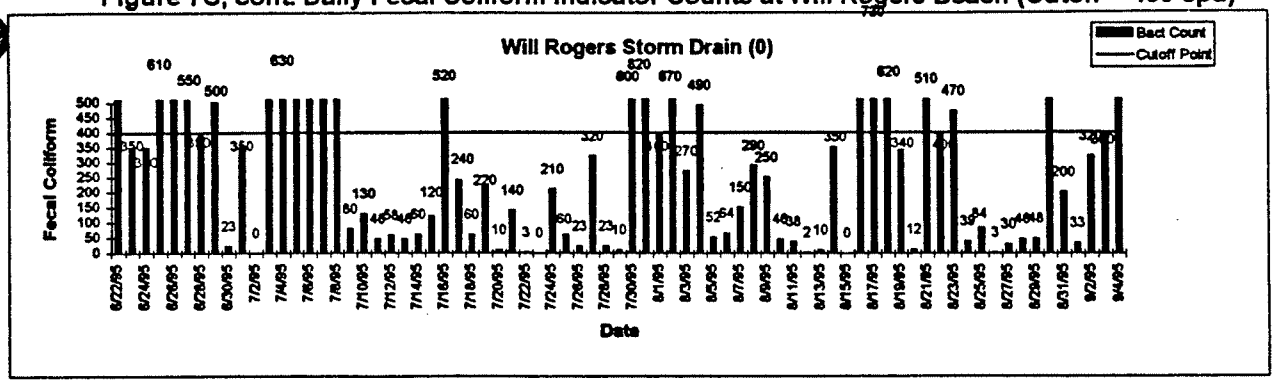
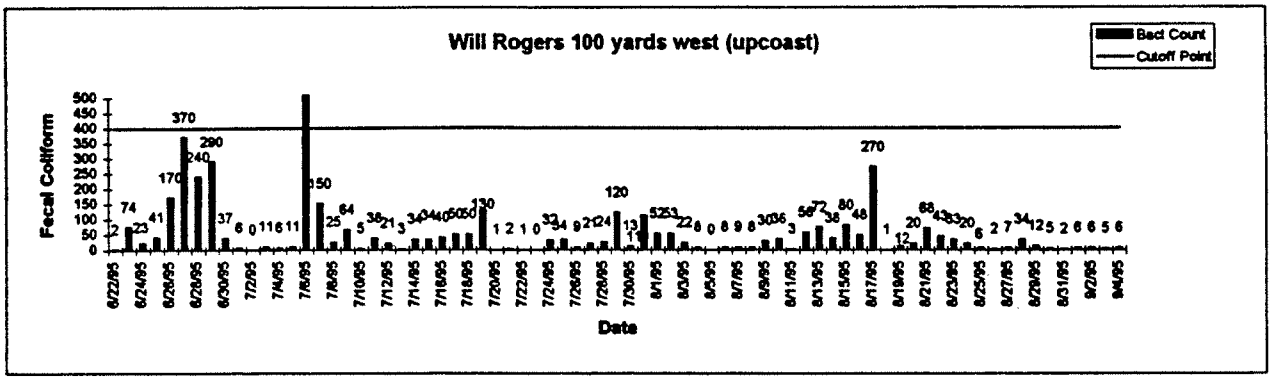
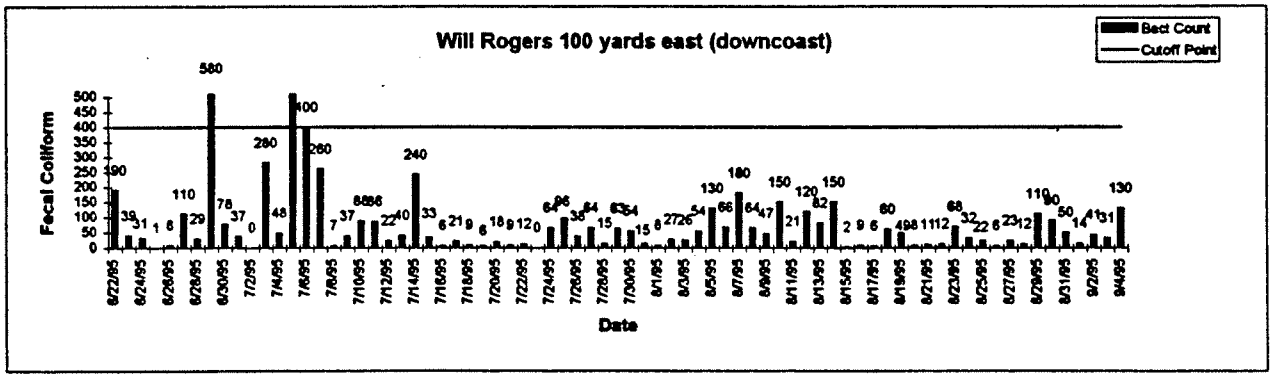


Figure 7C, cont. Daily Fecal Coliform Indicator Counts at Will Rogers Beach (Cutoff = 400 cpu)







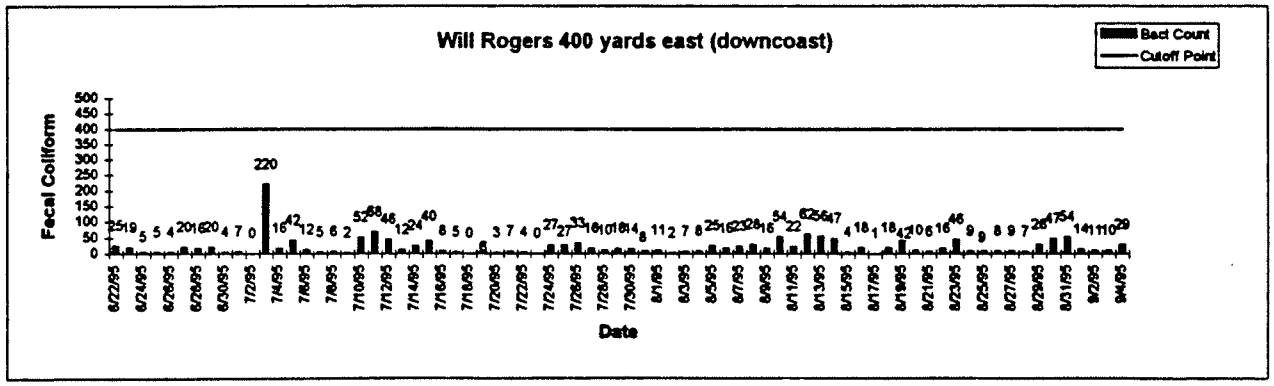
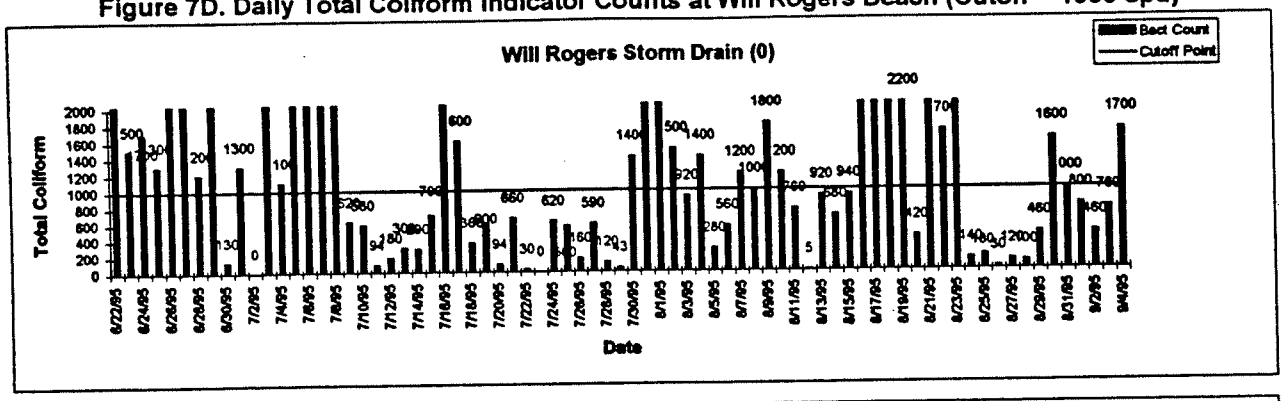
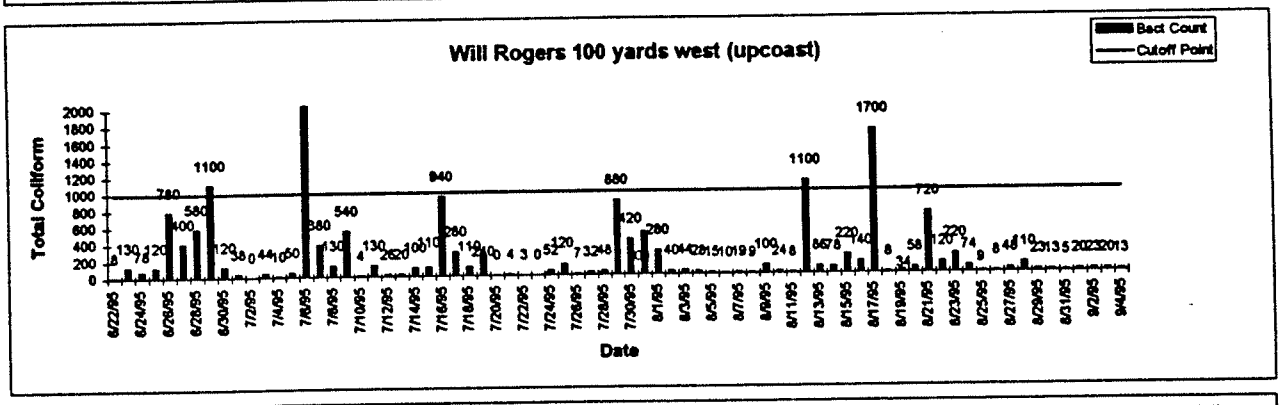
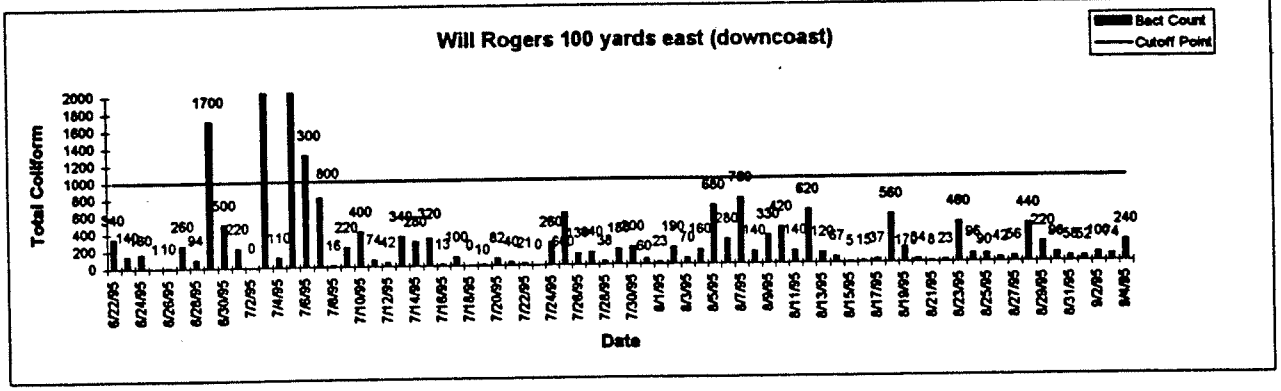


Figure 7D. Daily Total Coliform Indicator Counts at Will Rogers Beach (Cutoff = 1000 cpu)







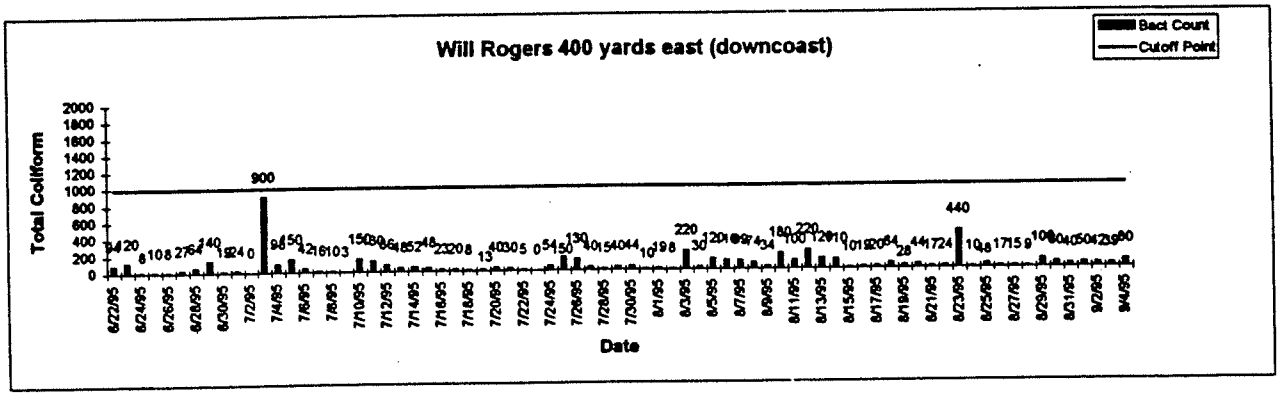
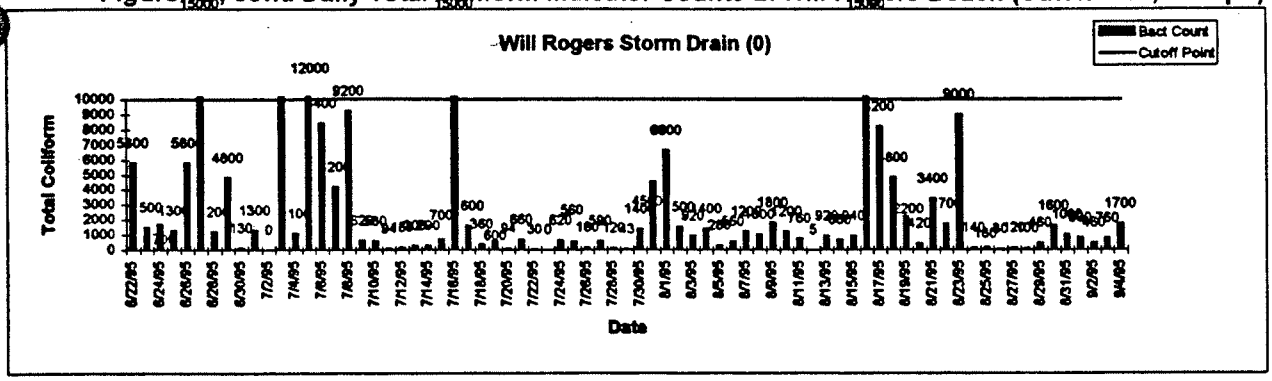
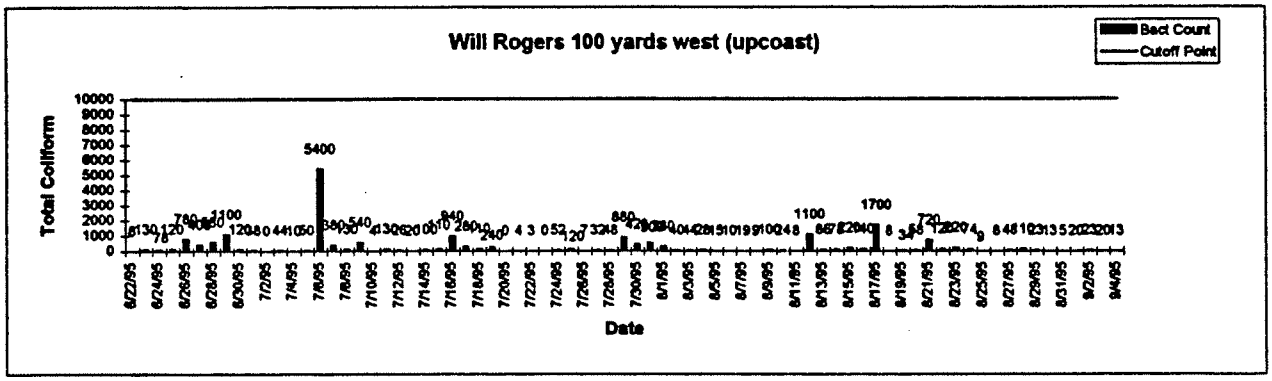
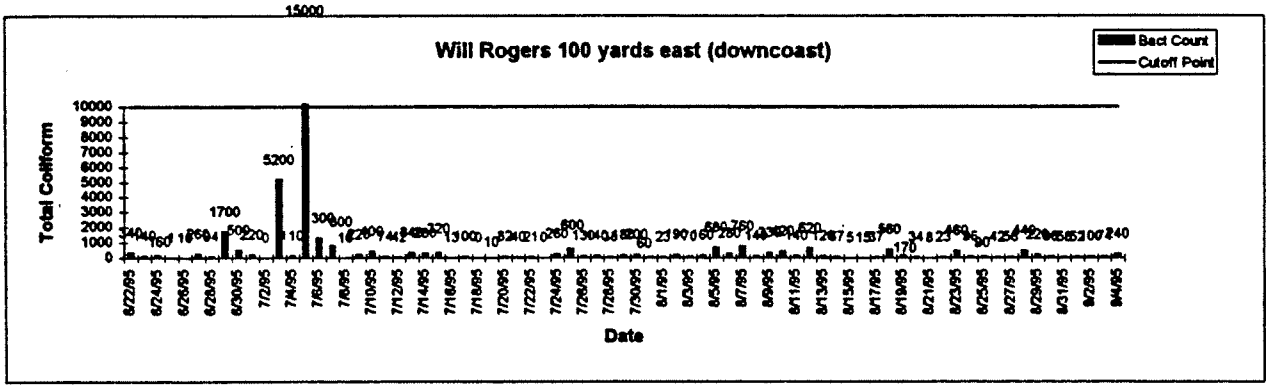


Figure 7D, cont. Daily Total Coliform Indicator Counts at Will Rogers Beach (Cutoff = 10,000 cpu)







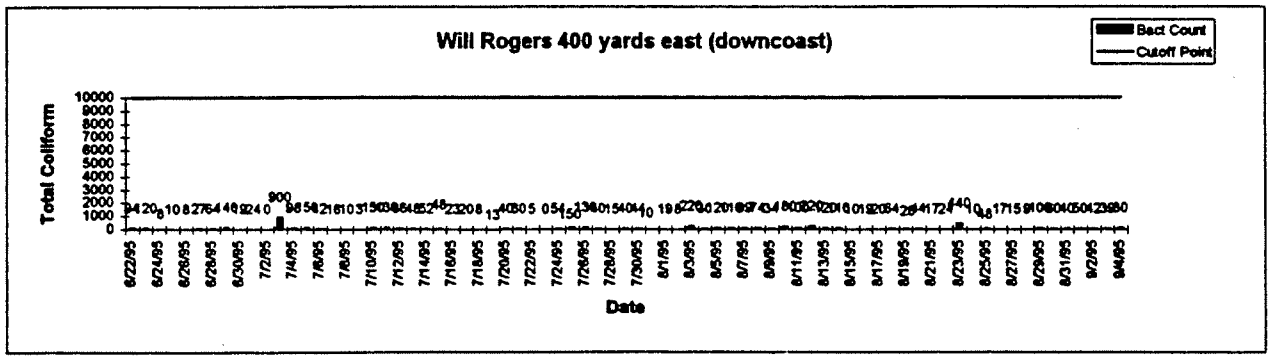


Table 17. Risks Among Swimmers at the Drain vs. Risks Among Controls

ALL BEACHES

SYMPTOMS	Total Exposed = 827 0 yds		Total Unexposed = 3030 400+ yds				
	Ill	Risks	Ill	Risks	RR	Lower 95%CI	Upper 95% CI
Fever*	59	0.071	138	0.046	1.57	1.17	2.10
Chills*	31	0.037	72	0.024	1.58	1.04	2.39
Eye discharge	19	0.023	61	0.020	1.14	0.69	1.90
Earache	38	0.046	116	0.038	1.20	0.84	1.72
Ear discharge*	13	0.016	21	0.007	2.27	1.14	4.51
Skin rash	4	0.005	23	0.008	0.64	0.22	1.84
Infected cut	6	0.007	17	0.006	1.29	0.51	3.27
Nausea	40	0.048	133	0.044	1.10	0.78	1.56
Vomiting*	25	0.030	57	0.019	1.61	1.01	2.56
Diarrhea	53	0.064	204	0.067	0.95	0.71	1.27
Diarrhea w/ blood	2	0.002	7	0.002	1.05	0.22	5.03
Stomach pain	61	0.074	206	0.068	1.08	0.82	1.43
Coughing	55	0.067	209	0.069	0.96	0.72	1.28
Phlegm*	39	0.047	90	0.030	1.59	1.10	2.29
Nasal congestion	74	0.089	273	0.090	0.99	0.78	1.27
Sore throat	59	0.071	190	0.063	1.14	0.86	1.51
HCGI 1	35	0.042	102	0.034	1.26	0.86	1.83
HCGI 2*	15	0.018	26	0.009	2.11	1.12	3.97
SRD*	63	0.076	139	0.046	1.66	1.25	2.21

*** statistically significant at $p < 0.05$**

Table 18. Risks Among Swimmers at 1-50 Yards Upcoast vs. Risks Among Controls

ALL BEACHES

SYMPTOMS	Total Exposed = 2592 1-50 yds		Total Unexposed = 3030 400+ yds				
	Ill	Risks	Ill	Risks	RR	Lower 95%CI	Upper 95% CI
Fever	114	0.045	138	0.046	0.99	0.78	1.26
Chills	63	0.025	72	0.024	1.05	0.75	1.46
Eye discharge	50	0.020	61	0.020	0.98	0.68	1.42
Earache	81	0.032	116	0.038	0.84	0.63	1.11
Ear discharge	19	0.008	21	0.007	1.08	0.58	2.01
Skin rash*	35	0.014	23	0.008	1.82	1.08	3.08
Infected cut	23	0.009	17	0.006	1.62	0.87	3.03
Nausea	82	0.032	133	0.044	0.74	0.56	0.97
Vomiting	36	0.014	57	0.019	0.76	0.50	1.14
Diarrhea	120	0.047	204	0.067	0.70	0.57	0.88
Diarrhea w/ blood	1	0.000	7	0.002	0.17	0.02	1.39
Stomach pain	163	0.064	206	0.068	0.95	0.78	1.16
Coughing	173	0.068	209	0.069	0.99	0.82	1.20
Phlegm	80	0.032	90	0.030	1.06	0.79	1.43
Nasal congestion	205	0.081	273	0.090	0.90	0.76	1.07
Sore throat	177	0.070	190	0.063	1.12	0.92	1.36
HCGI 1	71	0.028	102	0.034	0.83	0.62	1.12
HCGI 2	20	0.008	26	0.009	0.92	0.52	1.65
SRD	112	0.044	139	0.046	0.97	0.76	1.23

* statistically significant at $p < 0.05$

Table 19. Risks Among Swimmers at 51-100 Yards Upcoast vs. Risks Among Controls

ALL BEACHES

SYMPTOMS	Total Exposed = 2186 51-100 yds		Total Unexposed = 3030 400+ yds				
	Ill	Risks	Ill	Risks	RR	Lower 95%CI	Upper 95% CI
Fever	109.00	0.050	138	0.046	1.09	0.86	1.40
Chills	54	0.025	72	0.024	1.04	0.73	1.47
Eye discharge	45	0.021	61	0.020	1.02	0.70	1.50
Earache	81	0.037	116	0.038	0.97	0.73	1.28
Ear discharge	10	0.005	21	0.007	0.66	0.31	1.40
Skin rash	20	0.009	23	0.008	1.21	0.66	2.19
Infected cut	10	0.005	17	0.006	0.82	0.37	1.78
Nausea	75	0.034	133	0.044	0.78	0.59	1.03
Vomiting	40	0.018	57	0.019	0.97	0.65	1.45
Diarrhea	96	0.044	204	0.067	0.65	0.52	0.83
Diarrhea w/ blood	1	0.000	7	0.002	0.20	0.02	1.61
Stomach pain	126	0.058	206	0.068	0.85	0.68	1.05
Coughing	164	0.075	209	0.069	1.09	0.89	1.32
Phlegm	69	0.032	90	0.030	1.06	0.78	1.45
Nasal congestion	214	0.098	273	0.090	1.09	0.92	1.29
Sore throat	168	0.077	190	0.063	1.23	1.00	1.50
HCGI 1	63	0.029	102	0.034	0.86	0.63	1.17
HCGI 2	19	0.009	26	0.009	1.01	0.56	1.83
SRD	114	0.052	139	0.046	1.14	0.89	1.45

Table 20. Risks Among Swimmers at 1-50 Yards Downcoast vs. Risks Among Controls

ALL BEACHES

	Total Exposed = 1926		Total Unexposed = 3030				
	1-50 yds		400+ yds				
SYMPTOMS	Ill	Risks	Ill	Risks	RR	Lower 95% CI	Upper 95% CI
Fever	94	0.049	138	0.046	1.07	0.83	1.38
Chills	45	0.023	72	0.024	0.98	0.68	1.42
Eye discharge	23	0.012	61	0.020	0.59	0.37	0.95
Earache	55	0.029	116	0.038	0.75	0.54	1.02
Ear discharge	6	0.003	21	0.007	0.45	0.18	1.11
Skin rash	18	0.009	23	0.008	1.23	0.67	2.28
Infected cut	14	0.007	17	0.006	1.30	0.64	2.62
Nausea	61	0.032	133	0.044	0.72	0.54	0.97
Vomiting	27	0.014	57	0.019	0.75	0.47	1.17
Diarrhea	82	0.043	204	0.067	0.63	0.49	0.81
Diarrhea w/ blood	2	0.001	7	0.002	0.45	0.09	2.16
Stomach pain	108	0.056	206	0.068	0.82	0.66	1.03
Coughing	123	0.064	209	0.069	0.93	0.75	1.15
Phlegm	63	0.033	90	0.030	1.10	0.80	1.51
Nasal congestion	166	0.086	273	0.090	0.96	0.80	1.15
Sore throat	127	0.066	190	0.063	1.05	0.85	1.31
HCGI 1	50	0.026	102	0.034	0.77	0.55	1.08
HCGI 2	12	0.006	26	0.009	0.73	0.37	1.44
SRD	93	0.048	139	0.046	1.05	0.81	1.36

Table 21. Risks Among Swimmers at 51-100 Yards Downcoast vs. Risks Among Controls

ALL BEACHES

	Total Exposed = 1125		Total Unexposed = 3030				
	51-100 yds		400+ yds				
SYMPTOMS	Ill	Risks	Ill	Risks	RR	Lower 95% CI	Upper 95% CI
Fever	49	0.044	138	0.046	0.96	0.70	1.32
Chills	31	0.028	72	0.024	1.16	0.77	1.76
Eye discharge	14	0.012	61	0.020	0.62	0.35	1.10
Earache	35	0.031	116	0.038	0.81	0.56	1.18
Ear discharge	9	0.008	21	0.007	1.15	0.53	2.51
Skin rash	10	0.009	23	0.008	1.17	0.56	2.45
Infected cut	6	0.005	17	0.006	0.95	0.38	2.40
Nausea	40	0.036	133	0.044	0.81	0.57	1.15
Vomiting	18	0.016	57	0.019	0.85	0.50	1.44
Diarrhea	67	0.060	204	0.067	0.88	0.68	1.16
Diarrhea w/ blood	1	0.001	7	0.002	0.38	0.05	3.12
Stomach pain	68	0.060	206	0.068	0.89	0.68	1.16
Coughing*	99	0.088	209	0.069	1.28	1.01	1.60
Phlegm	45	0.040	90	0.030	1.35	0.95	1.91
Nasal congestion*	137	0.122	273	0.090	1.35	1.11	1.64
Sore throat	76	0.068	190	0.063	1.08	0.83	1.39
HCGI 1	33	0.029	102	0.034	0.87	0.59	1.28
HCGI 2	9	0.008	26	0.009	0.93	0.44	1.98
SRD	63	0.056	139	0.046	1.22	0.91	1.63

* statistically significant at $p < 0.05$

Table 22. Risks Among Swimmers At Each Distance vs. Risks Among Controls

ALL BEACHES – downcoast

	drain (0 yds)			1 - 50 yards			51 - 100 yards		
SYMPTOMS	RR	Lower 95% CI	Upper 95% CI	RR	Lower 95% CI	Upper 95% CI	RR	Lower 95% CI	Upper 95% CI
Fever	1.57	1.17	2.10	1.07	0.83	1.38	0.96	0.70	1.32
Chills	1.58	1.04	2.39	0.98	0.68	1.42	1.16	0.77	1.76
Eye discharge	1.14	0.69	1.90	0.59	0.37	0.95	0.62	0.35	1.10
Earache	1.20	0.84	1.72	0.75	0.54	1.02	0.81	0.56	1.18
Ear discharge	2.27	1.14	4.51	0.45	0.18	1.11	1.15	0.53	2.51
Skin rash	0.64	0.22	1.84	1.23	0.67	2.28	1.17	0.56	2.45
Infected cut	1.29	0.51	3.27	1.30	0.64	2.62	0.95	0.38	2.40
Nausea	1.10	0.78	1.56	0.72	0.54	0.97	0.81	0.57	1.15
Vomiting	1.61	1.01	2.56	0.75	0.47	1.17	0.85	0.50	1.44
Diarrhea	0.95	0.71	1.27	0.63	0.49	0.81	0.88	0.68	1.16
Diarrhea w/ blood	1.05	0.22	5.03	0.45	0.09	2.16	0.38	0.05	3.12
Stomach pain	1.08	0.82	1.43	0.82	0.66	1.03	0.89	0.68	1.16
Coughing	0.96	0.72	1.28	0.93	0.75	1.15	1.28	1.01	1.60
Phlegm	1.59	1.10	2.29	1.10	0.80	1.51	1.35	0.95	1.91
Nasal congestion	0.99	0.78	1.27	0.96	0.80	1.15	1.35	1.11	1.64
Sore throat	1.14	0.86	1.51	1.05	0.85	1.31	1.08	0.83	1.39
HCGI_1	1.26	0.86	1.83	0.77	0.55	1.08	0.87	0.59	1.28
HCGI_2	2.11	1.12	3.97	0.73	0.37	1.44	0.93	0.44	1.98
SRD	1.66	1.25	2.21	1.05	0.81	1.36	1.22	0.91	1.63

Table 23. Risks Among Swimmers At Each Distance vs. Risks Among Controls

ALL BEACHES – upcoast

	drain (0 yds)			1 - 50 yards			51 - 100 yards		
SYMPTOMS	RR	Lower 95% CI	Upper 95% CI	RR	Lower 95% CI	Upper 95% CI	RR	Lower 95% CI	Upper 95% CI
Fever	1.57	1.17	2.10	0.99	0.78	1.26	1.09	0.86	1.40
Chills	1.58	1.04	2.39	1.05	0.75	1.46	1.04	0.73	1.47
Eye discharge	1.14	0.69	1.90	0.98	0.68	1.42	1.02	0.70	1.50
Earache	1.20	0.84	1.72	0.84	0.63	1.11	0.97	0.73	1.28
Ear discharge	2.27	1.14	4.51	1.08	0.58	2.01	0.66	0.31	1.40
Skin rash	0.64	0.22	1.84	1.82	1.08	3.08	1.21	0.66	2.19
Infected cut	1.29	0.51	3.27	1.62	0.87	3.03	0.82	0.37	1.78
Nausea	1.10	0.78	1.56	0.74	0.56	0.97	0.78	0.59	1.03
Vomiting	1.61	1.01	2.56	0.76	0.50	1.14	0.97	0.65	1.45
Diarrhea	0.95	0.71	1.27	0.70	0.57	0.88	0.65	0.52	0.83
Diarrhea w/ blood	1.05	0.22	5.03	0.17	0.02	1.39	0.20	0.02	1.61
Stomach pain	1.08	0.82	1.43	0.95	0.78	1.16	0.85	0.68	1.05
Coughing	0.96	0.72	1.28	0.99	0.82	1.20	1.09	0.89	1.32
Phlegm	1.59	1.10	2.29	1.06	0.79	1.43	2.60	2.03	3.34
Nasal congestion	0.99	0.78	1.27	0.90	0.76	1.07	1.09	0.92	1.29
Sore throat	1.14	0.86	1.51	1.12	0.92	1.36	1.23	1.00	1.50
HCGI_1	1.26	0.86	1.83	0.83	0.62	1.12	0.86	0.63	1.17
HCGI_2	2.11	1.12	3.97	0.92	0.52	1.65	1.01	0.56	1.83
SRD	1.66	1.25	2.21	0.97	0.76	1.23	1.14	0.89	1.45

Table 24. Risks Among Swimmers at the Drain vs. Risks Among Controls

CONTROLS EXPOSED TO TOTAL/FECAL RATIOS > 5

SYMPTOMS	Total Exposed = 827 0 yds		Total Unexposed = 624 400+ yds				
	Ill	Risks	Ill	Risks	RR	Lower 95%CI	Upper 95% CI
Fever*	59	0.071	27	0.043	1.65	1.06	2.57
Chills*	31	0.037	11	0.018	2.13	1.08	4.20
Eye discharge	19	0.023	19	0.030	0.75	0.40	1.41
Earache	38	0.046	26	0.042	1.10	0.68	1.80
Ear discharge	13	0.016	4	0.006	2.45	0.80	7.48
Skin rash	4	0.005	3	0.005	1.01	0.23	4.48
Infected cut	6	0.007	1	0.002	4.53	0.55	37.51
Nausea	40	0.048	27	0.043	1.12	0.69	1.80
Vomiting	25	0.030	10	0.016	1.89	0.91	3.90
Diarrhea	53	0.064	36	0.058	1.11	0.74	1.67
Diarrhea w/ blood	2	0.002	0	0.000	–	–	–
Stomach pain	61	0.074	44	0.071	1.05	0.72	1.52
Coughing	55	0.067	34	0.054	1.22	0.81	1.85
Phlegm*	39	0.047	11	0.018	2.68	1.38	5.18
Nasal congestion	74	0.089	46	0.074	1.21	0.85	1.73
Sore throat	59	0.071	33	0.053	1.35	0.89	2.04
HCGI 1	35	0.042	23	0.037	1.15	0.69	1.92
HCGI 2*	15	0.018	2	0.003	5.66	1.30	24.66
SRD*	63	0.076	17	0.027	2.80	1.65	4.73

* statistically significant at $p < 0.05$

Table 25. Risks Among Swimmers at 1-50 Yards Upcoast vs. Risks Among Controls

CONTROLS EXPOSED TO TOTAL/FECAL RATIOS > 5

SYMPTOMS	Total Exposed = 2592		Total Unexposed = 624				
	1-50 yds		400+ yds				
	Ill	Risks	Ill	Risks	RR	Lower 95%CI	Upper 95% CI
Fever	114	0.045	27	0.043	1.04	0.69	1.57
Chills	63	0.025	11	0.018	1.41	0.75	2.67
Eye discharge	50	0.020	19	0.030	0.65	0.39	1.09
Earache	81	0.032	26	0.042	0.77	0.50	1.19
Ear discharge	19	0.008	4	0.006	1.17	0.40	3.43
Skin rash	35	0.014	3	0.005	2.88	0.89	9.33
Infected cut	23	0.009	1	0.002	5.67	0.77	41.94
Nausea	82	0.032	27	0.043	0.75	0.49	1.15
Vomiting	36	0.014	10	0.016	0.89	0.44	1.78
Diarrhea	120	0.047	36	0.058	0.82	0.57	1.18
Diarrhea w/ blood	1	0.000	0	0.000	–	–	–
Stomach pain	163	0.064	163	0.261	0.25	0.20	0.30
Coughing	173	0.068	34	0.054	1.26	0.88	1.79
Phlegm	80	0.032	11	0.018	1.79	0.96	3.35
Nasal congestion	205	0.081	46	0.074	1.10	0.81	1.50
Sore throat	177	0.070	33	0.053	1.32	0.92	1.90
HCGI_1	71	0.028	23	0.037	0.76	0.48	1.21
HCGI_2	20	0.008	2	0.003	2.47	0.58	10.53
SRD	112	0.044	17	0.027	1.63	0.98	2.69

Table 26. Risks Among Swimmers at 51-100 Yards Upcoast vs. Risks Among Controls

CONTROLS EXPOSED TO TOTAL/FECAL RATIOS > 5

	Total Exposed = 2186		Total Unexposed = 624				
	51-100 yds		400+ yds				
SYMPTOMS	Ill	Risks	Ill	Risks	RR	Lower 95%CI	Upper 95% CI
Fever	109	0.050	27	0.043	1.15	0.76	1.74
Chills	54	0.025	11	0.018	1.40	0.74	2.66
Eye discharge	45	0.021	19	0.030	0.68	0.40	1.15
Earache	81	0.037	26	0.042	0.89	0.58	1.37
Ear discharge	10	0.005	4	0.006	0.71	0.22	2.27
Skin rash	20	0.009	3	0.005	1.90	0.57	6.38
Infected cut	10	0.005	1	0.002	2.85	0.37	22.26
Nausea	75	0.034	27	0.043	0.79	0.52	1.22
Vomiting	40	0.018	10	0.016	1.14	0.57	2.27
Diarrhea	96	0.044	36	0.058	0.76	0.52	1.10
Diarrhea w/ blood	1	0.000	0	0.000	–	–	–
Stomach pain	126	0.058	44	0.071	0.82	0.59	1.14
Coughing	164	0.075	34	0.054	1.38	0.96	1.97
Phlegm	69	0.032	11	0.018	1.79	0.95	3.36
Nasal congestion	214	0.098	46	0.074	1.33	0.98	1.80
Sore throat*	168	0.077	33	0.053	1.45	1.01	2.09
HCGI 1	63	0.029	23	0.037	0.78	0.49	1.25
HCGI 2	19	0.009	21	0.034	0.26	0.14	0.48
SRD*	114	0.052	17	0.027	1.91	1.16	3.16

* statistically significant at $p < 0.05$

Table 27. Risks Among Swimmers at 1-50 Yards Downcoast vs. Risks Among Controls

CONTROLS EXPOSED TO TOTAL/FECAL RATIOS > 5

	Total Exposed = 1926 1-50 yds		Total Unexposed = 624 400+ yds				
SYMPTOMS	Ill	Risks	Ill	Risks	RR	Lower 95% CI	Upper 95% CI
Fever	94	0.049	27	0.043	1.13	0.74	1.71
Chills	45	0.023	11	0.018	1.33	0.69	2.55
Eye discharge	23	0.012	19	0.030	0.39	0.22	0.72
Earache	55	0.029	26	0.042	0.69	0.43	1.08
Ear discharge	6	0.003	4	0.006	0.49	0.14	1.72
Skin rash	18	0.009	3	0.005	1.94	0.57	6.58
Infected cut	14	0.007	1	0.002	4.54	0.60	34.43
Nausea	61	0.032	27	0.043	0.73	0.47	1.14
Vomiting	27	0.014	10	0.016	0.87	0.43	1.80
Diarrhea	82	0.043	36	0.058	0.74	0.50	1.08
Diarrhea w/ blood	2	0.001	0	0.000	–	–	–
Stomach pain	108	0.056	44	0.071	0.80	0.57	1.12
Coughing	123	0.064	34	0.054	1.17	0.81	1.69
Phlegm	63	0.033	11	0.018	1.86	0.98	3.50
Nasal congestion	166	0.086	46	0.074	1.17	0.85	1.60
Sore throat	127	0.066	33	0.053	1.25	0.86	1.81
HCGI 1	50	0.026	23	0.037	0.70	0.43	1.14
HCGI 2	12	0.006	2	0.003	1.94	0.44	8.66
SRD*	93	0.048	17	0.027	1.77	1.07	2.95

* statistically significant at $p < 0.05$

Table 28. Risks Among Swimmers at 51-100 Yards Downcoast vs. Risks Among Controls

CONTROLS EXPOSED TO TOTAL/FECAL RATIOS > 5

	Total Exposed = 1125		Total Unexposed = 624				
	51-100 yds		400+ yds				
SYMPTOMS	Ill	Risks	Ill	Risks	RR	Lower 95% CI	Upper 95% CI
Fever	49	0.044	27	0.043	1.01	0.64	1.59
Chills	31	0.028	11	0.018	1.56	0.79	3.09
Eye discharge	14	0.012	19	0.030	0.41	0.21	0.81
Earache	35	0.031	26	0.042	0.75	0.45	1.23
Ear discharge	9	0.008	4	0.006	1.25	0.39	4.04
Skin rash	10	0.009	3	0.005	1.85	0.51	6.69
Infected cut	6	0.005	1	0.002	3.33	0.40	27.58
Nausea	40	0.036	27	0.043	0.82	0.51	1.33
Vomiting	18	0.016	10	0.016	1.00	0.46	2.15
Diarrhea	67	0.060	36	0.058	1.03	0.70	1.53
Diarrhea w/ blood	1	0.001	0	0.000	–	–	–
Stomach pain	68	0.060	44	0.071	0.86	0.59	1.24
Coughing*	99	0.088	34	0.054	1.62	1.11	2.35
Phlegm*	45	0.040	11	0.018	2.27	1.18	4.36
Nasal congestion*	137	0.122	46	0.074	1.65	1.20	2.27
Sore throat	76	0.068	33	0.053	1.28	0.86	1.90
HCGI 1	33	0.029	23	0.037	0.80	0.47	1.34
HCGI 2	9	0.008	2	0.003	2.50	0.54	11.52
SRD*	63	0.056	17	0.027	2.06	1.21	3.48

*** statistically significant at $p < 0.05$**

Table 29. Risks Among Swimmers At Each Distance vs. Risks Among Controls

CONTROLS EXPOSED TO TOTAL/FECAL RATIOS > 5 – downcoast

	drain (0 yds)			1 - 50 yards			51 - 100 yards		
SYMPTOMS	RR	Lower 95% CI	Upper 95% CI	RR	Lower 95% CI	Upper 95% CI	RR	Lower 95% CI	Upper 95% CI
Fever	1.65	1.06	2.57	1.13	0.74	1.71	1.01	0.64	1.59
Chills	2.13	1.08	4.20	1.33	0.69	2.55	1.56	0.79	3.09
Eye discharge	0.75	0.40	1.41	0.39	0.22	0.72	0.41	0.21	0.81
Earache	1.10	0.68	1.80	0.69	0.43	1.08	0.75	0.45	1.23
Ear discharge	2.45	0.80	7.48	0.49	0.14	1.72	1.25	0.39	4.04
Skin rash	1.01	0.23	4.48	1.94	0.57	6.58	1.85	0.51	6.69
Infected cut	4.53	0.55	37.51	4.54	0.60	34.43	3.33	0.40	27.58
Nausea	1.12	0.69	1.80	0.73	0.47	1.14	0.82	0.51	1.33
Vomiting	1.89	0.91	3.90	0.87	0.43	1.80	1.00	0.46	2.15
Diarrhea	1.11	0.74	1.67	0.74	0.50	1.08	1.03	0.70	1.53
Diarrhea w/ blood	--	--	--	--	--	--	--	--	--
Stomach pain	1.05	0.72	1.52	0.80	0.57	1.12	0.86	0.59	1.24
Coughing	1.22	0.81	1.85	1.17	0.81	1.69	1.62	1.11	2.35
Phlegm	2.68	1.38	5.18	1.86	0.98	3.50	2.27	1.18	4.36
Nasal congestion	1.21	0.85	1.73	1.17	0.85	1.60	1.65	1.20	2.27
Sore throat	1.35	0.89	2.04	1.25	0.86	1.81	1.28	0.86	1.90
HCGI_1	1.15	0.69	1.92	0.70	0.43	1.14	0.80	0.47	1.34
HCGI_2	5.66	1.30	24.66	1.94	0.44	8.66	2.50	0.54	11.52
SRD	2.80	1.65	4.73	1.77	1.07	2.95	2.06	1.21	3.48

Table 30. Risks Among Swimmers At Each Distance vs. Risks Among Controls

CONTROLS EXPOSED TO TOTAL/FECAL RATIOS > 5 – upcoast

	drain (0 yds)			1 - 50 yards			51 - 100 yards		
SYMPTOMS	RR	Lower 95% CI	Upper 95% CI	RR	Lower 95% CI	Upper 95% CI	RR	Lower 95% CI	Upper 95% CI
Fever	1.65	1.06	2.57	1.04	0.69	1.57	1.15	0.76	1.74
Chills	2.13	1.08	4.20	1.41	0.75	2.67	1.40	0.74	2.66
Eye discharge	0.75	0.40	1.41	0.65	0.39	1.09	0.68	0.40	1.15
Earache	1.10	0.68	1.80	0.77	0.50	1.19	0.89	0.58	1.37
Ear discharge	2.45	0.80	7.48	1.17	0.40	3.43	0.71	0.22	2.27
Skin rash	1.01	0.23	4.48	2.88	0.89	9.33	1.90	0.57	6.38
Infected cut	4.53	0.55	37.51	5.67	0.77	41.94	2.85	0.37	22.26
Nausea	1.12	0.69	1.80	0.75	0.49	1.15	0.79	0.52	1.22
Vomiting	1.89	0.91	3.90	0.89	0.44	1.78	1.14	0.57	2.27
Diarrhea	1.11	0.74	1.67	0.82	0.57	1.18	0.76	0.52	1.10
Diarrhea w/ blood	--	--	--	--	--	--	--	--	--
Stomach pain	1.05	0.72	1.52	0.25	0.20	0.30	0.82	0.59	1.14
Coughing	1.22	0.81	1.85	1.26	0.88	1.79	1.38	0.96	1.97
Phlegm	2.68	1.38	5.18	1.79	0.96	3.35	1.79	0.95	3.36
Nasal congestion	1.21	0.85	1.73	1.10	0.81	1.50	1.33	0.98	1.80
Sore throat	1.35	0.89	2.04	1.32	0.92	1.90	1.45	1.01	2.09
HCGI_1	1.15	0.69	1.92	0.76	0.48	1.21	0.78	0.49	1.25
HCGI_2	5.66	1.30	24.66	2.47	0.58	10.53	0.26	0.14	0.48
SRD	2.80	1.65	4.73	1.63	0.98	2.69	1.91	1.16	3.16

Table 31. Adjusted Odds Ratios and 95% Confidence Intervals for Outcomes of Interest by Distance from Drain.†

	Distance from drain (in yards)				
	400	100-50	50-1	0	trend P
# exposed:	3030	3311	4518	827	
Fever *	138 1.00	158 1.06 0.83-1.34	208 1.04 0.84-1.30	59 1.53 1.10-2.12	0.10
Chills	72 1.00	85 1.06 0.77-1.46	108 1.03 0.76-1.40	31 1.54 0.99-2.40	0.24
Eye discharge	61 1.00	59 0.88 0.61-1.27	73 0.79 0.56-1.12	19 1.20 0.70-2.06	0.61
Earache	116 1.00	116 0.89 0.68-1.16	136 0.80 0.62-1.03	38 1.32 0.89-1.94	0.70
Ear discharge *	21 1.00	19 0.78 0.42-1.46	25 0.82 0.46-1.47	13 2.28 1.10-4.71	0.26
Skin rash	23 1.00	30 1.15 0.66-1.98	53 1.51 0.92-2.47	4 0.62 0.21-1.83	0.41
Infected cut	17 1.00	16 0.80 0.40-1.59	37 1.50 0.84-2.68	6 1.55 0.59-4.05	0.08
Nausea	133 1.00	115 0.77 0.60-1.00	143 0.74 0.58-0.94	40 1.10 0.75-1.60	0.22
Vomiting	57 1.00	58 0.97 0.67-1.40	63 0.76 0.53-1.09	25 1.40 0.85-2.31	0.86
Diarrhea	204 1.00	163 0.70 0.57-0.87	202 0.67 0.55-0.82	53 0.95 0.69-1.32	0.01
Diarrhea with blood	7 1.00	2 0.26 0.05-1.23	3 0.26 0.07-1.02	2 0.80 0.15-4.20	0.19
Stomach pain	206 1.00	194 0.85 0.70-1.05	271 0.91 0.75-1.09	61 1.06 0.78-1.43	0.78
Cough	209 1.00	263 1.18 0.97-1.42	296 0.97 0.81-1.17	55 0.99 0.72-1.35	0.53
Cough & phlegm *	90 1.00	114 1.15 0.87-1.53	143 1.08 0.82-1.41	39 1.65 1.11-2.46	0.11

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Table 31 (continued)

Runny nose	273 1.00	351 1.18 1.00-1.40	371 0.92 0.78-1.09	74 1.04 0.79-1.38	0.33
Sore throat	190 1.00	244 1.17 0.96-1.42	304 1.09 0.90-1.32	59 1.19 0.87-1.63	0.33
HCGI 1*	102 1.00	188 1.03 0.83-1.28	239 0.97 0.79-1.19	69 1.48 1.09-2.00	0.23
HCGI 2	26 1.00	28 1.03 0.60-1.76	32 0.88 0.52-1.49	15 1.58 0.81-3.08	0.57
Signif.* resp. disease	161 1.00	198 1.12 0.90-1.39	239 1.01 0.82-1.24	67 1.64 1.21-2.23	0.10

* Statistically significant at p<05.

† All results adjusted for: age, beach, gender, race, tourist versus local residence, socioeconomic status, and worry about potential hazards of swimming in the Santa Monica Bay. The number of diseased subjects are given on the first line for each outcome. Trend P is from a linear model.

SARB_000489

Table 32. Crude Odds Ratios and 95% Confidence Intervals for Outcomes of Interest by Distance from Drain Among Swimmers at Ashland Beach.†

	Distance from drain (in yards)				
	400	100-50	50-1	0	trend P
# exposed:	1523	1667	2534	154	
Fever	71 1.00	77 0.99 0.71-1.38	111 0.94 0.69-1.27	11 1.57 0.81-3.04	0.92
Chills*	27 1.00	42 1.43 0.88-2.33	57 1.28 0.80-2.02	7 2.64 1.13-6.16	0.15
Eye discharge*	38 1.00	32 0.76 0.48-1.23	39 0.61 0.39-0.96	11 3.01 1.50-6.01	0.67
Earache	66 1.00	57 0.78 0.54-1.12	62 0.55 0.39-0.79	7 1.05 0.47-2.33	0.01
Ear discharge	8 1.00	8 0.91 0.34-2.44	13 0.98 0.40-2.36	1 1.24 0.15-9.96	0.95
Skin rash	12 1.00	13 0.99 0.45-2.18	34 1.71 0.88-3.32	1 0.82 0.11-6.37	0.11
Infected cut	6 1.00	8 1.22 0.42-3.52	16 1.61 0.63-4.11	0 0.00 0.00-+INF	0.49
Nausea	66 1.00	57 0.78 0.54-1.12	67 0.60 0.42-0.85	4 0.59 0.21-1.64	0.00
Vomiting	34 1.00	32 0.86 0.53-1.40	35 0.61 0.38-0.99	3 0.87 0.26-2.87	0.06
Diarrhea	94 1.00	60 0.57 0.41-0.79	103 0.64 0.48-0.86	5 0.51 0.20-1.27	0.00
Diarrhea with blood	5 1.00	1 0.18 0.02-1.56	1 0.12 0.01-1.03	0 0.00 0.00-+INF	0.03
Stomach pain	93 1.00	90 0.88 0.65-1.18	144 0.93 0.71-1.21	6 0.62 0.27-1.45	0.44
Cough	111 1.00	133 1.10 0.85-1.43	176 0.95 0.74-1.21	9 0.79 0.39-1.59	0.44
Cough & phlegm	47 1.00	57 1.11 0.75-1.65	86 1.10 0.77-1.58	5 1.05 0.41-2.69	0.66

SARB_000490

Table 32 (continued)

...nny nose	140 1.00	169 1.11 0.88-1.41	200 0.85 0.68-1.06	12 0.83 0.45-1.54	0.08
Sore throat	99 1.00	127 1.19 0.90-1.56	156 0.94 0.73-1.22	6 0.58 0.25-1.35	0.27
HCGI 1	54 1.00	50 0.84 0.57-1.24	63 0.69 0.48-1.00	5 0.91 0.36-2.32	0.08
HCGI 2	13 1.00	14 0.98 0.46-2.10	16 0.74 0.35-1.54	0 0.00 0.00-+INF	0.24
Signif. resp. disease	84 1.00	99 1.08 0.80-1.46	140 1.00 0.76-1.32	10 1.19 0.60-2.34	0.93

* Statistically significant at p<.05

† The number of diseased subjects are given on the first line for each outcome. Trend P is from a linear model.

SARB_000491

Table 33. Crude Odds Ratios and 95% Confidence Intervals for Outcomes of Interest by Distance from Drain Among Swimmers at Malibu Beach.†

	Distance from drain (in yards)				
	400	100-50	50-1	0	trend P
# exposed:	1013	1012	1399	587	
Fever*	48 1.00	45 0.94 0.62-1.42	61 0.92 0.62-1.35	42 1.55 1.01-2.38	0.14
Chills	37 1.00	23 0.61 0.36-1.04	37 0.72 0.45-1.14	21 0.98 0.57-1.69	0.72
Eye discharge	15 1.00	14 0.93 0.45-1.94	24 1.16 0.61-2.23	7 0.80 0.33-1.98	0.97
Earache*	26 1.00	35 1.36 0.81-2.28	49 1.38 0.85-2.23	30 2.04 1.20-3.49	0.02
Ear discharge*	7 1.00	4 0.57 0.17-1.95	11 1.14 0.44-2.95	12 3.00 1.17-7.66	0.01
Skin rash	6 1.00	6 1.00 0.32-3.11	12 1.45 0.54-3.88	3 0.86 0.21-3.46	0.78
Infected cut	7 1.00	4 0.57 0.17-1.95	14 1.45 0.58-3.61	6 1.48 0.50-4.44	0.22
Nausea	46 1.00	36 0.78 0.50-1.21	53 0.83 0.55-1.24	34 1.29 0.82-2.04	0.47
Vomiting*	17 1.00	16 0.94 0.47-1.87	21 0.89 0.47-1.70	22 2.28 1.20-4.33	0.04
Diarrhea	67 1.00	61 0.91 0.63-1.30	67 0.71 0.50-1.01	48 1.26 0.86-1.85	0.92
Diarrhea with blood	2 1.00	1 0.50 0.05-5.52	1 0.36 0.03-3.99	2 1.73 0.24-12.30	0.79
Stomach pain	7 1.00	65 0.91 0.64-1.29	95 0.97 0.70-1.33	52 1.29 0.89-1.87	0.28
Cough	61 1.00	79 1.32 0.93-1.87	88 1.05 0.75-1.47	40 1.14 0.76-1.72	0.86
Cough & phlegm*	25 1.00	38 1.54 0.92-2.57	41 1.19 0.72-1.98	29 2.05 1.19-3.54	0.05

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Table 33 (continued)

Runny nose	88 1.00	103 1.19 0.88-1.61	122 1.00 0.75-1.34	58 1.15 0.81-1.63	0.76
Sore throat	59 1.00	76 1.31 0.92-1.87	100 1.24 0.89-1.74	44 1.31 0.87-1.96	0.21
HCGI 1	33 1.00	27 0.81 0.49-1.36	41 0.90 0.56-1.43	28 1.49 0.89-2.49	0.22
HCGI-2*	10 1.00	10 1.00 0.41-2.42	9 0.65 0.26-1.60	15 2.63 1.17-5.89	0.08
Signif. resp. disease*	49 1.00	63 1.31 0.89-1.92	70 1.04 0.71-1.51	49 1.79 1.19-2.70	0.05

* Statistically significant at p<.05.

† The number of diseased subjects are given on the first line for each outcome. Trend P is from a linear model.

SARB_000493

Table 34. Crude Odds Ratios and 95% Confidence Intervals for Outcomes of Interest by Distance from Drain Among Swimmers at Will Roger's Beach.†

	Distance from drain (in yards)				
	400	100-50	50-1	0	trend P
# exposed:	494	632	585	86	
Fever	19 1.00	36 1.51 0.86-2.67	36 1.64 0.93-2.90	6 1.87 0.73-4.84	0.08
Chills	8 1.00	20 1.99 0.87-4.55	14 1.49 0.62-3.58	3 2.20 0.57-8.44	0.35
Eye discharge	8 1.00	13 1.28 0.52-3.10	10 1.06 0.41-2.70	1 0.71 0.09-5.78	0.89
Earache	24 1.00	24 0.77 0.43-1.38	25 0.87 0.49-1.55	1 0.23 0.03-1.73	0.29
Ear discharge	6 1.00	7 0.91 0.30-2.73	1 0.14 0.02-1.16	0 0.00 0.00-+INF	0.04
Skin rash	5 1.00	11 1.73 0.60-5.02	7 1.18 0.37-3.76	0 0.00 0.00-+INF	0.74
Infected cut	4 1.00	4 0.78 0.19-3.14	7 1.48 0.43-5.10	0 0.00 0.00-+INF	0.81
Nausea	21 1.00	22 0.81 0.44-1.49	23 0.92 0.50-1.69	2 0.54 0.12-2.33	0.58
Vomiting	6 1.00	10 1.31 0.47-3.62	7 0.99 0.33-2.95	0 0.00 0.00-+INF	0.57
Diarrhea	43 1.00	42 0.75 0.48-1.16	32 0.61 0.38-0.98	0 0.00 0.00-+INF	0.00
Stomach pain	42 1.00	39 0.71 0.45-1.11	32 0.62 0.39-1.00	3 0.39 0.12-1.28	0.02
Cough	37 1.00	51 1.08 0.70-1.68	32 0.71 0.44-1.17	6 0.93 0.38-2.27	0.23
Cough & phlegm	18 1.00	19 0.82 0.43-1.58	16 0.74 0.38-1.47	5 1.63 0.59-4.52	0.94

SARB_000494

Table 34 (continued)

Runny nose	45 1.00	79 1.43 0.97-2.10	49 0.91 0.60-1.39	4 0.49 0.17-1.39	0.21
Sore throat	32 1.00	41 1.00 0.62-1.62	48 1.29 0.81-2.05	9 1.69 0.78-3.67	0.12
HCGI 1	15 1.00	19 0.99 0.50-1.97	17 0.96 0.47-1.93	2 0.76 0.17-3.39	0.78
HCGI 2	3 1.00	4 1.04 0.23-4.68	7 1.98 0.51-7.71	0 0.00 0.00-+INF	0.55
Signif. resp. disease	28 1.00	36 1.01 0.60-1.67	29 0.87 0.51-1.48	8 1.71 0.75-3.88	0.80

* Statistically significant at p<.05.

† The number of diseased subjects are given on the first line for each outcome. Trend P is from a linear model.

SARB_000495

Table 35. Crude Odds Ratios and 95% Confidence Intervals for Outcomes of Interest by Distance from Drain Among Children Under 12 Years Old.†

	Distance from drain (in yards)				
	400	100-50	50-1	0	trend P
# exposed:	1551	1470	2079	514	
Fever*	86 1.00	78 0.95 0.70-1.31	113 0.98 0.73-1.31	42 1.52 1.03-2.22	0.18
Chills	38 1.00	37 1.03 0.65-1.63	44 0.86 0.55-1.34	20 1.61 0.93-2.80	0.51
Eye discharge	43 1.00	27 0.66 0.40-1.07	36 0.62 0.39-0.97	12 0.84 0.44-1.60	0.13
Earache	54 1.00	50 0.98 0.66-1.44	58 0.80 0.55-1.16	22 1.24 0.75-2.06	0.82
Ear discharge*	8 1.00	6 0.79 0.27-2.28	7 0.65 0.24-1.80	7 2.66 0.96-7.38	0.31
Skin rash	13 1.00	14 1.14 0.53-2.43	26 1.50 0.77-2.93	2 0.46 0.10-2.05	0.81
Infected cut	6 1.00	5 0.88 0.27-2.89	8 0.99 0.34-2.87	2 1.01 0.20-5.00	0.97
Nausea	75 1.00	45 0.62 0.43-0.91	61 0.59 0.42-0.84	25 1.01 0.63-1.60	0.12
Vomiting*	42 1.00	31 0.77 0.48-1.24	47 0.83 0.55-1.27	23 1.68 1.00-2.83	0.32
Diarrhea	110 1.00	69 0.65 0.47-0.88	85 0.56 0.42-0.75	38 1.05 0.71-1.53	0.05
Diarrhea with blood	2 1.00	1 0.53 0.05-5.82	2 0.75 0.10-5.30	2 3.03 0.43-21.53	0.42
Stomach pain	114 1.00	81 0.74 0.55-0.99	133 0.86 0.66-1.12	39 1.03 0.71-1.51	0.79
Cough	127 1.00	137 1.15 0.90-1.48	139 0.80 0.63-1.03	40 0.95 0.65-1.37	0.12
Cough & phlegm*	54 1.00	56 1.10 0.75-1.61	53 0.73 0.49-1.07	28 1.60 1.00-2.55	0.88

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Table 35 (continued)

Runny nose	146 1.00	148 1.08 0.85-1.37	152 0.76 0.60-0.96	48 0.99 0.70-1.40	0.09
Sore throat	100 1.00	102 1.08 0.81-1.44	106 0.78 0.59-1.03	37 1.13 0.76-1.66	0.37
HCGI 1	71 1.00	50 0.73 0.51-1.06	72 0.75 0.54-1.04	29 1.25 0.80-1.94	0.86
HCGI 2	22 1.00	14 0.67 0.34-1.31	26 0.88 0.50-1.56	14 1.95 0.99-3.83	0.19
Signif. resp. disease*	86 1.00	88 1.08 0.80-1.47	88 0.75 0.56-1.02	47 1.71 1.18-2.48	0.53

* Statistically significant at p<.05.

† The number of diseased subjects are given on the first line for each outcome. Trend P is from a linear model.

SARB_000497

Table 36. Crude Odds Ratios and 95% Confidence Intervals for Outcomes of Interest by Distance from Drain Among Swimmers Aged 12-25 Years Old.†

	Distance from drain (in yards)				
	400	100-50	50-1	0	trend P
# exposed:	739	892	1188	163	
Fever*	25 1.00	39 1.31 0.78-2.18	46 1.15 0.70-1.89	11 2.07 1.00-4.29	0.23
Chills	14 1.00	22 1.31 0.67-2.58	28 1.25 0.65-2.39	6 1.98 0.75-5.23	0.29
Eye discharge	7 1.00	14 1.67 0.67-4.15	15 1.34 0.54-3.30	3 1.96 0.50-7.66	0.49
Earache	33 1.00	38 0.95 0.59-1.53	38 0.71 0.44-1.14	10 1.40 0.67-2.90	0.53
Ear discharge	7 1.00	6 0.71 0.24-2.12	12 1.07 0.42-2.72	2 1.30 0.27-6.31	0.67
Skin rash	5 1.00	3 0.50 0.12-2.08	13 1.62 0.58-4.57	0 0.00 0.00-+INF	0.53
Infected cut	8 1.00	6 0.62 0.21-1.79	15 1.17 0.49-2.77	2 1.14 0.24-5.40	0.55
Nausea	25 1.00	40 1.34 0.81-2.23	34 0.84 0.50-1.42	7 1.28 0.54-3.02	0.61
Vomiting	7 1.00	19 2.28 0.95-5.44	5 0.44 0.14-1.40	2 1.30 0.27-6.31	0.20
Diarrhea	43 1.00	31 0.58 0.36-0.93	46 0.65 0.43-1.00	10 1.06 0.52-2.15	0.28
Diarrhea with blood	3 1.00	1 0.28 0.03-2.65	0 0.00 0.00-+INF	0 0.00 0.00-+INF	0.07
Stomach pain	52 1.00	54 0.85 0.57-1.26	77 0.92 0.64-1.32	11 0.96 0.49-1.88	0.78
Cough	43 1.00	71 1.40 0.95-2.07	87 1.28 0.88-1.87	13 1.40 0.74-2.67	0.25
Cough & phlegm*	21 1.00	32 1.27 0.73-2.23	48 1.44 0.85-2.42	10 2.23 1.03-4.84	0.05

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Table 36 (continued)

Runny nose	72 1.00 0.87-1.65	102 1.20 0.74-1.37	116 1.00 0.62-1.88	17 1.08	0.90
Sore throat	46 1.00	67 1.22 0.83-1.80	105 1.46 1.02-2.09	15 1.53 0.83-2.81	0.03
HCGI 1	16 1.00	24 1.25 0.66-2.37	21 0.81 0.42-1.57	4 1.14 0.38-3.45	0.58
HCGI 2	1 1.00	10 8.37 1.07-65.51	3 1.87 0.19-17.99	1 4.56 0.28-73.21	0.98
Signif. resp. disease	46 1.00	55 0.99 0.66-1.48	81 1.10 0.76-1.60	16 1.64 0.90-2.98	0.20

* Statistically significant at p<.05.

† The number of diseased subjects are given on the first line for each outcome. Trend P is from a linear model.

SARB_000499

Table 37. Crude Odds Ratios and 95% Confidence Intervals for Outcomes of Interest by Distance from Drain Among Adults Over 25 Years Old.†

	Distance from drain (in yards)				
	400	100-50	50-1	0	trend P
# exposed:	740	949	1251	150	
Fever	27 1.00	41 1.19 0.73-1.96	49 1.08 0.67-1.74	6 1.10 0.45-2.71	0.86
Chills	20 1.00	26 1.01 0.56-1.83	36 1.07 0.61-1.86	5 1.24 0.46-3.36	0.69
Eye discharge	11 1.00	18 1.28 0.60-2.73	22 1.19 0.57-2.46	4 1.82 0.57-5.78	0.48
Earache	29 1.00	28 0.75 0.44-1.26	40 0.81 0.50-1.32	6 1.02 0.42-2.51	0.65
Ear discharge	6 1.00	7 0.91 0.30-2.72	6 0.59 0.19-1.83	4 3.35 0.93-12.02	0.64
Skin rash	5 1.00	13 2.04 0.72-5.75	14 1.66 0.60-4.64	2 1.99 0.38-10.34	0.42
Infected cut	3 1.00	5 1.30 0.31-5.46	14 2.78 0.80-9.71	2 3.32 0.55-20.04	0.04
Nausea	33 1.00	30 0.70 0.42-1.16	48 0.85 0.54-1.34	8 1.21 0.55-2.67	0.98
Vomiting	8 1.00	8 0.78 0.29-2.08	11 0.81 0.32-2.03	0 0.00 0.00-+INF	0.37
Diarrhea	51 1.00	63 0.96 0.66-1.41	71 0.81 0.56-1.18	5 0.47 0.18-1.19	0.09
Diarrhea with blood	2 1.00	0 0.00 0.00-+INF	1 0.30 0.03-3.26	0 0.00 0.00-+INF	0.26
Stomach pain	40 1.00	59 1.16 0.77-1.75	61 0.90 0.60-1.35	11 1.38 0.69-2.77	0.87
Cough	39 1.00	55 1.11 0.73-1.69	70 1.07 0.71-1.59	2 0.24 0.06-1.02	0.44
Cough & phlegm	15 1.00	26 1.36 0.72-2.59	42 1.68 0.92-3.05	1 0.32 0.04-2.47	0.38
Runny nose	55 1.00	101 1.48 1.05-2.09	103 1.12 0.79-1.57	9 0.79 0.38-1.65	0.75

SARB_000500

Table 37 (continued)

Sore throat	44 1.00	75 1.36 0.92-2.00	93 1.27 0.88-1.84	7 0.77 0.34-1.75	0.66
HCGI 1	15 1.00	22 1.15 0.59-2.23	28 1.11 0.59-2.09	2 0.65 0.15-2.89	0.93
HCGI 2	3 1.00	4 1.04 0.23-4.66	3 0.59 0.12-2.93	0 0.00 0.00-+INF	0.35
Signif. resp. disease	29 1.00	55 1.51 0.95-2.39	70 1.45 0.93-2.26	4 0.67 0.23-1.94	0.48

* Statistically significant at p<.05.

† The number of diseased subjects are given on the first line for each outcome. Trend P is from a linear model.

SARB_000501

Table 38. Risks For High vs. Low E.Coli Indicator Counts

ALL BEACHES

	Total Exposed = 2654		Total Unexposed = 7724				
	> 70 cfu		≤ 70 cfu				
SYMPTOMS	Ill	Risks	Ill	Risks	RR	Lower 95% CI	Upper 95% CI
Fever	135	0.051	363	0.047	1.08	0.89	1.31
Chills	68	0.026	186	0.024	1.06	0.81	1.40
Eye discharge	43	0.016	146	0.019	0.86	0.61	1.20
Earache	98	0.037	259	0.034	1.10	0.88	1.38
Ear discharge	17	0.006	50	0.006	0.99	0.57	1.71
Skin rash	28	0.011	72	0.009	1.13	0.73	1.75
Infected cut	15	0.006	49	0.006	0.89	0.50	1.59
Nausea	94	0.035	290	0.038	0.94	0.75	1.19
Vomiting	44	0.017	138	0.018	0.93	0.66	1.30
Diarrhea	144	0.054	411	0.053	1.02	0.85	1.23
Diarrhea w/ blood	3	0.001	8	0.001	1.09	0.29	4.11
Stomach pain	171	0.064	477	0.062	1.04	0.88	1.24
Coughing	197	0.074	540	0.070	1.06	0.91	1.24
Phlegm	88	0.033	267	0.035	0.96	0.76	1.22
Nasal congestion	251	0.095	702	0.091	1.04	0.91	1.19
Sore throat	186	0.070	516	0.067	1.05	0.89	1.23
HCGI_1	83	0.031	234	0.030	1.03	0.81	1.32
HCGI_2	24	0.009	69	0.009	1.01	0.64	1.61
SRD	135	0.051	390	0.050	1.01	0.83	1.22

Table 39. Risks For High vs. Low Bacterial Indicators

E. coli

	> 35 cfu		> 70 cfu	
Symptoms	**RR**	**95% CI**	**RR**	**95% CI**
Fever	**1.16**	**0.98, 1.38**	**1.07**	**0.89 , 1.30**
Chills	**1.07**	**0.84, 1.37**	**1.06**	**0.80 , 1.39**
Eye discharge	**0.89**	**0.67, 1.20**	**0.85**	**0.61 , 1.19**
Earache	**0.94**	**0.77, 1.16**	**1.09**	**0.87 , 1.37**
Ear discharge	**0.83**	**0.51, 1.35**	**0.96**	**0.56 , 1.67**
Skin rash	**1.07**	**0.72, 1.59**	**1.13**	**0.73 , 1.74**
Infected cut	**0.74**	**0.44, 1.24**	**0.89**	**0.50 , 1.58**
Nausea	**1.10**	**0.90, 1.34**	**0.93**	**0.74 , 1.17**
Vomiting	**1.01**	**0.75, 1.35**	**0.92**	**0.65 , 1.28**
Diarrhea	**1.12**	**0.95, 1.31**	**1.00**	**0.83 , 1.21**
Diarrhea w/ blood	**1.70**	**0.52, 5.58**	**1.08**	**0.29 , 4.09**
Stomach pain	**1.18**	**1.01, 1.37**	**1.03**	**0.87 , 1.22**
Coughing	**0.94**	**0.81, 1.08**	**1.06**	**0.91 , 1.24**
Phlegm	**0.82**	**0.66, 1.01**	**0.97**	**0.77 , 1.22**
Nasal congestion	**0.97**	**0.86, 1.10**	**1.04**	**0.91 , 1.19**
Sore throat	**0.97**	**0.83, 1.12**	**1.04**	**0.89 , 1.22**
HCGI 1	**1.05**	**0.84, 1.30**	**1.02**	**0.80 , 1.31**
HCGI 2	**1.34**	**0.89 , 2.01**	**1.01**	**0.64 , 1.61**
SRD	**0.93**	**0.78, 1.10**	**1.01**	**0.83 , 1.22**

Table 40. Odds Ratios and 95% Confidence Intervals for E. Coli Dichotomized First at 160 cfu, then at 320 cfu. The Number of Diseased Subjects are Given on the First Line for Each Outcome.

	Cutpoint	
# exposed:	160 cfu 1509	320 cfu 991
Fever	74.00 1.03 0.80-1.32	45.00 0.94 0.69-1.28
Chills	40.00 1.10 0.78-1.55	22.00 0.90 0.58-1.39
Eye discharge	29.00 1.07 0.72-1.59	23.00 1.32 0.85-2.05
Earache*	65.00 1.32 1.00-1.74*	47.00 1.46 1.06-2.00*
Ear discharge	12.00 1.28 0.69-2.40	6.00 0.93 0.40-2.16
Skinrash	21.00 1.57 0.97-2.55	15.00 1.68 0.97-2.92
Infected cut	12.00 1.36 0.72-2.55	9.00 1.56 9.77-3.16
Nausea	60.00 1.09 0.82-1.45	42.00 1.17 0.84-1.62
Vomiting	28.00 1.07 0.71-1.61	20.00 1.17 0.73-1.88
Diarrhea	81.00 1.00 0.79-1.28	56.00 1.07 0.80-1.42
Diarrhea with blood	2.00 1.31 0.28-6.05	0.00 0.00 0.00-+INF
Stomache pain	101.00 1.09 0.88-1.36	70.00 1.16 0.90-1.50
Cough	111.00 1.05 0.85-1.29	82.00 1.20 0.95-1.53
Cough & phlegm	54.00 1.06 0.79-1.42	43.00 1.32 0.95-1.83

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Table 40 (continued)

Runny nose*	146.00 1.07 0.89-1.29	108.00 1.24 1.00-1.53*
Sorethroat	104.00 1.02 0.83-1.27	75.00 1.14 0.89-1.47
HCGI-1	53.00 1.19 0.88-1.60	36.00 1.22 0.86-1.74
HCGI-2	16.00 1.22 0.71-2.10	10.00 1.14 0.59-2.21
Signif. resp. disease	83.00 0.95 0.75-1.21	61.00 1.09 0.83-1.44

* Statistically significant at p<.05.

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Table 41. Crude Odds Ratios and 95% Confidence Intervals for E. Coli by Quintiles and from a Linear Model.†

	Quintile (cfu)					linear model
	1	2	3	4	5	
midpoints:	2.00	7.50	23.00	56.00	310.00	
# exposed:	2122	2096	2141	2052	2082	
Fever	99 1.00	104 1.07 0.80-1.41	85 0.84 0.63-1.14	119 1.26 0.96-1.65	98 1.01 0.76-1.34	0.99 0.94-1.04
Chills	56 1.00	48 0.86 0.59-1.28	48 0.85 0.57-1.25	56 1.04 0.71-1.51	50 0.91 0.62-1.34	0.99 0.92-1.07
Eye discharge	36 1.00	43 1.21 0.78-1.90	41 1.13 0.72-1.78	33 0.95 0.59-1.52	37 1.05 0.66-1.67	1.04 0.98-1.10
Earache	83 1.00	67 0.81 0.58-1.13	71 0.84 0.61-1.16	57 0.70 0.50-0.99	82 1.01 0.74-1.38	1.03 0.98-1.08
Ear discharge	16 1.00	14 0.89 0.43-1.82	16 0.99 0.49-1.99	9 0.58 0.26-1.32	14 0.89 0.43-1.83	0.98 0.84-1.14
Skin rash*	16 1.00	18 1.14 0.58-2.24	25 1.56 0.83-2.92	18 1.16 0.59-2.29	23 1.47 0.77-2.79	1.07 1.01-1.14
Infected cut	1 1.00	13 1.20 0.54-2.68	19 1.72 0.82-3.62	7 0.66 0.25-1.70	14 1.30 0.59-2.87	1.02 0.91-1.15
Nausea*	85 1.00	68 0.80 0.58-1.11	72 0.83 0.61-1.15	78 0.95 0.69-1.30	82 0.98 0.72-1.34	1.04 1.00-1.08
Vomiting	47 1.00	30 0.64 0.40-1.02	33 0.69 0.44-1.08	36 0.79 0.51-1.22	36 0.78 0.50-1.20	1.02 0.95-1.10
Diarrhea	125 1.00	86 1.17 0.90-1.53	122 0.77 0.58-1.03	115 1.17 0.89-1.52	1.08 0.82-1.41	1.03 0.99-1.07
Diarrhea with blood	2 1.00	1 0.51 0.05-5.58	2 0.99 0.14-7.04	3 1.55 0.26-9.30	3 1.53 0.26-9.16	0.85 0.38-1.87
Stomach pain*	141 1.00	119 0.85 0.66-1.09	109 0.75 0.58-0.98	145 1.07 0.84-1.36	135 0.97 0.76-1.24	1.04 1.00-1.07
Cough	150 1.00	157 1.06 0.84-1.34	140 0.92 0.72-1.17	141 0.97 0.76-1.23	149 1.01 0.80-1.28	1.02 0.98-1.06
Cough & phlegm	67 1.00	91 1.39 1.01-1.92	69 1.02 0.73-1.44	61 0.94 0.66-1.34	67 1.02 0.72-1.44	1.02 0.97-1.07

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Table 41 (continued)

Runny nose	197 1.00	204 1.05 0.86-1.29	173 0.86 0.69-1.06	189 0.99 0.80-1.22	192 0.99 0.81-1.22	1.02 0.99-1.06
Sore throat	145 1.00	154 1.08 0.85-1.37	131 0.89 0.70-1.13	138 0.98 0.77-1.25	139 0.98 0.77-1.24	1.01 0.97-1.05
HCGI 1	83 1.00	56 0.67 0.48-0.95	48 0.56 0.39-0.81	66 0.82 0.59-1.13	64 0.78 0.56-1.09	1.02 0.97-1.08
HCGI 2	22 1.00	14 0.64 0.33-1.26	14 0.63 0.32-1.23	24 1.13 0.63-2.02	19 0.88 0.47-1.63	1.02 0.93-1.12
Signif. resp. disease	114 1.00	147 1.33 1.03-1.71	113 0.98 0.75-1.28	116 1.06 0.81-1.38	107 0.95 0.73-1.25	1.01 0.97-1.06

* Statistically significant at p<.05.

† Linear results correspond to an increase in the exposure equal to the difference between the 90th and 10th percentiles. The number of subjects with each outcome are given on the first line.

SARB_000507

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March 9, 2011
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State Mandates

California Regional Water Quality Control Board
Santa Ana Region

RESOLUTION NO. 99-10

A Resolution Amending the Water Quality Control Plan
for the Santa Ana River Basin
to Establish a Total Maximum Daily Load for Fecal Coliform Bacteria
in Newport Bay

WHEREAS, the California Regional Water Quality Control Board, Santa Ana Region (hereinafter Regional Board), finds that:

1. An updated Water Quality Control Plan for the Santa Ana River Basin (Basin Plan) was adopted by the Regional Board on March 11, 1994, approved by the State Water Resources Control Board (SWRCB) on July 21, 1994 and approved by the Office of Administrative Law on January 24, 1995.

2. Water contact recreation (REC1) and shellfish harvesting (SHEL) are among the beneficial use designations specified in the Basin Plan for Newport Bay.

3. The Basin Plan includes numeric water quality objectives for fecal coliform bacteria in Newport Bay. For the protection of the water contact recreation beneficial use, these objectives specify that Newport Bay shall not contain fecal coliform in excess of a 5 sample/month log mean of 200 organisms/100 mL, and not more than 10% of the samples exceed 400 organisms/100 mL for any 30-day period. To protect the shellfish harvesting beneficial use, the Basin Plan also requires that Newport Bay have a median fecal coliform density of less than 14 MPN (most probable number)/100 mL, and not more than 10% of the samples exceed 43 MPN/100 mL.

4. These objectives for fecal coliform are not being consistently met in Newport Bay. Discharges of fecal coliform waste adversely impact beneficial uses by causing the Orange County Health Care Agency to close beach areas to body contact recreation, and/or to post notices to avoid body contact recreation. Shellfish harvesting is also banned in Upper Newport Bay. In part in response to these problems, the Regional Board listed Newport Bay as water quality limited in accordance with Section 303(d) of the Clean Water Act. Section 303(d) of the Clean Water Act requires the establishment of the Total Maximum Daily Load (TMDL) of fecal coliform that can be discharged while still ensuring compliance with water quality standards. Section 303(d) also requires the allocation of this TMDL among sources of fecal coliform, together with an

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implementation plan and schedule that will ensure that the TMDL is met and that compliance with water quality standards is achieved.

5. The Regional Board discussed this matter at public workshops held on December 11, 1998 and January 15, 1999, after notice was given to all interested persons in accordance with Section 13244 of the California Water Code. Based on that discussion and the testimony received, the Board directed staff to prepare the appropriate Basin Plan amendment and related documentation to establish a TMDL for fecal coliform in Newport Bay. The Board considered the proposed Basin Plan amendment during a public hearing held on March 5, 1999, and continued the public hearing until April 9, 1999.

6. The TMDL-related Basin Plan amendment attached to this resolution meets the requirements of Section 303(d) of the Clean Water Act. The amendment requires the implementation of Best Management Practices (BMPs) to control bacterial inputs to provide a reasonable assurance that water quality standards will be met.

7. The Regional Board prepared and distributed written reports (staff reports) regarding adoption of the Basin Plan amendment in compliance with applicable state and federal environmental regulations (California Code of Regulations, Section 3775, Title 23, and 40 CFR Parts 25 and 131).

8. The process of basin planning has been certified by the Secretary for Resources as exempt from the requirements of the California Environmental Quality Act (Title 14, Section 15251g of the California Code of Regulations) to prepare an Environmental Impact Report or Negative Declaration. The Basin Plan amendment package includes an Environmental Checklist, an assessment of the environmental impacts of the Basin Plan amendment, and a discussion of alternatives. The amended Basin Plan, Environmental Checklist, staff reports, and supporting documentation are functionally equivalent to an Environmental Impact Report or Negative Declaration.

9. The Regional Board has considered federal and state antidegradation policies and other relevant water quality control policies and finds the Basin Plan amendment consistent with those policies.

10. On April 9, 1999, the Regional Board held a Public Hearing to consider the Basin Plan amendment. Notice of the Public Hearing was given to all interested persons and published in accordance with Water Code Section 13244.

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11. The Basin Plan amendment must be submitted for review and approval by the SWRCB, the Office of Administrative Law (OAL), and the U.S. Environmental Protection Agency. Once approved by the SWRCB, the amendment is submitted to OAL. A Notice of Decision will be filed after the SWRCB and OAL have acted on this matter. The SWRCB will forward the approved amendment to the U.S. Environmental Protection Agency for review and approval.

NOW, THEREFORE, BE IT RESOLVED THAT:

1. The Regional Board adopts the amendment to the Water Quality Control Plan for the Santa Ana River Basin (Region 8) as set forth in the attachment.

2. The Executive Officer is directed to forward copies of the Basin Plan amendment to the SWRCB in accordance with the requirement of Section 13245 of the California Water Code.

3. The Regional Board requests that the SWRCB approve the Basin Plan amendment in accordance with Sections 13245 and 13246 of the California Water Code and forward it to the Office of Administrative Law for approval.

I, Gerard J. Thibeault, Executive Officer, do hereby certify that the foregoing is a full, true, and correct copy of a resolution adopted by the California Regional Water Quality Control Board, Santa Ana Region, on April 9, 1999.

_____

Gerard J. Thibeault
Executive Officer

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Attachment to Resolution No. 99-10

Amendment to the Santa Ana Region Basin Plan

Chapter 5 - Implementation Plan, Discussion of Newport Bay Watershed (page 5-39 et seq.)

(Language deleted is struck out; language added is underlined)

3. Bacterial Contamination

Bacterial contamination of the waters of Newport Bay can directly affect two designated beneficial uses: water-contact recreation (**REC-1**) and shellfish harvesting (**SHEL**). The Orange County Health Care Agency (OCHCA) conducts routine bacteriological monitoring and more detailed sanitary surveys as necessary, and is responsible for closure of areas to recreational and shellfish harvesting uses if warranted by the results.

Because of consistently high levels of total coliform bacteria, ~~T~~the upper portion of Upper Newport Bay (Upper Bay) has been closed to these uses since 1974. In 1978, the shellfish harvesting prohibition area was expanded to include all of the Upper Bay, and the OCHCA generally advises against the consumption of shellfish harvested anywhere in the Bay. Bacterial objectives established to protect shellfish harvesting activities are rarely met in the Bay. (Fecal coliform objectives for the protection of shellfish harvesting and water-contact recreation are shown in Chapter 4, "Enclosed Bays and Estuaries". The OCHCA has relied on total coliform standards specified in the California Health and Safety Code. Fecal coliform are a subset of total coliform.) ~~A number of storm channels empty into the Upper Bay and appear to be the principal sources of the high bacterial (coliform) concentrations. Statistical evaluation of the long-term data shows a significant reduction in bacterial concentrations in the Upper Bay in recent years. This reduction may be associated, at least in part, with the excavation of the in-bay basins, which have significantly increased tidal flushing.~~ Certain areas in the lower parts of the Upper Bay and in Lower Newport Bay (Lower Bay) are also closed to water-contact recreation on a temporary basis, generally in response to storms. In these areas, there is generally good compliance with water-contact recreation bacterial objectives in the summer.

~~Certain areas in the Lower Bay also show frequent high bacterial concentrations, particularly those locations which are subject to urban runoff and have limited tidal flushing. As in the Upper Bay, more violations of bacterial standards generally occur during storm runoff periods than during dry weather. However, an additional and more significant source of bacterial input contributes to these violations on occasion. This source is the discharge of vessel sanitary wastes.~~

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Data collected by the OCHCA demonstrate that tributary inflows, composed of urban and agricultural runoff, including stormwater, are the principal sources of coliform input to the Bay. As expected, there are more violations of bacterial standards in the Bay during wet weather, when tributary flows are higher, than in dry weather. There are few data on the exact sources of the coliform in this runoff. Coliform has diverse origins, including: manure fertilizers which may be applied to agricultural crops and to commercial and residential landscaping; the fecal wastes of humans, household pets and wildlife; and other sources. Special investigations by OCHCA have demonstrated that food wastes are a significant source of coliform. Many restaurants wash down equipment and floor mats into storm drains tributary to the Bay and may improperly dispose of food waste such that it eventually washes into the Bay. Such discharges likely contribute to the chronic bacterial quality problems in certain parts of the Bay.

Another source of bacterial input to the Bay is the discharge of vessel sanitary wastes. Newport Bay has been designated a no-discharge harbor for vessel sanitary wastes since 1976. Despite this prohibition, discharges of these wastes have continued to occur. Since these wastes are of human origin, they pose a potentially significant public health threat.

The Regional Board, the City of Newport Beach (City), the County of Orange, the City of Newport Beach Harbor Quality Committee, and other parties have taken or stimulated actions to enforce the vessel waste discharge prohibition. The principal focus of these efforts has been to make compliance with the prohibition convenient and therefore more likely. Vessel waste pumpouts have been installed at key locations around the Bay and are inspected routinely by the OCHCA. A City ordinance addresses people-intensive boating activities to ensure proper disposal of ~~that~~ sanitary wastes. ~~are appropriately disposed.~~ The ordinance requires that sailing clubs, harbor tour, and boat charter operations install pumpouts for their vessels. Another City ordinance addresses vessel waste disposal by persons living on their boats. Efforts have also been made to ensure that there are adequate public rest rooms onshore. The City also sponsors an extensive public education campaign designed to advise both residents and visitors of the discharge prohibition, the significance of violations, and of the location of pumpouts and rest room facilities. The effectiveness of these extensive vessel waste control efforts is not known.

As noted, the fecal waste of wildlife, including waterfowl that inhabit the Bay and its environs, is a source of coliform input. The fecal coliform from these natural sources may contribute to the violations of water quality objectives and the loss of beneficial uses, but it is currently unknown to what extent these natural sources contribute to, or cause, the violations of bacterial quality objectives in Newport Bay.

Reports prepared by Regional Board staff describe the bacterial quality problems in the Bay in greater detail and discuss the technical basis for the fecal coliform TMDL that follows (21, 22). Implementation of this TMDL is expected to address these

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bacterial quality problems and to assure attainment of water quality standards, that is, compliance with water quality objectives and protection of beneficial uses.

3.a. Fecal Coliform TMDL

A prioritized, phased approach to the control of bacterial quality in the Bay is specified in this TMDL. This approach is appropriate, given the complexity of the problem, the paucity of relevant data on bacterial sources and fate, the expected difficulties in identifying and implementing appropriate control measures, and uncertainty regarding the nature and attainability of the SHEL use in the Bay. The phased approach is intended to allow for additional monitoring and assessment to address areas of uncertainty and for future revision and refinement of the TMDL as warranted by these studies.

Table 5-9f summarizes the TMDL, Waste Load Allocations (WLAs) for point sources of fecal coliform inputs and Load Allocations (LAs) for nonpoint source inputs. As shown, the TMDL, WLAs and LAs are established to assure compliance with water contact recreation standards no later than (14 years after State approval of the TMDL)* and with shellfish standards no later than (20 years after State approval of the TMDL)*. WLAs are specified for vessel waste and urban runoff, including stormwater, the quality of which is regulated under a County-wide NPDES permit issued by the Regional Board. This runoff is thus regulated as a point source, even though it is diffuse in origin. LAs are specified for fecal coliform inputs from agricultural runoff, including stormwater, and natural sources. The TMDL is to be adjusted, as appropriate, based upon completion of the studies contained in Table 5-9g. Upon completion of these studies, an updated TMDL report will be prepared summarizing the results of the studies and making recommendations regarding implementation of the TMDL. The results of the studies may lead to recommendations for changes to the TMDL specified in Table 5-9f to assure compliance with existing Basin Plan standards (objectives and beneficial uses). The study results may also lead to recommendations for changes to the Basin Plan objectives and/or beneficial uses. If such standards changes are approved through the Basin Plan amendment process, then appropriate changes to the TMDL would be required to assure attainment of the revised standards. Revision of the TMDL, if appropriate, would also be considered through the Basin Plan amendment process.

Upon completion and consideration of the studies and any appropriate Basin Plan amendments, a plan for compliance with the TMDL specified in Table 5-9f, or with an approved amended TMDL, will be established. It is expected that this plan will

* Note: Upon State approval (i.e., approval by the Regional Board, the State Water Resources Control Board, and the Office of Administrative Law), this parenthetical "formula" will be replaced by the date certain, based on the date of approval.

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specify a phased compliance approach, based on consideration of such factors as geographic location, the priority assigned by the Regional Board to specific locations for control actions (see Section 3.a.ii, "Beneficial Use Assessment"), season, etc. Interim WLAs, LAs and compliance dates that lead to ultimate compliance with the TMDL will be established.

The TMDL and its allocations contain a significant margin of safety. The margin of safety can be either incorporated implicitly through analytical approaches and assumptions used to develop the TMDL or added explicitly as a separate component of the TMDL. A substantial margin of safety is implicitly incorporated in the TMDL in the fact that the TMDL does not apply criteria for dilution, natural die-off, and tidal flushing. The TMDL, WLAs, and LAs are established at concentrations equivalent to the water quality objectives.

Table 5-9f: Total Maximum Daily Load, Waste Load Allocations, and Load Allocations for Fecal Coliform in Newport Bay

Total Maximum Daily Load for Fecal Coliform In Newport Bay	Waste Load Allocations for Fecal Coliform in Urban Runoff, including stormwater, Discharges to Newport Bay	Load Allocations for Fecal Coliform in Agricultural Runoff, including stormwater, Discharges to Newport Bay	Load Allocations for Fecal Coliform from Natural Sources in all Discharges to Newport Bay	Waste Load Allocations for Vessel Waste
As soon as possible but no later than (14 years after State TMDL Approval)*			**In Effect**	**In Effect**
5-Sample/30-days Geometric Mean less than 200 organisms/100 mL, and not more than 10% of the samples exceed 400 organisms/ 100 mL for any 30-day period.	5-Sample/30-days Geometric Mean less than 200 organisms/100 mL, and not more than 10% of the samples exceed 400 organisms/ 100 mL for any 30-day period.	5-Sample/30-days Geometric Mean less than 200 organisms/ 100 mL, and not more than 10% of the samples exceed 400 organisms/ 100 mL for any 30-day period.	5-Sample/30-days Geometric Mean less than 200 organisms/100 mL, and not more than 10% of the samples exceed 400 organisms/ 100 mL for any 30-day period.	0 MPN/100 mL No discharge.
As soon as possible but no later than (20 years after State TMDL Approval)*				**In Effect**
Monthly Median less than 14 MPN/100 mL, and not more than 10% of the samples exceed 43 MPN/100 mL.	Monthly Median less than 14 MPN/100 mL, and not more than 10% of the samples exceed 43 MPN/100 mL.	Monthly Median less than 14 MPN/100 mL, and not more than 10% of the samples exceed 43 MPN/100 mL.	Monthly Median less than 14 MPN/100 mL, and not more than 10% of the samples exceed 43 MPN/100 mL.	0 MPN/100 mL No discharge.

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Table 5-9g: Fecal Coliform Implementation Plan/Schedule Report Due Dates

Task	Description	Compliance Date-As soon As Possible but No Later Than
Task 1	Routine Monitoring Program (Section 3.a.ii.a) a) Submit Proposed Routine Monitoring Plan(s)[1] b) Implement Routine Monitoring Plan(s) c) Submit Monthly and Annual Reports (Reporting Period: April 1-March 31)	 a) (Within 30 days)[2] b) Upon Regional Board Approval of Plan(s) c) Monthly within 30 days, Annual Report by September 1
Task 2	Water Quality Model for Bacterial Indicators (Section 3.a.ii.b) a) Submit Proposed Model Development Plan b) Submit Calibrated Model and Model Documentation	 a) (Within 30 days)[2] b) 13 months after Regional Board approval of plan(s)
Task 3	Beneficial Use Assessment Plan (Section 3.a.ii.c) Submit Proposed Assessment Plan for: a) REC-1 b) SHEL	 a) (Within 30 days)[2] b) (Within 13 months)[2]
Task 4	Beneficial Use Assessment Report (3.a.ii.c) Submit Beneficial Use Assessment Report for: a) REC-1 b) SHEL	 a) 13 months after Regional Board approval of plan(s) b) 13 months after Regional Board approval of plan(s)
Task 5	Source Identification and Characterization Plan(s) (Section 3.a.ii.d) Submit Proposed Source Identification Plans for: a) The Dunes Resort b) Urban Runoff (including stormwater) c) Agriculture (including stormwater) d) Natural Sources	 a) (Within 60 days)[2] b) (Within 60 days)[2] c) (Within 3 months)[2] d) (Within 3 months)[2]

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Table 5-9g: Fecal Coliform Implementation Plan/Schedule Report Due Dates		
Task	**Description**	**Compliance Date-As Soon As Possible but No Later Than**
Task 6	Source Identification and Characterization Reports (Section 3.a.ii.d) Submit Source Identification and Characterization Reports for: a) The Dunes Resort b) Urban Runoff (including stormwater) c) Agriculture (including stormwater) d) Natural Sources	 a) 7 months after Regional Board approval of plan(s) b) 13 months after Regional Board approval of plan(s) c) 16 months after Regional Board approval of plan(s) d) 16 months after Regional Board approval of plan(s)
Task 7	Evaluation of Vessel Waste Program (Section 3.a.ii.e) a) Submit Proposed Plan for Evaluating the Current Vessel Waste Program b) Submit Report on the Evaluation of the Vessel Waste Program	 a) (Within 3 months)[2] b) 12 months after Regional Board approval of plan
Task 8	TMDL, WLA, and LA Evaluation and Source Monitoring Program (Section 3.a.ii.f) a) Submit Proposed Evaluation and Source Monitoring Program Plan(s) b) Implement Evaluation and Source Monitoring Plan(s) c) Submit Monthly and Annual Reports (Reporting Period: April 1-March 31)	 a) 3 months after completion of Tasks 2, 4a, and 6 b) Upon Regional Board approval of plan(s) c) Monthly within 30 days, Annual Report by September 1
Task 9	Updated TMDL Report Submit updated TMDL report for: a) REC-1 b) SHEL	 a) 6 months after completion of Tasks 2, 4a, 6, and 7 b) 6 months after completion of Tasks 2, 4b, 6, and 7

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Table 5-9g: Fecal Coliform Implementation Plan/Schedule Report Due Dates		
Task	**Description**	**Compliance Date-As Soon As Possible but No Later Than**
Task 10	Adjust TMDL, if necessary; adopt interim WLAs, LAs, and Compliance Dates (Section 3.a.ii.h) a) REC-1 b) SHEL	 a) 12 months after completion of Updated TMDL Report for REC-1 (Task 9.a) b) 12 months after completion of Updated TMDL Report for SHEL (Task 9.b)
[1]Note: Provided that the monitoring program plan(s) fulfills the minimum requirements specified in this TMDL, approval of the TMDL shall constitute Regional Board approval of the monitoring program plan(s).		
[2]Note: Within specified time periods of State TMDL approval (i.e., approval by the Regional Board, the State Water Resources Control Board, and the Office of Administrative Law). Upon State TMDL approval, this parenthetical "formula" will be replaced by the date certain, based upon the date of approval.		

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3.a.i. TMDL Implementation

As soon as possible but no later than the dates specified in Table 5-9g, the County of Orange, the Cities of Tustin, Irvine, Costa Mesa, Santa Ana, Orange, Lake Forest and Newport Beach and agricultural operators in the Newport Bay watershed shall submit the plans and schedules shown in Table 5-9g and described in Section 3.a.ii. Subsequent phases of TMDL implementation shall take into account the results of the monitoring and assessment efforts required by the initial study phase of the TMDL implementation plan and other relevant studies.

The following sections describe the requirements for the submittal of plans by dischargers in the Newport Bay watershed to complete specific monitoring, investigations and analyses. In each and every case, the plans submitted by the named dischargers will be considered for approval by the Regional Board at a duly noticed public hearing as specified in Chapter 1.5, Division 3, Title 23 of the California Code of Regulations (Section 647 et seq.). The plans are to be implemented upon Regional Board approval and completed as specified in Table 5-9g.

3.a.ii. Monitoring and Assessment

Routine monitoring and special investigations and analyses are an important part of this phased TMDL. Routine monitoring is necessary to assess compliance with the bacterial quality objectives in the Bay and with the WLAs and LAs specified in the TMDL. Special investigations and analyses are needed to identify and characterize sources of fecal coliform input and to determine their fate in the Bay so that appropriate control measures can be developed and implemented. The effectiveness of current and future bacterial control measures needs to be evaluated. The results of these studies may warrant future changes to this TMDL.

3.a.ii.a. Routine Monitoring

By (30 days after State TMDL approval)* the County of Orange, the Cities of Tustin, Irvine, Costa Mesa, Santa Ana, Orange, Lake Forest and Newport Beach, and the agricultural operators in the Newport Bay watershed shall propose a plan for routine monitoring to determine compliance with the bacterial quality objectives in the Bay. At a minimum, the proposed plan shall include the collection of five (5) samples/30-

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days at the stations specified in Table 5-9h and shown in Figure 5-1 and analysis of the samples for total and fecal coliform and enterococci. Reports of the collected data shall be submitted monthly. An annual report summarizing the data collected for the year and evaluating compliance with the water quality objectives shall be submitted by September 1 of each year.

In lieu of this coordinated, regional monitoring plan, one or more of the parties identified in the preceding paragraph may submit an individual or group plan to conduct routine monitoring in areas solely within their jurisdiction to determine compliance with the bacterial objectives in the Bay (if appropriate). Any such individual or group plans shall also be submitted by (30 days after State TMDL approval).* Reports of the data collected pursuant to approved individual/group plan(s) shall be submitted monthly and an annual report summarizing the data and evaluating compliance with water quality objectives shall be submitted by September 1 of each year.

The monitoring plan(s) shall be implemented upon Regional Board approval.

Table 5-9h

Newport Bay Sampling Stations for Routine Compliance Monitoring with Bacterial Quality Objectives (see Figure 1 for Station Locations)

Ski Zone	33rd Street	Park Avenue
Vaughns Launch	Rhine Channel	Via Genoa
Northstar Beach	De Anza	Alvarado/Bay Is.
Abalone Avenue	Promontory Pt.	10th Street
Dunes East	Bayshore Beach	15th Street
Dunes Middle	Onyx Avenue	19th Street
Dunes West	Garnet Avenue	Lido Island Yacht Club
Dunes North	Ruby Avenue	Harbor Patrol
43rd Street	Sapphire Avenue	N Street Beach
38th Street	Newport Blvd. Bridge	Rocky Point
San Diego Creek @ Campus Dr.	Santa Ana Delhi Channel	Big Canyon Wash
Backbay Dr. Drain		

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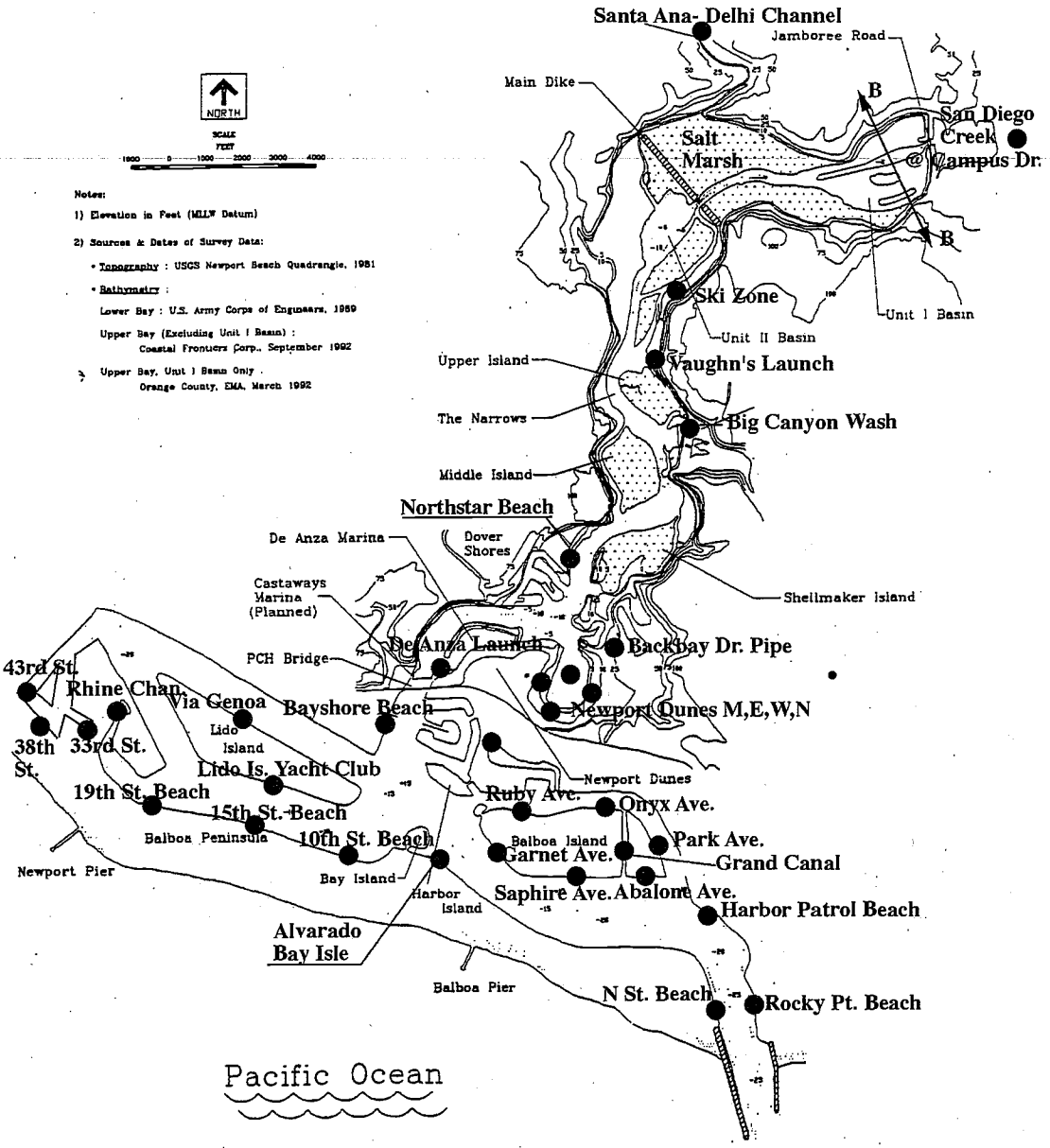

Figure 5-1: Newport Bay Bacterial Quality Monitoring Stations

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3.a.ii.b. Fate of Bacterial Inputs

By (30 days after State TMDL approval),* the County of Orange, the Cities of Tustin, Irvine, Costa Mesa, Santa Ana, Orange, Lake Forest, and Newport Beach and the agricultural operators in the Newport Bay watershed shall submit a plan for the development and submittal of a water quality model to be completed by 13 months after Regional Board approval of the plan. The model shall be capable of analysis of fecal coliform inputs to Newport Bay, the fate of those inputs, and the effect of those inputs on compliance with bacterial quality objectives in the Bay.

3.a.ii.c. Beneficial Use Assessment

By (30 days after State TMDL approval),* the County of Orange , the Cities of Tustin, Irvine, Costa Mesa, Santa Ana, Orange, Lake Forest and Newport Beach shall submit a plan to complete, by 13 months after Regional Board approval of the plan, a beneficial use assessment to identify and quantify water contact recreation activities in Newport Bay. By 13 months after Regional Board approval of the beneficial use assessment plan, these parties shall submit a report of the results of the water contact recreation beneficial use assessment.

By (13 months after State TMDL approval),* the County of Orange , the Cities of Tustin, Irvine, Costa Mesa, Santa Ana, Orange, Lake Forest and Newport Beach shall submit a plan to complete, by 13 months after Regional Board approval of the plan, a beneficial use assessment to identify and quantify shellfish harvesting activities in Newport Bay. By 13 months after Regional Board approval of the beneficial use assessment plan, these parties shall submit a report of the results of the shellfish harvesting beneficial use assessment.

The beneficial use assessment reports shall contain recommendations for prioritizing areas within Newport Bay for purposes of evaluation and implementation of cost-effective and reasonable control actions as part of the TMDL process. The Regional Board will consider these recommendations and make its determinations regarding high priority water contact recreation and shellfish harvesting areas at a duly noticed public hearing. These determinations will be considered in establishing interim WLAs and LAs and compliance dates (Task 10, Table 5-9g).

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3.a.ii.d. Source Identification and Characterization

By (60 days after State TMDL approval),* the County of Orange and the City of Newport Beach shall submit a proposed plan for a program, to be completed within 7 months after Regional Board approval of the plan to identify and characterize fecal coliform inputs to The Dunes Resort. In lieu of this coordinated plan, each of these parties may submit an individual plan to identify and characterize fecal coliform inputs to The Dunes Resort. Any such individual plan shall also be submitted by (60 days after State TMDL approval)* and completed within 7 months after Regional Board approval of the plan(s).

By (60 days after State TMDL approval),* the County of Orange and the Cities of Tustin, Irvine, Costa Mesa, Santa Ana, Orange, Lake Forest, and Newport Beach shall submit a proposed plan for a program, to be completed within 13 months after Regional Board approval of the plan to identify and characterize fecal coliform inputs to Newport Bay from urban runoff, including stormwater. In lieu of this coordinated, regional plan, one or more of these parties may submit an individual or group plan to identify and characterize fecal coliform inputs to the Bay from urban runoff from areas within its jurisdiction. Any such individual or group plan shall also be submitted by (60 days after State TMDL approval)* and completed within 13 months after Regional Board approval of the plan(s).

By (3 months after State TMDL approval),* the agricultural operators in the Newport Bay watershed shall submit a proposed plan for a program, to be completed within 16 months after Regional Board approval of the plan, to identify and characterize fecal coliform inputs to Newport Bay from agricultural runoff, including stormwater. In lieu of this coordinated plan, one or more of the agricultural operators may submit an individual or group plan to identify and characterize fecal coliform inputs to the Bay from agricultural runoff from areas within their jurisdiction. Any such individual or group plan shall also be submitted by (3 months after State TMDL approval)* and completed within 16 months after Regional Board approval of the plan(s).

By (3 months after State TMDL approval),* the County of Orange and the Cities of Tustin, Irvine, Costa Mesa, Santa Ana, Orange, Lake Forest, and Newport Beach shall submit a proposed plan for a program, to be completed within 16 months after Regional Board approval of the plan, to identify and characterize fecal coliform inputs to Newport Bay from natural sources. In lieu of this coordinated, regional plan, one or more of these parties may submit an individual or group plan to identify and characterize fecal coliform inputs to the Bay from natural sources from areas within its jurisdiction. Any such individual or group plan shall also be submitted by (3

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months after State TMDL approval)* and completed within 16 months after Regional Board approval of the plan(s).

3.a.ii.e. Evaluation of Vessel Waste Control Program

By (90 days after State TMDL approval), * the County of Orange and the City of Newport Beach shall submit a plan to complete, by one year after Regional Board approval of the plan, an assessment of the effectiveness of the vessel waste control program implemented by those agencies in Newport Bay. The plan shall be implemented upon approval by the Regional Board. A report of the study results shall be submitted, together with recommendations for changes to the vessel waste program necessary to ensure compliance with this TMDL.

The Regional Board will consider appropriate changes to the vessel waste control program. These changes shall be implemented in accordance with a schedule to be established by the Regional Board.

3.a.ii.f. TMDL, WLA and LA Evaluation and Source Monitoring Program

By (3 months after completion of Tasks 2, 4a, and 6 as shown in Table 5-9g)* the County of Orange, the Cities of Tustin, Irvine, Costa Mesa Santa Ana, Orange, Lake Forest and Newport Beach, and the agricultural operators in the Newport Bay watershed shall propose a plan for evaluation and source monitoring to determine compliance with the WLAs and LAs specified in Table 5-9f. In lieu of this coordinated, regional plan, one or more of these parties may submit an individual or group plan to conduct TMDL, WLA, LA and Source Evaluation monitoring from areas solely within their jurisdiction. Any such individual or group plan shall also be submitted by (3 months after completion of Tasks 2, 4a, and 6 as shown in Table 5-9g).* Reports of the data collected pursuant to approved individual/group plan(s) shall be submitted monthly and an annual report summarizing the data and evaluating compliance with WLAs and LAs shall be submitted by September 1 of each year. The annual report shall also include an evaluation of the effectiveness of control measures implemented to control sources of fecal coliform, and recommendations for any changes to the control measures needed to ensure compliance with the TMDL, WLAs, and LAs.

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The evaluation and source monitoring plan(s) shall be implemented upon Regional Board approval.

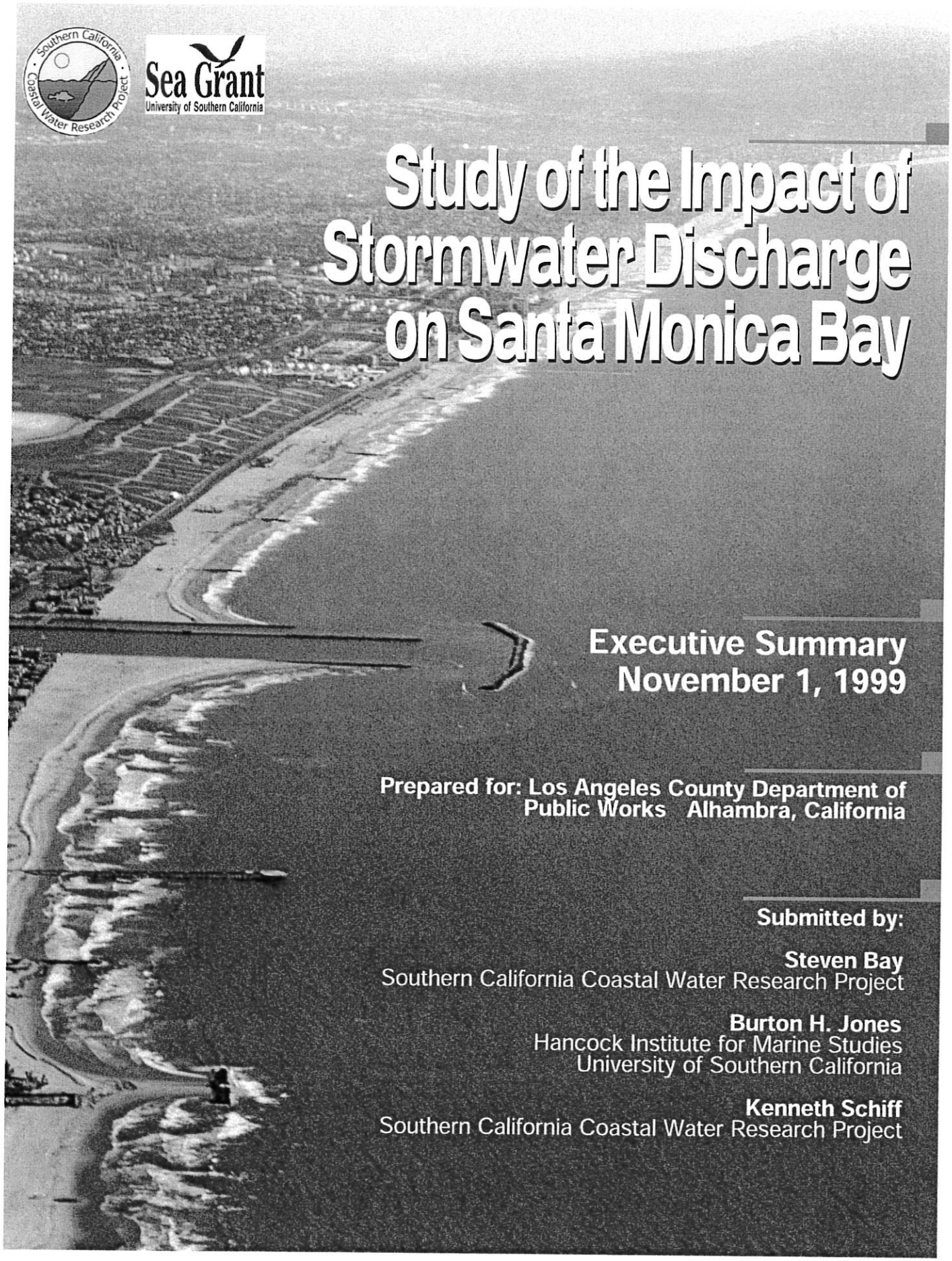
3.a.ii.g. Updated TMDL Report

The County of Orange, the Cities of Tustin, Irvine, Costa Mesa, Santa Ana, Orange, Lake Forest and Newport Beach, and the agricultural operators in the Newport Bay watershed shall submit Updated TMDL Reports as specified in Table 5-9g. These updated TMDL reports shall, at a minimum, integrate and evaluate the results of the studies required in Table 5-9g (Task 1 – 7). The reports shall include recommendations for revisions to the TMDL, if appropriate and for interim WLAs, LAs and compliance schedules

3.a.ii.h. Adjust TMDL; Adopt Interim WLA, LAs and Compliance Dates

Based on the results of the studies required by Table 5-9g and recommendations made in the Updated TMDL Reports, changes to the TMDL for fecal coliform may be warranted. Such changes would be considered through the Basin Plan Amendment process. Upon completion and consideration of the studies and any appropriate Basin Plan amendments, interim WLAs and LAs that lead to ultimate compliance with the TMDL specified in Table 5-9f, or with an approved amended TMDL, will be established with interim compliance dates. Schedules will also be established for submittal of implementation plans for control measures to achieve compliance with these WLAs, LAs, and compliance dates. These implementation plans will be considered by the Regional Board at a duly noticed public hearing.

The Regional Board is committed to the review of this TMDL every three years or more frequently if warranted by these or other studies. The County of Orange, the Cities of Tustin, Irvine, Costa Mesa, Santa Ana, Lake Forest, and Newport Beach, The Irvine Company and the Irvine Ranch Water District have undertaken to prepare a health risk assessment for Newport Bay for water contact recreation and shellfish harvesting beneficial uses. This study will evaluate whether exceedances of fecal coliform objectives correlates with actual impairment of beneficial uses and may recommend revisions to the Basin Plan objectives and/or beneficial use designations. Because this study is in progress, it is not required by this TMDL implementation plan, but will be considered in conjunction with the studies required by the implementation plan.



Study of the Impact of Stormwater Discharge on Santa Monica Bay

Executive Summary
November 1, 1999

Prepared for: Los Angeles County Department of Public Works Alhambra, California

Submitted by:

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The conclusions presented in this document are the views of the authors and do not necessarily represent positions of the Los Angeles County Department of Public Works, the Natural Resources Defense Council, or other collaborating agencies.

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Bob Van Wagenen, Ecoscan Resource Data, Watsonville, CA

INTRODUCTION

Urban stormwater runoff is now regarded as one of the largest sources of pollution to the coastal waters of the United States. In Southern California, point source control and advanced sewage treatment have greatly reduced the emissions of contaminants from sewage treatment plant and industrial discharges into the ocean. As a consequence, mass emissions from stormwater runoff now constitute a much larger portion of the constituent inputs to receiving waters and may represent the dominant source of some contaminants such as lead and zinc.

Stormwater runoff is widely believed to be one of the largest sources of contaminants to coastal waters.

While stormwater runoff can produce impacts in both freshwater and seawater environments, effects on the ocean are of greatest concern in urban Southern California. Our coastal waters provide many beneficial uses, including recreation, aesthetic enjoyment, fishing, marine habitat, fish reproduction, industrial water supply, and navigation. Ocean-dependent activities contribute approximately $9 billion annually to the economies of coastal communities in Southern California.

Substantial resources are spent monitoring the chemical constituents in stormwater runoff, yet little is known about the effects of these inputs once they enter the ocean. Of greatest concern to the public are whether impairments are occurring to the beneficial uses that relate to human health (safety of swimming and seafood consumption) or ecosystem health (presence of a natural balance of species). Stormwater discharge has the potential to impair these beneficial uses through: 1) contamination of recreational waters or seafood with disease-causing microbes, 2) aesthetic degradation from trash and reduced water clarity, and 3) ecosystem degradation from contaminants or other stormwater constituents.

Current water quality monitoring programs do not assess the effects of stormwater runoff on the environment.

Understanding the effects of stormwater on beneficial uses is essential. Information about the extent and type of adverse impacts is useful to guide and refine management actions to improve water quality. The monitoring programs of various agencies collect information that is useful for assessing some beneficial use impairments, primarily those related to human health. For example, public health and sanitation agencies regularly conduct shoreline microbiological monitoring near storm drain discharges, which indicates impacts to swimming and shellfish consumption. However, very little information is available to assess the impacts of urban stormwater on ecosystem health. Studies of impacts to freshwater systems (particularly in the west) are rare; impacts to the coastal ocean have never been assessed.

This report summarizes a three-year study funded by the Los Angeles County Department of Public Works, Southern California Coastal Water Research Project (SCCWRP), and University of Southern California (USC) Sea Grant Program.

This study is one of the first to assess stormwater impacts on the marine ecosystem.

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This study examined plume characteristics, water column and seafloor biology.

The purpose of the study was to assess the impacts of urban stormwater runoff to the receiving waters of Santa Monica Bay. The goal of this study was to examine impacts that were relevant to ecosystem health, rather than impacts related to human health or recreation issues. This effort was conducted by an interdisciplinary team of scientists from SCCWRP, the University of Southern California, and the University of California at Santa Barbara.

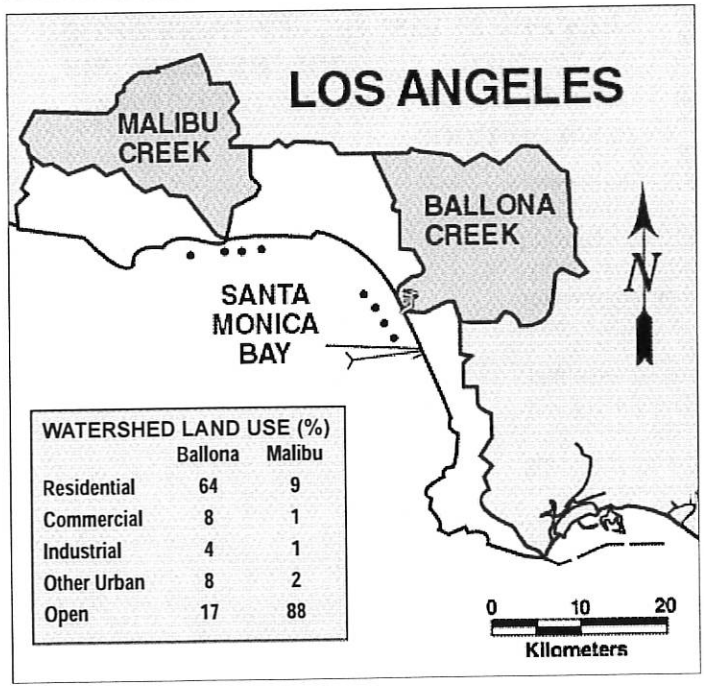
The Santa Monica Bay Receiving Waters Study incorporated four design elements. The first element used physical and optical oceanographic instruments to characterize the size, composition, and mixing of stormwater plumes, providing information on the impacts to beneficial uses that are associated with water clarity. The second element used toxicity tests to assess the biological effects of runoff on water column biota and to identify the responsible toxicants. The third element examined seafloor biota and chemistry in order to assess the long-term effects of storm-discharged particles with their associated contaminants.

Comparisons between Ballona and Malibu Creeks evaluated effects of different watershed types.

The fourth element of the study design was a comparison of stormwater impacts from different watershed types. Land use patterns and development within a watershed are thought to influence the composition and quantity of stormwater runoff. The influence of watershed type was investigated by comparing stormwater impacts in the receiving water offshore of the highly urbanized Ballona Creek watershed with impacts in the receiving water offshore of the less-urbanized Malibu Creek watershed (Figure 1).

Sampling and analysis were conducted over three wet seasons (1995/96 to 1997/98). This document provides a summary of the study and focuses on major concepts and important findings. For the detailed results and raw data, we encourage readers to consult the Annual Progress Reports, available through USC Sea Grant.

FIGURE 1



Locations of Ballona Creek and Malibu Creek sub-watersheds and the offshore sampling stations for sediment measurement. Other portions of the Santa Monica Bay watershed are shown in white.

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STORMWATER PLUME CHARACTERIZATION

The impact of stormwater on the coastal ocean is determined by the composition of the stormwater and the dynamics (mixing, transport, and persistence) of the stormwater plume once it enters the coastal ocean. These dynamics influence the location, duration, and magnitude of impacts from stormwater.

The research team mapped the three-dimensional distribution of the stormwater plumes resulting from several winter storm events during 1996-1998. Mapping was performed using a towyo system, which carried sensors to measure temperature, salinity, light transmission (turbidity), chlorophyll fluorescence (plant biomass), and ambient visible light. The towyo was towed through the water in a vertical zigzag pattern that enabled us to map the horizontal and vertical distributions of the measured parameters. In addition, surface water was pumped to similar sensors on the boat so that the distribution of these parameters at the water's surface could be mapped. Maps were constructed for two regions of Santa Monica Bay, the receiving waters offshore of Ballona Creek and those offshore of Malibu Creek.

The low salinity and high turbidity of stormwater provide markers that allow plumes to be mapped in the ocean.

The characteristics of stormwater discharged into Santa Monica Bay from the two watersheds were similar in several respects. The most obvious and important physical characteristic was that the stormwater, being primarily composed of freshwater, had very little salinity. This low salinity enabled us to trace the stormwater plume in the ocean and differentiate it from the ambient seawater, which was not directly influenced by stormwater discharge. The stormwater also contained high concentrations of suspended particulate material, derived from various sources such as land erosion, street dust, aerial deposition, and litter. Suspended particulate material increased the turbidity of water by scattering and absorbing light. The turbidity and salinity together allowed the differentiation of seawater influenced by stormwater discharge from seawater containing freshwater from direct rainfall input.

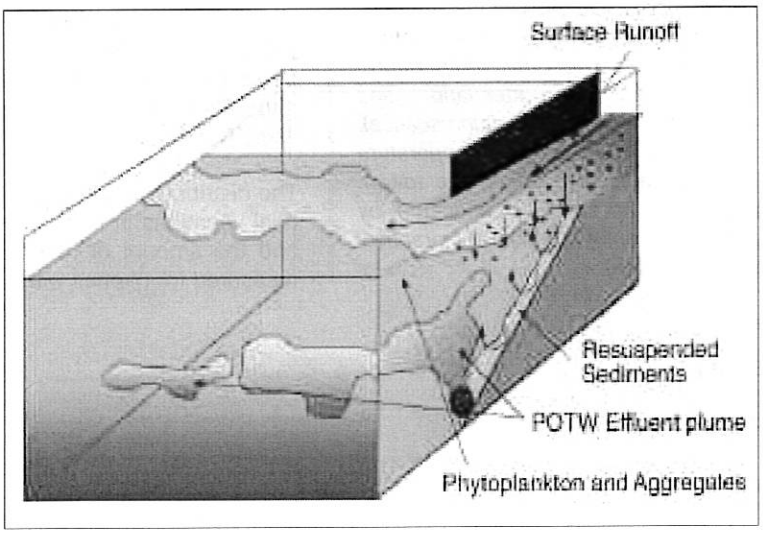

FIGURE 2

Schematic of coastal ocean with several sources of suspended particulate matter. Sources include surface runoff, Publicly Owned Treatment Works (POTW) discharge, bottom resuspension, and naturally occurring phytoplankton and detiritus.

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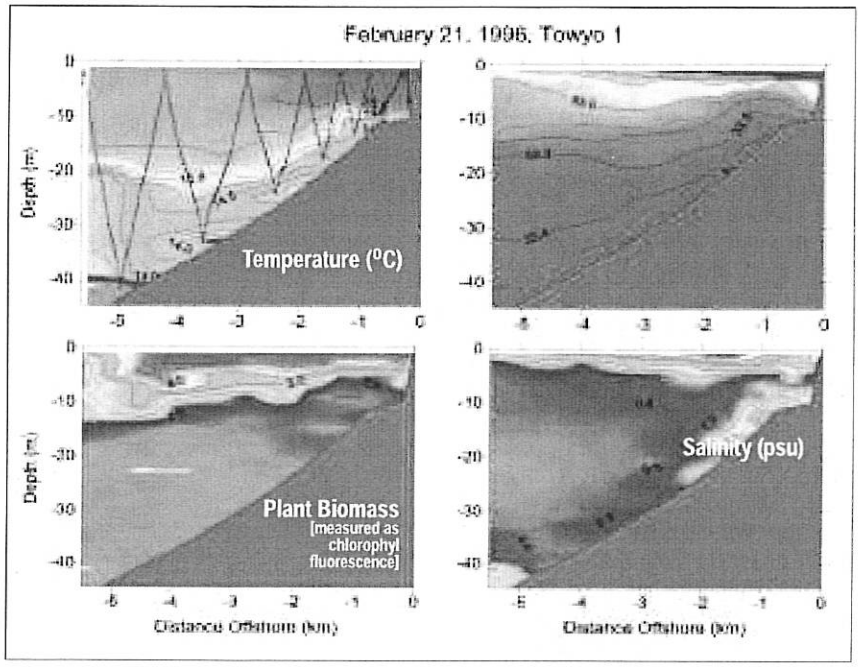
The stormwater plume was most concentrated in the surface layer.

Understanding the dispersion and fate of stormwater plumes is a complex task. The distribution of dissolved components such as nutrients and small particles is dependent upon the amount of rainfall, the coastal currents, and the winds, which can drive currents and cause vertical mixing (Figure 2). Large stormwater particles often have a different fate; they settle out of the low salinity plume, become incorporated into bottom sediments, and may be redistributed later by wave resuspension and transport. As the plume disperses, the components of stormwater mix with other sources of suspended particles, nutrients, and freshwater in the receiving water. These sources include bottom resuspension, phytoplankton growth, and wastewater discharge.

FIGURE 3



Vertical cross-shelf sections of the Ballona Creek discharge plume following a storm event in February, 1996. The maps shown were generated using a towyo system, which carried sensors for temperature, salinity, turbidity (beam attenuation), and plant biomass (chlorophyll fluorescence). The zigzag pattern on the temperature section indicates the path of the towyo. The stormwater plume is indicated by water with a salinity less than 33.0 practical salinity units (psu).

Stormwater plumes usually formed relatively thin layers at the surface of the ocean that are 2-10 m deep (Figure 3). The depth of penetration increased with time as winds mixed the upper layer vertically. The horizontal scales of the plumes studied in Santa Monica Bay were variable, with plumes extending from 1 to 6 miles cross-shelf (offshore) for storms of 1- to 2-year frequencies (0.8 to 4 in. of rainfall). During the February 19-21, 1996 storm (4 in. of rainfall), the plume spread approximately 4 miles offshore of Ballona Creek (Figure 4).

The speed and direction of coastal currents determine the cross-shelf scale of the plume. The Coriolis force (an apparent force that acts on oceans and lakes) also has an influence on the distribution of stormwater plumes. This force is due to the rotation of the earth and its motion through space, resulting in a tendency for currents to turn toward the right in the Northern Hemisphere. If the plume is carried to the north when it enters the ocean, it will be more likely to remain near the coast due to the influence of the Coriolis force.

The distribution of stormwater plumes along the coast depended upon the tidal variations in the currents, the presence of additional runoff sources, and the amount of runoff. Longshore distances of up to 6 miles were measured for plumes within Santa Monica Bay.

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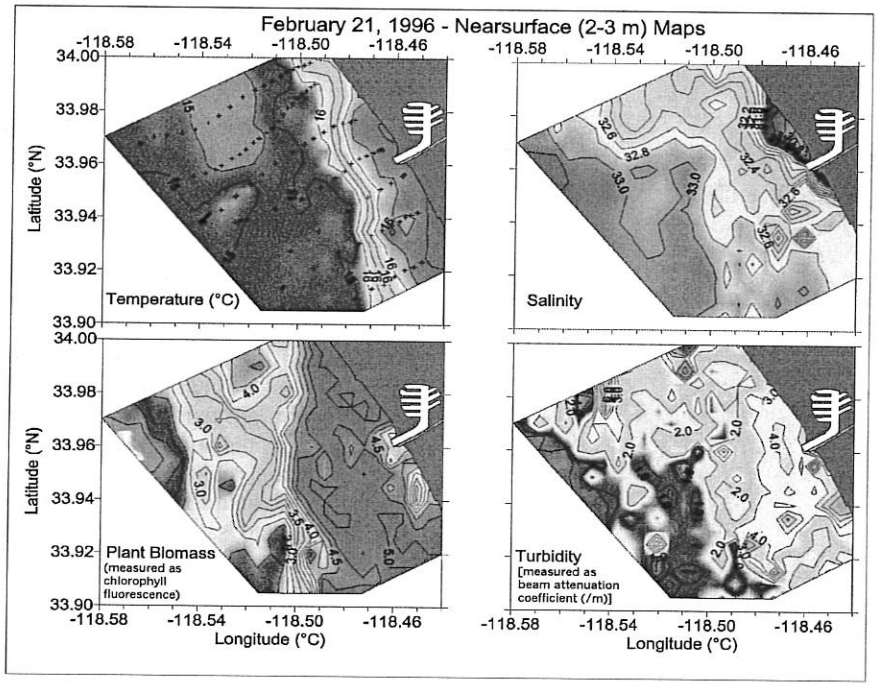
Spatial gradients in the dissolved and particulate components of the plume occurred as it was diluted through mixing with the receiving water. Although larger stormwater particles tended to settle out from the plume rapidly, smaller, lighter particles remained in suspension near the surface (Figures 3 and 4), where they can reduce the amount of light available for photosynthesis by marine plants. Measures of primary production were not part of this study, so adverse effects on phytoplankton in Santa Monica Bay resulting from turbid stormwater plumes were not determined.

Stormwater plumes reduced surface water clarity and persisted for several days after a storm.

The duration of stormwater plumes depends upon the rate of plume dispersion and particle sinking. Stormwater plumes were observed to persist in Santa Monica Bay for at least three days, even for the smallest storm sampled (0.8 in. rainfall). The maximum duration of stormwater plumes could not be assessed in this study because measurements did not extend more than three days after a storm.

FIGURE 4

High concentrations of the plant pigment chlorophyll were present in the surface layer during some storm events, indicating the presence of increased phytoplankton populations. Phytoplankton growth may have been stimulated by stormwater discharge due to the addition of nutrients to the surface layer, where light is readily available. Dense patches of phytoplankton were observed off of Malibu Creek on the boundary of stormwater plumes 1-2 days after rain events. Off of Ballona Creek, we observed increased phytoplankton in the plume even while a large proportion of suspended particulate material was still present in the surface water. The ecological effects of these changes in phytoplankton density were not determined in this study.



Near surface map of the February, 1996 stormwater plume from a 2-year storm off of Ballona Creek. The plume (surface water with a salinity less than 33.0 psu) extended approximately 4 miles offshore.

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WATER COLUMN BIOLOGY

The initial and most concentrated exposure to stormwater occurs in the upper few meters of the water column. A diversity of organisms occupies this habitat, ranging from mobile fish and mammals to drifting microscopic plants and animals (plankton). Plankton have a relatively high potential to be affected by stormwater toxicants because they have a limited ability to avoid the plume and are often more sensitive to contaminants than larger animals. Changes in the abundance and type of plankton present can have important consequences for the marine ecosystem. This group of organisms constitutes the base of the food chain for most marine life, so changes in plankton numbers may affect populations of other species. The larvae of many fish and other animals such as sea urchins, clams, and shrimp occur in the plankton, providing the potential for diminished reproductive success if their survival is reduced by water column toxicity.

Water column effects were measured using toxicity tests.

Toxicity tests were used to determine whether stormwater plumes contained harmful concentrations of dissolved constituents. Surface water samples were collected offshore of the two study sites in conjunction with measurements of the plume characteristics so that the data could be related to the concentration of the stormwater discharge plume. Samples of stormwater collected from Ballona Creek were also measured for comparison. The toxicity tests used sensitive stages of marine species that occur in Southern California. Most samples were measured using the sea urchin fertilization test, in which the effect of the sample on the ability of sea urchin sperm to fertilize eggs is measured. Sea urchin sperm are highly sensitive to some types of dissolved metals. The fertilization test is appropriate for stormwater monitoring because it is rapid (40 min exposure) and uses an organism which spends a portion of its life cycle in the water column of Santa Monica Bay. All tests were adjusted to the appropriate salinity prior to exposure so only the effect of chemical constituents were evaluated.

Virtually every sample of Ballona Creek stormwater tested was toxic.

Undiluted samples of urban stormwater collected from drainage channels (before discharge into the ocean) usually contained toxic concentrations of constituents. Toxicity was detected in virtually every sample obtained from Ballona Creek and this toxicity was often present even after the sample was diluted 10-fold in the laboratory. The results indicated that even though a large portion of the constituents present in stormwater may be bound to particles, the dissolved concentrations of some materials are high enough to cause toxicity. Prior research by SCCWRP and others has detected toxicity in stormwater from other watersheds in Los Angeles, Orange, and San Diego Counties.

The first storms of the year produced the most toxic stormwater.

The results showed that time of year was an important variable influencing stormwater toxicity (Figure 5). Samples of Ballona Creek stormwater, obtained from the first storm of the season, were between two and ten times more toxic than samples from later storms. These

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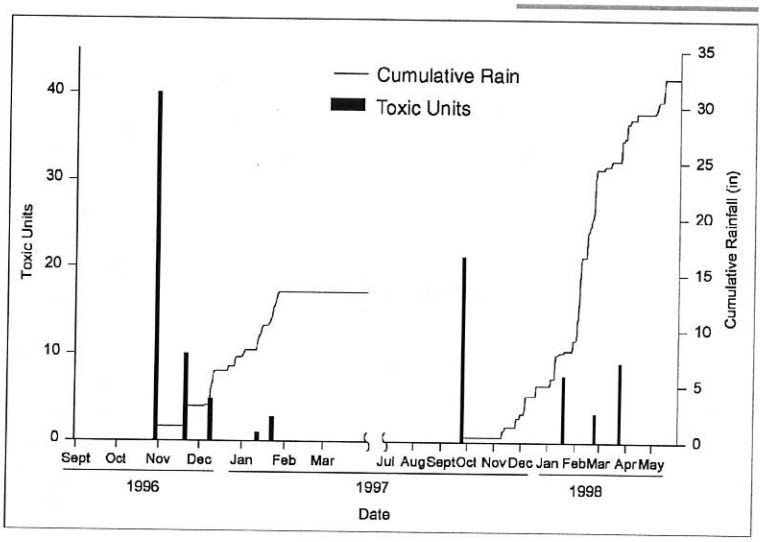
FIGURE 5



Seasonal changes in the toxicity of Ballona Creek stormwater over two storm seasons. Toxicity was measured using the sea urchin fertilization test. The greatest toxicity was observed in stormwater obtained from the first storm of each year.

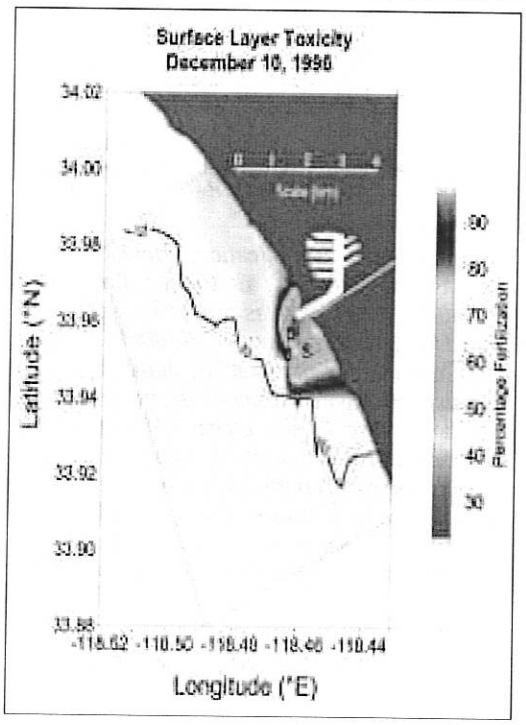
data indicated that the first storms of the year provide the most concentrated inputs of toxicants to the environment.

Toxicity was frequently detected in surface water within the stormwater plume offshore of Ballona Creek, indicating that the initial dilution of stormwater discharge from this watershed was not sufficient to reduce the concentrations of stormwater toxicants below levels that are harmful to marine organisms. The magnitude of toxicity was greatest in the portion of the plume nearest the mouth of Ballona Creek (Figure 6), where the highest concentrations of stormwater were present. Within the plumes studied, toxicity was usually present whenever stormwater concentrations above 10% were present. The duration of toxicity in surface waters was not specifically addressed in this study, but can be expected to be determined by the rate of plume dispersion. In this study, toxicity was detected in surface water near the mouth of Ballona Creek two days after a storm event.

Toxic portions of the stormwater plume were variable in size, extending from 1/4 to 2 miles offshore of Ballona Creek.

The spatial extent of surface water toxicity varied between storms, and was influenced by the amount of storm flow, the degree of toxicity of the stormwater, and the amount of mixing that occurred upon discharge. The greatest offshore extent of toxicity was measured following a storm on February 21, 1996, a two-year event, when toxicity was detected 2 miles offshore of Ballona Creek. For other storms, the toxic portion of the plume extended ¼-1 mile offshore. The distribution of toxicity along the shoreline was not determined in this study. The boundaries of stormwater plumes can be described using a number of parameters (i.e., salinity, turbidity, and toxicity) each with different thresholds of detection. Because a relatively high concentration of stormwater is

FIGURE 6



Map of surface layer toxicity (effect on sea urchin fertilization) from Ballona Creek stormwater discharge following a 2-year storm in December, 1996 (3.1 in. rainfall). Expected toxicity was calculated from measurements of salinity (indicates concentration of stormwater) and the concentration dose-response curve for the effects of stormwater on sea urchin fertilization. The greatest toxicity (lower fertilization percentage) was present closest to the point of discharge. The area of toxicity was smaller than the physical extent of the plume, as indicated by the solid line showing a salinity of 33 psu. This figure illustrates the relative size of the toxic portion of the plume for a single storm, but does not represent the largest plume offshore for other storms.

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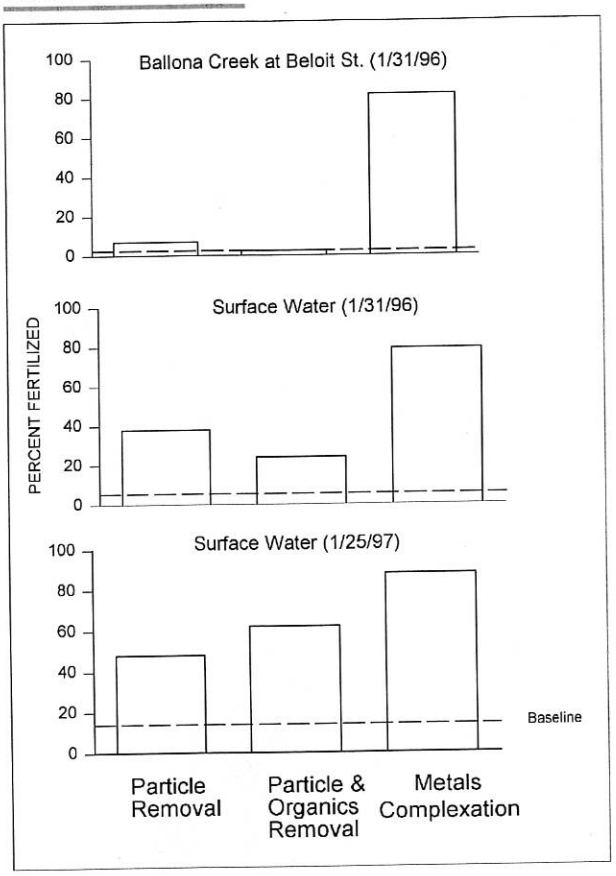
Surface water toxicity caused by unidentified sources was frequently encountered during dry weather.

FIGURE 7



Effect of toxicity identification evaluation treatments on the toxicity of Ballona Creek stormwater and two samples of surface water collected within the Ballona Creek discharge plume. Complexation of metals by addition of EDTA usually eliminated toxicity, as shown by the large increase in sea urchin fertilization above the untreated (baseline) value. Other treatments, removal of particles by filtration and removal of organic compounds, were of limited effectiveness. Similar results were found for other samples of stormwater and surface water.

needed to produce toxicity, the area of potential biological impact within a plume will be smaller than the region defined by physical characteristics such as salinity (Figure 6).

An unexpected result of this study was the detection of toxicity in receiving waters that appeared to be due to sources other than urban runoff. An average of 53% of the surface water samples collected offshore of Ballona and Malibu Creeks during periods of dry weather were found to be toxic. The location of the toxic samples was variable and there was no relationship between toxicity and the amount of freshwater in the samples, indicating that dry weather urban runoff was not the cause. Additional sources of receiving water toxicity were also indicated during the wet weather sampling, as some water samples were more toxic than could be accounted for by the amount of stormwater present.

The dry weather toxicity results suggest that factors other than stormwater discharge have a major influence on surface water quality in Santa Monica Bay. While the cause of dry weather toxicity was not determined, its frequent detection indicates that impaired surface water quality in Santa Monica Bay extends beyond the spatial and seasonal boundaries associated with stormwater discharge. Potential sources of dry weather toxicity include the deposition of contaminants from the atmosphere, biological events such as red tides, and inputs from boating activities.

Dissolved metals in stormwater were identified as important contributors to impaired water quality in Ballona Creek stormwater plumes. This conclusion was the result of experiments that combined chemical treatments designed to remove specific types of constituents in water samples with sea urchin toxicity tests, a process known as Toxicity Identification Evaluation (TIE). The toxicity of Ballona Creek stormwater and receiving water samples was usually eliminated when treatments were applied that neutralized toxic trace metals by complexation (Figure 7). Chemical analysis confirmed that dissolved concentrations of zinc, and occasionally copper, were at toxic levels in undiluted stormwater. The dissolved concentrations of other metals were below toxic levels for the sea urchin test. Measurements of receiving water also detected elevated concentrations of zinc (but not copper) in the stormwater plume offshore of Ballona Creek.

Chemical analysis were unable to attribute all of the toxicity measured to zinc and copper, indicating that additional constituents may contribute to the toxicity of stormwater discharged into Santa Monica Bay. The measured concentrations of zinc and copper in Ballona Creek stormwater were estimated to account for only 5-44% of the observed toxicity. Zinc concentrations in the toxic portion of the discharge plume were usually below levels shown to cause toxicity in the laboratory. The unaccounted-for toxicity may be due to synergistic interactions between toxic metals, variability in the

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chemical analysis, or the influence of other toxic chemicals, such as pesticides. Additional research is needed before these alternatives can be evaluated. TIE studies have not been completed for other stormwater discharges into the Bay, so we do not know if the pattern demonstrated for Ballona Creek is representative of other sites.

Zinc was the most important toxic constituent identified in stormwater. Copper and other unidentified constituents may also be responsible for some of the toxicity measured.

SEAFLOOR BIOLOGY

Much of the natural diversity and many of the commercially important species in the ocean occur on the seafloor. Clams and shrimp live in this environment, as well as worms and starfish, all of which serve as food for fish. This is also the location where stormwater particles, and associated contaminants, eventually settle. Unlike the water column, where a stormwater plume eventually mixes and disperses, the sediments on the seafloor can accumulate runoff inputs over an entire storm, over several storms, or over several seasons. These inputs can alter the seafloor biology by either changing the habitat, such as altering sediment grain size, or by the build-up of pollutants. The potential for impacts to seafloor organisms is great because they are not mobile and are therefore subjected to the accumulated stormwater inputs for long periods of time. Typically, these seafloor organisms are relatively sensitive and changes to the number or types of organisms may result in changes to fish populations.

The deposition of stormwater particles influences the physical and chemical characteristics of the seafloor.

We estimated impacts of stormwater runoff discharges on the seafloor by collecting samples from the ocean bottom between one and two weeks following large storm events, after the stormwater plumes had dispersed and particles had time to settle, and then again during dry weather. Seafloor samples were collected directly offshore of Ballona and Malibu Creeks at 75 ft. depth in the heart of the stormwater plumes, along intervals upcoast and downcoast representing gradients of plume impact, and then outside the area of the plume. The top 2 cm (< 1 inch) of these seafloor samples, which represented the most recent seafloor accumulations, were collected for contaminant analysis and toxicity testing. Sediment samples were analyzed for contaminants including trace metals, chlorinated hydrocarbons (DDTs and PCBs), and petroleum hydrocarbons (PAHs). The toxicity tests included survival of crustaceans (an amphipod) and sea urchins, fertilization success and development of sea urchin embryos, and bioaccumulation of contaminants from seafloor mud in adult sea urchins. A second sediment sample was collected, sieved through a fine mesh screen, and the organisms were enumerated to determine the abundance and diversity of the native seafloor fauna.

An increase in sediment constituents was present on the seafloor offshore Ballona Creek.

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TABLE 1

		Sediment Concentration	
		Ballona Ck (n=8)	Malibu Ck (n=7)
Fines	% dry	31.6	**53.1**
TOC	% dry	0.594	**0.963**
Aluminum	µg/dry g	11492	**17280**
Arsenic	µg /dry g	5.1	5.6
Cadmium	µg /dry g	0.5	0.7
Chromium	µg /dry g	40.7	**52.6**
Copper	µg /dry g	12	13
Iron	µg /dry g	14997	**21720**
Lead	µg /dry g	**26.4**	10.3
Mercury	µg /dry g	**0.18**	0.08
Nickel	µg /dry g	14.29	**27.76**
Silver	µg /dry g	**0.95**	0.31
Zinc	µg /dry g	54	56
Total DDTs	ng/dry g	**25.6**	15.5
Total PCBs	ng/dry g	**21.5**	3.0
Total PAHs	ng/dry g	**240.6**	56.2

Average concentrations of sediment constituents offshore (75 ft. depth) of creek mouths in Santa Monica Bay following storm events between 1995 and 1997. Boxed numbers indicate significantly higher concentrations. Sediment offshore of the less urbanized watershed (Malibu Creek) had higher levels of naturally occurring constituents such as aluminum and iron. Higher concentrations of anthropogenic constituents such as lead and PAHs were present offshore of the more urbanized watershed (Ballona Creek).

Alterations to the seafloor habitat and sediment constituent concentrations had occurred offshore of the Ballona Creek watershed (Table 1). The sediments offshore of Malibu Creek generally had higher concentrations of naturally abundant constituents including fine-grained particles, organic carbon, and trace metals such as chromium. In contrast, the sediments offshore of Ballona Creek generally had higher concentrations of urban contaminants including common stormwater constituents such as lead and zinc, as well as other rarely detected constituents in routine stormwater monitoring programs, such as DDTs, PCBs, and PAHs. Moreover, sediments offshore of Ballona Creek showed evidence of stormwater impacts over a large area. Concentrations of copper, lead, zinc, DDTs, PCBs, and PAHs were highest directly offshore of the creek mouth and then decreased in both the upcoast and downcoast directions at distances up to 3 miles away (Figure 8). The increased sediment contamination was also observed more than 1 mile offshore, where water depths reached over 100 feet.

Biological communities offshore of Ballona Creek were similar to those offshore of Malibu Creek (Table 2). Both areas had comparable abundance and similar species composition. Seventeen of the 19 most commonly found taxa offshore of Ballona Creek were present offshore of Malibu Creek, and both watersheds had a low abundance of so-called "pollution indicator" organisms. Both areas had healthy benthic communities, as measured by the Benthic Response Index, which is a tool for assessing the relative importance of pollution indicator species at a site. Species richness and diversity were statistically higher near Malibu Creek than Ballona Creek.

Biological communities offshore of Ballona and Malibu Creeks were also similar to background reference conditions established in previous studies of Southern California (Table 2). The mean abundance, mean number of taxa per sample, and mean diversity at the creek sites were comparable to reference sites located in waters of similar depth, but distant from river and creek mouths. The present study was limited to the area offshore of the Ballona Creek jetty; previous studies by other scientists have shown impacts to benthic communities and the presence of pollution indicator organisms inside of the jetty (adjacent to Marina del Rey).

The seafloor biology results were consistent with the results from sediment toxicity tests. Seafloor sediments offshore of Ballona Creek did not kill amphipods or impair the fertilization success or normal embryo development of sea urchins. However, seafloor sediments were found to be a potential source of contaminants that bioaccumulate in seafloor organisms such as adult sea urchins. Concentrations of lead, DDTs, and PCBs were three to ten times higher in sea urchins exposed to sediments collected offshore of Ballona Creek than in sea urchins living on sediments from our reference location. While the effect of this bioaccumulation on the sea urchin is not known, it does represent a mechanism by which sediment- associated pollutants can enter the food chain and biomagnify within fish.

The fate of most stormwater constituents is unknown.

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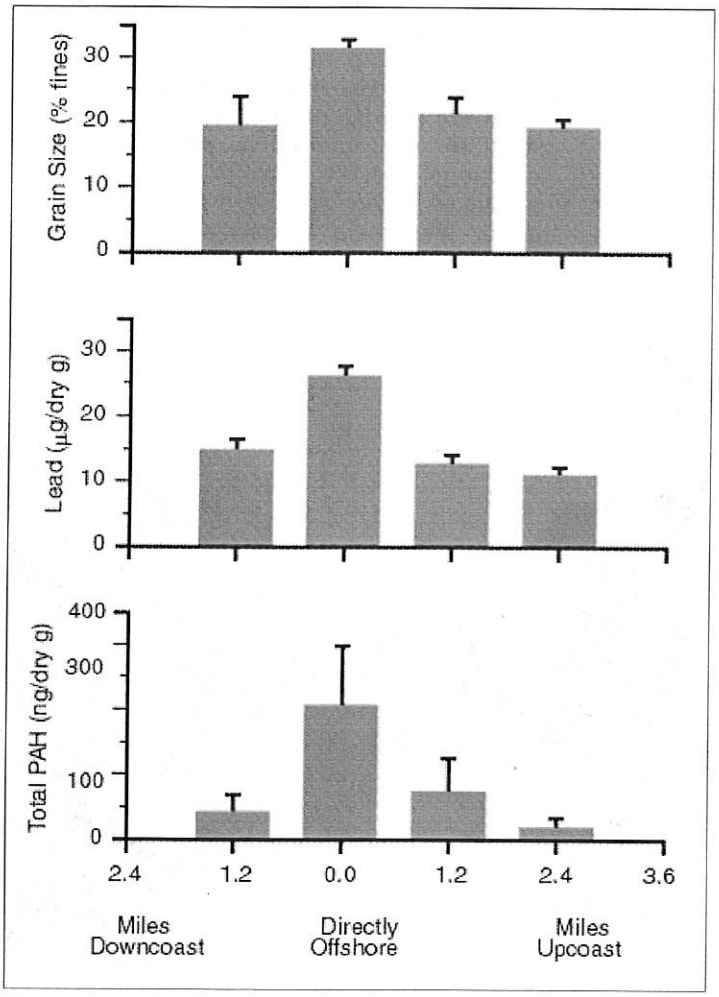
One significant finding of this study was that the fate of most stormwater constituents discharged to Santa Monica Bay is unknown. Although we documented the accumulation of contaminants on the seafloor offshore of Ballona Creek, these amounts were not permanent and represent only a fraction of the total mass emissions discharged. Further, reductions in constituent concentrations were observed at some locations that may have resulted from the resuspension and transport of sediments by waves and currents. Until the location where this material eventually settles is known, we cannot be certain that we have examined the seafloor areas having the greatest influence from stormwater or dry weather discharges. An additional concern is that constituents from other sources may have similar transport and fate mechanisms, producing enhanced impacts from the cumulative effects of multiple sources.

TABLE 2

	Ballona (n=8)	Malibu (n=7)	Reference (n=29)
Abundance (No. organisms/ 0.1 m²)	238 (±51)	316 (±55)	276 (±61)
No. Species (No. taxa/ 0.1 m²)	75 (±6)	91 (±8)	71 (±9)
Diversity (Shannon-Wiener H')	1.65 (±0.02)	1.73 (±0.04)	1.55 (±0.15)
Benthic Response Index (BRI units)	24.0 (±1.7)	1.65 (±0.7)	3.0 – 30.6

Biological community parameters offshore of a highly urbanized watershed (Ballona Creek), a less urbanized watershed (Malibu Creek), and other reference areas in near-coastal waters of Southern California at similar depths (30 to 75 feet). Values are the mean (±95% confidence limits).

FIGURE 8



Grain size and contaminant concentrations in surface sediments across the gradient of stormwater influence offshore of Ballona Creek. Sampling stations were located 1.5 miles offshore (75 ft. depth) and at various distances upcoast or downcoast of the creek. Each value represents the mean (±95% confidence interval) of eight samples, each collected after a storm event. The influence of stormwater particle deposition is shown by the elevated values directly offshore of Ballona Creek.

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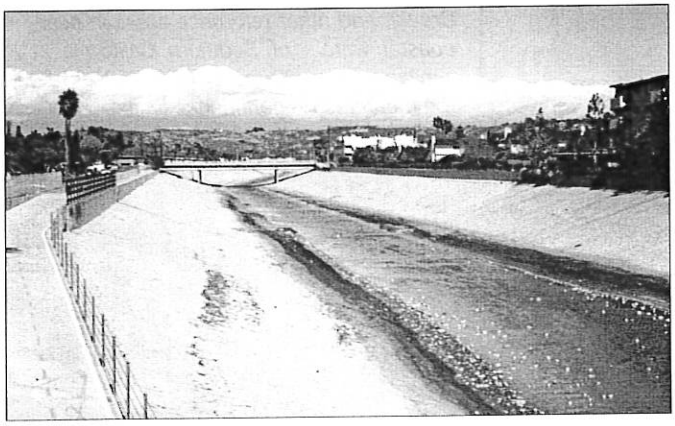
EFFECTS OF WATERSHED TYPE

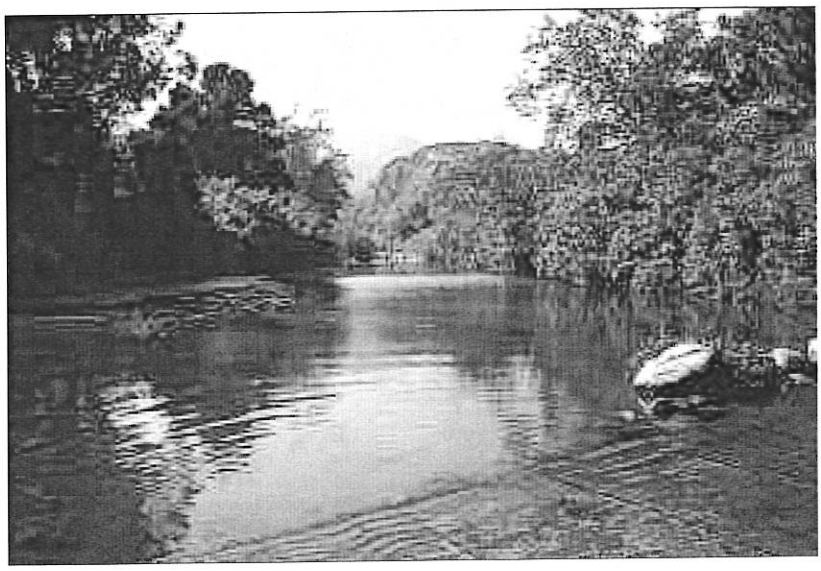
The comparison of receiving water impacts from different watersheds is a powerful tool to distinguish between natural and man-made effects. Although the Ballona Creek and Malibu Creek watersheds are similar in size and discharge into the same body of water (Santa Monica Bay), they differ in their degree of urbanization (Figure 1). The measurement of similar parameters in each receiving water area provides the information needed to distinguish between natural processes and impairment due to man-made factors. This approach also identifies which monitoring methods are most useful for detecting man-made impacts.

Different impacts to Santa Monica Bay were produced by an urbanized and an unurbanized watershed.

The characteristics and impacts of stormwater from the Ballona Creek and Malibu Creek watersheds were found to differ in a number of respects (Table 3). The impacts observed were the result of the interaction of three key factors: land use, flow characteristics, and receiving water conditions. Receiving water impacts were less near Malibu Creek and were related to the discharge of less toxic stormwater and lower peak flows.



Ballona Creek watershed is highly urbanized. Stormwater entering the concrete channel is rapidly transported to the ocean, with little opportunity for dilution.



Malibu Creek drains a mostly undeveloped watershed. Stormwater flow and particle inputs into the ocean are moderated by the presence of a natural creekbed and coastal lagoon.

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TABLE 3

	Ballona Creek	Malibu Creek
Watershed Characteristics	The largest watershed draining to Santa Monica Bay, 83% of its 130 square miles is developed. The principal land use is residential.	Similar in size to Ballona Creek (110 square miles), 88% of this watershed is undeveloped.
Flow Characteristics	The largely impermeable surface area (41% overall) and concrete channel drainage system results in rapid changes in flow following rainfall. Peak flows are relatively high and of shorter duration compared to other areas.	More permeable surface area (96% overall) absorbs early season rainfall and increases lag time between rainfall and peak flow. Discharges have relatively lower peak flows but duration can be days longer than concrete channelized systems. Discharge into Malibu Lagoon may reduce flows and particle loads to ocean.
Plume Characteristics	The stormwater plume in both areas consisted of a thin buoyant layer of low salinity water floating at the surface. The dissolved and particulate components of stormwater were most concentrated in the upper 2 m of the water column. Plumes extended up to 6 miles offshore and were widely distributed along the shore.	
	Higher flows and less mixing produced well-defined plumes that contained higher concentrations of stormwater near Ballona Creek.	Lower flows, more mixing, and discharges from adjacent canyons resulted in more complex and ill-defined plume boundaries near Malibu Creek.
Debris	Floating debris was often concentrated near the margins of the plume and contained many items of man-made origin, such as plastic.	Floating debris was dominated by organic materials of natural origin, such as twigs and charred wood.
Water Clarity	Less mixing of stormwater usually produced larger areas of reduced water clarity.	Stormwater inputs were often more turbid, but lower flows and greater dilution near the mouth resulted in better clarity.
Stormwater Toxicity	Samples from the creek were always toxic to sea urchins. Concentrations higher than 10% stormwater usually produced adverse effects in laboratory tests.	Samples were less toxic than Ballona Creek stormwater and occasionally nontoxic. High concentrations (>25%) usually needed to produce toxicity.

Characteristics of a highly urbanized watershed (Ballona Creek) and a less urbanized watershed (Malibu Creek) adjacent to Santa Monica Bay, California.

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TABLE 3 Continued

	Ballona Creek	Malibu Creek
Receiving Water Toxicity	Surface water in most concentrated portion of plume was often toxic to sea urchins. Toxicity was detected in receiving waters up to 2 miles from discharge.	Toxicity in water column was rarely present and was not related to plume concentration.
Cause of Toxicity	Zinc is responsible for a portion of the stormwater toxicity. The influence of pesticides and other organics is uncertain.	Metals are implicated but have not been confirmed as important toxicants.
Seafloor Habitat	Sediments were higher in urban stormwater associated contaminants, such as lead and zinc.	Higher concentrations of constituents were derived from natural sources, such as fine sediments and organic carbon.
Sediment Toxicity	Changes in sediment toxicity were minor and not related to stormwater discharges.	
Seafloor Biological Communities	Biological communities were similar among Malibu Creek, Ballona Creek, and background reference sites.	

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RECOMMENDATIONS FOR FUTURE STUDIES

The Santa Monica Bay Receiving Waters Study produced the first integrated assessment of impacts from stormwater discharges into the Bay. The presence of well-developed plumes containing toxic materials demonstrates the need for continued studies of the impacts from urban stormwater runoff in Santa Monica Bay and elsewhere. Additional information regarding the sources, characteristics, and extent of the receiving water impacts should be determined in order to refine management actions.

A high priority should be placed upon locating sources of toxicity and contamination within the Ballona Creek watershed. Identification of the land uses or regions of the watershed that contribute most to the impacts will enable management actions to be targeted where they will have the greatest beneficial impact. Source identification studies should include sampling of systems tributary to Ballona Creek for measurement of toxicity and chemical constituents.

Additional receiving water studies are recommended for Santa Monica Bay to provide a more complete understanding of the nature and magnitude of stormwater impacts. Future studies should include constituents of concern that were not emphasized in this study, such as bacteria, nutrients, pesticides, and trash. These constituents should be incorporated into studies of plume persistence, cause of toxicity, and constituent fate.

Information on the duration, size, and cause of adverse impacts is needed to identify appropriate stormwater management actions.

Plume persistence information is needed to estimate the duration of exposure of: 1) swimmers to bacteria and 2) marine life to stormwater toxicants and nutrients. Improved information on plume persistence can be obtained by the use of moored sensors in the discharge area in combination with data from remote sensing instruments (e.g., satellites). A goal of these studies should be to develop plume dilution and/or tracking models of plume duration and magnitude. This information is valuable because different management responses may be appropriate for stormwater discharges that produce short- versus long-lived impacts.

A suite of species should be used to identify toxicants in stormwater.

Toxicity testing using multiple marine species is also needed to provide a more complete assessment of the causes of toxicity in stormwater discharged into Santa Monica Bay. Identification of zinc and copper as contaminants of concern was based primarily on studies with a single species (sea urchin). Because different species vary in their sensitivity to contaminants, tests with multiple species are needed to determine if other contaminants are present at toxic concentrations. Tests with crustaceans (e.g., shrimp) are especially recommended as they are likely to be sensitive to pesticides such as diazinon and chlorpyrifos, which have been found to be important factors in the toxicity of stormwater from other watersheds. These tests should include toxicity identification procedures so that potential constituents of

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concern (e.g., metals and pesticides) can be confirmed and others can be discounted. Toxicant identification is needed to prioritize chemical-specific management actions.

The fate of stormwater particles must be determined in order to assess seafloor impacts.

Chemical and oceanographic studies are needed to determine the fate of stormwater particles discharged into Santa Monica Bay. Although some of the particles in Santa Monica Bay stormwater plumes may be deposited near the mouth of an urban watershed, they do not necessarily persist there for long periods of time. Since the spatial extent of particle dispersal in Santa Monica Bay was not determined, there may be areas of significant accumulation that were not investigated. Studies of currents, sediment resuspension, and sediment transport, coupled with chemical source identification methods, should be conducted to determine whether stormwater discharge is a significant source of adverse sediment contamination within Santa Monica Bay. This information is needed to identify areas of the seafloor with the greatest potential for biological impacts from stormwater discharge.

Additional receiving water systems should be studied to identify impairments from other watersheds.

The impacts of stormwater runoff on other receiving water systems should also be studied. This is because differences in watershed size and land use patterns will likely result in different levels of risk to the receiving water beneficial uses. For example, changes in land use may contribute different toxicants, and changes in watershed size will influence the magnitude of the toxicant input. The nature of the receiving water environment is also important. Semi-enclosed water bodies, such as most bays and harbors, do not have the mixing and dilution capacity of the open coastal environment studied in Santa Monica Bay. The potential for impairment will be greater in these areas because organisms will have an increased exposure to the stormwater plume and more stormwater particles will settle nearby and influence sediment quality. Until the effects of variations in watershed or receiving water characteristics can be accurately predicted, additional integrated studies will be necessary to assess impacts to receiving waters in other areas.

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Coastal Water Research Project
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Received
March 9, 2011
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State Mandates

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FEB 2 8 2000

Mr. Walt Pettit
Executive Director
State Water Resources Control Board
P.O. Box 100
Sacramento, CA 95814-0100

Dear Mr. Pettit:

Thank you for submitting the total maximum daily loads (TMDLs) and associated implementation plans to address fecal coliform bacteria impairments of Upper Newport Bay and Lower Newport Bay, California. The submission to EPA is dated January 31, 2000. Based on our review, we have concluded that the TMDLs adequately address the pollutant of concern and, upon implementation, will result in attainment of water quality standards. These TMDLs include allocations as needed, take into consideration seasonal variations and critical conditions, and provide an adequate margin of safety. The State has provided adequate opportunities for public review and comment on the TMDLs. All required elements are adequately addressed; therefore, the TMDLs are hereby approved.

We also hereby approve the inclusion of the TMDLs and associated implementation measures in the Basin Plan pursuant to Clean Water Act Section 303(e) and 40 CFR 130.6(c) and (e). The TMDL and implementation plan require attainment of the TMDL and associated allocations as soon as possible or no later than 14-20 years. We note that the implementation plan provides substantial detail concerning studies and monitoring to refine the TMDL, and less detail concerning specific implementation practices to implement the TMDL. In order to ensure that the TMDLs and associated allocations are implemented as soon as possible, we request that the Regional Board describe more specific implementation measures (1) when the NPDES permits for which WLAs are established are next reissued, and (2) when the TMDL implementation plan itself is next reviewed or revised pursuant to the TMDL review and implementation schedule.

The attached review discusses the basis for this approval decision in greater detail. We appreciate the State's work to complete and adopt these TMDLs and look forward to our continuing partnership in TMDL development. If you have questions concerning this approval, please call me at (415) 744-1860 or David Smith at (415) 744-2012.

Sincerely,

Alexis Strauss
Director
Water Division

enclosure
cc: Gerard Thibeault, Santa Ana RWQCB

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Staff Report Supporting Approval of TMDLs:
Fecal Coliform Bacteria- Upper Newport Bay and Lower Newport Bay, CA
February 17, 2000

Background

Pursuant to a consent decree (*Defend the Bay v. Marcus*, N. D. California No. C-97-3997 MMC), U.S. EPA is required to ensure that TMDLs are approved or established for bacteria for Upper and Lower Newport Bay, California by April 15, 2000. The Santa Ana Regional Water Quality Control Board (Regional Board) developed TMDLs for fecal coliform bacteria for Upper and Lower Newport Bay. The State of California adopted these TMDLs and submitted them for EPA approval in a submittal package dated January 31, 2000. By approving these State-adopted TMDLs, EPA's consent decree requirements are being met.

The implementation plan for each of the TMDLs is contained in the State's basin plan amendment submitted for EPA review. EPA is reviewing the basin plan amendment and implementation measures for the TMDL is submittal pursuant to the provisions of 40 CFR 130.6, based on the requirements of Clean Water Act Section 303(e). EPA is certifying that the implementation plan is consistent with the California water quality management plan and the requirements of the federal regulations at 40 CFR 130.6.

TMDL Review

Pursuant to Clean Water Act Section 303(d) and 40 CFR 130.2 and 130.7, EPA reviewed the State TMDL submittal package to ensure that all required TMDL elements have been adequately addressed. EPA's review is presented in the attached checklist for Upper and Lower Newport Bay, which documents EPA's findings that all required elements and an adequate level of technical justification for each element are included in the State TMDL submission. Therefore, the TMDLs should be approved.

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TMDL Checklist

State: California

Waterbodies: Upper Newport Bay, Lower Newport Bay

Pollutant(s): fecal coliform bacteria

Date of State Submission: January 31, 2000

Date Received By EPA: February 3, 2000

EPA Reviewer: David Smith

Review Criteria	Comments
1. Submittal Letter: State submittal letter indicates final TMDL(s) for specific water(s)/pollutant(s) were adopted by state and submitted to EPA for approval under 303(d).	Submittal letter, p. 1
2. Water Quality Standards Attainment: TMDL and associated allocations are set at levels adequate to result in attainment of applicable water quality standards.	Regional Board resolution 99-10, p.2; Attachment to resolution 99-10, p. 3. TMDL is expected to result attainment of applicable water quality standards within 14 years (for the water contact recreation standards) or 20 years (for shellfish standards).
3. Numeric Target(s): Submission describes applicable water quality standards, including beneficial uses, applicable numeric and/or narrative criteria. Numeric water quality target(s) for TMDL identified, and adequate basis for target(s) as interpretation of water quality standards is provided.	TMDL Staff report dated November 24, 1998 , p.5. TMDL applies both acute and chronic numeric standards for fecal coliform.
4. Source Analysis: Point, nonpoint, and background sources of pollutants of concern are described, including the magnitude and location of sources. Submittal demonstrates all significant sources have been considered.	TMDL Staff report dated November 24, 1998, pp. 28-36. TMDL identifies all likely sources and summarizes data describing bacteria levels associated with significant sources at different places in the watershed. Insufficient data were available to generate a specific source-by-source loading estimate; however, TMDL adequately accounts for bacteria loading uncertainty by setting TMDL and associated allocations equal to the applicable standards at all locations in Upper and Lower Newport Bay.
5. Allocations: Submittal identifies appropriate wasteload allocations for point sources and load allocations for nonpoint sources. If no point sources are present, wasteload allocations are zero. If no nonpoint sources are present, load allocations are zero.	Attachment to Resolution 99-10, table 5-9f (p. 5). TMDLs, WLAs and Las are expressed in terms of fecal coliform density. This is an appropriate way to express a bacteria TMDL because both human health and shell fish impacts associated with bacteria are a function of bacteria density in the water column rather than mass loading. This approach is also consistent with 40 CFR 130.2(i).
6. Link Between Numeric Target(s) and Pollutant(s) of Concern: Submittal describes relationship between numeric target(s) and identified pollutant sources. For each pollutant, describes analytical basis for conclusion that sum of wasteload allocations, load allocations, and margin of safety does not exceed the loading capacity of the receiving water(s).	TMDL Staff report dated November 24, 1998, pp. 36-40. By setting the TMDL equivalent to the numeric target and the applicable water quality standards, a direct and exact linkage exist.

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7. Margin of Safety: Submission describes explicit and/or implicit margin of safety for each pollutant.	Staff report dated November 24, 1998, pp. 40-41. TMDL provides implicit MOS by not accounting for likely bacteria dilution and dieoff prior to entry into Bay (e.g. likely dieoff due to exposure to sunlight), and after entry into Bay (e.g. due to exposure to salt water in the Bay). TMDL plan also provides rigorous monitoring and review plan and schedule, which provides an ongoing mechanism to adjust the TMDL if needed in the future.
8. Seasonal Variations and Critical Conditions: Submission describes method for accounting for seasonal variations and critical conditions in the TMDL(s)	Staff report dated November 24, 1998, pp. 41-42. TMDL accounts for seasonal variations and, in particular the critical warm weather period by setting the TMDL and allocations to meet WQS at all times and under all conditions. In addition, the implementation schedule calls for implementation of the TMDL to address the most important local beneficial use– warm weather body contact recreation– in the faster timeframe.
9. Public Participation: Submission documents provision of public notice and public comment opportunity; and explains how public comments were considered in the final TMDL(s).	The Regional Board public noticed the TMDL several times in a local newspaper of general distribution and held 4 public workshops and hearings to receive public comments. Regional Board responded to all written comments through responsiveness summaries included in the submittal package.. State Board also provided opportunities for public review and comment by sending notices of availability of the proposed TMDL to an extensive mailing list and by holding a public hearing to receive public comments. We understand that no additional comments were received by the State Board that were not addressed by the Regional Board.
10. Technical Analysis: Submission provides appropriate level of technical analysis supporting TMDL elements.	Staff report and responsiveness summaries provided detailed technical justifications for each TMDL element.
Note: **The following criteria do not apply to all TMDLs, but must be applied in the situations noted.**	
11. Monitoring Plan for TMDLs Under Phased Approach (where phased approach is used): TMDLs developed under phased approach identify implementation actions, monitoring plan and schedule for considering revisions to TMDL.	Submittal includes detailed schedule for implementation-related actions and monitoring and discusses implementation and monitoring approaches (pp. 6- 15). Staff report also discusses implementation and monitoring needs and plans in detail (pp.43-44).

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12. Reasonable Assurances (for waters affected by both point and nonpoint sources): Where point source(s) receive less stringent wasteload allocations because nonpoint source reductions are expected and reflected in load allocations, implementation plan provides reasonable assurances that nonpoint implementation actions are sufficient to result in attainment of load allocations in a reasonable period of time. Reasonable assurances may be provided through use of regulatory, non-regulatory, or incentive based implementation mechanisms as appropriate.	Not applicable– no WLAs were made less stringent based on expected nonpoint source controls.
Implementation Plan Review Criteria Pursuant to 40 CFR 130.6 and 303(e)	
13. Clear Implementation Plan: Submittal describes planned implementation actions or, where appropriate, specific process and schedule for determining future implementation actions . Plan is sufficient to implement all wasteload and load allocations in reasonable period of time. TMDL(s) and implementation measures are incorporated into the water quality management plan. Water quality management plan revisions are consistent with other existing provisions of the water quality management plan.	Attachment to Resolution 99-10 describes implementation plans in detail and notes that all sources for which WLAs are established are regulated either under NPDES permits or local regulatory mechanisms (pp. 6-15). Plan is sufficient to result in attainment of the TMDL and associated allocations within the scheduled timeframe. This finding is based on the rigorous actions to further characterize and identify control mechanisms for significant bacteria sources within the watershed are clearly scheduled for completion, and responsibility for each action is clearly assigned to one or more regulated entities. In addition, the NPDES permitting and local vessel waste discharge program provide a workable regulatory framework for ensuring compliance with WLAs. The TMDL requires compliance as soon as possible, but no later than 14-20 years from adoption, depending upon the applicable standard. This timeframe compels rapid action to comply with the TMDL, but properly recognizes that it will be technically difficult to control urban sources of bacteria discharges at levels which meet the stringent TMDL provisions. The approval letter should note that EPA expects the Regional Board to apply its best efforts to ensure that the TMDLs and associated allocations are implemented as soon as possible. In particular, the Regional Board should ensure that more specific implementation measures be described (1) when the NPDES permits for which WLAs are established are next revised or reissued, and (2) when the TMDL implementation plan itself is next reviewed/revised as scheduled in the implementation schedule provided with the submittal.

COUNTY OF ORANGE

PUBLIC FACILITIES & RESOURCES DEPARTMENT

MANAGEMENT GUIDELINES
FOR THE USE OF FERTILIZERS AND PESTICIDES

September 2000
(Revision to March 1993)

VICKI L. WILSON
Director

ORANGE COUNTY BOARD OF SUPERVISORS

CHARLES V. SMITH
First District

TODD SPITZER
Third District

JAMES W. SILVA
Second District

CYNTHIA P. COAD
Fourth District

THOMAS W. WILSON
Fifth District

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GLOSSARY

California Code of Regulations, Title 3, Division 6 (3 CCR)
The State of California Code regulating pesticides and pest control operations.

California Fertilizer Association (CFA)
An organization promoting progress in the fertilizer industry in the interest of an efficient and profitable agricultural community. Activities of CFA include developing and disseminating new information to its members and others; supporting production-oriented research programs to identify maximum yield systems for farmers; promoting argonomic topics at our schools, colleges and universities; and maintaining open communications among the industry, universities and other state and federal agencies.

Chemical Labels
As required by federal law, manufacturers of pesticides must provide chemical labels on the containers of all pesticides distributed. These labels include all necessary information on the chemical constituents of the pesticide, including recommendations and instructions for use, toxicity classification and the appropriate warning statements and emergency procedures in case of acute exposures. As required by state law, labels must be kept in good, readable condition and be attached to all pesticide containers at all times.

Drainage Area Management Plan (DAMP)
A document required under the municipal NPDES stormwater permits issued to the co-permittees by Santa Ana and San Diego Regional Water Quality Control Boards.

Equivalent Training
A term referring to public agency employees dealing with the application of pesticides who have not received a qualified applicator's license (QAL) from the State of California, but who has completed a training course in pesticide application offered by the County of Orange.

Eutrophication
A decrease in dissolved oxygen in a body of water to such an extreme extent that plant life is favored over animal life. For example, a lake that is overgrown in algae on the surface is likely in a state of eutrophication.

Integrated Pest Management
The trend in vegetation management that supports moving away from reliance on pesticides and toward an integrated approach of limited pesticide use with more environmentally friendly pest control techniques.

Maximum Extent Practicable (MEP)
MEP means taking into account equitable considerations of competing factors, including, but not limited to, the gravity of the problem, fiscal feasibility, public health risks, societal concern and social benefit.

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GLOSSARY (cont'd)

Materials Data Safety Sheet (MSDS)
Similar to chemical labels and also required by federal law, these sheets should contain all information necessary for the safe handling of pesticides. They include chemical identifications, hazardous ingredients, physical data, fire and explosion data, health hazards, reactivity data, spill or leak cleanup procedures, special protection and special precautions.

National Pollutant Discharge Elimination System (NPDES)
The national program under the Clean Water Act for controlling discharges from point sources directly into Waters of the United States.

Permittee
A permittee to an NPDES permit that is responsible for permit conditions relating to the discharge for which it its operator. As used in the Stormwater Permit Implementation Agreement, permittees are the County of Orange, the 33 cities of Orange County and the Orange County Flood Control District.

Pest Control Advisor (PCA)
Certification obtained from the State of California after demonstrating adequate knowledge of pests, pesticides and the implications of pesticide use. A recommendation for pesticide use must be obtained from a PCA before public agencies may approve any pesticide applications.

Qualified Applicator's License (QAL)
A license obtained from the State of California after demonstrating adequate knowledge of the proper techniques for handling, storing, transporting and applying pesticides. Workers must obtain a QAL before being permitted to apply or supervise application of Category 1 pesticides.

Qualified Fertilizer Specialist
A person designated by the governing public agency who is knowledgeable of the proper techniques for handling, storing, transporting and applying fertilizers as defined in the Management Guidelines for Use of Fertilizers and Pesticides. This person shall be able to sample, inspect, test and make analyses of fertilizers that are in use or being considered for use in the agency's jurisdiction to such an extent to adequately determine their compliance with the management guidelines.

Restricted Materials Permit
A permit that must be acquired by any public agency before application of the pesticides listed as restricted by the State of California in the Code of Regulations ("CCR"), Title 3, Division 6. In Orange County, this permit must be obtained from the County Agricultural Commissioner.

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GLOSSARY (cont'd)

State Code
In this report, referring to CCR, Title 3, Division 6, and noted as "3 CCR."

Storm Drain
Pipe or channel structure designed to convey only stormwater runoff for purposes of flood protection. Federal regulations use the term "storm sewer." Use of the word "sewer" for a stormwater conveyance structure should be discouraged, since the word "sewer" also includes sanitary sewers and combined sewers which carry human waste.

Toxicity Classification
The California Department of Food and Agriculture groups pesticides into three categories according to their toxicity or potential to cause injury to people. Category 1 pesticides are the most hazardous and their use is normally restricted, while Category 3 pesticides are the least toxic to people and are generally less hazardous.

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EXECUTIVE SUMMARY

This document was prepared to establish guidelines for the management of fertilizers and pesticides. The main objective of these guidelines is to safeguard to "the maximum extent practicable"* against unnecessary discharges of fertilizers and pesticides into surface and groundwater systems and to establish safe and reasonable standards for handling those materials. The guidelines are based on state and federal laws, environmental policies and "best management practices" established by various public and private agencies. Through this document, it is envisaged that these practices will establish a set of uniform standards and procedures.

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1.0 INTRODUCTION

1.1 Status of Fertilizer and Pesticide Use

Fertilizers and pesticides are a primary tool of vegetation management. Used properly, fertilizers provide important nutrient supplies for vegetation and agriculture, and pesticides help to protect those resources from potential harm.

Used improperly, fertilizers and pesticides can become an impairment to surface and groundwater supplies. Careless application, mixing, transportation, storage and disposal allow chemicals to enter surface and groundwater through runoff and infiltration; the same handling problems endanger human health through exposure to toxic chemicals; soil degradation often results from overuse and misuse of pesticides and fertilizers. Even under ideal conditions, there is still a high level of risk, and consequently, there is a need for considerable professional planning and management.

1.2 Management Options

Because of the risk involved in using fertilizers and pesticides, the development of management guidelines for use of fertilizers and pesticides is an essential element of the DAMP. These guidelines are designed not only to comply with the NPDES Stormwater Program, but also to minimize any threat to human health and environmental resources from improper use of fertilizers and pesticides. It is envisaged that consideration of these guidelines by the permittees will cause public agencies to re-evaluate their approach to using fertilizers and pesticides and move toward reducing dependence on them.

The guidelines that follow are intended for the use of the Permittees, although they may ultimately be used on a broader scale. They are based on the laws, management guidelines and "best management practices" established by other federal, state and local agencies. They recognize that the safe management of fertilizers and pesticides is a shared responsibility between the field worker and management. These guidelines address the concern for fertilizer and pesticide use at a basic level, and if followed, they should reasonably prevent environmental damage to the highest degree possible.

1.3 Definitions

For the purpose of these guidelines, fertilizers may be referred to as "nutrients" or "soil nutrients," and the term "pesticides" will encompass all herbicides, insecticides, fungicides and rodenticides. The California Food and Agricultural Code and the California Code of Regulations, Title 3 (3 CCR)*, constitute the laws and regulations referenced in this plan. They are referenced often and usually referred to as the "State Code."* Also, Permittees will be referred to as "public agencies," and employees working for these public agencies who handle fertilizers & pesticides will be referred to as "workers" or "public employees."

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2.0 FERTILIZER MANAGEMENT

2.1 Definition and Scope of Guidelines

Fertilizers are nutrients applied to soil to provide a better growing environment for plants. The fertilizers most commonly in use in Southern California today are nitrogen- and phosphorus-based. Both leach into soils easily in the presence of water and have become a water quality concern, causing algal blooms and eutrophication* and, in some cases, causing levels to exceed federal drinking water standards.

However, fertilizers also play the important role of promoting vegetation growth that protects soil from erosion and enhances landscape aesthetics. Because there is a necessity for soil nutrients and because there is a potential for adverse effects on local waterways due to the loss of these nutrients through runoff and infiltration, management guidelines are necessary as a means of reducing the loss of fertilizers into water supplies.

2.2 General Considerations

2.2.1 State and Federal Law

Because most fertilizers are not as toxic as pesticides, state and federal lawmakers have not developed regulations for their use. Fertilizers are not usually considered an immediate danger to public health or safety. However, the California Fertilizer Association (CFA)*, a Sacramento-based organization, has developed complete management guidelines for fertilizer use and the State Department of Food and Agriculture has recommendations for use of nitrate-based fertilizers, both of which are available for consultation.

2.2.2 General Recommendations

1. Public agencies should periodically have soils tested before applying fertilizers to be certain that application is appropriate for and compatible with soil conditions. The samples should be analyzed by a qualified specialist for fertilizer applications*, and workers should follow the recommendations.

2. Public agencies should choose to use organic fertilizers such as compost, peat and mulch wherever possible to increase soil porosity and water retention.

3. Workers should apply only the minimum amount of fertilizer needed and incorporate it directly into the soil around the plant, where possible, to minimize potential surface runoff.

4. Workers should not apply fertilizers in the rain or on the same day that rain is expected.

5. Workers should immediately cleanup any spill of fertilizers.

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6. Storage facilities should be covered and have impermeable foundations so that potential spills don't have the opportunity to runoff into surface water or leach into groundwater systems.

7. Fertilizers that may be carried by the wind should be stored in areas away from open loading spaces and entrances of storage warehouses.

8. Fertilizers should be securely covered in the vehicle before being taken to application sites so that none can spill or fly out during transport.

9. Use slow release fertilizers -- such as water soluble nitrogen fertilizers, coated fertilizers and fertilizers of limited solubility -- whenever possible to minimize the possibility of leaching.

2.3 Planning for Use of Fertilizers

2.3.1 Soil Testing

Most fertilizers travel quickly through water. Therefore, fertilizers will leach through soil and potentially contaminate groundwater more quickly after excess watering or irrigation, after heavy rains and where the water table is high. For this reason, soil testing is an important management technique to determine the safest fertilizer application rate.

The California Landscape Contractors Association (CLCA) has a complete list of organizations in Southern California that offer soil testing and analyzing for fertilizer use. To get a copy of that list, CLCA can be contacted at (916) 448-2522. If a reliable soil analyst is not already known, it is advisable for public agencies to consult CLCA and research a specialist who can make recommendations for fertilizer use.

2.3.2 Application Rates

The amount of fertilizer needed for different applications depends on a number of factors. For specific recommendations, a qualified specialist should be consulted. The following are some factors to be considered:

- The vegetation's ability to use fertilizer;
- The amount of nutrients already in the soil, including fertilizer that may still be present from a previous application;
- The amount of soil nutrients that will or can be obtained from natural processes;
- The expected loss of nutrients from the soil; and
- The temperature at the time of application.

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2.3.3 Timing

For vegetation with different growth patterns, fertilizers should be applied at different times and in different quantities. The vegetation being managed should be researched and fertilizers applied only according to the amounts and at the time intervals recommended by a qualified specialist for fertilizer applications. This should minimize the waste of fertilizer and reduce any risk of water contamination.

2.4 Application Methods of Fertilizers

This section details the most common methods for application of fertilizers. These are not the only acceptable methods of fertilizer application. Every application has its own circumstances and variables to consider. A qualified fertilizer specialist should be consulted to recommend the most appropriate application method.

2.4.1 Banding of Fertilizer

Probably the most common and safest application method, this involves physically working small amounts of fertilizer into the soil in a band beneath and around the sides of a seed. It allows new roots to efficiently use the nutrients and minimizes potential nutrient loss to surface runoff. However, given the labor involved, banding may not be practical for most public agency fertilizer applications.

2.4.2 Foliar Fertilization

This is fertilizer applied in solution form that is absorbed through leaves and stems. The method can reduce nutrient leaching into the soil when applied correctly and can be performed at the same time as pesticides application to avoid spraying twice. In this case, the guidelines for pesticide applications must also apply.

2.4.3 Broadcast Application

By this method, dry or liquid fertilizer is uniformly spread over the soil surface. This is often done mechanically, an example being the "drop spreader" which is usually an inverted triangle hopper. The simplest of mechanical applicators, the drop spreader is commonly mounted on wheels and pushed by hand or pulled by vehicle to drop fertilizer out of the bottom of the triangle.

Other types of broadcast applicators include spray booms for liquid fertilization or "spinning disks" mounted on a moving vehicle that throw dry fertilizer into the air. It should be noted that these latter methods do not offer much control over fertilizer drift in adverse weather conditions.

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2.4.4 Fertigation

Although not likely to be used by public agencies for fertilizer applications, this method is common among Californian farmers who incorporate fertilizers into irrigation water. The potential for nutrient leaching using this method, though, appears to be high.

2.5 Storage and Handling of Fertilizers

2.5.1 General Description

When stored and handled properly, fertilizers present no hazard to the users' health. Public employees responsible for the storage and handling of fertilizers should be aware that some fertilizers have properties that can result in dangerous chemical reactions if mixed with other substances or under unusual circumstances. For example, ammonium nitrate may become explosive if it becomes mixed in diesel fuel; a dehumidifier may be necessary for storage areas where sensitive fertilizers are stored. Also, because most fertilizers tend to be corrosive, concrete structures are preferred for fertilizer storage facilities.

2.5.2 Dry Fertilizer

In most cases, dry fertilizers are safe to store, transport and handle. However, because some fertilizers have unique, potentially dangerous properties, it is advisable for public agencies to consult a qualified fertilizer specialist for the safest storage and handling procedures for specific fertilizers.

2.5.3 Liquid Fertilizer

Fertilizers in liquid form are potentially more hazardous than dry fertilizer. Public employees responsible for storage and handling need to be aware of the specific properties of each liquid fertilizer in use, including corrosivity and tolerable temperature and pressure ranges. Protective equipment may be necessary for workers handling fertilizers such as sulfuric or phosphoric acid. A qualified fertilizer specialist should be consulted for recommending the safest handling and storage procedures for specific liquid fertilizers.

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3.0 PESTICIDE MANAGEMENT

3.1 Definition and Scope of Guidelines

Pesticides are designed to kill or restrict the growth of plants and organisms, and thus, are potentially dangerous chemicals. Increasing scientific concern for their safe use and heightened public awareness of health concerns has led to more and more regulations in the United States at both the state and federal level. Pesticide use by public agencies often involves applications to keep flood control channels and roadways clear or to minimize health and safety hazards of disease-bearing rodents and insects. Any of these applications can drain into stormwater basins if not controlled properly. Although safety concerns and the cost of complying with new regulations have encouraged some public agencies to cut back on the use of pesticides, use is still common, and their management is therefore essential.

3.2 General Considerations

3.2.1 State and Federal Law

The California Department of Food and Agriculture and the federal Toxic Substances Control Act (TSCA) have set forth extensive rules and regulations that must be met by all public agencies. At an absolute minimum, public agencies must comply with these laws or be subject to the penalties described in the statutes.

3.2.2 Chemical Labels and Materials Safety Data Sheets (MSDS)

1. Without exception, chemical labels* provided by the manufacturer of each pesticide are the first source of recommendations and instructions for chemical use. Whenever a chemical is to be used by a worker or a contractor of a public agency, the user needs to be intimately familiar with the label instructions and requirements.

   As described in the State Code (Ch. 2, Subch. 1, Art. 10), the label must appear on the immediate container of the chemical and include, in prominent, bold type, the appropriate warning or caution statement according to its toxicity classification*. If a chemical is transferred to another container, a copy of the label should be transferred with it.

   Workers should never handle a container that doesn't have a warning label attached, and the supervisor in charge should be immediately advised of the situation. If a label is badly damaged, the supervisor should replace it.

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2. Workers using pesticides should have readily available the Materials Safety Data Sheets (MSDS)* for each chemical they are using. Although the MSDS is a form that may vary in appearance for different chemicals, the information is the same, as required by law. Similar to the chemical labels, these sheets contain information necessary to handle each chemical safely, and all workers should be familiar with the information.

   MSDS sheets include chemical identifications, hazardous ingredients, physical data, fire and explosion data, health hazards, reactivity data, spill or leak cleanup procedures, special protection and special precautions.

3.2.3 General Recommendations

1. Public agencies should maintain a complete list of all chemicals and their uses.

2. Public agencies should thoroughly investigate and consider all alternatives to pesticide use.

3. Workers should use pesticides only according to label instructions.

4. Work crews should bring to the work site only the amount of chemical to be used during the application and use only the minimum amount the chemical necessary.

5. Workers should consider weather conditions that could affect application (for example, they shouldn't spray when winds are exceeding 5 mph, when raining or when rain is likely).

6. Workers should consider area drainage patterns (for example, they shouldn't apply near wetlands, streams and lakes or ponds unless it is for an approved maintenance activity).

7. Workers should consider soil conditions before applying pesticides (for example, they shouldn't apply to bare or eroded ground).

8. Workers should triple-rinse empty pesticide containers before disposal and use the leftover wash as spray.

9. Workers should never clean or rinse pesticide equipment and containers in the vicinity of storm drains*.

10. Pesticides should only be stored in areas with cement floors and in areas insulated from temperature extremes.

11. Workers should secure chemicals and equipment during transportation to prevent tipping or excess jarring in apart of the vehicle completely isolated from people, food and clothing.

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12. Workers or their supervisors should inspect pesticide equipment, storage containers and transportation vehicles daily.

13. Public agencies should adopt a plan for dealing with potential accidents before they happen.

14. Workers should immediately clean up any chemical spill according to label instructions and notify the appropriate supervisors and agencies.

3.3 Planning for Use of Pesticides

3.3.1 Selection of Appropriate Pesticides

1. Pesticides are to be used only after recommendation from a state-licensed or certified pest control advisor.

2. Public agencies should also seek advice for appropriate pesticide use from the Orange County Agricultural Commission, from other professional pesticide handlers and/or through professional publications. The County Agricultural Commission can be contacted at (714) 447-7100.

3. A special effort should be made to limit use of restricted pesticides and all other Category One pesticides.

3.3.2 Certification, Licensing and Permitting

1. Pesticides are only to be applied by or under the direct supervision of an individual with a qualified applicators license (QAL)* for pesticide applications or by workers with equivalent training*.

2. Chemicals listed as "restricted" in the State of California may be used only under a restricted materials permit* (StateCode Ch. 2, Subch. 4) to be issued by the Orange County Agricultural Commission. The permit must be renewed annually for continued use. For more information, contact the Commission at (714) 447-7100.

3. All other guidelines concerning permits, licensing and certification requirements to be followed before pesticide application are detailed in the State Code, Chapter 3, Subchapter 1.

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3.3.3 Employee Training

1. Public agency employees must know the information on the chemical label and its MSDS before using pesticides in any capacity. In addition, they should (a) know the immediate and long-term health hazards posed by chemicals to be used, the common symptoms of chemical poisoning and the ways poisoning could occur, and (b) know the safe work practices to be followed, including the appropriate protective clothing, equipment, mixing, transportation, storage, disposal and spill cleanup procedures that apply to the specific chemicals being used.

2. In addition to the training and annual continuing education required for licensing and certification (3 CCR, Ch. 3, Subch.3, Art. 2), public employees are encouraged to participate in continuing pesticide education programs whenever the programs are available.

3.3.4 Accident Mitigation

Public agencies using pesticides should have plans for dealing with potential accidents before they happen. These plans should consider:

1. Labels and MSDS Sheets -- All workers handling pesticides must be familiar with these instructions. The steps for accident mitigation are spelled out on chemical labels and MSDS sheets.

2. Spill Cleanup Kits -- Any time pesticides are being handled, there should be a cleanup kit on hand in case of an accident. This means there should always be a cleanup kit located in pesticide storage areas, on vehicles used to transport pesticides and on location where the chemicals are being applied. Although these kits may vary in what they contain depending on the chemical type and the situation, at a minimum they should include:

    - spill-control procedures
    - a five gallon drum with sealable lid
    - a dust pan and broom
    - a squeegee
    - a shovel
    - protective goggles, gloves, boots, coveralls
    - a tarp (for covering dry spills)
    - detergent and water (check label or MSDS for proper use)
    - barricade tape, florescent traffic safety cones or string to cordon off an area
    - large sponges, containment booms or some other absorbent material

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3. Cleanup Procedures -- Spilled pesticides must be prevented from entering the local surface and/or groundwater supplies. Specific recommendations for spill cleanup should be available on each chemical label or MSDS. Specific recommendations for the sequence of procedures may also vary depending on the situation. However, generally, in case of a spill, the responsible worker(s) should:

   EVALUATE the accident and quickly determine the most immediate concerns (medical and/or environmental).

   CONTAIN OR CONTROL the spill.

   NOTIFY the supervisor in charge who should, in turn, notify the proper authorities. If contact cannot be made, dial 911.

   ISOLATE the area with fluorescent traffic safety cones, ropes or some other cordoning device to be sure that no one walks, wanders or drives through the spill area.

   CLEAN UP the spill as best as possible following label instructions and using the appropriate spill cleanup kit.

   EVALUATE any damage that may have occurred resulting from the spill (property damage, health damage, equipment damage, etc.) and make notes on all relevant details and circumstances before leaving the scene.

   PREPARE A COMPLETE REPORT detailing the incident immediately after leaving the scene upon returning to the work place and submit it to the immediate supervisor.

3.3.5 Emergency Medical Care

Accident situations requiring emergency medical care are likely to involve acute exposure to potentially toxic chemicals. Instructions for handling these exposures appear on the chemical label. Workers should:

1. Be aware of the symptoms of acute exposures for each chemical being used.

2. Have a predetermined strategy for dealing with exposure scenarios, including knowing (a) the label recommendations for dealing with acute exposures and (b) the nearest medical facility where emergency care is available.

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3.3.6 Equipment and Equipment Maintenance

All equipment for the handling of pesticides should be inspected and cleaned by workers before each use to ensure that there are no problems that could lead to chemical leaks, spills or accidents during the day's work (State Code Ch. 3, Subch. 3, Art. 2).

3.3.7 Groundwater and Surface Water Protection

Similar to the discussion of leaching in fertilizer management, the main factors determining the rate at which pesticides enter groundwater and surface water systems are chemical mobility, solubility and persistence and the soil type. For example, potentially dangerous chemicals are likely to have a high solubility and an extremely long half-life, and they are not likely to be easily absorbed into the soil. Therefore, chemicals that decompose rapidly may be preferred. However, note that to choose a chemical that may need to be applied two or three times as often may not make sense from a transportation and application risk standpoint.

Because of these factors, regardless of the category of chemicals being used, pesticide advisors should always test the soil for compatibility with specific chemicals before recommending pesticides for a specific area.

Furthermore, because the effect of these uses is not always immediately apparent, public agencies should periodically test areas that could be particularly vulnerable to contamination or deterioration. The results of these tests should be kept on public record.

3.4 Application of Pesticides

3.4.1 Supervision

1. In cases where supervision of pesticide applications is required by the State Code, supervision must be handled by a state-licensed or certified pesticide applicator. For all other pesticide applications, supervision may be handled by workers with equivalent training.

2. Public agencies that contract pesticide applications should periodically inspect contracted work crews to be certain that contractors are following proper management guidelines. Public agencies handling their own applications should likewise inspect their work crews on a regular basis to ensure that safety standards are being met.

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3.4.2 Proper Techniques

1. Read the label carefully and follow application instructions exactly. Be absolutely certain that the right chemical is being used for the right job before applying.

2. To prevent potentially harmful runoff, only the absolute minimum amount of pesticides should be used to ensure vegetation safety.

3. Recommendations for best weather conditions to prevent pesticide spray drift are outlined in State Code Chapter 2, Subchapter 4, Article 2.

3.4.3 User Safety and Protection

1. Public agencies should have on hand equipment for application of pesticides should include eye protection, gloves, respiratory gear and impervious full-body, chemical resistant clothing when called for by the chemical label.

2. Even when wearing respiratory gear or masks, when dealing with spray applications of pesticides, workers should avoid directly inhaling in the spray mist.

3. Workers should avoid working alone, especially at night.

4. Workers should clean equipment, clothing and self thoroughly after each application.

5. State laws regarding re-entry into fields that have recently been treated with pesticides should be followed (State Code Chapter 3, Subchapter 3, Article 3).

6. Public agencies are responsible for knowing and informing workers about the specific pesticides being used including how they are properly handled, the dangers involved and the proper training and safety procedures.

7. Public agencies are responsible for keeping updated records and a complete list of the pesticides being used in their jurisdiction. This should include the chemicals, amount in storage, amount of applications, dates and location of applications and pests controlled with each application.

8. Public agencies should keep all relevant label and MSDS information for each chemical updated and readily available at all times to workers handling the materials.

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3.5 Storage, Disposal and Transportation

3.5.1 Proper Storage

1. Storage areas should be away from living areas and in a covered area that is well-insulated from temperature extremes; they should have a cement floor and good ventilation. Also, storage areas should be clearly marked according to state standards and be securely locked at all times when not in use.

2. Public agencies should ensure that chemical labels on pesticides being stored or used are kept in good condition and attached to all containers holding pesticides (State Code Ch. 3, Subch. 2, Art. 4).

3. Workers should ensure that storage equipment and containers are inspected daily for leaks or defects before being taken on the job. Containers should also be inspected and before storing at the end of the day.

3.5.2 Proper Disposal

1. Workers should make certain that chemical containers are triple-rinsed before disposal (State Code Ch. 3, Subch. 2)

2. It is recommended that cleaned containers be sent back to the manufacturer for recycling whenever possible. However, once triple-rinsed, most haulers will take them to most landfills.

3. Workers should use left over rinse water as spray.

4. Public agencies should ensure that surplus or out-of-date chemicals are given to a licensed hazardous waste hauler for disposal.

3.5.3 Safe Transportation Methods

1. Workers should ensure that all pesticides containers are tightly sealed and secured from tipping or excess jarring (State Code Ch. 3, Subch. 2, Art. 4).

2. Transportation compartments on vehicles should be isolated from the compartment carrying people, food and clothing and should be securely locked (State Code Ch. 3, Subch. 2, Art. 4).

3. Workers should transport only the amount of pesticide needed for the day to the site.

4. Workers should be certain that the appropriate chemical labels and MSDS sheets, a spill cleanup kit, the location of emergency medical care and a first aid kit are always brought along when transporting pesticides.

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5. Public agencies should encourage all vehicles used for pesticide transportation to include radio communications for contacting help in case of a spill or some other emergency.

4.0 INTEGRATED PEST MANAGEMENT*

4.1 Background on Pesticide Use

For most of the last 50 years, the trend in vegetation management has been toward a greater reliance on pesticides. The result has been not only a tremendous increase in the use of many dangerous chemicals, but also an enormous increase in the number of pests that are resistant to the pesticides being produced. In essence, as more pesticides have been produced, more resistant strains of pests have evolved. Worse, recent studies have shown that the end result of this global trend has been no net gain in vegetation survival rates.

With these realizations becoming well known, vegetation managers are now moving away from their reliance on pesticides and toward an integrated approach that combines limited pesticides use with more environmentally-friendly pest control techniques.

4.2 Scope of Guidelines

For public agencies in Orange County, IPM practices should be preferred to the sole use of pesticides as the primary means of vegetation management. These techniques are designed to prevent overuse and to reduce reliance on them. IPM should be considered by all public agencies or their contractors before intensive use of pesticides.

The goal of IPM is not to eliminate all pests, but to keep their populations at a manageable number. Pesticides are part of IPM techniques, but they are used in small quantities and only after all other alternatives have been reviewed.

4.3 Alternatives to Pesticides

Some of the alternatives to pesticides that may be considered as part of an IPM program include:

1. Introduction of natural predators such as ladybugs, lacewings, garter snakes and toads. Also, some bacteria, viruses and insect parasites may be preferable to pesticides.

2. Selected removal or rotation of vegetation habitat to eliminate the breeding places of specific pests.

3. Weeding, hoeing and trapping manually. Pruning and thinning of trees is also an effective means of preventing epidemic tree insects and diseases.

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Also, at certain times of the year and under certain environmental conditions, certain pests can be expected. Therefore, timely planting or well-timed use of small quantities of pesticides may avoid the need for some chemical use.

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Marine Pollution in the United States

Prepared for the Pew Oceans Commission by

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Abstract

Direct discharges of pollutants into the ocean and coastal waters from sewage treatment plants, industrial facilities, ships, and the at-sea dumping of sewage sludge and other wastes have been greatly reduced over the past 30 years as a result of the Clean Water Act and other federal statutes. Advances in waste treatment have kept ahead of increases in the volume of wastes, and that trend is likely to continue. Some persistent toxic pollutants, such as DDT and PCBs, were banned for manufacture or use in the United States, and ambient levels of these pollutants have been decreasing in most U.S. marine environments. On the other hand, pollution from land runoff went largely unabated during this period; in some cases it has increased. As a result, diffuse sources now contribute a larger portion of many kinds of pollutants than the more thoroughly regulated direct discharges.

Toxic pollutants, including pesticides, industrial organic chemicals and trace metals, are widespread contaminants of the marine environment. But they produce discernible adverse effects on ecosystems only in limited areas around population centers and ports. Some of these chemicals are known through experimental studies to affect the reproductive, immune, or endocrine systems of marine organisms at low concentrations, and may have subtle effects on marine organisms and populations over a broader area. While some of the most toxic substances have been banned for manufacture and use, material previously released may remain in the environment for decades to centuries. High

Nutrient Overenrichment

The dominant form of plant life in the world's oceans is free-floating, single-celled algae known as phytoplankton. Like all plants, phytoplankton need nutrients—nitrogen, phosphorus, and other minerals—and light to grow and reproduce. Most of the needed nutrients either wash into the ocean from the land or move from the deeper waters to the surface through upwelling.

The growth of phytoplankton is usually limited by the availability of nutrients. Nitrogen is the nutrient that is usually in the shortest supply. But if nitrogen becomes abundant, the growth of phytoplankton can increase dramatically. An explosive increase in the population of phytoplankton is known as an algal bloom. A bloom often contains more phytoplankton than can be eaten by marine animals. The uneaten algae—and wastes from animals that eat the algae—sink to the ocean bottom, and decompose.

Through the process of decomposition, the dissolved oxygen levels in the water near the bottom can decrease substantially.

The long-term increase in the supply of organic matter to an ecosystem—often as a result of excess nutrients, or nutrient overenrichment—is called eutrophication.

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concentrations of persistent contaminants in bottom sediments require careful consideration when removed by dredging or managed in place.

Overenrichment of coastal ecosystems by nutrients, particularly nitrogen, has emerged as the most widespread and measurable effect of pollution on living marine resources and biodiversity in U.S. coastal waters. Excessive nutrient levels (overenrichment or eutrophication; see sidebar on these pages) may result in serious depletion of the dissolved oxygen supplies needed by marine animals, loss of habitat (e.g., seagrasses and coral reefs), and algal blooms. Two-thirds of the surface area of estuaries and bays in the conterminous U.S. suffers one or more symptoms of overenrichment. Because a majority of the nutrients in most regions now come from diffuse sources rather than direct discharges, reversing coastal eutrophication will require management strategies for watersheds reaching far inland from the coastal environment. Feasible measures include advanced treatment of municipal wastewaters, reduction of nitrogen oxide emissions from power plants and vehicles, control of ammonia emissions from animal feedlots, more efficient use of fertilizers and manure, and restoration of wetlands and floodplains that act as nutrient traps.

Eutrophication creates two harmful effects: oxygen depletion and reduced water clarity. When dissolved oxygen levels drop to levels that equal two milligrams per liter or less, a condition called hypoxia occurs.

Anoxia refers to a complete absence of dissolved oxygen in the water.

More mobile marine animals, like fish and crabs, can often migrate out of hypoxic areas. Other animals—such as oysters and marine snails—that lack mobility or cannot move quickly enough to escape hypoxia may suffocate. When water clarity is reduced by greater concentrations of algae, less light can penetrate to the ocean bottom where seagrasses and seaweeds live. As a result, these plants may sicken and die.

Increased nutrient levels in surface water (rivers and streams) and in groundwater from the land can be attributed to human activity. Major sources of nitrogen, phosphorus, and other nutrients delivered to the oceans include discharges from wastewater-treatment plants, runoff and groundwater from cropland, urban and suburban stormwater (runoff from paved surfaces), farm animal wastes, and even nutrients found in airborne emissions from power plants, automobile exhaust, and industrial smokestacks.

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I. Introduction

"Pollution occurs when a substance, an organism, or energy (e.g., sound or heat) is released into the environment by human activities and produces an adverse effect on organisms or the environmental processes on which they depend."

This report provides background on the effects of pollution on life in the ocean and coastal waters of the United States for the Pew Oceans Commission, which is conducting a national dialogue on policies needed to restore and protect living marine resources. Pollution occurs when a substance, an organism, or energy (e.g., sound or heat) is released into the environment by human activities and produces an adverse effect on organisms or the environmental processes on which they depend.

Marine pollution comes in many forms and from many sources (Table 1). Some pollutants in sufficient concentrations are toxic to marine organisms. These include both naturally occurring chemicals present in much higher concentrations as a result of human activities (e.g., trace metals and oil) as well as compounds that did not exist in nature until manufactured by humans (e.g., pesticides such as DDT).

Other pollutants are harmful not because they are toxic but because they stimulate biological activity or alter habitats. The addition of large amounts of organic matter in the form of sewage or fish-processing wastes, for example, supports the growth of decomposer microbes that can exhaust the available oxygen supply. Inputs of nutrients (particularly forms of nitrogen and phosphorus), while responsible for the rich biological productivity of many coastal waters, can stimulate the production of more organic matter than an ecosystem can assimilate. Turbid waters, depletion of oxygen, and blooms of noxious algae may result. Sediments from land runoff or from dredging can decrease water clarity and smother sensitive bottom habitats such as reefs and seagrass beds.

Pollution emanates from either direct discharges or diffuse sources. Land-based industrial and municipal outfalls discharge wastewater into coastal waters or rivers that drain to the coast. Other direct discharges include those from vessel operations and at-sea waste disposal. Pollutants from diffuse sources include those released into the atmosphere by fossil-fuel and waste combustion; and land runoff of pesticides, toxic-waste products, nutrients, and sediments. Although chemical contaminants—released as a result of human activities—can now be found throughout the world's oceans, most demonstrable effects on living resources occur in coastal waters and are the result of pollution from land.

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Table 1

Forms of Marine Pollution

Form	Sources	Effects and Trends
Toxins (e.g., biocides, PCBs, trace metals)	Industrial and municipal wastewaters; runoff from farms, forests, urban areas and landfills; erosion of contaminated soils and sediments; vessels; atmospheric deposition	Poison and cause disease and reproductive failure; fat-soluble toxins may biocencentrate, particularly in birds and mammals, and pose human health risks. Inputs into U.S. waters have declined, but remaining inputs and contaminated sediments in urban and industrial areas pose threats to living resources.
Biostimulants (organic wastes, plant nutrients)	Sewage and industrial wastes; runoff from farms and urban areas; airborne nitrogen from combustion of fossil fuels	Organic wastes overload bottom habitats and deplete oxygen; nutrient inputs stimulate algal blooms (some harmful), which reduce water clarity, cause loss of seagrasses and coral reefs, and alter food chains supporting fisheries. While organic waste loadings have decreased, nutrient loadings have increased (NRC, 1993a, 2000a).
Oil	Runoff and atmospheric deposition from land activities; shipping and tanker operations; accidental spills; coastal and offshore oil and gas production activities; natural seepage	Petroleum hydrocarbons can affect bottom organisms and larvae; spills affect birds, mammals and nearshore marine life. While oil pollution from ships, accidental spills, and production activities has decreased, diffuse inputs from land-based activities have not (NRC, 1985).
Radioactive isotopes	Atmospheric fallout, industrial and military activities	Few known effects on marine life; bioaccumulation may pose human health risks where contamination is heavy.
Sediments	Erosion from farming, forestry, mining, and development; river diversions; coastal dredging and mining	Reduce water clarity and change bottom habitats; carry toxins and nutrients. Sediment delivery by many rivers has decreased, but sedimentation poses problems in some areas; erosion from coastal development and sea-level rise is a future concern.
Plastics and other debris	Ships, fishing nets, containers	Entangles marine life or is ingested; degrades beaches, wetlands and nearshore habitats
Thermal	Cooling water from power plants and industry	Kills some temperature-sensitive species; displaces others. Generally, less a risk to marine life than thought 20 years ago.
Noise	Vessel propulsion, sonar, seismic prospecting, low-frequency sound used in defense and research	May disturb marine mammals and other organisms that use sound for communication.
Human pathogens	Sewage, urban runoff, livestock, wildlife	Pose health risks to swimmers and consumers of seafood. Sanitation has improved, but standards have been raised (NRC, 1999a).
Alien species	Ships and ballast water, fishery stocking, aquarists	Displace native species, introduce new diseases; growing worldwide problem (NRC, 1996).

Adapted from Weber, 1993.

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The report first reviews accomplishments in reducing marine pollution, and then highlights the need for further reductions in the effects of toxic substances and nutrients as remaining major challenges. Diffuse sources of pollution via land runoff and atmospheric deposition are particularly important and have proved difficult to control. To provide grounding for policies needed to restore and protect living marine resources, the report: describes the forms, sources, movements, and effects of pollutants; assesses past and future trends of pollution in the U.S.; considers additional steps that could reduce pollution; and places pollution threats into a broader context of other threats to living resources.

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II. Reductions of **Pollution**

Municipal and Industrial Discharges

In 1972, Congress passed the landmark Federal Water Pollution Control Act, which was reauthorized in 1977, 1981, and 1987 as the Clean Water Act (CWA). The goal of the law is to eliminate pollution in the nation's waters. It imposes uniform minimum federal standards for municipal and industrial wastewater treatment based on best available technology. Facilities discharging wastes at discernible points are required to obtain permits from the U.S. Environmental Protection Agency (EPA) or from state pollution-control agencies. Permits include enforceable limits on pollutants in the discharges, and require dischargers to conduct monitoring and to file reports when limits are violated.

Most publicly owned treatment works (POTWs) handle industrial wastes as well as domestic sewage. Because discharges of untreated organic wastes had degraded many rivers, lakes, and coastal waters by depleting dissolved oxygen and causing fish kills, the Clean Water Act required POTWs to achieve at least "secondary" treatment. Secondary treatment adds biodegradation of the organic matter in the wastewater to the solids (sludge) removal and disinfection included in "primary" treatment. Consequently, it significantly reduces the biological oxygen demand (BOD) of wastewater effluent. The CWA provided substantial amounts of money to help pay for the required POTW improvements. About 125 billion dollars have been spent in constructing or expanding POTWs, mainly between 1972 and 1992 when federal grants provided three-quarters of the costs (NRC, 1993a). Waivers to this requirement were allowed for several deep ocean outfalls where it could be demonstrated that the organic wastes would not harm the environment. Additional waste treatment, such as reduction of suspended solids, was often required.

Technology-based standards and the National Pollutant Discharge Elimination System (NPDES) have resulted in a dramatic reduction in the amount of pollutants entering U.S. waters, including coastal waters. Reductions in discharges of organic matter improved conditions in the Delaware River estuary near Philadelphia to the point that low oxygen levels no longer prevent the upriver migration of juvenile striped bass and American shad (Weisberg et al., 1996). Oxygen levels in New York Harbor are approximately 50 percent higher (NRC, 1993a). The most thoroughly documented example of the benefits of

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improved treatment may be the Southern California Bight, off Los Angeles and San Diego (Box 1), where inputs of many pollutants have been reduced 90 percent or more over a 25-year period. Kelp beds, fish and invertebrate communities, and certain seabird populations have greatly, if not completely, recovered. These improvements have been accomplished despite a steady increase in population and in the volume of wastewater discharged.

Another long-term effort to restore water quality has recently come to fruition with the completion in September 2000 of a new deepwater outfall for treated effluents from the Boston region. The offshore discharge into Massachusetts Bay will result in improvements in environmental quality in Boston Harbor beyond those already achieved as a result of the cessation of sludge disposal, reductions in combined sewer overflow, and secondary treatment of

Box 1

Southern California Bight Ocean Discharges

Wastes from the nation's largest metropolitan center (17 million people) are discharged into a bight of the Pacific Ocean via deepwater (about 200 feet) outfalls. Pollution from publicly owned treatment works (POTWs) has been reduced significantly since the 1970s even though the population served and wastewater volumes grew steadily (Schiff et al., 2000; Figure 1). This reduction was accomplished through source control, pretreatment of industrial wastes, reclamation, and treatment-plant upgrades, including secondary or other advanced treatment (concentrating on chemical removal of suspended solids). Capital improvements to POTWs throughout the Southern California Bight cost more than five billion dollars.

Discharges from POTWs of most pollutants into the bight have decreased: 50 percent for suspended solids and biological oxygen demand, 90 percent for combined trace metals, and more than 99 percent for chlorinated hydrocarbons. Bight sediments show a record of decreasing contamination. Concentrations of contaminants in fish and marine mammals have declined. Kelp beds near the POTWs have returned. The extent of degraded bottom communities has contracted by about two-thirds; and the incidence of tumors and other maladies in bottom fish has returned to background levels.

A unique problem for the bight is the fact that large quantities of the pesticide DDT were previously discharged, particularly through the Los Angeles County's POTW. This facility received wastes from the world's largest DDT manufacturer. In 1971 an estimated 440,000 pounds of DDT were discharged via an outfall off Palos Verdes. Today, only 3 pounds of DDT are discharged from all Southern California POTWs combined (Schiff et al., 2000). Concentrations of DDT and its degradation products have declined greatly in fish and marine mammals. Populations of brown pelicans, which were decimated by the eggshell thinning induced by DDT contamination, have rebounded. However, brown pelicans, bald eagles, and peregrine falcons are still being affected by the residual DDT contamination in the bottom sediments of the bight. Although this "legacy" contamination is slowly being buried, some DDT is still remobilized into the food chain.

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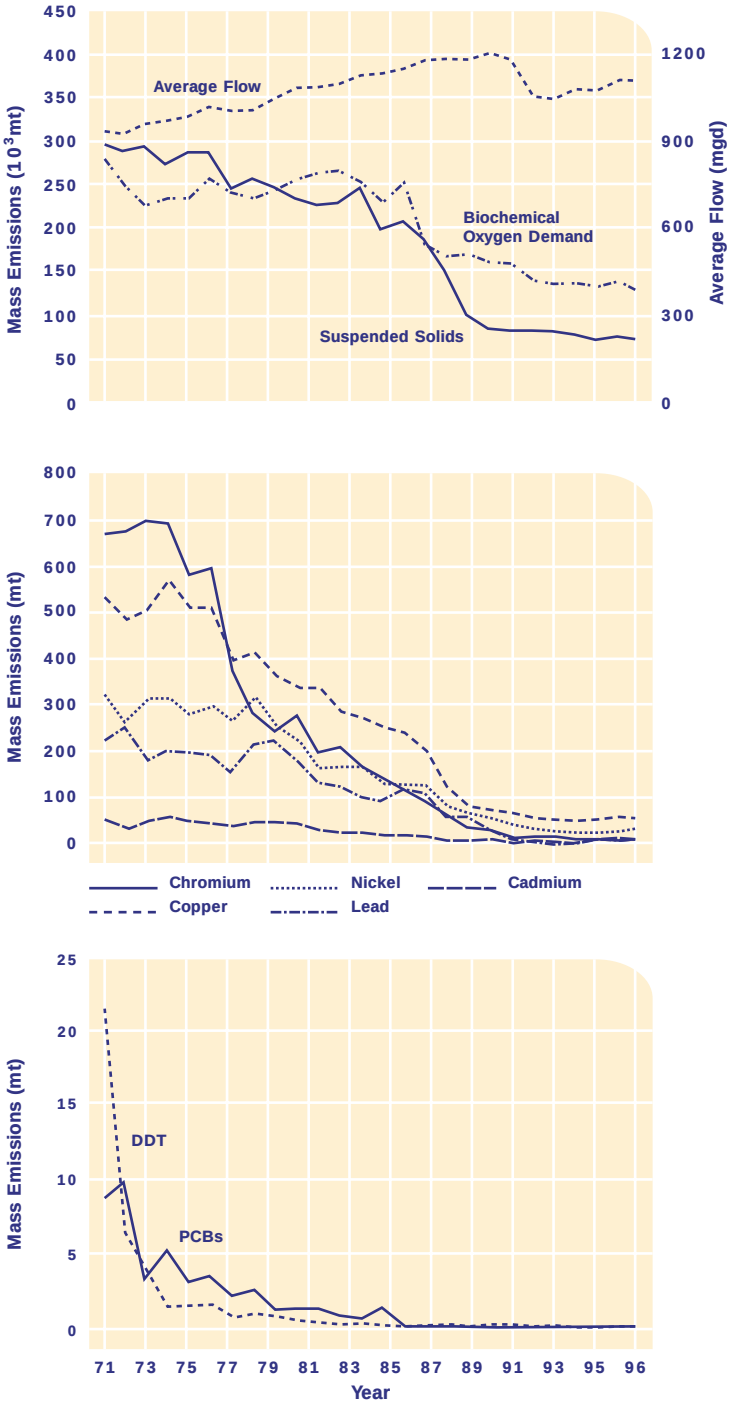
wastes. Although recovery is far from complete, liver tumors in flounder are less common, mussels accumulate lower levels of organic contaminants, and bottom invertebrate communities are recovering in the harbor (Rex, 2000). Field studies and computer models predict that moving the discharge offshore to deeper waters will not increase concentrations of pollutants, including nutrients, in Massachusetts Bay.

Although secondary treatment of municipal sewage removes at least 85 percent of the organic material and suspended solids in wastewater, only one-third of the nitrogen and phosphorus is eliminated (NRC, 1993a; NRC, 2000a). These two nutrients are the principal causes of eutrophication of receiving waters (see Section IV). Advanced treatment technologies, capable of eliminating up to 97 percent of the nitrogen and 99 percent of the phosphorus (NRC, 2000a), are being implemented in regions susceptible to nutrient overenrichment from direct discharges.

Pollutant levels have also been reduced in discharges from industries, including oil and gas production, refineries, chemical manufacturing, electric-power generation, and food processing. Although regionally important, industrial discharges contribute a relatively small portion of pollutant

Figure 1

Flow Volume and Pollutant Emissions from Four Largest Publicly Owned Treatment Works in the Southern California Bight, 1971 through 1996.



Source: Raco-Rands, 1999; Schiff et al., 2000.

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loadings on a national scale. Industrial discharges often have specific waste-reduction requirements that necessitate pollution prevention (elimination or reduction of the source in the industrial process), recycling and reuse, and advanced waste treatment.

Pollution from aquaculture—effluents from ponds or holding tanks on land and materials released from net pens and shellfish racks or rafts—is receiving new regulatory attention with the expansion of aquaculture in coastal waters. Pollutants include uneaten food, fecal and excretory material, and releases of antibiotics, pesticides, hormones, anesthetics, pigments, vitamins, and minerals. Organic deposits under net pens and shellfish rafts often alter the bottom habitat and affect seabed communities in the immediate vicinity. Extensive aquaculture operations can constitute a major source of nutrient inputs to the smaller bays and estuaries in which they are located. Antibiotic, pesticide, and hormone releases can also affect wild organisms in the region (Goldburg and Triplett, 1997).

Additional reductions of pollution from direct discharges will undoubtedly be required and more effective source controls and treatment technologies developed to meet those requirements. Two forces are driving these reductions. First, the Clean Water Act requires dischargers to implement advanced pollution controls where conventional technology is not sufficient to protect aquatic life and the human uses assigned to the water body receiving the discharge. Standards for designated uses are not currently met for one-third of U.S. waters (EPA 2000a). In such cases, the Clean Water Act specifies that total maximum daily loads (TMDLs) be determined and allocated among point and nonpoint sources. Second, ever-closer scrutiny is given to the inputs of chemicals that induce toxicity at very low concentrations, persist in the environment for long periods, and reach high levels of accumulation in the tissues of fish and wildlife.

Vessel Discharges

Pollutants are discharged to the ocean from the routine operations of ships and boats (including discharges of sewage and industrial-processing wastes and the release of petroleum hydrocarbons from engine exhausts and bilge and ballast waters). Vessel-related pollution may also occur as a result of accidental spills and solid-waste disposals.

At-sea release of oily water has been an international issue over the past 30 years and is regulated under the International Convention for the Prevention of Pollution from Ships. Compartments of oil tankers are typically filled with seawater for ballast when emptied of their cargo. Some ports, such as Port Valdez, Alaska, have ballast-water treatment facilities. Although ballast-water discharges may cause problems along some tanker routes and are responsible for tar

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balls that contaminate the surface of high seas, they comprise a relatively small percentage of oil pollution in the marine environment (NRC, 1985). Exhaust emissions into the water from smaller vessels may be a significant source of petroleum hydrocarbons in more confined coastal waters.

Atmospheric emissions from ships are being recognized as a significant source of global air pollution (Corbett and Fischbeck, 1997), yet they are not subject to the same restrictions for protection of air quality as are land-based power plants and manufacturers. Seagoing vessels are responsible for an estimated 14 percent of emissions of nitrogen from fossil fuels and 16 percent of the emissions of sulfur from petroleum uses into the atmosphere (Corbett and Fischbeck, 1997).

Cruise ships, although not a major source of pollution to U.S. coastal waters as a whole, can cause problems in areas such as Caribbean island harbors, which accommodate intense cruise-ship activity, or relatively pristine areas such as the inland passages of Alaska. Cruise ships generate sewage, gray water, solid wastes, oily wastes, and waste from photo processors, swimming pools and dry cleaners. (EPA, 2000b).

Ocean Dumping

The practice of transporting wastes for disposal in the ocean became a cause for national and international concern in the 1970s (CEQ, 1970). The Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matters, or the London Dumping Convention, came into force in 1975, acknowledging through its regulatory framework that different materials have vastly different impacts on the marine environment. Nationally, ocean disposal in U.S. waters has been regulated under the Marine Protection, Research, and Sanctuaries Act of 1972 (MPRSA) by a permit procedure that prohibits dumping of some materials, establishes criteria to authorize dumping of others, and identifies sites for disposal. The Clean Water Act also regulates discharges into the territorial sea and navigable waters of the United States. In the ten years following passage of the MPRSA, dumping of industrial waste, construction debris, solid waste, and incineration of chemicals remained low, but dumping of sewage sludge doubled (Burroughs, 1988). Although the amount of dredged sediment disposed in coastal waters remained constant, it was approximately an order of magnitude greater in volume than the sludge dumped (Figure 2).

During the 1980s, public apprehension about ocean dumping grew. Sewage sludge dumped in the New York Bight was blamed for an apparent decline in water quality and health risks to bathers. Controversy also erupted over ocean incineration of chemical wastes in the Gulf of Mexico. In 1988,

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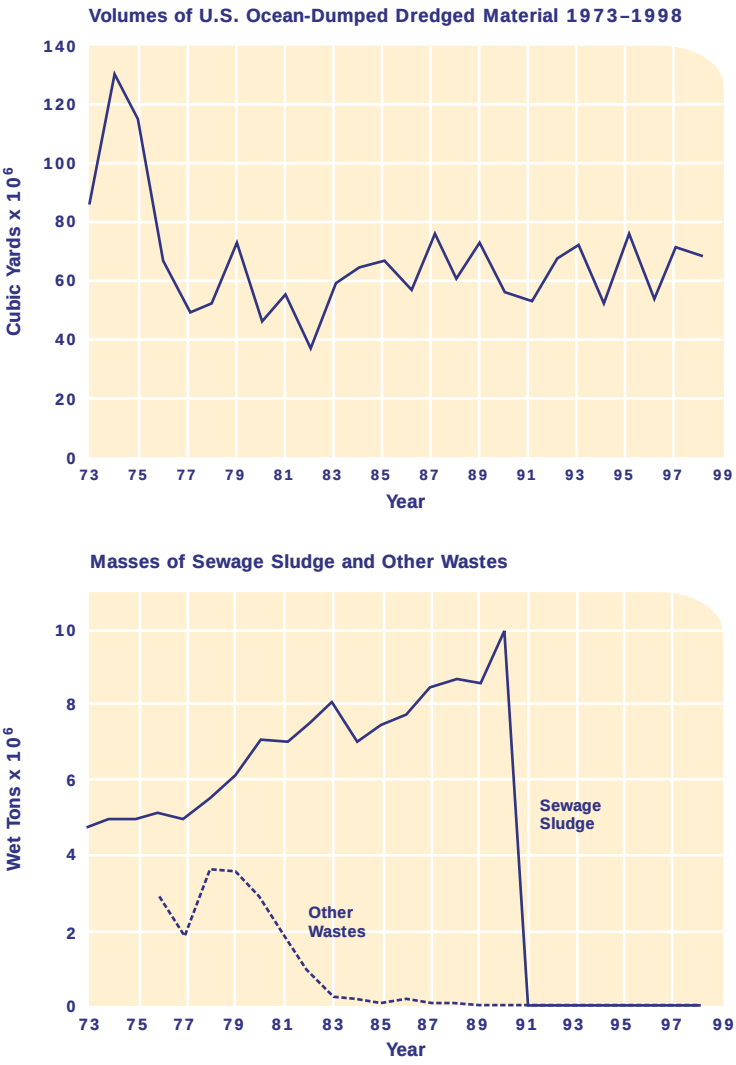
Figure 2

Amounts of Dredged Material and Other Wastes Dumped in U.S. Waters, 1973 through 1998



Source: U.S. Army Corps of Engineers, 1999; EPA, 1991.

Congress enacted the Ocean Dumping Ban Act that prohibited ocean dumping of sewage sludge and industrial chemicals. Sewage sludge must now be incinerated, disposed of on land, or reused—alternatives that have their own set of environmental impacts, including pollution of the marine environment via land runoff and atmospheric deposition.

Today, virtually all the material dumped into coastal and marine waters is bottom sediment removed by dredging (Figure 2). Under the Clean Water Act, the U.S. Army Corps of Engineers issues permits for disposal of dredged material, subject to guidelines established by EPA. Protocols have been developed to determine whether dredged sediments are suitable for placement in the ocean or coastal environment. These protocols involve an assessment based on the sediment characteristics, contaminant levels, the toxicity of contaminants present, and the potential for the contaminants to accumulate in the tissues of organisms (EPA, 1991). Based on these criteria, dredging may not be permitted at all or the dredged sediments may be deemed unacceptable for overboard disposal. Placement in a landfill, in a confined disposal facility, or in a contained underwater disposal site is then required. Approximately five to ten percent of the sediments dredged require management as contaminated sediments (NRC, 1997).

Although the federal laws governing dredged material disposal have eliminated the practice of discarding heavily contaminated harbor sediments in the marine environment, they have not eliminated controversies. Despite the protections afforded by regulatory requirements and testing

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protocols, significant controversies surround the overboard disposal of dredged sediments that are deemed acceptably "clean." These controversies are related in part to the physical impacts of dredged sediment placement, including increased turbidity, siltation, burial of bottom organisms, and permanent changes in the quality of bottom habitat. In addition, the public, resource users, and environmental managers are concerned that contaminants in the dredged sediment will be mobilized and made more bioavailable by overboard disposal. As a result, many ports struggled to resolve impasses in selecting and permitting alternatives for dredged sediment placement (Box 2). On one side, there is an aversion to placing wastes of any kind into the ocean and coastal waters; on the other, there are constraints related to costs, limits in the feasibility of beneficial uses, and opposition to disposal alternatives outside of the marine environment.

The volume of commerce moving through U.S. ports is increasing and will continue to do so because of increased world trade and dependence on foreign

Box 2

San Francisco Bay: Long-Term Strategy for Dredged Material

Navigation channels and berths in San Francisco Bay tend to fill in rapidly because of the large amount of mobile sediments in the bay—a legacy of placer mining following the California Gold Rush—and strong tidal currents. Dredged sediments were typically placed back into the bay, mostly at a site near Alcatraz Island, where strong tidal currents dispersed them. However, disposal of large quantities of sediments generated from channel deepening changed the current patterns at the Alcatraz site so that sediments placed there no longer dispersed.

The limitations of this site, the lack of readily available alternatives, public concerns, lawsuits, and fragmented agency management coalesced to create an impasse, or so-called mudlock, that halted most dredging. This caused significant problems for both commercial and military shipping. The U.S. Navy, citing national security requirements, broke the impasse by dumping dredged sediments at a deepwater site in the ocean. Subsequently, EPA designated an ocean disposal site to receive sandy sediments dredged by federally funded projects.

In 1990, federal, state, and regional agencies joined with navigation interest groups, fishing groups, environmental organizations, and the public to develop a Long-Term Management Strategy for Bay Area dredged material (U.S. Army Corps of Engineers, 1998). The strategy emphasizes a balance between ocean disposal and beneficial reuse at upland/wetland sites with limited in-bay disposal. During a transitional period, the amount of dredged material deposited at in-bay sites would be reduced from 80 percent to 20 percent, while upland sites, reuses, and wetland restoration are developed. Toxicity testing and monitoring would be bolstered. Nonetheless, environmental interest groups are calling for the elimination of in-bay disposal altogether.

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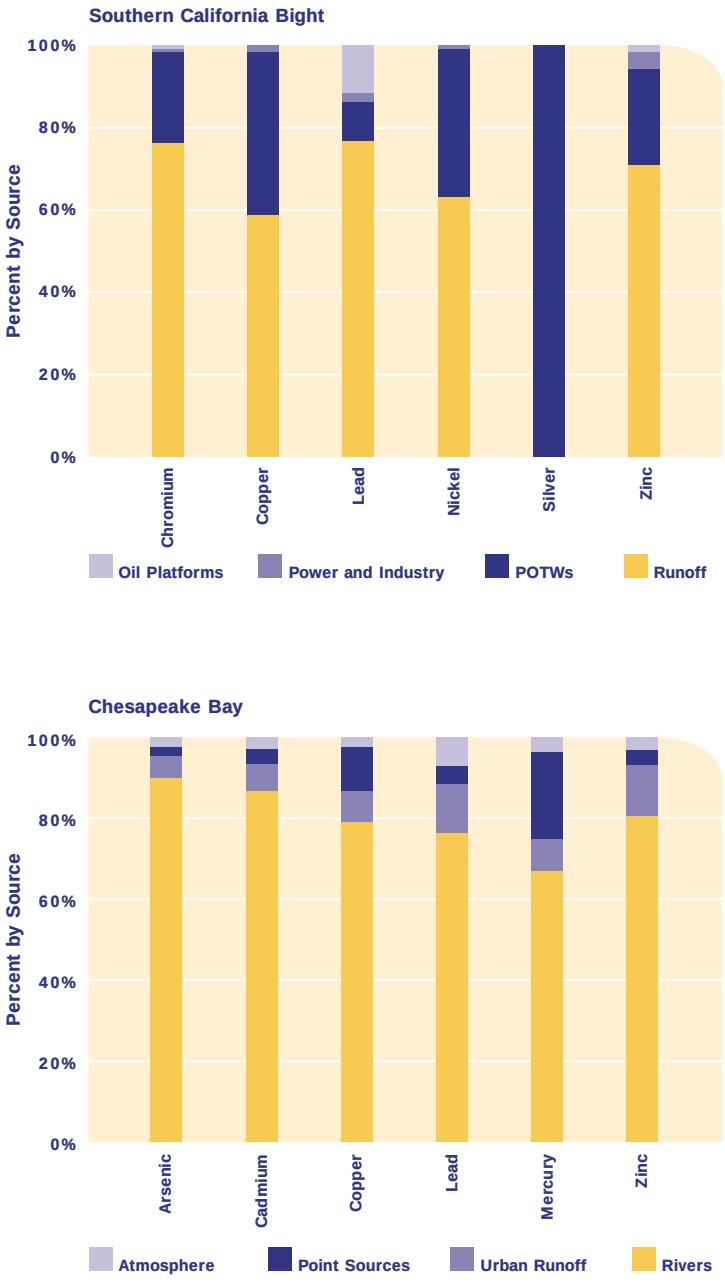
Figure 3

Sources of Loadings of Trace Metals to the Southern California Bight



Source: Schiff et al., 2000; Chesapeake Bay Program, 1999.

energy resources (Bureau of Transportation Statistics, 2000). This is driving a trend toward larger ships with deeper drafts and, thus, continued pressure for deeper channels. Although there has been an effort to develop a national policy for screening dredged material and evaluating disposal options (Maritime Administration, 1994), the U.S. lacks a coherent port development policy that is compatible with the environmental quality objectives articulated in federal environmental statutes.

Diffuse Sources of Pollution

In most U.S. coastal regions, diffuse sources of pollution—including land runoff and atmospheric deposition—are now responsible for most serious water-quality problems (EPA and USDA, 1998). Because of the reduced loadings of many contaminants achieved by point-source controls, land runoff is currently the dominant source of many contaminants in both the Southern California Bight and Chesapeake Bay (Figure 3).

Except where the manufacture or use of a contaminant has ceased or changed dramatically—such as for DDT and some other pesticides, PCBs, or lead additives in gasoline—the contribution of diffuse sources of pollution in coastal and ocean waters has not been significantly reduced by the programs implemented over the last 30 years. Moreover, loadings of some pollutants from diffuse sources, such as nitrogen (Howarth et al., 1996; Goolsby et al., 2000) and mercury

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(Swain et al., 1992), appear to have increased during that time period.

The importance of diffuse sources of pollutants has long been recognized. There are provisions in the Clean Water Act and Coastal Zone Management Act intended to achieve reductions in pollution of coastal waters from diffuse sources. Nonetheless, improvements have been slow and difficult. This is due to the diversity of diffuse sources, resistance to regulatory solutions, and the multiple pathways through which the pollutants may reach coastal and ocean environments.

Fallout from the atmosphere is an important and previously under-appreciated source of a number of important pollutants, including nitrogen, lead, mercury, and organochlorine compounds such as DDT and PCBs (Box 3). Some of these pollutants can be transported over long distances before falling onto the ocean or on watersheds draining to the coast. Atmospheric transport is the primary mechanism for contamination of oceanic regions remote from human activities, such as polar seas and the open ocean. In a recent report to Congress, the EPA (2000c) indicated that atmospheric deposition of PCBs, banned and restricted pesticides, and lead has been declining in recent years for the Great Lakes and some coastal waters, but that deposition of other pollutants such as nitrogen has not fallen off.

Contaminants and nutrients in runoff are influenced by: (1) land uses, i.e., whether the land is forested, agricultural, industrial or urban; (2) human activities that involve the purposeful or unintended placement of fertilizers, pesticides, atmospheric contaminants, and wastes on the land surface; and (3) natural phenomena and land-use decisions that affect water infiltration, retention, groundwater movement, runoff, and transport in streams and rivers.

Sediments that erode from the land and reach the coast in runoff carry various contaminants bound to sediment particles, including trace metals, organic compounds, and phosphorus. The sediments themselves can constitute a serious form of pollution, silting up shallow water environments, increasing the need for dredging, altering benthic habitats, and decreasing water clarity. Alternatively, improved soil conservation practices and the entrapment of riverine sediments behind dams have resulted in decreased delivery of sediments to many U.S. coastal environments over the last half century (Meade, 1982). For some coastal environments, this has improved the conditions for living resources by increasing water clarity and decreasing sedimentation; however, other coastal ecosystems, such as sandy beaches and subsiding deltas (Milliman, 1997), are experiencing problems because a continued supply of sediments is needed to sustain them. *(Continued on page 14)*

"Atmospheric transport is the primary mechanism for contamination of oceanic regions remote from human activities, such as polar seas and the open ocean."

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Box 3

The Atmosphere: An Important Pathway for Some Pollutants

Atmospheric deposition of pollutants involves a variety of physical processes that transport chemicals to the Earth's surface (Baker, 1997; Figure 4). Wet deposition involves processes by which gases and airborne particles are washed from the atmosphere during precipitation. Dry deposition results from the impact of fine particles (aerosols) on surfaces and on gas exchange at terrestrial and aquatic surfaces. The magnitude of atmospheric deposition depends directly on the concentration of pollutants in the atmosphere, the form of each chemical (gas or particulate), the size of the aerosol particles, and the extent of precipitation and physical mixing.

Pollutants are introduced into the atmosphere from a variety of sources, travel through several pathways, and reach various fates. Materials such as soot, NO_X, and SO_2, are released from natural sources (forests, volcanoes, and fires) as well as from human activities (anthropogenic sources). However, many atmospheric pollutants (e.g., PCBs, CFCs) are only derived from anthropogenic sources. Sources of air pollutants are commonly categorized as stationary (e.g., power plants, refineries, and incinerators), mobile (vehicles, aircraft, locomotives, and ships), or area (e.g., volatilization of ammonia from manure).

The lifetime of a pollutant in the atmosphere is dependent on its chemical reactivity and its partitioning among gas, liquid, and solid phases. In general, chemicals on particles or in liquid water have a shorter lifetime in the atmosphere and are not transported far from their source, while gaseous chemicals may remain in the atmosphere a long time and travel great distances. Persistent chemicals that are revolatilized after being deposited can travel like a grasshopper over great distances. Because these chemicals are more prone to evaporation under warmer temperatures, they tend to be redistributed to higher latitudes (Wania and Mackay, 1996).

Atmospheric deposition is an important source of nitrogen, some trace metals (e.g., lead and mercury), and organochlorine compounds (e.g., DDT and PCBs) to coastal and ocean environments:

- Lead emissions to the atmosphere in the U.S. and Europe are now orders of magnitude lower than in the early 1970s due to ending the use of leaded additives to gasoline. The impact can be seen in the reduction of lead concentrations in surface waters of the open ocean (Wu and Boyle, 1997), coastal sediments (Bricker, 1993; Cochran et al., 1998; Hornberger et al., 1999), and shellfish tissues (Lauenstein and Daskalakis, 1998).
- The global reservoir of atmospheric mercury has increased by a factor of two to five since the beginning of industrialization (Boening, 2000) and is dominated by anthropogenic emissions (Mason et al., 1994). Principal sources (>80 percent) are combustion processes, primarily coal burning and municipal and medical-waste incineration (EPA, 1997). Higher mercury concentrations in wet deposition are found in urban areas, reflecting local power plant and incinerator sources (Mason et al., 2000). Surface waters of the North Atlantic have higher mercury concentrations compared to the equatorial Pacific (Mason and Fitzgerald, 1996), probably as a result of long-distance transport of gaseous forms of mercury from sources in North America.
- The discovery of organochlorine pesticides such as DDT and industrial chemicals such as PCBs in the waters and biota of the Arctic and Antarctic ecosystems fundamentally altered our view of the role of the atmosphere in distributing pollutants on a global scale (Wania and Mackay, 1996).

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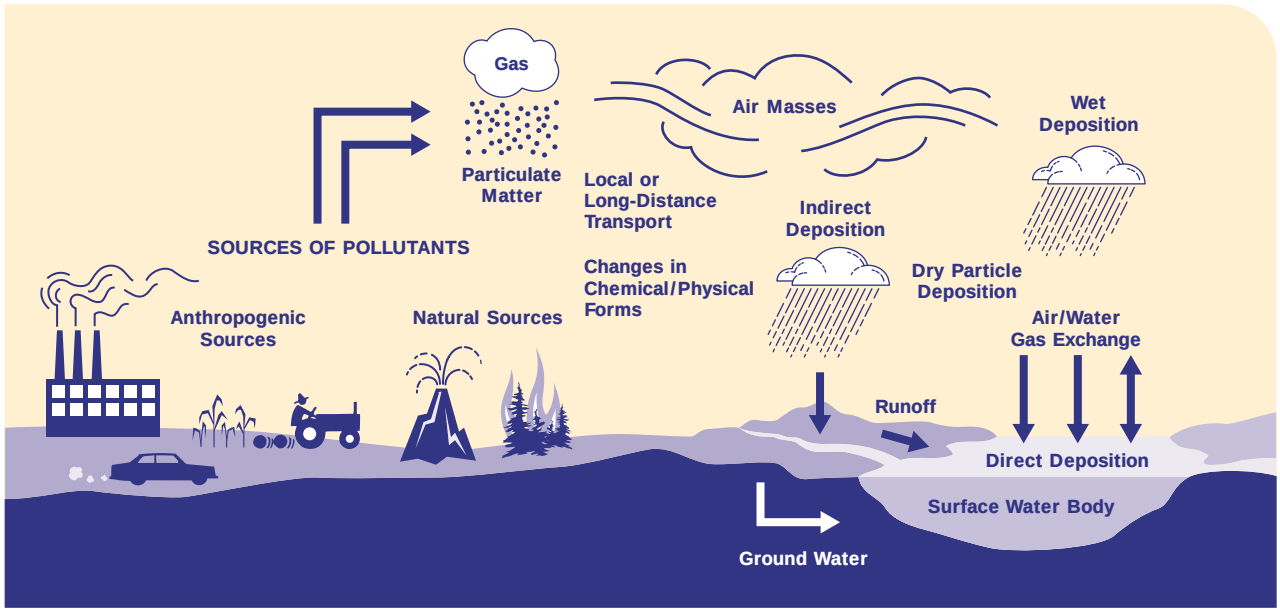
Conversion of lands to urban and suburban uses has been proceeding at a rate far greater than the rate of population growth in many coastal communities as a result of the U.S. tendency for low-density residential development (sprawl). The conversion of previously undisturbed land surfaces that allowed the infiltration and slow release of water to impervious surfaces such as roofs, driveways, roads, and parking lots results in higher peak runoff, which carries greater pollution loads and alters the salinity balance in bays and estuaries during both wet and dry weather periods.

While direct discharges still contribute significant toxic contaminants and nutrients to coastal waters, it is clear that protecting the marine environment from the many adverse effects of pollution will require more effective control of land runoff and atmospheric deposition—now the principal sources of the most damaging pollutants in many coastal ecosystems.

"...it is clear that protecting the marine environment from the many adverse effects of pollution will require more effective control of land runoff and atmospheric deposition...."

Figure 4

Atmospheric Release, Transport, and Deposition Processes



Source: EPA, 2000c.

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III. The Challenge of Toxic Contaminants

"The historic use of some compounds no longer manufactured or used in the United States—like DDT, PCBs, and lead additives in gasoline—has left a legacy of contamination."

Nature of Toxic Contaminants

Toxic pollutants include trace metals (e.g., cadmium, copper, lead, and mercury), a variety of biocides (e.g., DDT, tributyl tin) and their by-products, industrial organic chemicals (e.g., PCBs and tetrachlorobenzene), and by-products of industrial processes and combustion (e.g., polycyclic aromatic hydrocarbons, or PAHs, and dioxins). Those pollutants meriting greatest attention are widespread and persistent in the environment, have a propensity to accumulate in biological tissues, or induce biological effects at extremely low concentrations.

The historic use of some compounds no longer manufactured or used in the United States—like DDT, PCBs, and lead additives in gasoline—has left a legacy of contamination. Generally, legacy contaminants in U.S. coastal environments have declined. However, these compounds are still in use in other countries and they continue to run off the land. For example, it has been estimated that less than 10 percent of the total lead deposited from the atmosphere onto the Sacramento and San Joaquin river basins has yet been delivered to San Francisco Bay (Steding et al., 2000). As the concentrations of some heavy metals and organochlorine compounds decrease in the marine environment, other contaminants are still being released and do not show a clear downward trend. Some may even be increasing. For example, analyses of lake and reservoir sediments show increasing levels of PAHs associated with suburban development (Van Metre et al., 2000). PAHs come from multiple sources, including petroleum and the combustion of fossil fuels and biomass, some of which have been reduced (e.g., coal coking) and some of which continue (e.g., urban runoff and atmospheric deposition of combustion by-products).

Humankind will be dealing with legacy contaminants of the marine environment well into the future. Repositories of persistent contaminants in marine sediments can be sources of long-term exposure to marine life well after the inputs of these contaminants have largely ceased. Examples of this include DDT in the Southern California Bight (Box 1) and PCBs in San Francisco Bay (San Francisco Estuary Institute, 1996). The deep sea may be the final sink for some persistent organic pollutants (Looser et al., 2000).

Biological Effects

Toxic effects, both lethal and sublethal, have been extensively documented in laboratory experiments, but concrete examples of con-

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taminant effects on populations of marine organisms are limited (McDowell et al., 1999). Key issues considered here include the potential for bioaccumulation of toxicants by marine life; the effects of disruptions of organisms' immune, endocrine, and reproductive systems on their populations; and the effects on marine communities of chronic exposure to the high concentrations of contaminants found in coastal sediments.

Organisms may accumulate contaminants from water, sediments, or food in their tissues. This can result in concentrations of the contaminant many times higher than those found in the environment. The degree of bioaccumulation depends on the level of exposure and the mechanisms by which the organism expels, stores, or metabolically breaks down the contaminant. Compounds such as organochlorine pesticides and PCBs tend to accumulate in fatty tissues (lipophilic compounds), where they may remain for long periods of time. Animals in the upper levels of the food web may accumulate these compounds from prey until lipid storage sites are saturated. Their metabolism is then challenged to degrade and excrete the contaminants or their metabolic by-products, some of which are much more toxic than the original form. In this way, highly persistent and bioaccumulative compounds can magnify through the food web, having little noticeable toxic effect except at the highest trophic levels. Trace metals are also subject to bioaccumulation, but except for metal-containing organic compounds (e.g., methyl mercury) do not biomagnify in marine organisms.

Bioconcentration and biomagnification of toxicants pose particular risks to predators of fish, including birds, marine mammals, and humans. High concentrations of toxicants, such as PCBs and mercury, necessitate health advisories for frequent consumers of fish in some regions (EPA, 1999). Perhaps the most widely recognized effect of persistent contaminants on marine populations is the decline of populations of bald eagles and brown pelicans during the 1960s and 1970s. DDT and its breakdown products accumulated in adult birds from their prey, leading to changes in calcium metabolism in breeding females. The birds produced abnormally thin eggshells and ultimately experienced reproductive failures (Hickey and Anderson, 1968; Blus et al., 1971).

Extensive evidence demonstrates that toxicants can disrupt the metabolic, regulatory, or disease defense systems of an organism, eventually compromising its survival or reproduction. For example, genetic damage, malformations, and reduced growth and mobility were observed in Pacific herring embryos exposed to PAH (from weathered oil) levels as low as 0.7 ppb (Carls et al., 1999). Mollusks exposed to PCBs in New Bedford Harbor, Massachusetts, experienced both a loss of

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reproductive output and increased susceptibility to disease (McDowell et al., 1999). Accumulation of PCBs and PAHs in Puget Sound rock sole has been correlated with reductions in spawning success (Johnson et al., 1998). Bioconcentration of PCBs has also been linked with impaired immune defenses that lead to disease and death in marine mammals, including seals and dolphins (Kuehl and Haebler, 1995).

Particular attention is currently being devoted to the disruption of endocrine systems by toxic contaminants. Some organochlorine pesticides, PCBs, dioxins, and other compounds functionally mimic or alter the production of hormones (NRC, 1999b). Tributyl tin (TBT), a biocide used in antifouling paints, has been shown to disrupt hormones controlling sexual development in mollusks exposed to concentrations as low as 10 parts per trillion, leading to irreversible reproductive abnormalities (e.g., females developing male sex organs) and reproductive failures (NRC, 1999b). Significant declines in marine snail populations have been documented in regions of North America and Europe where use of TBT was intense (Matthiessen and Gibbs, 1998; Nehring, 2000). Most uses of TBT paints in the U.S. were discontinued as a result of these findings. Feminization of males due to exposure to estrogen mimics and masculinization of females exposed to estrogen blockers have been observed in various animals, including mollusks, fish, reptiles, birds, and mammals (NRC, 1999b; Royal Society, 2000). For example, endocrine-disrupting chemicals have been implicated in the incidence of hermaphroditism in Norwegian polar bears and St. Lawrence beluga whales (De Guise et al., 1994).

Toxic substances in sediments appear to have localized effects in U.S. bays and estuaries and in certain offshore regions that received wastes, such as the New York and Southern California Bights. In the past decade, EPA's Environmental Monitoring and Assessment Program (EMAP) and National Sediment Quality Survey and NOAA's National Status and Trends Program have extensively measured the concentrations of contaminants in bottom sediments in the nation's bays and estuaries, collected collateral data on the communities of benthic organisms living in those sediments, and assayed toxicity of sediments to sensitive amphipod crustaceans. Using these three components—contaminant concentrations (and their probable effects based on an extensive database), the health of the communities living in the sediments, and experimental toxicity—Long (2000) concluded that biologically significant chemical contamination and toxic responses occurred throughout the nation's coastal waters, especially in the most urbanized and industrialized regions. Chemical concentrations exceeding guidelines for probable effects

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occurred in 26 percent of samples, representing 7.5 percent of the bays and estuaries surveyed. Generally, sediments proved toxic to the crustaceans where contaminant concentrations were high and benthic communities degraded.

This three-pronged approach involving field studies does not fully resolve which contaminants and other factors are actually responsible for the toxicity and community degradation. The synergistic, additive, or antagonistic interactions among contaminants are poorly understood and challenging to assess, thus making it difficult to predict biological responses simply based on knowledge of the types and concentrations of contaminants present in a given area (Yang, 1998).

Pollution Abatement and Remediation

The most effective way to reduce the harmful impacts of toxic contaminants on marine ecosystems is to eliminate or restrict their use or production. The experiences with lead additives in gasoline, DDT, and PCBs show that in the long term this approach can reduce environmental concentrations and exposure for marine organisms. In addition to discontinuing the use or production of these substances, source controls, recycling and reuse, and other forms of "pollution prevention" provide the first line of defense (NRC, 1993a). Treatment and removal of pollutants from effluents and atmospheric emissions provide a second line of defense. Improved knowledge of the fate and effects of various classes of compounds and screening processes for new chemical products have reduced, but not totally eliminated, the risk of "surprises" such as DDT, PCBs, and TBT.

Legacy contaminants must be managed for decades to centuries into the future. Options include control of losses from waste sites and contaminated soils on land, treatment of urban stormwater, and remediation of contaminated sediments. Contaminated sediments exist in many ports, where they pose a risk of reintroduction of toxicants into the water column by physical disturbance of sediments or transferal through the food chain. Options for managing contaminated sediments include: leaving them in place to allow recovery to proceed through degradation and burial, capping them with clean sediments, treating them in place, and removing them for containment or treatment (NRC, 1997).

In the case of the pesticide kepone in the James River estuary, Virginia, the decision was to leave the contaminated sediments in place, and subsequent reductions of contaminants levels in the ecosystem and organisms were observed (NRC, 1997). However, when contaminant levels are high and the risks of reintroduction are great, capping may speed recovery of the ecosystem. The EPA has proposed placing clean

"The most effective way to reduce the harmful impacts of toxic contaminants on marine ecosystems is to eliminate or restrict their use or production."

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sediments atop portions of the DDT deposits off Palos Verdes, California, in order to test the feasibility and effectiveness of this remediation method. Representatives of the DDT manufacturer have criticized this method because DDT concentrations in surface sediments have been declining and the process may expose heavily contaminated sediment below the surface (Whitaker, 2000). A similar controversy surrounds proposals to cap the dredged sediment disposal site in the apex of the New York Bight. These cases exemplify the dilemma faced in making decisions regarding remediation of contaminated sediments.

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IV. The Challenge of Nutrient Pollution

Nutrient Overenrichment

An increase in the supply of organic matter in a water body is termed eutrophication (Nixon, 1995; see sidebar in Abstract). Over the last 30 years the discharge of organic wastes from municipal and industrial sources declined as a result of improved treatment. At the same time, eutrophication in many areas became more extensive due to increased loadings of mineral nutrients, particularly nitrogen and phosphorus, which stimulate the production of organic matter within the marine ecosystem. There are many consequences of this increased organic production, both beneficial and harmful. The latter include hypoxia, or stressfully low dissolved oxygen, reductions of seagrass beds and corals, and, potentially, noxious or toxic blooms of algae.

Nutrient pollution has been increasingly recognized as a key threat to coastal environments over the past 20 years because of both new scientific understanding and declining trends in water quality (Nixon, 1995). Loadings of nitrogen flowing in rivers to the Atlantic and Gulf coasts of the United States have increased four to eight fold from the time of European colonization (Howarth et al., 1996). Most of that increase came in the last half of the 20th century. Scientific research has demonstrated that nutrient overenrichment was a major contributor to the extensive changes observed in coastal ecosystems during that period. Three recent scientific assessments addressed nutrient pollution in U.S. coastal waters.

The National Oceanic and Atmospheric Administration characterized the symptoms of eutrophication for 138 bays and estuaries around the U.S. coast based on data review and expert consultations (Bricker et al., 1999). Approximately one-third of the water bodies had high expressions of eutrophic conditions (Figure 5). Altogether, 82 water bodies, representing 67 percent of the combined surface area of these bays and estuaries exhibited moderate to high degrees of depleted dissolved oxygen, loss of seagrasses, or harmful algal blooms. Moreover, it was predicted that eutrophic conditions would become more severe in 86 of these ecosystems by 2020. Systems having low inflow, poor flushing, or strong stratification are particularly susceptible to eutrophication. While this assessment was limited to estuaries and bays in the conterminous states, nutrient pollution has also resulted in loss of coral reef habitat and seagrasses in U.S. tropical regions (Bell, 1992; Lapointe, 1999). *(Continued on page 22)*

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Figure 5

Areas of Significant Eutrophication in U.S. Coastal Waters

A recent National Oceanic and Atmospheric Administration (NOAA) study examined 138 estuaries along the coasts of the conterminous United States. A group of experts identified 44 estuaries and coastal areas (labeled on the map below) with high levels of eutrophication and found an additional 40 estuaries (not shown) with moderate symptoms of eutrophication. The highest percentage of estuaries with high levels of eutrophication occurs in waters along the coasts of the Middle Atlantic and the Gulf regions.

Eutrophication is the long-term increase in the supply of organic material to an ecosystem, often as a result of excess nutrients. Signs of eutrophication in coastal waters include increased phytoplankton growth, increased growth of macroalgae and epiphytes (plants that overgrow other plants), low dissolved oxygen, harmful algal blooms, and loss of seagrasses. Typically one or more of these symptoms is seen over large areas and/or persistently within the estuary. The "Dead Zone" in the Gulf of Mexico refers to an extensive area of seasonal hypoxia, or depletion of dissolved oxygen, in the bottom waters.

Adapted from Bricker et al., 1999.

Box 4

Gulf of Mexico's "Dead Zone"

In a large region of the inner continental shelf off the coast of Louisiana and Texas, the bottom water oxygen levels fall too low (<2 mg/L) to support fish, crustaceans, and many other invertebrates during the warmer months of April to September. This hypoxic zone, or Dead Zone, has been as large as 12,000 square miles (20,000 km^2) but varies in dimensions from year to year and within years, depending on river runoff, and meteorological and oceanographic factors. A recently completed integrated assessment conducted under the auspices of the President's National Science and Technology Council (CENR, 2000) concluded that:

1. the hypoxia is caused primarily by excess nutrient runoff (particularly of nitrogen) from the Mississippi-Atchafalaya River Basin in combination with stratification of Gulf waters;
2. landscape alterations and river channelization during the late 19th century and first half of the 20th century reduced the river basin's hydrologic buffering capacity;
3. eutrophication and hypoxia increased during the latter half of the 20th century during which the flux of nitrate-nitrogen almost tripled (between 1955–1970 and 1980–1996), concomitant with the rapid increase in the use of chemical fertilizers;
4. about 90 percent of the nitrate load comes from diffuse sources, particularly from agricultural lands along the upper Mississippi and Ohio rivers, nearly 1000 miles upstream from the river's mouth; and
5. Gulf ecosystems and fisheries are affected by hypoxia, but economic impacts are difficult to quantify.

Models predicted significant reductions in hypoxia would occur with a 20 to 30 percent nitrogen load reduction. Two approaches are required to achieve that level of reduction: (1) improved agronomic practices that reduce nitrogen losses from farm fields and (2) trapping nitrogen lost from fields in restored wetlands, vegetated buffers, reconnected floodplains, and coastal wetlands. These recommendations have been met with considerable controversy regarding both the certainty of the science and the costs and impacts on food production among midwestern states and agricultural interests. In October 2000, a task force including senior policymakers from eight federal agencies, nine states, and two tribal governments set a general goal to reduce the average area experiencing hypoxia to less than 5,000 km^2 (1,930 square miles or about 40 percent of its average dimensions during the 1990s), which the task force recognized would probably require the reduction of nitrogen inputs by 30 percent.

The President's National Science and Technology Council produced an integrated assessment of large-scale hypoxia in the northern Gulf of Mexico (CENR, 2000) (Box 4). The assessment concluded that diffuse sources of nutrient pollution have caused more extensive hypoxia, covering up to 12,000 square miles of the northern Gulf continental shelf, since the 1950s. It identified more efficient use of fertilizers and restoration of wetlands in the river basin as effective means to reduce the extent and severity of hypoxia in the Gulf.

Finally, the National Research Council (2000a) recently published an in-depth evaluation of the causes and effects of

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overenrichment in coastal waters and of abatement strategies, including monitoring and modeling, goal setting, and source reduction and control. Noting the substantial adverse impacts of nutrient pollution and the likelihood that nutrient loads will increase as human populations grow, the NRC calls for a nationwide strategy for reducing impairment by nutrient pollution and protecting unimpaired waters. One goal suggests a 10 percent reduction by the year 2010 in the number of coastal water bodies demonstrating severe impacts and a 25 percent reduction by 2020.

Large-scale eutrophication has also occurred in seas around other developed nations, including the Baltic Sea, eastern North Sea, northern Adriatic Sea, northwestern Black Sea, and Japan's Seto Inland Sea. As in the U.S., these problems also developed during the last half of the 20th century with expanded use of chemical fertilizers and combustion of fossil fuels. Coastal eutrophication is but one dimension of the significant modification of the nitrogen cycle (Vitousek et al., 1997). Globally, the amount of biologically available nitrogen added to the biosphere each year has more than doubled the amount made available by the natural sources of plant fixation and lightning. In addition to impacts on marine ecosystems, acid rain, loss of forest soil fertility, emissions of nitrous oxide (a greenhouse gas), and reduction of plant biodiversity are other consequences of the increasing flow of biologically available nitrogen in the biosphere.

Consequences for Living Marine Resources

Nutrients are generally in short supply in most ecosystems and microscopic and macroscopic plants have adapted mechanisms to assimilate them and grow when they are available. The addition of nutrients to an ecosystem affects not only how fast plants grow but also which plants grow most rapidly. These responses are affected by many factors, including light, temperature, mixing and stratification of the water column, the ratio of the various nutrients, and grazing by animals. In marine ecosystems, the rate at which plants create new organic matter (primary production) is closely related to nitrogen inputs (NRC, 2000a). Primary production doubled from the beginning of the 1960s to 1990 in the southern Kattegat between Denmark and Sweden (Richardson and Heilman, 1995), one of the few areas where primary production has been consistently measured. Similar dramatic increases in primary production in the Chesapeake Bay (Cooper, 1995) and the northern Gulf of Mexico (Rabalais et al., 1996) have been inferred based on chemicals and fossils laid down in bottom sediments.

Although much of the increased organic matter is consumed by zooplankton, bacteria, and bottom filter feeders, the amount

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of organic matter that falls to the bottom in the form of dead plant cells and fecal matter from grazing organisms is also increased. This changes the food regime of organisms living on the bottom or within bottom sediments, initially increasing the abundance of animals and microorganisms that consume the rich organic deposits. However, the respiration of these decomposer organisms consumes oxygen. At first oxygen is depleted in bottom sediments and, if organic loading is heavy enough, the deficit of oxygen reaches into the water column above the seabed. The severity and persistence of resulting hypoxia depend on the stratification of the water column. Less dense (warmer or fresher) surface waters overlying more dense (colder or saltier) bottom waters, with little mixing between the layers, prevents supplies of oxygen from surface waters from replenishing the oxygen consumed by decomposers.

Severe hypoxia near the bottom has become a more regular and extensive seasonal phenomenon in ecosystems such as the Louisiana continental shelf (Rabalais et al., 1996), Chesapeake Bay (Boesch et al., in press), the western basin of Long Island Sound (Long Island Sound Study, 1998), and many other parts of the world (Diaz and Rosenberg, 1995).

As bottom oxygen is depleted, many organisms unable to swim away succumb. Crustaceans, echinoderms, and mollusks are particularly sensitive to the lack of oxygen and the hydrogen sulfide that emanates from putrefying sediments. Consequently, benthic communities experiencing eutrophication and hypoxic stress are altered and have less species diversity. Substantial changes in the production and composition of benthic communities may be evident well before severe hypoxic conditions occur in overlying waters (Diaz and Rosenberg, 1995).

Hypoxic conditions in waters above the seabed force fish and swimming invertebrates to avoid the stressful conditions. Catches of fish and shrimp in bottom trawls in the Gulf of Mexico are dramatically lower or nonexistent where bottom dissolved oxygen levels fall below 2 mg/L (CENR, 2000). Fish and crustaceans often move up in the water column, where they are more susceptible to predation. Hypoxia can also block normal onshore-offshore migration. Despite these apparent obstacles to survival, large-scale hypoxia has not decimated the important shrimp fisheries of the northern Gulf of Mexico (CENR, 2000), although it may have reduced the catch of brown shrimp (Zimmerman and Nance, in press). Many other factors affect shrimp populations, rendering less-than-catastrophic effects due to hypoxia difficult to detect. Bottom hypoxia has resulted in declines in the catches in demersal (living near the bottom) fisheries in Europe and Japan (Caddy, 1993, 2000).

"Hypoxic conditions in waters above the seabed force fish and swimming invertebrates to avoid the stressful conditions."

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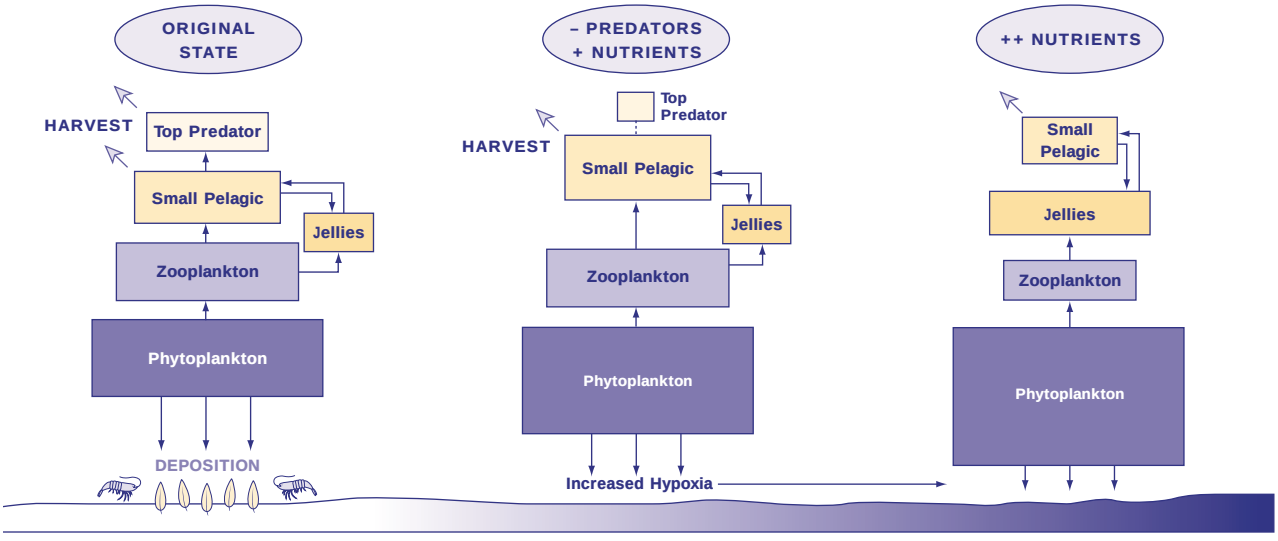
Nutrients are necessary to support the productivity of marine food webs. Across the full range of marine ecosystems, the supply of nutrients—particularly nitrogen—is positively correlated with fisheries yield (Nixon et al., 1986). Although the general relationship is undeniable, the strength of coupling between nutrients and the production of animals within a given ecosystem has been called into question (Micheli, 1999). Nonetheless, increases in the catch of some fisheries have been observed in the North and Baltic Seas and Seto Inland Sea in Japan, concurrent with increases in nutrient loading (Caddy, 1993). While some increases are attributable to increased fishing pressure or more efficient fishing paralleling increased nutrient loadings, greater yields appear to be at least in part due to nutrient stimulation of the food chains supporting the fisheries. Other factors can affect fisheries yield, however, including climatic variation and the effects of fishing itself on the food chain. There is a strong global trend of "fishing down the food chain," wherein fishing is targeted on smaller species once stocks of higher predators are depleted (Pauly et al., 1998). Under these conditions there is less predation on mid-trophic level species, allowing them to become more abundant. These factors may result in increased yields measured as biomass, but the economic value of the fishery is typically smaller.

Eutrophication combined with increased fishing intensity, results in higher yields of small pelagic (living in the water column) species and reduced yields of top

Figure 6

imultaneous Effects of Eutrophication and Fishery Harvest on Marine Food Chains



ource: Caddy, 2000.

predators and demersal (living near the bottom) species (Figure 6). In the extreme case, severe hypoxia and highly enriched food chains favor gelatinous predators (jellyfish and comb jellies) and result in the virtual elimination of demersal resources and reduction in small pelagic fish stocks (e.g., anchovies in the Black Sea). European seas can be ordered based on relative harvests of demersal and pelagic fisheries from the Irish Sea, with low nutrient inputs and proportionally greater demersal fisheries, to the Adriatic and Black Seas, with high nutrient inputs and predominantly pelagic fisheries (Caddy, 2000). In the U.S., enriched systems such as the Chesapeake Bay and northern Gulf of Mexico exhibit high yields of a small pelagic fish (menhaden). These systems have also experienced overharvesting of top predators such as striped bass, red snapper, and red drum and face current management problems for demersal crustaceans such as blue crabs and penaeid shrimp. The interactions between fishing pressure and eutrophication require that fisheries resources be managed not only in a multispecies context but also within an ecosystem framework. That framework may need to take into account human activities and natural processes extending even into the watersheds that deliver fresh water and nutrients to the sea (Caddy, 2000).

Seagrasses, seaweeds, and coral reefs create important habitats that provide food and shelter for a rich diversity of marine organisms, but are very sensitive to nutrient pollution. High nutrient levels in the water column can stimulate luxuriant growth of seagrass leaves, but there is insufficient rhizome growth to tide the plants over during periods of reduced photosynthesis. Reductions in available light caused by increased phytoplankton density and the proliferation of microscopic and macroscopic algae growing on seagrass blades also adversely affect the plants (Duarte, 1995). Seagrasses sometimes give way to fast growing macroalgae. Ultimately, conditions may become too turbid to support any macroscopic plants. As seagrass beds are lost, sediments are more easily eroded, causing the pace of loss to accelerate. Significant seagrass losses caused by excessive nutrient loadings have been observed in bays and coastal lagoons in New England, the mid-Atlantic region, Florida, Texas, and California (Bricker et al., 1999), as well as in Europe, Australia, and Japan (Duarte, 1995). On the other hand, partial recovery of seagrass beds in Sarasota, Tampa, and Chesapeake Bays has been observed as a result of efforts to abate nutrient pollution.

In the Baltic Sea, shallow rocky areas once covered with brown seaweeds that provide important spawning sites for fishes changed to a plant community dominated by rapidly growing green algae of little habitat value (Jansson and Dahlberg, 1999).

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In the northwestern Black Sea, an extensive meadow of red algae covering 4,000 square miles in the 1950s was reduced to 200 square miles by the 1990s, causing a loss of a harvested resource, the disappearance of a unique fauna, and reduction in an important source of oxygen (Zaitsev, 1999).

Reef-building corals have a symbiotic relationship with algae (zooxanthellae) that live in coral tissue and efficiently recycle available nutrients. This relationship allows corals to build reefs in clear waters with low nutrient levels. Even small increases in nutrient loads can stimulate phytoplankton and reduce light availability for zooxanthellae in the deeper parts of the reef. Elevated nutrient levels or reduced light availability may make already temperature-stressed corals more prone to expelling zooxanthellae, producing a "bleaching" effect (Brown, 2000).

Increased availability of nutrients can shift an ecosystem dominated by corals and coralline algae toward dominance by algal turf and macroalgae (Bell, 1992; Lapointe, 1999). Nutrient stimulation due to sewage additions was responsible for overgrowth of coral reefs by macroalgae in Kaneohe Bay, Hawaii, during the 1960s. Redirecting sewage out of the bay reversed this situation (Smith et al., 1981). Grazing animals normally prevent algal overgrowth, so when overfishing reduces grazers, reefs may be particularly susceptible to nutrient pollution (Lapointe, 1999). Overenrichment may also contribute to environmental stresses that make corals susceptible to diseases that appear to be increasing in distribution and virulence (Harvell et al., 1999). Finally, a recent study in Barbados found that boring sponges, which weaken coral structures, were more common in reefs experiencing eutrophication (Holmes, 2000).

Probably no effect of nutrient pollution has captured more public attention than harmful algal blooms, though, in fact, the causes of these blooms are complex and incompletely understood. Harmful blooms involve a variety of unicellular organisms that create nuisance conditions in high concentrations, cause mass mortalities of marine organisms, or illness—or even death—in humans (Smayda, 1997). Included are microscopic organisms (including red tides, brown tides, and the notorious phantom dinoflagellate, *Pfiesteria piscicida*) that result in shellfish poisoning of humans, cause fish kills, and jeopardize aquaculture operations. The distribution, incidence, and severity of harmful algal blooms have been rising in recent decades, not only in the United States but also in Europe, Japan, and China (Hallegraeff, 1993). While nutrient pollution is clearly not the cause of some blooms, in other cases there is evidence that changes in nutrient supplies and ratios are a contributing factor (NRC, 2000a).

The chemical form and relative ratios of available plant nutrients can cause shifts

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in phytoplankton composition and unusual algal blooms. Organic nitrogen seems to favor the organism causing brown tides and possibly *Pfiesteria* in mid-Atlantic bays. A shortage of silicon, a nutrient needed for diatom growth, relative to the supplies of nitrogen and phosphorus favors the growth of flagellated phytoplankton, some species of which are toxic (NRC, 2000a). Even if the species favored are not toxic, changes in the proportions of various nutrients delivered to coastal waters could change the type as well as the amount of phytoplankton that grows, with significant consequences throughout the food web. Inputs of silicon from land have declined in many regions as a result of sediment entrapment behind dams, while phosphorus inputs have remained steady and nitrogen inputs have increased (Justić et al., 1995; CENR, 2000).

Eutrophication usually results in reductions in species diversity of the affected ecosystems and, if extensive and severe, can impact biodiversity on a regional scale. In the northwestern shelf of the Black Sea, for example, only one-third as many benthic animal species could be found within a given depth zone in the 1980s as were found in the 1960s (Diaz and Rosenberg, 1995). There is at this point no evidence that eutrophication is threatening the global extinction of any species. However, by isolating distinct subpopulations, local extinction of a species in one or two estuaries along a coast could affect the genetic flow within the regional population (NRC, 1995).

Eutrophication can also adversely affect the services provided by marine ecosystems. Nutrient removal by denitrification and burial in bottom sediments may be one of the most important services provided by coastal ecosystems (Costanza et al., 1997). However, when severe seasonal hypoxia occurs, both phosphorus and ammonia are released from bottom sediments, turning an important sink for nutrient pollution into a source—thereby fueling more hypoxia (Boesch et al., in press). Through this and other feedback mechanisms, eutrophic ecosystems appear to be less resilient, i.e., they have less capacity to buffer changes and recover from disturbances more slowly.

"Eutrophication usually results in reductions in species diversity of the affected ecosystems and, if extensive and severe, can impact biodiversity on a regional scale."

Sources and Trends

Human activities have increased the flow of phosphorus to the world's ocean by a factor of three over natural rates and the flow of nitrogen to U.S. coastal waters by four to eight times (NRC, 2000a). The largest human-controlled addition of nitrogen to the environment is the manufacture of inorganic nitrogen fertilizer. However, other activities, including the combustion of fossil fuels and cultivation of nitrogen-fixing crops, also convert atmospheric nitrogen into reduced, oxidized, or organic forms that are more biologically available than the gaseous nitrogen that comprises most of the air we breathe. About 20 percent of the fertilizer nitrogen

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applied in North America leaches into waters and 65 percent is removed in crops (NRC, 2000a). Most of the crops (70 percent) are fed to animals rather than humans; thus the amount of nitrogen reaching water bodies from animal wastes probably exceeds that from fertilizer runoff. Ammonia released into the air from animal wastes can be an important pathway though which nitrogen reaches coastal waters (Box 5). Human sewage is also an important avenue for nitrogen originally contained in crops or meat to reach coastal waters.

The relative importance of the sources of nutrients varies greatly among U.S. coastal regions, depending on the characteristics of their drainage basins, human populations, intensity of agricultural activities, and amount of atmospheric deposition. The percentages in Figure 7 are based on relating source estimates to fluxes measured through stream monitoring. Other statistical analyses across many watersheds (NRC, 2000a) suggest that atmospheric sources are a somewhat more significant contributor to diffuse source inputs than shown here, but the interregional differences depicted are in any case similar. Direct discharges of sewage dominate nitrogen inputs in northeastern bays; otherwise diffuse sources predominate. Agricultural sources generally are

Box 5

Ammonia Emissions: An Emerging Issue

Atmospheric deposition of nitrogen has been considered primarily in terms of the nitrogen oxides (NO_X) produced by fossil-fuel combustion. However, recent evidence shows that ammonia emissions from agricultural operations can be a significant pathway for nitrogen inputs to coastal waters, accounting for as much as half of the total nitrogen deposition in regions with extensive livestock production (Walker et al., 2000).

In the Chesapeake Bay watershed, agricultural livestock contribute an estimated 81 percent of the annual atmospheric burden of ammonia (Chimka et al., 1997). Ammonia volatilizes from animal wastes in feeding operations, waste-storage facilities, and land application of manure. Increases in deposition of ammonia have occurred with expanding animal production. For example, a 60 percent increase in ammonia wet deposition was observed on the Delmarva Peninsula during the past two decades when this region experienced a 20-fold increase in poultry production (Scudlark and Church, 1999). In eastern North Carolina, ammonia wet deposition more than doubled over the same time period (Paerl and Whitall, 1999) in a region in which swine production tripled during the last ten years (Mallin, 2000).

Ammonia emissions also occur from various urban sources, including combustion, POTWs, and chemical plants. Recent modifications to gasoline-powered vehicles designed to reduce NO_X emissions (i.e., three-way catalytic converters running rich air-fuel conditions) actually increase ammonia emission rates (Fraser and Cass, 1998).

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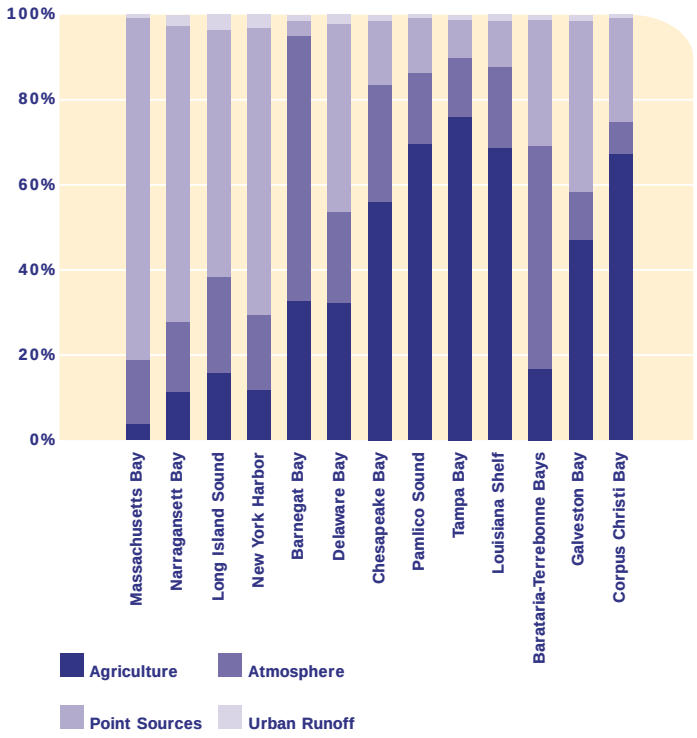
most important from the Chesapeake Bay south, while atmospheric sources are greater than agricultural sources in the Northeast.

Although global additions of nitrogen to the biosphere are continuing to increase rapidly (Vitousek et al., 1997), current trends in nitrogen loadings to U.S. coastal waters are in aggregate generally stable or growing slowly (NRC, 2000a), while inputs of phosphorus are stable or declining. Although the worldwide use of chemical fertilizers is growing and projected to increase substantially to support an expanding world population and increased meat consumption (Forsberg, 1998), the use of chemical fertilizers in the U.S. nearly plateaued in the 1980s (NRC, 2000a). However, increased inputs of both nitrogen and phosphorus have occurred in regions of the country experiencing an expansion and intensification of animal-feeding operations or human population growth. Future consumption of fertilizers and generation of animal wastes in the U.S. could increase, depending on global market forces. Atmospheric deposition of nitrogen from combustion of fossil fuels in vehicles and power plants has stabilized over much of the country as a result of pollution controls imposed under the Clean Air Act, and future efforts to improve air quality should result in reductions (EPA, 2000c).

Population growth increases the amount of sewage generated—a problem for rapidly growing parts of the country.

Figure 7

Estimated Nitrogen Loadings to Selected Atlantic and Gulf Coast Bays and Estuaries and Their Sources



Source: Castro et al., 2000.

However, where eutrophication is a recognized problem, implementation of advanced nitrogen removal technologies in POTWs can keep pace with population increases. In many coastal regions of the U.S., however, the rate at which land that produces relatively little nutrient runoff is converted into suburban development, roads, and parking lots—which increase water and nutrient runoff—has been progressing much faster than that of population growth.

The NOAA national eutrophication assessment estimated that eutrophic conditions are likely to worsen in two-thirds of the bays and estuaries examined

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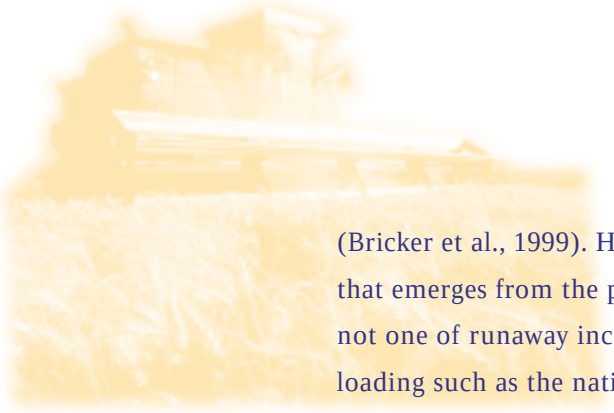

(Bricker et al., 1999). However, the prospect that emerges from the preceding analysis is not one of runaway increases in nutrient loading such as the nation experienced between 1960 and 1990, but one of stability or slower growth. This offers the real potential for substantial reductions with aggressive application of technologies. This outlook varies, of course, among regions, and coastal population growth near presently unaffected but susceptible bays and estuaries could greatly increase nutrient pollution in those areas. One should not infer from this that nutrient pollution is no longer a serious problem. The effects of eutrophication on coastal ecosystems are severe and widespread, making its abatement worthwhile, while at the same time challenging.

Pollution Abatement

Significant reduction in nutrient pollution may be achieved by approaches that: (1) reduce the use of the nutrients in the first place; (2) control losses to the environment at the point of release (e.g., farm field, animal feeding operation, lawn or subdivision, vehicle, power plant, or POTW); and (3) sequester or remove pollutants as they are transported to the sea.

Phosphorus can be almost completely removed from wastewaters by additional chemical and biological treatment. Phosphorus removal from discharges into the Potomac estuary below Washington, D.C., produced substantial improvements in water quality and living resources (Jaworski, 1990). Significant nitrogen removal has been achieved in Chesapeake, Tampa, and Sarasota Bays by biological nutrient removal—a process in which one group of microorganisms convert wastewater ammonia to nitrate and another converts nitrate to nitrogen gas (NRC, 1993a, 2000a).

Reductions in nitrogen oxide (NO_X) emissions to the atmosphere have been driven by air quality considerations generally outside the influence of water quality or coastal ecosystem managers. For example, in 1987 the Chesapeake Bay Program established a goal to reduce the controllable nitrogen inputs by 40 percent, but specifically excluded atmospheric deposition from the sources considered "controllable." Nitrogen oxide emissions from power plants and vehicles are regulated under the Clean Air Act (CAA); a key goal of the 1990 amendments of the act is to reduce ground-level ozone that poses human health risks and stresses forests and crops. Significant reductions in NO_X emissions from stationary and mobile sources are in the offing to meet CAA requirements. The EPA estimates that a 40 percent reduction in NO_X emissions can ultimately be achieved as a result of new standards, technologies, and efficiencies being pursued under the Clean Air Act. Atmospheric deposition of nitrogen may be far more "controllable" than previously thought.

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Abatement of agricultural sources of nutrient pollution may prove to be a more difficult challenge. To be practical, abatement of agricultural sources of nutrients must focus not only on reducing fertilizer use but also on plugging the many leaks in agricultural nutrient cycles. Efficiencies in fertilizer use in U.S. agriculture, measured by the ratio of nitrogen in harvested crops to nitrogen in fertilizer applied, have been slowly but steadily increasing since the mid-1970s (Frink et al., 1999). Nevertheless, about one-third of the nitrogen applied is not recovered in harvested crops (NRC, 2000a). Not all of the missing nitrogen contributes to eutrophication of coastal waters. Much is denitrified in soils or aquatic systems en route to the sea or is stored in soils or groundwater. In addition to increasing the efficiency of nitrogen uptake by crops, the return of nitrogen gas to the atmosphere can be enhanced through management practices.

Various agricultural practices affect nitrogen and phosphorus runoff and losses to groundwater (which ultimately seeps into surface waters). Practices employed to reduce soil erosion, such as contour plowing, timing of cultivation, conservation tillage (little or no tilling), stream-bank protection, grazing management, and grassed waterways also reduce nutrient pollution. Other practices are more specifically targeted to the efficient use and retention of nutrients: (1) soil testing to precisely match fertilizer applications to crop nutritional needs (many farmers still overapply to ensure maximum crop yields); (2) applying fertilizer only at the time the crop needs it; (3) crop rotation; (4) planting cover crops in the fall; (5) using soil and manure amendments; and (6) specialized methods of application (NRC, 1993b, 2000a). Landscape practices such as maintaining buffer strips between cultivated fields and nearby streams, moderating excessive drainage by ditches and tile lines, and maintaining wooded riparian areas can further reduce the leakage of agricultural nutrients to surface waters. By combining these approaches a significant portion of the edge-of-field nitrogen losses can be reduced (Boesch and Brinsfield, 2000).

Often, animal wastes are the most significant source of nutrient pollution from agriculture. Although the total production of livestock in the U.S. has not dramatically increased in recent years, the number and size of concentrated animal feeding operations have. Enclosures or trapping devices may eventually be required to stem ammonia emissions from animal wastes. Manure management also presents a risk of pollution if holding facilities fail or do not function properly (Mallin, 2000). Finally, frequently too much manure is produced within a geographic area for it to be applied to nearby land without overloading soils with nutrients (NRC, 2000a).

"Significant reductions in NO_X emissions from stationary and mobile sources are in the offing to meet CAA requirements."

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"Geographically targeting riparian and wetland restoration is critical to its effectiveness in nutrient control."

Urban runoff can also be an important diffuse source of nutrients. Reduction and control of urban and suburban diffuse sources can be achieved through: (1) reductions in the use of fertilizers; (2) effective and well-maintained stormwater collection systems (retention ponds can remove 30 to 40 percent of the total nitrogen and 50 to 60 percent of the total phosphorus); and (3) improved septic systems that promote denitrification (NRC, 2000a). Preservation and restoration of riparian zones and streams within urban and suburban areas is also an important aspect of effective nutrient control. However, the ability of streams to function effectively in nutrient removal is compromised when a significant portion of their watersheds is covered by impervious surfaces and the amplified runoff scours the streambeds (Booth and Jackson, 1997).

Removing or sequestering pollutants as they are transported downstream can also abate nutrient pollution. Many American watersheds were once sponge-like, containing extensive floodplains and wetlands that slowed the flow of water and served as sinks for dissolved and suspended nutrients. However, well over half of the wetlands present in the conterminous United States at the time of European settlement have been converted to other land uses and the percentage of inland swamps and riparian wetlands lost is even greater (Mitsch and Gosselink, 2000). Many floodplains have been disconnected from their rivers by flood-control projects or agricultural conversion and no longer serve as nutrient sinks.

Reducing and controlling diffuse sources of land runoff must involve large-scale landscape management, including restoration of riparian zones and wetlands (NRC, 1999c). The integrated assessment of hypoxia in the Gulf of Mexico estimated that 5 million acres of restored wetlands in the Mississippi River Basin would reduce nitrogen loading to the Gulf by 20 percent. Coupled with feasible controls in agriculture, this would achieve a nearly 40 percent reduction in nitrogen delivered to the Gulf. Similarly, the Chesapeake Bay Program is striving to reforest 2,000 miles of riparian zones and restore 25,000 acres of wetlands by 2010 in order to achieve nutrient-reduction goals (Boesch et al., in press).

Geographically targeting riparian and wetland restoration is critical to its effectiveness in nutrient control. Statistical models based on water quality measurements throughout the Mississippi River Basin show that the percentage of nitrogen leached from a field that reaches the Gulf of Mexico depends greatly on its proximity to larger streams and rivers (Alexander et al., 2000). Biological uptake and denitrification are already effective in small watercourses; therefore restoration of riparian and wetland habitats along moderate to large streams should be more cost-effective. However, because of equity considerations, both

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incentives (subsidies and cost sharing, technical assistance, and insurance) and disincentives (regulatory controls, taxes, and fees) for abatement tend to be applied uniformly.

Watershed Approaches

A given body of coastal water (bay, estuary, or continental shelf region) receives nutrients from numerous sources; thus an integrated strategy for effective abatement of nutrient pollution is required. Because of the importance of diffuse sources, the strategy should encompass the catchment basin, or watershed, draining into the coastal waters. Moreover, it may have to consider nutrients originating outside the watershed but

Box 6

Nonpoint Sources: Acts and Actions

Provisions of both the Clean Water Act (CWA) and Coastal Zone Management Act (CZMA) address diffuse, or nonpoint, sources of nutrient pollution; however, neither law has been very effective in controlling these sources. The implementation of provisions has been poorly funded, and arguably too much discretion is granted to states and local authorities (Adler, 1995; Johnson, 1999). A central programmatic shortcoming is the fundamental difficulty of influencing local land uses in order to obtain water-quality objectives. Under Section 208 of the 1972 CWA amendments, states were provided support and wide latitude in developing regional plans that identified point and nonpoint sources of pollution and methods, including land-use requirements, to control the sources (Anderson, 1999). However, the plans developed proved difficult to implement (Adler, 1995).

Section 319 of the 1987 CWA amendments requires the states to report on waters where nonpoint sources are problematic and identify best management practices and programs for source control. Section 319 moved toward, if not fully embraced, a watershed approach. State participation remained voluntary and EPA did not require states to penalize nonpoint-source polluters failing to adopt best management practices (Johnson, 1999). Lack of authority, enforcement, and monitoring clearly limited the effectiveness of the 319 efforts (Ruhl, 2000; Anderson, 1999).

In 1990 the reauthorized CZMA included Section 6217, under which states were required to implement enforceable policies to control nonpoint sources affecting coastal waters. Plans were originally required by 1995, but difficulties in implementation and coordination arose. Greater flexibility in plans was allowed and the period of implementation was extended to 15 years (NOAA, 2000).

Section 303 of the CWA requires the determination of a total maximum daily load (TMDL) of pollutants, including those from nonpoint sources, that can be accommodated by an impaired water body in order for it to meet water-quality standards for its designated use (Healy, 1997). A waste-load allocation then apportions the TMDL among the sources. This provision was not applied until lawsuits in the 1990s mandated EPA to establish TMDLs. Technical difficulties in determining TMDLs, legal issues regarding allocating loads among the sources, and the weak authority to regulate nonpoint sources remain serious barriers (Ruhl, 2000). Meanwhile, Congress prohibited EPA expenditures on further implementation of TMDLs during Fiscal Year 2001 (Copeland, 2000).

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"Monitoring is critical in determining the effectiveness of abatement strategies, evaluating responses of the ecosystem, and placing these responses in the context of ecosystem variability."

transported into it through the atmosphere. These are nonconventional units for ocean and coastal resource management and pose numerous challenges.

Recognition of the importance of diffuse-source pollution within a watershed is not new. Federal water-quality and coastal-management statutes include provisions for the assessment and control of nonpoint source pollution (Box 6), but to date they have been largely ineffective in limiting or reversing nutrient pollution of coastal waters. Their implementation has been long on planning and short on actions needed to control diffuse sources. In addition to the difficulties in determining management goals, acceptable nutrient loads, and efficient and equitable allocations among sources, substantial reliance on voluntary rather than mandatory reductions of diffuse sources has constrained the effectiveness of source-reduction efforts (NRC, 2000a).

These shortcomings are evidenced by the fact that 44 percent of the estuarine area assessed in 1998 did not fully meet the standards to support the designated uses (EPA, 2000a). Pathogens, organic enrichment, low dissolved oxygen, municipal point sources, urban runoff, and atmospheric deposition were the primary reasons, and diffuse-source pollution was a common culprit.

Concerted efforts to reverse nutrient pollution have been undertaken in some watersheds. In 1987 Pennsylvania, Maryland, Virginia, the District of Columbia, and the federal government committed to a 40 percent reduction in the "controllable" inputs of both nitrogen and phosphorus into the Chesapeake Bay by the year 2000. At about that same time, commitments were also being made for reductions of 50 percent of nutrient inputs into the North and Baltic Seas (Boesch and Brinsfield, 2000). Current estimates for the Chesapeake are that a 34 percent reduction in controllable phosphorus and a 28 percent reduction in controllable nitrogen will have been achieved by the end of 2000 (equivalent to 31 and 15 percent of the total loads, respectively; Blankenship, 2000). These are model simulations, but significant reductions in nutrient concentrations in rivers flowing into the Chesapeake Bay and in point-source discharges have been documented (Boesch et al., in press). These gains for the Chesapeake and European waters indicate that a watershed approach to reducing nutrient pollution can work, but so far successes have relied disproportionately on point-source controls. Under a new Chesapeake Bay agreement, more significant load reductions necessary to attain water-quality goals are being determined through a TMDL process (Box 6). Achieving these reductions will require a more rigorous effort to control diffuse sources.

Nitrogen inputs to Tampa Bay have also been reduced, again largely as a result of advanced treatment of sewage. Seagrass

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beds showed some recovery as a result (Lewis et al., 1998). A decrease in anthropogenic nitrogen inputs of 58.5 percent is the management goal for Long Island Sound (Long Island Sound Study, 1998). Direct discharges dominate nutrient sources there, thus biological nutrient removal at POTWs—at an estimated capital cost of more than 300 million dollars—is being counted on for most of this reduction.

Watershed approaches are being pursued in controlling diffuse sources of nutrients and other pollutants in many other U.S. bays and estuaries. In most, voluntary approaches to the pollution abatement are preferred; however, regulatory approaches are becoming more necessary, particularly as a result of the TMDL process (NRC, 2000a).

Watershed approaches place a premium on environmental modeling and monitoring (NRC, 2000a) in an adaptive management framework (Lee, 1993; CENR, 2000). Models are needed to track sources through the watershed, target abatement, and relate pollutant inputs to marine ecosystem responses. Monitoring is critical in determining the effectiveness of abatement strategies, evaluating responses of the ecosystem, and placing these responses in the context of ecosystem variability.

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V. Implications for National Ocean Policy

Pollution in Context

Determining the degree to which pollution affects marine living resources, biodiversity, and ecosystem services and comparing these effects to those due to fishing, habitat modification, and global climate change are extremely difficult. Effects of pollution must be separated from those due to natural variability and other human activities. Furthermore, the broader consequences of sublethal or localized effects for populations and ecosystems are seldom clear. The ramifications for biodiversity and living resource production of localized toxic effects or even the more extensive effects of nutrient pollution are difficult to quantify.

For the most part, the effects of pollution are reversible and respond to pollution abatement. The exception may be when marine mammals and birds are endangered by mass mortalities or reproductive failures resulting from toxic contaminants. Recovery can, however, be problematic and recovery times long, particularly with regard to persistent contaminants and permanent landscape changes that affect the delivery of pollutants from the watershed.

The nation's ocean and coastal ecosystems are being simultaneously affected by fishing activities (exploitation of target species, "bycatch," and effects of trawling), habitat modification from coastal development, and climate change, as well as by pollution. The relative importance of pollution as a threat to living resources depends on the region. Pollution is a fundamental concern in areas such as Boston Harbor, the northern Gulf of Mexico continental shelf, or the Chesapeake Bay. It is difficult to imagine environmental restoration and adequate resource management without controlling pollution. In other areas, pollution is much less a factor and habitat modification or fishing effects are far more important.

Most coastal ecosystems, in fact, experience multiple stresses. These stresses interact and, consequently, require integrated management solutions. Many coastal bays, for example, have been made less resilient to nutrient pollution because their oyster populations, which can filter out substantial amounts of organic matter, have been depleted. Furthermore, eutrophication will be influenced by the effects of climate change on freshwater runoff and water stratification (Justić et al.,1996; Najjar et al., 2000). And, overfishing of grazers makes coral reefs more susceptible to nutrient pollution (Lapointe, 1999). Multiple

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stresses can influence biodiversity on regional scales. For example, of 31 species of mammals, birds, and fish that have disappeared along the coast of the Netherlands over the past 2,000 years, 18 to 22 were as a result of overexploitation, 9 to 12 due to physical destruction of habitat, and 3 to 5 attributable to pollution (Wolff, 2000).

Priorities

Considerable strides have been made in reducing "conventional" forms of pollution over the last 30 years by implementation of the Clean Water Act and other federal, state, and local programs. Although further improvements are undoubtedly needed, technology-driven requirements and discharge permitting have been successful in greatly lowering the inputs of many contaminants into U.S. coastal waters. The dumping of sewage sludge and other wastes in the ocean was eliminated. The adverse effects of several manufactured chemicals (DDT, PCBs, and TBT) were uncovered and their use was discontinued or severely restricted.

This is not to say that protection of living marine resources from toxic wastes is no longer an important consideration for ocean policy. Decisions about managing legacy contamination and allowing the use of new chemicals still confront us. Atmospheric deposition and runoff from urban, suburban, and agricultural lands are now predominant pathways for toxic contaminants entering many coastal ecosystems. Abating these sources will require major commitments and innovative approaches.

We now realize that nutrients leaking from our land-based economy—from agriculture, transportation, power generation, and people—are having profound effects on coastal marine ecosystems over larger scales than imagined 30 years ago. The National Research Council (2000a) recommended that reducing nutrient pollution should be a national priority. Our society has just barely begun to accept and address this problem. Significant challenges lie ahead, particularly in ameliorating nitrogen pollution from diffuse sources.

Scales of Pollution Abatement

Meeting environmental quality objectives for the coastal ocean will require pollution abatement efforts at several scales. At the largest scale, managing anthropogenic alterations of the atmosphere and landscape well beyond the traditional "coastal zone" is required. Abating diffuse sources of pollution necessitates national laws and programs that harmonize agriculture, water resource, air quality, transportation, and land conservation policies with coastal environmental quality objectives. For example, the next reauthorization of the Farm Act should contribute to the reduction of nutrient pollution of coastal waters by targeting incentives, subsidies, and assistance while also

"We now realize that nutrients leaking from our land-based economy—from agriculture, transportation, power generation, and people—are having profound effects on coastal marine ecosystems over larger scales than imagined 30 years ago."

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ensuring economically and socially viable agriculture for the nation.

At the programmatic scale, controlling diffuse sources is clearly the principal challenge for marine pollution abatement. The missing link for the next level of environmental advance is the design and implementation of sustained programs and institutions that address these diffuse sources and provide solutions that are acceptable to American society. Watershed approaches provide a framework but are constrained by weak authorities and the preeminence of traditional governance at state and local levels. The National Research Council (2000a) noted that effective control of multiple sources of nutrients and contaminants on watershed scales would require a mix of voluntary and mandatory approaches and hybrids of these two extremes. Incentives and disincentives included in statutes and management practices can be very important in promoting and shaping voluntary actions involving agriculture and land uses. At the same time, more effective compliance with mandates, such as those already applicable to urban stormwater runoff, should be required.

At the individual scale, many discrete gains may be realized. More demanding treatment standards than those generally applicable can be required where water quality is seriously impaired. Such case-specific requirements generally force technological innovations that are eventually applied more broadly.

Marine Ecosystem Management and Science

Effective ocean resource policies and management regimes must be integrated. Not only must they manage the fish, habitats, and pollution of the coastal ocean more compatibly, but they must also consider and coordinate with land-based activities. Existing regional programs that link activities in the watershed with coastal ecosystem management represent an important start, but much more remains to be accomplished to achieve full integration.

Recognizing inherent uncertainties, policies, and management regimes must also be precautionary and adaptive. As stated in the United Nations' Rio Declaration, the precautionary principle requires that: "where there are threats of serious or irreversible damage, lack of full scientific certainty shall not be used as a reason for postponing cost-effective measures to prevent environmental degradation." Environmental decision-making in the United States has increasingly adopted a more precautionary approach—for example, in the testing of new pesticides and other chemicals before their release in the environment. While application of the precautionary principle may be straightforward in the screening of new chemicals or determining the suitability of dredged material

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for ocean disposal, it is harder when the ecosystems are already degraded or decisions concern which of many pollutant sources to reduce. Adaptive management involves periodic reevaluation and adjustment of the abatement approach based on careful observation of outcomes.

Integration, precaution, and adaptation in environmental policies and management all rely heavily on science. Scientific research and assessment must not only integrate across scientific disciplines but also address the interactions among the atmosphere, watersheds, and the ocean and relate pollution and other stresses to living marine resources and ecosystem services. The precautionary principle challenges science to quantify risk and determine the level of potential harm required to trigger its application. Adaptive management depends heavily on careful observations and comparison of outcomes to predictions.

Research, monitoring, and assessment relevant to marine pollution need improved strategic focus, organization, and commitment in order to fulfill these roles. The fundamental underpinnings of knowledge of complex environmental processes must be bolstered. The National Research Council (2000b) has identified grand challenges for environmental sciences, several of which are appropriate to marine pollution issues: biogeochemical cycles, biological diversity and ecosystem functioning, climate variability, hydrological forcing, land-use dynamics, and reinventing the use of materials.

Traditional environmental monitoring programs have emphasized relatively static parameters (e.g., contaminant concentrations in sediments or shellfish) rather than the dynamic parameters (e.g., primary production and dissolved oxygen) associated with the effects of nutrient pollution. Observing and understanding the effects of pollution should be an important objective of the sustained, integrated coastal ocean-observing system that is being developed for the nation (Nowlin and Malone, 1999). New sensor technologies, satellite measurements, and vast data storage and computational capabilities provide breakthrough opportunities to observe the environment on the appropriate space and time scales needed to address phenomena, such as eutrophication and harmful algal blooms, which occur over large areas but are highly variable in time.

Observations and research must be brought together in assessments that address key management questions and make useful predictions of probable outcomes. Predictions and observations must continually interact to support adaptive management. This will require new institutional arrangements and sustained commitments that support scientific integration and applied predictions.

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VI. Conclusions

"Overenrichment by plant nutrients, particularly nitrogen, has emerged as the most pervasive pollution risk for living resources and biodiversity in coastal ocean ecosystems."

Significant accomplishments were realized during the last 30 years in reducing the pollution of U.S. ocean and coastal waters by improving the treatment of waste discharges, ceasing most ocean dumping, and eliminating or restricting the use of certain persistent toxicants. Substantial reductions were realized in the inputs of a number of potentially toxic contaminants and organic wastes. Pollutant inputs from regulated discharges will likely continue to decline in order to attain water-quality standards. However, except for the banned and restricted chemicals, inputs of pollutants from diffuse sources—including land runoff—were largely unabated or actually increased during the same 30 years. Diffuse sources now contribute more than direct discharges for many pollutants.

Although it is difficult to extrapolate effects observed in laboratory experiments, it is clear that toxic contaminants chronically affect marine organisms at least over limited, but widely distributed areas in U.S. coastal waters near heavily populated areas. Toxicants can also affect marine mammals and birds that concentrate organic compounds in fatty tissues, sometimes far from the pollution source.

Persistent and bioaccumulative toxicants remain in the ocean and coastal environment for long periods after their sources have been eliminated or substantially reduced. In many cases little can be done until the substances are gradually degraded or removed from the ecosystem. However, isolated sites have extremely high concentrations of toxicants in bottom sediments, from which they can be reintroduced to the ecosystem. Capping and removal options should be thoroughly evaluated by carefully weighing risks of alternative options.

Overenrichment by plant nutrients, particularly nitrogen, has emerged as the most pervasive pollution risk for living resources and biodiversity in coastal ocean ecosystems. Many of the nation's coastal environments exhibit symptoms of overenrichment, including algal blooms (some of which may be toxic), loss of seagrasses and coral reefs, and serious oxygen depletion. Consequences include reduced production of valuable fisheries, threats to biodiversity on regional scales, diminished ecosystem services, and less resilient ecosystems.

Hard-to-control, diffuse sources—often from far inland—dominate nutrient inputs into most overenriched ecosystems. These

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sources grew dramatically in the last half of the 20th century as a result of increases in the use of chemical fertilizers, more intensive animal agriculture, and the combustion of fossil fuels that release nitrogen oxides into the air. Only recently has nutrient removal been incorporated in advanced treatment of point sources of wastes. New emission standards to meet air-quality objectives, if fully implemented, could reduce atmospheric deposition of nitrogen by 40 percent. Reduction of agricultural sources of nutrients has been more recalcitrant but it is feasible through improved practices and watershed restoration.

Reversing and controlling diffuse sources of pollution, including nutrients, requires an integrated approach on the scale of an entire drainage basin. The legal and institutional mechanisms available for reducing diffuse-source pollution have thus far been only modestly successful, but watershed management approaches are beginning to have an effect. A combination of voluntary and mandatory actions will be required, assisted by governmental incentives such as tax benefits and subsidies and disincentives. To be most effective, these incentives and disincentives should be targeted geographically. From the broadest policy perspective, effective ocean policy must extend well beyond the ocean and coastal zone to influence agricultural, energy, transportation, water resources, and land-use policies.

Science must play a key role in advancing marine ecosystem management that is integrated, precautionary, and adaptive. Sustained observations of changes related to pollution should be a key part of the nation's integrated ocean-observing system. These results should be coupled with strategic research and models to improve predictions needed for adaptive ecosystem management.

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Pew Oceans Commisssion

Connecting People and Science to Sustain Marine Life

The Pew Oceans Commission is an independent group of American leaders conducting a national dialogue on the policies needed to restore and protect living marine resources in U.S. waters. After reviewing the best scientific information available, the Commission will make its formal recommendations in a report to Congress and the nation in 2002.

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The El Toro INFO SITE

SCAG County Population Forecasts

Southern California Association of Governments

POPULATION PROJECTIONS

COUNTY	1994	2000	2005	2010	2015	2020
Imperial	138,400	149,000	172,000	207,000	241,000	280,000
Los Angeles	9,231,600	9,818,200	10,329,500	10,868,900	11,513,400	12,249,100
Orange	2,595,300	2,859,200	3,005,800	3,105,300	3,165,400	3,244,600
Riverside	1,376,900	1,687,800	1,976,900	2,265,300	2,531,700	2,816,000
San Bernardino	1,558,600	1,772,500	2,005,400	2,239,600	2,512,700	2,830,100
Ventura	709,900	712,700	744,900	804,300	861,600	932,300
SCAG	15,610,700	16,999,000	18,234,000	19,491,000	20,826,000	22,352,000

Source: SCAG, 1998 RTP Adopted Forecast, April 1998

NOT INCLUDED ABOVE: (San Diego is not a member of SCAG)

San Diego	na	2,911,500	3,223,490	3,437,697	na	3,853,297

Source: County of San Diego Fact Sheet

PERCENTAGE GROWTH

COUNTY	GROWTH 2000 - 2020	PERCENT GROWTH
Imperial	131,000	87.92%
Los Angeles	2,430,900	24.76%
Orange	385,400	13.48%
Riverside	1,128,200	66.84%
San Bernardino	1,057,600	59.67%
Ventura	219,600	30.81%
SCAG		

	5,353,000	31.49%

Orange County's percent of total 6 county SCAG area growth - 7.2%

NOT INCLUDED ABOVE: (San Diego is not a member of SCAG)

San Diego	**941,797**	**32.35%**

Source: County of San Diego Fact Sheet

Orange County's percent of total 7 county So. Cal. growth - 6.1 %

Click here for pdf file map depicting population growth areas according to SCAG

SCAG Regional Draft 2001 RTP Update
Distribution of Population Increase 1997-2025

The El Toro Airport INFO SITE

Revised 03/13/01

California Regional Water Quality Control Board
Santa Ana Region

ORDER NO. R8-2002-0010
NPDES No. CAS618030

Waste Discharge Requirements
for
the County of Orange, Orange County Flood Control District
and
The Incorporated Cities of Orange County Within the Santa Ana Region
Areawide Urban Storm Water Runoff
Orange County

The California Regional Water Quality Control Board, Santa Ana Region (hereinafter Regional Board) finds that:

1. The 1987 amendments to the Clean Water Act (CWA) added Section 402(p) establishing a framework for regulating municipal and industrial (including construction) storm water discharges under the National Pollutant Discharge Elimination System (NPDES). Section 402(p) of the CWA requires NPDES permits for storm water discharges from municipal separate storm sewer systems (MS4) as well as other designated storm water discharges that are considered significant contributors of pollutants to waters of the United States. On November 16, 1990, the United States Environmental Protection Agency (hereinafter EPA) amended its NPDES permit regulations (40 CFR Parts 122, 123 and 124) to describe permit application requirements for storm water discharges.

2. Prior to EPA's promulgation of the storm water permit regulations, the three counties (Orange, Riverside, and San Bernardino) and the incorporated cities within the jurisdiction of the Santa Ana Regional Board requested areawide NPDES permits for urban storm water runoff. On July 13, 1990, the Regional Board adopted Order No. 90-71 for urban storm water runoff from urban areas in Orange County within the Santa Ana Region. The County of Orange was named as the principal permittee and the Orange County Flood Control District (OCFCD) and the incorporated cities were named as the co-permittees. Order No. 96-31, issued by the Regional Board on March 8, 1996, renewed the permit for another five years.

3. Order No. 96-31 expired on March 1, 2001. On September 1, 2000, the County of Orange Public Facilities and Resources Department (OCPFRD) and the Orange County Flood Control District (OCFCD) in cooperation with the cities of Anaheim, Brea, Buena Park, Costa Mesa, Cypress, Fountain Valley, Fullerton, Garden Grove, Huntington Beach, Irvine, Laguna Woods, La Habra, La Palma, Lake Forest, Los Alamitos, Newport Beach, Orange, Placentia, Santa Ana, Seal Beach, Stanton, Tustin, Villa Park, Westminster, and Yorba Linda (hereinafter collectively referred to as permittees or dischargers), submitted NPDES Application No. CAS618030 and a Report of Waste Discharge for reissuance of their areawide storm water permit. In order to more effectively carry out the requirements of this order, the permittees have agreed that the County of Orange will continue as principal permittee and the OCFCD and the incorporated cities will continue as co-permittees. On March 5, 2001, Order No. 96-31, NPDES No. CAS618030, was

administratively extended in accordance with Title 23, Division 3, Chapter 9, §2235.4 of the California Code of Regulations.

4. The permittees serve a population of approximately 2.8 million, occupying an area of approximately 786 square miles (including unincorporated areas and the limits of 33 cities, 25 of which are within the jurisdiction of this Regional Board; two of the cities, Laguna Woods and Lake Forest, are within both the San Diego and Santa Ana Regional Boards' jurisdictions). The permitted area is shown on Attachment A. The permittees have jurisdiction over and /or maintenance responsibility for storm water conveyance systems within Orange County. The County's systems include an estimated 400 miles of storm drain systems. A major portion of the urbanized areas of Orange County drains into waterbodies within this Regional Board's jurisdiction. In certain cases, where a natural streambed is modified to convey storm water flows, the conveyance system becomes both an MS4 and a receiving water. The major storm drain systems and drainage areas in Orange County, which are within this Region, are shown on Attachment B. A portion of the Orange County drainage area is within the jurisdiction of the San Diego Regional Board and is regulated under an order issued by that Board.

5. Storm water outfalls from the MS4 systems in Orange County enter, or are tributary to, various water bodies of the Region. The permitted area can be subdivided into five tributary watersheds: the San Gabriel River drainage area, the Huntington Harbour and Bolsa Bay drainage area, the Santa Ana River drainage area, the Newport Bay drainage area, and the Irvine and Newport Coast Areas of Special Biological Significance (see Attachment B). These watersheds are tributary to the Pacific Ocean. The surface water bodies in Orange County include:

   Inland Surface Streams

   a. Santa Ana River, Reaches 1 and 2,
   b. Silverado Creek (tributary to Santiago Creek),
   c. Santiago Creek, Reaches 1, 2, 3, and 4 (tributary to the Santa Ana River),
   d. San Diego Creek, Reaches 1 and 2 (tributary to Newport Bay),
   e. San Joaquin Freshwater Marsh (tributary to San Diego Creek),
   f. All other tributaries to these Creeks: Bonita Creek, Serrano Creek, Peters Canyon Wash, Hicks Canyon Wash, Bee Canyon Wash, Borrego Canyon Wash, Agua Chinon Wash, Laguna Canyon Wash, Rattlesnake Canyon Wash, Sand Canyon Wash, Black Star Creek, Carbon Canyon Creek, Coyote Creek and other tributaries.

   Bays, Estuaries, and Tidal Prisms

   a. Anaheim Bay,
   b. Sunset Bay,
   c. Bolsa Bay and Bolsa Chica Ecological Reserve,
   d. Lower and Upper Newport Bay,
   e. Tidal Prism of Santa Ana River (to within 1000 feet of Victoria Street) and Newport Slough, Santa Ana Salt Marsh,

f. Tidal Prism of San Gabriel River (River Mouth to Marina Drive),

g. Tidal Prisms of Flood Control Channels Discharging to Coastal or Bay Waters (e.g. Huntington Harbour).

Ocean Waters

Nearshore Zone

a. San Gabriel River to Poppy Street in Corona Del Mar,

b. Poppy Street to Southeast Regional Boundary.

Offshore Zone

a. Waters between Nearshore Zone and Limit of State Waters.

Lakes and Reservoirs

a. Anaheim Lakes,

b. Irvine Lake (Santiago Reservoir),

c. Laguna, Peters Canyon, and Rattlesnake Reservoirs.

The beneficial uses of these water bodies include: municipal and domestic supply, agricultural supply, industrial service and process supply, groundwater recharge, navigation, hydropower generation, water contact recreation, non-contact water recreation, commercial and sportfishing, warm freshwater and limited warm freshwater habitats, cold freshwater habitat, preservation of biological habitats of special significance, wildlife habitat, preservation of rare, threatened or endangered species, marine habitat, shellfish harvesting, spawning, reproduction and development of aquatic habitats, and estuarine habitat . The ultimate goal of this storm water management program is to protect the beneficial uses of the receiving waters.

6. The Santa Ana River Basin is the major watershed within the jurisdiction of the Regional Board. The lower Santa Ana River Basin (downstream from Prado Basin) includes the Orange County drainage areas and the Upper Santa Ana River Basin includes the San Bernardino and the Riverside drainage areas. Generally, the San Bernardino County drainage areas drain to the Riverside County drainage areas, and Riverside County drainage areas discharge to Orange County.

7. Within the Region, runoff from the San Bernardino County areas is generally conveyed to the Riverside County areas through the Santa Ana River or other drainage channels tributary to the Santa Ana River. These flows are then discharged to Reach 2 of the Santa Ana River through Prado Basin (Reach 3 of the Santa Ana River). Most of the flow in Reach 2 is recharged in Orange County. During wet weather, some of the flow is discharged to the Pacific Ocean through Reach 1 of the Santa Ana River.

8. The three county areas within this Region are regulated under three areawide permits for urban storm water runoff. These areawide NPDES permits are:

a. Orange County, NPDES No. CAS618030;

b. Riverside County, NPDES No. CAS618033; and,

c. San Bernardino County, NPDES No. CAS618036.

For an effective watershed management program, cooperation and coordination among the regulators, the municipal permittees, the public, and other entities are essential.

9. Studies conducted by the EPA, the states, flood control districts and other entities indicate the following major sources for urban storm water pollution nationwide:

   a. Industrial sites where appropriate pollution control and best management practices (BMPs)[1] are not implemented;

   b. Construction sites where erosion and siltation controls and BMPs are not implemented; and,

   c. Urban runoff where the drainage area is not properly managed.

10. A number of permits were adopted to address pollution from the sources identified in Finding 9, above. The State Board issued two statewide general NPDES permits: one for storm water runoff from industrial activities (NPDES No. CAS000001, General Industrial Activities Storm Water Permit) and a second one for storm water runoff from construction activities (NPDES No. CAS000002, General Construction Activity Storm Water Permit). Industrial activities (as identified in 40 CFR 122.26(b)(14)) and construction sites of five acres or more, are required to obtain coverage under these statewide general permits. The permittees have developed project conditions of approval requiring coverage under the State's General Permit for new developments to be implemented at the time of grading or building permit issuance for construction sites on five acres or more and at the time of local permit issuance for industrial facilities. The State Board also adopted Order No. 99-06-DWQ, NPDES No. CAS000003, for storm water runoff from facilities (including freeways and highways) owned and/or operated by Caltrans. The Regional Board adopted Order 99-11, NPDES No. CAG018001, for concentrated animal feeding operations, including dairies. The Regional Board also issues individual storm water permits for certain industrial facilities within the Region. Currently there are 22 individual storm water NPDES permits; 8 of these facilities are located in the Orange County area. Additionally, for a number of facilities that discharge process wastewater and storm water, storm water discharge requirements are included with the facilities' NPDES permit for process wastewater.

11. In most cases, the industries and construction sites covered under the Statewide General Industrial and Construction Permits discharge into storm drains and/or flood control facilities owned and operated by the permittees. These industries and construction sites are also regulated under local laws and regulations. A coordinated effort between the permittees and the Regional Board staff is critical to avoid duplicative and overlapping efforts when overseeing the compliance of dischargers covered under the Statewide General Permits. As part of this coordination, the permittees have been notifying Regional Board staff when they observe conditions that pose a threat or potential threat to water quality, or when an industrial facility or

[1] Best Management Practices (BMPs) are water quality management practices that are maximized in efficiency for the control of storm water runoff pollution.

construction activity that has failed to obtain required coverage under the appropriate general storm water permit.

12. The permittees have the authority to approve plans for residential, commercial, and industrial developments. If not properly controlled and managed, urbanization could result in the discharge of pollutants in storm water runoff. Urban area runoff (Finding 9.c) may contain elevated levels of pathogens (bacteria, protozoa, viruses), sediment, trash, fertilizers (nutrients, compounds of nitrogen and phosphorus), pesticides (DDT, Chlordane, Diazinon, Chlorpyrifos), heavy metals (cadmium, chromium, copper, lead, zinc), and petroleum products (oil, grease, petroleum hydrocarbons, polycyclic aromatic hydrocarbons). Storm water can carry these pollutants to rivers, streams, lakes, bays and the ocean (receiving waters).

13. Pollutants in urban runoff can impact the beneficial uses of the receiving waters and can cause or threaten to cause a condition of pollution or nuisance. Pathogens (from sanitary sewer overflows, septic system leaks, spills and leaks from portable toilets, pets, wildlife and human activities) can impact water contact recreation, non-contact water recreation and shellfish harvesting. Microbial contamination of the beaches from urban runoff and other sources has resulted in a number of health advisories issued by the Orange County Health Officer. Floatables (from trash) are an aesthetic nuisance and can be a substrate for algae and insect vectors. Oil and grease can coat birds and aquatic organisms, adversely affecting respiration and/or thermoregulation. Other petroleum hydrocarbon components can cause toxicity to aquatic organisms and can impact human health. Suspended and settleable solids (from sediment, trash, and industrial activities) can be deleterious to benthic organisms and may cause anaerobic conditions to form. Sediments and other suspended particulates can cause turbidity, clog fish gills and interfere with respiration in aquatic fauna. They can also screen out light, hindering photosynthesis and normal aquatic plant growth and development. Toxic substances (from pesticides, herbicides, petroleum products, metals, industrial wastes) can cause acute and/or chronic toxicity, and can bioaccumulate in organisms to levels that may be harmful to human health. Nutrients (from fertilizers, confined animal facilities, pets, birds) can cause excessive algal blooms. These blooms can lead to problems with taste, odor, color and increased turbidity, and can depress the dissolved oxygen content, leading to fish kills.

14. A major portion of Orange County is urbanized with residential, commercial and industrial developments. Urban development increases impervious surfaces and storm water runoff volume and velocity and decreases vegetated, pervious surface available for infiltration of storm water. Increase in runoff volume and velocity can cause scour, erosion (sheet, rill and/or gully), aggradation (raising of a streambed from sediment deposition) and can change fluvial geomorphology, hydrology and aquatic ecosystems. The local agencies (the permittees) are the owners and operators of the MS4 systems and have established appropriate legal authority to control some but not all discharges to these systems (see Finding 16). The permittees have established appropriate legal authority to control discharges into the MS4 systems. They adopted grading and/or erosion control ordinances, guidelines and best management practices (BMPs) for municipal, commercial, and industrial activities, and a drainage area management plan (DAMP). The permittees must exercise a combination of these programs, policies, and legal authority to ensure that pollutant loads resulting from urbanization are properly controlled and managed.

15. This order regulates urban storm water runoff from areas under the jurisdiction of the permittees. Urban storm water runoff includes those discharges from residential, commercial, industrial and construction areas within the permitted area and excludes discharges from feedlots, dairies, and farms (also see Finding 16). Storm water discharges consist of surface runoff generated from various land uses in all the hydrologic drainage areas that discharge into the water bodies of the U.S. The quality of these discharges varies considerably and is affected by land use activities, basin hydrology and geology, season, the frequency and duration of storm events, and the presence of illicit[2] disposal practices and illegal connections.

16. The permittees may lack legal jurisdiction over storm water discharges into their systems from some State and Federal facilities, utilities and special districts, Native American tribal lands, waste water management agencies and other point and non-point source discharges otherwise permitted by the Regional Board. The Regional Board recognizes that the permittees should not be held responsible for such facilities and/or discharges. Similarly, certain activities that generate pollutants present in storm water runoff may be beyond the ability of the permittees to eliminate. Examples of these include operation of internal combustion engines, atmospheric deposition, brake pad wear, tire wear and leaching of naturally occurring minerals from local geography.

17. This order is intended to regulate the discharge of pollutants in urban storm water runoff from anthropogenic (generated from human activities) sources within the jurisdiction and control of the permittees and is not intended to address background or naturally occurring pollutants or flows.

18. Water quality assessments conducted by Regional Board staff have identified a number of beneficial use impairments due, in part, to urban runoff. Section 303(b) of the CWA requires each of the regional boards to routinely monitor and assess the quality of waters of the region. If this assessment indicates that beneficial uses and/or water quality objectives are not met, then that waterbody must be listed under Section 303(d) of the CWA as an impaired waterbody. The 1998 water quality assessment listed a number of water bodies within the Region under Section 303(d) as impaired waterbodies. In the Orange County area, these include: (1) San Diego Creek, Reach 1 (listed for sedimentation/siltation, metals, nutrients, pesticides); (2) San Diego Creek, Reach 2 (listed for sedimentation/siltation, nutrients, metals, unknown toxicity); (3) Upper Newport Bay Ecological Reserve (listed for sedimentation/siltation, metals, nutrients, pathogens, pesticides); (4) Lower Newport Bay (listed for metals, pesticides, pathogens, nutrients, priority organics); (5) Anaheim Bay (listed for metals, pesticides); 6) Huntington Harbour (listed for metals, pesticides, pathogens); 7) Santiago Creek, Reach 4 (listed for salinity, TDS, chlorides); and 8) Silverado Creek (listed for pathogens, salinity, TDS, chlorides). For some of these impaired waterbodies, one of the listed causes of impairment is urban runoff.

19. Federal regulations require that a total maximum daily load (TMDL) be established for each 303(d) listed waterbody for each of the pollutants causing impairment. The TMDL is the total amount of the problem pollutant that can be discharged while water quality standards in the receiving water are attained, i.e., water quality objectives are met and the beneficial uses are protected. It is the sum of the individual wasteload allocations (WLA) for point source inputs,

[2] Illicit Disposal means any disposal, either intentionally or unintentionally, of material or waste that can pollute storm water or create a nuisance.

load allocations (LA) for non-point source inputs and natural background, with a margin of safety. The TMDLs are the basis for limitations established in waste discharge requirements. TMDLs have been developed for sediment and nutrients for San Diego Creek and Newport Bay. A fecal coliform TMDL for Newport Bay has also been established The WLAs from these TMDLs are included in this order. Dischargers to these water bodies are currently implementing these TMDLs. This order specifies the WLAs and includes requirements for the implementation of these WLAs.

20. The MS4s generally contain non-storm water flows such as irrigation runoff, runoff from non-commercial car washes, runoff from miscellaneous washing and cleaning operations, and other nuisance flows. Discharges of non-storm water containing pollutants into the MS4 systems and to waters of the U.S. are prohibited unless they are regulated under a separate NPDES permit, or are exempt, as indicated in Discharge Prohibitions, Section III.3 of this order.

21. Order No. 90-71 (first term permit) required the permittees to: (1) develop and implement the DAMP and a storm water and receiving water monitoring plan; (2) eliminate illegal[3] and illicit discharges[4] to the MS4s; and (3) enact the necessary legal authority to effectively prohibit such discharges. The overall goal of these requirements was to reduce pollutant loadings to surface waters from urban runoff to the maximum extent practicable (MEP)[5]. Order No. 96-31 (second term permit) required continued implementation of the DAMP and the monitoring plan, and required the permittees to focus on those areas that threaten beneficial uses.

22. This order (Order No. R8-2002-0010, third term permit) outlines additional steps for an effective storm water management program and specifies requirements to protect the beneficial uses of all receiving waters. This order requires the permittees to examine sources of pollutants in storm water runoff from activities which the permittees conduct, approve, regulate and/or authorize by issuing a license or permit.

23. The Report of Waste Discharge (the permit renewal application) included the following major documents:

    a. A summary of status of current Storm Water Management Program;

    b. A Proposed Plan of Storm Water Quality Management Activities for 2001-2006, as outlined in the Updated DAMP. The 2000 DAMP includes all the activities the permittees propose to undertake during the next permit term, goals and objectives of such activities, an evaluation of the need for additional source control and/or structural and non-structural BMPs and proposed pilot studies;

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[3] Illegal discharge means any discharge (or seepage) to the municipal separate storm sewer that is not composed entirely of storm water except for the authorized discharges listed in Section III of this permit. Illegal discharges include the improper disposal of wastes into the storm sewer system.

[4] Illicit Discharge means any discharge to the storm drain system that is prohibited under local, state, or federal statutes, ordinances, codes, or regulations. The term illicit discharge includes all non storm-water discharges except discharges pursuant to an NPDES permit, discharges that are identified in Section III, Discharge Limitations/Prohibitions, of this order, and discharges authorized by the Regional Board Exectutive Officer.

[5] Maximum Extent Practicable (MEP) means to the maximum extent feasible, taking into account considerations of synergistic, additive, and competing factors, including but not limited to, gravity of the problem, technical feasibility,fiscal feasibility, public health risks, societal concerns, and social benefits.

c. A Performance Commitment that includes new and existing program elements and compliance schedules necessary to implement controls that reduce pollutants to the maximum extent practicable;

d. A summary of procedures implemented to detect illegal discharges and illicit disposal practices;

e. A summary of enforcement procedures and actions taken to require storm water discharges to comply with the approved storm water management programs;

f. A summary of public agency activity, results of monitoring program, and program effectiveness; and,

g. A fiscal analysis.

24. The permittees own and/or operate facilities where industrial or related activities take place that may have an impact on storm water quality. Some of the permittees also enter into contracts with outside parties to carry out municipal related activities that may also have an impact on storm water quality. These facilities and related activities include, but are not limited to, street sweeping, catch basin cleaning, maintenance yards, vehicle and equipment maintenance areas, waste transfer stations, corporation and storage yards, parks and recreational facilities, landscape and swimming pool maintenance activities, storm drain system maintenance activities and the application of herbicides, algaecides and pesticides. The permittees have prepared and implemented an environmental performance report for appropriate fixed public facilities under their jurisdiction, and identified best management practices for those activities found to require pollution prevention measures. Non-storm water discharges from these facilities and/or activities could also affect water quality. This order prohibits non-storm water discharges from public facilities, unless the discharges are exempt under Section III, Discharge Limitations, 3 & 5 of this order, or are permitted by the Regional Board under an individual NPDES permit. The second term permit required the permittees to prepare an Environmental Performance Reporting Program to identify significant issues and to implement corrective actions at municipal facilities and activities. Most of this work has been completed. However, this is a continuing process and this order requires the permittees to continue this process at least on an annual basis.

25. Successful implementation of the provisions and limitations in this order will require the cooperation of all the public agency organizations within Orange County having programs/activities that have an impact on storm water quality. A list of these organizations is included in Attachment C. As such, these organizations are expected to actively participate in implementing the Orange County NPDES Storm Water Program. The Regional Board has the discretion and authority to require non-cooperating entities to participate in this areawide permit or obtain individual storm water discharge permits, pursuant to 40 CFR 122.26(a). The permittees have developed a Storm Water Implementation Agreement among the County, the cities and the Orange County Flood Control District. The Implementation Agreement establishes the responsibilities of each party and a funding mechanism for the shared costs, and recognizes the Technical Advisory Committee (TAC).

26. The major focus of storm water pollution prevention is the development and implementation of an appropriate DAMP, including best management practices (BMPs). The ultimate goal of the urban storm water management program is to support attainment of water quality objectives for

the receiving waters and to protect beneficial uses through the implementation of the DAMP. The permittees developed and submitted a DAMP.

27. The DAMP is a dynamic document and the permittees have implemented, or are in the process of implementing, the various elements of the DAMP. A revised DAMP was included with the NPDES permit renewal application. This order requires the permittees to continue to implement the BMPs listed in the revised DAMP; update or modify the DAMP, when appropriate, consistent with the MEP and other applicable standards; and to effectively prohibit illegal and illicit discharges to the storm drain system.

28. Urban runoff contains pollutants from privately owned and operated facilities, such as residences, businesses, private and/or public institutions, and commercial establishments. Therefore, a successful storm water management plan should include the participation and cooperation of the public, businesses, the permittees and the regulators. The DAMP has a strong emphasis on public education.

29. The Orange County DAMP defined: (1) a management structure for the permittees' compliance effort; (2) a formal agreement to underpin cooperation; and (3) a detailed municipal effort to develop, implement, and evaluate various BMPs or control programs in the areas of public agency activities, public information, new development and construction, public works construction, industrial discharger identification, and illicit discharger/connection identification and elimination.

30. In order to characterize storm water discharges, to identify problem areas, to determine the impact of urban runoff on receiving waters, and to determine the effectiveness of the various BMPs, an effective monitoring program is critical. The principal permittee administers the monitoring program for the permittees. This program included storm water monitoring, receiving water monitoring, dry weather monitoring and sediment monitoring. The monitoring data indicate some spatial differences in water quality among Orange County's major watersheds. Based on these monitoring data, the monitoring program was revised in 1998 to focus on "warm spots" (areas where the pollutant concentrations were above the average for the watershed) and "special value" areas (critical aquatic resources). Another element of the monitoring program is the Reconnaissance and Source Identification component that targets areas that are known to exhibit unusually high levels of storm water pollutants. The 1998 monitoring program was approved and the data collection under this program will be completed by July 1, 2003. By January 1, 2003, the State Board is required by SB 72 (Water Code Section 13383.5) to develop a statewide municipal strom water monitoring program. By July 1, 2003, the permittees are required to develop a revised monitoring program as specified in the monitoring and reporting program and consistent with any new requirements developed by the State Board.

31. In accordance with the Strategic Plan and Initiatives for the State and Regional Boards (June 22, 1995), the Regional Board recognizes the importance of an integrated watershed management approach. The Regional Board also recognizes that a watershed management program should integrate all related programs, including the storm water program and TMDL processes. Consistent with this approach, some of the municipal storm water monitoring programs have already been integrated into regional monitoring programs.

32. Illegal discharges to the storm drains can contribute to storm water and other surface water contamination. A reconnaissance survey of the municipal storm drain systems (open channels and underground storm drains) was completed by the permittees. The permittees also developed a program to prohibit illegal/illicit discharges to their storm drains and flood control facilities. Continued surveillance and enforcement of these programs are required to eliminate illicit discharges. The permittees have a number of mechanisms in place to eliminate illicit discharges to the MS4s, including construction, commercial, and industrial facility inspections, drainage facility inspections, water quality monitoring programs, and public education. The permittees also established a 24-hour water pollution problem reporting hotline. In February 1997, the permittees certified that they had completed a reconnaissance survey of the MS4s to detect and eliminate any illegal connections (undocumented or unpermitted connections to the MS4s). A reconnaissance survey is now being conducted as a part of the routine inspections of all MS4s.

33. The permittees have the authority to control pollutants in storm water discharges, to prohibit illegal connections and illicit discharges, to control spills, and to require compliance and carry out inspections of the storm drain systems within their jurisdictions. The permittees have various forms of legal authority in place, such as charters, State Code provisions for General Law cities, city ordinances, and applicable portions of municipal codes and the State Water Code, to regulate storm water/urban runoff discharges. In order to insure countywide consistency and to provide a legal underpinning to the entire Orange County storm water program, a model water quality ordinance was completed on August 15, 1994 and was adopted by all the permittees. The permittees are required by this order to review their existing enforcement authority to determine whether any additional legal authority is needed in order for permittees to administer civil and/or criminal penalties in enforcement actions for violations of the Water Quality Ordinance.

34. Pollution prevention techniques, appropriate planning processes and early identification of potential storm water impacts and mitigation measures can significantly reduce storm water pollution problems. The permittees should consider these impacts and appropriate mitigation measures in the planning procedures and in the California Environmental Quality Act (CEQA) review process for specific projects, Master Plans, etc. The permittees already require a Water Quality Management Plan, which addresses permanent post-construction BMPs, in addition to the SWPPP, which is required by the statewide general permit for construction activity. The

    permittees are encouraged to propose and participate in watershed wide and/or regional water quality management programs.

35. The permittees have developed inter-departmental training programs and have made commitments to conduct a certain number of these training programs during the term of this permit.

36. In accordance with the Clean Water Act and its implementing regulations, this order requires the permittees to develop and implement programs and policies necessary to reduce the discharge of pollutants in urban runoff to waters of the U. S. to the maximum extent practicable (MEP).

37. The legislative history and the preamble to the federal storm water regulations indicate that the Congress and the U.S. EPA were aware of the difficulties in regulating urban storm water runoff solely through traditional end-of-pipe treatment. However, it is the Regional Board's intent that this order require the implementation of best management practices to reduce to the maximum extent practicable, the discharge of pollutants in storm water from the MS4s in order to support attainment of water quality standards. This order, therefore, includes Receiving Water Limitations[6] based upon water quality objectives, prohibits the creation of nuisance and requires the reduction of water quality impairment in receiving waters. In accordance with Section 402 (p) of the Clean Water Act, this order requires the permittees to implement control measures, in accordance with the DAMP, that will reduce pollutants in storm water discharges to the maximum extent practicable. The Receiving Water Limitations similarly require the implementation of control measures to protect beneficial uses and attain water quality objectives of the receiving waters.

38. The Regional Board finds that the unique aspects of the regulation of storm water discharges through municipal storm sewer systems, including the intermittent nature of discharges, difficulties in monitoring and limited physical control over the discharge, will require adequate time to implement and evaluate the effectiveness of BMPs. Therefore, the order includes a procedure for determining whether storm water discharges are causing exceedances of receiving water limitations and for evaluating whether the DAMP must be revised in order to comply with this aspect of the order. The order establishes an iterative process to maintain compliance with the receiving water limitations.

39. The permittees are required to conduct inspections of construction sites, industrial facilities and commercial establishments. To avoid duplicative efforts, the permittees need not inspect facilities that have been inspected by Regional Board staff, if the inspection was conducted during the specified time period. Regional Board staff inspection data will be posted regularly on its internet site. It is anticipated that many of the inspections required under this order can and will be carried out by inspectors currently conducting inspections for the permittees (i.e., grading, building, code enforcement, etc.), during their normal duties.

40. A revised Water Quality Control Plan (Basin Plan) was adopted by the Regional Board and became effective on January 24, 1995. The Basin Plan contains water quality objectives and beneficial uses for water bodies in the Santa Ana Region. The Basin Plan also incorporates by reference all State Board water quality control plans and policies, including the 1990 Water Quality Control Plan for Ocean Waters of California (Ocean Plan) and the 1974 Water Quality Control Policy for Enclosed Bays and Estuaries of California (Enclosed Bays and Estuaries Plan).

41. The requirements contained in this order are necessary to implement the plans and policies described in Finding 40, above. These plans and policies contain numeric and narrative water quality standards for the water bodies in this Region. This order requires permittees to comply with load allocations for constituents with established load allocations for urban runoff, by implementing the necessary BMPs. Continuation of water quality/biota monitoring and analysis

[6] Receiving Water Limitations are requirements included in the Orders issued by the Board to assure that the regulated discharge does not violate water quality standards established in the Basin Plan at the point of discharge to waters of the State.

of the data are essential to better understand the impacts of storm water discharges on the water quality of the receiving water. The existing Basin Plan, or any further changes to the Basin Plan, may be grounds for the permittees to revise some or all of the DAMP and/or the ROWD.

42. Permittees will be required to comply with any applicable future water quality standards or discharge requirements that may be imposed by the EPA or State of California prior to the expiration of this order. This order may be reopened to include TMDLs and/or other requirements developed and adopted by the Regional Board.

43. The permittees may petition the Regional Board to issue a separate NPDES permit to any discharger of non-storm water into storm drain systems that they own or operate.

44. The permittees under the aegis of the TAC, and in collaboration with the City and County Attorneys, Orange County Sanitation District, the Orange County Building Industry Association, the Food Sanitation Advisory Council, and Western States Petroleum Association, developed an Enforcement Consistency Guide and a Water Quality Ordinance. All of the permittees adopted the Enforcement Consistency Guide and the Water Quality Ordinance. These documents establish legal authority for enforcing storm water ordinances and countywide uniformity in the enforcement actions.

45. It is important to control litter to eliminate trash and other materials in storm water runoff. In addition to the municipal ordinances prohibiting litter, the permittees participate or organize a number of other programs such as "Coastal Cleanup Day", "Pride Days", "Volunteer Connection Day", etc. The permittees also organize solid waste collection programs, household hazardous waste collections, and recycling programs to reduce litter and illegal discharges. Additionally, the permittees have installed debris booms at a number of locations.

46. The permittees are required to continue their drainage system inspection and maintenance program.

47. At a number of locations along the Orange County coast, elevated bacterial levels were detected during the summer of 1999 and 2000. One of the studies conducted to determine the source of bacterial contamination indicated that there is only a minor contribution to the bacterial problems from urban runoff. The permittees currently divert dry weather low flows from some of these areas to sanitary sewer systems on a temporary basis to address this bacterial problem. A number of studies have been initiated to determine the source of this microbial contamination and to develop permanent remedial measures. This order requires the permittees to further investigate and address the coastal bacterial problems.

48. The sampling data indicate the presence of elevated levels of pesticides in storm water runoff from urban areas. The permittees have developed and implemented a model plan entitled, "Management Guidelines for Use of Fertilizers and Pesticides". The permittees are required to review this plan to determine its effectiveness and to make any needed changes. TMDLs are being developed for some of these pesticides for the Newport Bay watershed.

49. Public education is an important part of storm water pollution prevention. The permittees have employed a variety of means to educate the public, business and commercial establishments, industrial facilities and construction sites, and in 1999 developed a long term public education strategy. The permittees are required to continue their efforts in public education programs.

50. The permittees established a taskforce consisting of the principal permittee, Building Industry Association, Association of General Contractors and Civil Engineers and Land Surveyors of California and developed "Best Management Practices for New Development Including Non-Residential Construction Projects (1-5 acres)". The permittees are implementing the BMPs from this guidance document and are requiring new developments and significant redevelopments to develop and implement appropriate Water Quality Management Plans. This order requires structural and non-structural BMPs for new developments and significant redevelopments, only if adequate regional and/or watershed wide management programs are not being implemented.

51. The Regional Board and the permittees recognize the importance of watershed management initiatives and regional planning and coordination in the development and implementation of programs and policies related to water quality protection. A number of such efforts are underway in which the permittees are active participants. This order encourages continued participation in such programs and policies. The Regional Board also recognizes that, in certain cases, diversion of funds targeted for certain monitoring programs to regional monitoring programs may be necessary. The Executive Officer is authorized to approve, after proper public notification and consideration of all comments received, the watershed management initiatives and regional planning and coordination programs and regional monitoring programs. The permittees are required to submit all documents, where appropriate, in an electronic format. All such documents will be posted at the Regional Board's website and all interested parties will be notified. In addition, the website will include the administrative and civil procedures for appealing any decision made by the Executive Officer.

52. The storm water regulations require public participation in the development and implementation of the storm water management program. As such, the permittees are required to solicit and consider all comments received from the public and submit copies of the comments to the Executive Officer of the Regional Board with the annual reports due on November 15. In response to public comments, the permittees may modify reports, plans, or schedules prior to submittal to the Executive Officer.

53. In accordance with California Water Code Section 13389, the issuance of waste discharge requirements for this discharge is exempt from those provisions of the California Environmental Quality Act contained in Chapter 3 (commencing with Section 21100), Division 13 of the Public Resources Code.

54. The permitted discharge is consistent with the anti-degradation provisions of 40 CFR 131.12 and the State Board Resolution 68-16. This order requires implementation of programs (i.e., BMPs) to reduce the level of pollutants in the storm water discharges. The combination of programs and policies required to be implemented under this order for new and existing developmens are designed to improve urban storm water quality.

55. The Regional Board has notified the permittees and interested parties of its intent to issue waste discharge requirements for this discharge and has provided them with an opportunity to submit their written views and recommendations.

56. The Regional Board, in a public hearing, heard and considered all comments pertaining to the discharge and to the tentative requirements.

IT IS HEREBY ORDERED that the permittees, in order to meet the provisions contained in Division 7 of the California Water Code and regulations adopted thereunder, and the provisions of the Clean Water Act, as amended, and regulations and guidelines adopted thereunder, shall comply with the following:

I. RESPONSIBILITIES OF PRINCIPAL PERMITTEE

The principal permittee shall be responsible for the overall program management and shall:

1. Conduct chemical and biological water quality monitoring, as required by the Executive Officer of the Regional Board.
2. Conduct inspections and maintain the storm drain systems within its jurisdiction.
3. Review and revise, if necessary, policies/ordinances necessary to establish legal authority as required by the Federal Storm Water Regulations.
4. Respond and/or arrange for responding to emergency situations, such as accidental spills, leaks, illicit discharges and illegal connections, etc., to prevent or reduce the discharge of pollutants to storm drain systems and waters of the U.S. within its jurisdiction.
5. Take appropriate enforcement actions for illicit discharges to the MS4 systems owned or controlled by the principal permittee.
6. Prepare and submit to the Executive Officer of the Regional Board unified reports, plans, and programs as required by this order, including the annual report.

The activities of the principal permittee shall include, but not be limited to, the following:

1. Coordinate and conduct Management Committee meetings on an as needed basis. The principal permittee will take the lead role in initiating and developing area-wide programs and activities necessary to comply with the NPDES Permit.
2. Coordinate permit activities and participate in any subcommittees formed as necessary to coordinate compliance activities with this order.
3. Provide technical and administrative support and inform the co-permittees of the progress of other pertinent municipal programs, pilot projects, research studies, etc.
4. Coordinate the implementation of area-wide storm water quality management activities such as public education, pollution prevention, household hazardous waste collection, etc.
5. Develop and implement mechanisms, performance standards, etc., to promote uniform and consistent implementation of BMPs among the permittees.
6. Pursue enforcement actions as necessary within its jurisdiction to ensure compliance with storm water management programs, ordinances and implementation plans, including physical elimination of undocumented connections and illicit discharges.
7. In conjunction with the other permittees, implement the BMPs listed in the DAMP, and take such other actions as may be necessary to meet the MEP standard.
8. Monitor the implementation of the plans and programs required by this order and determine their effectiveness in protecting beneficial uses.

9. Coordinate all the activities with the Regional Board, including the submittal of all reports, plans, and programs, as required under this order.
10. Obtain public input for any proposed management and implementation plans, where applicable.
11. Cooperate in watershed management programs and regional and/or statewide monitoring programs.

II. RESPONSIBILITIES OF THE CO-PERMITTEES

The co-permittees shall be responsible for the management of storm drain systems within their jurisdictions and shall:

1. Implement management programs, monitoring programs, implementation plans and all BMPs outlined in the DAMP within each respective jurisdiction, and take any other actions as may be necessary to meet the MEP standard.
2. Coordinate among their internal departments and agencies, as appropriate, to facilitate the implementation of this Order and the DAMP.
3. Establish and maintain adequate legal authority, as required by the Federal Storm Water Regulations.
4. Conduct storm drain system inspections and maintenance in accordance with the criteria developed by the principal permittee.
5. Take appropriate enforcement actions for illicit discharges to the MS4 system owned or controlled by the co-permittee.

The co-permittees' activities shall include, but not be limited to, the following:

1. Participate in a Management Committee comprised of the principal permittee and one representative of each co-permittee. The principal permittee will take the lead role in initiating and developing area-wide programs activities necessary to comply with the NPDES Permit. The committee will meet on a regular basis (at least six times per year). Each permittee shall designate one official representative to the Management Committee.
2. Review, approve, implement, and comment on all plans, strategies, management programs, and monitoring programs, as developed by the principal permittee or any permittee subcommittee to comply with this order.
3. Pursue enforcement actions as necessary to ensure compliance with the storm water management programs, ordinances and implementation plans, including physical elimination of undocumented connections and illicit discharges.
4. Conduct and coordinate with the principal permittee any surveys and characterizations needed to identify the pollutant sources and drainage areas.
5. Submit storm drain system maps with periodic revisions, as necessary.

6. Respond to emergency situations, such as accidental spills, leaks, illicit discharges and illegal connections, etc., to prevent or reduce the discharge of pollutants to storm drain systems and waters of the U.S.
7. Prepare and submit all required reports to the principal permittee in a timely manner.

III. DISCHARGE LIMITATIONS/PROHIBITIONS

1. In accordance with the requirements of 40 CFR 122.26(d)(2)(i)(B) and 40 CFR 122.26(d)(2)(i)(F), the permittees shall prohibit illicit/illegal discharges (non-storm water) from entering into the municipal separate storm sewer systems.
2. The discharge of storm water from the MS4s to waters of the United States containing pollutants that have not been reduced to the maximum extent practicable is prohibited.
3. The permittees shall effectively prohibit the discharge of non-storm water into the MS4s, unless such discharges are authorized by a separate NPDES permit or as otherwise specified in this provision. Certain discharges identified below need not be prohibited by the permittees. If, however, any of these discharges are identified by the permittees or the Executive Officer as a significant source of pollutants, coverage under the Regional Board's De Minimus permit may be required.
    a. Discharges composed entirely of storm water,
    b. Potable water line flushing and other potable water sources,
    c. Air conditioning condensate,
    d. Landscape irrigation, lawn garden watering and other irrigation waters,
    e. Passive foundation drains,
    f. Passive footing drains,
    g. Water from crawl space pumps,
    h. Dechlorinated swimming pool discharges,
    i. Non-commercial vehicle washing,
    j. Diverted stream flows,
    k. Rising ground waters and natural springs,
    l. Ground water infiltration as defined in 40 CFR 35.2005 (20) and uncontaminated pumped groundwater,
    m. Flows from riparian habitats and wetlands,
    n. Emergency fire fighting flows (i.e., flows necessary for the protection of life and property) do not require BMPs and need not be prohibited. However, where possible, when not interferring with health and safety issues, BMPs should be considered (also see Section XIX, Provision 4),
    o. Waters not otherwise containing wastes as defined in California Water Code Section 13050 (d), and

p. Other types of discharges identified and recommended by the permittees and approved by the Regional Board.

The Regional Board may add categories of non-storm water discharges that are not significant sources of pollutants or remove categories of non-storm water discharges listed above based upon a finding that the discharges are a significant source of pollutants.

4. For purposes of this order, a discharge may include storm water or other types of discharges, identified in Section III.3.

5. Non-storm water discharges from public agency activities into waters of the U.S. are prohibited unless the non-storm water discharges are permitted by an NPDES permit or are included in Section III.3. If permitting or immediate elimination of the non-storm water discharges is impractical, the permittees shall include in the Environmental Performance Report, a proposed plan to eliminate the non-storm water discharges in a timely manner.

6. The permittees shall reduce the discharge of pollutants, including trash and debris, from the storm water conveyance systems to the maximum extent practicable.

7. Discharges from the MS4s shall be in compliance with the applicable discharge prohibitions contained in Chapter 5 of the Basin Plan.

8. Discharges from the MS4s of storm water or non-storm water, for which a Permittee is responsible, shall not cause or contribute to a condition of nuisance, as that term is defined in Section 13050 of the Water Code.

IV. RECEIVING WATER LIMITATIONS

1. Discharges from the MS4s shall not cause or contribute to exceedances of receiving water quality standards (designated beneficial uses and water quality objectives) for surface waters or groundwaters.

2. The DAMP and its components shall be designed to achieve compliance with receiving water limitations. It is expected that compliance with receiving water limitations will be achieved through an iterative process and the application of increasingly more effective BMPs. The permittees shall comply with Sections III.2 and IV of this order through timely implementation of control measures and other actions to reduce pollutants in urban storm water runoff in accordance with the DAMP and other requirements of this order, including any modifications thereto.

3. If permittees continue to cause or contribute to an exceedance of water quality standards, notwithstanding implementation of the DAMP and other requirements of this order, the permittees shall assure compliance with Sections III.2 and IV of this order by complying with the following procedure:

   a. Upon a determination by either the permittees or the Executive Officer that the discharges from the MS4 systems are causing or contributing to an exceedance of an applicable water quality standard, the permittees shall promptly notify and thereafter submit a report to the Executive Officer that describes BMPs that are currently being

implemented and additional BMPs that will be implemented to prevent or reduce any pollutants that are causing or contributing to the exceedance of water quality standards. The report may be incorporated in the annual update to the DAMP, unless the Executive Officer directs an earlier submittal. The report shall include an implementation schedule. The Executive Officer may require modifications to the report;

b. Submit any modifications to the report required by the Executive Officer within 30 days of notification;

c. Within 30 days following approval by the Executive Officer of the report described above, the permittees shall revise the DAMP and monitoring program to incorporate the approved modified BMPs that have been and will be implemented, the implementation schedule, and any additional monitoring required; and,

d. Implement the revised DAMP and monitoring program in accordance with the approved schedule.

So long as the permittees have complied with the procedures set forth above and are implementing the revised DAMP, the permittees do not have to repeat the same procedure for continuing or recurring exceedances of the same receiving water limitations unless the Executive Officer determines it is necessary to develop additional BMPs.

V. IMPLEMENTATION AGREEMENT

1. By July 1, 2002, the existing Implementation Agreement shall be revised to include the cities that were not signatories to this agreement. A copy of the signature page and any revisions to the Agreement shall be included in the annual report.
2. By July 1, 2002, the permittees shall evaluate the storm water management structure and the Implementation Agreement and determine the need for any revision. The corresponding annual report shall include the findings of this review and a schedule for any needed revisions.

VI. LEGAL AUTHORITY/ENFORCEMENT

1. The permittees shall maintain adequate legal authority to control the contribution of pollutants to the MS4 by storm water discharges and enforce those authorities.
2. The permittees shall take appropriate enforcement actions against any violators of their Water Quality Ordinance, in accordance with the adopted/established guidelines and procedures. All enforcement actions shall be consistent with the Enforcement Consistency Guide.
3. Permittees' ordinances or other local regulatory mechanisms shall include sanctions to ensure compliance. Sanctions shall include but are not limited to: monetary penalties, non-monetary penalties, bonding requirements, and/or permit denials/revocations/stays for non-compliance. If the permittees' current ordinances do not have a provision for civil or criminal penalties for violations of their water quality ordinances, the permittees shall enact such ordinances by November 15, 2003.

4. By November 15, 2003, each permittee shall submit a statement, signed by legal counsel, that the permittee has obtained all necessary legal authority to comply with this Order through adoption of ordinances and/or municipal code modifications.

5. The permittees shall continue to provide notification to Regional Board staff regarding storm water related information gathered during site inspections of industrial and construction sites regulated by the Statewide General Storm Water Permits and at sites that should be regulated under the State's General Permits. The notification should include any observed violations of the General Permits, prior history of violations, any enforcement actions taken by the permittee, and any other relevant information.

6. By November 15, 2003, the permittees shall review their water quality ordinances and provide a report on the effectiveness of these ordinances and associated enforcement programs, in prohibiting the following types of discharges to the MS4s (the permittees may propose appropriate control measures in lieu of prohibiting these discharges, where the permittees are responsible for ensuring that dischargers adequately maintain those control measures):

   a. Sewage, where a co-permittee operates the sewage collection system;

   b. Wash water resulting from the hosing or cleaning of gas stations, auto repair garages, and other types of automobile service stations;

   c. Discharges resulting from the cleaning, repair, or maintenance of any type of equipment, machinery, or facility, including motor vehicles, concrete mixing equipment, portable toilet servicing, etc.;

   d. Wash water from mobile auto detailing and washing, steam and pressure cleaning, carpet cleaning, and other such mobile commercial and industrial activities;

   e. Water from cleaning of municipal, industrial, and commercial sites, including parking lots, streets, sidewalks, driveways, patios, plazas, work yards and outdoor eating or drinking areas, etc.;

   f. Runoff from material storage areas or uncovered receptacles that contain chemicals, fuels, grease, oil, or other hazardous materials[7];

   g. Discharges of runoff from the washing of toxic materials[8] from paved or unpaved areas;

   h. Discharges of pool or fountain water containing chlorine, biocides, or other chemicals; pool filter backwash containing debris and chlorine;

   i. Pet waste, yard waste, litter, debris, sediment, etc.; and,

   j. Restaurant or food processing facility wastes such as grease, floor mat and trash bin wash water, food waste, etc.

[7] Hazardous Material is defined as any substrate that poses a threat to human health or the environment due to its toxicity, corrosiveness, ignitability, explosive nature or chemical reactivity. These also include materials named by EPA to be reported if a designed quantity of the material is spilled into the waters of the United States or emitted into the environment.

[8] Toxic Material is a chemical or a mixture that may present an unreasonable risk of injury to health or the environment.

7. The Principal Permittee shall, on or before July 1, 2002, develop a restaurant inspection program which shall, at a minimum, address:

   a. Oil and grease disposal to verify that these wastes are not poured onto a parking lot, street or adjacent catch basin;

   b. Trash bin areas to verify that these areas are clean, the bin lids are closed, the bins are not filled with liquid and the bins have not been washed out;

   c. Parking lot, alley, sidewalk and street areas to verify that floormats, filters and garbage containers are not washed in those areas and that no washwater is poured in those areas;

   d. Parking lot areas to verify that they are cleaned by sweeping, not by hosing down and that the facility operator uses dry methods for spill cleanup; and,

   e. Inspection of existing devices designed to separate grease from wastewater (e.g., grease traps or interceptors) to ensure adequate capacity and proper maintenance.

VII. ILLEGAL CONNECTIONS; LITTER, DEBRIS AND TRASH CONTROL

1. The permittees shall continue to prohibit all illegal connections to the MS4s through their ordinances, inspections, and monitoring programs. If routine inspections or dry weather monitoring indicate any illegal connections, they shall be investigated and eliminated or permitted within 120 days of discovery and identification.
2. All reports of spills, leaks, and/or illegal dumping shall be promptly investigated and, where appropriate, reported to the Executive Officer within 24 hours (those incidents which may pose an immediate threat to human health or the environment, e.g., sewage spills that could impact water contact recreation, an oil spill that could impact wild life, a hazardous substance spill where residents are evacuated, etc.) by phone or e-mail, with a written report within 5 days. At a minimum, all sewage spills above 1,000 gallons and all reportable quantities of hazardous waste spills as per 40CFR 117 and 302 shall be reported within 24 hours and all other spill incidents shall be included in the annual report. The permittees may propose a reporting program, including reportable incidents and quantities, jointly with other agencies, such as the County Health Care Agency, for approval by the Executive Officer.
3. The permittees shall continue to implement appropriate control measures to reduce and/or to eliminate the discharge of trash and debris to waters of the U.S. These control measures shall be reported in the annual report.
4. By July 1, 2003, the permittees shall review their litter/trash control ordinances to determine the need for any revision. The permittees are encouraged to characterize trash, determine its main source(s) and develop and implement appropriate BMPs to control trash in urban runoff. The findings of this review shall be included in the annual report for 2002-2003.
5. By July 1, 2003, the permittees shall determine the need for any additional debris control measures. The findings shall be included in the annual report for 2002-2003.

VIII. MUNICIPAL INSPECTIONS OF CONSTRUCTION SITES

1. Each permittee shall develop by October 15, 2002, an inventory of all construction sites within its jurisdiction for which building or grading permits are issued and activities at the site include: soil movement; uncovered storage of materials or wastes, such as dirt, sand or fertilizer; or exterior mixing of cementaceous products, such as concrete, mortar or stucco. Sites will be included regardless of whether the construction site is subject to the California Statewide General NPDES Permit for Storm Water Discharges Associated with Construction Activities (General Permit) or other individual NPDES permit. This database shall be updated prior to each rainy season thereafter. This inventory shall be maintained in a computer-based database system and shall include relevant information on site ownership, General Permit WDID # (if any), size, location, etc. Inclusion of a Geographical Information System (GIS) is recommended but not required.

2. To establish priorities for inspection requirements under this Order, the permittees shall prioritize construction sites within their jurisdiction as a high, medium or low threat to water quality. Evaluation of construction sites should be based on such factors as soil erosion potential, project size, proximity and sensitivity of receiving waters and any other relevant factors. At a minimum, high priority construction sites shall include: sites over 50 acres; sites over 5 acres that are tributary to Clean Water Act section 303(d) waters listed for sediment or turbidity impairments; and sites that are tributary to and within 500 feet of an area defined by the Ocean Plan as an Area of Special Biological Significance (ASBS) .

3. Each permittee shall conduct construction site inspections for compliance with its ordinances (grading, Water Quality Management Plans, etc.) and local permits (construction, grading, etc.). Inspections shall include a review of erosion control and BMP implementation plans and an evaluation of the effectiveness and maintenance of the BMPs identified. Inspection frequency will, at a minimum, include the following:

   a. During the wet season (i.e., October 1 through April 30 of each year), all high priority sites are to be inspected, in their entirety, once a month. All medium priority sites are to be inspected at least twice during the wet season. All low priority sites are to be inspected at least once during the wet season. When BMPs or BMP maintenance is deemed inadequate or out of compliance, an inspection frequency of once every week will be maintained until BMPs and BMP maintenance are brought into compliance. During the 2001-2002 wet season, prior to the development of the inventory database, all construction sites must be visited at least twice. If a site is deemed out of compliance, an inspection frequency adequate to bring the site into compliance must be maintained;

   b. During the dry season (i.e., May 1 through September 30 of each year), all construction sites shall be inspected at a frequency sufficient to ensure that sediment and other pollutants are properly controlled and that unauthorized, non-storm water discharges are prevented; and,

   c. Information including, at a minimum, inspection dates, inspectors present and the results of the inspection, must be maintained in the database identified in Section VIII.1 or must be linked to that database. A copy of this database must be provided to the Regional Board with each annual report.

4. Each permittee shall enforce its ordinances and permits at all construction sites, as necessary, to maintain compliance with this Order. Sanctions for non-compliance must include: monetary penalties, bonding requirements and/or permit denial or revocation.

5. Within 24 hours of discovery, each permittee shall provide oral or e-mail notification to the Santa Ana Regional Water Quality Control Board of non-compliant sites within their jurisdiction that are determined to pose a threat to human health or the environment (e.g., sewage spills that could impact water contact recreation, an oil spill that could impact wildlife, a hazardous substance spill where residents are evacuated, etc.). Following oral notification, a written report must be submitted to the Santa Ana Regional Water Quality Control Board within 10 days, detailing the nature of the non-compliance, any corrective action taken by the site owner, other relevant information (e.g., past history of non-compliance, environmental damage resulting from the non-compliance, site owner responsiveness) and the type of enforcement that will be carried out by the permittee. Further, incidences of non-compliance shall be recorded along with the information noted in the written report and the final outcome/enforcement for the incident in the database identified in Sections VIII.1 and 3.c or must be linked to these databases.

6. The inspectors responsible for ensuring compliance at construction sites shall be trained in and have an understanding of: federal, state and local water quality laws and regulations as they apply to construction and grading activities; the potential effects of construction and urbanization on water quality; and implementation and maintenance of erosion control BMPs and sediment control BMPs and the applicable use of both. Each permittee shall have adequately trained its inspection staff by October 15, 2002, and on an annual basis, prior to the rainy season, thereafter. Training programs should be coordinated with the Santa Ana Regional Water Quality Control Board and prior notification of training shall be provided to Regional Board staff. New hires or transfers that will be performing construction inspections for the permittees must be trained within one month of starting inspection duties.

7. The permittees need not inspect facilities already inspected by Regional Board staff if the inspection was conducted within the specified time period.

IX. MUNICIPAL INSPECTIONS OF INDUSTRIAL FACILTIES

1. Each permittee shall develop by July 1, 2003, an inventory of industrial facilities within its jurisdiction with business permits or other authorization by permittees, that have the potential to discharge pollutants to the MS4. Facilities will be listed, regardless of whether the facility is subject to the California Statewide General NPDES Permit for Storm Water Discharges Associated with Industrial Activities (General Industrial Permit) or other individual NPDES permit. This database must be updated on an annual basis. This inventory must be maintained in a computer-based database system and must include relevant information on ownership, SIC code(s), General Industrial Permit WDID # (if any), size, location, etc. Inclusion of a Geographical Information System (GIS) is recommended but not required.

2. To establish priorities for inspection requirements under this Order, the permittees shall prioritize industrial facilities within their jurisdiction as a high, medium or low threat to water quality. Evaluation of these facilities should be based on such factors as type of

industrial activities (SIC codes), materials or wastes used or stored outside, pollutant discharge potential, facility size, proximity and sensitivity of receiving waters and any other relevant factors. At a minimum, a high priority shall be assigned to: facilities subject to section 313 of Title III of the Superfund Amendments and Reauthorization Act of 1986 (SARA); facilities requiring coverage under the General Industrial Permit; facilities with a high potential for, or history of, unauthorized, non-storm water discharges; and facilities that are tributary to, and within 500 feet of, an area defined by the Ocean Plan as an Area of Special Biological Significance (ASBS).

3. Each permittee shall conduct industrial facility inspections for compliance with its ordinances and permits. Inspections shall include a review of material and waste handling and storage practices, pollutant control BMP implementation and maintenance and evidence of past or present unauthorized, non-storm water discharges. All high priority facilities identified in IX.2 shall be inspected and a report on these inspections shall be submitted by November 15, 2003 and a report of inspections during subsequent years shall be included in the annual report for that year.

4. After July 1, 2003, all high priority sites are to be inspected at least once a year; all medium priority sites are to be inspected at least once every two years; and all low priority sites are to be inspected at least once per permit cycle. In the event that inappropriate material or waste handling or storage practices are observed or there is evidence of past or present unauthorized, non-storm water discharges, an inspection frequency adequate to bring the site into compliance must be maintained (at a minimum, once a month). Once compliance is achieved, a minimum inspection frequency of once every four months will be maintained for the next calendar year.

5. By July 1, 2005, each permittee shall identify the remaining industrial facilities that do not have business permits or other authorization by the permittees. These facilities shall be added to the database identified in Section IX.1 and shall be prioritized in accordance with the specifications identified in Section IX.2.

6. Information including, at a minimum, inspection dates, inspectors present and the results of the inspection must be maintained in the database identified in Section IX.1 or must be linked to that database. A copy of this database must be provided to the Regional Board with each annual report.

7. Each permittee shall enforce its ordinances and permits at all industrial facilities as necessary to maintain compliance with this Order. Sanctions for non-compliance must include: monetary penalties, bonding requirements and/or permit denial or revocation.

8. Within 24 hours, each permittee shall provide oral or e-mail notification to the Santa Ana Regional Water Quality Control Board of non-compliant facilities within their jurisdiction that are determined to pose a threat to human health or the environment (e.g., sewage spills that could impact water contact recreation, an oil spill that could impact wildlife, a hazardous substance spill where residents are evacuated, etc.). Following oral notification, a written report must be submitted to the Santa Ana Regional Water Quality Control Board within 10 days, detailing the nature of the non-compliance, any corrective action taken by the site owner, other relevant information (e.g., past history of non-compliance, environmental

damage resulting from the non-compliance, facility owner responsiveness) and the type of enforcement that will be carried out by the permittee. Further, incidences of non-compliance shall be recorded along with the information noted in the written report and the final outcome/enforcement for the incident, in the database identified in Section IX.1.

9. The inspectors responsible for ensuring compliance at industrial facilities shall be trained in and have an understanding of: federal, state and local water quality laws and regulations as they apply to industrial activities; the potential effects of industrial discharges and urbanization on water quality; and implementation and maintenance of pollutant control BMPs. Each permittee shall have adequately trained their inspection staff by July 1, 2003, and on an annual basis thereafter. Training programs should be coordinated with the Santa Ana Regional Water Quality Control Board and prior notification of training shall be provided to Regional Board staff. New hires or transfers that will be performing industrial inspections for the permittees must be trained within one month of starting inspection duties.
10. The permittees need not inspect facilities already inspected by Regional Board staff, if the inspection was conducted within the specified time period.

X. MUNICIPAL INSPECTIONS OF COMMERCIAL FACILITIES

1. Each permittee shall develop by July 1, 2003, an inventory of the following commercial facilities/companies listed below within its jurisdiction. This database must be updated on an annual basis. This inventory must be maintained in a computer-based database system and must include relevant information on ownership, size, location, etc. Inclusion of a Geographical Information System (GIS) is recommended but not required.

    a. Automobile mechanical repair, maintenance, fueling or cleaning;

    b. Automobile and other vehicle body repair or painting;

    c. Mobile automobile or other vehicle washing;

    d. Mobile carpet, drape or furniture cleaning;

    e. Mobile high pressure or steam cleaning;

    f. Painting and coating;

    g. Nurseries and greenhouses;

    h. Landscape and hardscape installation;

    i. Pool, lake and fountain cleaning;

j. Other commercial sites/sources that the Permittee determines may contribute a significant pollutant load to the MS4; and,

k. Any commercial sites or sources that are tributary to and within 500 feet of an area defined by the Ocean Plan as an Area of Special Biological Significance (ASBS).

2. To establish priorities for inspection requirements under this Order, the permittees shall prioritize commercial facilities/companies within their jurisdiction as a high, medium or low threat to water quality based on such factors as the type, magnitude and location of the commercial activity, potential for discharge of pollutants to the MS4 and any history of unauthorized, non-storm water discharges.

3. Each permittee shall conduct commercial facility inspections for compliance with its ordinances and permits. Inspections shall include a review of material and waste handling and storage practices, pollutant control BMP implementation and maintenance and evidence of past or present unauthorized, non-storm water discharges.

4. After July 1, 2003, each permittee shall establish inspection frequencies and priorities as determined by the threat to water quality prioritization described in X.2. In the event that inappropriate material or waste handling or storage practices are observed, or there is evidence of past or present unauthorized, non-storm water discharges, an inspection frequency adequate to bring the site into compliance must be maintained.

5. By July 1, 2004, all high priority sites shall be inspected at least once.

6. Information including, at a minimum, inspection dates, inspectors present and the results of the inspection must be maintained in the database identified in Section X.1 or must be linked to that database. A copy of this database must be provided to the Regional Board with each annual report.

7. Each permittee shall enforce its ordinances and permits at commercial facilities. Sanctions for non-compliance must include: monetary penalties, bonding requirements and/or permit denial or revocation.

8. Within 24 hours, each permittee shall provide oral or e-mail notification to the Santa Ana Regional Water Quality Control Board of non-compliant facilities within their jurisdiction, that are determined to pose a threat to human health or the environment (e.g., sewage spills that could impact water contact recreation, an oil spill that could impact wildlife, a hazardous substance spill where residents are evacuated, etc.). Following oral notification, a written report must be submitted to the Santa Ana Regional Water Quality Control Board within 5 days. For incidents that do not pose a threat to human or environmental health, the permittees shall submit a written report within 30 days of the incident. All written reports shall detail the nature of the non-compliance, identify any corrective action taken by the site owner, note other relevant information (e.g., past history of non-compliance, environmental damage resulting from the non-compliance,

facility owner responsiveness) and the type of enforcement that will be carried out by the permittee. Further, incidences of non-compliance shall be recorded along with the information noted in the written report and the final outcome/enforcement for the incident in the database identified in Section X.1.

9. The inspectors responsible for ensuring compliance at commercial facilities shall be trained in, and have an understanding of, Federal, State and local water quality laws and regulations as they apply to industrial and commercial activities; the potential effects of industrial discharge and urbanization on water quality; and implementation and maintenance of pollutant control BMPs. Each permittee shall have adequately trained their inspection staff by July 1, 2003 and on an annual basis thereafter. Training programs should be coordinated with the Santa Ana Regional Water Quality Control Board and prior notification of training shall be provided to Regional Board staff. New hires or transfers that will be performing commercial inspections for the permittees must be trained within one month of starting inspection duties.

10. The permittees need not inspect facilities already inspected by Regional Board staff if the inspection was conducted within the specified time period.

XI. SEPTIC SYSTEM FAILURES AND PORTABLE TOILET DISCHARGES

1. By July 1, 2003, the permittees, whose jurisdictions have 50 or more septic tank or sub-surface disposal systems in use, shall identify with the appropriate governing agency, a mechanism to determine the effect of septic system failures on storm water quality and a mechanism to address such failures.
2. By July 1, 2003, the principal permittee shall review the permittees' current oversight programs for portable toilets to determine the need for any revision.

XII. NEW DEVELOPMENT (INCLUDING SIGNIFICANT RE-DEVELOPMENT)

A. GENERAL REQUIREMENTS:

1. By July 1, 2002, the permittees shall establish a mechanism to ensure (prior to issuance of any local permits or other approvals) that all construction sites that are required to obtain coverage under the State's General Storm Water Permit for construction sites have filed with the State Board a Notice of Intent to be covered by the relevant general permit.
2. Each permittee shall minimize the short and long-term impacts on receiving water quality from new developments and re-developments, as required in Section XII.B.1., below. In order to reduce pollutants and runoff flows from new developments and re-developments to the maximum extent practicable, permittees should, at a minimum:
   a. Review General Plan/CEQA Processes
   b. Modify the Project Approval Process
   c. Conduct Public/Business Education

3. By December 19, 2002, the permittees shall review their planning procedures and CEQA document preparation processes to ensure that urban runoff-related issues are properly considered and addressed. If necessary, these processes should be revised by that date to consider and mitigate impacts to storm water quality. These changes may include revising the General Plan, modifying the project approval processes, including a section on urban runoff related water quality issues in an addendum CEQA checklist, and conducting training for project proponents. The findings of this review and the actions taken by the permittees shall be reported to the Regional Board by January 2, 2003. The following potential impacts shall be considered during CEQA review:

    a. Potential impact of project construction on storm water runoff;

    b. Potential impact of project's post-construction activity on storm water runoff;

    c. Potential for discharge of storm water pollutants from areas of material storage, vehicle or equipment fueling, vehicle or equipment maintenance (including washing), waste handling, hazardous materials handling or storage, delivery areas. loading docks or other outdoor work areas;

    d. Potential for discharge of storm water to affect the beneficial uses of the receiving waters;

    e. Potential for significant changes in the flow velocity or volume of storm water runoff to cause environmental harm; and,

    f. Potential for significant increases in erosion of the project site or surrounding areas.

4. By July 1, 2004, the permittees shall review their watershed protection principles and policies in their General Plan or related documents (such as Development Standards, Zoning Codes, Conditions of Approval, Development Project Guidance) to ensure that these principals and policies are properly considered and are incorporated into these documents. The findings of this review and the actions taken by the permittees shall be reported to the Regional Board by November 15, 2004. These principles and policies should include, but not be limited to, the following considerations:

    a. Limit disturbance of natural water bodies and drainage systems; conserve natural areas; protect slopes and channels; and minimize impacts from storm water and urban runoff on the biological integrity of natural drainage systems and water bodies;

    b. Minimize changes in hydrology and pollutant loading; require incorporation of controls, including structural and non-structural BMPs, to mitigate the projected increases in pollutant loads and flows; ensure that post-development runoff rates and velocities from a site have no significant adverse impact on downstream erosion and stream habitat; minimize the quantity of storm water directed to impermeable surfaces and the MS4s; and maximize the percentage of permeable surfaces to allow more percolation of storm water into the ground;

    c. Preserve wetlands, riparian corridors, and buffer zones and establish reasonable limits on the clearing of vegetation from the project site;

d. Encourage the use of water quality wetlands, biofiltration swales, watershed-scale retrofits, etc., where such measures are likely to be effective and technically and economically feasible;

e. Provide for appropriate permanent measures to reduce storm water pollutant loads in storm water from the development site; and,

f. Establish development guidelines for areas particularly susceptible to erosion and sediment loss.

5. Each permittee shall provide the Regional Board with the draft amendment or revision when a pertinent General Plan element or the General Plan is noticed for comment in accordance with Govt. Code § 65350 et seq.

6. By July 1, 2003, the permittees shall review and, as necessary, revise their current grading/erosion control ordinances in order to reduce erosion caused by new development or significant re-development projects.

7. The permittees shall, through conditions of approval, ensure proper maintenance and operation of any permanent flood control structures installed in new developments. The parties responsible for the maintenance and operation of the facilities and a funding mechanism for operation and maintenance, shall be identified prior to approval of the project.

8. By November 15, 2003, the principal permittee shall submit a proposal for a study to evaluate the effectiveness of a group of selected BMPs for controlling erosion during new development. Based on the results of this study, one or more BMPs will be identified as (a) County-preferred BMP(s) for erosion control during new development. This proposal shall include details of the new development project site, the BMPs selected for the study, and a proposed schedule. The proposed and final BMP selection shall be approved by the Regional Board Executive Officer and the study shall be completed by the end of this permit term.

9. The permittees shall continue to implement the new development BMPs (DAMP, Appendix G) and BMPs for public works construction (DAMP, Appendix H).

10. Within six months of adoption of this order, the permittees shall review their DAMP to determine the need for:

    a. Re-establishing the New Development Task Force

    b. Establishing a Water Quality Plan verification program.

B. WATER QUALITY MANAGEMENT PLAN (WQMP) FOR URBAN RUNOFF (FOR NEW DEVELOPMENT/SIGNIFICANT REDEVELOPMENT):

1. By March 1, 2003, the permittees shall review their existing BMPs for New Developments (Appendix G of the DAMP) and submit for review and approval by the Executive Officer, a revised WQMP for urban runoff from new developments/ significant re-developments for the type of projects listed below:

a. All significant re-development projects, where significant re-development is defined as the addition of 5,000 or more square feet of impervious surface on an already developed site. This includes additional buildings and/or structures, extension of existing footprint of a building, construction of parking lots, etc.

b. Home subdivisions of 10 units or more. This includes single family residences, multi-family residences, condominiums, apartments, etc.

c. Commercial and industrial developments of 100,000 square feet or more. This includes non-residential developments such as hospitals, educational institutions (to the extent the permittees have authority to regulate these developments), recreational facilities, mini-malls, hotels, office buildings, warehouses, and light & heavy industrial facilities.

d. Automotive repair shops (with SIC codes 5013, 5014, 5541, 7532-7534, 7536-7539).

e. Restaurants where the land area of development is 5,000 square feet or more.

f. All hillside developments on 10,000 square feet or more, which are located on areas with known erosive soil conditions or where the natural slope is twenty-five percent or more.

g. Developments of 2,500 square feet of impervious surface or more adjacent to (within 200 feet) or discharging directly into environmentally sensitive areas, such as areas designated in the Ocean Plan as areas of special biological significance or waterbodies listed on the CWA Section 303(d) list of impaired waters.

h. Parking lots of 5,000 square feet or more exposed to storm water. Parking lot is defined as a land area or facility for the temporary storage of motor vehicles.

2. The permittees are encouraged to include in the WQMP the development and implementation of regional and/or watershed management programs that address runoff from new development and significant re-development. The WQMP shall include BMPs for source control, pollution prevention, and/or structural treatment BMPs. For all structural treatment controls, the WQMP shall identify the responsible party for maintenance of the treatment system, and a funding source or sources for its operation and maintenance. The goal of the WQMP is to develop and implement practicable programs and policies to minimize the effects of urbanization on site hydrology, urban runoff flow rates or velocities and pollutant loads. This goal may be achieved through watershed-based structural treatment controls, in combination with site-specific BMPs. The WQMP shall reflect consideration of the following goals, which may be addressed through on-site-and/or watershed-based BMPs.

   a. The pollutants in post-development runoff shall be reduced using controls that utilize best available technology (BAT) and best conventional tecnology (BCT).

   b. The discharge of any listed pollutant to an impaired waterbody on the 303(d) list shall not cause an exceedence of receiving water quality objectives.

3. During the time that the WQMP is being revised, the permittees shall implement their existing requirements for new development (Appendix G of the DAMP). If the Executive Officer does not approve the revised WQMP by October 1, 2003, as meeting

the goals proposed in XII.B.2, above and providing an equivalent or superior degree of treatment as the sized criteria outlined in XII.B.3.A, B and C, below, structural BMPs shall be required for all new development and significant redevelopment[2]. Minimum structural BMPs must either be sized to comply with one of the following numeric sizing criteria or be deemed by the Principal Permittee to provide equivalent or superior treament, either on a site basis or a watershed basis:

A. Volume

Volume–based BMPs shall be designed to infiltrate, filter, or treat either:

1. The volume of runoff produced from a 24-hour, 85th percentile storm event, as determined from the local historical rainfall record; or,
2. The volume of annual runoff produced by the 85th percentile, 24-hour rainfall event, determined as the maximized capture storm water volume for the area, from the formula recommended in Urban Runoff Quality Management, WEF Manual of Practice No. 23/ASCE Manual of Practice No. 87 (1998); or,
3. The volume of annual runoff based on unit basin storage volume, to achieve 80% or more volume treatment by the method recommended in California Stormwater Best Management Practices Handbook – Industrial/Commercial (1993); or,
4. The volume of runoff, as determined from the local historical rainfall record, that achieves approximately the same reduction in pollutant loads and flows as achieved by mitigation of the 85th percentile, 24-hour runoff event;

OR

B. Flow

Flow-based BMPs shall be designed to infiltrate, filter, or treat either:

1. The maximum flow rate of runoff produced from a rainfall intensity of 0.2 inch of rainfall per hour; or,
2. The maximum flow rate of runoff produced by the 85th percentile hourly rainfall intensity, as determined from the local historical rainfall record, multiplied by a factor of two; or,
3. The maximum flow rate of runoff, as determined from the local historical rainfall record, that achieves approximately the same reduction in pollutant loads and flows as achieved by mitigation of the 85th percentile hourly rainfall intensity multiplied by a factor of two.

C. Groundwater Protection

[2] Where new development is defined as projects for which tentative tract or parcel map approval was not received by July 1, 2003 and new re-development is defined as projects for which all necessary permits were not issued by July 1, 2003. New development does not include projects receiving map approvals after July 1, 2003 that are proceeding under a common scheme of development that was the subject of a tentative tract or parcel map approval that occurred prior to July 1, 2003.

Any structural infiltration BMPs shall meet the following minimum requirements:

1. Use of structural infiltration treatment BMPs shall not cause or contribute to an exceedance of groundwater water quality objectives.
2. Source control and pollution prevention control BMPs shall be implemented to protect groundwater quality.
3. Structural infiltration treatment BMPs shall not cause a nuisance or pollution, as defined in Water Code Section 13050 .

4. The permittees may propose any equivalent sizing criteria for treatment BMPs or other controls that will achieve greater or substantially similar pollution control benefits. In the absence of approved equivalent sizing criteria, the permittees shall implement the above stated sizing criteria.

5. If a particular BMP is not technically feasible, other BMPs should be implemented to achieve the same level of compliance, or if the cost of BMP implementation greatly outweighs the pollution control benefits, the permittees may grant a waiver of the numeric sizing criteria. All waivers, along with waiver justification documentation, must be reported to the Regional Board in writing within 30 days. The permittees may propose to establish an urban runoff fund to be used for urban water quality improvement projects within the same watershed that is funded by contributions from developers granted waivers. If it is determined by the Regional Board that waivers are being inappropriately granted, this Order may be reopened to modify these waiver conditions.

6. The obligation to install minimum structural BMPs at new development is met if, for a common scheme of development, BMPs are constructed with the requisite capacity to serve the entire common scheme, even if cerain phases of the common scheme may not have BMP capacity located on that phase in accordance with the requirements specified above.

XIII. PUBLIC EDUCATION AND OUTREACH

1. The permittees shall continue to implement the public education efforts already underway and shall implement the most effective elements of the comprehensive public and business education strategy contained in the Report of Waste Discharge/DAMP. By July 1, 2002, the permittees shall complete a public awareness survey to determine the effectiveness of the current public and business education strategy and provide a future action plan.
2. When feasible, the permittees shall participate in joint outreach with other programs including, but not limited to, the State of California Storm Water Quality Task Force, Caltrans and other municipal storm water programs to ensure that a consistent message on storm water pollution prevention is disseminated to the public. The permittees shall sponsor or staff a storm water table or booth at community, regiona, and/or countywide events to distribute public education materials to the public. Each permittee shall participate in at least one event per year.

3. By March 1, 2002, the permittees shall establish a Public Education Committee to provide oversight and guidance for the implementation of the public education program. The Public Education Committee shall meet at least twice per year. The Public Education Committee shall make recommendations for any changes to the public and business education program. The goal of the public and business education program shall be to target 100% of the residents, including businesses, commercial and industrial establishments. Through use of local print, radio and television, the permittees must ensure that the public and business education program makes a minimum of 10 million impressions per year and that those impressions measurably increase the knowledge and measurably change the behavior of the targeted groups. By November 15, 2002, the Public Education Committee shall propose a study for measuring changes in knowledge and behavior as a result of the education program. Upon approval by the Regional Board Executive Officer, the study shall be completed by the end of the permit cycle. By July 1, 2002, the Public Education Committee shall develop BMP guidance for restaurants, automotive service centers and gasoline service stations for the industrial facility inspectors to distribute to these facilities during inspections. Further, for restaurant, automotive service centers and gasoline service station corporate chains, information is to be developed that will be provided to corporate environmental managers during outreach visits that will take place twice during the permit term.
4. By July 1, 2002, the permittees shall develop public education materials to encourage the public to report (including a hotline number and web site to report) illegal dumping and unauthorized, non-storm water discharges from residential, industrial, construction and commercial sites into public streets, storm drains and other waterbodies; clogged storm drains; faded or missing catch basin stencils and general storm water and BMP information. This hotline and web site shall be included in the public and business education program and shall be listed in the governmental pages of all regional phone books.
5. By July 1, 2003, the permittees shall develop BMP guidance for the control of those potentially polluting activities not otherwise regulated by any agency including guidelines for the household use of fertilizers, pesticides, herbicides and other chemicals, and guidance for mobile vehicle maintenance, carpet cleaners, commercial landscape maintenance, and pavement cutting. These guidance documents shall be distributed to the public, trade associations, etc., through participation in community events, trade association meetings and/or mail.
6. By July 1, 2003, the permittees shall conduct an evaluation to determine the best method of establishing a mechanism(s) for providing educational and General Industrial Permit materials to businesses within their jurisdiction.

XIV. MUNICIPAL FACILITIES/ACTIVITIES

1. Each permittee shall implement the recommendations in the Environmental Performance Report to ensure that public agency facilities and activities do not cause or contribute to a pollution or nuisance in receiving waters. By July 1 of each year, the permittees shall review all their activities and facilities to determine the need for any revisions to the Environmental Performance Reports. The annual report shall include the findings of this review and a schedule for any needed revisions. All revisions should consider a pollution prevention

strategy to ensure that the public agency facilities and/or activities that are currently not required to obtain coverage under the State's general storm water permits reduce the discharge of pollutants into the waters of the U.S. to the maximum extent practicable.

2. By July 1, 2003, the permittees shall complete an assessment of their flood control facilities to evaluate opportunities to configure and/or to reconfigure channel segments to function as pollution control devices and to optimize beneficial uses. These modifications may include in-channel sediment basins, bank stabilization, water treatment wetlands, etc. This shall be reported in the 2002-2003 annual report.
3. By July 1, 2002, the principal permittee shall develop and distribute model maintenance procedures for public agency activities such as street sweeping; catch basin stenciling; drainage facility inspection, cleaning and maintenance, etc. This shall be reported in the 2001-2002 annual report.
4. By July 1, 2002, the principal permittee shall develop and distribute BMP guidance for public agency and contract field operations and maintenance staff to provide guidance in appropriate pollution control measures, how to respond to spills and reports of illegal discharges, etc. This shall be reported in the 2001-2002 annual report.
5. At least on an annual basis, the principal permittee shall provide training to public agency staff and to contract field operations staff on fertilizer and pesticide management, model maintenance procedures, implementation of environmental performance reporting program and other pollution control measures. Each permittee shall attend at least three of these training sessions during the five year term of this permit (from 2001 to 2006).
6. By July 1, 2002, the principal permittee shall develop a model maintenance procedure for drainage facilities. This shall be included in the 2001-2002 annual report. Each permittee shall inspect, clean and maintain at least 80% of its drainage facilities on an annual basis, with 100% of the facilities included in a two-year period, using the model maintenance procedures developed by the principal permittee. This shall be included in the annual report.
7. By July 1, 2004, the permittees shall develop and submit for approval by the Executive Officer, a more aggressive program for cleaning out drainage facilities, including catch basins. This program should be based on a list of drainage facilities, prioritized on such factors as distance to receiving water, receiving water beneficial uses and impairments of beneficial uses, historical pollutant types and loads from past inspections/cleanings and the presence of downstream regional facilities that would remove the types of pollutants found in the drainage facility. Using this list, the permittees shall propose clean out schedules for all drainage facilities with a minimum frequency of once a year and a maximum frequency of monthly, during the storm season. The permittees should be prepared to implement the approved clean out program beginning with the 2004-2005 storm season.
8. By July 1, 2002, the permittees shall evaluate the applicability of the Environmental Performance Program to municipal maintenance contracts, contract for field maintenance operations, and leases. This shall be included in the 2001-2002 annual report.

XV. MUNICIPAL CONSTRUCTION PROJECTS/ACTIVITIES

1. This order authorizes the discharge of storm water runoff from construction projects that may result in land disturbance of five (5) acres or more (or less than five acres, if it is part of a larger common plan of development or sale which is five acres or more) that are under ownership and/or direct responsibility of any of the permittees. All permittee construction activities shall be in accordance with DAMP, Appendix H.
2. Prior to commencement of construction activities, the permittees shall notify the Executive Officer of the Regional Board of the proposed construction project. Upon completion of the construction project, the Executive Officer shall be notified of the completion of the project.
3. The permittees shall develop and implement a storm water pollution prevention plan (SWPPP) and a monitoring program that is specific for the construction project, prior to the commencement of any of the construction activities. The SWPPP shall be kept at the construction site and released to the public and/or Regional Board staff upon request.
4. The SWPPP and the monitoring program for the construction projects shall be consistent with the requirements of the latest version of the State's General Construction Activity Storm Water Permit.
5. The permittees shall give advance notice to the Executive Officer of the Regional Board of any planned changes in the construction activity, which may result in non-compliance with the latest version of the State's General Construction Activity Storm Water Permit.
6. All other terms and conditions of the latest version of the State's General Construction Activity Storm Water Permit shall be applicable.

XVI. SUB-WATERSHEDS AND TMDL IMPLEMENTATION

1. The permittees shall meet the following target load allocations for nutrients in urban runoff by implementing the BMPs contained in Appendix N (DAMP, Section 12) and in accordance with the approved TMDL implementation plan incorporated in the Basin Plan.

(This section intentionally left blank.)

Table 1. Seasonal Load Allocations of Total Nitrogen for the Newport Bay Watershed

Nutrient TMDL	1990-1997 Loading	2002 Summer Allocation (Apr-Sept)[5]	2007 Summer Allocation (Apr-Sept)[5]	2012 Winter Allocation (Oct-Mar)[4, 5, 6]
Newport Bay Watershed	lbs/year TN[1,2]	lbs/season TN	lbs/season TN	lbs/season TN
Wasteload Allocation				
Urban runoff	277,131[3]	20,785	16,628	55,442
		5 year target	10 year target	15 year target

1 TIN = (NO3+NH3).
2 TN = (TIN + Organic N).
3 Estimated annual average (summer and winter loading).
4 Total nitrogen winter loading limit applies between October 1 and March 31 when the mean daily flow rate at San Diego Creek at Campus Drive is below 50 cubic feet per second (cfs), and when the mean daily flow rate in San Diego Creek at Campus Drive is above 50 cubic feet per second (cfs), but not as the result of precipitation.
5 Compliance to be achieved no later than this date. The Regional Board may require earlier compliance with these targets when it is feasible and reasonable.
6 Assumes 67 non-storm days.

Table 2. Annual Total Phosphorous Load Allocations For The Newport Bay Watershed

	2002 Allocation lbs/year TP[1]	2007 Allocation lbs/year TP[1]
TMDL	86,912	62,080
Urban areas	4,102	2,960

1 Compliance to be achieved no later than this date. The Regional Board may require earlier compliance with these targets when it is feasible and reasonable.

Table 3. Annual Total Nitrogen Load Allocations For San Diego Creek, Reach 2 During Non-Storm Conditions.[1]

	2012 Allocation lbs/day TN[2]
TMDL	14 lbs/day (TN)
Waste Load Allocation (Urban runoff)	5.5 lbs/day (TN)

[1] Total nitrogen loading limit applies when the mean daily flow rate at San Diego Creek at Culver Drive is below 25 cubic feet per second (cfs), and when the mean daily flow rate in San Diego Creek at Culver Drive is above 25 cubic feet per second (cfs), but not as the result of precipitation.

[2] Compliance to be achieved no later than this date. The Regional Board may require earlier compliance with these targets when it is feasible and reasonable.

2. The permittees shall meet the following target load allocations for sediment in urban runoff by implementing the BMPs contained in Appendix N of the DAMP and the "March 1999 Technical Report on the Implementation of the TMDL for Sediment in the Newport Bay Watershed, the October 1999 Preliminary Sediment Load Allocation Analysis for San Diego Creek and Newport Bay, and the February 2000 Sediment Yield and Transport Investigation for San Diego Creek and Newport Bay".
    a. The load allocations for sediment discharges to Newport Bay from urban areas shall not exceed 2,500 tons per year, implemented as a 10-year running annual average.
    b. The load allocations for sediment discharges to San Diego Creek and its tributaries from urban areas shall not exceed 2,500 tons per year, implemented as a 10-year running annual average.
3. The permittees shall revise Appendix N of the DAMP to include implementation measures and schedules for further studies related to the TMDL for fecal coliform in Newport Bay, as set fourth in the January 2000, March 2000 and April 2000 Newport Bay Fecal Coliform TMDL Technical Reports submitted by the permittees.
4. This order may be reopened to include additional requirements based on new or revised TMDLs.

XVII. PROGRAM MANAGEMENT/DAMP REVIEW

1. By July 1 of each year, the permittees shall evaluate the DAMP to determine whether any revisions are necessary in order to reduce pollutants in MS4 discharges to the maximum extent practicable. In addition, the first annual review after adoption of this order shall include the following:
    a. Review of the formal training needs of municipal employees
    b. Review of coordinating meeting/training for the designated NPDES inspectors.
2. The annual report shall include the findings of this review and a schedule for any needed revisions or a copy of the amended DAMP with the proposed changes.

3. The permittees shall modify the DAMP, at the direction of the Regional Board Executive Officer, to, as necessary, incorporate additional provisions. Such provisions may include regional and watershed-specific requirements and/or waste load allocations developed and approved pursuant to the TMDL process.
4. The Permittee Committee shall meet at least six times a year to discuss issues related to permit implementation and regional and statewide issues. Each permittee's designated representative or a designated alternate should attend at least 75% of these meetings.

XVIII. FISCAL RESOURCES

1. The permittees shall prepare and submit a unified fiscal analysis to the Executive Officer of the Regional Board. The fiscal analysis shall be submitted with the Annual Report document no later than November 15th of each year and shall, at a minimum, include the following:
    a. Each permittee's expenditures for the previous fiscal year,
    b. Each permittee's budget for the current fiscal year,
    c. A description of the source of funds, and
    d. Each permittee's estimated budget for the next fiscal year.

XIX. PROVISIONS

1. All reports submitted by the permittees as per the requirements in this Order for the approval of the Executive Officer shall be publicly noticed and made available on the Regional Board's website, or through other means, for public review and comments. The Executive Officer shall consider all comments received prior to approval of the reports. Any unresolved significant issues shall be scheduled for a public hearing at a Regional Board meeting prior to approval by the Executive Officer.
2. The purpose of this Order is to require the implementation of best management practices to reduce, to the maximum extent practicable, the discharge of pollutants from the MS4 in order to support reasonable further progress towards attainment of water quality objectives.

    Permittees shall demonstrate compliance with all the requirements in this order and specifically with Section III.2 Discharge Limitations and Section IV. Receiving Water Limitations, through timely implementation of their DAMP and any modifications, revisions, or amendments developed pursuant to this order approved by the Executive Officer or determined by the permittee to be necessary to meet the requirements of this order. The DAMP, as included in the Report of Waste Discharge, including any approved amendments thereto, is hereby made an enforceable component of this order.
3. The permittees shall, at a minimum, implement all elements of the DAMP. Where the dates in the DAMP are different than those of this order, the dates in this order shall prevail. Any proposed revisions to the DAMP shall be submitted with the Annual Report to the Executive Officer of the Regional Board for review and approval. All

approved revisions to the DAMP shall be implemented as per the time schedules approved by the Executive Officer. In addition to those specific controls and actions required by (1) the terms of this Order and (2) the DAMP, each permittee shall implement additional controls, if any are necessary, to reduce the discharge of pollutants in storm water to the maximum extent practicable as required by this Order.

4. The permittees shall comply with Monitoring and Reporting Program No. R8-2002-0010, and any revisions thereto, which is hereby made a part of this order. The Executive Officer is authorized to revise the Monitoring and Reporting Program to allow the permittees to participate in regional, statewide, national or other monitoring programs in lieu of or in addition to Monitoring and Reporting Program No. R8-2002-0010.
5. By November 15, 2002, the permittees, in coordination with the Orange County Fire Chiefs Association, shall develop a list of appropriate BMPs to be implemented to reduce pollutants from training activities, fire hydrant/sprinkler testing or flushing, non-emergency fire fighting and any BMPs feasible for emergency fire fighting flows.
6. The permittees should consult the Orange County Vector Control District to ensure that structural treament systems are designed to minimize the potential for vector breeding.
7. Upon approval by the Executive Officer of the Regional Board, all plans, reports and subsequent amendments required by this order shall be implemented and shall become an enforceable part of this order. Prior to approval by the Executive Officer, these plans, reports and amendments shall not be considered as an enforceable part of this order.
8. The permittees shall report to the Executive Officer of the Regional Board:
   a. Any enforcement actions and discharges of storm or non-storm water, known to the permittees, which may have an impact on human health or the environment,
   b. Any suspected or reported activities on federal, state, or other entity's land or facilities, where the permittees do not have any jurisdiction, and where the suspected or reported activities may be contributing pollutants to waters of the US.

   (Also see reporting requirements in Monitoring and Reporting Program No. R8-2002-0010)
9. The permit application and special NPDES program requirements contained in 40 CFR 122.21 (a), (b), (d)(2), (f), (p); 122.41 (a), (b), (c), (d), (e), (f), (g), (h), (i), (j), (k), (l); and 122.42 (c) are incorporated into this order by reference.

XX. PERMIT EXPIRATION AND RENEWAL

1. This order expires on January 18, 2007 and the permittees must file a Report of Waste Discharge (permit application) no later than 180 days in advance of such expiration date as application for issuance of new waste discharge requirements. The Report of Waste Discharge shall, at a minimum, include the following:
   a. Any revisions to the Drainage Area Management Plan including, but not limited to, all the activities the permittees propose to undertake during the next permit term,

goals and objectives of such activities, an evaluation of the need for additional source control and/or structural BMPs, any proposed pilot studies, etc.;

b. Changes in land use and/or population including land use map updates;

c. Any significant changes to the storm drain systems, outfalls, detention or retention basins or dams and other controls including map updates of the storm drain systems; and,

d. Any new or revised program elements and compliance schedule(s) necessary to comply with Section IV of this order.

2. This Order may be modified, revoked or reissued prior to its expiration date for the following reasons:

   a. To address significant changes in conditions identified in the technical reports required by the Regional Board which were unknown at the time of the issuance of this order;

   b. To incorporate applicable requirements of statewide water quality control plans adopted by the State Water Resources Control Board or any amendments to the Basin Plan approved by the Regional Board, the State Board and, if necessary, by the Office of Administrative Law;

   c. To comply with any applicable requirements, guidelines, or regulations issued or approved under the Clean Water Act, if the requirements, guidelines, or regulations contain different conditions or additional requirements than those included in this order; or,

   d. To incorporate any requirements imposed upon the permittees through the TMDL process.

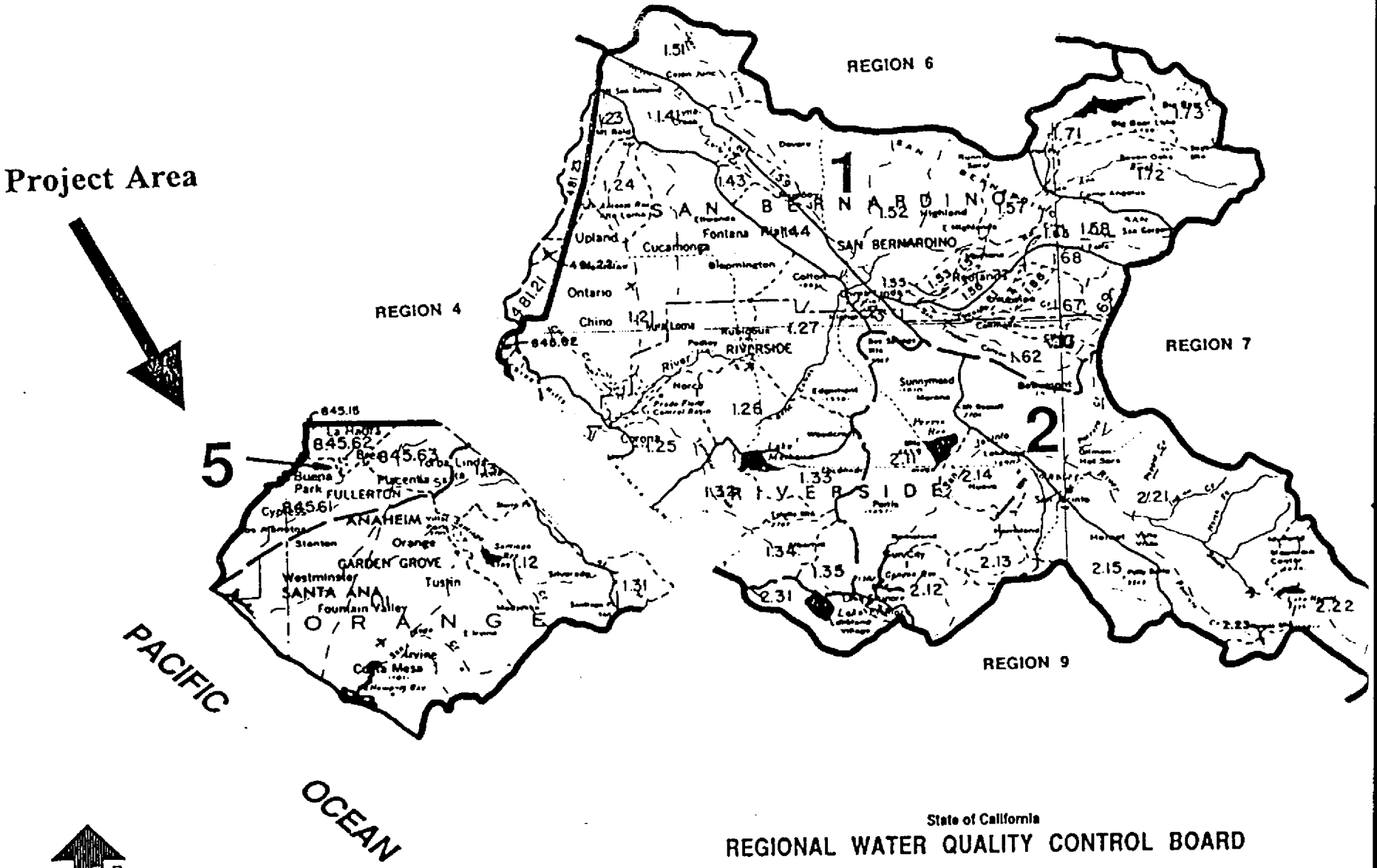
3. This order shall serve as a National Pollutant Discharge Elimination System (NPDES) Permit pursuant to Section 402 (p) of the Clean Water Act, or amendments thereto, and shall become effective ten days after the date of its adoption, provided the Regional Administrator of the U. S. EPA has no objections. If the Regional Administrator objects to its issuance, the permit shall not become effective until such objection is withdrawn.

4. Order No. 96-31 is hereby rescinded.

I, Gerard Thibeault, Executive Officer, do hereby certify that the foregoing is a full, true, and correct copy of an order adopted by the California Regional Water Quality Control Board, Santa Ana Region, on January 18, 2002.

_____

Gerard J. Thibeault
Executive Officer



April 1973
Revised: July 1976
Revised: August 1986

State of California
REGIONAL WATER QUALITY CONTROL BOARD

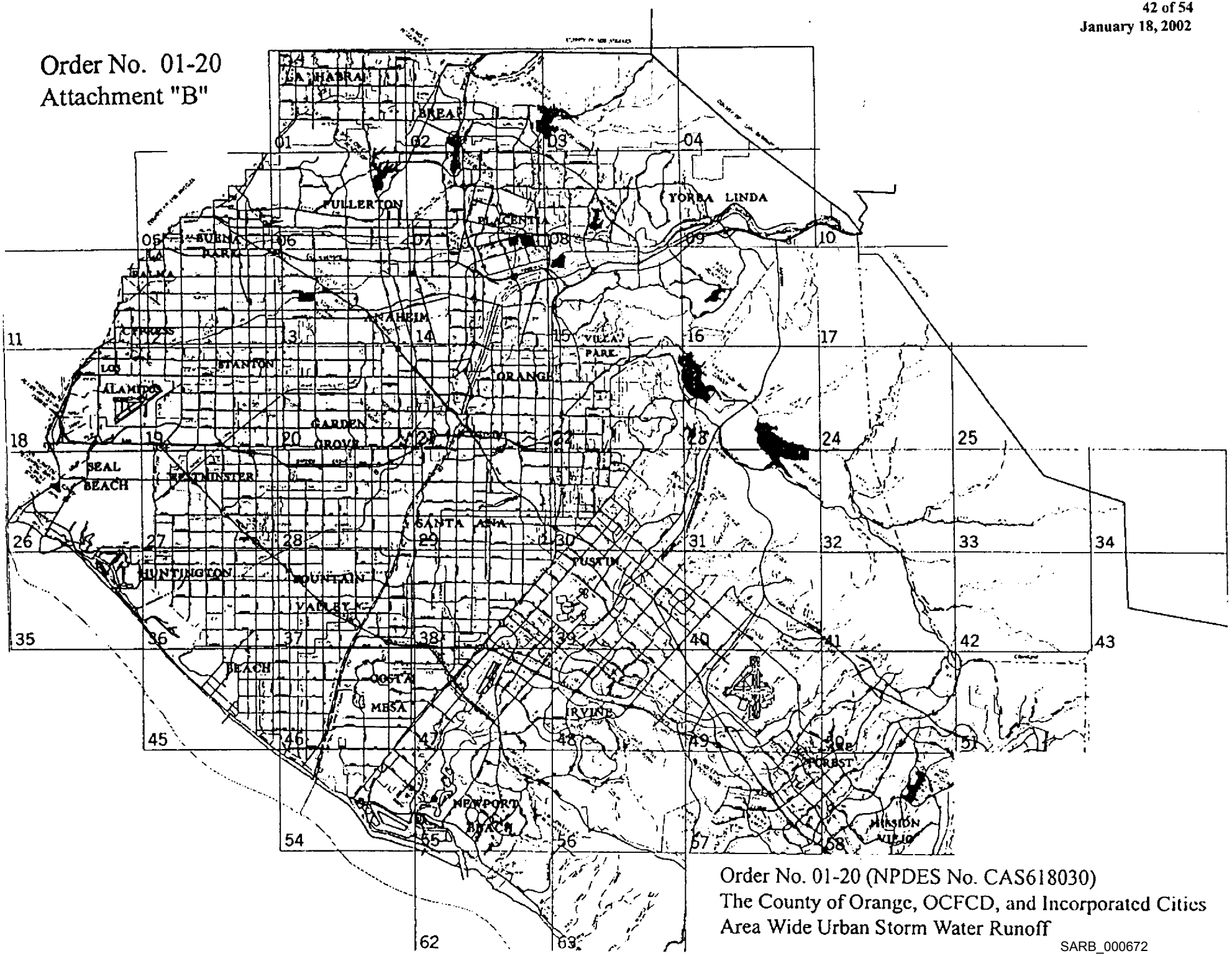
Santa Ana Region (8)

SANTA ANA HYDROLOGIC BASIN PLANNING AREA (SA)

Scale in miles
0 6 8 16 24 32
Scale 1:500,000

SARB_000671

Order No. 01-20
Attachment "B"



Order No. 01-20 (NPDES No. CAS618030)
The County of Orange, OCFCD, and Incorporated Cities
Area Wide Urban Storm Water Runoff

SARB_000672

Order No. R8-2002-0010
Attachment "C"
LIST OF OTHER ENTITIES WITH THE POTENTIAL TO DISCHARGE POLLUTANTS TO THE ORANGE COUNTY STORM WATER SYSTEM

California Department of Transportation (Caltrans), District 12
Southern Pacific Railroad
Atchison, Topeka & Santa Fe Railway Company
Seal Beach Naval Weapons Station
Seal Beach Naval Reserve Center, Los Alamitos
U. S. Marine Corps Air Station, El Toro
National Forest Service

Universities and Colleges

University of California, Irvine
California State University, Fullerton
Chapman College
Coastline College
Cypress College
Fullerton College
Irvine Valley College
Golden West College
Orange Coast College
Rancho Santiago College

School Districts

Anaheim Elementary School District
Anaheim Union High School District
Brea-Olinda Unified School District
Buena Park Joint Union High School District
Centralia Elementary School District
Cypress Elementary School District
Fountain Valley Union High School District
Fullerton Joint Union High School District
Garden Grove Unified School District
Huntington Beach Elementary School District
Huntington Beach Union High School District
Irvine Unified Union High School District
La Habra Joint Union High School District
Los Alamitos Unified School District
Lowell Joint Union High School District
Magnolia Elementary School District
Newport-Mesa Unified School District

Ocean View Union High School District
Orange Unified School District
Placentia Unified School District
Santa Ana Unified School District
Savanna Union High School District
Tustin Unified School District
Westminster Union High School District
Yorba Linda Joint Union High School District

Hospitals

Anaheim General Hospital
Brea Community Hospital
Chapman General Hospital
Children's Hospital of Orange County, Orange
Coastal Communities Hospital, Santa Ana
Fairview Hospital
FHP Hospital, Fountain Valley
Fountain Valley Regional Hospital and Medical Center
Hoag Hospital, Newport Beach
Kaiser Foundation Hospital, Anaheim
Orange County Community Hospital, Buena Park
Pacifica Community Hospital, Huntington Beach
Placentia Linda Community Hospital
Santa Ana Hospital and Medical Center
St. Joseph's Hospital, Orange
U.C. Irvine Medical Center
Vencor Hospital of Orange County, Westminster
Whittier Hospital and Medical Center, Buena Park

Water/Wastewater Agencies

Santa Ana Watershed Project Authority
Irvine Ranch Water District
Los Aliso Water District
El Toro Water District
San Bernardino County Flood Control District
Riverside County Flood Control & Water Conservation District
L.A. County Department of Public Works
County Sanitation Districts of Orange County
Orange County Water District
Metropolitan Water District

California Regional Water Quality Control Board
Santa Ana Region

Monitoring and Reporting Program No. R8-2002-0010
NPDES No. CAS618030

for
the County of Orange, Orange County Flood Control District,
and
Incorporated Cities of Orange County Within the Santa Ana Region
Areawide Urban Storm Water Runoff

I. GENERAL

1. Revisions of the monitoring and reporting program are appropriate to ensure that the permittees are in compliance with requirements and provisions contained in this order. Revisions may be made under the direction of the Executive Officer at any time during the term, and may include a reduction or increase in the number of parameters to be monitored, the frequency of monitoring, or the number and size of samples collected.

2. The Executive Officer is authorized to allow the permittees to participate in statewide, national, or other monitoring programs in lieu of this monitoring program.

3. All sample collection, handling, storage, and analysis shall be in accordance with 40 CFR Part 136 or other methods approved by the Executive Officer.

4. The permittees are authorized to complement their monitoring data with other monitoring sources, provided the monitoring conditions and sources are similar to those in the Santa Ana Watershed.

II. OBJECTIVES

The 1999 Water Quality Monitoring Program prioritized selected monitoring locations in Orange County based on a list of Critical Aquatic Resources and "Warm Spots". This prioritization is based on an analysis of prior years' monitoring data and other available data. It is expected that data collection for the 1999 monitoring program will be completed by July 1, 2003. The permittees also participate in the Regional Monitoring Program for San Diego Creek Nutrient TMDL and other regional monitoring programs, such as those conducted by the Southern California Coastal Water Research Project. The overall goal of these monitoring programs is to develop and support an effective watershed management program. The following are the major objectives:

1. To develop and support an effective municipal urban runoff and non-point source control program.

2. To define water quality status, trends, and pollutants of concern associated with urban storm water and non-storm water discharges and their impact on the beneficial uses of the receiving waters.

3. To characterize pollutants associated with urban storm water and non-storm water discharges and to assess the influence of urban land uses on water quality and the beneficial uses of receiving waters.

4. To identify significant water quality problems related to urban storm water and non-storm water discharges.

5. To identify other sources of pollutants in storm water and non-storm water runoff to the maximum extent possible (e.g., atmospheric deposition, contaminated sediments, other non-point sources, etc.)

6. To identify and prohibit illicit discharges.

7. To identify those waters, which without additional action to control pollution from urban storm water discharges, cannot reasonably be expected to attain or maintain applicable water quality standards required to sustain the beneficial uses in the Basin Plan (TMDL monitoring).

8. To evaluate the effectiveness of existing municipal storm water quality management programs, including an estimate of pollutant reductions achieved by the structural and nonstructural BMPs implemented by the permittees.

9. To evaluate costs and benefits of proposed municipal storm water quality control programs to the stakeholders, including the public.

The Regional Board recognizes that these objectives may not be attainable during this permit period and authorizes the Executive Officer to evaluate and to determine adequate progress toward meeting each objective.

III. MONITORING PROGRAM REQUIREMENTS

1. The permittees shall complete the 1999 Water Quality Monitoring Program.

2. The permittees shall revise, by July 1, 2003, their Water Quality Monitoring Program to include, at a minimum, the following monitoring components or their equivalence:

   A. Mass Emissions Monitoring.

      (1) The principal permittee shall monitor mass emissions in order to: (a) estimate the total mass emissions from the MS4; (b) assess trends in mass emissions over time; and (c) to determine if the MS4 is contributing to exceedances of water quality objectives or beneficial uses, by comparing results to the California Toxics Rule (CTR), Basin Plan, Ocean Plan and/or other relevant standards.

(2) A minimum of seven mass emissions stations shall be placed at locations to include coastal outfalls at Huntington Harbor/Anaheim Bay, the coastline between Huntington Harbor and Newport Bay, Upper/Lower Newport Bay, the Crystal Cove Area of Special Biological Significance (ASBS), and north Orange County where surface flows have not been well-characterized (e.g., Fullerton Creek Channel, Carbon Creek Channel, or Coyote Creek). Additional locations should be based on large discharge volumes, large subwatershed drainage areas, and/or land use distribution.

(3) Autosamplers shall be programmed to collect representative samples from the first storm event and two more storm events during the rainy season. A minimum of three dry-weather samples shall also be collected. Samples from the first rain event each year shall be analyzed for the entire suite of priority pollutants. All samples must be analyzed for metals, pH, TSS, TOC, pesticides/herbicides, and constituents which are known to have contributed to impairment of local receiving waters. Dry weather samples should also include an analysis for oil and grease. Sediments associated with mass emissions should be analyzed for constituents of concern.

B. Estuary/Wetlands Monitoring

(1) The permittees shall monitor the Upper Newport estuary, Talbert Marsh, and Bolsa Chica wetlands areas to determine the effects of storm water and non-storm water runoff associated with increased urbanization on these systems.

(2) Monitoring locations shall include representative areas surrounding channel outfalls and areas away from channel outfalls. Sampling strategies shall be designed to enable the determination of storm water and non-storm water effects on sediment chemistry, toxicity, benthic communities, nutrient status, and spatial extent of sediment fate within the estuarine environment. Additionally, other indicators of biological integrity should be evaluated, such as bird populations or endangered plant/animal species.

C. Water Column Toxicity Monitoring

(1) Analyses for toxicity to freshwater and marine species shall be performed on mass emissions samples to determine the impacts of storm water and non-storm water runoff on toxicity of receiving waters.

(2) *Ceriodaphnia dubia* and *Strongylocentrotus purpuratus* fertilization shall be used to evaluate toxicity on the sample from the first rain event, plus one other wet weather sample and two dry weather samples.

(3) Criteria shall be identified which will trigger the initiation of Toxicity Identification Evaluations (TIEs) and Toxicity Reduction Evaluations (TREs).

D. Bacteriological/Pathogen Monitoring

(1) The permittees shall obtain monitoring data from other entities (such as the Orange County Health Care Agency) and/or monitor representative areas along the Orange County coastline, as well as a minimum of six inland water bodies/channels, for total coliform, fecal coliform, and Enterococcus in order to determine the impacts of storm water and non-storm water runoff on loss of beneficial uses to receiving waters. Inland monitoring stations shall be located to include channels/creeks which are currently impaired for pathogens.

(2) Where possible, data shall be obtained from monitoring efforts of Orange County Health Care Agency, POTWs, and/or other public or private agencies/entities. Monitoring shall be conducted directly by the permittees only to the extent that data gaps exist.

E. Bioassessment

(1) The permittees shall cooperate with the Southern California Coastal Water Research Project (SCCWRP) in efforts to evaluate the biological index approach for Southern California and to design a research project for developing an Index of Biological Integrity (IBI) for the region.

(2) The permittees shall coordinate with SCCWRP and the Regional Board to identify appropriate bioassessment station locations. Station selection and sampling scheme shall be identified in the revised Monitoring Program, and sampling should commence no later than October 2003.

F. Reconnaissance

(1) The permittees shall develop new reconnaissance strategies to identify and prohibit illicit discharges. Where possible, the use of GIS to identify geographic areas with a high density of industries associated with gross pollution (e.g. electroplating industries, auto dismantlers) and/or locations subject to maximum sediment loss (e.g. new development) may be used to determine areas for intensive monitoring efforts. Additionally, the permittees shall coordinate with the Regional Board to develop a comprehensive database to include all enforcement actions for storm water violations and unauthorized, non-storm water discharges, that can then be used to more effectively target reconnaissance efforts.

G. Land Use Correlations

(1) The permittees shall develop and implement strategies for determining the effects of land use on the quality of receiving waters. While it is recognized that a wide range of land uses exist across the region and within each subwatershed, one relationship that may be easily determined is the impact of development on sediment loading within receiving waters, since developed areas contribute relatively little sediment loading compared to areas under construction. Consequently, the permittees shall, at a minimum, analyze the impacts of increasing development and the conversion of agricultural land to the sediment loading of the Upper Newport Bay.

(2) Where possible, data shall be obtained from monitoring efforts of other public or private agencies/entities (e.g., Caltrans, The Irvine Company).

H. TMDL/303(d) Listed Waterbody Monitoring

The Permittees shall continue to participate in the Regional Monitoring Program for the San Diego Creek Nutrient TMDL. In addition, strategies must be revised/developed to evaluate the impacts of storm water or non-storm water runoff on all impairments within the Newport Bay watershed and other 303(d) listed waterbodies. Since the 303(d) listing is dynamic, with new waterbodies and new impairments being identified over time, the permittees shall revise their monitoring plan to incorporate new information as it becomes available.

3. By July 1, 2003, the permittees shall develop and submit for approval of the Executive Officer, their revised Water Quality Monitoring Program, which should yield an integrated watershed-monitoring approach capable, to the maximum extent possible, of achieving the above-stated goals. In order to minimize cost and maximize benefits, it is highly recommended that this program be developed in cooperation with the SCCRWP, the Orange County Health Care Agency, neighboring coastal regions and/or other public or private agencies/entities. The development and implementation of the monitoring program shall be in accordance with the time schedules prescribed by the Executive Officer. At a minimum, the program shall include the following and any requirements developed by the State Board in accordance with Water Code Section 13383.5:

A. Uniform guidelines for quality control, quality assurance, data collection and data analysis that conform to current US EPA standards.

B. A mechanism for the collection, analysis and interpretation of existing data from local, regional or national monitoring programs. These data sources may be utilized to characterize different storm water sources; to determine pollutant generation, transport and fate; to develop a relationship between land use, development size, storm size and the event mean concentration of pollutants; to determine spatial and temporal variances in storm water quality and seasonal and other bias in the collected data; and to identify any unique features of the Santa Ana Watershed. The permittees are encouraged to use data from similar studies, if available.

C. A description of the monitoring program, including:

(1) The number of monitoring stations;

(2) Monitoring locations within flood control channels, bays and estuaries, coastal areas, major outfalls, and other receiving waters;

(3) Environmental indicators (e.g., ecosystem, biological, habitat, chemical, sediment, stream health, etc.) chosen for monitoring;

(4) Parameters selected for field screening and for laboratory work;

(5) Total number of samples to be collected from each station, frequency of sampling during wet and dry weather, short duration or long duration storm events, type of samples (grab, 24-hour composite, etc.), justification for composite versus discrete sampling, type of sampling equipment, quality assurance/quality control procedures followed during sampling and analysis, analysis protocols to be followed (including sample preparation and maximum reporting limits), and identity and qualifications of laboratories performing analyses;

(6) A mechanism for analyzing the collected data and interpreting the results including protocols for handling of non-detects and 'outliers', an evaluation of the effectiveness of the management practices, and need for refinement of the management practices; and,

(7) A description of the responsibilities of all the participants in this program including cost sharing.

IV. REPORTING

1. All progress reports and proposed strategies and plans required by this order shall be signed by the principal permittee, and copies shall be submitted to the Executive Officer of the Regional Board under penalty of perjury.

2. The permittees shall submit an **ANNUAL PROGRESS REPORT** to the Executive Officer of the Regional Board and to the Regional Administrator of the U.S. EPA, Region 9, no later than November 15th, of each year. This progress report may be submitted in a mutually agreeable electronic format. At a minimum, annual progress report shall include the following:

A. A review of the status of program implementation and compliance (or non-compliance) with the schedules contained in this order;

B. An assessment of the effectiveness of control measures established under the illicit discharge elimination program and the Drainage Area Management Plan. The effectiveness may be measured in terms of how successful the program has been in eliminating illicit/illegal discharges and reducing pollutant loads in storm water discharges;

C. An assessment of any storm water management program modifications made to comply with Clean Water Act requirements to reduce the discharge of pollutants to the maximum extent practicable;

D. A summary and analysis of monitoring results from the previous year and any changes to the monitoring program for the following year;

E. A fiscal analysis progress report as described in Section V., Provision, 25., of this order;

F. A draft workplan which describes the proposed implementation of the DAMP for next fiscal year. The workplan shall include clearly defined tasks, responsibilities, and schedules for implementation of the storm water program and each permittee actions for the next fiscal year;

G. Major changes in any previously submitted plans/policies; and

H. An assessment of the permittees compliance status with the Receiving Water Limitations, Section IV of the Order, including any proposed modifications to the DAMP if the Receiving Water Limitations are not fully achieved.

3. The permittees shall be responsible for the submittal to the principal permittee of all required information/materials needed to comply with this order in a timely manner. All such submittals shall be signed by a duly authorized representative of the permittee under penalty of perjury.

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V. REPORTING SCHEDULE

All reports required by this order shall be submitted to the Executive Officer of the Regional Board in accordance with the following schedule:

ITEM	COMPLETION DATE	REPORT DUE DATE
Review planning procedures and CEQA document preparation processes	December 19, 2002	January 2, 2003
Establish Public Education Committee	March 1, 2002	Nov 15, 2002
Review DAMP	July 1, 2003	Nov 15, 2003
Develop public education materials including reporting hot-line and web site	July 1, 2002	Nov 15, 2002
Develop and update construction site, including site information, priority, and inspection information	October 1, 2002	Nov 15, 2003
Establish mechanism to ensure local permits for proposed construction sites and industrial facilities are conditioned upon proof of obtaining coverage under the state General Permit	July 1, 2002	Nov 15, 2002
Develop and distribute model maintenance procedures for public agency activities	July 1, 2002	Nov 15, 2002
Develop and distribute BMP guidance for public agency and contract field operations and maintenance staff	July 1, 2002	Nov 15, 2002
Develop model maintenance procedures for drainage facilities	July 1, 2002	Nov 15, 2002
Evaluate Environmental Performance Program applicability to municipal maintenance contracts, contract for field maintenance operations, and leases	July 1, 2002	Nov 15, 2002
Review and revise current grading/erosion control ordinances	July 1, 2003	Nov 15, 2003

Implementation Agreement Revision	July 1, 2002	Nov 15, 2002
Litter/Trash Control Ordinance review	July 1, 2003	Nov 15, 2003
Additional Debris Control Measures Determination	July 1, 2003	Nov 15, 2003
Complete Public Awareness Survey	July 1, 2002	Nov 15, 2002
Proposed Monitoring Program	July 1, 2003	July 1, 2003
Develop restaurant inspections program, which includes runoff, grease blockage and spill reduction aspects	July 1, 2002	Nov 15, 2002
Legal Authority & Enforcement Strategy Certification	November 1, 2003	Nov 15, 2003
Review effectiveness of ordinances in prohibiting discharges to MS4's as listed in Section 7.	July 1, 2003	Nov 15, 2003
Develop and update an industrial site database, including facility information, priority, and inspection information	July 1, 2003	Nov 15, 2003
Develop and update a commercial site database, including facility information, priority, and inspection information	July 1, 2003	Nov 15, 2003
Propose mechanism to determine effect of septic system failures on storm water quality and a mechanism to address failures	July 1, 2003	Nov 15, 2003
Review oversight of portable toilets to determine need for any revision	July 1, 2003	Nov 15, 2003
BMP Guidance for Restaurants, Automotive Service Centers, and Gasoline Service Stations, developed by Public Education Committee	July 1, 2002	Nov 15, 2002
BMP Guidance for Control of Potential Polluting Activities not otherwise regulated	July 1, 2003	Nov 15, 2003

Review existing BMPs for New Developments and Water Quality Management Plan to determine need for development of Water Quality Protection Plan	July 1, 2003	Nov 15, 2003
Propose study of erosion control BMPs for new development	November 15, 2003	Nov 15, 2003
Incorporate watershed protection principles and policies into the General Plan	July 1, 2004	Nov 15, 2004
Report of Waste Discharge	180 days before permit expires	Dec. 1, 2005
Annual Report/Fiscal Analysis	November 15th of each year	Nov 15
Evaluate Storm Water Management structure and Implementation Agreement	July 1st of each year	Nov 15
Review Environmental Performance Reports	July 1st of each year	Nov 15
Provide training to public agency staff and to contract field operations staff	Annually	Nov 15
Re-evaluate monitoring program priorities based on previous year's data	Annually	Nov 15
Evaluate the DAMP	July 1st of each year	Nov 15
Permittee Committee meetings to discuss permit implementation and regional and state-wide issues	Held at least 6 times each year	Nov 15

Ordered by_____

Gerard J. Thibeault
Executive Officer
January 18, 2002

California Regional Water Quality Control Board
Santa Ana Region
3737 Main Street, Suite 500
Riverside, CA 92501-3348

FACT SHEET

January 18, 2002

ITEM: **2**

SUBJECT: **Waste Discharge Requirements for the County of Orange, Orange County Flood Control District, and the Incorporated Cities of Orange County within the Santa Ana Region, Urban Storm Water Runoff Management Program, Orange County, Order No. R8-2002-0010 (NPDES No. CAS 618030)**

I. INTRODUCTION

The 1972 Clean Water Act (CWA) established the National Pollutant Discharge Elimination System (NPDES) permit program to regulate the discharge of pollutants from point sources to waters of the United States (U.S.). Since then, considerable strides have been made in reducing conventional forms of pollution, such as from sewage treatment plants and industrial facilities, through the implementation of the NPDES program and other federal, state and local programs. The adverse effects of some of the persistent toxic pollutants (DDT, PCB, TBT) were addressed through manufacturing and use restrictions and through cleanup of contaminated sites. On the other hand, pollution from land runoff (including atmospheric deposition, urban, suburban and agricultural) was largely unabated until the 1987 CWA amendments. As a result, diffuse sources, including urban storm water runoff, now contribute a larger portion of many kinds of pollutants than the more thoroughly regulated sewage treatment plants and industrial facilities. The National Urban Runoff Program (NURP) final report to the Congress (U.S. EPA, 1983) concluded that the goals of the CWA could not be achieved without addressing urban runoff discharges. The 1987 CWA amendments established a framework for regulating urban storm water runoff. Pursuant to these amendments, the Santa Ana Regional Water Quality Control Board (Regional Board) began regulating municipal storm water runoff in 1990.

The attached pages contain information concerning an application for renewal of Waste Discharge Requirements and a NPDES permit, which prescribe waste discharge requirements for urban storm water runoff from the cities and unincorporated areas in Orange County within the jurisdiction of the Santa Ana Regional Board. On September 1, 2000, the County of Orange and the Orange County Flood Control District (OCFCD), in cooperation with the cities of Anaheim, Brea, Buena Park, Costa Mesa, Cypress, Fountain Valley, Fullerton, Garden Grove, Huntington Beach, Irvine, Laguna Woods, La Habra, La Palma, Lake Forest, Los Alamitos, Newport Beach, Orange, Placentia, Santa Ana, Seal Beach, Stanton, Tustin, Villa Park, Westminster, and Yorba Linda (hereinafter collectively referred to as permittees or dischargers), submitted NPDES Application No. CAS 618030 (Report of Waste Discharge) for reissuance of their areawide storm water NPDES permit. The permit application was submitted in accordance with the requirements of the previous NPDES permit (Order No. 96-31, NPDES No. CAS618030) which expired on March 1,

2001. Additionally, the permit application follows guidance provided by staff of the State Water Resources Control Board (State Board), the Regional Water Quality Control Boards (Regional Boards), and the United States Environmental Protection Agency (U.S. EPA).

On March 5, 2001, Order No. 96-31, NPDES No. CAS618030, was administratively extended in accordance with 40 CFR Part 122.6 and Title 23, Division 3, Chapter 9, §2235.4 of the California Code of Regulations.

Order No. R8-2002-0010 regulates discharges of urban storm water from the lower Santa Ana watershed to waters of the U.S., which ultimately drain into the Pacific Ocean.

II. REGULATORY BACKGROUND/CLEAN WATER ACT REQUIREMENTS

Urban runoff includes dry and wet weather flows from urbanized areas through a storm water conveyance system. As water flows over streets, parking lots, construction sites, and industrial, commercial, residential and municipal areas, it can intercept pollutants from these areas and transport them to waters of the U.S. If appropriate pollution control measures are not implemented, urban runoff may contain pathogens (bacteria, protozoa, viruses), sediment, trash, fertilizers (nutrients, mostly nitrogen and phosphorus compounds), oxygen-demanding substances (decaying matter), pesticides (DDT, Chlordane, Diazinon, Chlorpyrifos), heavy metals (cadmium, chromium, copper, lead, zinc) and petroleum products (oil & grease, PAHs, petroleum hydrocarbons). If not properly managed and controlled, urbanization can change the stream hydrology and increase pollutant loading to receiving waters. As a watershed undergoes urbanization, pervious surface area decreases, runoff volume and velocity increase, riparian and wetland habitat decrease, the frequency and severity of flooding increase and pollutant loading increases. Most of these impacts are due to human activities that occur during and/or after urbanization. The pollutants and hydrologic changes can cause declines in aquatic resources, toxicity to marine organisms, and impact human health and the environment.

However, properly planned high-density development, with sufficient open space, can reduce urban sprawl and problems associated with sprawl. Urban in-fill development can be an element of smart growth, creating the opportunity to maintain relatively natural open space elsewhere in the area.

The U.S. EPA recognizes urban runoff as the number one source of estuarine pollution in coastal communities[1]. Recent studies[2] conducted in the Southern California area have reported a definite link between storm water runoff from urban areas and pollution in nearshore zones. A number of Orange County beaches were closed during 1999 and 2000 due to microbial contamination. One of the studies conducted to determine the source of this microbial contamination indicated that urban runoff may be one of the sources of this contamination. If not properly controlled, urban runoff could be a significant source of

[1] US EPA, 1999, 40CFR Parts 9, 122, 123, 124, National Pollutant Discharge Elimination System – Regulations for Revision of the Water Pollution Control Program Addressing Storm Water Discharges; Final Rule, 64FR 68727.

[2] Bay, S., Jones, B. H. and Schiff, K, 1999, Study of the Impact of Stormwater Discharge on Santa Monica Bay. Sea Grant Program, University of Southern California; and Haile, R.W., et. al., 1996, An Epidemiological Study of Possible Adverse Health Effects of Swimming in Santa Monica Bay.

pollutants in waters of the U.S. Table 1 includes a list of pollutants, their sources, and some of the adverse environmental consequences mostly resulting from urbanization.

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Table 1[3]. Pollutants/Impacts of Urbanization on Waters of the U.S. (Marine Pollution)

Pollutants	Sources	Effects and Trends
Toxins (e.g., biocides, PCBs, trace metals, heavy metals)	Industrial and municipal wastewaters; runoff from farms, forests, urban areas, and landfills; erosion of contaminated soils and sediments; vessels; atmospheric deposition	Poison and cause disease and reproductive failure; fat-soluble toxins may bioconcentrate, particularly in birds and mammals, and pose human health risks. Inputs into U.S. waters have declined, but remaining inputs and contaminated sediments in urban and industrial areas pose threats to living resources.
Pesticides (e.g., DDT, diazinon, chlorpyrifos)	Urban runoff, agricultural runoff, commercial, industrial, residential, and farm use	Legacy pesticide (DDT, Chlordane, Dieldrin, etc.) use has been banned; still persists in the environment; some of the other pesticide uses are curtailed or restricted.
Biostimulants (organic wastes, plant nutrients)	Sewage and industrial wastes; runoff from farms and urban areas; nitrogen from combustion of fossil fuels	Organic wastes overload bottom habitats and deplete oxygen; nutrient inputs stimulate algal blooms (some harmful), which reduce water clarity, cause loss of seagrass and coral reef, and alter food chains supporting fisheries. While organic waste loadings have decreased, nutrient loadings have increased.
Petroleum products (oil, grease, petroleum hydrocarbons, PAHs)	Urban runoff and atmospheric deposition from land activities; shipping and tanker operations; accidental spills; coastal and offshore oil and gas production activities; natural seepage; PAHs from internal combustion engines	Petroleum hydrocarbons can affect bottom organisms and larvae; spills affect birds, mammals and nearshore marine life. While oil pollution from ships, accidental spills, and production activities has decreased, diffuse inputs from land-based activities have not.
Radioactive isotopes	Atmospheric fallout, industrial and military activities	Few known effects on marine life; bioaccumulation may pose human health risks where contamination is heavy.

[3]Adapted from "Marine Pollution in the United States" prepared for the Pew Oceans Commission, 2001.

Sediments	Erosion from farming, construction activities, forestry, mining, development; river diversions; coastal dredging and mining	Reduce water clarity and change bottom habitats; carry toxins and nutrients; clog fish gills and interfere with respiration in aquatic fauna. Sediment delivery by many rivers has decreased, but sedimentation poses problems in some areas; erosion from coastal development and sea-level rise is a future concern.

Plastics and other debris	Ships, fishing nets, containers, trash, urban runoff	Entangles marine life or is ingested; degrades beaches, wetlands and nearshore habitats. Floatables (from trash) are an aesthetic nuisance and can be a substrate for algae and insect vectors.
Thermal	Cooling water from power plants and industry, urban runoff from impervious	Kills some temperature-sensitive species; displaces others. Generally, less a risk to marine life than thought 20 years ago.
Noise	Vessel propulsion, sonar, seismic prospecting, low-frequency sound used in defense and research	May disturb marine mammals and other organisms that use sound for communication.
Pathogens (bacteria, protozoa, viruses)	Sewage, urban runoff, livestock, wildlife, discharges from boats and cruise ships	Pose health risks to swimmers and consumers of seafood. Sanitation has improved, but standards have been raised.
Alien species	Ships and ballast water, fishery stocking, aquarists	Displace native species, introduce new diseases; growing worldwide problem.

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The Clean Water Act (CWA) prohibits the discharge of any pollutant to navigable waters from a point source unless an NPDES permit authorizes the discharge. Efforts to improve water quality under the NPDES program traditionally and primarily focused on reducing pollutants in discharges of industrial process wastewater and municipal sewage. The 1987 amendments to the CWA required municipal separate storm sewer systems (MS4s) and industrial facilities, including construction sites, to obtain NPDES permits for storm water runoff from their facilities. On November 16, 1990, the United States Environmental Protection Agency (EPA) promulgated the final Phase I storm water regulations. The storm water regulations are contained in 40 CFR Parts 122, 123 and 124.

The areawide NPDES permit for Orange County areas within the Santa Ana Regional Board's jurisdiction is being considered for renewal in accordance with Section 402 (p) of the CWA and all requirements applicable to an NPDES permit issued under the issuing authority's discretionary authority. The requirements included in this order are consistent with the CWA, the federal regulations governing urban storm water discharges, the Water Quality Control Plan for the Santa Ana River Basin (Basin Plan), the California Water Code, and the State Board's Plans and Policies.

The Basin Plan is the basis for the Regional Board's regulatory programs. The Plan was developed and is periodically reviewed and updated in accordance with relevant federal and state law and regulation, including the Clean Water Act and the California Water Code. As required, the Basin Plan designates the beneficial uses of the waters of the Region and specifies water quality objectives intended to protect those uses. (Beneficial uses and water quality objectives, together with an antidegradation policy, comprise federal "water quality standards"). The Basin Plan also specifies an implementation plan, which includes certain discharge prohibitions. In general, the Basin Plan makes no distinctions between wet and dry weather conditions in designating beneficial uses and setting water quality objectives, i.e., the beneficial uses, and correspondingly, the water quality objectives are assumed to apply year-round. (Note: In some cases, beneficial uses for certain surface waters are designated as "I", or intermittent, in recognition of the fact that surface flows (and beneficial uses) may be present only during wet weather.) Most beneficial uses and water quality objectives were established in the 1971, 1975 and 1983 Basin Plans.

Water Code Section 13241 requires that certain factors be considered, at a minimum, when water quality objectives are established. These include economics and the need for developing housing in the Region. (The latter factor was added to the Water Code in 1987).

During this permit development process, the permittees raised an issue regarding compliance with Section 13241 of the California Water Code with respect to water quality objectives for wet weather conditions, specifically the cost of achieving compliance during wet weather conditions and the need for developing housing within the Region and its impact on urban storm water runoff. During the next review of the Basin Plan, staff will recommend that this matter be incorporated on the triennial review list. In the meantime, the provisions of this order will result in reasonable further progress towards the attainment of the existing water quality objectives, in accordance with the discretion in the permitting authority recognized by the United States Court of Appeals for the Ninth Circuit in Defenders of Wildlife v Browner, 191 F.3d 1159, 1164 (9th Cir. 1999).

III. BENEFICIAL USES

Storm water flows that are discharged to municipal storm drain systems in Orange County are tributary to various water bodies (inland surface streams, bays and tidal prisms, ocean waters, and lakes and reservoirs) of the state. The beneficial uses of these water bodies include municipal and domestic supply, agricultural supply, industrial service and process supply, groundwater recharge, navigation, hydropower generation, water contact recreation, non-contact water recreation, commercial and sportfishing, warm freshwater habitat, cold freshwater habitat, preservation of biological habitats of special significance, wildlife habitat, preservation of rare, threatened or endangered species, marine habitat, shellfish harvesting, spawning, reproduction and development of aquatic habitats and estuarine habitat. The ultimate goal of this storm water management program is to protect the beneficial uses of the receiving waters.

IV. PERMITTED AREA

The permitted area is delineated by the Los Angeles County-Orange County boundary line on the northwest, the San Bernardino-Orange County boundary line on the north and northeast, the Riverside County-Orange County boundary line on the east, the Santa Ana Regional Board-San Diego Regional Board boundary line on the southeast, and the Pacific Ocean on the southwest (see Attachment A of the order). The permittees serve a population of approximately 2.8 million, occupying an area of approximately 786 square miles (including unincorporated areas and the limits of 33 cities, 25 of which are within the Santa Ana Regional Board's jurisdiction). The permittees have jurisdiction over, and/or maintenance responsibility for, storm water conveyance systems within Orange County. The County's systems include an estimated 400 miles of storm drain systems. A major portion of the urbanized areas of Orange County drains into water bodies within this Regional Board's jurisdiction. Storm water discharges from urbanized areas consist mainly of surface runoff from residential, commercial, and industrial developments. In addition, there are storm water discharges from agricultural land uses, including farming and animal operations. However, the CWA specifically excludes agricultural discharges from regulation under this program. Other areas of the County not addressed or which are excluded by the storm water regulations and areas not under the jurisdiction of the permittees are excluded from the area requested for coverage under this permit. This includes the following areas and activities:

- Federal lands and state properties, including, but not limited to, military bases, national forests, hospitals, schools, colleges, universities, and highways;
- Native American tribal lands; and
- Utilities and special district properties.

Discharges from the permitted area drain into the Pacific Ocean. The watershed regulated under this order is generally referred to as the Lower Santa Ana River Basin.

V. WATERSHED MANAGEMENT/LOWER SANTA ANA RIVER BASIN

To manage the water resources of the Region efficiently, it is critical to have a holistic approach. The entire storm drain system in Orange County is not controlled by a single entity; the County of Orange, the OCFCD, several cities, Caltrans, U.S. Army Corps of Engineers and a number of other entities own, operate and/or manage the storm drain systems. In addition to the cities, the County and the OCFCD, there are a number of other significant contributors of storm water runoff to these storm drain systems. These include: large institutions such as the State University facilities, schools, hospitals, etc.; federal facilities such as Department of Defense facilities; State agencies such as Caltrans; water and wastewater management agencies such as Orange County Water District, Metropolitan Water District etc.; the National Forest Service; state parks; and entertainment centers such as Disneyland. The quality and quantity of storm water runoff into and out of Orange County also depends upon runoff from San Bernardino and Riverside County areas that are tributary to Orange County. Some of the runoff from Orange County enters systems controlled by other entities, such as the Los Angeles County Flood Control District, which is under the Los Angeles Regional Board's jurisdiction.

Some of these facilities, such as U.S. Marine Corps, Tustin and El Toro Air Stations, Disneyland and Caltrans, are already under individual permits for storm water runoff. The Los Angeles and San Diego Regional Boards have also issued areawide storm water permits for areas within their jurisdiction.

Cooperation and coordination among all the stakeholders are essential for efficient and economical management of the watershed. It is also critical to manage nonpoint sources at a level consistent with the management of urban storm water runoff in a watershed in order to prevent or remedy water quality impairment. Regional Board staff will facilitate coordination of monitoring and management programs among the various stakeholders, where necessary.

An integrated watershed management approach is consistent with the Strategic Plan and Initiatives (June 22, 1995) for the State and Regional Boards. A watershed wide approach is also necessary for implementation of the load and waste load allocations developed under the TMDL process (see Section B, below). The MS4 permittees and all the affected entities should be encouraged to participate in regional or watershed solutions instead of project-specific and fragmented solutions.

The pollutants in urban runoff originate from a multitude of sources and effective control of these pollutants requires a cooperative effort of all the stakeholders and many regulatory agencies. Every stage of urbanization should be considered in developing appropriate urban runoff pollution control methodologies. The program's success depends upon consideration of pollution control techniques during planning, construction and post-construction operations. At each stage, appropriate pollution prevention measures, source control measures and, if necessary, treatment techniques should be considered.

1. SUB-WATERSHEDS AND MAJOR CHALLENGES

The Lower Santa Ana River Watershed can be subdivided into five tributary watersheds:

a. *The San Gabriel River Drainage Area:* Carbon Canyon Creek and Coyote Creek drain into the San Gabriel River. Only a portion of the San Gabriel River is within the Santa Ana Regional Board's jurisdiction. The River empties into the Pacific Ocean at the boundary between two Regional Boards (Regions 4 and 8). Region 4 regulates most of the discharges to the San Gabriel River.

   The Los Angeles Regional Board (Region 4) listed the San Gabriel River as an impaired waterbody on the CWA Section 303(d) list of impaired waters. It is listed for ammonia, toxicity, algae, eutrophication, pH, odors, low dissolved oxygen, trash, lead, arsenic, copper, silver, mercury (tissue), coliform, DDT, PCBs, chlordane, and abnormal fish histology. A trash TMDL for the East Fork of the River was adopted by the Regional Board (Region 4) and approved by the US EPA. A nutrient TMDL is scheduled for adoption in November 2002, a coliform TMDL for May 2003, and a metals TMDL for June 2005.

b. *The Huntington Harbour and Bolsa Bay Drainage Area:* This includes Anaheim Bay, Huntington Habour, Bolsa Bay, and Bolsa Chica Ecological Reserve. A number of flood control channels discharge into this area, including Anaheim-Barber, East Garden Grove-Wintersberg, and Bolsa Chica Channel. The area historically had a number of oil production facilities and an oil-well drilling mud disposal area. There are still some production wells in the area. Certain areas of the Bolsa Chica wetlands have been impacted by the oil production and related activities in the area. The drilling mud disposal area has been cleaned up, and there is a collaborative effort of a number of state, federal, and local agencies and other entities to restore the Bolsa Chica wetlands.

   Anaheim Bay and Huntington Harbour are listed as impaired waterbodies (see Table 2), and TMDLs will be developed to address the pollutants causing the impairment.

c. *The Santa Ana River Drainage Area:* This includes Santa Ana River Reaches 1 and 2, Santiago Creek Reaches 1, 2, 3 and 4, Silverado Creek, Black Star Creek, Talbert Channel, Talbert Marsh and Greenville-Banning Channel. The major problem for the area is microbial contamination of the coastal zone. The initial studies conducted by the Orange County Sanitation District determined that their facilities were probably not the cause of the microbial problems in the nearshore zone. Subsequently, the Executive Officer issued a directive to the County of Orange and the cities of Santa Ana, Costa Mesa, Fountain Valley and Huntington Beach (urban storm water dischargers to this tributary area) under Section 13267 of the Water Code. This directive required the dischargers to provide a plan to identify, characterize and control sources that contributed to the microbial problems in the Huntington Beach area.

The first phase of this study is complete, and the second phase is underway. The first phase of the study indicated that urban runoff, including dry weather flows, may be a contributor to this microbial problem. Some of the dry weather flows from the flood control channels are now being diverted to the sanitary sewer. However, other sources of contamination are also suspected and the second phase of the study is intended to further investigate these sources.

The Executive Officer issued a Cleanup and Abatement Order to the City of Huntington Beach requiring the City to investigate any leaking sanitary sewers in the area and to determine if exfiltration from these sources to storm sewer systems or to ocean waters through other channels was causing or contributing to the microbial problems at Huntington State and City beaches. This investigation is also currently under way.

The Orange County Sanitation District is investigating the impact of its ocean discharge (treated sanitary wastewater) on nearshore microbial problems at Huntington Beach.

It is expected that a combination of requirements included in this order and the programs discussed above will address the urban runoff pollution problems in this sub-watershed.

d. *The Newport Bay Drainage Area:* Tributaries include Bonita Creek, Serrano Creek, Peters Canyon Wash, Hicks Canyon Wash, Bee Canyon Wash, Borrego Canyon Wash, Agua Chinon Wash, Laguna Canyon Wash, Rattlesnake Canyon Wash, Sand Canyon Wash, San Diego Creek Reaches 1 and 2, and San Joaquin Freshwater Marsh.

   The Newport Bay watershed has a number of impaired waterbodies listed under Section 303(d) of the CWA (see Section 2, below for details). The impairments are mostly due to nutrients, sediment, pesticides, pathogens and metals. To date, TMDLs have been developed for nutrients, sediment, and fecal coliform bacteria. These TMDLs are being implemented. Recent monitoring data indicate that the target goals for nutrients for the year 2007 are now being met.

   Other TMDLs for the Newport Bay watershed are being developed by the Regional Board (for diazinon, chlorpyrifos and selenium) and U.S. EPA (for legacy pesticides and other metals).

   The Irvine Ranch Water District (IRWD), which provides sewage collection and treatment services for most areas in this watershed, has been also accepting dry weather flows from some of the storm sewer systems. Recently, IRWD proposed to construct a number of water quality treatment wetlands for treating urban storm water runoff. These treatment wetlands would be strategically located to capture and treat flows from different portions of the watershed. The IRWD is also exploring the possibility of sponsoring legislation that would authorize the District to collect storm water fees. These treatment wetlands are expected to remove sediment and nutrients from urban runoff but may be

less efficient in removing pathogens and toxics (metals, pesticides, etc.). It is anticipated that a combination of other best management practices and these treatment wetlands will help to control the discharge of pollutants in urban runoff.

e. *Irvine Coast and Newport Coast Areas of Special Biological Significance (ASBSs)* The Ocean Plan has 35 designated areas of special biological significance throughout the State; two of these ASBSs are within the Santa Ana Region, Irvine Coast Areas of Special Biological Significance, Newport Coast Areas of Special Biological Significance. The ASBSs require protection of species or biological communities to the extent that alteration of natural water quality is undesirable. The Crystal Cove area, which is within the Irvine Coast ASBS, is currently experiencing increased urban runoff from new developments in the area. The Ocean Plan contains a prohibition on discharges of wastes to ASBS. Regional Board staff identified a number of dischargers potentially violating or threatening to violate this Ocean Plan discharge prohibition in the Crystal Cove area. These dischargers included The Irvine Company, California Department of Transportation, and the California Department of Parks and Recreation. On November 16, 2000, the Regional Board adopted Cease and Desist Order No. 00-87 requiring these dischargers to cease and desist from any violations of the waste discharge prohibition. All future waste discharges to the ASBS governed by the prohibition in the Ocean Plan are prohibited and a time schedule is provided in the Cease and Desist order to eliminate the existing waste discharges.

2. CWA SECTION 303(d) LIST AND TMDLs:

The 1998 water quality assessment conducted by the Regional Board identified a number of waterbodies within the Region as impaired waterbodies, under Section 303(d) of the CWA. These are waterbodies where the designated beneficial uses are not met and/or the water quality objectives are being violated. These waterbodies were placed on the CWA Section 3030(d) list of impaired waters. The impaired waterbodies in Orange County within the Santa Ana Regional Board's jurisdiction are listed in Table 2.

Federal regulations require that a total maximum daily load (TMDL) be established for each 303(d) listed waterbody for each of the pollutants causing impairment. The TMDL is the total amount of the problem pollutant that can be discharged while water quality standards in the receiving water are attained, i.e., water quality objectives are met and the beneficial uses are protected. It is the sum of the individual wasteload allocations (WLA) for point source inputs, load allocations (LA) for non-point source inputs and natural background, with a margin of safety. The TMDLs are the basis for limitations established in waste discharge requirements. TMDLs have been developed for sediment and nutrients for San Diego Creek and Newport Bay and for fecal coliform bacteria in Newport Bay. The stakeholders in this watershed are collaborating in the development and implementation of the TMDLs. The Regional Board's Executive Officer has issued requirements for the submittal and implementation by the responsible parties of plans and schedules to address the TMDL requirements. To avoid any duplicative efforts, this permit does not include any further

implementation requirements based on TMDLs. However, this permit may be reopened to include TMDL implementation, if other implementation methodologies are not effective.

Table 2. Clean Water Act Section 303(d) Listed Waterbodies

Water Body	Hydro Unit	Pollutant Stressor	Source	Priority	Size Affected	Unit	TMDL End Date
Anaheim Bay	801.110	Metals	Urban Runoff/Storm Sewers, Unknown Nonpoint Source	Medium	180	Acres	0111
		Pesticides	Unknown Nonpoint Source	Medium	180	Acres	0111
Huntington Harbour	801.110	Metals	Urban Runoff/Storm Sewers, Boatyards	Medium	150	Acres	0111
		Pathogens	Urban Runoff/ Storm Sewers	Medium	150	Acres	0111
		Pesticides	Unknown Nonpoint Source	Medium	150	Acres	0111

Newport Bay, Lower	801.110	Metals	Urban Runoff/Storm Sewers, Contaminated Sediments, Boatyards	High	700	Acres	0107
		Nutrients	Agriculture, Urban Runoff/Storm Sewers	High	700	Acres	0198
		Pathogens	Urban Runoff/Storm Sewers	High	700	Acres	0100
		Pesticides	Agriculture, Contaminated Sediments	High	700	Acres	0102
		Priority Organics	Contaminated Sediments, Unknown Nonpoint Source	High	700	Acres	0102
Upper Newport Bay Ecological Reserve	801.110	Metals	Urban Runoff/Storm Sewers	High	752	Acres	0102
		Nutrients	Agriculture, Urban Runoff/Storm Sewers, Groundwater Loadings	High	752	Acres	0198
		Pathogens	Urban Runoff/Storm Sewers	High	752	Acres	0100
		Pesticides	Agriculture, Unknown Nonpoint Source	High	752	Acres	0102
		Sedimentation/ Siltation	Agriculture, Construction/Land Development, Channel Erosion, Erosion/Siltation	High	752	Acres	0198
San Diego Creek, Reach 1	801.110	Metals	Unknown Nonpoint Source	High	6	Miles	0102
		Nutrients	Agriculture, Urban Runoff/Storm Sewer, Groundwater Loadings	High	6	Miles	0198
		Pesticides	Unknown Nonpoint Source	High	6	Miles	0102
		Sedimentation/ Siltation	Agriculture, Construction/Land Development, Channel Erosion, Erosion/Siltation	High	6	Miles	0198

San Diego Creek Reach 2	801.110	Metals	Urban Runoff/Storm Sewer	High	6	Miles	0102
		Nutrients	Agriculture, Urban Runoff/Storm Sewer, Groundwater Loadings	High	6	Miles	0198
		Sedimentation/ Siltation	Agriculture, Construction/Land Development, Channel Erosion, Erosion/Siltation	High	6	Miles	0198
		Unknown Toxicity	Unknown Nonpoint Source	High	6	Miles	0102
Santiago Creek R4	801.120	Salinity/ TDS/ Chlorides	Source Unknown	Low	2	Miles	0111
Silverado Creek	801.120	Pathogens	Unknown Nonpoint Source	Low	2	Miles	0111
		Salinity/ TDS/ Chlorides	Unknown Nonpoint Source	Low	2	Miles	0111

(This section intentionally left blank.)

VI. FIRST AND SECOND TERM PERMITS: STORM WATER POLLUTION CONTROL PROGRAMS/POLICIES

Prior to EPA's promulgation of the final storm water regulations, the counties of Orange, Riverside and San Bernardino applied for areawide NPDES permits for storm water runoff. On July 13, 1990, the Regional Board issued Order No. 90-71 to the permittees (first term permit). In 1996, the Board adopted Order No. 96-31 (second term permit). First and second term permits included the following requirements as outlined in the storm water regulations:

1. Prohibited non-storm water discharges to the MS4s, with certain exceptions.
2. Required the municipalities to develop and implement a drainage area management plan (DAMP) to reduce pollutants in urban storm water runoff to the maximum extent practicable (MEP[4]).
3. Required the discharges from the MS4s to meet water quality standards in receiving waters.
4. Required the municipalities to identify and eliminate illicit connections and illegal discharges to the MS4s.
5. Required the municipalities to establish legal authority to enforce storm water regulations.
6. Required monitoring of dry weather flows, storm flows, and receiving water quality, and required program assessment.

The following programs and policies have been implemented or are being implemented by the permittees. During the first term permit, the permittees developed a Drainage Area Management Plan (1993 DAMP) which was approved by the Executive Officer of the Regional Board on April 29, 1994. The 1993 DAMP included a number of best management practices (BMPs) and a very extensive public education program. The monitoring program for the first term permit included 89 monitoring stations within streams and flood control channels and 21 stations within the bays, estuaries and the ocean. The findings and conclusions from these monitoring stations and monitoring programs of other municipal permittees (Riverside and San Bernardino Counties and others) have been used to identify problem areas and to re-evaluate the monitoring program and the effectiveness of the BMPs. The future direction of some of these program elements will depend upon the results of the ongoing studies and a holistic approach to watershed management.

Other elements of the storm water management program included identification and elimination of illegal/illicit discharges and establishment of adequate legal authority to control pollutants in storm water discharges. The permittees have completed a survey of their storm drain systems to identify illegal/illicit connections and have adopted appropriate ordinances to establish legal authority. Some of the more specific achievements during the first and second term permits are as follows:

[4] Maximum Extent Practicable (MEP) means to the maximum extent feasible, taking into account equitable considerations of synergistic, additive, and competing factors, including but not limited to, gravity of the problem, technical feasibility, fiscal feasibility, public health risks, societal concerns, and social benefits.

1. *Interagency Agreements and Coordination*: Established a program management structure through an Interagency Implementation Agreement. Participated in regional monitoring programs and focused special studies/research programs. Worked with the County Sanitation Districts, Health Care Agency, Integrated Waste Management Agency, and the Water Districts to provide a consistent urban storm water pollution control message to the public. Worked with Caltrans, other transportation agencies, the Storm Water Quality Task-Force, and others to further study and understand urban runoff problems and control measures.
2. *Ordinances, Plans and Policies:* Adopted a Model Water Quality Ordinance and Enforcement Consistency Guide; prepared a Water Pollution Enforcement Implementation Plan, Public Agency Activity BMP guideline, a Public Pesticide and Fertilizer Use guideline, Criteria for MS4 Inspections, and a Water Quality Monitoring Plan; and established a Technical Advisory Committee for overall program development and implementation.
3. *Program Review*: A number of existing programs were reviewed to determine their effectiveness in combating urban pollution and to recommend alternatives and or improvements, including litter control measures, street sweeping frequencies and methods, public agency activities and facilities, illegal and illicit connections to the MS4 systems, and existing monitoring programs.
4. *Public Education:* A number of steps were taken to educate the public, businesses, industries, and commercial establishments regarding their role in urban runoff pollution controls. The appropriate industrial dischargers were notified of the storm water regulatory requirements. For a number of unregulated activities, BMP guidance was developed (mobile detailing, automotive service centers, restaurants, pool maintenance). Finally, a countywide hotline was established for reporting any suspected water quality problems.
5. *Public Agency Training:* Training was provided to public agency employees on how to implement New Development Guidelines and Public Works BMPs, how to conduct investigations of reported water quality problems and how to conduct inspections of industrial facilities and public work projects. The municipal planners were trained to recognize water quality related problems in proposed developments.
6. *Related Activities:* Flood control channels were stabilized, sediment basins were constructed, and debris booms were installed; illegal connections were eliminated and illicit connections to the MS4s were documented and/or permitted.

VII. FIRST AND SECOND TERM PERMITS - WATER QUALITY IMPROVEMENTS

An accurate and quantifiable measurement of the impact of the above stated storm water management programs is difficult for a variety of reasons, such as the variability in chemical water quality data, the incremental nature of BMP implementation, lack of baseline monitoring data, and the existence of some of the programs and policies prior to initiation of formal storm water management programs. There are generally two accepted methodologies for assessing water quality improvements: (1) conventional monitoring such as chemical-specific water quality monitoring; and (2) non-conventional monitoring such as monitoring of the amount of household hazardous waste collected and disposed off at

appropriate disposal sites, amount of used oil collected, debris removed by the debris boom, etc.

The water quality monitoring data collected during the first and second term permits did not indicate any discernible trends or significant changes. However, the non-conventional monitoring data indicate that other programs and policies have been very effective in keeping a significant quantity of wastes from being discharged into waters of the U.S.

During the second term permit, there was an increased focus on watershed management initiatives and coordination among the municipal permittees in Orange, Riverside and San Bernardino Counties. These efforts resulted in a number of regional monitoring programs and other coordinated program and policy developments.

It is anticipated that with continued implementation of the revised DAMP and other requirements specified in this order, the goals and objectives of the storm water regulations will be met, including protection of the beneficial uses of all receiving waters.

VIII. FUTURE DIRECTION/2000 DAMP

The NPDES permit renewal application included an updated DAMP (2000 DAMP) that includes programs and policies the permittees are proposing to implement during the third term permit. The 2000 DAMP is the principal guidance document for urban storm water management programs in Orange County and includes the following major components:

1. Continues to provide a framework for the program management activities and plan development.
2. Continues to provide the legal authority to control discharges to the MS4s.
3. Improves current BMPs to achieve further reduction in pollutant loading to the MS4s.
4. Includes programs and policies to increase public education processes and to seek public support for urban storm water pollution prevention BMPs.
5. Increases requirements for controls on new developments and significant redevelopments.
6. Continues to ensure that construction sites implement appropriate pollution control measures.
7. Continues to ensure that industrial sites are in compliance with storm water regulations.
8. Continues to include programs and policies to eliminate illegal discharges and illicit connections to the MS4s.
9. Continues to include monitoring of urban runoff.
10. Includes provisions for any special focus studies and/or control measures.

A combination of these programs and policies and the requirements specified in this order should ensure control of pollutants in storm water runoff from facilities owned and/or controlled by the permittees.

IX. PERMIT REQUIREMENTS

The legislative history of storm water statutes (1987 CWA Amendments), U.S. EPA regulations (40CFR Parts 122, 123, and 124), and clarifications issued by the State Water Resources Control Board (State Board Orders No. WQ 91-03 and WQ 92-04) indicate that a non-traditional NPDES permitting strategy was anticipated for regulating urban storm water runoff. Due to the economic and technical infeasibility of full-scale end-of-pipe treatments and the complexity of urban storm water runoff quality and quantity, MS4 permits generally include narrative requirements for the implementation of BMPs in place of numeric effluent limits.

The requirements included in this order are meant to specify those management practices, control techniques and system design and engineering methods that will result in maximum extent practicable protection of the beneficial uses of the receiving waters. The State Board (Orders No. WQ 98-01 and WQ 99-05) concluded that MS4s must meet the technology-based maximum extent practicable (MEP) standard and water quality standards (water quality objectives and beneficial uses). The U.S. Court of Appeals for the Ninth Circuit subsequently held that strict compliance with water quality standards in MS4 permits is at the discretion of the local permitting agency. Any requirements included in the order that are more stringent than the federal storm water regulations are in accordance with the CWA Section 402(p)(3)(iii), and the California Water Code Section 13377 and are consistent with the Regional Board's interpretation of the requisite MEP standard.

The Report of Waste Discharge (ROWD) included a discussion of the current status of Orange County's urban storm water management program and the proposed programs and policies for the next five years (third term permit). The order incorporates these documents and the performance commitments made in the ROWD.

This order recognizes the significant progress made by the permittees during the first and second term permits in implementing the storm water regulations. The permit also recognizes regional and innovative solutions to such a complex problem. For these reasons, the order is less prescriptive compared to some of the MS4 NPDES permits for urban runoff issued by other Regional Boards. However, it should achieve the same or better water quality benefits because of the programs and policies already being implemented or proposed for implementation, including regional and watershed wide solutions.

The major requirements include: (1) Discharge prohibitions; (2) Receiving water limitations; (3) Prohibition on illicit connections and illegal discharges; (4) Public and business education; (5) Adequate legal authority; (6) Programs and policies for municipal facilities and activities; (7) Inspection Activities by the municipalities; (8) New development/re-development requirements; (9) Waste load allocations for nutrients, sediment, and fecal coliform bacteria; and, (10) Monitoring and reporting requirements.

These programs and policies are intended to improve urban storm water quality and protect the beneficial uses of receiving waters of the region.

1. DISCHARGE PROHIBITIONS

   In accordance with CWA Section 402(p)(3)(B)(ii), this order prohibits the discharge of non-storm water to the MS4s, with a few exceptions. The specified exceptions are consistent with 40 CFR 122.26(d)(2)(iv)(B)(1). If the permittees or the

Executive Officer determines that any of the exempted non-storm water discharges contain pollutants, a separate NPDES permit or coverage under the Regional Board's De Minimis permit will be required.

2. RECEIVING WATER LIMITATIONS

   Receiving water limitations are included to ensure that discharges from MS4 systems do not cause or contribute to violations of applicable water quality standards in receiving waters. The compliance strategy for receiving water limitations is consistent with the U.S. EPA and State Board guidance and recognizes the complexity of storm water management.

   This order requires the permittees to meet water quality standards in receiving waters in accordance with US EPA requirements as specified in State Board Order No. WQ 99-05. If water quality standards are not met by implementation of current BMPs, the permittees are required to re-evaluate the programs and policies and to propose additional BMPs. Compliance determination will be based on this iterative BMP implementation/compliance evaluation process.

3. ILLEGAL DISCHARGES AND ILLICIT CONNECTIONS TO MS4s

   The permittees have completed their survey of the MS4 systems and eliminated or permitted all identified illicit connections. The permittees have also established a program to address illegal discharges and a mechanism to respond to spills and leaks and other incidents of discharges to the MS4s. The permittees are required to continue these programs to ensure that the discharges from MS4s do not become a source of pollutants in receiving waters.

4. PUBLIC AND BUSINESS EDUCATION OUTREACH PROGRAM

   Public outreach is an important element of the overall urban pollution prevention program. The permittees have committed to implement a strategic and comprehensive public education program to maintain the integrity of the receiving waters and their ability to sustain beneficial uses. The principal permittee has taken the lead role in the outreach program and has targeted various groups including businesses, industry, development, utilities, environmental groups, institutions, homeowners, school children, and the general public. The permittees have developed a number of educational materials, established a storm water pollution prevention hotline, started an advertising and educational campaign and distribute public education materials at a number of public events. The permittees are required to continue these efforts and to expand public participation and education programs.

5. LEGAL AUTHORITY

   During the first two permit cycles, each permittee adopted a number of ordinances, municipal codes, and other regulations to establish legal authority to control discharges to the MS4s and to enforce these regulations as specified in 40 CFR 122.26(d)(2)(I)(B, C, E, and F). The permittees are required to enforce these ordinances and to take enforcement actions against violators (40 CFR 122.26(d)(2)(iv)(A-D)). The enforcement activities undertaken by a majority of the permittees have consisted primarily of Notices of Violation, which act to educate the public on the environmental consequences of illegal discharges. In the case of the County, additional action has sometimes included recovery of investigation and

clean-up costs from a responsible party. In the event of egregious or repeated violations, the option exists for a referral to the County District Attorney for possible prosecution. In order to eliminate unauthorized, non-storm water discharges, reduce the amount of pollutants commingling with storm water runoff and thereby protect water quality, an additional level of enforcement is required between Notices of Violation and District Attorney referrals. Therefore, by November 15, 2003, the permittees are required to establish the authority and resources to administer either civil or criminal fines and/or penalties for violations of their local water quality ordinances (and the Federal Clean Water Act). The progress in establishing this program must be fully documented in the annual reports submitted by the permittees and the number, nature and amount of fines and/or penalties levied must be reported, beginning with the 2003/2004 annual report.

6. PUBLIC FACILITIES AND ACTIVITIES

Education of municipal planning, inspection, and maintenance staff is critical to ensure that municipal facilities and activities do not cause or contribute to an exceedance of receiving water quality standards. The second term permit required the permittees to prepare an Environmental Performance Report to address public agency facilities and activities that are not regulated under the State's General Industrial Activities Storm Water Permit. It also required the permittees to report on an annual basis the actions taken to eliminate the discharge of pollutants from public agency activities and facilities. The permittees are required to inspect and maintain drainage facilities free of waste materials to control pollutants in storm water runoff flowing through these systems. This order requires the permittees to re-evaluate their facilities and activities on an annual basis to see if additional BMPs are needed to ensure water quality protection.

7. MUNICIPAL INSPECTION PROGRAM

Inspections by the municipalities, of construction, industrial, and commercial activities within their jurisdiction will be conducted, in order to control the loading of pollutants entering the MS4 system. The municipalities will inventory companies and sites in the above categories; prioritize those companies and sites with respect to their potential for discharge of pollutants in runoff and their proximity to sensitive receiving waters; and perform regular inspections to insure compliance with local ordinances. While initial observations of non-compliance may result in 'educational' type enforcement, repeated non-compliance will result in more disciplinary forms of enforcement, such as, monetary penalties, stop work orders or permit revocation.

8. NEW DEVELOPMENT

During the second term permit, the permittees developed new development guidelines. The permittees are required to implement these guidelines. Additionally, this order requires the permittees to work towards the goal of restoring and preserving the natural hydrologic cycles in approving urban developments. To accomplish this goal, the permittees have the option of using a combination of methodologies. The permittees/project proponents may propose BMPs based on a watershed approach, establish a storm water pollution prevention fund for such BMPs, or any other innovative and proven alternatives to address storm water pollution. If a set of measures, acceptable to the Executive Officer, is not developed

and approved by October 1, 2003, the permittees are required to use the numeric sizing criteria specified in this order. The numeric criteria are identical to the ones used by the San Diego Regional Board in its MS4 permit for permittees within the San Diego County area (Order No. 2001-01).

9. SEPTIC SYSTEM FAILURES AND PORTABLE TOILET DISCHARGES

   A number of beach closures in Orange County have been due to spills, overflows, and leaks from sanitary sewer lines. To address these concerns, a set of separate waste discharge requirements for local sanitary sewer agencies is being prepared by the Regional Board. Failing septic systems and improper use of portable toilets have also been linked to microbial contamination of urban runoff. The permittees shall identify, with the appropriate local agency, a mechanism to determine if failure of these septic systems are causing or contributing to urban storm water pollution problems in their jurisdictions. The permittees shall also review their local oversight program for the placement and maintenance of portable toilets to determine the need for any revision.

10. MONITORING REQUIREMENTS

    During the first term permit and part of the second term permit, the permittees conducted extensive monitoring of the storm water flows, receiving water quality and sediment quality. These early programs focused on identifying pollutants, estimating pollutant loads, tracking compliance with water quality objectives, and identifying sources of pollutants. The Orange County monitoring program, like other monitoring programs nationwide, has established that there is a high degree of uncertainty in the quality of storm water runoff and that there are significant variations in the quality of urban runoff spatially and temporally. However, most of the monitoring programs to date have indicated that there a number of pollutants in urban storm water runoff. Only in a few cases has a definite link between pollutants in urban runoff and beneficial use impairment been established.

    In 1999, the permittees re-evaluated their monitoring program and proposed a revised monitoring program. The goals of the 1999 Water Quality Monitoring Program are:

    a. To determine the role of urban runoff in beneficial use impairment;

    b. To collect technical information to develop an effective urban storm water management plan; and

    c. To determine the effectiveness of a number of BMPs, also as an aid to the overall urban storm water management plan.

    To accomplish these goals, the monitoring program focuses on three areas:

    a. Areas where constituent concentrations are substantially above system-wide averages. These areas are referred to as “warm spots” and the designation is based on monitoring data from prior years.

    b. Areas of Critical Aquatic Resources (sites with important aquatic resources).

    c. Sub-watersheds where certain BMPs have been installed to study their effectiveness.

To accomplish these goals, it is anticipated that at least five years worth of monitoring data will be required (1999-2003).

In addition, the monitoring program will continue the Reconnaissance and Source Identification component that targets areas that are known to exhibit unusually high levels of storm water pollutants.

The permittees also participate in a number of other regional monitoring programs such as those conducted by the Southern California Coastal Water Research Project and the California Regional Marine Monitoring Program.

The permittees are encouraged to continue their participation in regional and watershed-wide monitoring programs. By July 1, 2003, the permittees are required to re-evaluate their Water Quality Monitoring Program and submit a revised plan for approval. The revised plan shall include the following monitoring elements: Mass Emissions, Estuary/Wetlands, Water Column Toxicity, Bacteriological/Pathogen, Bioassessment, Reconnaissance, Land Use Correlation, and TMDL/303(d) Listed Waterbodies.

X. WATER QUALITY BENEFITS/COST ANALYSIS/FISCAL ANALYSIS

There are direct and indirect benefits from clean beaches, clean water, and a clean environment. It is difficult to assign a dollar value to the benefits the public derives from fishable and swimmable waters. In 1972, at the start of the NPDES program, only 1/3 of the U.S. waters were swimmable and fishable. In 2001, 2/3 of the U.S. waters meets these criteria. In the 1995, *Money* magazine survey of the "Best Places to Live", clean water and air ranked as the most important factors in choosing a place to live. Thus, environmental quality has a definite link to property values. Clean beaches and other water recreational facilities also attract tourists. It is estimated that on average, an out-of-state visitor spends approximately $100.00 per day. Huntington Beach's 8.5-mile shoreline attracts 10 million visitors a year[5]. During the summer of 1999 and 2000 when the beaches were closed to water contact recreation, the beach communities reported multi-million-dollar losses in tourist revenues.

The true magnitude of the urban runoff problem is still elusive and any reliable cost estimate for cleaning up urban runoff would be premature. For urban storm water runoff, end-of-pipe treatments are cost prohibitive and are not generally considered as a technologically feasible option. Over the last decade, the permittees have attempted to define the problem and implemented best management practices to combat the problem. The costs incurred by the permittees in implementing these programs and policies can be divided into three broad categories (the costs indicated below are for the entire Orange County storm water program):

1. Shared costs: These are costs that fund activities performed mostly by the principal permittee under the Implementation Agreement. These activities include overall storm water program coordination; intergovernmental agreements; representation at the Storm Water Quality Task Force, Regional Board/State Board meetings and other public forums; preparation and submittal of compliance reports and other

[5] Los Angeles Times, May 9, 2001

reports required under the NPDES permits and Water Code Section 13267, budget and other program documentation; coordination of consultant studies, co-permittee meetings; and training seminars. The overall costs increased from $0.81M in 1996/97 to $0.94M in 1999/00.

2. Individual Costs for DAMP Implementation: These are costs incurred by each permittee for implementing the BMPs (drainage facility inspections for illicit connections, drain inlet/catchbasin stenciling, public education, etc.) included in the DAMP. A number of programs and policies for non-point and storm water pollution controls existed prior to the urban storm water runoff NPDES program. However, the DAMP that was developed and implemented in response to the urban storm water runoff NPDES program required additional programs and policies for pollution control. These costs are attributable to DAMP implementation. These costs increased from $2.6M in 1996/97 to $6.9M in 1999/00.

3. Individual Costs of Pre-Existing Programs: These are costs incurred by each permittee for water pollution control measures that were already in existence prior to the urban storm water runoff NPDES program. These programs included recycling, litter control, street sweeping, drainage facility maintenance, and emergency spill response. The overall costs for these programs increased from $48M in 1996/97 to $79M in 1999/00.

In addition to these expenditures, volunteer programs (such as the "Beach Cleanup Day", "Pride Days", "Coastal Cleanup Day", etc.) also contributed to the urban runoff pollution control efforts.

The permittees identified the following funding sources (1999/00):

FUNDING SOURCE	*PERCENTAGE*
General Funds	66%
Gas Taxes	9%
Sewer/Storm Drain Maintenance Fee	7%
Sanitation Fees	5%
Benefit Assessment	3%
Special District Funds	1%
Other Sources	9%

XI. ANTIDEGRADATION ANALYSIS

The Regional Board has considered whether a complete antidegradation analysis, pursuant to 40 CFR 131.12 and State Board Resolution No. 68-16, is required for these storm water discharges. The Regional Board finds that the pollutant loading rates to the receiving waters will be reduced with the implementation of the requirements in this order. As a result, the quality of storm water discharges and receiving waters will be improved. Since this order will not result in a lowering of water quality, a complete antidegradation analysis is not necessary, consistent with the federal and state antidegradation requirements.

XII. PUBLIC WORKSHOP

The Regional Board recognizes the significance of Orange County's Storm Water/Urban Runoff Management Program and will conduct, participate, and/or assist with any workshop during the term of this order to promote and discuss the progress of the storm water management program. The details of the workshop will be posted on the Regional Board's website, published in local newspapers and mailed to interested parties. Persons wishing to be included in the mailing list for any of the items related to this order may register their e-mail address and/or mailing address with the Regional Board office at the address given below.

XIII. PUBLIC HEARING

The Regional Board opened a public hearing regarding the proposed waste discharge requirements on Wednesday, December 19, 2001 at 9:00 a.m. at the City Council Chambers, City of Santa Ana. The public hearing was continued on Friday, January 18, 2002 at 9:00 a.m. at the City Council Chambers, City of Santa Ana, at which time Order No. R8-2002-0010 was adopted.

XIV. INFORMATION AND COPYING

Persons wishing further information may write to the above address or call Aaron Buck at (909) 782-4906. Copies of the application, proposed waste discharge requirements, and other documents (other than those which the Executive Officer maintains as confidential) are available at the Regional Board office for inspection and copying by appointment scheduled between the hours of 8:30 a.m. and 4:00 p.m., Monday through Friday (excluding holidays).

XV. REGISTER OF INTERESTED PERSONS

Any person interested in a particular application or group of applications may leave his/her e-mail and/or mailing address and phone number as part of the file for an application. Copies of tentative waste discharge requirements will be mailed to all interested parties.

In addition to the permittees, comments were solicited from the following agencies and/or persons:

U. S. Environmental Protection Agency – Terry Oda / Eugene Bromley (W-5-1)
U.S. Army District, Los Angeles, Corps of Engineers - Permits Section
NOAA, National Marine Fisheries Service
U.S. Fish and Wildlife Service - Carlsbad
State Water Resources Control Board - Ted Cobb, Office of the Chief Counsel
State Water Resources Control Board – John Youngerman/Bruce Fujimoto, Division of Water Quality
State Department of Water Resources - Glendale
California Regional Water Quality Control Board, North Coast Region (1) – John Short
California Regional Water Quality Control Board, San Francisco Bay Region (2) – Dale Bowyer
California Regional Water Quality Control Board, Central Coast Region (3) – Jennifer Bitting
California Regional Water Quality Control Board, Los Angeles Region (4) – Wendy Phillips
California Regional Water Quality Control Board, Central Valley Region (5S) – George D. Day/Dani Berchtold
California Regional Water Quality Control Board, Central Valley Region (5R), Redding - Carole Crowe
California Regional Water Quality Control Board, Central Valley Region (5F), Fresno – Jarma Bennett
California Regional Water Quality Control Board, Lahontan Region (6SLT), South Lake Tahoe – Mary Fiore-Wagner
California Regional Water Quality Control Board, Lahontan Region (6V), Victorville – Gene Rodash
California Regional Water Quality Control Board, Colorado River Basin Region (7) – Abdi Haile/Pat Garcia
California Regional Water Quality Control Board, San Diego Region (9) – Bob Morris/Dave Gibson
State Department of Fish and Game - Long Beach
State Department of Health Services - Santa Ana
State Department of Parks and Recreation – Don Ito
Orange County Health Care Agency – Larry Honeybourne
South Coast Air Quality Management District, Diamond Bar -
Caltrans, District 12, Santa Ana – Grace Pina-Garrett
Southern Pacific Railroad
Atchison, Topeka & Santa Fe Railway Company
Seal Beach Naval Weapons Station
Seal Beach Naval Reserve Center, Los Alamitos
U. S. Marine Corps Air Station, El Toro -
National Forest Service
URS/Greiner - Bob Collacott
The Irvine Company - Sat Tamaribuchi
Building Industry Association – Tim Piasky/David Smith
Latham & Watkins – Paul Singarella

Best, Best, and Krieger – Anne Thomas
Southern California Association of Governments, Los Angeles - Tabi Hiwot

Universities and Colleges (Chancellor)
University of California, Irvine
California State University, Fullerton
Chapman College
Coastline College
Cypress College
Fullerton College
Irvine Valley College
Golden West College
Orange Coast College
Rancho Santiago College

School Districts (Superintendent)
Anaheim Elementary School District
Anaheim Union High School District
Brea-Olinda Unified School District
Buena Park Joint Union High School District
Centralia Elementary School District
Cypress Elementary School District
Fountain Valley Union High School District
Fullerton Elementary School District
Fullerton Joint Union High School District
Garden Grove Unified School District
Huntington Beach Elementary School District
Huntington Beach Union High School District
Irvine Unified Union High School District
La Habra Joint Union High School District
Los Alamitos Unified School District
Lowell Joint Union High School District
Magnolia Elementary School District
Newport-Mesa Unified School District
Ocean View Union High School District
Orange Unified School District
Placentia Unified School District
Santa Ana Unified School District
Savanna Union High School District
Tustin Unified School District
Westminster Union High School District
Yorba Linda Joint Union High School District

Hospitals (Administrator)
Anaheim General Hospital
Brea Community Hospital
Chapman General Hospital, Orange
Children's Hospital of Orange County. Orange
Coastal Communities Hospital, Santa Ana

Fairview Hospital
FHP Hospital, Fountain Valley
Fountain Valley Regional Hospital and Medical Center
Hoag Hospital, Newport Beach
Kaiser Foundation Hospital, Anaheim
Orange County Community Hospital, Buena Park
Pacifica Community Hospital, Huntington Beach
Placentia Linda Community Hospital
Santa Ana Hospital and Medical Center
St. Joseph's Hospital, Orange
U.C. Irvine Medical Center
Vencor Hospital of Orange County, Westminster
Whittier Hospital and Medical Center, Buena Park

Environmental Organizations
Lawyers for Clean Water – Kim Lewand/Daniel Cooper
Orange County Coastkeeper – Garry Brown
Defend the Bay – Bob Caustin
Sierra Club, Orange County Chapter
Sierra Club, Los Angeles Chapter - Dick Hingson
Natural Resources Defense Council (NRDC) – David Beckman
Cousteau Society
Amigos De Bolsa Chica
Audobon Sea & Sage Chapter
Huntington Beach Wetlands Conservancy
Surfrider Foundation- Nancy Gardner
Alliance to Rescue Crystal Cove – Laura Davik

Newspapers
Orange County Register – Pat Brennan
Los Angeles Times – Seema Metha
Press Enterprise –
Daily Pilot – Paul Clinton

Major Water/Wastewater Agencies
Santa Ana Watershed Project Authority – Joseph Grindstaff
Irvine Ranch Water District – General Manager
Los Alisos Water District - General Manager
El Toro Water District - General Manager
San Bernardino County Flood Control District - Naresh Varma
Riverside County Flood Control & Water Conservation District – Steve Stump/Mark Wills
L.A. County Department of Public Works - Gary Hildebrand
Orange County Sanitation Districts - Blake Anderson
Orange County Water District - Bill Mills
Metropolitan Water District - Ed Mean

Model Urban Runoff Program

A How-To Guide for Developing Urban Runoff Programs for Small Municipalities

Prepared by:
City of Monterey
City of Santa Cruz
California Coastal Commission
Monterey Bay National Marine Sanctuary
Association of Monterey Bay Area Governments
Woodward-Clyde Consultants
Central Coast Regional Water Quality Control Board

July 1998 (revised February 2002, by the California Coastal Commission)

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The California Coastal Commission's Water Quality Unit (Vanessa Metz and Janna Shackeroff) updated this manual in 2002, with technical assistance from Andrew McIntyre. The MURP manual is available online at the California Coastal Commission website at: www.coastal.ca.gov/la/landx.html.

1 Overview

1.1 A Guide for Addressing Polluted Urban Runoff

1.2 The Problem

1.3 The Solution

1.4 MURP Manual Organization

1.1 A "How-To" Guide for Addressing Polluted Urban Runoff

This document is a "how-to" guide for addressing an environmental problem that affects every urban community in California: polluted runoff. Polluted runoff threatens the water quality of our oceans and streams and degrades our groundwater supplies. Storm runoff can flush a multitude of toxic chemicals, including oils and pesticides, into sensitive wildlife habitats. Trash and other runoff debris often litter our beaches. Ultimately, the combined effects of polluted urban runoff can have serious negative impacts on a community's economy — it is not simply an environmental health problem.

As a recipient of this guide, you play a key role in addressing polluted runoff in your community. In contrast to more traditional point source pollution problems, polluted runoff presents some distinct management challenges for local government. Polluted runoff comes from thousands of different sources made up of homes, cars, factories, restaurants, and construction sites. Many everyday activities result in polluted runoff — often unbeknownst to the "polluter". Direct regulation of such a wide array of "nonpoint" sources is extremely difficult, if not impossible. In addition, unlike individual factory outfalls, it is difficult to identify, establish or measure the links between these sources and the overall water quality of a community.

Nonetheless, we know the problem of polluted urban runoff is real and requires a new strategy that combines the best of the regulatory approach of traditional environmental management with community-wide education, participation, and outreach; incentive-based and volunteer programs; and practical, cost-effective implementation mechanisms. Everyday pollution activities require everyday solutions, particularly true in an era of dwindling municipal resources.

The widespread nature of the polluted runoff problem requires a comprehensive solution. That is why all citizens and all aspects of your municipality — planning, public works, health and safety, etc. — should work on the solution. Thus, the purpose of this guide is to provide your municipality with a cookbook of sorts with the recipes necessary to put a serious dent in the urban runoff problem in your community in the most cost-effective way. The key ingredients of these recipes are "best management practices" or BMPs — practical ways to initiate a polluted runoff management program without heavy-handed regulatory requirements. In some cases, polluted runoff can be curtailed simply by regular street sweeping or by an outreach program that teaches local businesses how to prevent urban runoff pollutants from entering the environment at all.

While this guide emphasizes BMPs, it is important to realize that new federal and state regulatory requirements will soon address urban runoff in local communi-

ties. Indeed, the U.S. Environmental Protection Agency (EPA) has already placed such requirements on municipalities with populations greater than 100,000. This guide, therefore, also provides you with the best information available from federal, state and local agencies specifically developed in anticipation of new urban runoff management requirements. If you begin using this guide today, you will be ahead of the game when these requirements are formally put in place.

Finally, this guide acknowledges that lasting polluted runoff solutions are best built by local officials, organizations, and community members, who best understand their watersheds, their community's unique features, and, most importantly, their water quality needs and goals. As a result, this guide is not a top-down, regulatory compliance vehicle, but rather a bottom-up "how-to" guide for tailoring a comprehensive urban runoff program (URP) responsive to your community's water quality concerns. With information and practical solutions culled from the best polluted runoff management programs and experts in the field, this guide should be a valuable working tool for your community.

The following pages provide a framework for understanding the problem of polluted urban runoff and why it is essential to act now. More importantly, the pieces of an URP and how these pieces fit together are mapped out to make the potentially overwhelming problem of polluted urban runoff quite manageable. To be sure, after reading this overview, you will realize that your municipality has already taken several steps towards reducing urban runoff pollution.

1.2 The Problem

What is Polluted Urban Runoff and Why is it a Problem?

Runoff from storm events is part of the natural hydrologic process: rainwater that does not infiltrate into the ground flows by the force of gravity into water bodies such as lakes, streams, rivers, and oceans. As runoff heads for receiving waters, naturally vegetated depressions and rills slow the water and filter it for pollutants and sediments. In urban settings, however, natural vegetation and topography have been altered, graded, or paved and storm water is diverted in storm drain pipes. When the drainage pattern of a watershed is so altered, flows increase in concentration and velocity and pick up sediments and pollutants from land surfaces at an increased rate. Storm water that flows through urbanized areas to receiving waters is called "urban runoff."

Pollutants of Concern Found in Urban Runoff

- Sediments
- Nutrients (nitrogen, phosphorous, etc.)
- Pathogens (bacteria, viruses, etc.)
- Oxygen-Demanding Substances (plant debris, animal wastes, etc.)
- Petroleum Hydrocarbons (oil, grease, solvents, etc.)
- Heavy Metals (lead, zinc, cadmium, copper, etc.)
- Toxic Pollutants
- Floatables (litter, yard wastes, etc.)
- Synthetic Organics (pesticides, herbicides, polychlorinated biphenyls, etc.)
- Physical Parameters (salinity, elevated temperature, pH)

Trash and debris that collect in storm drain inlets are carried into the receiving waters by runoff

Urban runoff is known to carry a wide range of pollutants including nutrients, trash and debris, sediments, heavy metals, pathogens, petroleum hydrocarbons, and synthetic organics such as pesticides. Because urban runoff does not originate from a distinct "point" source (e.g., an industrial discharge pipe), it is also often referred to as nonpoint source pollution. These pollutants in urban runoff could negatively impact the vitality of your municipality on many levels. Urban runoff can alter the physical, chemical, and biological characteristics of water bodies to the detriment of aquatic and terrestrial organisms; can make beaches and rivers unsightly or unsafe for human contact; and can negatively impact beneficial activities and uses including water recreation, commercial fishing, tourism and aquatic habitat. In some cases pollutants of concern may not even be visible to the naked eye.

How is Urban Runoff Regulated?

California is currently involved in two parallel, complementary approaches to address urban runoff from municipalities: the State's Nonpoint Source (NPS) Pollution Control Program, and the U.S. EPA's National Pollutant Discharge Elimination System (NPDES) Storm Water permit program. The State's NPS Pollution Control Program details how the state will promote the implementation of management measures and BMPs to control and prevent polluted runoff, as required by Section 319 of the federal Clean Water Act (CWA). Because of the diffuse nature of polluted runoff, which originates from multiple sources and has a widespread reach, the State's NPS Pollution Control program has emphasized financial incentives, technical

Beneficial Uses and Activities Negatively Impacted by Polluted Runoff

- Aesthetic Enjoyment
- Agricultural Supply
- Aquaculture/Mariculture
- Cold Fresh-water Habitat
- Commercial and Sport Fishing
- Estuarine Habitat
- Fresh-water Replenishment
- Groundwater Recharge
- Industrial Service and Process Supply
- Inland Saline Water Habitat
- Marine Habitat
- Migration of Aquatic Organisms
- Municipal and Domestic Water Supply
- Biological Habitats of Special Significance
- Rare, Threatened, or Endangered Species
- Shellfish Harvesting
- Spawning, Reproduction, and Early Development of Aquatic Organisms
- Warm Fresh-water Habitat
- Water Contact/Noncontact Recreation
- Wildlife Habitat

assistance, and public education, rather than regulatory activities.

Coastal states are also required to develop programs to protect coastal waters from nonpoint source pollution, as mandated by the federal Coastal Zone Act Reauthorization Amendments (CZARA) of 1990. CZARA Section 6217 identifies polluted runoff as a significant factor in coastal water degradation, and requires implementation of management measures and enforceable policies to restore and protect coastal waters.

In lieu of developing a separate NPS program for the coastal zone, California's NPS Pollution Control Program was updated in 2000 to address the requirements of both the CWA section 319 and the CZARA section 6217 on a statewide basis. The California Coastal Commission (CCC), the State Water Resources Control Board (SWRCB), and the nine Regional Water Quality Control Boards (RWQCBs) are the lead State agencies for upgrading the program, although 20 other State agencies also participate. This guide should help you in developing a local urban runoff control program that is consistent with the State's NPS implementation plan.

Urban point source pollution is addressed by the NPDES permit program of the Clean Water Act. Although urban nonpoint sources contribute to stormwater runoff, runoff may be channeled into a storm drain and ultimately become a point source. Therefore, stormwater is regulated as a point source under the NPDES permit program. In 1990, the EPA established Phase I of the NPDES Storm Water program mandated by the CWA Section 402 (p). The Phase I Storm Water program requires NPDES permits for storm water discharges from (1) medium and large municipal separate storm sewer systems (MS4s), generally serving populations greater than 100,000, (2) specific industrial activities, and (3) construction activities disturbing 5 or more acres of land. In California, the NPDES program is administered by the SWRCB, and the nine RWQCBs.

The SWRCB has issued a statewide General Permit for all industrial and construction-related stormwater discharges that require a NPDES Storm Water Phase I permit. The General Permit requires operators to develop and implement a Storm Water Pollution Prevention Plan (SWPPP) incorporating appropriate BMPs. Municipalities, however, must obtain an individual NPDES Storm Water permit for their entire storm drain system. Municipal Phase I Storm Water permits require implementation of structural and nonstructural control measures to reduce pollutant loads from industrial, commercial, and residential areas. In California, the RWQCBs required Phase I permits for many municipalities serving ur-

Sights such as this are common in urban areas

banized areas with populations that were less than the specified 100,000.

Phase II of the NPDES Storm Water program expands the coverage to include all municipalities within designated urbanized areas, as well as designated small municipalities outside of urbanized areas (generally those with a population of at least 10,000 and/or a population density of at least 1,000 persons per square mile). The program will also expand to include construction sites that disturb between 1 and 5 acres. Final Phase II regulations were established by the EPA in 1999 (Federal Register Vol. 64, No. 235, Dec. 8, 1999); these regulations require Phase II storm water permits by March 10, 2003. Appendix 1A lists California municipalities designated by the EPA as automatically or potentially regulated under Phase II; additional municipalities may also be designated by California's RWQCBs. Establishing an URP according to this guide will, in all likelihood, help your community comply with the upcoming NPDES Phase II program.

The health of your community depends on clean water

While different legal authorities may apply to different situations, the goals of the NPDES and the NPS/CZARA programs are complementary. Many of the techniques and practices used to control urban runoff are equally applicable to both programs, even though the programs do not work identically. EPA's NPDES Phase II regulations indicate that an urban area covered by an NPDES Storm Water Permit (Phase I or Phase II) will be excluded from explicit CZARA requirements, provided the permit addresses the polluted storm water/urban runoff management measures and enforceable policies identified in the State NPS Plan. The bottom line is that the State's current and developing approaches to addressing urban runoff are and will be consistent with both the NPDES and the NPS/CZARA programs. This guide is intended to help your community establish an URP that is consistent with both programs as well.

Why Should You do Something About Polluted Runoff in Your Community?

Clean water is crucial to the continued vitality of your community. Whether for recreational purposes, commercial fishing, habitat preservation, or community aesthetics, your community deserves — and demands — clean water. As summarized above, polluted urban runoff is a widespread water quality threat. If left unchecked, it WILL negatively impact your community through resource impacts, public health impacts, economic impacts, or more likely a combination of all, given the interwoven nature of beneficial waterbody uses. It may even have a domino effect where,

for example, polluted ocean waters drive off tourists, which in turn hurts local merchants, which in turn undermines the local economy. In short, water quality is an important part of a healthy community. Protecting your community's water quality should be pursued because it's the right thing to do. It's what the Model Urban Runoff Program (MURP) calls the water quality ethic.

In addition to your commitment to the water quality ethic, the new regulatory reality is that your municipality will be required (by NPDES Phase II and/or CZARA Section 6217) to implement a program that addresses polluted runoff and reduces the discharge of pollutants in storm water runoff. Many municipalities currently lacking formal urban runoff programs (URPs) will be required to develop them with the next few years. Will each municipality need to develop a new URP from scratch to ensure regulatory compliance? No. Your municipality is likely already instituting elements of such a formal URP that your "new" URP will build upon. The key is to ensure that your URP covers the basic regulatory requirements and that it translates into water quality improvements. In short, your community needs clean urban water runoff and will soon be required to make sure it is clean, which is where this guide comes in.

1.3 The Solution

This MURP is an off-the-shelf guidebook for small municipalities looking to develop their own URPs. The MURP will help you to develop, finance, implement, and enforce a comprehensive program for managing runoff and improving water quality in your municipality. In addition, every effort has been made to ensure that if you develop an URP as described in this guide, you will be well on your way to compliance with upcoming NPDES Phase II regulations and the CZARA Section 6217 Implementation Plan.

Implementing Best Management Practices

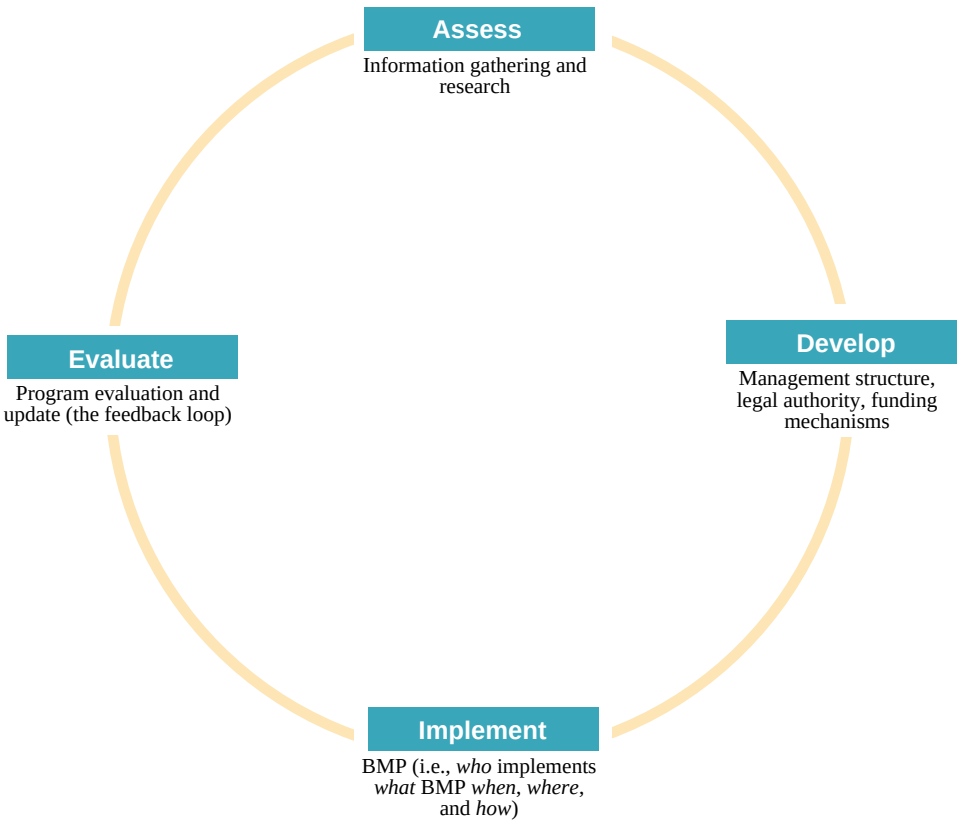
The foundation of your URP should consist of BMPs selected to fit local conditions and water quality problems. The term BMPs may sound formal, but in reality BMPs are common sense methods for controlling, preventing, reducing, or removing pollutants in urban runoff. Street sweeping, for example, is an effective BMP. Source control BMPs are intended to prevent or minimize the introduction of pollutants into runoff. Dry cleanup of gas station fueling areas is an example of a source control BMP. Treat-

A silt fence can help keep sediment out of storm drains and creeks

ment BMPs, on the other hand, are designed to remove the pollutants from storm water runoff. A silt fence that effectively filters sediment from water is a good example of a treatment BMP. Considered together, the BMPs you select should form a comprehensive programmatic framework that reduces storm water pollution to the maximum extent practicable.

A wealth of information about BMPs is available. The real test lies in selecting control measures that address problems specific to your municipality and your watershed, effectively implementing those practices, and monitoring their success. In other words, effective BMP implementation requires a comprehensive program. Developing your comprehensive URP requires you to:

- ✓ Assess. You need to assess the polluted runoff problem in your jurisdiction and watershed, as well as your existing polluted runoff management efforts, so that your program is tailored to your needs. This step involves information gathering and research to identify resources, problems, opportunities, and priorities for implementing BMPs.
- ✓ Develop. You must develop effective urban runoff control policies and create an efficient, adequately funded program within the existing administrative structure of your agency. This step involves developing legal authority, funding, and management structures to ensure long-term program sufficiency, accountability, and enforcement of BMPs. This step also involves educating your community about the problem as a means to promote public participation in identifying the solution.



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- ✓ Implement. You must carry out the BMPs to address your urban runoff problems. This step is the heart of your URP, as it details who implements what BMPs, when, where, and how.
- ✓ Evaluate. You must evaluate the success of your program to remain accountable, and to maintain and improve its effectiveness. Program evaluation and updating allow your URP to adapt to new information, new problems, new BMPs, and other changing circumstances.

These four components form the conceptual framework for your URP.

How to Begin

As you develop your URP, keep in mind that the conceptual framework does not necessarily represent a sequence of events but rather a set of activities that must be completed in order for your URP to be effective. As your program evolves over time and you learn more about the problem of urban runoff in your town, each component informs the others.

The first step in the development of your URP is to investigate the existing urban runoff framework in your municipality, which means conducting both an institutional and a resource-based analysis of your current urban runoff climate. Institutionally, you need to know the existing players, policies, programs, fiscal resources, authorities, and management structures. Likely your community already has elements of an URP, and part of the development process is recognizing, coordinating, and building upon these existing efforts. In fact, as you develop your municipality's URP, a parallel track is reaching out to other municipalities within the larger watershed to coordinate water pollution prevention efforts regionally. Watersheds provide the fundamental resource unit for managing polluted runoff since runoff within a watershed flows to a common outlet. Banding together in a larger watershed management plan can help to coordinate BMP implementation, pool resources, and most of all, better protect beneficial uses.

As a complement to the institutional assessment, you will also need to assess the current state of your water resources. This assessment involves identifying and prioritizing watershed resources, problems, and opportunities for improving water quality and the management of urban runoff within your jurisdictional boundaries. The idea here is to identify priority areas of concern based upon watershed and water quality conditions and issues. This portion of your assessment helps you to determine where your URP should be focused and why. The institutional and resource assessments are covered in detail in the Assessment chapter of this guide (Chapter 2).

The next step in the development of your URP is to establish a program management structure. Part of this structure may fall out of your preliminary institutional assessment, part may be influenced by the type of program that you want to implement, and part may be impacted by public participation — all subject to change. Remember that the process is not linear and that the idea here is to establish a

general framework for your URP so that you can begin your program. Subsequent events are likely to impact these arrangements. Overall program management is covered in detail in the Program Development chapter of this guide (Chapter 3).

After performing a preliminary assessment and establishing a general management structure, the concurrent and overlapping third step in the process is to develop your program elements. For implementing BMPs, this step is the heart of your URP, and this guide is primarily a vehicle for providing guidance on this topic (Chapter 4).

Because the MURP is a model document, a full array of runoff management measures is presented. You should choose those controls and elements that are applicable to your community's concerns. However, while the document is structured to allow you to tailor a program to your needs, the MURP also defines minimum program elements.

All municipalities should begin with at least the minimum program elements. The minimum program elements recommended by the MURP are the "minimum control measures" required in the NPDES Phase II regulations:

- ✓ Public education and outreach
- ✓ Public involvement and participation
- ✓ Illicit discharge detection and elimination
- ✓ Pollution prevention and good housekeeping in municipal operations
- ✓ Construction site urban runoff control
- ✓ Post-construction runoff management in new development and redevelopment

These Phase II requirements (Sections 4.1 through 4.6) form the minimum URP. Within each of these Phase II-required control measures (or control programs), MURP further recommends minimum strategies for BMP implementation. Thus, the minimum URP would involve implementing BMPs within each of the six Phase II-required control measures above.

Note that NPDES Phase II regulations do not target any specific land-use categories other than activities falling under the scope of municipal operations. Industrial land uses that are considered significant sources of pollutants are already addressed under the Phase I regulations (i.e., required to control pollutants under a General Permit). With respect to general commercial establishments and residential sources, the regulations emphasize education and outreach as the method to achieve pollutant reduction. However, if you determine that commercial or industrial facilities in your town are significant sources that need to be controlled more rigorously, this guide also presents control programs to help you do that (Sections 4.7-4.8). Please note that these additional programs are only the tip of the iceberg and that any number of individual control programs are available from the sources listed in this guide should you decide to tailor your URP accordingly. The range of URP controls are presented in detail in the Implementation section of this guide.

The Feedback Loop

The culmination of the initial development process, and the first step in the iterative improvement process, is to evaluate and improve your URP's performance. Is water quality improving? Is your program functioning? Are you doing too much? Too little? The evaluation step in the URP conceptual framework allows you to take stock of your program and adjust it accordingly. While often conceived as a reporting requirement, evaluation is more aptly described as a daily process. Overall program appraisal and updating are covered in detail in the Evaluation chapter of this guide (Chapter 5).

1.4 MURP Manual Organization

Structurally, the MURP consists of this overview, the main document, and appendices of supplementary information. This overview chapter acts as both a general issue and program summary as well as a guide that shows how each of the individual components relate to the larger program.

The main document itself is further divided into four main chapters: Assessment, Program Development, Implementation, and Evaluation. Each of these chapters has a corresponding appendix with additional information. For example, Chapter 3, Program Development, corresponds to Appendices 3A through 3E, which consist of additional program management tools such as a model urban runoff ordinance and model general plan language.

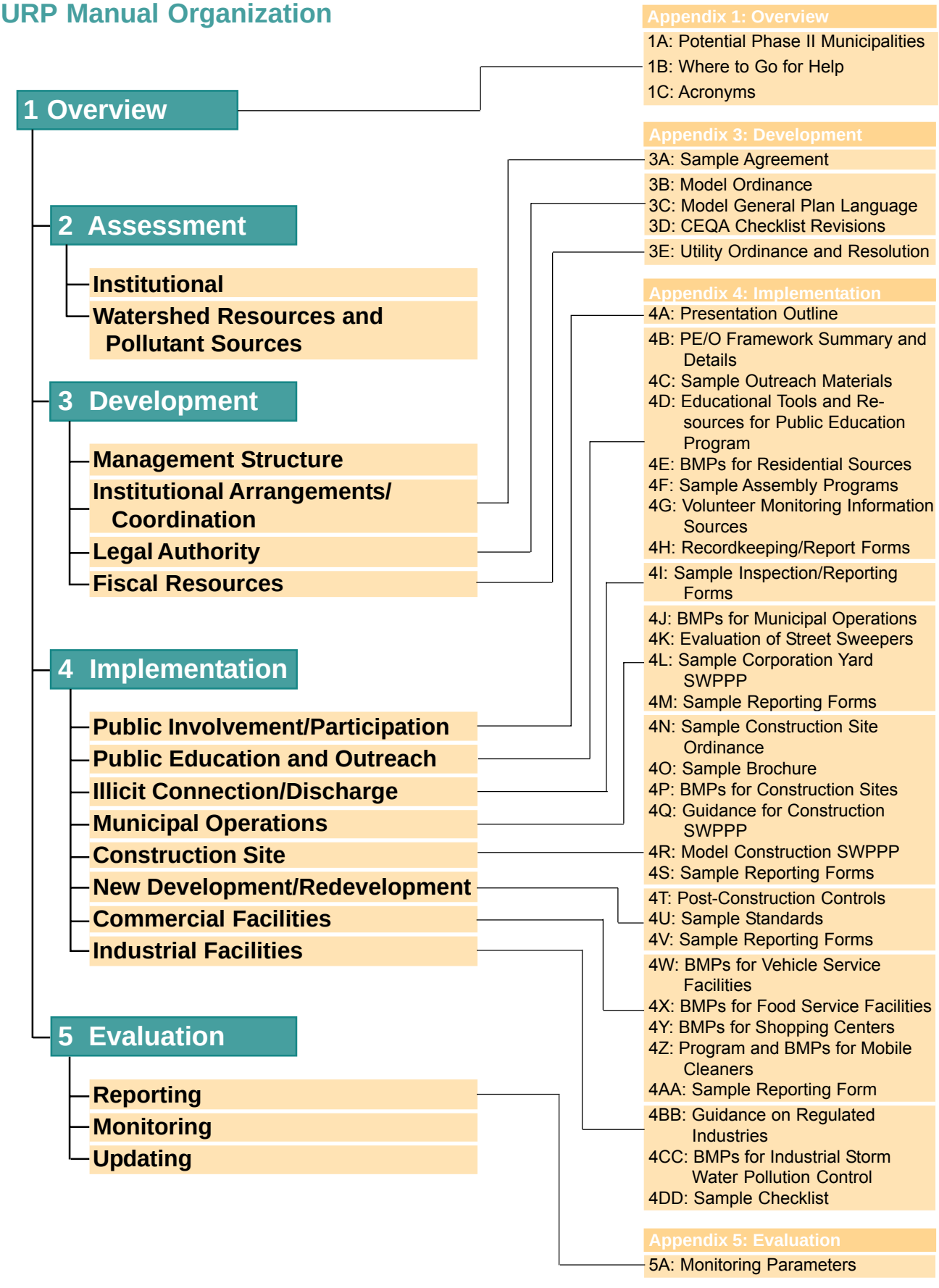
The relationship of the appendices to the main document is particularly important in terms of Implementation (Chapter 4). Chapter 4 describes the individual control programs and how each of these control programs can, and should, be a part of your URP. However, the actual BMPs (and any other appropriate tools) for each of these programs are contained in corresponding Appendix 4. For example, Section 4.4 describes a Municipal Operations Pollution Prevention Program that is supplemented by a BMP guide for municipal operations (Appendix 4J), as well as a variety of other materials relevant to the program (e.g., a model corporation yard Storm Water Pollution Prevention Plan, Appendix 4L). See the document layout on the next page for a visual cue to the guide.

Go to It!

This MURP guide is easy to follow and examples, references, and contacts are provided. While some of the information in this guide is general and can be used by a small municipality anywhere in the U.S., this guide has been designed primarily for users in California. In fact, the MURP was developed and tested by two small municipalities — the City of Monterey and the City of Santa Cruz. As you make your way through the guide, you will find examples of how these two cities adapted the MURP to their local conditions. Much is to be gained from develop-

ing an URP as described in this guide, including regulatory compliance with NPDES Phase II and consistency with CZARA Section 6217. However, the most important product for the citizens of your community is cleaner water and its many resulting beneficial uses. Go to it!

MURP Manual Organization



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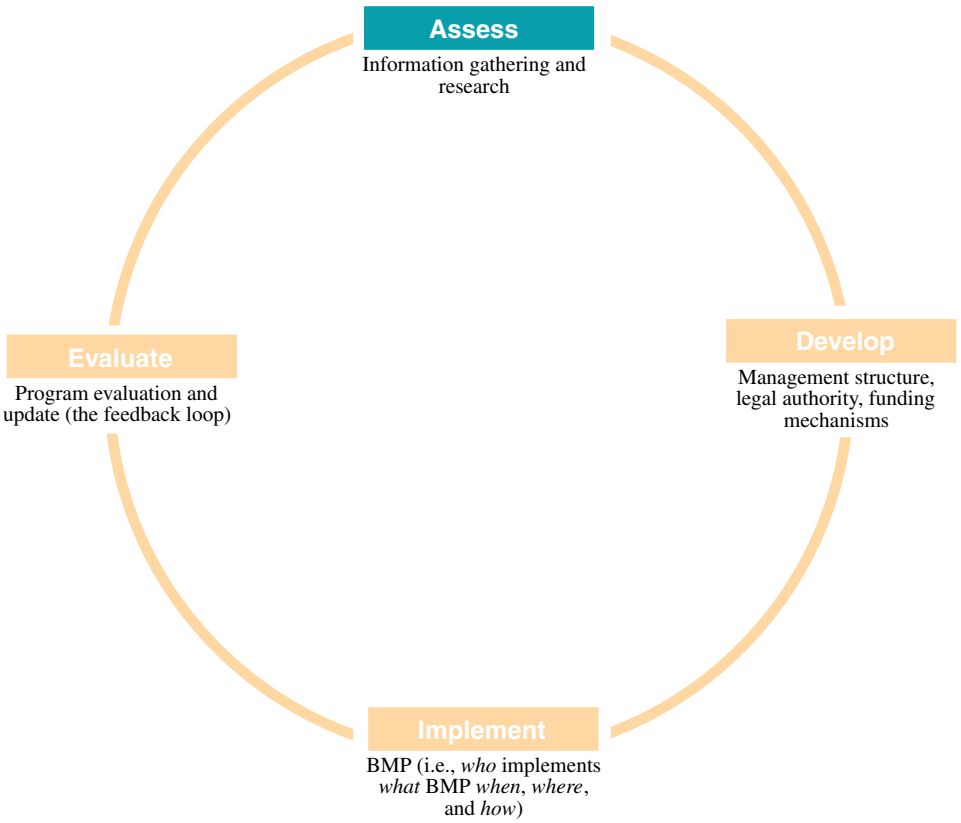
2 Assessment



2.1 Institutional Assessment

2.2 Assessment of Watershed Resources and Pollutant Sources

This section describes some of the initial planning activities for developing your URP. As explained below, these activities can be useful in designing and tailoring your URP to better address local conditions and concerns, to coordinate your program with other environmental programs, and to avoid duplication of effort.

2.1 Institutional Assessment

Departmental Leaders

One of the very first questions to be answered is *who in your municipality should commence the development of your URP?* In most Phase I municipalities the Public Works Department typically assumed this role because the storm drain system was its responsibility. Since the URP and NPDES Phase II requirements involve many more functions than only public works, you may choose a different approach (e.g., forming a multidepartmental steering committee responsible for coordinating your URP). Regardless, once the leaders are identified, staff need to be assigned to this program. Based on the experience of the Cities of Monterey and Santa Cruz, you need to dedicate one staff person (junior engineer or equivalent) 3/4 to full time to your URP's development. You may be able to reduce costs by "piggybacking" onto existing environmental programs in your community, but some funding to pay for personnel time must be alloted. Since small municipalities may not have the resources to dedicate a person to this program, you can also explore the possibility of developing a regional program with neighboring municipalities as a way of sharing overall costs.

Internal Institutional Assessment

Before you begin developing and implementing your URP, you need to informally assess the existing urban runoff framework in your municipality. Elements of an URP may already exist in your community — part of the development process is recognizing, coordinating, and building upon these existing efforts. By taking stock of existing players, policies, programs, fiscal resources, authorities, and management structures you can better understand how your new URP elements may fit into this environment.

To understand your municipality's current urban runoff efforts, as well as to identify potential participants in your new URP, you need to understand what is currently being done to address urban runoff. How is your municipality organized to address polluted urban runoff in new development, existing development, illegal

dumping, and accidental spills? Each municipality will be organized differently; however, most municipalities will share similar functional duties. As an example, all municipalities review new development pursuant to the California Environmental Quality Act (CEQA); however, in some cases, this review is done by a planning department, in others an environmental programs division, and in others a City Manager. It is important for you to understand **who** is doing **what** to address polluted runoff within your own municipality. See Table 2-1 for an example of such an analysis performed by the City of Santa Cruz.

Once you have a general idea of the players within your municipality, the next step is to get a preliminary idea of your existing polluted runoff policies, programs, legal authorities, and fiscal resources. Some of this will likely fall out of the functional analysis, but you will also need to look at existing ordinances, general plan policies, local coastal program policies (if applicable), fiscal resources (if any), and any other runoff-related programs in your municipality. Remember that you do not need to perform an in-depth analysis here, but rather try to get a general sense of what you have to work with. (Note: The more in-depth program analysis that will eventually be necessary for your URP is covered in greater detail in the Program Management section of this guide.)

Start your URP with an internal meeting to go over issues and goals

Armed with a general sense of your municipality's players, policies, programs, fiscal resources, authorities, and management structures you are now ready to call an internal meeting to discuss your potential URP. The overview section of this guide (at least) and any accumulated materials are appropriate background information to distribute to participants prior to this meeting. While the goal of this meeting should be primarily informative, some important preliminary decisions must be made.

Following your internal meeting, you should have some initial options and a general sense of the existing urban runoff management framework for your municipality. You are now ready to reach out to other urban runoff players and programs outside of your municipality.

External Institutional Assessment

A useful step in developing your URP is to review existing regional programs, plans, and policies for relevance to your municipality's URP. These programs can include federal, state, regional, or municipal programs that directly or indirectly address urban runofff issues. For instance, a watershed management plan/program may exist in your region developed by another entity. It would be useful for your municipality to understand that plan and coordinate your URP with the existing watershed management program. The main objectives of conducting such a review of existing external programs are to:

Table 2-1. City of Santa Cruz Departments Responsible for URP

Division/Section	Current Activity	Potential Future Role/Responsibility for URP Implementation
Public Works		
Wastewater Treatment/Industrial Waste Inspection	Storm water monitoring; detection of illicit connections; training and information to businesses on proper disposal of liquid wastes	Industrial and Commercial Program Elements (inspections and education)
Operations/Wastewater Mains	Maintain sewer mains to avoid overflows that could affect surface water quality; perform annual cleaning of catchbasins; investigate complaints of illegal dumping and connections	Catchbasin Cleaning Program Illicit Connection Program
Operations/Refuse and Recycling Collection and Processing	Conduct street sweeping; provide refuse and recycling services including curb-side pickup of used motor oil; assist with river and creek clean-up; organize hazardous waste drop-off days and work with the County on hazardous waste drop-off	Street Sweeping Program; Hazardous Waste Control Program
Operations/Streets and Flood Control	Maintain storm drain system and flood control facilities; assist with detection of illicit connections; assist with river and creek clean-up	
Traffic Engineering/Traffic Maintenance	Conduct storm drain stenciling; implement trip reduction locally for city personnel; planning; signal coordination to improve traffic flow and reduce air pollution; promote alternative transportation modes; participate in CMP monitoring	Storm Drain Stenciling Program; Coordination with CMA
Engineering/Design and Development	Design and construction of storm drain system improvements; mapping of facilities; conduct land development review; storm drain monitoring plan development to coordinate storm drain water quality planning efforts locally and regionally	Construction Site Inspection Program
Administration	Assist all divisions with educational and outreach efforts on recycling, refuse collection and disposal; industrial waste issues; training; and maintaining stormwater utility	Public Education and Outreach Program
Planning and Community Development		
Current Planning	Review new development and redevelopment projects (under CEQA)	Implementation of revised CEQA checklist
Future Planning	Prepare General Plan revisions and amendments	New Development Program
Building Inspection	Review erosion control plans for private development; inspection of on-site improvements	Construction Site Inspection Program
Fire Department	Respond to hazmat spills; inspection of city facilities for proper storage and use of hazardous materials	Hazardous Materials Control Program; Industrial/Commercial Program
Parks and Recreation	Implement pesticide and herbicide application program based on state guidelines; in-house training to city personnel on hazardous materials handling at city facilities	Program for parks, golf courses, swimming pools, and public water bodies

- ✓ Ensure that your URP **does not duplicate** any existing activities.
- ✓ Ensure that your URP within your municipality is **coordinated with** and **does not conflict with** other existing environmental programs.
- ✓ Identify **areas not previously addressed** by other programs so that elements can be included in your URP to address these areas.

Regional programs may include, for example, basin plans, state nonpoint source programs, and the Caltrans storm water management program. Local programs may include city construction and grading program, hazardous waste recycling and disposal programs, maintenance programs, and local resource conservation district programs. Table 2-2 shows the programs and plans reviewed by the Cities of Monterey and Santa Cruz during the development of their URPs, and can be used as a guide in identifying the programs and plans to review for your municipality.

Some key items to keep in mind while conducting this review are:

- ✓ Does the program address any urban runoff issues?
- ✓ If so, what is currently being done under that program to address the identified urban runoff issue?
- ✓ It is appropriate to continue handling the identified issue under the existing program or should it be addressed in the URP that you are developing?
- ✓ How can effort and cost be reduced by coordinating your URP with other existing programs?

Again, in conducting this review, remember that the goal is not to expend a large effort to create a polished report, but to identify programs with which to coordinate your URP.

Once you have identified such programs, plan to meet with people responsible for implementing them to see whether they are willing to emphasize urban runoff concerns within their programs. An example is the hazardous materials (Hazmat) program in your area. Such a program will emphasize the proper handling, storage, and disposal of hazardous materials through outreach and education of the public and through site inspections at industrial and commercial facilities. You could meet with the staff from the Hazmat program to ask if they would emphasize urban runoff issues in their public education and outreach materials. Remember the idea is to utilize existing resources where possible, and avoid duplication of effort by different programs.

A parallel track is to reach out to other municipalities within the larger watershed to coordinate water pollution prevention efforts regionally. Watersheds provide the fundamental resource unit for managing polluted runoff since runoff within a watershed flows to a common outlet. Banding together in a larger watershed management plan can help to coordinate BMP implementation, pool resources, and, most of all, better protect water quality.

Table 2-2. Existing Plans and Programs Reviewed by Cities of Monterey and Santa Cruz

Program	Agency Primarily Responsible for Implementation	Urban Runoff Issues Addressed by the Program
Regional/Areawide Programs		
Basin Plans	RWQCB	Establishes regional water quality objectives, beneficial uses, and implementation strategies
Water Quality Protection Program, Action Plan I	Lead coordinating agency Monterey Bay National Marine Sanctuary. Coalition of federal, state, and local agencies, and local municipalities.	Public education and outreach, technical training, regional urban runoff management, structural and nonstructural controls, storm drain inspection, sedimentation and erosion control, planning controls (CEQA)
Urban Runoff Water Quality Management Plan	Association of Monterey Bay Area Governments	Illicit discharge elimination, public education and participation, controls for new development, monitoring
State Nonpoint Source Control Program (CWA Section 319 and CZARA Section 6217)	SWRCB	Includes recommendations for implementing urban runoff pollution controls from new and existing development, construction sites, other urban sources, and transportation infrastructure
California Coastal Management Program [CCMP] (includes CZARA Section 6217)	California Coastal Commission	Development and periodic review of Local Coastal Plans, review and issuance of coastal development permits, review for consistency with the CCMP of federal projects (projects conducted, permitted, or funded by federal agencies), public education and outreach
Caltrans Storm Water Management Program	Caltrans	Pollutant and sediment controls on Caltrans facilities
General Industrial/General Construction Storm Water Permit	RWQCB	Controls pollutant discharge from industrial and construction sites
Clean Air Program	Air Quality Management District	Controls air emissions of pollutants that enter urban runoff through deposition and fallout
CWA Section 404	Army Corps of Engineers	Regulates activities involving filling of the waters of the U.S.; requires a water quality certification from the RWQCB, which in turn regulates pollutant discharge and erosion during and after project construction
California Department of Fish and Game Code Section 1600	Department of Fish and Game	Regulates activities such as grading, filling, and dredging in state waters or stream beds; controls sedimentation, erosion, and pollutant discharge into streams
Wastewater Reuse/Recycling Programs	Monterey Regional Water Pollution Control Agency	Primary function is wastewater collection and treatment; some storm water reuse has been looked at for future role
Water Allocation Program	Monterey Peninsula Water Management District	Joint Powers Authority to manage portable water allocations for the Monterey Peninsula
City of Monterey Programs		
City of Monterey Storm Water Utility	City of Monterey	A funding mechanism for storm drain maintenance and construction
General Plan/ Local Coastal Plan/ Zoning	City of Monterey	Controls land use
CEQA review process	City of Monterey	Controls water quality degradation from new development and redevelopment
Laguna Grande/Roberts Lake Land Use Plan	City of Monterey	Regulates development and land use in plan area

Table continues on following page

Table 2-2 (continued). Existing Plans and Programs Reviewed by Cities of Monterey and Santa Cruz

Program	Agency Primarily Responsible for Implementation	Urban Runoff Issues Addressed by the Program
City of Santa Cruz Programs		
City of Santa Cruz Storm Water Utility	City of Santa Cruz	A funding mechanism to fund flood control improvements and habitat restoration projects in the San Lorenzo River watershed, develop a storm drain Master Plan, and implement storm water BMPs throughout the City
General Plan/ Local Coastal Plan/ Zoning	City of Santa Cruz	Controls land use
CEQA review process	City of Santa Cruz	Controls water quality degradation from new development/ redevelopment
Grading Ordinance	City of Santa Cruz	Controls erosion and sedimentation
Hazardous Materials Storage Ordinance	City of Santa Cruz	Indirectly reduces improper discharges of pollutants to storm drains
San Lorenzo River Watershed Management Plan	Santa Cruz County Environmental Health Services	Addresses low flows, toxic pollutants, sedimentation, and erosion from a variety of sources including urban
San Lorenzo River Caretakers	Santa Cruz County Resource Conservation District	Steering committee of land users and residents working closely with public agencies on watershed planning, restoration, and education
Arana Gulch	Santa Cruz County Resource Conservation District	Steering committee of land users and residents working closely with public agencies on watershed planning, restoration, and education

Reference: Woodward-Clyde. 1997. Review of Existing Plans, Programs, and Policies. Prepared for City of Monterey and City of Santa Cruz.

What Next?

At this point, you should have a pretty good idea of the existing polluted runoff management framework in and around your municipality, and you should also have developed some preliminary ideas on the type of URP that your municipality may be able to implement. As you continue with the resource assessment described in the next section of this document, your URP options should become even clearer.

As you begin to develop these options and move forward with your URP, you will need to get the decision makers involved, possibly in the form of an informal briefing or a formal presentation. You may want to wait until you have worked through the assessment completely or you can give out some signals that an URP is potentially coming down the pike. Whatever the method, early buy-in from policy and decision makers is crucial to your URP's success. The Program Management section of this guide discusses this issue in more detail, but it is never too early to cultivate management and politcal support.

2.2 Assessment of Watershed Resources and Pollutant Sources

The two ways to approach this assessment are:

- ✓ Conduct a limited assessment (as presented in NPDES Phase II regulations), and rely on the presumption that you have a general urban runoff problem.
- ✓ Geographically identify more precisely the nature of your municipality's watershed resources, pollutants of concern and their sources, and opportunities for water quality improvements. Through this analytic mapping exercise, determine *where* the specific problems are within your jurisdiction and develop evidence as to *why* you should be focusing your URP resources on those problems.

Minimum Requirement: Presume a General Urban Runoff Problem Exists

NPDES Phase II regulations emphasize the presumptive approach. The presumption is that each municipality has a general urban runoff problem and that this problem can be addressed through the implementation of six minimum control programs. The regulations, therefore, ask for a limited local assessment that demonstrates an awareness of the storm drain system (i.e., map of major pipes, outfalls, and topography and areas of concentrated activities likely to be sources of storm water pollution). The advantage of the presumptive approach is twofold: (1) it focuses limited program resources on program implementation without a lot of time and resources invested in up-front studies and (2) it is the most cost-effective way to implement the required elements of your program (Section 4). A great deal of evidence supports the premise that polluted runoff is a problem in urban environments and you can be fairly confident that your municipality shares these general runoff problems. By accepting this premise, you can directly implement the six minimum control measures described in the regulations secure in the knowledge that the elements of your program satisfy the regulatory requirements.

The disadvantage is that your municipality may have unique watershed resources or unique urban runoff problems that require custom-crafted program elements. Lacking a detailed assessment that allows your URP to target specific concerns, water quality improvements may not be achieved. Furthermore, and just as importantly, without a more detailed assessment of your specific urban runoff problems, educating both the public and decision makers as to the nature of the problem — and the need for a program — may be more difficult.

Optional: Identify Specific Urban Runoff Problems in Your Municipality

The essence of a detailed municipal assessment is a working map of your municipality supplemented by a descriptive analysis of the relevant mapped features.

The idea is to use the working map as an analytical tool for identifying pollutant sources and prioritizing opportunities for water quality improvements (both structural and

nonstructural measures) in a geographical manner.

While the goal of geographically identifying and prioritizing watershed resources is clear, methods for achieving this goal vary greatly depending upon the level of resources available. For example, your municipality may be equipped with a working geographic information system (GIS) containing water quality monitoring information that helps you to pinpoint resource concerns at the click of a mouse. Or, conversely, your working map may be the product of a staff meeting in which resource areas and potential concerns are mapped out using the best professional judgment and the local knowledge possessed by your city engineers, maintenance supervisors, planners, etc. Table 2-3 presents a list of urban runoff pollution sources with the pollutants associated with these sources. You can use this table to guide you in identifying the sources that are signficant in your area.

Your working map can be the product of a staff meeting

Regardless of the mapping method, always remember that the analytical mapping process is only a means to an end and not an end in itself. Municipal assessments have been known to eat up large portions of development budgets as the assessors attempt to quantify and characterize every component of the municipality's built and natural environment. While a comprehensive assessment detailing acres of different land uses, numbers of targeted industries (e.g., number of gas stations), linear coverage (e.g., miles of road), etc., can be quite useful for prioritizing resources, it can also quite easily become a boundless work task that may or may not be justified by the result. You need to clearly define the parameters for this task prior to beginning because it is easy to commit resources over and beyond what is necessary to arrive at your municipality's urban runoff priorities.

There is growing evidence that the degree of urbanization has evidenced by the percentage of directly connected impervious area, or DCIA) can indicate the extent of urban runoff pollution. Considering the percentage of DCIA in your municipality can provide a tool for assessment and choosing control measures for programs. For example, an area with a low percentage of DCIA probably indicates few urban runoff impacts and new development controls should be emphasized to prevent an increase in impacts. An area with a higher percentage of DCIA will likely have greater urban runoff impacts. These areas should consider other control programs tailored to the existing land uses in the municipality.

Table 2-3. Relationship of Sources to Primary Pollutants of Concern

Pollutant Source/ Activity	Primary Pollutants of Concern in Urban Runoff								
	Physical Parameters	Synthetic Organics[1]	Petroleum Hydrocarbons	Heavy Metals[2]	Nutrients	Pathogens	Sediments	Oxygen-Demanding Substances	Floatables
Vehicle Service Facilities		●	●	●					
Gas Stations		●	●	●					
Metal Fabrication Shops		●	●	●					
Restaurants									●
Auto Wrecking Yards	●	●	●	●					
Mobile Cleaners		●							
Parking Lots	●		●	●					●
Residential Dwellings	●	●		●	●	●	●	●	
Parks/Open Spaces					●	●	●	●	●
Construction Sites	●						●	●	
Corporation Yards	●	●	●	●					
Streets and Highways	●		●	●				●	●
Marinas									●
Golf Courses		●			●		●	●	
Sewer Overflows	●					●		●	

[1] Pesticides, herbicides, and PCBs
[2] Lead, copper, zinc, and cadmium

Do You Need to Proceed with the Municipal Assessment?

This guide presents a *minimum* program that can be undertaken without a detailed municipal assessment, which satisfies regulatory requirements and which should result in general water quality improvements. However, this guide does *not* advocate that you proceed without some level of municipal assessment. Such an assessment is necessary not only to develop optional program elements to address your municipality's specific runoff problems, but also to help frame your URP for decision makers, affected businesses, and the general public. Furthermore, even if you should choose to institute only the minimum program, program evaluation and subsequent program revisions (Section 5) will require establishment of baseline conditions and some amount of descriptive analysis. Hence, a robust URP **requires** a descriptive municipal characterization as illustrated in the remainder of this section.

Developing Your Working Map

Your municipal assessment should consist of two elements:

- ✓ A map of your municipality identifying resources, problem areas, and opportunities for water quality improvements
- ✓ A textual companion document or list describing the mapped features

The basic elements of the municipal assessment working map are shown in Table 2-4. Keep in mind that these elements represent a 'laundry list' of sorts meant primarily to accelerate your own thought process relevant to your municipality's urban runoff concerns and is not a required set of elements. Each municipality is different, both in terms of built and natural environment as well as the level of time and effort expended on municipal assessment. Remember, the goal is not to create a polished municipal characterization but rather to identify and prioritize (by any means available) opportunities for improving water quality and the management of urban runoff.

If the above-described elements of the working map appear daunting, remember, *the working map is **only** a tool*. If much of the information is unavailable, or if the development budget would be unduly strained by the process of developing the mapped information, pick and choose the elements of the assessment most useful for your jurisdiction. For example, if you can easily locate land-use categories or specific sources, but have no monitoring or other water quality information that substantiates a problem, the land-use information alone can be used to target potential polluted runoff sources (e.g., vehicle service facilities).

Figures 2-1 and 2-2 show working maps prepared by the Cities of Monterey and Santa Cruz with the assistance of the California Coastal Commission.

These cities began the development of their URPs by mapping existing industries, commercial facilities, and municipal facilities. Each city was presented with different challenges and results due to differing levels of available resources.

The City of Monterey identified land use of parcels on a large paper map colored by hand with information from a phone book. The working map showed specific types of facilities chosen because of their potential for urban runoff pollution (e.g., restaurants, auto service facilities, and park and school grounds).

The City of Santa Cruz working map, on the other hand, represented the "Cadillac" of this effort, computer-generated using an existing GIS with land-use layers overlaid on a City map.

Whatever your resources may be, this type of effort is doable and informative. Both cities used these land-use maps to identify potential polluters to target with educational campaigns. The City of Monterey correlated the types of businesses found nearest the most polluted storm drain outfalls to use education funds most effectively.

Table 2-4. Elements of Municipal Assessment Working Map

Mapped Features The map should identify:	Textual Companion Each of the mapped features should be described:
Resources Watersheds Wetlands Riparian areas Rivers Streams Lakes Ponds Springs	■ Describe water quality condition (e.g., good, bad, moderate, unknown) ■ Describe beneficial uses (e.g., water supply, recreation, habitat, fishing) **How?** • SWRCB Water Quality Assessment documents for your area • RWQCB Basin Plan for your area • Municipal staff observations • Municipal GIS, aerial photos, topo maps
Infrastructure Roads Drainage facilities Storm drain system Treatment works Outfalls	■ Describe types and quantities (e.g., miles of roads, length of storm drain pipe of different diameter, numbers of outfall locations, etc.) ■ Describe existing control measures and their effectiveness (e.g., catch basin cleaning) ■ Describe general condition (e.g., good, bad, deteriorating, needs replacement) **How?** • Your municipality's capital improvement plan • Municipal staff observations • Municipal street maps
Natural Environment Topography Vegetation cover Soils Sensitive habitat areas	■ Describe in general (e.g., predominant topography) and in detail as feasible (e.g., large pervious or impervious areas) ■ Describe areas susceptible to erosion ■ Describe areas where infiltration (for treatment) is possible (from the viewpoint of soil quality, groundwater, etc.) **How?** • U.S. Geologic Survey maps • Municipal staff observations • Municipal park maps
Other Water quality monitoring stations	■ Describe water quality monitoring trends by location **How?** • RWQCB Basin Plan for your area • Municipal staff observations
By Land-Use Types Industrial Commercial Residential Agricultural Public roads Municipal operations Parking lots Undeveloped/open space Parks and recreation	■ Describe numerically (e.g., number of parking lots), linearly (e.g., miles of road), by area (e.g., acres of open space), and/or by percentage (e.g., percent residential) ■ Describe clustering of land-use types, if any **How?** • County Assessor's data • General plan documents • Municipal staff observations • Aerial photos, land-use maps Note: the land-use categories can be collapsed, expanded, and/or modified as appropriate.

Table continues on following page

Table 2-4 (continued). Elements of Municipal Assessment Working Map

Mapped Features The map should identify:	Textual Companion Each of the mapped features should be described:
By Specific Sources Auto repair shops* Auto wrecking yards* Boatyards/Marinas Corporation yards* Dry cleaners Equipment rental and storage yards* Furniture makers Gas stations* Golf courses Hospitals/medical facilities Landfills Landscaping activities Metal fabrication shops* Mobile cleaners* Nurseries Painting activities Photoprocessing Pool, spa, and fountain maintenance Pottery studios Printers/publishers Public water and wastewater treatment facilities Residential activities Restaurants* Tanneries	■ Describe numerically (e.g., number of vehicle service facilities) ■ Describe clustering of potential sources, if any ■ Describe pollutants expected from each type of source **How?** • Municipal staff observations • County Assessor's data • RWQCB database Note: Specific sources will fall into the larger land-use categories. The sources listed here do not represent a complete listing of potential runoff sources, but rather a starting point for thinking about your own jurisdiction. Known significant sources are marked with an asterisk (*).
By Known "Hot-Spots" Illegal dumping area Cross connection with sanitary sewer Animal 'walking' area Leaking underground tank(s)	■ Describe any known polluted runoff "hot-spots" in your area and how these problems became known, status of repair, etc. **How?** • Municipal staff observations • Municipal enforcement proceedings • RWQCB

As you develop your working map, opportunities for targeting specific problem areas or pollutant sources should become apparent. If you identify a clustering of restaurants upstream of an outfall location where observations or monitoring data have consistently identified the presence of detergents or grease, your commercial program can be supplemented with a program that targets the food service industry. Or maybe your assessment identifies general degradation of watershed resources (i.e., wetlands, streams, etc.) in a particular sector of your municipality, pointing to the need to target your program geographically. Or maybe your assessment results do not identify any readily apparent targets but rather point to the need for better water quality monitoring data. The possibilities are endless and each municipality's assessment techniques, results, and priorities will be different. Whatever you experience, remember that targeting priorities is particularly important when resources are limited — your URP should attack both the most important and the most easily approached problems first.

Conclusion

While the more you "know" about the characteristics of your municipality the better, do not lose sight of the goal in your pursuit of quantifying everything within your jurisdictional boundaries (and/or the larger watershed). Remember that the minimum program elements do not require an expansive assessment to ensure NPDES Phase II compliance and CZARA Section 6217 consistency. However, if your municipality chooses to address additional issues relevant to your particular resource issues and constraints, the municipal assessment exercise can provide you with evidence to support that decision.

The product of the municipal assessment should be a written report, developed from the working map and descriptive textual companion, summarizing your findings and supporting your program elements.

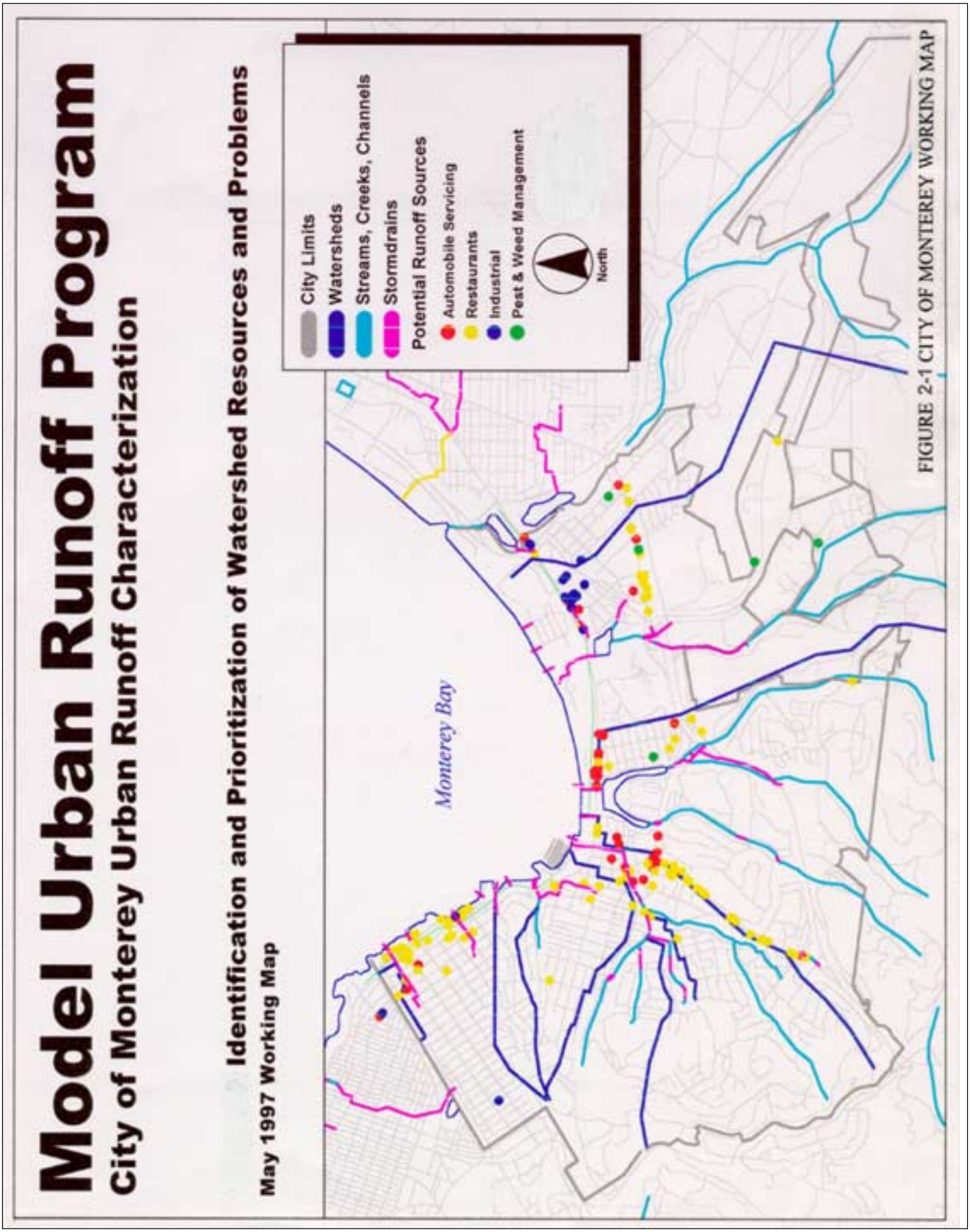


FIGURE 2-1 CITY OF MONTEREY WORKING MAP

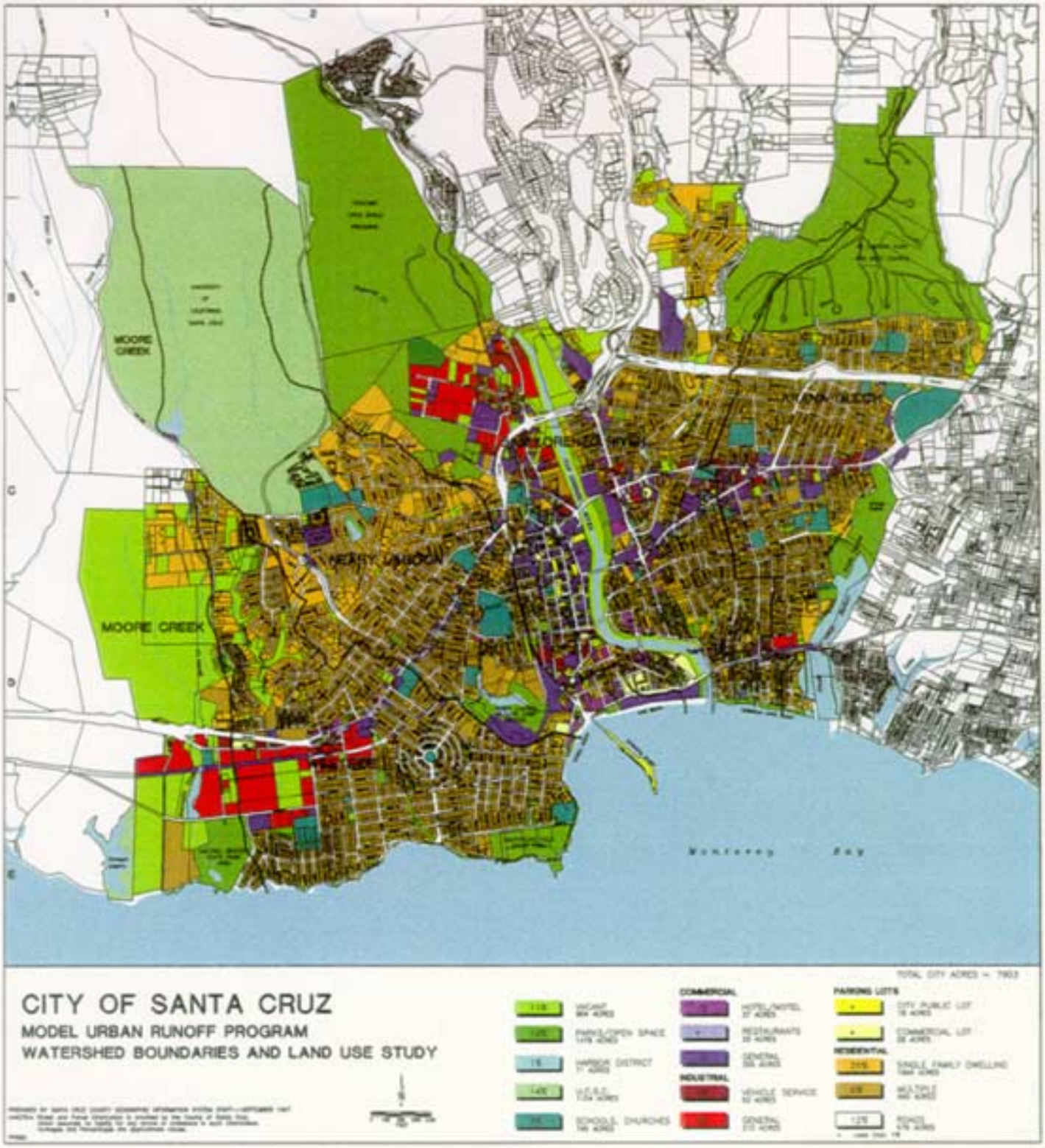
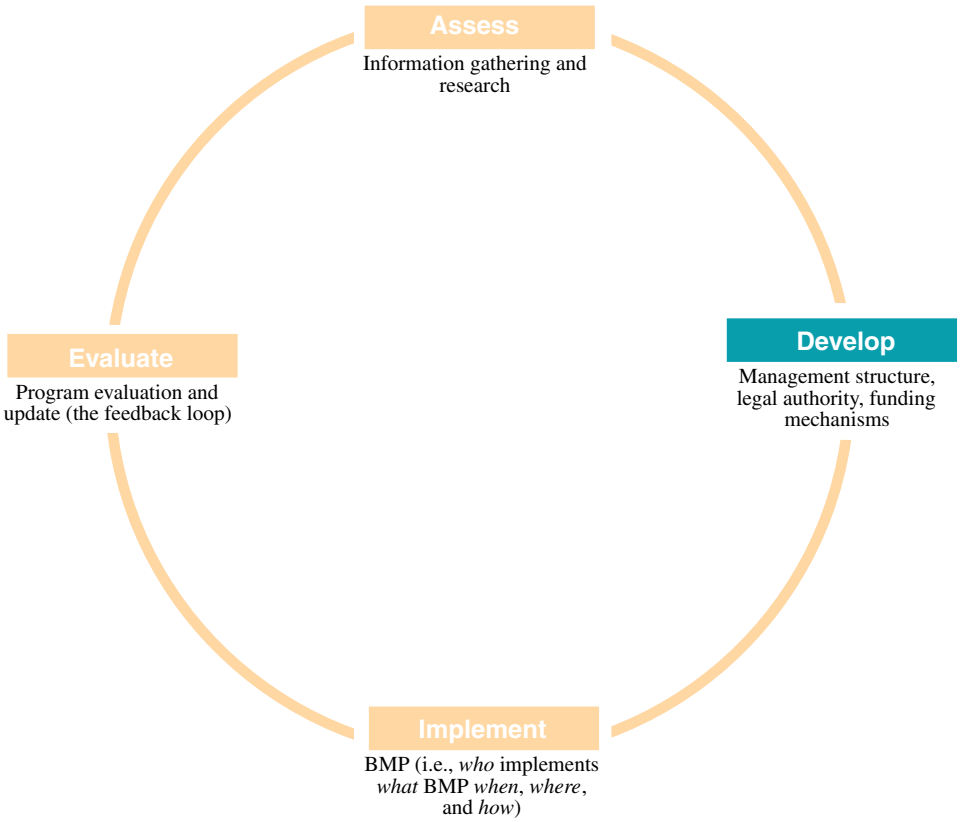


FIGURE 2-2 CITY OF SANTA CRUZ WORKING MAP

3 Development of Urban Runoff Program



3.1 Program Management

3.2 Institutional Arrangements/Coordination

3.3 Legal Authority

3.4 Fiscal Resources

3.1 Program Management

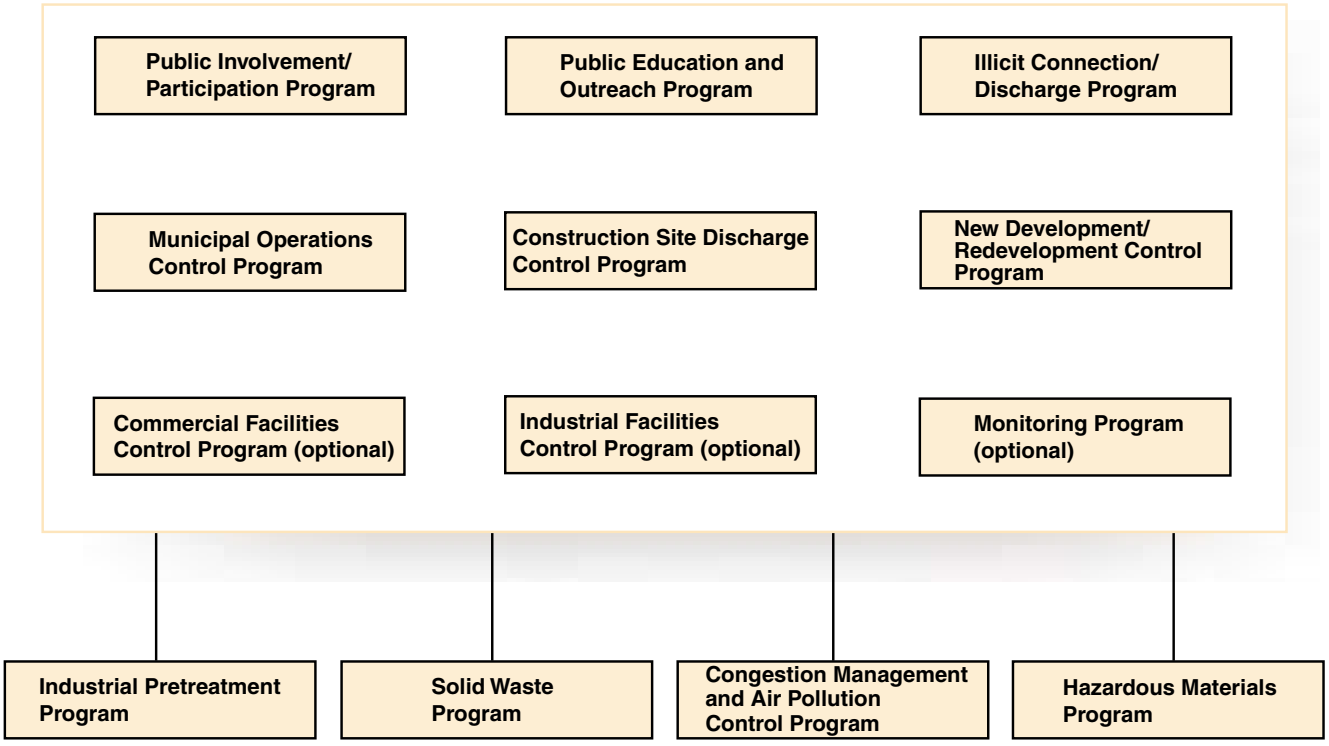
Given the variety of elements that make up an URP, its development and implementation require participation and coordination between numerous agencies and municipal departments. This section presents a picture of how your overall URP should look, describes the role of the lead department or oversight committee, identifies key departments for each of the program elements, and identifies areas where the lead department needs to ensure that urban runoff-related activities are coordinated.

Overall Management

The lead department or oversight committee is responsible for the URP's development and works with others to ensure that legal authority is established and that a funding source is identified and established. This lead entity is also responsible for conducting evaluations of the program and reporting to the governing and permitting authorities.

Figure 3-1 shows the various elements or control programs that make up an URP, including some other environmental programs that you are likely to coordinate and even share resources with.

Figure 3-1. Urban Runoff Program and Supporting Programs



Management of Program Elements

Some ideas on how to manage your program elements are presented below:

- ✓ The **Public Involvement and Participation Program** should be managed by the lead department or committee in charge of the overall URP. This program is integral to the entire development process and requires an intimate knowledge of all aspects of the URP. This program is the public's initial contact with the URP concept, and must be headed by staff who convey a good image as well as bring back public input to each of the programs. This program must also be closely coordinated with the public education and outreach program.

- ✓ The **Public Education and Outreach Program** should be developed and coordinated with any public education efforts currently underway in your municipality. This program can be managed by a number of departments in the municipality. A public education person or a public relations/media coordinator is an obvious fit. Another option is to contract this program out to an individual or another local agency that does public education campaigns. This program works well on a regional basis as it can save on personnel and printing costs, and it ensures that a consistent message is being conveyed to the public.

- ✓ The **Illicit Connection/Discharge Program** is likely to be managed and implemented by (1) wastewater or industrial waste inspectors, (2) building inspectors, (3) streets maintenance, (4) code enforcement, or any combination of the above. The City Manager's and/or City Attorney's office could be involved if a serious noncompliance problem is noted.

- ✓ The **Municipal Operations Control Program** is specifically for the day-to-day operations of the municipality, and includes numerous departments. An initial training should be held for each department affected by this program to set goals and define any changes that should be made; then the program becomes the responsibility of each affected department. The lead entity should be responsible for obtaining data for yearly reports from each implementing department.

- ✓ The **Construction Site Control Program** should be included as part of any existing inspection efforts for projects in your jurisdiction. Any building inspectors (e.g., Building Officials, construction management, or project development representatives, etc.) can add proper site controls to inspection lists.

- ✓ The **New Development/Redevelopment Control Program** should be integrated into current practices within the Planning and Public Works Departments. The Planning Department issues development permits, performs CEQA review, and comments and makes recommendations on plans. This program must begin with recommendations and requirements for mitigating the effects of new development on storm water conveyance systems and water quality. Often the Public Works Department is also involved in site plan reviews in

which they should implement requirements for on-site storm water structures and future maintenance of those structures. This process should be coordinated between the two departments to minimize overlap and ensure that requirements are implemented.

- ✓ The **Commercial Facilities Control Program** includes some public education, technical training, and later, site inspections. Either one department or a team can implement this program. Public education and involvement for this program consist of meetings held during the development process to gain input from those affected by any new requirements (BMPs). Technical training is required to teach employees of commercial facilities how to implement BMPs, and later site inspections measure the success of the program and lead to enforcement actions if necessary. One department should manage all aspects of this program, though coordination with public education and outreach and other programs is required. If a department within your agency already does commercial site inspections, then incorporate this program into existing procedures. Possible managers include individuals from an industrial waste inspection or building inspection division, or it may be best to coordinate this program with your county environmental health department.

- ✓ The **Industrial Facilities Control Program** is included here as an optional program because many significant industrial facilities are required to have an NPDES permit or other environmental regulatory program in place, which should reduce the potential for polluted runoff to enter a municipal storm drain system. If the municipality decides to implement its own program, it could be run by an industrial waste inspection division, wastewater inspection, or public works.

Coordination Between Program Elements

Here are some ways to ensure coordination between the multiple players involved and to reduce the potential for confusion:

- ✓ Based on the experience of NPDES Phase I municipalities, it is recommended that the lead department or oversight committee convene meetings of representatives of all departments and agencies responsible for specific program elements during the development stage on an as-needed basis; regular meetings should be scheduled during the implementation phase. The objectives of these meetings are for all involved to report on work completed, hear about problems encountered or envisioned, and hear what others in the municipality are doing. These meetings are useful in developing ideas on sharing resources, avoiding duplication of effort, and providing a coordinated consistent message on management of urban runoff pollutants.

- ✓ Note that site inspections for existing development are a component of three program elements: illicit connection/discharge, commercial facilities, and industrial facilities control programs. To avoid problems associated with mul-

tiple inspections, consider combining the inspection/site visit function from all these programs under one agency/department. If you do not choose to combine the inspection function, then make sure the inspectors under each program are informed about the other programs so that they do not convey conflicting messages to the affected businesses and the public.

- ✓ Site inspections are also involved in construction site and development control programs. These inspection functions can and should be combined because the inspector checking for construction controls can also check to see if postconstruction controls are installed.

- ✓ Both the municipal operations and the commercial facilities control program likely involve implementation of BMPs related to building maintenance and repair and vehicle service facilities. Make sure that the BMPs you are requiring the commercial operators to implement are the same you are requiring your own municipal staff to adopt and implement. Inspections should take place on the same schedule and should require the same types of modifications. Remember that your municipal program should provide a model that the private sector can emulate.

Coordination with Other Supporting Programs

Since several existing environmental programs indirectly reduce urban runoff pollution, use them to the extent possible.

- ✓ For instance, many municipalities are extending their solid waste pickup service to include curbside pickup of used motor oil. Your URP could share the costs of this effort, which can reduce incidents of used motor oil being discharged to the storm drains.
- ✓ Consider using a single hotline number for all calls related to urban environmental issues — urban runoff, hazardous materials, recycling, or solid waste. You may want to do it on a coordinated regional basis.
- ✓ In urban settings, many of the pollutants in runoff come from automobiles — either as tailpipe emissions picked up by rain and carried into the storm drain system or as particulates from the wear, tear, and operation of vehicles (brakepads, tires, drips). Support your local congestion management agency to reduce vehicle trips in your area and also help clean up the water.

3.2 Institutional Arrangements/Coordination

A municipality's URP may be implemented with a variety of institutional arrangements. Small municipalities are not expected to develop an entirely new program on their own. Many aspects of URPs can be developed and implemented by building on and coordinating local, existing institutional arrangements:

- ✓ A municipality may choose to develop and implement a program on its own. Existing internal arrangements may already accommodate key components of an URP, or at least provide the basic building blocks. For example, many municipalities have assigned illicit connections and discharge detection and elimination activities to their wastewater department. This approach has been efficient because the staff is already trained to conduct inspections, has experience working with underground sewers and storm drains, and has the equipment for sampling.

- ✓ A municipality may also consider joining an existing URP in an adjacent municipality. This approach is recommended to small municipalities to help reduce their program development costs. Note that if an existing program is operating under an NPDES Phase I permit, the permit can be modified to accommodate a new municipality. However, NPDES Phase II municipalities are advised to consider the pros and cons associated with joining a Phase I URP as listed in Table 3-1.

- ✓ A municipality may consider creating a joint program with other nearby municipalities. This approach to working with other municipalities has taken the form of Memorandums of Agreement/Understanding (e.g., municipalities in Santa Clara and Alameda counties) and Joint Powers Authority (e.g., municipalities in Marin County). A sample agreement is presented in Appendix 3A. In the event that you decide to develop a joint URP with other adjacent municipalities, you need to consider the following issues:

Table 3-1. Advantages and Disadvantages of Joining a Phase I Urban Runoff Program

Advantages	Disadvantages
■ Uniform program in urbanized areas	■ Could require implementation of control measures beyond the six minimum control measures
■ Share administrative expenses and staff expertise	■ Individual NPDES program could receive greater regulatory scrutiny than small municipalities regulated under a general NPDES permit
■ Share of monitoring costs, if required, of small municipalities	■ Potentially more comprehensive reporting requirements
■ Phase I municipalities could, by agreement, implement control measures	■ Water quality monitoring required
■ Earlier program implementation and improvement to water quality and protection of beneficial water uses	■ Requires compliance with all applicable requirements of Section 122.26 of the regulations including those for Phase I and terms and conditions of the applicable permit
■ Could be a small entity or source if a watershed approach is implemented and could rely on municipalities areawide program to represent and support interests	
■ Phase II municipalities would not be required to develop program	

- Determine the formal institutional arrangements used to make decisions for each co-permittee. The mechanism for making decisions may be a Management Committee made up of co-permittee representatives. The Management Committee needs to evaluate how its responsibilities fit into the overall URP framework, how it communicates and coordinates activities, what its authority is, and what its procedures for decision making are. The Management Committee needs to formalize any agreements by adopting official bylaws.

- Subcommittees may also be formed to address specific program elements. Each subcommittee should define its focus, participants, tasks to be accomplished, and the time frame allowed to accomplish the tasks. Ideally, all co-permittees should participate in at least one subcommittee. Each subcommittee should define a chairperson responsible for maintaining written documentation of subcommittee deliberations and recommendations, to the extent needed to achieve the subcommittee's objectives. Some examples of possible subcommittees include a Monitoring and Special Studies Subcommittee, a Municipal Operations Activities Subcommittee, or a Policy Level Subcommittee.

- A lead agency should also be identified whose responsibilities may include coordinating day-to-day business, scheduling meetings, and representing the URP at external meetings. However, the lead agency should assume no responsibility for specific programs, and should not be viewed as the responsible agency for the permit (because the entire program area should be responsible for the URP's implementing).

✓ An alternative to a full joint program is project/program element-specific agreements. Informal cooperative agreements can effectively share staff and financial responsibility for a specific project, such as developing outreach materials.

✓ A municipality can arrange for another governmental or other entity to implement appropriate control measures or BMPs (with memorandums of agreement or contracts). For example, a municipality can arrange to have a citizen's monitoring group conduct visual inspections and/or collect samples to supplement lack of staff or financial resources. Similarly, a municipality can utilize the expertise of a local resource conservation district for review of applications for grading permits for inclusion of established BMPs.

✓ A municipality can coordinate with existing, local watershed-based or regional programs. For example, in the Monterey Bay region, municipalities can coordinate with the Water Quality Protection Program for Monterey Bay National Marine Sanctuary, a partnership effort among 25 federal, state, local, and nonprofit groups to address water quality issues including urban, marina, agricultural, and monitoring. Pooling local resources helps to develop joint urban education products and outreach and volunteer programs that can be used

throughout the region. It also works with various local jurisdictions to help obtain grant funding for urban runoff projects, and to identify a variety of existing watershed-related government and volunteer efforts in the region that can partner with the cities in their URPs. The program's various committee members and watershed efforts can provide a coordination link for local jurisdictions in building their programs.

- ✓ A municipality may chose different implementation mechanisms for different elements of the program using some hybrid of the above-described arrangements.

Using local, existing institutional arrangements has several advantages. Time and money can be saved by avoiding reinvention of the wheel or duplication of effort. An upfront effort to review potential arrangements within a municipality, as well as those previously developed by other municipalities and programs, is a worthwhile investment. Additionally, coordination and consistency within a municipality, with adjacent municipalities, and with other programs in the area is beneficial. This effort may "level the playing field" for dischargers, businesses, and property owners participating in or affected by the URP. These parties are invited to participate and are affected similarly by all URPs within a geographic region, which is highly preferable to dealing with one approach in one municipality and a different approach in the municipality next door. Additionally, good coordination and consistency facilitate keeping regulatory agencies informed and more able to provide assistance.

3.3 Legal Authority

This section describes the various actions that may be required to establish the legal authority to develop, implement, and enforce an URP in a municipality. Each municipality decides the extent to which each of these actions is necessary.

In California, the following three mechanisms/tools can be used as legal authority for an URP: an ordinance, a General Plan element (including Local Coastal Program provisions for coastal zone areas), and CEQA. For a municipality, the ordinance is the ultimate legal authority to control all improper discharges to the storm drain system. The General Plan or Local Coastal Program amendment can be used to establish policies, especially to control runoff from new development and redevelopment. The CEQA process can also be used to control urban runoff from new development. At a minimum, each municipality has to ensure that an ordinance provides adequate authority to enforce the program, and that the General Plan supports the URP's objectives.

Model Ordinance

Clean Water Act Section 402(p)(3)(B)(iii) notes that municipalities "Shall require controls to reduce the discharge of pollutants to the maximum extent practicable,

including management practices, control techniques and system[s], design and engineering methods, and such other provisions as the [EPA] Administrator or the State determines appropriate for the control of such pollutants." This section requires municipalities to adopt and implement a set of BMPs that control pollution to the maximum extent practicable. To make such a program work, municipalities need to have the legal authority to implement and enforce BMPs written into their code. Similarly, CZARA Section 6217 requires that the CNPCP include management measures that can be implemented by "unforceable authorities" such as ordinances.

A model ordinance is included in Appendix 3B. A municipality's Legal Counsel should review this model ordinance, discuss the implications of ordinance sections with those involved in developing the municipality's URP, and amend the language as appropriate. The Model Ordinance included in this document is comprehensive and includes sections that provide the legal authority necessary to implement the entire range of control programs necessary to protect water quality.

The Model Ordinance references the adoption of the BMP Guidance Series in Section 31.5-16(c). The BMP Guidance Series is an update table set of prescribed BMPs. A municipality may choose not to include this section if it decides not to explain how to control discharges in the ordinance. Most NPDES Phase I municipalities have elected not to reference any other documents in their ordinance, but have limited the scope of the ordinance to establishing legal authority to control nonstorm water discharges from the storm drain system.

General Plan and/or Local Coastal Program Amendment

California state law requires that each city adopt a General Plan for developing the area under its jurisdiction. Cities and counties within the coastal zone are also required to adopt a Local Coastal Program, which may be a stand-alone plan or may be found within the General Plan. A General Plan must include seven elements that together compose an integrated set of goals, policies, and action programs: land use, circulation, housing, conservation, open space, safety, and noise. In addition, a municipality may adopt optional elements that relate to the physical development of the community. Because of the overlap in subject matter, General Plan and/or Local Coastal Program elements can often be combined.

The General Plan and/or Local Coastal Program contains two approaches to incorporating urban runoff and water quality controls: (1) the addition of a comprehensive stand-alone element or (2) the insertion of essential statements within existing elements of the General Plan and/or Local Coastal Program. For any municipality, the first step in deciding which approach to choose should be a comprehensive review of its existing General Plan and/or Local Coastal Program done by the department responsible for maintaining the General Plan and/or Local Coastal Program with input from implementers of the water quality and quantity management additions. In many municipalities responsible departments include Planning, Public Works, Police (for code enforcement), and Fire (hazardous materials).

The language presented in Appendix 3C includes information taken from a number of San Francisco Bay Area cities who have conducted the General Plan review process pursuant to NPDES Phase I requirements. The sample language is intended as recommendations for inclusion in future revisions and amendments to general plans and local coastal programs by small municipalities. The first section is the "Comprehensive Stand-Alone General Plan Element," which is a self-sufficient water quality element that may be adopted as it is worded. The second section is a "List of Recommended Amendments to Existing General Plan Elements," broken into the seven required General Plan elements that should be standard for each municipality in the State of California and intended as a list of additions to the existing elements in the municipality's General Plan. Dependent upon the relationship of the General Plan to the Local Coastal Program, these modifications may also be necessary within the Local Coastal Program.

California Environmental Quality Act Checklist Revisions

The CEQA process consists of project assessment guidelines to be used by local governments in the planning process for new development and redevelopment. Those guidelines, while concerned with the environmental impacts of such development, often overlook the problems associated with urban runoff pollution from development.

The CEQA checklist revisions that are included in Appendix 3D are intended to provide planners with tools and information about urban runoff pollutants that they can use in the evaluation of new development or redevelopment projects. The packet is self-explanatory so that it can be given as a stand-alone element to those who will implement it within the municipality (typically the Planning/Community Development Department).

3.4 Fiscal Resources

One of the most important factors that must be examined when embarking on the development and implementation of an URP is identifying how it will be financed (see Table 3-2). Most local governments do not have the means to finance such a program from existing fiscal resources, so alternate financing mechanisms must be created. Since the November 1996 passage of Proposition 218 in California, which requires that a vote of the people must be taken before taxes can be levied or raised, funding mechanisms for URPs have become an even more challenging issue for California municipalities.

Urban runoff funding has in the past been accomplished through such mechanisms as bond measures for capital improvements, general funds, or special fees (e.g., utility fees). Throughout the NPDES Phase I program, municipalities spent a considerable amount of time and fiscal resources developing their storm water management plans, monitoring, and trying to obtain permits that were in compliance

Table 3-2. Estimated Staffing Requirements for Urban Runoff for Small Municipalities

Program	Activities	Staff/Department	Annual Hours	Annual Cost
Public Involvement	Coordinate with volunteers, event coordination and attendance	▪ Jr. and Asst. Civil Engineers ▪ Sanctuary Coordinator	600 400	City - $14,000 Sanctuary - $8,500 Printing - $10,000
Public Education and Outreach	Coordinate printing of materials, teacher workshops, loaning of tools	▪ Jr. and Asst. Civil Engineers ▪ Sanctuary Coordinator	200 300	City - $15,000 Sanctuary - $3,500 Contractor - $6,000
Illicit Connection/ Discharge Detection and Elimination	Inspections, response to citizen complaints, follow-up	▪ Jr. and Asst. Civil Engineers ▪ Maintenance Division ▪ Building Division ▪ Code Enforcement	500	City - $25,000
Construction Site Control	Develop requirements, SWPPP preparation, inspections	▪ Jr. and Asst. Civil Engineers ▪ Building and Public Works Inspectors	400	City - $20,000
New Development/ Redevelopment Control Management	Develop requirements; incorporate into site plan review, CCRs; follow-up	▪ Jr. and Asst. Civil Engineers ▪ Planning Dept. ▪ Site Plan Review	400	City - $20,000
Municipal Operations	Develop division requirements checklists; technical training for staff	▪ Jr. and Asst. Civil Engineers ▪ Maintenance Divisions	500	City - $25,000 Materials - $10,000
Best Management Practices for Commercial/ Industrial Facilities	Development of BMPs and training materials; printing; outreach and enforcement	▪ Jr. and Asst. Civil Engineers ▪ Code Enforcement	1000	City - $50,000 Materials - $20,000

Source: City of Monterey (1998).

with the federal regulations. NPDES Phase II municipalities should be able to reduce costs of preparing their management plans and application materials, because they should be able to build on the experience of Phase I municipalities. However, if your municipality does not have a storm water utility or other funding source established when you begin developing your URP, funding for the first few years may need to come out of the general fund.

Funding Urban Runoff Programs

Most cities have two alternatives to using general funds for urban runoff-related activities: to establish a citywide benefit assessment for all property owners, or to institute a user fee for allocating program costs to users of the storm water system.

Assessment Districts

A benefit assessment utilizes a special assessment district to recover specific costs on an equal basis from all properties deemed to receive benefits from those costs. Assessment districts are based on the special benefits that public improvements

confer upon assessed lands. Since drainage projects result in improvements to specific areas of the municipality, this approach is a piecemeal solution as it requires that the money collected for the assessment district be spent on improvements and maintenance to only those specific areas.

An alternative is a citywide assessment district. Although structural improvements could be funded through the use of a citywide benefit assessment, NPDES and NPS/CZARA compliance requirements are mostly operational. The legality of funding operational expenses through assessment districts is questionable. In addition, these assessments typically require voter approval. As a result, assessment districts should be used only for capital improvement projects.

Storm Water Utility Fees

Storm water utility fees are charges applied to a municipality's customers for services provided by that utility and are collected through an established schedule and method. The fee is based on the actual benefit of service and may provide for all or just a portion of the utility's cost of providing that service. A storm water utility is established by ordinance with the actual user fee established by resolution.

The storm water utility fee is often based on impermeable area calculated on a parcel-by-parcel basis throughout the city. The basic unit of measurement for the fee is often taken to be the average impermeable area of a single-family dwelling. All single-family dwellings are then charged the equivalent of one unit and other types of properties are charged based on their square footage and percentage of impermeable area. The basic units of measurement are variously called "Equivalent Residential Units," "Equivalent Storm Water Units," or "Basic Assessment Units." The utility fee is calculated by taking the required budget for necessary storm drain operations and maintenance, capital improvements, and emergency projects, or some portion thereof, and dividing by the number of equivalent units throughout the city. A municipality may choose to pay for a portion of the storm water operations and maintenance costs using other funds, or to fund all costs through the utility. This method is often the best for funding the URP when existing sources prove insufficient. Table 3-3 presents the residential monthly rates established by selected municipalities to fund their URPs.

Table 3-3. Examples of Single-Family Storm Water Fees in California

City	Year Authorized	Average Monthly Rate
Sacramento	1982	$11.31
Palo Alto	1990	$4.25
Santa Clarita	1994	$2.67
Monterey	1994	$2.76
Santa Cruz	1994	$1.77
Average		**$4.25**

Exemptions

When setting up a utility fee, a municipality may choose not to allow exemptions for any properties except those that remain completely undeveloped (zero impermeable area). Some municipalities allow an exemption (which would constitute a type of discretionary exemption) for low income, elderly persons, or nonprofit groups such as churches and schools. However, since the urban runoff utility fee is based on impermeable area and associated contribution of runoff that necessitates operations and maintenance activities, exemptions should be based on elimination or reduction of those runoff flows. For example, exemptions or credits may be considered for properties that can reduce their runoff to predevelopment flows through the installation of detention ponds or for properties that install retention ponds and reuse their captured rainwater for landscaping, flushing toilets, or for other on-site uses. Credits could also be based on whether (1) the property has on-site storm water facilities such as retention basins, (2) the on-site storm water facilities are privately maintained, and (3) the facilities are inspected and maintained to function as designed.

Public Education/Involvement

The introduction and/or adjustment of urban runoff utility fees requires a great deal of public outreach and involvement throughout the development process. The public first needs to understand the problem that is being addressed. Why are they paying for urban runoff management? Hasn't the municipality always taken care of that? Once the public understands the problem being faced and the costs involved, a willingness to pay the necessary fees is more likely. Public outreach to neighborhood associations, business associations, and large property owners is essential to an URP that will be supported throughout the municipality. Without public support at all levels, water quality preservation will not be a cooperative effort. Public education, outreach, and involvement are covered in greater detail in Sections 4.1 and 4.2.

Appendix 4A presents a sample of a briefing that can be made to neighborhood and business associations in your municipality. These materials can be tailored to your needs and requirements.

Ordinance and Resolution

The ordinance and resolution in Appendix 3E are examples of the mechanism that may be used to incorporate the utility fee into the municipal code. It is important that the municipality establish an ordinance specifying that the fee is established separately by resolution, because the adjustment of that fee is inevitable. With a fee established by resolution, it is much easier to change the fee without going through the ordinance process and amending the entire utility structure each time those fee adjustments take place.

The ordinance creates the urban runoff utility, appoints the manager of that utility, and gives the authority to City Council /Board of Supervisors to establish an urban runoff utility fee. The management of the utility is most often assigned to the department responsible for operation of the storm drain and surface water system, often the Public Works or Maintenance Department.

Billing

Two existing methods can be used to bill stormwater utility fees: your county's tax assessment system or an existing utility billing system. Either option requires a detailed calculation of the impermeable area of each commercial and multi-family residential parcel in your jurisdiction and a calculated average impermeable area for single-family parcels. The costs associated with the two alternatives are comparable.

County Tax Assessor

The county assessor's office takes care of the property tax billing for all property owners in the county and can also be used as a billing mechanism for user charges by municipalities when the municipality does not have its own billing mechanism.

The advantages of using the county tax assessor's billing system are many. The percentage of collection is usually high. The municipality receives minimal customer service calls as it is a semiannual bill. The mechanism is in place. The disadvantages include high billing costs, initial billing errors, expensive setup fees, and cash flow limited to twice a year. Additional concerns have been raised about this method of billing with the passage of Proposition 218 in California. The distinction between a tax and a user fee becomes blurred if the user fee is collected along with property taxes.

Utility Billing System

The municipality may choose to use a utility billing system that is already in place for the collection of the storm water utility fee. That billing system may be either a municipal system or it may be a separate utility with which the city has a contract.

The advantages of using the utility billing system include a flexible schedule for fee implementation and continuous cash revenue. The disadvantages include the sorting required (because this fee applies only to utility customers within city limits), possible special handling of utility accounts billed to renting tenants, and higher initial customer calls and complaints than under the tax mechanism. However, this system is overall more flexible for initial implementation and later fee adjustments.

Other Funding Sources

Taxes

Taxes that could be used to generate revenue for the URP include commodity taxes, tax surcharges, or real estate transfer taxes. However, the passage of Proposition 218 in California requires a vote of the people to impose any of the above taxes, making these strategies difficult if not impossible to use.

Fees

User fees are the most effective way of recovering the costs of providing a service and can be tied directly to users of a resource or facility. One example of a user fee is the State of Maryland's license plate program to fund its Chesapeake Bay Trust. The license plates are sold for $10 each and have raised over $4 million.

Plan review fees can be assessed by local planning or public works departments that review development plans. The technical review includes storm water management facilities and wetland protection. Inspection fees can be charged to cover the costs of on-site inspection of erosion and sediment controls, BMP implementation, and wetland protection. Both of these fees can help to cover the cost of staff time and resources spent on private development sites.

Impact fees are charged to cover the costs of infrastructure needed for private development . These fees are usually collected as a lump sum from developers or property owners who receive a direct benefit from the project. These fees have been used for roads, sewers, and storm water improvements.

Bonds/Debt Financing

Bonds or debt financing raise capital at the beginning of the project and distribute the burden of repayment over the life span of a capital project among those who receive direct benefit. Bonds are generally used to finance projects that have proven life expectancies. Short-term bonds have a life of 1 year or less, while long-term bonds have a life equal to a project's life expectancy.

State Revolving Funds

State Revolving Funds (SRFs) were established by the CWA Amendments of 1987 by EPA grants and matching state funds. These SRFs provide long-term, low-interest loans to local government for major capital projects including storm water and wastewater improvements. The State of California uses its SRF for nonpoint source projects. Eligible projects include construction of demonstration projects, retention/detention basins, and a variety of BMPs to reduce or remove pollutants.

Grants

Grants are sums of money awarded to state or local governments or nonprofit organizations that do not have to be repaid. Grants are awarded for a specific project or activity with secific criteria that must be met before funds can be acquired and spent. Many private and public sources of grant funds are available. A good reference is the EPA.

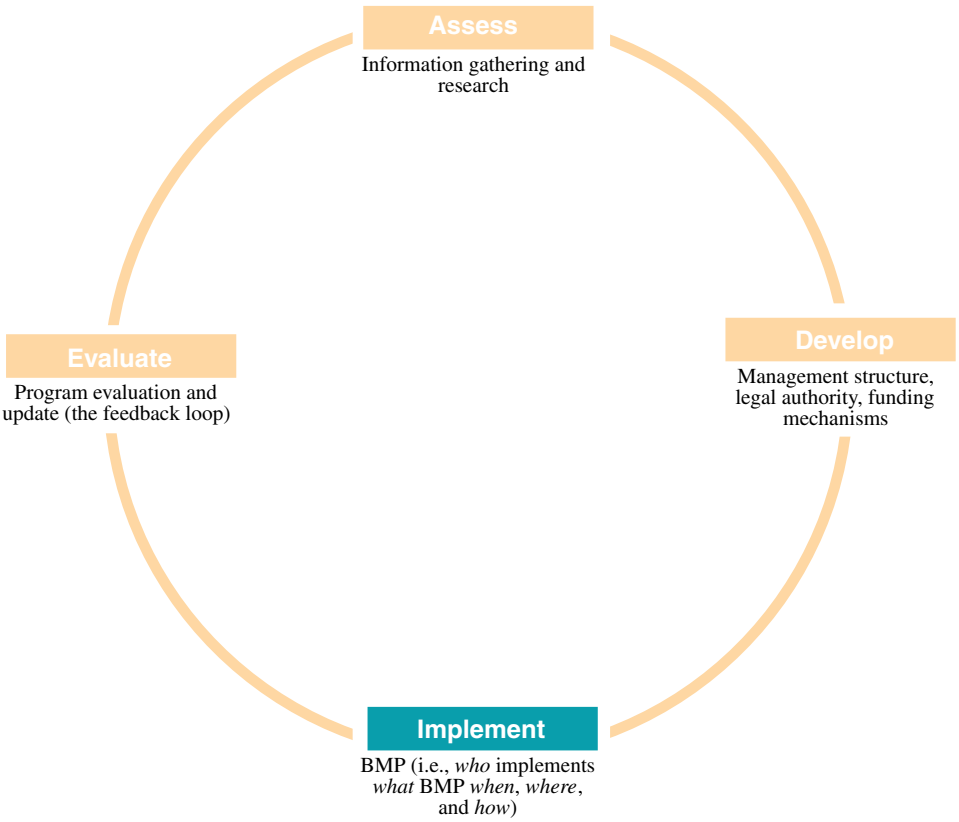
Sources of Additional Information

American Public Works Association (APWA). 1991. Financing Stormwater Facilities: A Utility Approach. Available through APWA Publications; call (816) 472-1610 x3560.

Water Environment Federation (WEF). 1994. User-Fee-Funded Stormwater Utilities. Available through APWA Publications; call (816) 472-1610 x3560. Order Number: PB.XUFF

U.S. Environmental Protection Agency (EPA). 1996. Protecting Natural Wetlands: A Guide to Stormwater Best Management Practices. Available through Office of Water (http://www.epa.gov). Document No. EPA-843-B-96-001. October .

4 Implementation of Urban Runoff Program



4.1 Model Public Involvement/ Participation

4.2 Model Public Education and Outreach Program

4.3 Model Illicit Connection/ Discharge Detection and Elimination Program

4.4 Model Municipal Operations Pollution Prevention Program

4.5 Model Construction Site Runoff Control Program

4.6 Model New Development/ Redevelopment Runoff Control Program

4.7 Model Commercial Facilities Runoff Control Program (Optional Program)

4.8 Model Industrial Facilities Runoff Control Program (Optional Program)

Once you have identified a lead department or entity to develop your URP, conducted an assessment of your municipality, and researched other regional and local programs that you can work with to improve urban runoff in your municipality or region, you are ready to start developing and implementing elements of your URP.

The URP consists of several control programs. Each control program consists of a series of actions that the municipality and its citizens and businesses can undertake to address specific sources of urban runoff pollution. The following table summarizes these program elements and the pollutant sources they address.

Elements of an Urban Runoff Program

Program Element	Urban Runoff Pollutant Source
Public Involvement/Participation (Section 4.1)**	
Public Education and Outreach Program (Section 4.2)**	Improper dumping of pollutants by residents and businesses; conduct of everyday activities that result in pollution
Illicit Connection/Discharge Detection and Elimination Program (Section 4.3)**	Illegal dumping of pollutants and inappropriate physical connections to the storm drains
Municipal Operations Pollution Prevention Program (Section 4.4)**	Publicly owned facilities (streets, sidewalks, public parking lots, corporation yards, landscaped areas, etc.)
Construction Site Runoff Control Program (Section 4.5)**	Construction sites (sediment and other pollutants)
New Development/Redevelopment Runoff Control Program (Section 4.6)**	Proposed new and redevelopment project sites (where urban runoff problems can be avoided through planning)
Commercial Facilities Runoff Control Program (Section 4.7)	Commercial facilities
Industrial Facilities Runoff Control Program (Section 4.8)	Industrial facilities

** Minimum requirements of NPDES Phase II regulations.

The first six program elements in the above table are specified in NPDES Phase II regulations as minimum URP requirements. Sections 4.1 through 4.6 in this guide outline a model control program for each of these minimum NPDES requirements. The regulations do not require control programs for commercial and industrial facilities (they suggest relying on public education and outreach to control pollut-

ants from these sources); however, since commercial and industrial facilities are often sources of concern for most urban areas, model control programs for these sources are also included (Sections 4.7 and 4.8) to help you develop focused programs, if necessary. Likewise, Phase II relies on residential sources. Changes in residential practices can have a great impact on reducing pollutants in urban runoff.

A robust URP may require additional controls to those found in Sections 4.1 through 4.8. In fact, improved water quality within your community may require community-specific solutions not present in this document. Do not feel constrained or limited by the control programs presented herein. As presented in the control programs that follow, any number of appropriate URP permutations are possible depending upon your unique circumstances. Nonetheless, your URP development will likely take one of three general approaches:

- ✓ You may choose to limit your program to the six minimum control programs required by NPDES Phase II regulations with uniform emphasis on all six control programs (the presumptive approach, see Section 2.2).
- ✓ Alternately, you may choose to conduct a thorough municipal assessment and focus your effort and budget on those control programs that address activities and pollutants of special concern within your jurisdiction.
- ✓ Or you may kick off your URP by implementing the six minimum program elements and make efforts to incorporate community-specific control measures as your program matures.

4.1 Model Public Involvement/Participation Program

The success of your URP depends upon securing support from your elected officials, citizens, business groups, and municipal staff even before you begin to institute changes.

To secure this support, you need to implement a public involvement/participation program that not only informs these audiences of the urban runoff concerns, but also asks them to participate in the URP's development.

The NPDES Phase II regulations also require that the owner or operator of a small municipal separate storm sewer system include a public involvement and participation program throughout the development and implementation of its URP to ensure that the public accepts and owns the program.

Objectives

The objectives should be to:

- ✓ Raise public awareness about urban runoff pollution through involvement in the municipal URP.
- ✓ Involve the public in the development and implementation process to secure "buy in" and generate public support for municipal water quality protection efforts.

The following information outlines the types of activities that a municipality can undertake to achieve public participation in its URP.

Public Presentations

Public presentations are an important element of your public involvement program. The first audiences for the presentation should be City Councils and municipal staff who will be involved in later implementation. Support for the program must first be achieved within the organization or implementation will not be successful. Elected officials are instrumental in conveying a water quality ethic to the community and municipal staff actually implement the plan. The presentation should then be taken to everyone open to listening, including among others neighborhood and business associations, commercial property owners, and local service clubs.

The foremost objectives of this presentation are to convince your community that a problem exists and that they should fix that problem. You need to acheive buy-in from your citizens and elected officials so that not only are they willing to support your program but also to pay for it. Funding is a challenge that must be faced and unless it is addressed the program cannot proceed. This second empha-

sis of the public presentation incorporates your overall financing strategy and addresses current financial needs.

Use photos and slides to inform your audience about the problem

As a first step, develop a "stock presentation" that basically informs the public of the need for an URP. Begin the presentation with a description of the problem, including a list of the water quality contaminants of concern, highlighting any that are of specific concern in your community, as well as drainage system deficiencies. A table of capital replacement and improvement projects along with their estimated costs for implementation is a good way to communicate the problem of funding deficiencies in your community.

The presentation should go on to include possible solutions to the problems, including URP implementation, which addresses the water quality concerns, and a financing strategy for that program that addresses both water quality and conveyance system solutions. This portion of the presentation may also go into the regulatory background for the water quality efforts being proposed with a brief history of the CNPCP and NPDES Phase II programs. It may be helpful to provide a list of other local jurisdictions to be affected by the programs so that the audience understands the mandates are statewide as well as nationwide. See Appendix 1A for a list of affected jurisdictions in California. A detailed breakdown of the six minimum MURP or NPDES Phase II required elements should include your specific plans for addressing each of those elements. To address funding, a chart or table should be created that breaks down the existing funding sources for urban runoff projects, programs, and operations and maintenance; shortfalls in funding; and your financing strategy for addressing those shortfalls. Include a list or table of any additional resource requirements that will be necessary to implement the URP.

This presentation should be easily adaptable to various audiences and interest groups. Your job in tailoring the presentation to each audience is to assess which facts to present and to add pictures of a local flavor to your presentation. Pictures of rusted corrugated metal pipes, outfalls that have visual water quality problems such as excessive trash, and other "problem areas" are essential in conveying the urgency of the URP. In this case a picture really is worth a thousand words.

The public information campaign will be both time and cost-consuming from the outset. Most municipalities do not have existing financing mechanisms for URPs, so staff time and other resources need financing through other means until a new mechanism is in place. A sample presentation outline is presented in Appendix 4A.

Involvement of Stakeholder Groups

Groups that should be involved in developing the URP include industrial and commercial representatives such as the chamber of commerce, for their input on developing specific URP elements. Meetings should be held with these groups to include their input on developing elements that directly affect the way that they perform their business activities. Commercial and Industrial Runoff Control Programs use BMPs as the cornerstone of their requirements. Representatives should be invited to become involved in developing those requirements so that they become somewhat "self-governed."

The establishment of a Program Advisory Committee could provide a forum for citizen involvement. This forum was used by some NPDES Phase I URPs during program development and implementation. A Program Advisory Committee includes interested citizens, representatives from local environmental groups, and commercial and industrial representatives among others. By opening the committee to any interested participant, additional input and support can be generated for the URP.

Program Implementation

In its URP planning process, the municipality should identify the department to lead this program, as well as any supporting departments. If the municipality has a department already conducting outreach efforts, that department should be used in the public involvement process as well. This coordination provides cost savings and ensures continuity of the methods used to get information out to the public. The City of Monterey did not have a public outreach person or department when this process began, so developing the entire program remained the responsibility of the Public Works Department.

The municipality should establish a timeline for developing the public involvement and participation program. Make sure that resources are available to fund this portion of the program until a funding mechanism is secured.

Program Evaluation and Documentation

Establish Measurable Goals

Your URP should include measurable goals for control programs. Goals should be set at the beginning of the planning process and may include:

- ✓ Conducting presentations to the City Council/Board of Supervisors in the URP's first year
- ✓ Holding public meetings to involve restaurant and auto service industries in the BMP development process within the URP's first 18 months
- ✓ Attending neighborhood meetings throughout the municipality to involve the residential community in the development of the illicit discharge detection and elimination program within the URP's first 2 years

4.2 Model Public Education and Outreach Program

Residential areas constitute the majority of land use in most municipalities. It is important for your URP to reduce discharge of pollutants from these sources. Education and outreach have been found to be the best methods to reach the residents of a community.

The NPDES Phase II regulations also require that the owner or operator of small municipal separate storm sewer systems implement a public education/outreach (PE/O) program to distribute educational materials to the community about the impacts of nonstorm water discharges on water bodies and steps the individuals and households can take to control urban runoff pollution.

"Public education" refers to curriculum-based programs (e.g., school programs), while "public outreach" pertains to methods that disseminate information (e.g., volunteer programs, advertising, displays at public facilities).

Objectives of the Program

The objectives should be to:

- ✓ Understand public perceptions and attitudes towards the problem of urban runoff.
- ✓ Get the message out and raise public awareness about urban runoff pollution and its impact on the community's water resources.
- ✓ Educate the community about specific pollutant sources and on what they can do to reduce urban runoff pollution (alternative pollution prevention solutions).
- ✓ Foster participation through community-based projects or volunteer activities focused on pollution prevention.

For purposes of developing public education and outreach that addresses specific sources, the community can be considered as composed of several sectors or audiences, namely (1) the residential community, (2) the commercial/ business sector, (3) the industrial sector, (4) the development community, (5) the construction sector, and (6) the government (city council, etc.). This section of the MURP guide addresses education and outreach to the public at large and the residential community. The outreach programs for commercial, industrial, and construction sectors, and the development community are addressed in other sections of the guide. Public involvement is discussed in Section 4.1.

Elements of a Public Education/Outreach Program

The municipality should consider the following steps in developing its PE/O program:

- ✓ Contact other municipal, regional/county organizations that conduct public education about other programs in your community. Most communities have recycling, hazardous waste disposal, water conservation, and other such programs in place. Determine if the urban runoff PE/O program can be conducted in cooperation with these entities.
- ✓ Contact other URPs in California to use materials already developed or to be developed, to reduce costs, and to be consistent. See framework summary in Appendix 4B for details.
- ✓ More and more municipalities are forming consortiums with neighboring municipalities to maximize resources.

Increase Public Awareness about Urban Runoff Pollution

Implement a program that increases the awareness in the community about urban runoff pollution and discourages nonstorm water discharges into storm drains. Note that this PE/O program supports MURP's Illicit Connections/Discharge Program (Section 4.3). The following tasks are recommended:

- ✓ Develop materials to get the message out that
  - The storm drain does not lead to a wastewater treatment plant but to the stream, creek, bay, or ocean.
  - Discharges into storm drains result in impacts to wildlife, water quality, health, and eventually the quality of life in the community.
  - Teach the vocabulary related to urban runoff issues. Samples of these outreach materials are included in Appendix 4C.
- ✓ Identify a mechanism appropriate for your municipality for distribution of these outreach materials and establish a frequency of distribution for these materials. Distribution methods may include direct mail, billing statements, television (public cable access), internet, handouts, or radio. Contact other existing local/regional environmental programs to find out about distribution methods that these programs are using and the frequency at which they are sending their messages out.
- ✓ Timing can be critical. If planning a big event, time it with the first rains of winter, Earth Day, or Spring Cleaning so it will have a greater impact.
- ✓ Establish a "Hotline" number that residents can call to inform about illegal dumping incidents or spills and can receive information or recycling, and waste disposal alternatives.

Develop Outreach Programs that Target the Residential Sector of Your Community

Develop a PE/O program that targets specific residential sources in the community. The following steps are recommended:

- ✓ Depending on resources, a municipality can annually prioritize the specific residential sources it will target. Most Phase I municipalities have targeted the following sources:

- Automotive maintenance and washing
- General home maintenance, including building repair, painting, and remodeling, and disposal of swimming pool and spa water
- Landscape maintenance, irrigation, weed and pest control, fertilization, yard debris, and pet waste disposal

✓ The residential outreach program should first target home auto maintenance activities; followed by landscape maintenance, weed and pest control, and painting, the most common residential pollutant sources in any community. If your municipality contains a large number of homes with swimming pools, you may consider that another target source.

✓ Prepare outreach materials for these targeted residential sources. BMPs that address these major residential pollutant sources are presented in BMPs for Residential Sources (Appendix 4E). Examples of effective printed outreach materials are presented in Appendix 4C and in Appendix 4D, Educational Tools and Resources for Public Education Program. Additional brochures, flyers, and handouts can be obtained by contacting the Phase I URPs or statewide storm water organizations.

✓ Identify a mechanism for distribution of these outreach materials and establish a frequency of distribution for these materials. A list of distribution centers is presented in Appendix 4D. Distribution methods include public counters, billing inserts, schools, and libraries.

✓ Note that if your community contains certain ethnic or socioeconomic groups, it may be necessary not only to translate these materials into other languages, but you may also need to consider alternate distribution mechanisms. Contact the Sacramento Storm Water Management Program or the Los Angeles County Urban Runoff Management Program for more information on outreach to socioeconomic and ethnic groups; both programs have conducted extensive studies on this subject. Also, refer to the 2-page summary in Appendix 4B for ideas to reach targeted audiences.

Develop An Outreach Program that Targets Children in the Community

Studies have shown that one of the most effective ways of educating the community is through children's programs because children carry the messages home. Contact and develop with your local Office of Education materials and a curriculum aimed at urban runoff. Inform children about urban runoff concerns using the following techniques:

✓ School Assembly Program (presentations)
✓ Teacher Workshops (using "WET" curriculum)
✓ Activity Packages (games, laboratory experiments)
✓ Enviroscape Model (three-dimensional watershed model)
✓ Science Fairs (promote an urban runoff award)

An effective way to get the message out is through outreach presentations at School Assemblies. School Assembly Programs reach a large number of students relative

to the amount of money and effort spent, especially if the event is coordinated as a countywide event. In a two week countywide tour of the educational show "Canopy" in San Mateo County in 1997, 24 schools participated and over 8,000 students attended the interactive assembly program.

Several theater companies specialize in school assembly programs presenting shows on natural sciences and stormwater pollution. The highly regarded Los Angeles-based theater company *Will and Company*, has created and tours two educational assembly programs "Canopy" and "WaterCycles" focused on stormwater pollution. Both programs have been well received in Los Angeles County elementary schools and are a continuous part of their stormwater education program.

The assembly program presents an excellent opportunity to send outreach materials and resource guides to teachers and schools. Materials sent prior to the event may be used by teachers to prepare for the event, increase interest, and compliment state-approved science curricula. An example of a resource guide and program assessment for teachers, and assembly program information are included in Appendix 4F.

Activity Packages can be created and distributed to schools, afterschool programs, youth camps and to organizations which conduct environmental outreach. CD roms with educational games can be created and distributed to school computer labs. CH2M Hill's computer program Eco-Masters is just one of the many water-related educational computer programs available. See Appendix 4D for a list of resources.

The Enviroscape model is an interactive model of a city scape which identifies multiple pollution sources and demonstrates their routes to our waterways. Participants may "pollute" the scape with cocoa, indicating soil from a construction site, powdered drink mix, indicating industrial pollution, etc. and then watch as the rains from a spray bottle send their pollution down streets, into streams, and eventually into the principle water body. It is portable and can be used at events or classroom presentations. In order to increase participation while demonstrating with large groups, it is recommended that the presenter call upon individuals to help set up, "pollute" and "rain". For information on ordering this, see Appendix 4D. This model has educated over 6,000 children and adults in Monterey and Santa Cruz.

The Enviroscape model has proven to be an effective tool

An effective way of promoting urban runoff issues, especially to secondary school students and the community, is by sponsoring and promoting a Storm Water or Water Quality Award at the Science Fair. Some steps required include:

- ✓ Coordinate with the Office of Education
- ✓ Conduct promotional presentations in science classrooms to plant the seed of interest
- ✓ Create a committee of at least three to attend the science fair and select finalists
- ✓ Interview the selected candidates
- ✓ Choose the award recipient
- ✓ Present the award at the awards ceremony

A science fair is a fun event which can create interest in urban runoff issues as parents and friends view the different displays and through publicity received by the award.

Since school outreach costs can add up, try to obtain local sponsors to pay for printing of materials and other associated program costs.

Public Involvement Through Volunteer Activities

Storm drain stenciling is an effective way to get the community involved

Three of the most effective volunteer participation efforts include a storm drain stenciling program, a citizen water quality monitoring program, and a volunteer education program. All three of these efforts enlist the support of volunteers from the community to participate and later to become leaders in educating others.

Volunteers are invaluable for creating support for the URP, spreading the word about urban runoff issues, creating a sense of community ownership and getting important tasks accomplished. A long-term commitment from volunteers is essential, as training is a time-consuming and costly effort. Often it is actually more costly to use volunteers to accomplish certain tasks than it is to do them in-house, but the other benefits that come from using volunteers far outweigh the costs. You need to develop a press release on urban runoff pollution to recruit volunteers for public involvement and participation activities. Earth Day and Coastal Cleanup Day are national celebrations that may be good days to gain attention as well as during large storm events. Useful volunteer activities are summarized below. For further details on these, see Appendix 4B.

- ✓ **Storm Drain Stenciling.** The easiest activity to get volunteers involved in is a storm drain stenciling program, which can be a short- or long-term project at

the volunteers' discretion. One aspect of a solid URP is to have all catch basins and drainage inlets in a municipality marked so that the public understands that materials going down those drains flow directly to your local receiving water. Stencils often say: "No Dumping - Flows to Bay (Creek/River/Lake)." The plastic or paper stencils can be ordered from a number of companies and can be customized to include the name of the receiving water or remain generic. Some municipalities have started using a thermoplastic label instead of painted stencils, which must be applied by in-house personnel or a contractor. These thermoplastic labels last much longer than painted stencils, which have a life of approximately 3 years, but keep in mind that volunteer forces are always available to repaint. Also, the cost of thermoplastic is high and the machine can do a few stencils at a time.

Storm drain stenciling can be done as a weekend volunteer activity centered around certain events such as Earth Day or Coastal Cleanup Day, or it can be a long-term project given to local groups such as the Boy Scouts, business groups, or Surf Rider or other nonprofit groups. City staff person must supervise the event. Training for this activity takes about half an hour and a group of three people can stencil between 8 and 10 storm drains per hour. See Appendix 4B for specific instructions and storm drain stencil samples. Adapt the design and message to your needs and situation. Time must be put in before to buy all the supplies and have the kits assembled.

✓ **Water Quality Monitoring.** Water quality monitoring takes a long-term commitment from volunteers because of the time involved in training. Monitoring training can take anywhere from a few hours to a full day depending on previous experience. Note that training should emphasize proper protocol. A directory of volunteer monitoring programs is available for California including a number of nonprofit organizations that run those programs. Nonprofit organizations can be enlisted to either run a program for your municipality or to be used as support for your training programs. More detailed information on monitoring programs is presented in Section 5.2 of this document. Appendix 4G contains information on how to obtain available monitoring manuals.

Volunteers can be trained to assist with water quality monitoring

✓ **Volunteer Educators.** A number of activities can be implemented by volunteers who have been trained for specific audiences. Volunteer educators can be used to present educational materials to local businesses and school groups. You may choose to educate volunteers who have already spent time in other municipal urban runoff volunteer programs for this task. Due to the potential for the URP to be politically sensitive for certain types of businesses, make

sure that volunteers are aware of business concerns and that they educate rather than creating tension between local government and the business community. Volunteer educators can be used to hand out educational materials at fairs, festivals, farmer's markets, and other public events.

- ✓ **Other Volunteer Programs.** The programs described in detail above are ideas that have been used by the Cities of Monterey and Santa Cruz in their URPs in collaboration with the Monterey Bay National Marine Sanctuary. These activities have been proven to involve large groups with a limited amount of resources. Other programs that could be used for public involvement purposes, some of which were used in Phase I municipalities, include creek restoration activities, such as Adopt-A-Creek/Watershed Program, or Kids in the Creek (trash pickup program).

Other Outreach Activities

Point-of-Sale Program for used oil is another useful activity

This MURP guide recommends the activities listed above as the core elements of a municipality's PE/O program, which is not to suggest that other outreach activities should not be undertaken. If the municipality has the resources and establishes the need to conduct other PE/O activities, some other effective PE/O programs include outreach to community groups, youth groups and business organizations. A point-of-sale program can be effective with respect to improper disposal of used oil. Table 4-1 presents a matrix that shows the types of outreach activities that can be undertaken to reach specific audiences in any municipality.

Other Sources of Information

Several Phase I URPs are good sources of information about PE/O programs. In addition, a Public Information/Public Participation Committee of the State Storm Water Quality Task Force meets on a regular basis at locations in northern and southern California. Contact the Committee (LA County Public Works (818) 458-5947 or Riverside County (909) 275-1111) to find out about the current status of PE/O programs. In 1993, the Committee prepared a report entitled *A Program Development Guide for Storm Water Public Education in California*, which provides a good overview of elements of PE/O programs for urban runoff. A list of educational tools and resources for public education is included in Appendix 4D.

Program Implementation

The following guidelines should be used to set up this program.

Table 4.1. Types of Outreach by Audiences

ACTIVITY/TASK	AUDIENCES										
	Residents	Socioeconomic Group	Children	Business	Industry	Construction/New Development	Community Groups	Media (PSAs)	Municipal Personel	Officals/Regulators	Allied Organizations
COMMUNITY OUTREACH											
Stormwater Information Hotline*	●	●	●	●	●	●	●	●	●	●	●
Interactive Model*	●	●	●				●			●	●
Fact Sheets*	●	●	●			●	●	●		●	●
Display Exhibit*	●	●	●	●			●			●	●
Tip Sheets	●	●						●			
Utility Inserts	●	●									
Door Hangers	●	●									
Direct Mail Campaign	●	●									
Newsletter	●						●				
Promotional Items	●		●					●			
Educational Video	●	●	●	●	●		●	●	●	●	
Interested Parties Database	●	●	●	●	●		●	●	●	●	
Computer Game/Quiz	●	●	●				●				
Community Grant Program	●	●	●				●				
Storm Drian Stenciling Program	●	●	●	●	●	●	●	●	●	●	●
VIP Breakfast and Tour				●	●			●		●	
Amateur Photo Contest	●			●			●	●			
Speakers Bureau: Community Group Focus							●				
Volunteer Program	●						●	●			
Best (No) Pest Gadening Contest	●			●			●				
Special Community Events	●	●					●	●			
Celebrity Spokespersons	●	●									
CHILDERN'S OUTREACH											
School Assembly Program		●	●								
Kid's Activity Packages			●					●			
Coloring Books			●								
Restaurant Table Mats			●	●							
Children's Television Club			●					●			
Teacher Training/Workshops			●								
Science Fairs/Projects		●	●								
Calanders			●								
Field Trips			●								
Adopt a Watershed/Creek			●	●							
BUSINESS OUTREACH											
COMMERCIAL SECTION OUTREACH				●				●			
Business Incentives Program				●							
Public/Private Partnerships		●		●							
Speakers Bureau: Commercial Sector Focus		●		●							
Educational Workshops for Targeted Businesses											
Point-of-Purchase Campaigns											

Based on Sacramento Stormwater Management Program

Table 4-1 (continued). Types of Outreach by Audiences

ACTIVITY/TASK	AUDIENCES										
	Residents	Socioeconomic Group	Children	Business	Industry	Construction/New Development	Community Groups	Media (PSAs)	Municipal Personel	Officals/Regulators	Allied Organizations
BUSINESS OUTREACH CON'T											
b. Automotive Fluids	●	●		●				●			
c. Home Improvement Products	●			●			●	●			
Sponsorship of Program Elements				●							
INDUSTRIAL SECTOR OUTREACH											
Educational Workshops for Targeted Industries					●						
Industrial Employee Education					●						
Recognition Program					●			●		●	●
Sponsorship of Program Elements					●						
CONSTRUCTION/NEW DEVELOPMENT OUTREACH						●					
Grading/Erosion Control Workshops						●					
Contractor-Focused Workshops						●					
Tailgate Training	●					●	●				
Outreach to Residents of New Developments						●					
Sponsorship of Program Elements						●					
MEDIA RELATIONS											
Media Sponsorship/Partnership								●			
Press Kits	●	●						●			
Pre-Written Articles	●	●					●	●			
Media Interviews/Briefings	●	●						●			
ADVERTISING											
Television (Cable Public Access)	●	●	●	●					●		
Radio	●	●	●	●					●		
Billboards	●	●		●					●		
Print	●	●	●	●	●	●	●	●	●	●	
MULTI-CULTURAL COMMUNITY OUTREACH											
Multi-Lingual Bulletins		●									
Community Leader Outreach		●									
Speakers Bureau: Multi-Ethnic Community Focus		●									
Multi-Cultural Radio PSA's		●						●			
Multi-Cultural Community Events		●									
OUTREACH TO POLITICAL OFFICALS/REGULATORS											
City Council Presentations										●	
Presentations to Regulators										●	
OUTREACH TO MUNICIPAL PERSONNEL											
Educational Workshops for Municipal Personal									●		
COORDINATION WITH ALLIED ORGANIZATIONS											
Coordinate with NPDES Permittees											●
Coordinate with Regional Organizations											●
Coordinate with Other Stormwater Programs											●

Based on Sacramento Stormwater Management Program

Identify Responsible Departments and Personnel Requirements

In its URP, the municipality should identify the department to be responsible for the implementation of the PE/O program, and the personnel to assist in the program. If the municipality has a department already conducting outreach for other environmental programs, consider assigning this task to that department. Significant cost savings, as well as reducing the potential for sending conflicting messages out to your community, can be achieved through coordination with other environmental or adjacent URPs. In several Phase I municipalities, the task of managing public outreach was assigned to a Public Works Department staff person, in others a specific staff position was created. Also, see "How to Begin" section in Appendix 4B for an educator to begin the program.

Establish Timetable for Implementation

The municipality should establish a timetable for setting up the initial program. This timetable should clearly indicate the activities it will undertake each year, depending on the resources (personnel and funding) available to the municipality to implement the program.

Based on the experience of Phase I municipalities, it is recommended that for the first 4 to 5 years, the emphasis of the PE/O program should be on getting the basic message out. The municipality may commence outreach with respect to targeted residential sources or children's outreach programs in years 2 or 3 of the program, but the basic message on runoff pollution should be continued for at least 5 years.

Program Evaluation And Documentation

Establish Measurable Goals

Your URP should include measurable goals for BMPs or control programs. These goals are useful in checking progress of efforts made each year in reducing pollutants to the maximum extent practicable. The municipality may consider some of the following goals for inclusion in its program:

- ✓ Label storm drain inlets within first two years of the program.
- ✓ Distribute outreach materials on *getting the message out* to 100 percent of homes in the first/second year of the program.
- ✓ Distribute outreach materials on targeted residential sources to 100 percent of homes in the third year of program.

Documentation and Annual Reporting

The municipality should develop forms for record keeping and reporting on this program in an annual report. Information that should be reported includes progress made relative to the measurable goals. Sample forms that can be used by the municipality are provided in Appendix 4H.

4.3 Model Illicit Connection/Discharge Detection and Elimination Program

An illicit connection is defined as "a point source discharge of pollutants to separate storm drain system which is not composed entirely of storm water and not authorized by an NPDES permit." Inspections of urban storm drain systems in many areas have shown that a high percentage of industrial and commercial establishments (such as auto shops and restaurants) have improper or illicit plumbing or connections to the storm drain system. Illicit discharges of sanitary wastes through illicit connections can cause high bacterial counts in receiving water and dangers to public health. Because the storm drain and sanitary sewer systems develop cracks and leaks with age, and because these lines are often in close proximity, problems of infiltration from one system to the other are also common.

Improperly disposed materials make their way to the receiving waters via storm drains

Improperly disposed of pollutants are also problematic. While some pollutants are knowingly dumped into storm drain inlets and streams, a multitude of contaminants are inadvertently carried by runoff into storm drain systems — during accidental spills on urban streets, sidewalks, and other exposed areas; for example, pollutants are carried to the storm drains by water used to clean up the spill. Materials disposed of improperly include used oil, household toxic wastes, radiator fluid, washdown water from restaurants and gas stations, and litter such as fast-food packaging, cans, and disposable cups.

To address these sources, your URP should include an illicit connection and discharge detection and elimination program (hereinafter illicit connection/discharge program), and such a program is also one of the six minimum requirements in NPDES Phase II regulations.

Objectives of the Program

Your objectives in developing this program should be to:

- ✓ Control illicit discharges by conducting methodical field surveys/investigations of the storm drain system to identify and eliminate existing improper physical connections.
- ✓ Prevent improper disposal of wastes through a program that combines public education with provision of alternative disposal options and incentives.
- ✓ Contain and clean up accidental spills using proper methods of cleanup and disposal.

The information that follows outlines the specific actions or tasks that a municipality will need to undertake to establish and implement an illicit connection/discharge program that addresses all three of these objectives. Although illicit physical connections can also occur in the course of new development, procedures that can be used to prevent these in new development are addressed in Section 4.6.

Elements of the Illicit Connection/Discharge Program

Figure 4-1 shows an implementation approach for this program, and illustrates the sequence of actions that should be involved in (1) conducting a field inspection program to detect and eliminate improper connections and discharges and (2) responding to illicit disposal and spills. In addition, you need to take certain preparatory steps such as establishing permissible discharges and enforcement procedures.

Establish Permissible Discharges

Your municipality needs to establish a policy specifying the flows or discharges that it will allow to be discharged to the storm drain system and those that it will control via its illicit connection/discharge program.

NPDES Phase II regulations note that the illicit connection/discharge program would need to eliminate certain types of nonstorm water discharges if found to be significant contributors of pollutants. The regulations list the following types of discharges as those nonstorm water discharges that the municipality should examine to determine if they are a significant source and then either ban their discharge or require implementation of controls — *water line flushing, landscape irrigation, diverted stream flows, rising ground waters, uncontaminated ground water infiltration to separate storm sewers, uncontaminated pumped ground water, discharges from potable water sources, foundation drains, air conditioning condensation, irrigation water, water from crawl space pumps, footing drains, lawn watering, individual residential car washing, flows from riparian habitats and wetlands, dechlorinated swimming pool discharges, and street wash water*.

Table 4-2 presents how several of these nonstorm water discharges have been handled by Phase I municipalities. You can use this information to help you determine which nonstorm water discharges to allow to be discharged unconditionally, which to ban, or which require implementing controls. If you are preparing an ordinance focused on the URP (or amending an existing ordinance), you should list the permissible and nonpermissible discharges in your urban runoff ordinance. Once these discharges are defined, communicate this information to both city personnel and the citizens and businesses within your jurisdiction.

Establish Enforcement Procedures

Most URPs generally emphasize education and cooperation as their preferred methods for enforcement, and you may also elect to use these methods to implement

Figure 4-1. Implementation Approach

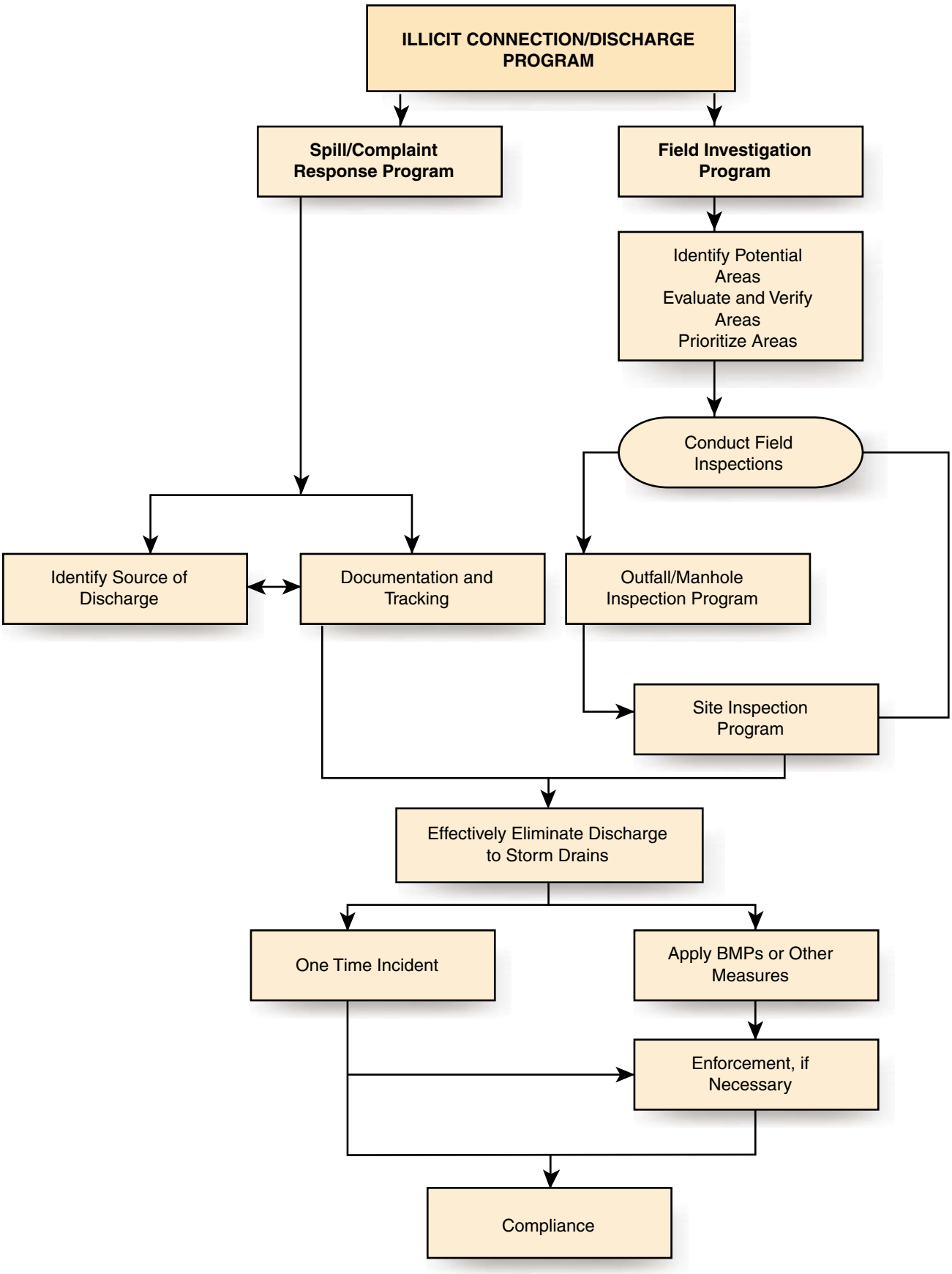


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Table 4-2. Nonstorm Water Discharges

Type of Discharge	When is the Discharge to the Storm Sewer Permissible?	Preferred Disposal Options				Note
		Storm Drain	Sanitary Sewer	Recycle/ Reuse	Hazardous Waste or Other Disposal	
1. Residential lawn irrigation	Always[a]	●				
2. Dumping of oil, anti-freeze, paint, cleaning fluids	Never			●	●	1
3. Residential car washing	Always, but not recommended[a]	●				2
4. Commercial car wash	Never		●	●		
5. Industrial dischargers (excluding cooling water)	Never		●	●	● when above pretreatment limits	3
6. Swimming pool water	Only when dechlorinated[a]	●		●		4
7. Water line flushing	Always[a] [b]	●		●		
8. Fire fighting flows	Emergency only[c]	●			● when heavily contaminated	
9. Potable water sources	Always[a]	●		●		
10. Uncontaminated foundation drains	Always[a]	●		●		
11. Contaminated foundation drains	Never		●	●		
12. Pumped groundwater for cleanup operations	Only if in compliance with NPDES permit	NPDES permit required		●		
13. Cooling water	Never unless no chemicals added and has NPDES permit	Permit required	●	●		5
14. Roof drains	Always except when contaminated or drains industrial area	●				
15. Air conditioner condensate	Always[a]	●		●		
16. Washwaters from commercial/ industrial facilities	Never		●			6
17. Uncontaminated groundwater infiltration	Always[a]	●		●		
18. Contaminated groundwater infiltration	Only if in compliance with NPDES permit	NPDES permit required		●		

Developed by Woodward-Clyde and provided courtesy of the Santa Clara Valley Nonpoint Source Pollution Control Program

Table Notes continue on following page

Table 4-2 (continued). Nonstorm Water Discharges

Table Notes:

(a) Discharges are considered conditionally exempt by RWQCB, unless they are identified by either a permittee or the executive officer as being a significant source of pollutants to receiving waters. If identified as a significant pollutant source, appropriate BMPs must be developed and implemented under the storm water management plan to minimize the adverse impacts of these sources.

(b) Exempt when superchlorinated or chemically cleaned; then discharge goes to sanitary sewer.

(c) Granted a discharge exemption by RWQCB.

1. The illegal dumping program should concentrate on eliminating the dumping of oil, anti-freeze, and other pollutants in industrial and commercial areas. The public education program will concentrate on eliminating dumping in residential areas.

2. It would be impracticable to prevent individuals from washing their cars and the illegal dumping program should not devote resources in this area. Minimize the environmental effects of car washing by washing on permeable surfaces (gravels, lawns, etc.).

3. All industrial discharges to storm drains should not be permitted. If discharge appears contaminated, then record as an illicit connection or illegal dumping.

4. Chlorinated swimming pool water should not be discharged to the storm sewer. Some sewer districts do not allow swimming pool water to the sanitary sewer. In these cases the water will have to be dechlorinated before discharging to the storm sewer. Filter back washwater is not allowed in the storm sewer and must go the sanitary sewer. Public education program needed.

5. Cooling water should always have a NPDES permit to discharge. Recycle is checked as a preferred disposal option. Where practicable, industries should be encouraged to either construct cooling ponds so the water is reusable or possibly find other uses on site for the water.

6. Washwaters from commercial and industrial facilities include runoff from vehicle and equipment washing, steam cleaning, and cleaning of areas used for industrial or commercial activities. Due to the wide range of washwaters from commercial facilities, disposal options should be evaluated on a facility-specific basis.

7. Since all discharges are not acceptable to sanitary sewer agencies, the municipality should coordinate with the sewer agency.

your illicit connection/discharge program. However in some circumstances, penalties may be needed to achieve compliance. Given the fairly long lead time involved in establishing enforcement procedures, it is recommended that the municipality initiate this process early.

The municipality must decide what approach to enforcement to take and what penalties it is willing to impose on violators. Violations detected through an illicit connection/discharge program fall under two categories: (1) illicit physical connections into the storm drain system and (2) illicit dumping and discharges. A phased approach to enforcement is suggested below that includes issuance of a warning as a first step, followed (if compliance does not occur) by administrative action or legal action. The municipality can use this in its original or a revised form.

- ✓ **Warning.** Could be a verbal notice or a written informational letter to the owner/operator. A time frame to correct the identified problem should be specified based on the severity or complexity of the problem.
- ✓ **Administrative Action.** Similar to a warning except a more formal notice and a structured process, including a Notice of Violation, Cease and Desist Order, Order to Abate, Notice to Clean, or any other similar notification outlined in the municipality's storm water ordinance that identifies a problem,

requires correction or abatement but does not assess fines. A time frame to correct the identified problem should be specified based on the severity or complexity of the problem.

- ✓ **Administrative Action with Fine and/or Cost Recovery.** Same as above with the addition that fine(s) are assessed administratively and/or the municipality's abatement costs are recovered.
- ✓ **Legal Action.** Includes any actions taken by the municipality that brings the facility into the court system (e.g., citation, court action, etc.)

This enforcement protocol is based on the assumption that the municipality escalates the level of enforcement until compliance is achieved. Also this approach does not prevent the municipality from skipping certain steps for more serious problems. The municipality's department heading the URP should consult with the municipality's legal counsel in this regard.

Establish a Field Investigation Program

Ideally, an illicit connection/discharge program should aim at detecting and eliminating all existing illicit connections (improper plumbing) in a municipality, as well as eliminating improper disposal of pollutants into the storm drain system. Several procedures can be used to detect improper connections or trace discharges to their origins:

- ✓ Television camera inspection
- ✓ Outfall/manhole inspection program
- ✓ Site inspection program

The most effective way to conduct a citywide investigation is to utilize a **television camera inspection** of the storm drain system. Some communities have done so as part of their storm drain improvement/retrofit programs and have detected connections that otherwise would have gone undetected. This method is expensive, and some pipeline television cameras have been found to suffer damage when used in storm drains due to the rough nature of interior storm drain surfaces.

Most municipalities have utilized outfall/manhole inspection programs and site inspections to detect illicit connections as well as illicit discharges. The **outfall/manhole inspection program** (called the field screening program in Phase I regulations) utilizes the "belowground" approach, which involves tracking dry-weather flows from the outfalls or manholes to their source. The **site inspection program** utilizes the "aboveground" approach, which involves conducting inspections at or near potential sources such as businesses that are known, from observation in the municipality or from other URPs, to result in illicit discharges. The municipality should utilize both methods because both have been shown to be effective and complementary.

Since illicit connections are the main source of bacteria and pathogens in urban runoff, a systematic survey of the city's entire storm drain system to check for

illicit connections is very valuable and recommended, especially for those municipalities (such as coastal towns/cities) where storm drain outfalls discharge into coastal waters used for swimming. However, since high cost is involved in a citywide survey, another alternative is to prioritize source areas or geographical areas that should be investigated first for illicit connections and dumping. Studies based on outfall monitoring and sampling have shown that the largest numbers of improper discharges emanate from industrial and commercial areas and from the older sections of communities. In fact URPs developed under Phase I permitting have generally focused their illicit connection/discharge elimination programs on these types of land-use areas.

Outfall/Manhole Inspection Program

An outfall/manhole inspection program generally include the following steps:

- ✓ **Identify and prioritize areas where illicit connections/discharges are most likely to occur.** A municipality can identify and prioritize areas to focus its program in several different ways. Depending on the geography of the municipality, its size, and the number of outfalls, it can conduct a field investigation of all storm system outfalls during the dry season to check for dry-weather flows. This investigation helps point out those outfalls that are of concern and those that are not (note that, because such discharges tend to be intermittent, this investigation may need to be repeated a few times before certain outfalls can be dismissed).

Dry-weather flows are indicators of improper connections and discharges

In the event that a dry-weather investigation of all outfalls is not possible, the municipality may rely on land-use information and the storm drain system mapping (as described in Section 2.2 of this guide) to determine potential areas of illicit connections and discharges. Using the storm drain map of the city, the municipality should mark out outfalls that are associated with industrial/commercial areas of the city and/or the older sections of the city, identify the areas that drain to these outfalls, and note the businesses located within these marked areas.

- ✓ **Establish a program of checking specific manholes and outfalls periodically for dry-weather flows.** Once the municipality has confirmed its focus on certain areas, it should prepare maps showing which manholes and outfalls to check periodically and establish a timetable or frequency. The municipality should develop forms for use by inspectors during field inspections. Sample inspection forms are presented in Appendix 4I.

- ✓ **Track flows back to potential dischargers and conduct aboveground inspections.** As a next step, field inspections of the targeted outfalls and manholes should be conducted to (1) verify whether the correct outfalls and manholes have been included in the field inspection program and (2) check for signs of improper discharges. Signs of an illicit connection or discharge can include:
  - Abnormal water flows during the dry season
  - Unusual flows in subdrains used for dewatering
  - Pungent odors
  - Discoloration or oily substances in the water, or stains and waste residue in ditches, channels, or drain boxes

  If during inspections, any of these signs are observed, the inspector should (1) record the flow data and take photographs and (2) begin storm drain investigations by tracing the flow upstream using storm drain maps and by inspecting upgradient manholes. Sampling and testing of water at the manhole or outfall where it is first detected is generally not considered necessary if the water appears to be "clear" but, if deemed appropriate, can be performed using field kits or taking grab samples for analysis in a lab. If tracking a discharge through visual inspection of upgradient manholes is not possible, alternate techniques that can be used include zinc chloride smoke testing, fluorometric dye testing, physical inspection testing (of pipes greater than 39 inches), or television camera inspection.

- ✓ **Once the origin of flow is established, require illicit discharger to eliminate the discharge.** Once the suspected origin of the flow is determined, the inspector should inspect the source to see if it is a case of improper dumping or if it is an improper physical connection. Once confirmed, the inspector should instruct the owner/operator of the property to rectify the situation. The inspector should provide the operator/owner information on alternative disposal options (from Table 4-2). The operator/owner should also be informed at this time that, should the discharge continue, enforcement procedures will be implemented.

Site Inspection Program

As noted above, the municipality may elect to simultaneously conduct inspections of establishments that it feels could either have illicit connections or could be improperly discharging pollutants into the storm drain system. If the municipality chooses to use this approach, it must develop inspection forms and train inspectors on how to detect illicit connections and discharges through systematic site inspections of facilities. Many communities under Phase I have included this under their Industrial Discharge Control Programs or assigned this activity to the City's wastewater department to be handled in parallel with the pretreatment program.

Establish Illicit Discharge Complaint/Spill Response Program

Citizens when properly educated and informed, can assist the municipality in its task of eliminating illicit discharges. Public education and involvement focused on elimination of illicit disposal and spill control is described in Section 4.3 of this guide, and includes the establishment of a "hotline" for citizens to call in incidents of illicit discharges and spills.

Program Implementation

The following guidelines should be used to set up this program.

Identify Department Responsible and Personnel Requirements

As a first step, identify the department to implement this program. Most Phase I communities with publicly owned treatment works (POTWs) have assigned this program to their wastewater department, because POTW staff are trained to conduct inspections, work with underground sewers that are typically at the same locations as the storm drains, and have the equipment for sampling as well as pipeline television cameras. Also in the event that they discover illicit discharges, they can readily inform the discharger about the alternatives available for disposal, i.e., whether that discharge can go to the sanitary sewer system or whether that discharge must be contained, placed in drums or other containers, and hauled elsewhere for disposal. In the event that a municipality does not have a POTW, it can consider contracting with the regional POTW for this service (which has been done in some areas), or assign this program to the Hazmat or Fire Department.

Personnel requirements include minimum 3-person teams for outfall/manhole inspections (for safety reasons) and staff for record-keeping and program coordination. Larger staff teams are required for zinc chloride smoke and fluorometric dye testing or television camera inspection.

Establish Timetable for Implementation

The municipality should establish a timetable for implementation of the program. This timetable should clearly indicate the activities to undertake each year.

Most Phase I municipalities typically spent the first year identifying the priority areas, conducting field inspections of outfalls and manholes to rule out areas that did not require inspection and monitoring under this program, and training its personnel in important aspects of the illicit connection/discharge program. Some municipalities have then proceeded to check the entire city for illicit connections, while others have focused on the older and/or industrial and commercial areas and have found at the end of about 2 years that further investigations of illicit connec-

tions are not necessary. The latter group of municipalities have after that point focused their efforts on elimination of illegal discharges through visual monitoring by municipal personnel.

Train Personnel in Inspections

The following types of training are necessary:

- ✓ Procedural training (outfall/manhole inspections, sampling, record keeping, etc.)
- ✓ Occupational Safety and Health Administration (OSHA)-required Health and Safety training
- ✓ OSHA Confined Space Entry training

Program Evaluation And Documentation

Establish Measurable Goals

Your URP should include measurable goals for BMPs or control programs. These goals are useful for checking progress made each year as well as demonstrating the efforts made to reduce pollutants to the maximum extent possible. The municipality may consider some of the following goals for inclusion in its program;

- ✓ Establish percent total area of the city that will be checked each year for illicit connections, with the ultimate objective of checking the entire city or all areas of concern.
- ✓ For areas in the city known for dumping, establish a goal to conduct inspections at a fixed frequency.
- ✓ Establish a goal to eliminate documented or confirmed illicit connections within a specified period of time.
- ✓ Establish a goal to reduce incidents of illicit discharges by 25, 50, and 100 percent by certain years.

Documentation and Annual Reporting

The municipality should also develop forms or a format for reporting on this program in an annual report. Information that should be reported includes progress made relative to the measurable goals; the number of cases of illicit connections detected, eliminated, or status towards elimination; and the number of cases of illicit discharges detected, investigated and actions taken to rectify the problem. Sample forms are included in Appendix 4I.

Sources of Additional Information

Additional information on this program can be found in the following publications:

U.S. Environmental Protection Agency (EPA). 1992. Manual of Practice - Identification of Illicit Connections. EPA 833/R-90-100.

U.S. Environmental Protection Agency (EPA). 1993. Investigation of Inappropriate Pollutant Entries into Storm Drainage Systems - A User's Guide. EPA 600/R-92-238.

City of Stockton. Municipal Storm Water Discharge Management Program.

Storm Water Quality Task Force. 1993. California Storm Water Best Management Practice Handbook - Municipal. Available from BPS Reprographic Services, 1700 Jefferson Street, Oakland. (510) 287-5485.

4.4 Model Municipal Operations Pollution Prevention Program

Significant amounts of urban pollutants are associated with street and road surfaces resulting from pavement and vehicle wear, atmospheric deposition, and littering. Hydrocarbons, copper, and other heavy metals are deposited on roads from clutch and brake wear, vehicle exhaust, and leaking motor fluids. Road surfaces abrade and add particulates to the runoff. Litter and trash are pollutants in urban runoff. In areas that have snow, deicing materials can add pollutants to the runoff. Similarly, public sidewalks, plazas, parking lots, parks, and corporation yards are some of the other areas from where pollutants are swept into storm drains by runoff.

To address these sources, your URP needs to include a control program focused on municipal operations. NPDES Phase II regulations also require the owner or operator (of a regulated, small municipal separate storm sewer system) to develop and implement a cost-effective operation and maintenance program with the ultimate goal of preventing and reducing pollutant runoff from municipal operations. Municipal operations of concern include parks and open-space maintenance, fleet maintenance, planning, building oversight, and storm water system maintenance.

Under such a program, the operator is encouraged to develop BMPs for maintenance activities; schedules and inspection procedures for structural storm water controls; controls for reducing discharge of pollutants from streets, roads, municipal parking lots, storage and maintenance yards, and waste stations; procedures for disposal of wastes removed from the system; and ways to ensure that new flood management projects assess impacts on water quality.

Objective of the Program

The objective of this program should be to:

- ✓ Identify, develop, and implement BMPs/good housekeeping procedures to address urban runoff pollution associated with municipal operations.

The information that follows outlines the specific actions or tasks that a community will need to undertake to meet these objectives. It should be noted that this section focuses only on best management practices that the municipality can incorporate into its municipal functions and operations. Many of the pollutants in urban areas can be controlled through education and outreach of the residents and businesses. These strategies are discussed in the Public Education and Outreach Program (Section 4.2) of this guide.

Elements of a Municipal Operations Control Program

Street Sweeping and Cleaning

Most municipalities conduct street sweeping for aesthetic, safety, and public health reasons and, therefore, have a street-sweeping program in place. Several improvements can be made to the municipality's street-sweeping program to achieve better pollutant reduction in runoff from streets:

- ✓ Increase street-sweeping frequency in areas most prone to litter and dust/dirt accumulation.
- ✓ Time street sweeping to improve pollutant removal efficiency (sweeping before the onset of wet weather).
- ✓ Replace aging and ineffective street sweepers with technologically advanced equipment that is able to pick up finer particulates.
- ✓ Improve signage and dissemination of street sweeping schedules to ensure that curbs are cleared before sweeping takes place (i.e., parked vehicles are removed).

If the municipality uses contract sweeping, make sure the contractor maintains the equipment, and the operator provides feedback on key issues.

Good housekeeping practices that can be incorporated into the municipality's street sweeping program are listed in Appendix 4J, BMPs/Good Housekeeping Practices for Municipal Operations. A municipality can use this guidance to develop its improved street-sweeping program. Appendix 4K presents an evaluation of available street sweepers for the municipality's use if it decides to replace street-sweeping equipment.

Sidewalks, Plazas, and Municipal Parking Lot Cleaning

Like streets, the pollutants on sidewalks, plazas, and parking lots are associated with litter and vehicle use. Good housekeeping practices that can be incorporated into the municipality's existing cleanup program for these areas are listed in Appendix 4J.

Medians and Other Municipal Landscaped Areas

The primary pollutants of concern from medians and other landscaped areas, including municipal golf courses, are sediment from erosion, nutrients from fertilizer use and organic matter (grass clippings and leaves), and heavy metals and toxic organics from pesticide/herbicide use. Fertilizers applied in excessive amounts could run off with irrigation. Pesticides used in parks and around structures could run off into storm drains and streams. Litter and illegal dumping are also problems in parks. Good housekeeping practices that will help reduce urban runoff pollution can be incorporated into the municipality's existing maintenance program for medians, landscaped areas, and parks (see Appendix 4J). For additional

information pertaining to golf courses (municipal and privately owned), refer to *Environmental Principles for Golf Courses in the United States*, developed by the Center for Resource Management, and *Environmental/Design Guidelines for Standard Development Requirements for Golf Courses,* prepared by the Santa Clara County Planning Office.

In most municipalities, these maintenance functions are performed by the Department of Parks and Recreation and by Streets Maintenance Divisions, although a recent study shows that pesticide use decisions are made by several other departments including utilities, real estate, and maintenance managers of the city hall or community center. Training should include everyone in your municipality who makes these types of decisions.

Storm Drain Inlet/Catch Basin and Line Cleaning

Implement a program to clean storm drain inlets before the onset of rains

A variety of urban pollutants can be carried into and accumulate in storm drain facilities. Often the season's first heavy storm flushes out large amounts of pollutants into the receiving waters resulting in adverse effects on aquatic life and water quality. Many municipalities clean out storm drain inlets and catch basins before the onset of the wet season mainly to ensure that storm water can flow into the inlets and flooding of streets and adjacent properties is avoided or at least minimized. A storm drain inspection and cleaning program can be effective in reducing pollutants discharged to receiving waters.

Appendix 4J lists good housekeeping practices that the municipality should incorporate in its storm drain system maintenance program for water quality protection. This table only lists practices associated with the cleaning of these facilities. Note that illicit connections are another major source of pollutants in storm drains and are addressed in the illicit connection/discharge program (Section 4.3).

Corporation Yard and Other Municipal Operation Areas

Due to the nature of activities conducted at corporation yards and other municipal operation areas, pollutants could be released into runoff.

To address these sources, the municipality should:

- ✓ Examine existing conditions at its corporation yard, transit yard, fueling station(s), or other such areas to determine the need for improving the opera-

tion and maintenance of existing controls, and also providing additional controls. Table 4-3 lists typical urban runoff pollutant sources at corporation yards and similar facilities.

- ✓ If potential pollutant sources are noted, either implement practices to address each source or a plan to address all sources at the site.
- ✓ Given the diverse sources of pollutants from such sites, possibly elect to develop and implement a site-specific Storm Water Pollution Prevention Plan (SWPPP). A generic SWPPP is presented in Appendix 4L to assist the municipality in preparing a SWPPP.
- ✓ Alternately, select and implement controls listed in BMPs for Vehicle Service Facilities (Appendix 4W) at its corporation yard and other similar facilities.

Table 4-3. Typical Sources/Activities at Corporation Yards that Contribute to Urban Runoff Pollution

Source/Activity	Urban Runoff Concern
Vehicle Washing, Equipment Cleaning, and Auto Steam Cleaning	Discharge of washwaters to storm drain
Changing Auto Fluids	Spills of fluids, especially in outdoor and uncovered areas
Parked Vehicles and Equipment	Fuel leaks and drips in outdoor areas
Vehicle Fueling	Fuel spills during fueling in outdoor/uncovered areas
Outdoor Waste/Materials Storage	Release/spill of stored materials in uncovered areas with no secondary containment
Illicit Connections	Floor drains from work areas and covered areas discharging to storm drains
Handling of Materials from Street Sweeping	Release of dust, sediments, dirt, and other trash during unloading/cleaning of sweeping equipment
Unpaved/Uncompacted Surfaces	Release of dust and sediment due to vehicle movement across such surfaces

Municipal Swimming Pools, Fountains, Lakes, and Other Water Bodies

Chemical algaecides can result in pollution of urban waters

The primary pollutant of concern in municipal (and privately owned) swimming pool water is chlorine or chloramine used as a disinfectant. This water, if discharged to the storm drain system, will be toxic to aquatic life. In lakes, lagoons, and fountains, the pollutants of concern are chemical algaecides that are

added to control algae mainly for aesthetic reasons (visual and odor). BMPs that can be implemented to control this form of pollution are listed in Appendix 4J.

Repair and Maintenance of City Surfaces (Streets, Roads, Sidewalks, etc.)

Activities to repair and replace pavement surfaces can lead to urban runoff pollution. Pollutants of concern are broken-up asphalt and concrete debris, saw-cutting slurry of concrete and asphalt concrete, concrete truck washout, sediment, fuel, oil and other fluids from construction equipment. Urban runoff pollution can also result from other municipal activities that include removing graffiti and building cleaning (e.g., power washing, sand blasting). BMPs to control pollution of runoff from these activities are listed in Appendix 4J.

Most municipalities contract out street repair and paving. Therefore, these measures should be included in the municipality's standard contract for such services and in the specifications of the individual paving/repair project. Training should be held for any city maintenance personnel involved with this type of work. Some minor repair work (typically patching of pot holes) is conducted by the municipality's maintenance personnel; therefore, these measures should also be explained to the municipality's maintenance crews through a training program.

Structural Retrofit of Storm Drain Facilities

Most of the control measures discussed in the sections above are BMPs and good housekeeping procedures to prevent pollutants from being released into receiving waters. If you are undertaking improvements to your storm drain facilities for other reasons (such as flood control), you should utilize this opportunity to incorporate structural controls where appropriate. Before implementing structural controls, the municipality should:

- ✓ Examine its storm drain facilities and identify the need to retrofit. One way to do so is through field observation of inlets and catch basins in problem areas. Inspect to see where certain types of pollutants are commonly observed in the inlets and sumps. Pollutants can generally be classified in terms of (1) trash and litter, (2) oil and grease, and (3) dirt and sediment. Track these inlets for a number of months and if a pattern to the accumulation of these pollutants develops, consider retrofitting.
- ✓ Once these locations and the type of pollutant typically seen have been identified, check with other municipalities or the NPDES permit authority about available retrofit devices to identify types that address the pollutant.
- ✓ Examine existing conditions at such locations. Factors to consider include area available to construct the device, existing drainage system, characteristics, hydrology, land ownership, access for maintenance, etc.
- ✓ If construction is feasible, install the device in a few test locations and monitor success before using it at other potential locations in the municipality.

Program Implementation

The following guidelines should be used to set up this program.

Identify Responsible Departments and Personnel Requirements

Many of the good housekeeping practices for municipal operations are improvements to existing municipal activities/functions; therefore, the departments currently responsible for those activities could continue in those roles. If no municipal program exists for storm drain system inspection and cleaning (note that most municipalities clean storm drains only as needed), then identify a department and assign this task to it. Table 4-4 lists the manner in which many of the NPDES Phase I California municipalities have assigned BMP implementation for municipal operations, which can be used by the municipality to assign roles/functions.

The responsible department should:

- ✓ Examine the BMP list of its area of responsibility in Appendix 4J and select the practices to implement.
- ✓ Incorporate the selected BMPs into the municipality's standard operating procedures for that activity/area of responsibility, and appropriately document so that all involved employees then consistently implement the BMPs.

Establish Timetable for Implementation

The municipality should establish a timetable for implementation of the program. This timetable should clearly indicate the activities to undertake each year, depending on the resources (personnel and funding) available to the municipality to implement the improvements. For instance, in the first year the municipality may only increase the frequency of street sweeping and increase the enforcement of its

Table 4-4. Elements of Municipal Operations Program by Responsible Department

Element/Activity	Responsible Department
Street Sweeping and Cleaning	Public Works Street Maintenance
Sidewalks, Plazas, and Municipal Parking Lot Cleaning	Public Works Street Maintenance; Parks and Recreation
Medians, Other Landscaped Areas, and Golf Courses	Public Works; Parks and Recreation
Storm Drain Inlet/Catch Basin Cleaning	Public Works; Street and Sewer Maintenance
Corporation Yard and Other Municipal Operations Areas	Public Works; Fleet Maintenance
Swimming Pools, Fountains, Lakes, and Other Water Bodies	Parks and Recreation; Community Services
Repair and Maintenance of City Surfaces	Public Works Construction Division; Street Maintenance
Structural Retrofit of Storm Drain Facilities	Public Works Design/Construction Divisions

parking restrictions program. It may decide to replace street-sweeping equipment at a later date or closer to the end of the useful life of its existing equipment. Specific guidance on the schedule cannot be provided in this guide because conditions in each municipality will differ.

Train Personnel

The following types of training are useful for the success of this program:

- ✓ Training of street-sweeping equipment operators
- ✓ Training of street maintenance crews (tree trimming, median work)
- ✓ Training of park maintenance crews
- ✓ Training of municipality's construction crews (minor street repair)

Program Evaluation And Documentation

Establish Measurable Goals

Your URP should include measurable goals for BMPs or control programs. These goals would be useful for checking progress made each year as well as demonstrating the efforts made to reduce pollutants to the maximum extent possible. The municipality may consider some of the following goals for inclusion in its program:

- ✓ Establish percent of streets to be swept and at what frequency under the municipality's street-sweeping program.
- ✓ Establish percent of streets to be swept prior to the first major storm of the wet-weather season (or before October 1 of each year).
- ✓ Establish goal of inspecting and, where necessary, cleaning all catch basins and storm drain inlets once before the onset of the wet season (before October 1 of each year).

Documentation and Annual Reporting

The municipality should develop forms for record keeping and reporting on this program in an annual report. Information that should be reported includes progress made relative to the measurable goals. Sample forms that can be used by the municipality are provided in Appendix 4M.

Sources of Additional Information

Additional information about environmental guidelines for golf courses can be found in the following publications:

The Center for Resource Management. 1996. Environmental Principles for Golf Courses in the United States.

Santa Clara County Planning Office. 1996. Environmental/Design Guidelines and Standard Development Requirements for Golf Courses. July 23.

4.5 Model Construction Site Runoff Control Program

Erosion is the primary source of pollution at most construction sites

In the absence of proper management, construction sites can release significant amounts of sediment into storm water and eventually into the municipality's storm drain system. Activities conducted at construction sites (storage and handling of construction materials, hazardous materials storage and handling, and fueling, use, and cleanup of vehicles and equipment) can also release other pollutants to the storm drain system. An increase in compaction and impervious surfaces at construction sites can cause an increase in volume of surface runoff and increase peak flows which can cause erosion and other changes in stream hydrology and morphology.

Objective of the Program

The objective of this program should be to:

- ✓ Develop a control program to reduce the potential for discharge of pollutants into urban runoff from construction sites.

The following information outlines the specific actions or tasks that a municipality will need to undertake to develop a construction site discharge control program. Note that long-term post-construction controls for new development/redevelopment projects are discussed in Section 4.6.

All construction sites (regardless of location) that are 5 or more acres in size are covered by Phase I NPDES Construction Site General Permits. NPDES Phase II regulations discuss the use of a General Permit to control discharges from sites that are greater than 1 but less than 5 acres. The exact form of this permit process (whether similar to a Phase I General Permit or not) is unknown at this time. This guide assumes that all sites greater than 1 acre will be subject to the General Permit requirements of the RWQCBs. The control program that follows describes the actions a municipality should take to control discharge of pollutants from sites that are greater than 1 acre, and also from sites that are less than 1 acre, so that construction activities within the municipality do not result in urban runoff impacts.

Elements of a Construction Site Runoff Control Program

Review and Revise Existing Grading Ordinance

As a first step, if you do not have a grading ordinance, consider adopting a construction site control ordinance. If you have a grading ordinance, review and revise it to address the following guiding principles:

- ✓ Use of good site planning
- ✓ Minimization of soil movement
- ✓ Capture of sediment to the greatest extent possible
- ✓ Good housekeeping practices
- ✓ Minimization of impacts of postconstruction storm water discharges.

Since the grading ordinance is the basis of the municipality's grading permit, it is essential that it includes provisions consistent with these five guiding principles. The grading ordinance carries out the General Plan/LCP policies that you have put in place to protect water quality.

Most grading ordinances address minimization of soil movement and capturing of sediments. In some municipalities that have flooding problems, the grading ordinance may contain a requirement that site storm water discharge volumes and peak flows should not exceed preconstruction levels. Generally, the other three principles, i.e., site planning, good housekeeping practices, and minimization of postconstruction storm water discharges, are typically not addressed in grading ordinances. The municipality's construction site ordinance should note that the municipality requires all construction projects to implement BMPs that address the five guiding principles. To assist the municipality in revising its grading ordinance, a model construction site ordinance that incorporates the five guiding principles is attached to this guide (Appendix 4N).

Prepare Construction Community Outreach/Information Materials

The municipality should provide materials to the development/construction community to consider when they are planning their projects or filing for permits. These informational materials should focus on the five guiding principles and should include practical, cost-effective measures that can be incorporated into the project to reduce the potential for urban runoff impacts.

The following materials are recommended for development and use in the construction site permit process:

- ✓ A handout/brochure that explains the construction site permit process for sites 1 acre and greater, and for sites less than 1 acre (See sample brochure for construction sites 5 acres or more in Appendix 4O)

- ✓ A handout explaining the five guiding principles for controlling runoff from construction sites: construction site planning, minimization of soil movement, capturing of sediment, good housekeeping practices, and minimization of postconstruction discharges.

Storm drain inlets can be protected using sandbags and filter fabric over the inlet

- ✓ A handout on good housekeeping practices for all construction sites regardless of size
- ✓ A handout on BMPs for small (less than 1 acre) sites, including the following:
  - Information on good housekeeping practices
  - Information on storm drain protection (to control construction site pollutants from entering storm drains)

BMPs for construction sites, organized by the five guiding principles, are listed in Appendix 4P, BMPs for Construction Sites. Existing documents that provide detailed information on these BMPs are cited in that guidance.

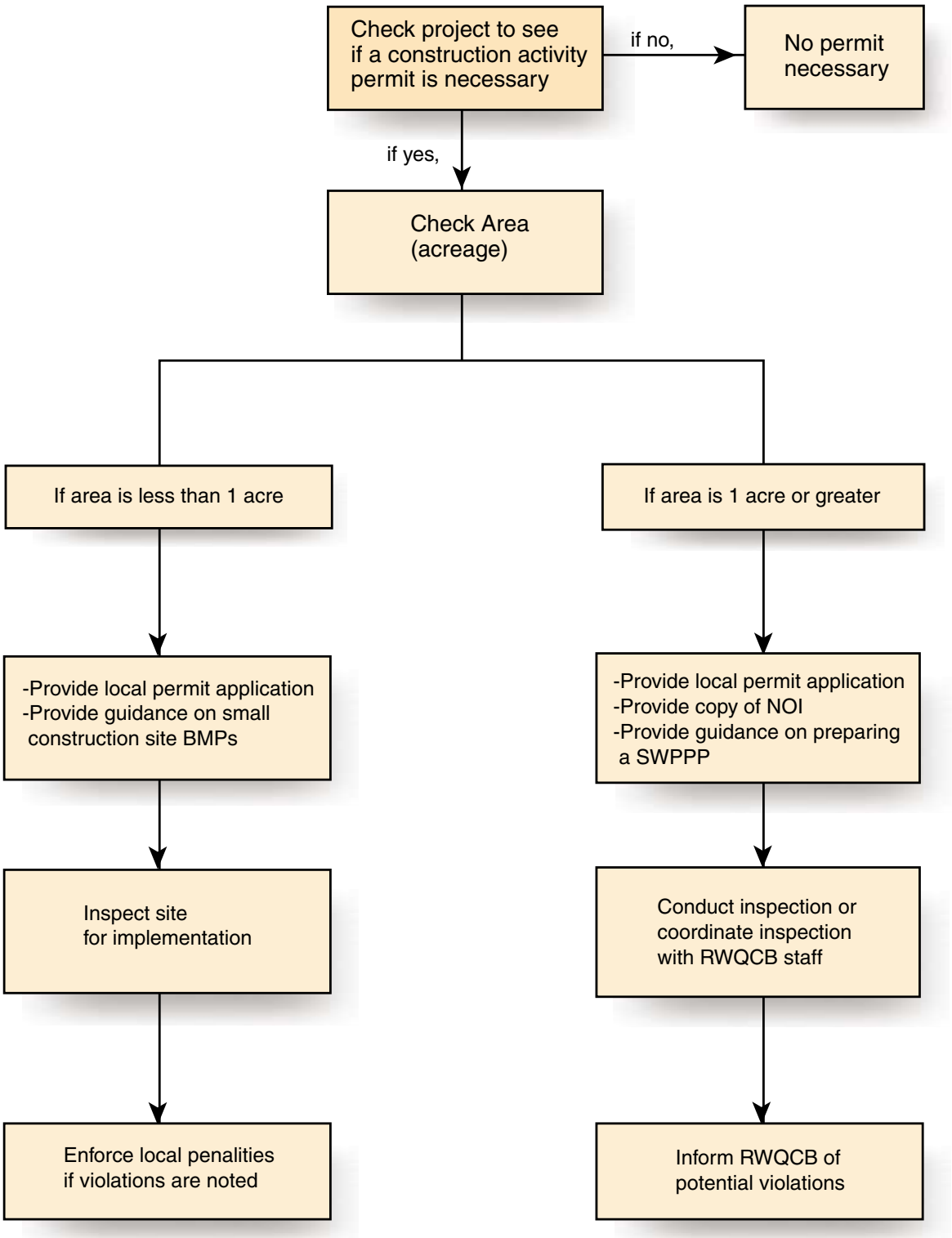
Review and Revise Plan Review Process

The municipality's project review process needs to be revised to ensure it addresses urban runoff issues. Figure 4-2 shows the steps involved in a review process.

- ✓ As a first step, check if the size of the project is less or more than 1 acre. Projects less than 1 acre will continue to be subject to the current permit processes, or appropriate local state and/or federal authorities (this may include the California Coastal Commission, Department of Fish and Game, U.S. Army Corps of Engineers, or others). Those projects 1 acre or more will need to be covered by a general permit for construction activity storm water discharges from the SWRCB/RWQCB in addition to existing permit processes.

Construction site controls can include silt fences, hay bale barriers, and erosion control blankets

Figure 4-2. Construction Project Review Process



Sites 1 Acre or More in Size

- ✓ For sites 1 acre or greater, inform applicants of the various permits. Specifically, provide information about the NPDES permit requirements, including the NOI filing process and the need to develop a construction site SWPPP. Keep blank copies of the NOI form at the Public Works/Community Development department counters. Inform applicants that the requirements of both permits are the same, i.e, a SWPPP is needed for both permits.
- ✓ Provide applicants with guidance on preparing a construction site SWPPP (this guidance is included in Appendix 4Q and a Model Construction Site SWPPP is presented in Appendix 4R). Also provide applicants with brochures and materials on BMPs for construction sites. Coordinate site inspections with the RWQCB staff. Develop standard operating procedures and checklists to assist inspectors in conducting inspections.
- ✓ Leave enforcement authority unchanged, i.e., the RWQCB to enforce per its permit process in case violations are noted during inspections.

Sites Less than 1 Acre

- ✓ Inform the applicant of the local permit process, and provide brochures and materials on BMPs for construction sites.
- ✓ Conduct site inspections during and after construction. Use municipality's standard operating procedures and checklist for inspections.
- ✓ Enforce if violations are noted.

Program Implementation

The following guidelines should be used to set up this program.

Identify Responsible Departments and Personnel Requirements

Since the issuance of grading permits in most municipalities is the responsibility of Public Works or Community Development departments, the construction site runoff control program should be assigned to them.

Personnel needed to implement this program include plan review staff trained to inform the applicant about the permitting process and to review site plans, and site inspectors to inspect sites for the implementation and maintenance of BMPs during and after construction.

Establish Timetable for Implementation

The municipality should establish a timetable for implementation of the program. This timetable should clearly indicate the activities to undertake each year, depending on the resources (personnel and funding) available to the municipality to implement the program.

Train Personnel

The following types of training are important for the success of this program.

- ✓ Training of plan check staff
- ✓ Training of site inspectors
- ✓ Training of developer/contractor staff
- ✓ Training of municipal personnel (i.e., construction division) for city projects

Program Evaluation and Documentation

Establish Measurable Goals

Your URP should include measurable goals for BMPs or control programs. These goals would be useful for checking progress made each year as well as demonstrating the efforts made to reduce pollutants to the maximum extent possible. The municipality may consider some of the following goals for inclusion in its construction site control program:

- ✓ Achieve 100 percent compliance with local and SWRCB's construction site runoff control programs (all construction projects are covered by either a current, up-to-date SWPPP or controls to reduce storm water pollution).
- ✓ Achieve zero complaints from the public regarding hydrological and water quality impacts from construction sites.
- ✓ Achieve full compliance with inspection checklists (i.e., inspection checklists show that all construction sites are implementing BMPs and meeting permit requirements).

Documentation and Annual Reporting

The municipality should develop forms for record keeping and reporting on this program in an annual report. Information that should be reported should include progress made relative to the measurable goals. Forms that can be used by the municipality are provided in Appendix 4S.

Challenges encountered by Phase I Programs in Implementing Construction Site Control Programs

- ✓ **Lack of support of municipal staff from managers**
- ✓ **Communications/coordination among municipal staff and departments**
- ✓ **Communications/coordination among local agencies and regional board staff**
- ✓ **Improper application, installation, and maintenance of BMPs**
- ✓ **Outreach to small developers and contractors**

4.6 Model New Development/Redevelopment Runoff Control Program

Primarily two concerns are associated with new development and significant redevelopment. As communities are progressively built out, impervious surfaces replace natural topography, and storm water peak flows and volume increase, resulting in changes to stream morphology. Secondly, new urban areas add to the urban runoff pollutant loads by creating new sources. Numerous studies show that controlling pollutants after they have entered the storm drain system is far more difficult and expensive than preventing or reducing the discharge at the source. If areas of the municipality proposed for new development or redevelopment are planned, designed, and constructed in a manner that is sensitive to issues of quantity and quality of urban runoff, then future pollutant loads from these areas will be reduced.

The NPDES Phase II regulations also require that the owners or operators of small municipal separate storm sewer systems develop, implement, and enforce a program to address storm water runoff from new development and redevelopment projects. The program should use site-specific and cost-effective structural and nonstructural BMPs as appropriate. The program should ensure adequate long-term operation and maintenance of BMPs through inspection and enforcement programs. CZARA and NPDES Phase II regulations recommend that municipalities utilize BMPs that attempt to maintain predevelopment runoff conditions, including water quality and quantity.

Objective of the Program

The objective of this program should be to:

- ✓ Reduce the potential for discharge of pollutants into urban runoff from new development and redevelopment areas using a strategy that combines reducing/eliminating sources of pollutants, managing site runoff volumes and flow rates such that they are similar to preconstruction levels, and treating runoff as appropriate.

The following information outlines the specific actions or tasks that a municipality will need to undertake to develop this program.

Elements of a New Development/Redevelopment Urban Runoff Control Program

New development/redevelopment urban runoff issues can be addressed at various levels: at the municipal/regional/watershed level or at the individual project level. Land-use planning at the municipal level can control the amount of impervious surfaces or pollutant sources added to a community. This can be accomplished by acquiring land and placing a conservation easement on it or developing it into

public parks or open space, designing the community to reduce reliance on vehicles, or avoiding areas susceptible to erosion and sediment loss through zoning restrictions. Those types of regional/municipality-level measures and controls are not the focus of this MURP guide, rather this guide focuses on project-level controls.

A program to control flow and water quality from new development/redevelopment projects may include a variety of elements that are intended to form an integrated program: general plan/LCP policies, ordinances, development review procedures, outreach, and BMP selection.

Adopt Policies/Ordinance Related to Impervious Area Reduction, Pollutant Source Control, and Treatment Controls

A new development/redevelopment urban runoff control program involves adoption of policies through General Plan/LCP amendment, or an ordinance for requiring new development/redevelopment to address urban runoff quantity and quality issues during project planning and implementation, or a combination of the two. Regardless of whether the preferred option is General Plan/LCP amendments or an ordinance, the adopted document should clearly state that the municipality may require a new development or a redevelopment project to:

- ✓ Minimize impervious area
- ✓ Control pollutants by eliminating or reducing potential new sources
- ✓ Install treatment controls, as appropriate to the site
- ✓ Participate in the funding of regional/municipality-level BMPs in accordance with a regional/municipality-level plan

Note that a municipality may choose to do both, i.e., amend the General Plan/LCP as well as adopt an ordinance for this purpose.

Conduct Outreach and Prepare Informational/Outreach Materials for the Development Community

Urban runoff controls that address runoff quantity include minimization of impervious surfaces, maximization of infiltration, and on-site storm water detention. Urban runoff controls that address urban runoff quality require design changes that eliminate potential pollutant sources and structural controls to detain, retain, and/or treat urban runoff from a site. These postconstruction controls can impose costs on new development/redevelopment, and many controls generally impose maintenance costs and requirements (controls do not work if they are not maintained). Structural control measures require ongoing inspection and maintenance and the municipality must provide or ensure that those important elements of a BMP are addressed during the development review and approval process. As a result, before a municipality develops and adopts a new development/redevelopment urban

runoff control program, it should work with the development community (e.g., developers and construction contractors) to arrive at postconstruction controls that are cost-effective, feasible in the local setting, and can be maintained.

Grassy areas can be included in parking lot design to filter runoff

Potential postconstruction controls are listed in Post-Construction Controls for New Development/Redevelopment (Appendix 4T). Postconstruction controls can be classified into three types: **site planning measures** that avoid or reduce disturbance of sensitive areas and limit addition of impervious surfaces, **pollution prevention/source control measures** that reduce or eliminate potential future sources of pollutants, and **treatment control measures** that treat polluted runoff from new development/redevelopment sites. The guidance presents the pros and cons associated with these controls, and provides suggestions that the municipality may use in selecting postconstruction controls for implementation. This guidance may be used in discussions with the development community and to prepare handouts and informational materials for developers/applicants.

Revise Development Review Procedures

The permitting process provides the municipality the opportunity to review a new development or redevelopment project during its planning stage and to direct its design and development in regards to urban runoff issues.

Projects in California communities require approvals from the local jurisdiction in which they are proposed. Approvals fall into two groups: discretionary and administrative/ministerial. Discretionary approvals typically include subdivision or tentative map approval, use permit, conditional use permit, or design review. Administrative or ministerial permits generally include building, grading, well, and septic system permits. Discretionary approvals trigger CEQA compliance whereas (ministerial) permits are categorically exempt under CEQA. Both private and public projects are handled in a similar manner in most communities.

Almost all projects except minor infill development require discretionary approval from the local jurisdiction. This discretionary approval process is commonly the design review process, although other discretionary approvals such as a use permit or a subdivision map approval may also be triggered depending on the characteristics of the project.

Small improvement projects that conform with the site zoning requirements and include either a new single-family unit or minor modifications to an existing single-family unit or a single structure typically do not need a discretionary approval, but will in all cases need a ministerial permit – a building or a grading permit.

Given this manner of project approval in most California communities the municipality is recommended to consider revisions to its development review process for both types of projects, projects that are subject to discretionary approval and projects that require only ministerial permits, to ensure that all opportunities for improving the quality of urban runoff are addressed. Figure 4-3 shows the manner in which urban runoff concerns can be addressed by refining the municipality's permit process.

Changes to the Discretionary Approval Process

In general, this process applies to larger developments. Typically when parcels are large more opportunities exist to reduce or control pollutants in urban runoff from such developments. The following changes can be made to the approval process to protect urban runoff quality:

- ✓ If there is a pre-application meeting, the municipal permitting staff (often planning/public works counter staff) should inform the applicant of the municipality's General Plan/LCP policies/ordinance requirements regarding runoff quantity and quality, and provide guidance on potential design measures and postconstruction controls available for the type of project proposed by the applicant. Note that some Phase I municipalities have chosen to impose standard conditions on all new businesses. A sample from the City of Pittsburg is included in Appendix 4U.

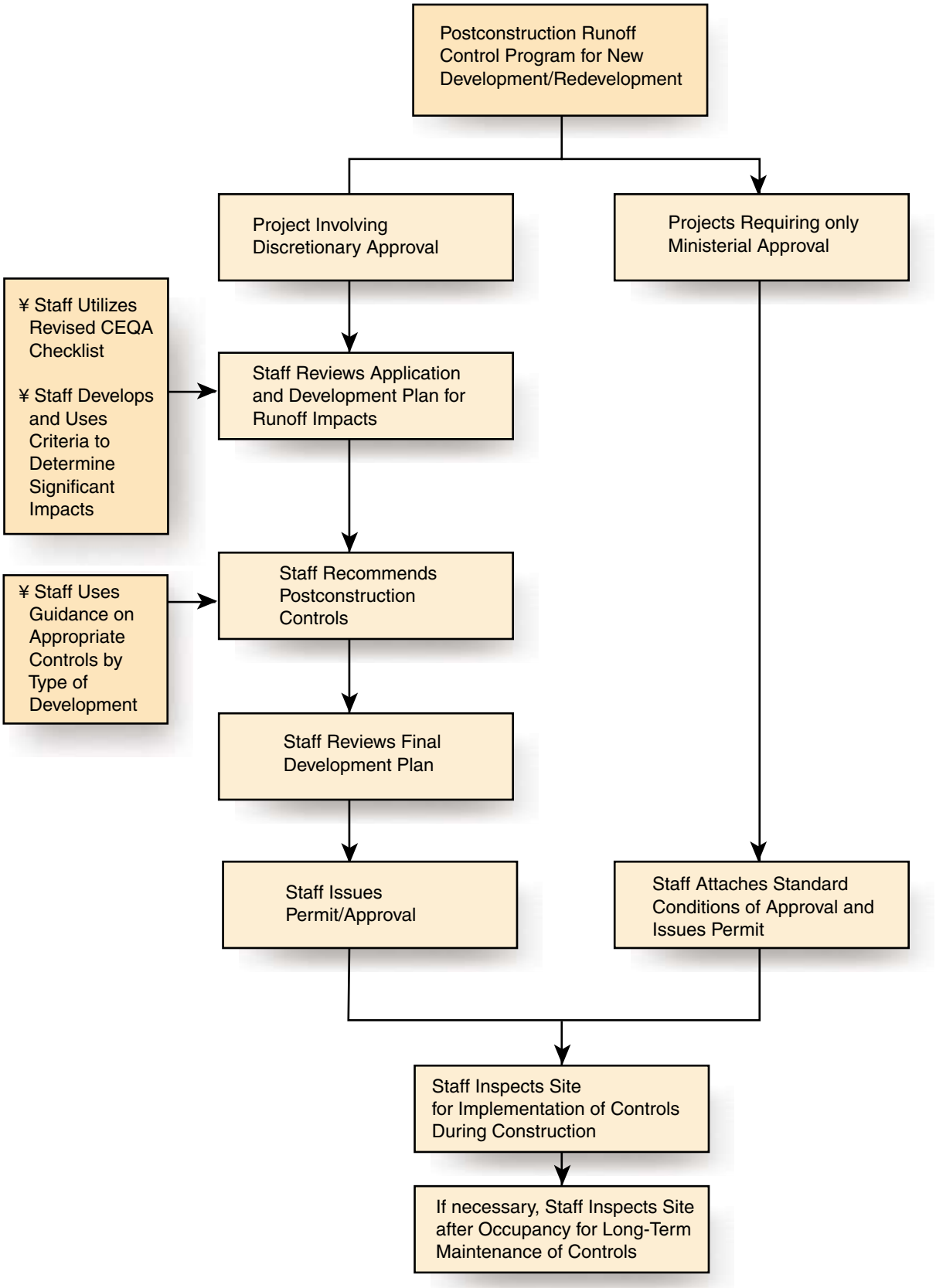
- ✓ Once an application is received, the staff should review the application for urban runoff issues. The staff should use a revised CEQA checklist to examine the project's potential to affect urban runoff quantity and quality (See Section 2.4 of this guide for CEQA checklist revisions). Note that for staff to review applications, the municipality should develop criteria to use in determining if controls are necessary for a project. The municipality also needs to provide training to its staff that reviews applications for discretionary approvals.

Train permitting staff to review plans for urban runoff issues

- ✓ If impacts are considered likely and the applicant has included postconstruction controls in the development plan, the staff should review them for appropriateness and adequacy. The municipality should develop guidance that the staff can use to evaluate adequacy of proposed controls.

  If appropriate postconstruction controls are not proposed by the applicant, the staff should inform the applicant of the municipality's requirements and pro-

Figure 4-3. Revised Project Approval Process



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vide guidance on potential controls or design changes. The municipality should develop guidance for staff to use in selecting and recommending site-specific changes and controls. Some of this information is in Appendix 4T, which the municipality may want to tailor to its own needs.

In some instances, on-site controls may not be possible. For such developments, the municipality should consider contribution by the developer towards the development of regional controls (such as detention basins or constructed wetlands).

- ✓ The municipality's Public Works/Engineering Department should be consulted during the review because many postconstruction runoff controls are engineered structures that are best reviewed by the city engineers to evaluate their impact on the downstream drainage system. In fact the municipality may consider a project review process (if it does not already do so) that routes all discretionary applications to key municipal departments for review and comment. If this practice is instituted, the Public Works/Engineering Department could be assigned the responsibility of reviewing proposed project design for postconstruction runoff controls to address urban runoff issues.

- ✓ As a final step, the municipal staff should review the final development plan for adequacy of postconstruction runoff controls. The plan must address the design, operation, and maintenance of these controls.

Changes to the Ministerial / Administrative Permit Process

As noted above, minor improvement projects not subject to the discretionary approval process nonetheless need an ministerial permit (building or grading permits). Note that most projects that fall in this category are minor improvement projects where inclusion of postconstruction runoff controls are generally difficult. Therefore a simple, standardized list of BMPs for such sites should be developed by the municipality and attached as conditions of approval to the building permit. Such a list is provided in Appendix 4T.

Inspection Program

All communities have existing inspection programs that involve inspection of a completed project by municipal building inspectors.

- ✓ List postconstruction runoff controls in the inspection checklist so that inspectors can make sure the urban runoff controls were implemented.
- ✓ Inspectors should also check the completed project to make sure no improper connections are made to the storm drain system that could discharge nonstorm water into the storm drain.

Long-Term Maintenance and Monitoring Program

One of the main problems with many new development runoff controls is the long-term operation and maintenance of postconstruction controls. The problem has many aspects:

- ✓ Most of the postconstruction runoff controls require maintenance and fail when maintenance is inadequate.
- ✓ Often the project is built by one entity and then occupied/owned by another entity. Ownership may change several times, and the maintenance procedures and responsibilities may not be passed down to subsequent owners.
- ✓ Occupants/owners may not wish to take on maintenance responsibilities or costs.
- ✓ Occupants/owners may be ignorant of the maintenance needs.

NPDES Phase II regulations note that if postconstruction runoff controls are recommended for new development/redevelopment, the municipality should put a mechanism in place to ensure that the controls are maintained in the long run.

This issue is still being examined in Phase I municipalities and at the state level. The municipality should track the progress made on this issue through its RWQCB. However, some guidance on this issue is provided below:

- ✓ At the time of the discretionary approvals issuance, the municipality should require the applicant to provide a clear explanation of who is to maintain the controls, the frequency at which the maintenance is to be conducted, and who is liable if maintenance is not done.
- ✓ To address the issue of the responsible party in the long run, the municipality may use some of the following ideas:
  - For projects involving multi-family residential units, a Planned Unit Development, or a master plan development, the maintenance of the controls can be ensured through covenants, conditions, and restrictions adopted for the development. Inform the developer that this requirement must be conveyed to the Home Owners Association/property owner when the project is handed over.
  - For commercial/industrial developments, the maintenance aspects can be ensured through conditions in lease agreements. Inform the developer that the lease agreements must note the maintenance requirements for postconstruction runoff controls at the site.
  - The most problematic developments are single-family residential developments where homes or lots are sold by the developer to individuals and maintenance functions cannot be assigned to any one entity. In such instances, the municipality may consider taking upon itself the maintenance of postconstruction runoff controls, and charging the property owners for the service provided through a user fee or an assessment (based on an assessment district).

- ✓ The municipality must also establish or expand any existing inspection programs to check whether the postconstruction runoff controls are being maintained. For industrial/commercial facilities, this inspection could be combined with the illicit connection/discharge program. For large residential developments, this inspection task could be assigned to the local flood control agency or department. Note that a municipality has the authority to place a lien on the property if it discovers that the postconstruction runoff controls are not being properly maintained.
- ✓ For public projects, maintenance of postconstruction runoff controls can be ensured by (1) establishing a maintenance and monitoring plan for each municipal project, (2) assigning the task to the department responsible for the general maintenance of the site, and (3) providing adequate funding.

Program Implementation

The following guidelines should be used to set up this program.

Identify Responsible Departments and Personnel Requirements

The department identified to handle this control program varies with the municipality. In some communities a specific department handles permitting. In other communities, planning department staff covers the counter for application filing for all projects, and if it is determined that the project does not need a discretionary approval, forwards the applicant to the building/public works counter for administrative/ministerial permits. Normally, inspections of the completed private projects are conducted by the building inspectors, and inspections of completed public projects are conducted by public works inspectors.

In its URP, the municipality should clearly identify the department to lead the implementation of this program. Also given that multiple departments may be involved in the project review and implementation, the municipality should convene regular meetings of staff from the relevant departments to seek feedback to improve the permit process and to ensure that all involved clearly understand their responsibilities under the URP.

Establish Timetable for Implementation

The municipality should establish a timetable for setting up the initial program. This timetable should clearly indicate the activities to undertake each year, depending on the resources (personnel and funding) available to the municipality to implement the improvements.

Train Personnel

The following types of training are important for the success of this program.

- ✓ Outreach and education of the development community
- ✓ Training of staff responsible for plan review and permit issuance
- ✓ Training of inspection staff

Program Evaluation and Documentation

Establish Measurable Goals

Your URP should include measurable goals for BMPs. These goals would be useful for checking progress made each year as well as demonstrating the efforts made to reduce pollutants to the maximum extent practicable. The municipality may consider some of the following goals for inclusion in its program:

- ✓ Include some postconstruction controls to address urban runoff concerns for all new development/redevelopment projects approved in the next fiscal year.
- ✓ Check all completed projects for implementation of structural runoff controls.
- ✓ Inspect all structural controls annually to ensure that maintenance is performed.

Documentation and Annual Reporting

The municipality should develop forms for record keeping and reporting on this program in an annual report. Information that should be reported includes progress made relative to the measurable goals. Forms that can be used by the municipality are provided in Appendix 4V.

Challenges encountered by Phase I Programs in Implementing New Development Runoff Control Programs

- ✓ **Local agency standards/specifications preclude implementation of many potential storm water quality controls**
- ✓ **Conflict between storm water quality controls and other agencies requirements**
- ✓ **Effectiveness/cost/maintenance of treatment controls**
- ✓ **Lack of communication/coordination among municipal staff/departments**
- ✓ **Outreach to land-use decision makers**

4.7 Model Commercial Facilities Runoff Control Program (Optional Program)

Activities conducted at commercial facilities can contribute pollutants to urban runoff. Potentially significant sources of pollutants common to many commercial facilities are litter and improper disposal of wastes; outdoor waste and material storage areas; illicit connections; and parking lots that not only discharge auto-related pollutants to runoff but also, due to their impervious nature, increase the volume and rate of runoff.

Ten types of industrial/commercial activities are regulated under the Phase I general permit program. This program requires these industries to file a NOI to be covered by the General NPDES permit, prepare and implement a SWPPP, and establish a monitoring program for storm water discharges (see Section 4.8 of this guide). The NPDES Phase II regulations do not require small municipalities to regulate commercial or industrial facilities. The regulations note that the local permitting authority (RWQCB) has the discretion to regulate other industries or commercial facilities if some of the nonregulated facilities are considered a significant pollutant source in a particular watershed.

Some of the unregulated commercial facilities include gas stations

Some of the unregulated commercial facilities include gas stations, other vehicle service and repair shops, golf courses, restaurants, fast-foot establishments, lumber and building material stores, farm machinery and supplies, etc.

Objective of the Program

The objective of this program is to:

- ✓ Develop a program based on outreach and education to reduce the potential for discharge of pollutants into urban runoff from unregulated commercial facilities.

Specific tasks that a municipality may undertake to develop this program follow.

Elements of a Commercial Facilities Runoff Control Program

The municipality should consider the following steps in developing its urban runoff control program for commercial facilities.

Adopt Policies/Ordinance

Although MURP's emphasis is on voluntary implementation of BMPs by all types of businesses, it is in the municipality's interest to include in its Urban Runoff Ordinance a section that allows it to require BMP implementation by commercial facilities. The legal authority provided by the Ordinance can be used to visit commercial facilities, assist them in BMP implementation, and help them eliminate nonstorm water discharges and illicit connections. Note that the NPDES Phase II regulations do not require adoption of an ordinance to control commercial sources, although it would serve as one approach to implementing management measures that address commercial source with "enforceable authorities" as may be identified in the NCPCP.

Identify Commercial Facilities to be Targeted for Outreach

Outdoor storage areas at commercial facilities can be a source of urban runoff pollution

Every municipality has different types and concentrations of commercial businesses. Coastal and other resort towns and cities likely have numerous restaurants, fast-food establishments, hotels, motels, and gas stations. More rural communities may have a concentration of businesses that deal in farm and garden machinery rental and repair, farm supplies, lumber and building materials, agricultural chemicals, and small unregulated animal feedlots. The municipality should first identify the business sectors to target each year. The municipality is recommended to limit itself to one to two sectors each year, and once outreach to those sectors is complete, select the next sectors to target. (The businesses selected as target businesses for the next year should be taken before the City Council for public hearing during the Public Works Director's annual report to the Council on the URP.) Once business sectors for the next year are identified, obtain lists of the establishments in each targeted group. The municipal license department, Dunn and Bradstreet (commerical database provider), and local yellow pages are some sources from where these lists can be obtained. Table 4-5 below shows the commerical businesses that are potential pollutant sources and those that typically are not.

Develop an Outreach Program

The following steps are typical for establishing an outreach program:

- ✓ **Contact local Chamber of Commerce and other local business organization** and discuss the program; specifically the commercial facilities to target

Table 4-5. Common Commercial Businesses in Urban Areas

Commercial Businesses of Concern	Commercial Businesses Not of Concern
■ Automotive Repair Shops	■ Dry Cleaners
■ Gas Stations	■ Photo Development Stores
■ Restaurants and Fast-Food Chains	■ Copier Centers
■ Feed and Grain Stores	■ Furniture Stores
■ Home and Garden Stores	■ Hair Salons
■ Mobile Cleaners	■ Veterinary Clinics
	■ Paint Stores
	■ Pottery Studios

Note: Most commercial businesses do not have significant outdoors activities that could release pollutants to storm drains; the only common outdoor source are dumpsters and outdoor storage areas.

the types of BMPs recommended for implementation, and the municipality's approach (including periodic visits to the facilities by municipal staff to check on progress, and any incentive programs that the municipality may choose to put in place). Use feedback from the business community to identify BMPs and to develop a program acceptable to the business community and therefore a better chance of success.

✓ **Establish an Incentive Program.** Several Phase I communities have established Green Business programs that provide recognition to responsible businesses through green business stickers, or features on the business in the municipality's monthly/quarterly newsletter or other mailings. Note that a Green Business sticker can be issued only if the business is complying with all environmental laws and not just the URP. The effort to confirm that can be significant, and could impose a higher cost on the municipality's URP.

Work with your Chamber of Commerce to identify BMPs that will not place a big burden on businesses

A good incentive program is being implemented by the City of Palo Alto. Contact that city's URP for information on the incentives.

✓ **Prepare Outreach Materials For Targeted Businesses.** BMPs that address three types of common commercial facilities in most communities are presented in *BMPs for Vehicle Service Facilities, Food Service Facilities, and Shopping Centers* (Appendices 4W through 4Y). The municipality can use these materials to develop outreach materials. Alternately, brochures and handouts prepared by Phase I municipalities can be obtained by contacting the Phase I programs.

- ✓ **Establish a Mechanism for Distribution of Outreach Materials,** which is specific to the municipality but could be through the Chamber of Commerce, direct mailings, distribution during permit/license application/renewal process, or distribution by municipal staff at public counters.
- ✓ **Establish a Frequency of Distribution** for follow-up mailings that describe how the program is doing.

Conduct Site Visits

Visit targeted businesses periodically to check on the status of BMP implementation. Use existing inspection programs and expand them to include urban runoff concerns.

- ✓ During these site visits (and through outreach materials) inform businesses that the first objective of the visit is to check how the BMPs are being implemented and to suggest improvements where possible; the second objective is to use the information gathered during the visit as a basis of awarding the business recognition under the Incentive Program (should the municipality choose to establish such a program). Inform businesses of the municipality's program for addressing urban runoff, and actions needed by the business.
- ✓ The municipality should decide how frequently to conduct site visits.
- ✓ The municipality should develop BMP checklist forms that inspectors/municipal staff can effectively use during site visits.

The City of Monterey adapted this model commercial facilities runoff control program to its local conditions and needs. The City decided that it would target a few selected businesses each year and included a provision in its Urban Runoff Ordinance that would allow the Public Works Director to identify target businesses for the upcoming fiscal years and a provision that would allow the City to adopt a BMP series for the targeted business sector. The BMP series would contain high-, medium-, and low-priority BMPs for the targeted business sector, with implementation of high-priority BMPs required by a certain date. The City plans to meet with the targeted sector and discuss the BMPs and their implementation schedule. It proposes to achieve BMP implementation through consultation and cooperation with the affected businesses (voluntary implementation of high-priority BMPs by a certain date). If businesses do not cooperate, the City would enforce the compliance procedures per its new urban runoff ordinance.

Program for Mobile Cleaners

Washwaters are some of the commonly observed non-storm water discharges to storm drains in urban areas. Mobile cleaners (surface cleaners who steam clean or pressure wash sidewalks, plazas, parking lots, driveways and building exteriors; janitorial service providers; window cleaners; carpet cleaners; and auto detailers) have been identified as a significant source of non-storm water discharges. Your

municipality likely has a number of businesses that provide these services. If you determine that washwaters are a significant problem in your community, you will need to develop a program that targets these types of businesses. A good program based on cooperation and education has been developed and used in the San Francisco Bay Area to address this source. That program is presented in Appendix 4Z. A list of BMPs to control discharges from mobile cleaning activities developed by the Cleaning Equipment Trade Association and endorsed by the San Francisco Bay Area RWQCB is also presented in Appendix 4Z. For more information on this sources and BMPs, contact the Bay Area Stormwater Management Agencies Association.

Program Implementation

The following guidelines should be used to set up this program.

Identify Responsible Departments and Personnel Requirements

A municipality's URP should clearly identify the department to lead this effort and the personnel to be involved in the program.

Establish Timetable for Implementation

The municipality should create a timetable that indicates the activities by year. The activity level varies depending on the resources (personnel and funding) available to implement the program.

Train Personnel

The following types of training are key to the success of this program:

- ✓ Outreach and education of the business community on the program and BMPs
- ✓ Training of inspection staff

Program Evaluation and Documentation

Establish Measurable Goals

Your URP should include measurable goals for BMPs or control programs. These goals would be useful for checking progress made each year as well as demonstrating the efforts made to reduce pollutants to the maximum extent practicable. The municipality may consider some of the following goals for inclusion in this effort.

- ✓ Some level of outreach/education (mailing, telephone contact, workshop, etc.) to all businesses (100 percent) in the targeted sector in the first year of this optional program.
- ✓ Site visits to all businesses (100 percent) in the targeted sector at least once in the second year of this optional program.

Documentation and Annual Reporting

The municipality should develop forms for record keeping and reporting on this program in an annual report, i.e., progress made relative to the measurable goals. Forms that can be used by the municipality are provided in Appendix 4AA.

4.8 Model Industrial Facilities Runoff Control Program (Optional Program)

Several activities at industrial facilities could release pollutants to the storm drain system, including industrial processes that are conducted outdoors, storage of materials, loading and unloading, etc.

The NPDES Phase II regulations do not identify industrial activities or facilities as specific pollutant sources that must be addressed through a focused control program. This is because selected industrial activities (based on Standard Industrial Classifications [SICs]) are regulated by the SWRCB and RWQCB under the Phase I General Permit program. This permitting program requires 10 types of industries to file a NOI to be covered by the General Industrial Activities Storm Water Permit (General Industrial Permit), and to prepare and implement a SWPPP and a storm water monitoring program. The 10 industrial categories are:

- ✓ Heavy manufacturing facilities
- ✓ Manufacturing facilities if materials are exposed to storm water
- ✓ Active and inactive mining and oil and gas facilities
- ✓ Recycling facilities
- ✓ Transportation facilities
- ✓ Facilities subject to the requirements of 40 CFR subchapter N
- ✓ Hazardous waste treatment, storage, or disposal facilities
- ✓ Landfill, land application sites, and open dumps
- ✓ Steam electric generating facilities
- ✓ Wastewater treatment plants with design flows greater than 1 million gallons per day

For specific information on the industries in each of the categories above, see Appendix 4BB.

Similar to Phase I regulations, the NPDES Phase II regulations note that if it is determined that a nondesignated industrial unit has the potential to cause an adverse impact on water quality, it may be designated for a NPDES permit. With respect to the unregulated industries, the regulations encourage the control of storm water discharges through self-initiated, voluntary BMPs (note that the unregulated industries are largely commercial businesses and are addressed under the commercial facilities control program [Section 4.7] of this guide). This approach would be consistent with implementation of management measures identified in the CNPCP.

The Concern

A municipality may choose not to establish a runoff control program for industries for two reasons. Firstly, the General Industrial Permit process administered by the

state is expected to address potential industrial sources, and secondly the municipality may not contain a large enough industrial sector to justify the establishment of an industrial facilities control program. However, if your municipality contains a large number of industrial facilities that have the SICs listed in Appendix 4BB, you may wish to develop a local control program for industries because:

- ✓ Several compliance problems have been noted with respect to industries regulated under the General Permit process. Many facilities have not filed a NOI or an individual permit application either because they are unaware of the requirement, or the assigned SIC does not accurately reflect the activities at the site that may impact water quality, or because they do not see repercussions from not filing due to lack of enforcement. Other industries have filed the NOI but not developed or implemented a SWPPP because of ignorance or lack of enforcement.
- ✓ Many industries are small and do not have the resources to track and comply with environmental regulations, and the municipality may wish to assist these industries by providing information and education.
- ✓ Many industries that have complied with the requirements are considered by regulatory agencies as being placed in unfair business practice compared with industries that have not complied.

Objective of the Program

Your objective should, therefore, be to:

- ✓ Develop a program to assist industrial facilities subject to the General Permit in complying with permit requirements.
- ✓ Make the playing field even for all affected industries in your municipality.

The following information outlines the specific actions or tasks that a municipality needs to undertake to meet this objective.

Elements of a Local Industrial Facilities Runoff Control Program

The following steps are involved in developing and implementing a runoff control program for industries.

Develop A Municipal Database of Industries

As a first step, develop a comprehensive list of industries in your community. Use Dunn and Bradstreet to develop this list, or contact your fire department, planning department, or wastewater treatment plant, which likely have their own lists.

Assign/Identify SIC Codes

If SICs are not already identified for the industrial facilities on the list, identify the codes using the *Standard Industrial Classification Manual* developed by the U.S. Office of Management and Budget (1997).

Obtain a List of NOI Filers from the RWQCB and Compare with Municipal List of Industrial Facilities

Obtain from the RWQCB a list of industries in your municipality that have filed NOIs. Compare with the municipal list of industrial facilities to check if all regulated facilities have filed NOIs. If discrepancies are noted, inform both the RWQCB and the industrial facility owners/operators.

Interview nonfilers to check for correctness of SICs. Since industrial facilities assign the SIC to themselves, the use of the wrong code may be responsible for the facility not being designated for a General Industrial permit.

Research in the Santa Clara Valley showed that many industrial facilities may not have filed for a permit because their SIC is not among the listed codes or does not accurately represent the activities conducted at the site (particularly an issue at large, more complex facilities).

Develop and Implement a Site Visit Program for All Regulated Industries

Within 1 year of setting up the municipality's industrial facilities runoff control program, conduct site visits at all regulated industrial sites. Coordinate with or assign the task to the municipality's or county's hazmat program or the wastewater treatment plant's pretreatment program (both programs involve inspections of industrial facilities). This site visit should focus on the following actions:

- ✓ Check to see if a SWPPP is in place and is being implemented. If no SWPPP is available and/or is not being implemented, inform owner/operator of potential violation and the need to rectify the situation.
- ✓ Provide guidance on appropriate BMPs for industrial sites. See Appendix 4CC, BMPs for Industrial Storm Water Pollution Control, developed by the Santa Clara Valley Urban Runoff Control Program (previously called Santa Clara Valley Nonpoint Source Pollution Control Program) and the *California Storm Water Best Management Practice Handbook - Industrial/Commercial* prepared by the Storm Water Quality Task Force.
- ✓ Develop and internal policy on whether the municipality should inform the RWQCB immediately or allow the operator/owner time to rectify the violation. If the owner/operator fails to bring the facility into compliance, inform the RWQCB.

- ✓ Use the first year's site visits to prioritize industries for follow-up site visits. For industries considered to be significant/critical sources, the municipality can establish a follow-up visit frequency of once a year or once every 2 years. For those considered noncritical sources, the municipality may establish lower frequencies for follow-up visits, or merely visit in response to complaints.

  The industrial composition of every municipality differs; therefore, the municipality is the best judge to determine the industries to classify as critical sources. However, some guidance can be obtained from a study conducted in 1997 for Los Angeles County. This study took into account factors such as presence of pollutant sources, the number of units in a given SIC code, etc., to rank the industrial groups as shown in Table 4-6. The municipality should evaluate its industries following the methodology used for the study. An appropriate list should be generated, following Table 4-6, by adding or deleting industries as appropriate.

Prepare General Information Materials for New Industries

If your municipality is anticipating significant industrial growth, prepare informational materials and maintain them at the permit counters for new facilities. This material should inform new industries of the General Industrial Permit process, and the municipality's own program for industrial facilities.

Program Implementation

The following guidelines should be used to set up this program.

Identify Responsible Department and Personnel Requirements

The municipality should identify the department to assigned this program to. In Phase I municipalities, this program has been assigned to the Fire/Hazmat department or to the wastewater department because these departments typically conduct inspections of industrial facilities.

Establish Timetable for Implementation

The municipality should establish a timetable for implementation of the program. This timetable should clearly indicate the activities it would undertake each year. A suggested timeline is completion of the municipal list of industries and cross-checking with the NOI list in the first year and commencing site visits of all regulated industries or the more critical sources in the second year.

Table 4-6. Results of Ranking of Candidate Critical Sources in Los Angeles County

Ranking Based on Pollution Potential	Industrial Category	SIC
1	Wholesale Trade (scrap, auto dismantling)	50
2	Automotive Repair/Parking	75*
3	Fabricated Metal Products	34
4	Motor Freight	42
5	Chemical Manufacturing	28
6	Automotive Dealers/Gas Stations	55*
7	Primary Metals Products	33
8	Electric/Gas/Sanitary	49*
9	Air Transportation	45
10	Rubbers/Miscellaneous Plastics	30
11	Local/Suburban Transit	41
12	Railroad Transportation	40
13	Oil & Gas Extraction	13
14	Lumber/Wood Products	24
15	Machinery Manufacturing	35
16	Transportation Equipment	37
17	Stone, Clay, Glass, Concrete	32
18	Leather/Leather Products	31
19	Miscellaneous Manufacturing	39
20	Food & Kindred Products (except restaurants)	20
21	Petroleum Refining	29
22	Mining of Nonmetallic Minerals	14
23	Printing & Publishing	27
24	Electric/Electronic	36
25	Paper & Allied Products	26
26	Furniture & Fixtures	25
27	Personal Services (laundries)	72*
28	Instruments	38
29	Textile Mills Products	22
30	Apparel	23

Source: Los Angeles County Department of Public Works. 1997. Critical Source Selection and Monitoring Report.

Notes:

(1) The LA County study did not distinguish between industries (critical sources) subject to General Permit requirements and industries that are exempt. * indicates exempt industries.

(2) Although the LA County study used two-digit SIC codes and the General Permit utilizes four-digit SIC codes, the information is useful because in general all industrial units in a two-digit class such as SIC 50 would be a concern.

Training

The following types of training are necessary:

- ✓ Training of municipal staff (hazmat/pretreatment inspectors) in urban runoff issues.

Program Evaluation and Documentation

Establish Measurable Goals

Your URP should include measurable goals for BMPs or control programs. These goals would be useful for checking progress made each year as well as demonstrating the efforts made to reduce pollutants to the maximum extent possible. The municipality may consider goals similar to those presented below for inclusion in its program:

- ✓ Identify critical industries (names and addresses) by end of the first year of program.
- ✓ Prepare general information on appropriate BMPs for critical industries by the second year of program.
- ✓ Train staff by end of second year of program.
- ✓ Conduct site visits at 50% of regulated industries in the third year of the program.
- ✓ Conduct site visits at 75% of regulated industries in the fourth year of the program, and all sites by the fifth year.

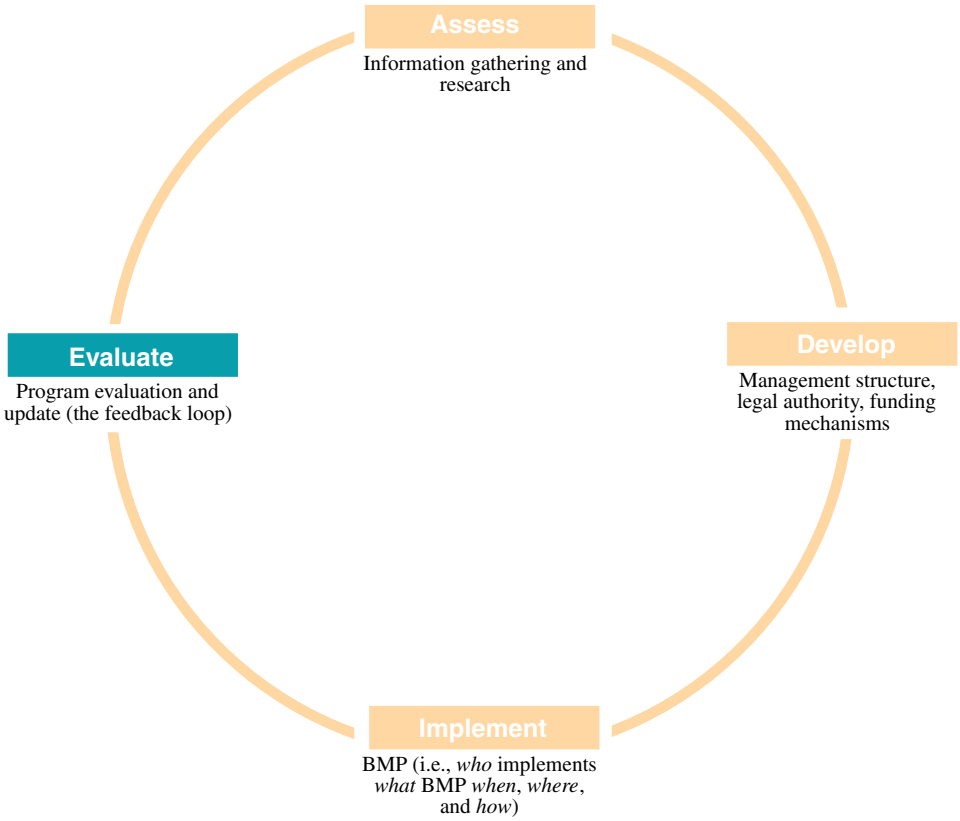
Documentation and Annual Reporting

The municipality should develop checklists for use by inspectors during site visits. Sample checklists are presented in Appendix 4DD. It should also develop forms or a format for reporting on this program in an annual report. Information that should be reported includes progress made relative to the measurable goals.

Sources of Additional Information

Storm Water Quality Task Force. 1993. California Storm Water Best Management Practice Handbook - Industrial/Commercial. Available from BPS Reprogrpahic Services, 1500 Jefferson Street, Oakland (510) 287-5485.

5 Evaluation of Urban Runoff Program



5.1 Progress Reporting and Evaluation

5.2 Water Quality Monitoring

5.3 Program Updating

Regardless of whether you choose to implement the six minimum control programs or you tailor your URP based on your assessment of significant pollutant sources or geographical areas of concern, it is necessary and important for you to review your URP periodically. This review helps to determine if water quality is improving in your area and whether the efforts and resources are directed at the right source or pollutant of concern. Then if the current use of resources is not providing the improvements you expected, then what should you do differently? This review is also important from the viewpoint of your permit because the permit is likely to require the municipality to demonstrate progress made towards measurable goals and to justify the appropriateness of the BMPs that it has chosen to implement. Periodic evaluations are also useful to help gain program support. This section of the MURP presents some ideas on how to report on progress and how to evaluate and revise your URP.

5.1 Progress Reporting and Program Evaluation

NPDES Phase II municipalities will be required at least during the first 5-year permit period to submit annual reports to the RWQCB. NPDES Phase II regulations also suggest that the municipality establish measurable goals for URP elements. Progress made relative to these goals can then be reported in a simple annual report.

This MURP guide suggests measurable goals for BMPs in each of the control programs in Sections 4.1 through 4.8. The municipality should use these ideas to establish such goals for each year. Note that measurable goals are somewhat similar to performance standards that are being used by some Phase I municipalities; performance standards also define the level of implementation necessary for a given BMP or control program to be effective. Compliance with the performance standards is being used by these URPs to demonstrate that they are achieving pollution reduction to the maximum extent practicable. In some instances, it may not be possible to identify a measurable goal. In such cases, it would be appropriate to report work completed in that year.

Progess made relative to measurable goals is adequate for purposes of annual reporting, and under the presumption approach if measurable goals are met, the program can be considered to be improving water quality to the maximum extent possible. This approach will not, however, answer questions such as (1) whether all that you are doing is in fact improving water quality, (2) whether the BMPs you are implementing are appropriate for your area and its problems, or (3) whether

your resources would be better directed at another pollutant source. You likely need to use other evaluation techniques to answer these questions. Table 5-1 summarizes commonly used techniques to evaluate effectiveness of urban runoff programs.

Note that water quality monitoring is the most commonly used technique to assess the effectiveness of the overall URP (as opposed to other techniques that assess a single control program). However, monitoring data from urban waterbodies have not shown any marked water quality improvements and some NPDES Phase I programs are questioning the usefulness of water quality monitoring. Also NPDES Phase II regulations state that small municipalities are not expected to undertake independent water quality monitoring but that they should continue with any monitoring that they are currently doing and/or participate in available regional monitoring programs. Further details on water quality and other forms of monitoring are provided in Section 5.2.

Public awareness surveys are another program evaluation tool used by NPDES Phase I municipalities to assess the effectiveness of outreach programs. Since surveys are expensive to conduct, you should assess your resources before using them for program evaluation. You may want to consider coordinating these surveys with other municipalities or entities to reduce costs. Survey data can be useful in justifying PE/O budgets for subsequent years. As human awareness or behavior is unlikely to change significantly in 1 year, the appropriate frequency for these surveys is every 2 years or so.

Table 5-1. Commonly Used Program Evaluation Techniques

Quantitative Measures

- ✓ Chemical monitoring of practices
- ✓ Chemical monitoring of receiving waters
- ✓ Biological monitoring of receiving waters
- ✓ Stream flow monitoring
- ✓ Sediment monitoring

Qualitative Measures

- ✓ Public opinion surveys and pre- and post-event evaluation forms by targeted groups
- ✓ Indirect indices such as:
  - Increases in the amount of used oil collected
  - Increases in the amount of sediment/debris removed from streets and catch basins
  - Decline in the number of spills of petroleum products, pesticides, etc.
  - Decline in the number of illicit connections detected
  - Decline in the number of illegal dumping incidents/complaints
  - Decline in response time for complaints/spills
  - Decline in the number of enforcement actions taken
  - Increase in number of calls to the Hazmat/URP Information hotline regarding disposal options
- ✓ Increase in the number of new development projects that are being required to implement BMPs
- ✓ Increase in the number of construction sites that are implementing BMPs
- ✓ Increase in maintenance frequencies; inspection frequencies
- ✓ Special studies to evaluate effectiveness of specific BMPs (examples of such studies include testing of catch basin inserts or testing the performance of grassy swales)

5.2 Water Quality Monitoring

This section provides recommendations to small municipalities regarding how they may wish to incorporate monitoring into their programs. Under NPDES Phase II regulations, monitoring requirements are left to the discretion of the permitting authority and the EPA in general does not recommend that small municipalities conduct monitoring in the first permit period beyond what they are already conducting. On the other hand, the EPA is requiring the State to identify how monitoring will show progress regarding implementation of BMPs and water quality improvement pursuant to CWA Section 319, and many local governments have found monitoring to be a useful component in stewardship programs.

Monitoring of urban streams and storm water conveyances can provide valuable information for cities in their efforts to manage water quality. However, not every city, county, or other local entity will see the same benefits of ongoing monitoring programs. The needs of some areas are greater, as potential or known impacts are more severe, and local resources for addressing them are scarce. Other areas may have relatively well-maintained infrastructures that provide for ongoing maintenance of water quality, as well as resources to monitor the effectiveness of their management programs and overall environmental quality. Individual cities and constituents should decide if a monitoring program, whether citizen-based or insitutional, is needed or can provide added water quality protection. Otherwise, these entities may see more value in using resources for implementing as wide a range of BMPs as possible.

Utilize Existing Water Quality Data (Collected as Part of Phase I Effort)

Monitoring to evaluate water quality trends, water quality differences related to land use, or to relate improvements in water quality from implementation of program control measures is quite difficult and usually requires technical expertise and substantial resources. Moreover, extensive water quality monitoring to characterize the pollutants from different land uses has already been accomplished by the Phase I URPs at considerable expense and these data should generally be adequate for most Phase II applications.

Therefore, in lieu of implementing an aggressive water quality monitoring program, the municipality may choose to evaluate results of monitoring conducted by other storm water programs (e.g., programs regulated under Phase I) under conditions representative of your municipality. Use this information to (1) help characterize expected water quality from different land uses and/or facility types, (2) identify constituents of concern based on toxicity testing and/or evidence of beneficial uses impairment, (3) understand important pollutant sources within your jurisdiction, and (4) evaluate the effectiveness of alternative control measures. Three studies conducted for other URPs provide useful information on variations in pol-

lutants of concern and land use (Woodward-Clyde 1996; Strecker et al. 1997; Bannerman et al. 1996).

Document and Participate in Regional Monitoring Efforts

Municipalities should participate as appropriate in regional monitoring strategies and use data from existing monitoring, rather than undertaking expensive monitoring on your own. Such coordination is especially relevant for receiving water monitoring and watershed-scale monitoring where multiple pollutant sources (i.e., point and nonpoint sources) are usually involved and cooperatively funded monitoring programs can provide multiple benefits at a low cost.

As a first step, identify other regional monitoring efforts. The programs to consider include the POTW monitoring program, other point source dischargers, and the other wet-weather flow monitoring programs to determine if the monitoring objectives and protocol of the regional programs address the URP's needs. Next, coordinate sampling locations, frequency, sampling protocol, data analysis, and presentation with the larger program(s).

In many areas, the RWQCBs are working with other groups to develop regional monitoring programs. Currently the Central Coast RWQCB is working with the Monterey Bay National Marine Sanctuary's Water Quality Protection Program and its member agencies to develop a monitoring program in the Monterey Bay area that can better coordinate and build on the individual monitoring conducted by various permit holders, county, state, and federal programs. The Central Coast RWQCB is also developing a monitoring program for its entire region. Participating in regional efforts can help cities interpret their data and water quality issues in relationship to other watershed sources, and the city's local data can in turn strengthen the regional assessments.

Develop Monitoring Objectives

The development of any monitoring program should begin by assessing what questions to address. In part, the municipality should determine what type of information municipal departments (Environmental Health, Public Works, Flood Control, etc.) are collecting for general purposes. The various departmental entities can then determine what types of data need to be collected, and as a result, may share information more effectively.

Data should only be collected to address real needs. For example, if an existing program already ensures no cross connections between wastewater and storm water conveyances with appropriate chemical monitoring, no reason exists to include more of that monitoring of the same conveyances. If measures are taken to ensure no cross connections, monitoring for wastewater parameters (e.g., indicator bacteria, ammonia, detergents, etc.) may be justified to assess the effectiveness of these measures, or the possibility that these pollutants are coming from other, nonwastewater sources.

Assessment studies and monitoring programs can address questions that local city staff are unable to answer due to lack of information. In many cases the results of these assessments will indicate that the cities are doing a good job of controlling pollution. In others, they may indicate that urban runoff is being contaminated by common commercial or residential practices, or illicit discharges, and may suggest studies appropriate to more thoroughly determine the sources, or measures that should be taken to improve these practices. In most cases it is important to try and define questions that are fairly narrow in scope, and that can be addressed with the simple tools available. Questions regarding the "health" of the ecosystem are quite broad and generally not required by this type of program.

Elements to Consider in Developing a Water Quality Monitoring Program

In the event no regional program is available to participate in, and/or the municipality elects to develop its own monitoring program, consider the following while developing this program:

- ✓ Begin with visual monitoring and introduce grab sampling and water quality analysis only as needed and appropriate.
- ✓ Limit the scope of chemical analysis to a few parameters (e.g., total settleable solids, pH, dissolved oxygen, and temperature) within the staff's capability.
- ✓ Utilize volunteers to the extent possible, providing them with training and simple kits to use.
- ✓ Conduct short-term focused studies rather than long-term monitoring efforts.
- ✓ Focus monitoring on water bodies within the jurisdiction of the muncipality, leaving the monitoring of larger regional receiving waters (such as the Bay) to the regional programs.

Urban runoff problems can be identifed through visual monitoring

The municipality or agency responsible for coordination of monitoring should indicate what the minimum parameters for the program will be. Even though some of the basic parameters (e.g., dissolved oxygen, pH, temperature) do not measure a pollutant directly, they are potentially impacted by a wide range of pollutants from a variety of sources. Monitoring of these basic parameters may be included in a program as a broad screen to indicate other sources of impacts.

Each program should develop a list of physical, chemical, and biological parameters to address important questions, and appropriate tests/analyses that are effective and within the capabilities of the groups conducting them. Appendix 5A summarizes the parameters and tests that are applicable and appropriate. Procedures

should be chosen from an appropriate set of standard methods (e.g., APHA 1994; Rigney et al. 1996; SFEI 1997; EPA 1993) that will result in data of a quality acceptable to municipal, county, and state agencies. The list should include assessments of the accuracy, detection limits, and utility of the methods so the appropriate one is chosen for a given problem. For example, a nitrate method that has a lower detection limit of 5 mg/L for nitrate-nitrogen may by acceptable for assessing potability, but is not sensitive enough to address potential eutrophication in surface waters. Depending on the data's intended use, different levels of precision may be required. For monitoring programs intended as a screening level assessment of gross water quality, or for educational purposes, accuracy and precision may not be as critical as for characterization studies that may need to describe these physical and chemical features on a fine scale.

Sampling for water quality monitoring will require training of staff

Each monitoring program should adopt a quality assurance project plan to assure the quality of data from collection through analysis and reporting (EPA 1993, 1994a,b). The intent of any plan should be to make the data acceptable to as wide an audience as possible, but particularly to regulatory agencies that may need to respond to the problems the data suggest, or to accept the view that water quality is being protected and maintained. The plan should be the basis of the type of information/data collected, the precision of measurements required to meet the goals of the program, the methods used to obtain the information, and a discussion of the appropriate use of the data, with stated intentions for analysis and interpretation methods. Quality control methods (e.g., duplicate samples, spiked samples, analysis of standards) and how frequently they are included in the sampling regime should be defined.

This plan should also include descriptions of methods to be used (standard operating procedures) for sampling, analysis and transfer. It should include a copy of standardized forms, including:

- ✓ Station log forms that include all aspects of the field sampling effort, dates, times, sample identification numbers (if appropriate), names of field crew members, and signatures of field crew leaders
- ✓ A "chain of custody" for samples that are transferred from one individual or laboratory to another between collection and analysis

Aside from forming the "blueprint" for all monitoring activities, quality assurance project plans are required by many agencies that may be sources of funding for the program.

As stated above, data should only be collected for specific purposes and the intended methods of analysis and interpretation should be planned ahead of time. The means of reporting the results of the monitoring program and the intended audiences should be planned before the program begins. Collecting data simply to say that monitoring is being done is pointless. Ideally, a schedule for producing reports should be part of the overall plan.

Select and Apply Environmental Indicators in Lieu of Water Chemistry Monitoring Alone

The monitoring community generally recognizes that traditional compliance-type chemical monitoring developed for continuous point source discharges under NPDES permits is not effective for transient discharges typical of nonpoint sources. In response to this concern, EPA has developed the concept of environmental indicators that rely on a variety of methods to assess the environmental consequences of nonpoint source discharges. These indicators include water quality indicators, physical and hydrologic indicators, biological indicators, social indicators, programmatic indicators, and site indicators. The Center for Watershed Protection (1996) has provided guidance in selecting appropriate indicators for monitoring based on local conditions. The overall concept relies on a program selecting a set of integrated indicators that provide more insight than with only one monitoring tool. A number of these indicators use observational information and other easily obtainable data that can be collected through citizen volunteer programs.

How to Begin a Volunteer Monitoring Program

Should you decide to conduct monitoring by involving volunteers from your municipality, several basic steps should be followed in developing a volunteer monitoring program:

- ✓ Meet with city public works officials who can tell you what information is needed that might be within the capabilities of a volunteer monitoring program and fall within the city budget constraints.
- ✓ Map out the problem areas that could be safely monitored by a citizen volunteer force.
- ✓ Contact local nonprofit organizations, colleges, or watershed groups in your area who are involved with monitoring. Decide on a volunteer program that works for your region.
- ✓ Recruit volunteers through press releases to local papers and radio stations, and distribute flyers through nonprofit organizations, community centers, city information counters, and public meetings.

The benefits of a citizen-based monitoring program are illustrated in a program developed for the City of Monterey. An Urban Watch monitoring program was implemented for dry-weather period (July-October) sampling. In addition to generating data for the City, it helped build community involvement and interest. The City purchased a dry-weather *Urban Watch Kit* (approximate cost $350) to moni-

tor possible contaminants coming from storm drain outfalls. The kit is sold through NAPCO chemical company (phone 800-929-5976) and includes all the parameters required in EPA's NPDES permit regulations for dry-weather storm drain monitoring (chlorine, copper, detergents, phenols, pH, turbidity, and color), plus a thermometer and a test for ammonia-nitrogen.

A local nonprofit organization, the Coastal Watershed Council from Santa Cruz, was contracted to train the volunteers on how to properly use the monitoring kit and tabulate the data for the city. Monterey Bay National Marine Sanctuary was used for media recruitment notices and to coordinate with local nonprofit organizations to enlist volunteer assistance. Volunteers were divided into teams and given a monitoring schedule with dates and times (to coordinate with low-tide schedule).

Volunteers were able to detect consistent detergent runoff from a storm drain outfall bordered by a large restaurant community. Agencies and volunteers were able to trace the pollutant source by walking up the street and peering through grates and following the detergent plume to a restaurant where it appeared that the kitchen mats were being washed off and runoff allowed to enter storm water catch basins. This exercise led to another outreach technique — training volunteers to educate restaurant staff about proper techniques to prevent urban runoff. Posters in English and Spanish were distributed to restaurant staff, explaining how clean water is not only a health concern but also an economic one. A collaborative approach between cities and other local groups, linking monitoring to outreach and project prioritization can be an effective environmental protection tool.

Monitoring programs can also be piggybacked on existing events, such as National Coastal Clean Up Day, which takes place every September. This nationwide cleanup concentrates on collecting and tabulating amounts and types of trash from beaches, lakes, and rivers. Volunteers could collect trash from storm drains and tabulate this data to be included with cleanup day.

The regulatory and scientific community has some concerns about using volunteer groups to collect water quality data. Some of these concerns relate to field kits that have subjective measurements and may vary depending on the sampler, the commitment of the volunteers to work for the entire season to obtain consistent results; and lack of precision and accuracy. Many of these problems can be overcome by properly training volunteers. Reference materials have been developed by EPA and SWRCB to guide volunteer groups to ensure that they use appropriate methods and quality control/assurance measures. Bear in mind the type of information volunteers can provide at a useful level of quality can be limited, and that monitoring by your municipal staff or a regional monitoring program is likely to be necessary. At the same time, volunteer monitoring has enormous benefits beyond just data gathering, including public involvement and support, and eventual ownership of the program.

5.3 Program Updating

The Feedback Loop

Thus far, this section of the MURP guide has described methods to be used to evaluate your own URP through performance standards, water quality monitoring, and other indicators and effectiveness measures. Assuming that you have gone through this evaluation exercise, developed an annual report and submitted it to decision makers, the question before you now is, "so what?" If this report simply takes its place among other dusty documents on the shelf, then you may have satisfied reporting requirements, but what have you really *gained*?

For your evaluation to have meaning, you need to *use* this knowledge to modify your URP as necessary to address the new opportunities, new problems, and new information accumulated since your URP's initial development. You have learned important lessons and your priorities may be shifting and expanding — or even contracting. In essence, you are now ready to begin the process anew. That is not to say that you will now need to re-craft a "new" URP, rather that you need to take a step back and revisit the iterative development process that is the URP conceptual framework. You now "know" more about your municipality's particular urban runoff issues and this information can be used to prove and disprove initial assumptions, programmatic and BMP choices, implementation strategies, etc. Welcome to the feedback loop.

A review of NPDES Phase I municipalities shows that some programs adopted an annual workplan approach to program implementation. At the time they submitted the annual report for the previous year, they also submitted a workplan for the next fiscal year indicating therein the programs they would continue with unchanged, the programs they would suspend, and the new programs they would launch. These municipalities incorporated changes in their programs each year. Other Phase I municipalities chose to conduct an evaluation in the third and fourth years of their permits when they had had some time to establish and run their URPs, and were able to see the problems and shortcomings more clearly.

Regardless of when you do it, as you become more familiar with your municipality's unique urban runoff problems and as your control programs are developed and implemented, you are likely to make several changes. Changing does not mean that you need to prepare a new URP, you merely need to revise it by removing those control programs or BMPs that don't work or are not appropriate or necessary in your municipality, or by adding other new programs. In some instances, the changes may be limited to a change in the frequency at which inspections are conducted for a particular control program such as the illicit connections program or the geographic area of focus (i.e., increased frequency of street sweeping in

certain problem areas in your municipality). In some instances that change could be a reduced emphasis on a certain BMP or an increased emphasis on another BMP.

Points to Note

Remember to institutionalize program update.

Initial program development of any kind is typically a very involved, time and resource-consuming process that has a clearly defined end (i.e., the finished 'program'). Program update, on the other hand, is oftentimes viewed as an afterthought. Once a program is developed, the collective sigh of relief can give way to the rote predictability of long-term implementation where update is perceived as an infrequent undertaking. For your URP, you need to be sure that program update is an institutionalized portion of your program. By that we mean that not only should a portion of the yearly evaluative report be given over to potential URP modifications, but also that staff must be assigned to utilize the new information to reprioritize program components and strategies as necessary. Just as your URP required an initial investment in program development (e.g., your municipal assessment), it also requires an ongoing investment in program development.

Remember to keep up with changing regulatory requirements.

While this MURP guide has been designed to achieve regulatory compliance with NPDES Phase II and consistency with CZARA 6217 as of the date of its printing, these programs are more than likely to change over time. For example, while NPDES Phase II does not currently require water quality monitoring, future compliance may depend upon yet to be determined monitoring standards. To ensure that your program continues to comply with all water quality requirements, program update must include an analysis of the current federal, state, and local regulatory framework.

Remember to reach out to the watershed and/or region.

If your initial URP was specific only to your own jurisdictional borders, you have an opportunity now to expand the program regionally to encompass watershed and/or regional concerns. This process can be viewed as a spiral of expanding coverage and achievement. Remember, watersheds provide the fundamental resource unit for managing polluted runoff since runoff within a watershed flows to a common outlet. It may be that the specific shortcomings that you have identified in evaluating your URP are actually due to activities outside of your jurisdictional boundaries. Now that you have successfully implemented a program to address polluted runoff within your own jurisdiction (you have put your own house in

order, so to speak), you can help neighboring jurisdictions to achieve similar results. You may choose to pursue a regional URP, expanding your own to encompass the watershed or other regional boundary, or you may choose to help your neighbors institute their own URPs. Either way, you are seen as a regional leader in addressing urban runoff at the same time as reaping the direct benefits of reduced pollutant loading within the watershed, but outside of your own URPs current enforcement boundaries.

Remember the main goal of your URP.

The purpose of your URP is to improve water quality within your community. If your program evaluation indicates improvement is not happening, then program update is all the more critical. As you have seen through the course of this MURP guide, a myriad of proven methods, with innumerable implementation options, exist. If your focused URP elements do not seem to be working, by all means change the URP. It may take subtle tweaking, or it may take full scale revisions, but regardless, you need to make the changes.

Sources of Additional Information

American Public Health Association (APHA). 1992. Standard methods for the examination of water and waste (18th edition). A. E. Greenber, L. S. Cleseri, and A. D. Eaton eds. Washington, D. C.

Bannermann et al. 1996. Quality of Wisconsin Storm Water 1989 - 94.

Center for Watershed Protection. 1996. Environmental Principles for Golf Courses in the United States.

Rigney, M., C. Fischer, and E. Sawyer. 1996. Riparian Station How-to Manual. Published by San Francisco Estuary Institute.

San Francisco Estuary Institute (SFEI). 1997. Volunteer Monitoring Protocols: a manual for protocols for monitoring ecological changes in California.

Strecker, E. et al. 1997. Analysis of Oregon Urban Runoff Water Quality Data, 1990-1996. Prepared for the Oregon Association of Clean Water Agencies.

U.S. Environmental Proteciton Agency (EPA). 1993. Volunteer estuary monitoring: a methods manual. Office of Water. EPA 842-B-93-004.

U.S. Environmental Proteciton Agency (EPA). 1994a. Environmental Monitoring and Assessment Program: pilot field operations and methods manual for streams. Office of Research and Development. EPA/620/R-94/004.

U.S. Environmental Proteciton Agency (EPA). 1994b. Proceedings: Fourth national citizens's volunteer monitoring conference. Portland State University. EPA 841-R-94-003.

Woodward-Clyde. 1996. San Francisco Bay Area Storm Water Runoff Monitoring Data Analysis 1988 - 1995.

California Incorporated Places and Counties Proposed to be Automatically Designated Under the Storm Water Phase II Proposed Rule (From the 1990 Census of Population and Housing U.S. Census

Apple Valley
Belvedere
Benicia
Brentwood
Butte County
Capitola
Carmel-by-the-Sea
Carpinteria
Ceres
Chico
Compton
Corte Madera
Cotati
Davis
Del Rey Oaks
Fairfax
Hesperia
Imperial County
Lakewood
Lancaster
Larkspur
Lodi
Lompoc
Marin County
Marina
Marysville
Merced
Merced County
Mill Valley
Monterey
Monterey County
Morgan Hill
Napa
Napa County
Novato
Pacific Grove
Palm Desert
Palmdale
Piedmont
Redding
Rocklin
Rohnert Park
Roseville
Ross
San Anselmo
San Buenaventura (Ventura)
San Francisco
San Joaquin County
San Luis Obispo
San Luis Obispo County
San Rafael
Sand City
Santa Barbara
Santa Barbara County
Santa Cruz
Santa Cruz County
Santa Maria
Sausalito
Scotts Valley
Seaside
Shasta County
Solano County
Sonoma County
Stanislaus County
Sutter County
Tiburon
Tulare County
Vacaville
Victorville
Villa Park
Visalia
Watsonville
West Sacramento
Yolo County
Yuba City
Yuba County

California Incorporated Places and Counties Potentially Designated (Outside Urbanized Areas) Under the Storm Water Phase II Proposed Rule

(Proposed to be Examined by the Permitting Authority Under Sec. 123.35[b] [2])

Arcata
Arroyo Grande
Atwater
Auburn
Brawley
Calexico
Clearlake
Corcoran
Delano
Dinuba
Dixon
E1 Centro
E1 Paso De Robles
Eureka
Gilroy
Grover City
Hanford
Hollister
Lemoore
Los Banos
Madera
Manteca
Oakdale
Oroville
Paradise
Petaluma
Porterville
Red Bluff
Reedley
Ridgecrest
Sanger
Selma
Tracy
Tulare
Turlock
Ukiah
Wasco
Woodland

This document is only a starting point for improving urban runoff management. If you need further guidance, or would like additional information and sources to help with the effort, you can contact the following offices:

Agencies to Contact for More Information

US EPA Region 9
Water Management Division
75 Hawthorne Street
San Francisco, CA 94105
Phone: (415) 744-2125

RWQCB - Region 1
North Coast
5550 Skyline Boulevard, Suite A
Santa Rosa, CA 95403
Phone: (707) 576-2220

RWQCB - Region 2
San Francisco Bay
2101 Webster Street, Suite 500
Oakland, CA 94612
Phone: (510) 286-1255

RWQCB - Region 3
Central Coast
81 Higuera Street, Suite 200
San Luis Obispo, CA 93401-5427
Phone: (805) 549-3147

RWQCB - Region 4
Los Angeles
101 Center Plaza Drive
Monterey Park, CA 91754-2156
Phone: (213) 266-7500

RWQCB - Region 5
Central Valley
3443 Routier Road, Suite A
Sacramento, CA 95827-3098
Phone: (916) 255-3000

RWQCB - Region 6
Lahontan
2092 South Lake Tahoe Blvd.
South Lake Tahoe, CA 96150
Phone: (916) 542-5400

RWQCB - Region 7
Colorado River Basin
73-720 Fred Waring Drive, Suite 100
Palm Desert, CA 92260
Phone: (619) 346-7491

RWQCB - Region 8
Santa Ana
2010 Iowa Avenue, Suite 100
Riverside, CA 92507-2409
Phone: (909) 782-4130

RWQCB - Region 9
San Diego
9771 Clairmont Mesa Boulevard, Suite B
San Diego, CA 92124
Phone: (619) 467-2952

California Coastal Commission
Coastal Nonpoint Pollution Control Program
45 Fremont Street, Suite 2000
San Francisco, CA 94105-2219
Phone: (415) 904-5200

SWRCB
Division of Water Quality
901 P Street (PO Box 100)
Sacramento, CA 95812-0100
Phone: (916) 657-0687

California Storm Water Quality Task Force
City of Sacramento
Department of Utilities
5770 Freeport Boulevard, #100
Sacramento, CA 95822
Phone: (916) 433-6634

Bay Area Storm Water Management Agencies Association
2101 Webster Street, Suite 500
Oakland, CA 94612
Phone: (510) 286-0615

You can also contact Phase I URPs for information. A listing is provided in the following pages.

State of California
Listing of Phase I Permittees

City of Santa Rosa
69 Stony Circle
Santa Rosa, CA 95401
Phone: (707) 524-5145

Regional Board Contact: Nathan Quarles
Phone: (707) 576-2684

Santa Clara Valley Urban Runoff Pollution Prevention Program
EOA, Inc.
Jackson Street
Oakland, CA
Primary Contact: Jill Bicknell
Phone: (510) 832-2852

Regional Board Contact: John West
Phone: (510) 286-0429

Contra Costa County Clean Water Program
Contra Costa Clean Water Program
255 Glacier Drive
Martinez, CA 94553
Primary Contact: Don Freitas
Phone: (925) 313-2373

Regional Board Contact: Martin Musonge
Phone: (925) 286-4264

Alameda County Countywide Clean Water Program
Alameda County Public Works
951 Turner Court
Hayward, CA 94545
Primary Contact: Robert Hale
Phone: (510) 670-5543

Regional Board Contact: Keither Lichten
Phone: (510) 286-1357

Fairfield-Suisun Sewer District
1010 Chadbourne Road
Fairfield, CA 94585
Primary Contact: Larry Bahr
Phone: (707) 429-8930

Regional Board Contact: Stephen Berger
Phone: (510) 286-0846

City of Vallejo
Valley Sanitation and Flood Control District
450 Ryder Street
Vallejo, CA 94590
Primary Contact: Daniel TaFolla
Phone: (707) 644-8949

Regional Board Contact: Stephen Berger
Phone: (510) 286-0846

Los Angeles County Area-Wide Municipal Permit
Los Angeles County, Department of Public Works
Waste Management Division, Storm Water Program
P.O. Box 1460
Alhambra, CA 91802
Phone: (818) 458-5948

Regional Board Contact: Carlos Urrunaga
Phone: (213) 266-7598
Regional Board Contact: Winnie Jesena
Phone: (213) 266-7594

Sacramento County Area-Wide Municipal Permit
City of Sacramento
Department of Utilities, Engineering Division
5770 Freeport Boulevard, Suite 100
Sacramento, CA 95822
Primary Contact: David Brent
Phone: (916) 433-6634

Regional Board Contact:
Phone: (916) 255-3024

Caltrans Region-Wide Storm Water Municipal Permit
Caltrans, District 3
P.O. Box 911
Marysville, CA 95901
Primary Contact: Andrew Streng
Phone: (916) 741-4585

Caltrans, District 4
P.O. Box 23660
Oakland, CA 94623
Primary Contact: Dragomir Bogdanic
Phone: (510) 286-5669

Caltrans, District 6
P.O. Box 12616
Fresno, CA 93778
Primary Contact: Larsen Boyer
Phone: (209) 488-4378

Caltrans, District 10
P.O. Box 2048
Stockton, CA 95201
Primary Contact: Tina Buras Gassen
Phone: (209) 942-6019

Regional Board Contact: Pat Leary
Phone: (916) 255-3023

Stockton Area-Wide Municipal Permit
City of Stockton
2500 Navy Drive
Stockton, CA 95206
Primary Contact: Glen Birdzell
Phone: (209) 944-8750

State of California
Listing of Phase I Permittees (continued)

County of San Joaquin
Department of Public Works
P.O. Box 1810
Stockton, CA 95201
Primary Contact: Manual Lopez
Phone: (209) 468-3101

Regional Board Contact: Pat Leary
Phone: (916) 255-3023

City of Modesto
P.O. Box 642
Modesto, CA 95353
Phone: (209) 577-5470

Regional Board Contact: Sterling Davis
Phone: (916) 255-3062

Fresno County Area-Wide Municipal Permit
Fresno Metropolitan Flood Control District
5469 East Olive
Fresno, CA 93727
Primary Contact: Doug Harrision
Phone: (209) 456-3292

Regional Board Contact: Darrel Evensen
Phone: (209) 445-5145

Bakersfield Area-Wide Municipal Permit
City of Bakersfield
Department of Public Works
1501 Truxtun Avenue
Bakersfield, CA 93301
Primary Contact: Fred Kloepper
Phone: (805) 326-3724

County of Kern
Department of Engineering and Surveying Services
2700 "M" Street, Suite 570
Bakersfield, CA 93301
Primary Contact: William Wilbanks
Phone: (805) 861-2201

Regional Board Contact: Kevin Long
Phone: (209) 445-6126

Tahoe Area-Wide Municipal Permit
City of South Lake Tahoe
Department of Public Works
1900 Lake Tahoe Boulevard
South Lake Tahoe, CA 96150
Primary Contact: Chuck Taylor
Phone: (916) 542-6030

El Dorado County
Department of Transportation
P.O. Box 7396
South Lake Tahoe, CA 96158
Primary Contact: Dave Zander
Phone: (916) 573-3182

Placer County
Department of Public Works
11444 "B" Avenue
De Witt Center
Auburn, CA 95603
Primary Contact: Bill Zimmerman
Phone: (916) 889-7545

Regional Board Contact: Laurie Kemper
Phone: (916) 542-5436

Coachella Valley Area-Wide Municipal Permit
Riverside County
Transportation Department
1695 Spruce Street
Riverside, CA 92507
Primary Contact: John Ristow
Phone: (909) 275-6775

Riverside County Flood Control District
P.O. Box 1033
1995 Market Street
Riverside, CA 92502
Primary Contact: Mark Wills

Coachella Valley Water District
P.O. Box 1058
Coachella, CA 92236
Primary Contact: Steve Beigley
Phone: (619) 398-2651

Regional Board Contact: Todd Thompson
Phone: (916) 776-8941

Riverside County Area-Wide Municipal Permit
Riverside County Flood Control and Water Conservation District
1995 Market Street
Riverside, CA 92501
Primary Contact: Mark Wills

Riverside County
Transportation Department
1695 Spruce Street
Riverside, CA 92507
Primary Contact: John Ristow
Phone: (909) 275-6775

Regional Board Contact: Pavlova Vitale
Phone: (909) 782-4920

State of California
Listing of Phase I Permittees (continued)

San Bernardino County Area-Wide Municipal Permit
San Bernardino County
Department of Transportation and Flood Control
825 E. Third Street, Room 120
San Bernardino, CA 92415
Primary Contact: Naresh Varma
Phone: (909) 387-2620

Regional Board Contact: Reza Akhtarshad
Phone: (909) 320-2024

Orange County Area-Wide Municipal Permit
Orange County EMA
Storm Water Section
P.O. Box 4048
Santa Ana, CA 92702
Primary Contact: Richard Boon
Phone: (714) 567-6371

Regional Board Contact: Laurie Taul
Phone: (909) 782-4906

San Diego County Area-Wide Municipal Permit
City of San Diego
Engineering and Development Department
1010 Second Avenue, Suite 1200
San Diego, CA 92101
Primary Contact: Robert Cain
Phone: (619) 533-3773

San Diego County
Department of Public Works
5555 Overland Avenue, Building 2
San Diego, CA 92123
Primary Contact: Joe Hill
Phone: (619) 694-2138

Regional Board Contact: Deborah Jayne
Phone: (619) 467-2979

Ventura County Area-Wide Municipal Permit
County of Ventura
800 South Victoria Avenue
Ventura, CA 93009
Primary Contact: Alex Sheydayi
Phone: (805) 654-2040

Regional Board Contact: Mark Pumford
Phone: (213) 266-7596

List of Acronyms Used in the MURP Guide

BMP	best management practice
CCMP	California Coastal Management Program
CEQA	California Environmental Quality Act
CNPCP	Coastal Nonpoint Pollution Control Program
CWA	Clean Water Act of 1972
CZARA	Coastal Zone Act Reauthorization Amendments of 1990
EPA	U.S. Environmental Protection Agency
GIS	geographic information system
HAZMAT	hazardous materials
MURP	Model Urban Runoff Program
NOI	Notice of Intent
NPS	nonpoint source
NPDES	National Pollutant Discharge Elimination System
OSHA	Occupational Safety and Health Administration
PE/O	public education/outreach
POTW	publicly owned treatment work
RWQCB	Regional Water Quality Control Board
SIC	Standard Industrial Classification
SRF	State Revolving Fund
SWPPP	Storm Water Pollution Prevention Plan
SWRCB	State Water Resources Control Board
URP	Urban Runoff Program

3A Sample Memorandum of Understanding

AGREEMENT

PROVIDING FOR IMPLEMENTATION OF THE ALAMEDA COUNTY URBAN RUNOFF CLEAN WATER PROGRAM

THIS AGREEMENT is made and entered into this day of , 1991 by and between the following undersigned public agencies, all which are referred to collectively as the Parties.

THE ALAMEDA COUNTY FLOOD CONTROL AND WATER CONSERVATION DISTRICT, a local public agency of the State of California;

Zone 7 of ALAMEDA COUNTY FLOOD CONTROL AND WATER CONSERVATION DISTRICT, a local public agency of the State of California;

COUNTY OF ALAMEDA, a subdivision of the State of California;

CITY OF ALAMEDA, a municipal corporation of the State of California;

CITY OF ALBANY, a municipal corporation of the State of California;

CITY OF BERKELEY, a municipal corporation of the State of California;

CITY OF DUBLIN, a municipal corporation of the State of California;

CITY OF EMERYVILLE, a municipal corporation of the State of California;

CITY OF FREMONT, a municipal corporation of the State of California;

CITY OF HAYWARD, a municipal corporation of the State of California;

CITY OF LIVERMORE, a municipal corporation of the State of California;

CITY OF NEWARK, a municipal corporation of the State of California;

CITY OF OAKLAND, a municipal corporation of the State of California;

CITY OF PIEDMONT, a municipal corporation of the State of California;

CITY OF PLEASANTON, a municipal corporation of the State of California;

CITY OF SAN LEANDRO, a municipal corporation of the State of California;

and CITY OF UNION CITY, a municipal corporation of the State of California.

RECITALS

A. The 1986 Water Quality Control Plan for the San Francisco Bay Basin (Basin Plan), adopted by the Regional Water Quality Control Board in implementation of the Federal Clean Water Act, requires that the PARTIES develop a Program to control the discharge of pollutants from urban runoff.

B. In furtherance of their responsibilities pursuant to the Basin Plan, the PARTIES have previously entered into a series of agreements to jointly fund the cost of preparing an action plan to evaluate nonpoint source pollutants, monitor identified pollutants and develop control measures to mitigate or reduce nonpoint sources of pollutants. Collectively, the measures undertaken pursuant to the previous agreements and anticipated to continue pursuant to this Agreement, are known as the Alameda County Urban Runoff Clean Water Program (hereinafter "Program"). The Program contains certain elements which provide a general benefit to the parties (such as monitoring, public education, program administration, etc.), and these elements of joint responsibility among the parties are termed the "General Program". In addition, the Program contains other elements

which are an individual Party responsibility and which provide individual benefits (such as construction site controls, catch basin cleaning, and illicit and illegal connection inspections, monitoring and enforcement), and these elements are termed the "Individual Programs". A description of the General and Individual Programs' elements, major tasks, schedules, and budgets will be developed as part of the "Work Plan for Cities in Alameda County, Alameda County, and the Alameda County Flood Control and Water Conservation District to file for a NPDES Permit" dated August 24, 1990.

C. The previous Agreements that have been executed are the following: The November 10, 1987 "Agreement Regarding Evaluation of Non-Point Source of Water Pollution" and the October 17, 1989 "Agreement Regarding Implementation of Nonpoint Source Control Evaluation Program". In addition there is a pending agreement titled "Agreement Regarding Development of a Proposed Alameda County Nonpoint Source Control Management Plan" which will provide funding through June 1991 for implementation of the August 24, 1990 work plan.

D. The PARTIES desire to continue the Program and to enter into this Agreement for the purpose of ensuring continued participation, in terms of cost and administrative responsibilities.

E. This Agreement does not amend or supersede any prior agreement among the PARTIES regarding the Program, but is to be read as in accord with and implementation thereof.

F. The Alameda County Flood Control and Water Conservation District (District) is a local public agency of the State of California duly organized and existing and empowered to conserve water and to provide maintenance and flood control management of the water courses and has the authority to control the discharge of surface waters to its facilities. The County of Alameda and all of the cities therein are subdivisions of the State with authority to control the discharge of surface waters from their respective jurisdictions.

NOW, THEREFORE, THE PARTIES AGREE AS FOLLOWS:

1. A Management Committee is hereby created to provide overall program direction, review and recommend an annual budget for approval by the PARTIES, and budget oversight, all in accordance with the Alameda County Urban Runoff Clean Water Program. Management Committee members, and their alternates, shall be appointed by the City Manager or the equivalent of the respective Parties and a confirming letter sent to the authorized representative of the District. The Management Committee shall adopt bylaws for its governance.

(a) Each Party to this agreement is allocated the number (or fraction thereof) of votes shown in Exhibit A. This allocation of voting strength is based on the formulas stated in Exhibit B to the Agreement.

(b) A quorum for the conduct of business by the Management Committee shall be a majority of the voting Parties to the Agreement. The voting strength allocated to a Party shall not be considered in the determination of a quorum.

(c) Approval of actions by the Management Committee shall require a two-thirds affirmative vote of all allocated votes as shown in Exhibit A.

No action shall be taken by the District which requires expenditures by any party other than the District without prior Management Committee approval.

2. Pursuant to direction of the Management Committee, the District shall administer and coordinate the Program, which duties include but are not limited to:

(a) Applying on behalf of the PARTIES to become co-applicants for a National Pollutant Discharge Elimination System (NPDES) permit;

(b) Preparing draft annual budget and, periodic status reports on Program activities and expenditure and distributing same to PARTIES at least quarterly;

(c) Consolidating and submitting reports prepared by the several PARTIES required by the NPDES permit;

(d) Letting and administering approved consultant contracts according to District policies and procedures and considering other members' requirements. All consultant contracts will contain hold harmless and indemnity provisions and insurance requirements for the benefit of all PARTIES;

(e) Conducting audits of consultant contracts in accordance with District policies and procedures;

(f) Maintaining knowledge of and advising the PARTIES regarding current and proposed state and federal policies, regulations and programs that impact nonpoint source pollutant control programs; assisting the PARTIES in development and presentation of positions on these issues before local, State and Federal agencies;

(g) Preparing an annual report on the implementation of the Program;

(h) Representing the PARTIES in participation in the Bay Area Stormwater Management Agencies Association; and

(i) Formally advising the appropriate State and Federal agencies of termination or amendment of this Agreement.

3. The PARTIES accept and agree to perform the following duties:

(a) Each will authorize a representative to apply for an NPDES permit as co-applicants with the other Parties;

(b) Each will fully comply with the NPDES permit conditions applicable to its Individual Program and its identified portion of the General Program;

(c) Each will select a representative and an alternate to participate in Management Committee meetings and other required meetings of the PARTIES;

(d) Each will fund and implement its own Individual Program, and will fund and implement its share of the General Program. The District intends to provide funding to support new and expanded activities required by the

General and Individual Programs for Cities located in District zones with Benefit Assessment Programs. Such funding will be provided to the extent that it is available and with the concurrence of the applicable City if it results in deferring flood control projects.

(e) Each will provide agreed upon reports (certified under penalty of perjury) to the District on compliance with applicable provisions of the NPDES permit and program implementation.

4. A proper accounting of funds and reports of all receipts and disbursements shall be made, including funds disbursed to individual parties for implementation of permit programs. Upon completion of the purposes of this Agreement, any surplus money on hand shall be returned in proportion to the contributions made. In the event a Party terminates this Agreement, any unexpended portion of its share of cost funds shall be returned to it.

5. By agreement of the PARTIES, budget allocations for the General Program shall be made according to a formula which for the municipalities allocates proportional shares based on a 50 percent weight given to the area and a 50 percent weight given to the population within each municipalities' jurisdiction (excluding open water and wetland areas of San Francisco Bay). The attached Exhibit B provides a copy of the formulas which are used to allocate costs. Each Parties' share of the General Program's costs for fiscal year 1991/92 will be according to the percentages provided in Exhibit A.

Cost shares will be recalculated based on updated information on population and area using the formulas in Exhibit B for fiscal year 1992/93 and at appropriate future intervals as specified in the bylaws. The budget allocation for the Individual Programs shall be made directly by the individual responsible parties.

6. This Agreement shall have a term of six (6) years from the first day of April 1991, subject to automatic renewal for a five (5) year period in the absence of objection thereto made in writing by any Party 90 days in advance of the renewal date. The participation of any Party to this Agreement may be terminated by a two-thirds affirmative vote of all allocated votes in any year in which the funds necessary for its continued involvement are not appropriated by its legislative body.

7. The PARTIES shall retain the ability to individually (or collectively) request permit modifications and initiate permit appeals for permit provisions to the extent that a provision affects an individual party or group of PARTIES.

8. This agreement may be amended from time to time by written agreement of the Parties' governing bodies representing two-thirds or more of all allocated votes as shown in Exhibit A.

9. Participation in this Agreement may be terminated by any Party for any reason after the Party complies with all of the conditions of termination. The conditions of termination include the

following: the Party shall notify all of the other Parties to the Agreement 90 days prior to its termination in the Agreement, the Party shall obtain its own NPDES permit for urban runoff, and the Party shall have its name deleted as a co-permittee of the Parties' NPDES permit through an amendment of the Parties' NPDES permit. Any expenses associated with terminating the Agreement including but not limited to filing for and obtaining the individual NPDES permit and the amendment of the Parties' NPDES permit will be solely the responsibility of the Party terminating its participation in the Agreement.

10. It is understood and agreed that, pursuant to Government Code 895.4, each Party ("indemnitor") shall, to the extent permitted by law, defend, indemnify and save harmless every other Party, and its officers and employees from all claims, suits or actions of every name, kind and description resulting from indemnitor's performance of this Agreement, excluding any injuries, death, damage or liability resulting from the negligence or willful misconduct of the other Parties or their officers or employees.

EXHIBIT A

ALAMEDA COUNTY URBAN RUNOFF CLEAN WATER PROGRAM MANAGEMENT COMMITTEE

	Voting and General Program Cost Share Percentages
• Alameda	4.96
• Alameda County	9.28
• Alameda County Flood Control and Water Conservation District	0.00
• Zone 7 of Alameda County Flood Control and Water Conservation District	0.00
• Albany	0.80
• Berkeley	6.22
• Dublin	2.34
• Emeryville	0.40
• Fremont	17.04
• Hayward	11.52
• Livermore	5.40
• Newark	3.04
• Oakland	23.80
• Piedmont	0.76
• Pleasanton	4.46
• San Leandro	4.84
• Union City	5.14
Total	100.00

EXHIBIT B

FORMULAS FOR CALCULATING PERCENTAGE CONTRIBUTIONS TO SUPPORT GENERAL PROGRAM

$$\text{Alameda County Percentage Share} = \frac{\text{Population within Alameda County Unincorporated Areas}}{\text{Total Population Within Alameda County}} \times 100\%$$

$$\text{Each Municipality's Percentage Share} = (100 - \text{Alameda Co. Share}) \times \left[\frac{0.5\ (\text{Area within Municipality})}{(\text{Total Area of All Municipalities})} + \frac{0.5\ (\text{Population within Municipality})}{(\text{Total Population of All Municipalities})} \right]$$

SARB_000857

ALAMEDA COUNTY FLOOD CONTROL AND WATER CONSERVATION DISTRICT, a local public agency of the State of California

By: _____
President, Board of Supervisors

APPROVED AS TO FORM:

_____
County Counsel

ATTEST: _____

_____
William Mehrwein, Clerk
The Board of Supervisors, Alameda County Flood Control and Water Conservation District

I hereby certify under penalty of perjury that the President of the Board of Supervisors was duly authorized to execute this document on behalf of the Alameda County Flood Control and Water Conservation District by a majority vote of the Board on MAY 14 1991, and that a copy has been delivered to the President as provided by Government Code Section 25103.

Dated: MAY 14 1991

_____
WILLIAM MEHRWEIN, Clerk, Board of Supervisors
Alameda County Flood Control and Water Conservation District, State of California

By _____
Deputy

V.B.1.

newmoa_7.wpd *Draft 4/16/98*

AGREEMENT

PROVIDING FOR IMPLEMENTATION OF THE SANTA CLARA VALLEY URBAN RUNOFF POLLUTION PREVENTION PROGRAM

THIS AGREEMENT, is made and entered into this _____ day of _____ 1998 by and between the

SANTA CLARA VALLEY WATER DISTRICT (District), a local public agency of the State of California; COUNTY OF SANTA CLARA, a subdivision of the State of California; CITY OF CAMPBELL, a municipal corporation of the State of California; CITY OF CUPERTINO, a municipal corporation of the State of California; CITY OF LOS ALTOS, a municipal corporation of the State of California; TOWN OF LOS ALTOS HILLS, a municipal corporation of the State of California; TOWN OF LOS GATOS, a municipal corporation of the State of California; CITY OF MILPITAS, a municipal corporation of the State of California; CITY OF MONTE SERENO, a municipal corporation of the State of California; CITY OF MOUNTAIN VIEW, a municipal corporation of the State of California; CITY OF PALO ALTO, a municipal corporation of the State of California; CITY OF SAN JOSE, a municipal corporation of the State of California; CITY OF SANTA CLARA, a municipal corporation of the State of California; CITY OF SARATOGA, a municipal corporation of the State of California; and CITY OF SUNNYVALE, a municipal corporation of the State of California.

All of the previous above-mentioned entities are hereinafter collectively referred to as "PARTIES" or individually as "PARTY."

SECTION I

RECITALS:

A. The 1986 Water Quality Control Plan for the San Francisco Bay (Basin Plan), adopted by the California Regional Water Quality Control Board, San Francisco Bay Region, in implementation of the Federal Clean Water Act, required that PARTIES develop a program to control pollution from urban runoff, or nonpoint sources of water pollution in the Santa Clara Valley.

B. In furtherance of their responsibilities pursuant to the Basin Plan, the PARTIES have previously entered into a series of agreements to jointly fund the cost of preparing an action plan to evaluate nonpoint source pollutants, monitor identified pollutants, and develop control measures to mitigate or reduce nonpoint source pollution. Collectively, the measures undertaken pursuant to the previous agreements and anticipated to continue pursuant to this Agreement, were known as the Santa Clara Valley Nonpoint Source Pollution Control Program and upon execution of this agreement henceforth shall be known as the Santa Clara Valley Urban Runoff Pollution Prevention Program (hereinafter called "Program").

C. Congress in 1987 added Section 402(p) to the Federal Clean Water Act (CWA) (33 U.S.C. Section 1342(p)), which requires certain municipalities and industrial facilities to obtain a National Pollutant Discharge Elimination System (NPDES) permit for the discharge of stormwater to navigable waters. NPDES permits are also required under Section 402(p) for any stormwater discharge which EPA or a State has determined contributes to a violation of a water quality standard or is a significant contributor of pollutants to surface waters.

D. Section 402(p) further required the Federal Environmental Protection Agency (EPA) to promulgate regulations for initial NPDES permit applications for stormwater discharges. The EPA promulgated such regulations in November 1990.

E. The EPA has delegated authority to the California State Water Resources Control Board to administer the NPDES permit process within California and, in turn, the California Regional Water Quality Control Board - San Francisco Bay Region (RWQCB-SFBR) to administer the NPDES permit process within the region.

F. Pursuant to Section 402(p) of the CWA and EPA regulations, the RWQCB-SFBR adopted the following orders further defining the program that the PARTIES are to develop and implement:

1. Order No. 90-094 (NPDES Permit No. CA0029718); adopted June 20, 1990
2. Order No. 92-021 Amendment to Order 90-094; adopted February 19, 1992
3. Order No. 93-164 (further addressing Order 90-094); adopted December 15, 1993
4. Order No 95-180 (NPDES Permit No. CAS029718); adopted August 23, 1995 (which rescinds and supersedes Orders No. 90-094, 92-021 and 93-164)

G. In and for the mutual interest of the PARTIES, the PARTIES wish to continue the Program by entering into this Agreement for the purpose of ensuring continued participation, in terms of cost and administrative responsibilities.

H. The District is a local public agency of the State of California duly organized and existing and empowered to provide maintenance and flood control management of the streams and to manage the discharge of storm waters in certain surface streams, reservoirs, or conduits within the area of the County of Santa Clara. The County of Santa Clara and all of the other PARTIES therein are subdivisions of the State of California with limited authority to regulate the discharge of certain storm waters within and from their respective jurisdictions.

I. The RWQCB-SFBR is conducting a Watershed Management Initiative (WMI) in Santa Clara County. The Program is required, as part of its NPDES permit, to develop and implement a Watershed Management Measures Strategy. The Urban Runoff Management Plan of the Program contains the Program's Watershed Management Measures Strategy. This strategy, consistent with the NPDES permit, coordinates Program activities with the WMI to develop and implement cost-effective approaches to address specific urban runoff pollution problems. The Program, through a continuous improvement process, annually reviews the strategy.

SECTION II

NOW, THEREFORE, THE PARTIES HERETO FURTHER AGREE, AS FOLLOWS

A. The Santa Clara Valley Nonpoint Source Pollution Control Program is hereby continued as the Santa Clara Valley Urban Runoff Pollution Prevention Program to fulfill the requirements of NPDES Permit No. CAS029718 or subsequent NPDES permit(s); (hereinafter referred to as "NPDES Permit").

B. A Management Committee is hereby reconfirmed to provide for overall Program coordination, review, and budget oversight, in accordance with the NPDES Permit. The Management Committee membership is comprised of one representative from each agency shown on Exhibit A hereto.

C. The Management Committee shall, as necessary, adopt Bylaws for its governance and further definition of the Program or assignment of duties.

D. The PARTIES shall pay a yearly assessment into a fund established for Program operations for their assigned portion of the Program budget. The amount of the Program budget that each PARTY shall pay shall be in the proportions shown in the schedule marked Exhibit B hereto. The Management Committee may re-evaluate and modify the proportion of the annual Program contribution that each PARTY shall pay. This cost-share allocation re-evaluation may be conducted periodically, as deemed necessary, by the members of the Management Committee in accordance with a process set forth in the Bylaws (Section 400.2).

E. The Management Committee shall select an agency or PARTY to act as fiscal agent for Program Management. The Fiscal Agent shall be the treasurer of the Program Fund. The Fiscal Agent, in accordance with generally accepted accounting procedures, shall keep the Program Fund segregated from other funds, credit the Program Fund with its appropriate interest income earned in each fiscal year, and shall not expend any funds except in accordance with the annual budget approved by the Management Committee or as otherwise directed by the Management Committee. The Management Committee, through its Bylaws, may establish procedures for tracking, accounting for, and auditing the Program Fund. The Fiscal Agent, at its discretion, may be reimbursed, from the Program Fund, for costs incurred while providing services as treasurer.

F. The Management Committee shall select an agent or PARTY to act as contracting agent for the Program. The Contracting Agent shall be a legal government entity capable of executing contracts with consultants or contractors. The Management Committee shall be responsible for selecting the consultant or contractor in a manner acceptable to the Contracting Agent and for providing the Contracting Agent with the scope of work for the contract. The Contracting Agent shall act in a reasonable amount of time to execute the contract. A copy of the executed contract shall be sent to the Management Committee Chairperson, the Program Manager and any co-permittee upon request. The Contracting Agent at its discretion, and with Management Committee approval, may be reimbursed, from Program funds, for the cost incurred while providing the services noted herein.

G. The Management Committee shall select a consultant or PARTY to act as Program Manager for the Program. The Program Manager shall be responsible for Program Management and Administration, Permit Management, and Technical Program Management all in accordance with the PARTIES' NPDES Permit, this Agreement, Program Bylaws, and as directed by the Management Committee in the best interest of the PARTIES as a whole and individually. The Program Manager shall be reimbursed, from Program funds, for the cost incurred while providing the services noted herein.

H. The Management Committee shall select a consultant or PARTY to act as legal agent for the Program. The legal agent is responsible for providing legal advice to the Management Committee on all matters affecting compliance with NPDES permits for the Program.

I. In addition to the participation in the Management Committee, the PARTIES accept and agree to perform the following duties:

1. Each will comply with the NPDES Permit conditions set forth in its Community-Specific plan;

2. Each will participate in Management Committee meetings and other required meetings of the PARTIES;

3. Each will implement its Community-Specific program; and

4. Each will provide agreed upon reports to the Program for purposes of reporting, on a joint basis, compliance with applicable provisions of the NPDES Permit and Program implementation.

J. The term of this Agreement shall commence on the date the last duly authorized representative of the PARTIES executes it.

K. Any PARTY may terminate its participation in this Agreement in any year by giving the Chair of the Management Committee a 30 day written notice. The terminating PARTY will bear the full responsibility for its compliance with the NPDES Permit commencing on the date it terminates its participation. Termination shall constitute forfeiture of all of the terminating PARTY's share of the Program budget, as described in Section F., for the fiscal year that the termination occurred (both paid and obligated but unpaid amounts) and all previous fiscal years. The cost allocations for the remaining PARTIES shall be recalculated for the following fiscal year pursuant to Section II. D.

L. This Agreement does not restrict the PARTIES from the ability to individually (or collectively) request NPDES Permit modifications and/or initiate NPDES Permit appeals for permit provisions to the extent that a provision affects an individual party (or group of PARTIES); however, any such PARTY (or PARTIES) shall make reasonable efforts to provide advance notice of their action to the other PARTIES and allow them to comment upon or join in their action before proceeding.

M. This Agreement supersedes any prior agreement among all the PARTIES regarding the Program, but does not supersede any other individual agreements between any of the PARTIES.

N. This Agreement may be amended by unanimous written agreement of the PARTIES. All PARTIES agree to bring any amendment to this agreement to their Council or Board, as applicable, within three (3) months following acceptance by the Management Committee.

O. This Agreement shall have a term of five (5) years subject to automatic renewal for a like period in the absence of objection thereto made in writing by any party 90 days in advance of the renewal date.

P. This Agreement may be executed and delivered in any number of copies ("counterpart") by the PARTIES, including by means of facsimile. When each PARTY has signed and delivered at least one counterpart to the Program, each counterpart shall be deemed an original and, taken together, shall constitute one and the same Agreement, which shall be binding and effective as to the PARTIES hereto.

IN WITNESS WHEREOF, the PARTIES hereto have executed this Agreement as of the day and year first above written.

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SANTA CLARA VALLEY WATER DISTRICT, a body corporate and politic of the State of California

Date:_____

By:_____
Chair, Board of Directors

Date:_____

By:_____
General Manager

APPROVED AS TO FORM:

Date:_____

By:_____
General Counsel

ATTEST:

Date:_____

By:_____

EXHIBIT A

SANTA CLARA VALLEY URBAN RUNOFF POLLUTION PREVENTION PROGRAM MANAGEMENT COMMITTEE

- Campbell
- Cupertino
- Los Altos
- Los Altos Hills
- Los Gatos
- Milpitas
- Monte Sereno
- Mountain View
- Palo Alto
- San Jose
- Santa Clara
- Santa Clara County
- Santa Clara Valley Water District
- Saratoga
- Sunnyvale
- Regional Water Quality Control Board (ex-officio)

EXHIBIT B

SANTA CLARA VALLEY NONPOINT SOURCE PROGRAM
SCHEDULE OF COST-SHARING PROPORTIONS

Jurisdiction	Proportional Share
Campbell	1.88%
Cupertino	2.46%
Los Altos	1.59%
Los Altos Hills	0.43%
Los Gatos	1.74%
Milpitas	2.75%
Monte Sereno	0.14%
Mountain View	3.91%
Palo Alto	4.06%
Santa Clara	6.23%
Saratoga	1.59%
Sunnyvale	7.25%
Santa Clara County	5.94%
Subtotal	39.97%
San Jose	30.01%
District	30.02%
TOTAL	100.00%

Santa Clara Valley Urban Runoff Pollution Prevention Program ***Management Committee*** ***Agenda Item***	AGENDA ITEM #: V.A.2. ACTION: Information Only DATE: February 19, 1998

SUBJECT: Information on Storm Water Program Funding Methods Used by San Mateo County and Alameda County

RECOMMENDED ACTION: None

DISCUSSION: The attached sheets provide information on the methods of funding used by the San Mateo Countywide Stormwater Pollution Prevention Program (STOPPP) and the Alameda Countywide Clean Water Program.

In San Mateo County, the Flood Control District is authorized by AB 2635 (1992) to impose a parcel tax to fund storm drainage programs such as STOPPP. In FY 97-98, the charge was $3.44 per household. The participating municipalities must approve a resolution each year allowing these charges.

In Alameda County, the cost of the stormwater program is allocated based half on population and half on area within each municipality (the area of the County used in the formula represents the urbanized area only). The Alameda Flood Control and Water Conservation District pays Oakland and Emeryville's contributions as well as half of the County's contribution (a total of about 30%) because of historical benefit assessment collections.

Helm

SAMPLE

RESOLUTION NO._____

A RESOLUTION OF THE CITY COUNCIL OF THE CITY OF_____ RECOMMENDING THAT THE SAN MATEO COUNTY FLOOD CONTROL DISTRICT IMPOSE CHARGES FOR FUNDING COUNTY-WIDE NATIONAL POLLUTION DISCHARGE ELIMINATION SYSTEM (NPDES) GERNERAL PROGRAM

WHEREAS, The Environmental Protection Agency, under amendments to the 1987 Federal Clean Water Act, imposed regulations that mandate local governments to control and reduce the amount of stormwater pollutant runoff into receiving waters.

WHEREAS, under the authority of California Porter-Cologne Water Quality Act, the State Water Resources Control Board has delegated authority to its regional boards to invoke permitting requirements upon counties and cities.

WHEREAS, in July 1991, the San Francisco Bay Regional Water Quality Control Board notified San Mateo County of the requirement to submit an NPDES Permit Application by November 30, 1992.

WHEREAS, in furtherance of the NPDES Permit Process, San Mateo County in conjunction with all incorporated cities in San Mateo County has prepared a Stormwater Management Plan which has a General Program as a fundamental component of the Management Plan.

WHEREAS, the Stormwater Management Plan has been submitted to the San Francisco Bay Regional Water Quality Control Board and the Management Plan has been approved by the Board and made part of the NPDES Waste Discharge Permit CA 0029921, issued September 13, 1993 and remaining in effect through June 30, 1998.

WHEREAS, the San Mateo County Flood Control District Act, as amended by the State Legislature in 1992 (Assembly Bill 2635), authorizes the San Mateo County Flood Control District to impose charges to fund storm drainage programs such as the NPDES Program; County-wide General Program charges for Fiscal Year 1997/98 as anticipated to be $958,900 or; Single Family Resident: $3.44/APN; Miscellaneous, Agricultural, Vacant and Condominium: $1.72/APN; all other land uses a base rate of $3.44/APN plus $0.3127 per 1,000 additional square feet of parcel area.

WHEREAS, the City of ____ _____ has held a hearing upon the proposal to fund the County-wide NPDES General Program through the San Mateo County Flood Control District; and City Council makes the below resolve following that hearing.

NOW, THEREFORE, BE IT RESOLVED BY THE City Council of the City of _____ that:

1. The City of _____ _____ respectfully requests the San Mateo County Board of Supervisors, acting as the governing board of the San Mateo County Flood Control District, to impose those charges necessary to fund the County-wide NPDES General Program; and

2. The City Clerk is hereby directed to forward a copy of this Resolution to the San Mateo County Board of Supervisors.

I,_____, City Clerk of the City of _____, do hereby certify that the foregoing Resolution was introduced at a regular meeting of the City Council held on the _____ day of _____, 1997 and was adopted thereafter by the following vote:

AYES: COUNCILMEMBERS:

NOES: COUNCILMEMBERS:

ABSENT: COUNCILMEMBERS:

_____
City Clerk

Jan-12-98 04:10P Bob Davidson 415 593 3820 P.04

EXHIBIT B

FORMULAS FOR CALCULATING PERCENTAGE COST AND VOTING SHARES TO SUPPORT GENERAL PROGRAM

$$\textit{Each Municipality's Percentage Cost Share} = \left[\frac{0.5\ (\textit{Area within Municipality})}{(\textit{Total Area of All Municipalities})} + \frac{0.5\ (\textit{Population within Municipality})}{(\textit{Total Population of All Municipalities})}\right] x\ 100$$

If based on this calculation the share would be <1.00, assign a value of 1.00% to the municipality and recalculate the other municipalities allocation based on the remaining unallocated percentage.

For Alameda County the population of the entire unincorporated portion of the county is used, but the area of the county used in the formula is 50.2 square miles.

The cost allocation percentage equals the voting share for each agency except as follows:

Alameda County's Voting Share = Calculated Cost Share - 1.00%

District's Voting Share = 1.00%

SARB_000869

3B Model Urban Runoff Ordinance

MODEL ORDINANCE

ORDINANCE NO. _____ C.S.
ORDINANCE ADDING NEW ARTICLE 2 TO CHAPTER 31.5
OF THE [Municipality] CITY CODE REGARDING
URBAN STORM WATER QUALITY MANAGEMENT AND DISCHARGE CONTROL

- - - - -

THE COUNCIL OF THE CITY OF **[Municipality]** DOES ORDAIN AS FOLLOWS:

SECTION 1. A new Article 2 is hereby added to Chapter 31.5 of the **[Municipality]** City Code regarding Urban Storm Water Quality Management and Discharge Control, which shall read in its entirety as follows:

"ARTICLE 2.

URBAN STORM WATER QUALITY MANAGEMENT AND DISCHARGE CONTROL.

Division I.

Title, Purpose and General Provisions.

Section 31.5-4. Title.

This Article shall be known as the "Urban Storm Water Quality Management and Discharge Control Ordinance" of the City of **[Municipality]** and may be so cited.

Section 31.5-5. Purpose and Intent.

The purpose and intent of this Article is to ensure the health, safety, and general welfare of citizens, and protect and enhance the water quality of watercourses and water bodies in a manner pursuant to and consistent with the Federal Clean Water Act (33 U.S.C. §1251 et seq.) by reducing pollutants in storm water discharges to the maximum extent practicable and by prohibiting non-storm water discharges to the storm drain system.

Section 31.5-6. Definitions.

The terms used in this Article shall have the following meanings:

(a) Best Management Practices. Activities, practices, and procedures to prevent or reduce the discharge of pollutants directly or indirectly to the municipal storm drain system and

waters of the United States. Best Management Practices include but are not limited to: treatment facilities to remove pollutants from storm water; operating and maintenance procedures; facility management practices to control runoff, spillage or leaks of non-storm water, waste disposal, and drainage from materials storage; erosion and sediment control practices; and the prohibition of specific activities, practices, and procedures and such other provisions as the City determines appropriate for the control of pollutants. Please refer to the City of **[Municipality]** *BMP Guidance Series*, as discussed further in Section 31.5-16(c) herein, for specific requirements.

(b) City. The City of **[Municipality]**.

(c) Clean Water Act. The federal Water Pollution Control Act (33 U.S.C. § 1251 et seq.), and any subsequent amendments thereto.

(d) Construction Activity. Activities subject to NPDES Construction Permits. These include construction projects resulting in land disturbance of 5 acres or more. Such activities include but are not limited to clearing and grubbing, grading, excavating, and demolition.

(e) Hazardous Materials. Any material, including any substance, waste, or combination thereof, which because of its quantity, concentration, or physical, chemical, or infectious characteristics may cause, or significantly contribute to, a substantial present or potential hazard to human health, safety, property, or the environment when improperly treated, stored, transported, disposed of, or otherwise managed (California Health and Safety Code §25117).

(f) Illegal Discharge. Any direct or indirect non-storm water discharge to the storm drain system, except as exempted in Division II, Section 31.5-12 of this chapter.

(g) Illicit Connections. An illicit connection is defined as either of the following:

1. Any drain or conveyance, whether on the surface or subsurface, which allows an illegal discharge to enter the storm drain system including but not limited to any conveyances which allow any non-storm water discharge including sewage, process wastewater, and wash water to enter the storm drain system and any connections to the storm drain system from indoor drains and sinks, regardless of whether said drain or connection had been previously allowed, permitted, or approved by a government agency; or

2. Any drain or conveyance connected from a commercial or industrial land use to the storm drain system which has not been documented in plans, maps, or equivalent records and approved by the City.

(h) Industrial Activity. Activities subject to NPDES Industrial Permits as defined in 40 CFR, Section 122.26 (b)(14).

(i) National Pollutant Discharge Elimination System (NPDES) Storm Water Discharge Permits. General, group, and individual storm water discharge permits which regulate facilities defined in federal NPDES regulations pursuant to the Clean Water Act. The California Regional

Water Quality Control Board, Central Coast Region (hereinafter, Regional Board) and the State Water Resources Control Board have adopted general storm water discharge permits, including but not limited to the General Construction Activity and General Industrial Activity permits.

(j) Non-Storm Water Discharge. Any discharge to the storm drain system that is not composed entirely of storm water.

(k) Pollutant. Anything which causes or contributes to pollution. Pollutants may include, but are not limited to: paints, varnishes, and solvents; oil and other automotive fluids; non-hazardous liquid and solid wastes and yard wastes; refuse, rubbish, garbage, litter, or other discarded or abandoned objects, articles, and accumulations, so that same may cause or contribute to pollution; floatables; pesticides, herbicides, and fertilizers; hazardous substances and wastes; sewage, fecal coliform and pathogens; dissolved and particulate metals; animal wastes; wastes and residues that result from constructing a building or structure (including but not limited to sediments, slurries, and concrete rinsates); and noxious or offensive matter of any kind.

(l) Pollution. The human-made or human-induced alteration of the quality of waters by waste to a degree which unreasonably affects, or has the potential to unreasonably affect, either the waters for beneficial uses or the facilities which serve these beneficial uses (California Water Code §13050).

(m) Porter-Cologne Act. The Porter-Cologne Water Quality Control Act and as amended (California Water Code §13000 et seq.).

(n) Premises. Any building, lot, parcel of land, or portion of land whether improved or unimproved including adjacent sidewalks and parking strips.

(o) Storm Drain System. Publicly-owned facilities operated by the City by which storm water is collected and/or conveyed, including but not limited to any roads with drainage systems, municipal streets, gutters, curbs, inlets, piped storm drains, pumping facilities, retention and detention basins, natural and human-made or altered drainage channels, reservoirs, and other drainage structures which are within the City and are not part of a publicly owned treatment works as defined at 40 CFR Section 122.2.

(p) Storm Water. Any surface flow, runoff, and drainage consisting entirely of water from rain storm events.

(q) Waters of the United States. Surface watercourses and water bodies as defined at 40 CFR § 122.2. including all natural waterways and definite channels and depressions in the earth that may carry water, even though such waterways may only carry water during rains and storms and may not carry storm water at and during all times and seasons.

Section 31.5-7. Applicability.

This Article shall apply to all water entering the storm drain system generated on any developed and undeveloped lands lying within the City of [**Municipality**] including any amendments or revisions thereto.

Section 31.5-8. Responsibility for Administration.

The Public Works Director of the City shall administer, implement, and enforce the provisions of this Article. Any powers granted or duties imposed upon the Public Works Director may be delegated in writing by the Public Works Director to persons or entities acting in the beneficial interest of or in the employ of the City.

Section 31.5-9. Severability.

The provisions of this Article are hereby declared to be severable. If any provision, clause, sentence, or paragraph of this Article or the application thereof to any person, establishment, or circumstances shall be held invalid, such invalidity shall not affect the other provisions or application of this Article.

Section 31.5-10. Regulatory Consistency.

This Article shall be construed to assure consistency with the requirements of the Clean Water Act and Porter-Cologne Act and acts amendatory thereof or supplementary thereto, or any applicable implementing regulations.

Section 31.5-11. Ultimate Responsibility of Discharger.

The standards set forth herein and promulgated pursuant to this Article are minimum standards; therefore this Article does not intend nor imply that compliance by any person will ensure that there will be no contamination, pollution, nor unauthorized discharge of pollutants into waters of the U.S. caused by said person. This Article shall not create liability on the part of the City of [**Municipality**], or any agent or employee thereof for any damages that result from any discharger's reliance on this Article or any administrative decision lawfully made thereunder.

Division II.

Discharge Prohibitions.

Section 31.5-12. Prohibition of Illegal Discharges.

No person shall discharge or cause to be discharged into the municipal storm drain system or watercourses any materials, including but not limited to pollutants or waters containing any pollutants that cause or contribute to a violation of applicable water quality standards, other than storm water.

The commencement, conduct or continuance of any illegal discharge to the storm drain system is prohibited except as described as follows:

(a) Discharges from the following activities will not be considered a source of pollutants to the storm drain system and to waters of the U.S. when properly managed to ensure that no potential pollutants are present, and therefore they shall not be considered illegal discharges unless determined to cause a violation of the provisions of the Porter-Cologne Act, Clean Water Act, or this ordinance: potable water line flushing; uncontaminated pumped groundwater and other discharges from potable water sources; landscape irrigation and lawn watering; diverted stream flows; rising groundwater; groundwater infiltration to the storm drain system; uncontaminated foundation and footing drains; uncontaminated water from crawl space pumps; air conditioning condensation; uncontaminated non-industrial roof drains; springs; individual residential and occasional non-commercial car washing; flows from riparian habitats and wetlands; dechlorinated swimming pool discharges; street wash waters; and flows from fire fighting.

(b) The prohibition shall not apply to any non-storm water discharge permitted under an NPDES permit, waiver, or waste discharge order issued to the discharger and administered by the State of California under the authority of the Federal Environmental Protection Agency, provided that the discharger is in full compliance with all requirements of the permit, waiver, or order and other applicable laws and regulations, and provided that written approval has been granted by the City of **[Municipality]** for any discharge to the storm drain system.

(c) With written concurrence of the Regional Board, the City of **[Municipality]** may exempt in writing other non-storm water discharges which are not a source of pollutants to the storm drain system nor waters of the U.S.

Section 31.5-13. Prohibition of Illicit Connections.

(a) The construction, use, maintenance or continued existence of illicit connections to the storm drain system is prohibited.

(b) This prohibition expressly includes, without limitation, illicit connections made in the past, regardless of whether the connection was permissible under law or practices applicable or prevailing at the time of connection.

Section 31.5-14. Waste Disposal Prohibitions.

No person shall throw, deposit, leave, maintain, keep, or permit to be thrown, deposited, left, or maintained, in or upon any public or private property, driveway, parking area, street, alley, sidewalk, component of the storm drain system, or water of the U.S., any refuse, rubbish, garbage, litter, or other discarded or abandoned objects, articles, and accumulations, so that the same may cause or contribute to pollution. Wastes deposited in streets in proper waste receptacles for the purposes of collection are exempted from this prohibition.

Section 31.5-15. Discharges in Violation of Industrial or Construction Activity NPDES Storm Water Discharge Permit.

Any person subject to an industrial or construction activity NPDES storm water discharge permit shall comply with all provisions of such permit. Proof of compliance with said permit may be required in a form acceptable to the Public Works Director prior to or as a condition of a subdivision map, site plan, building permit, or development or improvement plan; upon inspection of the facility; during any enforcement proceeding or action; or for any other reasonable cause.

Division III.

Regulations and Requirements.

Section 31.5-16. Requirement to Prevent, Control, and Reduce Storm Water Pollutants.

(a) Authorization to Adopt and Impose Best Management Practices. The City will adopt requirements identifying Best Management Practices for any activity, operation, or facility which may cause or contribute to pollution or contamination of storm water, the storm drain system, or waters of the U.S. as a separate *BMP Guidance Series*. Where Best Management Practices requirements are promulgated by the City or any federal, State of California, or regional agency for any activity, operation, or facility which would otherwise cause the discharge of pollutants to the storm drain system or water of the U.S., every person undertaking such activity or operation, or owning or operating such facility shall comply with such requirements.

The Public Works Director will report to the City Council annually on the status of implementation of BMP's, the pollutants of concern to be addressed the next year, and any new BMPs to be developed. BMP's developed under this program will be included in the City of **[Municipality]** *BMP Guidance Series*.

(b) New Development and Redevelopment. The City may adopt requirements identifying appropriate Best Management Practices to control the volume, rate, and potential pollutant load of storm water runoff from new development and redevelopment projects as may be appropriate to minimize the generation, transport and discharge of pollutants. The City shall incorporate such requirements in any land use entitlement and construction or building-related permit to be issued relative to such development or redevelopment. The owner and developer shall comply with the terms, provisions, and conditions of such land use entitlements and building permits as required in this Article and the City Storm Water Utility Ordinance, Chapter 31.5, Article 1.

(c) Responsibility to Implement Best Management Practices. Notwithstanding the presence or absence of requirements promulgated pursuant to subsections (a) and (b), any person engaged in activities or operations, or owning facilities or property which will or may result in pollutants entering storm water, the storm drain system, or waters of the U.S. shall implement Best Management Practices to the extent they are technologically achievable to prevent and

reduce such pollutants. The owner or operator of a commercial or industrial establishment shall provide reasonable protection from accidental discharge of prohibited materials or other wastes into the municipal storm drain system or watercourses. Facilities to prevent accidental discharge of prohibited materials or other wastes shall be provided and maintained at the owner or operator's expense.

Best Management Practices required by the City can be obtained from the Public Works Department by requesting the BMP manual appropriate to a commercial or industrial activity from the *BMP Guidance Series*. BMP's are broken into three categories: "high priority" which are required to be implemented, "medium priority" which are desirable to implement, and "low priority."

Section 31.5-17. Requirement to Eliminate Illegal Discharges.

Notwithstanding the requirements of Division IV, Section 31.5-23 herein, the Public Works Director may require by written notice that a person responsible for an illegal discharge immediately, or by a specified date, discontinue the discharge and, if necessary, take measures to eliminate the source of the discharge to prevent the occurrence of future illegal discharges.

Section 31.5-18. Requirement to Eliminate or Secure Approval for Illicit Connections.

(a) The Public Works Director may require by written notice that a person responsible for an illicit connection to the storm drain system comply with the requirements of this Article to eliminate or secure approval for the connection by a specified date, regardless of whether or not the connection or discharges to it had been established or approved prior to the effective date of this Article.

(b) If, subsequent to eliminating a connection found to be in violation of this Article, the responsible person can demonstrate that an illegal discharge will no longer occur, said person may request City approval to reconnect. The reconnection or reinstallation of the connection shall be at the responsible person's expense.

Section 31.5-19. Watercourse Protection.

Every person owning property through which a watercourse passes, or such person's lessee, shall keep and maintain that part of the watercourse within the property reasonably free of trash, debris, excessive vegetation, and other obstacles that would pollute, contaminate, or significantly retard the flow of water through the watercourse. In addition, the owner or lessee shall maintain existing privately owned structures within or adjacent to a watercourse, so that such structures will not become a hazard to the use, function, or physical integrity of the watercourse. The owner or lessee shall not remove healthy bank vegetation beyond that actually necessary for maintenance, nor remove said vegetation in such a manner as to increase the vulnerability of the watercourse to erosion. The property owner shall be responsible for maintaining and stabilizing that portion of the watercourse that is within their property lines in

order to protect against erosion and degradation of the watercourse originating or contributed from their property.

Section 31.5-20. Requirement to Remediate.

Whenever the Public Works Director finds that a discharge of pollutants is taking place or has occurred which will result in or has resulted in pollution of storm water, the storm drain system, or water of the U.S., the Public Works Director may require by written notice to the owner of the property and/or the responsible person that the pollution be remediated and the affected property restored within a specified time pursuant to the provisions of sections 31.5-25 through 31.5-28 below.

Section 31.5-21. Requirement to Monitor and Analyze.

The Public Works Director may require by written notice of requirement that any person engaged in any activity and/or owning or operating any facility which may cause or contribute to storm water pollution, illegal discharges, and/or non-storm water discharges to the storm drain system or waters of the U.S., to undertake at said person's expense such monitoring and analyses and furnish such reports to the City of [**Municipality**] as deemed necessary to determine compliance with this Article.

Section 31.5-22. Notification of Spills.

Notwithstanding other requirements of law, as soon as any person responsible for a facility or operation, or responsible for emergency response for a facility or operation has information of any known or suspected release of materials which are resulting or may result in illegal discharges or pollutants discharging into storm water, the storm drain system, or water of the U.S. from said facility, said person shall take all necessary steps to ensure the discovery, containment, and cleanup of such release. In the event of such a release of a hazardous material said person shall immediately notify emergency response officials of the occurrence via emergency dispatch services (911). In the event of a release of non-hazardous materials, said person shall notify the City's Public Works Department in person or by phone or facsimile no later than 5:00 p.m. of the next business day. Notifications in person or by phone shall be confirmed by written notice addressed and mailed to the City's Public Works Department within three business days of the phone notice. If the discharge of prohibited materials emanates from a commercial or industrial establishment, the owner or operator of such establishment shall also retain an on-site written record of the discharge and the actions taken to prevent its recurrence. Such records shall be retained for at least three years.

Division IV.

Inspection and Monitoring.

Section 31.5-23. Authority to Inspect.

Section 31.5-26 Appeal.

Notwithstanding the provisions of Section 31.5-29 below, any person receiving a Notice of Violation under Section 31.5-25 above may appeal the determination of the Public Works Director to the City Manager. The notice of appeal must be received by the City Manager within 5 days from the date of the Notice of Violation. Hearing on the appeal before the City Manager or his/her designee shall take place within 15 days from the date of City's receipt of the notice of appeal. The decision of the City Manager or designee shall be final.

Section 31.5-27 Abatement by City.

If the violation has not been corrected pursuant to the requirements set forth in the Notice of Violation, or , in the event of an appeal under section 31.5-26, within 10 days of the decision of the City Manager upholding the decision of the Public Works Director, then the City or a contractor designated by the Public Works Director shall enter upon the subject private property and is authorized to take any and all measures necessary to abate the violation and/or restore the property. It shall be unlawful for any person, owner, agent or person in possession of any premises to refuse to allow the City or designated contractor to enter upon the premises for the purposes set forth above.

Section 31.5-28 Charging Cost of Abatement/Liens.

Within 30 days after abatement of the nuisance by City, the Public Works Director shall notify the property owner of the property of the cost of abatement, including administrative costs. The property owner may file a written protest objecting to the amount of the assessment with the City Clerk within 15 days. The City Clerk shall set the matter for public hearing by the City Council. The decision of the City Council shall be set forth by resolution and shall be final.

If the amount due is not paid within 10 days of the decision of the City Council or the expiration of the time in which to file an appeal under this Section, the charges shall become a special assessment against the property and shall constitute a lien on the property for the amount of the assessment. A copy of the resolution shall be turned over to the County Auditor so that the auditor may enter the amounts of the assessment against the parcel as it appears on the current assessment roll, and the tax collector shall include the amount of the assessment on the bill for taxes levied against the parcel of land.

Section 31.5-29 Urgency Abatement.

The Public Works Director is authorized to require immediate abatement of any violation of this Article that constitutes an immediate threat to the health, safety or well-being of the public. If any such violation is not abated immediately as directed by the Public Works Director, the City of [**Municipality**] is authorized to enter onto private property and to take any and all measures required to remediate the violation. Any expense related to such remediation undertaken by the City of **[Municipality]** shall be fully reimbursed by the property owner and/or

Whenever necessary to make an inspection to enforce any provision of this Article, or whenever the Public Works Director has cause to believe that there exists, or potentially exists, in or upon any premises any condition which constitutes a violation of this Article, the Director may enter such premises at all reasonable times to inspect the same and to inspect and copy records related to storm water compliance. In the event the owner or occupant refuses entry after a request to enter and inspect has been made, the City is hereby empowered to seek assistance from any court of competent jurisdiction in obtaining such entry.

Section 31.5-24. Authority to Sample, Establish Sampling Devices, and Test.

During any inspection as provided herein, the Public Works Director may take any samples and perform any testing deemed necessary to aid in the pursuit of the inquiry or to record site activities.

Division V.

Enforcement.

Section 31.5-25. Notice of Violation.

Whenever the Public Works Director finds that a person has violated a prohibition or failed to meet a requirement of this Article, the Director may order compliance by written notice of violation to the responsible person. Such notice may require without limitation:

(a) The performance of monitoring, analyses, and reporting;

(b) The elimination of illicit connections or discharges;

(c) That violating discharges, practices, or operations shall cease and desist;

(d) The abatement or remediation of storm water pollution or contamination hazards and the restoration of any affected property; and

(e) Payment of a fine to cover administrative and remediation costs; and

(f) The implementation or maintenance of source control or treatment BMPs.

If abatement of a violation and/or restoration of affected property is required, the notice shall set forth a deadline within which such remediation or restoration must be completed. Said notice shall further advise that, should the violator fail to remediate or restore within the established deadline, the work will be done by the City or a contractor designated by the Public Works Director and the expense thereof shall be charged to the violator pursuant to Section 31.5-27 below.

responsible party. Any relief obtained under this section shall not prevent City from seeking other and further relief authorized under this Article.

Section 31.5-30. Violations.

It shall be unlawful for any person to violate any provision or fail to comply with any of the requirements of this Article. A violation of or failure to comply with any of the requirements of this Article shall constitute a misdemeanor and shall be punished as set forth in City Code Section 1.7.

Section 31.5-31. Compensatory Action.

In lieu of enforcement proceedings, penalties, and remedies authorized by this Article, the Public Works Director may impose upon a violator alternative compensatory actions, such as storm drain stenciling, attendance at compliance workshops, creek cleanup, etc.

Section 31.5-32. Violations Deemed a Public Nuisance

In addition to the enforcement processes and penalties hereinbefore provided, any condition caused or permitted to exist in violation of any of the provisions of this Article is a threat to public health, safety, and welfare, and is declared and deemed a nuisance, and may be summarily abated or restored by the City at the violator's expense, and/or a civil action to abate, enjoin, or otherwise compel the cessation of such nuisance may be taken by the City.

Section 31.5-33. Acts Potentially Resulting in a Violation of the Federal Clean Water Act and/or California Porter-Cologne Act.

Any person who violates any provision of this Article or any provision of any requirement issued pursuant to this chapter, may also be in violation of the Clean Water Act and/or the Porter-Cologne Act and may be subject to the sanctions of those acts including civil and criminal penalties. Any enforcement action authorized under this Article shall also include written notice to the violator of such potential liability."

SECTION 2. All ordinances and parts of ordinances in conflict herewith are hereby repealed.

SECTION 3. This ordinance shall be in full force and effect 30 days after its final passage and adoption.

PASSED AND ADOPTED BY THE COUNCIL OF THE CITY OF [**Municipality**] this ____ day of _____, 19__, by the following vote:

AYES: COUNCILMEMBERS:

NOES: COUNCILMEMBERS:

ABSENT: COUNCILMEMBERS:

- - - - -

APPROVED:

/s/
Mayor of said City

ATTEST:

/s/
City Clerk thereof

Date of Publication:

3C Model General Plan Language

GENERAL PLAN AMENDMENTS

I. THE MODEL ELEMENT

A. Urban Runoff Water Quality

1. Introduction

Nationwide there are many major sources of water pollution. Pollution that originates from a specific, discrete location, referred to as a "point" source, includes: effluent from municipal wastewater treatment plants; regulated industrial wastewater discharges; hazardous wastes and materials from spills, mishandling, and industrial accidents;effluent from inadequately functioning septic systems; and illegal dumping activities.

There are also pollutants contained in urban stormwater runoff, referred to as "non-point" source pollution, due to the diffuse origins of such pollutants. These include metals, organic wastes, pesticides, and a variety of other pollutants. Other types of pollutants include those which result from disinfection of drinking water and the intrusion of salt water from the ocean into nearby groundwater aquifers. The Water Quality and Watershed Management element is designed to protect receiving waters from those pollutants referred to as "non-point" source.

In both urban and rural areas of the state, substances are deposited on the surface of the land which are carried into the area's drainage system by stormwater runoff. However, given the much more extensive amount of impervious surface area within urbanized areas, non-point source pollution is often an urban area pollution problem. Although it is a much less obvious source of pollution, it can be a significant contributor of pollutants to receiving waters throughout the state.

2. Urban Runoff Pollution Control

GOAL: Protection and enhancement of local urban creeks, lakes, wetlands, and beaches is a city goal. Policies and programs should reflect this goal by providing ways to prevent water pollution before it occurs. Achievement of this goal will result in maintaining and enhancing the quality of life valued by residents and visitors.

Policies & Programs

The intent of this general plan is to provide policies and programs that will protect receiving waters from pollutants discharged to the storm drain system. The following policies and programs address non-point source pollution issues and their "solutions."

a. Public Education

Policy 1 Coordinate with other agencies in the watershed area to develop public education programs that will get the most exposure for the money spent.

Program 1a Encourage local schools, business and neighborhood associations to become educated in urban runoff issues using the available resources of the City and other involved agencies.
Program 1b Establish a business education program to provide information and incentives to local businesses for the implementation of "Best Management Practices" for pollution prevention and control.

b. Public Outreach
Policy 2 Coordinate with existing public outreach programs and create programs to involve the community in addressing urban runoff pollution problems and raising awareness of how individuals' activities contribute to urban runoff pollution.
Program 2a: Establish a storm drain stenciling program and/or coordinate with an existing program to label catch basins with warning signs (No Dumping-Flows to Bay/Creek/River/Lake).
Program 2b: Establish a local pollution sampling and monitoring program including citizens monitoring and/or coordinate with existing regional programs.
Program 2c: Encourage public input on development and implementation of urban runoff pollution control and programs by meeting with or sending copies of proposed plans to neighborhood and business association representatives.

c. Illicit Discharge Detection and Elimination
Policy 3: Encourage measures to promote proper disposal of pollutants to the sanitary sewer or hazardous waste facilities rather than to the storm drainage system.
Program 3a: Establish and promote used oil recycling and/or hazardous waste recycling facilities and drop-off locations.
Program 3b: Review plans for new development and redevelopment for connections to storm drain system. Inspectors should field check for such connections when performing building inspections.
Program 3c: Establish a city program for following up on complaints of illegal discharges to the storm drain and creeks.

d. Construction Site Storm Water Discharge Control
Policy 4: Encourage contractors to comply with accepted storm water pollution prevention planning practices for all projects subject to erosion potential.
Program 4a: Institute routine inspection practices and training for Building Inspectors and Public Works Inspectors to check for proper erosion control methods and housekeeping practices during construction.
Program 4b: Enforce requirements for contractors to provide Storm Water Pollution Prevention Plans, grading and housekeeping plans including erosion control measures as necessary.
Program 4c: Enforce erosion control ordinances.

e. Post-Construction Controls for Development and Redevelopment

Policy 5: Establish requirements for installation and maintenance of storm water structural controls to reduce peak discharges and to maximize pollutant removal from runoff.

Program 5a: Establish discharge limits and/or maintenance requirements to be included in site plan review covenants, conditions, and restrictions(CC&R's) for private development, and requirements for City projects. These requirements should be included by Public Works and Community Development Departments responsible for project management.

Program 5b: Where feasible, encourage establishment or re-establishment of vegetated wetland areas, which can effectively serve as natural water pollutant removal filtration systems. Other vegetated areas (eg. buffer strips) can also effectively remove pollutants from runoff, and their establishment should also be encouraged.

f. Good Housekeeping Practices for Municipal Operations

Policy 6: Establish and coordinate good housekeeping procedures for all City Departments to assure that water quality objectives are not threatened by in-house operations and an example is established for the community.

Program 6a: Incorporate water quality objectives into existing regular safety inspections. Institute additional inspections as necessary.

Program 6b: Establish Best Management Practices to be followed by City Departments and hold training sessions on a regular basis to ensure that employees are familiar with those practices.

Program 6c: Educate City employees on sources and impacts of pollutants in urban runoff and actions that can be taken to reduce these sources.

Program 6d: Ensure that contractors used by City are aware of and implement urban runoff control programs.

LIST OF RECOMMENDED AMENDMENTS TO EXISTING ELEMENTS

Background Statements

Surface Runoff

The U.S. Environmental Protection Agency has identified urban surface runoff as a significant cause of water pollution in the United States. Surface runoff water may contain a variety of pollutants including: paints, varnishes and solvents; oil and other automotive fluids; non-hazardous liquid and solid wastes and yard wastes; refuse, rubbish, garbage, litter, or other discarded or abandoned objects, articles, and accumulations so that same may cause or contribute to pollution; floatables; pesticides, herbicides, and fertilizers; hazardous substances and wastes; sewage, fecal coliform and pathogens; dissolved and particulate metals; animal wastes; wastes and residues that result from constructing a building or structure (including but not limited to sediments, slurries, and concrete rinsates); and noxious or offensive matter of any kind. These pollutants are typically generated from a variety of diffuse sources present throughout the urban environment, and are referred to herein as "nonpoint" source pollution.

Common pollutants contained in urban runoff generally include:

- tire wear material;
- metals such as copper, chromium, lead, cadmium and other toxics produced by combustion, leakages, metal plating, vehicle wear, and weathered paint;
- motor fuels, lubricants, and other fluids which are inadvertently spilled or leak from vehicles, or which are purposely dumped into the ground or into the storm drainage system;
- pesticides, herbicides, and fertilizers applied to agricultural crops, landscaping, and roadsides;
- biological contaminants from litter, organic matter, and animal wastes; and
- detergents and solvents used to clean urban surfaces.

Some of these pollutants are introduced to the drainage system by individuals who are uninformed of their effects on the environment. One of the most notorious examples is that of individuals who dump used motor oil into storm drains or onto the ground. Few are aware that one quart of used motor oil is capable of contaminating 250,000 gallons of water, or that substances disposed of into the stormwater drainage system are not treated before entering receiving waters. Other substances are introduced as the result of intentional efforts to avoid the costs of legal disposal and conformance with water quality regulations. The "Illegal Dumping Elimination Program" is one component of the overall Nonpoint Source Pollution Control Program intended to help reduce such activities.

The variety of sources and concentrations of pollutants, as well as the variability of runoff, make the "end-of-pipe" treatment methods, which are often used to address industrial discharges, impractical and ineffective alternatives for non-point source pollution control. Although not without its own difficulties, the most effective means of reducing non-point source pollution are those which prevent pollutants from being introduced into, or prevent their conveyance through, the storm drainage system to receiving waters. Prevention is the key to a successful urban runoff

program with treatment of non-point source pollution used only if prevention fails to meet the goals of the Clean Water Act.

Comprehensive Watershed Management Planning

Increasingly, the governmental entities responsible for water supply will rely upon comprehensive watershed management planning in order to ensure that the quality of the waters entering local reservoirs and rivers recharging groundwater are of the highest quality. These plans involve the cooperation and coordination of many jurisdictions having land use authority and regulatory powers within the watershed or drainage area. Subjects of major concern include retention of ground cover and vegetation, timber harvesting, development impacts, land use, grading and earth moving, grazing practices, and other activities which affect urban runoff, primarily in the rural areas of the watershed.

Strategies, Policies, and Implementation

A comprehensive approach to managing water quality should include the following basic strategies, in addition to ongoing point source regulation:

Strategy #1: Reduce Non-Point Source Pollution
Strategy #2: Restore Wetlands, Riparian Areas, and Other Habitats that Improve Water Quality
Strategy #3: Prepare and Implement Comprehensive Watershed Management Plans

These strategies reflect a comprehensive approach to safeguard water resources, improve water quality, and protect the health of species dependent on them, including humans.

Insertions

Urban Runoff

Urban runoff from [municipality] is discharged into local creeks which empty into [local receiving water]. Both state and federal authorities have identified urban runoff as a major source of pollution adversely affecting the beneficial uses of waters statewide. Some of those impaired beneficial uses are recreation, commercial and sport fishing, estuarine habitat, and the preservation of rare and endangered species. [The state has issued a National Pollutant Discharge Elimination System (NPDES) Permit to [municipality] for which a municipal storm water management program must be developed and implemented.]

It is extremely difficult and expensive to control the composition of urban runoff discharges through conventional wastewater treatment technologies. Therefore, it is critical that [municipality] implement measures to identify and control the sources of pollutants before they are actually discharged into the storm drain system. In order to control the nonpoint sources of pollutants, [municipality] has reviewed the types of land uses and practices which have the potential to discharge pollutants into the storm drain system. In doing so, [municipality] has identified several key areas to control and reduce potential pollutants in urban runoff including: industrial and commercial discharges, new development and redevelopment, construction activities, illegal dumping, illicit connections to storm drains, public information and participation, and public agency activities.

General Plan Elements

A. Land Use

Apply the following watershed protection activities to all new development and redevelopment proposals during the planning, project review, and permitting processes:

• Avoid conversion of areas particularly susceptible to erosion and sediment loss (e.g., steep slopes) and/or establish development guidance that identifies these areas and protects them from erosion and sediment loss. It is a general policy to limit grading permits or allow grading in those areas susceptible to erosion from October through April.

• In order to prevent undue erosion of creek banks, [municipality] should seek to retain creek channels in their natural state. Regulate development near water courses to reduce erosion and pollution and to provide open natural areas.

• Preserve or restore areas that provide water quality benefits and/or are necessary to maintain riparian and aquatic biota.

• Promote site development that limits impact on and protects the natural integrity of topography, drainage systems, and water bodies.

• Promote integration of storm water quality protection into construction and post-construction activities at all development sites. Evaluate the ability of a land parcel to detain excess storm water runoff and require incorporation of appropriate controls, for example, through use of detention facilities. As part of site approval or as a condition of tentative maps, require permanent storm water pollution control measures or systems and an ongoing maintenance program, as necessary.

B. Circulation

• Work to reduce transportation related sources of water pollution, particularly in storm water runoff. Any means by which vehicle-miles-traveled are reduced benefits congestion and reduces air and water pollution.

• Recognize and publicize the relationship between air pollution and water pollution in the deposition onto streets and other surfaces of airborne contaminants, including metals and fine particulate matter (PM10).

C. Housing

• Housing policies and programs stated in the General Plan should be consistent with water quality preservation goals stated within the conservation element.

D. Conservation

• Comprehensive watershed management plans should be developed and implemented for drainage basins in [municipality]. In order to do this, close coordination should take place among the County, the cities, and the various special districts whose decisions and activities affect the county's and cities' watersheds and other natural resources.

• [Municipality] shall implement urban runoff pollution control measures and programs to attempt to reduce and control the discharge of pollutants into the municipality's storm drains and local creeks to the maximum extent practicable.

• Reduce the quantity of runoff and discharge of pollutants to the maximum extent practicable by integrating surface runoff controls into new development and redevelopment land use decisions.

• [Municipality] should support, and contribute to, the acquisition of areas of open space that have water quality significance by City and County Parks, State Parks, and other agencies and non-profit organizations for permanent preservation.
• Work with other local government agencies on land use issues county-wide in order to maintain a watershed-based approach to land use, flood control, and nonpoint source pollution prevention.
• Hazard and resource areas with the following characteristics shall be considered unsuited for urban development: flood potential; wetlands; riparian corridors; and areas generally above 25% slope.
• Land uses which pose a major threat to water quality, including commercial and industrial uses such as automobile dismantlers, transportation and vehicle storage facilities, waste transfer disposal facilities, light industries, and other uses that have a significant potential for pollution, shall not be located within the vicinity of streams, reservoirs, or percolation facilities or where pollutants could easily come in contact with flood waters, high groundwater, flowing streams, or reservoirs. Such uses shall be required to reduce any threat of pollution to an insignificant level as a condition of approval.
• Particulate matter pollution shall be minimized through control over new and redevelopment (including erosion and sediment controls on grading, quarrying, vegetation removal, construction and demolition), industrial processes, parking lots, and other activities which pose such a threat to water quality.

E. Open Space

• Open space policies and programs should be consistent with those water quality policies and programs set forth in the conservation element. Open space areas should be managed with erosion control and pollution prevention measures in the forefront.

F. Safety

• Water quality protection measures set forth throughout the General Plan are the result of United States Environmental Protection Agency legislation under the Clean Water Act. The intent of these measures is to protect the health and safety of humans as well as to protect the beneficial uses of receiving waters.

G. Noise

• Not applicable to water quality.

3D CEQA Checklist Revisions

Appendix H: Environmental Information Form

▶ Adapted from Appendix H of the 1996 CEQA Guidelines with MURP's suggested revisions in **bold underline**.

(To be completed by applicant)

Date filed: _____

General Information

1. Name and address of developer or project sponsor: _____

   _____

2. Address of project: _____

   Assessor's Block and Lot Number: _____

3. Name, address, and telephone number of person to be contacted concerning this project:

   _____

4. Indicate number of the permit application for the project to which this form pertains: _____

5. List and describe any other related permits and other public approvals required for this project, including those required by city, regional, state and federal agencies:

   _____

   _____

   _____

6. Existing zoning district: _____

7. Proposed use of site (Project for which this form is filed): _____

   _____

   _____

Project Description

8. Site size.
9. Square footage.
10. **Existing and proposed impervious surface coverage.**
11. Number of floors of construction.
12. Amount of off-street parking provided.
13. Attach plans.
14. Proposed scheduling.
15. Associated project.
16. Anticipated incremental development.
17. If residential, include the number of units, schedule of unit sizes, range of sale prices or rents, and type of household size expected.
18. If commercial, indicate the type, whether neighborhood, city or regionally oriented, square footage of sales area, and loading facilities.
19. If industrial, indicate type, estimated employment per shift, and loading facilities.

Appendix H continued (note MURP's suggested revisions in **bold underline**)

20. If institutional, indicate the major function, estimated employment per shift, estimated occupancy, loading facilities, and community benefits to be derived from the project.

21. If the project involves a variance, conditional use or rezoning application, state this and indicate clearly why the application is required.

Are the following items applicable to the project or its effects? Discuss below all items checked yes (attach additional sheets as necessary).

	Yes	No
22. Change in existing features of any bays, tidelands, beaches, **wetlands, riparian areas, ponds, springs, creeks, streams, rivers, lakes, estuaries,** or hills, or substantial alteration of ground contours.	☐	☐
23. Change in scenic views or vistas from existing residential areas or public lands or roads.	☐	☐
24. Change in pattern, scale or character of general area of project.	☐	☐
25. **Generate** significant amounts of solid waste or litter.	☐	☐
26. Change in dust, ash, smoke, fumes or odors in vicinity.	☐	☐
27. Change in ocean, bay, lake, stream, **wetland, riparian area, pond, spring, creek, river, estuary, tidal area** or ground water quality or quantity, ~~or~~ alteration of existing drainage patterns, **or untreated runoff will leave the site**.	☐	☐
28. Substantial change in existing noise or vibration levels in the vicinity.	☐	☐
29. Site on filled land or on slope of 10 percent or more.	☐	☐
30. Use or disposal of potentially hazardous materials, such as toxic substances, flammables or explosives.	☐	☐
31. Substantial change in demand for municipal services (police, fire, water, sewage, **storm drain,** etc.).	☐	☐
32. Substantially increase fossil fuel consumption (electricity, oil, natural gas, etc.).	☐	☐
33. Relationship to a larger project or series of projects.	☐	☐

Environmental Setting

34. Describe the project site as it exists before the project, including information on topography, soil stability, plants and animals, **waterbodies (wetlands, riparian areas, ponds, springs, creeks, streams, rivers, lakes, estuaries, tidal areas, bays, ocean, etc.),** and any cultural, historical or scenic aspects. Describe any existing structures on the site, and the use of the structures. Attach photographs of the site. Snapshots or polaroid photos will be accepted.

35. Describe the surrounding properties, including information on plants and animals, **adjacent waterbodies (wetlands, riparian areas, ponds, springs, creeks, streams, rivers, lakes, estuaries, tidal areas, bays, ocean, etc.),** and any cultural, historical or scenic aspects. Indicate the type of land use (residential, commercial, etc.), intensity of land use (one-family, apartment houses, shops, department stores, etc.), and scale of development (height, frontage, set-back, rear yard, etc.). Attach photographs of the vicinity. Snapshots or polaroid photos will be accepted.

Certification

I hereby certify that the statements furnished above and in the attached exhibits present the data and information required for this initial evaluation to the best of my ability, and that the facts, statements, and information presented are true and correct to the best of my knowledge and belief.

Date _____ Signature _____

For _____

(Note: This is only a suggested form. Public agencies are free to devise their own format for initial studies.)

Appendix G: Environmental Checklist Form

▶ MURP's suggested revisions in **bold underline**.

Page 8, Section VII (Hydrology and Water Quality); The following additional questions should be added:

h) Will the project result in discharge, directly or through a storm drain system, into surface waters (including, but not limited to, wetlands, riparian areas, ponds, springs, creeks, streams, rivers, lakes, estuaries, tidal areas, bays, ocean, etc.)?

i) Will the project alter ground water or surface water quality, temperature, dissolved oxygen, or turbidity?

j) Will the project introduce typical storm water pollutants (including, but not limited to: paints, varnishes, and solvents; hydrocarbons and metals from vehicle use or business operations; non-hazardous solid wastes and yard wastes; sediment from construction activities (including silts, clays, slurries, concrete rinsates, etc.); ongoing sedimentation due to changes in land cover/land use; nutrients, pesticides, herbicides, and fertilizers (e.g., from landscape maintenance); hazardous substances and wastes; sewage, fecal coliforms, animal wastes, and pathogens; dissolved and particulate metals; other sediments and floatables; metals and acidity from mining operations.) into ground or surface water?

----- OR, ALTERNATIVELY, QUESTION J COULD READ (with or without footnote) -----

j) Will the project introduce typical storm water pollutants[1] into ground or surface water?

Page 11, Section XVI (Utilities and Service Systems), Question c should be revised as follows:

c) Require or result in the construction of new storm water drainage **or water quality control** facilities or expansion of existing facilities, the construction of which would cause significant environmental effects?

[1] "Typical storm water pollutants" include, but are not limited to: paints, varnishes, and solvents; hydrocarbons and metals from vehicle use or business operations; non-hazardous solid wastes and yard wastes; sediment from construction activities (including silts, clays, slurries, concrete rinsates, etc.); ongoing sedimentation due to changes in land cover/land use; nutrients, pesticides, herbicides, and fertilizers (e.g., from landscape maintenance); hazardous substances and wastes; sewage, fecal coliforms, animal wastes, and pathogens; dissolved and particulate metals; other sediments and floatables; metals and acidity from mining operations.

3E Utility Ordinance and Resolution

ORDINANCE NO. _____ C.S.

ORDINANCE CREATING A NEW MONTEREY CITY CODE CHAPTER 31.5 ENTITLED "STORM WATER MANAGEMENT UTILITY" AND A NEW STORM AND SURFACE WATER MANAGEMENT ENTERPRISE AND UTILITY.

- - - - - - - - - - - - - - -

THE COUNCIL OF THE CITY OF MONTEREY DOES ORDAIN AS FOLLOWS:

SECTION 1. The City Council is aware of the problems facing the City relating to storm and surface water runoff in terms of public safety, flooding, property damage, erosion, water quality, and potential pollution of Monterey Bay, and finds as follows:

1. All developed real property in the City contributes to increased storm and surface water runoff into the storm drainage system by virtue of increased runoff from impervious improvements to the property, thereby adding to the storm drainage problem; and

2. All developed real property in the City uses and benefits from an adequate, functioning, storm and surface drainage system; and

3. The City has studied the storm and surface water runoff and the existing and proposed storm and surface water management system and associated improvements, and determined that the storm and surface water management system should be operated, maintained, constructed, and reconstructed as an enterprise and utility of the city; and

4. The City currently maintains the ditches, pipes, culverts, streamways, and other portions of the storm and surface water management system through general fund expenditures; and

5. The City is faced with increased state and federal mandates to reduce deposits of toxic substances and pollutants into Monterey Bay from storm water runoff; and

6. A need exists for additional funding for the storm and surface water management program of the City, and creation of an enterprise and utility of the City for this purpose will best facilitate and control the funding and maintenance of this program.

7. The provisions of this Ordinance do not constitute a project under the provisions of the California Environmental Quality Act.

SECTION 2. A new Chapter 31.5 is hereby created to establish a Storm Water Management Utility to read as follows:

"CHAPTER 31.5
STORM WATER MANAGEMENT UTILITY

§ 31.5-1 Utility created.
§ 31.5-2 Management of system.
§ 31.5-3 Fee; Collection.

Sec. 31.5-1 Utility created.

A Storm Water Management Utility is created as a City enterprise and utility to operate, maintain, and fund the City's storm and surface drainage system. The purpose of this utility includes, but is not limited to, permitting, maintenance, planning, design, construction, regulation, surveying, water quality testing, and inspection relating to storm and surface water management facilities.

Sec. 31.5-2 Management of system.

(a). The Public Works Director shall act as director of the Utility and shall be responsible for administering and managing the operations of the storm and surface water management system in accordance with the provisions of management programs adopted by the City Council.

(b). The City Council may adopt a storm and surface water management program or regulations to facilitate operation of the Utility.

Sec. 31.5-3 Fees; Collection.

(a). The City Council may establish a Storm Water Management Utility fee to be imposed upon users of the storm water drainage system, with the basis and amount of the fee to be established by Resolution. The purpose of the fee is to provide for the costs and expense of improving the water quality of storm and surface water control facilities, the costs of planning, permitting, designing, establishing, acquiring, developing, constructing, or improving storm and surface water management facilities or improvements, or to pay or secure the payment of any indebtedness incurred for such purpose.

(b). Collection. Any fee imposed pursuant to this Chapter shall be collected by the Finance Director in accordance with provisions set forth in the Resolution establishing the basis and amount of the fee. The fees may be collected directly from users, or the collection may be contracted to other public or private utilities for collection in conjunction with their utility bills."

SECTION 3. All ordinances and parts of ordinances in conflict herewith are hereby repealed.

SECTION 4. This ordinance shall be in full force and effect 30 days after its final passage and adoption.

PASSED AND ADOPTED BY THE CITY COUNCIL OF THE CITY OF MONTEREY this 6th day of July, 1993, by the following vote:

AYES: _____ COUNCILMEMBERS:
NOES: _____ COUNCILMEMBERS:
ABSENT:_____ COUNCILMEMBERS:

- - - - - - - - - - - - - - - - - - - -

APPROVED:

/s/_____
Mayor of said City

ATTEST:

/s/_____
City Clerk thereof

Date of Publication:

ATTACHMENT A

RESOLUTION NO._____

RESOLUTION AMENDING UTILITY FEE FOR STORM AND SURFACE WATER MANAGEMENT

The Council of the City of Monterey does RESOLVE as follows:

WHEREAS, the City Council finds that the City is subject to damage from storm waters from existing water courses and drainage facilities such that existing storm and surface water drainage facilities require continuous operation, maintenance, renewal and replacement; and

WHEREAS, each owner and occupier of a lot or parcel of real property within the City, to the extent that such person and property makes use of, and is served by the City's storm and surface water runoff beyond that amount of storm and surface water which would occur if that real property were undeveloped in its natural state, should pay for the use and the availability for use of such facilities; and

WHEREAS, the City Council has adopted an ordinance which established the Storm and Surface Water Management System Enterprise and Utility; and

WHEREAS, the City Council intends to establish reasonable storm drainage fees computed on a basis of the use made of, and the need for, and the service provided by the storm drainage system of the City; and

WHEREAS, the purpose of the fees established herein is to provide a method for payment of all or any part of the cost and expense of improving the quality of storm and surface water runoff, maintaining and operating storm and surface water control facilities, all or any part of the cost and expense for of planning, designing, establishing, acquiring, developing, constructing and improving of such facilities, or to pay or secure the payment of all or any portion of any indebtedness incurred for such purpose.

NOW, THEREFORE, the Council of the City of Monterey does RESOLVE that this Resolution will establish rates and regulations for the storm and surface water management system as a City enterprise and utility. The Council hereby approves and adopts Utility Rate Schedule and Special Storm and Surface Water Management Utility Regulations attached hereto and incorporated herein by this reference to be effective as of January 1, 1996. Purposes for establishing such enterprise and utility include, but are not limited to, maintenance, planning, design, construction, regulation, surveying, and inspection relating to surface and storm water management facilities of the City.

AND BE IT FURTHER RESOLVED that, since larger floods from storm water runoff may occasionally occur which exceed the capacity of storm drainage facilities constructed and maintained by funds made available under this division, neither this Resolution nor the Rate

Schedule and Rule and Regulation adopted herewith imply that property liable for the fees and charges established herein will always be free from storm water flooding or flood damage. Nor shall this Resolution create a liability on the part of, or cause of action against, the City of any officer or employee thereof for any flood damage that may result from such storms or the runoff thereof. Nor does this Resolution purport to reduce the need or the necessity for obtaining flood insurance;

AND BE IT FURTHER RESOLVED that if any section, sentence, clause, or phrase of this resolution or the Rate and Regulation adopted herewith is held to be invalid or unconstitutional by any court of competent jurisdiction, then said holding shall in no way affect the validity of the remaining portions of this resolution;

AND BE IT FURTHER RESOLVED that the Council finds that the provisions of the Resolution do not constitute a project under the provisions of the California Environmental Quality Act.

PASSED AND ADOPTED BY THE COUNCIL OF THE CITY OF Monterey this 17th day of October ,1997 by the following vote:

AYES:_____ COUNCILMEMBERS:
NOES:_____ COUNCILMEMBERS:
ABSENT:_____ COUNCILMEMBERS:

Approved:

/s/Daniel Albert
Mayor of said City

Attest:

/s/Cynthia Parham
City Clerk thereof

SPECIAL STORM AND SURFACE WATER MANAGEMENT UTILITY REGULATIONS

A. DEFINITIONS

For the purposes of the attached Utility Rate Schedule and these Special Storm and Surface Water Management Utility Regulations, the following words and terms shall be defined as follows, unless the context in which they are used clearly indicates otherwise.

1. "Developed Parcel" shall mean any lot or parcel of land altered from its natural state by the construction, creation or addition of impervious area, except public streets and highways.

2. "Equivalent Residential Unit (ERU)" shall mean the basic unit for the computation of storm drainage fees. All single-family and duplex units are considered one (1) ERU based on data for City of Monterey, and are considered to have an average impervious area of 3,313 square feet. All other properties will have ERUs computed to the nearest 1/10 ERU using the following formula:

$$\text{No. of ERU} = \frac{\text{Impervious Area (Sq. Ft.)}}{\text{3,313 Sq. Ft.}}$$

No property shall have an ERU less than 1.0.

3. "Impervious Area" shall mean any part of any developed parcel of land that has been modified by the action of persons to reduce the land's natural ability to absorb and hold rainfall.This includes any hard surface are which either prevents or retards the entry of water into the soil mantle as it entered under natural conditions pre-existent to development, and/or a hard surface area which causes water to run off the surface in greater quantities or at an increased rate of flow from the flow present under natural conditions pre-existent to development. By way of example, common impervious areas include, but are not limited to, roof tops, walkways, patios, driveways, parking lots or storage areas, concrete or asphalt paving, gravel roads, or any cleared, graded, paved, graveled, or compacted surface or packed earthen materials, or

areas covered with structures of other surfaces which similarly impede the natural infiltration of surface water into the soil mantle.

4. "Non-Single-Family Residential Property" shall include all developed parcels zoned or used for multi-family, commercial, industrial retail, governmental, or other non-single family residential purposes and shall include all developed parcels in the City not defined as single-family residential property herein.

5. "Parcel" shall mean the smallest separately segregated lot, unit or plot of land having an identified owner, boundaries, and surface area which is documented for property tax purposes and given a tax lot number by the Monterey County Assessor.

6. "Single-Family Residential Property" shall include all developed parcels with either one single-family detached housing units or one two-unit attached dwelling structures commonly known as "duplexes."

7. "Storm and Surface Water Control Facilities" shall mean all man-made structures or natural water courses facility improvement, development, property or interest therein, made, constructed or acquired for the conveyance of storm or surface water runoff for the purpose of improving the quality of, controlling, or protecting life or property from any storm, flood or surplus waters.

8. "Storm Drainage Facilities" shall mean the storm and surface water drainage systems comprised of storm water control facilities and any other natural features which store, control, treat and/or convey surface and storm water. The Storm Drainage Facilities shall include all natural and man-made elements used to convey storm water from the first point of impact with the surface of the earth to a suitable receiving body of water of location internal or external to the boundaries of the City. The storm drainage system includes all pipes, appurtenant features, culverts, streets, curbs, gutters, pumping stations,

channels, streams, ditches, wetlands, detention/retention basins, ponds, and other stormwater conveyance and treatment facilities whether public or private. Regardless of whether or not the City shall have recorded rights-of-way or easements, it is presumed that the City has a prescriptive right of access to all stormwater management facilities for operation, maintenance, rehabilitation, or replacement.

9. "Surface Water" shall mean water occurring on the surface of the land, from natural causes such as rainfall, whether falling on the land in question or flowing onto the land in question.

10. "Undeveloped Parcel" shall mean any parcel which has not been altered from its natural state by the construction, creation, or addition of impervious area.

B. STORM DRAINAGE FEES:

There is hereby imposed on each and every developed parcel of land within the City, and the owners and occupiers thereof, jointly and severally, a storm drainage fee. This fee is deemed reasonable and is necessary to pay for (1) improving the quality of storm and surface water runoff, (2) the operation, maintenance, improvement and replacement of the existing and future City storm drainage facilities, and (3) the planning, designing, establishing, acquiring, developing and construction of such facilities. All of the proceeds of these fees are deemed to be in payment for use of City storm drainage facilities by the developed parcels on, and with respect to, which the fee is imposed, and the owners and/or occupiers thereof.

The storm drainage fee shall be payable monthly and shall be paid to the City (or the collection may be contracted to other public or private utilities for collection in conjunction with their utility bills), as billed by the City, by the owner or occupier of each and every developed parcel in the City who shall be presumed to be the primary utility rate payer unless otherwise agreed in writing by the City. In any event, the parcel owner or occupier shall be responsible to pay all delinquent or unpaid storm drainage fees. If a developed parcel does

not have a utility account on the effective date of this Rule and Regulation, a new account shall be established for that parcel and billed to the owner as shown on the latest County Assessor's property tax rolls. When an undeveloped parcel is developed, a new account shall be established and billed to the owner of that parcel as shown on the latest property tax rolls of the Monterey County Assessor.

1. Basis for Calculation:

The storm drainage fee shall be based on the relative contribution of surface and storm water runoff from a given developed parcel to City storm drainage facilities. The relative contribution of surface and storm water runoff from each developed non-single family residential property parcel shall be based on the amount of impervious area on that parcel and shall determine that parcel's storm drainage fee. The extent of impervious area will be established to the nearest square foot by any of the following methods to be selected by the City Engineer:

a. Computation of the impervious area using on-site measurements of the apparent outside boundaries of the impervious area in or on such developed parcels made by the City or on its behalf; or

b. Computation of the impervious area using the dimensions of the impervious area in or on the developed parcels which are set forth and contained in the records of the office of the County Assessor.

c. Estimation, calculation and computation of the impervious area using aerial photography or photogrammetry, or using the information and data from on-site measurements of like or similar property or features or as contained in the records of the City or County.

d. The burden of reestablishing the extent of impervious area shall be on the parcel owner and to the satisfaction of the City Engineer under Administrative Review Procedures.

2. Calculation of Monthly Fee:

a. Single-Family Residential: Monthly fees for single family residential parcels shall be equal to the rate for 1 ERU as set forth in Utility Rate Schedule.

b. Non-Single-Family Residential: Monthly fees for non-single-family residential parcels shall be computed in accordance with the following formula:

Number of ERUs x Rate per ERU as set forth in Utility Rate Schedule

3. Application:

a. Developed Parcels: storm drainage fees shall apply to all developed parcels within the City, including those classified as non-profit or tax-exempt for ad valorem tax
purposes. It shall apply to all government properties, to the full extent permitted by the constitutions of the United States and the State of California, including (some but not all) developed parcels of the City of Monterey, including (some but not all) City-owned buildings and parks, but excluding public streets and highways.

b. Undeveloped Parcels: Storm drainage fees shall not be levied against undeveloped parcels that have not been altered from their natural state as defined herein under "Impervious Area."

c. Proportional Reduction of Fees: Developed parcels that have their own maintained stormwater management facility or facilities that do not fully utilize City facilities or make no substantial or only a partial contribution of storm or surface water to the City's

storm drainage facilities shall be subject to the storm drainage fee only to the extent they do contribute storm or surface water runoff to City storm drainage facilities or utilize storm and surface water treatment services of the City. Developed parcels that have a portion of their impervious area within the City shall be charged only for that portion of impervious area which is in the City. The burden of establishing the reduced extent of contribution to the City's storm drainage facilities or utilization of City storm and surface water treatment services shall be on the parcel owner and to the satisfaction of the City Engineer under Administrative Review Procedures.

C. ADMINISTRATIVE REVIEW:

Any person who disputes the amount of any storm drainage fee made against their developed parcel or who requests a deferred payment schedule therefore may request a revision or modification of such fee from the City Engineer. The City Engineer may notify any owner or occupier in the event he considers the fee for any developed parcel to be inadequate or improper. The parcel owner shall make such request in writing to the City Engineer.

GENERAL STORM AND SURFACE WATER DRAINAGE
UTILITY RATE SCHEDULE

APPLICABILITY:

This schedule applies to all storm and surface water drainage service, excepting only those users and to the extent that they are constitutionally exempt under the Constitution of the State of California or who are determined to be exempt pursuant to the Special Storm and Surface Water Management Utility Regulations.

TERRITORY:

Inside the incorporated limits of the City of Monterey and land owned or leased by the City.

RATES:

Per Month:

Storm Drainage Fee per Equivalent Residential Unit (ERU). . . . . $2.09]

Special Notes:

1. An Equivalent Residential Unit (ERU) is the basic unit for computation of storm drainage fees for residential and non-residential customers. All single-family and duplex units are considered 1 ERU based on data for Monterey and are considered to have an average impervious area of 3,313 square feet. All other properties will have ERUs computed to the nearest 1/10 ERU using the following formula:

$$\text{No. of ERU} = \frac{\text{Impervious Area (S. Ft.)}}{}$$

3,313 S. Ft.

2. For more details on the storm drainage fee, refer to the Special Storm and Surface Water Management Utility Regulations.

3. The fee does not exceed the reasonable cost of providing storm and surface water management.

4A Presentation Outline

[*Municipality*]
Urban Runoff Utility Presentation
[*Date*]

I. [*Municipality*] Stormwater Management Program

- Current Problems
  - Capital Replacement/Improvement Program [*funding status, ie: funded, unfunded, underfunded*]
  - Operations & Maintenance [*funding status*]
  - Federal Regulations [*funding status*]

- Water Quality Contaminants
  - Floatables
  - Petroleum Products
  - Heavy Metals
  - Pesticides and Fertilizers (Diazinon, etc.)
  - Fecal Coliform
  - Detergents
  - Erosion (turbidity/sediment)

- Conveyance System Deficiencies & Requirements

- Urban Runoff Program Capital Improvement/Replacement Plan
  [*Table including costs for individual projects*]

- NPDES Phase II History
  - 2/87 Water Quality Act Amendments
  - 11/90 Phase I Regulations
  - 10/92 Permit Deadline for Phase II from 1987 Act
  - 8/7/95 Phase II Rule and Schedule
    - 9/1/97 Proposed Regulations
    - 3/1/99 Final Regulations
    - 8/7/01 Permit Applications Due from Selected Sources

II. EPA Water Quality Requirements (Clean Water Act)
NPDES Phase II (Six minimum measures)

- Public Education & Outreach
  - Education Materials
  - Teacher Education Workshops
  - Best Management Practices Handouts
  - Door Hangers

- Public Involvement
    - Volunteer Storm Drain Stenciling Program
    - Volunteer Storm Water Monitoring Program
    - Volunteer Industry Educators

- Illicit Discharge Detection & Elimination
    - Inspections
    - Utilize Volunteer Monitoring Program for Early Detection and Tracing Pollutants to their Sources

- Construction Site Erosion Control
    - Develop requirements
    - Inspect sites
    - Storm Water Pollution Prevention Plans

- Post-Construction Storm Water Management
    - Develop requirements for new development inclusions for stormwater (detention/retention, maintenance, etc.)
    - Include requirements in site plan review comments
    -Maintenance

- Good Housekeeping/Pollution Prevention for Municipal Operations
    - Employ Pollution Prevention Practices
    - Technical Training for all Staff involved in Urban Runoff Issues

- Additional Staffing Requirements for Urban Runoff Programs

- Solutions
    - Ordinance
        - Prohibit Illicit Discharges
        - Prohibit Illegal Connections
        - Provide for Development and Implementation of BMPs
        - Require Structural Controls for New Development/Redevelopment
    - Comply with NPDES Phase II Permitting Requirements
    - Technical Training
        - Public: BMPs
        - Staff: Good Housekeeping/ Pollution Prevention Practices
    - Public Outreach: [*Monitoring, Storm Drain Stenciling, etc.*]
    - Public Education: [*School Programs, Displays, Media, etc.*]
    - Financing

4B PE/O Framework Summary and Details

FRAMEWORK SUMMARY		
	General Public - page 2	
nonprofits, schools,	Events	roving displays, publications
volunteers, schools, nonprofits	Volunteer Monitoring	storm drain monitoring kit
businesses, schools, volunteers	Storm Drain Stenciling	city stenciling kits
city newsletters, city inspectors	Written Materials	brochures, posters, BMP's
neighborhood groups	Publicity	newspaper, TV, radio, PSA
libraries, schools, DMV's	Roving Displays	storm drain display
nonprofits, volunteers	Points of Purchase	automotive posters
utility bills, city newsletters	Mailing Inserts	various publications
city public works department	BMP's	brochures (BMP)
businesses	Business coupons	coupon incentives
	Teachers - page 5	
schools, parks, nonprofits	Teacher Workshops	WET curriculum, model
nonprofits, interns, educators	School Outreach	enviroscape model, materials
mailing or school distribution	Written Materials	posters, brochures, etc.
schools	Roving Displays	storm drain, model
schools, city officials, students	Storm Drain Stenciling	city stenciling kit
schools, city officials	Volunteer Monitoring	monitoring kit, print matter
	K-12 Students - page 6	
	See teacher outreach methods	
	College Students - page 6	
	See teacher outreach plus:	
city official, students	Business outreach	printed matter
nonprofit, students, volunteers	Earth Day events	model, display, print matter
nonprofit, student	National Coastal Clean Up Day	publicity, beach clean up tools
	Businesses - page 7	
city officials, businesses, volunteer	Storm Drain Stenciling	city stenciling kits
city officials, nonprofits, interns	Clean Seal Business Program	workshops, free publicity
college students	University Outreach	printed matter
monitoring volunteers	Volunteer Outreach	printed matter
city officials, agencies	Targeted Workshops	specific printed matter
business owners, schools	Adopt A Watershed	monitoring kit, publicity
city inspectors, volunteers, interns	Restaurant Owners	food handling posters
city inspectors, volunteers, interns	Automotive Owners	automotive posters
volunteers, nonprofits, interns	Business Owners	business surveys
nonprofits, volunteers, interns	Outreach Presentations	model, printed materials

	City Officials - page 8	
educator, nonprofit, intern	Roving Displays	storm drain exhibit
educator	Presentations	model
city officials, educator,	Printed Materials	posters, brochures, etc.
	Specific Socioeconomic Groups -p.8	
university students, volunteers	Door Knob Hangers	oil recycling jugs, print
educator, volunteer, intern	Presentations	model, printed matter
schools, auto stores, DMV, library	Roving Display	storm drain exhibit, print
nonprofits, volunteers	Point of Purchase	bilingual printed material
Cinco de Mayo, Earth Day	Events	model, roving display, print
businesses	Coupon Incentives	incentive for oil recycling
nonprofits, schools, educators	Teacher Workshop	WET curriculum translated

FRAMEWORK DETAILS FOR PUBLIC EDUCATION PROGRAM

by Maris Sidenstecker - Monterey Bay National Marine Sanctuary (MBNMS)
Phone: (408)647-4216 Fax: (408) 647-4250 revised 1/98

The public education program is divided into three sections:
1. Framework Summary (two pages) which is divided by target audience and lists tools and organizations to help reach targeted audience. Page numbers after target audience refer to pages in Framework Details.
2. Framework Details which gives details and suggestions to execute city outreach program including efforts tried in the cities of Monterey and Santa Cruz.
3. Educational Tools & Resources For Public Education Program

PROGRAM OBJECTIVE:

The objective is to offer a framework for cities to begin an urban runoff public education program to educate the public about urban runoff and possible methods to reduce/eliminate sources of pollution. This is achieved through educating various segments of the community through: teacher workshops, educational materials, school presentations, storm drain monitoring, roving educational displays, publicity, and printed materials. This includes but is not limited to the following:

educational tools - teacher watershed curriculum activities, activities with hands-on model, written materials.
target audiences - school children, teachers, general public, Hispanic community, business community, city officials.
outreach methods - events, workshops, radio, print & television media, PSA's, flyers, brochures, posters, videos, student outreach, public presentations, school presentations, roving storm drain exhibit, volunteer monitoring, coupon incentives, point of purchase displays, and storm drain stenciling events.
existing educational tools and resources is included with hands-on tools, curriculum, websites, monitoring kits, printed materials, and contacts.

HOW TO BEGIN:

1. The first step for an educator is to become familiar with how a city functions. Every city is set up differently, with different departments and has various resource constraints. A flow chart of the city will provide an orientation to the various departments within the city. Find the people in the city departments who can help implement and shape your educational outreach program. This may require interviewing and speaking with several people within the public works department to establish a working partnership. Find out what educational materials the city is using for outreach - various departments may use different educational materials. Brainstorm education outreach ideas with city officials based on what they have in place and what is needed.

2. Order a "Stormwater Resource Guide of Public Outreach Materials in California"- see Educational Tools and Resources Section for obtaining a copy.

3. Build strong community partnerships as this will be the heart of your education program. Contact and network with possible partners: organizations, agencies, educators, universities, students, student interns, school groups, cities, and individuals who share an interest in watershed protection / urban runoff issues. Brainstorm with partners on ways to build upon already existing efforts in your community or how you can work together to start new outreach methods.

Strong partnerships utilizing the resources, skills, knowledge and effort of your community will enhance program implementation and longevity. Involving the community from program inception builds community support. Community support is critical for not only the success of your program but also for funding revenues.

4. Partnerships with other organizations and agencies can help maximize funding efforts by writing cooperative grants. Sources to seek funding from: The Integrated Waste Management Board, The Environmental Protection Agency (EPA), The State Water Resources Control Board, and private foundations.

TARGET AUDIENCE:

General Public:

Educating the general public about urban runoff can be done in a variety of ways. Listed below are suggestions to reach the public.

Events: Local fairs and national events are good forums to educate the public about urban runoff. Using an interactive model or demonstration is a good way to draw the public to your booth. One of the most effective tools we have used at a series of events is the Enviroscape model which is described in detail under the Educational Tools and Resources section located toward the end of this document. In one year of use in the Monterey Bay area, a single model has been effective in educating over 5,000 children and adults, many of them at events.

Possible events or existing forums to educate the general public and city councils on the problems and issues of urban runoff.

Events:
Annual Gray Whale Migration (if you are a coastal city)
Car racing events (Laguna Seca - Monterey region)
Cinco de Mayo Day - annual event
Coordinated Resource Management and Planning (CRMP) meetings
Earth Day (National)- annual event (April)
Farmers Market
"First Flush" - first big rainfall
National Coastal Clean Up Day (National) - annual event (September)
Pollution Prevention Week - event
Sanctuary , Park or Reserve Celebrations
Storm Drain Stenciling Events
Watershed Festivals

Fora:
Automotive stores - Point of Purchase displays
City Council Meetings
Conference
Highschool Automotive Presentations
Hospitality Center Meetings
Neighborhood Watch Meetings
Nonprofit organization meetings
Public Works directors meetings
Publicity - print, radio, and television
Volunteer storm drain monitoring
Workshops (Teachers or City Officials)

Volunteer Monitoring: The beauty of this endeavor is it involves community volunteers collecting data for the city in order to locate potential pollutant sources. While volunteers are monitoring they are approached by curious people who ask what they are doing. In turn the volunteers educate the general public about urban runoff.

With the purchase of *"The Urban Watch Kit"* (see Educational Tools and Resources - page 5), recruited volunteers, and an agency, nonprofit, or individuals to process data and oversee the "Urban Watch"monitoring program your city can begin dry weather storm drain monitoring.

Implemented in Monterey city and suggested for Santa Cruz city. The Coastal Watershed Council (CWC) a nonprofit organization, was contracted to work with the city of Monterey to begin a citizen monitoring program. The CWC had experience using the Urban Watch Kit in the Arana Gulch area of Santa Cruz.

This effort was funded by the city of Monterey. It has been a successful effort in terms of community interest , involvement, and obtaining data on storm drain pollution. Baynet (a nonprofit) and the Coastal Watershed Council worked with the city of Monterey and The Monterey Bay National Marine Sanctuary to recruit volunteers to participate in the pilot urban watch monitoring program. Volunteers were recruited through articles in local papers and flyers distributed in the community. A one day training session was led by the Coastal Watershed Council to teach volunteers how to use the kit. From July through October 1997, volunteers were successful in collecting data using the urban watch kit.

The volunteers were able to detect consistent detergent runoff from a storm drain bordered by a large restaurant community.On one occassion, a detergent plume was traced to the source by walking up the street, peering through grates and following suds back to a restaurant. It was concluded that kitchen mats were being washed off into storm drains.

Train volunteers to make restaurant outreach presentations. Meet with restauraunt staff and management to educate them about proper restaurant mat washing techniques and how this can prevent storm drain pollution. Food handling posters (in english/spanish) can be left with the establishment after presentations.

The urban watch volunteer monitoring program can be incorporated around already existing events such as National Coastal Clean Up Day, and Earth Day, in order to maximize publicity and draw attention to storm drain pollution.

Storm Drain Stenciling: Great event to pull in community members, university students, schools, teachers, and local businesses to work with city public works departments to stencil storm drains. Ask local businesses to have their staff volunteer a weekend day to participate. Gives businesses an opportunity for community involvement and this is an activity that people enjoy. It is rewarding to be able to see completed tasks.

Write a press release on storm drain pollution for local papers and ask for volunteers to participate in storm drain stenciling events. Good national events to build attention / events around are Earth Day (April each year) and National Coastal Clean Up Day (September each year).

If the city has a volunteer coordinator work with them to recruit business groups, school groups, and girl & boy scout troops to participate. In Monterey, local businesses (insurance agencies, and the "Gap") sign up their staff to participate in one day storm drain stenciling events. This builds good community ties and is a great way to draw businesses in.

Written Materials: The most extensive list of written materials in California can be found in the Stormwater Resource Guide of Public Outreach Materials in California. See Educational Tools and Resources Section to order. Call agencies and organizations that have printed materials your city is interested in. Request permission from agencies and artists to reprint existing materials, and ask to obtain artwork and text on discs, if possible. This will save financial resources

The Educational Tools and Resources is a compilation of helpful materials based on a extensive review of existing materials. For this Model Urban Runoff Program we adapted storm drain, food handling and automotive posters, and BMP brochure artwork from the city of Los Angeles. They were generous in sharing their print materials and allowing modifications for local names and numbers. We adapted a nonpoint source brochure from the city of Arcata for the Monterey Bay region and had the same artist revamp the artwork done for Arcata to fit the Monterey region, and this saved financial resources. Since there is alot of good information already made it is a matter of finding what will work best for your city and their budget restraints. A few good pieces of printed materials can reach out to many segments of the public.

Publicity: Write a press release on storm drain pollution for local papers and ask for volunteers to participate in storm drain stenciling events. Good national events to build attention / events around are Earth Day (April each year) and National Coastal Clean Up Day (September each year).

Roving Displays: Enviroscape model: (see Educational Tools and Resources) section for more detailed information. At meetings, events, and teacher workshops you can display the model and educate people how to use the model. Publicize availability of model to nonprofits, teachers, and agencies on a check out system.

A check out process has worked out successfully for the Monterey region allowing us to maximize outreach with this roving display. Teachers and nonprofits call in advance to reserve the model. They are responsible for picking up and returning the model after use. Through this check-out method we have reached over 5,000 children and adults in 16 months.

Storm Drain Display: See Educational Tools and Resources for details on how to order.
Storm drain hands-on exhibit approved for replication by the Monterey Bay Aquarium for the cities of Monterey and Santa Cruz. The storm drain grate with a plasticized motor oil can spilled on top of the grate can be lifted up. Text underneath the grate (in english and spanish) explains how motor oil poured down storm drains affects water quality and animal life in the ocean. The exhibit is being used as a mobile regional outreach tool by the cities. The cost to build each exhibit was approximately $4,000 each. The roving storm drain exhibit can be displayed at libraries, DMV's, schools, nonprofit organizations and events. They are free standing and self expanatory and do not need a person in attendance.

Points of Purchase: Tear off motor oil recycling numbers (english/spanish) inserted in the motor oil sections of automotive stores can be an effective tool. This educates the public about local places that will recycle motor oil. Nonprofits and volunteers could help get the information to the automotive stores and assist in keeping up the displays.

Mailing Inserts: Flyers or coupon incentives for motor oil recycling could be mailed with water bills, city newsletters, local nonprofit newsletters, or local newspapers.

BMP Brochures: Best Management Practices brochures that are targeted for specific industries as well as residents can be made available at city public works counters. BMP's have been developed by other cities and could be tailored to fit your own city. The city of Los Angeles offers a good selection of BMP brochures.

Coupon Incentives: Work with local businesses to offer incentives for the general public to recycle motor oil. Offer car wash coupons or food item coupons from a fast food chain to people who bring used motor oil to a certified oil recycling depository. Publicize coupon incentives in local papers and radio spots.

Teachers:

Educators in the community who have a committment to watershed protection are one of your most valuable resources. Contact local educators in your area to see who is already involved in watershed activities.

Teacher Training Workshops : Find educators who are willing to assist with and or present and coordinate workshops. Or you can contact Project WET (Educational Tools and Resources) and have them put together a workshop for you. Setting up a workshop takes a fair amount of time, but is definitely worth the effort. You can impact alot of people to promote positive change for watershed protection and urban runoff prevention.

One teacher taught to use a curriculum will educate hundreds of students. One workshop with 20 teachers can reach thousands of students over the years. This is one activity where you can maximize the number of people you can educate, and in my opinion one of the most effective tools. Once you complete a workshop you can perfect techniques for duplicate workshops and you have the mold for future workshops. Invite local educators to present activities at watershed workshops in order to add their own expertise and knowledge. This will serve as a networking opportunity for teachers to work together on watershed activities.

The Monterey Bay National Marine Sanctuary (MBNMS) and The Monterey Bay Aquarium (a nonprofit organization) co-sponsored two Teacher Watershed Workshops focusing on urban runoff. One workshop was held at the Monterey Bay Aquarium and one at an elementary school in Santa Cruz. The Project WET curriculum with water related activities geared toward grades K-12 was used. The focus was on urban runoff with activities extracted from the curriculum. Local teachers led activities and added their expertise on water monitoring, watersheds, and local water related activities. MBNMS had several of the WET activities translated into Spanish for teachers to be able to take back to their classroom in order to reach bilingual students.

By using school sites as places to hold teacher workshops you can avoid the cost of having to pay for a site space. It also brings in the support of the school which is hosting the workshop. If a school site is not available contact recreation centers, conference centers, town meeting halls, or a library.

To advertise the workshops we used mailing lists on hand from the aquarium and the Sanctuary. We advertised in community newsletters and through county offices of education. Other avenues for publicity include flyer distribution in schools, libraries, or at events where there is a large group of educators. Announce workshops at meetings, and call local groups in your area to get the word out, put a description in their newsletter, or distribute flyers. This is also an activity that can garner publicity. MBNMS also combined efforts with Elkhorn Slough Reserve for a successful one day teacher workshop focusing on agriculture and urban runoff activities. Teachers were shown how to use the urban runoff model which several teachers checked out after the workshop to use in their classroom.

We designed a students urban runoff contest which we gave out to workshop participants for their students. The contest was broken down for younger and older grade levels.

School Outreach: Bringing presentations to the school site is a good way to reach teachers and students. Presentations using hands-on tools such as the Enviroscape model or storm drain exhibit

is a good way to get students and teachers actively involved. Presentations can be made by nonprofit groups, volunteers, and educators.

Written Materials: *(See page 4)* Distributing written materials to teachers and students is an effective outreach tool.

Roving displays - At the workshops you can show teachers how to use the Enviroscape model (see Educational Tools and Resources section for more detailed information) and tell them they can check the model out for their classroom from your office. This check out process has worked out successfully for the Monterey region allowing us to maximize outreach with this roving display. Teachers pick up the model with koolaid pollutants and deliver back to the educator after they have used the model at their school. Through this check-out method we have reached over 5,000 children and adults in 16 months.

Never underestimate the power of the trickle up theory. Educating elementary students also leads to education of adult family memebers. Students often impart what they have learned in school to parents.

Storm Drain Stenciling: see page 3

Monitoring: See page 3 and Educational Tools and Resources for monitoring kits that may be appropriate for schools.

K-12 Students:

Many of the same methods used to reach teachers are also useful to reach K-12 students. Listed below are suggestions to reach this audience.

School Outreach: *See page 5.*

Roving Displays: *See page 4.*

Written Materials: Such as storm drain posters and brochures that can be used by teachers for educating students about urban runoff and watershed pollution. A brochure we created " Who's Polluting Monterey Bay" is a four color brochure with the inside panel becoming a mini poster of a residential area with urban runoff activitites that students have to find and identify. This is an effective teaching tool.

Storm Drain Stenciling: See page 3 .

Volunteer Monitoring: See page 3.

College Students:

A good way to reach college students is to involve them in community events. Listed below are suggestions in ways to reach students.

Storm Drain Stenciling: Contact local colleges/universities to locate students who do community internships and senior projects for college credit. The city of Monterey and MBNMS worked with the volunteer coordinator for the city of Monterey who made the initial contact with the university. Students from Cal State Monterey Bay in an Economics, Policy, & Management Class received semester units by fulfilling a Service Learning Requirement by participating in community activities.

This community outreach entailed many hours of planning, preparation, and clean up time on behalf of the Junior Engineer for the City of Monterey and MBNMS. For program success the university teacher must be actively involved and participate in all the projects the students do.

CSUMB students attended and participated in the following:

Monterey City Council Meeting: students attended the meeting which featured an urban runoff agenda item.

Business outreach: students designed a brief business survey questionnaire for local businesses which asked about their efforts to curtail urban runoff pollution.

Volunteer monitoring: which will serve as a base for ongoing monitoring efforts in the city and help build a data base. See monitoring on page 3.

Earth Day celebration where students set up the urban runoff model at their campus and in the city of Monterey in order to interact and educate the public. Students also handed out urban runoff flyers in english and spanish and participated in a storm drain stenciling event.

Businesses:

Getting businesses involved with preventing urban runoff pollution is perhaps one of the more challenging targeted audiences as there is such a variety of businesses. A long term project with businesses is to begin a "Clean Seal Business Program" which is discussed in more detail below.

Storm Drain Stenciling: See page 3.

Clean Seal Business Program: Based loosely upon the successful "Clean Bay Business Program " in Palo Alto, which has been operating for several years. Business owners would help formulate procedures for their specific business to become involved in energy conservation, solid waste reduction, and pollution prevention. Business owners are invited to work with the team in formulating a workable program.

This progam is in the initial stages of planning and development in Santa Cruz. The Public Works Dept. of Santa Cruz will be involved in possible workshops to teach business owners practical solutions to prevent urban runoff. Businesses who attend and adopt protocols would be given a Seal of recognition which would be displayed in a store front window and receive free publicity.

University Outreach: College students could take information to businesses or a small mobile display to discuss nonpoint source pollution and how the business can become involved. Trained college students could give presentations to businesses on urban runoff reduction and how this is important to their business.

Volunteer Outreach: River Clean Up- San Lorenzo, Down town Santa Cruz. (Suggested) Through the City Serve Program volunteers could:
- Assist citizens and the city in efforts to clean rivers/watersheds on a more regular basis.
- Local business around the river will be informed by the volunteers about urban runoff.

Community volunteers cleaning the area of debris is a way to increase awareness among business owners. This would help build partnerships and help initiate efforts for a "Clean Seal Business Program" in the future.

Targeted Workshops: Target workshops to reach various segments of the business community to cut down urban runoff pollution. Offer technical training and solutions for specific business needs. Work with the city public works departments to put on workshops.

Adopt A Watershed: Ask local business to help support a school that is helping to protect watersheds. This provides good press opportunities and promotes community ties between entities that otherwise may not work together.

Restaurant Owners: Through workshops designed specifically for the food handling industry. Work with the city public works department on solutions for problems in your city. Example: If detergent runoff from restaurants washing kitchen mats in storm drains is a consistent problem - offer solutions in workshops to curtail the problem.

Another way to reach restaurant owners is to train a volunteer group about proper restaurant techniques and possible solutions. In the city of Monterey, since we have a returning volunteer urban monitoring group we will train some of the volunteers to reach out to the restaurants. This builds upon programs in place and helps keep your volunteer staff motivated.

Along with food handling posters, printed in english/spanish volunteers will give presentations to the restaurant staff about urban runoff and how they can help. If the staff has a number of Hispanic employees, have a volunteer fluent in Spanish give the presentation.

Automotive Owners: Reach them through targeted workshops that are specifically for this audience and offer solutions to common problems - such as oil disposal, etc. Work with city officials in designing and implementing the workshop. Distribute educational materials targeted for the automotive industry.

Business Owners: Reach them through targeted workshops that are specifically for this audience and offer solutions to common problems. Work with city officials in designing and implementing the workshop. Distribute educational materials targeted for the specific businesses you are reaching out to.

Outreach Presentations: Train a nonprofit or volunteer staff to give outreach presentations. Work with city officials to formulate a cohesive message that you want presented to the business community. Nonprofit groups and volunteers can give presentations to the entire staff on how to help reduce non point source pollution emphasizing why this is an important issue and distribute information to the business.

City Officials:

Educate city officials about urban runoff pollution and why this is important for the community.

Roving Displays: Using the enviroscape model (see Educational Tools and Resources section) to educate city officials is an effective tool. Having something visual helps the presentation.

Presentations: Work with city officials to schedule a date to give a presentation to city council members. Presentations were given to the to the city council members for the cities of Monterey and Santa Cruz. At each meeting council members were invited the to pollute the enviroscape model (see Educational Tools and Resources), with food pollutants after a discussion about urban runoff pollution. The model helped make a lasting impression and stick out among the many agenda items presented to council members.

Printed Matter: Share printed materials with city officials. Work with city staff to adapt already existing materials to fit your city. See "A Stormwater Resource Guide Of Public Outreach Materials In California" inEducational Tools and Resources, for a comprehensive list of materials.

Specific Socio Economic Groups:

Door Knob Hangers: Proposed by the city of Santa Cruz.
Through City Serve bilingual volunteers or University students will walk Hispanic neighborhoods on weekends and speak to and hand out bilingual door knob hangers with information on motor oil recycling and curbside collection for Santa Cruz. Give residents collection jugs for the Santa Cruz used motor oil curbside collection program.

Presentations: To schools with a bilingual speaker as well as using hands-on models are effective means to reach students. A presentation at auto parts stores with point of purchase information in Spanish is a way to reach out. Have volunteers or nonprofit groups give presentations, after a training session.

Roving Displays: See page 4.

Point of Purchase: See page 4.

Events: See page for 2 for ideas.

Coupon Incentives: See page 4.

Teacher Workshops:
We have had several Project WET (see Educational Tools and Resources) activities translated into Spanish for teachers to be able to take back to their classroom in order to reach the bilingual students.

TOOLS:

The Enviroscape hands-on model (" The Box"): See Educational Tools and Resources on how to order a model.

Urban Watch Storm Drain Monitoring Kit: See Educational Tools and Resources on how to order kit. The kit is produced by NAPCO Chemical Company (approximately $350).

Roving Storm Drain Display: See Educational Tools and Resources for details.

National Coastal Clean Up Day: takes place every year in September. Beaches, lakes, rivers, and waterways are cleaned by volunteers. Debris collected from waterways across the nation are collected on data sheets which are called in to Coastal Commission where the data is tabulated for the nation. In order to build upon this effort we will have volunteers from the Monterey community assist our Urban Watch Volunteer monitoring group in collecting debris from storm drains in Monterey. This twist on National Coastal Clean Up day will help focus attention specifically to storm drains and urban runoff pollutants. **A college student** will assist the Sanctuary staff in coordinating the project Coastal Clean Up day, getting publicity, and interacting with volunteers, for next year.

Publicity: Watershed Report Card: If you have several schools or groups monitoring different watershed areas report cards of watershed health could be printed every year in conjunction with nationwide Coastal Clean Up Day (September) or Earth Day (April). This is a good way to generate publicity. Heal The Bay generates a "Report Card" for the Los Angeles area beaches and puts out an annual report with good information. See Educational Tools and Resources for more information on Heal The Bay.

Publicity: "First Flush": The first big rain of the season is a good time to generate radio, television, and newspaper publicity about urban runoff.
Work with other organizations to generate publicity.

WET curriculum: See Educational Tools and Resources: for detailed information on this excellent watershed curriculum for grades K-12.

City Stenciling Kits:
The city will need to get storm drain stenciling kits together, including stencils. Volunteers need to work with the city public works department.

Written Materials: See Task 5.2 below and Appendix A.

Task 5.2:

Educational Materials:
Develop and distribute educational materials currently being developed by the WQPP:
to the general public and what the public can do to prevent pollution.

Educational Materials on hand in the Sanctuary WQPP:
Pelican Urban Runoff Poster English/Spanish
Watershed activities from Project WET Curriculum translated in Spanish
Urban runoff hands-on model - checked out to teachers/organizations.
Urban runoff flyer English/Spanish
- Auto Repair clean business operating poster
- Food and restaurant clean business operating poster.
- Storm Drain pollution poster

In Progress:

The city of Los Angeles Stormwater Management Division is kindly donating the following products on disc.
- BMP graphics and text (on disc) in english /spanish for 8 trifold brochures for public works counters.

- Urban runoff color brochure "Monterey Bay is Closer than You Think", Spanish version in progress.

- Door Knob Hangers English/Spanish on Oil Recycling and curbside pick up. (City of Santa Cruz)

Target various audiences:

b) general public - through events, Hispanic population with bilingual information, University student outreach, literature distribution, exhibit outreach, and community events: storm drain stenciling, volunteer monitoring programs.
c) K-12 - Teacher workshops and class presentations with urban runoff model and storm drain exhibit.
d) small business - See below list: Workshops targeting restaurants and automotive business as outreach & education methods. Poster distribution.
e) development - through BMP's and workshops.
f) industry - through BMP's and Workshops

D) Small Business To Target:
- Automotive Outlets & Automotive Stores
- Copier Centers
- Dry Cleaners
- Fast Food Chains
- Home & Garden Stores
- Gas Station
- Grocery Stores
- Hair Salons & Nail Salons
- Hotels - door knob hanger, tent, or decal on recycling
- Veternary Clinics
- Paint Stores
- Photo Development Stores
- Restaurants -to see how they wash their mats.

Task 5.4:
Distributing information and continuing outreach activities.

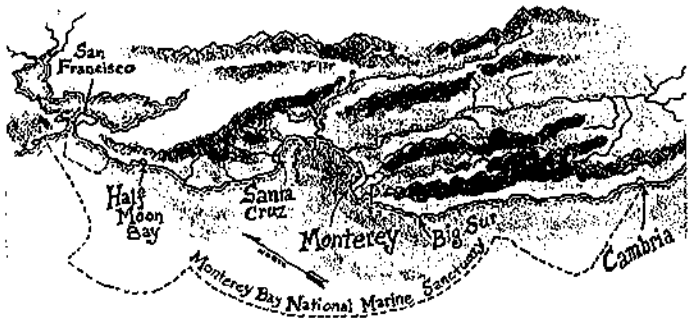
Distribution Centers:

- 4H Groups
- Architecture Firms (BMP's).
- Automotive stores.
- Bingo Groups
- Book Stores
- Boys and Girls Clubs
- Business stores.
- California University Student Information/Travel Centers and Environmental Ed.Departments
- Chamber of Commerce
- Churches
- City information counters.
- City inspectors when they do site visits.

- City Newsletters.
- City Websites.
- College students interacting with public.
- County Santa Cruz Task Force - Economic Development
- Cub Scouts/ Girl Scouts
- Dive stores
- Department of Motor Vehicles with roving storm drain display
- Fire Department Inspectors bring urban runoff information.
- Harbor Masters.
- Hospitality Associations
- Kayaking and Eco Boating Tours.
- Libraries
- Lions Clubs / Kiwanis Clubs
- Local Business Associatians.
- Local groups and nonprofit organizations (in Monterey and Santa Cruz: SOS, CMC, Baynet, Coastal Watershed Council, Ecology Action Network, Surfrider, CRMP - Coordinated Resource Management and Planning, SEP -Sanctuary Education Panel, SAC- Sanctuary Advisory Council, WEC- Watershed Education Committee.)
- Mailing enclosures in various watershed newsletters.
- Networking group for nonprofit volunteer coordinators - (in Monterey "DOVIA")
- Post Offices
- Recreation Centers
- Rotary Club
- Senior Centers
- State Parks Visitor Centers (Elkhorn Slough Visitor Center)
- Surf Shops
- Teachers
- University Campus Service Learning Centers
- Visitor Centers
- Whale watching boats.
- Workshops: teacher, business, city (training for municipal employees), and parks & recreation.
- Youth Centers

4C Sample Outreach Materials

The lead. cause of oil spills in the ocean is NOT from tanker accidents, it's from citizens. Nationwide every year <u>350 million</u> gallons of oil is discarded in storm drains, waterways, and soil. This is 30 times greater than the largest tanker spill!



MONTEREY BAY is the nation's largest Marine Sanctuary, encompassing over 5,300 square miles along the Central California coast from Marin County near San Francisco southward to Cambria in San Luis Obispo County. The Sanctuary protects many habitats, ranging from sand flats along the shoreline to the nation's most extensive kelp forests and one of the world's largest underwater canyons. Surrounding wetlands provide nursery grounds for juvenile fish, help protect against flooding and improve water quality by filtering out harmful pollutants. Nutrient-rich currents nourish the area, supporting a productive and diverse marine ecosystem where countless species, many of them threatened or endangered, make their homes.

SARB_000928

INFORMATION SOURCES

For motor oil collection services, household hazardous waste disposal, and recycling — See Yellow Pages under Recycling or call your city public works department.

Please do not mix used motor oil with antifreeze, transmission fluid, gasoline, or other contaminants.

MOTOR OIL RECYCLING:

City of Monterey	(408) 372-7977
City of Salinas	(408) 758-7925
City of Santa Cruz	(408) 429-3666
City of Watsonville	(408) 728-6133
Half Moon Bay	(415) 726-4718
Marin County	(415) 499-7868
Monterey County	(408) 384-5313
	(408) 755-4541
San Benito County	(408) 637-3725
San Luis Obispo County	(805) 782-8530
San Mateo County	(415) 363-4718
Santa Cruz County	(408) 454-2606

For location of local motor oil collection centers throughout the state call: **(800) CLEAN-UP** or on the Internet: **http://www.ciwmb.ca.gov/wpe/usedoil/hotsrch.htm**

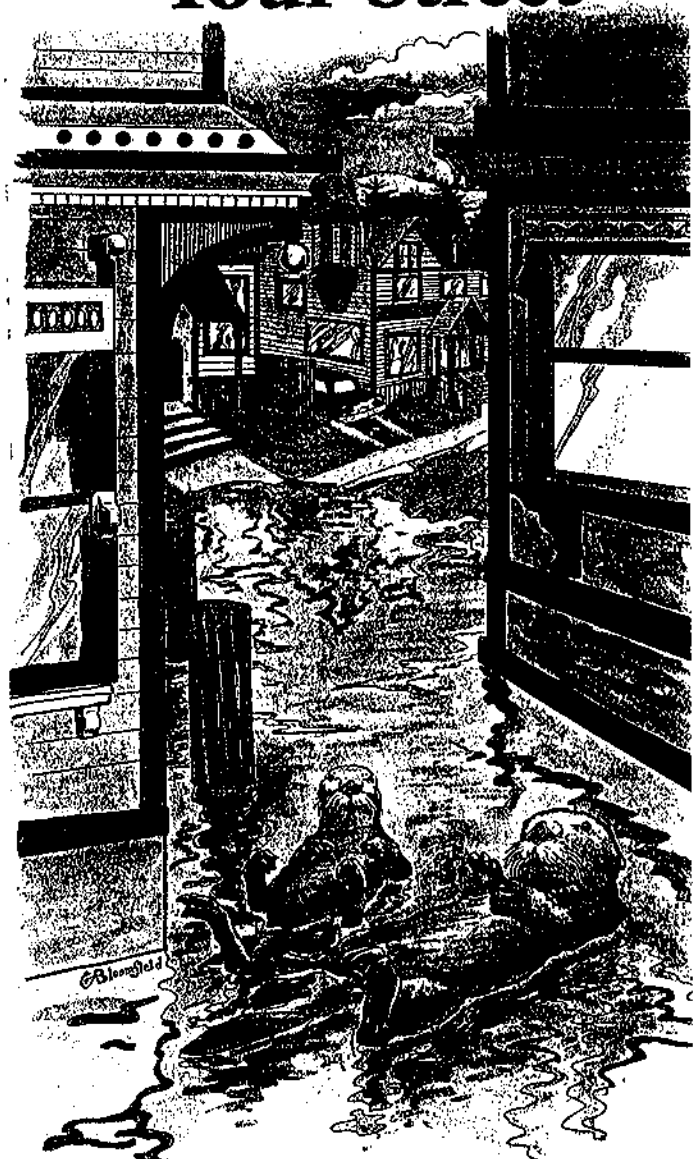
For statewide recycling, composting, and household hazardous waste information and referrals to local service sites call: **California Integrated Waste Management Board Recycling Hotline: (800) 553-2962**

For more information on how to prevent polluted runoff and protect watersheds call: The Water Quality Protection Program at the **Monterey Bay National Marine Sanctuary: (408) 647-4201**

This brochure is a joint effort of the Water Quality Protection Program for the Monterey Bay National Marine Sanctuary and the cities of Monterey and Santa Cruz. Funded in part by the United States Environmental Protection Agency Assistance Agreement No. C9-999266-95-0 to the State Water Resources Control Board, contract No. 5-139-253-0, and a used motor oil grant provided by the California Integrated Waste Management Board. The contents of this document do not necessarily reflect the views and policies of the Environmental Protection Agency or the State Water Resources Control Board.

Special thanks to the City of Arcata Environmental Services Department, City of Eureka Utilities Department, Santa Clara Valley Nonpoint Source Pollution Control Program, artist Gary Bloomfield, the County of Monterey and the California Integrated Waste Management Board.

Monterey Bay Begins on Your Street



Help prevent pollution of Monterey Bay waters

Storm Drain Pollution & You!

Even if you live miles from the Sanctuary, you may be contributing harmful pollutants to coastal waters. Urban runoff is caused by chemicals and other materials that are poured or washed down storm drains. Unlike household sewer systems, storm drain pollution is **NOT** cleansed by sewage treatment plants - it flows directly through storm drains and out into Sanctuary waters untreated. You, your friends and family all depend on healthy waterways and oceans. Remember this when you go to the beach, surf, swim in the ocean, go fishing, and eat local sea food.

TYPES OF POLLUTION

Motor oil, pesticides, animal waste, automotive fluids, fertilizers, chemicals, and litter, all make their way into oceans every day.

- One quart of motor oil dumped down a storm drain can contaminate 250,000 gallons of water. Oil from one engine (4-6) quarts can cause an 8 acre slick.
- Every year 350 million gallons of used motor oil is discarded in storm drains, waterways, and soil. This is 30 times greater than the Exxon Valdez oil spill!
- Some wildlife get their water from polluted storm drains. Animals not only get sick from the water, but oil and gasoline stick to feathers and fur. When this happens, feathers and fur lose the ability to provide warmth for the animal.

WHAT YOU CAN DO

RECYCLE

- It takes 42 gallons of crude oil to make two and a half quarts of lubricating oil. The same two and a half quarts can be produced with half as much energy from only one gallon of recycled oil. Take used motor oil and antifreeze to a gas station or hazardous waste site that recycles these products. Call the Recycling Hotline: (408) 384-5313 Monterey County (408) 454-2606 Santa Cruz County
- Recycle plastic, aluminum, and paper. Trash poses a threat to marine animals as they try to eat it or get trapped or tangled in the debris.

REUSE

- Rinse paint brushes in the sink. Filter and reuse paint thinner or brush cleaners. Dispose of used paint and thinners at a hazardous waste site.

REDUCE

- Use pesticides (look for nontoxic alternatives whenever possible) and fertilizers carefully and sparingly. Do not use if rain is forecast.
- Dipose of animal waste in garbage cans or toilets, not in storm drains
- Wash cars with biodegradable, phosphate free detergent.

For more information on urban runoff call the Monterey Bay National Marine Sanctuary (408) 647-4201

CRWB_000920

CONTAMINACIÓN DE LAS ALCANTARILLAS (ESCAPE URBANO) Y TÚ

Incluso si tú vives muchas millas del santuario, es possible que estés contribuyendo a la contaminación peligrosa de las aguas costales. El escape urbano está causado por químicos y otros materiales que son echados, o lavados por el sistema de drenaje/alcatarillas. Desafortunadamente, en el caso del sistema de drenaje de las casas, la contaminación del sistema de drenaje de las lluvias/alcantarillas no es limpiado por una planta de tratamiento de aguas residuales—corre directamente, por medio de las alcantarillas, al agua del santuario sin tratamiento. Tú, tus amigos y familia dependen de canales de agua saludable y los océanos. Recuerda esto cuando vas a la playa, nadas en el mar, pescas, y comes comida del mar local.

TIPOS DE CONTAMINACIÓN

Aceite de motor, pesticidas, heces de animales, fluidos de automovil, fertilizadores, químicos, y basura, todos estos encuentran su camino a los océanos todos los días.

- Un cuarto de aceite de motor botado por las alcantarillas puede contaminar 250,000 galones de agua. Aceite de un motor(4-6) cuartos de galón, puede causar la contaminación de 8 acres.
- Cada año 350 millones galones de aceite usado por motor son desechado en las alcantarillas, canales, y suelo. ¡Esto es 30 veces más grande que el derrame de aceite del Exxon Valdez!
- Alguna vida salvaje consigue su agua de alcantarillas contaminadas. Los animales no sólo se enferman por el agua, pero también el aceite y la gasolina se les pegan a las plumas y pelaje. Cuando esto ocurre, las plumas y pelaje pierden su abilidad de proveer calor al animal.

¿QUÉ PUEDES HACER TÚ?

RECICLAR

- Se necesitan 42 galones de aceite crudo para hacer dos cuartos y medio de aceite lubricante. Esos dos galones y medio pueden ser producidos con la mitad de la energía de un galon de aceite reciclado. Tome su aceite de motor usado y su anticongelante a una gasolinera, o a un sitio de deshechos peligrosos que recicla estos productos. Llame a la línea urgente de reciclaje: (408) 384-5313 Condado de Monterey
  (408) 454-2606 Condado de Santa Cruz
- Recicle plásticos, aluminio, y papel. La basura es una amenaza a la vida marina, ya que ellos tratan de comersela , o quedan atrapados o enredados en los esconbros.

USAR DE NUEVO

- Lave sus brochas de pintura en el lavamanos. Filtre y use de nuevo los aclaradores de pintura, o limpiadores de brochas. Desheche pintura usada e aclaradores de pintura en un sitio de deshechos peligrosos.

REDUCIR

- Use pesticidas (busque alternativas no tóxicas cuando sea posible) y fertilizadores con mucho cuidado y escasamente. No use si el previsión es de lluvia.
- Lave su automovil con detergente biodegradable sin fosfato.
- Desheche las heces de animal en los basureros o tasas de bano, no en los alcantarillados.

Para mas información, lame al número (408) 647-4201

000930

Know Your Enemy!

If you don't know what the pest is, bring a sample of the pest and the damage it is causing, in a closed jar, to:

- a reputable nursery
- County Agricultural Commissioner (510) 670-5232
- U.C. Cooperative Extension Office (510) 670-5200

How Safe Is This Pesticide?

For information on pesticide safety, contact:

- Poison Control Center (415) 476-6600
- National Pesticide Telecommunications Network, EPA-funded. For emergencies and information on health effects, 24-hr hotline: 1-800-858-7378.
- *Citizen's Guide to Pesticides*, EPA; R. Woods, Consumer Information Center-Y. P.O. Box 100, Pueblo CO 81002. (50¢) Request #426X.

How Do I Get Rid of Old Pesticides?

If pesticides cannot be used up, or given to neighbors, community organizations or gardening clubs, they can be stored until one of the Alameda County household hazardous waste collection facilities opens. These facilities will receive hazardous waste, free of charge, from Alameda County residents and certain small businesses. For more information call **1-800-606-6606** (from within the County) or **1-510-670-6460** (from outside the County).

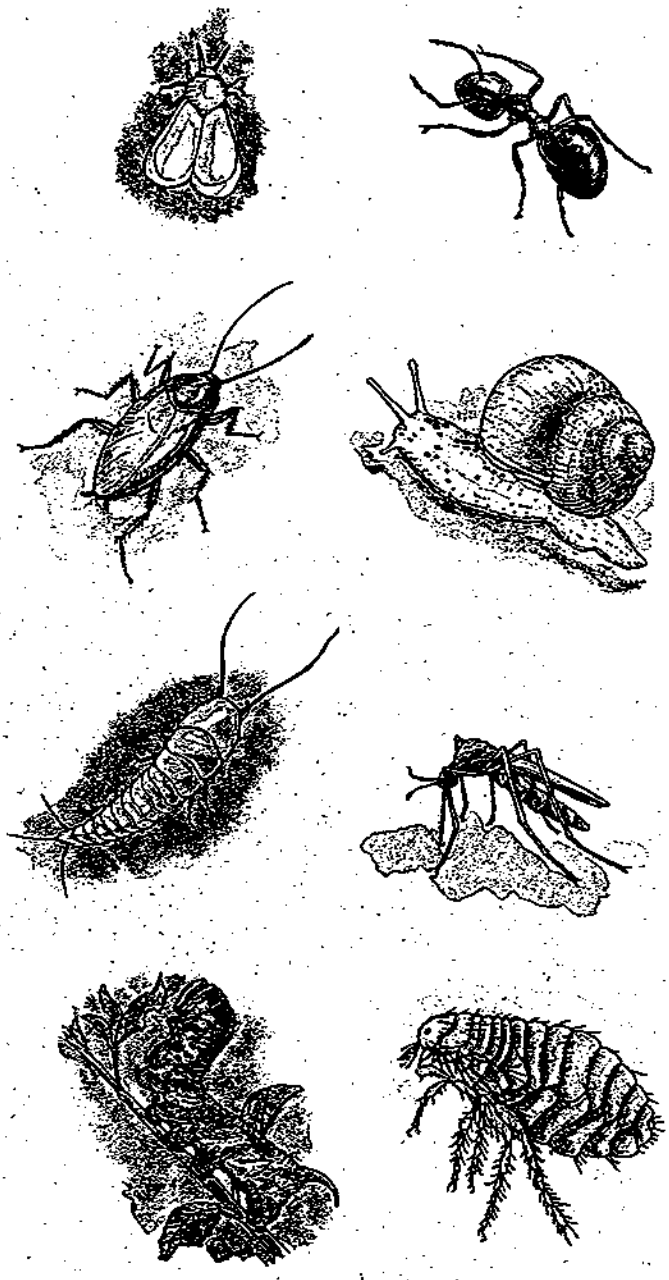
For More Copies of This Brochure, contact:

Alameda County
Urban Runoff
Clean Water Program

399 Elmhurst Street, Hayward CA 94544
(510) 670-5543 FAX (510) 782-1939

Printed on Recycled Paper ♻

Bugged?



Common-Sense Techniques & Less-Toxic Products For Pest Control...

Grow It!

The Less-Toxic Garden.

Control Pests & Plant Disease Using Less-Toxic Methods.

B A S M A A

Bay Area Stormwater Management Agencies Association

Congratulations! You have taken the first step to create a safer place for yourself, your family and our environment. This guide will help you create a vibrant garden and do the earth a good turn by showing you how to:

- Create healthy soil
- Plant the right plants
- Reduce toxic chemical use
- Control pests naturally

A word about garden chemicals:

Fish and wildlife are harmed by improper use and disposal of chemicals:

- Chemicals over-applied or not used according to label directions
- Chemicals poured down household drains
- Chemicals washed into storm drains by rain or overwatering
- Chemicals thrown away in the garbage can cause problems for landfills

Local resources for proper disposal of chemicals exist to help you. Keep reading for better alternatives.

For more information to help protect our Bay Area waters call:
1-888-Bay-Wise
(1-888-229-9473)

The Bay Area Stormwater Management Agencies Association (BASMAA) is a group of local water quality agencies focused on regional challenges and opportunities to improving the quality of storm water runoff to the San Francisco Bay and Delta.

SAMPLE BROCHURE FOR HOME MAINTENANCE ACTIVITIES

Printed on Recycled Paper.

Santa Clara Valley
Nonpoint Source
Pollution Control Program

Home Maintenance Tips for a Cleaner Bay

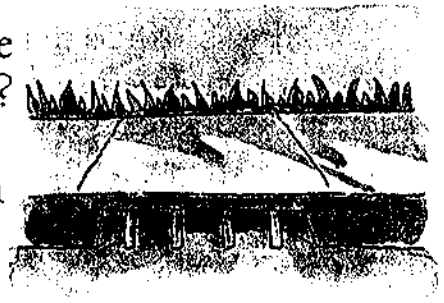
Whether you do the work yourself or hire someone, you can help protect water quality

Santa Clara Valley
Nonpoint Source
Pollution Control Program

SARB_000933

SAMPLE BROCHURE ON DEALING WITH SWIMMING POOL WATERS

Dirty Words Every Kid Should Know.



Catch Basins—You know those Catch Basins on your street corner? Well, all that trash you see there gets washed down into the Catch Basins and eventually ends up at the beach. So, if you don't want to swim in garbage, don't toss things into the Catch Basins.

Toxins—Toxins are chemicals that can make you sick. Do you know why you can find them at the beach? Because some people break the law and wash Toxins into the Catch Basins. These Toxins end up at the beach in Storm Drains and Toxic Puddles. So look out.

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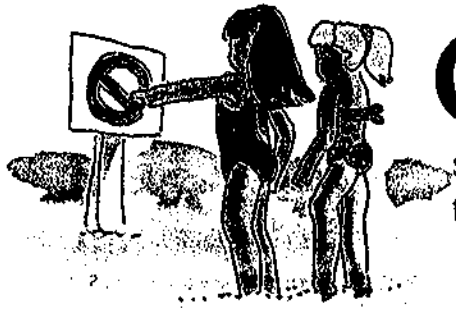
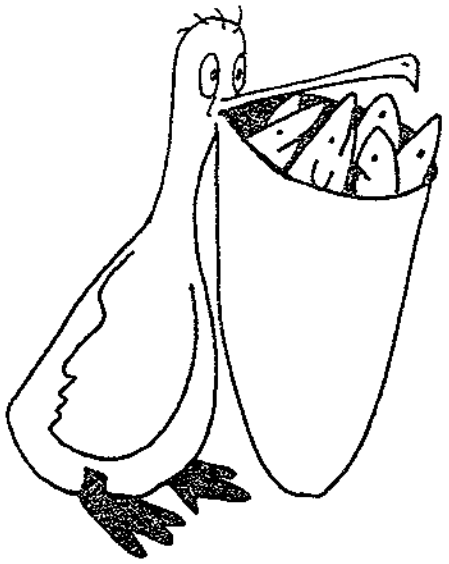
Runoff—After it rains, or people turn on their sprinklers or hoses, you can see water running into catch basins. There it mixes

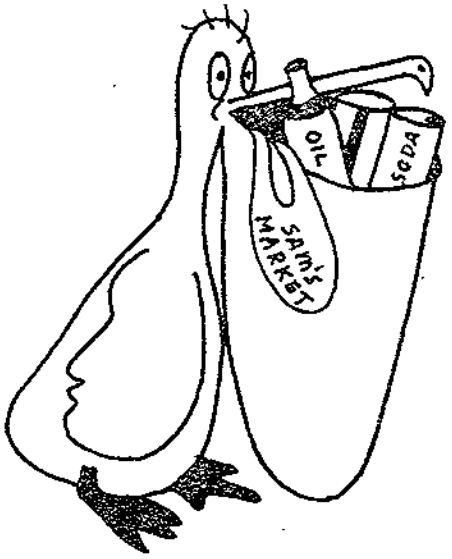


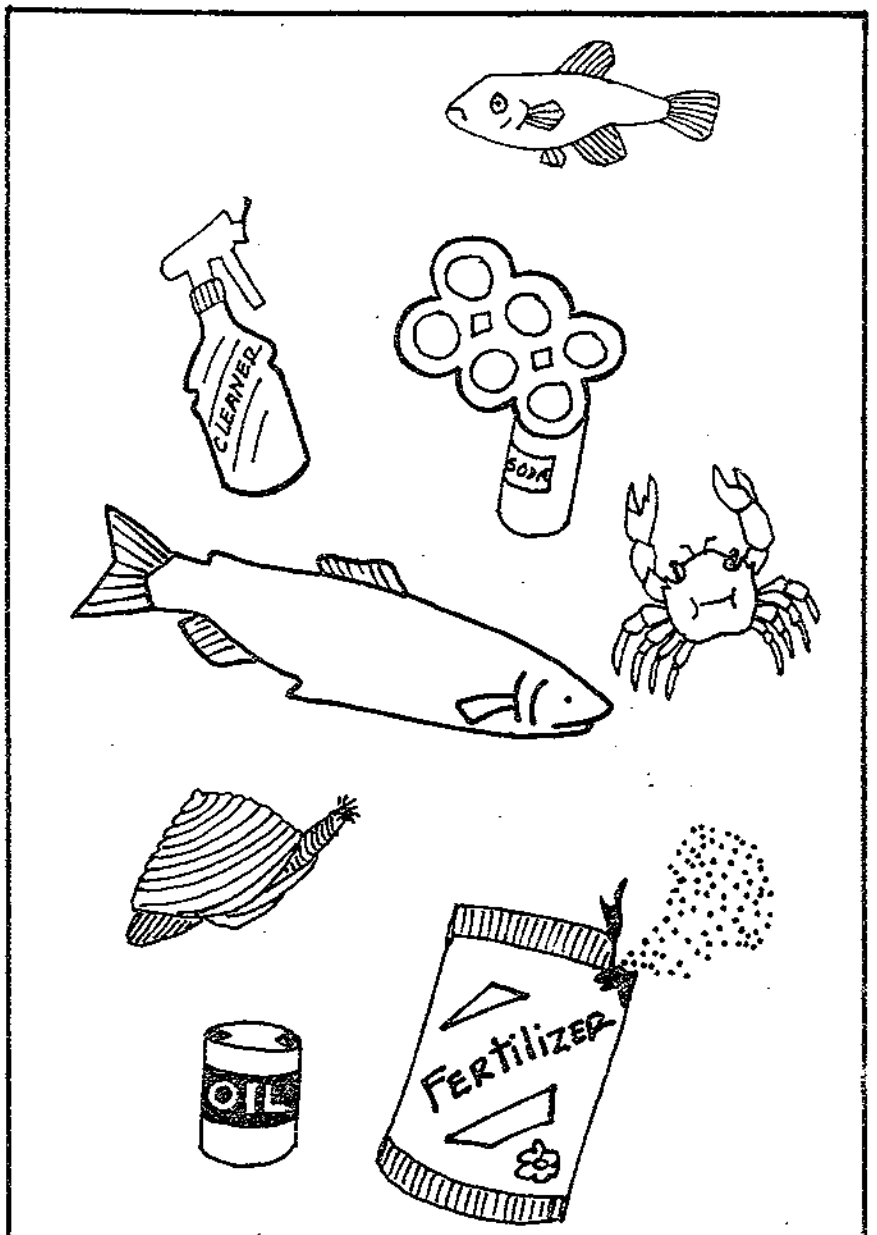
Contamination—When something dirty, unhealthy or toxic gets in the ocean, the ocean becomes Contaminated. Unfortunately that happens whenever

Urban runoff is all the stuff that enters the Bay with storm drain water. If the storm drains contain trash, leaves, and oil in them, then all that junk ends up in the bay. Preschoolers can do both the activities below.

Pelicans eat a lot. Which mouthful do you think the pelican would choose?







Circle the items that do not belong in our Bay water.

GATES © 1997

Mud 'N Fun is a regular feature in your Tidal Tales newsletters by Naturalist Randy Gates. Each month, one or more nature-related activities will be included for children and adults. These activities are designed to heighten your appreciation of the natural world. Adults and children can make these activities into family fun.

SARB_000936

CITY OF MONTEREY STORM DRAIN STENCILING

City Contact Person:

Jennifer Hays
Public Works Engineering Division
City Hall- Room 7
(408) 646-3920

Storm Drain Stenciling Materials:

Each kit should contain:

3 traffic cones-
latex gloves
1 trash bag
1 stir stick
1 scraper
1 4" roller brush
masking tape
catch basin map
pencil
3 orange vests
2 buckets- one for carrying stuff, one for white paint
paper towels
1 can blue spray paint
1 wire brush
1 paint brush
1 stencil
Wet Paint signs

Procedure for Obtaining Kits (team leaders):

1. Please call Jennifer Hays at 646-3920 in advance to request kits. Specify number of kits. Each kit is set up for two or three people. (In high traffic areas please have three people per team for traffic safety.)

2. Stop by City Hall to pick up kits. (Engineering Office is Room 7 above the City Council Chambers.)

3. When your group is done, please clean brushes and rollers (we do reuse the rollers) in a sink (not down a catch basin!)... Also, please try to clean the stencils as well as you can (they are pretty tough to clean off).

4. Return kits to Jennifer Hays at City Hall. Please have your volunteers keep track of which catch basins have been stenciled by marking them on the provided maps. If you find catch basins that are not marked on the maps (and they are on City property) go ahead and stencil them, but please mark on the map as well. We are trying to keep track of how many are getting done.

Stenciling Procedure:

1. Please wear orange vests at all times when stenciling. You will be working in traffic areas. Please place orange cones around the area that you are working. You should not have to close traffic lanes, but make yourself visible to cars that will be driving by.

2. You will be stenciling the concrete area on the curb above the catch basin grate. If there is no curb, either stencil on the concrete "apron" next to the catch basin or on a relatively flat asphalt area behind the grate where a curb would normally be.

3. Clean the area first with the wire brush provided. This will be to get the excess dirt off so that the paint will stick. If there is an old peeling stencil that you are going to paint over, use the scraper to get as much of the peeling paint off as possible.

4. Tape off the boundaries of the area to be painted with masking tape. You will be painting the white background first (with the roller brush provided and/or the paint brush). The white background should be painted about as long as the outer edges of the stencil (approximately 26") and as wide as the curb (6").

5. Put on your latex gloves. Make sure your white paint is stirred well (with you stir stick). Paint the area that you have taped. You can use either the roller or the paint brush (make sure it's not too thick or else it won't dry quickly).

6. After allowing the white paint to dry, have one person hold the plastic stencil in place over the white paint, and have another person use the blue can of spray paint to fill in the stencil. Be careful! This is the trickiest part. The stencil should be positioned so that someone standing in the street can read it right-side up. Make continuous passes with the spray paint approximately 6-8" above the stencil. Make sure everyone is wearing their gloves for this part! It can be very messy.

7. Please leave a "Wet Paint" taped to the curb next to the stencil. When you are done painting and the stencils are all dry please come back and remove them.

8. Go on to the next catch basin and repeat... When you are finished, please go back to all of your catch basins and retrieve "Wet Paint" signs and masking tape and dispose of properly.

Item Number PTNDDTSWBFSH

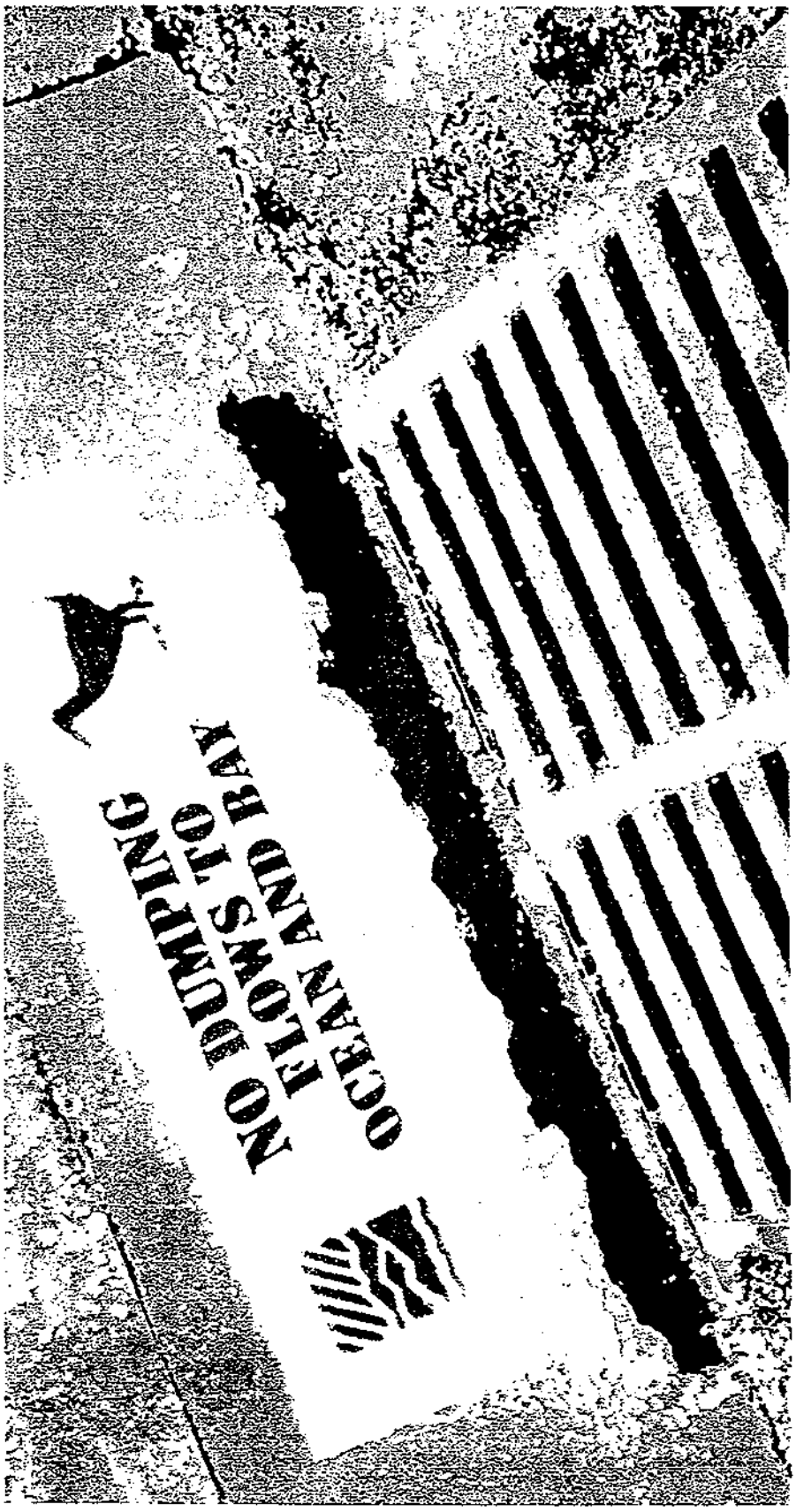
Item Number PTNDDTRWBFSH

Item Number PTNDDTBWBFSH

Item Number PTNDDTOWBFSH

Item Number PTNDFTBWBHEN

Pave Mark Corporation



Designed by Patrick Urquhart for San Mateo County

4D Educational Tools and Resources for Public Education Program

Educational Tools & Resources For Public Education Program

Compiled by Maris Sidenstecker, Monterey Bay National Marine Sanctuary.
Phone: (408) 647-4216.

The following is a list of quality educational materials that can assist teachers, individuals, park rangers, nonprofit organizations, government, state, city and local agencies in setting up a watershed / urban runoff outreach program for their region.

A Stormwater Resource Guide Of Public Outreach Materials In California
Contact: Joyce Neil
Stormwater Management Division
City of Los Angeles
650 S. Spring St., Suite 700
Los Angeles, CA 90014
(213) 847-4842
Fax: (213) 847-5443

To begin a city outreach program you ***must*** obtain a copy of the Stormwater Resource Guide. This is the most comprehensive list of stormwater related outreach materials in California. Many stormwater programs actively share public information materials. Use this guide to utilize existing materials and share products that your program has developed with others.

Curriculum:

Adopt A Watershed
PO Box 356
Hayfork, CA 96041
Phone: (916) 628-5334
Fax: (916) 628-4212

Offers curriculum for grade levels K-12. Curriculum is divided into the following categories: Biology, Chemistry, Earth Science, Geography, Language Arts, Math, and a fild manual for Water Quality Monitoring which is useful for educators monitoring the effects of urban runoff in local watersheds. Cost varies with each item. Offer a teacher workshop with a maximum of 30 teachers per workshop. Facilitator cost is $375 / day, plus travel expenses.

Water Education Foundation (WET)
717 K. Street, Suite 517
Sacramento, CA 95814
Phone: (916) 444-6240
Fax: (916) 448-7699
Contact: Judy Wheatley

Offer a Project WET curriculum / activity book for educators levels K-12. The WET workbook has several activities related to urban runoff. One of the best curriculums in terms of layout, design, and content. All water Education Foundation classroom materials are consistent with the California State Frameworks for Science and History/Social Science. In addition WET will facilitate a teacher workshop for free, in exchange for the purchase of educator activity books. If funds are unavailable you can find a sponsor and or charge the teachers $9.50 each book. Judy Wheatley will gladly assist your organizing a teacher workshop.

In addition to offering teacher workshop training WET watershed curriculum books, WET has a catalog which has a variety of educational products: A California Water Map, Colorado River Map, Groundwater Map, Videos and slide shows on water issues, water cards, preventing pollution card, stickers, notecards, a No-Know Game - relates to urban runoff isues, Hydroexplorer Computer Games, variety of educational clasroom materials.

Aquatic Project Wild (K-12)
Project Wild Headquarters, Aquatic Project Wild
Western Regional Environmental Education Council
Salina Star Route, Colorado 80302
Phone: 303-444-2390

WILD is an award winning interdisciplinary, conservation and environmental education program.The waters of the earth, in some form, are walking distance from any classroom on the planet. Project WILD Aquatic Education materials serve as an invitation to explore and understand the fascinating worlds of water and the aquatic habitats they support. WILD offers instructional workshops to train teachers how to use the curriculum.

Biological Activity Packet
Colorado River Watch Network
Att: Mary Gilroy H 219
PO Box 220
Austin, TX 78767-0220

A teachers companion to the Biomonitoring Guide with twelve classroom activities emphasizing aquatic ecosystem structure and function. Teaching activities range from traditional lab investigations to cooperative learning activities, simulations, and even a taxonomy card game, "Bug Rummy". Concepts covered in the activities include taxonomy, genetics, biochemistry and ecology. Grade levels 7-12. Fee.

Biomonitoring Guide
See address above

A manual that provides citizens the necessary background and instruction to use benthic macroinvertebrates as key indicators of the health of a water body. Step be step instructions guide the reader through habitat assessment as well as a collection and identification of macroinvertebrates. The dichotomous key and pocket-size key card have simple line drawings to help with field identification of organisms. Fee.

Biological Monitoring Video
See address above
This instructional video explains the use of benthic macroinvertebrates in determining the health of a water body. Fiels procedures are demonstrated for riffle habitat assessment as well as collection and identification of organisms. Microscopic footage of at least 20 species of benthic macroinvertebrates is included to assist with identification. Designed to complement the Biomonitoring Guide, this video is appropriate for middle school through adult. Fee.

Blue Thumb Project
c/o American Water Works Association
6666 West Quincy Avenue
Denver, CO 80235
Phone: 800-926-7337

Offers an assortment of products related to water. Includes pencils, magnets, stickers, brochures, erasers, project kits, flags, guides and resources.

Channing L. Bete Co., Inc.
200 State Road
So. Deerfield, MA 01373-0200
Phone: 800-628-7733
Fax: 800-499-6464

Offers a variety of water education materials including booklets, posters, curriculums, coloring and activity books, water week kits. Fee.

Earth: The Water Planet (grades 6-8) $10.00
The National Science Teachers Association
1742 Connecticut Ave NW
Washington, DC 20009

Educating Young People About Water: A Guide to Goals and Resources with an emphasis on nonformal and school enrichment settings.
Elaine Andrews
University of Wisconsin-Madison
216 Agriculture Hall
1450 Linden Dr.
Madison, WI 53706

A guide for professionals who design and develop water quality training programs and curricula, and for coordinators of water education programs. Coordinators can use it to make initial program decisions or to find complimentary materials for a program already in place.

Hands On Save Our Streams (K-12) SOS Kit $8.00
Izaak Walton League
707 Conservation Lane
Gaithersburg, MD 20878
Phone: 800-BUG-IWLA

Is an interdisciplinary curriculum that can be used to teach social studies, biology, chemistry, math, history, language arts or english and includes all background needed to teach lessons and field studies.

Investigating Streams and Rivers: An Interdisciplinary Curriculum Guide
See the address for Green under Catalogs

A collection of activities to encourage student inquiry, investigation, and action regarding local streams and rivers.

Living In Water (grades 4-6) $4.00
National Aquarium in Baltimore
Education Department, Pier 3
501 E. Pratt Street
Baltimore, MD 21202

S.T.E.P.

Monterey Salmon and Trout Project
c/o Matt MacCaslin
2524 Parker Street
Santa Cruz, CA 95065

Offer curriculum binder, revised lesson packet, Science kit (slides, videos, posters). There is a fee.

The Stream Scene: Watersheds, Wildlife, and People (grades 6-12) $15.00
Oregon Department Fish and Game
Office of Public Affairs
PO Box 59
Portland, OR 97207
Phone: 503-229-5400 Ext: 432

Water, Water Everywhere But.... (grades 7-10)
Hach Company
PO Box 389
Loveland, CO 80539

This material is not intended for use as "text material". It is a reference work to be used by students while interpreting their water test results. Everything was written with the assumption that students have no background in chemistry and only a limited knowledge of mathematics and general science. Hach also offers curriculum, resource materials, resource guide, and monitoring kits (see address under monitoring kits).

Hands-on Educational Tools:

enviroscape Models
c/o JT & A, inc. or
4 Herbert Street
Alexandria, VA 22305
Phone: (703) 519-2180
Fax: (703) 519-2190

Terrene Institute
1717 K Street, NW, Suite 801
Washington, DC 20006
Phone: (202) 833-8317
Fax: (202) 296-4071

Enviroscape is a **three-dimensional, hard plastic model of a miniature city**.This interactive portable model offers a hands-on approach to demonstrate water pollution of watersheds caused by various urban runoff sources. The model is (approximately 25"x 30"x5") and comes complete with a kit containing components you need to demonstrate the movement of water through a watershed. The exhibit includes scaled-down homes, shopping areas, commercial districts and industrial locations placed at different elevations. The lowest point on the model is a water body. Participants spray water on the model to simulate a rain storm which shows how various media simulating motor oil, paint, antifreeze, herbicides, and pesticides drain from upland areas to the water body. The ingredients of cocoa, powdered drink mixes, and cake decorations act as toxic pollutants.

The enviroscape base remains the same and interchangeable add on surfaces can be purchased seperately, including: hazardous waste, wetlands, groundwater, and riparian, urban, coastal, and landfill. Prices range from $299 for base only, with each add on costing approximately the same amount. This has been one of the **most effective tools** to demonstrate non-point source pollution to a variety of target audiences in the cities of Monterey and Santa Cruz.
They also offer a Resource Guide for Wetlands to accompany the model which lists a variety of products, posters, programs and projects.

For approximately $800 you will have a valuable educational outreach tool which makes the topic of urban runoff **fun.** In addition to the buildings supplies with your model you can purchase small plastic animals (from toy stores) found in your local watersheds. Label local watersheds on the model. Perfect the urban runoff pollutants by using different colors of koolaid and cake decorations.

The Sanctuary office checks the model out to educators and nonprofits in order to increase urban runoff awareness. This outreach effort combined with community events has reached over 5,000 children and adults in 18 months. We advertise the availability of the urban runoff model through presentations, word of mouth, newsletter articles, announcements at meetings, events, teacher workshops, and county district school office mailings. In the future we would like to aquire more models to be placed in various cities and school districts in order to expand this outreach to a regional effort.

This is a great tool to be used by schools, community groups, government agencies, nonprofit groups, park services. Due to the cost this is an item that could be shared by a few groups or by soliciting local business for funds, or getting a grant to purchase the enviroscape.

Roving Storm Drain Exhibit (a Replica of Monterey Bay Aquarium exhibit)
Contact: Martha Manson - Exhibit Design Manager
Monterey Bay Aquarium
886 Cannery Row
Monterey, CA 93940-4810
Phone: (408) 648-4889

To have an **interactive storm drain exhibit** built for your city like the one on display at the Monterey Bay Aquarium, Monterey, California. Please call for aquarium approval to duplicate the exhibit. These are displays that can be adapted for bilingual outreach and sturdy enough to be left unattended at libraries, DMV's, schools, and events.The display is approximately three feet tall by two feet wide and sits on rollers. The top of the exhibit is the size of a storm drain. Attached to the grate is a plastic motor oil bottle spilling plasticized oil down the storm drain. The grate lifts up to display text in English and Spanish which explains how motor oil affects water quality and marine life.

The person who built the exhibit is an outside contractor - Chris Poehlman and his phone number is (707) 886-5182. He made modifications to the exhibits built for the cities of Monterey and Santa Cruz, in order to make them more portable for a roving display. The cost is approximately $4,300 for the entire display.

Monitoring Kits/ Resources:

California Directory of Volunteer Monitoring Organizations
Gwen Starrett
Water Resources Education Coordinator
State Water Resources Control Board
P.O. Box 100
Sacramento, CA 95812-0100
Phone: (916) 657-0518 Fax: (916) 657 -2127

The directory is designed to identify community groups in California that are monitoring aquatic resources such as creeks, rivers, bays, lakes, estuaries, and ocean waters. This serves as an excellent source to connect interested volunteers, potential mentors, and resource managers with existing monitoring groups and increase communication betweeen community groups in order to learn from other successes and challenges.

Urban Watch Kit
NAPCO Chemical Company
Contact :Marilyn Grychka
Phone: (800) 929-5976

The kit used by Urban Watch volunteers was developed jointly by City of Fort Worth staff and Lamotte company. It includes all the parameters required in EPA's NPDES permit regulations for **dry-weather storm drain monitoring** (chlorine, copper, detergents, phenols, pH, turbidity, and color), plus a thermometer and a test for ammonia-nitrogen. Kit cost $310.00. This kit was successfully used by a volunteer monitoring program for the City of Monterey Public Works Department, California.

Hach Company
560 Lindbergh Dr.
PO Box 389
Loveland, CO. 80539
Phone: 800-227-4224
Fax: 303-669-2932

La Motte
PO Box 329
Rt. 213 North
Chestertown, MD 21620
Phone: 800-344-3100
Fax: 410-778-6394

Minnows Monitoring Storm Water
Brian Camp
Fort Worth DEM
5000 Martin Luther King Highway
Fort Worth, TX 76119
Phone: 817-871-5460

The Fort Worth Department of Environmental Management has produced a video and manual explaining how to construct and use the Stream Sentinel, a low cost, long term method of monitoring storm drainage outfalls using six fathead minnows in a two-litter soda bottle. Both are available at no cost from charles Howell, EPA Region 6, First Interstate Bank Tower, Fountain Place, 1445 Ross Ave:, 12th floor, Suite 1200, Dallas, TX 75202-2733. Phone: 214-665-8354.

Chemetrics
Route 28
Calverton, VA 22016
Phone: 800-356-3072

Millipore
80 Ashby Rd
Bedford, MA 01730
800-645-5476

Catalogs:

GREEN
721 East Huron Street
Ann Arbor, Michigan 48104
Phone: 313-761-8142
Fax: 313-761-4951
http://www.econet.apc.org/green/

Offers a catalog of quality watershed education resources, international newsletter, cross cultural watershed opportunities, training and support to help you initiate or enhance local watershed education efforts.

Compendium of Educational Materials on the Water Environment
Alliance For Environmental Education
51 Main Street
PO Box 368
The Plains, VA 22171
Phone: 703-253-5812

A collection of broad range of topics related to water environment and emphasizes diffuse or nonpoint sources of water pollution. It is organized into three major areas: institutions, education, public involvement; pollutants; and resources. Fee.

Terrene Institute
4 Herbert Street,
Alexandria, VA 22305
Phone: 703-548-5473 Fax: 703-548-6299
e-mail: terrene@gnn.com

Offers a wide variety of valuable resources including Projects/Resources, Partnership programs, Teacher kits, Community kits (designed for use by citizen and community groups to increase awareness on watershed issues), Professional kits (assembled by professionals, academics, and government employess for local planners and stormwater issues), Brochures, Buttons, Stickers, Watershed Note Cards, Books, Fact Sheets, Posters, Models and Games, Newsletters, Data Bases.

Water Education Foundation
717 K Street, Suite 517
Sacramento, CA 95814
Phone: 916-444-6240
Fax: 916-448-7699
e-mail wateredfdn@aol.com

Offers a variety of products including one of the best watershed curriculums (see description above under curriculum) and School Programs. Layperson's Guides, Brochures and Bill Stuffers, Maps, Videos and Slide Shows, Water Awareness, Notecards, Computer Games.

Conservation Technology Information Center
1220 Potter Drive, Room 170
West Lafayette, IN 47906
Phone: 317-494-9555
Fax: 317-494-5969
e-mail: CTIC@expert.cc.purdue.edu

CTIC is a nonprofit information/data transfer center. CTIC is represented by an interactive ag-based partnership of individuals, corporations, associations, governmental agencies, foundations, universities, and media. Videos, manuals, directories, brochures, guides, computer disks and fact sheets give information that will help you better manage your natural resources. Manuals about manure management include open lot livestock production, composting and constructed wetlands. Information available on Nutrient, Pest, and Watershed Management, and Wetlands materia

Publications:

City of Palo Alto
Public Works Dept.
Suzanne Healy
2501 Embarcadero Way
Palo Alto, CA 94303
Phone: 415-329-2598
Fax: 415-494-3531

One of the best sources of information on a wide variety of topics. Offers a large selection **Best Management Practices (BMP's)** and Program Reports on a wide range of topics including automotive, food handling services, and construction sites. Also have **Pollution Prevention Outreach Materials** - stickers, posters, postcards, magnets, buttons, utility bill inserts, door hangers, and school workbooks. **Fact Sheets** - describe program design and implementation for auto part stores, construction sites, copper installation, dry cleaners, hospital/medical facilities, metal plating, machine works, pools and spas, volunteers for stencil storm drains, zinc in floor wax. Have extensive information on the **Clean Bay Business Program** which has been successfully growing in poularity among business owners.

Heal The Bay
2701 Ocean Park Blvd. Suite 150
Santa Monica, CA 90405
Phone: (310) 581-4188
Fax: (310) 581- 4195
www.healthebay.org/healthebay

Heal The Bay has excellent brochures including "Dirty Words Every Kid Should Know" which describes storm drain pollution in english/spanish. They also have door hangers on storm drain pollution for Los Angeles county. Provide an **"Annual Beach Report Card"** on water quality health of beaches which is publicized in local papers and the media. This is a good addition to taylor and ~~add to your~~ own monitoring program in order to get media attention for local monitoring efforts. Offer a variety of test kits and portable laboratories for use in the field, laboratory and on site.

Los Angeles County
Department of Public Works
Att: Hulio Fontura
Phone: (626) 458-3531

Los Angeles county has very nice storm drain posters, BMP brochures, information brochures and stickers. If your city is on a limited budget you can purchase posters and brochures from them at a reasonable price.

Wetlands Reading List (Pre-K -12)

EPA
Office of Wetlands, Oceans, and Watersheds
Office of Water
Washington, D.C. 20460
Phone: 800-832-7828

Books are listed and described in sections according to reading level: Primary, Elementary, Intermediate, and Secondary.

The Magic School Bus at the Waterworks (in English and Spanish)
Published by Scholastic Inc.
by Joanna Cole $4.95 Paperback
Purchase at bookstores.
A popular childrens series of books also seen on TV PBS series. This topic takes children on an adventure to find out how cities get their water through the waterworks. A fresh and amusing way to teach kids (and adults) science and concepts.

Field Manual for Water Quality Monitoring
William Stapp
2050 Delaware Ave.
Ann Arbor, MI 48103

Public Opinion Surveys:

Public Opinions Toward Water Issues Among Residential Users Serviced by The City of Watsonville Water Division and The Aromas Water District
February 1996

Research conducted by Pearson Research Associates; Adrian Pearson.
PO Box 1778
Santa Cruz, CA 95061
Phone: (408) 429-9757
Fax: (408) 426-7010

Web Sites:

Water Education Foundation's Web Site:
http://www.water-ed.org

Heal The Bay
www.healthebay.org/healthebay

Educating Young People about Water
http://www.uwex.edu/erc/ywc/index.html

GREEN
WWW:http://www.igc.apc.org/green

EPA internet homepage with basic watershed data from around the country.
"www.epa.gov/surf"

For information on the State Water Resources Control Board monitoring activities.
http: \\www.swrcb.ca.gov

Local:
http://www.santacruz.k12.ca.us/-jpost/projects/Watershed/mbwat1.html

The Wells National Estuarine Research Reserve - an educational telecommunications project that investigates non-point source pollution and supports watershed management.
mewells@alice.terc.edu

Newsletters:

The Volunteer Monitor Newsletter - Twice a year
Eleanor Ely, Editor
1318 Masonic Ave.
San Francisco, CA 94117
Phone: 415-255-8049

Coastal Links
The Water Quality Protection Program for the
Monterey Bay National Marine Sanctuary
299 Foam Street Suite D
Monterey, CA 93940
Phone: 408-647-4201
Fax: 408-647-4250

Coastal Watershed Council - quarterly newsletter
Donna Meyers - Executive Director
204 Laguna Stret
Santa Cruz, CA 95060
Phone: 408-426-9012

California Coast and Ocean - quarterly
State Coastal Conservancy
1330 Broadway, Suite 1100
Oakland, CA 94612
Phone: 510-286-0934

Adopt A Watershed
PO Box 1850
Hayfork, CA 96041
Phone: 916-628-5334
Fax: 916-628-4212

Coastlines
Urban Harbors Institute
UMASS Boston
100 Morrissey Blvd.
Boston, MA 02125-3393
Fax: 617-287-5575

Runoff Report
c/o JT & A, inc.
1000 Connecticut Avenue, NW
Suite 802
Washington, DC 20036
Phone: 202-833-3380

Wetlands Celebration
Terrene Institute
1717 K Street, NW, Suite 801
Washington, DC 20006
Phone: 202-833-8317
Fax: 202-296-4071

Nonpoint Source
News Notes
c/o Terrene Institute
see address above

The Riparian Zone
Longfellow Creek Watershed Project
c/o Camp Long 5200 35th Ave. SW
Seattle, WA 98126
Phone: 206-233-2046

GREEN
721 East Huron Street
Ann Arbor, MI 48104
Phone: 313-761-8142

Biodiversity News
1416 Ninth Street Room 1311
Sacramento, CA 95814

The Water Foundation
PO Box H2O
Brainerd, MN 56401-2000

Outfall
Santa Clara Valley Nonpoint Source Pollution Control Program
5750 Almaden Expressway
San Jose, CA 95118
Phone: 408-265-2600
Fax: 408-266-0271

Visions for the Whippany Watershed
Whippany River Watershed Project
NJ Department of Environmental Protection
Office of Environmental Planning
CN 418
Trenton, NJ 08625-0418
Phone: 609-984-0058

Western Water Magazine
Water Education Foundation
717 K Street, Suite 517
Sacramento, CA 95814
Phone: 916-444-6240

Teaching Water Science Newsletter

4E BMPs for Residential Sources

Residential Sources

Focus of Document

This guidance presents BMPs that address the discharge of pollutants to the storm drain system from residential sources.

Sources of Pollutants

There are several activities conducted in and around residences that can cause the discharge of pollutants. These activities of concern are:

- ✓ Cleaning and maintenance of automobiles
- ✓ Landscaping and irrigation
- ✓ Weed and pest control
- ✓ Pet waste
- ✓ Draining of pools and spas
- ✓ Home repair and remodeling (including painting)

Pollutants of Concern

Some of the pollutants of concern are:

- ✓ Organic matter
- ✓ Oil and grease
- ✓ Toxic chemicals in cleaning products, paints, and related products
- ✓ Pesticides and herbicides
- ✓ Chlorine and other disinfectants

Best Management Practices

BMPs are common sense, environmentally responsible alternatives and good house-keeping measures that can be implemented with relatively low effort and cost to the residents of the Municipality. Structural controls or physical improvements are not recommended here, although opportunities for such improvements should be utilized when homes are remodeled (see New Development/Redevelopment Control Program in the MURP for types of structural improvements).

Home Automobile Maintenance and Repair

- ✓ Don't wash cars on a driveway where soapy water may flow to the storm drain. Wash cars on a lawn or unpaved surface, and use non-toxic/biodegradable soap. Dispose leftover water into a sink/toilet, and not on the street or in the storm drain.

- ✓ If you change motor oil or antifreeze, dispose through your local recycling program. Do not dump into the storm drain or on the ground.

- ✓ Check vehicle for leaks. Soak up spills and leaks with absorbent rags or kitty litter. If you have a leaking car, place a piece of remnant carpet under the leak to capture it while you fix the leak.

- ✓ Show your support of the Urban Runoff Program by washing your vehicles at commercial car washes that recycle water, and taking your vehicle to repair shops that implement environmentally sound practices (to identify these businesses, check to see if they have green stickers, if this green sticker program has been implemented).

General Home Maintenance

- ✓ Dispose of all waters from cleaning of carpets, upholstery, and other surfaces into the sink or toilet and not the storm drain.

- ✓ If you hire someone to clean carpets and upholstery for you, make sure they empty the cleaning water tanks into a sink or toilet, and not the storm drain.

- ✓ Discharge swimming pool or spa water into the sanitary sewer. Call local wastewater treatment plant before you discharge for guidance. Alternatively, dechlorinate the water and reuse for lawn irrigation.

- ✓ Dispose of pool or spa filter rinsewater and backwash into soil or sanitary sewer, and not into the storm drain.

- ✓ Dispose of water-based paint (but do not throw away unused portions if possible) and paint cleaning water into the sink or toilet, and not the storm drain. Empty (clean) paint cans may be disposed in the trash. Oil-based paint and paint cleaning products require disposal at an appropriate waste disposal facility.

- ✓ Sweep walkways and driveways before washing, and use non-toxic soap.

Landscaping, Irrigation, Yard and Other Waste Disposal

- ✓ Minimize use of chemical fertilizers.

- ✓ Limit fertilizer applications to twice a year (fall and spring).
- ✓ Don't apply fertilizer if rain is forecast.
- ✓ Do not over-water and cause irrigation water to runoff into storm drains. This will carry soil, fertilizers, herbicides and pesticides into the storm drain.
- ✓ Collect lawn and garden clippings, pruning wastes, and tree trimmings. Compost or dispose appropriately. Do not place these materials on the sidewalk, street or gutter.
- ✓ Do not blow or rake leaves, etc. into the street.
- ✓ Pick up and dispose of pet waste. Do not leave it on the sidewalks or the street from where it could wash into the storm drain.
- ✓ Sweep street, sidewalk and patios before storm events, and dispose of litter into the trash.

Weed and Pest Control

- ✓ Use pesticides and herbicides only if there is an actual problem (not as a preventative measure).
- ✓ Use the least toxic pesticide if alternatives are available. Products labeled with terms such as "caution" and "danger" are generally toxic.
- ✓ Use minimum amounts of pesticides and herbicides necessary for the job.
- ✓ Don't use pesticides or herbicides if rain is expected.
- ✓ Don't mix or prepare pesticides for application near storm drains.

Minor Concrete, Masonry, and Asphalt Repair

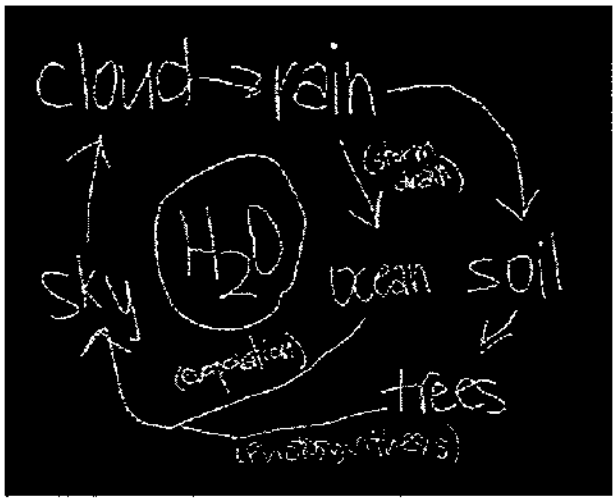
- ✓ Place tarps or dropcloths under mixers or in areas to be used for mixing.
- ✓ Hose down mixers, tools, and other equipment in a dirt area where the rinse water can soak into the ground and not run into the creek or storm drain.
- ✓ Clean up surfaces with a broom at the end of day. Don't hose down to clean.
- ✓ Apply asphalt sealant to driveways when no rain is forecast.
- ✓ If you are contracting the work, inform the contractor of these best management practices.

4F Sample Assembly Programs

Following the success of last year's show "CANOPY"

STOPPP and Will & Co. present

Water Cycle



Design: Minoe Bonere, Ink

A highly interactive assembly for K-6. Water Cycle is a two-person play that introduces children to our urban forest and the natural cycles at work within it. The play reaches for a child's imagination through drama, visual humor and student interaction. Through the use of non-verbal disciplines, students discover they can make a difference and are able to translate what they have learned into new daily habits!

When Nell is sent to the store, her simple journey takes her through the City Forest. She meets Mr. Tree, who is dehydrating, Mr. Squirrel, who's got the blues from lack of food from the trees, Catch Basin, who's choking from the trash in the streets, and Grass-iolio, who mourns the loss of his beloved Chlorophylla.

COST

Water Cycle is a FREE! program to San Mateo County Schools, support provided by STOPPP.

TIME

Water Cycle will be available from May 4 - 6. For booking call (510) 874-3193

LENGTH

Performances are 30-40 minutes long depending on the age range of the audience.

LANGUAGE

Performances are available in English, Spanish or English/Spanish.

ONLY RAIN IN THE STORM DRAIN

To book call
(510) 874-3193

Canopy

Written by Colin Cox & JuliAnn Taylor
Produced in conjunction with TreePeople

Canopy is a two-person play enabling young audiences, through a hands-on experience, to understand the importance of preserving and nurturing the world around us. Melaleuka and Jack Aranda take us on a fabulous journey through the treasures of the city forest, recruiting audience participation and surprise student "guest stars". As they meet the tree surgeon, the treasure man and the litterbug, we discover what needs to be done to preserve our natural heritage. A perfect introduction for primary level, it is a vital piece of theatre supporting the aims of the teacher in the classroom.

photo credit: Fran de Leon

The first in the series of education through interactive theatre, Canopy was co-created by TreePeople and initially contracted by theStormwater Division of the City of Los Angeles. Canopy has played to over 250,000 schoolchidren and parents.

Available in English, Spanish and Spanish/English.
Running Time: 40 minutes
Grade levels: 1-6

Also see:
Oil's Well That Ends Well
Water Cycle: Where Does it Come From Where Does It Go?
Juan & Oona's Math Adventure

Touring Programs Home Page About Will & Company E.Mail

SARB_006959

"CANOPY" PRE-ASSESSMENT

San Mateo Countywide Stormwater Pollution Prevention Program (STOPPP) welcomes your class to "Canopy," an assembly program which teaches children about the importance of trees in our environment and the purpose of the storm drain system in our communities. To evaluate the effectiveness of the "Canopy" assembly program, STOPPP depends on teacher and student feedback. Students' responses recorded on this pre-assembly gauge will be used to quantify what they learned from the assembly program. Please take a few minutes to go over this gauge and the vocabulary list to introduce "Canopy" to your students before the performance. (Please note that the instructional materials enclosed were developed for 4th grade students. The materials may be adapted accordingly for upper and lower grades.)

Teacher's Name: _____ School: _____

Grade: _____ Number of students in your class: _____

Ask students what some of their favorite beach activities are. Do they fish? Do they surf, jet ski, water ski, swim, play in the sand? *List responses on the board.*
Which beaches do they go to? *List responses on the board.*
Ask students if there has ever been a time when they didn't want to play in the beach water. Ask them to describe the situation. (Maybe it was too cold, the water didn't look clean, or they would rather play in the sand or explore.)

Tell students that an assembly program entitled "Canopy" is coming to their school to talk about trees and how we can help keep our water—the Bay, Ocean, Lagoon—clean. Before they see "Canopy," STOPPP would like their responses to the following questions:

(1) Ask students to think a minute about storm drains, those grates you see along curbsides. When water enters a storm drain, it flows underground through some pipes and channels. Where does it go after that? How many of you think that: *(Count the number of students for each response.)*

_____ a. the water flows directly to the Bay/Lagoon/Ocean.
_____ b. the water gets cleaned at a treatment facility then goes to the Bay/Lagoon/Ocean.
_____ c. other: _____

(2) How about when you flush the toilet, or take a bath, the water flows through the pipes in your home. Where does that wastewater go after it leaves your home? How many of you think that:

_____ a. the water flows directly to the Bay/Lagoon/Ocean.
_____ b. the water gets cleaned at a treatment facility then goes to the Bay/Lagoon/Ocean.
_____ c. other: _____

Review the attached vocabulary list with your students to familiarize them with words they might hear during the assembly.

While supplies last, receive a free gift for each of your students
by mailing your completed pre- and post-assessments (blue sheets) to:
Robin Plutchok, Woodward-Clyde Consultants, 500 12th Street, Suite 500, Oakland, CA 94607.

"CANOPY": POST-ASSESSMENT

In order for the San Mateo Countywide Stormwater Pollution Prevention Program to improve its "Canopy" assembly program, we depend on teacher and student feedback. Please take a few minutes to go over this questionnaire with your students.

Teacher's Name: _____ School: _____

Grade: _____ Number of students in your class who attended the assembly program? _____

After the students watch "Canopy," gauge what they have learned by asking them the following questions:

(1) When water enters a storm drain, it flows underground through some pipes and channels. Where does it go after that? How many of you think that: *(Count the number of students for each response.)*

_____ a. the water flows directly to the Bay/Lagoon/Ocean.
_____ b. the water gets cleaned at a treatment facility then goes to the Bay/Lagoon/Ocean.
_____ c. other: _____

(2) When you flush the toilet, or take a bath, the water flows through the pipes in your home. Where does that wastewater go after it leaves your home? How many of you think that:

_____ a. the water flows directly to the Bay/Lagoon/Ocean.
_____ b. the water gets cleaned at a treatment facility then goes to the Bay/Lagoon/Ocean.
_____ c. other: _____

(3) Ask your students to name some things we can do to prevent stormwater pollution?

(4) What did the students learn that they didn't know before?

(5) What did the students like about the performance?

(6) What did the students not like about the performance?

STOPPP would be very interested in hearing about follow up activities that you have conducted in your class. Please contact Vern Bessey at (415) 579-7751 if you have an exciting project you'd like to share with the County, e.g., videotape of student plays, correspondence with policy makers, pictures of a field trip, journal entries, dioramas... anything showing your students engaged in stormwater pollution prevention activities.
Thank you for your participation.

While supplies last, receive a free gift for each of your students by mailing your completed pre- and post-assessments (blue sheets) to:
Robin Plutchok, Woodward-Clyde Consultants, 500 12th Street, Suite 500, Oakland, CA 94607.

VOCABULARY LIST

Stormwater	⇒ Rain water
Waterways	⇒ Streams, creeks, rivers, the Bay and the Pacific Ocean.
Stormwater Pollution or Urban Runoff	⇒ Water from rain, hoses or sprinklers that falls on roof tops, streets, sidewalks, and yards in urban areas. This water does not get absorbed into the ground but flows to lower areas. Urban runoff normally flows through storm drains directly into local creeks and waterways, without treatment.
Storm Drain System	⇒ A network of aboveground and underground drains, pipes, and ditches that collects stormwater and runoff and carries it to local waterways. The system was designed to protect property and people in case of floods.
Watershed	⇒ The upstream land area whose runoff contributes to a common body of water, e.g., the San Francisco Bay watershed consists of all mountains, hills, cities and towns bordering and upstream from the Bay.
Wastewater	⇒ Sewage water from toilets, sinks, showers, and washing machines, from residential or commercial buildings. Industries also have wastewater, e.g., an oil refinery has a stream of toxic wastewater that must be treated.
Wastewater Collection System	⇒ Through underground pipes, wastewater from homes, industries and businesses is carried to a local treatment plant where it is cleaned before the wastewater reaches local waterways. These pipes are separate from those used in the storm drain system.
Wastewater Treatment Facility	⇒ A facility that cleans sewage water before releasing it into local waterways.

"CANOPY" ASSEMBLY PROGRAM: SUGGESTED FOLLOW-UP CLASS FIELD TRIPS

A visit to any one of the following facilities/locations would provide greater understanding of the importance of clean water.

The **Coyote Point Museum** in San Mateo familiarizes visitors with the Bay Area ecology and environmental issues via live animal presentations, innovative dioramas, and stimulating programs. Programs include on-site, hands-on activities; hikes to the foothills, tidepool explorations; and in-class presentations.
(415) 342-7755

The **Bay Model Visitor Center** in Sausalito, Marin County, displays a hydraulic model of the San Francisco Bay which is used to "examine issues of oil spills, salt water intrusion and the dispersion of pollutants." Guided tours are available.
(415) 332-3871, Ron McDonald

The **Harry Tracy Filter Plant** in San Bruno is a water filtration plant which provides drinking water to residents from San Francisco all the way to Redwood City.
(415) 872-5936, Paul Mazza

The **Pulgas Water Temple,** near the Filoli Flower Center, in Redwood City mimics a Greek temple and was originally built in commemoration of the beginning of the Hetch-Hetchy water system, from Moccasin, California to Palo Alto, California. See your local library for more information. For directions to the site, call the San Francisco Water Department (415) 872-5900.

Local wastewater (sewage) treatment plants: See for yourself how wastewater from residences, businesses and industries is treated before discharged into local waterways.

- Burlingame Wastewater Treatment Facility
  (415) 342-3727
- Daly City, North San Mateo County Sanitation District
  (415) 991-8208
- Half Moon Bay, Sewer Authority Mid-Coastside
  (415) 726-0124
- Millbrae, Wastewater Treatment Plant
  (415) 259-2388
- Pacifica, Wastewater Treatment Plant
  (415) 738-7348
- Redwood City, South Bayside System Authority
  (415) 591-7121
- San Mateo, EMID Wastewater Treatment Plant
  (415) 377-4690
- South San Francisco, Water Quality Control Plant
  (415) 877-8634

The **Palo Alto Baylands Nature Center** promotes habitat preservation and appreciation. This program features nature walks through the Palo Alto Baylands in addition to arts and crafts projects.
(415) 329-2506

The **Hidden Villa Environmental Education Program** "engages children and adults in hands-on, innovative programs promoting environmental awareness and multi-cultural understanding" through participation on a 1600-acre organic farm and wilderness preserve. The HVEEP program shows children the impact of human lifestyles on the environment.
(415) 949-8644

The **Marine Science Institute** provides marine science education to students via a boat trip, a Bayside discovery lab, and a Marine Science Mobile which brings the Bay to the classrooms. Students conduct hands-on activities, explore living organisms in their natural habitats, and learn to appreciate the natural vitality of the area.
(415) 364-2760

The **San Mateo Outdoor Education Program** is a week long residential program for fifth and sixth graders. Conducted in La Honda, California, the program develops students' knowledge about the environment, appreciation of nature, and involvement as citizens in an increasingly interdependent world.
(415) 802-5360

Visit your **local recycling facility** to find out what happens after your waste hauler collects your recyclable paper, cans, plastic bottles, or used motor oil. Students can observe the process of recycling first hand. Call your local recycling facility. See the yellow pages or call the local garbage company.
(415) 637-1411, BFI Recyclery in San Carlos

"CANOPY" ASSEMBLY PROGRAM: SUGGESTED FOLLOW-UP CLASS ACTIVITIES

Be Part of the Solution: Class Action

Participate in local **Coastal Cleanup** activities in September, or adopt-a-beach, local creek or waterway. (415) 904-5200, Chris Perry

Stencil school or local storm drains. The most effective message has been the "No Dumping, Flows to Bay/Lagoon/Ocean" stencil on storm drains. Call your local STOPPP representative for more information.

Atherton	688-6529
Belmont	595-7426
Brisbane	467-1853
Burlingame	696-7230
Colma	997-8300
Daly City	991-8200
East Palo Alto	853-3189
Foster City	349-1200
Half Moon Bay	726-8260
Hillsborough	579-3811
Menlo Park	858-3420
Millbrae	259-2300
Pacifica	738-7348
Portola Valley	851-1700
Redwood City	780-7464
San Bruno	877-8828
San Carlos	595-1456
San Mateo, City of	377-4632
San Mateo County	363-4708
South San Francisco	877-8634
Woodside	851-6790

Write letters to your local elected official. See your local yellow pages for addresses.

Small Group Or Individual Activities: Learn More about the Importance of Keeping Our Local Waterways Clean

Invite a **guest speaker** from STOPPP to your class. Call your local STOPPP representative (see phone number listed under stenciling activities).

Visit your local library for **books or videos** associated with a clean water message, such as:

- Island of the Blue Dolphin
- Magic School Bus: Weather
- Magic School Bus: The Water Works

Create a **diorama, poster, map, slide show, brochure or video** illustrating the difference between the sewage system and the storm drain system.

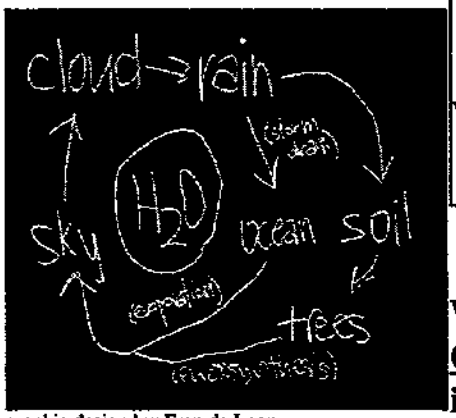
Create a **model of a watershed** (including mountains, towns, rivers, creeks, farms, cities, bay, and the ocean) demonstrating how communities and nature can impact water quality.

Develop a **skit, song, or poem** related to stormwater pollution prevention and perform it to the class (video tape if possible).

Develop and **conduct a survey** to find out how many of your neighbors and family members understand the difference between the storm drain system and the wastewater system. Compare results. Develop a brochure to educate those surveyed.

Have small groups of students **inspect 3 local storm drains** for stormwater pollution. What do they see in or around the storm drain? Have each group present findings. Compare findings among all the groups.

Create a chart of family practices which contribute to storm water pollution (e.g., car washing, changing motor oil, using a lot of fertilizers, etc.). Discuss alternatives which would prevent stormwater pollution (e.g., washing one's car at a car washing facility not in one's driveway; recycling used motor oil; or applying proper amounts of fertilizer).



graphic design by: Fran de Leon

Water Cycle

Where Does It Come From and Where Does It Go?

Written by
Colin Cox & Fran de Leon
in a co-production with
TreePeople

When Nell is sent to the store to pick up some water, her simple journey takes her through the City Forest. She meets Mr. Tree who is dehydrating, Mr. Squirrel who's got the blues from lack of food from the trees, Grass-olio who mourns the loss of his beloved Chlorophylla, and Catch Basin who is choking from the amount of trash in the streets.

A highly interactive theatre assembly for K-6, the audience participates by representing landfills, recycling centers and the earth, with several students making on-stage appearances.

Co-created by TreePeople, "Water Cycle" is the long-awaited follow up to the hit show "Canopy", and once again utilizes Will & Company's trademark style of education through entertainment. Keep 'em laughing while they learn with "Water Cycle: Where Does It Come From and Where Does It Go?".

Running Time: 45 minutes
Available in English, Spanish, and English/Spanish

Also see:
"Canopy"
"Juan & Oona's Math Adventure"

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©Will & Company

Canopy

Written by Colin Cox & JuliAnn Taylor
Produced in conjunction with TreePeople

Canopy is a two-person play enabling young audiences, through a hands-on experience, to understand the importance of preserving and nurturing the world around us. Melaleuka and Jack Aranda take us on a fabulous journey through the treasures of the city forest, recruiting audience participation and surprise student "guest stars". As they meet the tree surgeon, the treasure man and the litterbug, we discover what needs to be done to preserve our natural heritage. A perfect introduction for primary level, it is a vital piece of theatre supporting the aims of the teacher in the classroom.

photo credit: Fran de Leon

The first in the series of education through interactive theatre, Canopy was co-created by TreePeople and initially contracted by theStormwater Division of the City of Los Angeles. Canopy has played to over 250,000 schoolchidren and parents.

Available in English, Spanish and Spanish/English.
Running Time: 40 minutes
Grade levels: 1-6

Also see:
Oil's Well That Ends Well
Water Cycle: Where Does it Come From Where Does It Go?
Juan & Oona's Math Adventure

Touring Programs Home Page About Will & Company E.Mail

SARB_000966

4G Volunteer Monitoring Information Sources

VOLUNTEER MONITORING INFORMATION SOURCES

California's Directory of Volunteer Monitoring Organizations

State Water Resources Control Board
Contact: Gwen Starrett
(916) 657-0518 or "starg@gwgate.swrcb.ca.gov".

Designed to identify community groups in Califronia that are monitoring aquatic resources such as: creeks, rivers, bays, lakes, estuaries, and ocean waters. Intended to increase communication between the community groups of California so that groups might learn from one another's successes and challenges.

Riparian Station How-to Manual

Contact: Steve Cochran
Friends of the Estuary/San Francisco Estuary Project
2101 Webster Street, Suite 500
Oakland, CA 94612-3060
Phone: (510) 286-6798

Designed to help interested individuals start up a volunteer monitoring group. Addresses key issues which challenge groups as they establish and maintain riparian stations in their watersheds. Not intended as a "cookbook" guide to starting a Riparian Station. ($5.00)

Volunteer Monitoring Protocols

Contact: Steve Cochran
Friends of the Estuary/San Francisco Estuary Project
2101 Webster Street, Suite 500
Oakland, CA 94612-3060
Phone: (510) 286-6798

Lists protocols available for California monitoring. Intended to assist local groups in understanding key elements of their surrounding environment. Some of the protocols included are for rainfall, water quality, low flow profile, vegetation resources, birds, reptiles/amphibians, and macroinvertebrates. Each protocol includes the steps involved and the value and constraints of the data. For each protocol, sample sheets are included to promote consistency in data management. ($5.00)

4H Recordkeeping/Report Forms

PUBLIC EDUCATION/OUTREACH REPORTING AND EVALUATION FORM

Name:_____

City:_____

Date:_____

Summary of Public Education/ Outreach Activities Sponsored/Produced This Year:

Education/Outreach Activity	Target Audience	Location	Date(s)	Was Education/ Outreach Effort Successful?	Changes for Next Year
				☐ Yes ☐ No	
				☐ Yes ☐ No	
				☐ Yes ☐ No	
				☐ Yes ☐ No	
				☐ Yes ☐ No	
				☐ Yes ☐ No	

Summary of Additional Educational/ Outreach Activities Planned for Next Year:

Education/Outreach Activity	Target Audience	Target Start Date

4I Sample Inspection/Reporting Forms

CITY OF_____FIELD DATA SHEET
SANTA CLARA VALLEY ILLEGAL DUMPING PROGRAM

A) GENERAL INFORMATION: LOCATION ID #:_____ SHEET #:_____ DATE:_____
LOCATION NAME:_____ TIME:_____

FIRST VISIT? Y / N TIME SINCE LAST VISIT_____.
WEEKS SINCE LAST RAIN: (≥ 0.1") <1 2 >3 INSPECTION TEAM:_____

B) FIELD SITE DESCRIPTION:

OPEN CHANNEL MANHOLE OUTFALL OTHER_____

DOMINANT WATERSHED LAND USES: INDUSTRIAL COMMERCIAL RESIDENTIAL UNKNOWN OTHER_____
IF KNOWN, LIST THEM:_____

C) FLOW ESTIMATION: FLOW OBSERVED YES NO APPROXIMATE PIPE DIAMETER:_____
see Tables on back of this sheet for calculating flowrates if no calculator is available.

1.) WIDTH OF WATER SURFACE(feet) (1)_____ft.
2.) APPROX DEPTH OF WATER (inches)_____in. DIVIDE BY 12 TO GET feet (2)_____ft.
3.) APPROX FLOW VELOCITY (3a)_____feet in (3b)_____seconds. OR (3a/3b) = feet per second_____ft/s.
4.) FLOW RATE (cubic feet per second) = (1) x (2) x (3a/3b) = _____cfs.

D) VISUAL OBSERVATIONS: PHOTO TAKEN NO YES...ROLL(S) AND PHOTO NUMBER(S)_____

ODOR. NONE MUSTY AMMONIA SEWAGE ROTTEN EGGS SOUR MILK OTHER_____

COLOR: CLEAR RED YELLOW BROWN GREEN GREY OTHER_____

CLARITY: CLEAR CLOUDY OPAQUE SUSPENDED SOLIDS

FLOATABLES: NONE OILY SHEEN GARBAGE/SEWAGE OTHER_____

DEPOSITS / STAINS: NONE SEDIMENTS OILY OTHER_____

VEGETATION CONDITION: NONE NORMAL EXCESSIVE GROWTH INHIBITED GROWTH

STRUCTURAL CONDITION: NORMAL CONCRETE CRACKING/SPAULING METAL CORROSION OTHER_____

BIOLOGICAL: MOSQUITO LARVAE BACTERIA/ALGAE OTHER_____

E) FIELD ANALYSES:

DO:_____ mg/l
WATER TEMP: _____degrees C
pH _____
AMMONIA: _____mg/l
CHLORINE (FREE): _____mg/l
CHLORINE (TOTAL): _____mg/l

FIELD ANALYSES:

CHROMIUM (HEX): _____mg/l
COPPER: _____mg/l
CYANIDE: _____mg/l
GLYCOL: _____mg/l
PHENOL _____mg/l

LABORATORY SAMPLE COLLECTED YES NO IF YES, ATTACH COPY OF CHAIN-OF-CUSTODY RECORD
NOTE LABORATORY SAMPLE ID NUMBERS AND SAMPLE DESCRIPTIONS: _____

F) COMMENTS: _____

DATA SHEET FILLED OUT BY (SIGNATURE):_____

Illicit Discharge/Connection Reporting and Response

Date/Time:

Reported by:

Address:

Phone:

Location:

Report:

Material

- ☐ Hazardous
- ☐ Wastewater
- ☐ Oil/Grease
- ☐ Sediment
- ☐ Other_____
- ☐ Unknown

Land Use

- ☐ Residential
- ☐ Commercial
- ☐ Industrial
- ☐ Public

Est. Quantity:

Direct/Constructed Connections Found? ☐ Yes ☐ No

Description:

Source Investigation Conducted? ☐ Yes ☐ No

Source Identified? ☐ Yes ☐ No

Source/Owner of Discharge/ Connection:

Entered Storm Drain System/Receiving Waters? ☐ Yes ☐ No

Action and Closure

Referred To:

Phone:

City:

Dept.:

Action Taken:

Date Closed:

Performance Standard and Supporting Documents for
Illicit Connection & Illegal Dumping Elimination Activities

Co-permittees should report annually the results of their program using the following standard reporting form. Co-permittees should also maintain documentation of illicit connection and illegal dumping incident type(s); results should be available upon request. See Table 3, pg.12 for model format.

Co-permittee Reporting Form

Resource Commitment

1) Have you identified where responsibility for ICID enforcement is located within your jurisdiction?

☐ Yes ☐ No If no, provide a detailed explanation and time schedule for implementation.

Training/Education/Outreach

2) Have your ICID inspectors received necessary training?

☐ Yes ☐ No If no, provide a detailed explanation and time schedule for implementation.

3) Have you implemented appropriate outreach efforts to reduce non-permissible non-storm storm water discharges?

☐ Yes ☐ No If no, provide a detailed explanation and time schedule for implementation.

4) Have you conducted annual spill response drills (if no event occurred to evaluate your plan) in cooperation with other agencies or industries?

☐ Yes ☐ No If no, provide a detailed explanation and time schedule for implementation.

5) When a responsible party for an illegal dumping incident and/or illicit connection to the storm drain system has been identified, have you educated the party on the impacts of their actions?

☐ Yes ☐ No If no, provide a detailed explanation and time schedule for implementation.

Complaint Referral/Incident Response System

6) Have you followed existing spill response and clean-up programs used within your jurisdiction?

☐ Yes ☐ No If no, provide a detailed explanation and time schedule for implementation.

7) Have you developed and/or are you implementing a formalized inter-agency referral process for internal referrals (within a co-permittee's jurisdiction) and referrals between co-permittees?

☐ Yes ☐ No If no, provide a detailed explanation and time schedule for implementation.

Field Investigations

8) Have you conducted field investigations which include inspecting portions of the municipal storm drain system for potential sources of non-storm water discharges?

☐ Yes ☐ No If no, provide a detailed explanation and time schedule for implementation.

9) Are observed discharges referred to the appropriate agency?

☐ Yes ☐ No If no, provide a detailed explanation and time schedule for implementation.

SARB_000974

Alameda Countywide
Clean Water Program
A Consortium of Local Agencies

Illicit Discharge Inspection Quarterly Summary Report

Fiscal Year: _____

Municipality: _____

Contact: _____

Reporting Period: July, August, September — October, November, December
January, February, March — April, May, June

I. Field Activities

1. *Describe field surveys.*

	Industrial Areas	Commercial Areas	Residential Areas
Number of screening points (as defined in the Annual Action Plans)			
Channel Miles			

2. *List how many discharges were identified by the following methods.* Include only discharges that could have been prevented by BMPs. Do not include fluid releases associated with minor traffic accidents.

a. During field surveys at defined screening points:

_____ identified by maintenance crews

_____ identified by illicit discharge inspectors

b. Calls from:

_____ maintenance crews

_____ other agencies

_____ public

3. *List the number of times the following materials were identified.*

_____ Paint

_____ Concrete

_____ Construction Debris

_____ Medical Wastes

_____ Food Wastes

_____ Yard Wastes

_____ Industrial Wastes (solvents, metals, corrosives, cooling tower blowdown, etc.)

_____ Concrete Cutting Slurry/Washwaters

_____ Vehicle Cleaning Washwaters

_____ Building/Sidewalk Washwaters

_____ Other Washwaters

_____ Sewage

_____ Automotive Fluids (antifreeze, used motor oil, fuels, etc.)

_____ Other (describe):

II. Follow-up Activities

1. *Describe whether sources of discharges were identified.*

_____ Number of sources that were identified

_____ Number of incidents when source of discharge was not identified

2. *Describe whether discharges were abated.*

_____ Number of discharge incidents that were abated

_____ Number of new discharge incidents where discharge is continuing, as of the end of the reporting period; Attach the inspection report

_____ Number of continuing discharges that have already been reported in previous quarter(s).

3. *Describe enforcement activities conducted.*

_____ Verbal Notice

_____ Administrative Action

_____ Legal Notice

_____ Warning Notice

_____ Administrative Action w/Penalty &/or Fine

TABLE 3 - Model Format

(Co-permittees Name) Illegal Dumping and Illicit Connection Incident Type(s)

TYPE OF INCIDENT	NUMBER OF INCIDENTS
Auto Dealers	
Washing Cars	
Auto Shops	
Radiator Fluid	
Waste Water	
Auto-Residential	
Fuel Leaking	
Car Washing	
Car Repair	
Radiator Draining	
Oil Dripping	
Residential	
Apartments	
Other	
Commercial	
Irrigation	
Construction	
Sediment	
Asphalt Cuttings	
Other Materials	
Carpet Cleaning	
Cement Washing	
Commercial	
Industrial	
Residential	
Responses to Non-problems	
No Discharge	
Allowable Non-storm Water Discharge	
Cooling Water	
Drums Abandoned	
Equipment Cleaning	
Commercial	
Residential	
Industrial	
Grocery Store	
Dumpsters	
Grey Water	

TYPE OF INCIDENT	NUMBER OF INCIDENTS
Gas Stations and Vehicle Service Facilities	
Washing Cars	
Radiator Fluids	
Industrial	
Fuel Leaking	
Paint	
Parking Lots	
Pools & Spas	
Residential	
Grey Water	
Sediment	
Irrigation	
Restaurants	
Dumpsters	
Grey Water	
Oil & Grease	
RV Waste Dumping	
Sewage Spills	
Shops (Non Auto)	
Washing	
Spills	
Sumps	
Used Oil Dumping	
Res.- Apt.	
Res. - Other	
Comm. - All	
Misc. Incidents (total)	
Resolved	
Under Investigation	
Illegal Dumping (total)	
Resolved	
Under Investigation	
Illicit Connections (total)	
Resolved	
Under Investigation	

4J BMPs for Municipal Operations

Good Housekeeping Practices for Municipal Operations

Focus of Document

This guidance presents BMPs or good housekeeping practices to address the discharge of pollutants to the storm drain system from municipal facilities. These facilities include:

- ✓ Streets, Roads, and Highways
- ✓ Sidewalks, Plazas, and Municipal Parking Lots
- ✓ Street Medians, Other Landscaped Areas, and Golf Courses
- ✓ Storm Drain Systems Including Open Channels, Inlets, Catchbasins, and Storm Drain Pipelines
- ✓ Corporation Yard and Other Municipal Operations Areas
- ✓ Municipal Swimming Pools, Fountains, Lakes, Lagoons and Other Urban Water Bodies

As discussed in Section 4.4 of the MURP, most municipalities have existing municipal programs that involve cleaning and maintenance of these facilities. The BMPs listed below are recommended improvements to existing activities or functions in order to reduce the potential for urban runoff pollution. Also, see Appendix 3L for additional BMPs for Corporation Yards.

Pollutants of Concern and Their Sources

Some of the pollutants of concern from these areas may be:

- ✓ Metals (from roads, sidewalks, parking lots, corporation yard, and other municipal areas)
- ✓ Oil and Grease (from corporation yard)
- ✓ Organic matter (from streets and landscaped areas)
- ✓ Fertilizers, pesticides, and herbicides (from landscaped areas)
- ✓ Chemical products used for disinfection and algae control (from pools, fountains, and water bodies)
- ✓ Gasoline and radiator fluid (from streets, parking lots, and corporation yard)

- ✓ Sediment; asphalt; concrete; trash and debris; and soil (all urban areas)

Street Sweeping and Cleaning

Sweeping Frequency and Timing

- ✓ Establish street sweeping frequency for your municipality, or portions of it, based on factors such as traffic volume, land use, field observations of sediment and trash accumulation, proximity to water courses, etc. In general, the following frequencies are recommended:
  - Sweep weekly in high traffic downtown areas
  - Sweep twice a month for moderate traffic collector streets, and
  - Sweep monthly in residential, low traffic areas.

  One way to determine the areas that should be swept more frequently is to collect data on the total volume or weight of materials collected per mile of road swept. Use this data to prioritize areas to be swept more frequently.

- ✓ Where there is a pronounced dry and wet season, sweep streets just before onset of the wet season.

- ✓ Establish and maintain a consistent sweeping schedule.

- ✓ Avoid wet cleaning or flushing of street, and utilize dry methods where possible.

- ✓ If wet cleaning or flushing is absolutely necessary, sweep and remove debris before flushing; plug storm drain inlet and direct washwater to the sanitary sewer. Alternately, allow washwater to drain to the storm drain and collect it downstream at a manhole or storm drain cleanout.

Maximum Access for Sweepers

- ✓ Institute restrictive parking policy to allow sweepers better access to areas close to the curb and storm drain inlets.

- ✓ Post permanent street sweeping signs. If installation of permanent signs is not possible, use temporary signs.

- ✓ Develop and distribute flyers notifying residents of street sweeping schedules.

Equipment

- ✓ Maintain cleaning equipment in good working condition.

- ✓ Use your most effective sweepers in the high sediment and trash areas (typically industrial/commerical).
- ✓ Replace old sweepers with new technologically advanced sweepers (see Appendix 3K for an evaluation of available sweepers).
- ✓ Clean sweepers at a wash rack that drains to the sanitary sewer.

Residuals Disposal

- ✓ Dispose of street sweeping debris and dirt at a landfill.
- ✓ Do not leave street sweeping debris and dirt in piles along the side of the road or by a riparian area.
- ✓ If dewatering of dirt collected is necessary, the water should be discharged to a sanitary sewer.

Sidewalks, Plazas, Structures, and Parking Lot Cleaning

- ✓ Post "No Littering" signs and enforce anti-litter laws.
- ✓ Provide litter receptacles in busy, high pedestrian traffic areas of the community.
- ✓ Clean out and cover litter receptacles frequently to prevent spillage.
- ✓ Establish frequency of public parking lot sweeping based on usage and field observations of waste accumulation. Sweep all parking lots at least once before the onset of the wet season.
- ✓ Use dry methods of cleaning such as sweeping and vacuuming to clean sidewalks and other paved surfaces rather than hosing, pressure washing or steam cleaning. If water must be used, implement methods specified in Table 1 to minimize illegal discharges.
- ✓ Use instructions in Table 1 for cleaning of structures.
- ✓ Clean up spills using methods listed below.
  - Prepare a spill response plan.
  - Store spill response materials (containment materials such as booms; absorbents, etc) on municipality's vehicles (as appropriate) or at a central location.

Table 1. Cleaning of Surfaces and Structures

Type of Surface	Characteristics	Cleaning Technique	Discharge to Storm Drain	Disposal Alternatives
Sidewalks, Plazas	No oily deposits	Sweep, collect and dispose of debris and trash; then wash.	Okay to discharge to storm drain.	
Sidewalks, Plazas, Driveways	Light oily deposits	Sweep, collect and dispose of debris and trash. Clean oily spots with absorbent, place oil-absorbent boom around storm drain, or a screen or filter fabric over inlet.	Okay to discharge to storm drain, provided an oil-absorbent boom or filter fabric is used. No oily sheen should be visible in the water draining into the storm drain.	
Parking lots and driveways	Heavy oily deposits	Sweep, collect and dispose of debris and trash. Clean oily spots with absorbent materials. Use a screen or filter fabric over inlet, then wash surfaces.	Seal storm drains. Can not be discharged to the storm drain.	Vacuum/pump wash water to a tank or discharge to sanitary sewer.
Building exteriors and walls	Glass, steel, or painted surfaces (post1978/no lead in paint	Washing without soap.	Okay to discharge to storm drain provided the drain is sealed first with a fabric filter to capture dirt, paint particles and flakes or oil absorbent boom.	Can alternately be sent to landscape areas.
		Washing with soap.	Can not be discharged to storm drain.	Direct washwater to sanitary sewer or vacuum/pump water to a tank.
Building exteriors	Painted with lead-based or mercury-additive paint	Washing with or without soap.	Seal storm drains. Cannot be dischsrged to storm drain.	Vacuum/pump to a tank. Check with POTW for discharge to sanitary sewer.
Graffiti Removal	Graffiti	Using wet sand blasting. Minimize use of water; sweep debris and sand.	Can be discharged to storm drain if washwater is filtered through a boom.	Can alternately be directed to landscaped areas.
		Using high pressure washing and cleaning compounds.	Seal storm drains. Cannot be dischsrged to storm drain.	Vacuum/pump washwater to sanitary sewer. Check with POTW about pre-treatment.
Masonary	Mineral Deposits	Acid Washing.	Seal storm drains. Cannot be discharged to storm drain.	Rinse treated area with alkaline soap and direct washwater to a landscaped or dirt areas. Alternately, washwater may be collected and neutralized to a pH between 6 and 10, then discharged to landscaping or pumped to sanitary sewer.

Source: Santa Clara Valley Urban Runoff Pollution Prevention Program

- Use dry methods of cleaning including vacuuming, scooping, using rags and absorbents. Avoid hosing where possible. If washing is necessary, clean to extent possible before hosing or power-washing.
- Appropriately dispose of spilled materials and absorbents.
- If a spill occurs on dirt, excavate and remove the contaminated (stained) dirt.

Street Medians, Parks, and Other Municipal Landscaped Areas

Erosion Control

- ✓ Maintain vegetative cover on medians and embankments to prevent soil erosion. Apply mulch or leave clippings in place to serve as additional cover.
- ✓ Do not use disking as a means of vegetation management because the practice results in erodable barren soil.
- ✓ Provide energy dissipators (e.g., riprap) below culvert outfalls to minimize potential for erosion.

Vegetation Management/Irrigation

- ✓ When conducting vegetation pruning/removal, remove clipped or pruned vegetation from gutter, paved shoulder and area around storm drain inlet.
- ✓ When conducting mechanical or manual weed control, avoid loosening the soil which could erode into stream or storm drain.
- ✓ Inspect irrigation system periodically to ensure that the right amount of water is being applied and that excessive runoff is not occurring. Minimize excess watering, and repair leaks in the irrigation system as soon as they are observed.
- ✓ When bailing out muddy water, do not put it in the storm drain; pour over landscaped areas.

Pesticides (Diazinon, Chlorpyrifos, and other Similar Products)

- ✓ Follow federal, state, and local laws governing the use, storage, and disposal of pesticides/herbicides.
- ✓ Use pesticides only if there is an actual pest problem (not on a regular preventative schedule).

- ✓ Avoid use of copper-based pesticides if possible. Use the least toxic pesticide for the job if alternatives are available.

  California Department of Pesticide Regulation is conducting a review of pesticidal and non-pesticidal alternatives to diazinon and chlorpyrifos for urban uses (see DPR site on the Internet at www.cdpr.ca.gov).

- ✓ Do not use pesticides if rain is expected.

- ✓ Do not mix or prepare pesticides for application near storm drains.

- ✓ Use the minimum amount needed for the job.

- ✓ Use up pesticides. Rinse containers, and use rinse water as product. Dispose of unused pesticide as hazardous waste.

Herbicides

- ✓ Replace existing vegetation with fire-resistant and native vegetation to reduce the need for herbicides.

- ✓ Do not use herbicides if rain is expected.

Fertilizers

- ✓ Minimize use of chemical fertilizers.

- ✓ Calibrate the distributor to avoid excessive application.

- ✓ Check irrigation system to ensure that over-watering and runoff of fertilizer does not occur. Clean pavement and sidewalk if fertilizer is spilled on these surfaces before applying irrigation water.

Storm Drain System Cleaning

- ✓ Establish a frequency for inspecting all catch basins, inlets, debris basins, and storm drain pipelines, and implement this schedule. Clean facilities where sediment, trash, and other pollutant accumulation is observed. In general, the guidance is as follows:

  - Conduct periodic visual inspections during the dry season to determine if there are problem inlets where sediment/trash accumulate. Clean if necessary. The main objective of the dry season inspections is to identify problem areas.

  - Inspect and clean all inlets and basins before onset of wet season (to ensure drainage capacity and to avoid resuspension of pollutants during a storm event)

- Conduct inspections of storm drain inlets once a month or more frequently during the wet season. The frequency may be as high as once a week for problem areas where sediment or trash accumulates more often. Clean as needed.

✓ Inspect and clean storm drain pipelines and inlets in areas affected by pollutant generating incidents immediately or at a minimum before the wet season (incidents include spills, fires, and other events that may have released pollutants to the storm drain system and residues may be present in the system in the vicinity of the event).

✓ Store wastes collected from the cleaning in appropriate containers or temporary storage sites in a manner that prevents discharge to the storm drain.

✓ Dewater the wastes if necessary with outflow into the sanitary sewer. Do not dewater near a storm drain or stream.

✓ Sediment (less the debris) removed from the catchbasin or inlet cleaning should be analyzed for disposal. Pollutants of concern are lead; oil and grease; and hydrocarbons. In general, based on the analysis of sediments from inlet cleaning, it appears that in older cities all these pollutants have been found at elevated levels whereas, in the newer cities, the main pollutants in inlet sediments are hydrocarbons. If concentrations are elevated, the sediment should be disposed of as hazardous waste.

Municipal Swimming Pools, Fountains, Lakes, and Other Water Bodies

Alternate Discharge Options for Chlorinated Water

✓ Test water for chlorine level and consider using it for irrigation in landscaped area or for dust suppression at a city construction project site, or

✓ If acceptable to the wastewater treatment plant in your community, discharge pool water to the sanitary sewer, or

✓ Discontinue use of chlorine before planned discharge to the storm drain and allow the active chlorine to dissipate through aeration. Test water to see if chlorine can be detected. Also test for residual chlorine every half-hour during the discharge event.

Pool maintenance personnel will have a good idea about the length of time it will take before chlorine reaches non-detect levels. Chlorine testing kits are also available with these personnel because they use these to check the water periodically before adding more chlorine.

Note that the main drawback with this option is the potential for bacteria to grow when the water is left in the pool for chlorine dissipation.

- ✓ Alternately, dechlorinate or neutralize the waters before discharge. Add minimum amounts of neutralizing chemicals necessary to produce a zero chlorine reading (see Table 2 for amounts). Test water before discharge to the storm drain. Monitor for residual chlorine at the discharge point every half hour during the discharge event.

Table 2. Amount of Neutralization Chemical Required to Neutralize 100,000 Gallons of Chlorinated Water

Neutralization Chemical	Chlorine Concentration Before Neutralization			
	1.0 mg/l	2.0 mg/l	10.0 mg/l	50.0 mg/l
Sulfur Dioxide (SO_2)	0.8 lbs	1.7 lbs	8.3 lbs	41.7 lbs
Sodium Bisulfite ($NaHSO_3$)	1.2 lbs	2.5 lbs	12.5 lbs	62.6 lbs
Sodium Sulfite (Na_2SO_3)	1.4 lbs	2.9 lbs	14.6 lbs	73.0 lbs
Sodium Thiosulfate ($Na_2S_2O_3$-$5H_2O$)	1.2 lbs	2.4 lbs	12.0 lbs	60.0 lbs

Source: Santa Clara Valley Water District. Water Utility O&M Pollution Prevention Plan

Alternative Methods to Control Algae in Lakes and Lagoons

- ✓ Reduce fertilizer use in areas around the water body.
- ✓ Discourage the public from feeding birds and fish.
- ✓ Consider introducing fish species that consume algae. *Silver carp is being studied in UK for algae control in reservoirs and results appear promising. However, use of silver carp is prohibited in California. Other candidate species are grass carp and black fish. Contact the California Department of Fish and Game for more information on this issue.*
- ✓ Mechanically remove pond scum (blue-green algae) using a 60 micron net.
- ✓ Educate the public on algae and that no controls are necessary for certain types of algae that are beneficial to the water body.

Repair and Maintenance of City Surfaces

Asphalt/Concrete Demolition

- ✓ Schedule asphalt and concrete removal activities for dry weather.
- ✓ Take measures to protect any nearby storm drain inlets and adjacent watercourses, prior to breaking up asphalt or concrete (e.g., place sand bags around inlets or work areas).

- ✓ After breaking up old pavement, sweep up materials thoroughly to avoid contact with rainfall and storm water runoff. Recycle as much material as possible, and properly dispose of nonrecyclable materials.

- ✓ During saw-cutting and grading operations, use as little water as possible. Block or place berms around nearby storm drain inlets, in drainage channel (if no inlet is nearby), or around work areas (when bordering watercourse) using sand bags or an equivalent appropriate barrier, or absorbent materials such as pads, pillows and socks to contain slurry. If slurry enters the storm drain system, remove material immediately.

- ✓ Remove saw-cut slurry (e.g., with a shovel or vacuum, or sweep up when dry) as soon as possible.

Concrete Installation and Repair

- ✓ Avoid mixing excess amounts of fresh concrete or cement mortar on-site.

- ✓ Store dry and wet materials under cover, protected from rainfall and runoff.

- ✓ Wash out concrete transit mixers only in designated wash-out areas where the water will flow into drums or settling ponds or onto dirt or stockpiles of aggregate base or sand. Pump water from settling ponds to the sanitary sewer, where allowed. Whenever possible, recycle washout by pumping back into mixers for reuse. Never dispose of washout into the street, storm drains, drainage ditches, or creeks.

- ✓ Whenever possible, return left-over materials in the mixer barrel to the yard for recycling. Dispose of or recycle small amounts of excess concrete, grout, and mortar in the trash. Dispose of excess at landfill site.

Patching, Resurfacing, and Surface Sealing

- ✓ Schedule patching, resurfacing and surface sealing during dry weather.

- ✓ Stockpile materials away from streets, gutter areas, storm drain inlets or watercourses. During wet weather, cover stockpiles with plastic tarps or berm around them if necessary to prevent transport of materials in runoff.

- ✓ Pre-heat, transfer or load hot bituminous material away from drainage systems or watercourses.

- ✓ Cover and seal nearby storm drain inlets and manholes before applying seal coat, slurry seal, etc. Leave covers in place until job is complete and until all water from emulsified oil sealants has drained or evaporated. Clean any collected materials from these covered manholes and drains for proper disposal.

- ✓ Designate an area for clean up and proper disposal of excess materials.
- ✓ Use only as much water as necessary for dust control, to avoid runoff.
- ✓ Sweep up as much material as possible and dispose of properly. Only wash down streets if runoff is controlled or contained.
- ✓ After the job is complete, remove stockpiles (asphalt materials, sand, etc.) as soon as possible.
- ✓ If it rains unexpectedly, take appropriate action to prevent pollution of storm water runoff (e.g., divert runoff around work areas, cover materials).

Equipment Cleaning, Maintenance and Storage

- ✓ Inspect equipment daily and repair any leaks.
- ✓ Perform major equipment repairs at the corporation yard, when practical.
- ✓ If refueling or repairing vehicles and equipment must be done on-site, use a location away from storm drain inlets and creeks.
- ✓ Recycle used motor oil, diesel oil, and other vehicle fluids and parts whenever possible.
- ✓ Clean equipment including sprayers, sprayer paint supply lines, patch and paving equipment, and mudjacking equipment at the end of each day. Conduct cleaning at a corporation or maintenance yard if possible.

Painting and Paint Removal

- ✓ Do not transfer or load paint near storm drain inlets or watercourses.
- ✓ Where there is significant risk of a spill reaching storm drains, plug nearby storm drain inlets prior to starting painting and remove plugs when job is completed.
- ✓ Clean up spills immediately.
- ✓ Capture all clean-up water, and dispose of properly.
- ✓ If sand blasting is used to remove paint, cover nearby storm drain inlets prior to starting work.
- ✓ If the bridge crosses a watercourse, perform work on a maintenance traveler or platform, or use suspended netting or traps to capture paint, rust, paint

removing agents, or other materials, to prevent discharge of materials to surface waters.

- ✓ Recycle paint when possible. Dispose of paint at an appropriate household hazardous waste facility.

Graffiti Removal

- ✓ When graffiti is removed by painting over, implement the BMPs under Painting and Paint Removal above.
- ✓ Protect nearby storm drain inlets (using tarps in work areas, sand bags, and/or booms or barriers around inlets) prior to removing graffiti from walls, signs, sidewalks, or other structures needing graffiti abatement. Clean up afterwards by sweeping or vacuuming thoroughly, and/or by using absorbent and properly disposing of the absorbent.
- ✓ Direct runoff from sand blasting and high pressure washing (with no cleaning agents) into a landscaped or dirt area. If a landscaped area is not available, filter runoff through an appropriate filtering device (e.g., filter fabric) to keep sand, particles, and debris out of storm drains.
- ✓ If a graffiti abatement method generates washwater containing a cleaning compound (such as high pressure washing with a cleaning compound), plug nearby storm drains and vacuum/pump washwater to the sanitary sewer.
- ✓ Consider using a waterless and non-toxic chemical cleaning method for graffiti removal (e.g., gels or spray compounds).
- ✓ Avoid graffiti abatement activities during a rain storm.

Note: For information on storm drain inlet protection, see BMPs for Construction Sites (Appendix 3P).

Outdoor Storage Materials (Hazardous and Nonhazardous Materials)

- ✓ Store hazardous materials and wastes in secondary containment where they are protected from rain and in a way that prevents spills from reaching the sanitary sewer or storm drain.
- ✓ Keep lids on waste barrels and containers, and store them indoors or under cover to reduce exposure to rain.
- ✓ All hazardous wastes must be labeled according to hazardous waste regulations. Consult the Fire Department or your local hazardous waste agency for details.

- ✓ Keep wastes separate to increase your waste recycling/ disposal options and to reduce your costs.
- ✓ Never mix waste oil with fuel, antifreeze, or chlorinated solvents. Consult your hazardous waste hauler for details.
- ✓ Double-contain all bulk fluids and wastes to prevent accidental discharges to the sewer and storm drain. Consult the Fire Department for details.
- ✓ Keep storage areas clean and dry. Conduct regular inspections so that leaks and spills are detected as soon as possible.
- ✓ When receiving vehicles to be parted or scavenged, park them on a paved surface and immediately drain and collect gasoline and other fluids properly. Place drip pans
- ✓ Drain all fluids from components, such as engine blocks, which you may store for reuse or reclamation. Keep these components under cover and on a drop pan or sealed floor.
- ✓ Store new batteries securely to avoid breakage and acid spills during earthquakes. Shelving should be secured to the wall. Store used batteries indoors and in plastic trays to contain potential leaks. Recycle old batteries.to catch leaking fluids.
- ✓ Wood products treated with chromated copper arsenate, ammonical copper zinc arsenate, creosote, or pentachlorophenol should be covered with tarps (or stored indoors).

Structural Retrofit of Storm Drain Inlets/Catch Basins

Numerous structural "improvements" are available for the removal of pollutants from storm water, either as a modification to existing catch basins, or as a structural addition to the system. Studies have found these structural devices to be only marginally effective for removing pollutants of concern. Municipalities should, before installing, assess the pollutant of concern, validate effectiveness of the device to reduce those pollutants, and provide guarantee of maintenance.

Structural Retrofit of Storm Drains

Given the distinct dry and wet season climatic regime in California, often the runoff from the first storm carries very high pollutant loads. A potential structural control would be to direct the water from the first storm to the sanitary sewer system for treatment at the wastewater treatment plant. This BMP is not recommended for City-wide application, rather for urban runoff from limited areas where

the runoff is known to be highly polluted. Also, this will need to be coordinated with the local/regional wastewater treatment plant. This has been done in some California communities mainly to handle polluted runoff from industrial areas. The following steps will be necessary:

- ✓ Determine areas where the runoff is extremely polluted.
- ✓ Estimate the drainage area and volume of runoff from a design storm. Note that although the first flush runoff from a storm is generally the worst, runoff from the latter part of the first storm is also polluted. Therefore, estimate the runoff from the entire storm (and not just the first portion of it).
- ✓ Contact the local/regional wastewater treatment plant to determine if the facility has capacity to handle these projected flows.
- ✓ If capacity is available, develop appropriate connections (pipe and valve) between the storm drain and sewer system, after obtaining permission from the local wastewater treatment agency.
- ✓ Designate staff in the Public Works Department to handle the valve system to direct flows just before the first major storm.

Sources of Additional Information

The information presented above is based mainly on information from the Santa Clara Valley Urban Runoff Program. Additional information is available in the publications listed below.

Stormwater Quality Task Force. 1993. California Storm Water Best Management Practice Handbook - Municipal.

Stormwater Quality Task Force. 1993. California Storm Water Best Management Practice Handbook - Industrial/Commercial. (for more information on structural controls)

BASMAA 1997. Compilation of New Development in the San Francisco Bay Area Treatment Controls (for more information on structural controls). June.

King County Surface Management Division 1995. Evaluation of Commercially-Available Catch Basin Inserts for the Treatment of Stormwater Runoff from Developed Sites. October. (for more information on structural controls)

4K Evaluation of Street Sweepers

Table 4-1
SUMMARY OF STREET SWEEPING STUDIES (from Santa Clara Literature Review)

Study Title	Objectives	Equipment Evaluated	Locations	Results on Street Sweeping Effectiveness
Evaluation of Regenerative-air, Vacuum street Sweeping on Geological Contributions to PM^{10} (Chow *et al.* 1990)	Effect of street sweeping on air quality	Tymco 350 regenerative air, FMC mechanical sweeper, mobil AV345L blow air suction, re-circulating air sweeper	Reno, Nevada	Small particles of 10 microns are often impacted back into the street by regenerative air. Regenerative-air ineffective for particles smaller than 10 microns. Mobil sweeper appeared to leave dust after sweeping Regenerative air seems to resuspend more small particles.
Bellevue Urban Runoff Program (Pitt and Bissonette, 1984), and Quantity and Quality of Storm Runoff from Three Urban Catchments in Bellevue, Washington (Pyrch and Ebbert 1986).	Street sweeping effectiveness, equipment performance, across street distribution	Broom, regenerative air	Bellevue, Washington	Water quality is not significantly improved from street sweeping. There is less dirt on swept streets than unswept streets.

SARB_000992

Table 4-1
SUMMARY OF STREET SWEEPING STUDIES (from Santa Clara Literature Review)

Study Title	Objectives	Equipment Evaluated	Locations	Results on Street Sweeping Effectiveness
Evaluation of Urban Non-Point Source Pollution Management in Milwaukee County, Wisconsin, Vol. 1 &2 (Bannerman *et al.* 1983).	Compare the following options: 1. Increase frequency during March and October. 2. Increase frequency during March through November. The control and increased sweeping rates were as follows: commercial - weekly, 2 to 3 times per week, residential - monthly, weekly or twice weekly parking Lot - bi-monthly, bi-weekly or weekly	Mechanical	Milwaukee	Street sweeping results in a 10 percent reduction of pollutant loadings. Only a slight reduction for option 2 compared to option 1. Street sweeping is effective at removing winter residue (after snowmelt) and for leaf removal.
An Evaluation of Street Sweeping as a Runoff Pollutant Control (U.S. EPA 1983).	Street pollutant accumulation rate, pollutant particle size across street distribution, street sweeping effectiveness, and water quality effectiveness	Tymco sweepers	Winston-Salem, North Carolina	Average pickup was 393lbs/mi/day in business dist. 281lbs/mi/day in residential Most pollutants are within 1 ft of the curb Smaller particles have a higher concentration of pollutants Highest removal efficiency for particles bigger than 45 microns No benefit to water quality from street sweeping

SARB_000993

Table 4-1
SUMMARY OF STREET SWEEPING STUDIES (from Santa Clara Literature Review)

Study Title	Objectives	Equipment Evaluated	Locations	Results on Street Sweeping Effectiveness
Washoe County Urban Stormwater Management Program, Vol. 2: Street Particulate Data Collection and Analysis (CH2MHill 1982).	Street pollutant accumulation rates, no of passes, street texture, equipment performance, speed tests, street distribution of pollutants	Ecolotec vacuum assisted mobil, mechanical sweepers	Reno, Nevada	Rough streets have more particles than others. Street texture, street/gutter interface, and wind are the most important factors for accumulation. Fugitive dust affects accumulation rates. Multiple passes are not better. 4 mph minimizes residual loading. Driving lanes have less particles except on rough surface where they have the most). Driving lane particles are not easily swept or washed off.

SARB_000994

Table 4-1
SUMMARY OF STREET SWEEPING STUDIES (from Santa Clara Literature Review)

Study Title	Objectives	Equipment Evaluated	Locations	Results on Street Sweeping Effectiveness
Nationwide Urban Runoff Project, Champaign, Illinois; Evaluation of the Effectiveness of Municipal Street Sweeping in the Control of Urban Storm Runoff Pollution (Terstrierp *et al.* 1982)	Street pollutant accumulation rate, pollutant particle size, water quality effectiveness	1973 Elgin model Pelican S (3-wheeled mechanical sweeper)	Champaign, Illinois	Mechanical sweeping with frequencies of up to 2 times per week is not effective at reducing the mean concentration or load. Mechanical sweeping at a frequency of once per week does reduce the amount and variability of street dirt. The overall removal efficiency for mechanical sweeper was 30 to 67 percent.
A Demonstration of Non-Point Source Pollution Management on Castro Valley Creek (Pitt and Shawley 1981).	Street pollutant accumulation rates, sweeping frequency, equipment performance	Mobil-broom sweeper, regenerative air	Castro Valley, California	Regenerative air sweepers are effective in removing particles from street surfaces for areas that have a low quality of dust/dirt or trash. As the quantity of street dust/dirt increases, regenerative air sweeper effectiveness diminishes. Mechanical sweepers are best for trash and large particles. Broom sweeper efficiency was 40 percent After 2 to 3 sweepings per week, there is little improvement in material removed from the street surfaces.

SARB_000995

Table 4-1

SUMMARY OF STREET SWEEPING STUDIES (from Santa Clara Literature Review)

Study Title	Objectives	Equipment Evaluated	Locations	Results on Street Sweeping Effectiveness
Demonstration of Non-Point Pollution Abatement through Improved Street Cleaning Practice (Pitt 1978).	Street pollutant accumulation rates, sweeping frequency, equipment performance	Sweeper, vacuum assisted sweepers	San Jose, California	Graphs to determine street sweeping frequency. 2 passes better than one except for oily areas. Median particle size in hopper larger than on street Street sweeping can reduce particle emission rates from asphalt to the atmosphere by 2/3 if done weekly compared to every 2 to 3 months.
System Analysis of Street Cleaning Techniques (Pitt *et al.* 1976)	Literature review of previous studies			Parking restrictions are needed. 50% of the particles larger than 1/4in. are removed. Fast broom rotations are better
Water Pollution Aspects of Street Surface Contaminants (Sartor and Boyd 1972)	Simulated runoff, removal effectiveness (using control areas and artificial contaminant)	Broom sweepers	Milwaukee, Baltimore, Scottsdale, Atlanta, Tulsa Phoenix, San Jose	Fine particles have a higher concentration of metals, pesticides, and organics than larger particles. Street sweeping effectiveness for removing fine particles is low. Street parking reduces the efficiency of sweepers.

Source: Literature Review for Santa Clara Non Point Source Control Program (WCC 1993)

SARB_000996

4L Sample Corporation Yard SWPPP

D1.1 Facility

Maintenance Yard #3
1234 Facilities Way
XYZ, California 99999

Facility Owner: **City of XYZ**

Date Prepared: **June 18, 1997**
Prepared By: **C. Lin**

Updated:

D1.2 Objectives

The municipal stormwater permit for discharges in the County of Los Angeles requires those Permittees who own and operate facilities where vehicle maintenance and/or material storage activities occur, as defined in Section IV.3.a of the Permit, to implement a pollution prevention plan. The purpose of the regulations is to protect water quality by reducing the amount of pollutants that could potentially reach the storm drainage system and receiving waters.

The minimum objectives of the Vehicle Maintenance/Material Storage Facilities Management program are to:

- Identify and evaluate sources of pollutants from public vehicle maintenance/material storage facilities that may affect the quality of stormwater discharges from the facility.
- Identify and implement site-specific best management practices (BMPs) to reduce or prevent pollutants in stormwater discharges.

A copy of this plan should be kept at the facility. It should be reviewed periodically to assure all information and measures are current and accurate and should be updated as conditions change.

SOURCE : ALAMEDA CLEAN WATER PROGRAM

D1.3 Planning and Organization

D1.3.1 Pollution Prevention Team

Name	Function
C. Lin Public Works, Streets & Roads Division (999) 555-1212	Program Coordinator / Pollution Prevention Plan Development
A. Martinez Maintenance Staff (999) 555-1222	Pollution Prevention Plan Implementation
D. Jones Maintenance Staff (999) 555-1232	Pollution Prevention Plan Implementation

D.1.2 Site Map

Figure 1 is a detailed site map of the Maintenance Yard #3 facility.

Site Map - Maintenance Yard #3

Area = 4.5 acres
95% impervious (paved/covered)

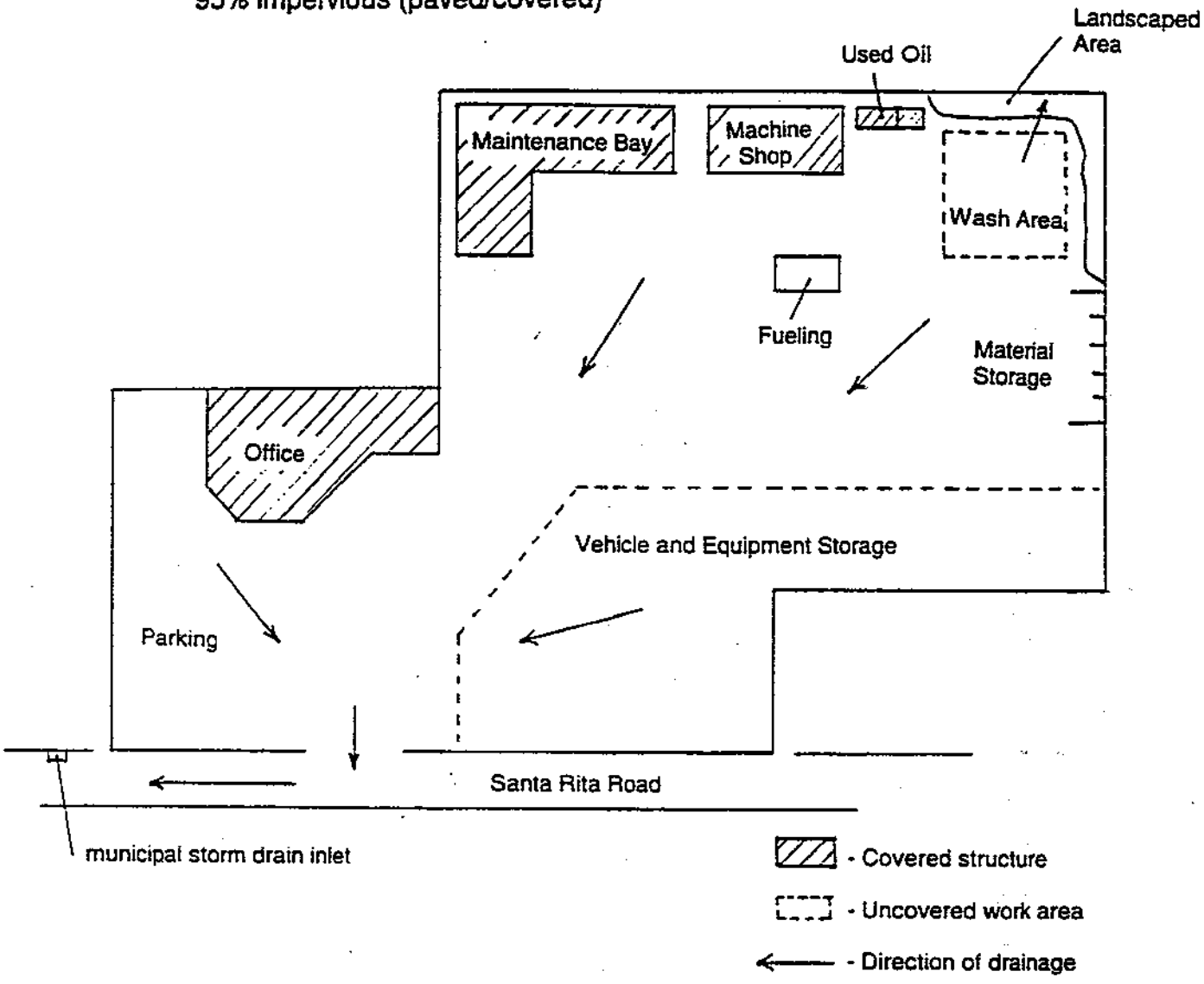

Figure 1
Site Map

D.1.3 List of Significant Materials

Table 1 describes materials that are handled and stored at the Maintenance Yard #3 facility:

Table 1: Significant Materials		
Material	***Handling and Storage Location***	***Typical Quantity/ Frequency***
Gasoline	Center of yard at fueling area	250 gal/day
Diesel fuel	Center of yard at fueling area	200 gal/day
Motor oil	North section of yard in Maintenance Bay	90 gal/wk
Used motor oil	North section of yard in Used Oil Storage Area	30 gal/wk
Lubricants	North section of yard in Maintenance Bay	15 gal/mo
Brake fluid	North section of yard in Maintenance Bay	40 gal/wk
Hydraulic fluid	North section of yard in Maintenance Bay	5 gal/day
Adhesives and sealants	North section of yard in Material Storage Area	10 gal/mo
Antifreeze	North section of yard in Maintenance Bay	30 gal/day
Used Antifreeze	North section of yard in the Used Antifreeze Storage Area	10 gal/day
Solvents	North section of yard in Chemical Storage Area	50 lb/wk
Detergents	North section of yard in Chemical Storage Area	40 lb/wk
Paint	North section of yard in Chemical Storage Area	20 gal/mo
Concrete	East section of yard in Raw Materials Area	1 ton/mo
Gravel	East section of yard in Raw Materials Area	200 lb/wk
Sand	East section of yard in Raw Materials Area	250 lb/wk
Aggregate	East section of yard in Raw Materials Area	100 lb/wk
Pesticides and herbicides	North section of yard in Chemical Storage Area	85 gal/mo
Fertilizers	North section of yard in Chemical Storage Area	100 lb/wk
Soil Amendments	North section of yard in Chemical Storage Area	50 lb/wk

D.1.4 Description of Potential Pollutant Sources

Table 2 describes potential pollutant sources at the Maintenance Yard #3 facility:

Table 2: Potential Pollutant Sources		
Area / Activity	***Pollutant Source***	***Pollutant***
Vehicle and Equipment Fueling performed in the center of the yard at the fueling area; containing both unleaded and diesel fuel for smaller vehicles and large equipment. Both pumps in the fueling area are covered by a raised roof.	Spills caused by topping off fuel tanks	gasoline
	Spills and leaks during deliveries	fuel, oil
	Hosing or washing down fuel area.	fuel, oil
	Rainfall running onto and off of fueling area	fuel, oil
Vehicle and Equipment Maintenance performed at the Maintenance Bay Building in the northwest section of the yard. Activities include fluid changes, vehicle repairs, equipment repairs, and other necessary maintenance.	Vehicle fluid spills or leaks	transmission fluids, luring materials, radiator fluids, etc.
	Container spills or leaks	solvents, degreasers, other cleansers
Vehicle and Equipment Washing performed in the northeast section of the yard. Washing Area is uncovered and not bermed.	Washing particulates and debris off vehicles and equipment	sediment, metals, toxic materials, vehicle fluids
Material, Chemical, Vehicle and Equipment Storage located at the north and east sections of the yard. All areas are covered. See Table 1 for yard materials stored.	Container spills or leaks	antifreeze, oil, pesticides, herbicides, solvents, etc.
	Vehicle and equipment leaks	gasoline, oil

D.1.5 Assessment of Potential Pollutant Sources

Vehicle and Equipment Fueling is a potential source of stormwater pollution at the Maintenance Yard #3 facility. Stormwater runon has the potential to wash away any spills or leaked fluids located at the fueling area and subsequently drain onto the street and into the storm drain. Pollutants located at the fueling area include oil and gasoline (unleaded and diesel). With the washing area currently northeast and upgrade of the fueling area, pollutants may be carried via wash water flows to the storm drain in a non-stormwater discharge.

Vehicle and Equipment Maintenance is a minimal potential source of stormwater pollution. Vehicle and equipment fluids are handled and changed in the Maintenance Bay and may eventually flow into the storm drain only if staff cleans the bay area with the use of water hose. Maintenance pollutants include transmission and radiator fluids, solvents, degreasers, as well as gasoline.

Vehicle and Equipment Washing has a high pollutant potential as alluded to above. Without a bermed area or covered structure for this activity, non-stormwater discharges from washing may flow south-southwest, crossing the fueling area, concentrating pollutant flow even more. Pollutants from washing include sediment, metals, toxic materials, and vehicle fluids such as oil and gasoline.

Material, Chemical, Vehicle and Equipment Storage also has a potential for stormwater pollution. Particularly, vehicles and equipment, stored outside and uncovered, are susceptible to leaking. Rainfall at the facility has the potential to wash leaked fluids into the storm drain system. Material and chemical storage at the facility are covered and carefully protected, minimizing the potential for any stormwater pollution.

D1.6 Stormwater Best Management Practices

Table 3 describes applicable best management practices for the Maintenance Yard #3 facility:

Table 3: Applicable Best Management Practices

Area / Activity	*Pollutant Source*	*Pollutant*	*Best Management Practice*
Vehicle and Equipment Fueling	Spills caused by topping off fuel tanks	gasoline	■ Train employees in proper fueling and cleanup procedures ■ Discourage "topping off" of fuel tanks ■ Install "shut-off" valves on nozzles ■ Use adsorbent materials on spills as opposed to hosing down ■ Install covered spill kits next to fueling area
	Spills and leaks during deliveries	fuel, oil	
	Hosing or washing down fuel area.	fuel, oil	
	Rainfall running onto and off of fueling area	fuel, oil	
Vehicle and Equipment Maintenance	Vehicle fluid spills or leaks	transmission fluids, luring materials, radiator fluids, etc.	■ Train employees in proper cleanup procedures of spills and leaks ■ Keep equipment clean, disallowing excessive grease/oil buildup ■ Use drip pans for any leaking vehicle/equipment ■ Complete all maintenance in proper location (covered) ■ Sweep up daily ■ Install spill kits in Maintenance Bay
	Container spills or leaks	solvents, degreasers, other cleansers	
Vehicle and Equipment Washing	Washing vehicle particulates and debris off	sediment, metals, toxic materials, vehicle fluids	■ Wash vehicles and equipment at an off-site commercial washing location whenever possible ■ If on-site, direct wash water towards surrounding, existing vegetation ■ Evaluate the feasibility of constructing a bermed or covered wash area draining to the sanitary sewer
	Washing equipment particulates and debris off	sediment, metals, toxic materials, vehicle fluids	
Material, Chemical, Vehicle and Equipment Storage	Container spills or leaks	antifreeze, oil, pesticides, herbicides, solvents, etc.	■ Store materials in enclosed or covered areas
	Vehicle and equipment leaks	gasoline, oil	■ Use drip pans underneath leaking vehicles and equipment

4M Sample Reporting Forms

ALAMEDA COUNTYWIDE CLEAN WATER PROGRAM
Municipal Government Maintenance Activities
FY 1995/96 Monthly Record Keeping Form

Month of: _____

Municipality: _____

Completed by: _____ **Date:** _____

STREET CLEANING

1. Sweeping	Volume of material collected (cubic yards)	Miles swept* (curb miles)
Residential Areas:		
Broom	_____	_____
Regenerative Air	_____	_____
Vacuum	_____	_____
Commercial Areas:		
Broom	_____	_____
Regenerative Air	_____	_____
Vacuum	_____	_____
Industrial Areas:		
Broom	_____	_____
Regenerative Air	_____	_____
Vacuum	_____	_____
Other Areas Swept: (e.g., parking lots, major arterials)		
Broom	_____	_____
Regenerative Air	_____	_____
Vacuum	_____	_____
TOTAL	_____	_____

2. Have there been any changes in your street sweeping program? (efforts to have parked cars removed, changed sweeping frequency, new equipment, significant downtime, etc.)

_____

_____

_____

_____

_____

LEAF REMOVAL

Volume of leaves removed by City crews: _____ cubic yards

Leaves bagged by residents and picked up by City: _____ bags

Check box if you do not have a leaf removal program other than routine street sweeping: ☐

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* Report total miles covered by sweepers including areas operated in tandem or repeated.

EOA, Inc.
November 1995

ALAMEDA COUNTYWIDE CLEAN WATER PROGRAM
Municipal Government Maintenance Activities
FY 1995/96 Monthly Record Keeping Form

Month of: _____

Municipality: _____

Completed by: _____ **Date:** _____

MAINTENANCE OF STORM DRAINAGE FACILITIES

	Inspected		Cleaned	
Number of storm drain inlets	_____		_____	
Number of cross culverts, conduits, and/or culverts used to convey stormwater around street corners	_____		_____	
V ditches	_____	miles	_____	miles
Storm drain lines	_____	miles	_____	miles
Channels	_____	miles	_____	miles
Creeks	_____	miles	_____	miles
Culverts	_____	linear feet	_____	linear feet
Number of junction boxes	_____		_____	
Number of pump stations	_____		_____	

Other (please specify) _____

_____

Total volume of material removed _____ cubic yards or _____ tons

Describe any observed illegal discharges or illicit connections below or check the box if activities are included in the Illicit Discharge Quarterly Summary Form: ☐

_____

_____

_____

_____

Have you responded to complaints or noticed areas which should be targeted for more frequent cleaning?

Yes _____ No _____ If yes, explain _____

_____

_____

_____

LITTER CONTROL

	Areas Targeted	Volume Removed
City/County Personnel (including receptacles)	_____	_____
Court Referred Crews	_____	_____
Other (e.g., contractors)	_____	_____
Total (specify cubic yards or pounds)		_____

SANTA CLARA VALLEY URBAN RUNOFF POLLUTION PREVENTION PROGRAM

PUBLIC STREETS, ROADS, AND HIGHWAYS OPERATION AND MAINTENANCE

Co-permittee Reporting Form

1. Are you implementing best management practices (BMPs) for the street, road, and highway operation and maintenance (O&M) activities that you are responsible for conducting, in order to reduce pollutants in storm water to the maximum extent practicable and eliminate illicit discharges?

   ☐ yes ☐ no If yes, describe any changes in your BMPs during the past year.
   If no, explain:

2. Have you developed and implemented a process for ensuring that any contractors you employ to conduct street, road, and highway O&M activities use the appropriate BMPs adopted by the agency?

   ☐ yes ☐ no If yes, describe any changes in your process during the past year.
   If no, explain:

3. Have you provided training on an annual basis to your municipal staff in the use of appropriate BMPs?

   ☐ yes ☐ no If yes, describe training conducted during the past year.
   If no, explain:

   Have you provided a mechanism for obtaining feedback from municipal staff on the implementation and effectiveness of the BMPs?

   ☐ yes ☐ no If no, explain:

4. Have you informed other parties conducting street, road, and highway O&M activities within your jurisdiction that they are expected to implement BMPs to reduce pollutants in storm water to the maximum extent practicable and eliminate illicit discharges?

   ☐ yes ☐ no If no, explain:

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Co-permittee Reporting Form, continued

5. Have you reviewed and evaluated the effectiveness of your BMPs in achieving the goals of reducing pollutants in storm water to the maximum extent practicable and eliminating illicit discharges?

☐ yes ☐ no If no, explain:

Did this review include input from municipal maintenance staff that implement the BMPs?

☐ yes ☐ no If no, explain:

What were your findings from this review? Describe how BMPs have been modified as a result of this evaluation:

4N Sample Ordinance

MANAGEMENT PRACTICES ADMINISTRATIVE RULE R-6.645

R-6.645-A **Purpose and Intent.**

1. **Purpose.** These rules implement Sections 6.625 to 6.645 of the Eugene Code, 1971, which were adopted to restrict the discharge of sediments or other construction related materials, including hazardous substances, into the City's stormwater system in order to:

1.1 Prevent or minimize, to the maximum extent possible, negative impacts to adjacent properties, water quality and related natural resources resulting from construction activities; and

1.2 Maintain the capacity of the City's stormwater system by minimizing sedimentation.

2. **Intent.** The intent of these rules, in implementing sections 6.625 to 6.645 of the Eugene Code, 1971, is to ensure that construction related activities prevent or minimize erosion, sedimentation, and other stormwater related problems identified in subsection 1 above. To carry-out the intent of the these rules, it is the goal of the City's erosion prevention program to review and respond to all erosion permit applications in a timely manner so that these provisions do not increase the time frame for issuing other permits. These rules are designed to provide developers and property owners with broad discretion for addressing potential impacts of construction related activities, so long as the erosion prevention measures achieve the desired outcomes. These rules therefore do not specify or mandate the use of certain erosion prevention measures, and instead, provide applicants with flexibility to choose or design erosion prevention measures subject to review by the City. The issuance of an erosion prevention permit by the City will not necessarily reflect concurrence by the City that the proposed measures will work. Instead, the City's review may be more limited in many cases, relying on the certification of the owners' certified professional that the proposed measures will achieve the mandated outcomes. In such cases, the City's review may be limited to making an evaluation that the proposed measures address anticipated impacts. Where the City is uncertain about the likely success of the proposed measures, the City may issue the permit, and monitor the site to determine whether the measures are achieving the outcomes. If the erosion prevention measures have not been successful in achieving those outcomes, the City will require compliance.

R-6.645-B **Definitions.**

In additions to the definitions contained in Sections 6.405 and 6.625 to 6.645 of the Eugene Code, 1971, as used herein, the following words and phrases mean:

Adjacent property. Property where erosion and/or sedimentation or construction

S'ARB_001011

material impacts are occurring and the cause of impact is directly related to a construction activity from a separate parcel.

Annual landscape activities. Activities necessary to maintain the health and function of developed landscaped areas, including but not limited to: tilling, sodding, mowing, aerating, and pruning.

Certified professional. A person who holds an Oregon license in one of the following professions: engineer, architect, landscape architect, or is in a similar profession as determined by the City Manager; or a person who is certified as a geologist or as a professional in erosion and sedimentation control by the International Erosion Control Association, or any other similar organization, or by the City, as determined by the City Manager.

City Manager. The City Manager of the City of Eugene, or the Manager's designee.

Construction activity. An activity used in the process of developing, redeveloping, enhancing, or maintaining land, including but not limited to: land disturbance, building construction, paving and surfacing, storage and disposal of construction related materials.

Construction footprint. That area of a parcel where disturbance to vegetation and landform is necessary for the construction of buildings, parking lots, walkways, landscaping, utilities, and for staging of construction equipment and other similar uses associated with construction activities.

Construction related materials. Potential water quality pollutants that are used or created during construction activities including, but not limited to; off-site deposits of sediments by vehicles (e.g. tracking, spilling); building material wastes (e.g.. scrap metals, rubber, plastic, glass, masonry, wood; paints and thinners; packaging materials; insulation, plaster grout); hazardous substances (e.g. cleaning solvents; chemical additives; concrete curing compounds; acids for cleaning masonry surfaces; paints, thinners); and concrete washout.

Construction Site Management Plan. A set of maps, data, drawings, and narrative that describes expected runoff from new construction sites and establishes measures to be taken for preventing erosion, sediments, and other pollutants from construction related activities.

Designated buffer. An area established by the Eugene Code, 1971, including but not limited to sections 9.262(3)(b) and 9.264(3), that separates a protected natural resource site, such as a wetland or water feature, from a conflicting use, or its designated buffer area.

Dewatering. The removal and disposal of surface water or groundwater for purposes

of preparing a site for construction.

Directly drains. The conveyance and discharge of stormwater runoff - either on the surface or by an open channel or pipe - into a water feature that is located on or adjacent to the parcel or tax lot of record for which construction activities are planned, or its designated buffer area.

Disturbed area. A parcel or a portion of a parcel of land where the vegetation, landform, or topography is altered due to logging, clearing, grubbing, grading, paving, stock piling, or building.

Emergency condition. An immediate danger to life, property, or the environment due to circumstances beyond the control of the property owner, including, but not limited to, natural and human-caused disasters such as fires, floods, slides, earthquakes, sinkholes, and tree blow-down.

Enforcement Officer. The person designated by the City Manager to enforce the provisions of Sections 6.625 to 6.645 of the Eugene Code, 1971 and these rules.

Erosion prevention. Measures to be taken for preventing and/or minimizing impacts to the City's stormwater system and related natural resources due to soil erosion from water and wind forces, sedimentation, and other potential impacts associated with construction activities such as handling and storage of building materials and disposal of building material wastes.

Fully developed property. A parcel of land that contains buildings, pavement and other facilities, including landscaped areas and due to these uses is not capable of additional expansion.

Highly erodible soils. Soil map units as classified by the Natural Resources Conservation Service (NRCS - formerly the Soil Conservation Service) as being highly erodible. Based on factors from the Universal Soil Loss Equation, the NRCS classification system considers soil erodibility (K factor), climate, slope, steepness, length, and soil loss tolerance (T factor).

Immediate clean-up. Not later than the end of the work shift in which the violation occurred, but in no event shall it occur later than midnight of the day in which it occurred.

Improper disposal. Disposal of any construction related material in a manner that causes, or has the potential to cause, the discharge of pollutants to the City's stormwater system or related natural resource, the depletion of the capacity of the City's stormwater system, or the contamination of soils.

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Improper storage. Handling or storing of any construction related materials in a manner that, due to leaks, spills, leachates, deposits or dumps, causes or has the potential to cause the discharge of pollutants to the City's stormwater system or related natural resources, the depletion of the capacity of the City's stormwater system, or the contamination of soils.

Jurisdictional wetlands. Any parcel or portion of a parcel which meets the state or federal definition of wetlands that are under the jurisdiction of state or federal laws. Synonymous with wetlands.

Land disturbance. Activities that can change the physical conditions of landform, vegetation, and hydrology including, but not limited to, clearing, grading, grubbing, excavating, filling, logging, and storing of materials.

Maximum extent practicable. A level of effort to be undertaken where technical feasibility and financial costs to be incurred are appropriate, as determined by the criteria in Section R-6.645-D.2 of this Rule, for the probable negative impacts to water quality to be minimized.

Minor Recurring Activities. Repetitive construction activities that are performed as part of an overall work plan and no individual disturbance exceeds more than 500 square feet of land area and 50 cubic yards of fill or excavated material.

Permit Holder. The property owner or easement holder of record of the parcel or tax lot for which construction activities are planned.

Person. An individual, trust, firm, joint stock company, joint venture, consortium, commercial entity, partnership, association, corporation, commission, state and any agency thereof, political subdivision of the state, interstate body or the federal government, including any agency thereof;

Related Natural Resources. Natural resources located within or adjacent to the City's stormwater system, such as waterways, wetlands, and riparian areas, that provide one or more of the following stormwater functions: flood control, water quality treatment, and streambank stabilization.

Routine Maintenance. Activities and practices that are necessary to maintain the operating capacity, functional integrity, or aesthetics of a place or facility. Routine maintenance includes, but is not limited to, landscaping, repair of recreation facilities (e.g., ball diamonds, play areas, fields), cleaning of stormwater facilities, and patching of streets.

Sensitive area. Sites that meet the criteria contained in R-6.645-E.1.

Template. An example of a construction site management plan provided by the City

of Eugene that - when modified by the erosion prevention permit holder to address site specific conditions - can be used to satisfy permit requirements for a single dwelling or duplex dwelling. The template may be prepared by the permit holder or the permit holder's designee.

Untreated runoff. Contaminated stormwater runoff due to construction activities that has not been filtered, screened, settled, or otherwise treated for the removal of pollutants, prior to discharge into the City's stormwater system or related natural resources.

Water features. Permanent or intermittent bodies of water, including creeks, streams, ponds, rivers, lakes, drainage channels and jurisdictional wetlands.

Vegetative buffer. A strip of land not less than 25 feet in width separating a construction activity from either a water feature or a property line, whichever is nearest, containing a vegetation that covers at least 75% of the buffer area.

Visible or measurable erosion. The deposit of mud, soil, sediment or similar material exceeding one-half cubic foot in volume for every 1,000 square feet of lot size onto public rights of way or private streets, into the City's stormwater system or related natural resources, either by direct deposit, dropping, discharge, or as a result of the action of erosion; evidence of concentrated flows of water over bare soils, turbid or sediment laden flows, or evidence of on-site erosion such as rivulets on bare soil slopes where the flow of water is not filtered or captured on the site using the techniques recommended in the City's Erosion Prevention and Construction Site Management Practices Planning and Design Manual, or comparable techniques; and, earth slides, mud flows, earth sloughing, or other earth movement which leaves the property.

Wetlands. Any parcel or portion of a parcel which meets the state or federal definition of wetlands that are under the jurisdiction of state or federal laws. Synonymous with jurisdictional wetlands.

R-6.645-C Applicability.

1. These rules, and Sections 6.625 to 6.645 of the Eugene Code, 1971 apply to all construction related activities that result in any one or all of the following:

1.1 Land disturbance;

1.2 Structural development, including, but not limited to buildings, bridges, roads, and other infrastructure;

1.3 Impervious surfaces, including, but not limited to parking lots, driveways,

walkways, and patios; or

1.4 Dewatering.

2. No person shall engage in any construction related activity covered by Subsection R-6.645-C.1 of these Rules except as allowed by the Eugene Code 1971 and these rules. All persons shall prevent and/or control erosion, sedimentation, and other construction related impacts to stormwater quality in a manner designed to meet the outcomes specified in R-6.645-D. Failure to implement measures that meet those outcomes shall subject the person to the same enforcement provisions as those applicable to a permit holder under section 6.640 of the Eugene Code and R-6.645-F of the Rules. This requirement shall be implemented through one of the following provisions:

2.1 Issuance of an Erosion Prevention Permit in accordance with Section R-6.645-F of these Rules;

2.2 For all other construction activities not subject to the erosion prevention permit requirements, compliance by property owners with the standards for preventing and controlling erosion, sedimentation, and other impacts associated with construction site management practices. The City will make information about these requirements available through a variety of techniques, including public outreach programs, handout materials, and other educational efforts to assist property owners in meeting this obligation.

3. Notwithstanding Subsection 1 above, the following activities are exempt from the provisions of Sections 6.625 to 6.645 of the Eugene Code, 1971 and these rules:

3.1 Actions by a public utility, the City, or any other governmental agency, to remove or alleviate an emergency condition, restore utility service, or reopen a public thoroughfare to traffic; or

3.2 Actions by any other person when the City determines, and documents in writing, that such actions are necessary to remove or alleviate an emergency condition, restore utility service, or reopen a public thoroughfare to traffic.

R-6.645-D **Outcomes.**

1. All persons conducting construction activities covered by R-6.645-C.1. shall employ, to the maximum extent practicable, erosion prevention and construction site management practices which result in the following outcomes:

1.1 No deposit or discharge of sediment from a site onto adjacent properties or into water features and related natural resources in excess of those that occur through natural

processes;

1.2 No degradation of water features due to removal of streambank vegetation from construction sites in excess of those that occur through natural processes;

1.3 No deposit of mud, soil, sediment, concrete washout, trash, or other similar construction related material exceeding one-half cubic foot in volume for every 1,000 square feet of lot size onto public rights of way and private streets, and into the City's stormwater system and related natural resources, either by direct deposit, dropping, discharge, erosion, or tracking by construction vehicles, in excess of those that occur through natural processes. Any such discharge shall be cleaned-up at the end of the current work shift in which the deposit occurred, or at the end of the current work day, whichever comes first.

1.4 No exposure of soils and stockpile areas to stormwater runoff without secondary containment and treatment measures.

1.5 No earth slides, mudflows, earth sloughing, or other earth movement which may leave the property, in excess of those that occur through natural processes;

1.6 No discharge of runoff containing construction related contaminants into the City's stormwater system or related natural resources; and

1.7 No release onto the site of hazardous substances, such as paints, thinners, fuels and other chemicals.

2. Maximum extent practicable. Implementation of a stormwater management practice is considered practicable unless one or more of the following applies:

2.1 The practice is not technically feasible for the proposed use and physical characteristics of the site;

2.2 The cost of implementing the practice would outweigh the benefits of maintaining water quality. Costs are considered to outweigh benefits if they exceed $0.50 per square foot of disturbed area.

Costs to be considered under subparagraph R-6.645-D.2.2 include permit fees, design preparation (construction site management plan/template), construction of construction site management measures, and monitoring by a professional. Costs do not include: maintenance of management measures, actions taken to correct violations, and permanent landscape and associated design fees.

3. When designing and implementing management measures to meet the above outcomes, the applicant shall consider the seasonal variation of rainfall, temperature, and other climatic factors relative to the timing of land disturbance activities. Management measures shall be

adjusted to meet increased stormwater runoff flows and velocities between November 1 and April 30 of the following calendar year.

4. No permit or other approval issued pursuant to these rules shall be deemed to authorize any violation of the above prohibitions.

R-6.645-E **Designation of Sensitive Areas.**

1. **Criteria for Sensitive Area Designation.** For the purposes of administering these Rules, any construction site that meets one or more of the following criteria shall be considered a sensitive area for which an erosion prevention permit will be required:

1.1 The slope of the parcel in the area of disturbance is greater than 10%;

1.2 The site contains highly erodible soils; or

1.3 The parcel or tax lot of record has the potential to directly drain into a water feature or its designated buffer area.

2. **Determination of Sensitive Area.** To assist with the administration of these provisions, the City has prepared a map indicating sites that appear to meet the above criteria. The Public Work s Director, or designee, shall use this map to make a preliminary determination of a site's sensitive area status. The map is on file at the City's Public Works Engineering Department (858 Pearl Street) and Permit & Information Center (99 West 10th Avenue).

An applicant may challenge the Director's preliminary determination that a site is a sensitive area through submission of actual field or site information that demonstrates to the City's satisfaction that the site's existing physical features, such as a continuous vegetative perimeter buffer which prevents discharge of sediments, mitigate potential stormwater quality impacts, and the Director shall thereafter make a final determination of whether the site is a sensitive area.

If an applicant chooses not to contest the designation or is unable to satisfy the above criteria, the site shall be considered a sensitive area and an erosion prevention permit shall be required.

3. **Appeal of designation.** An applicant who disagrees with the Director's final determination may appeal that decision within the time and manner prescribed in section R-6.645-F.11 of these Rules.

R-6.645-F **Erosion Prevention Permits.**

1. **Permit Required.** Except as otherwise provided in these rules or provisions of the

Eugene Code, 1971, no person shall commence any construction related activity without first obtaining from the City an erosion prevention permit if the construction related activity will:

1.1 Disturb five or more acres of land at any one time by one or more phases of development, and the disturbance is located on the same parcel of land or on contiguous parcels of land under the same ownership; or

1.2 Is located in a sensitive area as designated pursuant to R-6.645-E of these rules.

2. **Waiver of Erosion Prevention Permit.** Notwithstanding any other provisions of this section, the following activities shall not require an erosion prevention permit. However, under no circumstances shall this waiver be construed to mean that these activities are exempt from any of the erosion prevention requirements of the Eugene Code, 1971 and these rules other than the requirement to obtain an erosion prevention permit; the following activities are subject to other provisions, including but not limited to Outcome requirements in Section R-6.645-D of this Rule.

2.1 Construction activities involving the disturbance of less than 500 square feet of land surface area, or which consist of the excavation and/or fill of less than 20 cubic yards of material;

2.2 The issuance of permits and/or approvals for land divisions, interior improvements to an existing structure, or other approvals for which there is no physical disturbance to the surface of the land; and

2.3 Annual landscape maintenance activities on fully developed properties, necessary to maintain the existing developed landscape.

3. **Permit Classifications.** A variety of permits may be issued to address different circumstances. Regardless of permit type, the property owner or easement holder of record is the responsible party for the permit. If property ownership changes before the permit is finalized, the new property owner assumes the responsibility of the permit and any outstanding issues associated with the permit. The following permits may be issued to meet the requirements of these rules provided the associated eligibility requirements are met:

3.1 Individual Permit. A property owner or easement holder of record may obtain a separate, individual permit for each construction activity on the same parcel of land. For example, the individual permit allows a property owner to obtain a permit for building construction activities and a utility to obtain a separate permit for utility purposes.

3.2 Umbrella Permit. A property owner or easement holder of record may obtain an umbrella permit for multiple construction activities on the same parcel of land that are proposed in connection with a development, including utility work, private infrastructure,

structures, and other site improvements. This permit allows one permit to be issued for all construction activities and all phases of development.

3.3 Annual Permit. An annual permit may be issued for minor recurring activities. The annual permit is intended to provide a streamlined permit process for entities that perform repetitive activities on a frequent basis. This provision allows one permit to be issued for more than one project within a calendar year. To qualify for an annual permit, the following criteria shall be met:

3.3.1 Construction activities are minor and recur on a frequent basis. Examples include but are not limited to: utility service connections and extensions, repair of utility and infrastructure facilities.

3.3.2 Permits may be issued for a full calendar year, and shall expire on or before December 31 of the year issued.

4. **Application**. In addition to the payment of any required fees, an application for an erosion prevention permit shall include a completed Construction Site Management Plan (except for an Annual Permit, refer to Section R-6.645-F7.4), prepared in accordance with Subsection 7 of this Section, or a template prepared in accordance with subsection 7.3.

5. **Independent Permit Processing**. The application and processing of other City of Eugene permits, such as, but not limited to, grading, privately engineered public improvements, foundation and building permits, are independent of the Erosion Prevention permit process. The City of Eugene shall not issue any of these other permits:

5.1 Unless and until the City has approved and issued a required Erosion Prevention permit;

5.2 Until the City has determined an Erosion Prevention permit is not required; or

5.3 If the property owner or applicant is in violation of an Erosion Prevention permit, or any conditions contained therein.

6. **Completeness Check**. At the time of application submittal, the City shall conduct a completeness check to determine if the application meets all of the submittal requirements. The City shall not accept the application until all requirements have been met. After the application has been accepted, the City may find after a more thorough review that the applicant submitted inadequate or inaccurate information. In that case, the City may require that certain additional information be submitted. A complete application submittal includes:

6.1 Completed and signed application form;

6.2 Fee;

6.3 Construction Site Management Plan prepared by a certified professional, except as provided in subsections 7.3 and 7.4 of these rules.

7. **Construction Site Management Plan.**

7.1 Individual and Umbrella Permits. A Construction Site Management Plan shall be required in order to identify potential water quality impacts associated with the proposed construction activity and ensure that appropriate and effective techniques and methods are utilized to prevent and control erosion and sedimentation and other pollutants associated with construction activities. The Construction Site Management Plan (Plan) shall be prepared by a Certified Professional. The Plan shall outline the techniques and methods to be used to achieve the required outcomes, describe conditions before and after development, and the proposed methods to prevent and control water quality impacts during and after construction. The Certified Professional, as part of the Plan, shall certify that in his or her professional opinion, implementation of the Plan will ensure compliance with R-6.645-D.1. The City shall review the Plan prior to issuance of an erosion prevention permit and may monitor the development thereafter for continued compliance.

7.2 Contents. At a minimum, the Construction Site Management Plan shall consider and address the follow factors as appropriate:

7.2.1 A site location and vicinity map;

7.2.2 A site development drawing at a standardized engineering or architectural scale, such as 1"= 40', containing the following site conditions: (a) soil type; (b) on-site elevations and/or topographic information adequate to determine drainage patterns and slopes; (c) hydrology, including surface drainages and wetlands; (d) existing vegetation; and (e) natural resource sites and designated buffer areas.

7.2.3 Plans that show site control measures for preventing erosion and sedimentation into the City's stormwater system and related natural resources, including supporting calculations, such as hydraulics and soil loss equation, and assumptions for the 5-year or 10-year storm event as required by City design policy;

7.2.4 Off-site and on-site access routes for construction and maintenance vehicles;

7.2.5 Borrow and waste disposal areas;

7.2.6 Debris and garbage disposal areas;

7.2.7 Vegetation specifications for temporary and permanent stabilization;

7.2.8 Construction schedule, including the implementation of construction site management practices and expected time period of land disturbing activities;

7.2.9 Manner of storage and disposal of materials (e.g., sand, lumber, insulation, paints, thinners, fertilizers, fuels);

7.2.10 Temporary and permanent storm drainage facilities;

7.2.11 Measures to be undertaken to minimize the extent of exposed soils;

7.2.12 Areas where construction vehicles' wheels will be washed; and

7.2.13 Methods and places for concrete-wash disposal;

7.2.14 Disturbed areas and other areas that are physically protected from potential disturbance, such as fencing.

7.3 Template. If the proposed construction is for one single family dwelling, or one duplex dwelling, the property owner need not utilize the services of a certified professional in the preparation of the Plan. A template plan may be submitted to satisfy requirements for the single family dwelling and duplex construction activities.

7.4 Annual Permit. If the proposed construction activity qualifies for an annual permit, preparation of a construction site management plan is not necessary. In lieu of a construction site management plan, the applicant shall submit the following information as part of the application submittal:

7.4.1 Description of the scope of work and types of construction activities to be performed; and

7.4.2 Description of the erosion, sedimentation, and construction site management practices to be employed during construction activities for meeting the requirements of the Eugene Code, 1971 and these Rules.

7.5 Availability. The approved Construction Site Management Plan and Template shall be kept at the construction site and be available during on-site inspections.

8. **Review Criteria and Approval.** The City shall review the Erosion Prevention Permit application, including the Construction Site Management Plan, and such other documents as may be submitted, and approve, approve with special conditions, or deny the permit application. If the City finds that the construction related activities will result in visible or measurable erosion, or

will otherwise violate the conditions specified in R-6.645-D.1., then the City shall deny the permit, or approve the permit with special conditions. In the absence of such an affirmative finding, the City shall approve the permit, with or without special conditions.

9. **Conditions.** Every Erosion Prevention Permit shall include as conditions the outcomes set forth in R-6.645-D of these rules.

10. **Permit Duration.** An approved erosion prevention permit shall remain in effect for the full period of construction activity. The permit may be extended for a period of up to, but not to exceed, two years after completion of the construction activities if the City Manager determines the extension is necessary to ensure the construction activity has stabilized in accordance with the outcomes listed in these rules.

11. **Appeal.** An applicant may appeal (a) the denial of a permit, (b) any conditions imposed on a permit, or (c) the designation of a site as a sensitive area within the time and in the manner prescribed in section 2.021 of the Eugene Code, 1971.

R-6.645-G **Construction Site Control Measures and Design Standards.**

1. **Construction Site Practices.** In addition to compliance with specific requirements contained in an approved permit, all permittees shall establish and implement construction site management practices that will prevent toxic materials and other debris from entering the City's storm drainage and waterway systems. The following construction site practices are prohibited and constitute a violation of these rules:

1.1 Improper storage of chemicals (pesticides, fertilizers, fuels, paints, thinners);

1.2 Improper disposal of construction waste material, garbage, rubbish, and sanitary waste, plaster, dry-wall, grout, gypsum;

1.3 Failure to immediately clean up spills of toxic materials;

1.4 Washing excess concrete material into a street, catch basin, or other public facility or a related natural resource;

1.5 Leaving stockpiles uncovered; or

1.6 Allowing construction vehicles to track or spill soil or debris into or onto a street or public right of way.

2. **Prevention Measures and Design Standards.** The City's Erosion Prevention and Construction Site Management Practices Manual may be utilized to obtain ideas as to how to achieve the outcomes mandated by R-6.645-D.1. These ideas include:

2.1 Keep vehicles on gravel or paved surfaces.

2.2 Surface stabilization measures (seeding, sodding, mulching, riprap);

2.3 Runoff control measures (temporary and permanent diversions, grassed-

swales, slope drains, riprap channels);

2.4 Outlet protection measures (energy spreaders/dissipaters);

2.5 Inlet protection measures (fabric-sod type protectors);

2.6 Sediment trap measures (basins, fences, rock dams);

2.7 Stream protection measures (temporary and permanent stream crossings, buffers, vegetated and structural stabilizers);

2.8 Construction timing and sequence;

2.9 Areas not to be disturbed; and

2.10 Other measures such as: subsurface drains, check dams, dust control, practices and procedures of operations.

The Manual is a guidance document only. It is not adopted as part of these rules. It is not necessary to utilize any of the specific concepts contained in the Manual, nor is the use of one or more of those ideas a guarantee that a permit will be issued. Each site and the proposed construction related activities need to be examined to determine what measures are required for that specific site.

R-6.645-H **Enforcement.**

1. **Intervention.** The primary focus of sections 6.625 to 6.645 of the Eugene Code, 1971 and these Rules is to achieve compliance with the outcomes specified in R-6.645-D and prevent erosion and control stormwater impact, and the City will use the amount of enforcement necessary to achieve compliance. Where possible the City will rely on education rather than enforcement. The City Manager may provide educational programs or other informational materials that will assist permittees in meeting the desired erosion and sedimentation controls, and other construction site management practices outcomes.

2. **Stop Work Order.** Whenever any construction related activity is being done contrary to and in violation of Sections 6.625 to 6.645 of the Eugene Code, 1971, these rules, or an erosion prevention permit, the enforcement officer may order the construction related activity stopped by notice in writing, posted on the premises, or served on the permittee. The permittee shall forthwith stop such work until authorized by the enforcement officer to proceed.

3 **Citation for Violation.** Upon a determination that a person is violating Sections 6.625 to 6.645 of the Eugene Code, 1971 or these rules, a citation may be issued to the permittee to appear in Municipal Court.

4 **Administrative Compliance Order.** The City may issue an Administrative Compliance Order for any violation. The Order shall be in writing, specify the violation(s) and require compliance measures. The order also may include a Notice of Imposition of Administrative Civil Penalty Assessment for the violation.

5 **Notice of Imposition of Administrative Civil Penalty.** If a person fails to comply

with applicable provisions of the Eugene Code, 1971, these rules, an erosion prevention permit, conditions imposed thereon, or an administrative compliance order, the enforcement officer may issue to the person a Notice of Imposition of an administrative civil penalty pursuant to the provisions of Section 2.018 of the Eugene Code, 1971.

6. **Service.** All notices/orders shall be served by personal service or sent by certified mail and first class mail. Any notice/order served by mail shall be deemed received for purposes of any time computations hereunder, three days after the date mailed, if to an address within this state, and seven days after the date mailed, if to an address without this state.

7. **Penalties Not Exclusive.** Any administrative civil penalty imposed pursuant to this section shall be in addition to, and not in lieu of, any other penalty authorized by Section 6.992 of the Eugene Code, 1971, or any other action authorized by law.

8. **Settlement of Administrative Civil Penalty Assessment.** Upon receipt of Notice of Administrative Civil Penalty Assessment, the violator may request a conference with the City Manager or designee. The City Manager or designee may compromise or settle any unpaid administrative civil penalty assessment where authorized under Section 2.582 of the Eugene Code, 1971. A request under this paragraph shall not act as a stay, or otherwise affect the filing or processing of an appeal under R-6.645-I.

R-6.645-I **Appeals.**

1. **Stop Work Order, Administrative Civil Penalty, Administrative Compliance Order.** Any person to whom a Stop Work Order, Notice of Imposition of an Administrative Civil Penalty or Administrative Compliance Order is issued pursuant to these rules may appeal that determination to the City Manager. A Stop Work Order or Administrative Compliance Order shall be effective upon issuance, and shall continue in effect during the pendency of any appeal. The notice of appeal must be in writing, and filed with the City Manager within 15 days from the date of the Notice being appealed. The appeal shall state the name and address of the appellant, the nature of the determination being appealed, the reason the determination is incorrect, and what the correct determination of the appeal should be. Failure to file such a statement within the time or in the manner required waives the appellant's objections, and the appeal shall be dismissed. Unless the appellant and City agree to a longer time period, the appeal shall be heard by a hearings official within 30 days of receipt of the notice of appeal. At least ten days prior to the hearing, the City shall mail notice of the time and place of the hearing to the appellant. The hearings official shall hear and determine the appeal on the basis of the appellant's written statement and any additional evidence deemed appropriate. The appellant may present testimony and oral argument at the hearing either personally or by counsel. The hearings official shall issue a written decision within ten days of the date of the hearing. The decision of the hearings official is final, and may include a determination that the appeal fee be refunded to the appellant upon a finding by the hearings official that the appeal was not frivolous.

SARB_001025

2. Appeal Fees. Appeals filed under this section shall be accompanied by an appeal fee in an amount established by the City Manager pursuant to Section 2.020 of the Eugene Code, 1971.

The foregoing Rule is adopted this 22nd day of January, 1997, and shall become effective February 1, 1997.

SARB_001026

ADMINISTRATIVE ORDER NO. 58-96-27-F
of the
CITY MANAGER PRO TEM

ESTABLISHING FEES FOR PROCESSING EROSION PREVENTION AND CONSTRUCTION SITE MANAGEMENT PRACTICES PERMITS

The City Manager Pro Tem of the City of Eugene finds that:

A. Pursuant to the authority contained in Sections 2.019 and 6.635 of the Eugene Code, 1971, on December 5, 1996 I adopted Administrative Order No. 58-96-27 proposing the adoption of fees for processing erosion prevention and construction site management practices permits. The fee structure provides a basis for determining the amount of cost for an erosion prevention permit for a variety of land use conditions.

B. Notice of the proposed fees was provided to the Mayor and City Councilors, published in the Register Guard, a newspaper of general circulation within the City, and posted at two locations at City Hall on Dec 10, 1996. The Notice was also provided to persons who had requested notice, and made available for inspection by interested persons at the City's Public Works Department, Engineering Division, 858 Pearl Street, Eugene, Oregon 97401 during normal business hours (9:00 a.m. to 5:00 p.m., Monday through Friday, exclusive of holidays), and made available to the general public through Eugene's Home Page on the Internet.

C. The Notice provided that written comments would be received thereon until midnight, January 7, 1997, more than 15 days from the first date of publication and posting. Written comments were received from William Slattery and Robert L. Breeden to which I make the following findings:

Comment 1: How will the fees be used?

Finding: The fees will be used to pay staff costs associated with the review of erosion permit applications, inspection of erosion-related work, and enforcement activities. Two erosion specialists will be hired to implement the program. The fees will cover costs for these resources.

Comment 2: Is there a plan check fee also?

Finding: The fees that were sent out for public comment were listed as permit fees but in reality they are plan check permit and inspection fees combined. The title of the fees will be changed to reflect this reality.

SARB_001027

Comment 3: Is there a fee to determine if a lot is in a sensitive area?

Finding: Determination of sensitive area will be done at the Permit and Information Center prior to the submittal of a permit application. Therefore, a fee is not required for this determination. Once the determination is made and finalized, a formal appeal of this determination requires a fee.

Comment 4: Appeal fees are too high.

Finding: The amount of the appeal fee, $175, includes an estimate of time and materials to hire a hearings official. This amount represents a straight forward appeal issue. Therefore, there is no need to adjust the rule at this time.

D. In addition to the specific findings set forth above, I find that the fees set forth in Exhibit A hereto are consistent with applicable policies and directives of the City Council, including policies developed during the Eugene Decisions process; are comparable to the fees charged for similar services; and are necessary t o comply with the Council's directive to recover the City's costs and expenses in administering such programs from the beneficiaries of the services.

Based on the above findings, which are hereby adopted, I order that:

The fees set forth in the Erosion Prevention and Construction Site Management Practices Permits Fee Schedule attached as Exhibit A hereto are hereby established as the fees to be charged for the services set forth therein, effective February 1, 1997.

Dated this 29th day of January, 1997.

SARB_001028

EROSION PREVENTION AND CONSTRUCTION SITE MANAGEMENT PRACTICES PERMITS FEE SCHEDULE
(Effective February 1, 1997)

Plan Check/Inspection Fee:	
Single & Two-Family Residential (new)	$100.00
Single & Two-Family Residential (addition)	$ 75.00
Single & Two-Family Residential (utility)	$ 50.00
Multiple Family, Commercial, Subdivisions:	
(a) 1 acre or less of disturbed area	$150.00
(b) >1 acre of disturbed area	$150 + $25/acre or increment of acre over 1 acre
Annual Permit Plan Check/Inspection Fee	$1,500 or $40/hr (whichever is less)
Appeal:	
Permit denial	$175.00
Permit conditions	$175.00
Sensitive area designation	$175.00
Stop work order, administrative civil penalty, administrative compliance order	$175.00
Reinspection:	$40.00/hr (min.1 hr)

SARB_001029

4O Sample Brochure

When should the SWPPP be submitted?

The SWPPP, whether an abbreviated SWPPP or a complete SWPPP per the General Permit, must be submitted with the Grading Permit application. One copy of the SWPPP should be submitted to the City, along with the Grading Permit application. A second copy of the SWPPP should be mailed to the Fairfield-Suisun Urban Runoff Management Program (URMP) *(see address on back of this brochure)*.

Additional Requirements for developments covering five acres or more

In addition to local grading and building permits, owners/developers who disturb five or more acres of total land area must obtain coverage under the State General Construction Activity Storm Water Permit. This General Permit requires the owner/developer to do the following:

- Submit a Notice of Intent to the State Water Resources Control Board prior to commencement of construction activity;
- Prepare and Implement a Storm Water Pollution Prevention Plan (SWPPP);
- Conduct inspections of storm water controls before and after storm events;
- Annually certify compliance with the General Permit and SWPPP; and
- File a Notice of Termination at the completion of construction.

Notice of Intent forms, guidelines for SWPPPs and General Permit information can be obtained by calling the State Water Resources Control Board Construction Activity Storm Water Hotline.

Copies of the SWPPP must be submitted to the City and Fairfield-Suisun URMP as stated above.

Where to Get More Information

City of Fairfield	1000 Webster Street Fairfield, CA 94533
Planning & Development Dept	(707) 428-7461
Public Works Dept	(707) 428-7485
City of Suisun City	701 Civic Center Blvd Suisun City, CA 94585
Planning Dept	(707) 421-7335
Public Works Dept	(707) 421-7340

Fairfield-Suisun Urban Runoff Management Program
1010 Chadbourne Rd
Fairfield, CA 94585
(707) 429-8930

State Water Resources Control Board
Construction Activity Storm Water Hotline
(916) 657-1146

For information about obtaining the California Storm Water BMP Handbooks contact:

Blue Print Service	1700 Jefferson Street Oakland, CA 94612 (510) 444-6771

Additional information available from your Planning or Public Works Department:

- Storm Water Controls in New Development and Redevelopment Projects (brochure)
- Fairfield-Suisun URMP Construction BMP Brochures (a series of seven brochures)

Fairfield-Suisun Urban Runoff Management Program, 6/95

Storm Water Controls for Small Construction Sites (less than 5 acres)

or

How to Prepare an Abbreviated Storm Water Pollution Prevention Plan (SWPPP)

A Guidance Brochure for Developers

City of Fairfield

City of Suisun City

Fairfield-Suisun Sewer District

10/29/97 16:32 FAX 408 720 8812 EOA SUNNYVALE 002

Why are storm water controls needed?

Storm water pollution is a growing concern in the Fairfield-Suisun area. Storm water pollution results when contaminants such as oil, wastes and sediment flow through the storm drain system into our creeks and ultimately into the Suisun Marsh and San Francisco Bay.

How do construction activities affect storm water quality?

A primary source of storm water pollution is construction sites. The largest causes of storm water pollution from construction sites are:

- Poor sediment control
  - poor erosion control (especially during the rainy season),
  - mud tracked off-site by vehicles
  - poor management of excavated or stock-piled materials
  - discharge of sediment laden water from dewatering activities
- Poor housekeeping practices
  - uncovered dumpsters
  - poor vehicle maintenance practices
  - improper clean up and wash down practices
  - improper disposal practices
- Poor materials management
  - uncovered or inappropriate storage of fuel, raw materials, waste materials and stock-piles

When is a Storm Water Pollution Prevention Plan (SWPPP) required?

All development sites in the Fairfield-Suisun area must have a SWPPP prior to the start of construction.

<u>For sites less than five acres,</u> an abbreviated SWPPP may be prepared. Guidelines for an abbreviated SWPPP are provided below.

<u>For sites five acres and larger,</u> the owner must obtain coverage under the State General Construction Activity Storm Water Permit by filing a Notice of Intent with the California State Water Resources Control Board and preparing a complete SWPPP (see other side for information).

What information does the abbreviated SWPPP need to contain?

The abbreviated SWPPP (for sites less than 5 acres) should contain the following information:

- General site information
  - Project name and address
  - Type of project (residential, commercial, etc.)
  - Total number of acres to be disturbed by project
  - Contact name, title, address and telephone number
  - Approximate construction schedule with estimated start and finish dates
- Description of site topography and site map showing:
  - Spoils and/or raw materials stock-pile areas
  - Direction of drainage
  - Storm drain inlets or creeks in the vicinity of the site
  - Vehicle fueling and maintenance locations
  - Dumpster location
  - Construction materials storage areas
- Description of sediment control practices
  - Steps to be taken to trap and retain sediment on site during and after construction (*)
  - Methods to stabilize slopes during the rainy season (*)
  - Protection of storm drain inlets from polluted runoff

  (*) Can refer to the site's Erosion Control Plan.
- Description of housekeeping practices
  - Describe proposed practices and how the project supervisor will ensure that these are properly implemented by all job site personnel
- Description of materials management practices
  - Describe how the following will be accomplished without causing storm water pollution:
    - Demolition activities
    - Concrete truck or mixer washout
    - Painting cleanup
    - Plaster and stucco cleanup
    - Sand/water blasting
    - Concrete/asphalt saw cutting and removal
    - Landscaping
  - Describe materials siting and storage practices to be used to prevent storm water pollution

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10/29/97 16:32 FAX 408 720 8812 EOA SUNNYVALE 003

4P BMPs for Construction Sites

Construction Sites

Focus of Document

This guidance lists BMPs for construction sites and indicates the documents where further details can be obtained.

The Municipality should provide informational materials on these BMPs, as well as a general handout that explains the importance of each of the five principles in reducing construction site runoff pollution.

The Municipality should ensure training of its plan review staff and inspectors in all aspects of these BMPs including the details of the BMP, its applicability and effectiveness, and conditions under which it should be recommended or required for a construction site.

Construction Site Planning BMPs

Site Plan

- ✓ Plan the development to fit the topography, soils, drainage pattern and natural vegetation of the site.
- ✓ Remove existing vegetation only when absolutely necessary.
- ✓ Delineate clearing limits, easements, setbacks, sensitive or critical areas, trees, drainage courses, and buffer zones to prevent excessive or unnecessary disturbances and exposure.
- ✓ Avoid construction on steep slopes*
- ✓ Minimize cuts and fills*
- ✓ Align temporary and permanent roads and driveways along slope contours*

Other Measures

- ✓ Phase grading operations to reduce disturbed areas and time of exposure
- ✓ Avoid excavation and grading during wet weather
- ✓ Winterize construction site*

***For additional details, see Erosion and Sediment Control Field Manual prepared by the California Regional Water Quality Control Board, San Francisco. 1997.**

BMPs to Minimize Soil Movement

Soil Cover

- ✓ Install cover materials such as vegetative debris, mulch, crushed stone, geotextile fabric, erosion control blankets*
- ✓ Use soil stabilizers as appropriate*
- ✓ Use temporary seeding and planting to reduce erosion potential*

Tracking Control

- ✓ Construct stabilized access roads and entrances*
- ✓ Construct entrance/exit tire wash*
- ✓ When cleaning sediments from streets, driveways and paved areas on construction sites, use dry sweeping methods where possible. If water must be used to flush pavement, collect runoff in temporary storage tanks to settle out sediments prior to discharge to the storm drains, and protect storm drain inlets.

Structures to Control and Convey Runoff

- ✓ Earth dikes, drainage swales and ditches*
- ✓ Slope drains and subsurface drains*
- ✓ Velocity dissipation devices*
- ✓ Flared culvert end sections*
- ✓ Check dams*

Other Measures

- ✓ Slope roughening/terracing/rounding*
- ✓ Level spreader*

***For details, see Erosion and Sediment Control Field Manual prepared by California Regional Water Quality Control Board, San Francisco, Bay Region, 1997.**

BMPs to Capture Sediment

- ✓ Use terracing, riprap, sand bags, rocks, straw bales, and/or temporary vegetation on slopes to reduce runoff velocity and trap sediments. Do not use asphalt rubble or other demolition debris for this purpose.
- ✓ Protect storm drain inlets from sediment-laden runoff. Storm drain inlet protection devices include sand bag barriers, filter fabric fences, block and gravel filters, and excavated drop inlet sediment traps.*
- ✓ When dewatering the site, remove sediment from the discharge using filtration methods. Mobile units specifically designed for construction site dewatering can be rented for this purpose.

Other Controls

- ✓ Silt fence*
- ✓ Straw bale barrier (other than at storm drain inlets)*
- ✓ Sand bag barrier*
- ✓ Brush or rock filter*
- ✓ Sediment trap*
- ✓ Temporary sediment basin*

***For details, see Erosion and Sediment Control Field Manual prepared by California Regional Water Quality Control Board, San Francisco, Bay Region, 1997.**

Good Housekeeping Practices

All Construction Sites

- ✓ Identify all storm drains, drainage swales and creeks located near the construction site and make sure all subcontractors are aware of their locations to prevent pollutants from entering them.
- ✓ Clean up leaks, drips, and other spills immediately.
- ✓ Refuel vehicles and heavy equipment in one designated location.
- ✓ Wash vehicles at an appropriate off-site facility. If equipment must be washed on-site, do not use soaps, solvents, degreasers, or steam cleaning equipment, and prevent wash water from entering the storm drain.

- ✓ Never wash down pavement or surfaces where materials have spilled. Use dry cleanup methods whenever possible.

- ✓ Avoid contaminating clean runoff from areas adjacent to your site by using berms and/or temporary or permanent drainage ditches to divert water flow around the site.

- ✓ Keep materials out of the rain. Schedule clearing or heavy earth moving activities for periods of dry weather. Cover exposed piles of soil, construction materials and wastes with plastic sheeting or temporary roofs. Before it rains, sweep and remove materials from surfaces that drain to storm drains, creeks, or channels.

- ✓ Place trash cans around the site to reduce litter. Dispose of non-hazardous construction wastes in covered dumpsters or recycling receptacles. Recycle leftover materials whenever possible.

- ✓ Dispose of all wastes properly. Materials that can not be reused or recycled must be taken to an appropriate landfill or disposed of as hazardous waste.

- ✓ Cover open dumpsters with plastic sheeting or a tarp during rainy weather. Secure the sheeting or tarp around the outside of the dumpster. If your dumpster has a cover, close it.

- ✓ Train your employees and inform subcontractors about the stormwater requirements and their own responsibilities.

Construction Projects Involving Paint Work

- ✓ Non-hazardous paint chips and dust from dry stripping and sand blasting may be swept up or collected in plastic drop cloths and disposed of as trash. Chemical paint stripping residue and chips and dust from marine paints or paints containing lead or tributyl tin must be disposed of as a hazardous waste.

- ✓ When stripping or cleaning building exteriors with high-pressure water, cover or berm storm drain inlets. If possible (and allowed by your local wastewater treatment plant), collect (mop or vacuum) building cleaning water and discharge to the sanitary sewer.

- ✓ Never clean brushes or rinse paint containers into a street, gutter, storm drain, or creek.

- ✓ For water-based paints, paint out brushes to the extent possible and rinse to a drain leading to the sanitary sewer (i.e., indoor plumbing).

- ✓ For oil-based paints, paint out brushes to the extent possible, and filter and reuse thinners and solvents. Dispose of unusable thinners and residue as hazardous waste.

- ✓ Recycle, return to supplier or donate unwanted water-based (latex) paint.

- ✓ Dried latex paint may be disposed of in the garbage.

- ✓ Unwanted oil-based paint (that is not recycled), thinners, and sludges must be disposed of as hazardous waste.

Construction Projects Involving Cement and Concrete Work

- ✓ Avoid mixing excess amounts of fresh concrete or cement mortar on-site.

- ✓ Store dry and wet materials under cover, protected form rainfall and runoff.

- ✓ Wash out concrete transit mixers only in designated wash-out areas where the water will flow into settling ponds or onto dirt or stockpiles of aggregate base or sand. Pump water from settling ponds to the sanitary sewer, where allowed. Whenever possible, recycle washout by pumping back into mixers for reuse. Never dispose of washout into the street, storm drains, drainage ditches, or creeks.

- ✓ Whenever possible, return contents of mixer barrel to the yard for recycling. Dispose of small amounts of excess concrete, grout, and mortar in the trash.

Construction Projects Involving Roadwork/Pavement Construction

- ✓ Apply concrete, asphalt, and seal coat during dry weather to prevent contaminants from contacting stormwater runoff.

- ✓ Cover storm drain inlets and manholes when paving or applying seal coat, slurry seal, fog seal, etc.

- ✓ Always park paving machines over drip pans or absorbent materials, since they tend to drip continuously.

- ✓ When making saw-cuts in pavement, use as little water as possible. Cover each storm drain inlet completely with filter fabric during the sawing operation and contain the slurry by placing straw bales, sandbags, or gravel dams around the catch basins. After the liquid drains or evaporates, shovel or vacuum the slurry residue from the pavement or gutter and remove from site.

- ✓ Wash down exposed aggregate concrete only when the wash water can: (1) flow onto a dirt area; (2) drain onto a bermed surface from which it can be

pumped and disposed of properly; or (3) be vacuumed from the area along the curb where sediment has accumulated by blocking a storm drain inlet.

- ✓ Allow aggregate rinse to settle, and pump the water to the sanitary sewer if allowed by your local wastewater authority.

- ✓ Never wash sweepings from exposed aggregate concrete into a street or storm drain. Collect and return to aggregate base stockpile, or dispose with trash.

- ✓ Recycle broken concrete and asphalt.

BMPs to Minimize Impacts of Post-Construction Storm Water Discharges

See Appendix 4T of the MURP.

Note: This guidance is primarily based on "Blueprint for a Clean Bay. Best Management Practices to Prevent Stormwater Pollution from Construction-Related Activities," published by BASMAA and the Santa Clara Valley Nonpoint Source Pollution Control Program. 1995.

Sources Of Additional Information

Additional information on Construction Site Controls is available in the publications listed below.

Stormwater Quality Task Force. 1993. California Storm Water Best Management Practice Handbook - Construction.

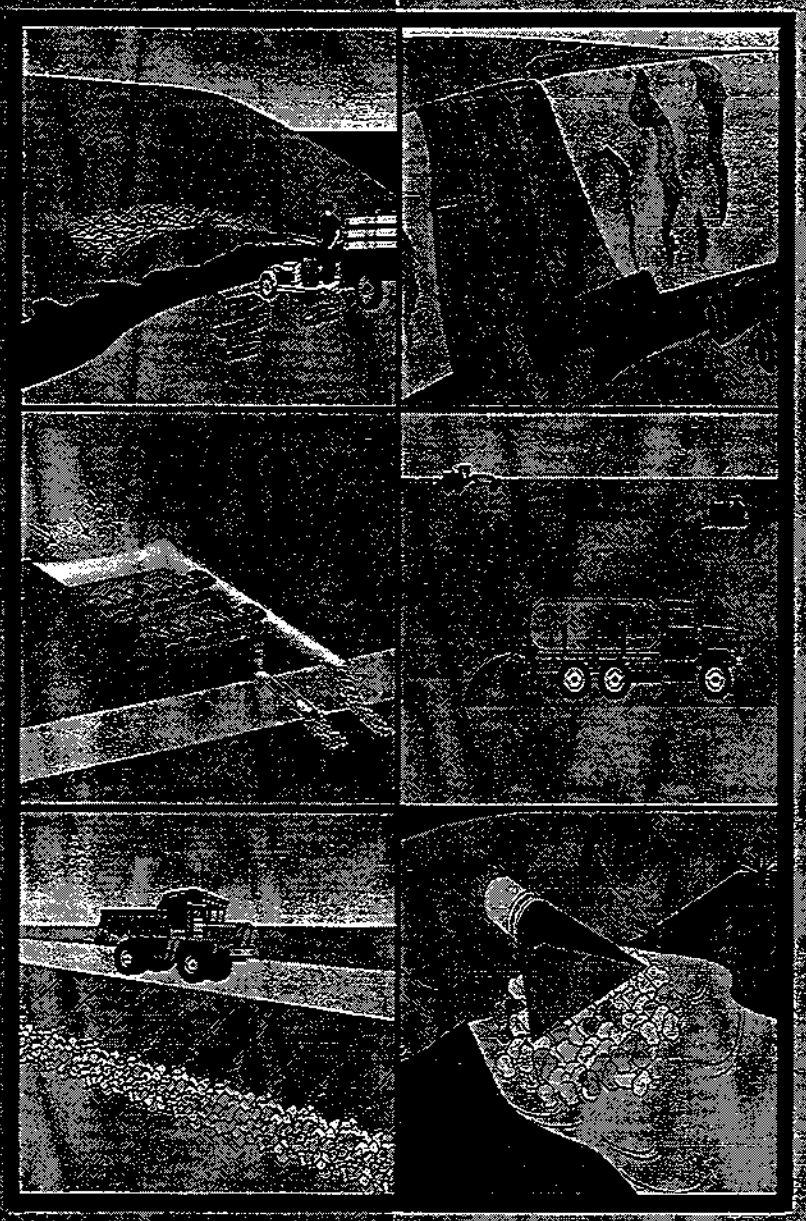
Association of Bay Area Governments. 1995. Manual of Standards for Erosion and Sediment Control Measures. A comprehensive filed guide for controlling soil erosion in California. May.

BASMAA. 1996. Start at the Source — Residential Site Planning and Design Guidance Manual.

Caltrans. 1996. Storm Water Quality Handbooks – Construction Contractors Guide and Specifications. May.

4Q Guidance for Construction SWPPP

stormwater



INFORMATION ON EROSION & SEDIMENT CONTROLS FOR CONSTRUCTION PROJECTS

CALIFORNIA
REGIONAL WATER QUALITY
CONTROL BOARD

SAN FRANCISCO BAY REGION

SARB_001041

The State's General Permit

Construction-related erosion and sedimentation can cause problems for downgradient property owners, create nuisance problems on adjacent streets, clog streams and storm drains, and lead to premature silting up of reservoirs. The cumulative toll on the environment can be devastating. Uncontrolled erosion is costly, violates state and federal pollution laws, exposes developers, contractors, and landowners to legal liablilities, and provides ammunition to those who argue that the development process itself is out of control. As more and more development in the San Francisco Bay Area takes place on steep hillsides, the threat from erosion is increasing.

In 1990, the U.S. Environmental Protection Agency published regulations requiring that discharges of storm water runoff associated with construction activities causing soil disturbance of five or more acres must be covered by a federal National Pollution Discharge Elimination System (NPDES) permit. In California, the State Water Resources Control Board (State Board) is responsible for issuing such permits and has adopted a statewide General Permit to address discharges of storm water runoff associated with construction activities. The nine Regional Boards oversee implementation of the General Permit statewide.

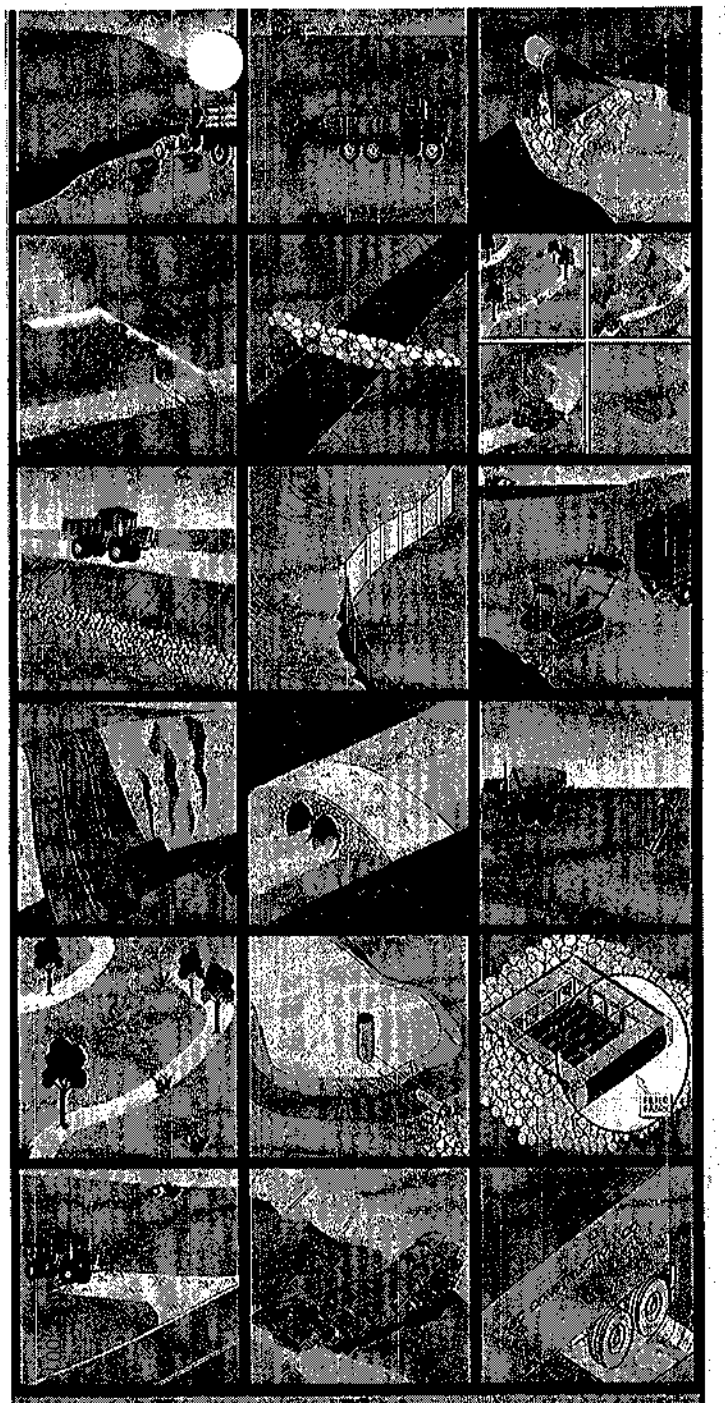
What does the General Permit require?

The General Permit requires all owners of land where storm water discharges associated with construction activity (i.e. clearing, grading, and excavation) results in a land disturbance of five or more acres to:

1. Submit a Notice of Intent (NOI) to comply with the General Permit and the appropriate filing fee to the State Board. A package containing an NOI and the General Permit can be obtained from the Regional Board at (510) 286-0968;
2. Eliminate or minimize non-storm water discharges from the construction site to storm drains and other water bodies. Non-storm water discharges to be eliminated or minimized are primarily silt comprised of earthen materials from erosion and sediment runoff. In addition to non-storm water discharges, runoff from storage and maintenance areas, building materials, and spillage of waste chemicals and materials should be eliminated or minimized.
3. Develop, implement, and update a Storm Water Pollution Prevention Plan (SWPPP) for the site. The Regional Board has prepared "Directions for Preparing a SWPPP," which is available from the Regional Board at (510) 286-0968 (copy attached).
4. Develop a site monitoring program and perform inspections of the measures implemented as part of the SWPPP. If implemented measures do not adequately minimize non-storm water discharges, those measures must be modified;
5. Annually certify, based on inspections, that the site is in compliance with the General Permit.

What activities are not covered by the General Permit?

Construction activity <u>not</u> covered by the General Permit includes routine maintenance, maintaining original line and grade, hydraulic capacity, and original purpose of the facility. In addition, Storm water discharges in the Lake Tahoe Hydrologic Unit will be regulated by a separate permit(s) adopted by the California Regional Water Quality Control Board, Lahontan Region, and may not seek coverage under the State Water Board's general permit. Storm water discharges on Indian lands will be regulated by the U.S. Environmental Protection Agency.



BEST MANAGEMENT PRACTICES

BEST MANAGEMENT PRACTICES FOR CONSTRUCTION PROJECTS

Why Control Erosion?

When raindrops strike bare soil, large amounts of topsoil are eroded and carried downstream in stormwater runoff.

Construction-related erosion can cause problems for downgradient property owners, clog storm drains, create nuisance problems on adjacent streets, and lead to the sedimentation and silting of streams, reservoirs and other water bodies.

Steep and bare slopes have the greatest potential for erosion and sedimentation. Any medium which adequately covers the soil and protects it from raindrop impact will virtually eliminate erosion, reducing it by 90 to 98%. Once erosion has occured, it is extremely difficult to remove the soil suspended in runoff.

By protecting soil from raindrop impact and consequently preventing erosion, the burden on less effective sediment controls is greatly reduced.

Uncontrolled erosion is costly, violates state and federal pollution laws, and exposes developers, contractors, and landowners to legal liabilities.

Fortunately, most erosion and sediment problems can be prevented or greatly reduced through proper planning and implementation of simple and low-cost control practices.

But unless control measures are properly planned, designed and installed, they will not work.

If you are the owner of land associated with construction activit[illegible]using soil disturbance of more than five acres, you are required to file for a National Pollution Discharge Elimination System (NPDES) General Permit from your local Regional Water Quality Control Board.

The General NPDES Permit requires all owners of land where construction activity occurs to:

1) Submit a Notice of Intent agreeing to comply with the General Permit and the appropriate filing fee to the State Water Resources Control Board.

2) Develop and implement a Storm Water Pollution Prevention Plan (SWPPP) for the site **based on best managent practices.** *Directions for Preparing a SWPPP* is available from your local Regional Board.

3) Develop a site monitoring program and perform inspections of measures implemented as part of the SWPPP. If these measures do not adequately minimize pollutants in stormwater runoff, they must be modified.

4) Annualy certify, based on inspections, that the site is in compliance with he General Permit.

The *Erosion and Sediment Control Field Manual* provides the latest information on Best Management Practices and is intended to help you develop a program in compliance with Storm Water Discharge Requirements.

Order Form

SARB_001044

The Field Manual

Erosion & Sediment Control for Construction Projects

California Regional Water Quality Control Board
- San Francisco Bay Region -

$25.00 Donation Required

(Checks payable to Friends of the San Francisco Estuary)

Mail completed Order Form with Full Payment to:

Friends of the San Francisco Estuary
c/o RWQCB
2101 Webster Street, Suite 500
Oakland, California
94612-3060

Number of Copies _____

Name _____

Affiliation _____

Address _____

City _____

State _____ Zip _____

Telephone _____

Questions? Call 510-286-0924

CONTRA COSTA CLEAN WATER PROGRAM
Make a Clear Difference

Donald P. Freitas
Program Manager

ORDER FORM
FOR
CALIFORNIA STORMWATER BEST MANAGEMENT PRACTICE HANDBOOK(S)
AND
BAY AREA PREAMBLE TO THE CALIFORNIA STORMWATER BEST MANAGEMENT PRACTICE HANDBOOK(S) AND NEW DEVELOPMENT RECOMMENDATIONS

Item		Cost	No. of Copies	Total Cost
Municipal Handbook	:	$12.50 ea	_____	$_____
Construction Handbook	:	$12.00 ea	_____	$_____
Industrial/Commercial Handbook:		$13.00 ea	_____	$_____
Bay Area Preamble	:	$10.00 ea	_____	$_____
			Handbook Subtotal	$_____
			Shipping Subtotal	$_____
			Total	$_____

SHIPPING COSTS:

Shipment **within** California can be prepaid by including the cost of $4.25 for UPS-shipping for 1 to 3 handbooks and preamble ($7.20 for 4 to 6 handbooks, etc.). Contact BPS for shipments outside California.

Make checks payable to **"BPS"** to cover costs of handbooks and postage and mail to:

Blue Print Service (BPS)
1700 Jefferson Street
Oakland, CA 94612
Phone: (510) 444-6771
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4R Model Construction SWPPP

STORM WATER POLLUTION PREVENTION PLAN

Name of Project _____

Owner and Contractor of Project _____

Waste Discharge Identification Number _____

Contact Person/address/daytime and emergency phone numbers

_____

CERTIFICATION

"I certify under penalty of law that this document and all attachments were prepared under my direction or supervision in accordance with a system designed to ensure that qualified personnel properly gather and evaluate the information submitted. Based on my inquiry of the person or persons who manage the system, or those persons directly responsible for gathering the information, the information submitted, is, to the best of my knowledge and belief, true, accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine and imprisonment for knowing violations."

_____ _____

Name, Title Date of Preparation

AMENDMENTS

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INTRODUCTION

Type of Project/Project Description

Location of Project

Project Schedule

Start Date _____

End Date _____

Unique Features

Supplemental Documents

SOURCE IDENTIFICATION

Topographic Map (Attachment 1)

Site Map (Attachment 2)

NARRATIVE DESCRIPTIONS

A. Site Estimates and Description of On-site Soil

Size of Construction Site (acres/square feet) _____
Runoff Coefficient before construction _____
Runoff Coefficient after construction _____
Percent Site that is impervious before construction _____
Percent Site that will be impervious after construction _____

B. List of Likely Non-Toxic Pollutants at the Site

Sources/Activities that could release these pollutants into site runoff

C. Toxic Materials to be treated, stored, used, or disposed of, on or near the site.

Methods that will be employed to prevent and control pollution from these toxic materials.

D. Erosion and Sediment Control Practices

1. General Practices

2. Soil Stabilization Practices

3. Practices to Reduce Tracking of Sediment onto public and private streets

4. Practices to address Wind Erosion

a. Dust Control

b. Sweeping

5. Practices to Minimize Contact with Storm Water

a. Construction Vehicles and Equipment

i) Maintenance

Yes No

- ☐ ☐ Maintain all construction equipment to prevent oil or other fluid leaks.
- ☐ ☐ Keep vehicles and equipment clean, prevent excessive build-up of oil and grease.
- ☐ ☐ Use off-site repair shops.
- ☐ ☐ Keep stockpiled spill cleanup materials readily accessible.
- ☐ ☐ Regularly inspect on-site vehicles and equipment for leaks, and repair immediately.
- ☐ ☐ Check incoming vehicles and equipment (including delivery trucks, and employee and subcontractor vehicles) for leaking oil and fluids. Do not allow leaking vehicles or equipment on-site.
- ☐ ☐ Segregate and recycle wastes, such as greases, used oil or oil filters, antifreeze, cleaning solutions, automotive batteries, hydraulic, and transmission fluids.

ii) Fueling

Yes No

- ☐ ☐ If fueling must occur on-site, use designated areas away from drainage.
- ☐ ☐ Locate on-site fuel storage tanks within a bermed area designed to hold the tank volume.
- ☐ ☐ Cover retention area with an impervious material and install it in a manner to ensure that any spills will be contained in the retention area.
- ☐ ☐ Always use secondary containment, such as a drain pan or drop cloth, to catch spills or leaks when removing or changing fluids.
- ☐ ☐ Use drip pans for any oil or fluid changes.

iii) Washing

Yes No

- ☐ ☐ Use as little water as possible to avoid installing erosion and sediment controls for the wash area.
- ☐ ☐ If washing must occur on-site, use designated, bermed wash areas to prevent waste water discharge into storm water, creaks, rivers, and other water bodies.
- ☐ ☐ Use phosphate-free, biodegradable soaps.
- ☐ ☐ Do not permit steam cleaning on-site.

b. Materials

Materials to be Stored on-site

_____

_____

Methods that will be employed to minimize the amount of these materials on site.

_____

_____

Methods of Secondary containment of materials stored.

_____

_____

Chemical Storage Methods.

_____

_____

6. Construction Materials Loading, Unloading and Access Areas.

_____

_____

_____

7. Waste Management and Disposal

a. Concrete Wash-Out

_____

_____

b. Miscellaneous Wastes

_____

_____

8. Pre-Construction Control Practices

E. Non-Storm Water Management

F. Maintenance, Inspection, and Repair of Structural Controls

G. Spill Prevention and Control

1. Minor Spills

2. Major Spills

H. Post-Construction Storm Water Management

I. Personnel Training

J. List of Contractors/Subcontractors

K. Other Plans/Permits

L. Monitoring

1. General Plan Summary

2. Site Inspections

3. Compliance Certification

4. Noncompliance Reporting

5. Records

4S Sample Reporting Forms

Contractor Self-Inspection Form

C4.1 Construction Site Inspection Checklist

Inspected By: _____

Project: _____

Contractor: _____

Date: _____

Check "Yes" or "No" or "N/A" if not applicable.

YES	NO	N/A		
_____	_____	_____	1.	Has there been an absence of rain since the last inspection?
_____	_____	_____	2.	Are all sediment barriers (e.g., sandbags, straw bales, and silt fences) in place in accordance with the Plan and are they functioning properly?
_____	_____	_____	3.	If present, are all exposed slopes protected from erosion through the implementation of acceptable soil stabilization practices?
_____	_____	_____	4.	If present, are all sediment traps/basins installed and functioning properly (if applicable)?
_____	_____	_____	5.	Are all material handling and storage areas reasonably clean and free of spills, leaks, or other deleterious materials?
_____	_____	_____	6	Are all equipment storage and maintenance areas reasonably clean and free of spills, leaks, or any other deleterious materials?
_____	_____	_____	7.	Are all materials and equipment properly covered?
_____	_____	_____	8.	Are all external discharge points (i.e., outfalls) reasonably free of any noticeable pollutant discharges?
_____	_____	_____	9.	Are all internal discharge points (i.e., storm drain inlets) provided with inlet protection?

SOURCE : ALAMEDA CLEAN WATER PROGRAM

Check "Yes" or "No" or "N/A" if not applicable.

YES	NO	N/A		
_____	_____	_____	10	Are all external discharge points reasonably free of any significant erosion or sediment transport?
_____	_____	_____	11.	Are all BMPs identified on the Plan installed in the proper location and according to the specifications for the plan?
_____	_____	_____	12.	Are all structural control practices in good repair and maintained in functional order?
_____	_____	_____	13.	Are all on-site traffic routes, parking, and storage of equipment and supplies restricted to areas designated in the Plan for those uses?
_____	_____	_____	14.	Are all locations of temporary soil stockpiles or construction materials in approved areas?
_____	_____	_____	15.	Are all seeded or landscaped areas properly maintained?
_____	_____	_____	16.	Are sediment treatment controls in place at discharge points from the site?
_____	_____	_____	17.	Are slopes free of significant erosion?
_____	_____	_____	18.	Are all points of ingress and egress from the site provided with stabilized construction entrances?
_____	_____	_____	19.	Is sediment, debris, or mud being cleaned from public roads at intersections with site access roads?
_____	_____	_____	20.	Does the Plan reflect current site conditions?

If you answered "no" to any of the above questions (except Number 1), describe any corrective action(s) that must be taken to remedy the problem and when the corrective action is to be completed:

C4.2 Inspection Log

The site shall be inspected before and after storm events with 0.25 inches or greater predicted or actual precipitation, and documented on the Construction Site Inspection Checklist. Incidents of noncompliance must be reported to the Engineer.

Date	Inspector	Type of Inspection			Observations (If post-storm inspection, note size of storm in inches)
		Routine	Pre-Storm	Post-Storm	

Attachment C5
Standard Permittee
Inspection Form Requirements

C5.1 Construction Site Inspection Checklist

Inspected By: _____

Project: _____

Contractor: _____

Date: _____

Level I	Yes	No	N/A
1. Are all discharge points reasonably free of any noticeable pollutant discharges? If Yes, go to Question 2. If No, is the project a Priority Project? If Yes, go to Level II. If No, continue below.			
a. Are all material handling and storage areas reasonably clean, and free of spills, leaks, or other deleterious materials?			
b. Are all equipment storage and maintenance areas reasonably clean, and free of spills, leaks, or other deleterious materials?			
c. Are all materials and equipment properly covered?			
If you answered "no" to any of the above questions, describe on the next page any corrective actions that will be required to remedy the problem and when the corrective actions are to be completed.			
2. Are all discharge points reasonably free of any significant deposition of sediment? If Yes, go to Question 3. If No, is the project a Priority Project? If Yes, go to Level II. If No, continue below			
a Are sediment control BMPs installed downslope of all disturbed areas of the site?			
b Are sediment control BMPs in proper repair and free of excessive sediment buildup?			
c Are site entrance and exit points free of tracked sediment?			
d Are all discharge points (e.g., storm drain inlets) provided with inlet protection?			
If you answered "no" to any of the above questions, describe on the next page any corrective actions which will be required to remedy the problem and when the corrective action is to be completed.			
3. Are all discharge points, downstream channels, and slopes not actively under construction free of erosion? If Yes, inspection is complete. If No, is the project a Priority Project? If Yes, go to Level II. If No, continue below.			
a. Are erosion control BMPs in place at or upstream of these locations?			
b. Are erosion control BMPs in proper repair?			
c. Are areas not actively under construction stabilized and access properly restricted from these areas?			
If you answered "no" to any of the above questions, describe on the next page any corrective actions which will be required to remedy the problem and when the corrective action is to be completed.			

Level II - Priority Projects	Yes	No	N/A
4. a. Has a local SWPPP been prepared for the project?			
b. Has the local SWPPP been implemented?			
c. Are the BMPs implemented under the local SWPPP effective at meeting the minimum construction material and waste management requirements?			
If you answered "no" to any of the above questions, describe below any corrective actions which will be required to remedy the problem and when the corrective action is to be completed.			
5. Are soil disturbing activities occurring during the rainy season? If Yes, continue below. If No, inspection is complete.			
a. Has a WWECP been prepared?			
b. Has the WWECP been implemented?			
c. Are the BMPs implemented under the WWECP effective at meeting the minimum sediment and erosion control requirements?			
If you answered "no" to any of the above questions, describe below any corrective actions which will be required to remedy the problem and when the corrective action is to be completed.			

Corrective Action(s) Needed and Schedule for Completion:

Attachment C6
BMP Checklist

C6.1 Erosion Control Practices

BMP Description	*Will BMP Be Used?*		*If Yes, Explain How*
	Yes	*No*	*If No, State Reason*
Site Planning Considerations			
Scheduling			
Preservation of Existing Vegetation			
Vegetative Stabilization			
Seeding & Planting			
Mulching			
Physical Stabilization			
Geotextiles & Mats			
Dust Control			
Temporary Stream Crossing			
Construction Road Stabilization			
Diversion of Runoff			
Earth Dike			
Temporary Drains & Swales			
Slope Drain			
Velocity Reduction			
Outlet Protection			
Check Dams			
Slope Roughening/Terracing			

C6.2 Sediment Control Practices

BMP Description	*Will BMP Be Used?*		*If Yes, Explain How*
	Yes	*No*	*If No, State Reason*
Silt Fence			
Straw Bale Barrier			
Sand Bag Barrier			
Brush or Rock Filter			
Storm Drain Inlet Protection			
Sediment Trap			
Sediment Basin			

C6.3 Tracking Control Practices

BMP Description	*Will BMP Be Used?*		*If Yes, Explain How*
	Yes	*No*	*If No, State Reason*
Tracking Control			
Stabilized Construction Entrance			

C6.4 Non-Stormwater and Material and Waste Management Practices

BMP Description	*Will BMP Be Used?*		*If Yes, Explain How*
	Yes	*No*	*If No, State Reason*
Construction Practices			
Dewatering Operations			
Paving Operations			
Structure Construction & Painting			
Vehicle & Equipment Management			
Vehicle & Equipment Cleaning			
Vehicle & Equipment Fueling			
Vehicle & Equipment Maintenance			
Material Management			
Material Delivery and Storage			
Material Use			
Spill Prevention and Control			
Waste Management			
Solid Waste Management			
Hazardous Waste Management			
Contaminated Soil Management			
Concrete Waste Management			
Sanitary/Septic Waste Management			
Contractor Training			
Employee/Subcontractor Training			

4T Post-Construction Controls

Post-Construction Controls for New Development and Redevelopment

The focus of this guidance is post-construction controls for new development or redevelopment projects. Post-construction controls can be generally grouped into three types: **site planning measures** that avoid or reduce disturbance of the site and limit the addition of impervious surfaces; **pollution prevention/source control measures** that reduce or eliminate potential future sources of pollutants; and **treatment control measures** that treat polluted runoff from new development/redevelopment sites.

This guidance is focused strictly on specific controls that can be incorporated into individual development projects proposed by public and private entities to avoid or reduce the pollutants from the particular project. Where appropriate, pros and cons are described along with typical conditions under which these controls have been found to be effective.

As noted in Section 4.6 of the MURP, the best opportunities for post-construction controls are available in larger projects or when implemented on a regional basis, and most of this guidance emphasizes controls that can be introduced in larger new development/redevelopment projects through the discretionary approval process. The second section of this guidance presents a list of controls that can be employed for small infill-type projects (ministerial approval process) where the opportunities are limited.

Post-Construction Controls for Projects Requiring Discretionary Approvals

Site Planning Measures

This group of post-construction controls includes site planning to protect sensitive resources at or near the site and the use of alternate paving and cover materials to reduce the amount of impervious surfaces added by a new development.

Studies have shown that in single-family residential areas, streets are the primary producers of runoff, and sidewalks and lawns, if properly vegetated, are a minor source. In multi-family developments, streets, parking lots and roofs generate similar quantities of runoff. In commercial/industrial areas, parking lots and roofs are the main generators of runoff. It follows then that to reduce impervious surfaces, in single-family residential areas reduction of street width and driveway lengths should be the primary strategy, while in multi-family developments and industrial/commercial areas, strategies should focus on reducing parking lots and the footprint of buildings. *For more information on site planning, refer to Start at the Source Residential Site Planning and Design Guidance Manual for Stormwater Quality Protection, available from BASMAA.*

Site planning measures that minimize impervious surface and maximize infiltration are described below:

- ✓ **Cluster development** - Concentrate the development on a limited portion of the site and leave the remaining portion undisturbed. This should be used where appropriate without creating other hazards such as those of access during emergencies.

- ✓ **Preserve natural drainages** - This measure includes not filling in the natural drainage features at the site, maintaining invert/streambeds to maximize capacity, and providing vegetated setbacks or buffer strips outside of the maximum water surface level. Main concerns are related to safety especially of children and future need for mosquito/pest control.

- ✓ **Reduce sidewalk widths, especially in low-traffic areas** - This control provides limited runoff reduction benefits, and reduction of width may not possible due to Americans with Disabilities Act (ADA) requirements.

- ✓ **Avoid curb and gutter along driveways and streets where appropriate** - This is recommended in areas where flooding and ponding of water creating mosquito habitat is not a problem. Replace with swales.

- ✓ **Use alternate paving materials/porous/permeable materials, where appropriate** - This measure includes use of alternate paving materials (e.g., porous asphalt, pervious concrete, pavers), landscaping, mulch, gravel and cobbles where appropriate to provide ground cover, and reduce the use of asphalt or other impervious pavement.

  Pavers are recommended for driveways, walkways, and patios in single-family residences where the site does not generate highly polluted runoff (that could contaminate groundwater if it were to infiltrate) and where ADA requirements do not have to be met. In non-residential areas, pavers are recommended for emergency access roads, overflow parking areas, and non-handicapped parking stalls. These are not recommended where heavy loads (e.g. truck movement) are anticipated. *For more information on alternate paving materials, see Post-Construction Controls for New Development Fact Sheets available from BASMAA.*

- ✓ **Reduce the length of driveways or infiltrate driveway runoff** - This control applies mainly to single-family residential units. Note that in most of the large metropolitan areas of California, driveways in new development are generally short due to the high cost of land. If long driveways in the Municipality are due to the fact that the structures have to be set back from the property line per the zoning ordinance, then the Municipality should consider changes in its zoning ordinance. If reduction of the driveway length is not possible, grade and construct driveway so that runoff from driveway is directed to the adjacent landscaped areas.

- ✓ **Reduce street width by eliminating on-street parking (where such actions do not pose a safety hazard)** - This measure can be generally used in new residential areas. In addition to reducing the impervious area, this control has the added benefit of removing cars from streets and making street sweeping easier and more effective. If on-street parking in residential areas is eliminated, the developer must provide adequate off-street visitor parking.

- ✓ **Reduce alley width or use alternate materials for paving alleys** - Alleys are generally not built in residential areas in California due to the high cost of land and concerns regarding safety and maintenance (alleys are often used for illegal dumping). However if alleys are included in a proposed development, width should be minimized or alternate paving materials should be used.

- ✓ **Mandate that all developments set aside open space** - This control is recommended for all developments (residential and non-residential). The main concern with open space relates to maintenance, weed control, and fire prevention.

Source Controls

This group includes controls that can be incorporated into new development/redevelopment projects to avoid pollution in the long run by eliminating sources.

- ✓ **Provide green areas where pets can be exercised** - Pet excrement is a major source of bacteria in urban runoff. In addition to instituting ordinances requiring owners to collect their pet's excrement, provide green areas in new residential developments where people can walk their pets and keep pet excrement away from sidewalks and streets.

- ✓ **Install landscaping or other cover** - Clearing and grading of surfaces in new development can increase potential for erosion. Install landscaping or other cover materials to minimize erosion from graded surfaces. Use of native plant materials is recommended because native plants require less maintenance and irrigation, and are typically more resistant to fires than non-native grasses. Native plants do take longer to cover slopes therefore during the first few years, supplemental protection (erosion blanket, mulch, etc.) will be necessary.

- ✓ **Incorporate low-maintenance landscaping** - At some sites where erosion may not be a concern but landscaping is proposed as part of the development, require or recommend use of low-maintenance landscaping that does not require frequent fertilizer, pesticide and herbicide application. In this regard, the Municipality should identify the types of trees, shrubs, and ground cover that would work in the community based on local climatic and soil conditions, and should make such lists available to municipal staff responsible for reviewing projects.

- ✓ **Require labeling of storm drains (to discourage dumping)** - Developer should be required to label all storm drains with the appropriate legend used in the city, cautioning against dumping.

- ✓ **Where possible, eliminate gutters/roofdrains or direct runoff to landscaped areas** - Roofdrains can be eliminated only in one to two-story buildings. Where these cannot be eliminated, direct the downspout of the gutter to a landscaped area or into an infiltration trench. Install several gutters to distribute the flow.

- ✓ **Construct designated vehicle wash area** - In new residential developments involving more than 50 units, require applicant to construct a designated vehicle wash area that is plumbed to discharge to the sanitary sewer (the Municipality should check with the local wastewater treatment plant before instituting this control).

- ✓ **Encourage underground parking and the construction of multi-storied parking structures** - For commercial projects, encourage developers to build underground or multi-story parking structures so that not only is impervious surface minimized but the parking surfaces are under a roof and not exposed to storm water.

- ✓ **Encourage cooperative or shared parking** - This control is recommended for commercial areas, and can be a cooperative effort between commercial entities or between commercial entities and the Municipality.

- ✓ **Encourage use of alternate paving materials for parking lots** - This control is recommended for overflow parking areas and for less frequently used parking spaces (typically these are spaces along the periphery of the parking lot that will not have to meet ADA requirements and due to low usage there will be less concern regarding pollution of groundwater through infiltration of stall runoff).

- ✓ **Encourage measures to reduce building footprint and increase use of taller structures (where appropriate)** - This control is recommended for commercial and municipal structures.

- ✓ **Require that waste storage areas be bermed** - Require all developments to grade and pave outdoor waste receptacle area to prevent run-on of storm water, and install a low containment berm around it. Alternately, construct a covered enclosure with wash-down capabilities outletting into the sanitary sewer.

- ✓ **Require installation of valves on storm drain inlets in loading dock areas** - At commercial/industrial facilities where loading docks are proposed, require the applicant to install a valve to control runoff in the event of spills.

Treatment Controls

This group includes controls that can be built at new development/redevelopment sites to capture and treat the polluted runoff before it enters the city's storm drain system or other receiving waters.

- ✓ **Rooftop Catchment Systems** - These are rooftops which are designed to pool stormwater, which following the storm, evaporates. This effectively eliminates rooftop runoff from the storm drain system, and thereby reduces the hydraulically-connected impervious area. Another function of these systems is to slow down the runoff to reduce peaks. Problems with rooftop catchment systems are mainly related to leakage. Such systems are usually recommended for large commercial and industrial sites, and in climatic zones where rainfall is intermittent and temperatures are above freezing.

- ✓ **Vegetated Filter Strips** - Vegetated filter strips, buffer strips, or riparian buffer zones are strips of vegetation placed between receiving waters (e.g., along streams) and pollutant sources. The effectiveness of the strips depend primarily on the width of the strip, and the vegetation type and condition. Strips of 100-300 feet in width are often considered. Such strips have been successfully applied to urban, agricultural, and forestry situations. Vegetation type selection in California must take into account the semi-arid climate and usually should be drought-resistant. Maintenance is primarily annual cutting. Such strips are recommended for new development located along receiving waters such as streams, rivers and lakes, but outside the flood control boundary.

- ✓ **Vegetated Swales** - Swales are shallow low gradient channels that are vegetated. They are commonly applied in rural residential areas in lieu of traditional curb/gutters and underground stormwater drainage pipes. Water quality improvement is achieved primarily through filtration, and performance is dependent on the swale hydraulic capacity and vegetation type and condition. Influent water should be relatively free of coarse sediment to avoid burying the vegetation. Where sediment loads are of concern, sediment settling basins can be provided upstream of the swales. Maintenance consists primarily of vegetation management and settling basin cleanouts. Swales are generally recommended for low-density residential developments located in relatively flat terrain.

- ✓ **Infiltration Basins** - Infiltration basins store and infiltrate stormwater into the surficial groundwater aquifer. Performance is critically dependent on soil porosity and adequate depth to groundwater. In California, such conditions are typical of inland valleys, in contrast to low lying coastal areas. In order to maintain recharge rates, influent water may require pretreatment to remove sediments. Infiltration basins are effective at reducing runoff rates and volumes and can provide water supply benefits through aquifer recharge. Maintenance primarily consists of periodic removal of accumulated trash, debris and sediments to maintain recharge rates. Infiltration basins are generally recom-

mended in semi-arid areas where the depth to groundwater is relatively high and the soils are highly pervious. Where such conditions exist, this technology is generally applicable to the entire range of urban development, although the potential for groundwater contamination is often of concern in industrial areas.

- ✓ **Infiltration Trenches** - Infiltration trenches are shallow drains filled with high porosity materials (e.g. gravel). Stormwater discharged to these trenches is stored during the runoff event and infiltrates into the groundwater during dry weather periods. As with infiltration basins, performance requires porous subsoils and adequate depth to the groundwater table. The acceptability and designs of infiltration trenches may be covered by building codes where there is concern that infiltrating water may adversely affect soil strength around foundations. Infiltration trenches are generally not recommended for roof runoff near buildings because of building code requirements; but can be effective as part of the overall open channel drainage system.

- ✓ **Dry Detention Ponds/Basins** - These are basins designed to temporarily store and treat storm water prior to gradually releasing it downstream. Such basins can provide flood control and storm water treatment benefits. Treatment performance depends on storage volume (12-24 hours of residence time is considered a good rule of thumb), and good circulation (avoidance of short circuiting). A major factor limiting good performance is that, during larger storm runoff events, water entering a dry basin may resuspend previously settled material in which case the ponds may act as a source of sediment and associated chemicals. In general dry basins are not as effective as wet basins(discussed below), however, in certain arid areas, wet basins are not feasible. Performance of dry basins can be improved by incorporating slow release outlet structures. Such basins are generally applicable to residential, commercial, and industrial development in arid areas where there is insufficient runoff to maintain wet basins. The cost of urban lands often preclude this type of treatment in the more dense portions of urban areas.

- ✓ **Retention Ponds/Wet Basins** - These are basins that contain a permanent pool of water. Such ponds can provide flood control, ecological, and water quality benefits. The performance of wet basins depends on the size of the basin, watershed characteristics, and influent conditions. The primary treatment process in retention ponds is settling. Maintenance is required for removing debris, vegetation management, and maintaining the inlet and outlet structures. Accumulation rates in such basins typically require that accumulated sediment be removed about once every 10-20 years. Retention ponds are generally applicable to most urban situations, as long as there is adequate space for the facility and acceptable geological conditions. The cost of land often precludes this type of treatment in the more densely developed portions of urban areas.

- ✓ **Constructed/Restored Wetlands** - In addition to providing flood control and water supply benefits through artificial recharge of groundwater, constructed wetlands designed for stormwater management provide water quality benefits

through a number of processes including sedimentation, filtration, absorption, biological processes, and nutrient uptake. Pollutant removal performance depends on the size of the wetland relative to the watershed, the design of the wetland, and the type and composition of wetland vegetation. Wetlands also provide additional ecological and recreational benefits. If a significant amount of sedimentation is anticipated, a deep settling basin could be constructed (which the water would enter prior to reaching the wetland). The basin would require periodic maintenance to remove accumulated sediment. Constructed wetlands require maintenance, especially in the first 5-10 years during which vegetation is growing and natural seeding is occurring. Providing suitable hydrologic conditions for vegetation growth and water treatment is key to successful performance of constructed wetlands. Constructed wetlands are generally applicable to most urban situations, as long as there is adequate space for the facility, an adequate source of water, and appropriate soils. In California, such wetlands would likely be seasonal in nature. The cost of urban lands often preclude this type of treatment in the more densely developed portions of urban areas.

A variation of this control is the use of existing wetlands for urban runoff treatment. Existing wetlands at or downstream of a new development/redevelopment project can be enhanced to improve hydrology, and runoff from the development project can be directed to the wetlands.

Note that the dry detention ponds/basins, retention ponds/wet basins, and the constructed wetlands need to be periodically monitored for accumulation of toxic materials, and provisions made for cleanout and disposal pretreatment may be added (to remove heavy sediment trash and debris) to reduce maintenance. If a significant amount of sediment is anticipated, a deep settling basin could be constructed. This would also need to be periodically cleaned out to maintain capacity.

✓ **Filtration Systems -** Filtration systems convey stormwater through filter media (e.g., sand, compost, charcoal) to treat the storm water. The chemicals treated vary depending on the type of media and may include fine sediment, colloidal material, hydrocarbons, organics, nutrients and dissolved metals. Such systems come in many sizes and designs including: (1) inserts placed in individual storm drain inlets, (2) linear units that treat stormwater from small impervious areas such as parking lots, and (3) large 1-2 acre sand filters that treat runoff from urban catchments. Filters are effective as long as the capacity of the filter is not exceeded, and the filter is not allowed to clog. Filter inserts are particularly problematic in this regard, and recent testing and evaluation questions their applicability where material in runoff will clog or block the filter. In stormwater applications filter systems are required to remove blocking materials (leaves, trash, debris, sediments, oil and grease) and storage to better manage flowrates.

Experience to date with filter type inserts for drain inlets suggest that the units are easily clogged with sediment and debris, with resultant bypassing of most of the flows. Therefore, inserts are not recommended unless require frequent inspection and cleaning is performed. Filtration systems will have limited application in small well-maintained parking lots.

✓ **Oil/Grit Separators** - Oil/grit (gravity) separators are usually multi-chambered treatment units that are placed underground and treat stormwater from a drainage catchment. The individual chambers often are designed to trap grit and floatables, and adsorb hydrocarbons. Flows in excess of the design capacity should be diverted around the unit, otherwise there is the possibility that sediment previously trapped in the chambers will be resuspended and flushed downstream. Inspection and maintenance is required to ensure that the units are not filling up with sediment, as accumulation can affect performance. Traditional gravity oil/water separators that utilize skimming devices and coalescing plates (to increase droplet size and capture) are generally not applicable to stormwater conditions where total hydrocarbon concentrations are generally less than 10 mg/l. The performance of oil/grit separators varies depending on the chosen design and cannot be generally recommended at this time, pending more data from ongoing testing. In general, oil/grit separators are useful only at sites where there are chances that oil spills could occur and to a limited degree at development sites that have high oil and grease loadings such as petroleum storage yards and vehicle storage facilities.

General Design Considerations for Treatment Controls

Treatment control design standards, depending on the type of units, are based on either treating a given volume of runoff (e.g., first 0.5 inch of runoff) or a peak flowrate associated with a design storm. The volume approach is often utilized for small catchments where there tends to be a "first flush" condition (e.g., a parking lot). Design storms for storm water controls tend to be small (e.g. recurrence intervals of 3 months to 2 years) compared to flood control designs standards because of the need to minimize the size and cost of the unit, and because most runoff is associated with the more frequent smaller events. Treatment controls must be designed such that volumes and flows in excess of the design standard bypass the unit, otherwise there is the possibility of aggravating flooding and also causing resuspension of previously captured sediments or other constituents. Also, all of the treatment devices above require some inspection, maintenance, and disposal of solids to ensure optimum performance and often to avoid flooding.

Post-Construction Controls for Projects Requiring Administrative Permits

✓ **Incorporate low-maintenance landscaping** - The applicant should be instructed to use low-maintenance drought-tolerant landscaping that does not require frequent fertilizer, pesticide and herbicide application.

- ✓ **Require labeling of storm drains (to discourage dumping)** - The applicant should be instructed to label all storm drains with the appropriate legend used in the municipality, cautioning against dumping.

- ✓ **Where possible, direct gutters to landscaped areas** - Roof drains may be eliminated only in one to two-story buildings. Where these cannot be eliminated, instruct the applicant to direct the downspout of the gutter to landscaped area or into an infiltration trench. Install several gutters to distribute the flow. Note that roof drains may be eliminated in residential and some commercial areas only, and should not be eliminated in industrial areas.

- ✓ **Use alternate paving materials/porous/permeable materials, where appropriate** - Instruct applicant to use alternate paving materials (pavers), landscaping, mulch, gravel and cobbles where appropriate to provide ground cover, and reduce the use of asphalt or other impervious pavement. As noted earlier, pavers are recommended for driveways, walkways, and patios in single-family residences where the site does not generate highly polluted runoff (that could contaminate groundwater if it were to infiltrate) and where ADA requirements do not have to be met. In non-residential areas, pavers are recommended for emergency access roads, overflow parking areas, and non-handicapped parking stalls. These are not recommended where heavy loads (e.g. truck movement) are anticipated. *For more information on alternate paving materials, see Post-Construction Controls for New Development Fact Sheets available from BASMAA.*

Sources of Additional Information

For additional information on post-construction controls for new development and redevelopment projects, see the following:

Bay Area Stormwater Management Agencies Association. 1996. Start at the Source. Residential Site Planning and Design Guidance Manual for Stormwater Quality Protection.

City of Olympia. 1994. Impervious Surface Reduction Study. Conducted by the Public Works Department. Water Resources Program. November. (for information on reducing impervious surfaces such as street widths, sidewalks, and parking facilities).

Wilson, A. 1994. "Stormwater Management, Environmentally Sound Approaches", published in the Environmental Building News, Vol. 3, No. 5, September/October. (for a general discussion of new development controls).

City of San Rafael. 1991. Hillside Residential Design Guidelines Manual. Prepared by Gast Hilmer Associates. (for more information on designing and building residential developments in hilly areas).

Bay Area Stormwater Management Agencies Association (BASMAA). 1997. Compilation of New Development Stormwater Treatment Controls in the San Francisco Bay Area. June. (For treatment controls)

California State Stormwater Quality Task Force. 1993. California Stormwater Best Management Practice Handbook - Municipal. March. (For treatment controls)

US Environmental Protection Agency. 1993. Guidance Specifying Management Measures for Sources of Nonpoint Pollution in Coastal Waters, Issued Under Authority of Section 6217(g) of the Coastal Zone Act Reauthorization Amendments of 1990. EPA 840-B-92-002. January.

Center for Watershed Protection, Watershed Protection Techniques, A Quarterly Bulletin on Urban Watershed Restoration and Protection Tools.

Center for Watershed Protection. 1996. Design of Stormwater Filtering Systems, prepared for Chesapeake Research Consortium, December.

Center for Watershed Protection. 1995. Site Planning for Urban Stream Protection, prepared by T. Schueler for Metropolitan Washington Council of Governments. (For information on cluster development, stream protection buffers, street reduction controls)

4U Sample Standards

City of Pittsburg
Community Development Department
65 Civic Avenue, Pittsburg CA 94565
Phone (510)439-4920, Fax 439-0527

N.P.D.E.S. STANDARD CONDITIONS FOR BUSINESSES

The following are conditions of approval that are required to be placed on all projects to address the Federally mandated **National Pollutant Discharge Elimination System (N.P.D.E.S.)**. All conditions might not apply to each specific project therefore each project must be reviewed individually with a Community Development staff person at the time of application.

- ☐ Restaurants designed with contained areas for cleaning mats and containers. Sinks connected to the sanitary sewer. Any grease disposed to the sanitary sewer must be collected in a contained area and removed regularly by a disposal and recycling service.
- ☐ Trash enclosures and dumpster areas covered (in a non-combustible material) and protected from roof and surface drainage.
- ☐ All areas used for washing, steam cleaning, maintenance, repair or processing to have impermeable surfaces and a sand trap, containment berms, roof covers, recycled water wash facilities, and to discharge into the sanitary sewer, as approved by the City Engineer.
- ☐ Oils, fuels, solvents, coolants, and other chemicals stored outdoors to be in containers and protected from drainage by secondary containment structures such as berms and roof covers. Amounts shall be regulated by the Fire District.
- ☐ Efficient irrigation, appropriate landscape design and proper maintenance (Compliance with Article 7, *Landscaping Ord.*) implemented to reduce excess irrigation runoff, promote surface filtration, and minimize use of fertilizers, herbicides and pesticides.
- ☐ To the extent practicable, drainage from paved surfaces to be routed through grassy swales, buffer strips or sand filters prior to discharge to the storm drain system.
- ☐ A parking lot sweeping program be implemented that, at a minimum, provides for sweeping immediately prior to, and once during, the storm season.
- ☐ All storm drain inlets within the project site shall labeled by stenciling, branding or plaques reading *"No Dumping - Drains to Delta."*

SARB_001079

4V Sample Reporting Forms

NEW DEVELOPMENT INSPECTION FORM

Project:_____

BMP:_____

Location:_____

INSTALLATION	MAINTENANCE			
Date Installed:_____	Inspected By:	Date Inspected	Maintenance Satisfactory?	If No, Correction Action Needed
Date Inspected:_____	1)_____	_____	☐ Yes ☐ No	_____
Inspected By:_____	2)_____	_____	☐ Yes ☐ No	_____
Installation Satisfactory?	3)_____	_____	☐ Yes ☐ No	_____
☐ Yes ☐ No	4)_____	_____	☐ Yes ☐ No	_____
If No, Corrective Actions Needed	5)_____	_____	☐ Yes ☐ No	_____
_____				

BMP:_____

Location:_____

INSTALLATION	MAINTENANCE			
Date Installed:_____	Inspected By:	Date Inspected	Maintenance Satisfactory?	If No, Correction Action Needed
Date Inspected:_____	1)_____	_____	☐ Yes ☐ No	_____
Inspected By:_____	2)_____	_____	☐ Yes ☐ No	_____
Installation Satisfactory?	3)_____	_____	☐ Yes ☐ No	_____
☐ Yes ☐ No	4)_____	_____	☐ Yes ☐ No	_____
If No, Corrective Actions Needed	5)_____	_____	☐ Yes ☐ No	_____
_____				

BMP:_____

Location:_____

INSTALLATION	MAINTENANCE			
Date Installed:_____	Inspected By:	Date Inspected	Maintenance Satisfactory?	If No, Correction Action Needed
Date Inspected:_____	1)_____	_____	☐ Yes ☐ No	_____
Inspected By:_____	2)_____	_____	☐ Yes ☐ No	_____
Installation Satisfactory?	3)_____	_____	☐ Yes ☐ No	_____
☐ Yes ☐ No	4)_____	_____	☐ Yes ☐ No	_____
If No, Corrective Actions Needed	5)_____	_____	☐ Yes ☐ No	_____
_____				

4W BMPs for Vehicle Service Facilities

Vehicle Service Facilities

Focus of Document

This guidance presents BMPs to address the discharge of pollutants to the storm drainage system from vehicle service facilities. These facilities include:

- ✓ Vehicle Repair Shops, Body Shops, Car Washes (SIC Major Group 75)
- ✓ Gasoline stations (SIC 5541)

Sources of Pollutants

There are several activities that could potentially cause the discharge of pollutants to the storm drainage system from these facilities. These activities of concern include:

- ✓ Facility maintenance and management (Keeping a clean shop, storage, spill control, outdoor waste receptacle areas, education and training)
- ✓ Changing oil and other fluids
- ✓ Cleaning engines and parts, and flushing radiators
- ✓ Washing cars and other vehicles
- ✓ Body repair and painting
- ✓ Fuel dispensing

Pollutants of Concern

Some of the pollutants of concern from these facilities are:

- ✓ Metals (copper, zinc, chromium, nickel, and lead)
- ✓ Oil and grease
- ✓ Gasoline (e.g. Polyaromatic Hydrocarbons (PAHs) and Methyl Tertiary-Butyl Ether (MTBE))
- ✓ Solvents

Best Management Practices

Best management practices for the most part are common sense, good housekeeping measures that can be implemented without resulting in excessive effort and cost to the facility owner/operator. BMPs listed below apply mainly to the operations of such facilities. Structural controls or physical improvements are generally not recommended for existing facilities although opportunities for structural controls should be utilized when new vehicle service facilities are constructed or existing ones are remodeled.

To assist the City in selecting BMPs for implementation by the vehicle service facility operator/owner, BMPs that are considered high priority are marked "• • •"; medium priority are marked "• •" and low priority are market "•". Rationale used in this prioritization is presented at the end of the section.

Facility Maintenance and Management Practices

Keeping a Clean Shop

• • Use drip pans under leaking vehicles to capture fluids.

• • • Regularly sweep or vacuum the shop floor and other paved surfaces at your facility. Use mopping as an alternative to hosing down or washing work areas. If mopping is used to clean shop floors:

1) Spot clean any spilled oil or fluids using absorbents or rags.

2) Use dry cleanup methods: Sweep the floor using absorbents.

3) After steps 1 and 2 above (if mopping is still needed), mop and dispose of mop water to the sanitary sewer.

4) Do not pour mop water into the paved areas, street, gutter, or storm drain.

(See Rationale 1 at the end of section)

• Remove unnecessary hoses to discourage washing down floors and outside paved areas.

• Collect all metal filings, dust, and paint chips from grinding, shaving, and sanding, and dispose of the waste properly. Never discharge these wastes to the storm drain or sanitary sewer.

- Collect all dust from other activities (e.g. brake pad dust) and dispose of the waste in compliance with local requirements. Never discharge these wastes to the storm drain or sanitary sewer.

- Recycle cleaning rags through an industrial laundry.

- Inspect and clean if necessary, storm drain inlets and catch basins within the facility boundary before October 1 each year (see Rationale 2 at the end of section).

- Label storm drains with "No Dumping – Discharges to Ocean" (see Rationale 3 at the end of section).

Storage

- Store hazardous materials and wastes in secondary containment where they are protected from rain and in a way that prevents spills from reaching the sanitary sewer or storm drain (see Rationale 4 at the end of section).

- Keep lids on waste barrels and containers, and store them indoors or under cover to reduce exposure to rain (see Rationale 4 at the end of section).

- All hazardous wastes must be labeled according to hazardous waste regulations. Consult the Fire Department or your local hazardous waste agency for details.

- Keep wastes separate to increase your waste recycling/ disposal options and to reduce your costs.

- Never mix waste oil with fuel, antifreeze, or chlorinated solvents. Consult your hazardous waste hauler for details.

- Double-contain all bulk fluids and wastes to prevent accidental discharges to the sewer and storm drain. Consult the Fire Department for details.

- Keep storage areas clean and dry. Conduct regular inspections so that leaks and spills are detected as soon as possible (see Rationale 4 at the end of section). Document all inspections.

- When receiving vehicles to be parted or scavenged, park them on a paved surface and immediately drain and collect gasoline and other fluids properly. Place drip pans to catch leaking fluids (see Rationale 4 at the end of section).

- Drain all fluids from components, such as engine blocks, which you may store for reuse or reclamation. Keep these components under cover and on a drop pan or sealed floor.

- Store new batteries securely to avoid breakage and acid spills during earthquakes. Shelving should be secured to the wall. Store used batteries indoors and in plastic trays to contain potential leaks. Recycle old batteries.

Spill Control

The Best Spill Control is Prevention

- Maintain and keep current, as required by other regulations, a spill response plan and ensure that employees are trained on the elements of the plan (see Rationale 5 at the end of section).

- Minimize the distance between waste collection points and storage areas.

- Contain and cover all solid and liquid wastes – especially during transfer.

- Purchase and maintain absorbent materials in accordance with local regulations and procedures for containment and cleanup of different spills, and make sure they are easily accessible anywhere in the shop. Saturated absorbents generally must be disposed of as hazardous waste.

- "Spot clean" leaks and drips routinely. Leaks are not cleaned up until the absorbent is picked up and disposed of properly.

- Check floor drains to ensure that they are not connected to or discharge to the storm drain system (see Rationale 6 at the end of section).

Outdoor Waste Receptacle Areas

- Spot clean leaks and drips routinely to prevent runoff of spillage.

- Minimize the possibility of pollution from outside waste receptacles by doing at least one of the following:

  - use only watertight waste receptacle(s) and keep the lid(s) closed, or

  - grade and pave the waste receptacle area to prevent run-on of storm water, and install a low containment berm around the waste receptacle area, or

  - install a roof over the waste receptacle area.

Education and Training

- Train all employees upon hiring - and annually thereafter - on personal safety, chemical management, and proper methods for handling and disposing of waste. Make sure that all employees understand storm water discharge prohibitions, wastewater discharge requirements, and these best management practices. Use a training log or similar method to document training (see Rationale 1 and 5 at the end of section).

- Post instructional/informational signs around your shop for customers and employees. Put signs above all sinks prohibiting discharges of vehicle fluids and wastes. Put signs on faucets (hose bibbs) reminding employees and customers to conserve water and not to use water to clean up spills.

- Label drains within the facility boundary, by paint/stencil (or equivalent), to indicate whether they flow to an on-site treatment device, directly to the sanitary sewer, or to a storm drain. Labels are not necessary for plumbing fixtures directly connected to the sanitary sewer (see Rationale 3 at the end of section).

- Post emergency telephone numbers of the wastewater treatment plant and the fire department.

Changing Oil and Other Fluids

- Whenever possible, change vehicle fluids indoors and only on floors constructed of non-porous materials. Avoid working over asphalt and dirt floors – surfaces that absorb vehicle fluids.

- If vehicle fluids must be removed outdoors, always use a drip pan. Prevent spills from reaching the street or storm drain by working over an absorbent mat and covering nearby storm drains, or working in a bermed area. If necessary, you can use absorbent socks to create a bermed area.

- When draining fluids into a drain pan, place a larger drip pan (e.g., 3’ x 4’) under the primary drain pan to catch any spilled fluids.

- Transfer fluids drained from vehicles to a designated waste storage area as soon as possible. Drain pans and other open containers of fluids should not be left unattended unless they are covered and within secondary containment.

- Store waste containers of antifreeze and oil within secondary containment. Antifreeze and waste oil should be stored separately and recycled, or disposed of as hazardous waste.

- • • Never pour vehicle fluids or other hazardous wastes into sinks, toilets, floor drains, outside storm drains, or in the garbage. These substances should be kept in designated storage areas until recycled or safely disposed of (see Rationale 4 at the end of section).

- • Drain fluids from leaking or wrecked vehicles as soon as possible, to avoid leaks and spills.

Cleaning Engines and Parts, and Flushing Radiators

- • • Eliminate discharges from engine cleaning and flushing of radiators to the sanitary sewer and storm drains. Use a licensed service to haul and recycle or dispose of wastes (see Rationale 4 at the end of section).

- • Steam cleaning of engines must be done in a closed-loop water recycling system. No steam cleaning water may be discharged to the sanitary sewer or the storm drain.

- • Designate specific areas or service bays for engine, parts, or radiator cleaning. Do not wash or rinse parts outdoors.

- • Use self-contained sinks and tanks when working with solvents. Keep sinks and tanks covered when not in use.

- • Inspect degreasing solvent sinks regularly for leaks, and make necessary repairs immediately.

- • Avoiding soldering over drip tanks. Sweep up drippings and recycle or dispose as hazardous waste.

- • Rinse and drain parts over the solvent sink or tank, so that solvents will not drip or spill onto the floor. Use drip boards or pans to catch excess solvent solutions and divert them back to a sink or tank.

- • Allow parts to dry over the hot tank. If rinsing is required, rinse over the tank as well.

- • Collect and reuse parts cleaning solvent solutions and water used in flushing and testing radiators. When reuse is no longer possible, these solutions are hazardous wastes unless otherwise determined, and must be disposed of properly.

- • Never discharge cleaning solutions used for engines or parts into the sewer sanitary system without adequate treatment. Most facilities have these so-

lutions hauled off-side as hazardous waste because of the permits necessary for on-site treatment.

- Rinsewater may only be discharged to the sanitary sewer after adequate treatment and approval by the sewage treatment plant.

- Never discharge wastewater from steam cleaning, or engine/parts cleaning to a street, gutter, storm drain, or sanitary sewer.

Washing Cars and Other Vehicles

Regular Activity

- If car washing is a central activity of your business, the most desirable option is to treat and recycle the wash water.

- Designate a vehicle washing area and wash cars and trucks only in that area. This "wash pad" should be bermed to prevent discharges to storm drains and should discharge to the sanitary sewer after adequate treatment and approval of the sewage treatment plant.

- Cover an outside wash pad or minimize the area of an uncovered pad to reduce the amount of rainwater reaching the sanitary sewer. Consult your local sewage treatment plant for guidance.

- Acid-based wheel cleaners and other specialized cleaners may be prohibited or require additional treatment before discharge to the sewer.

Occasional Activity

- Even biodegradable soap is toxic to fish and wildlife. Whenever possible, take vehicles to a commercial car wash that recycles.

- If soap is used in washing, the wash water must be collected and discharged, preferably with treatment, to the sanitary sewer. This water cannot be discharged to a storm drain (see Rationale 7 at the end of section).

- Never rinse off spray-on acid-based wheel cleaners where rinsewater may flow to a street, gutter, or storm drain.

Washing New Vehicles

- If cleaning the exterior of new vehicles with water only, the discharged water may go to the storm drain directly unless the vehicle has been coated.

- Always protect the storm drains from solvents used to remove protective coatings from new cars. Discharges of these solvents to the sanitary sewer must receive adequate treatment and approval of the sewage treatment plant.

Body Repair and Painting

- Whenever possible, conduct all body repair and painting work indoors or under cover.

- When receiving damaged vehicles, inspect for leaks. Use drip pans if necessary.

- When cleaning auto body parts before painting, do not use hose-off degreasers. Brush off loose debris and use rags to wipe down parts.

- Use dry cleanup methods such as vacuuming or sweeping to clean up dust from sanding metal or body filler. Debris from wet sanding can be allowed to dry overnight on the shop floor, then swept and vacuumed. Liquid from wet sanding should not be discharged to the storm drain.

- Minimize waste paint and thinner by carefully calculating paint needs based on surface area and using the proper sprayer cup size.

- Do not use water to control overspray or dust in the paint booth unless you collect this wastewater. This water should be treated before discharge into the sanitary sewer system.

- Clean spray guns in a self-contained cleaner. Recycle the cleaning solution when it becomes too dirty to use. Never discharge cleaning waste to the sanitary sewer or storm drain.

Fuel Dispensing

- Maintain fuel dispensing areas using dry cleanup methods such as sweeping for removal of litter and debris, or use of rags and absorbents for leaks and spills. Fueling areas should never be washed down unless dry cleanup has been done and the wash water is collected and disposed of in the sanitary sewer system (see Rationale 1, 4, and 5 at the end of section.)

- Fit underground storage tanks with spill containment and overfill prevention systems meeting the requirements of Section 2635(b) of Title 23 of the California Code of Regulations.

- Fit fuel dispensing nozzles with “hold-open latches” (automatic shutoffs) except where prohibited by local fire departments.

- Post signs at the fuel dispenser or fuel island warning vehicle owners/ operators against "topping off" of vehicle fuel tanks.

New or Substantially Remodeled Vehicle Service Facilities

The elements listed below should be included in the design and construction of new or substantially remodeled fuel dispensing facilities.

- Fuel dispensing areas must be paved with portland cement concrete (or, equivalent smooth impervious surface), with a 2% to 4% slope to prevent ponding, and must be separated from the rest of the site by a grade break that prevents run-on of storm water. The fuel dispensing area is defined as extending 6.5 feet from the corner of each fuel dispenser or the length at which the hose and nozzle assembly may be operated plus 1 foot, whichever is less. The paving around the fuel dispensing area may exceed the minimum dimensions of the "fuel dispensing area" stated above.

- The fuel dispensing area must be covered and the cover's minimum dimensions must be equal to or greater than the area within the grade break. The cover must not drain onto the fuel dispensing area.

Note*:* Substantially Remodeled Facilities – One of the following criteria must be met before a facility is deemed to be substantially remodeled and' the design elements described above are required to be included in the new design and construction:

- ✓ the canopy cover over the fuel dispensing area is being substantially replaced (not including cosmetic/facial appearance changes only) and the footing is structurally sufficient to support a cover of the minimum dimensions described above, or

- ✓ one or more fuel dispensers are relocated or added in such a way that the portland cement concrete (or, equivalent) paving and grade break or the canopy cover over the fuel dispensing area do not meet the minimum dimensions as defined above. Replacement of existing dispensers does not, by itself, constitute a substantial remodel.

The following element should be included in the design and construction of new or substantially remodeled vehicle service facilities.

- ✓ Grade and pave the outdoor waste receptacle area to prevent run-on of storm water.

Rationale for assigning high priority to selected BMPs

BMPs that are assigned high priority (•••) are mostly preventative practices that are inexpensive to implement versus collection, treatment and disposal of water that has picked up pollutants. The rationale used in this report is listed below:

1) Rationale: Prevention practices are cost effective and relatively inexpensive to implement vs. collection, treatment and disposal of wastewater. Materials to achieve dry cleaning are readily available and material can be disposed of through existing practices.

2) Rationale: Pollutants from incidental spills and leaks and trash will collect in storm drain facilities during dry weather period and will be a significant source of pollutants during the first significant storm. Cleaning will remove this potential source.

3) Rationale: The public in general do not realize that storm drains flow directly through to the ocean without treatment. Labeling of storm drains is an effective method of public education.

4) Rationale: HAZMAT and HAZWASTE are toxic to aquatic life and waterfowl in streams and ocean and prevention of spills is more cost effective than cleanup.

5) Rationale: Spills are cheaper to clean up when quickly contained. A spill response plan will prepare employees to use equipment and material available for contaminated and cleanup and to ensure their safety while doing the cleanup.

6) Rationale: Improperly plumbed floor drains can become a direct point of discharge of spills that occur indoor and outdoors, to streams and other surface waters.

7) Rationale: Car washing compounds including soaps and wheel cleaners are toxic to aquatic life and wildlife and must be prevented from entering the storm drainage system.

Note: This guidance is based primarily on Best Management Practice Guide – Retail Gasoline Outlets, prepared by California Retail Gasoline Outlet Work Group of SWQTF 1997.

Sources of Additional Information

Additional information on BMPs for vehicle service facilities is available in the following publications:

Alameda County Urban Runoff Clean Water Program, 1994. *Auto Radiator Service And Fishing.* Alameda County, California.

Alameda County Urban Runoff Clean Water Program, 1994. *Auto Body Repair and Refinishing and Fishing.* Alameda County, California.

Alameda County Urban Runoff Clean Water Program, 1994. *Auto Wrecking And Fishing.* Alameda County, California.

Alaska Health Project, 1987. *Waste Reduction Makes Good Business Sen$e for Vehicle Repairers.*

BADA/BASMAA, 1995. *Your Shop Can Make a Difference! What vehicle service shops can do to protect water quality in the Bay and Delta.* Bay Area Dischargers Association and Bay Area Stormwater Management Agencies Association. Prepared by the Bay Area Pollution Prevention Group. Oakland, California.

California DTSC, 1992. *Hazardous Waste Minimization Fact Sheet for Auto Paint Shops.* Doc. No. 202. California Department of Toxic Substances Control. Sacramento, California.

California DTSC, 1992. *Hazardous Waste Minimization Checklist* s *Assessment Manual for Auto Paint Shops.* Doc. No. 406. California Department of Toxic Substances Control. Sacramento, California.

California DTSC, 1993. *Fact Sheet, Handling and Transport of Spent Lead-Acid Storage Batteries for Recycling.* Doc. No. 102. California Department of Toxic Substances Control, Office of Pollution Prevention and Technology Development. Sacramento, California.

California DTSC, 1993. *Fact Sheet, Used Oil: Handling, Storage, and Transport for Recycling.* Doc. No. 103. California Department of Toxic Substances Control, Office of Pollution Prevention and Technology Development. Sacramento, California.

California DTSC, 1993. *Fact Sheet, Used Oil Filters: Handling, Storage, and Transport for Recycling.* Doc. No. 104. California Department of Toxic Substances Control, Office of Pollution Prevention and Technology Development. Sacramento, California.

California SWQTF, 1993. *California Storm Water Best Management Practices Handbooks - Industrial.* Prepared by Camp Dresser & McKee, Larry Walker Associates, Uribe & Associates, and Resource Planning Associates.

California SWQTF, 1997. *Best Management Practice Guide – Retail Gasoline Outlets.* Prepared by Retail Gasoline Outlet Work Group.

City and County of San Francisco, 1991. *Service Station Hazardous Waste Reduction and Management Checklist.* San Francisco Hazardous Waste Program.

City and County of San Francisco, 1994. *The Green Wrench Guide, Pollution Prevention Tips for Auto Repair and Body Shops.* San Francisco Water Pollution Prevention Program, Bureau of Environmental Regulation and Management.

City and County of San Francisco, *1994. Shop Information Package, Automotive Repair Facilities.* San Francisco Water Pollution Prevention Program, Bureau of Environmental Regulation and Management.

County Sanitation Districts of Los Angeles County, 1990. *Radiator Repair Industry, Pollution Prevention Opportunities Checklist.*, California.

City of Los Angeles, 1991. *Fact Sheet: The Automotive maintenance Industry - Basic Environmental and Business Requirements.* Hazardous & Toxic Materials Office, Board of Public Works.

City of Los Angeles, 1992. *Fact Sheet: The Radiator Repair Industry - Basic Environmental and Business Requirements.* Hazardous & Toxic Materials Office, Board of Public Works.

City of Manhattan Beach,1994. *Ocean Safe Practices for the Auto-Industry* and *How to Become an Ocean Safe Enterprise, A Guide for the Automotive* Industry. Manhattan Beach, California.

City of San Jose, 1992. *The Pollution Solution For The Automotive Industry.* San Jose, California.

City of Santa Monica. *Hazardous Waste Reduction Facts: Automotive Painting.* Department of General Services. Santa Monica, California.

City of Santa Monica. *Hazardous Waste Reduction Facts: Vehicle* S *Equipment Repair and Maintenance Shops.* Department of General Services. Santa Monica, California.

City of Sunnyvale, 1994. Automotive Best Management Practices Handbook. City of Sunnyvale Industrial Waste Pretreatment Program. Sunnyvale, California.

Connecticut Technical Assistance Program. *Waste Reduction Checklist, Automotive Repair.* Hartford, Connecticut.

MnTAP, 1991. *Auto Body Repair: Hazardous waste management and reduction. #28.* Minnesota Technical Assistance Program Minneapolis, Minnesota.

MnTAP, 1993. *Autobody Repair Shop Waste Reduction Measures. #91.* Minnesota Technical Assistance Program Minneapolis, Minnesota.

MnTAP, 1994. *Waste Management Guidance for Oil Cleanup.* #65. Minnesota Technical Assistance Program. Minneapolis, Minnesota.

MnTAP, 1994. *Vehicle Maintenance and Repair Self-Assessment.* #47. Minnesota Technical Assistance Program. Minneapolis, Minnesota.

MnTAP, 1994. *Managing Used Oil Sorbents.* #52. Minnesota Technical Assistance Program. Minneapolis, Minnesota.

MnTAP, 1994. *Waste Reduction Alternatives for Spray Painting and Coating.* #85. Minnesota Technical Assistance Program. Minneapolis, Minnesota. ,

NEIWPCC, 1994. *The Tuned-Up Shop, Best Management Tips For A Smooth-Running Environmentally Friendly Auto Repair Operation.* New England Interstate Water Pollution Control Commission. Wilmington, Massachusetts.

New Jersey Department of Environmental Protection. *Vehicle Maintenance, Technical Information Publication (TIP).* Division of Hazardous Waste Management. Hazardous Waste Minimization Program. Trenton, New Jersey.

North Carolina Department of Natural Resources and Community Development, 1986. *Pollution Prevention Tips, Waste Reduction Options: Radiator Service Firms.* Pollution Prevention Pays Program. Raleigh, North Carolina.

North Carolina Department of Environment, Health, and Natural Resources, 1990. *Pollution Prevention Tips, Waste Reduction Options: Automobile Salvage Yards.* Pollution Prevention Program. Raleigh, North Carolina.

Regional Water Quality Control Plant-Palo Alto, 1992. *Best Management Practices for Automotive-Related Industries, Sewer Use Ordinance for Vehicle Service Repair.* Palo Alto, California.

Regional Water Quality Control Plant-Palo Alto, 1993. *Shop Information Package, Vehicle Service Facility Waste Minimization Program.* Palo Alto, California.

San Mateo Countywide STOPPP, 1995. *Pollution Prevention Practices for Automotive Service and Repair Shops.* San Mateo Countywide Stormwater Pollution Prevention Program. San Mateo County, California.

USEPA,1990. *Vehicle Maintenance.* EPA/530-SW-90-027a. U.S. Environmental Protection. Agency.

USEPA. *Does your facility generate automotive service wastes ? U.S.* Environmental Protection Agency, Underground Injection Control Program.

USEPA. *Pit Stops, The Be-Kind-To-The-Environment-In-Your-Shop Game. U.S.* Environmental Protection Agency, Region I. Boston, Massachusetts.

Virginia DEQ. *Pollution Prevention, Stop Driving Up Your Costs.* Virginia Department of Environmental Quality, Office of Pollution Prevention. Richmond, Virginia.

Washington DOE, 1992. *Managing Hazardous Wastes: A Guide for Transmission Shops.* 92-BR-10. Washington State Department of Ecology, Hazardous Waste and Toxics Reduction Program. Olympia, Washington.

Washington WE, 1992. *Managing Hazardous Wastes: A Guide for Automotive Repair Shops.* 92BR-1S Washington State Department of Ecology, Hazardous Waste and Toxics Reduction Program. Olympia, Washington.

Washington DOE, 1992. *Managing Hazardous Wastes A Guide for Service Stations.* 92-BR-13. Washington State Department of Ecology, Hazardous Waste and Toxics Reduction Program. Olympia, Washington.

Washington DOE, 1993. Auto *Body Restoration and Painting A Success Story in Waste Reduction.* #6. Washington State Department of Ecology, Waste Reduction, Recycling, and Litter Control Program. Olympia, Washington.

Washington DOE, 1995. *Best Management Practices Manual for Automobile Dealerships.* 95405A. Washington State Department of Ecology, Hazardous Waste and Toxics Reduction Program. Olympia, Washington.

4X BMPs for Food Service Facilities

Food Service Facilities

Focus of Document

This guidance presents BMPs to address the discharge of pollutants to the storm drainage system from food service facilities. These facilities include:

- ✓ Restaurants
- ✓ Institutional cafeterias
- ✓ Grocery stores, bakeries, and delicatessens
- ✓ Any facility requiring a Health Department permit for food preparation

Note: BMPs for drive-through food facilities are discussed under BMPs for shopping centers.

Sources of Pollutants

There are several activities that can potentially cause the discharge of pollutants to the storm drainage system from these facilities. These activities of concern include:

- ✓ Cleaning of equipment
- ✓ Grease handling and disposal
- ✓ Spill cleanup and surface cleaning
- ✓ Dumpster and loading dock area
- ✓ Cooling and refrigeration equipment maintenance
- ✓ Landscaping and grounds maintenance
- ✓ Parking lots
- ✓ Illegal connections
- ✓ Use of toxic cleaners

Pollutants of Concern

Some of the pollutants of concern from these facilities are:

- ✓ Organic materials (food wastes)
- ✓ Oil and grease
- ✓ Toxic chemicals in cleaning products, disinfectants, and pesticides

Best Management Practices

Best management practices are common sense, good housekeeping measures that can be implemented at reasonable effort and cost to the facility owner/operator. Many facility owners/operators are already implementing some of these practices. BMPs listed below apply mainly to the operations of such facilities. Structural controls or physical improvements are generally not recommended for existing facilities although opportunities for structural controls should be utilized when new food service facilities are constructed or existing ones are remodeled.

To assist the Municipality in selecting BMPs for implementation by the food service facility operator/owner, BMPs that are considered high priority are marked "• • •"; medium priority are marked "• •" and low priority are marked "•". Rationale used in this prioritization is presented at the end of the section.

Facility Maintenance and Management Practices

Cleaning Equipment

- • • Clean equipment in a designated indoor area, such as a mop sink, pot sink, or floor area with a drain connected to the sanitary sewer (indoor plumbing).
- • • Clean equipment in a designated covered, bermed outdoor area with a drain connected to the sanitary sewer (indoor plumbing). Don't allow food wastes to accumulate in this area.
- • • Do not clean equipment outdoors in any area where water may flow to a street, gutter, storm drain, or creek.
- • • If possible, use floor mats that are small enough to be cleaned inside in a mop sink or near a floor drain.
- • • If floor mats are too big to clean indoors, take them to a self-service car wash to clean. Alternately, identify a large enough area in your facility for washing mats, and make sure washwater drains to the sanitary sewer.
- • For hood filter cleaning companies, see "Restaurant Equipment Repairing and Servicing" in the yellow pages.

Grease Handling and Disposal

• • • Never pour oil, grease, or sauces or salad dressings or waste grease down a storm drain, or into a dumpster. Use a recycler or a liquid disposal company.

• For disposal of waste grease from grease interceptors and traps, contact a disposal firm listed under "Grease Traps" and 'Septic tanks" in the yellow pages. Most landfills will not accept grease or other liquid waste from businesses. It is in your best interest to ensure that your waste grease is disposed of properly. Ask your waste grease hauler where your waste grease is disposed of.

Spill Cleanup and Surface Cleaning

Spill Prevention

• • • Maintain and keep current, as required by other regulations, a spill response plan.

• Minimize the distance between waste collection points and storage areas.

• Contain and cover all solid and liquid wastes — especially during transfer.

• • Purchase and maintain absorbent materials and other spill response equipment in accordance with local regulations and procedures for containment and cleanup of different spills, and make sure they are easily accessible anywhere in the shop. Saturated absorbents generally must be disposed of as hazardous waste.

• • "Spot clean" leaks and drips routinely. Leaks are not cleaned up until the absorbent is picked up and disposed of properly.

• • • Check floor drains to ensure that they are not connected to or discharge to the storm drain system (see Rationale 6 at the end ofsection).

Spill Cleanup

• • • First, stop any spill at its source.

• • • Do not clean up spills by hosing down washwater into the gutter or a storm drain.

• • • If the spill could enter a storm drain, protect the drain with sandbags, absorbent rags, or a pile of dirt. You can temporarily seal the storm drain with plastic sheeting.

- Use granular absorbents (e.g. cat litter) to absorb the spill. Dry sweep and dispose of used absorbent in the garbage (if hazardous materials are not spilled).

- If wet cleaning (including high-temperature or high pressure washing) is required, dry clean first and then mop (or if it is absolutely necessary, wash) and collect water. Dispose of water in sink or other indoor drain, not the storm drain.

- If a final rinse is necessary for health reasons, collect the rinse-water and dispose to sink or indoor floor drain. If outdoors, block storm drain before applying water. Mop up or wet-vacuum water, and dispose to sink or indoor drain.

- Do not use bleach or disinfectants if there is a possibility that the rinse water could flow to a street, gutter, or storm drain.

Education and Training

- Train all employees upon hiring – and annually thereafter – on personal safety, chemical management, and proper methods for handling and disposing of waste. Make sure that all employees understand storm water discharge prohibitions, wastewater discharge requirements, and these best management practices. Use a training log or similar method to document training (see Rationale 1 and 5 at the end of section).

- Post instructional/informational signs around your shop for customers and employees. Put signs above all sinks prohibiting discharges of vehicle fluids and wastes. Put signs on faucets (hose bibbs) reminding employees to conserve water and not to use water to clean up spills.

- Label outdoor drains by paint/stencil (or equivalent) to indicate whether they flow to an on-site treatment device or to a storm drain. Labels are not necessary for plumbing fixtures directly connected to the sanitary sewer (see Rationale 3 at the end of section).

Dumpster and Loading Dock Areas

- Keep dumpster lids closed to keep out rainwater.

- Keep dumpsters or the dumpster enclosure locked to prevent illegal dumping.

- Never place liquid waste or leaky garbage bags into a dumpster.

• • • Don't hose out dumpster interior in areas that drain to the storm drain system. Apply absorbent if any fluids are spilled in the dumpster. (Dumpster may be hosed if the wash area drains to the sanitary sewer.)

• • • Leaking dumpsters and compactors, and dumpsters that need to be cleaned out, should be serviced by the dumpster leasing company.

• • • Make sure tallow bins (cooking oil/meat fat recycling bin), and any containers of waste grease are always tightly covered to prevent contamination of the grease and to prevent problems with rats and insects.

• • • Have spill cleanup materials handy near the dumpster and loading dock areas.

Cooling and Refrigeration Equipment Maintenance

• • • Make sure all discharges from cooling and refrigeration equipment go to the sanitary sewer and not to the street, storm drain, or creek.

• • Make sure your maintenance contractor is knowledgeable and skilled at minimizing corrosion with correct chemical treatments.

Landscaping and Grounds Maintenance

• • Use up pesticides. Rinse containers, and use rinse water as product. Dispose of unused pesticide as hazardous waste.

• • Collect lawn and garden clippings, pruning waste, and tree trimmings. Chip if necessary, and compost or dispose appropriately. Do not place clippings, pruning waste, or tree trimmings in gutters. Do not blow or rake leaves, etc. into the street.

• • In communities with yard waste recycling, leave clippings and pruning waste for pickup in approved bags or containers. Or, take to a landfill that composts yard waste.

New or Substantially Remodeled Food Service Facilities

The elements listed below should be included in the design and construction of new or substantially remodeled food service facilities.

✓ Grade and pave the outdoor waste receptacle area to prevent run-on of storm water.

✓ Alternately, store the waste receptable in a covered enclosure with wash down capability.

Rationale for assigning high priority to selected BMPs

BMPs that are assigned high priority (• • •) are mostly preventative practices that are inexpensive to implement versus collection, treatment and disposal of water that has picked up pollutants. The rationale used in this report is listed below:

1) Rationale: Prevention practices are cost effective and relatively inexpensive to implement vs. collection, treatment and disposal of wastewater. Materials to achieve dry cleaning are readily available and material can be disposed through existing practices.

2) Rationale: Pollutants from incidental spills and leaks and trash will collect in storm drain facilities during dry weather period and will be a significant source of pollutants during the first significant storm. Cleaning will remove this potential source.

3) Rationale: The public in general do not realize that storm drains flow directly through to the ocean without treatment. Labeling of storm drains is an effective method of public education.

4) Rationale: HAZMAT and HAZWASTE are toxic to aquatic life and waterfowl in streams and the ocean and prevention of spills is more cost effective than cleanup.

5) Rationale: Spills are cheaper to clean up when quickly contained. A spill response plan will prepare employees to use equipment and material available for containment and cleanup, and to ensure their safety while doing the cleanup.

6) Rationale: Improperly plumbed floor drains can become a direct point of discharge of spills that occur indoor and outdoors to streams and waterways.

7) Rationale: Cleaning products, disinfectants, and pesticides are toxic to aquatic and wildlife and must be prevented from entering the storm drainage system.

Sources of Additional Information

Additional information on BMPs for food service facilities is available in the following publications:

BASMAA, 1996. *Pollution for Surface Cleaning*. Bay Area Stormwater Management Agencies Association. Oakland, California.

California SWQTF, 1996. *Stormwater Resource Guide*. Prepared by the Public Information/Public Participation Subcommittee.

City of Manhattan Beach, 1994. *How to Become an Ocean Safe Enterprise, A Guide for the Restaurant Industry*. Manhattan Beach, California.

City of Manhattan Beach, 1994. *Ocean Safe Practices for Restaurants.* Manhattan Beach, California.

Eastern Municipal Water District, 1993. *Grease...Help for the Food Service Establishment*. San Jacinto, California.

Los Angeles County, no date. *Good Cleaning Practices for a Cleaner Ocean-Food & Restaurant Industry,* Poster. Los Angeles County, California.

Los Angeles River Watershed Cities, 1996. *Stormwater Best Management Practices (BMPs) - Food Service Industry, Brochure 7, Restaurants, Grocery Stores, Bakeries, Food Producers and Distributors*. Los Angeles County, California.

Regional Water Quality Control Plant-Palo Alto, no date. *Food Service Facilities - Selecting and installing a grease removal device.* Palo Alto, California.

Regional Water Quality Control Plant - Palo Alto, no date. *Water Quality Protection Guidelines for Food Handling Facilities.* Palo Alto, California.

San Antonio Water System, 1996. *Storm Water Pollution Housekeeping Handbook.* San Antonio, Texas.

San Antonio Water System, 1996. *What Temporary Food Establishment Vendors Need to Know About Pollution Prevention.* San Antonio, Texas.

Santa Clara Valley Nonpoint Source Pollution Control Program, 1994. *Good Practices to Protect Our Creeks and Bay, Guidelines for Restaurants, Grocery Stores, Cafeterias, Bakeries, Delicatessens,* Booklet in English and brochures in English, Spanish, Vietnamese, and Chinese. San Jose, California.

Santa Clara Valley Nonpoint Source Pollution Control Program, 1994. *Good Practices to Protect Our Creek and Bay,* Poster. San Jose, California.

4Y BMPs for Shopping Centers

Shopping Centers

Focus of Document

This guidance presents BMPs to address the discharge of pollutants to the storm drain system from shopping centers. Shopping centers include:

- ✓ Single Business (i.e., convenience stores, automotive parts stores)
- ✓ Multi-Business Centers

Sources of Pollutants

There are several activities that can potentially cause the discharge of pollutants to the storm drain system from shopping centers. These activities of concern include:

- ✓ Facility maintenance and management (sidewalk, parking areas, and building cleaning, storage, spills, outdoor waste receptacle areas, landscaping and grounds maintenance)
- ✓ Parking lots

Pollutants of Concern

Some of the pollutants of concern that may originate from shopping centers are:

- ✓ Metals (copper, zinc, chromium, nickel, and lead) (from parking lots and paved surfaces)
- ✓ Petroleum hydrocarbons (from parking lots and paved surfaces)
- ✓ Organic decaying material (from landscaped areas)
- ✓ Fertilizers, pesticides, and herbicides (from landscaped areas)
- ✓ Sediment (from landscaped areas)

Best Management Practices

Best management practices are common sense, good housekeeping measures that can be implemented with reasonable effort and cost to the property owner or management. BMPs listed below apply mainly to the operations of such facilities. Structural controls or physical improvements have generally not been required for retrofit of existing facilities although opportunities for structural controls should be utilized when new stores/ shopping centers are constructed or exteriors of existing shopping centers are remod-

eled.

To assist the Muncipality in selecting BMPs for implementation by the shopping center operator/owner, BMPs that are considered high priority are marked "• • •"; medium priority are marked "• •" and low priority are marked "•". Rationale used in this prioritization is presented at the end of the appendix.

Parking Lots

• • • Littering in parking lots produces parking lot pollution. Signs prohibiting littering, as well as conveniently located trash cans, can help to reduce this problem.

• • • Spot clean by applying absorbent materials to spilled or leaded automotive or similar fluids (i.e., gasoline, oil, antifreeze). Absorbents can be used in any parking lot where leaks are observed, on wet areas or in frequently used stalls.

• • • Saturated absorbent material should be collected in approved disposal containers, and disposed of properly. In some jurisdictions, oil-soaked absorbent is considered a hazardous waste. Check with your local administering agency (usually Department of Health).

• • • Inspect and clean if necessary, storm drain inlets and catch basins within the property boundary before October 1 each year. Inlet cleaning is usually conducted using one of two methods, manual cleaning or by vacuum truck.

- Manual cleaning is the removal of debris and sediment using shovels, buckets, etc. Manual cleaning is recommended for a few (5 or less) small sized inlets (approximately 3' x 3' x 3').

- For sites with greater than 5 small inlets or large sized inlets, the vacuum truck method should be used. The vacuum truck method includes manual removal of debris (trash, branches, etc.) followed by removal of sediment and/or water with a vacuum truck. A vacuum truck company in your area can be found in the Yellow Pages under Sewer Contractors or Pumping Contractors.

• Signs should be posted prohibiting oil changing and other automotive repairs that could lead to a spill of parking lot pollutants.

• Sediment (less the debris) removed from the catchbasin or inlet cleaning should be analyzed for disposal. Pollutants of concern are lead; oil and grease; and hydrocarbons. In general, based on the analysis of sediments from inlet cleaning, it appears that in older cities all these pollutants have been found at elevated levels whereas, in the newer cities, the main pollutants in inlet sediments are hydrocarbons. If concentrations are elevated, the sediment should be disposed of as hazardous waste.

Landscaping and Grounds Maintenance

- Follow federal, state, and local laws governing the use, storage, and disposal of pesticides/herbicides.

- Use pesticides only if there is an actual pest problem (not on a regular preventative schedule).

- Avoid use of copper-based pesticides if possible. Use the least toxic pesticide for the job if alternatives are available.

  California Department of Pesticide Regulation is conducting a review of pesticidal and non-pesticidal alternatives to diazinon and chlorpyrifos for urban uses (see DPR site on WorldWide Web, www.cdpr.ca.gov).

- Do not use pesticides if rain is expected.

- Do not mix or prepare pesticides for application near storm drains, and use the minimum amount needed for the job.

- Use up pesticides. Rinse containers, and use rinse water as product. Dispose of unused pesticide as hazardous waste.

- Collect lawn and garden clippings, pruning waste, and tree trimmings. Chip if necessary, and compost.

- In muncipalities with yard waste recycling, leave clippings and pruning waste for pickup in approved bags or containers. Or, take to a landfill that composts yard waste.

- Do not place clippings, pruning waste, or tree trimmings in gutters. Do not blow or rake leaves, etc. into the street.

- Protect stockpiles and landscaping materials from wind and rain by storing them under tarps or secured plastic sheeting.

- Store pesticides, fertilizers, and other chemicals indoors or in a shed or storage cabinet.

- Schedule grading and excavation projects for dry weather.

Storage of Hazardous Materials

- • • Store hazardous materials and wastes where they are protected from rain and in a way that prevents spills from reaching the sanitary sewer or storm drain.
- • • Keep lids on waste barrels and containers, and store them indoors or under cover to reduce exposure to rain.
- • All hazardous wastes must be labeled according to hazardous waste regulations. Consult the Fire Department or your local hazardous waste agency (typically County Environmental Health) for details.
- • Keep wastes separate to increase your waste recycling/ disposal options and to reduce your costs.
- • Never mix waste oil with fuel, antifreeze, or chlorinated solvents. Consult your hazardous waste hauler for details.
- • Double-contain large quantities of hazardous fluids to prevent accidental discharges to the sanitary sewer and storm drain. Consult the Fire Department for details.
- • • Keep storage areas clean and dry. Conduct regular inspections so that leaks and spills are detected as soon as possible.

Outdoor Waste Receptacle Areas

- Spot clean leaks and drips routinely to prevent runoff of spillage.
- Minimize the possibility of pollution from outside waste receptacles by doing at least one of the following:
  - use only watertight waste receptacle(s) and keep the lid(s) closed, or
  - grade and pave the waste receptacle area to prevent run-on of storm water, and install a low containment berm around the waste receptacle area, or
  - install a roof over the waste receptacle area.

Fountain/Cooling Equipment Maintenance

- • • Never discharge fountain water to a street or storm drain.
- • When emptying a fountain, let chlorine dissipate for a few days, and then recycle/reuse water by draining it gradually onto a landscaped area, or
- • • Contact the local sewage treatment authority. You may be able to discharge to the sanitary sewer.

• • • Do not use copper-based algaecides unless absolutely necessary. Control algae with chlorine or other alternatives to copper-based pool chemicals. Copper is a powerful herbicide. Sewage treatment technology cannot remove all of the metals that enter a treatment plant.

• • • Make sure all discharges from cooling towers or boiler blowdown go to the sanitary sewer and not to the street, storm drain or creek. It is okay to discharge condensate from cooling equipment into the storm drain.

• • Make sure your maintenance contractor is knowledgeable and skilled at minimizing corrosion with proper chemical treatment.

Shopping Center Maintenance

Table 1 lists BMPs that should be used during maintenance of shopping center structures and surfaces, including sidewalks.

Spill Control

• • • Maintain and keep current, as required by other regulations, a spill response plan and ensure that employees are trained on the elements of the plan.

• Contain and cover all solid and liquid wastes – especially during transfer.

• • Purchase and maintain absorbent materials in accordance with local regulations and procedures for containment and cleanup of different spills, and make sure they are easily accessible anywhere in the shop. Saturated absorbents generally must be disposed of as hazardous waste.

• • "Spot clean" leaks and drips routinely. Leaks are not cleaned up until the absorbent is picked up and disposed of properly.

• • • Check floor drains to ensure that they are not connected to or discharge to the storm drain system.

Education and Training

• • • Train all maintenance employees upon hiring – and annually thereafter - on personal safety, chemical management, and proper methods for handling and disposing of waste. Make sure that employees understand storm water discharge prohibitions, wastewater discharge requirements, and these best management practices. Use a training log or similar method to document training.

• • Post instructional/informational signs around your place of business for customers and employees. Put signs above all sinks prohibiting discharges of vehicle fluids and wastes. Put signs on faucets (hose bibbs) reminding employees and customers to conserve water and not to use water to clean up spills.

Table 1. Cleaning of Surfaces and Structures

Type of Surface	Characteristics	Cleaning Technique	Discharge to Storm Drain	Disposal Alternatives
Sidewalks, Plazas	No oily deposits	Sweep, collect and dispose of debris and trash; then wash.	Okay to discharge to storm drain.	
Sidewalks, Plazas, Driveways	Light oily deposits	Sweep, collect and dispose of debris and trash. Clean oily spots with absorbent, place oil-absorbent boom around storm drain, or a screen or filter fabric over inlet.	Okay to discharge to storm drain, provided an oil-absorbent boom or filter fabric is used. No oily sheen should be visible in the water draining into the storm drain.	
Parking lots and driveways	Heavy oily deposits	Sweep, collect and dispose of debris and trash. Clean oily spots with absorbent materials. Use a screen or filter fabric over inlet, then wash surfaces.	Seal storm drains. Can not be discharged to the storm drain.	Vacuum/pump wash water to a tank or discharge to sanitary sewer.
Building exteriors and walls	Glass, steel, or painted surfaces (post1978/no lead in paint	Washing without soap.	Okay to discharge to storm drain provided the drain is sealed first with a fabric filter to capture dirt, paint particles and flakes or oil absorbent boom.	Can alternately be sent to landscape areas.
		Washing with soap.	Can not be discharged to storm drain.	Direct washwater to sanitary sewer or vacuum/pump water to a tank.
Building exteriors	Painted with lead-based or mercury-additive paint	Washing with or without soap.	Seal storm drains. Cannot be dischsrged to storm drain.	Vacuum/pump to a tank. Check with POTW for discharge to sanitary sewer.
Graffiti Removal	Graffiti	Using wet sand blasting. Minimize use of water; sweep debris and sand.	Can be discharged to storm drain if washwater is filtered through a boom.	Can alternately be directed to landscaped areas.
		Using high pressure washing and cleaning compounds.	Seal storm drains. Cannot be dischsrged to storm drain.	Vacuum/pump washwater to sanitary sewer. Check with POTW about pre-treatment.
Masonary	Mineral Deposits	Acid Washing.	Seal storm drains. Cannot be discharged to storm drain.	Rinse treated area with alkaline soap and direct washwater to a landscaped or dirt areas. Alternately, washwater may be collected and neutralized to a pH between 6 and 10, then discharged to landscaping or pumped to sanitary sewer.

Source: Santa Clara Valley Urban Runoff Pollution Prevention Program

• • • Label storm drain inlets within the property boundary, by paint/stencil (or equivalent), to indicate whether they flow to an on-site treatment device, directly to the sanitary sewer, or to a storm drain. Labels are not necessary for plumbing fixtures directly connected to the sanitary sewer.

Rationale for Assigning High Priority to Selected BMPS

BMPs that are assigned high priority (• • •) are mostly preventative practices that are inexpensive to implement versus collection, treatment and disposal of water that has picked up pollutants. The rationale used in this report is listed below:

1) Rationale: Prevention practices are cost effective, already widely used and relatively inexpensive to implement vs. collection, treatment and disposal of wastewater.

2) Rationale: Pollutants from incidental spills and leaks and trash will collect in storm drain facilities during dry weather period and will be a significant source of pollutants during first significant storm. Cleaning will remove this potential source.

3) Rationale: The public in general do not realize that storm drains flow directly through to the ocean without treatment. Labeling of storm drains is an effective method of public education.

4) Rationale: HAZMAT and HAZWASTE are toxic to aquatic life and waterfowl in streams and ocean and prevention of spills is more cost effective than cleanup.

5) Rationale: Spills are cheaper to clean up when quickly contained. A spill response plan will prepare employees to use equipment and material available for cleanup, and to ensure their safety while doing the cleanup.

6) Rationale: Improperly plumbed floor drains can become a direct point of discharge of spills that occur indoor and outdoors to streams and other waterways.

7) Rationale: Cleaning products, disinfectants, and pesticides are toxic to aquatic organisms and wildlife and must be prevented from entering the storm drainage system.

Most of the information on shopping center BMPs was derived from the following sources:

Santa Clara Valley Urban Runoff Pollution Prevention Program

Tahoe Regional Planning Agency Handbook of Best Management Practices

Sources of Additional Information

4Z Program and BMPs for Mobile Cleaners

Alameda Countywide
Water Program

Contra Costa
Clean Water Program

Fairfield-Suisun
Urban Runoff
Management Program

Marin County
Stormwater Pollution
Prevention Program

San Mateo Countywide
Stormwater Pollution
Prevention Program

Santa Clara Valley
Nonpoint Source Pollution
Control Program

Vallejo
Sanitation and Flood
Control District

BASMAA

August 22, 1996

David Wyett
Cleaning Equipment Trade Association - San Francisco Bay Area Chapter
1441 Terminal Avenue
San Jose, CA 95112

Dear Mr. Wyett:

This letter serves as our endorsement of the "Mobile Cleaner Best Management Practices for Waste Water Runoff" dated September 23, 1994 developed by the San Francisco Bay Area Chapter of the Cleaning Equipment Trade Association (CETA). This endorsement is based on our recognition that the best management practices (BMPs) are intended to apply to the most common mobile cleaning applications and are based on best professional judgment. As such, we recognize that there will be situations where the recommended procedures will have to be tested to affirm their applicability and effectiveness. We also recognize that the BMPs are recommendations and that the most appropriate, and environmentally and regulatory sound practices must be determined on a case-by-case basis, with consideration of the type and location of actual mobile cleaning applications. The recommended practices provide a sound basis for making such case-by-case determinations.

DRAFT

To that end, we started a source control/recognition program for a subset of mobile cleaners—surface cleaners—to promote use of the BMPs and to establish a model for dealing with discharges of this type. In reviewing the CETA BMPs and developing educational materials for this subset of cleaners, we made small changes to the BMPs for some surface cleaning activities to clarify and simplify decision making for cleaners on the job site. We join with the San Francisco Bay Regional Water Quality Control Board in strongly recommending that surface cleaners participate in the source control/recognition program, become Recognized Mobile Cleaners, and use the BMPs when cleaning.

In conjunction with the Regional Board, BASMAA also fully supports and endorses the practice of no discharge of wastewater to storm drains in all circumstances where soaps or chemicals are used. Such discharges would violate discharge prohibitions established by our member storm water programs. They would also be in violation of the California Water Code and Federal Clean Water Act unless the discharge is specifically authorized by a NPDES permit issued by the State. Please note that this endorsement by BASMAA does not legally authorize any discharge, whether or not a BMP is used.

Bay Area
Stormwater Management
Agencies Association
[illegible] Webster Street
[illegible] 500
Oakland, CA 94612
510.286.0615

B A S M A A

We appreciate CETA's efforts to coordinate the implementation of the BMPs. We believe the best approach to resolving water quality and waste disposal issues is through the involvement and participation of affected parties. This cooperative approach will promote environmental protection while meeting the demand for mobile cleaning services.

If you have any questions, please call BASMAA Executive Director, Geoff Brosseau at (510) 286-0615.

Sincerely,

Donald P. Freitas, Chair
BASMAA Board

DRAFT

STATE OF CALIFORNIA
REGIONAL WATER QUALITY CONTROL BOARD
SAN FRANCISCO BAY REGION

STAFF SUMMARY REPORT
MEETING DATE: August 21, 1996

ITEM: 15

SUBJECT: PILOT SOURCE CONTROL AND RECOGNITION PROGRAM FOR MOBILE CLEANERS - Status Report

DISCUSSION: The intent of this item is to inform the Board on this pilot program and to raise issues pertinent to its success. The pilot program is noteworthy for two reasons: it targets a largely unregulated source of polluted discharges to waters in the Region; and it is an outreach based program, based on resolving problems through involvement and education of all affected parties. The pilot program emphasizes recognition of good businesses versus "bad actors".

A major action area of municipal storm water management programs is the elimination and prevention of discharges other than storm water to storm drain systems. Washwaters are some of the more commonly observed "non-storm water discharges". Specifically, mobile cleaners (surface cleaners, janitorial services, auto detailers, carpet cleaners, window cleaners) have been identified as a significant source of discharges of material, wastes, and polluted waters to storm drain systems in the San Francisco Bay Area. However, these discharges are difficult to deal with because of the variable quantity and quality of the discharge, the intermittent nature of the discharge, and the mobility of the discharger. Consequently, we have worked with the Bay Area Stormwater Management Agencies Association (BASMAA) on the development of a pilot source control/recognition program for mobile cleaners to resolve these issues.

The pilot program focusses on surface cleaners as a target group of mobile cleaners. Surface cleaners include steam cleaners and pressure washers that clean sidewalks, plazas, parking areas, driveways, drive-throughs, and building exterior surfaces. The surface cleaner pilot program will be used as a prototype for developing materials and approaches for the remaining types of mobile cleaners.

To develop the surface cleaners pilot program, meetings were held with surface cleaners and their customers in which the participants were given a chance to express opinions on what would constitute a successful program. One finding was that customers need educating, as well as the surface cleaners, to ensure that the value of hiring a responsible surface cleaner is understood. As a result, a program consisting of education and recognition has been produced. Surface cleaners who demonstrate awareness of and implement the prescribed pollution prevention practices will be issued a "recognition letter". The list of recognized cleaners will be provided to businesses and agencies that hire surface cleaners.

To date, the pilot program has completed the development of outreach material (including identification of pollution prevention practices) and scheduled an outreach/recognition workshop for surface cleaners on August 13, 1996. The main premise behind the pollution prevention measures is that washwaters containing soaps or other cleaning agents are toxic and should not be discharged to storm drains. There are scenarios, however, in which discharges would not be considered polluted if the appropriate pollution prevention measures are implemented, and as such, discharge to storm drains would be allowed. The complete list the outreach materials and events scheduled are described in Appendix A.

We have also sent outreach letters to entities affected by the program to make them aware of the program and how it may affect them and to solicit their cooperation and participation. These include surface cleaners and cleaning equipment distributors, surface cleaner customers, wastewater treatment authorities, municipal storm water management programs, and municipal departments that hire or inspect mobile cleaners. Issues pertinent to these entities and recommended actions are described in Appendix A.

One of the outstanding issues that still needs to be resolved pertains to acceptance of these washwaters by wastewater treatment authorities. Currently, conditions for acceptance of these discharges do not exist or otherwise vary in terms of quantity and quality criteria and disposal costs. For example, some systems will readily accept these discharges, while others impose conditions and costs that may be prohibitive. We intend to work with the Bay Area Dischargers Association and the Bay Area Pollution Prevention Group to resolve this issue. Our intent is to promote acceptance of these discharges such that recognized cleaners are provided incentive and reward for their efforts, and wastewater treatment authorities are provided appropriate credit for acceptance of new discharges.

Another issue concerns the appropriate mechanism for Regional Board endorsement of the program and the proposed allowance of certain discharges to storm drains. Potential actions may include prohibition of discharges that are not in accordance with prescribed pollution prevention measures, NPDES permit(s) for certain discharges, or non-regulatory endorsement of "recognized mobile cleaners". These and other options will be evaluated during the pilot program, and we will provide the Board with regular updates on the progress of the program.

RECOMMENDATION: This is an information item. No action is necessary at this time.

Appendices:

A - Outreach Materials and Scheduled Events
Affected Entities, Issues, and Recommended Actions

APPENDIX A

PILOT SOURCE CONTROL AND RECOGNITION PROGRAM FOR MOBILE CLEANERS

Outreach Materials and Scheduled Events

"Pollution from Surface Cleaning" - This folder was prepared to educate surface cleaners about the effects of wash water discharges to the storm drain system and to prescribe effective, low-cost pollution prevention practices.

"We'll do the Job Right!" - This card will be distributed by "Recognized Mobile Cleaners" to potential customers. Surface cleaners will use this card to proclaim their qualifications and their intent to prevent water pollution while conducting the cleaning work.

"When You Contract for Surface Cleaning....." - This flyer is geared towards customers who regularly hire surface cleaners. It alerts the customers about the outreach/ recognition program and specifies the pollution prevention practices that should be used to prevent surface cleaning discharges to the storm drain system. The flyer is suitable for photocopying and will be made available for mass mailings by the municipalities.

Pollution Prevention Voucher - The voucher is to be filled out in duplicate by a Recognized Mobile Cleaner upon completion of a cleaning project. Retention of a copy by both the cleaner and the customer provides a record for municipal or State inspectors of the type of surface cleaned, the cleaning method used, and how the wash water was disposed.

Outreach/Recognition Workshop - Outreach workshops will be held to provide surface cleaners with the technical information required to protect the environment, comply with the law, and become a Recognized Mobile Cleaner. The first workshop is scheduled for August 13 and two additional workshops are in the planning stages. The workshops will be videotaped for viewing by surface cleaners who were unable to attend one of the scheduled dates.

Recognition Test and Letter - The true/false, multiple choice exam will take 15-20 minutes to complete. Surface cleaners that correctly answer a minimum percent of the questions will receive a "recognition letter" from BASMAA. This letter can be displayed to customers as proof that the cleaner is qualified to complete the job in an environmentally responsible manner.

Database of Recognized Cleaners - BASMAA will prepare and update a database of Recognized Mobile Cleaners. Municipalities can request a copy of the database to promote recognized cleaners in their area, while potential customers can request a copy of the database when soliciting bids for cleaning projects.

Workshop Training Kit - A workshop training kit will be assembled to allow municipalities and/or wastewater treatment authorities the opportunity to offer the Outreach/Recognition Workshop at their discretion. Included in the kit will be a videotape of one of the scheduled workshops, outreach materials to be distributed, the recognition test, a scoring key, and instructions on how to conduct the workshop and administer the test.

PILOT SOURCE CONTROL AND RECOGNITION PROGRAM FOR MOBILE CLEANERS

Affected Entities, Issues, and Recommended Actions

ENTITY	ISSUES	RECOMMENDED ACTIONS
Surface Cleaner	• Surface cleaners are liable for pollutant discharges to the storm drain system resulting from their cleaning activities. • Municipalities will soon be enforcing discharge prohibitions more reliably and possibly more severely. • An opportunity is available for surface cleaners to become educated on appropriate methods of wash water disposal and gain some good publicity for environmentally responsible cleaning.	• Participate in the program by attending a source control / recognition workshop and becoming a Recognized Mobile Cleaner. • Use pollution prevention practices when cleaning.
Surface Cleaner Customer	• Surface cleaner customers are liable for pollutant discharges to the storm drain system resulting from contracted cleaning activities. • Municipalities will soon be enforcing discharge prohibitions more reliably and possibly more severely. • Customers will be required to take responsibility for the method of disposal utilized by a contracted cleaner.	• Participate by becoming familiar with the prescribed pollution prevention practices. • Make use of mobile cleaners who participate in the program by only hiring "Recognized Mobile Cleaners". • Supervise contracted cleaners to ensure that appropriate pollution prevention practices are used to dispose of any wash water generated from their activities.
Wastewater Treatment Authority	• Wash water determined to be inappropriate for disposal in the storm drain system may be discharged to the sewer system. • Mobile cleaners are being directed to contact the local wastewater authority for discharge requirements prior to disposal in the sewer system.	• Participate by becoming familiar with the prescribed pollution prevention practices and incorporating them into pretreatment or pollution prevention programs if appropriate. • Assist mobile cleaners who call for advice in determining acceptability of their wash water for sewer disposal.
Municipality	• A key component of the municipal storm water permit program is the effective prohibition of non-storm water discharges to storm drain systems. • Municipalities and businesses that hire mobile cleaners are liable for discharges from these cleaning activities.	• Participate by becoming familiar with the prescribed pollution prevention practices and incorporating them into the municipality's own storm water management program. • Become aware of surface cleaners and customers in the municipality's jurisdiction. • Make use of mobile cleaners who participate in the program by only hiring "Recognized Mobile Cleaners".

Mobile Cleaner

BEST MANAGEMENT PRACTICES

for Waste Water Runoff

Presented by

Cleaning Equipment Trade Association

2535 Pilot Knob Road • Suite 105
St. Paul, Minnesota 55120

Phone: 1-800-441-0111 or 612-686-7086 Fax: 612-686-7088

September 23, 1994

Cleaning Equipment Trade Association

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SAN FRANCISCO BAY AREA CETA
(Cleaning Equipment Trade Association)

September 23, 1994

To: Members of the Cleaning Industry

Subject: Mobile Cleaner Best Management Practices for the San Francisco Bay Area (dated August 2, 1994)

Attached for your review and use are Best Management Practices (BMP's) for the more common mobile washing applications. These BMP's have evolved from many discussions among mobile users, distributors, and sewer and storm water officials over the past year and a half.

This document will continue to be refined and updated as testing results and other data become available. However, the current document has the endorsement of the County of Alameda and the San Francisco Bay Area Regional Water Quality Control Board. Our objective is to obtain similar endorsements from all applicable agencies in the Bay Area.

SF Bay Area CETA

SARB_001123

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Alameda County
Urban Runoff
Clean Water Program
A Consortium of Local Agencies

951 Turner Court, Hayward CA 94545
(510) 670-5543 FAX (510) 670-5262

Member Agencies:

Alameda County

Alameda County Flood Control District

Alameda

Albany

Berkeley

Dublin

ryville

Fremont

Hayward

Livermore

Newark

Oakland

Piedmont

Pleasanton

San Leandro

Union City

Zone 7 of the Alameda County Flood Control District

September 12, 1994

Cleaning Equipment Trade Association (CETA)
c/o Mr. David Wyett
2535 Pilot Knob Road, Suite 105
St. Paul, Minnesota 55120

On behalf of the Industrial Subcommittee, I wish to acknowledge the cooperative effort in compiling the Mobile Cleaner Best Management Practices, version dated August 2, 1994. Our Alameda County Urban Runoff Clean Water Program appreciated the chance to work with your organization to update the document.

This document has been reviewed and approved by our Management Committee and Industrial Subcommittee. We believe that you have incorporated the best management practices (BMPs) known to date to eliminate pollutant discharges to storm water. As with most of the provisions associated with the Urban Runoff Program, this approval process is dynamic. I would like to request continued dialog to assist in further refining these BMPs. Our group would like to revisit these BMPs annually. I look forward to continuing to work together to exchange information and refine field techniques.

Paul Zoltarelli
Chair, Industrial Subcommittee

STATE OF CALIFORNIA PETE WILSON, Governor

CALIFORNIA REGIONAL WATER QUALITY CONTROL BOARD
N FRANCISCO BAY REGION
1 WEBSTER STREET, SUITE 500
OAKLAND, CA 94612
(510) 286-1255

September 6, 1994

David Wyett, Chairman
San Francisco Bay Area
Cleaning Equipment Trade Association
1441 Terminal Avenue
San Jose, CA 95112

Subject: Mobile Cleaner Best Management Practices

Dear Mr. Wyett:

This letter serves as our endorsement of the Mobile Cleaner Best Management Practices (BMPs), dated August 2, 1994, developed by the San Francisco Bay Area Cleaning Equipment Trade Association (CETA). This endorsement is based on our recognition that the BMPs are intended to apply to the most common mobile washing applications and are based on best professional judgement. As such, we recognize that there will be situations where the recommended procedures will have to be tested to affirm their applicability and effectiveness. We also recognize that the BMPs are recommendations and that the most appropriate and environmentally and regulatory sound practices must be determined on a case-by-case basis, with consideration of the type and location of actual mobile washing applications. The recommended procedures provide a sound basis for making such case-by-case determinations.

Most importantly, we fully support and endorse the practice of *no discharge* of wash waters to storm drains in all circumstances where soaps or chemicals are used. Such discharges would violate discharge prohibitions established by municipalities. They would also be in violation of the California Water Code and the Federal Clean Water Act unless the discharge is specifically authorized by a NPDES permit issued by the State. The appropriate disposal option is discharge to the sanitary sewer. We will continue to work with sanitary sewer agencies (Publicly Owned Treatment Works) to secure their acceptance of these discharges.

We appreciate CETA's efforts to coordinate the development of the BMPs. We believe the best approach to resolving water quality and waste disposal issues is through the involvement and participation of affected parties. The work group that you have sponsored provides the best opportunity to identify the most economically and technically feasible management practices for mobile cleaning applications. This cooperative approach will enable streamlining any required permits at the local and state levels. If you have any questions, please call me at 510-286-0962.

Sincerely,

Thomas Mumley
Storm Water Program Coordinator

CETA

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Introduction

Storm drains and sanitary sewers are the two principal routes by which pollutants reach the South San Francisco Bay. Storm drains carry runoff from streets, urban centers, industrial sites and open spaces into local streams, creeks, marshes and Bay waters. Sanitary sewers carry wastes to wastewater treatment plants, but small amounts of some pollutants reach the Bay in the treated water.

Since the Clean Water Act was passed in 1972, a lot of effort has gone into cleaning our creeks, waterways and the Bay. One of the contributors to this pollution has been wash water runoff from pressure washing and steam cleaning.

These Best Management Practices (BMP's) for mobil cleaners describe the most common types of cleaning and the proper waste water disposal for each one.

Remember, this is a general purpose booklet and not an attempt to describe each and every washing application. If you have questions about a specific waste disposal problem, contact your city or county non-point source group, your local Public Owned Treatment Works (POTW), your equipment supplier, or the Cleaning Equipment Trade Association (CETA) office for a referral.

It is the responsibility of each contractor to operate his/her business in a manner that complies with local stormwater and wastewater discharge requirements. Understanding and using this manual will help you comply.

SARB_001126

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SAN FRANCISCO BAY AREA CETA
(Cleaning Equipment Trade Association)

Working Group Non-Government Participants

Distributors:			
Jack Keeler	Bay Area Chemex	(415)952-9997	So San Fran
Hugh Jenkins	Hi Tech Pressure	(510)887-1755	Hayward
Charlene Laymon	Hotsy Bay Area	(408)998-3051	San Jose
Dave Wyett	Kleen Quip	(408)452-0727	San Jose
Joseph Flores	Kleen-Rite	(408)453-4543	San Jose
Contract Cleaners:			
Rick Christi[redacted]	Power Washing Service	(510)449-6890	Livermore
Jesus Valerio	Rainbow Mobile Wash	(415)967-0367	Mt. View

Acknowledgment

Special recognition to the Santa Clara County Nonpoint Source Pollution Control Program group for their help and encouragement on this project from day one.

Appreciation and thanks to Alameda County for their recommendations and endorsement; to the Regional Water Quality Control Board representative Tom Mumley for his participation, encouragement and letter of endorsement; and to the many POTW representatives from Santa Clara County and Alameda County who contributed their ideas and support.

SARB_001127

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Mobile Cleaner BMPs

Recommendations for disposal of washwater are listed in the order of preference.

I. Transportation-Related Washing

A. Fleet Washing - Exterior Only - removing mainly dirt; with or without soap:

No storm drain disposal permitted; must discharge to sanitary sewer/dirt; some unavoidable evaporation off paved surfaces.

Washwater can not be discharged to the storm drain. For disposal:

Best: Use wash pads that capture the washwater and discharge it to the sanitary sewer. (Ideally, the customer has established a separate wash area that captures the washwater. Or, contract cleaner can use temporary wash pad and pump to sanitary sewer.)

2nd: Seal storm drains. Washwater runoff and excess soapy water must be collected and pumped or otherwise discharged as follows:

- Best: Sanitary sewer (Pump into sanitary system clean out/sink or into an on-site private sanitary sewer manhole; verify with the facility manager that it is not a storm drain manhole.)
- 2nd: Landscaped[1] or dirt area (Note: Be aware that soapy washwater may adversely affect landscaping. Should be directed onto dirt area sufficiently large enough to contain all the water. Discuss with the building owner.)

If a significant amount of washwater runoff evaporates at the site before it can be collected, and the site is routinely used for this purpose, the paved area itself must be cleaned either before **October 15th** (the formal beginning of the rainy season) or at the end of contract (whichever comes first). That washwater must be collected and discharged to sanitary.

[1] For minimal discharge flows only. Repetitive use of the same area or excessive waste volume to the same area may be illegal.

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B. Engine/Equipment Degreasing

Auto/truck drive train cleaning
Engine degreasing
Airplane cleaning, including landing gear

With or without soap, no storm drain disposal permitted; requires pre-treatment before discharge to sanitary; should be cleaned on a wash pad; requires discussion with customer's facility operator

Because it is likely that pollutants (esp. petroleum products and metals) are concentrated in these washwaters, the local POTW (Public Owned Treatment Works) will require some type of pre-treatment before discharge to sanitary sewer. Contact the POTW for requirements and additional information. Contact the facility operator regarding wash pad and pre-treatment equipment available on-site (i.e. oil/water separators, coalesors,...). A partial list of local distributors who may carry this equipment is on page 2. See the yellow pages for additional distributors.

C. Acid Cleaning of Unpainted Trucks/Containers

Trucks and metal containers (unpainted) using acid detergents

Acid runoff from cleaning unpainted trucks or containers with acid detergents must be neutralized to a pH between 6 and 10 before pumping to sanitary. Contact local POTW for additional information. *Never discharge to storm drain.*

D. Mobile Auto Detailing - infrequent, light cleaning, using soap

(rarely at same site; removing mainly dirt; with minimum water volume)

Run off:

Best: Minimized runoff may remain on paved surfaces to evaporate. If there is sufficient water volume to reach the storm drain, plug the storm drain and pump the water to the sanitary sewer.

2nd: Landscaped[1] or dirt area (Note: Be aware that soapy washwater may adversely affect landscaping. Should be directed onto dirt area sufficiently large enough to contain all the water. Discuss with the building owner.)

Remaining soapy water in bucket:

Best: Should be discharged to sanitary.

2nd: May be distributed over a dirt area.

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E. Car Lot Rinsing for Dust Removal - no soap

If rinsing dust from exterior surfaces using **water only**, and no soap/solvent, may discharge runoff to storm drain or to landscaped or dirt areas. Prevent contamination of the runoff by not allowing it to run through oil deposits on the pavement or in the gutter.

F. Semi Trailers and Boats

Truck trailer, interior cleaning (food-related)

Sweep, collect and dispose of debris. Use dry cleaning methods as much as possible. Food residue must be disposed of as garbage or sent to the sanitary sewer. Avoid hosing down the trailer. Washwater can not be discharged to storm drain; it should be pumped to sanitary sewer. Contact POTW for more information.

Truck trailer, interior cleaning (toxic substances) - may require special training

If toxic materials have been shipped in the trailer, and there has been a spill:

* Do not hose down the spill,
* Protect nearby storm drains, and
* Contact the local fire department for guidance.

Boat cleaning (if paint chips are being removed in preparation for painting)

Filtered washwater must be discharged to sanitary sewer. Contact POTW for further information. Dispose of paint particles appropriately according to paint type: dispose of as hazardous waste if paint is lead-based, copper-based, or contains tributyl tin or PCBs; otherwise, dispose of paint particles as garbage.

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II. Surface Cleaning

A. Sidewalks and Plazas - using soap

Washwater must go to sanitary sewer.

Sweep, collect and dispose of debris and absorbent. The BMPs in this section do not apply if there has been an oil or other hazardous material spill on the site. In the case of a spill, contact the local fire department for guidance.

B. Sidewalks and Plazas with no oil deposits - no soap

Sweep, collect and dispose of debris. Washwater may go to storm drain.

C. Sidewalks, Plazas, Driveways ,Drive-through Window Areas with light oil, *frequently cleaned* - no soap

Sweep, collect and dispose of debris. Dry clean oil spots with absorbent and dispose of absorbent as garbage. Place oil absorbent boom around storm drain. Washwater may go to storm drain through an oil-absorbent boom. No oil sheen should be visible on the water flowing into the storm drain.

D. Drive-throughs, Driveways, Parking Garages, Service Stations with excess oil deposits - with or without soap; *not frequently cleaned.*

Seal storm drains. Sweep, collect and dispose of debris. Dry clean oil spots with absorbent and dispose of absorbent in a legal manner. Vacuum/pump washwater to sanitary. Washwater disposal options should be discussed with the facilities operator/site manager. Best to discharge through an oil/water separator. One may be available at the site, however, do not use an oil/water separator intended to capture cooking oil. See attached (p. 2) partial list of oil/water separator distributors, or check your local yellow pages. Pre-treatment may not be required, but contact the local POTW for more information. If there has been an oil spill, contact the local fire department for guidance.

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E. Building Exteriors and Walls

Note: If soap is used, washwater must not go to storm drain. All debris must be kept out of storm drains.

Glass and Steel Buildings - no soap used

Best: Direct washwater runoff to dirt/landscaped areas.

2nd: Discharge directly to storm drain. We recommend that you seal the drain with a fabric filter to capture the dirt in the washwater.

Painted buildings, with paint job in good shape - no soap used

Painted after 1978, i.e. no lead

Best: Direct washwater runoff to dirt/landscaped areas.

2nd: Use filter fabric to prevent paint particles from entering storm drain. Washwater may go to storm drain through the filter fabric--never directly. Dispose of collected particles as garbage.

Painted buildings, with lead-based or mercury-additive paint - with or without soap)

Seal storm drains and vacuum/pump washwater to a tank. Water and sludge may need to be disposed of as hazardous waste. Consult POTW and local hazardous waste regulators (i.e. County Health or Fire Department)

Painted buildings, *to remove paint* and clean in preparation for painting - with or without soap

Consult POTW and local hazardous waste regulators (i.e. County Health or City Fire Department). These BMPs do not address the disposal of paint.

F. Graffiti Removal

Using wet sand blasting

Minimize quantity of water used. Any runoff should be:

Best: Directed to landscaped or dirt area.

2nd: Filtered through boom to keep sand out of drain.

Sweep debris and sand. Dispose of all waste to avoid future run off contamination.

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Using high pressure washing and cleaning compound

Best: Direct washwater run off to dirt/landscaped area. No run off can go to storm drain.

2nd: Seal storm drains and vacuum/pump washwater to sanitary. Contact POTW for guidance, as harsh cleaning compounds may require pre-treatment.

G. Masonry Efflorescence using acid wash to remove mineral deposits on masonry

Seal/block storm drain.

Best: Rinse treated area with alkaline soap and direct rinse water to a landscaped/dirt area.

2nd: Collect washwater. Neutralize washwater to a pH between 6 and 10. Pump to a sanitary cleanout at the site, into a sink or a toilet, or contact the POTW.

III. Food-Related Cleaning

A. Restaurant Alleys, Grocery Dumpster Areas (outdoors)

No discharge allowed to storm drain.

Best: Dry Clean only, if possible (e.g. using rags, absorbents, and sweeping debris)

2nd: Dry clean first. Seal storm drain. Wash area. Vacuum or pump washwater to sanitary sewer. Screen washwater for particles.

B. Restaurant Cleaning of Floor Mats, Exhaust Filters, etc.

Note: Washing mats outdoors and allowing the washwater to drain to a storm drain is prohibited.

Best: Clean mats, etc. inside building with discharge to sanitary sewer (sink or a floor drain).

2nd: Clean mats, etc. outside, in bermed area with a drain that is connected to the sanitary sewer system.

C. Kitchen Grease

Kitchen recyclable oil, grease, and meat fat

Save for recycling in tallow bin or other sealed containers. Never pour into a sink, floor drain, or storm drain. Do not contaminate recyclable fats with waste grease from an interceptor or trap. See "Tallow" in the yellow pages.

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Kitchen waste grease from interceptor or trap

Never dispose of waste grease in the storm drain or creek, or into the sanitary sewer system. For waste grease disposal, see "Grease Traps" or "Septic" in the yellow pages.

D. Grocery Carts

If soap is used, washwater must be captured, filtered for particles, and pumped to sanitary.

If no soap is used:

Best: Capture washwater, filter for particles, and pump to sanitary sewer. If hot water is used, hot/warm water discharge to a creek is prohibited.

2nd: Washwater may be discharged to storm drain through a filter barrier (e.g. using boom) to filter out debris.

E. Lunch Wagons/Food Carts

Washwater must be discharged at a commissary equipped to accept and discharge wastewater to the sanitary sewer system. Never discharge any wastewater (except melted ice) to gutters or storm drains. Trucks and carts and any equipment should be cleaned on a properly equipped wash pad at the commissary. For a list of licensed commissaries see your county Health Department.

IV. Misc. or other

A. Mobile Homes

Decks

Roofs/Shingles

Awnings

Residential/Commercial Pool Decks

1. Landscaped[1] or dirt area (Note: Be aware that soapy washwater may adversely affect landscaping. Should be directed onto dirt area sufficiently large enough to contain all the water. Discuss with the building owner.)
2. If washwater doesn't go to dirt/landscaping:
   a. If soap is used, washwater must go to sanitary sewer.
   b. If soap is not used, washwater can be discharged to storm drain through a filtering apparatus (i.e. boom) to capture debris and particles.

   Exception: Treated wood shingles are often treated with a toxic material. Treated shingles should be dry cleaned only. Runoff from cleaning may be toxic to plants in a landscaped area and should never be discharged to the storm drain or sanitary sewer.

SARB 001115

4AA Sample Reporting Form

Alameda Countywide
Clean Water Program

Standard Stormwater Facility Inspection Report Form

Municipality: _____

Date: _____

Reason for Inspection: ☐ First Inspection ☐ Routine Inspection ☐ Response to Complaint ☐ Facility has closed or Facility Information has changed

NAME OF FACILITY	SITE ADDRESS

CONTACT NAME	PHONE	BUSINESS TYPE/ACTIVITY	SIC

Is the property owner different than the facility owner? ☐ yes ☐ no If yes, complete the following:

NAME PHONE

MAILING ADDRESS

Is the facility covered under any other programs or permits? (Check all that apply.) ☐ None ☐ Sanitary sewer

☐ Air quality ☐ Hazmat business plan ☐ Underground storage tanks ☐ Aboveground storage tanks

☐ Fire department(hazmat storage) ☐ Hazmat waste generator ☐ Other _____

Is the facility covered under a storm water permit? ☐ Does not need Coverage ☐ No, but may need to be (Refer to Regional Board)

☐ Individual ☐ General: Does the facility have a SWPPP? ☐ yes ☐ no

N/A = Not Applicable; PTNL = POTENTIAL for Pollutant Discharge: 1 = low potential, 2 = medium potential, 3 = high potential
ACTUAL Type of Discharge: BMP: 0 = BMPs are effective, 1 = BMPs are fairly/almost effective, 2 = BMPs are not effective, 3 = No BMPs are implemented
PEX = Pollutant Exposure, NSW = Non-Stormwater Discharge

AREAS OF ACTIVITY	N/A	PTNL	ACTUAL Type of Discharge			REMARKS: Describe recommendations, requirements, and time to implement. Check box if remark is a *requirement.*
			BMP	PEX	NSW	
A. Outdoor Process/Manufacturing Areas						☐
B. Outdoor Material Storage Areas						☐
C. Outdoor Waste Storage/Disposal Areas						☐
D. Outdoor Vehicle and Heavy Equipment Storage, Maintenance Areas						☐
E. Outdoor Parking Areas and Access Roads						☐
F. Outdoor Wash Areas						☐
G. Rooftop Equipment						☐
H. Outdoor Drainage from Indoor Areas						☐
I. Other (describe):						☐

ADDITIONAL COMMENTS/REMARKS

☐ See attached for more comments.

FIRST Follow-up Inspection (Date & Findings)	SECOND Follow-up Inspection (Date & Findings)

IORITY FOR RE-INSPECTION: ☐ 1; First ☐ 2; Second ☐ 3; Third

NFORCEMENT: ☐ None ☐ Verbal Notice ☐ Warning Notice ☐ Administrative Action ☐ Administrative Action w/ Penalty &/or Cost Recovery ☐ Legal Action

Facility Representative Signature: _____ Date: _____

Print Name of Facility Representative: _____ Inspector's Signature: _____

4BB APWA Guidance on Regulated Industries

APWA STORM WATER TASK FORCE

OVERVIEW OF THE NPDES GENERAL PERMIT FOR DISCHARGES OF STORM WATER ASSOCIATED WITH INDUSTRIAL ACTIVITIES

The California NPDES GENERAL PERMIT FOR DISCHARGES OF STORM WATER ASSOCIATED WITH INDUSTRIAL ACTIVITIES, EXCLUDING CONSTRUCTION ACTIVITIES (General Permit) was adopted by the State Water Resources Control Board (SWRCB) on November 19, 1991. Notices of Intent for coverage under the General Permit must be submitted to the SWRCB between the dates of January 15, 1992 and March 30, 1992. A California General Permit for Discharges of Storm Water Associated with Construction Activities is scheduled for adoption in Summer 1992.

The Federal storm water regulations identify the industry types, which are subject to storm water runoff, that require a permit. These industry types are described either by a specific description or by Standard Industrial Classifications (SIC) Code. The industry types identified include some facilities which may not typically be thought of as "industrial" and some facilities which are typically owned and operated by public agencies.

The General Permit covers storm water runoff from 10 of the following 11 categories listed in the Federal storm water regulations. The facilities included in each category are described in Attachment I and listed in the tables shown below in parentheses.

EPA Categories

i. Facilities subject to storm water effluent guidelines, new source performance standards or toxic pollutant effluent standards under 40CFR Subchapter N (Table 1)

ii. Certain manufacturing facilities (Table 2)

iii. Active and inactive oil and gas operations and mining facilities (Table 2)

iv. Hazardous waste treatment, storage, or disposal facilities (Table 4)

v. Landfills, land application sites, and open dumps that receive or have received any industrial wastes from facilities listed herein (Table 4)

vi. Recycling facilities, including metal scrap yards, battery reclaimers, salvage yards, and automobile junkyards (Table 2)

vii. Steam electric power generating facilities (Table 4)

viii. Transportation facilities which have vehicle maintenance shops, equipment cleaning operations, or airport deicing operations (Table 2)

ix. Wastewater treatment plants with design flows greater than 1.0 mgd or plants required to have a pretreatment program (Table 4)

x. Construction (will be covered under the separate General Permit for Discharges of Storm Water Associated with Construction Activities)

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xi. Other manufacturing facilities where materials, machinery, or products are exposed to storm water (Table 3)

General Information

A. Permit Fee

1. $250 in areas with a municipal NPDES permit
2. $500 in all other areas

B. To obtain a permit application form (NOI), call Stefanie Gordon at 916/657-0752

C. You will receive a letter 2 to 3 weeks after submitting your application confirming that you are covered by the General Permit

D. If you fail to submit an NOI by the March 30, 1992 deadline, submit an NOI anyway with an explanation why you were delayed

E. Certain determinations about this permitting process by the U.S. Environmental Protection Agency (EPA) may not apply in California. Procedures and applicability of the General Permit will be determined by the State Water Resources Board

F. The two major requirements of the General Permit are development and implementation of a Storm Water Monitoring and Reporting Program and a Storm Water Pollution Prevention Plan

G. Submit your completed NOI and permit fee to:

State Water Resources Control Board
Division of Water Quality
P.O. Box 1977
Sacramento, CA 95812-1977

Attention: Storm Water Permitting Section

H. A Standard Industrial Classification (SIC) Manual can be found at most libraries. To order a manual call:

1-800-872-6386 or 1-800-562-0245
Specify Title Code #84161-9.

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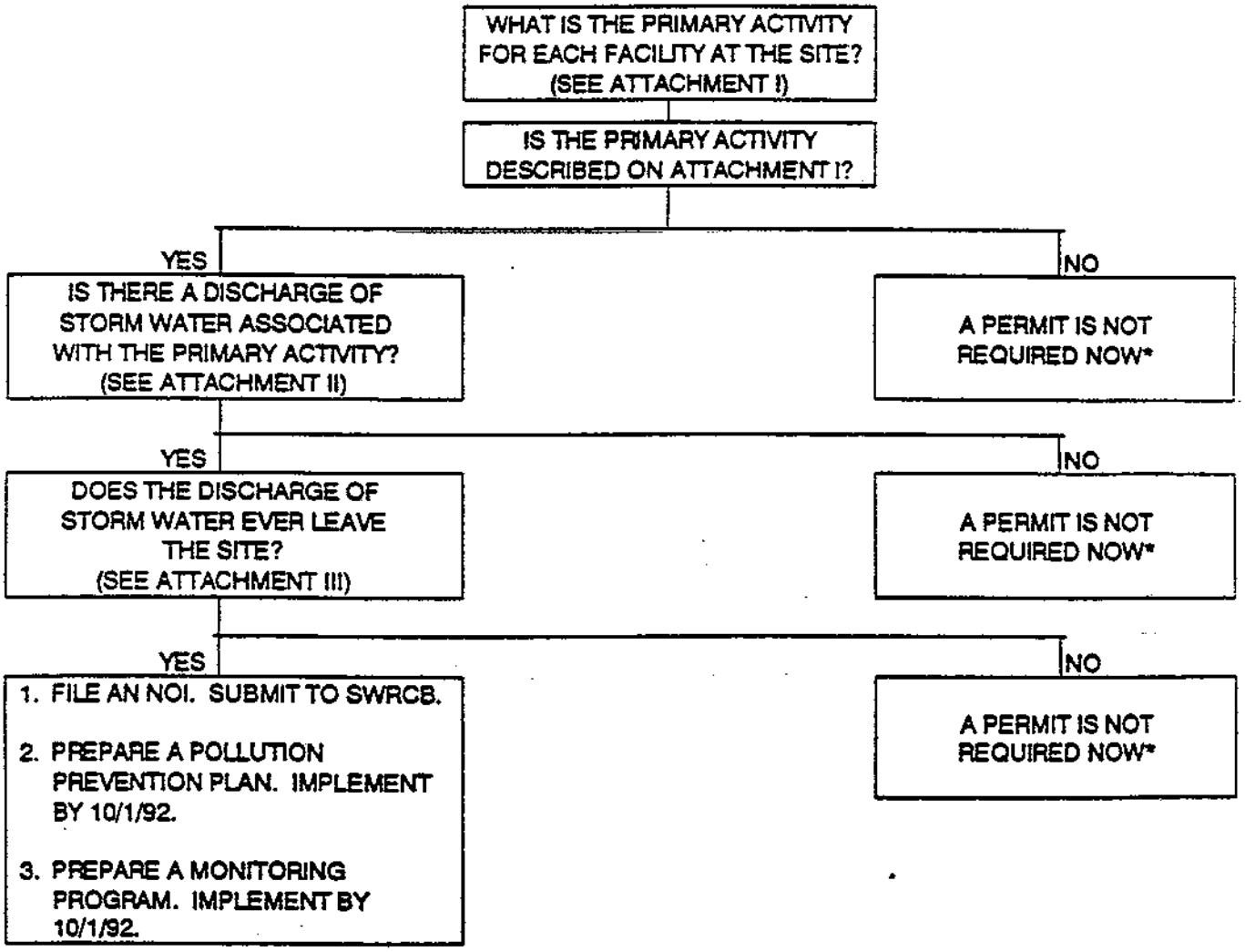
DECISION TREE

DOES THE GENERAL PERMIT FOR DISCHARGES OF STORM WATER ASSOCIATED WITH INDUSTRIAL ACTIVITIES APPLY TO MY SITE?



* LOCAL AGENCIES MAY ADOPT OTHER PERMITS, CONDITIONS, RULES OR ORDINANCES THAT APPLY TO YOUR INDUSTRY.

ATTACHMENT I

INTRODUCTION

The State NPDES General Permit for Discharges of Storm Water Associated with Industrial Activities (General Permit) covers 10 of the 11 categories of industrial facilities described in the federal storm water regulations. All 11 categories are described below. Industrial facilities owned or operated by governmental entities (including federal, state, and municipal facilities) and included in any of the 10 designated categories (Categories i through ix, and xi) are subject to General Permit requirements. Category x facilities will be covered by a separate General Permit for Discharges of Storm Water Associated with Construction Activities (scheduled for adoption in Summer 1992).

Category i through ix facilities must file a Notice of Intent to be covered by the General Permit if they discharge industrial storm water (see Attachment II) to waters of the United States (see Attachment III). Category xi facilities must file a Notice of Intent to be covered by the General Permit only if they have equipment or material (outdoor activities) exposed to storm water (see Attachments II and III).

Five categories of facilities (ii, iii, vi, viii, and xi) are defined by Standard Industrial Classification (SIC) codes. Application of SIC codes is described below. Affected SIC codes are listed in Tables 2 and 3.

The remaining six categories of facilities (i, iv, v, vii, ix, and x) are defined by industrial activity descriptions.

APPLICATION OF SIC CODES

Identify Each Facility Contained at the Site

A facility is defined as "something that is built, installed, or established to serve a particular purpose" (Webster's Ninth New College Dictionary, 1986). Therefore, identifying the "purpose" is critical in defining a facility, i.e., each facility will achieve a particular end which can be described with a SIC code.

If more than one activity is occurring, the site may involve two separate, but contiguous facilities. Factors to consider include physical barriers and separate management. For example, a hotel complex could include a marina facility managed by a separate party or separated by a physical barrier from the hotel complex. In this case, the marina would be considered a separate facility associated with industrial activity subject to the Permit requirements (Transportation SIC 4493).

Identify Primary Activity

Once all facilities are identified, determine the primary purpose for each facility. The primary purpose is determined by the principal product or groups of products produced or distributed, or services rendered. The principal product or service should be determined by its relative share of value added (gross production, sales, receipts, or revenues) at the facility. Once the primary purpose of facility is identified, you will be able to determine if the primary purpose is described by one of the listed SIC codes.

In issuing the General Permit, the SWRCB indicated that a facility must be permitted if the primary activity (purpose) at the facility is described by one of the listed SIC codes (whether or not the activity is primary or auxiliary to the owner or operator of the facility). Thus, the primary activity at the facility should be considered when applying the SIC codes rather than the primary business of the owner or operator.

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For example, a school bus maintenance facility is required to obtain a permit since establishments operating school buses (SIC 4151) are in one of the categories described in the storm water permit regulations, even though the facility is owned by an educational institution (e.g., a school district) which is not described by one of the listed SIC codes.

If a site contains two or more facilities each described by designated SIC codes, only one NPDES permit may be necessary if the owner of the site assumes responsibility for all facilities (see Attachment III - Who is Responsible for Obtaining the NPDES permit?). As an alternative, the operators for each facility could apply for separate permits.

GENERAL DESCRIPTION OF INDUSTRIAL FACILITY CATEGORIES

Category i

Facilities Listed Under 40 CFR Subchapter N

These consist of all facilities subject to promulgated: a) storm water effluent limitation guidelines, b) new source performance standards, or c) toxic pollutant effluent standards under 40 CFR Subchapter N. All affected industrial categories are identified in Table 1.

Industries listed with the new source performance standards group need only be permitted if they are a "new source"; meaning an industrial facility built after the performance standards were promulgated by EPA. Industries that believe that they may be included in Category i should review the Subchapter N guidelines and/or consult their local Regional Water Quality Control Board.

Excluded are facilities with toxic pollutant effluent standards which are exempted under Category xi (i.e. because materials, equipment, and products are not exposed to storm water).

Category ii

Manufacturing Facilities

These consist of facilities engaged in the mechanical or chemical transformation of materials or substances into new products, and are usually described as plants, factories, or mills and characteristically use power driven machines and materials handling equipment. Establishments engaged in assembling component parts of manufactured products or in the blending of materials such as lubricating oils, plastics, or liquors are included. Table 2 includes all four digit SIC codes within this category.

All facilities identified by this category are required to file to be covered by the General Permit, regardless of whether equipment and/or materials are exposed to storm water. These facilities should also note that the definition of "storm water discharge associated with industrial activity" (see Attachment II) includes, but is not limited to, discharges from the specified industrial activity areas. Included in the definition are manufacturing buildings and material and waste storage areas (whether totally enclosed or not) including tank farm areas. Activities of concern include emissions from stacks or air exhaust systems, use of unhoused manufacturing and heavy industrial equipment, and generation of dust or particulates.

Excluded are facilities engaged in services or wholesale or retail trade.

Category iii

Oil and Gas/Mining Facilities

These consist of active or inactive mining operations and oil and gas exploration, production, processing, or treatment operations, or transmission facilities that discharge storm water

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contaminated by contact with or that has come into contact with any overburden, raw material, intermediate products, finished products, by-products, or waste products located on the site of such operations. Inactive mining operations are mined sites that are not being actively mined, but which have an identifiable owner/operator. Included are SIC Codes 10 (Metal Mining), 11 (Anthracite Mining), 12 (Coal Mining), 13 (Oil and Gas Extraction), and 14 (Mining and Quarrying of Nonmetallic Minerals, Except Fuels). Table 2 includes all four digit SIC codes within this category.

Excluded are inactive mining sites where mining claims are being maintained prior to disturbances associated with the extraction, benefaction, or processing of mined material, nor sites where minimal activities are undertaken for the sole purpose of maintaining a mining claim. Also excluded are certain areas of coal mining meeting the definition of a reclamation area under 40 CFR 434.11(1) and certain areas of non-coal mining which have been released from state or federal reclamation requirements after December 17, 1990.

Category iv

Hazardous Waste Treatment, Storage, or Disposal Facilities

These consist of hazardous waste treatment, storage, or disposal facilities, including those that are operating under interim status or permit under Subtitle C of the Resource Conservation and Recovery ACT (RCRA). These include only hazardous waste facilities under the federal definition of hazardous waste (RCRA hazardous waste as defined in Title 22, Section 66261.3, CA Health and Safety Code). The California definition of hazardous waste is broader and includes non-RCRA hazardous wastes. Only hazardous waste facilities based on the federal definition are required to obtain a NPDES storm water permit. However, non-RCRA hazardous waste facilities are still expected to effectively manage storm water discharges and may be required by a Regional Board to obtain a permit on a case-by-case basis. They must also comply with any conditions imposed by a permitted municipal storm water agency. See Table 4 for further detail.

Category v

Landfills, Land Application Sites, and Open Dumps

These consist of landfills, land application sites, and dumps that received any industrial wastes, including active and inactive sites that receive or have received industrial waste from any of the types of facilities described as industrial facilities in the storm water regulations (i.e., these eleven categories), sites subject to regulation under Subtitle D of RCRA, and sites that have accepted wastes from construction activities (construction activities include any clearing, grading, or excavation that results in disturbance of five acres or more). It is probable that most active and inactive landfills have received industrial waste. See Table 4 for further detail.

Excluded are properly closed landfills that now function as a different land use (e.g., park, golf course, etc.) and which do not pose a threat of discharging storm water exposed to landfill waste.

Category vi

Recycling Facilities

These consist of facilities involved in the recycling of materials, including facilities engaged in assembling, breaking up, sorting, and wholesale distribution of motor vehicle motors and parts, scrap, and other waste materials, and include metal scrap yards, battery reclaimers, salvage yards, and automobile junkyards. Included are facilities which store and recycle paper, glass, metals, oil, rubber, plastics, and other synthetics. These include SIC Code 5015-Used Motor Vehicle Parts and SIC Code 5093-Scrap and Waste Materials.

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Excluded are municipal waste collection sites where bottles, cans, and papers are collected for recycling purposes.

Category vii

Steam Electric Power Generating Facilities

These consist of steam electric power generating facilities, including coal handling sites. See Table 4 for further detail.

Excluded are onsite and offsite ancillary transformer facilities, as long as such facilities have regular inspections and management practices in place, including spill prevention, response, and clean up.

Category viii

Transportation Facilities

These consist of transportation facilities classified by the SIC indicated below which have vehicle maintenance shops, equipment cleaning operations, or airport deicing operations. Only those portions of the facility involved in vehicle maintenance (including vehicle rehabilitation, mechanical repairs, painting, fueling, and lubrication), equipment cleaning operations, airport deicing operations, or other operations identified under Categories i through vii or ix through xi must be permitted.

In determining whether a facility is covered by the transportation category, first determine whether the facility is involved in providing transportation to individual customers or for other companies or establishments, or provides long-distance trucking services to anyone. Maintenance facilities owned or operated by companies or public agencies which are involved in providing transportation services to the public or other businesses are covered, including the transportation of individuals (such as by buses, vans, or taxies) and goods (such as by trucks, rail, ships, or airplanes). All long-distance trucking facilities are covered.

Excluded are transportation facilities which only transport goods for the company or enterprise of which it is a part or only transport its own employees. Municipal corporation yards are excluded unless they perform the functions described in the SIC codes below, such as the service of an urban or suburban bus line (SIC 4111 - Local and Suburban Transit), or contain a warehousing and storage facility described by SIC codes 4225 or 4226. However, all municipal corporation yards are still expected to effectively manage storm water discharges and may be required by a Regional Board to obtain a Permit on a case-by-case basis. They must also comply with any conditions imposed by a permitted municipal storm water agency.

Also excluded are fuel stations, vehicle repair or service stations, and body shops which are not associated with the establishments described in the SIC codes below. However, these establishments are still expected to effectively manage storm water discharges and may be required by a Regional Board to obtain a permit on a case-by-case basis. They must also comply with any conditions imposed by a permitted municipal storm water agency.

Major transportation groups covered by the Permit are described below:

SIC 40 - Railroad Transportation

This major group includes establishments furnishing transportation by line-haul railroad, and switching and terminal establishments. Railways serving a single municipality, contiguous municipalities, or a municipality and its suburban areas are classified in Major Group 41.

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SIC 41 - Local and Suburban Transit and Interurban Highway Passenger Transportation

This major group includes establishments primarily engaged in furnishing local and suburban passenger transportation, such as those providing passenger transportation within a single municipality, contiguous municipalities, or a municipality and its suburban areas by bus, rail, or subway, either separately or in combination, and establishments engaged in furnishing transportation to local scenic features. Also included are establishments primarily engaged in furnishing highway passenger transportation and establishments furnishing highway passenger terminal or maintenance facilities. Intercity bus lines are included in this major group, but interurban railways are classified in Major Group 40.

SIC 42 - Motor Freight Transportation and Warehousing (except SIC 4221-25 (Public Warehousing) which are included in Category xi)

This major group includes establishments furnishing local or long-distance trucking or transfer services or those engaged in the storage of special products (SIC 4226) such as automobiles (dead storage only), furs (for the trade), textiles, whiskey, and goods at foreign trade zones.

SIC 43 - United States Postal Service

SIC 44 - Water Transportation

This major group includes establishments engaged in freight and passenger transportation on the open seas or inland waters, and establishments furnishing such incidental service as lighterage, towing, and canal operation. This major group also includes excursion boats, sightseeing boats, and water taxis. Establishments engaged in the operation of charter or party fishing boats are not included.

SIC 45 - Transportation by Air

This major group includes establishments engaged in furnishing domestic and foreign transportation by air and also those operating airports and flying fields and furnishing terminal services. Establishments primarily engaged in performing services which may incidentally use airplanes (e.g. crop dusting and aerial photography) are not included.

SIC 5171 - Petroleum Bulk Stations and Terminals

These include establishments primarily engaged in the wholesale distribution of crude petroleum and petroleum products, including liquefied petroleum gas, from bulk liquid storage facilities.

Table 2 includes a complete list of all four digit SIC codes within this category. All facilities identified by this category are required to obtain NPDES permits for the discharge of industrial storm water regardless of material, equipment, or product exposure.

Category ix

Sewage or Wastewater Treatment Works

These consist of treatment works treating domestic sewage or any other sewage sludge or wastewater treatment device or system used in the storage, treatment, recycling, and reclamation of municipal or domestic sewage, including land dedicated to the disposal of sewage sludge that are located within the confines of the facility, with a design flow of one million gallons per day (MGD) or more, or required to have an approved pretreatment program under 40 CFR Part 403. Industrial activity areas at these facilities include, but are not limited to, onsite sludge composting;

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storage of chemicals such as ferric chloride, alum polymers, and chlorine; and areas which experience spills and bubbleovers. See Table 4 for further detail.

Excluded are farm lands, domestic gardens, or lands used for sludge management or reclamation of municipal wastewater where the sludge or wastewater is beneficially reused and which are not physically located in the confines of the facility.

Category x

Construction Activities

These include, but are not limited to, clearing, grading, and excavation activities. The State intends to issue a separate General Permit for Discharges of Storm Water Associated with Construction Activities to cover storm water discharges from these activities. The General Permit for Construction Activities will further delineate the extent of affected construction activities.

Excluded from the General Permit for Construction Activities will be operations that result in the disturbance of less than five acres of total land area which are not part of a larger common plan of development or sale. However, such operations are still expected to effectively manage storm water discharges and may be required by a Regional Board to obtain a permit on a case-by-case basis. They must also comply with any conditions imposed by local permitted municipal storm water agencies.

Category xi

Manufacturing Facilities

These consist of manufacturing facilities identified by SIC code which have storm water discharges "associated with industrial activities" from areas where material handling equipment or activities, raw materials, intermediate products, final products, waste materials, by-products, or industrial machinery are exposed to storm water. Discharges of storm water "associated with industrial activity" and "exposure" to storm water are addressed in Attachment II.

Areas of industrial activity include manufacturing buildings and storage areas. Areas of industrial activity do not include access roads and rail lines.

Table 3 is a complete list of four digit SIC codes included in this category.

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ATTACHMENT II

IS THERE A DISCHARGE OF STORM WATER ASSOCIATED WITH INDUSTRIAL ACTIVITY?

The term "discharges of storm water associated with industrial activity" means discharges of storm water from areas at a facility where storm water may contact pollutants or activities may release pollutants to storm water. Such discharges include, but are not limited to, discharges from the following:

a. Industrial plan yards;
b. Immediate access roads and rail lines used or traveled by carriers of raw materials, manufactured products, waste material, or by-products used or created by the facility (except for category xi);
c. Material handling sites;
d. Refuse sites;
e. Sites used for the application or disposal of process waste waters; 40 CFR 401
f. Sites used for the storage and maintenance of material handling equipment;
g. Sites used for residual treatment, storage, or disposal;
h. Shipping and receiving areas;
i. Storage areas (including tank farms) for raw materials, and intermediate and finished products;
j. Manufacturing buildings; and
k. Areas where industrial activity has taken place in the past and significant materials remain and are exposed to storm water.

Significant materials include, but are not limited to, raw materials; fuels; materials such as solvents, detergents, and plastic pellets; finished materials such as metallic products; raw materials used in food processing or production; hazardous substances; fertilizers; pesticides; and waste products such as ashes, slag and sludge that have the potential to be released with storm water discharges.

Access roads and rail lines include those used or traveled by carriers of raw materials, manufactured products, waste materials, or by-products used or created by the facility. Included are haul roads or rail lines dedicated to transportation of industrial products at facilities and roads and rail lines which are exclusively or primarily dedicated for use by the facility. They do not include public access roads or roads used to transport bulk samples of raw materials or products in small-scale prior to industrial production.

Note that the definition of industrial activity areas is not limited to the specified areas. Any area at a facility where storm water may contact pollutants or activities may release pollutants to storm water must be considered. Also note that the definition includes manufacturing buildings and material and waste storage areas (whether totally enclosed or not). Activities of concern in these areas include emissions from stacks or air exhaust systems, use of unhoused manufacturing and heavy industrial equipment, generation of dust or particulates, use of material handling equipment, and material handling activities.

Non-industrial Areas are areas located at facilities such as office buildings and accompanying parking lots are generally excluded, as long as the drainage from the excluded areas is discharged separately from storm water drained from areas with industrial activities. The intent of the regulations is to control industrial activity storm water discharges. Non-industrial areas are considered equivalent to residential or commercial land-use areas and should be managed as such. These areas may be subject to other requirements imposed by local agencies which have jurisdiction over or manage storm drain systems or waterways.

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For the manufacturing facilities identified by Category xi, storm water discharge associated with industrial activity includes only storm water discharges from the areas (except access roads and rail lines) that are listed above where material handling equipment or activities, raw materials, intermediate products, final products, waste material, by-products, or industrial machinery are exposed to storm water.

Exposure means either direct contact with storm water or the possibility of release (e.g., spills) of pollutants to storm water. For example, roof drainage from manufacturing buildings must be considered when determining exposure. Exposure in this circumstance would include direct or potential contact or release of pollutants (associated with raw materials, products, or waste) from roof stacks to storm water. Manufacturing facilities may also be sources of dust or particulates associated with material handling equipment or activities, raw materials, products, or waste, or industrial machinery. Enclosed storage areas are also defined as areas of industrial activity where there may be exposure during loading/unloading of materials or exposure due to spills.

Category xi facilities are expected to use reasonable and professional judgment when making the determination of exposure from the listed areas and activities. In order to demonstrate that these areas are not exposed to storm water, the following conditions must be met:

1. All illicit (un-permitted) connections to the storm drainage system must be eliminated;

2. All materials must be completely contained at all times so, if spilled, they will not directly or indirectly contact storm water, and

3. All emissions from stacks or air exhaust systems, unhoused manufacturing and heavy industrial equipment, and emissions of dust or particulates must not be exposed to storm water.

If a facility demonstrates that there is no exposure, documentation of the rationale for the determination should be retained on site. Written approval by a Regional Board and a NPDES industrial storm water discharge permit is not required for such facilities. However, such facilities are expected to effectively manage storm water discharges and may be required by a Regional Board to obtain a permit on a case-by-case basis. They must also comply with any conditions imposed by a permitted municipal storm water agency.

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ATTACHMENT III

IS THERE A DISCHARGE OF STORM WATER ASSOCIATED WITH INDUSTRIAL ACTIVITY TO WATERS OF THE UNITED STATES?

The answer is yes, and a General Permit is required, if either of the following applies:

a. The discharge of industrial storm water is directly to waters of the United States through any conveyance. The conveyance does not have to be a pipe or ditch. It includes "sheet flow" discharges resulting from any manipulation of land surface (e.g., pavement).

b. The discharge of industrial storm water is to a storm drain system which ultimate discharges to waters of the United States. In this case all "sheet flow" discharges are included.

The answer is no, and General Permit is not required, if either of the following applies:

a. The discharge of industrial storm water is to a municipal sanitary sewer system or combined sewer system (combined sanitary and storm sewer system).

b. The discharge of industrial storm water is to evaporation ponds, percolation ponds, or dry wells (groundwater injection wells), and there is no discharge to surface waters under any circumstances.

Even though these types of discharges are not required to obtain a General Permit, the discharges may be subject to separate waste discharge requirements issued by a Regional Water Quality Control Board (Regional Board) if they pose a threat to groundwater. If there is a question, call the local Regional Board to obtain guidance.

IS A SEPARATE STORM WATER PERMIT REQUIRED IF THE FACILITY ALREADY HAS A NPDES PERMIT?

A separate General Permit is not required if an existing NPDES permit identifies and addresses all industrial storm water discharges from the facility.

An existing NPDES permit may be modified to address all industrial storm water. Normally, this modification will occur when the existing permit is reissued or amended by a Regional Board. In the interim, the facility should obtain coverage under the General Permit.

WHO IS RESPONSIBLE FOR OBTAINING THE GENERAL PERMIT?

Either the owner or operator of the facility may obtain the Permit. Generally, the operator will be responsible for obtaining the permit. The operator is usually responsible for the industrial activity, and therefore, more appropriately, the best entity to manage the activity in compliance with the permit. However, owners may obtain coverage for a facility with the understanding that they will be directly responsible for the storm water discharge and consequently, responsible for compliance with permit conditions.

For example, a tenant which operates an industrial facility at an airport complex may be responsible for submitting a NOI for coverage under the General Permit and would be responsible for implementing a Storm Water Pollution Prevention Plan (SWPP Plan) for its facility. Alternatively, the airport owner may choose to assume responsibility for its tenants, in addition to its own industrial activities. In this case, the airport owner would submit a NOI and would be responsible for implementing a SWPP Plan that addresses all noted activities at the airport complex.

TABLE 1
SUBCHAPTER N - EFFLUENT GUIDELINES AND STANDARDS
(Category i)

Group 1	Group 2	Group 3	Part	Description
	X		405	Dairy products processing point source category
	X		406	Grain mills point source category
	X		407	Canned and preserved fruits and vegetables processing point source category
	X		408	Canned and preserved seafood processing point source category
	X		409	Sugar processing point source category
	X	X	410	Textile mills point source category
X	X		411	Cement manufacturing point source category
X	X		412	Feedlots point source category
	X	X	413	Electroplating point source category
	X	X	414	Organic chemicals, plastics, and synthetic fibers
	X	X	415	Inorganic chemicals manufacturing point source category
	X		417	Soap and detergent manufacturing point source category
X	X		418	Fertilizer manufacturing point source category
X	X	X	419	Petroleum refining point source category
	X	X	420	Iron and steel manufacturing point source category
	X	X	421	Nonferrous metals manufacturing point source category
X	X		422	Phosphate manufacturing point source category
X	X	X	423	Steam electric power generating point source category
	X	X	424	Ferroalloy manufacturing point source category
	X	X	425	Leather tanning and finishing point source category
	X	X	426	Glass manufacturing point source category
	X		427	Asbestos manufacturing point source category
	X	X	428	Rubber manufacturing point source category
	X	X	429	Timber products processing point source category
	X	X	430	Pulp, paper, and paperboard point source category
	X		431	The builders' paper and board mills point source category
	X		432	Meat products point source category
	X	X	433	Metal finishing point source category

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TABLE 1 (Continued)
SUBCHAPTER N - EFFLUENT GUIDELINES AND STANDARDS
(Category i)

Group 1	Group 2	Group 3	Part	Description
X	X		434	Coal mining point source category; BPT, BAT, BCT limitations and new source performance standards
			435	Oil and gas extraction point source category
X			436	Mineral mining and processing point source category
	X	X	439	Pharmaceutical manufacturing point source category
X	X	X	440	Ore mining and dressing point source category
X	X		443	Effluent limitations guidelines for existing sources and standards of performance and pretreatment standards for new sources for the paving and roofing materials (tars and asphalt) point source category
	X		446	Paint formulating point source category
	X		447	Ink formulating point source category
			454	Gum and wood chemicals manufacturing point source category
		X	455	Pesticide chemicals
			457	Explosives manufacturing point source category
	X		458	Carbon black manufacturing point source category
		X	459	Photographic point source category
			460	Hospital point source category
	X	X	461	Battery manufacturing point source category
	X		463	Plastics molding and forming point source category
	X	X	464	Metal molding and casting point source category
	X	X	465	Coil coating point source category
	X	X	466	Porcelain enameling point source category
	X	X	467	Aluminum forming point source category
	X	X	468	Copper forming point source category
	X	X	469	Electrical and electronic components point source category
	X	X	471	Nonferrous metals forming and metal powders point source category

Group 1: Storm water effluent limitations guidelines - Permit Mandatory
Group 2: New source performance standards - Permit Mandatory
Group 3: Toxic pollutant effluent standards - Permit conditional on exposure to storm water (Category xi)

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TABLE 2

MANDATORY INDUSTRIES (Categories ii,iii, vi, and viii)
Permit Required in Any Case

Metal Mining

1011	Iron Ores
1021	Copper Ores
1031	Lead & Zinc Ores
1041	Gold Ores
1044	Silver Ores
1061	Ferroalloy Ores, Except Vanadium
1081	Metal Mining Services
1094	Uranium-Radium-Vanadium Ores
1099	Miscellaneous Metal Ores, N.E.C.

Coal Mining

1221	Bituminous Coal and Lignite Surface Mining
1222	Bituminous Coal Underground Mining
1231	Anthracite Mining
1241	Coal Mining Services

Oil & Gas Extraction

1311	Crude Petroleum & Natural Gas
1321	Natural Gas Liquids
1381	Drilling Oil & Gas Wells
1382	Oil & Gas Field Exploration Services
1389	Oil & Gas Field Services, N.E.C.

Mining & Quarrying of Nonmetallic Minerals, Except Fuels

1411	Dimension Stone
1422	Crushed & Broken Limestone
1423	Crushed & Broken Granite
1429	Crushed & Broken Stone, N.E.C
1442	Construction Sand & Gravel
1446	Industrial Sand
1455	Kaoline & Ball Clay
1459	Clay & Related Minerals, N.E.C.
1474	Potash, Soda, & Borate Minerals
1475	Phosphate Rock
1479	Chemical & Fertilizer Mineral Mining, N.E.C.
1481	Nonmetallic Minerals Services, Except Fuels
1499	Miscellaneous Nonmetallic Minerals, Except Fuels, N.E.C.

Lumber & Wood Products, Except Furniture

2421	Sawmills & Planing Mills, General
2426	Hardwood Dimension & Flooring Mills
2429	Special Product Sawmills, N.E.C.
2431	Millwork
2435	Hardwood Veneer & Plywood
2436	Softwood Veneer & Plywood
2439	Structural Wood Members, N.E.C.
2441	Nailed and Lock Corner Wood Boxes & Shook
2448	Wood Pallets & Skids
2449	Wood Containers, N.E.C.
2451	Mobile Homes

Lumber & Wood Products, Except Furniture (Cont.)

2452	Prefabricated Wood Buildings
2491	Wood Preserving
2493	Reconstituted Wood Products
2499	Wood Products, N.E.C.

Paper & Allied Products

2611	Pulp Mills
2621	Paper Mills
2631	Paperboard Mills

Chemicals & Allied Products

2812	Alkalies & Chlorine
2813	Industrial Gases
2816	Inorganic Pigments
2819	Industrial Inorganic Chemicals, N.E.C.
2821	Plastics Materials, Synthetic Resins, & Nonvolcanizable Elastomers
2822	Synthetic Rubber
2823	Cellulosic Manmade Fibers
2824	Manmade Organic Fibers, Except Cellulosic
2841	Soap & Other Detergents, Except Specialty Cleaners
2842	Specialty Cleaning, Polishing, & Sanitation Preparations
2843	Surface Active Agents, Finishing Agents, Sulforated Oils, and Assistants
2844	Perfumes, Cosmetics, & Other Toilet Preparations
2851	Paints, Varnishes, Lacquers, Enamels, and Allied Products
2861	Gum & Wood Chemicals
2865	Cyclic Organic Crudes & Intermediates, & Organic Dyes & Pigments
2869	Industrial Organic Chemicals, N.E.C.
2873	Nitrogenous Fertilizers
2874	Phosphatic Fertilizers
2875	Fertilizers, Mixing Only
2879	Pesticides & Agricultural Chemicals, N.E.C.
2891	Adhesives & Sealants
2892	Explosives
2893	Printing Ink
2895	Carbon Black
2899	Chemicals & Chemical Preparations, N.E.C.

Petroleum Refining & Related Industries

2911	Petroleum Refining
2951	Asphalt Paving Mixtures & Blocks
2952	Asphalt Felts & Coatings
2992	Lubricating Oils & Greases
2999	Products of Petroleum & Coal, N.E.C.

Leather Tanning & Finishing

3111	Leather Tanning & Finishing

Note: N.E.C. means Not Elsewhere Classified.

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Stone, Clay, Glass, & Concrete Products

3211 Flat Glass
3221 Glass Containers
3229 Pressed & Blown Glass & Glassware, N.E.C.
3241 Cement, Hydraulic
3251 Brick & Structural Clay Tile
3253 Ceramic Wall & Floor Tile
3255 Clay Refractories
3259 Structural Clay Products, N.E.C.
3261 Vitreous China Plumbing Fixtures & China & Earthenware Fittings & Bathroom Accessories
3262 Vitreous China Table and Kitchen Articles
3263 Fine Earthenware (Whiteware) Table and Kitchen Articles
3264 Porcelain Electrical Supplies
3269 Pottery Products, N.E.C.
3271 Concrete Block & Brick
3272 Concrete Products, Except Block & Brick, N.E.C.
3273 Ready-Mixed Concrete
3274 Lime
3275 Gypsum Products
3281 Cut Stone & Stone Products
3291 Abrasive Products
3292 Asbestos Products
3295 Minerals & Earths, Ground or Otherwise Treated
3296 Mineral Wool
3297 Nonclay Refractories
3299 Nonmetallic Mineral Products, N.E.C.

Primary Metal Industries

3312 Steel Works, Blast Furnaces (Including Coke Ovens), & Rolling Mills
3313 Electrometallurgical Products, Except Steel
3315 Steel Wiredrawing & Steel Nails & Spikes
3316 Cold-Rolled Steel Sheet, Strip, & Bars
3317 Steel Pipe & Tubes
3321 Gray & Ductile Iron Foundries
3322 Malleable Iron Foundries
3324 Steel Investment Foundries
3325 Steel Foundries, N.E.C.
3331 Primary Smelting & Refining of Copper
3334 Primary Production of Aluminum
3339 Primary Smelting & Refining of Nonferrous Metals, Except Copper & Aluminum
3341 Secondary Smelting & Refining of Nonferrous Metals
3351 Rolling, Drawing, & Extruding of Copper
3353 Aluminum Sheet, Plate, & Foil
3354 Aluminum Extruded Products
3355 Aluminum Rolling & Drawing, N.E.C.
3356 Rolling & Drawing of Nonferrous Metals, Except Copper & Aluminum
3357 Drawing & Insulating of Nonferrous Wire
3363 Aluminum Die-Castings
3364 Nonferrous Die-Castings, Except Aluminum
3365 Aluminum Foundries
3366 Copper Foundries

Primary Metal Industries (Cont.)

3369 Nonferrous Foundries, Except Aluminum & Copper
3398 Metal Heat Treating
3399 Primary Metal Products, N.E.C.

Fabricated Structural Metal Products

3441 Fabricated Structural Metal

Electronic & Other Electrical Equipment & Components, Except Computer Equipment

3648 Lighting Equipment, N.E.C.
3652 Phonograph Records & Prerecorded Audio Tapes & Disks
3679 Electronic Components, N.E.C.

Ship & Boat Building & Repairing

3731 Ship Building & Repairing
3732 Boat Building & Repairing

Railroads

4011 Railroads, Line-Haul Operating
4013 Railroad Switching & Terminal Establishments

Local & Suburban Transit & Interurban Highway Passenger Transportation

4111 Local & Suburban Transit
4119 Local Passenger Transportation, N.E.C.
4121 Taxicabs
4131 Intercity & Rural Bus Transportation
4141 Local Bus Charter Service
4142 Bus Charter Service, Except Local
4151 School Buses
4173 Terminal & Service Facilities for Motor Vehicle Passenger Transportation

Motor Freight Transportation & Warehousing

4212 Trucking, Local Without Storage
4213 Trucking, Except Local
4214 Local Trucking & Storage
4215 Courier Services, Except By Air
4226 Special Warehousing & Storage, N.E.C.
4231 Terminal Facilities & Joint Terminal Maintenance Facilities for Motor Freight Transportation

United States Postal Service

4311 United States Postal Service

Water Transportation

4412 Deep Sea Foreign Transportation of Freight
4424 Deep Sea Domestic Transportation of Freight
4432 Freight Transportation on the Great Lakes - St. Lawrence Seaway
4449 Water Transportation of Freight, N.E.C.

Note: N.E.C. means Not Elsewhere Classified.

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Water Transportation (Cont.)

4481 Deep Sea Transportation of Passengers, Except by Ferry
4482 Ferries
4489 Water Transportation of Passengers, N.E.C.
4491 Marine Cargo Handling
4492 Towing & Tugboat Services
4493 Marinas
4499 Water Transportation Services, N.E.C.

Transportation By Air

4512 Air Transportation, Scheduled
4513 Air Courier Services
4522 Air Transportation, Nonscheduled
4581 Airports, Flying Fields, & Airport Terminal Services

Wholesale Trade - Durable Goods

5015 Motor Vehicle Parts, Used
5093 Scrap & Waste Materials

Petroleum & Petroleum Products

5171 Petroleum & Petroleum Product Wholesalers, Except Bulk Stations & Terminals

Note: N.E.C. means Not Elsewhere Classified.

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TABLE 3

CONDITIONAL INDUSTRIES (Category xi)
Permit required only if materials, machinery, or products are exposed to stormwater

Food & Kindred Products

2011	Meat Packing Plants
2013	Sausages & Other Prepared Meat Products
2015	Poultry Slaughtering & Processing
2021	Creamery Butter
2022	Natural, Processed, & Imitation Cheese
2023	Dry, Condensed, & Evaporated Dairy Products
2024	Ice Cream & Frozen Desserts
2026	Fluid Milk
2032	Canned Specialities
2033	Canned Fruits, Vegetables, Preserves, Jams, & Jellies
2034	Dried & Dehydrated Fruits, Vegetables, & Soups Mixes
2035	Pickled Fruits & Vegetables, Vegetable Sauces & Seasonings, & Salad Dessings
2037	Frozen Fruits, Fruit Juices, & Vegetables
2038	Frozen Specialities, N.E.C.
2041	Flour & Other Grain Mill Products
2043	Cereal Breakfast Foods
2044	Rice Milling
2045	Prepared Flour Mixes & Doughs
2046	Wet Corn Milling
2047	Dog & Cat Food
2048	Prepared Feeds & Feed Ingredients for Animals & Fowls, Except Dogs & Cats
2051	Bread & Other Bakery Products, Except Cookies & Crackers
2052	Cookies & Crackers
2053	Frozen Bakery Products, Except Bread
2061	Cane Sugar, Except Refining
2062	Sugar Cane Refining
2063	Beet Sugar
2064	Candy & Other Confectionery Products
2066	Chocolate & Cocoa Products
2067	Chewing Gum
2068	Salted & Roasted Nuts & Seeds
2074	Cononseed Oil Mills
2075	Soybean Oil Mills
2076	Vegetable Oil Mills, Except Corn, Cottonseed, & Soybean
2077	Animal & Marine Fats & Oils
2079	Shortening, Table Oils, Margerine, & Other Edible Fats & Oils, N.E.C.
2082	Malt Beverages
2083	Malt
2084	Wines, Brandy, & Brandy Spirits
2085	Distilled & Blended Liquors
2086	Bottled & Canned Soft Drinks & Carbonated Waters
2087	Flavoring Extracts & Syrups, N.E.C.
2091	Canned & Cured Fish & Seafoods
2092	Prepared Fresh or Frozen Fish & Seafoods
2095	Roasted Coffee
2096	Potatoe Chips, Corn Chips, & Similar Snacks
2097	Manufactured Ice
2098	Macaroni, Spaghetti, Vermicelli, & Noodles

Food & Kindred Products (Cont.)

2099	Food Preparations, N.E.C.

Tobacco Products

2111	Cigarettes
2121	Cigars
2131	Chewing & Smoking Tobacco & Snuff
2141	Tobacco Stemming & Redrying

Textile Mill Products

2211	Broadwoven Fabric Mills, Cotton
2221	Broadwoven Fabric Mills, Manmade Fiber & Silk
2231	Broadwoven Fabric Mills, Wool (Including Dyeing & Finishing)
2241	Narrow Fabric & Other Smallwares Mills: Cotton, Wool, Silk, & Manmade Fiber
2251	Women's Full-Length & Knee-Length Hosiery, Except Socks
2252	Hosiery, N.E.C.
2253	Knit Outerwear Mills
2254	Knit Underwear & Nightwear Mills
2257	Weft Knit Fabric Mills
2258	Lace & Warp Knit Fabric Mills
2259	Knitting Mills, N.E.C.
2261	Finishers of Broadwoven Fabrics of Cotton
2262	Finishers of Broadwoven Fabrics of Manmade Fiber & Silk
2269	Finishers of Textiles, N.E.C.
2273	Carpets & Rugs
2281	Yarn Spinning Mills
2282	Yarn Texturizing, Throwing, Twisting, & Winding Mills
2284	Thread Mills
2295	Coated Fabrics, Not Rubberized
2296	Tire Cord & Fabrics
2297	Nonwoven Fabrics
2298	Cordage & Twine
2299	Textile Goods, N.E.C.

Apparel & Other Finished Products Made From Fabrics & Similar Materials

2311	Men's & Boy's Suits, Coats, & Overcoats
2321	Men's & Boy's Shirts, Except Work Shirts
2322	Men's & Boy's Underwear & Nightwear
2325	Men's & Boy's Separate Trousers & Slacks
2326	Men's & Boy's Work Clothing
2329	Men's & Boy's Clothing, N.E.C.
2331	Women's, Misses' & Juniors' Blouses & Shirts
2335	Women's, Misses' & Juniors' Dresses
2337	Women's, Misses' & Juniors' Suits, Skirts, & Coats
2339	Women's, Misses'& Juniors' Outerwear, N.E.C.

Note: N.E.C. means Not Elsewhere Classified.

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Apparel & Other Finished Products Made From Fabrics & Similar Materials (Cont.)

2341	Women's, Misses, Children's, & Infants' Underwear & Nightwear
2342	Brassieres, Girdles, & Allied Garments
2353	Hats, Caps, & Millinery
2361	Girls' Children's & Infants' Dresses, Blouses, & Shirts
2369	Girls', Childrens', & Infants' Outerwear, N.E.C.
2371	Fur Goods
2381	Dress & Work Gloves, Except Knit & All-Leather
2384	Robes & Dressing Gowns
2385	Waterproof Outerwear
2386	Leather & Sheep-Lined Clothing
2387	Apparel Belts
2389	Apparel & Accessories, N.E.C.
2391	Curtains & Draperies
2392	Housefurnishings, Except Curtains & Draperies
2393	Textile Bags
2394	Canvas & Related Products
2395	Pleating, Decorative & Novelty Stitching, & Tucking for the Trade
2396	Automotive Trimmings, Apparel Findings, & Related Products
2397	Schiffli Machine Embroideries
2399	Fabricated Textile Products, N.E.C.

Millwork, Veneer, Plywood, & Structural Wood Members

2434	Wood Kitchen Cabinets

Furniture & Fixtures

2511	Wood Household Furniture, Except Upholstered
2512	Wood Household Furniture, Upholstered
2514	Metal Household Furniture
2515	Mattresses, Foundations, & Convertible Beds
2517	Wood Television, Radio, Phonograph, & Sewing Machine Cabinets
2519	Household Furniture, N.E.C.
2521	Wood Office Furniture
2522	Office Furniture, Except Wood
2531	Public Building and Related Furniture
2541	Wood Office & Store Fixtures, Partitions, Shelving, & Lockers
2542	Office & Store Fixtures, Partitions, Shelving, & Lockers, Except Wood
2591	Drapery Hardware & Window Blinds & Shades
2599	Furniture & Fixtures, N.E.C.

Paper & Allied Products

2652	Setup Paperboard Boxes
2653	Corrugated & Solid Fiber Boxes
2655	Fiber Cans, Tubes, Drums & Similar Products
2656	Sanitary Food Containers, Except Folding

Paper & Allied Products (Cont.)

2657	Folding Paperboard Boxes, Including Sanitary
2671	Packaging Paper & Plastics Film, Coated & Laminated
2672	Coated & Laminated Paper, N.E.C.
2673	Plastics, Foil & Coated Paper Bags
2674	Uncoated Paper & Multiwall Bags
2675	Die-Cut Paper, Paperboard, & Cardboard
2676	Sanitary Paper Products
2677	Envelopes
2678	Stationery Tablets & Related Products
2679	Converted Paper & Paperboard Products, N.E.C.

Printing, Publishing, & Allied Industries

2711	Newspapers: Publishing, or Publishing & Printing
2721	Periodicals: Publishing, or Publishing & Printing
2731	Books: Publishing, or Publishing & Printing
2732	Book Printing
2741	Miscellaneous Publishing
2752	Commercial Printing, Lithographic
2754	Commercial Printing, Gravure
2759	Commercial Printing, N.E.C.
2761	Manifold Business Forms
2771	Greeting Cards
2782	Blankbooks, Looseleaf Binders & Devices
2789	Bookbinding & Related Work
2791	Typesetting
2796	Platemaking & Related Services

Drugs

2833	Medicinal Chemicals & Botanical Products
2834	Pharmaceutical Preparations
2835	In Vitro & In Vivo Diagnostic Substances
2836	Biological Products, Except Diagnostic Substances

Paints, Varnishes, Lacquers, Enamels, & Allied Products

2851	Paints, Varnishes, Lacquers, Enamels, & Allied Products

Rubber & Miscellaneous Plastics Products

3011	Tires & Inner Tubes
3021	Rubber & Plastics Footwear
3052	Rubber & Plastics Hose & Belting
3053	Gaskets, Packing & Sealing Devices
3061	Molded, Extruded, & Lathe-Cut Rubber Mechanical Goods
3069	Fabricated Rubber Products, N.E.C.
3081	Unsupported Plastics Film & Sheet
3082	Unsupported Plastics Profile Shapes
3083	Laminated Plastics Plate, Sheet, & Profile Shapes
3084	Plastics Pipe
3085	Plastics Bottles

Note: N.E.C. means Not Elsewhere Classified.

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Rubber & Miscellaneous Plastics Products

3086	Plastics Foam Products
3087	Custom Compounding of Purchased Plastics Resins
3088	Plastics Plumbing Fixtures
3089	Plastics Products, N.E.C.

Leather & Leather Products

3131	Boot & Shoe Cut Stock & Findings
3142	House Slippers
3143	Men's Footwear, Except Athletic
3144	Women's Footwear, Except Athletic
3149	Footwear, Except Rubber, N.E.C.
3151	Leather Gloves & Mittens
3161	Luggage
3171	Women's Handbags & Purses
3172	Personal Leather Goods, Except Women's Handbags & Purses
3199	Leather Goods, N.E.C.

Glass Products, Made Of Purchased Glass

3231	Glass Products Made of Purchased Glass

Fabricated Metal Products, Except Machinery & Transportation Equipment

3411	Metal Cans
3412	Metal Shipping Barrels, Drums, Kegs, & Pails
3421	Cutlery
3423	Hand & Edge Tools, Except Machine Tools & Handsaws
3425	Saw Blades & Handsaws
3429	Hardware, N.E.C.
3431	Enameled Iron & Metal Sanitary Ware
3432	Plumbing Fixture Fittings & Trim
3433	Heating Equipment, Except Electric & Warm Air Furnaces
3442	Metal Doors, Sash, Frames, Molding, & Trim
3443	Fabricated Plate Work (Boiler Shops)
3444	Sheet Metal Work
3446	Architectural & Ornamental Metal Work
3448	Prefabricated Metal Buildings & Components
3449	Miscellaneous Structural Metal Work
3451	Screw Machine Products
3452	Bolts, Nuts, Screws, Rivets, & Washers
3462	Iron & Steel Forgings
3463	Nonferrous Forgings
3465	Automotive Stampings
3466	Crowns & Closures
3469	Metal Stampings, N.E.C.
3471	Electroplating, Plating, Polishing, Anodizing, & Coloring
3479	Coating, Engraving, & Allied Services, N.E.C.
3482	Small Arms Ammunition
3483	Ammunition, Except for Small Arms
3484	Small Arms
3489	Ordinance & Accessories, N.E.C.
3491	Industrial Valves
3492	Fluid Power Valves & Hose Fittings

Fabricated Metal Products, Except Machinery & Transportation Equipment (Cont.)

3493	Springs, Steel, Except Wire
3494	Valves & Pipe Fittings, N.E.C.
3495	Wire Springs
3496	Miscellaneous Fabricated Wire Products
3497	Metal Foil & Leaf
3498	Fabricated Pipe & Pipe Fittings
3499	Fabricated Metal Products, N.E.C.

Industrial & Commercial Machinery & Computer Equipment

3511	Steam, Gas, & Hydraulic Turbines, & Turbine Generator Set Units
3519	Internal Combustion Engines, N.E.C.
3523	Farm Machinery & Equipment
3524	Lawn & Garden Tractors & Home Lawn & Garden Equipment
3531	Construction Machinery & Equipment
3532	Mining Machinery & Equipment, Except Oil & Gas Field Machinery & Equipment
3533	Oil & Gas Field Machinery & Equipment
3534	Elevators & Moving Stairways
3535	Conveyors & Conveying Equipment
3536	Overhead Traveling Cranes, Hoists, & Monorail Systems
3537	Industrial Trucks, Tractors, Trailers, & Stackers
3541	Machine Tools, Metal Cutting Types
3542	Machine Tools, Metal Forming Types
3543	Industrial Patterns
3544	Special Dies & Tools, Die Sets, Jigs, & Fixtures, & Industrial Molds
3545	Cutting Tools, Machine Tool Accessories, & Machinists' Precision Measuring Devices
3546	Power Driven Handtools
3547	Rolling Mill Machinery & Equipment
3548	Electric & Gas Welding & Soldering Equipment
3549	Metalworking Machinery, N.E.C.
3552	Textile Machinery
3553	Woodworking Machinery
3554	Paper Industries Machinery
3555	Printing Trades Machinery & Equipment
3556	Food Products Machinery
3559	Special Industry Machinery, N.E.C.
3561	Pumps & Pumping Equipment
3562	Ball & Roller Bearings
3563	Air & Gas Compressors
3564	Industrial & Commercial Fans & Blowers, & Air Purification Equipment
3565	Packaging Machinery
3566	Speed Changers, Industrial High-Speed Drives, & Gears
3567	Industrial Process Furnaces & Ovens
3568	Mechanical Power Transmission Equipment, N.E.C.
3569	General Industrial Machinery & Equipment, N.E.C.
3571	Electronic Computers
3572	Computer Storage Devices
3575	Computer Terminals
3577	Computer Peripheral Equipment, N.E.C.

Note: N.E.C. means Not Elsewhere Classified.

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Industrial & Commercial Machinery & Computer Equipment

3578 Calculating & Accounting Machines, Except Electronic Computers
3579 Office Machines, N.E.C.
3581 Automatic Vending Machines
3582 Commercial Laundry, Drycleaning, & Pressing Machines
3585 Air Conditioning & Warm Air Heating Equipment & Commercial & Industrial Refrigeration Equipment
3586 Measuring & Dispensing Pumps
3589 Service Industry Machinery, N.E.C.
3592 Carburetors, Pistons, Piston Rings, & Valves
3593 Fluid Power Cylinders & Actuators
3594 Fluid Power Pumps & Motors
3596 Scales & Balances, Except Laboratory
3599 Industrial & Commercial Machinery & Equipment, N.E.C.

Electronic & Other Electrical Equipment & Components, Except Computer Equipment

3612 Power, Distribution, & Specialty Transformers
3613 Switchgear & Switchboard Apparatus
3621 Motors & Generators
3624 Carbon & Graphite Products
3625 Relays & Industrial Controls
3629 Electrical Industrial Apparatus, N.E.C.
3631 Household Cooking Equipment
3632 Household Refrigerators, & Home & Farm Freezers
3633 Household Laundry Equipment
3634 Electrical Housewares & Fans
3635 Household Vacuum Cleaners
3639 Household Appliances, N.E.C.
3641 Electric Lamps Bulbs & Tubes
3643 Current-Carrying Wiring Devices
3644 Noncurrent-Carrying Wiring Devices
3645 Residential Electric Lighting Fixtures
3646 Commercial, Industrial, & Institutional Electric Lighting Fixtures
3647 Vehicular Lighting Equipment
3648 Lighting Equipment, N.E.C.
3651 Household Audio & Video Equipment
3652 Phonograph Records & Prerecorded Audio Tapes & Disks
3661 Telephone & Telegraph Apparatus
3663 Radio & Television Broadcasting & Communications Equipment
3669 Communications Equipment, N.E.C.
3671 Electron Tubes
3672 Printed Circuit Boards
3674 Semiconductors & Related Devices
3675 Electronic Capacitors
3676 Electronic Resistors
3677 Electronic Coils, Transformers, & Other Inductors
3678 Electronic Connectors
3679 Electronic Components, N.E.C.
3691 Storage Batteries
3692 Primary Batteries, Dry & Wet

Electronic & Other Electrical Equipment & Components, Except Computer Equipment (Cont.)

3694 Electrical Equipment for Internal Combustion Engines
3695 Magnetic & Optical Recording Media
3699 Electrical Machinery, Equipment, & Supplies, N.E.C.

Transportation Equipment

3711 Motor Vehicles & Passenger Car Bodies
3713 Truck & Bus Bodies
3714 Motor Vehicle Parts & Accessories
3715 Truck Trailers
3716 Motor Homes
3721 Aircraft
3724 Aircraft Engines & Engine Parts
3728 Aircraft Parts & Auxiliary Equipment, N.E.C.
3743 Railroad Equipment
3751 Motorcycles, Bicycles, & Parts
3761 Guided Missiles & Space Vehicles
3764 Guided Missile & Space Vehicle Propulsion Units & Propulsion Unit Parts
3769 Guided Missile & Space Vehicle Parts & Auxiliary Equipment, N.E.C.
3792 Travel Trailers & Campers
3795 Tanks & Tank Components
3799 Transportation Equipment, N.E.C.

Measuring, Analyzing & Controlling Instruments; Photographic, Medical, & Optical Goods; Watches & Clocks

3812 Search, Detection, Navigation, Guidance, Aeronautical, & Nautical Systems & Instruments
3821 Laboratory Apparatus & Furniture
3822 Automatic Controls for Regulating Residential & Commercial Environments & Appliances
3823 Industrial Instruments for Measurement, Display, & Control of Process Variables, & Related Products
3824 Totalizing Fluid Meters & Counting Devices
3825 Instruments for Measuring & Testing of Electricity & Electrical Signals
3826 Laboratory Analytical Instruments
3827 Optical Instruments & Lenses
3829 Measuring & Controlling Devices, N.E.C.
3841 Surgical & Medical Instruments & Apparatus
3842 Orthopedic, Prosthetic, & Surgical Appliances & Supplies
3843 Dental Equipment & Supplies
3844 X-Ray Apparatus & Tubes & Related Irradiation Apparatus
3845 Electromedical & Electrotherapeutic Apparatus
3851 Ophthalmic Goods
3861 Photographic Equipment & Supplies
3873 Watches, Clocks, Clockwork Operated Devices, & Parts

Note: N.E.C. means Not Elsewhere Classified.

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Miscellaneous Manufacturing Industries

3911	Jewelry, Precious Metal
3914	Silverware, Plated Ware, & Stainless Steel Ware
3915	Jewelers' Findings & Materials, & Lapidary Work
3931	Musical Instruments
3942	Dolls & Stuffed Toys
3944	Games, Toys, & Children's Vehicles, Except Dolls & Bicycles
3949	Sporting & Athletic Goods, N.E.C.
3951	Pens, Mechanical Pencils, & Parts
3952	Lead Pencils, Crayons, & Artists' Materials
3953	Marking Devices
3955	Carbon Paper & Inked Ribbons
3961	Costume Jewelry & Costume Novelties, Except Precious Metal
3965	Fasteners, Buttons, Needles, & Pins
3991	Brooms & Brushes
3993	Signs & Advertising Specialties
3995	Burial Caskets
3996	Linoleum, Asphalted-Felt-Base, & Other Hard Surface Floor Coverings, N.E.C.
3999	Manufacturing Industries, N.E.C.

Public Warehousing & Storage

4221	Farm Product Warehousing & Storage
4222	Refrigerated Warehousing & Storage
4225	Warehousing & Storage, General

Note: N.E.C. means Not Elsewhere Classified.

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TABLE 4
MANDATORY INDUSTRIES (Categories iv, v, vii, and ix)
Permit Required in Any Case
April 1992

TYPE OF FACILITY	FACILITIES INCLUDED	FACILITIES EXCLUDED	COMMENTS
Hazardous Waste Treatment Facilities	Facilities regulated by the State Department of Toxic Substances Control, which: a) operate under interim status or a permit under Subtitle C of the Resource Conservation and Recovery Act (RCRA), and b) use any method, technique, or process, to change the physical, chemical, or biological character or composition of RCRA hazardous wastes for the purpose of neutralization; energy or material resource recovery; rendering such waste nonhazardous, less hazardous, or safer to transport, store, or dispose; reducing waste volume; or making such waste more amenable for recovery or storage.		RCRA hazardous wastes are defined in Section 66261.3 of Title 22 of the California Code of Regulations.
Hazardous Waste Storage Facilities	Facilities regulated by the State Department of Toxic Substances Control, which: a) operate under interim status or a permit under Subtitle C of the Resource Conservation and Recovery Act (RCRA), and b) hold RCRA hazardous wastes from onsite or offsite locations for a temporary period until the waste is treated, disposed of, or stored elsewhere.	Temporary hazardous wastes storage facilities operated for less than 90 days are not covered by RCRA.	RCRA hazardous wastes are defined in Section 66261.3 of Title 22 of the California Code of Regulations.
Hazardous Waste Disposal Facilities	Facilities regulated by the State Department of Toxic Substances Control, which: a) operate under interim status or a permit under Subtitle C of the Resource Conservation and Recovery Act (RCRA), and b) discharge, deposit, inject, or place RCRA hazardous wastes on or into any land or water.		RCRA hazardous wastes are defined in Section 66261.3 of Title 22 of the California Code of Regulations.
Landfills	Active, inactive, and closed sites that: a) receive or have received wastes from other facilities covered by the General Industrial Stormwater NPDES Permit, b) are subject to regulation under Subtitle D of RCRA, or c) have accepted wastes from construction activities involving clearing, grading, or excavation of five acres or more.		A Landfill is defined as an area of land or excavation in which wastes are placed for permanent disposal, excluding land application sites, surface impoundments, injection wells, and waste piles (40 CFR Part 257.2).

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TABLE 4
MANDATORY INDUSTRIES (Categories iv, v, vii, and ix)
Permit Required in Any Case
April 1992

TYPE OF FACILITY	FACILITIES INCLUDED	FACILITIES EXCLUDED	COMMENTS
Land Application Sites	Active, inactive, and closed sites that: a) receive or have received wastes from other facilities covered by the General Industrial Stormwater NPDES Permit, b) are subject to regulation under Subtitle D of RCRA, or c) have accepted wastes from construction activities involving clearing, grading, or excavation of five acres or more.	Manure spreading operations.	A Land Application Site is defined as an area where wastes are applied onto or incorporated into the soil surface for agricultural purposes or for treatment and disposal (40 CFR Part 257.2).
Open Dumps	Active, inactive, and closed sites that: a) receive or have received wastes from other facilities covered by the General Industrial Stormwater NPDES Permit, b) are subject to regulation under Subtitle D of RCRA, or c) have accepted wastes from construction activities involving clearing, grading, or excavation of five acres or more.		An Open Dump is a municipal landfill failing to satisfy the Criteria for Municipal Solid Waste Landfills specified in 40 CFR Part 258. Open dumps are prohibited under Section 4005 of RCRA.
Steam Electric Power Generating Facilities	Facilities that generate electricity utilizing fossil type fuel (coal, oil, or gas) ~~or nuclear fuel and thermal cycle~~ using a steam water system, and raw material storage areas, including coal handling sites.	Facilities with NPDES permits which regulate stormwater discharges.	
Wastewater Treatment, Storage, Recycling, or Reclamation Facilities	Facilities that treat, store, recycle, or reclaim municipal wastewater, including adjoining land dedicated to sewage sludge disposal.	1. Facilities with NPDES permits which regulate stormwater discharges. 2. Facilities with design capacities of less than 1 MGD which are not required to have a pretreatment program under 40 CFR Part 403. 3. Farm lands and domestic gardens where sludge is beneficially reused, or sludge management facilities which are not located on land adjoining the treatment, storage, recycling, or reclamation facilities site. 4. Facilities that are in compliance with Section 405 of the Clean Water Act (federal regulations governing sewage sludge disposal). 5. Facilities that collect all stormwater runoff and discharge the runoff back to the headworks of the treatment facility.	

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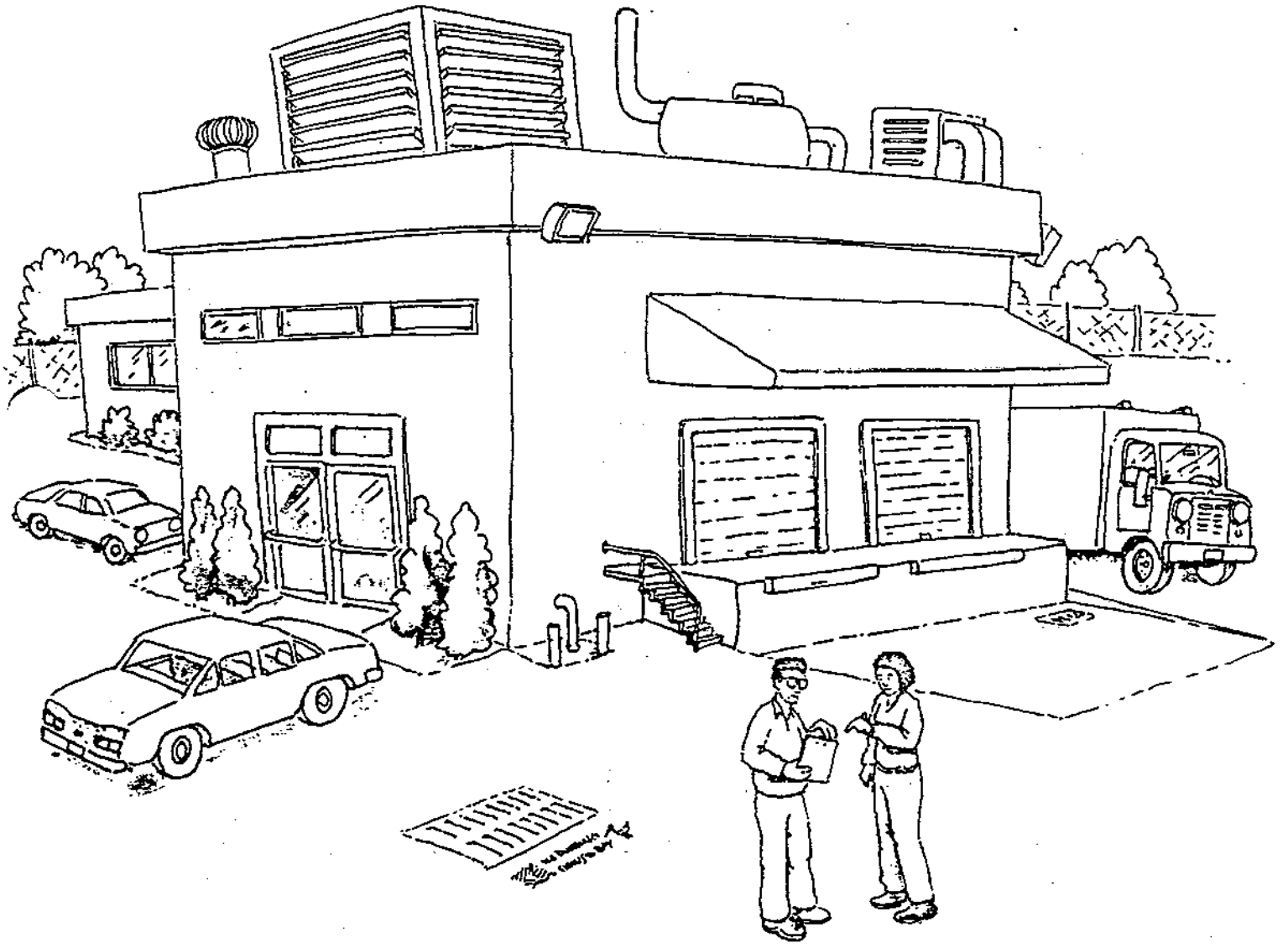
4CC BMPs for Industrial Storm Water Pollution Control

Best Management Practices for Industrial Storm Water Pollution Control



Santa Clara Valley
Nonpoint Source
Pollution Control Program

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Prepared for the Santa Clara Valley NPS Program by Woodward-Clyde Consultants: L. D. Duke, J. A. Shannon, June 1992.
Design and illustrations by John Finger, Finger Art & Design.

SARB_001165

Introduction: Storm Water Pollution Control for Industrial Facilities

Storm water is a source of pollutants in San Francisco Bay. Storm drains carry runoff from streets, urban centers, industrial sites, and open spaces into streams, creeks, marshes, and Bay waters. Industrial operations are only one contributor to this problem, but they are known to be a source of heavy metals, oily wastes, and other substances. Manufacturing, shipping, and storage operations that are exposed to storm water can be sources of pollutants in storm water.

Federal and state storm water regulations now require many kinds of industrial facilities to take steps to prevent storm water pollution. Your facility may need to be covered under the Regional Board's January 1992 Industrial Storm Water General Permit for the Santa Clara Valley. If so, you need to prepare a *Storm Water Pollution Prevention Plan*, or SWPP Plan, that is in part a collection of BMPs like the ones described in this manual. If your facility is *not* covered under the General Permit, you may still need to implement BMPs to comply with local pollution prevention requirements.

Storm water pollution, unlike some pollution problems, cannot be covered by one set of rules that applies to all industrial facilities. Regulated industrial facilities in the Santa Clara Valley range from manufacturing facilities that cover several square miles to storefront distributors. Different plants can have very different storm water quantities, flow patterns, and potential pollutants. Even different facilities of the same general industry may need different approaches to preventing storm water pollution.

The BMPs in this manual are recommended by the Santa Clara Valley Nonpoint Source Pollution Control Program to help you prevent storm water pollution; protect water quality in streams, the groundwater basin, and the Bay; and comply with storm water regulations. This manual is intended to help you identify and implement the best practices that are necessary and economically feasible for your facility to prevent storm water pollution.

The BMPs include both operating practices and structural controls that can reduce the amounts of pollutants in storm water. You need to determine which of these may apply to your facility, and implement them as necessary. Specific regulations may vary from one municipality to another, so you should become familiar with local storm water ordinances in your community.

This manual consists of two parts. The recommended BMPs in Part 1 are basic, everyday operational practices and relatively small structural or equipment requirements that can be effective in *preventing* pollution, reducing potential pollutants *at the source.*

In many industrial facilities, storm water pollution can be prevented with common-sense precautions and modest changes in routine operations or maintenance practices. The numbered sections are keyed to some industrial operations that are common to many kinds of facilities. The sections describe BMPs that typically can be applied to the operations. These practices alone might be sufficient to control storm water pollution for some industrial facilities.

In other cases, to prevent storm water pollution it will be necessary to establish new practices or build physical controls. Part 2 of this manual consists of "advanced management practices." The advanced BMPs require more costly or more intensive efforts to address pollutants that are not adequately controlled by the simpler operational BMPs. The advanced BMPs describe possible approaches if you need to go beyond the Part 1 BMPs.

SARB_001166

Recommended BMPs for Storm Water Pollution Prevention

Part 1 of this manual contains BMPs that are recommended to control storm water pollution from particular industrial activities. Part 1 is divided into numbered sections. Each section describes industrial activities common to many kinds of industrial facilities, and contains a collection of BMPs tailored to that kind of industrial activity or operation.

As a rule the recommended BMPs in this part of the manual are intended to describe "state of the practice." These are the preferred operational techniques that pertain to each of the industrial activities, recommended to control potential storm water pollution that could result from that activity. Many of these practices are straightforward housekeeping activities, and many may already be in place at your facility. In general, the recommended BMPs are *pollution prevention* measures: they are geared toward reducing pollutants at the source, preventing the release of potential pollutants to storm water.

The recommended BMPs are to be implemented on an ongoing basis for the indefinite future. Operators of industrial facilities in the Santa Clara Valley should expect to implement these BMPs or similar controls, wherever they would be effective at preventing pollutants from flowing with storm water from the site.

Review your current operating practices and, where they differ from the Part 1 preferred BMPs, modify your practices and train your employees in the new procedures. You need to evaluate your own facility and decide what works best, because storm water pollution control practices take a number of forms, and may include a wide range of solutions that are not included in this manual. Storm water pollution control may be guided by three general principles:

Prevent water from contacting working areas.

Shipping areas, outdoor equipment, material storage areas, vehicle maintenance spaces, and working areas of all sorts are subject to contamination with raw materials, process liquids, grease, oily wastes, heavy metals, and miscellaneous potential pollutants. If you prevent storm water, wash water, or water from other sources from contacting areas exposed to pollutants, you won't discharge pollutants into your storm drains.

- Keep rainfall from directly contacting working areas, by installing roofs, placing structures, or moving industrial operations indoors.
- Prevent *run-on* storm water from contacting industrial areas, indoors or out by using properly designed berms or grading. Run-on is water that flows across the industrial area. It picks up pollutants as it flows.
- Avoid practices where you use water that later enters the storm drains—for instance, washing in outdoor areas. Most of these practices, including many that were acceptable in the past, are now considered to be "illegal dumping" of non-storm water to the storm drain.

Keep pollutants off surfaces that come into contact with water.

Evaluate your site carefully to identify all areas that are contacted by storm water, wash water, cooling water that is otherwise unpolluted, or other water that is allowed to be discharged to the storm drain. Then take special care to keep pollutants off these surfaces. That means controlling minor leaks and spills that you might otherwise overlook, and taking a close look at your operating routines and equipment to determine whether any substances are exposed to storm water that do not need to be.

Manage storm water before it is discharged to the storm drain.

If you can't avoid adding pollutants to storm water, you may need to remove pollutants to meet water quality requirements before discharge. Storm water control regulations, and this manual, consider treatment as a last resort and emphasize source control options because they are usually less costly and more effective in the long run. In this manual, treatment measures appear only under Advanced Management Practices.

SARB_001167

1. Training and Education for Employees and Customers

Successful storm water pollution control relies in large part on proper training and education of employees. Many of the recommended BMPs in this part of the manual identify specific training needs for employees who conduct the activities. Train your employees in best management practices for storm water pollution control.

Train employees in these BMPs because a single employee's mistake or misunderstanding at the wrong time, in the wrong place, can lead to a costly pollution incident. When you have selected the BMPs that apply to your facility, add training in the BMPs to your regular employee training procedures.

Train employees to routinely inspect industrial activities and equipment that may be exposed to storm water. A once-a-week walk-through can help identify potential difficulties before they become major problems. Inspect structural BMPs to be sure that they continue to function properly.

Continue your training procedures in the future. Assign experienced workers to train new employees. Review procedures as a group at least once a year. You can coordinate this with worker safety training programs or "worker right-to-know" training for hazardous materials.

Periodically check employees' work practices to be sure the BMPs are implemented properly. Post informational and reminder signs, such as: proper equipment wash procedures at designated washing areas; "Close the cover" signs at dumpsters and other storage areas; and others. Stencil "No dumping! — flows to Bay" messages at storm drains. (Stencils are available from the NPS Program.)

Provide general information as well, because employees often respond best if they understand *why* they are being asked to conduct a new procedure. Employees' suggestions in return can help identify cost-effective storm water controls for your facility. Provide positive feedback so employees understand the difference they each make in protecting the Bay.

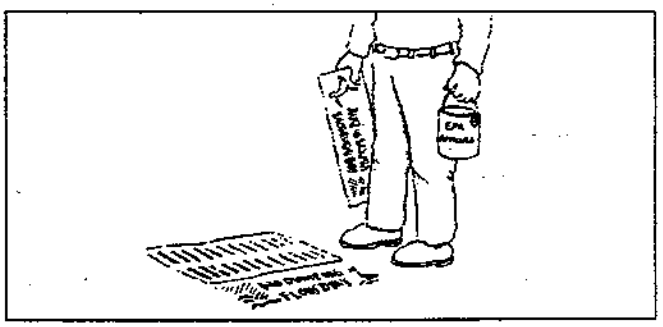
Emphasize the importance of keeping pollutants out of the storm drain, because the drains flow directly to streams and the Bay without benefit of the wastewater treatment that the sanitary sewers receive. Educate plant personnel about the harmful environmental effects of improper disposal of materials into the storm drain, so they understand the importance of preventing storm water pollution. Also, educate employees on what they can do at home to reduce storm water pollution in the Bay. Public information pamphlets are available from your municipality or the NPS Program — see the back cover.

If you subcontract for small construction jobs or other work on your premises, write contracts with your BMPs as conditions. Provide contractors with proper disposal options for wastes. Monitor contractors to be sure they comply with your BMPs.

To keep abreast of new developments, participate in workshops, trade association meetings, and seminars. Trade association publications can be valuable sources of information. Modify your practices whenever you find a new idea that serves your shop better.

If you serve customers at your facility, be aware of customer activities onsite. If they dispose of materials improperly, *you* will be responsible for the violation. Ask your customers not to discard liquids into your trash cans or storm drains. If you have persistent problems, you may need to monitor your customers more carefully at trash cans, storm drains, and other potential disposal areas on your property.

Let your customers know how you are minimizing wastes and recycling fluids to show that you are a "good neighbor," and encourage your customers to be the same. Showing clients what you are doing to protect the Bay is good public relations. Some businesses make the customer aware of their environmental requirements by including a modest environmental compliance fee, itemized on customers' billing statements, to cover handling and disposal costs for hazardous materials.



Label storm drain inlets so employees do not dispose waste there.

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2. Eliminating Improper Discharges to Storm Drains

The Industrial Storm Water General Permit generally prohibits discharges of *anything but storm water* to the storm drains. There are many ways in which non-storm water from industrial plants can enter the storm drainage system. In most cases, the discharges result from practices that are now illegal, even though they may be inadvertent or may have been permissible in the past. Industrial process water, building wastewater, and water from other sources are prohibited, with a few exceptions described in Table 1. Inspect your facility and yard to be sure no unauthorized discharges enter your storm drains.

Unauthorized discharges take two forms. **Illicit connections** are improper permanent connections that allow wastewaters to enter storm drains, including some that may have been allowed in the past. Connections that allow sanitary or process wastewater to enter the storm drain are prohibited, including all storm drain connections from indoor drains or sinks. More information on identifying and removing illicit connections is available in the Santa Clara Valley NPS Program's Guide to Compliance with the General Permit.

Illegal dumping is water that has been exposed to industrial activities, and then released to the properly-connected storm drainage system. Pollutants may be introduced to storm drains inadvertently, by routine practices that discharge water outdoors; or by routinely discharging wastes, wash water, and other materials to storm drains, catch basins, and other conveyance facilities either on your property or in the street. A large part of this improper discharge results from employees' lack of understanding, coupled with a lack of readily-available proper routes for the discharge.

You need to make a long-term ongoing effort to assure that no illegal discharges will occur. This requires continuing observation to identify potential sources of intentional or inadvertent improper discharges. Discontinue or re-route the water from those activities. Continuing employee training will be needed. Measures to help prevent illegal discharges include:

- Provide well-marked proper disposal or collection methods for waste water wherever you frequently use wash water, discharge cooling water, or produce a liquid waste that might otherwise reach the storm drain.
- Employee training should especially emphasize proper disposal of non-storm water (see Section 1). Educate employees to understand that storm drains connect directly to streams and the Bay without treatment.
- Label all storm drain inlets and catch basins "No dumping—flows to Bay" so employees will know which inlets are part of the storm drain system.
- Periodically inspect and maintain storm drain inlets. Clean out catch basins so that accumulated pollutants do not wash down the storm drains.

Table 1 is a summary of a 3-page table included in the Storm Water Industrial General Permit for the Santa Clara Valley. The table identifies some common sources of water in industrial plants that can enter storm drains. For each source, the table lists the preferred disposal option for facilities in the Santa Clara Valley. For water that is allowable for discharge to the storm drain, Table 1 lists conditions or restrictions on discharge.

A few discharge categories of special interest are:

- **Cooling tower condensate** for industrial process water must be discharged to the sanitary sewer, with the appropriate permits.
- **Internal coolant** for refrigeration or building air conditioning is prohibited from the storm drains.
- **Building air conditioner condensate** may be discharged to the storm drain *only* if it is not treated with algae inhibitors, corrosion control chemicals, or other additives. Do not allow it to run across parking lots or other paved surfaces that may be contact pollutants on its way to the storm drain; use a pipe or trough to direct the flow. In most Santa Clara Valley cities, the preferred course is to discharge to the sanitary sewer. (Some cities have made this a legal requirement.)

Table 1. Preferred disposal options for water discharges

Water source	Preferred disposal option	Restrictions or permit needed	Possible options for reuse or recycle
Industrial process wastewater	Sanitary sewer	POTW permit	Reuse in-plant whenever possible.
Non-contact cooling water	Onsite reuse		Reuse in closed-loop cooling system (cooling tower).
• Uncontaminated*	Storm drain if reuse is impossible	Storm water NPDES permit	
• Contaminated	Sanitary sewer	POTW permit	Treat and reuse
Industrial cooling equipment condensation		Storm water NPDES permit	Hold and apply to landscape
• Uncontaminated*	Storm drain	Must be tested and shown to be uncontaminated.	
• Contaminated	Sanitary sewer	POTW permit	
Building air conditioner condensation	Storm drain (if city allows)	Some localities require discharge to POTW with permit	
Building air conditioner coolant			Reuse in-plant whenever possible.
• Uncontaminated*	Storm drain	Storm water NPDES permit	
• Contaminated	Sanitary sewer	POTW permit	
Storm water in outdoor secondary containment			
• Uncontaminated*	Storm drain	Test to determine contamination.	Pump and apply to landscaping. (See Section 5)
• Contaminated	Sanitary sewer	POTW permit	
Storm water from outdoor material storage			
• Covered	No discharge	Zero contact with storm water.	
• Open	Storm drain	Water quality inlet or similar treatment. (See Section 20) Storm water NPDES permit	
Roof drain water	Storm drain if no pollutants	Roof vents may be source of pollutants. See BAAQMD air emissions regulations and Section 4.	
Industrial equipment wash water	Sanitary sewer	POTW permit	Reuse in-plant whenever possible
Vehicle maintenance wash water	Sanitary sewer	POTW permit	Capture and reuse for washing
One-time vehicle wash water	Storm drain (See Section 7)	Water only (no soap or solvents)	Minimize water; prevent flow across paved area.
Wash water from paved walkways in commercial and business districts	Storm drain	Sweep sidewalks before washing. No cleaning chemicals may be used.	Minimize water use and direct to landscape.**
Commercial exterior building wash water	Storm drain	Filter prior to entering catch basin.	Minimize water use and direct to landscape.**
Landscape irrigation	Storm drain		Minimize water so none runs off.**
Potable water and potable line flushing	Storm drain	Must be dechlorinated***	
Fire fighting flows	Storm drain	Block downstream channels to detain for testing as hazardous waste.	

Source: Storm Water Industrial General Permit for the Santa Clara Valley, Regional Water Quality Control Board /S. F. Bay Region, January 1992.
POTW permit: Permit to pretreat and discharge is required from your wastewater authority (Publicly Owned Treatment Works)
BAAQMD: Bay Area Air Quality Management District
* Biocides, corrosion inhibitors, or other additives are contaminants from a storm water point of view.
** Must comply with local water use restrictions during drought conditions.
*** Potable water, swimming pool water and other chlorinated sources must be dechlorinated by aeration, retention, or chemical additives to a "no measurable chlorine" standard before reaching receiving water. If the water is not dechlorinated it must be discharged to the sanitary sewer under a POTW permit.

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3. Spill Prevention, Control, and Cleanup

Small spills can have cumulative effects that add up to a significant source of potential pollutants in your storm water discharge. The best approach by far is to prevent spills and leaks: maintain a regular inspection and repair schedule, and correct potential spill situations before a spill can occur. Some prevention techniques are described in Sections 4, 5, and 6.

When a spill does occur, quick and effective response is the best way to prevent pollutants from reaching storm water. Prepare a set of well-defined procedures for responding to a spill of any liquids in an area that might be exposed to storm water. The procedures can be specific for your facility, and should consider all circumstances from small, minor releases that can be easily handled to a large emergency spill — including who to call to respond to the situation before it gets out of hand. Train employees in the procedures (Section 1).

The basic procedures should emphasize that spills be cleaned up promptly, not allowed to evaporate. Otherwise, pollutants remain on the pavement and may be washed to the storm drains with the next rain, or will remain in the soil to become a possible groundwater pollutant. If the spill is on an unpaved surface, determine whether you need to remove the contaminated soil to prevent it from being a source of future storm water pollutants.

Also, the standard procedures should specify cleaning up leaks, drips, and other spills without water whenever possible. Do not use a hose or wet mop to clean up a spill area. Hosing may remove the spill from the immediate area, but does not keep the pollutant out of the environment. On the contrary, it adds to the volume of the spill and spreads the spilled material around a larger area.

If you handle hazardous materials, spill prevention and response procedures are described in your hazardous materials management plan, filed with your fire department or other hazardous materials ("HazMat") authority (see Section 6). If a spill occurs, notify the authorities as required in your emergency response plan. Contain and collect the spilled substance, then dispose of the substances and any contaminated soil in compliance with hazardous materials regulations.

Small spills are those which can be wiped up with a shop rag. Don't put wet rags in the dumpster with the shop trash: store them in a covered rag bin, of the kind used at auto service stations. Avoid paper towels. You can avoid making this a waste stream by sending used rags to a professional cleaning service. (You need to inform your cleaning service of what the shop rags have been used for.) Do not saturate rags with gasoline, solvents, or other volatile liquids.

Medium-sized spills are too large to wipe up with a rag and require more attention. Contain and soak up the liquid using dry absorbent material such as vermiculite, specially-prepared sawdust, or "cat litter." Absorbent "snakes" may be used as temporary booms to contain and soak up the liquid. Sweep up the used absorbent and snakes and dispose of them appropriately: with the shop trash if non-hazardous, with the hazardous wastes if necessary. Another convenient option is to use a wet/dry shop vacuum cleaner to collect spills, and dispose of the liquid with your liquid or hazardous wastes. *Do not* use vacuums for gasoline, solvents or other volatile fluids, because the enclosed vacuum may become an explosion hazard.

Larger spills must be contained, then cleaned up. For spills of food waste or other non-hazardous liquid, take steps to contain and clean up the liquid, and minimize the wash water used in cleanup. Shut off or plug storm drain inlets or sewer inlets where the spill may enter. If necessary, keep temporary plugs on hand to fit your inlets and train employees in when and how to use them. For hazardous materials spills, implement your emergency procedures and alert your HazMat authority.

Wipe up small spills immediately with shop rags.

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4. Outdoor Process Equipment Operations and Maintenance

Storm water from your site can accumulate pollutants by exposure to numerous small leaks, spills, and other discharges of outdoor equipment. Large equipment may require specially-designed structural or advanced BMPs to reduce the potential for storm water to contact pollutants. Ordinary precautions, such as those below, may suffice for smaller equipment.

As a first step, identify all equipment at your site that may be exposed to storm water, or may discharge potential pollutants that may be exposed to storm water. Identify the kinds of pollutants each piece of equipment may generate — lubricants, coolants, and other possible sources of leaks or discharges.

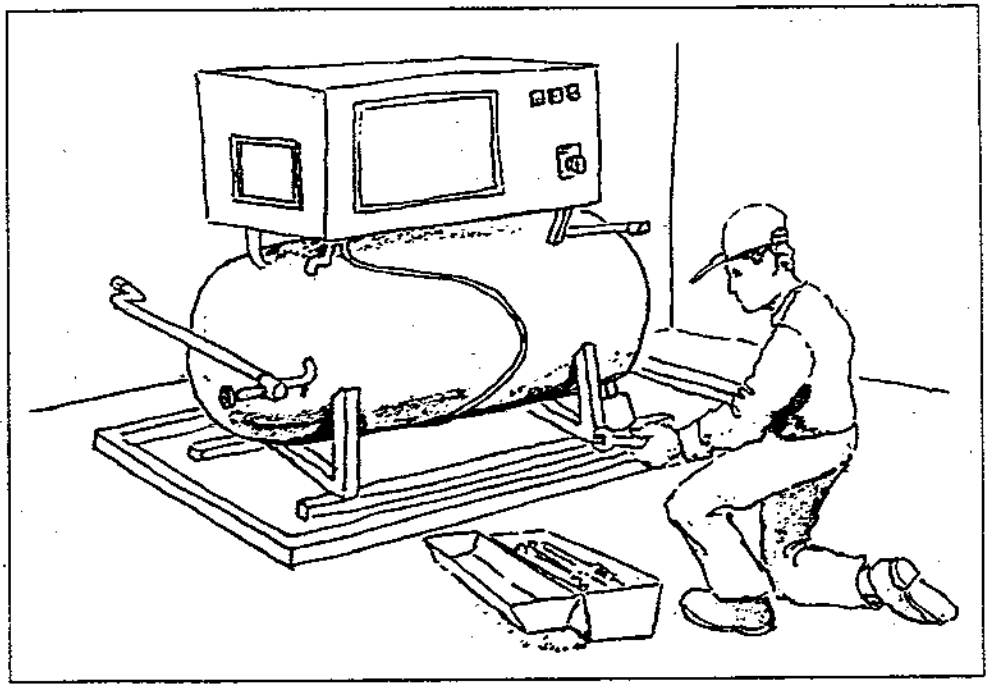
Be creative and thorough in developing your list. The inventory should include rooftop cooling towers or air conditioners; rooftop air vents for industrial equipment; outdoor air compressors and other service equipment; indoor wet processes where leaks or discharges may discharge to outdoor areas; and material transfer areas, such as loading areas where forklifts or trucks may carry pollutants outdoors on their tires.

Using the equipment inventory, assign an employee to inspect each piece of equipment on a regular basis to see that it is functioning properly. This could be the employee responsible for operating the equipment if it is used regularly, or may be a maintenance staff member for equipment on the roof or in seldom-seen places. Inspect for leaks, malfunctions, and staining on and around the equipment, and other evidence of leaks and discharges. Assign the inspecting person to be responsible for reporting a spill. Develop a routine for taking actions on the report: cleaning up the spill, and repairing the leak to prevent future spills.

Where possible, take the next step toward full pollution prevention and make modifications to prevent storm water from contacting the equipment or its discharges. Place equipment on an impermeable surface, or install a drip pan beneath potential leak points. To minimize the amount of rainwater that contacts the equipment, you may construct a simple roof and install a berm to prevent run-on and runoff. If the equipment requires a "wet" process — that is, operations inevitably releases wash water or process liquids — place it on a paved surface and install a connection to the sanitary sewer. Check with your municipality or wastewater authority to identify appropriate permits.

Air compressors and other equipment sometimes produce small quantities of automatic blowdown water, which commonly contains lubricating oil or other potential pollutants. This may not be discharged to the storm drain. Connect the blowdown to the sanitary sewer. Or, if the compressor has a frequent small bleed, place a drip pan or catchment to collect the water — do not let it soak into unpaved surfaces or run off paved surfaces.

Condensate on exterior surfaces of compressors, building cooling equipment, and other machinery need not be collected for discharge to the sanitary sewer, but may be directed to the storm drain. Prevent buildup of puddles or pools of condensate under the equipment; route it to a storm drain so it does not pick up pollutants while it flows across your site.



Keep drip pans under outdoor equipment to contain drips and leaks, especially during maintenance.

5. Outdoor Materials Storage and Handling

If you handle **bulk solid materials** outdoors, keep them covered, in appropriate containments, and protected from storm water. Apply this policy for raw materials, products, by-products, and construction materials or supplies. Materials of concern include gravel, sand, lumber, topsoil, compost, concrete, packing materials, metal products, and others.

Store the material in one of these ways:

- The preferred method is storage on a paved surface with a roof or covering so that no direct rainfall contacts them, and with appropriate berms or mounding to prevent run-on of storm water. Roofs are required by most municipalities for new facilities.
- Where a roof is not feasible, store on a specially constructed paved area with a drainage system. Pave the area with a slope of about 1.5% to minimize water pooling. Prevent runoff and run-on with berms or curbing along the perimeter. For many materials, the preferred alternative will be the installation of *no drain* and the testing and pumping of ponded water to the sanitary sewer, a treatment sytem, or offsite disposal as appropriate. Discharge to the storm drain is not allowed for many materials.
- Where a drain is allowed, install longitudinal drains that lead to treatment facilities or water quality catch basins along the lower edge of the pad. You may need a permit from your wastewater authority to discharge to the sanitary sewer, or may need the Regional Board to allow special provisions in your storm water NPDES permit (the General Permit).
- As a temporary arrangement, place the material on a paved surface and cover it with plastic sheeting, secured with weighted tires or sand bags. If possible, choose a mounded or bermed area that will prevent run-on of storm water through the material. Move the materials to a permanent storage place as soon as possible.

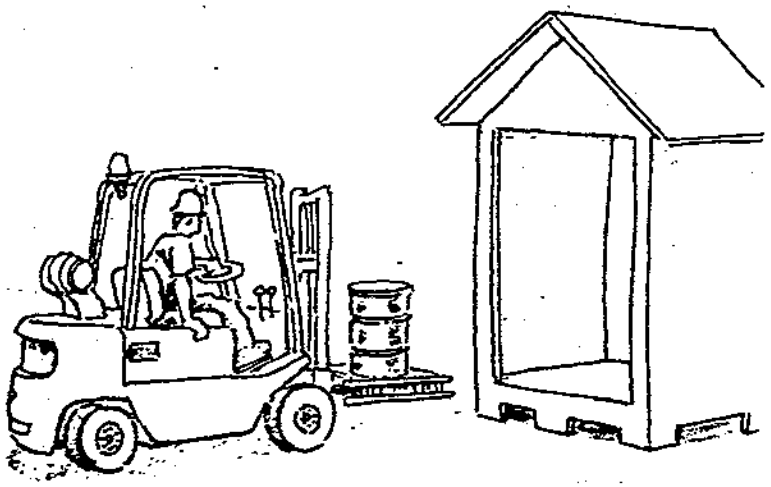
Parking lots or other surfaces near bulk materials storage facilities should be swept periodically to remove fines that may wash out of the materials, which will otherwise wash away with storm water. Larger bulk material storage facilities will need more extensive structural controls designed for the specific facility and material.

Hazardous materials need to be stored in accordance with federal, state, and local HazMat requirements. The requirements are generally more than adequate to prevent storm water pollution — for instance, HazMat secondary containment may have *no drain*.

If you store **liquid containers**, implement a plan and a design to control unexpected leaks and spills so the liquid does not reach storm drains or surfaces that will be exposed to storm water. If you store hazardous materials, the spill prevention plans required by your HazMat authority are adequate to ensure storm water protection. Non-hazardous materials storage should also incorporate spill control designs and procedures.

Select a storage method appropriate for the type of material. Keep liquid tanks in a designated area on a paved impermeable surface and within a berm or other secondary containment. Keep outdoor storage containers especially in good condition. Inspect containers regularly for damage or leaks, as described

"Doghouse" sheds are one way to keep storm water away from barrels and materials kept outdoors, and provide spill control at the same time.



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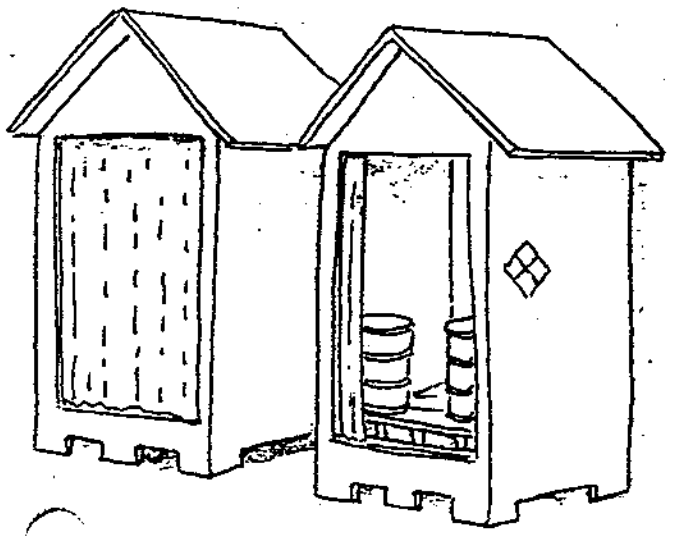
in Section 4. Clean up any leaks or spills immediately (using dry methods, described in Section 3), and repair the leaks promptly.

If the materials frequently leak during transfer, or the materials generally cause a wet environment when using or storing them, the area may need to be connected to the sanitary sewer (permitted by your wastewater authority), and should be covered and bermed to minimize contact with storm water.

Some localities *require* that secondary containments be connected to sanitary sewers, and prohibit any hard-plumbed storm drain connections within the secondary containment. On the other hand, large storage facilities and tank farms that have high-capacity bermed areas may receive rainfall over a wide area, and much of it may not contact the tanks or equipment; these might be better-served by a storm drain. As a rule, large facilities like this need site-specific storm water pollution prevention designs.

For smaller storage tanks, storage in roofed areas can prevent all contact with storm water (in combination with well-designed spill control procedures). Store liquids in a shed where one is available. New sheds, even if temporary, can be costly because of building permits and fire-code requirements. A possible option is the "doghouse" design used by some firms (illustrated). The roof and flooring prevent contact with direct rain or run-on storm water. Since it has only two walls, most fire departments do not require sprinklers. The flooring is wire mesh above secondary containment, so most HazMat authorities accept the structure for storing hazardous materials. (A permit may be required by local building or planning departments.)



Storm water in secondary containments often accumulates from direct rainfall into open containments. Water that has contacted storage vessels, or the pumping and transfer equipment associated with storage and handling, is considered to have contacted industrial activities and may not be discharged to the storm drains.

You may wish to roof the containment to avoid this problem. If that is not possible, or you wish to avoid the cost, you need to identify an acceptable disposal for water from the containment. One common solution is a portable pumping system that can be moved to accommodate separate containment structures on your site. The equipment can pump water into a truck or portable temporary holding tank. The water then can be tested and disposed according to whether any pollutants are present. Some disposal options are:

- If it meets criteria to be defined as hazardous waste, employ a certified hazardous waste hauler for disposal at a permitted hazardous waste facility.
- If it contains constituents similar to process wastewater for which your onsite wastewater pretreatment facilities are designed, pretreat the water and discharge to the sanitary sewer.
- If it meets standards for your industrial discharge permit, discharge it to the sanitary sewer without pretreatment (if your wastewater authority permits).
- Reuse it on your site in an appropriate manner: industrial process water, equipment wash water, steam cleaning makeup, or another use where the water will eventually be discharged as industrial or sanitary wastewater. You may need to invest in a truck or plumbing to convey the water to its reuse location.
- If it is free of hazardous constituents, use it on your facility grounds for landscape watering. Don't apply the water to landscaping if hazardous pollutants are present — even if not concentrated enough to be hazardous waste — because the pollutants may accumulate in the soil or vegetation, and create a health hazard over the long term.

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6. Waste Handling and Disposal

Table 2 summarizes the preferred storage and disposal practices for some common industrial facility wastes. For many wastes, reusing or recycling is the most cost-effective means to prevent potential pollution. Fluids that you hold for recycling are special categories of hazardous waste. You may store them on your site only for short periods, in accordance with hazardous waste requirements, but they can be transported under somewhat less stringent requirements than other hazardous wastes. Many recycling services have special variances or permits that reduce your paperwork requirements and allow shipping at reduced cost.

Keep general shop trash in a dumpster with the lid closed. Put the dumpster in a paved area, not on unpaved soil or your lawn. Keep the area clean by picking up dropped trash and sweeping the area regularly (perhaps once a week), but don't use a hose to clean up — keep water off the area. Nearly all dumpsters and trash compactors leak; keep liquid wastes out of them, and keep them closed to keep storm water out.

If you can't prevent leakage from trash containers, install a roof or lean-to that keeps direct rainfall off, and place asphalt curbing or berms around the dumpster to contain the leaks. (Check with your local agencies and comply with fire codes and building permits.)

If you store **scrap metal** or other materials outdoors, keep them under a roof, cover, or tarpaulin. Keep scrap parts or other used metals indoors. Oils and other potential pollutants can wash off long after you think the parts have been washed clean. Collect waste metal, such as used parts and metal lathe filings, for delivery to a scrap metal dealer.

If you store **empty drums** outdoors, do not hold them longer than necessary. Ship them to a drum reconditioner or another facility.

- Drain them completely to avoid spills.
- Seal them properly watertight, to keep storm water from entering; otherwise, the water would become a process wastewater, and can't be dumped to the storm drain.

Store and handle **hazardous wastes** properly. Hazardous materials or wastes are not a storm water problem if they are handled in accord with state and federal regulations, and the requirements of your local HazMat control authority.

Keep hazardous waste and materials indoors or under cover in a locked area, to keep nighttime trespassers away. Store them before disposal in special hazardous waste containers, or closed drums within a secondary containment that is approved by your HazMat authority.

Table 2. Preferred waste handling & disposal methods

		Recommended storage	Preferred disposal	Hazardous waste?
General plant wastes	Used parts: clean metal scrap	Bin (covered or indoors)	Scrap collector	No
	Used oily parts, contaminated	Drum	Hazardous waste hauler	Yes
	Metal shavings	Bin (covered or indoors)	Scrap collector	No
	Used rags	Rag bin with lid	Rag laundry	Possibly
	Soiled cleanup absorbent	Drum	Hazardous waste hauler	Yes
	Coolant from air conditioner or refrigeration equipment	Recycling machine	Reuse in-house (HVAC service company)	No
Liquid wastes	Paints*	Original container, with lid	Hazardous waste hauler	Yes
	Waste lubricating oil	Drum (segregate)	Oil recycler	Special**
	Solvents, thinners, and miscellaneous fluids*	Tank ("hot" waste) (Segregate different fluids to make recycling possible)	Solvent recycler (where possible) or waste hauler	Possibly
Liquid containers	Empty drums	Indoors or under cover	Drum reconditioner	
	Empty cans, bottles, aerosol cans, etc.	Drum	Municipal trash or hazardous waste hauler	Possibly
Vehicle wastes	Waste motor oil	Drum (segregate)	Oil recycler	Special**
	Brake fluid, gear oil, hydraulic fluids, etc.*	Bottle or tank ("hot" waste)	Hazardous waste hauler	Yes
	Antifreeze	Tank (segregate)	Recycler	Special**
	Batteries	Open rack	Battery supplier	Special**
	Tires	Covered or indoors	Tire hauler	No
	Oil filters	Drum (drain first)	Oil recycler	Special*

* *Unused pure product may sometimes be returned to the vendor rather than disposed as waste.* ** *Recyclable under special hazardous materials restrictions.*

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In most cities of Santa Clara County, the municipal fire department is the HazMat authority that controls hazardous materials storage, handling, and response. Some locales contract with the Central Fire District or the County Health Department. For information about handling solid wastes that might be controlled under hazardous waste regulations, contact the County's Environmental Health Department or Cal-EPA's Toxic Substances Control Division. (See the rear cover for a list of regulatory agencies.)

Empty containers such as storage barrels, oil cans, paint buckets, aerosol cans, and similar containers are hazardous wastes if they once held hazardous materials. You may not discard these with the regular trash. They must be stored properly so they do not leak outdoors. Some drum suppliers accept empty drums for reuse, under less-stringent hazardous material recycling regulations.

Vehicle maintenance waste materials often deserve special attention. Waste oil, antifreeze, spent solvents, and some other liquids can be recycled. Spent batteries may not be discarded with trash, but must either be disposed as hazardous waste, or returned to the dealer from whom you purchased them, for reclamation and reuse. Guidance on handling vehicle wastes may be found in the Automotive Industries BMP manual, available from the NPS Program and listed on the rear cover.

7. Equipment Washing and Steam Cleaning

Wash water for industrial equipment in most cases must be discharged as process wastewater to the sanitary sewer, and is not allowed in storm drains. To clean dirty, greasy field equipment or trucks you must install equipment to capture, pretreat, and discharge the wash water to the sanitary sewer as industrial process waste. It may be less costly in the long run to locate a commercial car wash which has all the appropriate equipment and municipal permits, and to contract with them for washing services offsite.

If you wash vehicles or equipment on your site, you may do so only in a designated area, designed and equipped as follows:

- Pave the area.
- Mark the area clearly as a wash area, and be sure all employees know they must wash in this area only. Post instructional signs that prohibit changing vehicle oil, washing with solvents, and other activities.
- Install sumps or drain lines to collect wash water for treatment and discharge to the sanitary sewer; reuse (for repeated washings); or recycle (used elsewhere onsite).
- If the equipment is a continuing source of grease or heavy dirt, cover the area to prevent contact with rain water when not in use.
- Grade or berm the area to prevent storm water from running on.
- If possible, wash inside a building designed for maintenance or equipment storage. Ensure that all drains connect to the sanitary sewers.

Steam cleaning should be done on your site *only* if you are equipped to capture all the water and other wastes. All the washing requirements above apply to steam cleaning as well. Steam cleaning wash water is prohibited from storm drains; requires a permit from your wastewater authority — including pretreatment requirements, such as an oil/water separator; and may require you to determine whether it is a hazardous waste treatment unit. If you steam clean, do it indoors or in a specially-prepared outdoor working area where you collect the wash water and treat it for discharge.

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8. Trucking and Shipping/Receiving

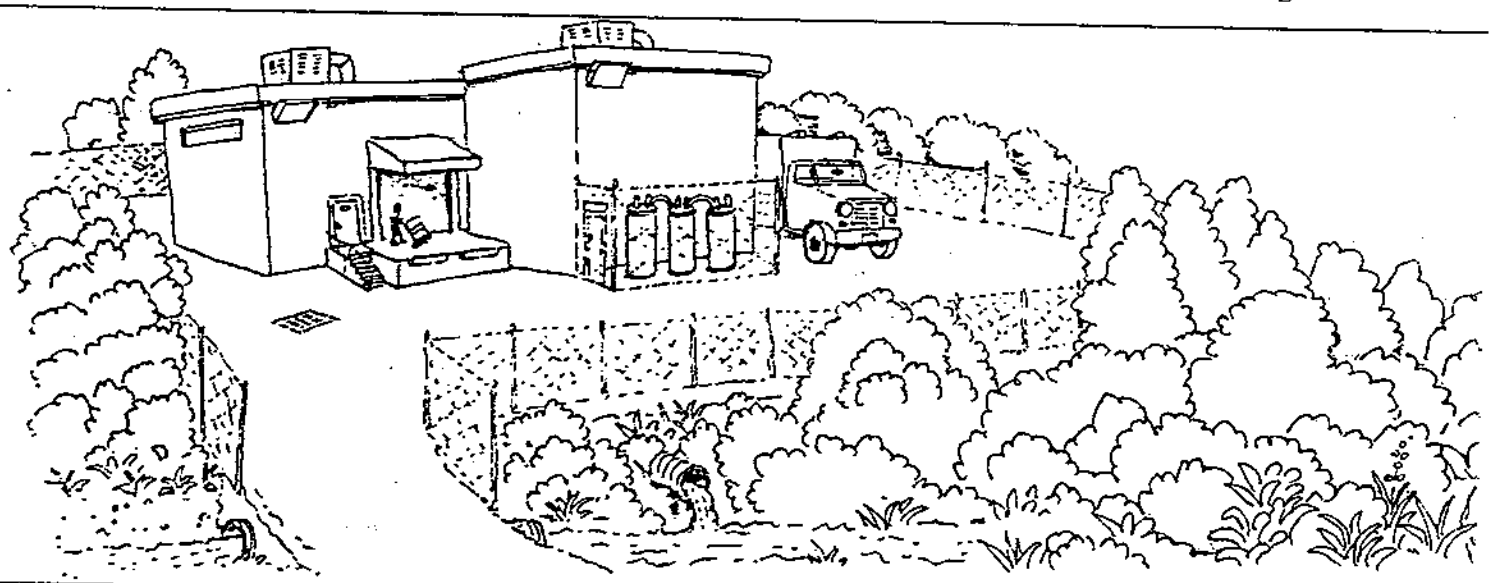
Truck loading and unloading are potential sources of pollutants when rainfall and run-on contact spilled raw materials, dust, and motor fluids that accumulate in this heavy-traffic area.

Load and unload raw materials, products, and other materials only at designated loading areas. In that way, you can isolate the potential source to areas that you can control, rather than unspecified areas throughout your site. The best areas from a storm water point of view are indoor bays. For facilities that must use an outdoor loading dock, some operational BMPs and simple design features can control storm water pollution.

- Cover the loading dock area with a roof overhang, or use a door skirt that fits snugly to both the building door and the truck door.
- Install curbs or berms around the loading area to prevent storm water from running on and any spilled material from running off. Accumulated liquids should be pumped out with a portable pump to the sanitary sewer unless concentrations exceed allowable limits. In those cases the material must be treated or shipped offsite.
- Designate the person who accepts the shipment, the truck driver, or someone else to check under the truck for leaked motor fluids, spilled materials, debris, and other foreign materials.
- If you own and operate the truck, make the driver responsible for identifying and reporting the spill — large or small.
- If you receive shipments from trucks operated by others (a trucking company or suppliers' trucks), i.e., the drivers are not your employees, have the person who signs for delivery responsible for inspecting for spills, leaks, and debris before the trucks leave.
- Detail a procedure so that a maintenance crew cleans up spilled materials promptly.
- If you have a small company that cannot spare a crew, make the driver responsible for cleaning up after unloading or before departing with a full load.
- If you identify the loading dock as a significant source of potential pollutants in your SWPP Plan, implement further control measures such as those described in Section 13.

If you load or unload liquids, you need further operational precautions and the loading dock needs further design features. If you handle hazardous materials, all the features you need are probably in place as part of a spill control and response plan. If they are not, you should select structural BMPs such as those described in Section 13.

Parking lots and access roads are sources of potential pollutants from the trucks themselves and from possible spills or leaks of the materials being transported. If you are re-grading roads and parking lots, or if you transport materials that you expect to be signifi-



Storm water runoff from industrial roofs, trucks, parking lots, and yards flows into storm drains and directly into streams and the Bay. It never receives treatment that would remove pollutants.

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cant sources of potential storm water pollutants, follow the structural BMPs recommended in Section 16. For existing facilities, especially smaller parking lots and short driveways where no hazardous materials are transported, you can effectively prevent storm water pollution by implementing routine maintenance activities, such as:

- Visually inspect your access roads and parking lots regularly to identify and clean up spills.
- Remove solid debris as soon as operations permit.
- Clean up liquid spills promptly, as if they were on your shop floor.

Conduct street sweeping-style cleanups periodically to remove loose debris, small amounts of spilled raw materials, road dust, and other potential pollutants.

- Smaller spaces can easily be swept by hand.
- Do not hose off paved surfaces.
- For larger spaces, use a vacuum truck or mechanical sweeper (that collects solids, not just brushes them aside). Whenever possible, do not use a wet-washing street sweeper unless you can collect the polluted wash water.
- Private corporations or your municipality might perform the work on a contract basis so you need not purchase the truck.

During the dry weather season, the appropriate frequency of sweeping for your facility depends on how heavily the road is used and the kinds of materials you transport. Some signs that you need to sweep more frequently:

- If your trucks commonly spill or drip bulk materials.
- If you notice debris or other materials accumulating on the access roads. The correct frequency is the one that prevents unwanted materials from accumulating.

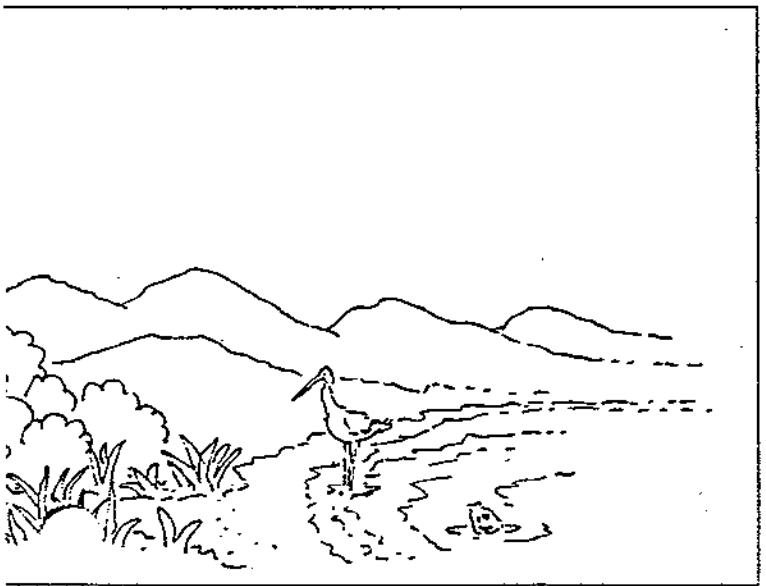
During the wet weather season, emphasize sweeping at times that will best prevent storm water from contacting potential pollutants:

- Clean the area once thoroughly in the fall, before the wet weather season begins.
- After that, you may stay close to your dry-season needs for debris removal, but add an additional thorough cleaning before a major rainfall (half an inch or more of rainfall forecast).

Dispose of the cleaned-up material with your regular facility trash if there are no hazardous materials. If you suspect it may be hazardous — if you handle hazardous materials, or if you know of a significant motor oil leak, for example — you should test the material or dispose of it with your facility's hazardous waste. You could face substantial penalties if you improperly dispose of hazardous waste.

If you **park trucks or heavy equipment** onsite, inspect the parking area for leaks of oil and motor fluids and design a procedure to report them, clean them up, and repair the leaking vehicle. Some practical techniques include:

- Designate consistent parking spots for each vehicle so that if a leak is indicated on the ground, the truck can be identified and repaired.
- Designate a responsible person to check under a vehicle for leaks or spills. If you employ drivers, the driver could be responsible as part of a vehicle check before driving.
- Clean up spills promptly, using dry cleanup procedures described in Section 3. Conduct the preferred cleanup procedures for unpaved as well as paved areas.
- Develop a reasonable procedure for identifying, reporting, repairing, and cleaning up leaking motor fluids and spilled materials. Make sure employees are fully trained in the procedures: who is responsible for checking each truck, who should be notified, and who should respond.



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9. Fleet Vehicle Maintenance

The Automotive BMP manual prepared by the Santa Clara Valley NPS Program addresses automotive and vehicle repair facilities. You should implement the BMPs in that manual if vehicle maintenance is a potentially significant source of pollutants on your site. Sections 9 and 10 of this manual merely summarize some of the appropriate BMPs for fleet maintenance at an industrial facility.

Whenever possible, perform vehicle maintenance in an indoor garage, not in outdoor parking areas. If you change oil and do other routine engine work outdoors, you need to create a designated area for vehicle maintenance. Keep the area clean as if it were part of your shop floor and use dry cleanup practices. The area should incorporate some specific design features, as described in Sections 14 and 15. Some operational methods also can be successful at preventing storm water pollution at vehicle maintenance areas. A few suggestions:

- Keep equipment clean; don't allow buildup of grease and oil, which will wash away when the equipment is exposed to rain.
- If you work on vehicles outdoors, keep drip pans or containers under the vehicles at all times while you work on them — leaks and spills occur unexpectedly. Place drip pans under vehicles as soon as you detect a leak.
- Drain fluids from any retired vehicles kept onsite for scrap or parts. Out-of-service vehicles you intend to restore and vehicles being held for resale should be checked periodically for leakage.
- Don't change motor oil or perform vehicle or equipment maintenance in the parking lot or storage yard; use the vehicle maintenance area. Don't allow customers or employees to change their personal vehicles' oil in your vehicle service areas.

Vehicle **parking or storage yards** need to be operated with some similar precautions:

- Inspect equipment in the yard for fluid leaks regularly — perhaps with a walk-by inspection for ground staining every day, and a closer visual inspection once a week.
- Keep the equipment yard clean and clear of debris, using dry sweeping methods as in Section 8. Do not hose off the area or wash with water, because any runoff becomes an illegal discharge to the storm drain.
- Maintain the yard's storm drain inlet(s) with special care. Clean them on a regular schedule and also after large storms. Pay attention to the kinds of potential pollutants that accumulate, so you can identify the sources and take measures to control the sources.

10. Fleet Vehicle and Equipment Fueling

If you have a vehicle fueling area it should be designed and operated to minimize spilled fuel and leaked fluids coming into contact with rain water. This section describes general principles, but simple operational controls may not be adequate for an industrial fueling facility. You may need to re-design your fueling area or install structural controls. Section 14 describes some general design approaches that may be useful in your eventual complete Storm Water Pollution Prevention Plan. In the near term, steps you can take for proper operation of a fueling area include:

- Use a paved area or provide a concrete slab for the fueling area — never place it on open ground. Concrete is preferred because fuel and oils cause asphalt to deteriorate.
- Clean up gasoline overflows and spills using dry methods as in Section 3. Do not allow spills to run off or evaporate, and do not flush the spill away with a hose. Spread absorbent material, sweep it up with a broom, and dispose of it as a hazardous waste.
- Post signs that instruct pump operators not to "top off" or overfill gas tanks. Keep dry cleanup materials in the fueling area, and instruct employees in the dry clean up methods described in Section 3. Assign someone responsibility to check the area every day for gasoline, motor oil, or other fluids that may have leaked.
- When you do routine cleaning, use a damp cloth on the pumps and a damp mop on the pavement rather than spraying with a hose to minimize clean water to the sump.

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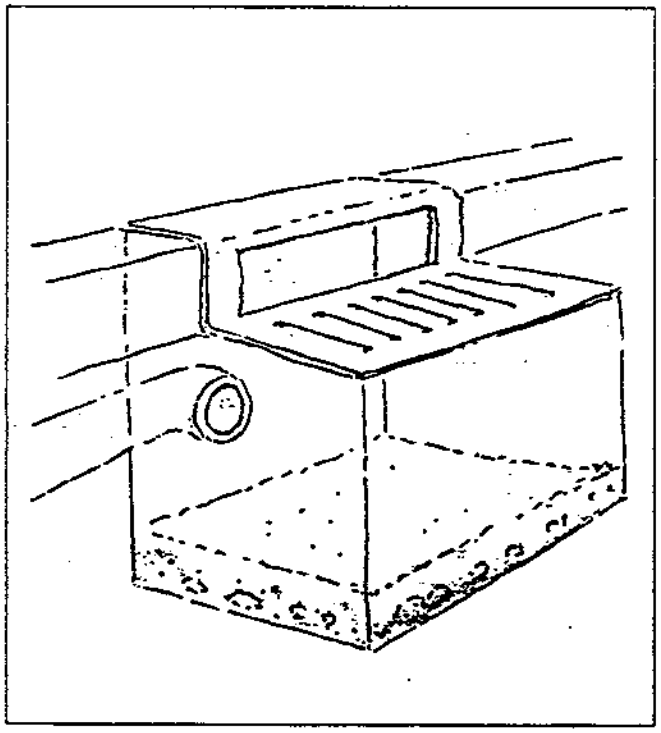
The main concept is to respond properly to fluid leaks in this spill-prone area. Even very small spills, when they happen every day, add up to a lot of fuel in the drainage system. This is an improper discharge that is illegal under the General Permit. Small spills do not present a problem if the fueling area is designed to handle spills — that is, if no storm water contacts it, and if it drains to a sump. But if the area drains to a valved-off storm drain or sewer connection, it must be pumped out before the valve may be opened during a rainfall.

Fuel tanks, including temporary tanks, need to be permitted by your HazMat authority. They will specify design features such as size of containments. Keep temporary fuel tanks in a bermed area that has an impervious lining, such as concrete or a heavy-gauge plastic liner.



A catch basin helps keep debris and sediments out of the storm drain, but needs to be cleaned out periodically.

11. Building Maintenance and Grounds Upkeep

Building maintenance and general outdoor cleanup should use the same principles as parking lot cleanup and spill prevention: clean up without water whenever possible, by sweeping or wiping; wash with as little water as possible; prevent and clean up spills; and clean up debris and solids so they do not reach the storm drains.

Arrange **rooftop** drains or downspouts so they don't drain directly onto paved surfaces. Connect them directly to a storm drain instead. Alternately, allow water to flow onto a grassy surface, if the grassy area is large enough that it can accept the roof's entire runoff from a medium-sized storm — that is, no water runs across the grassy area into a paved area except in the largest of storms.

Maintain the **storm water conveyance system** on your property. The "conveyance system" may be as simple as roof downspouts and a gutter in your driveway, or may be an extensive system of inlets, ditches, drainage channels, and underground lines. Keep all parts of the system clear of debris to avoid blockage that may cause storm water to back up. Remove from the system any spilled or leaked materials that can be transported by storm water.

Clean the storm drain inlets to remove sediment and debris at least twice a year — late in the dry weather season before the first storm, and after the first major storm of the wet weather season. After each large storm, inspect the inlet; remove debris; and determine whether you need to remove sediments or do other maintenance.

The storm drain inlet may have a **catch basin:** a below-grade chamber where the storm drain pipe connects. Catch basins are intended to collect debris and sediments to prevent clogging the lines. Therefore, the catch basins themselves must be cleaned out periodically to prevent flooding. If you clean catch basins annually, shortly before the wet weather season, you can keep them flowing freely and remove leaves, sediments, and other materials that would otherwise be washed down the storm drain. Don't flush the catch basin with water: use a shovel or vacuum device to remove the materials.

Other useful design features, such as vegetated ditches and water quality improvement inlets, are described in Sections 19, 20, and 21 as advanced BMPs.

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12. Building Repair, Remodeling, and Construction

This section describes some relatively simple BMPs that apply to minor building repairs, remodelling, and minor construction projects at an industrial facility that involve "industrial activity exposed to storm water."

Larger-scale projects, such as construction of new facilities, are covered under a separate General Permit for construction. These require more extensive storm water pollution prevention measures than described here. A separate BMP manual for construction activities is available from the Santa Clara Valley NPS Program. (See rear cover.)

The same practices are *recommended* for construction activities on industrial sites. Before you begin a construction or repair project, review the Construction BMP Manual to identify and implement the appropriate practices. If those BMPs do not apply, or are unduly elaborate for a simple construction activity that will be completed in a short time, consider the BMPs described in this section.

Store building materials under cover or in contained areas, using BMPs discussed above, in Section 5. For outdoor storage at a construction site, select a pollution prevention method such as:

- Put an impermeable tarp over piles of wood, gravel, or other materials. Don't wait for forecasts of rain — do this every day, to avoid being caught unaware. Also, it will keep materials from blowing off the pile and contributing pollutants to runoff later.
- Keep the working area clean every day for the same reason. Sweep up wood splinters, paint chips, and other residues every day, as well as a thorough cleanup at the end of the project.

Painting requires some basic procedures.

- Before painting, while you scrape to remove old paint, spread a ground cloth or tarpaulin to collect dust and paint chips. If the paint contains lead or tributyl tin, dispose of the paint chips as hazardous waste.
- Mix paints indoors before starting work.
- Use impermeable ground cloths, such as plastic sheeting, while you paint. Place in-use paint buckets in a pan or on plastic sheeting.
- At the end of the work day, store paint buckets and barrels of materials away from contact with storm water.
- Use a tarp or portable, inflatable berm to prevent spills.
- Treat a paint spill as a chemical spill: capture it before it flows to the storm drain, and clean it up promptly using dry methods.

During **painting cleanup,** proper procedures are:

- If you use water-based paint, clean brushes and equipment in a sink connected to the sanitary sewer.
- Clean up oil-based paint where you can collect the waste paint and solvents to be handled as small quantity hazardous waste — do not pour it to the sink or to a storm drain.
- Keep leftover paint, solvents, and other supplies for a later use, or deliver them to a solvent recycler with other plant wastes when you ship a batch.
- Handle empty paint cans and other containers as described in Section 6. Containers may be small-quantity hazardous waste. Latex paint cans are not hazardous waste if the paint is dry.

Do not fall back on old cleanup practices from days when storm water pollution was not known as a problem. Do not pour leftover paint down the storm drain or onto the ground. Do not clean brushes into the storm drain or pour buckets of cleanup water to the drain, or wash spilled paint down the storm drain with a hose. These practices are now categorized as "illegal dumping." Do not wipe brushes onto old newspapers, or pour leftover paint supplies into newspapers and discard the paper in the trash.

Spray painting requires a few extra precautions.

- Use temporary scaffolding to hang drop cloths or draperies to shield you from the wind and to collect overspray.
- Arrange the draperies to minimize the spreading of windblown materials.
- Be aware of air quality restrictions on spray paints that use volatile chemicals. Consider a water-based spray paint for better air quality compliance.

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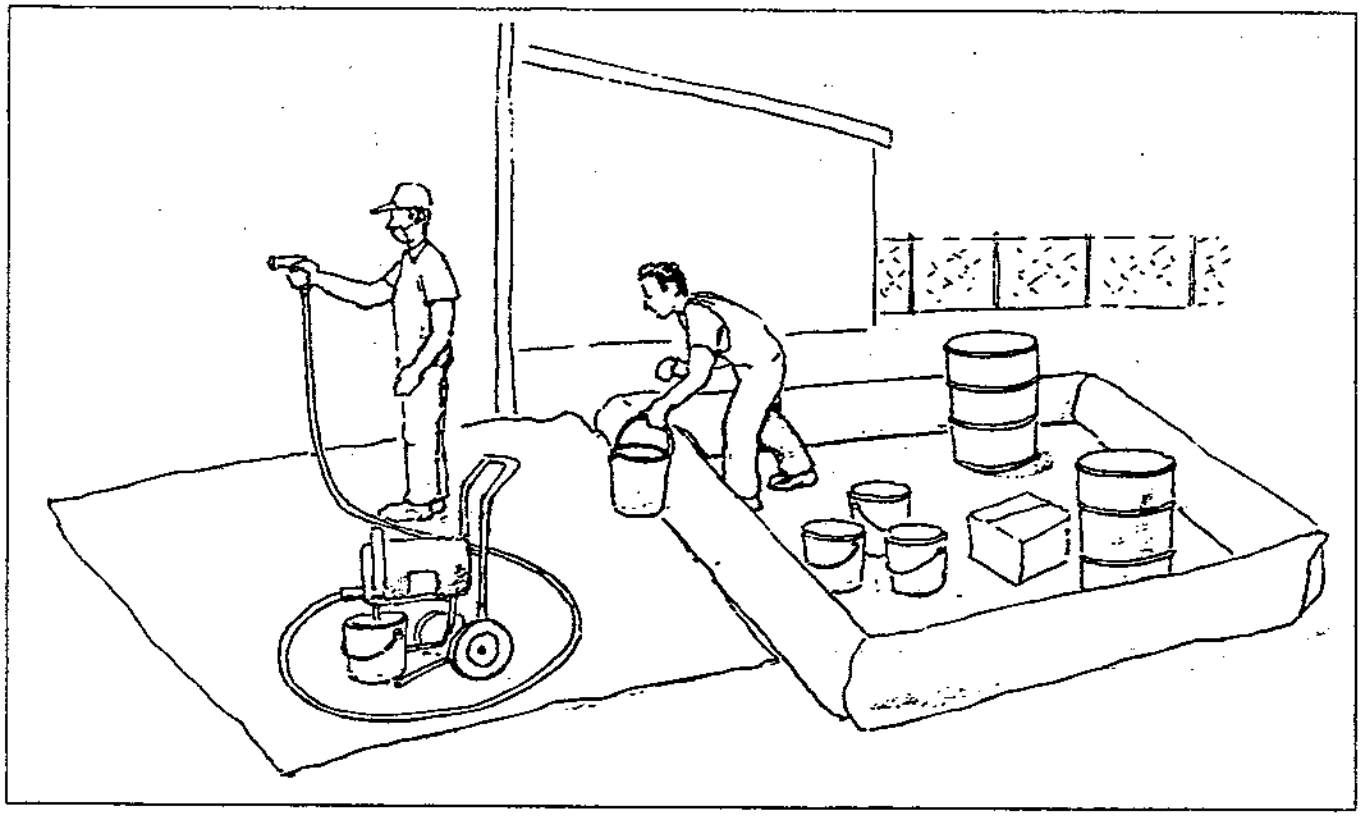
Sand blasting can be controlled to keep particles off of paved surfaces and out of storm drains. Ask your municipality whether building and construction codes place requirements on the size and type of blasting medium that is allowed. More complete instructions are available in the Construction BMP manual for full-sized jobs, but some basics should be applied for smaller projects, as well:

- Place a tarpaulin or ground cloth beneath your work to capture the blasting medium and particles from the surface being cleaned.
- Hang tarps or drop cloths to enclose the area, using temporary scaffolding if necessary. Arrange the drop cloths to protect the work area from wind, and to capture airborne particles.
- Curtail operations on a windy day.
- Clean up frequently: collect dust and particles from the drop cloths before you produce too large a pile to handle easily.

Wood preservatives, pavement seal coating, and other outdoor surface treatments commonly contain metals, pesticides, solvents, or polymers that are hazardous materials. Handle and dispose of them properly, as follows:

- Apply only as much of the chemical as the wood can absorb or as needed to cover the paved area.
- Soak up excess chemicals with absorbent material or rags rather than allowing them to flow to the storm drains or soak into the soil.
- If the chemicals spill, clean up promptly using dry techniques; see Section 3.
- When sealing a sidewalk, prevent the sealant from reaching the gutters or drains. Use absorbent booms, or stuff rags into storm drain openings.
- When treating a roof with wood preservative or sealant, line the gutters with rags. Dispose of the rags properly: with your hazardous waste if the substances you are using are hazardous.
- If you clean a roof or sidewalk before applying preservative, sweep thoroughly to remove loose particles first, then wash with water if necessary.
- Collect wash water from downspouts or drains where possible and remove particles.
- Avoid applying surface treatment chemicals during the wet weather season.



Outdoor painting requires practices to prevent paint and dust from becoming storm water pollutants.

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Advanced BMPS and Structural Controls

Some industrial operations and plant situations require more extensive measures to control storm water pollution. All but the smallest and least complex industrial facilities are likely to require some structural modifications. Depending on your facility, and your success at eliminating potential sources of storm water pollution, your long-term implementation plan may need to include more or fewer of these advanced BMPs.

The BMPs in this section are more extensive and, in general, more costly than the recommended BMPs in Part 1. These BMPs include structural controls — storm water management measures that require constructing new facilities or installing new equipment. Not all of the advanced practices are necessary for every facility, and some will not be of use in some facilities.

You will need to evaluate your own plant to determine which BMPs are applicable to your operations, and which combination will best succeed at controlling the storm water pollutants that may run off from your site. You may find you have a choice in selecting structural BMPs, unlike in implementing basic recommended practices. Evaluate and select controls that are adequate and most cost-effective for your site.

The BMP descriptions in Part 2 are not complete design standards, but describe the central principles you need to consider in identifying and controlling storm water pollution from various sources in your plant. Design standards, performance specifications, and detailed discussion of the design and application of structural and treatment BMPs are available in a BMP manual from the state of California, scheduled for publication in late 1992.

Advanced pollution control practices take a number of forms, and may include a wide range of solutions that are not listed here. You may develop other approaches that are more effective for your facility.

Or, you may need to develop and implement further BMPs than the ones described in this manual. If you conduct more complex activities, especially activities that are unavoidably exposed to storm water, you will need to develop more intensive source control and storm water management BMPs.

If you are renovating your shop or building a new facility, you should evaluate installing some of these structural controls even if the shop does not currently have a pollution problem with that specific area. Some of the structural measures in this section are much less costly to install during new construction than to retrofit afterwards.

For example, if you re-grade an equipment parking area, you should consider storm water design criteria even if the yard has not been in violation of standards in the past. If you put off implementing the measures, future more-stringent requirements may require these same measures to be retrofitted, which can be much more costly than if you do it while constructing a new facility or renovating for other reasons.

If your principal sources of pollutants do not originate with industrial activities, you may need to control sources that are not specifically named in the General Permit, such as: pesticides and fertilizers from landscape maintenance; oil and antifreeze from autos in large employee parking lots; and cooling water or equipment lubricants from large building ventilation and cooling equipment. Your municipality and the NPS Program hold their own permit that requires they reduce pollutants in storm water from *all* sources, and they may request your cooperation in developing controls for your pollutant sources that go beyond the BMPs in this manual.

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13. Loading Dock Design Features

Loading docks may require more intensive pollution controls than the operational BMPs described in Section 8. This is especially true of areas where you load or unload liquids in containers. Bulk liquid transfers are a more intensive industrial operation that requires specific control designs, and are not addressed in this manual.

Additional features of a properly-designed loading dock include:

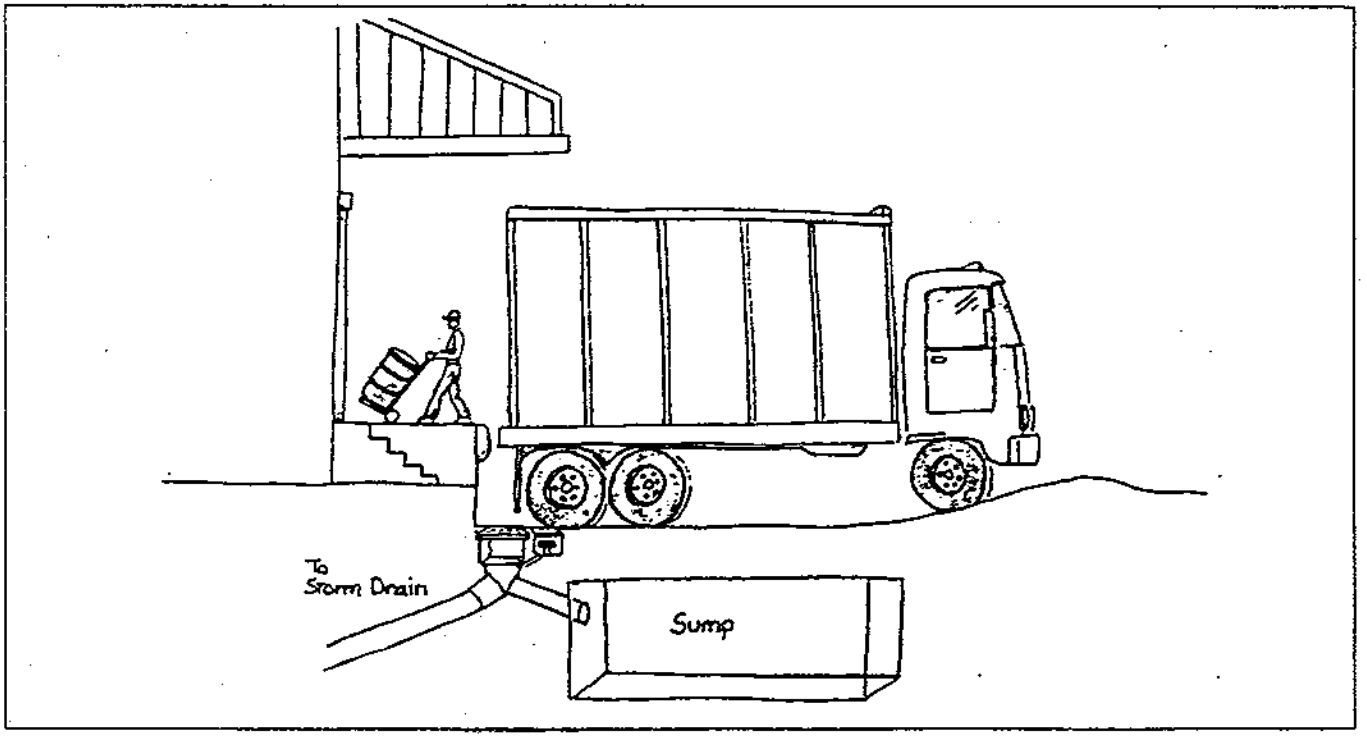
- Grade the loading area to be sloped or recessed to direct flow toward an inlet with a shutoff valve, or toward a dead-end sump.
- Make sure the inlet includes a sump with enough capacity to hold a spill while the valve is closed.
- Keep the valve closed at all times except when you need to release storm water or other liquids that are acceptable for discharge.
- Preferably, this inlet should connect to a sanitary sewer rather than a storm drain. Check with your wastewater treatment authority for permitting requirements.
- Consider completely preventing contact with storm water using a roof and berms, as described in Section 8. This will both avoid washing potential pollutants into the drain and avoid discharging clean storm water to the sanitary sewer.

If the inlet connects to a *storm drain:*

- Accumulated liquid must be tested and found to contain *no pollutants* before opening the valve for discharge.
- If the liquid does contain pollutants, you need to pump it from the sump and discharge to your sanitary sewer if the wastewater treatment authority agrees to accept it. (See the recommendation below.)

If the inlet connects to a *sanitary sewer:*

- Accumulated liquid must be tested and found to be within the parameters specified in your wastewater discharge permit before opening the valve for discharge.
- If you cannot discharge to the sanitary sewer, you need to convey the liquid to a hazardous waste disposal facility.



A dead-end sump provides secure spill control, but any accumulated liquids need to be pumped out, tested, and properly disposed. Use berms or slopes to prevent run-on so storm water is not added to waste in the sump.

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14. Equipment Yard Design Features

Parking and storage yards for large vehicles and heavy equipment generally require site-specific structural and operational controls. Follow the operational BMPs for vehicles recommended in Sections 7, 8, 9, and 10. Also assess your equipment yard to determine possible sources of pollutants, and install appropriate controls to keep potential pollutants out of the storm water. Design approaches may include:

- Grade the area to slope to a longitudinal drain, or install curbs to direct all storm water to a storm drain in the yard. If your yard is not too large and is properly designed, it should drain to a single storm drain. Even a small yard should include a storm drain on your property, and not rely on a city-operated drain in the street.
- If you determine that the equipment yard is a large source of oily materials in your storm water, consider fitting the inlet(s) with a sand filter (see Section 20) or removing oily pollutants (see Section 21).

Segregate the area where you service vehicles, and install special structural controls.

- If possible, perform all work indoors, or construct a roof over the specified area. This will require a building permit and compliance with appropriate fire codes.
- Pave the surface with concrete, not asphalt. Vehicle fluids may dissolve asphalt, or may be absorbed into the blacktop and released later.
- Drain the surface to a single drain, preferably connected to a sanitary sewer. The drain may require an oil/water separator or oil/grease trap, and must be approved by your wastewater treatment authority.
- Grade the working area to be higher than the parking lot, or surround it with a berm, to prevent storm water run-on.
- Construct a special area in which to segregate your "dirtiest" equipment (roof tar equipment, asphalt paving equipment, etc.) Handle its discharges, leaks, and runoff separately. This approach could save you from the need to treat *all* the runoff from the equipment yard.

15. Fleet or Equipment Fueling Area Design Features

If your facility's vehicle fueling area is one of the significant sources you identify in your SWPP Plan, you may need more intensive BMPs than the operational efforts described in Section 10. Some design features to consider are:

- Cover the fueling area to prevent rain from falling directly on the area. Install a roof over the fueling island, the area where vehicles park while fueling, and as much of the approach area as practical. Leaked engine fluids and spilled fuel inevitably accumulate on the pavement in these heavily-trafficked areas.
- Storm drain and sewer inlets that drain the fueling area must be equipped with a shutoff valve to keep fuel out of the drain in the event of a spill from the pumps. The valve should be kept closed at all times except during a rainfall.
- Curtail fueling activities when the valve must be open, or use extra precautions to capture any spilled fuel, such as a large drip pan under the vehicle.

A number of different approaches may serve as effective **drainage design.** The fueling area needs to be separated from the rest of the yard, both to contain any fuel spill and to prevent storm water from running on. Select or adapt a scheme such as one of these:

- Grade the fueling area to be "mounded" or elevated. The Automotive Industries BMP manual includes a suggested mounded grading scheme.
- Install berms around the area that are high enough to redirect water from a large storm.
- Grade the entire fueling area to drain to a single inlet. You can accomplish this with longitudinal drains at the perimeter along the "downhill" side of the fueling area, or with a depression in the middle of the fueling area. Either way, be sure to design the grading to avoid run-on.
- At the inlet, either install a sump, from which you will pump any accumulated liquids; or connect to a sanitary sewer, after checking to get all the permits the wastewater authority may require. The sump or connection should be operated as suggested for a loading dock area in Section 13.

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16. Access Roads and Rail Corridors

Access roads and rail corridors can be significant sources of pollutants for some industrial facilities. In the General Permit, access roads and rail corridors are defined as "industrial activities exposed to storm water" that you must include in identifying potential sources and selecting BMPs for your SWPP Plan.

Maintenance and operational BMPs for access roads are the same as those described for vehicle access and parking areas under Section 9. Some structural BMPs are described below.

Proper drainage design is a good place to start. Generally, this means the roads should be crowned and sloped outward; and that storm water should not be allowed to drain across the road, but be carried in ditches or culverts alongside the road. Grass-lining the roadside ditches can be an effective way to remove storm water pollutants — see Section 20. Maintain the ditch to be sure it does not clog or fill with sediments, allowing storm water to overflow. Plant vegetation by the roadside to control erosion and to promote rainwater infiltration.

If your site includes railroad access, an important source of pollutants is the preservatives on wooden railroad ties. Use a less-toxic preservative; avoid organic toxics such as creosote and pentachlorophenol. Or use concrete ties or other non-wooden ties.

Control spills and dust from railroad unloading. If your rail line delivers or picks up liquids, in bulk or in containers, you may need to add spill-control loading docks with shutoff valves. (See Section 3 for spill controls, and Section 13 for loading dock design features). If parked railroad cars drip, install a drip pan at the loading dock between the rails.

17. Onsite Storm Water Management

Some industrial facilities may still find potential pollutants exposed to storm water even after implementing source control measures like the operational BMPs in the first part of the manual and the structural source controls above. Further structural controls can be used to manage the storm water itself, either to control the flow of the runoff (described in Section 19), to remove some of the pollutants in passive devices (Section 20), or to remove pollutants using specially-designed equipment (Section 21).

The best way to avoid the need for storm water management or treatment is to use source controls, most likely in combination. The right combination for your facility will probably include conscientious implementation of BMPs such as those recommended in Sections 1 through 12 of this manual, attention to the sources of waste at your facility, and careful reduction of process wastes.

If you need to manage storm water onsite, the most important consideration is to minimize the quantity of storm water that contacts potential pollutants. For example, keep the area of industrial activities as small as possible; separate the area from parking lots, to prevent run-on; and roof or enclose the area if possible.

Design your storm water conveyance system to *isolate* the areas where storm water contacts potential pollutants, and convey water from those areas separately from water that runs off of "clean" and non-industrial parts of the site. This will allow you to control storm water with smaller and less-costly hydraulic or water quality controls. Or, if you plan to discharge to your wastewater treatment authority (Section 18), reducing the volume will reduce the discharge cost and increase the willingness of your wastewater authority to accept the discharge.

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18. Redirect Storm Water Discharge from Storm Drain to Sanitary Sewer

If source control BMPs are not adequate to prevent discharging pollutants in storm water from your facility, you may need to cease discharging storm water that contacts those pollutants. One way to avoid discharging potential pollutants with storm water is to isolate runoff from that part of your facility where the pollutants are contacted and discharge the storm water to the sanitary sewer rather than a storm drain.

Installing new connections and new piping can be quite costly, and the required permits may be a barrier, so this could be a costly BMP. Also, it will require a permit from your local wastewater authority. The permit will specify the volume of water you may discharge, the kind of pretreatment equipment you may need to install and operate, and requirements for monitoring your discharge.

Redirecting discharge to the sanitary sewer may not be allowable in all localities — some wastewater authorities have sections in their local ordinances that prohibit the discharge of storm water to the sanitary sewer. Requirements might differ from one municipality to another, so contact the authority that serves your area for information. (See the list on the rear cover.)

Your wastewater treatment authority, as a rule, would prefer to minimize the volume of storm water that passes through the treatment system. You should reduce the quantity of storm water you redirect, using techniques like those described in Section 17.

The wastewater authority may require temporary storage of your storm water onsite, to avoid overloading their facilities during a storm. Your authority is more likely to accept discharge of storm water that has contacted pollutants if you can store it temporarily and deliver it *after* the high flows from a storm event.

19. Storm Water Management: Hydraulic Controls

Hydraulic controls are intended to control *quantity* of storm water discharge, but can be useful for water *quality* as well by removing potential pollutants from storm water. BMPs of this type are widely used to control erosion of hillsides and to remove sediments from storm water runoff. Also, hydraulic-control BMPs can help to remove oils and heavy metals that adsorb to sediment particles in storm water.

Design standards and operating information for hydraulic controls are available in a number of references. The NPS Program is preparing a manual of "new development" BMPs recommended for newly-constructed buildings, which includes discussion of hydraulic BMPs for storm water pollution control and conditions under which hydraulic BMPs should be implemented. Design specifications for hydraulic controls will also be addressed in detail in a BMP manual being prepared by the state of California for storm water pollution control. Many local and regional regulations that target erosion control give specifications for hydraulic BMPs.

Hydraulic controls are designed for one of two purposes. One category serves to control the **rate of peak flow**, slowing the flow of water at the height of the storm to reduce its potential to carry away soils and other contaminants. The other type reduces **volume** of runoff, generally by causing some storm water to *infiltrate* (or soak into the soil) rather than running off into storm drains, streets, or streams. Some approaches control both peak rate and volume.

Hydraulic controls for a site are most effective if the overall site design is considered. The first step generally is to modify the site layout to increase the water-permeable surface, to increase infiltration and reduce runoff volume. If greater flow control is needed, the second step may be to strategically place *infiltration trenches* to intercept runoff and promote infiltration. (Infiltration may not be permitted in some areas — see Section 20.) For large quantities of flow, onsite ponds can be designed either to slow the peak flow of storm water or to hold water onsite until it infiltrates or evaporates. These are known as *detention ponds* or *retention ponds*. A variation is the *storm water wetland*, which similarly controls flow while wetland vegetation helps remove pollutants.

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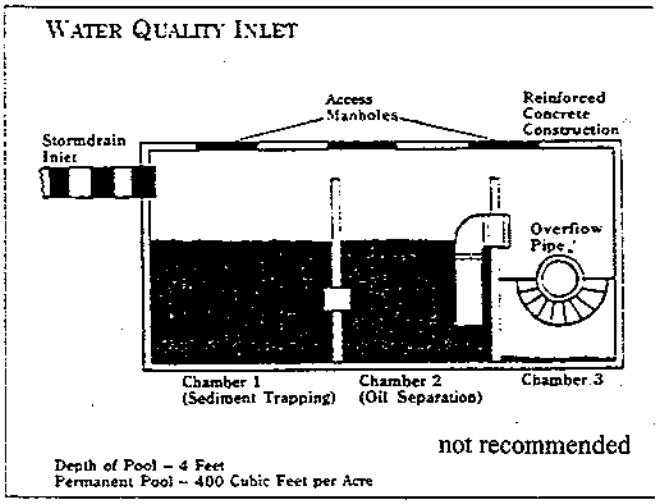
20. Storm Water Management: Water Quality Controls

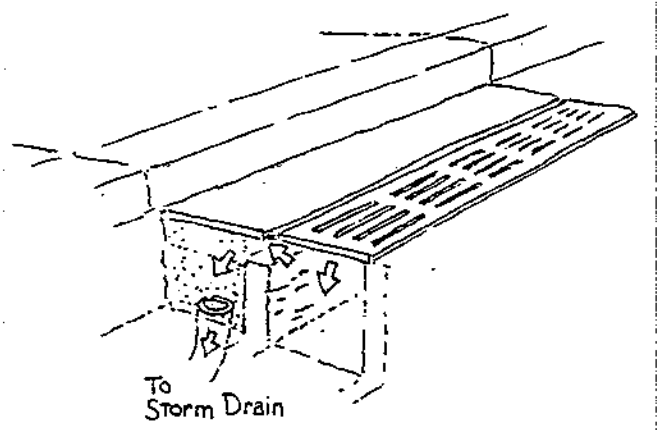
A number of specific storm water management controls are better suited to water quality control than hydraulic control. These features may be added to various parts of the storm water conveyance system on an industrial site to help control potential pollutants in the storm water before it leaves the site. They are for the most part passive design features rather than treatment devices in the usual sense. Information in existing references gives design parameters for these water quality controls, so this section merely summarizes a few types of controls.

A simple technique is a **vegetated swale** or **channel,** a ditch that carries storm water in which plants are permitted to grow. The plants provide some peak flow control by slowing the water. They also remove some pollutants by encouraging the deposition of sediments and minor oily wastes. This control can be retrofitted to some existing storm water conveyance ditches simply by allowing grasses to grow, if it does not interfere with storm water drainage and cause water to back up onto the site.



An API separator is only partly effective at removing oily wastes, but is more effective at removing sediments than an ordinary catch basin.

A **water quality inlet** is a simple multi-purpose device, shown in the diagram above. A storm drain inlet is fitted with an enlarged catch basin or grit chamber where solids and sediments settle out of the water. A baffle restricts the flow of surface-floating oil, which can be removed by hand later. Floatable debris also collects at the baffle. This type of inlet has in the past been used to help remove oily wastes, but is of limited effectiveness. Section 21 describes the inlet further, including its maintenance requirements.



A sand filter inlet can remove some pollutants before they enter the storm drain.

A **sand filter inlet** is a storm drain inlet that contains sand or another filter medium. The sand removes particulates and oily wastes from storm water as it enters the storm drain. An extension of the same concept is a **sand filter,** where storm water quality can be improved before discharge. Sand filters appear to be particularly effective if used in combination with detention or retention ponds, by diverting the first-flush of runoff (often carrying the most pollutants) to the filter and routing the remainder of the water to the pond.

Many of these water quality controls can be designed either of two ways: to control potential pollutants before discharging water to a storm drain; or to remove unwanted constituents and then direct the storm water into the ground as an *infiltration* device. Any of these controls that use infiltration techniques, or others designed specifically to promote infiltration, (porous pavement, infiltration trenches, and others), may be restricted or prohibited in some municipalities in the Santa Clara Valley as potential sources of ground water contamination. Dry wells for disposal of storm water are illegal under State and Federal Law.The Regional Board's newly-amended Basin Plan for the San Francisco Bay Region adopts some new policies that address infiltration devices. The NPS Program does not recommend them in areas where shallow ground water may be impacted. Check with your municipality before installing an infiltration device.

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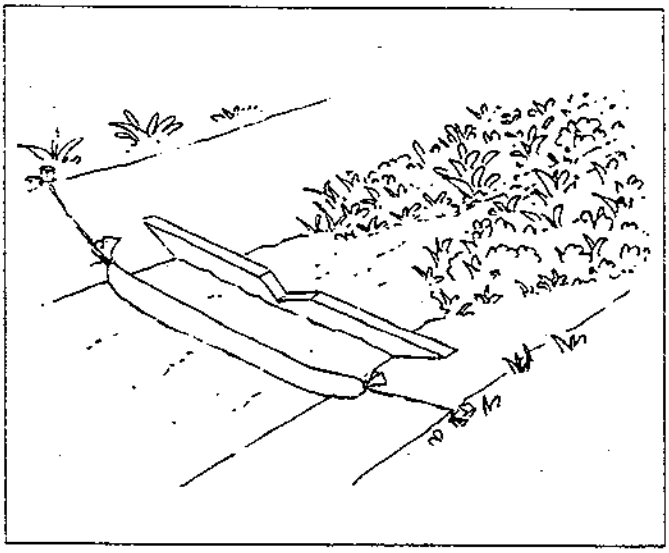
21. Storm Water Management: Removing Oily Pollutants

A simple technique to remove oils and grease from storm water uses **oil-absorbent materials** (or *oleophilic* materials), such as the booms used to contain oil spills. The absorbent material preferentially absorbs oil, and does not fill with water, so it can be used on storm water with small concentrations of oily materials.

Some facilities that have a storm water conveyance ditch where water flows season-long have found it convenient to install a permanent floating boom to control an occasional light surface sheen. When the boom is spent, it is full of oil and is visibly heavier, floating lower in the water. The booms are inexpensive enough that they may easily be replaced whenever the absorbent is saturated. Disposal is more costly, since they may be hazardous waste unless an oil recycler can accept the material.

Oil/water separators are a broad category of devices that are intended to remove oily constituents. There are many varieties of oil/water separators, and the term is not used in the same way by all equipment vendors or design specifications.

For most applications, oil/water separators are *not recommended* as a storm water management strategy. Source control BMPs are strongly preferred. Oil/water separators are fairly costly, and most designs do not operate best at the low concentrations commonly present in storm water. A sand filter inlet is typically more effective, and less costly, for the small quantities and low concentrations of oils in routine storm water runoff — that is, runoff that has not directly contacted oily industrial activities.



Oil-absorbent berms can remove oily sheen from storm water. Vegetation in an open ditch can slow the flow, helping sediments settle.

Separators may be useful in limited applications. They are sometimes useful as a retrofit measure, to temporarily help a facility comply while it installs more effective source control BMPs. Another use is in spill control sumps, upstream of a treatment process. The advanced designs are sometimes used as a treatment device (that will discharge to a sanitary sewer) for storm water that contacts industrial activities in isolated areas where contact cannot be avoided.

The API oil/water separator is a simple design, named for the American Petroleum Institute. The API separator is sometimes called an "oil and grease trap," to distinguish it from a true oil/water separator used for industrial wastewater. An API separator usually is a long basin with multiple chambers or vaults, typically installed below grade. It can be fitted to storm drains or storm water inlets in a variety of configurations — the water quality inlet described in Section 20 is one form. The intent is to slow water and stratify the flow so that oil rises. The floating oil is then retained by one or more baffles in the chambers.

An API separator removes the bulk of floating oily wastes, especially if the oil is not well-mixed but floats on top of the water. However, it is not highly efficient, so storm water can still be polluted unacceptably even after it flows through the inlet. The separator works by concentrating oily wastes within the chamber, so inevitably some of the collected wastes are carried away during heavier storms. It can be made somewhat more effective at oil removal if it includes pads or pillows of oleophilic material at the water surface level.

If you install an API separator, it *must be maintained* regularly. It requires a standing pool of water, which should be pumped out periodically and replaced with clean water. To clean, remove oil floating on the standing pool and greasy matter collected at the baffle. Some commercial oil recyclers accept this material for recycling; otherwise, it must be handled as hazardous waste. If you install oil-absorbent pillows, the pillows must be closely monitored and replaced when they are saturated, also disposed either as hazardous waste or to a recycler. If the inlet includes a sediment trap, as in the water quality inlet shown in Section 20, remove solids with a shovel between storms.

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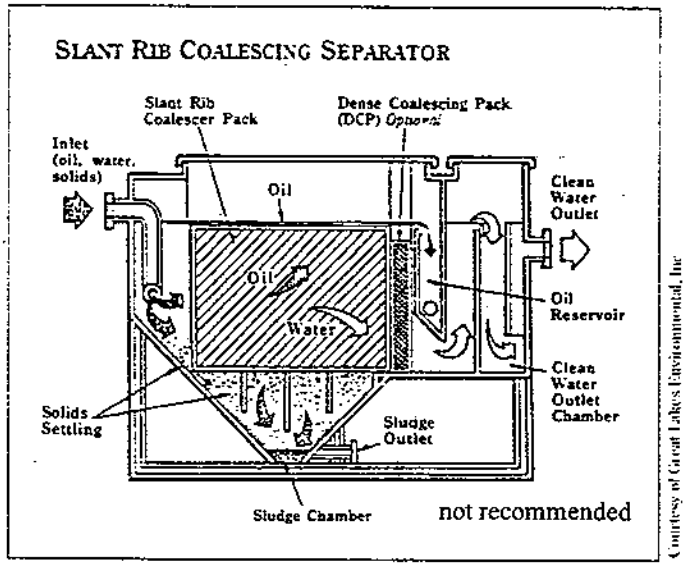
Develop a regular cleaning schedule appropriate for your facility. For inlets that don't carry much flow, three cleanings per year are sufficient: once before the rainy season (mid-September) to remove materials that have accumulated; once after the first major storm; and once at the end of the rainy season to prevent slow loss or evaporation of the collected oily wastes. If storm water flow is greater, the API separator may need to be cleaned monthly, or periodically between storms. As another guideline, clean the separator before three inches of oil accumulate in the entry chamber.

The **CPI, or coalescing plate interceptor** oil/water separator, is a more advanced design. These are common for treatment of oil-bearing industrial wastewater, but are less often cost-effective for storm water. The CPI separator generally achieves greater removal efficiency than an API type, but is more costly to purchase and operate. A CPI separator can attain a high removal efficiency, and accommodate a fairly high flow rate, but at ever-increasing capital costs for the equipment (by adding more separator plates). The best economics generally apply for relatively high concentrations of oil at low and constant flow rates.



Courtesy of Great Lakes Environmental, Inc

A CPI separator can be very effective at removing oil but requires upstream sediment control and can be costly to maintain.

A few design features can improve the effectiveness of an oil-water separator. Pollution removal effectiveness is highest if the concentration is high when the storm water enters the unit. Avoid diluting the water to be treated with water from other parts of the site, where it does not contact the potential pollutants, both to save on the capital investment and to increase treatment effectiveness. For industrial process applications, an evaporator can be used reduce the volume of water treated.

An oil-water separator works best if sediment is not present in the water — limit your water to be treated to isolated areas, free of mud and soils if possible. Efficiency is highest with a fairly steady flow, so you may require upstream detention. Also, don't site the separator downstream of a pump, because the pump mixes the oil and water and partially emulsifies the oil, so separators are less effective.

Storm water treatment generally is *not recommended* as a BMP. Some of the devices described in Section 21 may be considered to be treatment by the state or by your local wastewater treatment authority, which can open the door to some burdensome regulatory restrictions and permitting requirements.

For most industrial facilities, the best advice about onsite storm water treatment is to avoid it, for a number of reasons. Most of the available treatment equipment is costly to purchase and to receive permitting approval for. Operational costs can also be significant — you must monitor the equipment to assure continued effectiveness, and may need to prepare and submit chemical analyses to demonstrate continued compliance.

Further, in most places in the Santa Clara Valley, treatment of storm water means you must discharge it to the sanitary sewer rather than the storm drain (as described in Section 17). In effect, water on which you perform treatment is no longer considered to be storm water, but industrial wastewater instead. You will need to obtain or modify a discharge permit from your local wastewater authority or your municipality.

The most troublesome permitting procedures are for hazardous materials. Before installing any treatment equipment, determine whether your waste water is a hazardous waste. Cal-EPA/Toxics or the County Environmental Health Department can describe the necessary testing and approval procedures. If the wastewater that would enter the pretreatment equipment is considered to be hazardous you must obtain a permit from Cal-EPA/Toxics to operate a hazardous waste treatment facility. At present this may be true even for a simple water quality inlet. If you determine that the waste stream is not hazardous, and do not apply for a hazardous waste treatment permit, keep your testing documentation on hand to show regulators.

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Pollution Control Agencies and Sources of Information

Santa Clara Valley Nonpoint Source Pollution Control Program

For information about storm water pollution control requirements, contact the Program or your local municipality.

Santa Clara Valley NPS Program
5750 Almaden Expressway
San Jose CA 95118 (800) 794-2482

City of Campbell	(408) 866-2150
City of Cupertino	(408) 252-4505
City of Los Altos	(415) 948-1491
Town of Los Altos Hills	(415) 941-7222
Town of Los Gatos	(408) 354-6864
City of Milpitas	(408) 942-2360
City of Monte Sereno	(408) 354-7635
City of Mountain View	(415) 903-6329
City of Palo Alto	(415) 329-2129
City of San Jose	(408) 277-5533
City of Santa Clara	(408) 984-3151
City of Saratoga	(408) 867-3438
City of Sunnyvale	(408) 730-7270
Santa Clara County	(408) 411-1195
Santa Clara Valley Water District	(800) 794-2482

Documents available from the Program:
- BMP Manual for Automotive Repair Facilities
- BMP Manual for Construction Activities
- Industrial Storm Water Compliance Guidance Handbook (guidance for the Regional Board's Industrial Storm Water General Permit)
- Industrial Storm Water Compliance Binder
- Integrated Pest Management Brochure

Wastewater Treatment Authorities

For information on wastewater permitting and on allowable discharges to the sanitary sewer, contact your wastewater treatment authority

San Jose/Santa Clara Wastewater Treatment Plant
Department of Industrial Waste (408) 945-5300

Sunnyvale Wastewater Treatment Plant
Industrial Pretreatment Program (408) 730-7270

Palo Alto Regional Water Quality Control Plant
Environmental Compliance Division (415) 329-2117

Documents available fromPalo Alto:
- Storm Drain Pollution Prevention Guidelines

Emergency Response: Dial 911

County of Santa Clara

For information about compliance with hazardous waste regulations, contact:

Environmental Health Department—Toxics Enforcement Program (408) 299-6930

For information on waste minimization and guidance on contacting other agencies, contact:

Hazardous Waste Management Program (408) 441-1195

Document available:
- Hazardous Waste Management and Reduction—A Guide for Small and Medium-Sized Businesses (City of San Jose and Santa Clara County)

California Environmental Protection Agency

Regional Water Quality Control Board: San Francisco Bay Region, Region 2
2101 Webster Street, Suite 500, Oakland, CA 94612

For information on permitting of transportation, treatment, recycling, and disposal of hazardous wastes, contact:

Department of Toxic Substances Control Division (Cal-EPA/Toxics), Region 2 (510) 540-3739
700 Heinz Avenue, Bldg. S, Berkeley, CA 94710

For information on waste minimization and hazardous waste management technologies, contact:

Alternative Technology Division (916) 324-1807
744 P Street P.O. Box 942732, Sacramento, CA 94234-7320

Documents available from Alternative Technology:
- California Waste Exchange: A Newsletter/Catalog
- Fact Sheet: Waste Reduction for Automotive Repair Shops
- Hazardous Waste Reduction for Automotive Repair Shops:
  - Part 1: Checklist
  - Part 2: Assessment Manual
- List of CA Licensed Hazardous Waste Haulers

Association of Bay Area Governments

P.O. Box 2050, Oakland, CA 94604-2050 (510) 464-7900

Documents available from ABAG:
- Manual of Standards for Erosion & Sediment Control Measures

These agencies are concerned with environmental requirements for industrial facilities. It may be necessary to contact other agencies to verify compliance. These contact points are current at time of publication.

4DD Sample Checklist

NOTICE OF NONPOINT SOURCE INSPECTION

City of Palo Alto
Environmental Compliance Division
2501 Embarcadero Way, Palo Alto, CA 94303
Telephone: 415-329-2598 Fax: 415-494-3531

Facility Name:	**Inspection Date/Time:**
Site Address:	**SIC Code:**
Contact Person/Title:	**Primary Activity:** Industrial/Commercial/Construction
Telephone:	

Item	Section	Storm Water Problem	Recommended Control Measures	Compliance Date	Results*

OI has been submitted: Yes No N/A **SWPPP & SWMP are available:** Yes No N/A

Comments/Referrals

No Storm Water Problems Observed for this Inspection

You are hereby notified to implement all recommended control measures noted above on or before the compliance date(s). Time granted for the implementation of control measures does not preclude any enforcement actions by the City or other agencies.

Inspector: **Received by:**

***Reinspections:** __/__/__(____) __/__/__(____) __/__/__(____)
Date & Initial Date & Initial Date & Initial

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SECTIONS & DESCRIPTIONS

Section 2

Indoor Activities

2-1. Floor cleaning water improperly disposed.
2-2. Equipment cleaning wastewater improperly disposed.
2-3. Mfg. residues, spills, leaks properly cleaned.

Section 3

Outdoor Activities

3-1. Vehicle and equipment fueling (tank farm).
3-2. Vehicle and equipment washing: mats, filters, screens.
3-3. Vehicle and equipment maintenance and repair.
3-4. Storage and handling of raw materials, products and by-products.
3-5. Waste storage, handling and disposal (i.e., Hazardous Materials).
3-6. General construction activities/erosion.
3-7. Pavement cleaning or power washing (steam).
3-8. Scrap yards/Equipment/Vehicle storage.
3-9. Process residues.
3-10. General housekeeping.
3-11. Irrigation and landscape maintenance.

Section 4

Equipment

4-1. Air Compressors.
4-2. Air conditioning, chillers, refrigeration.
4-3. Air scrubbers.
4-4. Basement parking lots (sumps).
4-5. Boilers.
4-6. Catch basin/Drop inlet condition.
4-7. Compactors/Dumpsters.
4-8. Cooling tower blow down.
4-9. Emergency shower drains.
4-10. Filter back flushing.
4-11. Floor sinks/drains.
4-12. Grease interceptors/Tallow bin.
4-13. Groundwater treatment discharge.
4-14. Groundwater dewatering devices.
4-15. Loading/Unloading.
4-16. Parking lot.
4-17. Ponds/Fountains
4-18. Roof (vent)/Other roof equipment.
4-19. R.O./D.I. units.

Abbreviations/Definitions

NOI -Notice of Intent for the coverage under the States NPDES General Permit for dischargers of storm water associated with industrial activity in the Santa Clara County to the South San Francisco Bay(Order No. 92-011, NPDES No. CAG612001) which is submitted to the Cali fornia Regional Water Quality Control Board S.F. Bay Region.
SWMP - Storm Water Monitoring Plan
SWPPP - Storm Water Pollution Prevention Plan
NPDES - National Pollutant Discharge Elimination System
BMP - Best Management Practices
SIC - Standard Industrial Classifications Code

Mandatory Industries - A permit is required in any case
Conditional Industries - A permit is required only if materials, Machinery, or Products are exposed to stormwater.
Non-regulated - Those industries which were not identified by the Federal Storm Water Regulations/EPA Categories which are subject to storm water runoff.

Agency Phone Numbers

RWQCB (510) 286-1255
SCVWD (408) 265-2600
Fish & Game (408) 649-2370

5A Monitoring Parameters

Appendix 4A. Monitoring Parameters Methods

Parameter	Method and Range	Kit and/or Method Number[1]	Environmental Indications	Resolution and Accuracy	Considerations	Appropriate Use
Physical						
Temperature	Glass thermometer	SM 2550	Seasonal Patterns Heated effluents form Industrial plant	0.1-0.5°C 1% fullscale	Pre- and post-event calibration recommended	Volunteer or municipal staff
	Digital thermometer	SM 2550	Seasonal Patterns Heated effluents form Industrial plant	0.1 °C 1% fullscale	Pre- and post-event calibration recommended; very fast	Volunteer or municipal staff
Conductivity	Conductivity meter 1-19,000ms	SM 2510	Influence of seawater or high dissolved solids concentrations	10 ms	Pre- and post-event calibration against purchased standard required. Can be used to measure "Practical Salinity"	Volunteer or municipal staff
pH	Optical comparator to pH indicator solutions pH range: 4-10	Hach	General Conditions Illicit discharges (very low or high)	0.5 pH units	Not very accurate or precise	Volunteer or educational
	Electrometric probe inserted into solution to be measured pH range: 0-14	SM 4500-H^+ pH meter	General Conditions Illicit discharges (very low or high)	0.2 pH units or better Precision varies with instrument; 0.1 unit common	Accurate and reproducible if calibrated against standard according to manufacturer's recommendations	Volunteer or municipal staff
Dissolved Oxygen	Modified Winkler titration 0-10 mg/L	LaMotte SM 4500-OB	High oxygen demand (low) High productivity (high) Nutrient influences (high)	0.2 mg/L 1% of true concentration	Some interferences Used as the basis of Biochemical Oxygen Demand	Volunteer or municipal staff
	Membrane electrode	SM 4500-OG	High oxygen demand (low) High productivity (high) Nutrient influences (high)	0.1 mg/L accuracy 0.05 mg/L potential precision	Reported precision high, though in practice cannot be better than Winkler titrations	Volunteer or municipal staff

SARB_001196

Appendix 4A. Monitoring Parameters Methods

Parameter	Method and Range	Kit and/or Method Number[1]	Environmental Indications	Resolution and Accuracy	Considerations	Appropriate Use
Clarity	Turbidity	SM 2130	Sedimentation (high - natural or illicit sources) Productivity (low)	Accuracy depends on calibration of meter with appropriate standards	Onsite with optical comparator or meter	Volunteer or educational
	Total Suspended Solids	SM 2540 D	Sedimentation (high - natural or illicit sources) Productivity (low)	Accuracy is very high although depends on represent-ativeness of samples	Requires laboratory analysis, though can be done in simple setting Most suitable for calculating loads	Volunteer or municipal staff
Chemical						
Detergents	Solvent extraction and colorometric indicator	SM 5540C	Illicit connections Improper washdown practices	0.1 ppm	Common runoff component in residential and commercial zones	Volunteer or municipal staff
Phenols			Cleaning compounds Urban runoff	10% of true value	Common runoff component in residential and commercial zones	Volunteer or municipal staff
Oil and Grease	Visual	No reliable kit procedure	Illicit connections General runoff Illicit dumping	Depends on method used	Requires laboratory analysis - procedures in flux	Municipal staff Laboratory Volunteer for visual observation

SARB_001197

Appendix 4A. Monitoring Parameters Methods

Parameter	Method and Range	Kit and/or Method Number[1]	Environmental Indications	Resolution and Accuracy	Considerations	Appropriate Use
Biological						
Indicator Bacteria	Multiple-tube fermentation of serial dilutions	Total Coliform SM 9221B Fecal Coliform SM 9221E Enterococcus SM 9230B	Illicit connections Pet/livestock wastes Wildlife populations	Resolution depends on number of serial dilutions Precision may be low among replicates	Requires laboratory analysis - may be conducted in any facility with appropriate sterile and temperature control capabilities	Municipal staff Laboratory Volunteer/Educators under some conditions
	Selective media with indicator dyes show fecal or strep bacteria Range depends on serial dilutions of sample MPN or CFU/100 mL	Coli Kits and Membrane filtration of sample	Illicit connections Pet/livestock wastes Wildlife populations	Resolution depends on number of volume of sample precision may be low among replicates	Requires laboratory analysis - may be conducted in any facility with appropriate sterile and temperature control capabilities	
Nutrients						
Nitrates	SM 4500-NO_3 E	Laboratory No reliable kit procedure	Illicit connections Fertilizers moving off site	Accuracy poor with test kits	Requires laboratory analysis	Municipal staff Laboratory
	SM 4500-NO_3 D	Selective-ion electrode	Illicit connections Fertilizers moving off site	2.5% of concentration	Relatively costly probes	
Ammonia	SM 4500-NH_3 F	Laboratory No reliable kit procedure	Illicit connections Fertilizers moving off site	Accuracy poor with test kits	Requires laboratory analysis	Municipal staff Laboratory
	SM 4500-NH_3 D	Selective-ion electrode	Illicit connections Fertilizers moving off site	Reported recoveries of 91-96% [1]	Relatively costly probes	

SARB_004498

Appendix 4A. Monitoring Parameters Methods

Parameter	Method and Range	Kit and/or Method Number[1]	Environmental Indications	Resolution and Accuracy	Considerations	Appropriate Use
Phosphates		No reliable kit procedure	May indicate detergents Fertilizers moving off site	Accuracy poor with test kits	Requires laboratory analysis	Municipal staff Laboratory

[1] - Method numbers refer to specific sections of *Standard Methods for the Evaluation of Water and Wastes, 18th edition*. Holding times and container requirements are listed for most tests in 40 CFR 136.3.

References for Established Numerical Limits/ Water Quality Standards

EPA. Ambient Water Quality Criteria for Bacteria - 1986. Body Contact Standards for Recreational Waters

EPA. Ambient Water Quality Criteria for Ammonia - 1986 (Freshwater), 1989 (Seawater)

Water Quality Control Plan - Central Coast Region. 1994. Numerical limits may vary by beneficial use classification.

State Water Resources Control Board. 1993. Water Quality Control Plan for Ocean Waters of California (California Ocean Plan).

SARB_001199

Total Maximum Daily Loads
For Toxic Pollutants
San Diego Creek and Newport Bay, California

U.S. Environmental Protection Agency
Region 9

Established June 14, 2002

Alexis Strauss
Director
Water Division
EPA Region 9

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SARB_001201

I. Introduction

What Is the Purpose of This Action?

This document describes Total Maximum Daily Loads (TMDLs) being established for several toxic pollutants by U.S. Environmental Protection Agency (EPA) to help protect and restore the water quality of Newport Bay, San Diego Creek, and their tributaries. A TMDL identifies the maximum amount of a pollutant that may be discharged to a water body without causing exceedences of water quality standards and impairment of the uses made of these waters. The federal Clean Water Act requires development of TMDLs for polluted waters to assist in identifying pollutant control needs and opportunities. EPA is establishing these TMDLs pursuant to a 1997 consent decree in which EPA committed to ensure that these TMDLs would be established in 2002. EPA has worked closely with the California Regional Water Quality Control Board, Santa Ana Region (Regional Board) in the development of these TMDLs. Although the State has primary responsibility for developing TMDLs under the Clean Water Act, the State was unable to complete its formal adoption of these TMDLs by the consent decree deadline; hence EPA is required to establish the TMDLs at this time.

What Is A TMDL?

Section 303(d)(1)(A) of the Clean Water Act (CWA) requires that "Each State shall identify those waters within its boundaries for which the effluent limitations...are not stringent enough to implement any water quality standard applicable to such waters." The CWA also requires states to establish a priority ranking for waters on the 303(d) list of impaired waters and establish Total Maximum Daily Loads (TMDLs) for such waters. As part of California's 1996 and 1998 Section 303(d) lists, the Regional Board identified Newport Bay and San Diego Creek as water quality limited due to several toxic pollutants (in addition to other pollutants not addressed in these TMDLs) and designated this watershed as a high priority for TMDL development.

The elements of a TMDL are described in 40 CFR 130.2 and 130.7 and Section 303(d) of the CWA, as well as in EPA guidance documents (e.g., EPA 1991 and EPA 2001). A TMDL is defined as "the sum of the individual waste load allocations for point sources and load allocations for nonpoint sources and natural background" (40 CFR 130.2) such that the capacity of the water body to assimilate pollutant loadings (the Loading Capacity) is not exceeded. A TMDL is also required to be developed with seasonal variations and include a margin of safety to address uncertainty in the analysis. In addition, pursuant to the regulations at 40 CFR 130.6, states must develop water quality management plans which incorporate approved TMDLs and implementation measures necessary to implement the TMDLs.

Upon establishment of TMDLs by EPA or the State, the State is required to incorporate the TMDLs along with appropriate implementation measures into the State Water Quality Management Plan (40 CFR 130.6(c)(1), 130.7). The Regional Board Basin Plan, and applicable state-wide plans, serve as the State Water Quality Management Plan governing the Newport Bay watershed. If the State subsequently adopts and submits for EPA approval TMDLs which are different from the TMDLs established by EPA, EPA will review the State-submitted TMDLs to

determine if they meet all TMDL requirements. If EPA approves the State TMDLs, they will supercede the TMDLs being established now by EPA.

Why Is EPA Establishing These TMDLs?

The Environmental Protection Agency (EPA) has oversight authority for the 303(d) program and is required to review and either approve or disapprove the TMDLs submitted by states. If the EPA disapproves a TMDL submitted by a state, the EPA is required to establish a TMDL for that water body.

On October 31, 1997, EPA entered into a consent decree (decree), Defend the Bay, Inc. v. Marcus, (N.D. Cal. No. C 97-3997 MMC), which established a schedule for development of TMDLs in San Diego Creek and Newport Bay. The decree required development of TMDLs for several toxic pollutants by January 15, 2002. The agreement also provided that EPA would establish the required TMDLs within ninety (90) days, if the State failed to establish an approved TMDL by the deadline. In early April 2002, the decree was modified to extend the deadline for EPA establishment of these TMDLs to June 15, 2002.

Pursuant to the decree, EPA Region 9 and the Regional Board have already established sediment and nutrient TMDLs for San Diego Creek and Newport Bay. EPA has also approved state-adopted TMDLs for fecal coliform in Newport Bay.

The RWQCB has conducted extensive analysis in support of these toxic pollutant TMDLs and has proposed to adopt TMDLs and associated implementation plans for two pesticides and selenium. However, the State of California has not yet adopted TMDLs for any of the toxic pollutants covered by the decree. Therefore, in compliance with the terms of the decree, EPA is establishing the TMDLs for these toxic pollutants in order to meet the requirements of the decree. On April 12, 2002, EPA published a public notice seeking comment on the proposed toxic pollutant TMDLs for San Diego Creek and Newport Bay. EPA carefully considered comments received during the comment period and made some changes in the final TMDL decisions. EPA also completed a responsiveness summary that describes how EPA considered each comment received.

What TMDLs Are Being Established?

EPA is establishing TMDLs for several toxic pollutants which are exceeding applicable State water quality standards: selenium; several heavy metals; and several organic chemicals including modern pesticides (i.e., diazinon and chlorpyrifos) and legacy pesticides (DDT, Chlordane etc.) and polychlorinated biphenyls (PCBs). The pesticide diazinon is being addressed by these TMDLs because the State found that it is associated with significant water toxicity in San Diego Creek and concluded that it should be addressed by EPA concurrent with the similar pesticide chlorpyrifos, which is addressed by the consent decree. These TMDLs are being developed for specific water bodies in the Newport Bay watershed for which available data indicate that water quality is impaired. Table 1-1 lists the specific water bodies and associated pollutants for which TMDLs are being established.

Table 1-1. Toxic Pollutants per waterbody requiring TMDL Development

WaterBody (Type)	Element/ Metal	Organic compound
San Diego Creek (freshwater)	Cd, Cu, Pb, Se, Zn	Chlorpyrifos, Diazinon, Chlordane, Dieldrin, DDT, PCBs,Toxaphene
Upper Newport Bay (saltwater)	Cd, Cu, Pb, Se, Zn	Chlorpyrifos, Chlordane, DDT, PCBs
Lower Newport Bay (saltwater)	Cu, Pb, Se, Zn	Chlordane, Dieldrin, DDT, PCBs
Rhine Channel, within Lower Newport Bay (saltwater)	Cu, Pb, Se, Zn, Cr, Hg	Chlordane, Dieldrin, DDT, PCBs

Table 1-1 Toxic pollutants per waterbody requiring TMDL development.

California's Section 303(d) list of impaired waters does not specifically name each of these water body-pollutant combinations. The 1996 Section 303(d) list identified Newport Bay and San Diego Creek as impaired due to metals, pesticides and priority organics. The 1998 Section 303 (d) list added "unknown toxicity" to one specific part of San Diego Creek—Reach 2. During the negotiation of the consent decree, Regional Board staff provided a more specific list of pollutants covered by these general pollutant categories used in the listing decisions, and the consent decree refers to this more specific pollutant list. In 2001-02, EPA and Regional Board staff carefully evaluated more recent water quality data to help determine whether TMDLs were needed for each of the toxic pollutants identified in the decree. As described in EPA Region 9's assessment of water quality in San Diego Creek and Newport Bay (*Decision Document* 2002), and in this summary TMDL document below, EPA and the State determined that the list of water body-pollutant combinations warranting TMDL development should be fine-tuned to reflect the best current information concerning water body impairment. Based on our assessment of the most current local data and national EPA guidance concerning arsenic, EPA has concluded that TMDLs are not needed for arsenic for waters in the Newport Bay watershed.

Why Are These Pollutants Of Concern to EPA and the State?

By definition, toxic substances are poisonous through chemical action that may result in adverse impacts to humans or other living organisms. Adverse impacts may include, but are not limited to, cellular injury, mutagenic impairment, reduced reproductive success, and carcinogenic responses. The impacts of greatest potential concern in these water bodies are: a) chemical bioaccumulation through the aquatic food chain at levels which could harm human health when we consume fish or shellfish and b) chemical concentrations in water, sediment or biota that cause adverse effects in aquatic life or aquatic-dependent species. Available data indicate that the pollutants addressed in these TMDLs were found in water column, bottom sediments, or fish tissue at potentially unsafe levels which exceed applicable water quality standards. There is no current evidence of adverse effects on human health due to consumption of contaminated fish or direct exposure to toxic pollutants. Evidence of adverse impacts to aquatic life as a result of direct or indirect exposures to these toxic pollutants is limited. However, because the pollutants addressed in these TMDLs have the potential to cause short term adverse impacts to aquatic life or long term human health and aquatic life impacts due to pollutant bioaccumulation, actions to reduce discharges of these pollutants to the aquatic environment are warranted. The TMDLs are designed to assist in targeting pollutant reduction activities.

How Are the TMDL Documents Organized?

This document provides summary information about the Toxic Pollutant TMDLs, including a description of the environmental problems, water body goals, source analysis, loading capacity (i.e., TMDL), and loading allocations for each toxic pollutant TMDL. The document also describes how other federally-required TMDL components (i.e., margin of safety to account of analytical uncertainty, and critical conditions and seasonal variations associated with water body flow and pollutant loadings) are addressed. Individual pollutants have been grouped together based on chemical characteristics as follows:

Organophosphate (OP) Pesticides—diazinon and chlorpyrifos are two organophosphate pesticides with similar sources and impairment primarily limited to San Diego Creek.
Selenium—is a toxic bioaccumulative metal, with significant groundwater sources
Metals—cadmium, copper, lead and zinc have similar aqueous behavior and affect nearly all water bodies
Organochlorinated compounds—PCBs, DDT, chlordane, dieldrin and toxaphene have similar fate (bioaccumulation) and transport mechanisms (primarily from watershed soils to freshwater and saltwater sediments) for all waterbodies.
Mercury and Chromium—are two metals with very small geographical areas of impairment.

The State and EPA initially found that arsenic was present at levels of concern in Upper and Lower Newport Bay; however, based on more recent data and new information concerning arsenic risk in saltwater bodies, EPA has now concluded that Newport Bay and its tributaries are not impaired due to arsenic pollution. This summary document includes a section describing the basis for this conclusion in greater detail. The consent decree governing development of these TMDLs contains provisions that authorize EPA to make a determination that TMDLs are not needed for individual waters and/or pollutants if available data and information support those determinations. Pursuant to these decree provisions, EPA is making the determination that arsenic TMDLs are not needed for waters in the Newport Bay watershed.

EPA has prepared several Technical Support Documents (TSDs) to accompany this summary TMDL document. The TSDs provide considerably more detailed information relevant to each pollutant (grouped together as described above). The TSDs describe chemical characteristics of each toxicant, the basis for numeric targets, a complete source analysis, an explanation of how we calculated the loading capacity and TMDLs, and related information. A TSD is also provided that discusses EPA's analysis of freshwater flows in San Diego Creek, which was used to identify the appropriate numeric targets for certain pollutants, address seasonal variations and critical conditions in flows and pollutant loads, and evaluate the best approaches for calculating pollutant loading capacities and allocations. Another TSD provides more maps of the San Diego Creek, Santa Ana-Delhi Channel and Newport Bay watersheds and analysis concerning water residence times in Upper and Lower Bay. A summary of public comments and EPA's responses to those comments is provided in another TSD.

What Happens After The TMDLs Are Established?

TMDLs are not self-implementing – they must be implemented by the State and the entities that are discharging pollutants of concern. Federal regulations require states to adopt TMDLs and associated implementation measures in the State Water Quality Management Plan (i.e., the Basin Plan) (40 CFR 130.6). The State of California's procedure for adopting TMDLs and associated implementation measures is through amendments to the Basin Plans. These amendments are developed by the Regional Board staff, then approved by the Regional Board, State Water Resources Control Board, and State Office of Administrative Law. The amendments are then submitted to EPA for approval. (If the TMDLs adopted by the State are different from the TMDLs established by EPA then the TMDLs must be resubmitted to EPA for approval.)

EPA does not establish implementation plans as part of TMDLs under currently applicable federal regulations. However, we have included several implementation recommendations (see Section IX) which are intended to assist the State and local stakeholders in devising appropriate pollutant control and monitoring plans to address these toxic pollutants.

Three general categories of pollutant sources are identified in these TMDLs:

- Nonpoint sources, which discharge pollutants through diffuse runoff from the land, primarily in response to rainfall runoff, and which are addressed by the State through a combination of voluntary and regulatory measures outlined in California's State Nonpoint Source Management Plan.
- Point sources, which discharge pollutants through discrete pipes or conveyances and which are addressed through regulatory provisions of the National Pollutant Discharge Elimination System (NPDES) permit program. Several sources of pollutant runoff from roads and urban areas in the Newport Bay watershed are addressed through NPDES stormwater permits. There are a small number of additional permitted point source discharges in the watershed which are addressed in the TMDLs, including several groundwater dewatering operations.
- Pollutants already in water body sediments, which are usually associated with contaminated sediments discharged to water bodies in the past, but which retain and release significant quantities of pollutants to the ecosystem. These contaminated sediments may be concentrated to the point where remediation or removal action is warranted to remove the contaminated material, or they may be so diffuse that remedial action would be ineffective.

The federal Clean Water Act creates federal regulatory jurisdiction only over point sources. When NPDES permits for point source discharges addressed in the TMDLs are revised, their provisions must be consistent with the requirements and assumptions of any wasteload allocations contained in these TMDLs (see 40 CFR 122.44(d)(1)(vii)(B)). Permit modification may occur when the permits are reopened or reissued. The State has some discretion in determining the appropriate permit provisions to ensure consistency.

Although the TMDLs include allocations which address nonpoint source and contaminated sediments, implementation of these allocations is usually based on the TMDL

implementation plan developed by the State as part of its Basin Plan amendment process described above. The State of California has broad authority under State law to apply voluntary or regulatory approaches to addressing these source categories. Past TMDL implementation plans in California have provided for State-issued "Waste Discharge Requirements" for some nonpoint sources, remedial action plans to address contaminated sediment sites, and opportunities for voluntary action to comply with load allocations. The Regional Board is currently in the process of developing implementation plans for several of the toxic pollutant TMDLs and will address the remaining toxic pollutant TMDLs in the near future.

Environmental Setting

(see Figure 1-1 in TSD--Part A)

The Newport Bay/San Diego Creek watershed is located in Central Orange County in the southwest corner of the Santa Ana River Basin, about 35 miles southeast of Los Angeles and 70 miles north of San Diego (see Figure 1-1 in TSD—Part A). The watershed encompasses 154 square miles and includes portions of the Cities of Newport Beach, Irvine, Laguna Hills, Lake Forest, Tustin, Orange, Santa Ana, and Costa Mesa. Mountains on three sides encircle the watershed; runoff from these mountains drains across the Tustin Plain and enters Upper Newport Bay via San Diego Creek. Newport Bay is a combination of two distinct water bodies - Lower and Upper Newport Bay, divided by the Pacific Coast Highway (PCH) Bridge. The Lower Bay, where the majority of commerce and recreational boating exists, is highly developed. The Upper Bay contains both a diverse mix of development in its lower reach and an undeveloped ecological reserve to the north.

San Diego Creek flows into Upper Newport Bay and is divided into two reaches. Reach 1 is located downstream of Jeffrey Road and Reach 2 lies upstream of Jeffrey Road to the headwaters. The San Diego Creek watershed (ca. 105 square miles) is divided into two main tributaries:

- Peters Canyon Wash, which drains Peters Canyon, Rattlesnake Canyon, and Hicks Canyon Washes that have their headwaters in the foothills of the Santa Ana Mountains, and
- San Diego Creek itself, which receives flows from Peters Canyon Wash in Reach 1 and includes Bee Canyon, Round Canyon, Marshburn Channel, Agua Chinon Wash, Borrego Canyon Wash and Serrano Creek

Important freshwater drainages to Upper Newport Bay, together covering 49 square miles, include the San Diego Creek, Santa Ana-Delhi Channel, Big Canyon Wash, Costa Mesa Channel and other local drainages.

San Diego Creek is the largest contributor (95%) of freshwater flow into Upper Newport Bay, followed by Santa Ana-Delhi Channel (~5%) (ACOE 2000). Table 1-2 summarizes the drainage areas of the major tributaries.

Table 1-2 Drainage Areas of the Newport Bay Watershed

Tributary	**Drainage Area (acres)**	**Drainage Area (%)**
San Diego Creek	47,300	48
Peters Canyon Wash	28,200	29
Santa Ana-Delhi	11,000	11
Other Drainage Areas	12,000	12
Total	98,500	100

Upper Newport Bay contains one of the highest quality remaining wetland areas in Southern California. The Upper Bay estuary contains a State Ecological reserve in the upper half with habitat designated for sensitive species. Sediment capture basins exist in the Upper Bay and have been dredged periodically by Army Corps of Engineers (ACOE). Another sediment removal/ecological restoration project has been proposed and is currently being evaluated (ACOE 2000). Newport Dunes Recreation area—a small public beach—is in the lower portion of Upper Bay (outside of the Ecological Reserve) along with more small boat marinas down near Pacific Coast Highway Bridge. Historical water uses for Upper Bay included water skiing, commercial and sport fishing although it is now used mainly for wildlife habitat, preservation of rare species, marine habitat, recreation and shellfish harvesting. In Lower Bay, surrounding shores and two islands are highly urbanized with nine boatyards and many (~10,000) small boats. Rhine Channel, a dead-end reach in western side of Lower Bay, is an isolated area with poor tidal flushing and minimal storm drain input. The Regional Board has identified Rhine Channel as a toxic hotspot based on previous investigations (BPTCP 1997). The entire Newport Bay up to the mouth of San Diego Creek is subject to tidal influence.

Climate is characterized by short, mild winters, and warm dry summers. Average rainfall is approximately 13 inches per year. Ninety percent of annual rainfall occurs between November and April, with minor precipitation during summer months. In the past six years, San Diego Creek has a mean base flow rate of approximately 12 cubic feet per second (cfs) (for all flows <20 cfs). Storm events, depending on their magnitude, intensity, and antecedent conditions, can increase this daily mean flow to over 9000 cfs (Dec. 7, 1997). San Diego Creek is freshwater with wide range of hardness and small influences by the slightly saline water table (less than 1 or 2% salinity). Upper Bay is an estuary with saline water conditions during dry weather and yet there is heavy freshwater influx (from San Diego Creek and Santa Ana-Delhi Channel) during major storms. Lower Bay waters are dominated by twice-daily ocean tides via the jetty entrance, thus saline waters exist at 30 to 35 parts per thousand (ppt).

Watershed History

The description below is taken largely from Regional Board staff report prepared for its draft Newport Bay TMDLs (RWQCB 2000).

The nature of the Newport Bay watershed has changed dramatically over the last 150 years, both in terms of land use and drainage patterns. In the late 19th and early 20th centuries, land use changed from ranching and grazing to open farming. During this time the Santa Ana River flowed into Newport Bay, while San Diego Creek and the small tributaries from the

Santiago Hills drained into an ephemeral lake and the neighboring area called "La Cienega de las Ranas" (Swamp of the Frogs) and then into the River. To accommodate rural farming, the ephemeral lake and Swamp of the Frogs were drained and vegetation cleared. Channels were constructed (but often did not follow natural drainage patterns) to convey runoff to San Diego Creek and then Newport Bay. After a major flood event in 1920's, the Santa Ana River was permanently diverted into the current flood control channel which now discharges to the Pacific Ocean. As a result of these land use and drainage changes, surface and groundwater hydrology have been substantially altered from natural conditions. Following World War II, land use again began to change from grazing and open farming to residential and commercial development. As urban development in the watershed proceeded (and continues), drainages were further modified through removal of riparian vegetation and lining of stream banks to expand their capacity and to provide flood protection. These changes culminated in the channelization of San Diego Creek in the early 1960s by the Orange County Flood Control Department. The channelization isolated the San Joaquin Marsh, the last remaining portions of the historic marsh upstream of Upper Newport Bay, from San Diego Creek (Trimble 1987).

Conversion of rural farmland to residential, commercial and light industrial use has been constant in the watershed. Land use statistics supplied by Orange County demonstrate this urban development (ACOE 2000). In 1983, agriculture accounted for 22% and urban uses for 48% of the Newport Bay watershed. In 1993, agricultural uses accounted for 12% and urban uses for over 64% of the area. As of 2000, agriculture had dropped to approximately 7% (<7,500 acres), including row crops (primarily strawberries and green beans), lemons, avocados and commercial nurseries. Currently, San Diego Creek watershed is greater than 90% urbanized whereas Santa Ana-Delhi is approximately 95% urbanized. Projected land use suggests 81% urban land use, 11% open, 8% rural and no agriculture (ACOE 2000).

Land use and drainage modifications changed the nature and magnitude of toxic substance discharges to the Bay. Converting from grazing type agriculture to orchards and row crops has increased the amount of pesticide use in the watershed, resulting in discharges of pesticides from these areas. The commercial nurseries drain to Peters Canyon Wash via Central Irvine Channel and to San Diego Creek via Marshburn Channel and Serrano Creek. Tustin and El Toro military bases exist within the watershed and have historically used various toxic substances during operations. Both military sites are involved with base closure procedures and may ultimately be converted to more urban/suburban areas. Urban development introduced new sources of toxic substances, including different pesticides and metals associated with human habitation (e.g., buildings, landscaping, and motor vehicles). In addition, land use activities which cause erosion may contribute to the delivery of pesticides and other pollutants that adhere to sediments or normally remain in solid form.

Table 1-3 Land Use types in watersheds of Newport Bay

Land use type	San Diego Creek		Santa Ana Delhi		Newport Bay	
	Acres	% total	Acres	% total	Acres	% total
Agricultural/	5092	6.6	0	0	5147	5.2
Residential	11,668	15.2	5285	18.2	19420	19.7
Commercial	6381	8.3	2397	8.3	9641	9.8
Industrial	3965	5.2	1102	3.8	5263	5.4
Education/Religion/ Recreation	15,811	20.6	825	2.8	17,393	17.7
Roads	10,295	13.4	3446	11.9	15,774	16.0
Transportation	1177	1.5	99	0.3	1326	1.3
No assigned land code	440	0.6	339	1.1	936	0.9
Vacant	21,910	28.5	1060	3.7	23,462	23.9
Total	**76,739**	**99.9**	**29003**	**100**	**98,362**	**99.9**

Source: OCPFRD land use data defined by sub-watersheds to compose each watershed. (see TSD Part A) Most accurate and recent land use data provided by OCPFRD GIS Dept., March 1, 2002.

Public Participation

The State and EPA have provided for public participation through several mechanisms. The Regional Board staff has conducted numerous technical workshops (e.g., quarterly meetings since April 2000) on its assessment of toxic pollutant TMDL needs and the specific toxic pollutant TMDLs being developed by the State. The Regional Board held several public workshops as part of their regular meetings to discuss staff TMDL proposals (January 15, September 26, and October 26, 2001). EPA staff provided updates on its TMDL development activities at several of these Regional Board meetings. On October 26, 2001, the State's draft organophosphate (OP) pesticide and Selenium TMDLs were presented before the public as part of a Regional Board meeting. These draft State TMDLs were also available via the Regional Board website after that date.

On April 12, 2002, EPA publicly noticed the availability of the proposed Toxic Pollutant TMDLs and gave the public until May 28, 2002, to provide written comments. The EPA notice of availability was published in the Orange County Register, mailed to the Basin Plan distribution list provided by the Regional Board, and posted on the EPA Region 9 TMDL website. Two public meetings were held during the public comment period – a meeting to discuss the TMDLs in general in Newport Beach on April 16, 2002, and a meeting to discuss specific technical issues in Irvine on May 9, 2002. Copies of the TMDLs and TSDs were available at the public meetings, in EPA and Regional Board offices, and on the EPA Region 9 TMDL website.

Changes in the Final TMDL Documents

Several changes were made in the final TMDLs in response to comments received during the comment period:

- The numeric targets for some pollutants were modified to follow California screening guidelines or to reflect the most recent screening value studies. The organophosphate pesticide TMDL targets are based on values calculated by the California Department of Fish and Game. The California Office of Environmental Health Hazard Assessment guidelines were applied for organochlorine pollutant fish tissue targets. More recent literature values were applied for the freshwater organochlorine sediment targets.

- The flow records used to calculate flow tiers for several pollutant TMDLs were changed to reflect a longer period of record and to incorporate more recent flow data.

- The selenium TMDLs for the highest flow tier are based on acute water quality standards because, based on analysis of the longer flow record, flow patterns necessary to apply chronic standards were not expected to occur under the highest flow tier.

- The metals TMDLs for San Diego Creek are concentration-based; the metals TMDLs for Newport Bay are both concentration-based and mass-based.

- The organochlorine pollutant TMDLs were revised based on additional modeling analysis and consideration of more recent data. The flow tier approach applied for San Diego Creek organochlorine pollutant TMDLs was slightly modified. The description of analytical methods used for the organochlorine pollutant, chromium, and mercury TMDLs was revised to more clearly explain the analytical methods.

- The allocation methods used for each TMDL were clarified.

- A new section of implementation and monitoring recommendations was added to assist the State in preparing to adopt and implement TMDLs for these pollutants.

II. Overview of TMDLs and Available Data

TMDL Components

This section describes the components of a TMDL and discusses the analytical approaches used in the Newport Bay watershed TMDLs to address each component.

The goal of the TMDL process is to attain water quality standards and protect the beneficial uses of water bodies, including aquatic habitat, fishing, and recreation. A TMDL is a written, quantitative assessment of water quality problems and contributing pollutant sources. It identifies one or more numeric targets (endpoints) based on applicable water quality standards, specifies the maximum amount of a pollutant that can be discharged (or the amount of a pollutant that needs to be reduced) to meet water quality standards, allocates pollutant loads among sources in the watershed, and provides a basis for taking actions needed to meet the numeric target(s) and implement water quality standards.

For federally established TMDLs, seven components are included:

- **Problem Statement**—a description of the water body setting, beneficial use impairment of concern, and pollutants causing the impairment.
- **Numeric Targets—**for each pollutant addressed in the TMDL, appropriate measurable indicators and associated numeric target(s) based on numeric and/or narrative water quality standards which express the target or desired condition for the water body which will result in protection of the designated beneficial uses of water.
- **Source Analysis**—an assessment of relative contributions of pollutant sources or causes to the use impairment.
- **Loading Capacity/Linkage Analysis**—a connection between the numeric targets and pollutant sources which yields calculations of the assimilative capacity of the water body for each pollutant.
- **TMDL and Allocations**— an expression of the total allowable pollutant loads as divided between pollutant sources through load allocations for nonpoint sources and wasteload allocations for point sources. The TMDL is defined as the sum of the allocations and cannot exceed the loading capacity for each pollutant.
- **Margin of Safety**—an explicit and/or implicit margin of safety must be specified to account for technical uncertainties in the TMDL analysis.
- **Seasonal Variation/Critical Conditions—**an account of how the TMDL addresses various flows and/or seasonal variations in pollutant loads and effects.

Problem Statement

EPA includes problems statements in TMDL documents to assist readers in understanding the context for TMDL development and describe the water quality standards issue(s) which prompted development of the TMDL. The problem statements identify:

- name(s) and location(s) of waterbody segments for which the TMDL is being developed,
- the pollutant(s) for which the TMDL is being developed and information about why the pollutant(s) are being addressed,

- a description of the water quality impairment or threat which necessitated TMDL development, and
- adequate background information about the watershed setting for the TMDL to help the reader understand the key water quality, pollutant discharge, land use, and resource protection issues in the watershed.

As discussed above, California's Section 303(d) listing decisions only identified general pollutant categories for toxic pollutants impairing waters in the Newport Bay watershed. The consent decree identified suspected individual pollutants of concern, but the decree provides that TMDLs need not be established for individual pollutants and/or waters if subsequent analysis indicates TMDLs are not necessary at this time. To help define the scope of these TMDL studies, EPA Region 9, with assistance from the Regional Board, completed an assessment of available monitoring data for San Diego Creek and Newport Bay to determine which chemicals warrant TMDL development. In our assessment, we reviewed available toxicity and chemical data in three critical water quality categories: water column quality, sediment quality, and fish and shellfish tissue levels. We applied a two-tiered approach whereby all available data were analyzed to determine whether there is clear evidence of impairment with probable adverse effects (Tier 1) or incomplete evidence and/or evidence of possible adverse effects (Tier 2) (EPA Region 9, 2002). If a chemical exceeded the screening criteria in Tier 1 with respect to any *one* of the water quality categories, then it was determined a TMDL is necessary. If a chemical exceeded the screening criteria in Tier 2 with respect to *two or more* categories then a TMDL is necessary. EPA also considered whether TMDLs might be necessary based on evaluation of water quality trends and conditions in water segments adjacent to a segment in question. We examined monitoring data for the past fifteen years; however, to maximize the relevance of our assessment to present-day water quality, we focused on the most recent results (since 1995). Our assessment evaluated each chemical identified in the decree for four separate water bodies: San Diego Creek, Upper Newport Bay, Lower Newport Bay and Rhine Channel. The water body-pollutant combinations for which EPA determined TMDLs are needed at this time are listed in Table 1-1.

The introduction to this document provides a basic discussion of the problems associated with exposures to toxic pollutants addressed in these TMDLs and background information on the watershed setting.

Numeric Targets and Applicable Water Quality Standards

Numeric targets identify the specific water column, sediment, and/or tissue goals or endpoints for the TMDL which equate to attainment of the water quality standards (see EPA Region 9, 2000). In some cases, multiple indicators and associated numeric target values may be needed to interpret applicable water quality standards (e.g. where there is uncertainty that a single indicator is sufficient to measure protection of designated uses). In addition, some TMDLs may incorporate multiple numeric targets to account for differences in acceptable pollutant levels in a particular water body at different time scales (e.g., short term acute toxicity effects versus long term chronic exposure effects).

Water quality standards are comprised of the designated beneficial uses made of water bodies, narrative and numeric water quality criteria (known as "water quality objectives" in California), and anti-degradation policies. Applicable standards of concern for these toxic

pollutant TMDLs include the designated uses and both narrative and numeric water quality criteria, which are applied in a manner which is expected to result in protection of the designated beneficial uses.

The Regional Board Basin Plan (1995) designates the beneficial uses for Newport Bay, San Diego Creek and its tributaries. All water bodies are designated as wildlife habitat, with San Diego Creek identified as warm freshwater habitat and Upper and Lower Bay identified as estuarine and marine habitat, respectively. The recreation beneficial uses are designated for all of Newport Bay and San Diego Creek. Upper and Lower Bay are also designated for commercial and sport fishing, preservation of biological habitats—spawning, reproduction, development, rare, threatened and endangered species, recreation, and shellfish harvesting. The specific beneficial uses of San Diego Creek and Newport Bay are identified in Appendix A-1 at the end of this summary document.

These toxic pollutant TMDLs focus on two of the most sensitive designated aquatic life and wildlife beneficial uses of concern in the watershed—RARE and WILD. One primary objective is to protect the special biological and wildlife habitat of the Newport Bay Nature Preserve and Ecological Reserve, in the upper part of Upper Newport Bay. The Nature Preserve is considered a critical estuary of Southern California. The Upper Newport Bay Nature Preserve consists of approximately 1,000 acres of open space and is home to seven rare or endangered bird species: Light-footed clapper rail, Belding's savannah sparrow, least tern, brown pelican, peregrine falcon, black rail, and California gnatcatcher. Two endangered plants, the salt marsh birds-beak and the rare Laguna live-forever, are also found at the reserve. The second objective is to reduce build up of toxicants in fish and shellfish within all water bodies, thereby minimizing the potential for adverse impacts associated with wildlife and human consumption of contaminated food. Seventy-eight species of fish inhabit the Upper Newport Bay waters, including the California halibut and barred sand bass—two popular sport fishes.

Narrative water quality objectives considered for each TMDL are specified by the 1995 Regional Board Basin Plan:

- Toxic substances shall not be discharged at levels that will bioaccumulate in aquatic resources to levels which are harmful to human health;
- The concentrations of toxic substances in the water column, sediments or biota shall not adversely affect beneficial uses.

Numeric water quality objectives for several pollutants addressed in these TMDLs were promulgated by EPA in 2000 in the California Toxics Rule (CTR). Pollutants covered by CTR objectives include selenium, cadmium, copper, lead, zinc, chromium, chlordane, dieldrin, DDT, toxaphene and PCBs. Chlorpyrifos and diazinon are not listed as toxic pollutants pursuant to Section 307(a)(1) of the Clean Water Act (see 40 CFR 401.15), and the CTR did not establish numeric objectives for those pollutants. Additionally, the CTR did not establish aquatic life objectives for mercury and the selenium and cadmium objectives were established contingent on an EPA commitment to revise the objectives promptly to better protect wildlife.

In many cases where applicable standards are expressed in numeric terms, it is appropriate to set the numeric target equal to the numeric water quality standard. For most metals addressed in these TMDLs, the numeric targets are equal to the numeric objectives in the CTR. For selenium (Se) the freshwater and saltwater water quality standards are defined by

CTR. However, EPA acknowledged in its consultations with the U.S. Fish and Wildlife Service (USFWS) that the freshwater standards for Se may not be fully protective of wildlife, and EPA committed to revisit and, if necessary, revise the Se criteria in the near future. In its draft TMDL for Se, the Regional Board proposed to apply more protective Se targets based on USFWS recommendations. In the draft TMDL document, EPA proposed TMDLs based on the promulgated CTR standards, but invited comment on the alternative approach of basing the Se TMDLs on the more protective targets proposed by the Regional Board. The final TMDLs are based on the promulgated CTR standards. (See section IV—Se TMDL for further discussion.)

In some cases, it is necessary to interpret a numeric standard in terms other than the method through which the standard is expressed as long as the target(s) can be shown to relate back to achieving the water quality standard(s). For some pollutants (e.g., bioaccumulative toxins) or receiving water settings (e.g. embayments), it often makes more sense from the standpoint of source control and impact assessment to focus the TMDL on reductions of pollutant mass loads than solely on avoidance of exceedences of concentration-based standards. Moreover, use of sediment and/or fish tissue endpoints may provide more discriminating indicators of the beneficial use impacts of concern in a TMDL (e.g., pollutant bioaccumulation in the food chain and resultant human health or aquatic life impacts from consumption of contaminated organisms). Moreover, selection of targets based on these media enabled EPA to more completely utilize site specific data for several pollutants for which water column data were limited, consistent with the provisions of 40 CFR 130.7(c)(1)(i).

For several pollutants addressed in these TMDLs for which numeric objectives are in place (mercury, chromium, chlordane, dieldrin, DDT, toxaphene, and PCBs), the numeric targets are expressed in terms of protective sediment or fish/shellfish tissue levels. EPA's analysis of the relationship between the levels of these pollutants found in the water column, sediment, and fish/shellfish tissue found that attainment of the sediment and fish/shellfish tissue numeric targets will result in attainment of the water column numeric objectives. The sediment and tissue numeric targets are probably more protective than the numeric objectives for these pollutants. The use of sediment and tissue targets is appropriate in these cases in order to provide an implicit margin of safety to account for uncertainties in the relationship between pollutant loadings and beneficial use effects, and to ensure that both numeric and narrative standards are attained as required by 40 CFR 130.7(c)(1). In addition, EPA's decision to use sediment quality and fish tissue values as numeric targets for these pollutants is based in part on the fact that these substances are much more likely to be associated with particulate matter than to remain in the dissolved phase; that is, these compounds are either sorbed to bottom sediments or associated with extremely fine suspended sediments. Also, there are technological challenges accompanied with sampling and accurately detecting these compounds in water column samples. Therefore, these pollutants are unlikely to be detected in the water column in dissolved form even in waters where they may be present at levels of concern.

In situations where applicable water quality standards are expressed in narrative terms, it is necessary to develop a quantitative interpretation of narrative standards (EPA Region 9 2000). Since a TMDL is an inherently quantitative analysis, it is necessary to determine appropriate quantitative indicators of the water quality problem of concern in order to calculate a TMDL. It is sometimes possible to supplement water column indicators (i.e., pollutant concentrations in water) with measures in sediment or tissue media since these alternative indicators are more directly associated with the pollutant effects of concern.

Where sediment indicators are used in these TMDLs, they are based on sediment quality guidelines developed by several studies (Long et al. 1995, Smith et al.1996, MacDonald et al. 1996) and compiled by Long and MacDonald in the biological effects database system (BEDS) synthesizing many, many samples throughout North America. These sediment quality guidelines (equivalent to threshold effect levels) have been endorsed by NOAA in the screening quick reference tables (SQuiRTs) for contaminants in sediments (Buchman 1999). Where fish or shellfish tissue indicators are used, they are based on tissue screening values established by the California Office of Environmental Health Hazard Assessment (OEHHA 1999). The specific basis for these target indicators is discussed in the individual TMDL descriptions.

For the organophosphate (OP) pesticides, chlorpyrifos and diazinon, there are no promulgated water quality criteria established by EPA or the State of California. Several entities including EPA (USEPA 1986 and 2000c) and California Department of Fish and Game (CDFG 2000a) have recommended criteria values for these pollutants. To be protective of aquatic resources and to meet beneficial uses, EPA has selected the CDFG values for chlorpyrifos and diazinon at the recommendation of the Regional Board.

Source Analysis

An understanding of pollutant loading sources and the amounts and timing of pollutant discharges is vital to the development of effective TMDLs. These TMDLs provide estimates of the amounts of pollutants entering the receiving water of concern or, in some cases, the amount of pollutant that is bioavailable based on historic loadings stored in the aquatic environment. These pollutant source estimates are documented based on data analysis and modeling studies described in the individual TMDLs and associated TSDs. Source loading estimates can be categorized in many ways, including but not limited to discharge source, land use category, ownership, pollutant production process (e.g. sedimentation processes), and/or tributary watershed areas.

The source analysis for these TMDLs indicated that historical discharges of PCBs and chlorinated pesticides, all of which are no longer authorized to be used, are believed to be primarily responsible for the pollutant levels measured in Newport Bay. Metals loading is associated with historical and ongoing discharges of urban runoff. Selenium loadings are estimated to come primarily from erosion and runoff, and discharges of shallow groundwater. Discharges of OP pesticides are associated with past and ongoing uses of these pesticides for household and agriculture pest control. Some pollutant loads are also estimated to come from seawater and atmospheric deposition.

The individually permitted point sources listed below discharge into waters in the Newport Bay watershed. These TMDLs include wasteload allocations for some of these facilities. A general permit is in place to regulate discharges associated with groundwater cleanup, which affects 21 permittees and focuses principally upon total suspended sediment, petroleum hydrocarbons and chlorinated solvents. Another general permit is in place which regulates groundwater dewatering operations of 12 permittees and focuses principally on suspended sediment discharges. Finally, the statewide general permit for industrial stormwater discharges covers several facilities that may discharge in the Newport Bay watershed, including John Wayne Airport. Runoff from state highways is regulated through the statewide CalTrans NPDES permit.

Six boatyards are located around Newport Bay; all are regulated for indirect metals discharges to the sewer system. Discharges from these boatyards do not flow to the Bay. Instead, wastewater flows into sumps or into connections to the Orange County Sanitation District pre-treatment system.

Table 2-1: NPDES Permits In San Diego Creek/Newport Bay Watershed

NPDES permits in San Diego Creek watershed	**Comments**
Orange County Stormwater	MS4 Permit; Includes many cities as co-permittees
Tustin Marine Base/GW general	At present this is general permit, although RWQCB is currently drafting an individual permit
Silverado Constructors/GW cleanup	General permit, discharges under emergency conditions only
Irvine Ranch Water District	Individual permit, discharges tertiary treated water into Sand Canyon Reservoir and permit regulates stormwater overflows from Sand Canyon Reservior
Serrano Water Treatment Plant	Individual permit for a drinking water filtering plant
City of Tustin groundwater desalter	Individual permit, irregular discharges
Great Lakes Chemical/GW cleanup	Individual permit, no longer discharges
CalTrans Stormwater	Statewide permit for CalTrans facilities
Industrial Stormwater	Statewide general permit for industrial stormwater discharges

The Regional Board currently regulates three commercial nurseries through waste discharge requirements (WDRs): Bordier's, Hines and El Modeno Gardens. These nurseries are located in the upper reaches of the watershed, and their discharge (normally only during storm events) flows into Peter's Canyon Wash (for Hines and El Modeno) and Marshburn Channel (for Bordier's) before reaching the main stem of San Diego Creek. The Regional Board is currently evaluating whether WDRs are needed for two other nurseries (Nakase Nursery and AKI nursery). There are some unpermitted nurseries that are smaller in size than the permitted nurseries. Runoff from other agricultural operations in the watershed, including row crops, orchards, and vineyards, is not currently regulated.

Loading Capacity/ Linkage Analysis

The loading capacity is the critical quantitative link between the applicable water quality standards (as interpreted through numeric targets) and the TMDL. The loading capacity reflects the maximum amount of a pollutant that may be delivered to the water body and still achieve water quality standards. The linkage analysis investigates the relationship between pollutant loadings and water quality effects in order to calculate loading capacities for each pollutant and water body. The loading capacity sections discuss the methods and data used to estimate loading capacity. A range of methods were used to derive the loading capacities for the various pollutants, including predictive water quality models and linkage methods based principally on data analysis. The individual TMDLs and associated TSDs describe the linkage analysis in detail.

TMDLs and Allocations

For each pollutant and water body, this document identifies the necessary TMDL (total allowed pollutant amount) and its components: appropriate wasteload allocations for point sources and load allocations for nonpoint sources and natural background. The TMDLs and associated wasteload and load allocations are expressed in quantitative terms as required by federal regulations.

TMDL calculation methods are summarized in this document and described in greater detail in the TSDs. Separate wasteload and load allocations are identified for point and nonpoint sources, respectively. In cases where it is feasible, individual wasteload allocations are established for each existing point source discharge, including permitted stormwater discharges. For several pollutants, insufficient information was available to support delineation of individual WLAs for each NPDES-permitted discharge. Therefore, the TMDLs include wasteload allocations for a category of "other NPDES permittees." This wasteload allocation category covers discharges under the following permits:

- Tustin Marine Base groundwater
- Silverado Constructors
- Irvine Ranch Water District
- Serrano Water Treatment Plant
- City of Tustin desalter
- Great Lakes Chemical
- Statewide Industrial Stormwater
- Statewide Construction Stormwater

EPA is establishing the grouped allocations for the "other NPDES permittees" category based on the following assumptions, which are discussed here to provide information to assist in implementing the allocations through the NPDES permitting process. The State, in consultation with the permittee(s) where appropriate, should gather data and information necessary to characterize the discharge flows and, if feasible, the loads of the specific pollutants for which allocations are established. The State should consider this new data and information when it considers adoption of the TMDLs and associated implementation plans for these toxic pollutants. If this categorical wasteload allocation is not subdivided when the State adopts the TMDLs, we assume that when any permit in this category is considered for revision or reissuance, the State should prepare an analysis as part of the permit fact sheet that (1) identifies the specific proportion or amount of the categorical wasteload allocation that can be discharged by the individual discharger, and (2) shows that the sum of all discharges covered by these permits will not exceed the total categorical wasteload allocation and is otherwise consistent with the TMDLs. Several alternative approaches are available to the State to apportion available loading amounts among the facilities covered in this wasteload allocation category (see *Technical Support Document for Water Based Toxics Control*, (EPA-505-2-9-001), March, 1991, pp. 68-69 for guidance on allocation criteria).

In the absence of additional analysis by the State in support of individual permitting actions consistent with the assumptions discussed above, we assume that available loading capacity identified in the categorical wasteload allocation is to be divided equally among the 8 permitted discharges. We expect that the followup State analysis in support of TMDL adoption

or permit reissuance may result in different divisions of allocation capacity depending upon the combination of discharge flows, loads, and timing associated with each permitted discharge.

Load allocations for nonpoint sources may be expressed as specific allocations for specific dischargers or as "gross allotments" to nonpoint source discharger categories (40 CFR 130.2). TMDLs usually provide separate load allocations for natural background loads. Separate load allocations for background loads are calculated for the Newport Bay metals TMDLs; however, insufficient information is available to support a conclusion that these loads are completely natural. Separate natural background allocations are inappropriate for pesticides and organochlorine compounds because they of anthropogenic origin and because all known loading sources are accounted for in the TMDL analysis. Separate background allocations could not be calculated for selenium, chromium and mercury because insufficient information was available to support these calculations. Background levels of selenium associated with groundwater inputs to surface water may be significant; however, the physical and hydrological structure of the watershed has been highly altered as a result of hydrologic modifications, groundwater pumping, irrigation practices, and water imports to the watershed. As a result, it would be very difficult to estimate "naturally occurring" selenium discharge levels. Background levels of chromium and mercury are not expected to be substantial.

Allocations may be based on a variety factors. Federal regulations do not establish specific criteria which must be considered in dividing and allocating any available loading capacity between contributing sources. Criteria applied to determine the division of available pollutant loading capacity include:

- Organophosphate Pesticides: All allocations are concentration-based and are applied equally to all discharge sources.
- Selenium: Allocations were divided in proportion to land use areas of the different allocation categories for nonpoint sources and in proportion to discharge flow rates for point source categories. Consideration of flow rates in freshwater bodies, directly linked to precipitation events, is included.
- Metals: Load allocations and the stormwater wasteload allocation for San Diego Creek were generally divided in proportion to land areas associated with each source category. In defining the wasteload allocations for San Diego Creek, we considered the relative discharge flows associated with the different dischargers. We also included an undefined sources load allocation as a gross allotment to account for apparent loadings that could not be associated with other source categories.
- Organochlorine Compounds: Allocations to terrestrial watershed sources were generally divided in proportion to land use areas of different allocation categories, with some consideration of the feasibility of reducing loads for DDT. Newport Bay allocations are expressed as net available loads, taking into account as background loads loadings already allocated for "upstream" segments. For this reason, the allowable loads as expressed in the allocation tables in the TMDL document do not increase cumulatively in a downstream direction. The division of available loading capacity between terrestrial and in-Bay sediment sources was done in proportion to the percentage of total loads associated with watershed versus in-Bay sediment sources.
- Mercury and Chromium: Allocations to watershed sources were generally divided in proportion to land use areas of different allocation categories. Allocations between

watershed sources and in-Bay sediment sources were divided in proportion to the percentage of estimated contributions from new sources and resuspended sediments.

TMDLs (and thus, load allocations and wasteload allocations) can be expressed as *"mass per time, toxicity, or other appropriate measure"*, depending on the type of waterbody and the sources that contribute to impairment. The TMDLs for all pollutants except diazinon and chlorpyrifos are expressed in terms of mass loads per time, and the TMDLs for the pesticides diazinon and chlorpyrifos are expressed in terms of water column concentrations. It is appropriate to express these pesticide TMDLs in terms of water column concentrations because these pollutants cause adverse effects on aquatic life through relatively short term exposures. These pollutants are relatively short-lived in the environment before they break down into less toxic forms, and they do not bioaccumulate through the food chain in the same way several of the other pollutants addressed in these TMDLs do. Therefore, the water column concentrations of these pesticides are of greatest concern in preventing adverse ecosystem effects.

Margin of Safety

A margin of safety is incorporated in each TMDL analysis in order to account for uncertainty in the relationship between pollutant loads and water quality effects.

The margin of safety can be implicit (i.e., incorporated into the TMDL analysis through conservative assumptions) or explicit (i.e., expressed in the TMDL as a portion of the loadings) or a combination of both. The TMDLs described in this document include a margin of safety discussion for each pollutant that describes the basis for the provided margin of safety and shows why it is adequate to account for uncertainty in the TMDL. The document discusses sources of uncertainty in the analysis and how individual analytical assumptions or other provisions adequately account for these specific sources of uncertainty.

For all pollutants except metals, a 10% explicit margin of safety was applied to account for uncertainties in the analysis. An explicit margin of safety is appropriate for each TMDL because there is significant uncertainty in the analysis of pollutant effects, loads, fate (i.e. chemical transformations and degradation following discharge), and transport in the watershed. The data supporting the TMDLs were somewhat limited. For metals, a 20% explicit margin of safety was applied to account for (1) these analytical uncertainties and (2) the consideration that the metals TMDLs are expressed in terms of dissolved metals although it is likely that total metals loading levels are somewhat higher than dissolved metals loads, and that total metals loads may be of concern as a cause of sediment toxicity.

For all pollutants, the TMDLs also incorporate an implicit margin of safety because numerous conservative assumptions were made to ensure that the analytical methods applied are environmentally protective. Each TMDL section describes sources of uncertainty in the analysis and the assumptions made which provide an implicit margin of safety.

Seasonal Variations and Critical Conditions

TMDL must describe the methods used to account for seasonal variations and critical conditions (e.g., stream flows, pollutant loadings, and other water quality parameters) in the TMDL(s) [40 CFR 130.7 (c)]. In the semi-arid climate of Southern California there are two seasons—dry weather during most of the year and intermittent wet weather events typically between November and March. This two-season climate creates significant differences in flow through the creeks and streams. In general, 90% of the water flow occurs during less than 10% of the time; that is, most significant storm events and associated high flows usually occur during the months of December, January and February.

EPA has utilized two different approaches to seasonal variations and critical conditions in developing these TMDLs. One approach varies TMDLs on a seasonal basis. For example, the OP pesticide TMDLs (chlorpyrifos and diazinon) show there is considerable increase in pesticides applied during the dry season (when pests grow and create problems); however, aquatic impairment occurs during wet weather events as surface runoff pollutes the freshwater tributaries. OP pesticide critical conditions are explained more in section III below.

The other approach to addressing seasonal variations and critical conditions is to define critical conditions solely based on freshwater flow rates due to precipitation regardless of season. This flow based approach is applied to freshwater loading to metals, Se, and organochlorine (OC) compounds. Unlike the OP pesticides, the water quality effects associated with these pollutants are not expected to vary on a seasonal basis. In this flow-based approach, the continuous range of stream flows (measured as daily flow rates) that occur in San Diego Creek is broken down into several flow tiers. The loading capacity for each breakpoint in the flow tiers is established, and the sum of allowable loads under all tiers equals the total annual loading capacity for freshwater bodies. Thus the applicable allocation for a given source does not depend on the time of year, but on the actual stream flow (or associated sediment deposition rate for OC compounds) at the time of discharge. This flow approach is partially used for chromium and mercury TMDLs for Rhine Channel, where freshwater has little influence (6%) on deposition within that dead-end reach of Newport Bay.

To estimate the loading capacity of freshwater systems, EPA has utilized daily flow records at San Diego Creek at Campus Drive which were collected by USGS from 1977 - 79 and 1983 – 85 and Orange County Public Facilities and Resource Division (OCPFRD) from 1985 to present. EPA and Regional Board staff reviewed the entire daily mean flow record set from USGS and OCPFRD. The analysis was performed on a water year basis (e.g., July 1977 to June 1978). Incomplete USGS data for the period 1979/80 to 1982/83 were not used because only partial records were available for each year. Thus, the USGS and OCPFRD records yielded 19 water years of daily mean flow records for San Diego Creek. This time span covered water years: 1977-78, 1984/85 – 2000/01. EPA used these records for calculating the flow based approach to Se, dissolved metals, organochlorine, mercury and chromium TMDLs. EPA used annual flow records for water year 1996, 1997, 1998, 1999, 2000, 2001 to determine flow inputs from Santa Ana Delhi Channel. This time span covers a reasonable diversity of rainfall conditions based on precipitation measurements from 1958 to 2001. It includes the exceptionally wet El Nino year, 1998, as well as relatively drier years, 1999 and 2000. Table 2-2 shows

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rainfall recorded at Tustin/Irvine Ranch gage station for each year within the time span utilized by EPA, as well as historical high and low rainfall records. These data illustrate that the data years used by EPA for this approach are reasonably representative of the entire time period. Technical Support Document—Part B gives more explanation of freshwater flows and seasonal variations.

Table 2-2. Annual Precipitation Records at Tustin-Irvine Ranch Station

Water Year *	Rainfall (inches)	Water Year	Rainfall (inches)	Water Year	Rainfall (inches)	Water Year	Rainfall (inches)
1958-59	5.03	1971-72	5.02	1983-84	10.47	1995-96	11.17
1959-60	9.6	1972-73	14.9	1984-85	10.25	1996-97	16.19
1960-61	4.13	1973-74	9.81	1985-86	14.42	1997-98	34.72
1961-62	13.07	1974-75	12.36	1986-87	8.79	1998-99	8.6
1962-63	5.76	1975-76	5.11	1987-88	11.14	1999-00	8.8
1963-64	9.38	1976-77	10.2	1988-89	8.17	2000-01	14.6
1964-65	10.28	1977-78	27.96	1989-90	5.93	Summary	
1965-66	12.68	1978-79	18.59	1990-91	11.23	Min:	4.13
1966-67	14.22	1979-80	20.75	1991-92	17.18	Max:	34.7
1967-68	8.58	1980-81	8.47	1992-93	27.09	Mean:	13.03
1968-69	19.91	1981-82	13.22	1993-94	10.23	Median:	10.8
1969-70	8.48	1982-83	25.92	1994-95	24.65	Count:	42

*Source: OCPFRD; *Water years run from July 1 to June 30 of the following year.*

Rainfall data for water year 1970-71 not available

Available Data

Monitoring data used in these TMDLs came from numerous sources. Much of the analysis has been summarized in a Regional Board staff report describing the monitoring results in relation to water quality objectives, sediment guidelines and fish tissue screening values (SARWQCB 2000). EPA has included data from a few more recent studies and focused on monitoring results compiled over the past five years to assess present day water quality conditions. EPA has also reviewed ten years of sediment data and nearly twenty years of fish tissue results to determine long-term trends. Finally, the Regional Board has several projects currently in progress with the Southern California Coastal Research Water Project (SCCWRP). The studies relevant to these toxics pollutant TMDLs address sediment toxicity in Newport Bay (2001a), fish bioaccumulation in Newport Bay (2001b) and freshwater toxicity in San Diego Creek at Campus Dr. (2001c). Preliminary results for two studies (2001a, 2001b) were available as of Dec 1, 2001 and (where feasible) some data were included in these TMDLs. A summary of all monitoring data, the waterbodies sampled, measured parameters and citation/abbreviation is provided in Table 2-3.

Table 2-3 Overview of monitoring data

Organization	Period of record	Geographic Scope	Measured Features	Measured Parameters and comments
Lee & Taylor (2001a) 319(h) report (for SA RWQCB)	Winters 1999; 2000	San Diego Creek Watershed	stormwater runoff	Se; metals and OP pesticides in watershed, Draft report provided May 2001

Hibbs & Lee Se Study	1999	San Diego Creek; Groundwater	Surface and groundwater	Se in groundwater and SDCreek
Lee & Taylor (2001b) 205(j) report (for SA RWQCB)	1997-'99	San Diego Creek Watershed	Surface water toxicity	Toxicity and pesticides in watershed
CDPR Red Imported Fire Ant (RIFA) study	1999-present	San Diego Creek Watershed	Surface water	Toxicity and pesticides Insecticides and OP pesticides in watershed; toxicity and chemical concentrations
IRWD (1999) Database	Fall 1997 --March 1999	San Diego Creek; Upper and Lower Bay (10 sites)	Surface water; sediments	metals and organics using appropriate sampling and analytical techniques, one day composites, year round, no storm events
OCPFRD (2000) (NPDES annual report)	1996-2000	All freshwater tributaries, San Diego Creek; Upper and Lower Bay, Rhine Channel	Surface water; sediments	7 metals, some organics, dry and wet weather events; some four consecutive day sampling; semi-annual sediment data
Orange County Coastkeeper (1999)	Oct. 1999	Rhine Channel (2 sites); Lower Bay (1 site)	Sediments	Metals, sediment core in Rhine
Ogden Env. (1999, for City of Newport Beach)	June 1999	Lower Bay (12 sites)	Sediment	Metals; few priority organics in dredge studies
BPTCP (1997) (for SWRCB/ NOAA/EPA)	1994; '96	Upper and Lower Bay (18 sites total)	Sediment triad study	Metals; many organics; toxicity; benthic comm. Index
Bight '98 (coordinated by SCCWRP)	1998	Lower Bay (11 sites; not Rhine).	Sediment triad study	chemistry; toxicity; benthic comm. index; interstitial porewater data for AVS & SEM
Cal. Dept. Fish & Game	1999-2000	San Diego Creek watershed	Sediment; Fish tissue	OP Pesticides; insecticides in sediment and fish tissue as part of Red Imported Fire Ant project
Calif. Fish Contamin. Study (CFCS) (for SWRCB/ OEHHA)	1999–2000	Upper and Lower Bay	(sport) Fish tissue	Preliminary results for three metals; many organics in fish fillets with skin off
State Mussel Watch (SMW) (for SWCRB)	1980-2000	mostly Upper and Lower Bay	Shellfish tissue	Metals; organics in resident or transplanted mussels, no recent data in SDC
Toxic Substance Monitoring (TSM) (for SWRCB)	1983–1998	all Newport Bay waterbodies	Fish tissue	Total metals; organics in whole fish with skin on
SCCWRP (2001a) Sediment Toxicity Study (for SA RWQCB)	On-going	Upper and Lower Bay; including Rhine Channel (10 sites)	Sediment; Water Toxicity	chemistry; toxicity; benthic comm. index, some preliminary results available
SCCWRP (2001b) Fish Study (for SA RWQCB)	On-going	Upper and Lower Newport Bay	Fish tissue	Four metals; priority organics, sportfish samples in 2001; ecological risk samples in 2002
SCCWRP (2001c) Freshwater Study (for SA RWQCB)	On-going	San Diego Creek (1 site)	Freshwater Toxicity	TIEs for metals in Winter 2002; Se bioaccumulation study

III. Organophosphate (OP) Pesticide TMDLs

TMDLs are required for chlorpyrifos and diazinon for San Diego Creek. To address impairment specified in the 1998 Section 303(d) list, the TMDLs for San Diego Creek address both Reach 1 and Reach 2, unless otherwise explicitly indicated. A TMDL is also required for chlorpyrifos in the Upper Newport Bay. TMDLs are required despite recent re-registration agreements to phase out certain uses of these two OP pesticides by 2006 (EPA 2001b, 2000b). A large portion of information presented here and in the Technical Support Document – Part C is based on the OP Pesticide draft TMDLs written by Regional Board staff (SARWQCB 2001a).

Problem Statement

San Diego Creek

Water column acute and chronic toxicity to aquatic life in San Diego Creek and its tributaries has been identified and attributed largely to diazinon and chlorpyrifos through toxicity identification evaluation (TIE) studies. Over 300 toxicity tests have been performed on 123 water samples collected from the Newport Bay watershed. Toxicity occurred during virtually all monitored storm events and is viewed primarily as a wet weather problem. Dry weather toxicity was generally confined to upper reaches of the watershed (near the foothills) and diluted or otherwise remediated in downstream locations (Lee and Taylor 2001a, b). These TMDLs are structured to prevent toxicity under all flow conditions.

Average diazinon concentrations in San Diego Creek during baseflow (200 ng/L) and stormflow (445 ng/L) have exceeded the chronic numeric target of 50 ng/L. Ninety-five percent of the observed concentrations were also above the acute numeric target of 80 ng/L. Average chlorpyrifos concentrations in San Diego Creek during baseflow (111 ng/L) and stormflow (87 ng/L) have exceeded the chronic numeric target (14 ng/L). At least 59% of the observed concentrations also exceeded the acute numeric target of 20 ng/L.

Upper Newport Bay

Evidence exists indicating water column toxicity due to chlorpyrifos in Upper Newport Bay. This is restricted to storm events when freshwater inputs from San Diego Creek and Santa Ana Delhi linger in the Upper Bay (Lee and Taylor 2001a, b). Average chlorpyrifos concentrations observed in Upper Newport Bay (43.3 ng/L) have exceeded the saltwater chronic numeric target of 9 ng/L during stormflow conditions, and 80% of the concentrations exceeded the acute numeric target (20 ng/L). Toxicity attributed to chlorpyrifos does not extend into Lower Bay. Diazinon does not appear to cause toxicity in saltwater bodies such as Upper or Lower Newport Bay.

Bioaccumulation

In San Diego Creek watershed, fish tissue concentrations of chlorpyrifos have consistently remained orders-of-magnitude below the OEHHA screening value (10,000 ppb) for fish consumption. Diazinon fish tissue concentrations have exceeded the OEHHA screening value of 300 ug/kg only once (440 ug/kg), according to Toxic Substances Monitoring data.

Mussel tissue concentrations of both OP pesticides have never exceeded the OEHHA screening values. Therefore, there is no compelling evidence of bioaccumulation of these substances to levels of concern, an observation consistent with monitoring from other studies (CDFG 2000, EXTOXNET).

In short, there is conclusive evidence that diazinon and chlorpyrifos are causing acute and chronic toxicity in San Diego Creek and that chlorpyrifos causes toxicity in Upper Bay. Toxicity predominantly occurs during storm events and certainly affects lower level aquatic organisms such as *Ceriodaphnia* (Lee and Taylor 2001a, b).

Numeric Targets

At present, there are no promulgated water quality criteria for chlorpyrifos and diazinon. For these TMDLs, EPA has selected the numeric targets from recommended acute and chronic criteria derived by the California Dept. of Fish and Game for chlorpyrifos and diazinon in freshwater and saltwater (CDFG 2000a). These numeric targets serve as the quantitative interpretation of the narrative water-column quality objective as specified in the Basin Plan (1995). These numeric targets will be protective of aquatic life in San Diego Creek and Upper Newport Bay and sufficient to remove impairment caused by OP pesticide toxicity. Target concentrations are shown in Table 3-1; saltwater chronic and acute targets for diazinon are not applicable since TMDLs are not required for this pollutant in any of the saltwater bodies covered by these TMDLs.

Table 3-1 Selected Numeric Targets

		Concentration (ng/L)	
Pesticide	**Criterion**	**Freshwater**	**Saltwater**
Diazinon	Chronic	50	N/a
Diazinon	Acute	80	N/a
Chlorpyrifos	Chronic	14	9
Chlorpyrifos	Acute	20	20

from Calif. Fish & Game (2000a)
chronic means 4-consecutive day average

Source Analysis

This section of the TMDL presents a synopsis of the major sources of diazinon and chlorpyrifos to San Diego Creek and chlorpyrifos to Upper Newport Bay. This synopsis focuses on water column concentrations from several studies conducted in the watershed targeting aquatic life toxicity associated with pesticides (Lee and Taylor 2001a; 2001b; DPR studies). These studies were not detailed enough to identify discrete sources, but it appears that diazinon and chlorpyrifos are problems attributed to agricultural and residential use. Investigations of DPR pesticide use reports provide some estimates of pesticide applications by land use within the watershed; however this does not comprehensively depict all sources in San Diego Creek. Additional analysis via land use information indicates that residential contributions are also

significant. The synopsis is presented below, whereas the reader will find a more complete source analysis in the Technical Support Document – Part C.

Diazinon

Within freshwater bodies of San Diego Creek, monitoring results show extremely high detection frequency (>98%) of diazinon during storm events. This detection frequency decreases slightly (89%) during dry weather or base flow conditions. Maximum concentrations were observed in Hines Channel (which drains into Peters Canyon Channel, and is tributary to San Diego Creek Reach 1).

At virtually all the locations, the median stormflow concentration is significantly higher than the median baseflow concentration. Since stormwater runoff constitutes about 80% of the volume of water discharged to Newport Bay on an annual basis, this would indicate that the overwhelming majority of the pesticide load would derive from stormflow rather than baseflow. The average concentration is actually higher for baseflow, but this is biased by a few very high detections from 1998 near nurseries. These results have not been observed in later sampling and the nurseries have subsequently instituted measures targeted at reducing pesticide runoff.

Chlorpyrifos

Chlorpyrifos was detected less frequently (in 45% of samples) than diazinon. This is due in part, to the lower solubility of chlorpyrifos, and its greater affinity for sediment. The lower mobility of chlorpyrifos results in lower concentrations in the drainage channels. According to DPR Pesticide use database, over twice as much chlorpyrifos is applied as compared to diazinon (per pound of active ingredient).

Sample locations monitoring residential areas tended to have lower chlorpyrifos concentrations. Chlorpyrifos was not detected at three of the residential locations under both baseflow and stormflow conditions. The detection frequency, and maximum concentrations detected at another partly residential location (Santa Ana Delhi Channel) were low. The only residential site with relatively high chlorpyrifos concentrations was Westcliff Park (stormflow), but the baseflow concentrations were relatively low.

California DPR Pesticide Use Database

The California Department of Pesticide Regulation (DPR) Pesticide Use database provides information by county about application of pesticides by various licensed pesticide users. For the Newport Bay watershed, diazinon and chlorpyrifos applications have been estimated to comprise one-fifth the total reported for Orange County (because the watershed acreage is one-fifth that of Orange County). In addition, land use analyses indicate that commercial nurseries and residential areas are associated with high pesticide application rates, and much higher detection in water during wet weather. Urban uses account for over 90% of total diazinon and chlorpyrifos use in the Newport Bay Watershed, with residential use by homeowners accounting for roughly half the estimated total of 10,700 lbs of diazinon and 24,000 lbs of chlorpyrifos used in the watershed in 1999. Similar studies reported in literature of pesticide use and water monitoring results have indicated that residential hotspots (individual homes) can account for most of the diazinon runoff from a neighborhood (Scanlin and Feng 1997; Cooper 1996).

Based on data from investigations carried out from 1996-20001, about 36 pounds of diazinon is discharged annually to San Diego Creek, mostly during storm events. This is less than 0.4% of the estimated diazinon mass applied in the watershed. About 8 pounds of chlorpyrifos is discharged annually to San Diego Creek and Upper Newport Bay, with most of the load delivered during storm events. This amounts to about 0.03% of the applied chlorpyrifos mass. Available data and studies indicate that in normal use, OP pesticides break down quickly and therefore only a small percentage of the total amount applied is available to runoff to waterbodies. However, even small amounts of these pesticides are enough to cause acute and chronic toxicity in receiving water bodies.

In summary, surface runoff is the source of virtually all loadings. Contributions from sediment remobilization and groundwater are negligible, however, loading from atmospheric deposition to Upper Newport Bay is potentially significant, though not well quantified. The chemical properties of diazinon and chlorpyrifos ensure that they do not accumulate in the environment. Runoff derived from urban land uses accounts for about 88% of the diazinon baseflow load, and 96% of the stormflow load. Agricultural sources (including nurseries) account for the remainder of the load. For chlorpyrifos, runoff derived from urban land uses accounts for about 85% to 88% of the baseflow and stormflow loads, while agriculture (including nurseries) accounts for about 12% to 15% of the load. On a per acre basis, different land uses contribute diazinon and chlorpyrifos runoff at fairly equal rates within the watershed and distinct source areas are not readily identifiable. Median concentrations from 14 sampled drainage channels across the watershed did not exhibit large differences.

Although it appears that some of the nursery/agricultural locations yield higher chlorpyrifos concentrations than the residential areas, it should be noted that the nursery monitoring locations are selected to monitor undiluted nursery discharge, very close to where the chlorpyrifos is used. In contrast, runoff from individual homes where chlorpyrifos is applied is not monitored; rather the monitoring location is further away within a channel thereby collecting mixed/diluted runoff from many homes. In addition, because of the inherent immobility of chlorpyrifos, and its tendency to adsorb to sediment, higher chlorpyrifos concentrations are most likely to be encountered in areas nearby to where it is applied, before it partitions out of the aqueous phase and settles out along with the sediment.

Loading Capacity/Linkage Analysis

These OP pesticide TMDLs use a concentration-based loading capacity and allocations for diazinon and chlorpyrifos. The concentration-based loading capacity will address the problems of aquatic toxicity within the watershed and Upper Newport Bay. Because diazinon and chlorpyrifos are generally not known to bioaccumulate, there is no need to establish the loading capacity via mass based units. These concentration-based TMDLs will protect aquatic life from short-term exposure via acute targets and long-term exposure via chronic targets.

The concentration-based loading capacity values are exactly the same as those selected as the numeric targets (see Table 3-1). For San Diego Creek, the loading capacity for diazinon has two components: the chronic or 4-day average concentration (50 ng/L), and a maximum 1-hour average (acute) concentration of 80 ng/L. The loading capacity for chlorpyrifos in San Diego

Creek also has two components: the chronic or 4-day average concentration (14 ng/L), with a maximum 1-hour average (acute) concentration of 20 ng/L. For Upper Newport Bay, the loading capacity for chlorpyrifos has two components: the chronic or 4-day average concentration (9 ng/L), and a maximum 1-hour average (acute) concentration of 20 ng/L acute.

As discussed above regarding the numeric targets, this loading capacity (including the margin of safety discussed below) will result in achievement of the narrative water quality objective for aquatic toxicity because these numeric targets arise from aquatic toxicity tests completed during the development of these recommended water quality levels.

TMDL and Allocations

The TMDLs for diazinon and chlorpyrifos are being established at levels equivalent to the loading capacities identified above. We have also utilized concentration-based allocations for both wasteload allocations (WLA) and load allocations (LA). The WLA applies to point sources in the watershed, and includes the NPDES permittees. The LA applies to non-point sources such as agriculture, open space and atmospheric deposition.

For these OP pesticide TMDLs, EPA has established an explicit (10%) margin of safety (discussed below); therefore the concentration-based allocations are calculated as 90% of the numeric target level for each pesticide under acute and chronic exposure conditions. For example, the numeric target for diazinon under short term, acute conditions is 80 ng/L. The wasteload and load allocations are set at 72 ng/L, after subtraction of 8 ng/L to provide the 10% margin of safety.

Allocations for Freshwater Water Bodies

Table 3-2 presents the concentration-based freshwater allocations for chlorpyrifos and diazinon; these apply to all point sources (wasteload allocations) and to all non-point sources (load allocations). The diazinon allocations apply to freshwater discharges into San Diego Creek Reach 1 and Reach 2. The chlorpyrifos allocations apply to freshwater discharges into San Diego Creek (Reach 1 and Reach 2) and discharges into other freshwater tributaries into Upper Newport Bay including Santa Ana Delhi Channel, Big Canyon Channel and other drainages to Upper Bay. This includes discharges from agricultural and residential lands, including flows from the storm water systems. These limits apply regardless of season and flow; i.e., at all times of the year.

Table 3-2: Diazinon and Chlorpyrifos Allocations for San Diego Creek

Category	**Diazinon (ng/L)**		**Chlorpyrifos (ng/L)**	
	Acute	Chronic	Acute	Chronic
Wasteload Allocation	72	45	18	12.6
Load allocation	72	45	18	12.6
MOS	8	5	2	1.4
TMDL	**80**	**50**	**20**	**14**

Allocations for Upper Newport Bay

Table 3-3 presents the saltwater allocations for chlorpyrifos; these apply to all point sources (wasteload allocations) and to all non-point sources (load allocations). It applies to saltwater allocations in Upper Newport Bay, defined from San Diego Creek at Jamboree Rd. down to Pacific Coast Highway Bridge. These limits apply regardless of season and flow; i.e., at all times of the year.

Table 3-3. Chlorpyrifos Allocations for Upper Newport Bay

Category	**Acute (ng/L)**	**Chronic (ng/L)**
Wasteload allocation	18	8.1
Load allocation	18	8.1
MOS	2.0	0.9
TMDL	**20**	**9**

Chronic means 4-consecutive day average

Needed Reductions

Table 3-4 summarizes the estimated needed concentration based (load) reductions for diazinon and chlorpyrifos in order to achieve the TMDL numeric targets in San Diego Creek. Multiple samples are available from five separate storm events in the watershed from 1997-2000. The storm average concentrations in Table 3-4 are the maximum single storm averages at the San Diego Creek-Campus station. The difference between the current load and the allocation is the needed reduction. Chlorpyrifos concentrations may have begun to decline in 2000 and 2001, based on indications of a reduction in usage from the DPR database as well as from the Sales and Use Survey (Wilen 2001) conducted in late 2000. To date, there are no clear indications of declining trends in diazinon usage in the watershed. This table indicates the estimated needed reduction during average storm flows. As discussed above, the majority of the pesticide load derives from stormflow.

Table 3-4. Needed Load (concentration based) Reductions for San Diego Creek.

Constituent	**San Diego Creek Campus Station**		**Allocation**		**Needed Reduction**	
	Storm Average (ng/L)	Max (ng/L)	Chronic (ng/L)	Acute (ng/L)	Chronic (ng/L)	Acute (ng/L)
Chlorpyrifos	120	580	12.6	18	90%	97%
Diazinon	848	960	45	72	95%	93%

Phase out agreements

Diazinon – In January 2001, USEPA released a revised risk assessment and an agreement with registrants to phase out most diazinon uses (USEPA 2001b). Under the agreement, all indoor uses will be terminated, and all outdoor non-agricultural uses will be phased out over the next few years. In addition, on a national basis, about one-third of the agricultural crop uses will be removed. Within the Newport Bay watershed, non-agricultural and non-nursery uses account for over 90% of the diazinon use in Orange County. It is thus likely

that the EPA agreement will result in the cessation of most diazinon use in the Newport Bay watershed soon after the outdoor non-agricultural use registration expires on December 31, 2004.

Chlorpyrifos – In June 2000, the EPA published its revised risk assessment and agreement with registrants for chlorpyrifos (USEPA 2000b). The agreement imposes new restrictions on chlorpyrifos use in agriculture, cancels or phases out nearly all indoor and outdoor residential uses, and also cancels non-residential uses where children may be exposed. Application rates for non-residential areas where children will not be exposed will be reduced, and public health use for fire ant eradication and mosquito control will be restricted to professionals. In Orange County, residential use likely accounts for over 90% of total chlorpyrifos use. Thus, it appears that over 90% of the current chlorpyrifos use in the Newport Bay watershed will be eliminated by the EPA agreement. Retail sales are scheduled to stop by December 31, 2001, and structural uses will be phased out by December 31, 2005.

While these agreements should result in significant decreases in OP pesticide use and the resulting discharge concentrations to the waterbodies, additional measures may be necessary to achieve the reductions set forth above.

Seasonal variation/Critical conditions

Pesticide usage correlates roughly with the season, with increasing usage in the warmer months due to increased pest activity. However, runoff into the drainage channels is greatest during the wet season, and higher pesticide concentrations are observed during storm events. The higher pesticide concentrations primarily account for the toxicity observed in stormwater samples collected in the watershed. The chronic criteria used as the basis for the numeric targets are designed to ensure protection of aquatic life during all stages of life, including the most sensitive stages. Because the TMDL is being expressed as a concentration, a detailed analysis of critical conditions is unnecessary. The concentration-based allocations (Table 3-2 and 3-3) will apply and be protective during all flow conditions and seasons.

Margin of Safety

An explicit 10% margin of safety was applied to the recommended criteria derived by the CDFG (2000a) and EPA (1986) for diazinon and chlorpyrifos. This explicit margin of safety is intended to account for uncertainties in TMDL calculation methods and concerning pesticide effects (e.g., potential additive and synergistic impacts from exposure to multiple OP pesticides) that may aggravate water quality impacts due to diazinon and chlorpyrifos usage in the watershed.

In addition to the explicit margin of safety, conservative assumptions were used in applying the numeric targets within the watershed. These conservative assumptions serve as implicit margins of safety to provide additional protection for aquatic life and minimize aquatic toxicity.

1. No adjustment was made to reflect the possibility of pesticide breakdown from point of discharge to San Diego Creek. Scientists have measured that half-lives of diazinon and chlorpyrifos in water range from a few days up to six months, therefore some degradation is likely to be occurring after application and within flowing waters. Assuming discharges are

within the specified concentration-based allocations, and that such degradation (via biotic and abiotic processes) occurs, there will be sufficient protection for aquatic life.

2. No adjustment was made to reflect the possibility of mixing and dilution within the drainage channels. In particular, the dilution capacity provided by groundwater seepage has not been factored into the TMDLs.

IV. Selenium TMDLs

TMDLs are required for selenium (Se) for San Diego Creek, Upper Bay, Lower Bay, and Rhine Channel. Much of the work presented below and in the Technical Support Document—Part D for Selenium is based on the Se draft TMDLs written by Regional Board staff (2001b).

Problem Statement

Selenium is a naturally occurring element that persists in soils and aquatic sediments and readily bioaccumulates through the food chain at levels that can cause adverse effects on higher level aquatic life and wildlife including fish and birds that prey on fish and invertebrates. Selenium can become mobilized and concentrated by weathering and evaporation in the process of soil formation and alluvial fan deposition in arid and semiarid climates (Presser, 1994). Moreover, selenium may be leached from sediments as a result of irrigation practices, elevation of the groundwater table, or other modifications in the natural hydrologic regime.

Dissolved selenium concentrations in San Diego Creek at Campus, and in tributaries to San Diego Creek, consistently exceed the chronic (4-day average) CTR criterion for freshwaters (5 μg/L). This has been observed in numerous studies, which also cite occasional exceedances of the acute (1 hour max.) criterion (Hibbs and Lee 1999, IRWD 1999, Lee and Taylor 2001a). Dissolved selenium concentrations in Newport Bay do not exceed the CTR saltwater criterion (71 μg/L); nonetheless, fish tissue data indicate that selenium loadings *may* be causing toxicity or contributing to conditions threatening wildlife in Upper and Lower Bay (see next paragraph). Freshwater and saltwater toxicity tests (designed for metals and trace elements such as selenium) are currently in progress (SCCWRP 2001a, b).

In the majority of aquatic sediment samples analyzed from Newport Bay watershed, selenium concentrations are below levels of concern (2—4 mg/kg dry) as defined by Enberg et al. (1998). Mussel and fish tissue concentrations from all waterbodies are below the screening value (20 mg/kg wet) for protection of human health as established by OEHHA (1999). However, these same tissue results are within the range of levels of concern (4 – 12 mg/kg dry) for toxicological and reproductive effects to wildlife (Enberg et al. 1998 and Henderson et al. 1995). In San Diego Creek, tissue concentrations of selenium in small whole fish show an increasing trend from 1983 to 2000 (TSM 2000). Fish fillet results in Newport Bay do not appear to have the same trend and maximum levels barely approach 4 mg/kg dry (TSM database), which is below reported levels of concern. Studies of avian reproductive success, specifically including selenium concentrations in eggs, have not been completed.

Numeric Targets

As discussed in Section II, the California Toxics Rule (CTR) includes numeric water quality standards (objectives) for selenium which are designed to protect aquatic life (USEPA 2000a). EPA and Regional Board staff have re-evaluated freshwater flow histories for nearly 20 water year records (see TSD part B). These records have been divided into four flow tiers as shown in Table 4-3 for San Diego Creek. Our re-evaluation indicates that mean water residence time of 4 consecutive days occurs in flow rates below 814 cfs. Thus the CTR chronic target (5

µg/L) applies to base, small and medium storms. During the large flows, shorter residence time (<4 days) exists and so an acute value is applied, 20 µg/L. EPA has incorporated this high flow (or "large storm") value into selenium targets, flow tiers and loading capacity.

Mean water residence time in the Bay also exceeds 4 days on average. Because the more stringent chronic standards are applied based on a 4 day averaging period, EPA has determined that it is appropriate to apply the chronic selenium standards at three of four flow tiers in San Diego Creek and in Newport Bay. These are equivalent to the chronic freshwater and saltwater objectives included in the CTR. The acute freshwater objective is from National Toxics Rule (NTR, USEPA 1997) and is applied for the highest flow tier for San Diego Creek because the frequency of flows in this tier exceeds 4 days fewer than once in three years on average.

EPA is currently engaged in a process of revising its national criteria recommendations for selenium based, in part, on the USFWS opinion concerning the CTR. However, the numeric objectives for selenium water column concentrations have not yet been changed, and it is not clear whether the freshwater criteria will need to increase or decrease in order to protect aquatic life and aquatic dependent species. On one hand, several commenters supported the option of basing the TMDLs on more stringent targets based on the analysis provided by USFWS. On the other hand, several commenters identified site specific characteristics of Newport Bay watershed which could support a conclusion that objectives less stringent than the CTR would be protective. In light of these uncertainties concerning the need to either lower or raise the selenium standard, we concluded that it would be appropriate to set the TMDLs based on the existing numeric standard. The evidence that the CTR objectives are not be protective of San Diego Creek was not definitive enough to warrant selection of more stringent target values.

Freshwater targets

EPA is applying two numeric targets for different freshwater flow conditions in San Diego Creek. Based on re-evaluation analysis of daily flow records for water years 1977/78 and 1985 to 2001, EPA divided all observed flows into 4 flow categories or tiers: baseflow (≤ 20 cubic feet/second (cfs)), small flows (between 20 and 181 cfs), medium flow (between 181 and 814 cfs), and large flow (>814 cfs). EPA is basing these TMDLs on a different period of flow record than proposed in the draft TMDLs because we have concluded that the flow record for 1978/79 and 1983/84-2000/01 reflects more recently available data and is more reflective of long term flow patterns. The percentage of flows in the base, small and medium flow categories that exceeded 4 days in duration during this period far exceeded the once in 3 year recurrence interval that is assumed in calculation of selenium criteria. Therefore, it was appropriate to apply the more protective chronic standard under these flow conditions. During the high flows associated with large storms, the duration does not extend to four days more than once in 3 years on average, so it is appropriate to apply an acute target concentration for the high flow tier (20 µg/L, based on National Toxics Rule [USEPA 1999]). The Technical Support Document—Part B provides a complete explanation of these flow tiers and the associated mean annual flow volumes for calculating loads.

Saltwater target

The numeric target for dissolved selenium in saltwater is 71 µg/L from CTR (USEPA 2000a). The USFWS concurred with this saltwater value in its review of the CTR. Therefore, this target is expected to result in protection of all designated uses in Newport Bay. Additionally, since San Diego Creek is the major contributor of freshwater flows to Newport Bay (>95%), reductions of selenium in the creek should also result in reductions in the Bay.

Table 4-1. Numeric targets for Selenium in San Diego Creek and Newport Bay (µg/L).

Waterbody/type	Total Se*		Dissolved Se#
	Acute	Chronic	
San Diego Creek/freshwater	20	5	N/a
Newport Bay & Rhine Channel/saltwater	N/a	N/a	71

*Total recoverable = unfiltered sample
#dissolved = <0.45 µm filter

Source Analysis

Several monitoring studies, completed with a specific focus on selenium during short time periods, provide most of our current understanding of selenium sources (IRWD 1999, Hibbs and Lee 2000, Lee and Taylor 2001a). The synopsis is presented below; the Technical Support Document—Part D presents a more thorough source analysis and description of these studies.

An investigation of selenium sources shows that shallow groundwater is a significant and constant source of selenium to surface waters in the San Diego Creek watershed (Hibbs and Lee 2000). Groundwater may seep into surface waters via natural processes or it may be pumped as part of groundwater cleanup or dewatering operations which discharge into surface waters. Thus selenium contributions to the watershed include both non-point sources (seepage) and point sources (cleanup and dewatering). Surface channels immediately downstream of nurseries were found to have low selenium concentrations during base flow conditions (Hibbs and Lee 2000, Lee and Taylor 2001a).

San Diego Creek contributes the largest load of selenium among all tributaries to Newport Bay (Lee and Taylor 2001a). Of the load from San Diego Creek, Peters Canyon Wash, which conveys selenium from selenium-laden shallow groundwater, represents the major source in dry weather. These sources may include runoff from hillsides, open spaces, agricultural lands, and commercial nursery sites. High concentrations were found in nursery channels during rain events, although it remains unclear if the selenium sources are from the commercial nurseries or from sources existing upstream of the nurseries. During rain events, the selenium load from the upper reach of San Diego Creek was comparable to that from Peters Canyon Wash, suggesting runoff from open space is a significant source during rain events. Low concentrations were found in nursery channels during baseflow conditions.

Table 4.2 Reported Selenium conc. in San Diego Creek and Santa Ana-Delhi Channel (µg/L)

Location	Lee and Taylor* 5/31/00	Hibbs and Lee¥ 10/31/99	IRWD@ 12/97–3/99
San Diego Creek (at Campus Dr.)	22.1	19	42.5
Santa Ana-Delhi (at Irvine Ave.)	11.9	---	---

*Lee and Taylor (2001a) results for unfiltered samples
¥Hibbs and Lee (1999) results for dissolved sample
@ IRWD (1999) result is arithmetic average of time period indicated, dissolved sample

Urban runoff is found to contain very low selenium concentrations (< 1.5 µg/L) (Lee and Taylor 2001a). Atmospheric deposition of selenium is not significant compared to loading from San Diego Creek and other freshwater tributaries (Mosher and Duce 1989). The concentration of selenium in ambient seawater (0.080 µg/L) is unlikely to cause ecological impacts (Nriagu, 1989), and seawater is not believed to comprise a significant source of selenium loading to Newport Bay.

Figure 4-1 summarizes the sources of selenium in the watershed. The significance of these sources varies both on discharge location and season of the year. Nursery runoff shows moderate concentrations (~10 µg/L) in dry weather and are potential sources during storms (Lee and Taylor 2001a). There is some evidence that runoff from open space, hillsides, and agricultural lands are significant sources during rain events although this evidence is inconclusive. Groundwater seepage/infiltration, treated groundwater discharges, and groundwater dewatering discharges represent significant and constant sources.

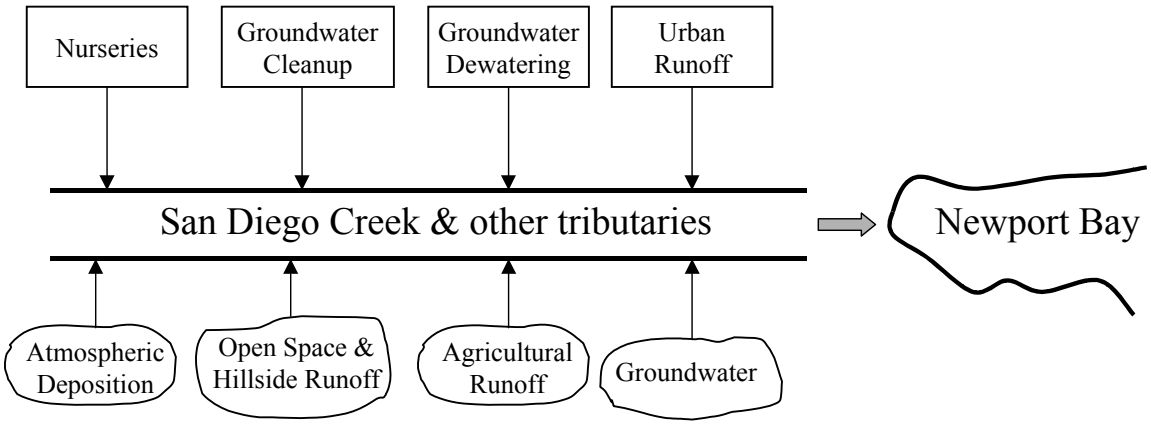

Figure 4.1 Sources of selenium in the Newport Bay/San Diego Creek watershed. (Nurseries have been grouped with agricultural runoff in Table 4-5 for allocations.)

Loading Capacity/Linkage Analysis

The loading capacities and associated TMDLs and allocations for selenium are expressed as mass loads per time. Different approaches were used to calculate loading capacities for the freshwater and saltwater water bodies in the watershed.

San Diego Creek

This TMDL uses a flow-based approach to determine the loading capacity for selenium in San Diego Creek. This approach addresses contributions of selenium under various flow regimes or tiers. Four flow tiers were chosen based on a statistical analysis of daily flow records for San Diego at Campus Drive. (See Technical Support Document – Part B for more explicit information about freshwater flows.) Specific loading capacities for each flow tier are calculated from the desired selenium concentration (i.e., the numeric target) and the annual mean flow volume associated with each tier (Table 4-3). The sum of loads in these four tiers constitutes the total loading capacity for San Diego Creek per year.

Table 4-3 Flow based tiers and corresponding volumes in San Diego Creek

Flow tier	Corresponding flow (cfs)	Flow Volume* associated with tier (million cubic ft.)	Se conc. with tier (ug/L)	Loading capacity per tier[@] (lbs/yr.)
Base flow	0—20	275.4	5	86
Small flows	21—181	347.5	5	108.4
Medium flows	182—814	357.6	5	111.6
Large flows	>814	468.8	20	585.4
Total annual amount		**1449.4**		**891.4**

*Annual mean volume based on USGS & OCPFRD records for water years: 1978, 1984 to 2001.
[@]Se per tier (lbs/yr) = flow volume (ft^3/yr) x desired Se target (ug/L) x conv. factor (6.243 x 10^{-8} lbs x L/mg x ft^3)

Newport Bay

The loading capacity for Newport Bay is presented in Table 4-4. This loading capacity is calculated using the selenium saltwater numeric target (71 µg/L) and the volume of water in Newport Bay. (Mean volume is 19 million cubic meters based on low and high tide estimates [RMA 1999]).

Table 4-4 Loading capacity of San Diego Creek and all Newport Bay waterbodies

Waterbody	Loading capacity (lbs/yr.)
San Diego Creek and tributaries	891.4
Santa Ana Delhi	185.3[¥]
Upper and Lower Bay and Rhine Channel	232,000[*]

[¥]Se value determined via similar method to those used for San Diego Creek but flow records for Santa Ana Delhi Channel were for water years 1995/96 – 00/01
*based on calculation of the CTR saltwater chronic value (71 µg/L) and the volume of Newport Bay water, adjusted to account for daily water movement into and out of the Bay from the Pacific Ocean.

TMDL and Allocations

EPA is setting the TMDL equal to the loading capacity for each waterbody presented above (Table 4-4). For this TMDL, EPA has defined wasteload allocations (WLAs) for point sources and load allocations (LA s) for non-point sources. Allocations for San Diego Creek are inclusive and have been sub-divided into categories presented below and allocations outlined in

Table 4-5. The loading capacity for Santa Ana Delhi has been defined to set an upper limit on selenium contributions from that waterbody into Newport Bay.

TMDL = Σ (wasteload allocations) + Σ (load allocations) + Margin of Safety

Sub-categories of allocations for Se in San Diego Creek.

Wasteload allocations	Load allocations
Groundwater cleanup Groundwater dewatering Urban runoff	Groundwater (background) Nurseries & Agricultural runoff Open space and hillside runoff Atmospheric deposition

EPA adopted the selenium allocation scheme developed by Regional Board staff for their draft selenium TMDL. Wasteload and load allocations are assigned based on the following general guidelines:

- Allocations among source categories are assigned in proportion to the relative significance of the sources, and indicated by available data concerning reported monitoring concentrations, discharge flow rates, and Se loading (see Source Analysis section), and/or acreage of land uses. In general, significant sources require larger reductions in loading than minor sources to attain the numeric target.
- Within the same source category, allocations for individual dischargers are prorated based on land area.
- For each flow tier, allocations are assigned based on the nature of each source. For example, runoff from hillside, open space, and agricultural lands is minimal in dry season but loads dramatically increase during high stream flows associated with wet weather. Loading from shallow groundwater is likely to change because creeks may change from gaining streams (water input from groundwater during dry weather) to losing streams (surface runoff percolates into shallow groundwater areas) as a result of high water level in the creeks during and/or immediately after rain events.
- Atmospheric deposition is not given a specific allocation due to the very low loading from this source (see TSD, pg. D-12). Any loading from atmospheric deposition is less than the explicit margin of safety discussed below and can be considered accounted for in the explicit MOS.
- Discharges from groundwater cleanup and groundwater dewatering are significant sources and loading from those operations depends on their location. However, the quantification of loading from individual discharges is not feasible at this time due to lack of Se data in effluent from those operations. In this TMDL, allocations are assigned as group allocations groundwater cleanup discharges and groundwater dewatering discharges. In addition, a separate wasteload allocation is provided to account for future new groundwater dewatering discharges.

Table 4-5 shows the wasteload and load allocations for San Diego Creek. The estimated current annual load is considered as the current load of selenium at Campus Drive based on IRWD monitoring data (4/98-3/99). The selenium TMDLs and allocations are expressed in mass-based annual loads. Daily loads could be calculated by dividing the annual TMDLs and allocations by 365. However, annual loading-based TMDLs and allocations are more appropriate because prospective adverse effects associated with selenium are associated more with long term

mass loadings and bioaccumulation effects than with short term or acute effects. An explicit margin of safety (MOS) of 10% was included to account for uncertainty in the analysis and ensure compliance with water quality objectives.

Table 4-5 Se allocations for San Diego Creek watershed

Source	**Loading capacity (lbs/year)**					**Current load #**	**Estimated reductions**
	Tier 1	Tier 2	Tier 3	Tier 4	Annual total*		
WLA							
MCAS Tustin	1.6	2.0	1.8	7.9	**13.2**		
GW clean up	6.2	7.8	7.5	36.9	**58.4**		
Silverado GW	3.1	3.9	4.0	21.1	**32.1**		
GW dewatering	3.9	4.9	4.5	21.1	**34.3**		
Future GW facilities	0.4	0.5	0.5	2.6	**4.0**		
Stormwater Permit	0.4	1.0	1.0	5.3	**7.6**		
WLA subtotal	15.5	20.0	19.3	94.8	**149.7**		
LA							
All nurseries	3.1	3.9	4.0	21.1	**32.1**		
Ag runoff	5.4	7.3	8.0	44.8	**65.6**		
Undefined sources @	53.4	66.4	69.1	366.2	**555.0**		
LA subtotal	61.9	77.6	81.1	432.0	**652.6**		
Total allocations	77.4	97.6	100.5	526.8	**802.3**	**2443**	67%
MOS					**89.1**		
Total TMDL					**891.4**		

* sum of loading capacity for San Diego Creek only (based on 5 ug/L applied to all flow tiers)
# undefined sources includes: open space and hillside runoff, shallow GW and saltwater Se
¥ current load based on IRWD Se data (1998-99) and corresponding OCPFRD flow records
§ other GW facilities refers to future permits

Seasonal variation/Critical conditions

As previously described, EPA is calculating these selenium TMDLs based on freshwater flow rates instead of seasons. The flow rates correspond to flow tiers which address the continuous range of San Diego Creek flow rates throughout the year. In this flow-based approach, allocations are based on in-stream flow rates which are influenced by precipitation and runoff. Given that storm events may occur at any time of the year, the corresponding elevated stream flows are addressed by this flow-based approach.

Margin of Safety

In this TMDL, an explicit margin of safety is used to account for other technical uncertainties. The margin of safety is set at 10% of the annual loading capacity (ca. 89 lbs/year). Some of the uncertainty associated with calculation of the TMDL for selenium relates to freshwater flow rates. Given the revised time period (nearly 20 years of daily flow records for San Diego Creek), this uncertainty has been reduced. That is, the draft TMDLs were based on five years of OCPFRD flow data, whereas these final TMDLs are based on flow records for 19 years that better represent the range of flows during wet and dry water years.

V. Metals TMDLs

TMDLs are required for dissolved copper, lead and zinc in San Diego Creek, Upper Bay, Lower Bay and Rhine Channel. TMDLs are required for cadmium in San Diego Creek and Upper Bay only. Information related to these metal TMDLs can be found in two Technical Support Documents, Part B which describes freshwater flows and Part E which describes metals source analysis and methods used to determine loading capacity and existing loads.

Problem Statement

Cadmium, Copper, Lead and Zinc—Dissolved heavy metal concentrations in San Diego Creek and other freshwater tributaries exceeded CTR standards during wet weather only. More specifically, cadmium, copper and lead results exceeded chronic CTR values; copper and zinc data exceeded acute CTR values (OCPFRD 2000). Water column concentrations measured in Newport Bay are highly variable. In general OCPFRD results exceed water quality standards and these data are much higher than data reported by IRWD (1999) which rarely exceed saltwater CTR values. While direct comparison of these results is not feasible, EPA has identified some quality control problems with metals analyses in saltwater by OCPFRD's contract lab and has concluded that they should be considered with caution in TMDL development.

Sediment metal concentrations generally increase along the gradient from freshwater to saltwater with maximum levels found in Rhine Channel. Sediment toxicity has been repeatedly observed in sediment and porewaters of Upper and Lower Bay, including Rhine Channel (BPTCP 1997; Bay et al. 2000, SCCWRP 2001a). Porewater is water found within the bottom sediments. Evidence of degraded benthic organisms also exists in these saltwater bodies. The cause of toxicity and benthic degradation is unknown, however a statistical correlation was found between sediment and porewater toxicity to amphipods and sea urchin larvae and elevated copper, lead and zinc sediment concentrations (BPTCP 1997). Toxicity identification evaluation (TIE) studies of saltwater bodies are currently in progress (SCCWRP 2001a).

Bioconcentration of copper and zinc has been observed in mussels within Lower Bay and Rhine Channel (SMW 2000). However, fish tissue concentrations of these metals are not elevated relative to respective metal screening values defined by OEHHA (1999). Cadmium, Copper, Lead and Zinc may bioconcentrate in lower organisms but these metals generally do not bioaccumulate and therefore are not likely to threaten organisms higher in the food chain such as fish-eating birds.

Numeric targets

In freshwater systems, the dissolved cadmium, copper, lead and zinc water quality criteria are hardness dependent as defined in CTR (USEPA 2000a). Like many flowing freshwater bodies in southern California, San Diego Creek waters exhibit a wide range of flow rates and hardness levels. Monitoring data show that low flow rates have high hardness values (e.g., 20 cfs corresponds to ≥400 mg/L hardness) whereas high flow rates have lower hardness (e.g., 814 cfs corresponds to 236 mg/L hardness). This inverse relationship between flow rate and hardness influences both acute and chronic metals numeric targets.

Based on re-evaluation of freshwater daily flow records measured at San Diego Creek at Campus (see TSD part B), EPA has identified four flow tiers for fresh water segments for use in TMDL calculation. A hardness value is defined for each flow tier which is used to calculate the associated acute and chronic targets for dissolved metal. (Table 5-2). For the baseflow tier, EPA used the maximum hardness value (400 mg/L) as allowed in CTR (USEPA 2000). A review of available data indicated that actual hardness associated with flows in these tiers often exceeds 400 mg/L; however, the CTR caps the allowable hardness value that can be used to calculate the resulting hardness. For the small and medium flow tiers EPA selected the highest flow value within this tier to determine the corresponding hardness value. For large flows, EPA used the median flow rate value to determine the corresponding hardness value.

EPA is identifying numeric targets and TMDLs for both chronic and acute conditions. It is appropriate to set TMDLs for chronic conditions in the lower three flow tiers based on an analysis of flow durations. The chronic standards for metals were calculated based on the assumption that flows of 4 days or longer in duration would reoccur no more than once in three years on average. Our analysis of the flow records showed that in each of the lower three tiers, the recurrence frequency of flows lasting 4 days or longer was greater than once in three years. For the highest flow tier, the recurrence frequency of flows lasting 4 days or longer was less than once in three years. Therefore, TMDLs are set for the high flow tier based solely on acute standards, which apply regardless of flow duration.

It was appropriate to calculate TMDLs for Newport Bay based on chronic targets because average water residence time in the Bay was estimated to exceed 4 days under all likely flow conditions. The investigation of precipitation, flow rates and the relationship to hardness is explained more thoroughly in the Technical Support Document—Part B.

Table 5-1. Flow based tiers and corresponding hardness values in San Diego Creek.

Flow tier	Corresponding flow rate (cfs)	Flow volume associated with tier # (million cubic ft.)	Flow rate used to determine hardness	Corresponding Hardness (mg/L)
Base flow	0 - 20	275.4	N/a*	400
Small flows	21 - 181	347.5	181	322
Medium flows	182 - 814	357.6	814	236
Large flow	>814	468.8	1595	197

mean volume for each tier based on daily flow records for 19 water years: 1977/78, 83/84 to 00/01. (combination of USGS and OCPFRD data)

* flow rate not used for these tiers; hardness determined by CTR (max = 400 mg/L)

Freshwater bodies

For freshwater bodies in San Diego Creek, EPA calculated the hardness-based dissolved metals numeric targets (Table 5-2) using equations provided in CTR. EPA is identifying targets representing concentrations of the metals in the water column for each flow tier. As discussed above, we are identifying targets for both acute and chronic conditions for base, small and medium flows and for acute conditions only in large flows (>814 cfs). Given that water residence time is longer than four days during most of the year, we anticipate the chronic targets

will be most important for compliance, however, the acute targets also set an upper limit for input concentrations. The Technical Support Document - Part E presents a step-by-step discussion of how numeric targets were calculated based on CTR equations for each pollutant, fresh water flow rates, and corresponding hardness values.

Table 5-2. Metals Numeric Targets (ug/L) based on flow tiers for San Diego Creek.

Dissolved Metal	**Base Flows (<20 cfs) hardness @ 400 mg/L**		**Small Flows (21 - 181 cfs) hardness @ 322 mg/L**		**Medium Flows (182 -815 cfs) hardness @ 236 mg/L**		**Large Flows (>815 cfs) @ 197 mg/L**
	Acute	Chronic	Acute	Chronic	Acute	Chronic	Acute
Cd	19.1	6.2	15.1	5.3	10.8	4.2	8.9
Cu	50	29.3	40	24.3	30.2	18.7	25.5
Pb	281	10.9	224	8.8	162	6.3	134
Zn	379	382	316	318	243	244	208

Note: actual ambient hardness must be determined for each monitoring sample regardless of which flow condition exists

Saltwater bodies

In saltwater systems, EPA uses the chronic dissolved metals numeric targets to develop mass based TMDLs. Saltwater targets are straightforward since hardness is not involved. The dissolved saltwater targets are outlined in Table 5-3. Additional numeric targets have also been selected to address toxicity in saltwater sediments. These sediment targets are the threshold effect levels for saltwaters as defined by NOAA SQuiRTs (Buchman 1999). Sediment metal concentrations below these target values are likely to alleviate toxicity to benthic organisms. Both dissolved water column and sediment targets apply for Cu, Pb and Zn within Upper Bay, Lower Bay and Rhine Channel, and for Cd only in Upper Bay.

Table 5-3. Numeric targets for metals in Newport Bay

Metal	**Dissolved saltwater acute target (ug/L)**	**Dissolved saltwater chronic target (ug/L)**	**Alternate target in saltwater sediments (mg/kg dry)**
Cd*	42	9.3	0.67
Cu	4.8	3.1	18.7
Pb	210	8.1	30.2
Zn	90	81	124

(Source: CTR values for dissolved metals in saltwaters; NOAA TEL values for sediments)
*Cd value applies to Upper Newport Bay only

EPA also considered setting targets for both fresh water and salt water in terms of total metals instead of dissolved metals due to the potential concern that particulate metals could become bioavailable. There are several reasons for selecting dissolved metal targets. The existing numeric standards are expressed in the CTR in terms of dissolved metals (EPA 2000a). The CTR rationale is that dissolved forms are the most bioavailable to aquatic organisms. Particulate/dissolved metal ratios were estimated from OCPFRD stormwater data and could be used to translate these dissolved metal mass loads into total loads. However, these translator values developed from paired metals data are close to unity. For example, we calculated a site-specific translator ratio for copper of 1.16 total Cu to dissolved Cu; this is reasonably close to the generic EPA value that dissolved is roughly 80% of total concentration. Therefore, dissolved

metals measures are probably fairly good predictors of total metals concentrations. Moreover, we have incorporated an extra explicit margin of safety to account for the possibility that a focus on dissolved metals does not fully account for total metals concentrations. EPA recognizes the Sediment TMDLs already established for these waterbodies will augment efforts to reduce total metal loadings into the saltwater bodies and help to achieve the sediment targets to protect benthic organisms by reducing discharges of metal-contaminated sediments.

Source Analysis

This section summarizes our analysis of the major sources of dissolved cadmium (Cd) for San Diego Creek and Upper Newport Bay and for dissolved copper (Cu), dissolved lead (Pb) and dissolved zinc (Zn) within all water bodies of Newport Bay. This synopsis draws conclusions from several different studies which report concentrations of metals in the water column and sediments of all water bodies. Where applicable this synopsis also presents information about inputs of copper from sediments and from recreational boats moored in Newport Bay. The Technical Support Document—Part E presents a more thorough presentation of all monitoring results and source analysis pertaining to metals.

Within San Diego Creek and its tributaries, metal inputs are heavily influenced by rainfall and stream flow rates. Base flow conditions yield approximately 25% of total loadings, storm events yield approximately 55% of total loadings, the remainder is associated with low and medium flows. Surface runoff is estimated to be the largest source of metals; this includes both natural and man-made contributions. A recent study of pollutant inputs from tributaries within the San Diego Creek watershed concluded that the largest metals inputs come from "urban stations", whereas agricultural and open space exhibit the lowest loadings (Lee and Taylor 2001a). The difference could be as much as five fold higher for urban areas based on estimates of total copper per acre of runoff (see Table E-7 in TSD – Part E). While this study does provide a basis for estimating the relative importance of metals loadings from different land uses within the watershed, insufficient data were available to accurately estimate annual loads from each source.

Currently, the only published annual metal loading estimates from freshwater tributaries are based on total (unfiltered) metal concentrations (OCPFRD 2000). These estimates for Cu, Pb and Zn indicate that San Diego Creek contributes up to ten times more of each metal than Santa Ana-Delhi Channel. Within San Diego Creek, inputs from Peters Canyon Wash and the rest of the San Diego Creek drainage are about the same. Table 5-4 summarizes these estimates for San Diego Creek and Santa Ana-Delhi Channel for the 1998 and 1999 water years. (The 1998 water year is defined from July 1997 to June 1998.) These results show considerable variability due to different rainfall amounts and fluctuating freshwater flows during each water year. The 1998 water year is considered an extremely wet year (38.4 inches of rainfall) due to El Nino conditions; whereas, 1999 water year is considered relatively dry (8.8 inches) relative to average annual rainfall (13.3 inches).

Another study of surface water runoff during storm events has approximated the relative contribution of metals associated with natural sources such as soil minerals versus the metal inputs from anthropogenic activities. The authors used results from unfiltered (i.e., total metal) samples in the Santa Ana River watershed and report the anthropogenic contribution is metal specific: Cd (63% human-caused), Cu(42%), Pb (35%) and Zn (33%) (Schiff and Tiefenthaler

2000). Total metals loading estimates in Table 5-4 have also been adjusted based on these results to report the approximate load believed to be associated with anthropogenic activities.

Table 5-4 Estimates of Total metal loadings from two freshwater inputs to Upper Bay

Metal	Site	1998 water year (OCPFRD)	Adjusted* 1998 results (Man-made)	1999 water year (OCPFRD)	Adjusted* 1999 results (Man-made)
		Total load (lbs.)	Total load (lbs.)	Total load (lbs.)	Total load (lbs.)
Cu	San Diego Creek	15,087	6261	1643	682
	Santa Ana –Delhi	1643	682	185	77
Pb	San Diego Creek	10,385	3977	449	172
	Santa Ana –Delhi	1297	497	124	47
Zn	San Diego Creek	63,021	20,985	3784	1260
	Santa Ana –Delhi	7031	2341	805	286

Source: 1998 and 1999 water year results from OCPFRD 2000
*Adjustments made from man-made approximations reported by Schiff and Tiefenthaler 2000

Several other sources of metals exist in the watershed: runoff from open spaces, nursery and agricultural applications, groundwater dewatering and cleanup, and atmospheric deposition. Monitoring data exist for background dissolved metals concentrations in surface runoff from hillsides and open spaces. EPA has selected wet weather results from the San Joaquin Channel site (Lee and Taylor 2001a) to serve as proxy for these open spaces because the area upstream from this site is essentially undeveloped. Much of the metals loading associated with open spaces is probably naturally occurring; however, it is likely than some portion of loads from these areas is human caused (e.g., from atmospheric deposition or historic land use activities). Based on State pesticide use reports (CDPR 1999) for some nurseries, applications of copper sulfate appears as the most prominent metal containing substance used in nurseries; nonetheless annual metal applications are small (e.g., 72 lbs/yr) relative to watershed wide surface runoff estimates (ranging from 1643 to 15,087 lbs/yr, Table 5-4). To date, reliable dissolved metal concentrations in shallow ground waters have not been reported. Atmospheric deposition—onto the watershed land surface and into San Diego Creek and other freshwater tributaries—has already been included within surface runoff estimates. It is considered minimal in comparison to other contributions to surface runoff because there are no likely local airborne sources of these metals.

For the salt waters of Upper and Lower Newport Bay, including the Rhine Channel, the largest ongoing sources of most dissolved metals (except for copper) are estimated to be the freshwater-borne loads from San Diego Creek (95% of freshwater-related loads), Santa Ana-Delhi Channel (<5%) and other drainages (<1%). Ambient surface seawater may be the next most significant source. Concentrations of dissolved metals in seawater collected off the Southern California coast range from 0.06 ug/L for Pb, 0.1 ug/L for Cd, 0.2 ug/L for Cu, to 2.4 ug/L for Zn (pers. commun., R. Gossett). The influence of ambient seawater on metal levels within Newport Bay depends on marine tides and freshwater flows from the watershed. During high tides and low freshwater flows, surface seawater contributions could be relatively higher, yet low tides concurrent with dramatically higher freshwater inputs during storm events would yield much lower ambient seawater contributions.

The phenomenon of dissolved copper inputs to marine waters from recreational boats has been repeatedly monitored in San Diego Bay as reported in the draft TMDL for dissolved Cu for Shelter Island yacht harbor (San Diego RWQCB 2001). Using mass loading calculations

presented in that TMDL and local data concerning boats in Newport Bay, passive leaching from recreational boats and underwater hull cleaning are estimated to comprise the most significant sources (>80%) for dissolved Cu into Lower Bay, Rhine Channel and, to some extent, Upper Bay.

To date, no study within Upper Bay has examined whether sediment resuspension or porewater fluxes contribute significant metals loads to the water column. Porewater concentrations measured in Lower Bay (not including Rhine Channel) suggest that Cu levels are elevated enough to create potentially negative impacts (Bight '98). Levels for the other metals are within the range of concentrations observed in ambient seawater and well below the dissolved saltwater numeric targets.

Air deposition of metals is traditionally assessed in two parts—indirect and direct. Indirect deposition, where metals are deposited onto dry land areas and then washed into streams via surface runoff, has already been included as part of the freshwater inputs from San Diego Creek, Santa Ana Delhi Channel and other drainages to Newport Bay. Direct deposition, where metals directly enter the water surface, comprises less than 1% of metal contributions to Upper and Lower Bay and can be considered accounted for in the explicit margin of safety.

Loading Capacity/Linkage Analysis

In the draft TMDLs, EPA outlined two options for defining dissolved metals loading capacity and associated TMDLs. These two options were to apply a concentration based or a mass based approach for to each water body. Based on our review of public comments and further analysis, we are establishing TMDLs based on concentration for San Diego Creek and both concentration and mass loads for Newport Bay as discussed below.

San Diego Creek and tributaries

The metals loading capacities and TMDLs for San Diego Creek are set on a concentration basis for dissolved metals. The rationale for addressing dissolved metals is that dissolved metal forms are the most bioavailable to aquatic organisms. These metals are generally not know to bioaccumulate from one organism to the next, nor has sediment toxicity attributed to metals in the Creek been reported; therefore, long term mass loading which could contribute to bioaccumulation or sediment toxicity concerns is less of an issue in San Diego Creek. For these reasons, a concentration-based approach is more appropriate for these pollutants. These concentration-based loading capacity will protect aquatic life from short term exposure via acute targets (for all flow conditions) and longer term exposure via chronic targets (for flows <814 cfs).

These concentration based loading capacity values are hardness dependent. Freshwater systems experience a wide range of flows and individual hardness conditions. In the future, it will be necessary to measure actual ambient hardness concurrent with each metals monitoring sample (grab or composite) in order to help determine compliance with the TMDLs. The CTR sets an upper limit for hardness is 400 mg/l; the lower recommended limit is 25 mg/l.

The acute and chronic targets and associated loading capacities and TMDLs apply to base, small and medium flows. However, targets, loading capacities, and TMDLs for the highest flow tier (>814 cfs) are based on acute standards only. As discussed above, this approach is based on our review of flow records for San Diego Creek to examine the duration of elevated flows and the frequency of chronic conditions (See TSD Part B for freshwater flow).

Newport Bay

For Upper and Lower Bay, including Rhine Channel, the loading capacities were calculated by multiplying the chronic numeric target by the volume of water in the Bay, accounting for water exchange rates between Newport Bay and the Pacific Ocean. The loading capacities are based on the saltwater dissolved metals targets (Table 5-3). The mass-based loading capacity for all of Newport Bay is shown in Table 5-5a. (A complete description of this calculation is presented in TSD – Part E.)

The rationale for setting mass-based metals TMDLs and allocations is to address observed sediment toxicity in all areas of Newport Bay. Over longer time frames, cumulative metals discharges are of concern in embayments and possibly fresh water waterbodies because metals may associate with sediment and accumulate in bottom sediments, where they may contribute to sediment toxicity and associated ecosystem impacts. The alternate metals sediment targets (Table 5-3) will help to evaluate acceptable conditions for benthic organisms.

Mass based allocations set a definitive upper limit on the amount of each metal allowed to be discharged from San Diego Creek into Newport Bay, which would probably be most effective in addressing long term sediment toxicity concerns. Loading contributions from San Diego Creek and Santa Ana Delhi Channel were calculated by multiplying the chronic numeric target for base, small and medium flow tiers and acute target for large flow tier (see Table 5-1) by the mean annual water flow volume associated with each tier to yield an allowable mass load for each flow tier. This approach is similar to that presented in the Se TMDLs. (An example of this calculation for dissolved copper is provided in the TSD – Part E.) The sum of all four tiers yields the upper limit to the mass-based loading capacity for San Diego Creek (Table 5-5a).

Table 5-5a. Mass-based dissolved metal loading capacity for Newport Bay

Dissolved Metal	Upper and Lower Bay including Rhine Channel Dissolved load (lbs/yr)
Cd	14,753*
Cu	11,646
Pb	27,136
Zn	285,340

*Cd load applies to Upper Bay only, where volume of Upper Bay is approximately 40% of the total volume of Newport Bay

To ensure that Newport Bay is protected from potential adverse effects of short term metals loading "spikes", the loading capacities and associated TMDLs for Newport Bay are also defined in terms of the concentration-based water quality standards for the Bay. In the absence of this complementary approach, it would be possible for the Bay to meet the annual loading-

based TMDL and still exceed water quality standards on a short term basis. The concentration based TMDLs are listed in Table 5.5b

Table 5.5b Concentration-based dissolved metal loading capacity for Newport Bay

Metal	Dissolved saltwater acute loading capcity (ug/L)	Dissolved saltwater chronic loading capacity (ug/L)
Cd*	42	9.3
Cu	4.8	3.1
Pb	210	8.1
Zn	90	81

TMDLs and Allocations

The freshwater dissolved metals TMDLs are concentration–based; whereas the saltwater TMDLs are both mass-based and concentration-based. The TMDLs and allocations may be expressed in terms of the following general equation:

TMDL = Σ (wasteload allocations for point sources) + Σ (load allocations from non-point sources and background) + Margin of Safety

San Diego Creek

As discussed in the loading capacity section, EPA is expressing the San Diego Creek metals TMDLs on a concentration basis. The freshwater allocations are equivalent to the concentration-based targets, reduced by 20% to provide the margin of safety discussed below (see Table 5-6 for freshwater TMDLs and allocations). These allocations apply to all freshwater discharges to San Diego Creek, Santa Ana-Delhi Channel, Big Canyon Channel, East Costa Mesa Channel and other drainages. This includes discharges from agricultural, urban and residential lands, including flows from the storm water systems. These allocations would apply at all times of the year. Because flow tiers for the freshwater channels other than San Diego Creek were not specifically calculated, it is assumed that the same TMDLs applicable to San Diego Creek during different flow conditions apply to the other channels at the same times. For example, when flow is 50 cfs in San Diego Creek, the "small flows" TMDLs and allocations listed in Table 5-6 apply in all the other freshwater channels in addition to San Diego Creek.

Table 5-6. Metals WLAs, and LAs in (ug/L) (based on flow tiers for San Diego Creek)

Dissolved Metal	Base Flows (<20 cfs) hardness @ 400 mg/L		Small Flows (21 - 181 cfs) hardness @ 322 mg/L		Medium Flows (182 -815 cfs) hardness @ 236 mg/L		Large Flows (>815 cfs) @ 197 mg/L
	Acute	Chronic	Acute	Chronic	Acute	Chronic	Acute
Cd	19.1	6.2	15.1	5.3	10.8	4.2	8.9
Cu	50	29.3	40	24.3	30.2	18.7	25.5
Pb	281	10.9	224	8.8	162	6.3	134
Zn	379	382	316	318	243	244	208

Values are 80% of freshwater numeric targets in Table 5-2
Note: actual ambient hardness must be determined for each monitoring sample regardless of which flow condition exists

The wasteload allocations apply to the following NPDES discharges:

- Orange County Stormwater
- CalTrans
- Other NPDES Discharges (see Section II, p. 19 for description of this allocation category)

The load allocations apply to the following source categories:

- Agricultural runoff (including nurseries)
- Air deposition
- Other sources (includes open space runoff, background, and undefined sources).

Newport Bay

Table 5-7a presents the mass based TMDLs and allocations for dissolved metals in Newport Bay. These allocations apply to the water column in Upper Newport Bay (defined from San Diego Creek at Jamboree Rd. down to Pacific Coast Highway Bridge), Lower Newport Bay (defined from PCH Bridge to the Newport Jetty) and to Rhine Channel (confined by line drawn from 20th St. across to Lido Beach St. to channel end). These allocations apply to the receiving waters of Newport Bay at all times of the year, regardless of freshwater flow from San Diego Creek, Santa Ana-Delhi, Costa Mesa Channel and other tributaries into Newport Bay.

Several methods were used to determine allocations. First, because NPDES boatyard permittees are not authorized to discharge into salt waters of Newport Bay, the wasteload allocation for boatyards is zero. Second, air deposition and undefined sources (background from medium and large storm runoff and ambient seawater contributions) were assigned mass loadings based on existing loading since reductions were not expected. Third, agriculture runoff was also assigned an explicit mass loading of one-half the total annual estimated loads based on the assumption that erosion control planned under the sediment TMDL implementation plan would result in approximately a 50% reduction in erosion-related metals loading, and that the small amount of metals load associated with agricultural chemical use could be reduced through use of best management practices (EPA, 1993). The allocations for the remaining sources (urban stormwater, CalTrans, other NPDES, and boats (for copper and zinc)) were based on best professional judgement, as discussed below, because insufficient data were available to accurately estimate their relative contributions to existing loads. The allocation for runoff from the watershed from urban stormwater and CalTrans facilities and discharges from the other NPDES permittee category is based on the assumption that approximately half the metals loading can be reduced through use of available management practices (EPA, 1993). The runoff allocation is divided between the Orange County stormwater permit, CalTrans permit, and other NPDES facility category based on the relative proportions of watershed land area under the jurisdiction of these three permits. The remaining allocation for boats represents a reduction in metals loadings from boats of greater than 80%, based on the assumption that changes in boat paint usage and maintenance practices could substantially reduce the direct loading of copper (and potentially zinc) into Bay waters (EPA 1993). Table 5-7b presents the concentration-based allocations for Newport Bay.

Table 5-7a. Mass-based Allocation Scheme for Metals in Newport Bay

Category	Type	Copper	Zinc	Lead	Cadmium*
WLA	Urban runoff	3,043	174,057	17,638	9,589
	CalTrans	423	22,866	2,171	1,185
	Boatyards	0	0	0	0
	Other NPDES permittees	190	17,160	1,154	596
	Sub-total	**3,656 lbs/yr**	**214,083 lbs/yr**	**20,963 lbs/yr**	**11,370 lbs/yr**
LA	Ag runoff	215	114	0	0
	Boats	4,542	1,056	0	0
	Air deposition	101	606	68	4
	Undefined (open space, existing sed.)	803	11,414	678	428
	Sub-total	**5,661 lbs/yr**	**13,189 lbs/yr**	**746 lbs/yr**	**431 lbs/yr**
MOS		**2,329 lbs/yr**	**57,068 lbs/yr**	**5,427 lbs/yr**	**2,951 lbs/yr**
Total TMDL		**11,646 lbs/yr**	**285,340 lbs/yr**	**27,136 lbs/yr**	**14,753 lbs/yr**

*values apply to Upper Bay only (estimated as 40% of Newport Bay volume)

Table 5.7b Concentration-based dissolved metal TMDLs, WLAs, and LAs for Newport Bay

Metal	Dissolved saltwater acute TMDLs and allocations (ug/L)	Dissolved saltwater chronic TMDLs and allocations (ug/L)
Cd*	42	9.3
Cu	4.8	3.1
Pb	210	8.1
Zn	90	81

The concentration based WLAs and LAs apply only to the sources which discharge directly to the Bay, including stormwater discharges from stormdrains directly to Bay segments (such as Costa Mesa Channel and Santa Ana Delhi Channel) and metals loading associated with boats. The concentration-based WLAs and LAs for San Diego Creek and the other fresh water tributaries will address short term metals concentrations associated with discharges to the fresh water system.

Seasonal Variations/Critical Conditions

These TMDLs rely on careful analysis of the full range of potential flow conditions to address seasonal variations and critical conditions in loads and flows. In general, base and low flows do not present conditions within San Diego Creek that result in either exceedances of numeric targets. This is due to higher hardness levels during low flows that mitigate metals toxicity through competitive binding by calcium and magnesium ions present in freshwater.

Wet weather conditions, which may occur at any time of the year, yield medium and large flows and a range of hardness values. High flows are more likely to produce both low

hardness and higher metal levels; these conditions are the biggest threat to aquatic organisms in San Diego Creek and its tributaries. For Newport Bay, the TMDLs address long term metals accumulations which are associated with metals-caused sediment toxicity measured in the Bay. Therefore, there is no single season or critical season of greatest concern for metals loadings and effects in Newport Bay. The saltwater allocations apply during all seasons, regardless of flow.

For both San Diego Creek and Newport Bay, the approach of setting concentration based TMDLs and allocations based on chronic and acute targets helps address and mitigate any short term effect associated with brief periods of high metals loading.

Margin of Safety

EPA has applied a 20% explicit margin of safety to the dissolved metals TMDLs for both freshwater and saltwater bodies of Newport Bay watershed. This explicit margin of safety is intended to account for uncertainty concerning total (particulate and dissolved) metal loads into San Diego Creek which are transported downstream and deposit in the sediments of Upper and Lower Bay, including Rhine Channel. These metals TMDLs address aquatic life toxicity due to concentrations in the dissolved fraction; this is consistent with current regulatory status for metals as defined by CTR (USEPA 2000a). In recognition of sediment toxicity in Newport Bay correlated to elevated metals, we have selected the 20% margin of safety based on the default total/dissolved metal translator provided in CTR. Our estimates of site-specific total/dissolved translator values are fairly close to the CTR value. It is reasonable to assume that reductions in the particulate metal load will achieve the concentration-based dissolved metal targets.

In addition to the explicit margin of safety, conservative assumptions were used in applying the numeric targets within the watershed. These conservative assumptions provide an implicit margin of safety to ensure that TMDLs are set at levels that will attain applicable standards and protect aquatic life.

1. No adjustment or lowering has been made to address mixing and dilution within the drainage channels contributing to San Diego Creek. Also, there has been no consideration of precipitation (forming particulate metals forms) of dissolved metals as freshwater mixes with saltwater.

2. Chemical speciation has not been included within calculations of loading capacity nor allocations. Aquatic chemists believe the truly bioavailable metal fraction (free metal ion concentration) is much lower (at least 10 times) than dissolved metal concentration. This has been reported for Cd, Pb, Cu and Zn within freshwater and saltwater systems (Buffle 1988, Bruland 1991, Sunda et al. 1987).

3. Setting both acute and chronic-based TMDLs and allocations for San Diego Creek and Newport Bay helps ensue that short-term toxic effects are not allow to occur even if longer term mass loading-based TMDLs and allocations are met. This approach helps ensure that water quality standards will be met throughout the year.

VI. Organochlorine TMDLs

TMDLs are being established for chlordane, total DDT and total PCBs in all waterbodies: San Diego Creek, Upper Bay, Lower Bay and Rhine Channel. Dieldrin TMDLs are being established for San Diego Creek, Lower Bay and Rhine Channel. A TMDL for toxaphene is being established for San Diego Creek only. The term "organochlorine compounds" includes all of these pollutants and the phrase "organochlorine (OC) pesticides" refers to DDT, chlordane, dieldrin and toxaphene.

Additional information on the source analysis, modeling approach and relevant monitoring results for these TMDLs is provided in Technical Support Document – Part F.

Problem Statement

Use of these pollutants has been banned because of potential harm to human health and/or wildlife. However, many of the environmental concerns associated with their use and ultimate transport to the environment are directly related to their ability to persist in water, soil, and biological tissue for long periods of time after their introduction to the environment.

Monitoring results show exceedances of EPA and State fish tissue screening values, which indicate the applicable narrative water quality standards are not being met. Specifically, toxaphene exceedances (87%, n=15) of the OEHHA tissue screening value occur only in San Diego Creek (TSM). Tissue exceedances have also occurred for Chlordane (40%), Dieldrin (93%), total DDT (93%), and total PCBs (67%) in San Diego Creek (n= 15 for all, TSM). Similar elevated fish tissue concentrations indicate bioaccumulation for Chlordane, Dieldrin, total DDT and total PCBs in all saltwater bodies of Newport Bay (except for dieldrin in Upper Bay). Conclusions for Newport Bay are based on finfish and shellfish tissue results from several monitoring efforts (SMW, TSM, CFCS and SCCWRP databases, see Table 2-2). A review of tissue data for a 20 year period indicates that fish tissue concentrations are declining for the OC compounds, yet exceedances of OEHHA tissue screening values are still occurring. Freshwater and saltwater tissue concentrations show declining trends, with higher levels generally occurring in San Diego Creek than in Newport Bay. The sediment data did not exhibit clear trends, rather erratic spikes, which is common for this heterogeneous media.

Numeric Targets

As discussed in Section II, EPA evaluated the applicable water quality criteria and sediment and tissue screening levels to determine the appropriate numeric targets for these organochlorine TMDLs. We have prioritized sediment quality guidelines over tissue screening values and water column criteria. This decision is based on the following factors:

1) these pollutants are directly associated with sediments (i.e., fine particulate matter);
2) sediments are the transport mechanism for these organochlorine compounds from freshwaters to salt waters;
3) limited water column data are available to adequately describe the past or current conditions
4) attainment of the sediment targets will be protective of the water column criteria and tissue screening values.

The use of sediment criteria in this analysis yields an environmentally conservative interpretation of water quality criteria, including the narrative water quality objectives in the Regional Board Basin Plan (1995).

The numeric targets for freshwater and saltwater systems for chlordane, dieldrin, DDT, PCBs and toxaphene, are shown in Table 6-1a and 6-1b. The primary target value is based on sediment levels, and the alternate targets are provided for fish and shellfish tissues and for water column concentrations in freshwater. The specific numeric values for sediment targets were selected from NOAA Sediment Screening Quick Reference Tables (SQuiRTs) (Buchman 1999). By selecting sediment targets, EPA will address protection of benthic organisms as well as bioaccumulation of these organochlorine compounds into tissues of higher organisms such as fish, wildlife predators and humans. Sediment targets are used for TMDL development except where sediment data were not available; e.g., toxaphene in San Diego Creek. The alternate targets – fish tissue screening values from OEHHA and water column objectives from the CTR– are included in this TMDL report as means of gauging improvement in the water quality and progress towards achievement of the TMDL, and to assist in assessing the accuracy of the analysis supporting the TMDLs.

Table 6-1a. Numeric targets for organochlorine compounds for all waterbodies.

Waterbody	Pollutant	Sediment target ¥ (ug/dry kg or ppm)	Fish tissue target# (ug/kg wet or ppb)
San Diego Creek and tributaries	Chlordane	4.5	30
	Dieldrin	2.85	2.0
	Total DDT	6.98	100
	Total PCBs	34.1	20
	Toxaphene	0.1*	30
Upper and Lower Newport Bay, and Rhine Channel	Chlordane	2.26	30
	Dieldrin	0.72	2.0
	Total DDT	3.89	100
	Total PCBs	21.5	30

*this value assumes 1% total organic carbon in sediment sample
¥sediment targets equivalent to threshold effect levels (TEL) from Buchman 1999, except toxaphene from NY Dept. Environmental Conservation
#all tissue targets from OEHHA

Numeric targets for water column concentrations are provided in Table 6-1b based on CTR criteria. These concentrations apply to freshwater bodies (USEPA 2001a); numeric objectives are not available for several of the pollutants in saltwater. We used these targets when modeling the maximum allowable concentrations for water-associated loads from particulate pollutants. (See modeling and analysis section).

Table 6-1b. Freshwater column target values for organochlorine compounds.

Pollutant	CMC (acute) (µg/L)	CCC (chronic) (µg/L)
PCBs	--	0.014
DDT *	1.1	0.001
Chlordane	2.4	0.0043
Dieldrin	0.24	0.056
Toxaphene	0.73	0.0002

* DDT value cited for 4,4' DDT, but value will apply to one one isomer or sum of all isomers detected

Source Analysis

Except for PCBs and possibly small amounts of DDT, the pollutants addressed in this TMDL are no longer believed to be discharged in the watershed except in association with erosion of sediments to which these pollutants may have adhered in the past. The source analysis is therefore primarily a qualitative assessment. The assessment is based on reviews of available information on the physical and chemical properties of each chemical, the expected uses of each, the likely locations of use, and available monitoring data that characterizes current conditions in the environment. A wide range of information was evaluated to identify potential sources and to characterize contributions, including monitoring data, data from national, state and county program databases, and scientific literature. More details on the efforts to identify and characterize potential sources of organochlorine compounds are provided in the Technical Support Document – Part F.

Available data and analyses indicate that there is an existing "reservoir" of historically-deposited organochlorine pollutants in Newport Bay sediment, to which continuing relatively low levels of ongoing pollutant loads are contributing from the watershed. The main source of continuing loadings of organochlorine compounds in the Newport Bay watershed is estimated to be erosion of surface soils or in-stream sediments to which these pollutants have adsorbed (binded). Sediment-adsorbed pollutants enter Newport Bay from San Diego Creek (88%) and various smaller tributaries and local drainages (12%). The sediment load is then distributed throughout Newport Bay via internal circulation patterns under a variety of flow conditions. In preliminary results from one sampling event of sub-surface waters in Lower Bay, SCCWRP (2001a) reported detections of total PCBs and DDT. At the Turning Basin, these compounds were associated with particulate matter (PCBs = 8.86 ug/kg dry; DDT = 15.3 ug/kg dry) and in the dissolved phase (PCBs = 0.15 ng/L; DDT 0.43 ng/L). Dieldrin and Chlordane were not reported.

These organochlorine compounds may also exist in groundwater (due to percolation), may transport via volatilization (from surface soils or water surface) and as implied above they may become resuspended into the water column via physical processes in water bodies. Insufficient data were available to estimate the loads from these sources. Ground water-related loading is expected to be minor because only a small proportion of organochlorine pollutant loads generally occurs in dissolved form. On the other hand, resuspension of sediments to which organochlorine pollutants have adhered is likely to be a more important "loading" source.

Organochlorine (OC) pesticides

Because of the legacy nature of the sources of the OC pesticides, assessment of possible nonpoint sources of these types of pollutants has been based on a review of available monitoring data, historical land use practices, literature reviews, and anecdotal information. One of the major routes for the OC compounds to enter Newport Bay and its tributaries is believed to be runoff and erosion processes. Masters and Inman (2000) have examined fluvial transport of DDT and other legacy pesticides in Upper Newport Bay; they hypothesize that historic agricultural and urban applications of these compounds are the primary upstream sources. In general, these runoff and erosion processes have the ability to pick up and transport these OC

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pesticides and deposit them in a different location in the watershed, to stream systems, or to the Bay. The amount of transport and the locations of deposition depend on many factors, including the presence of the pollutant and the intensity and duration of the precipitation event, which drives stream flow velocity and possibly direction. Because organochlorine residuals from past applications still remain in soils, the potential still exists for these chemicals (and their degraded metabolites) to be transported into water bodies during runoff-producing rainfall events. Insufficient information exists on the specific location and actual magnitude of these sources to support precise loading estimates; therefore, we inferred existing loadings based on limited data and we estimated the pollutant distributions amongst many diffuse sources. No local "hot spots"-specific locations with highly elevated levels of OC pesticides-- were identified.

The only potentially active application of any of the OC pesticides identified is the application of Dicofol, a registered pesticide that may contains small amounts of DDT (i.e., up to .015% based on its registered formulation). The actual DDT content of Dicofol, if any, is unknown. The DPR pesticide use database indicates that Dicofol (trade name "Kelthane") was recently applied to agricultural fields within the Newport Bay watershed (502 lbs. in 1998 and 470 lbs. in 1999). Relative to other sources of DDT (i.e., residuals in soils and aquatic sediments), Dicofol is not estimated to be a significant source of DDT to Newport Bay. However, because DDT in low concentrations may pose an continuing ecological concern, it may be appropriate to further investigate and reduce possible runoff of DDT associated with Dicofol.

Polychlorinated biphenyls (PCBs)

Electrical transformers are the most common use of PCBs. Existing PCB projects such as the Hudson River project in New York and the Housatonic River project in Massachusetts have found that historical discharges caused sediment contamination and that the contaminated soils tend to collect in slow river stretches or reservoirs (GE 1999). The contaminated soils remain there until they are dredged or dislodged by storms. Based on our review of limited information about PCB spills and waste sites containing PCBs, we hypothesize that accidental PCB spills, which were most likely to have occurred at the El Toro and Tustin Air Stations as well as other hazardous waste sites, are the most likely historical loading source of PCBs. Insufficient information exists on the specific location and actual magnitude of these sources, thus we inferred existing loadings based on limited data and we estimated the pollutant distributions amongst many diffuse sources.

Modeling and Analysis

This section describes the methods used to determine the loading capacity and to estimate the existing loads for each organochlorine contaminant with respect to each waterbody. The modeling approach and various resources utilized to complete these tasks are outlined here, although more details, such as equations and specific values, are provided in the Technical Support Document – Part F. To the extent possible, we used hydrologic and modeling information previously compiled by Resource Management Associates (RMA 1997, 1998, 1999) for the U.S. Army Corp of Engineers (ACOE). This model provides sediment deposition information used to determine both loading capacities and estimate existing loads for (for the Upper and Lower Bay, including Rhine Channel. RMA model calibration results were utilized because these results incorporate circulation patterns, spatial distribution and net settling rates for

each area of Newport Bay. These RMA results were generated using a wide spectrum of flow rates from San Diego Creek addressing a 12 year time span (1985 to 1997). Thus the RMA model has implicitly addressed sediment transport and resuspension in Newport Bay as well as dry and wet weather conditions and flow rates in San Diego Creek.

Within San Diego Creek, the RMA model does not provide more specific data such as spatial distribution of sediments, so sediment deposition and the corresponding pollutant load must be estimated via stream flow rates. EPA used nearly 20 water years of flow records for San Diego Creek. The time span of daily flow rates covers water years 1977/78 and 1984/85 - 00/01. This is discussed more in TSD Part B – Flow and consistent with flow records used in Se and dissolved metals TMDLs. For the OC TMDLS, three flow tiers were used -- low flow (0 to 181 cfs), medium (between 181 and 814 cfs) and high flow (>814 cfs). This was designed to represent conditions during dry weather and very light rains (low flow events), intermediate storms (medium flows) and those large storms (high flows) when extensive sediment transport occurs. Pollutants associated with fine particles (especially clay) and dissolved phase are assumed present in all three flow tiers.

Loading capacity

San Diego Creek

For the listed OC pollutants in San Diego Creek the loading capacities were calculated based on pollutant contributions from water column and sediments. The sediment associated loading capacity was determined from target sediment concentrations and sediment load estimates, which were based on regression results presented in RMA model (1997) to link flow rates with sediment loads. We estimated the associated water column loading capacity by backcalculating, from sediment loads to particulate concentrations and dissolved concentrations, using partition coefficients. Where appropriate, these water column derived loads were constrained by chronic water targets for low and medium flows and acute targets for large flows. The sum of the allowable loads in particulate form and dissolved form represents the loading capacity in San Diego Creek. The loading capacities are presented as long term annual loading estimates consistent with the patterns of sediment deposition in the system. Loading capacities for San Diego Creek are presented in Table 6-2.

Newport Bay

The loading capacity for Newport Bay relied on RMA (1998) sediment deposition budget and bottom sediment conditions with target concentrations. The Bay was sub-divided into discrete areas for which individual loading capacities were calculated and summed to provide loading capacities for each water body of the Bay (Upper, Lower and Rhine). To determine the particulate associated load, several factors were used and included: saltwater sediment target, net sediment deposition (volume), porosity, and sediment density. Sediment volume is converted to dry weight by an estimated porosity (0.65). The net loading capacities are presented as average mass per year for each water body to reflect the long-term accumulation patterns associated with sediment and pollutant accumulation in Newport Bay. Loading capacities for Newport Bay are presented in Table 6-3.

Existing Loads

San Diego Creek

A slightly different approach was required to estimate the existing loading to San Diego Creek. Due to incomplete sediment monitoring data for all organochlorine pollutants in San Diego Creek, we used recent fish tissue results (TSM data from 1998) to help estimate water and (indirectly) sediment loads. Water column associated loads were back calculated by using pollutant- and fish species- specific bioconcentration factors (BCFs). The particulate load was estimated from these water column derived values using partition coefficients. The sum of the particulate and water column associated loads yields the estimated existing loads for San Diego Creek based on the most reliable and current data for these hydrophobic compounds. Existing loading estimates for San Diego Creek are presented in Tables 6-5.

Newport Bay

The methods used to estimate existing loads in Newport Bay were similar to those described earlier for loading capacity in Newport Bay. Fortunately, more monitoring data exists for Newport Bay and, in particular recent sediment data (OCPFRD 1999/00 and SCCWRP 2001a) was maximized to give more representative or current conditions in each portion of the bay. These monitoring results were used with the RMA sediment deposition budget to yield the existing pollutant loads. Resuspension and recirculation of sediments, along with the water associated load was implicitly included since these conditions were included in the RMA approach for Newport Bay. (Upper and Lower Bay existing loads represent the sum of several individual areas, as defined in Appendix Table 3 in TSD – Part F.) The net pollutant existing loading estimates for Newport Bay segments are presented in Tables 6-6 to 6-8.

Loading Capacity/Linkage Analysis

The loading capacity for each pollutant was calculated for San Diego Creek, Upper and Lower Bay, and Rhine Channel. The loading capacity for each water body was derived as described above and in the Technical Support Document – Part F. The loading capacity was determined to define the maximum amount of loading which could occur and still result in attainment of the sediment targets, and at the same time, not exceed water quality targets. The model takes into consideration such factors as the particulate and dissolved contributions and flow rates in San Diego Creek. In Newport Bay, the loading capacities were determined via the RMA model and target sediment concentrations. The OC compound loading capacities for San Diego Creek and Newport Bay are listed in Tables 6-2 and 6-3, respectively.

The loading capacity was determined to define the maximum amount of loading which could occur and still result in attainment of the sediment targets. The model links estimates of ongoing pollutant contributions from the watershed with existing pollutant concentrations in the bottom sediments and predicts the cumulative effects in terms of future pollutant concentrations in the bottom sediments and associated trends. The model takes into consideration such factors as the existing water column concentrations (either observed or calculated based on fish or mussel tissue concentrations), data and modeling of sediment deposition into the water bodies, decay rate for a pollutant in the water column, thickness of the water column and active sediment layer, sediment resuspension rates, and sediment burial rates.

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Table 6-2. Loading Capacity for San Diego Creek

Pollutant Name	Sediment Target Concentration (ug/kg dry)	Loading capacity (g/year)
Chlordane	4.5	314.7
Dieldrin	2.85	261.5
DDT	6.98	432.6
PCBs	34.1	2226
Toxaphene	0.1	8.9

Table 6-3. Estimated Loading Capacity for Newport Bay

Waterbody	Sediment Target Concentration (ug/kg dry)				Loading Capacity (g/year)			
	Chlordane	Dieldrin	DDT	PCBs	Chlordane	Dieldrin	DDT	PCBs
Upper Bay	2.26	0.71	3.89	21.5	160.4	N / A	276.5	1528.2
Lower Bay*	2.26	0.71	3.89	21.5	59.2	18.6	101.85	562.9
Rhine Channel	2.26	0.71	3.89	21.5	1.7	0.53	2.92	16.2

(This table is summary of information presented in Table F-4 in TSD—Part F.)

TMDLs and Allocations

For these organochlorine TMDLs, we have expressed the TMDLs and allocations in mass-based units (grams per year) for each waterbody. For each organochlorine compound, the loading capacity in each waterbody is equal to the sum of allocations and an explicit margin of safety. Identification of the TMDL is based on a comparison of the existing loading with the loading capacity. In situations where existing loadings are less than the loading capacity, the TMDLs and allocations are set at the existing loading levels in order to ensure that the TMDL targets are eventually met, and to ensure that pollutant levels in the sediments do not increase in the future (defined as Condition 1 in Table 6-4 below). In situations where existing loads are greater than the loading capacity, the TMDLs and allocations are set equal to the loading capacity (after subtracting the explicit margin of safety). This situation is defined as Condition 2 in Table 6-4 below. Table 6-4 identifies the decision rules applied for each water segment and OC pollutant to define the individual TMDLs.

Table 6-4. Decision rules applied to define TMDLs based on condition applicable to each waterbody/pollutant combination.

Pollutant	San Diego Creek	Upper Newport Bay	Lower Newport Bay	Rhine Channel
Chlordane	Condition 2	Condition 2	Condition 1	Condition 1
Dieldrin	Condition 2	NL	Condition 1	Condition 2
DDT	Condition 2	Condition 2	Condition 2	Condition 2
PCBs	Condition 1	Condition 1	Condition 1	Condition 2
Toxaphene	Condition 2	NL	NL	NL

NL: Not listed for this pollutant

Tables 6-5 through 6-8 summarize the existing loads, the estimated loading capacity, and the total allocation for each pollutant with respect to each waterbody. For most pollutant/waterbody combinations, the loading capacity value is less than the existing load and thus the loading capacity determines the TMDL, as seen in Table 6-4. A 10% margin of safety was subtracted from the loading capacity or existing load, whichever is smaller value.

Table 6-5. Summary of San Diego Creek Loadings and TMDL

Pollutant	Existing Load[1] (g/year)	Loading Capacity[2] (g/year)	TMDL (g/year)	Margin of Safety (g/year)
Chlordane	615.7	314.7	314.7	31.5
Dieldrin	381.8	261.5	261.5	26.2
DDT	3733.8	432.6	432.6	43.3
PCBs	282.1	2226	282.1	28.2
Toxaphene	582.1	8.9	8.9	0.9

[1] existing load based on observed data (OCPFRD 1999/00 and SCCWRP 2001a)
[2] loading capacity based on sediment targets
TMDL is lesser value of existing load or loading capacity; TMDL = Total allocation + MOS

Table 6-6. Summary of Upper Newport Bay Loadings and TMDL

Pollutant	Existing Load[1] (g/year)	Loading Capacity[2] (g/year)	TMDL (g/year)	Margin of Safety (g/year)
Chlordane	290.7	160.6	160.6	16.1
DDT	1080.2	276.5	276.5	27.7
PCBs	858.7	1528.2	858.7	85.9

[1] existing load based on observed data (OCPFRD 1999/00 and SCCWRP 2001a)
[2] loading capacity based on sediment targets
TMDL is lesser value of existing load or loading capacity; TMDL = Total allocation + MOS

Table 6-7. Summary of Lower Newport Bay Loadings and TMDL

Pollutant	Existing Load[1] (g/year)	Loading Capacity[2] (g/year)	TMDL (g/year)	Margin of Safety (g/year)
Chlordane	50.2	59.2	50.2	5.0
Dieldrin	5.9	18.6	5.93	0.59
DDT	438.4	101.85	101.8	10.2
PCBs	409.8	562.95	409.8	41.0

[1] existing load based on observed data (OCPFRD 1999/00 and SCCWRP 2001a)
[2] loading capacity based on sediment targets
TMDL is lesser value of existing load or loading capacity; TMDL = Total allocation + MOS

Table 6-8. Summary of Rhine Channel Loadings and TMDL

Pollutant	Existing Load[1] (g/year)	Loading Capacity[2] (g/year)	TMDL Allocation (g/year)	Margin of Safety (g/year)
Chlordane	0.33	1.70	0.33	0.3
Dieldrin	3.76	0.53	0.53	0.05
DDT	5.60	2.92	2.92	0.23
PCBs	70.0	16.2	16.2	1.6

[1] existing load based on observed data (SCCWRP 2001a)
[2] loading capacity based on sediment targets
TMDL is lesser value of existing load or loading capacity; TMDL = Total allocation + MOS

Tables 6-9, 6-10, 6-11, and 6-12 present the allocations for each OC pollutant-waterbody combination. The explicit margin of safety (10%) has been included for clarification. Allocations were assigned for sources to San Diego Creek primarily in proportion to land use area. The allocations to nurseries and other agriculture factor in two considerations. First, it was assumed that erosion control activities pursuant to the sediment TMDL implementation plan would result in approximately a 50% reduction in OC pollutant runoff from agriculture. In addition, these load allocations factor in a small amount of possible DDT loading associated with possible DDT content in the pesticide Dicofol. The allocations are based on the assumption that only a small fraction of Dicofol reaches water ways, and that DDT loading to waterways associated with Dicofol is a minor source. Undefined sources (existing sediments, air deposition, possible groundwater contributions) were assigned 3% based on existing loading estimates. The remaining portion (approximately 72%) was allotted to urban runoff. We estimate that erosion control practices will result in substantial reduction in OC pollutant loadings associated with eroded sediments (EPA, 1993).

PCBs are particularly stable in aquatic sediment, so we assigned a slightly higher percentage of available allocations to undefined sources (10%) and 4% to other NPDES permits because PCBs chemicals are more likely to be present in groundwater and therefore they may be contained in discharges of groundwater clean up and treatment facilities. This quantity may be modified in subsequent TMDL revisions after subsequent monitoring with adequate sampling and analytical methods to verify PCB loads.

Table 6-9. Allocations for San Diego Creek watershed

Category	Type	DDT (including Dicofol)	Chlordane	Dieldrin	PCBs	Toxaphene
WLA	Urban runoff	302.8	220.3	183.4	177.7	6.2
	Caltrans	8.7	6.3	5.2	42.3	0.2
	Other NPDES permittees	34.6	25.2	21.0	5.6	0.7
	Sub-total	**346.1 g/yr**	**251.8 g/yr**	**209.6 g/yr**	**225.6 g/yr**	**7.1 g/yr**
LA	Ag runoff	8.6	6.2	5.2	5.6	0.2
	Undefined *	34.6	25.2	21.0	22.6	0.7
	Sub-total	**43.2 g/yr**	**31.4 g/yr**	**26.2 g/yr**	**28.2 g/yr**	**0.9 g/yr**
MOS		**43.3 g/yr**	**31.5 g/yr**	**26.2 g/yr**	**28.2 g/yr**	**0.9 g/yr**
Total TMDL		**432.6 g/yr**	**314.7 g/yr**	**262.0 g/yr**	**282.0 g/yr**	**8.9 g/yr**

*undefined = existing sediments + air deposition
Total TMDL = WLA + LA + MOS

Table 6-10. Allocations for Upper Newport Bay

Category	Type	DDT (including dicofol)	Chlordane	PCBs
WLA	Urban runoff	207.4	120.5	609.7
	CalTrans	2.8	1.6	8.6
	Other NPDES permittees	2.8	1.6	8.6
	Sub-total	**212.9 g/yr**	**123.7 g/yr**	**626.9 g/yr**
LA	Ag runoff	2.8	1.6	8.6
	Undefined*	33.2	19.3	137.4
	Sub-total	**35.9 g/yr**	**20.9 g/yr**	**146.0 g/yr**
MOS		**27.7 g/yr**	**16.1 g/yr**	**85.9 g/yr**
Total TMDL		**276.5 g/yr**	**160.6 g/yr**	**858.7 g/yr**

*undefined = existing sediments + air deposition
Total TMDL = WLA + LA + MOS

Table 6-11. Allocations for Lower Newport Bay

Category	Type	DDT (including dicofol)	Chlordane	Dieldrin	PCBs
WLA	Urban runoff	76.3	12.6	4.45	303.3
	CalTrans	0	0	0	4.10
	Other NPDES permittees	0	0	0	0
	Sub-total	**76.3 g/yr**	**12.6 g/yr**	**4.45 g/yr**	**304.7 g/yr**
LA	Ag runoff	0	0	0	0
	Undefined*	15.3	32.6	0.89	61.5
	Sub-total	**15.3 g/yr**	**32.6 g/yr**	**0.89 g/yr**	**73.8 g/yr**
MOS		**10.2 g/yr**	**5.0 g/yr**	**0.59 g/yr**	**41.0 g/yr**
Total TMDL		**101.8 g/yr**	**50.2 g/yr**	**5.93 g/yr**	**409.8 g/yr**

*undefined = existing sediments + air deposition
Total TMDL = WLA + LA + MOS

Table 6-12. Allocations for Rhine Channel

Category	Type	DDT	Chlordane	Dieldrin	PCBs
WLA	Urban runoff	0.7	0.1	0.13	4.1
	Other NPDES permittees	0	0	0	0
	Sub-total	**0.7 g/yr**	**0.1 g/yr**	**0.13 g/yr**	**4.1 g/yr**
LA	Undefined*	1.9	0.21	0.34	10.5
	Sub-total	**1.9 g/yr**	**0.21 g/yr**	**0.34 g/yr**	**10.5 g/yr**
MOS		**0.3 g/yr**	**0.03 g/yr**	**0.05 g/yr**	**1.6 g/yr**
Total TMDL		**2.9 g/yr**	**0.33 g/yr**	**0.53 g/yr**	**16.2 g/yr**

*undefined = existing sediments + air deposition
Total TMDL = WLA + LA + MOS

Margin of Safety

EPA has applied an explicit 10% margin of safety to the loading capacity for these OC TMDLs. The specific mass-based margin of safety for each pollutant with respect to each waterbody is included in Tables 6-5, 6-6, 6-7 and 6-8. This margin of safety will provide additional protection for aquatic life, wildlife predators and human health. The explicit margin of safety is intended to address uncertainties in the relationship between OC pollutant loadings and environmental responses in different areas of the watershed.

In addition, EPA is providing an implicit margin of safety through the selection of several conservative analysis approaches and assumptions used to calculate the TMDLs. Insufficient information is available to specifically quantify the potential uncertainty associated with each of the assumptions used in the analysis. The parameters used in analysis were based on best available information and were selected to be conservative (i.e., most protective) where possible. The use of an explicit margin of safety and recommendation of subsequent follow-up monitoring is intended to ensure that numeric targets are successfully achieved and that the adequacy of the load allocation is evaluated over time. Key areas of uncertainty recognized in the margin of safety include the following:

- The loading capacity is calculated as a long-term annual average that results in meeting water quality standards (expressed as sediment, water column, and/or tissue targets). Because the analysis is focused on long-term predictions, periodic fluctuations are not represented, and actual loading may differ in the short-term.

- Long-term sediment deposition patterns were used to calculate the total amount of sediment deposited in each region. This long-term average value does not represent short-term or localized fluctuations in deposition rates. Periodic accumulation or scouring could be significant during large storm events. This could result in higher or lower deposition rates than the predicted sediment deposition and pollutant concentrations.

- A constant sediment porosity value was used to calculate loads associated with deposited sediment. Sediment porosity values used in the model to estimate loading capacity for San Diego Creek and Newport Bay (0.65) were slightly lower than those used to estimate historical loads (0.80) by RMA. No sediment consolidation was assumed. This resulted in a conservative assumption, since consolidation would result in a lower porosity, which would increase the load associated with deposited sediment.

Seasonal variation/Critical conditions

OC pollutants are of potential concern in the Newport Bay watershed due to possible long term loading and food chain bioaccumulation effects. There is no evidence of short term potential effects. However, pollutant loads and transport within the watershed may vary under different flow and runoff conditions. Therefore the TMDLs consider seasonal variations in loads and flows but are established in a manner which accounts for the longer time horizon in which ecological effects may occur.

These TMDLs rely on careful analysis of the full range of potential flow conditions to address seasonal variation and critical conditions in loads and flows. The sediment transport and deposition within each waterbody is driven by the velocity and sheer conditions of flow. The annual deposition is accounted for by using the sediment budget developed by RMA (1998) which incorporates various flow regimes throughout each year. The sediment budget (generated via model) represents various weather patterns and flow conditions for 12 years.

Obviously the wet weather events, which may occur at any time of the year, produce extensive sediment redistribution and transport downstream. This would be considered the critical condition for loading. However, the effects of organochlorine compounds are manifested over long time periods in response to bioaccumulation in the food chain. Therefore, short term loading variations (within the time scale of wet and dry seasons each year) are not likely to cause significant variations in beneficial use effects.

VII. Chromium and Mercury TMDLs

TMDLs are being established for chromium (Cr) and mercury (Hg) only for the Rhine Channel area of Lower Newport Bay. Additional information on the source analysis, modeling approach and relevant monitoring results for these TMDLs is provided in Technical Support Document—Part G.

Problem Statement

Chromium—Chromium levels are elevated in Rhine Channel mussel tissue samples over the tissue screening value (1.0 mg/kg wet), providing some evidence of chromium bioaccumulation (31%, n= 13). Chromium in Rhine Channel sediments are occasionally (8%, n= 13) above the sediment quality guideline (52 mg/kg dry).

Mercury—Mercury sediment concentrations in Rhine Channel are above sediment quality guidelines levels associated with negative impacts on benthic organisms in all samples tested (100%, n=6). The mercury levels in the limited number of available samples were very high (e.g., recent data shows 5.3 ppm versus PEL level 0.7 ppm). Sediment toxicity has been consistently reported for Rhine Channel (BPTCP 1997, SCCWRP 2001a) although specific contaminants causing this toxicity have yet to be identified. Mussel tissue concentrations were not above the EPA tissue screening value (0.3 mg/kg wet methylmercury), and there is no current evidence that mercury has bioaccumulated to levels of concern.

Numeric Targets

The numeric targets for chromium and mercury in Rhine Channel are presented in Table 7-1. Two targets are provided for each chemical, one for sediment and one for tissue levels. The primary target value (sediment) is for TMDL development, whereas the alternate target (tissue) is designed to provide another means of assessing desired water quality conditions of Rhine Channel.

There are several available screening values for mercury concentrations in sediment and fish tissue. For mercury in Rhine Channel, EPA applied the sediment numeric target, 0.13 mg/dry kg, as the most appropriate indicator of desired water quality. This threshold effect level (TEL) is associated with no observed effect on benthic organisms as part of a study by MacDonald et al. 1996 and cited in NOAA SQuiRTs (Buchman 1999). For comparison, the TEL value is much lower than the probable effects level (PEL = 0.696 mg/kg dry). The NOAA Effects Range-Low (ERL) value for mercury (ERL = 0.15 mg/kg dry) is close to the TEL target value. The alternate mercury numeric target is fish tissue (0.3 mg/kg wet methylmercury), from EPA proposed criteria and analysis provided in the USFWS Biological Opinion on the CTR (2000). This methylmercury target is designed to protect human health, yet it will also be effective at reducing impacts to wildlife predators due to bioaccumulation.

EPA has also evaluated the available water quality criteria and levels for sediments and fish tissue to determine the appropriate numeric target for chromium TMDL in Rhine Channel. EPA selected the sediment target (52 mg/kg dry, Buchman 1999) as the best available target to

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protect both wildlife predators and benthic organisms. The alternate chromium numeric target is fish tissue, 0.2 mg/kg wet (USFWS 2001). This fish tissue target is more stringent than the screening value used to evaluate State mussel watch data in order to ensure protection of wildlife predators.

Table 7-1. Numeric targets for Chromium and Mercury in Rhine Channel.

Waterbody	Analyte	Sediment target (mg/kg dry)	Alternate Fish tissue target (mg/kg wet)
Rhine Channel	Chromium (Cr)	52	0.2
Rhine Channel	Mercury (Hg)	0.13	0.3*

*mercury tissue target is interpreted as 0.3 mg/kg wet methylmercury (EPA proposed criteria and USFWS 2000)

Source Analysis

Chromium (Cr)

Probable sources of chromium include the heavily contaminated sediments existing in Rhine Channel, previous discharges by metal plating facilities near Rhine Channel, historic deposits in the San Diego Creek watershed and atmospheric deposition. The Regional Board has documented two previous investigations of metals contamination at Newport Plating Company. These investigations found extremely high levels of chromium in sediment boring samples. Furthermore, a storm drain which drains runoff from the Newport Plating facility area discharges into Rhine Channel. This facility should be considered a potential source and should receive further investigation. More complete information on this source is presented in TSD part G – Chromium and Mercury.

Chromium may also be leaching from treated wood pylons in marine areas (Weis et al. 1991). Chromium is a naturally occurring element in many area, which can be found in volcanic dust and gases. However, chromium emissions can also come from commercial and industrial facilities, resulting in chromium discharges into the atmosphere. Currently, there is not sufficient information to estimate chromium atmospheric deposition rates in the Newport Bay watershed. The heavily contaminated sediments in Rhine Channel are most likely associated with historic discharges from industrial facilities around Rhine Channel, and these legacy sources are likely to be the largest current sources of chromium.

Mercury (Hg)

No investigation has been completed to explain elevated (total) mercury sediment concentrations within Rhine Channel. Orange County Coastkeeper (1999) measured mercury concentrations in one sediment core and the results provide historical perspective. Total mercury results show lowest concentrations at the core top (3.4 mg/kg dry) and highest concentrations (11 mg/kg dry) at the bottom of the one foot long core. Other researchers have found similar sediment concentrations in Rhine Channel; SCCWRP (2001a) reports 5.3 mg/kg dry and BPTCP (1997) reports (8.7 mg/kg dry) for surface (top six inches) sediment samples. Perhaps historical uses of ship anti-fouling paints which contained mercury are responsible for elevated sediment

levels based on previous activities in Rhine Channel (Regional Board 1998). Most likely the existing sediments are the largest sources of mercury in Rhine Channel.

Another potential source of mercury is the historical mining operations at the old Red Hill mine in the western part of San Diego Creek watershed (in Tustin). Historic records show mercury mining and processing occurred at Red Hill mine between 1880 and 1939 (CA Division of Mines 1976). The total amount of mercury produced is not known. Mine shafts were sealed off in 1976, though some shafts are still open and can receive storm runoff. The Red Hill mine is upgradient of the Swamp of Frogs and mine drainage may have flowed to Peters Canyon Wash. Other minor sources of Hg deposits have been mapped in the area. At this time, no additional information is available to accurately assess whether mercury from this mining location reached the Rhine Channel area. However, available evidence for all of Newport Bay suggests that mercury levels in the rest of Newport Bay are not elevated. It is unlikely that mercury loads from the upper watershed would have contributed to mercury contamination of Newport Bay sediments solely in the Rhine Channel area. Therefore, it is unlikely that discharges from the Red Hill mine area are a principal cause of mercury contamination in Newport Bay.

Based on water column measurements (IRWD 1999) of dissolved mercury (Hg) and chromium (Cr), the loads from San Diego Creek can be estimated. Analysis of previous hydrologic modeling studies for Newport Bay (RMA 1997), yields estimates of sediment transported from San Diego Creek to be deposited in the Rhine Channel annually (approx 6%). Assuming that most of the chromium and mercury is adsorbed by suspended sediment, the estimated annual loads for chromium and mercury from San Diego Creek that are delivered to Rhine Channel are about 46.9 kg/year and 0.054 kg/year, respectively (Table 7-2).

Table 7-2. Estimated Mercury and Chromium Loads from San Diego Creek.

Pollutant Name	Year	Water Column Conc. (ug/L)	Estimated Load to Rhine Channel (kg/yr)
Cr	'97-99	16	46.9
Hg	'97-99	0.0186	0.054

(source: water (IRWD 1999); sediment budget (RMA 1997, 1998)

Atmospheric deposition probably is contributing small amounts of mercury to the watershed; however, there are no likely nearby sources upwind of the watershed. In any event, atmospheric deposition is estimated to contribute very small amounts of mercury to Rhine Channel relative to the amounts of mercury in existing Rhine sediments as well as freshwater sediment deposition. Ambient seawater concentrations of mercury are extremely low, typically less than 1 ng/L.

Modeling

The approach to determining the loading capacities for mercury and chromium is similar to the approach used for the organochlorine compounds (TSD – Part F) and was based on an understanding of the sources of these compounds (past, present, and future) and the transport and ultimate fate of these compounds in various environmental media. Based on a review of literature sources, it was observed that mercury and chromium environmental persistence and affinity for adsorbing to sediment and accumulating in biota generally limits their presence in the water column, at least relative to sediment and biota.

Previous modeling studies, completed by RMA for the U.S. Army Corps of Engineers (USACE) have examined the circulation patterns, and transport and deposition of sediments in Newport Bay (RMA 1997, 1998). By examining model calibration results (RMA 1997) for Newport Bay from 1985-1997, the sediment deposition in Rhine Channel was estimated. The approach relies on the following key information: sediment deposition rates, deposition patterns (from the RMA (1997) model), pollutant targets (used for loading capacity) (see TSD Table G-2) and sediment moritoring data for mercury and chromium concentrations (used for existing loads) (see TSD, Table G-1 and Appendix 1) Historic pollutant loads to the bottom sediment were estimated by using observed pollutant concentrations in bottom sediments and net sedimentation rates. Sediment volume was converted to dry weight using an estimated porosity of 0.65. The loading capacities were determined by "back-calculating" the allowable load from the selected sediment target (Table 7-3) and the associated estimates of sediment loads.

Loading Capacity/Linkage Analysis

Determination of loading capacity has been described above and uses similar methods to those outlined for organochlorine TMDLs (see Section VI of this document and TSD Part G for more comprehensive explanation. These TMDLs express the loading capacities, TMDLs, and allocations in mass loading terms for Rhine Channel. Because most of the mercury and chromium loads are associated with contaminated sediments already in Rhine Channel, it will be necessary to remediate contaminated sediments in order to meet water quality standards and prevent adverse ecological effects.

TMDL and Allocations

For these TMDLs, EPA has calculated both wasteload allocations (WLA) and load allocations (LA). Inputs from historically deposited sediments and atmospheric deposition are included in load allocations. Ongoing sediment deposition (containing mercury and chromium) from San Diego Creek is addressed as a wasteload allocation because this source is generally subject to coverage under the existing NPDES stormwater permit.

For mercury, the on-going load, which is associated principally with local contaminated sediments, is higher than the estimated loading capacity. Therefore, the mercury TMDL (0.10 kg/yr)and associated allocations are set based on this loading capacity. The opposite is true for chromium, where the existing load is slightly lower than the loading capacity, therefore the

chromium TMDL is based on 33.1 kg/yr. The loading capacities for chromium and mercury are expressed as annual averages (Table 7-3).

Table 7-3. Historical Loading and Estimated Loading Capacity for Rhine Channel

Pollutant	existing conc. * (mg/kg dry)	Estimated Load (kg/yr)	Sediment Target (mg/kg dry)	Loading Capacity (kg/yr)
Chromium	44	33.1	52	39.1
Mercury	5.8	4.36	0.13	0.10

* (SCCWRP 2001a)

The wasteload and load allocations (Table 7-4) were calculated based principally on best professional judgement . Most of the available loads were assigned to sediments already in Rhine Channel, which are by the far the largest source. These allocations to existing sediments reflect substantial reductions in sediment loads from in-Channel sources based on the expected effectiveness of remedial actions identified in the 1997 remedial action plan. The remaining available load was allocated roughly in proportion to the land areas associated with the remaining source categories after allocating 5% of available loads for undefined sources. Further investigation of Newport Plating facility may warrant revision of such a high allocation to sediments in Rhine Channel for Chromium.

Table 7-4. Rhine Channel Wasteload and Load Allocations (kg/yr) and % of total loads

	Mercury (Hg)	Chromium (Cr)
Wasteload allocations		
Stormwater	0.0171 (19%)	5.66 (19%)
Caltrans	0.0027 (3%)	0.89 (3%)
Boat yards	0	0
Other NPDES permittees	0.0027 (3%)	0.89 (3%)
Load allocations:		
Existing sediment	0.063 (70%)	20.85 (70%)
Undefined sources: air deposition, ambient seawater	0.0045 (5%)	1.49 (5%)
Margin of safety	0.01	3.30
TMDL	**0.1 kg/yr**	**33.1 kg/yr**

TMDL = WLA + LA + MOS

Margin of Safety

EPA has applied an explicit 10% margin of safety to the loading capacity for these TMDLs. The specific mass-based quantity for each pollutant with respect to each waterbody is included in Table 7-5. This margin of safety will provide additional protection for aquatic life, wildlife predators and human health.

A number of assumptions were used in the derivation of each TMDL. Insufficient information is available to quantify the potential uncertainty associated with each of the assumptions used in the analysis. The parameters used in analysis were based on best available information and were selected to be conservative (i.e., most protective) where possible. The use of an explicit margin of safety and subsequent follow-up monitoring is intended to ensure that

numeric targets are successfully achieved and that the adequacy of the load allocation is evaluated over time. Key areas of uncertainty recognized in the margin of safety include the following:

- The loading capacity is calculated as a long-term annual average that results in meeting water quality standards (expressed as sediment, and tissue targets). Because the analysis is focused on long-term predictions, periodic fluctuations are not represented, and actual loading may differ in the short-term.

- Long-term sediment deposition patterns were used to calculate the total amount of sediment deposited in each region. This long-term average value does not represent short-term or localized fluctuations in deposition rates. Periodic accumulation or scouring could be significant during large storm events. This could result in higher or lower deposition rates than the predicted sediment deposition and pollutant concentrations.

- A constant sediment porosity value was used to calculate loads associated with deposited sediment. Sediment porosity values used in the model to estimate loading capacity for San Diego Creek and Newport Bay (including Rhine Channel) (0.65) were slightly lower than those used (0.80) in RMA model. No consolidation was assumed. This resulted in a conservative assumption, since consolidation would result in a lower porosity, which would increase the load associated with deposited sediment.

Seasonal variation/Critical conditions

These TMDLs rely on careful analysis of the full range of potential flow conditions to address seasonal variation and critical conditions in loads and flows. The sediment transport and deposition within each waterbody is driven by the velocity and sheer conditions of flow. The annual deposition is accounted for by using the sediment model developed by RMA (1997) which incorporates various flow regimes throughout each year. The model represents various weather patterns and flow conditions for 12 years.

As previously stated, freshwater flows from San Diego Creek and Santa Ana-Delhi Channel do not significantly transport sediments into Rhine Channel. The most important scenario may be the large flows associated with wet weather events, which may occur at any time of the year and produce extensive sediment redistribution and transportations downstream. This has yet to be verified in hydrologic modeling of chromium and mercury in Rhine Channel.

VIII. Arsenic Analysis

EPA has concluded that an arsenic TMDL is not required because available data indicate that applicable numeric water quality standards, and the best available screening guidelines used to interpret narrative standards, are not being exceeded. Although the State and EPA initially concluded that arsenic TMDLs were needed based on comparisons with older recommended screening values, we have revised our conclusions based on an updated data set and new information concerning arsenic toxicity and consumption risk. This section explains the basis for EPA's revised assessment of the need for arsenic TMDLs.

EPA's initial assessment of fish tissue monitoring results was based on comparisons with two screening values. Total arsenic concentrations in fish tissue were compared to the California OEHHA screening value (1.0 mg/kg wet for total arsenic). This screening value was developed from a human health study for chemical contaminants in sportfish from two California freshwater lakes (OEHHA 1999). OEHHA recognized that inorganic arsenic is the preferred contaminant to evaluate for potential human health risk; however, analytical methods to measure inorganic arsenic were not available during that study. OEHHA developed a plan to a) evaluate total arsenic fish tissue results against the screening value for freshwater species and b) delay further decisions about water quality impairment or potential health risk until they had actually measured inorganic arsenic in popular sportfish (pers. commun. B. Brodberg). Furthermore, OEHHA recognizes its total arsenic screening value is ill-suited for saltwater systems. EPA Region 9 has reconsidered using this *freshwater* total arsenic tissue screening value and has determined that it would be inappropriate to make final decisions based only on comparison of total arsenic in tissues with this screening value.

EPA's initial assessment also considered another fish tissue screening value, (0.026 mg/kg wet for inorganic arsenic); however no monitoring data exists for measurements of inorganic arsenic in Newport Bay fish. To enable a comparison of available data to the inorganic arsenic screening value, EPA estimated levels of inorganic arsenic present in Newport Bay fish as a percentage of total arsenic for finfish (4% of total) and for shellfish (60% of total). These percentages were based on information obtained from a literature search (for finfish, Donohue and Abernathy 1999) or discussion with analytical chemists (for shellfish, pers. commun. J. Creed). Upon further review of the screening values cited in recent EPA guidance for assessing fish advisories (USEPA 2000d), EPA has determined the 0.026 mg/kg wet inorganic screening value is incorrect and that 1.2 mg/kg wet inorganic arsenic is a more reliable risk-based screening value. Preferably this screening value should be compared to measurements of inorganic arsenic in local fish, although calculation of inorganic arsenic as a percentage of total arsenic is still acceptable.

In the process of developing these TMDLs, EPA reevaluated local fish tissue data in comparison with the new EPA screening value of 1.2 mg/kg wet inorganic arsenic based on EPA's fish advisory guidance. The most recently available set of fish tissue monitoring results was compiled from Toxics Substances Monitoring program (1995-1998), California Fish Contamination Study (1999-2000) Southern California Coastal Water Research Project (2001b) and State Mussel Watch program (1995-2000). We evaluated results from both San Diego Creek and saltwater bodies of Newport Bay but focused more on saltwater results since those results showed some exceedances with respect to the OEHHA screening value applied in EPA's earlier assessment. To be conservative and consistent with other agencies (e.g., FDA), EPA assumed

that inorganic arsenic comprised 10% of total arsenic for finfish and 60% of total for shellfish. We used only one screening value, 1.2 mg/kg wet for inorganic arsenic, which is consistent with both State and Federal agencies' determination that human health risk from arsenic exposure is attributed to inorganic arsenic exposures.

The final assessment of saltwater tissue results (using calculated values of inorganic arsenic) shows no exceedances of the EPA inorganic screening value (1.2 mg/kg wet). This is true for both finfish (0%, n = 80) and shellfish (0%, n = 24). There are also no exceedances of freshwater tissue results. Table 8-1 summarizes arsenic tissue concentrations for Newport Bay. Table 8-2 provides a perspective of arsenic tissue concentrations for Newport Bay and other saltwater bodies. The raw data and calculated results for this reassessment are provided in Appendix B at the end of this summary document. Therefore, based on this revised assessment, EPA concludes that San Diego Creek and Newport Bay are not exceeding water quality standards for arsenic and that no TMDLs are needed. This result is consistent with local ambient water column data for arsenic, which indicate that Bay arsenic levels are about the same as average sea water arsenic levels.

Table 8-1. Total Arsenic results in fish tissue in Newport Bay waterbodies (mg/kg wet)

Waterbody	Collection dates	Org.	n	Min	Max	Mean	Median
San Diego Creek	1995 -- 98	TSMP	15	0.06	0.88	0.18	0.13
Newport Bay (finfish)	1995 -- 98	TSMP*	4	0.4	8.6	2.93	1.3
	1999 -- 00	CFCS	26	0.2	4.0	1.29	0.79
	2000 - 01	SCCWRP	50	0.22	8.6	1.64	0.68
(shellfish)	1995 - 00	SMW	24	0.8	2.5	1.28	1.25

*these TSMP results for individual samples, all other results are tissue composites

Table 8-2. Total Arsenic results in marine waterbodies (mg/kg wet)

Tissue	Study	n	Range	Mean	Median
Finfish	Newport Bay	80	0.2 – 8.6	1.5	0.7
	Wash State	12	0.15 – 10.7	3.5	0.9
	Donohue	77	0.2 – 65	5.1	2.1
	Great Britain	720	0.9 – 30.1	5.6	4.3
Shellfish	Newport Bay	24	0.8 – 2.5	1.3	1.3
	Wash State	10	1.0 – 6.9	2.4	2.2
	Donohue	57	0.2 – 126	15.9	4.2

Newport Bay results compiled from Table 8-1
Washington State results from Yilmazer et al. 2000
Donohue results from various North American waterbodies (1996)
Great Britain results from Collins et al. 1996

IX. Implementation Recommendations

This section provides general recommendations of implementation actions and monitoring work to assist in implementing the TMDLs and allocations identified in this decision. Several commenters, including the Regional Board, dischargers, and environmental groups specifically requested that EPA discuss TMDL implementation recommendations when we made the final TMDL decisions. The implementation and monitoring actions are not required and are not part of the TMDL decisions being made by EPA at this time; rather, they are included with the TMDLs to assist followup planning and implementation work by the State and local stakeholders. As discussed in Section I above, the State—not EPA—is responsible for developing implementation plans necessary to attain TMDLs. In its comments concerning the EPA TMDLs, the Regional Board signaled its commitment to adopt TMDLs and implementation plans for these toxic pollutants in a timely manner.

General Recommendations

The toxic pollutant TMDLs address several pollutant types which come from a variety of sources. Therefore a range of pollutant management options will be available to the State to address them. Based on information we gathered in developing the TMDLs as well as feedback obtained from the State and local stakeholders during the development of the TMDLs, we have identified several appropriate implementation approaches for different pollutants.

Consistent with the State's approach to developing and implementing other TMDLs in the Newport Bay watershed for sediments, nutrients, and pathogens, EPA believes a phased, iterative approach to implementation and monitoring is appropriate to address the toxic pollutants of concern. Substantial uncertainty remains concerning pollutant sources and the relationship between pollutant loads and environmental effects in the watershed. EPA believes some specific implementation actions should be carried out to address pollutant sources which are most clearly of concern. Several of these actions are already underway or in the planning stages. It is also appropriate to collect and analyze additional monitoring data to improve the understanding of pollutant sources and effects, periodically review the TMDLs and implementation actions in light of new monitoring results, and revise the TMDLs and implementation actions if necessary. Depending upon the State's priorities, additional monitoring data could also assist in reviewing and, if necessary revising the applicable water quality standards to provide the appropriate level of beneficial use protection. This combination of early actions to address clear pollutant sources and an ongoing commitment to iterative monitoring and adjustments provides an appropriate balance in followup implementation work.

When the Regional Board considers adoption of TMDLs for toxic pollutants along with associated implementation plans, the State may adopt the TMDLs identified in this decision or further assess these pollutants and adopt different TMDLs if warranted. EPA recommends that the State consider the specific areas of analytical uncertainty identified in the analysis supporting our TMDL decisions as a starting point in targeting any additional analytical work (including monitoring) planned in support of TMDL adoption.

It is expected to take several years for toxic pollutant levels in the watershed to decline to the point where all applicable water quality standards are fully attained. For some pollutants

such as the diazinon and chlorpyrifos, the pollutant levels will probably decline quickly in response to actions to reduce their use. For some other pollutants with long residence times in the environment, or which are associated with historical discharge, there will probably be some lag time between the initiation of controls to reduce loading or remediate contaminated sites and the observation of decreased pollutant levels throughout the watershed. For these reasons, EPA supports the past State practice of identifying interim targets or benchmarks in terms of pollutant control actions, pollutant loadings and/or receiving water responses to help ensure that control actions are taken and progress is being made toward attaining water quality standards. Specification of clear interim targets also assists in the evaluation of whether the TMDLs or implementation actions need to be adjusted in the future.

EPA's TMDLs do not contain compliance timeframes or interim implementation targets because these elements are addressed by the State in the implementation planning process. EPA urges the State to work with local dischargers and stakeholders to design and carry out effective implementation actions sufficient to implement the TMDL in a timely manner.

As discussed in Section 1, the Clean Water Act creates federal regulatory jurisdiction only over point sources. Therefore, the direct implementation effect of EPA's TMDLs is that when NPDES permits for point source discharges are issued or revised for discharges to waters in the watershed, the State is required to ensure that the permits contain effluent limitations necessary to be consistent with the wasteload allocations (WLAs) contained in theTMDLs (40 CFR 122.44(d)). Permit modification may occur when existing permits are reopened or reissued, or when a new discharge source seeks a permit. NPDES permit holders should contact the Regional Board to discuss how and when action will be taken to implement applicable WLAs. The State has discretion to determine how the point source permit provisions will be made consistent with applicable WLAs. Depending upon the situation and the level of precision in the WLA, it may be appropriate to:

- incorporate numeric effluent limitations for the pollutant(s) of concern in the permit,
- identify best management practices and associated pollutant control effectiveness which demonstrate that the WLAs will be attained, and/or
- require the discharger to submit a WLA compliance plan and schedule which demonstrates how the WLA will be implemented.

In addition to addressing WLA implementation through the NPDES permitting process, the State should work with local stakeholders to identify specific actions necessary to carry out load allocations identified in the TMDLs. These actions may be based on voluntary or regulatory approaches. We note that CWA Section 319(h) nonpoint source implementation grant funds may be available to assist in implementing controls necessary to implement load allocations. Section 319(h) projects designed to implement TMDLs currently receive priority for funding. Landowners or land managers interested in seeking Section 319(h) funding assistance should contact the Regional Board staff for more information concerning the State's grant funding process.

OP Pesticide TMDL Implementation Recommendations

EPA's pesticide program has intiated a phase-out of household uses of diazinon and chlorpyrifos (EPA 2000b, EPA 2001b). It is expected that the phase-out will greatly assist in

reducing the levels of these pesticides found in the waters of Newport Bay watershed. Because approximately 90% of diazinon and chlorpyrifos use in the watershed is estimated to be associated with urban and household uses, the phase-out program may be sufficient to result in attainment of the TMDLs and associated allocations. We recommend that the Regional Board continue its work with nurseries in the watershed to minimize use of these pesticides. We recommend continued monitoring in San Diego Creek and its tributaries to assess reductions in OP pesticide runoff in the next several years. If monitoring demonstrates that the urban use phase-outs are inadequate to implement the TMDLs, it may be necessary in the future to implement additional controls on agricultural uses of these pesticides in coordination with the California Department of Pesticide Regulation

We are concerned by potential conflicts between programs to reduce use of these pesticides and mandates to use these pesticides for fire ant control. EPA urges that Regional Board to work with the State Water Resources Control Board, California Department of Pesticide Regulation, California Department of Food and Agriculture, and EPA's pesticide program to assess and, if necessary, reconcile these potentially conflicting mandates concerning OP pesticide use.

Selenium TMDL Implementation Recommendations

EPA is in the process of reviewing and potentially revising the numeric criteria for Se in freshwater. In addition, other local studies are underway to assess the potential effects of Se on aquatic organisms. EPA expects to complete this review within approximately 2 years. EPA recommends that the State review and, if necessary, revise the Se TMDLs following adoption or promulgation of the revised water quality standards. Several commenters raised concerns about whether the CTR criteria are appropriate for conditions in the San Diego Creek watershed, and identified several local factors (e.g. local water chemistry) which could support consideration of alternative site specific criteria. In consultation with EPA and the State Water Board, the Regional Board should consider whether it is feasible and appropriate to assess the applicable Se water quality standards in light of these concerns, and potentially adopt site specific water quality standards.

The TMDL analysis found that the most significant sources of Se loading appear to be associated with groundwater entering surface waters (sometimes directly and sometimes through discharge from dewatering operations). Control of these sources will be difficult. However, EPA recommends that the State begin working with permitted dischargers to assess options for reducing Se discharges through discharge management practices and/or treatment technologies. The State may wish to sequence its planning activities to settle issues concerning applicable standards before carrying out actions to further tighten discharge controls.

EPA recommends that the Regional Board monitor flow and Se concentrations in discharges from cleanup and ground water dewatering operations in order to provide the basis for establishing effluent limits in the permits consistent with the TMDLs. When NPDES permits for groundwater cleanup or dewatering operations are considered, the Regional Board will need to ensure that the total allowable Se loadings do not exceed the group WLA established in the TMDL.

Metals TMDL Implementation Recommendations

Metals loading in the watershed is associated primarily with ongoing runoff from urban and undeveloped areas, and aquatic sediments containing previously discharged metals. Our recommendations address all the metals for which TMDLs are established, including mercury and chromium. EPA recommends five areas of action to address metals loading in the watershed.

First, metals levels in the Rhine Channel area are estimated to be substantially higher than in other areas of the watershed. No significant ongoing loading sources were identified, and the aquatic sediments in Rhine Channel have been identified as a significant toxic hot spot. EPA recommends aggressive action to complete and implement the contaminated sediment remediation plan initiated by the State and Regional Boards in 1997. One potential ongoing source of concern with respect to chromium loading is the Newport Plating facility. EPA recommends that the State further assess this facility and, if necessary, carry out discharge controls or remedial actions necessary to address any ongoing loadings.

Second, the source analysis indicated that copper leaching from boat paints is probably a significant source of copper loading to the Bay. In coordination with marina and boatyard operators, other Regional Boards, the State Board, and EPA, the Santa Ana Regional Board should develop specific actions to reduce the use of copper-containing boat paints or their leaching to water bodies through use of additional boat storage and maintenance practices.

Third, the Regional Board should work with the stormwater discharge permittees to further assess the potential effectiveness of available management practices to reduce metals loading in discharges of urban runoff under high and low flows. In future iterations of the stormwater permits, provision should be made to implement effective metals reduction practices, with particular emphasis on implementation of the more cost-effective methods identified. Additional work will be needed in the immediate future to more thoroughly assess and document the prospective effectiveness of available practices.

Fourth, he State adopted a sediment TMDL and implementation plan in 1999 which called for an overall 50% reduction in sediment loading from San Diego Creek through implementation of a locally developed sediment reduction plan. Reductions in sediment loading should assist in reducing loadings of total metals. EPA recommends that the State continue implementation of this sediment reduction plan and monitor to determine whether both total and dissolved metals loading levels decline over time.

Fifth, the State may wish to consider reevaluation of the metals criteria and associated TMDLs in the future based on application of criteria calculation methods which are currently under development. Metals criteria calculation protocols are nearing completion which may enable States to calculate metals standards that more accurately represent the bioavailable portion of total metals loading through consideration of water effects ratios (WERs). It may be relatively straightforward recalculate metals criteria based on local hardness and organic carbon data and revised WER equations. In light of the potential cost of extensive actions to further control metals loading from urban runoff in the watershed, EPA believes it may be reasonable to consider whether newly emerging criteria calculation methods would result in protective but easier-to-implement standards.

Organochlorine Compound TMDL Implementation Recommendations

This TMDL decision addresses two types of organochlorine compounds whose use is no longer authorized: several chlorinated pesticides (DDT, chlordane, dieldrin and toxaphene) and PCBs, which were used in electrical equipment. Because these compounds are very stable in the environment and often adhere to sediments, they may continue to reach and remain in water bodies at levels of concern for many years following their discharge to the environment. Two potential routes of environmental exposure of these compounds are of greatest potential concern—ongoing loadings from the watershed of historically deposited pollutants and exposures to organochlorine compounds already present in aquatic sediments (principally in Newport Bay). There is substantial evidence indicating that levels of these compounds in Bay sediments and aquatic organisms has declined over the past 20 years or more.

No terrestrial "hot spots" (locations with significantly elevated levels of these pollutants were located during the TMDL development process; however, limited historical information indicates that there may have been some spills (e.g., PCB spills at El Toro and Tustin Air Stations). We recommend that the State conduct more thorough investigations of potential spill sites based on the preliminary information compiled for this TMDL effort in order to determine whether there are any significant hot spot sites in the watershed warranting further remedial action.

The most likely source of ongoing loading of organochlorine pollutants is erosion of sediments to which these compounds have adhered. The State adopted a sediment TMDL and implementation plan in 1999 which called for an overall 50% reduction in sediment loading from San Diego Creek through implementation of a locally developed sediment reduction plan. EPA recommends that the State continue implementation of this sediment reduction plan and monitor to determine whether levels of organochlorine compounds continue to decline. Monitoring should examine not only the levels of organochlorine pollutants in the water column, but also sediment running into tributary streams, sediment moving down San Diego Creek, and sediments in Newport Bay.

If future monitoring indicates that declines in levels of the pollutants in the watershed are continuing or accelerating, it may be unnecessary to implement additional erosion and sediment controls. If the levels of these pollutants in sediments and tissue do not decline or actually begin to rise, the State will need to revisit and potentially revise terrestrial sediment control strategies in the watershed as a whole and aquatic sediment management strategies in the Bay.

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Newport Bay sediment and tissue monitoring programs should continue to test for organochlorine pollutants. Although no obvious aquatic sediment "hot spots" were found for these pollutants (with the possible exception of Rhine Channel for some pollutants), the available data appear to indicate that the reservoir of these pollutants still found in Bay sediments far outweighs the additional loads to the Bay from the watershed. Therefore, in coordination with monitoring and assessment programs to evaluate the full suite of toxic pollutants of concern, the State should continue to consider whether any specific locations warrant remedial action to remove, cap, or otherwise immobilize Bay sediments. It is always important to consider whether the long term benefit of aquatic sediment remedial action is outweighed by the potential short term adverse effects associated with disturbing contaminated sediments. The remedial action plan adopted by the State for Rhine Channel should help reduce any ongoing availability of these pollutants at that location, and we repeat our recommendation that this remedial action plan be carried out in a timely manner.

The U.S. Army Corps of Engineers and Orange County have been examining the feasibility of removing sediment from containment basins in Upper Newport Bay (ACOE 2000). This study has refined various alternatives, obtained necessary funding and is presently entering the preconstruction, engineering and design phase. Restoration is *scheduled* to begin in 2003/2004. We recommend that the State work with the project sponsors to ensure that potential disturbance of sediments containing the pollutants addressed in this TMDL report is considered in the design process and minimized during project implementation.

Monitoring Recommendations

This action establishes TMDLs for numerous toxic pollutants, in a watershed for which several other TMDLs have previously been established. We recommend that the State work with the other State and federal agencies, the County, permitted cities, local industries, and perhaps local academic institutions to develop a coordinated monitoring program for Newport Bay and its tributary streams. While much of this work could be carried out pursuant to the NPDES stormwater permit, the scope of the monitoring needed to more fully characterize toxic pollutant trends in the watershed and the effectiveness of pollutant control strategies goes beyond the scope of traditional monitoring required under these permits. Substantial monitoring has conducted in the past but it was (with the exception of the County's monitoring) usually relatively narrow in scope in terms of pollutant coverage, geographical extent, and temporal scope. Newport Bay watershed is a good candidate for development of a more integrated and comprehensive monitoring approach which could result in a more cost-effective overall approach to monitoring than currently created by independent monitoring approaches.

We recommend that the State consider the areas of uncertainty in each TMDL analysis as discussed in the margin of safety sections and TSDs in order to identify the types of monitoring data which are most important to reduce analytical uncertainty and improve our ability to target meaningful control actions.

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XI. Glossary and abbreviations

205(j)	Section 205, part j of Clean Water Act, addresses water monitoring grants
319(h)	Section 319, part h of Clean Water Act, addresses non-point source pollution
ACOE	Army Corps of Engineers
ai	active ingredient
ambient	existing environmental conditions (or concentrations)
BAF	Bioaccumulation factor
BCF	Bioconcentration factor
BSAF	Biota-sediment accumulation factor
bgs	Below ground surface, relates to monitoring wells
Bight '98	Southern California Bight (coastal waters) study
BMP	best management practice
BPTCP	Bay Protection and Toxic Cleanup Program
CCC	criterion continuous concentration = chronic
CDFG	(California) Department of Fish and Game
cfs	Cubic feet per second, pertains to stream flow rates
CFCS	California Fish Contamination Study (OEHHA)
CMC	criterion maximum concentration = acute
CTR	California Toxics Rule
cv	coefficient of variation
CWA	Clean Water Act
DO	dissolved oxygen
DPR	(California) Department of Pesticide Regulation
DTSC	(California) Dept. of Toxic Substances Control
ELISA	Enzyme Linked Immunosorbant Assay
EPA	U.S. Environmental Protection Agency
ERL	Effects Range-Low, sediment quality guideline for low impact
ERM	Effects Range-Median, NOAA sediment quality guideline for median negative impact
FIFRA	Federal Insecticide, Fungicide and Rodenticide Act
f_{lip}	Fraction (of organic compound associated) with lipid
f_{oc}	Fraction (of organic compound associated) with octanol
GC	Gas chromatograph
GC/MS	Gas chromatography/mass spectrometry
HPLC/MS	high performance liquid chromatography/mass spectrometry
IPM	Integrated Pest Management, part of UC-Cooperative Extension
IRWD	Irvine Ranch Water District
LA	Load allocation for non-point sources (including background)
MLLW	mean low low water
MOS	Margin of safety
NAWQA	National Water Quality Assessment Program
ng/L	Nanograms per liter (= parts per trillion)
NOAA	National Oceanic Atmospheric Administration
NPDES	National Pollutant Discharge Elimination System
NY DEC	New York Dept. of Environmental Conservation
OC	Organochlorine compound; e.g., chlordane, dieldrin, DDT, PCB, toxaphene
OCHCA	Orange County Health Care Agency
OCPFRD	Orange County Public Facilities and Resources Department

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OEHHA	Office of Environmental Health Hazard Assessment
OP	Organophosphate, type of pesticide
OPP	Office of Pesticide Programs
PCB	polychlorinated biphenyl
PCH	Pacific Coast Highway
PCW	Peters Canyon Wash, a tributary of San Diego Creek
PEL	Probable Effects Level, sediment quality guideline for Florida Dept. of Env. Protection
PERA	probabilistic ecological risk assessment
POTW	Publicly owned treatment works
ppb	Part per billion = ug/L (for solution concentration) or ng/g (for dry soil conc.)
ppm	Part per million = mg/L (for solution concentration) or ug/g (for dry soil conc.)
PPT	parts per thousand (salinity)
Porewater	(interstitial) water contained in sediments
RIFA	Red Imported Fire Ant
RMA	Resource Management Associates, developed hydrologic models for US Army Corp of Eng.
SA RWQCB	Santa Ana Regional Water Quality Control Board
SD RWQCB	Santa Diego Regional Water Quality Control Board
SAD	Santa Ana-Delhi Channel
SCCWRP	Southern California Coastal Water Research Program
SDC	San Diego Creek
se	standard error [as used in table column headings]
SMW	State Mussel Watch
SWRCB	State Water Resources Control Board
TAC	Technical Advisory Committee
TEL	Threshold Effects Level, sediment quality guideline (for Florida Dept. of Env. Protection)
TIE	toxicity investigation evaluation = study to identify and characterize chemicals causing toxicity
TMDL	total maximum daily load
TOC	total organic carbon
TSMP	Toxic Substances Monitoring Program (State Water Board)
TUa	acute toxic units
UCD	University of California, Davis
ug/L	micrograms per liter (= parts per billion)
US FWS	United States Fish & Wildlife Service
USGS	United States Geological Survey
WDR	Waste discharge report,
WLA	Wasteload allocation for point sources (including general stormwater permit)
WYL	San Diego Creek at Culver sampling site
xe	mean error [as used in table column headings]

Appendix A

Designated beneficial uses for Newport Bay and San Diego Creek watershed.

Water Body	MUN	AGR	IND	PROC	GWR	NAV	POW	REC1	REC2	COMM	WARM	COLD	BIOL	WILD	RARE	SPWN	MAR	SHEL	EST
Lower NB	+					x		x	x	x				x	x	x	x	x	
Upper NB	+							x	x	x			x	x	x	x	x	x	x
San Diego Creek Reach 1	+							x	x		x			x					
San Diego Creek Reach 2	+							I	I		I			I					
Tributaries of San Diego Creek	+							I	I		I			I					

x present or potential beneficial use
I intermittent beneficial use
\+ excepted from MUN

MUN = municipal and domestic supply
AGR = agricultural supply
IND = industrial service supply
PROC = industrial process supply
GWR = groundwater recharge
NAV = navigation
POW = hydropower generation
REC1 = water contact recreation
REC2 = non-contact water recreation
COMM = commercial and sport fishing
WARM = warm freshwater habitat
COLD = cold freshwater habitat
BIOL = preservation of biological habitats
WILD = wildlife habitat
RARE = rare, threatened, or endangered species
SPWN = spawning, reproduction, and/or early development
MAR = marine habitat
SHEL = shellfish harvesting
EST = estuarine habitat

Appendix B

Arsenic Fish Tissue Monitoring data

	SPECIES NAME	**Date**		**Total Arsenic**		**Inorganic Arsenic**
	Screening Value (mg/kg wet)		OEHHA =	**1.0**	EPA =	**1.2**
			#/samp.		(4% Tot. As)	(10% Tot. As)
OEHHA data ' 00						
Newport Beach	Barred Surfperch	6/00/2000	10	0.601	**0.024**	**0.060**
Newport Beach	Shiner Surfperch	06/00/2000	10	1.130	**0.045**	**0.113**
Newport Beach	White Croaker	06/00/2000	5	0.778	**0.031**	**0.078**
Newport Beach Pier	Barred Surfperch	06/00/2000	10	0.577	**0.023**	**0.058**
Newport Beach Pier	White Croaker	06/00/2000	5	0.668	**0.027**	**0.067**
Balboa Pier	Barred Surfperch	06/00/2000	3	0.911	**0.036**	**0.091**
Balboa Pier	Diamond Turbot	06/00/2000	4	3.094	**0.124**	**0.309**
Newport Jetty	Black Surfperch	06/00/2000	5	0.774	**0.031**	**0.077**
Newport Jetty	Shiner Surfperch	06/00/2000	10	0.906	**0.036**	**0.091**
Newport Jetty	Spotted Turbot	06/00/2000	5	3.673	**0.147**	**0.367**
Newport Bay/above PCH Br	Shiner Surfperch	06/00/2000	10	0.969	**0.039**	**0.097**
Newport Bay/above PCH Br	Spotted Turbot	06/00/2000	5	1.775	**0.071**	**0.177**
Newport Bay/above PCH Br	Yellowfin Croaker	06/00/2000	4	0.585	**0.023**	**0.059**
Newport Beach	Barred Surfperch	8/4/99	5	0.811	**0.032**	**0.081**
Newport Beach	California Corbina	8/4/99	5	0.449	**0.018**	**0.045**
Newport Beach	Walleye Surfperch	6/22/99	3	0.618	**0.025**	**0.062**
Newport Pier	Barred Surfperch	8/4/99	5	1.06	**0.042**	**0.106**
Newport Pier	California Corbina	8/4/99	5	0.411	**0.016**	**0.041**
Newport Pier	Spotted Turbot	6/16/99	3	2.69	**0.108**	**0.269**
Newport Pier	Yellowfin Croaker	8/4/99	3	0.529	**0.021**	**0.053**
Balboa Pier	Diamond Turbot	6/15/99	5	4	**0.160**	**0.400**
Balboa Pier	Walleye Surfperch	6/9/99	5	0.587	**0.023**	**0.059**
Newport Jetty	Spotted Scorpionfish	5/19/99	5	0.202	**0.008**	**0.020**
Newport Jetty	Spotted Turbot	5/19/99	5	3.12	**0.125**	**0.312**
Newport Bay	Diamond Turbot	5/19/99	5	1.88	**0.075**	**0.188**
Newport Bay	Shiner Surfperch	5/27/99	5	0.672	**0.027**	**0.067**
SCCWRP		**Winter '01**				
barred sand bass	Outer Lower	1	1	0.65	**0.026**	**0.065**
black perch	Outer Upper	1	2	0.53	**0.021**	**0.053**
black perch	Outer Lower	1	3	0.96	**0.038**	**0.096**
black perch	Outer Lower	2	4	0.86	**0.034**	**0.086**
black perch	Outer Lower	3	5	0.69	**0.028**	**0.069**
California halibut	Outer Upper	1	6	0.58	**0.023**	**0.058**
California halibut	Outer Upper	2	7	0.85	**0.034**	**0.085**
California halibut	Outer Upper	3	8	0.47	**0.019**	**0.047**
California halibut	Outer Lower	1	9	0.91	**0.036**	**0.091**
California halibut	Outer Lower	2	10	0.41	**0.016**	**0.041**
C-O sole	Outer Lower	1	11	5.74	**0.230**	**0.574**

C-O sole	Outer Lower	2	12	5.01	**0.200**	**0.501**
diamond turbot	Outer Upper	1	13	1.82	**0.073**	**0.182**
diamond turbot	Outer Upper	2	14	3.89	**0.156**	**0.389**
diamond turbot	Outer Upper	3	15	2.85	**0.114**	**0.285**
diamond turbot	Outer Lower	1	16	4.20	**0.168**	**0.420**
diamond turbot	Outer Lower	2	17	3.45	**0.138**	**0.345**
fantail sole	Outer Lower	1	18	0.97	**0.039**	**0.097**
shiner perch	Outer Upper	1	19	0.67	**0.027**	**0.067**
spotted sand bass	Outer Upper	1	20	0.47	**0.019**	**0.047**
spotted sand bass	Outer Lower	1	21	0.63	**0.025**	**0.063**
spotted turbot	Outer Upper	1	22	3.92	**0.157**	**0.392**
spotted turbot	Outer Lower	1	23	7.28	**0.291**	**0.728**
spotted turbot	Outer Lower	2	24	8.57	**0.343**	**0.857**
spotted turbot	Outer Lower	3	25	5.53	**0.221**	**0.553**
SUMMER 2001						
barred sand bass	Outer Lower	1	13	0.44	**0.018**	**0.044**
black perch	Outer Lower	1	10	0.50	**0.020**	**0.050**
black perch	Outer Lower	2	11	0.40	**0.016**	**0.040**
black perch	Outer Lower	3	12	0.58	**0.023**	**0.058**
California corbina	Outer Lower	1	17	1.24	**0.050**	**0.124**
California corbina	Outer Lower	2	18	1.15	**0.046**	**0.115**
California corbina	Outer Lower	3	19	1.57	**0.063**	**0.157**
California halibut	Outer Lower	1	25	0.52	**0.021**	**0.052**
diamond turbot	Outer Upper	1	20	2.52	**0.101**	**0.252**
diamond turbot	Outer Upper	2	21	2.89	**0.116**	**0.289**
diamond turbot	Outer Lower	1	22	2.12	**0.085**	**0.212**
jacksmelt	Outer Upper	1	1	0.51	**0.020**	**0.051**
jacksmelt	Outer Upper	2	2	0.53	**0.021**	**0.053**
jacksmelt	Outer Upper	3	3	0.58	**0.023**	**0.058**
kelp bass	Outer Lower	1	4	0.49	**0.020**	**0.049**
spotfin croaker	Outer Lower	1	23	0.68	**0.027**	**0.068**
spotfin croaker	Outer Lower	2	24	0.93	**0.037**	**0.093**
spotted sand bass	Outer Lower	1	14	0.22	**0.009**	**0.022**
spotted sand bass	Outer Lower	2	15	0.24	**0.010**	**0.024**
spotted sand bass	Outer Lower	3	16	0.25	**0.010**	**0.025**
yellowfin croaker	Outer Lower	1	5	0.36	**0.014**	**0.036**
yellowfin croaker	Outer Lower	2	6	0.34	**0.014**	**0.034**
yellowfin croaker	Outer Lower	3	7	0.47	**0.019**	**0.047**
yellowfin croaker	Inner Lower	1	8	0.49	**0.020**	**0.049**
yellowfin croaker	Inner Lower	2	9	0.27	**0.011**	**0.027**
TSMP data '95--'98						
Upper NB/Dunes	Brown Sm. Shark (F)	6/10/98	1	8.620	**0.345**	**0.862**
Upper NB/Dunes	Diamond Turbot (F)	6/20/97		1.480	**0.059**	**0.148**
NB/Rhine Channel	Chub Mackerel (F)	7/11/97		0.427	**0.017**	**0.043**
NB/Rhine Channel	Black Croaker (F)	6/18/95		1.200	**0.048**	**0.120**

(Data is for Individual Filet Samples)

saltwater finfish results

count	80		
max	8.62	**0.34**	**0.86**
mean	1.59	**0.06**	**0.08**
median	0.78	**0.03**	**0.08**

				Tot. As	Inorg. As
State Mussel Watch	mussels				
Upper Newport Bay					(60% of As Total)
UNB/Mariner's Drive	TCM	1/27/97		1.10	**0.018**
UNB/Mariner's Drive	TCM	3/24/98		1.70	**0.028**
UNB/Mariner's Drive	TCM	NA			
UNB/Mariner's Drive	TCM	2/2/00		0.90	**0.015**
UNB/ PCH Bridge	TCM	1/30/95	NA		
UNB/ PCH Bridge	TCM	1/17/96		1.40	**0.023**
UNB/ PCH Bridge		NA	NA		
UNB/ PCH Bridge	TCM	3/24/98		1.40	**0.023**
UNB/ PCH Bridge	TCM	3/29/99		1.40	**0.023**
UNB/ PCH Bridge	TCM	2/2/00		1.00	**0.017**
Lower Newport Bay					
LNB/Turning Basin	TCM	1/30/95	NA		
LNB/Turning Basin	TCM	1/17/96		1.20	**0.020**
LNB/Turning Basin		na	NA		
LNB/Turning Basin	RBM	3/24/98		0.80	**0.013**
LNB/Turning Basin	TCM	3/29/99		1.30	**0.022**
LNB/Turning Basin	TCM	2/2/00		1.00	**0.017**
LNB/Police Docks	RBM	3/24/98		1.10	**0.018**
LNB/Entrance	TCM	3/29/99		2.50	**0.042**
Rhine Channel					
Rhine Ch./Crows Nest	TCM	1/30/95	NA		
Rhine Ch./Crows Nest	TCM	1/17/96		1.20	**0.020**
Rhine Ch./Crows Nest	TCM	1/27/97		1.20	**0.020**
Rhine Ch./Crows Nest	TCM	3/24/98		1.60	**0.027**
Rhine Ch./Crows Nest	TCM	3/29/99		1.50	**0.025**
Rhine Ch./Crows Nest	TCM	2/2/00		1.10	**0.018**
Rhine Ch./End	TCM	1/30/95	NA		
Rhine Ch./End	TCM	1/17/96		1.30	**0.022**
Rhine Ch./End	TCM	1/27/97		1.30	**0.022**
Rhine Ch./End	TCM	3/24/98		1.40	**0.023**
Rhine Ch./End	TCM	3/29/99		1.30	**0.022**
Rhine Ch./End	TCM	2/2/00		0.90	**0.015**
Rhine Ch./Upper	TCM	2/2/00		1.00	**0.017**

(Data is for Composite Mussel Samples)

Saltwater shellfish results

count	24	
max	2.50	**0.04**
mean	1.28	**0.02**
median	1.25	**0.02**

			Tot. As	Inorg. As	
TSMP data '96--'98				**4%**	**10%**
San Diego Creek					
San Diego Creek/Michelson	Red Shiner	6/9/98	0.344	**0.014**	**0.034**
Peters Canyon Channel	Red Shiner	6/9/98	0.116	**0.005**	**0.012**
San Diego Creek/Barranca	Red Shiner	6/9/98	0.200	**0.008**	**0.020**
Delhi Channel	Striped Mullet	6/9/98	0.882	**0.035**	**0.088**
San Diego Creek/Michelson	Red Shiner	6/19/97	0.134	**0.005**	**0.013**
Peters Canyon Channel	Red Shiner	6/19/97	0.057	**0.002**	**0.006**
Peters Canyon Channel	Red Shiner	6/19/97	0.063	**0.003**	**0.006**
San Diego Creek/Barranca	Red Shiner	6/19/97	0.148	**0.006**	**0.015**
Delhi Channel	Red Shiner	6/18/97	0.085	**0.003**	**0.009**
San Diego Creek/Michelson	Red Shiner	11/6/96	0.06	**0.002**	**0.006**
San Diego Creek/Michelson	Red Shiner	11/6/96	0.07	**0.003**	**0.007**
Peters Canyon Channel	Red Shiner	11/6/96	0.15	**0.006**	**0.015**
San Diego Creek/Michelson	Red Shiner	6/17/95	0.150	**0.006**	**0.015**
San Diego Creek/Michelson	Red Shiner	6/17/95	0.170	**0.007**	**0.017**
Peters Canyon Channel	Red Shiner	6/17/95	0.090	**0.004**	**0.009**

Freshwater finfish results

count	15		
max	0.88	**0.04**	**0.09**
mean	0.18	**0.01**	**0.02**
median	0.13	**0.01**	**0.01**

Part A—Relevant Maps/Figures

Figure 1-1. Newport Bay and surrounding watershed

Figure A-2. San Diego Creek watershed and land use data

Figure A-3. Santa Ana-Delhi Channel watershed and land use data

Figure A-4. Entire Newport Bay watershed and land use data

Figure A-5. Residence time for Newport Bay during neap tide

Figure A-6. Residence time for Newport Bay during spring tide.

Figure A-7. Rhine Channel storm drains and Newport Plating facility site.

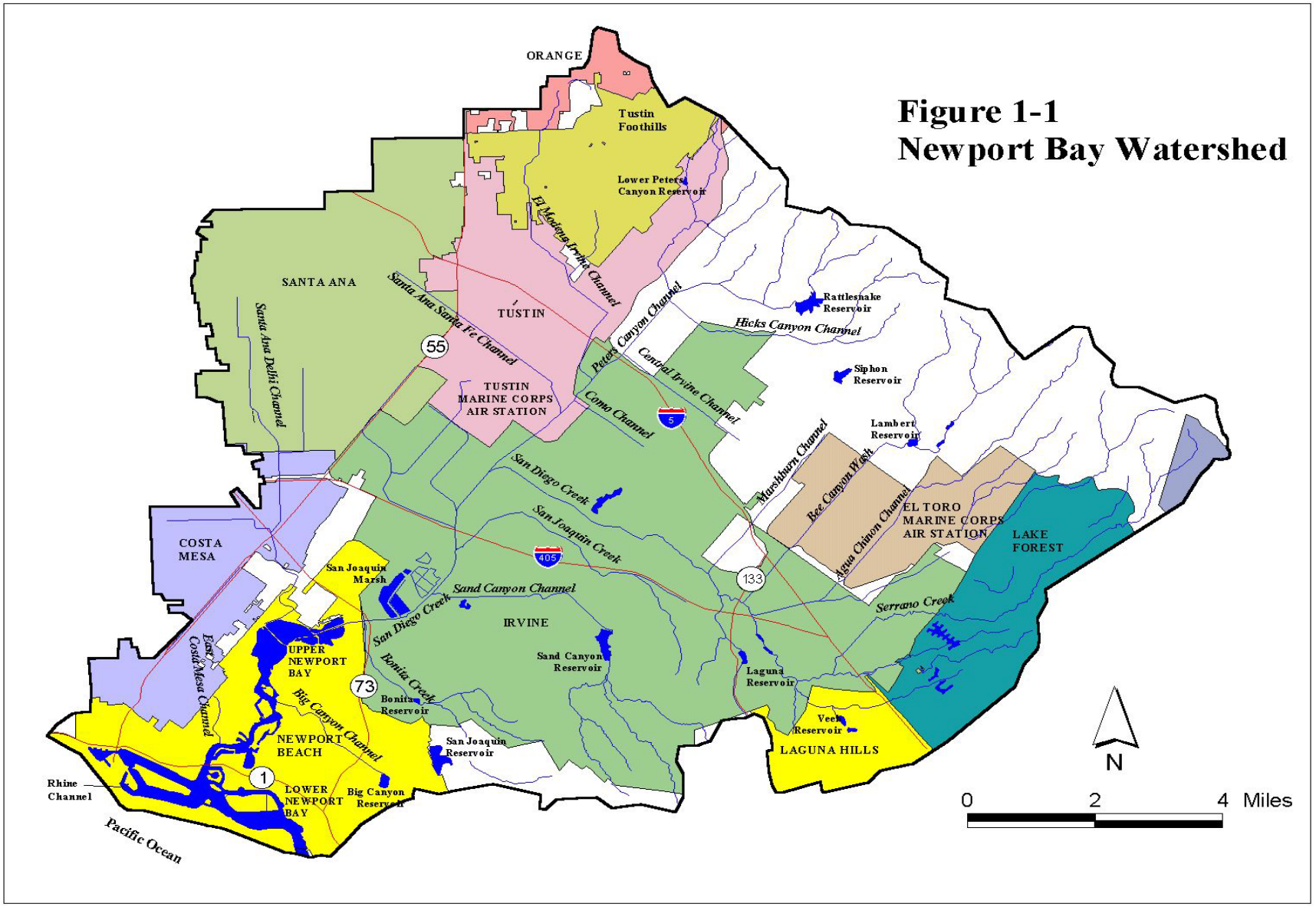
Figure 1-1
Newport Bay Watershed
ORANGE
Tustin Foothills
Lower Peters Canyon Reservoir
El Modena Irvine Channel
SANTA ANA
Santa Ana Santa Fe Channel
Santa Ana Delhi Channel
TUSTIN
55
TUSTIN MARINE CORPS AIR STATION
Peters Canyon Channel
Central Irvine Channel
Como Channel
5
Rattlesnake Reservoir
Hicks Canyon Channel
Siphon Reservoir
Lambert Reservoir
Marshburn Channel
Bee Canyon Wash
Agua Chinon Channel
EL TORO MARINE CORPS AIR STATION
LAKE FOREST
San Diego Creek
San Joaquin Creek
405
133
Serrano Creek
COSTA MESA
San Joaquin Marsh
Sand Canyon Channel
IRVINE
San Diego Creek
East Costa Mesa Channel
UPPER NEWPORT BAY
Bonita Creek
73
Sand Canyon Reservoir
Laguna Reservoir
Big Canyon Channel
Bonita Reservoir
Veeh Reservoir
NEWPORT BEACH
San Joaquin Reservoir
LAGUNA HILLS
1
Rhine Channel
LOWER NEWPORT BAY
Big Canyon Reservoir
Pacific Ocean
N
0
2
4 Miles

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SARB_001291

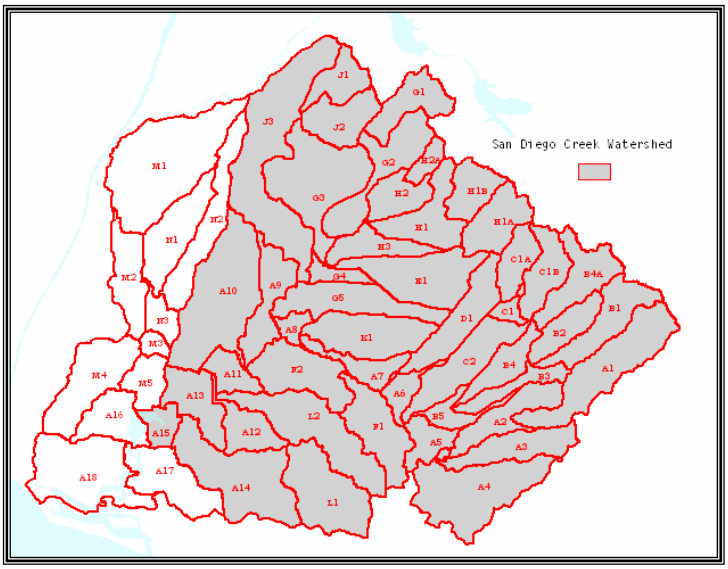


Figure A-2. San Diego Creek watershed land use data (as of January 2001). (Source: OCPFRD GIS Dept.)

San Diego Creek Land Use# - Jan 2001

Landuse	Acres	Total sq_miles	% using sq miles	% using acres
Agricultural	5091.90	7.96	6.55	6.54
Commercial	6381.47	9.97	8.20	8.20
Education and Religion	203.26	0.32	0.26	0.26
Industrial	3965.55	6.2	5.10	5.10
No Available Data	21910.06	34.23	28.15	28.16
Recreational	237.28	0.37	0.30	0.30
Residential-Income	11668.20	18.23	14.99	14.99
Trans., Comm. and Utility	1177.28	1.84	1.51	1.51
Vacant Land	15811.34	24.71	20.32	20.32
Roads*	11369.70	17.76	14.61	14.61
Total watershed	**77818.53**	**121.59**	**100.00**	**100.00**

#Does not include Santa Ana-Delhi and subwatersheds A15, A16, A17, A18

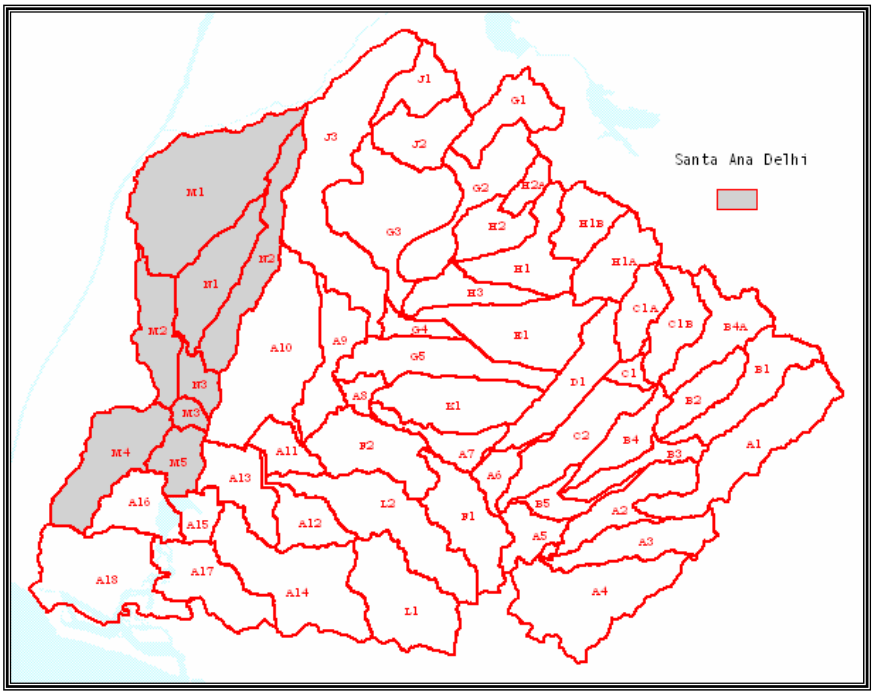


Figure A-3. Santa Ana Delhi watershed land use data (as of January 2001) (Source: OCPFRD GIS dept.)

Santa Ana Delhi = sum of sub-watersheds N1 ,N2, N3, M1, M2, M3, M4, M5

Landuse	Acres	Total sq_miles	% using sq miles	% using acres
Commercial	2397.83	3.75	16.61	16.60
Education and Religion	160.50	0.25	1.11	1.11
Industrial	1102.27	1.72	7.62	7.63
No Available Data	1060.35	1.66	7.35	7.34
Recreational	178.15	0.28	1.24	1.23
Residential-Income	5285.79	8.26	36.58	36.58
Trans., Comm. and Utility	98.70	0.15	0.66	0.68
Vacant Land	825.17	1.29	5.71	5.71
Roads*	3338.54	5.21	23.07	23.11
Total Watershed	**14448.75**	**22.58**	**99.96**	**100.00**

*Approximate figure based on the length of the centerline and the width of the ROAD
14448.75 is the total area of the watershed

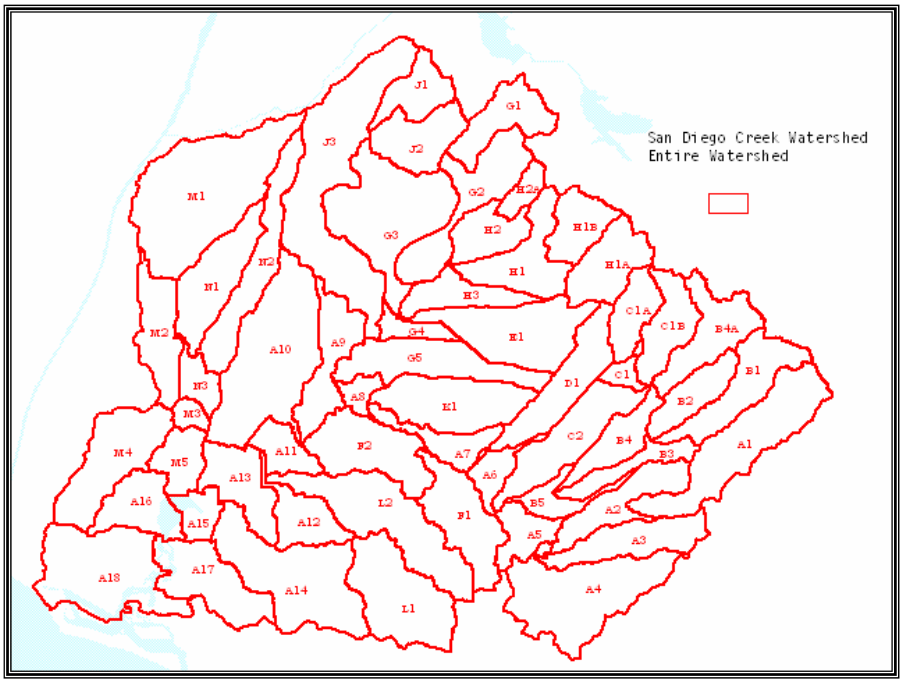


Figure A-4. Entire Newport Bay watershed land use data (as of January 2001) (Source: OCPFRD GIS dept.)

Entire Newport Bay watershed

Landuse	Acres	Total sq_miles	% using sq miles	% using acres
Agricultural	5146.911	8.04	5.21	5.21
Commercial	9640.795	15.06	9.75	9.75
Education and Religion	406.257	0.63	0.41	0.41
Industrial	5263.535	8.22	5.32	5.35
No Available Data	23461.998	36.66	23.74	23.85
Recreational	529.514	0.83	0.54	0.54
Residential-Income	19420.282	30.34	19.64	19.74
Trans., Comm. and Utility	1326.735	2.07	1.34	1.35
Vacant Land	17393.645	27.18	17.60	17.68
Roads*	15773.57	24.64	15.95	16.04
Total watershed	**98847.148**	**154.45**	**99.49**	**99.93**
	98363.242	**153.67**		

*Approximate figure based on the length of the centerline and the width of the ROW

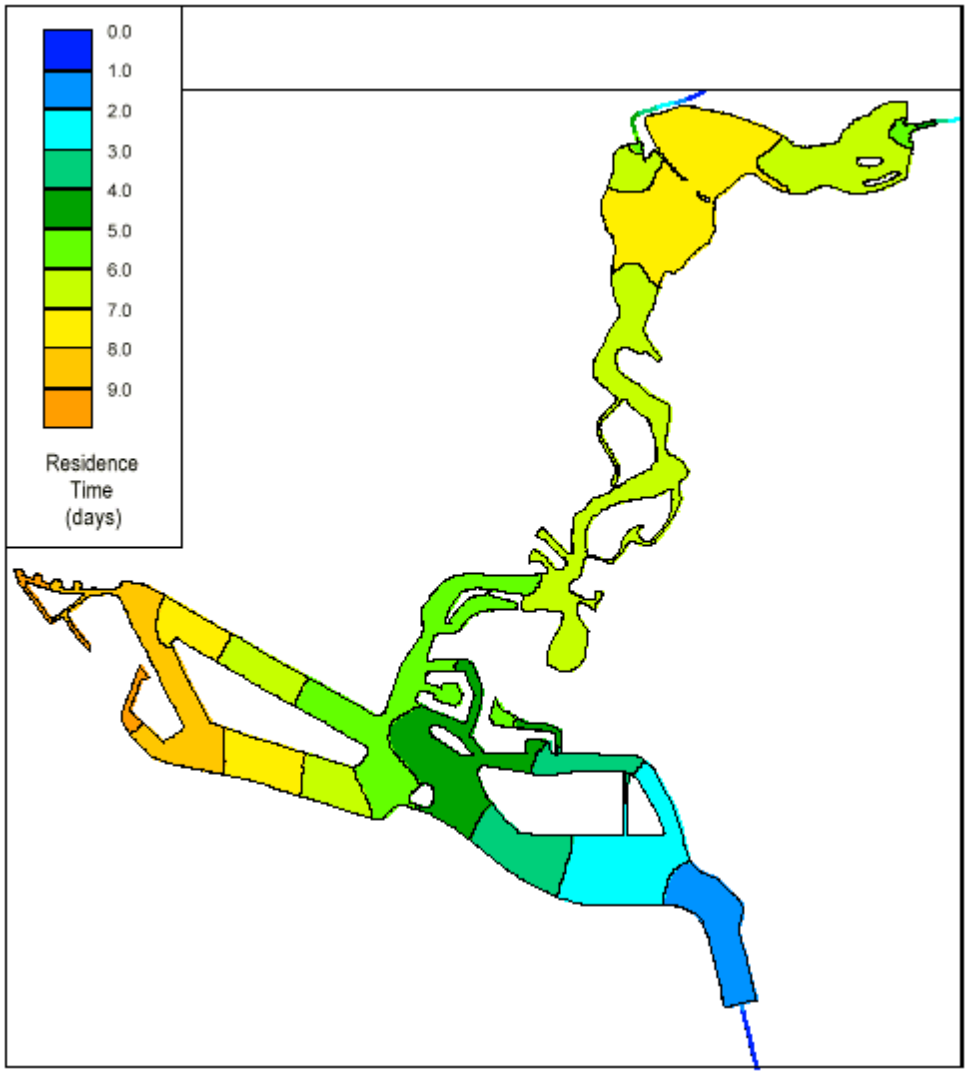


Figure A-5. Residence time for Newport Bay during neap tide conditions. (Source: RMA 2001)

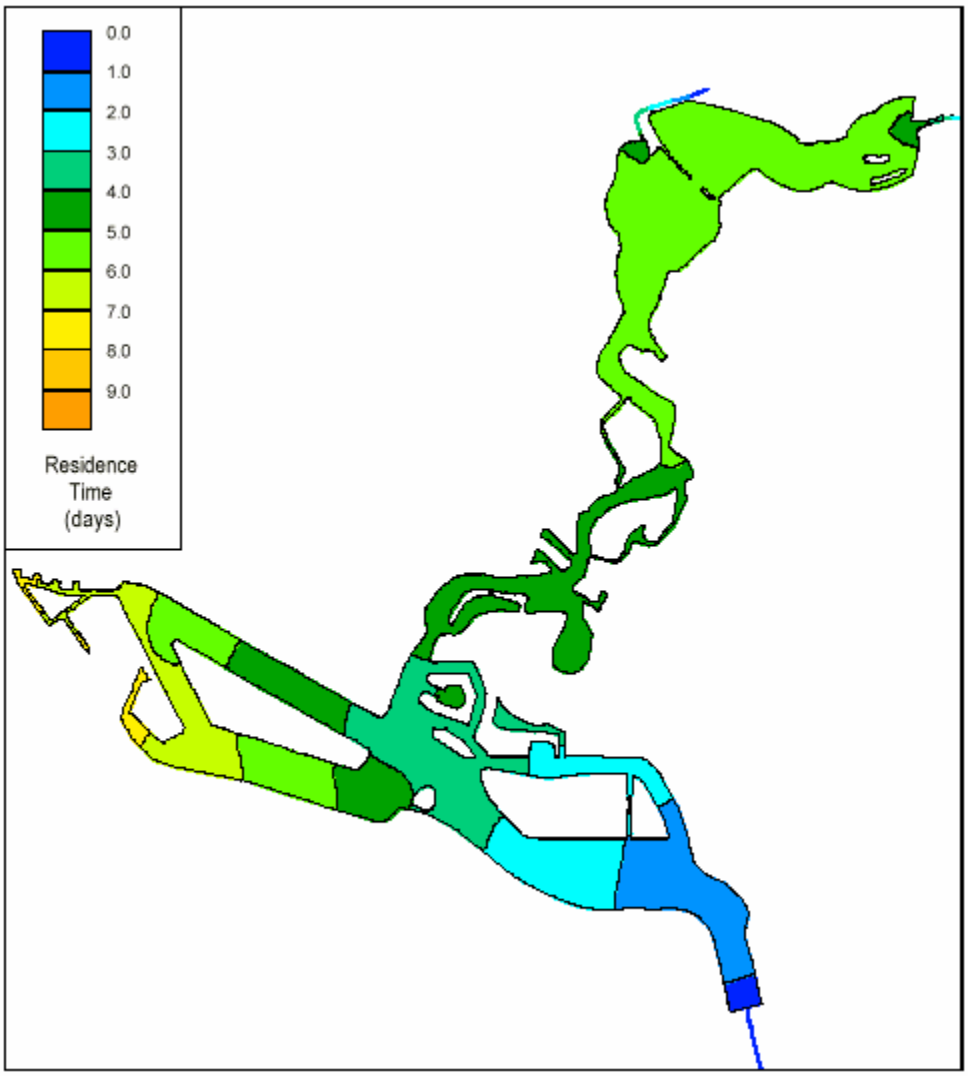
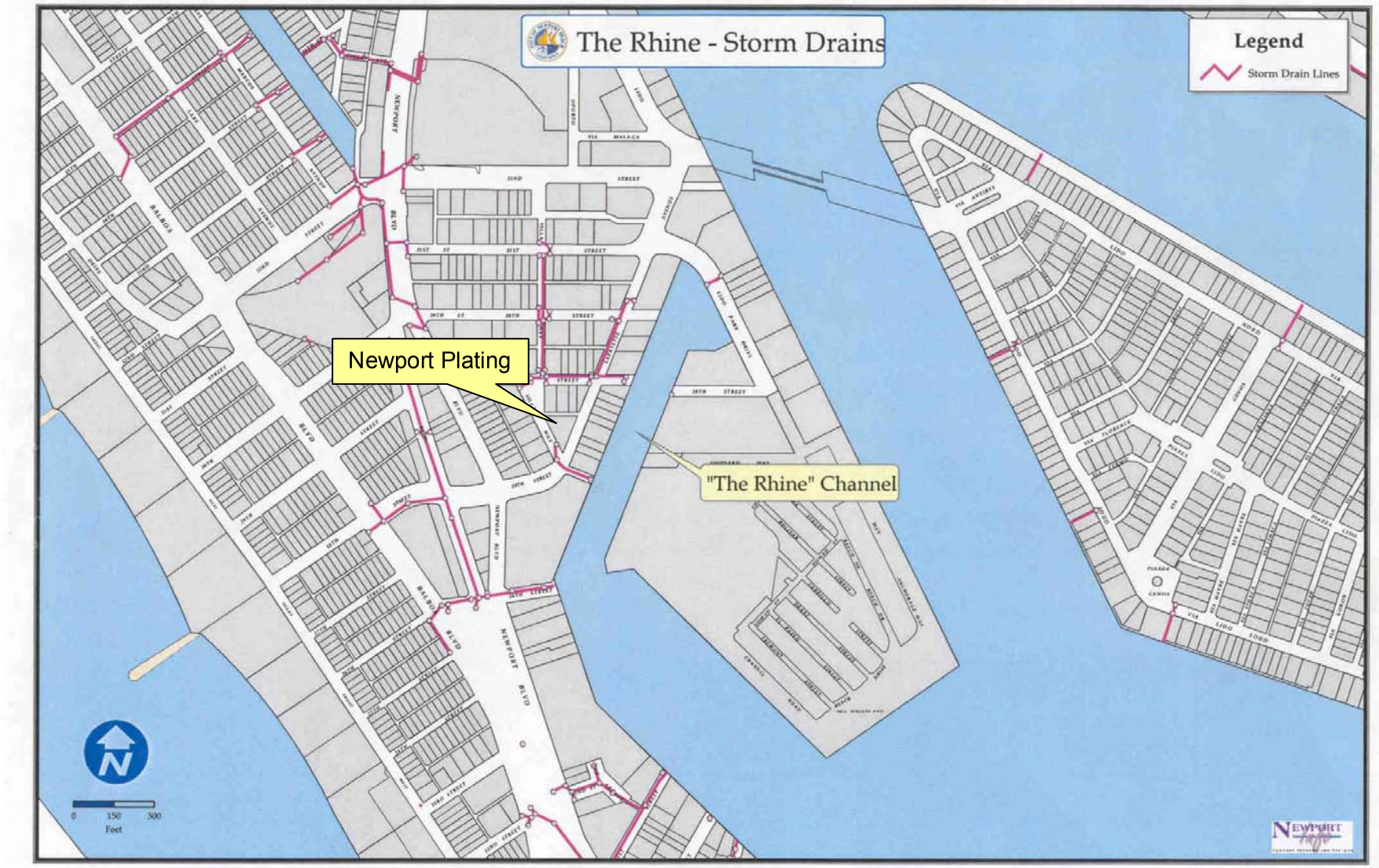


Figure A-6. Residence time for Newport Bay during spring tide conditions. (Source: RMA 2001)


The Rhine - Storm Drains
Legend
Storm Drain Lines
Newport Plating
"The Rhine" Channel
0
150
300
Feet

SARB_001299

Part B—Freshwater flow and seasonal variation

This Technical Support Document (TSD) provides additional analysis of freshwater flows in San Diego Creek and other tributaries that flow into Newport Bay. This TSD examines rainfall records, daily stream flow rates, flow-based tiers and associated flow volumes, and how hardness is associated with flow rates.

Overview

In the semi-arid climate of Southern California there are two seasons—dry weather occurs during most of the year and intermittent wet weather events occur typically between November and March. This two-season climate creates significant differences in freshwater flow through the creeks and streams. In general, storm events yield both high flow rates and high flow volumes; the vast majority of flow volume occurs during the months of December, January and February. Nonetheless, some storms occur in other months of the year.

EPA Region 9 has evaluated the merits of developing TMDLs for each pollutant (or group of pollutants) by using the seasonal variation approach (i.e., loading determined for wet versus dry weather seasons) or by using a flow-based approach. In the flow-based approach, the continuous range of stream flow that occurs at each target site is broken down into ranges or tiers. This incorporates high flows that may occur outside of the wet season as well as low flows that happen in between rain events. Thus the applicable loading capacity and total allocation for a given pollutant does not depend on the time of year, but on the actual stream flow at the time of discharge. A flow-based approach is used in the TMDLs.

The following discussion concentrates on establishing flow tiers for San Diego Creek, since it is the most significant source of freshwater (and associated pollutants) to Newport Bay. The flow-based approach is applied to Se and metals TMDLs where four flow tiers have been identified: base flows, small flows, medium flows and large flows. This interpretation of four tiers comes from analysis of nearly twenty years daily flow rate records for San Diego Creek at Campus Drive (USGS and OCPFRD data). For metals, flow rate is indirectly related to measurements of in-stream hardness. The flow-based approach is also applied to the organochlorine, chromium and mercury TMDLs, whereby two tiers were applied: mean flow and high flow. Further details are provided below.

Annual precipitation

Precipitation during a water year (defined from July 1 to June 30) will influence the total flow volume within each freshwater system. Average annual rainfall is 13 inches based on the Tustin / Irvine Ranch rain gage station; a site often used for precipitation analysis within the Newport Bay watershed. During water year 1998, 34.7 inches of rain fell (El Nino conditions), whereas in 1999, 8.6 inches of rain fell. Table B-1 summarizes rainfall records at Tustin / Irvine Ranch from 1958 / 59 to 2000 / 01.

Table B-1. Annual Precipitation Records at Tustin-Irvine Ranch Station

Water Year *	Rainfall (inches)	Water Year	Rainfall (inches)	Water Year	Rainfall (inches)	Water Year	Rainfall (inches)
1958-59	5.03	1971-72	5.02	1983-84	10.47	1995-96	11.17
1959-60	9.6	1972-73	14.9	1984-85	10.25	1996-97	16.19
1960-61	4.13	1973-74	9.81	1985-86	14.42	1997-98	34.72
1961-62	13.07	1974-75	12.36	1986-87	8.79	1998-99	8.6
1962-63	5.76	1975-76	5.11	1987-88	11.14	1999-00	8.8
1963-64	9.38	1976-77	10.2	1988-89	8.17	2000-01	14.6
1964-65	10.28	1977-78	27.96	1989-90	5.93	Summary	
1965-66	12.68	1978-79	18.59	1990-91	11.23	Min:	4.13
1966-67	14.22	1979-80	20.75	1991-92	17.18	Max:	34.7
1967-68	8.58	1980-81	8.47	1992-93	27.09	Mean:	13.03
1968-69	19.91	1981-82	13.22	1993-94	10.23	Median:	10.8
1969-70	8.48	1982-83	25.92	1994-95	24.65	Count:	42

*Source: OCPFRD; *Water years run from July 1 to June 30 of the following year.*
Rainfall data for water year 1970-71 not available

Annual flow volumes

Orange County Public Facilities and Resources Department (OCPFRD) have established stream gages at several locations in the Newport Bay watershed. Based on annual flow data from different sites, San Diego Creek is by far the largest freshwater contributor (95%) to Upper Newport Bay and it drains over three-quarters of the entire Newport Bay watershed. The remaining freshwater contributions are from Santa Ana / Delhi Channel (<5%), Costa Mesa Channel (<1%), and Big Canyon Creek (undetermined) and other minor storm drains.

As can be expected, total flow volumes for each stream or tributary are directly related to annual precipitation. For example, the total flow volumes recorded for San Diego Creek at Campus were 90,267 acre-ft. in water year 1997 / 98 (due to El Nino conditions) and 17,330 acre-ft in water year 1998 / 99 (due to slightly below normal annual rainfall). Within San Diego Creek, nearly equal flows have been recorded for Peters Canyon Wash (BARSED station) in comparison to San Diego Creek at Culver (WYLSED station), 38% and 35% respectively. Other channels (Lane Channel, Big Canyon, Sand Canyon, etc.) have very limited data and have not been adequately quantified.

Daily Flow Records

Daily flow records for San Diego Creek at Campus (OCPFRD data) reveal a wide range of flow rates. In dry weather base flows range typically range from 8 to 15 cfs; whereas, in wet weather, daily storm flows can fluctuate between 800 and 9,000 cfs (cubic feet per second). During the El Nino year, San Diego Creek registered the highest momentary peak flow (43,500 cfs on Dec. 6, 1997) in recent history. Records for Santa Ana-Delhi show average dry weather flows between 1 and 2 cfs and daily storm flows ranging from 100 to 1,370 cfs. The momentary peak discharge at Santa-Ana Delhi station for the El Nino season was 6,450 cfs.

EPA and Regional Board staff reviewed San Diego Creek at Campus daily flow records from two sources: USGS, who installed the gaging station in fall 1977 and OCPFRD who took over in fall 1985. We selected daily flow records corresponding to water year records. For example, July 1, 1978 to June 30, 1979 is water year 1979. This approach yielded 19 water year records for San Diego Creek at Campus Dr: three water years by USGS (78 / 79, 83 / 84, 84 / 85) and 16 water years by OCPFRD (1985 to 2001). Incomplete

USGS data for the period 1979/80 to 1982/83 were not used because only partial records were available for each year.

OCPFRD provided comments and alternate analysis of flow tiers based on recent daily flow records and precipitation records (1996 to 2001) for four nearby rainfall stations in the watershed. This analysis was based on four flow tiers as originally proposed in the draft Toxics TMDLs. The maximum base flow was determined to be approximately 20 cfs, based on comparison of rainfall and daily flow data. OCPFRD comments along with their analysis of records for 1996 to 2001 are highlighted here:

- Six years of flow and rainfall records were used (WY 1995/96 – 2000/01) and chosen due to reliability and representative nature of both rainfall and daily flow records over this period. Prior to the mid-1990s, base flows recorded at San Diego Creek at Campus Dr. were generally greater than current conditions. This is likely attributable to greater discharges stemming from nursery and agricultural operations and authorized discharges by Irvine Ranch Water District.
- Flow records were from the San Diego Creek at Campus Drive station. Daily rainfall records were derived from four Automated Local Evaluation in Real Time (ALERT) rainfall stations in the watershed (El-Modena-Irvine at Michelle, Sand Canyon at I-5 freeway, Peters Canyon Wash at Barranca Pkwy., and SDCreek at Culver). ALERT data were preferred over rainfall data from Tustin-Irvine precipitation records since rainfall amounts from ALERT stations more closely corresponded with daily mean flow determinations (12 midnight to 12 midnight).
- These six years of data provide a reliable picture of rainfall and daily flows in that it includes on very wet year (WY 1997/98) and two drier than average years (WY 98/99 and 99/00).
- Four flow tiers were partitioned from daily flow records based on corresponding rainfall data. Small storms correspond to >0" to 0.24", medium storms correspond to 0.25 to 0.74", large storms correspond to >0.75".
- Rainfall-runoff relationships by their nature are not precise, yet this basic analysis is more robust than methods provided in draft Toxics TMDLs. It is very rare to have daily mean flow above 20 cfs when no precipitation has occurred.

Flow Tiers for Se and Metals TMDLs

EPA and Regional Board staff evaluated daily flow records for 19 water years at San Diego Creek at Campus to determine the flow tiers used in developing Se and metals TMDLs. We utilized the rainfall-runoff information outlined by OCPFRD above and extended the analysis to include all available complete water year records; i.e., water years 1978/79, 1983/1984, 1984/85 and so on up to 2000/01. The rainfall-runoff breakpoints for each flow tier, and the associated percentiles are: base flows (0-20 cfs) correspond to 0" rainfall (90th%), small flows (21-181 cfs) correspond to <0.25" rainfall (96th%), medium flows (182-814 cfs) correspond to rainfall between 0.25" and 0.75" (99th%), and large storms (>814 cfs) correspond to >0.75" rainfall.

Flow volumes associated with each tier were calculated by summation of daily flow rates within each tier for all 19 water years. Table B-2 provides summary statistics for each of the flow tiers. Table B-3 provides a synopsis of the mean annual flow volume for each tier and the corresponding hardness values in San Diego Creek.

Table B-2. Flow rate summary statistics for flow tiers
San Diego Creek at Campus Station (1978/79 and 1983/84 to 2000/01 water years)

Flow Tier	Flow Rates (cfs)	Number of Days		Measured Flow Rate Statistics (cfs)				
		Total (days)	Annual Avg (days / year)	Min	Max	Mean	Std	Median
Base Flows	≤ 20	4,557	240	2	20	13.3	3.42	13
Small Flows	> 20 to ≤ 181	2,129	112	20	181	35.9	24.8	28
Medium Flows	> 181 to ≤ 814	198	10.4	182	808	397	170	365
Large Flows	>814	56	2.95	835	9,220	1,841	1,284	1,595
Non-Large Flows	≤814	6,884	362.32	2	808	31.3	71.4	16

Table B-3. Flow based tiers and corresponding hardness values in San Diego Creek.

Flow tier	Corresponding flow rate (cfs)	Mean annual flow volume associated with tier # (million cubic ft.)	Flow rate used to determine hardness	Corresponding Hardness (mg / L)
Base flows	≤ 20	275.4	N / a	400
Small flows	> 20 to ≤ 181	347.5	181	322
Medium flows	> 181 to ≤ 814	357.6	814	236
Large flows	>814	468.8	1595	197

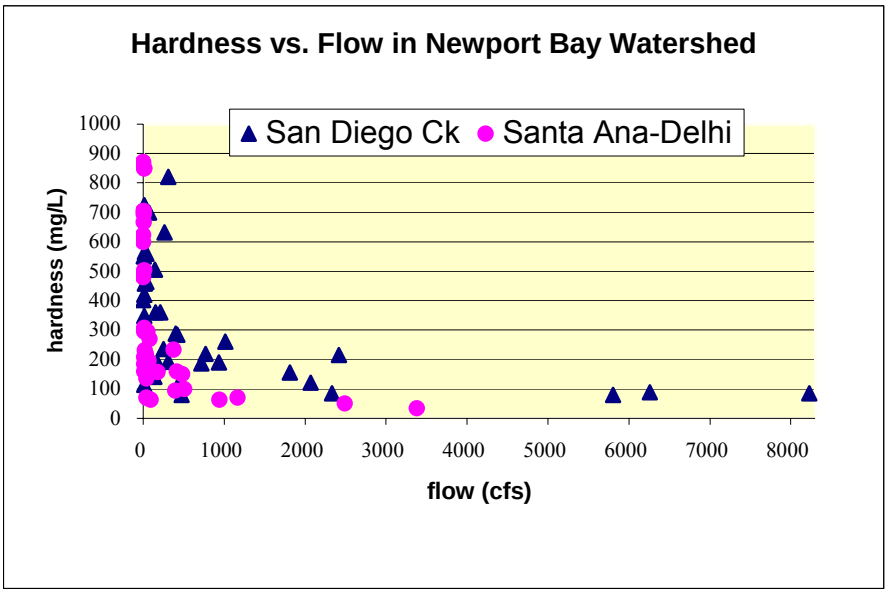
Mean annual volume for each tier based on daily flow records for 19 water years: 1977 / 78, 83 / 84 to 00 / 01 (combination of USGS and OCPFRD data).

Flow rate and Hardness values

To develop metal (Cd, Cu, Pb and Zn) TMDLs, EPA examined monitoring data (OCPFRD 1997 to 2000) collected during high and low flow sampling events to evaluate in-stream hardness values relative to flow rates. The paired data consist of composite samples of hardness results along with the corresponding composite flow rates. An indirect relationship exists between flow rate and hardness such that higher flow rates correspond with lower hardness values, and lower flow rates often have higher hardness values (Figure B-1). Of foremost concern, lower hardness values are associated with lower dissolved metals water criteria. Thus when storm events occur, flow rates are high, hardness is low and the correspondingly low dissolved metals criteria are most likely to be exceeded in freshwater systems.

The paired data show relatively high hardness values are observed during lower flows; in fact these values are often above 400 mg / L. However, for base flows, EPA used the maximum hardness value (400 mg / L) as allowed in CTR (USEPA 2000). To determine the hardness value associated with small, medium and large flow tiers, EPA used a linearization technique to transpose observed flow rates to the corresponding hardness values. (Hardness vs. natural log (flow rate) yields a linear relationship.) For the small and medium flows EPA selected the highest flow value within this tier to determine the corresponding hardness value. For large flows, EPA reviewed daily flow rates for 4-consecutive days and used the highest (4 day) mean flow rate to determine the corresponding hardness value. (See example for copper below.)

Figure B-1. Hardness vs. flow rate for two freshwater streams. (OCPFRD data)



Note: Linear equation for hardness and flow at San Diego Creek: y = -57.742 (ln[x]) + 622.5
(Linear equation for Santa Ana Delhi Channel: y = -102.43 (ln[x]) + 713.41)

Here is an explanation of the sequence of steps to determine metals criteria associated with each flow tier. We use small flow tier and dissolved copper criteria as an example.

1. Range of flow is 21 to 181 cfs. Choose highest flow rate within the tier = 181 cfs.
2. Use linear equation to find corresponding hardness value….start with natural log (flow rate)
3. For SDCreek, hardness = -57.742 (ln [flow])+ 622.5
4. Use this hardness value (322 mg / L as $CaCO_3$) in CTR equations to determine acute and chronic criteria for each metal.
5. Dissolved chronic Copper criteria = e(0.8545[ln(hardness)]-1.702)*0.96 =24.3 ug / L

Determination of dissolved metal numeric targets based on hardness

Once, the hardness value for each flow tier was determined, the dissolved metal numeric targets were based on (water quality criteria) equations presented in CTR (USEPA 2000). The hardness value for each flow tier yielded two possible dissolved numeric targets—the acute value and the chronic value. The acute value applies to one-day exposures, whereas the chronic value applies to exposures lasting 4-consecutive days. EPA reviewed daily flow records during the same 19 water years described above and observed that elevated flows (>181cfs) occur for 4-consecutive days or longer. This happens repeatedly within a water year (e.g., four times in WY 1997 / 98) as well as over the 19 years of daily flow records. Therefore, EPA selected both acute and chronic water quality criteria within base, small and medium flow tiers to serve as numeric targets for dissolved metals in San Diego Creek.

Similar methods of flow analysis were applied to daily flow records for Santa Ana Delhi Channel, however the time span covered only six water years: 1995 / 96 to 2000 / 01. Breakpoints in flow rates for Santa Ana Delhi were determined via similar percentages as those used for San Diego Creek: 90%, 96% and 99%. Table B-4 show corresponding flow rates, associated flow volumes, and hardness values for each flow tier.

Table B-4. Flow based tiers and corresponding hardness values in Santa Ana Delhi Channel.

Flow tier	Corresponding flow rate (cfs)	Flow volume associated with tier # (million cubic ft.)	Flow rate used to determine hardness	Corresponding Hardness (mg/L)
Base flows	0 – 3.5	49.3	N/a	400
Small flows	3.6 – 39	47.1	39	338
Medium flows	39.1 - 165	22.3	165	190
Large flows	>165	118.7	329	120

mean volume for each tier based on daily flow records for 6 water years: 1995/96 to 00/01 (OCPFRD data); chronic conditions for base, small, and medium flows, and acute for large flows

Flow Tiers for Organochlorine TMDLs

For the organochlorine TMDLs, we evaluated daily flow records for San Diego Creek at Campus Dr. We utilized the same 19 water year records as described above (USGS and OCPFRD database). Three flow tiers were defined to accommodate the range of flows: low flow (base and small flows), medium flow and high flow. The low flow rate (15 cfs) was determined from median value of all flow records < 181 cfs. The medium flow rate (365 cfs)was determined from the median value of flows between 181 and 814 cfs. The high flow rate was the median value (1595 cfs) within the large flows >814 cfs. For calculations of total annual flow and consequently the annual loads, the low flow rate was applied for 352 days, the medium flow rate for 10 days and the high flow rate for 3 days. Direct application of these three flow tiers was used to estimate loading capacity and existing loads of organochlorines within San Diego Creek only. More information can be found in Technical Support Document – Part F.

Part C—Organophosphate (OP) Pesticides

Introduction

This technical support document (TSD) provides additional information relevant to the development of the chlorpyrifos and diazinon TMDLs described in the TMDL summary document. In this TSD, Section I describes physical and chemical properties as well as the environmental fate of chlorpyrifos and diazinon. Section II follows with a usage analysis. Section III gives a summary of the monitoring data collected to date and an analysis of the major sources of chlorpyrifos and diazinon to San Diego Creek and Upper Newport Bay. Section IV presents calculations of current load estimates.

The source analysis focuses on water column concentrations, as these were associated with aquatic life toxicity and impairment of beneficial uses in San Diego Creek and Upper Newport Bay. Several investigations have been conducted in the watershed to characterize aquatic life toxicity associated with pesticides. These studies were not detailed enough to identify discrete sources; however, it is clear that diazinon and chlorpyrifos discharges are associated with nonpoint source runoff from areas where these pesticides are applied.

A large portion of information presented in this Technical Support Document was extracted from the OP Pesticide DRAFT TMDL written by Regional Board staff (2001a).

I. Physicochemical properties and environmental fate

The environmental fate of chlorpyrifos and diazinon can be inferred from their physical properties. Table C-1 presents properties for diazinon and chlorpyrifos along with several other pesticides that occasionally contribute to the aquatic life toxicity in San Diego Creek. In general, diazinon and chlorpyrifos are a more significant water quality threat because of the combined properties of higher toxicity, mobility, and persistence. Carbaryl for example, is mobile but less toxic and less persistent than diazinon and chlorpyrifos.

Table C-1. Pesticide properties

Pesticide	Ceriodaphnia LC 50 (ng/L)	Solubility (mg/L)	Adsorption coefficient	Soil half-life	Water half-life
Bifenthrin	78	0.1	1,000,000	7 days to 8 mos.	n/a
Carbaryl	3,380	40	300	7-28 days	10 days
Chlorpyrifos	60	2	6070	2-4 months	1-2.5 months
Diazinon	440	40	1000	2-4 weeks	6 months
DDT	4,700	<1	100,000	2-15 years	1-2 months
Malathion	1,140	130	2.75	1-25 days	< 1 week

Source: EXTOXNET Pesticide Information Profiles; CDFG (2000)
n/a=not available

Relative to most pesticides, diazinon is fairly soluble and mobile in aquatic systems. It is only weakly bound by sediment. In contrast, chlorpyrifos is much less soluble and has a much higher potential to adsorb to soil and sediment.

Diazinon

In general, diazinon is relatively persistent in aquatic environments with a half-life of about six-months under neutral pH conditions. The pH of the channel network in the Newport Bay watershed is generally between 7.5 and 8, a range that would maintain the stability of diazinon. In soil, the diazinon half life is shorter owing to greater microbial degradation.

For diazinon, the major routes for dissipation appear to be biodegradation , volatilization, and photolysis (USEPA 1999a). Degradation is fastest from bare soil, followed by vegetation, and aquatic environments. Biodegradation from impervious urban areas (walkways, pavement) would be slowest due to the relative absence of microbes. This indicates that diazinon may accumulate in residential areas until rainfall runoff carries it into the drainage channel network. In a residential runoff survey conducted in the Castro Valley Creek watershed, diazinon was found in all samples as long as seven weeks after application.

Diazinon dissipation half-lives did not appear to be correlated with formulation type (granular, wettable powder, or emulsifiable concentrate). The reported diazinon formulations in Orange County for 1999 are listed in Table C-2. The liquid formulations are likely to be the most mobile as they are already in soluble form. The granules would likely remain available until a storm event washed the remaining active ingredient into the storm drains.

Table C-2. Diazinon Formulations for Reported Uses in Orange County, 1999

Formulation	Use (lbs. ai)	Percent
Emulsifiable concentrate	14,776	60.4%
Granular / Flake	4675	19.1
Wettable Powder	2720	11.1
Flowable Concentration	1969	8.1
Liquid Concentration	275	1.1
Dust / Powder	36.8	0.2
Pressurized Liquid / Sprays / Foggers	0.465	0
Solution / Liquid (Ready to use)	0.184	0
Total	24,452	100%

ai =active ingredient

Regardless of the formulation used, runoff is likely to occur only after significant rainfall or irrigation. Aside from runoff, a potentially significant discharge could occur through improper disposal of old or leftover material. The degree of knowledge concerning proper disposal varies considerably and it is unlikely that homeowners apply the exact amount needed in a manner that does not cause runoff.

Large-scale aerial spray applications may drift and result in significant offsite migration. These are generally applied to orchard crops in the Central Valley and, as Table C-2 shows, they are not a significant application in Orange County.

There is evidence that the amount of diazinon in a watershed that reaches a receiving waterbody is generally less than one percent of that applied (Scanlin and Feng 1997). Thus, relatively limited instances of improper use (e.g. inappropriate disposal, excess outdoor application) could account for a large portion of the observed concentrations in the drainage channels.

Chlorpyrifos

Compared to diazinon, chlorpyrifos has a shorter half-life in water, but a longer half-life in soil. This is due in part to its higher adsorption coefficient, which results in chlorpyrifos partitioning out of the aquatic phase as it is bound by sediment and soil.

Table C-3 shows the chlorpyrifos formulations used in Orange County in 1999. As with diazinon, concentrates, powders, and granular / flake formulations account for over 99% of the uses. These formulations require mixing / preparation prior to use.

Table C-3. Chlorpyrifos Formulations used in Orange County, 1999

Formulation	Use (lbs. ai)	Percent
Emulsifiable concentrate	70,067	87.6%
Granular / Flake	6571	8.2
Wettable Powder	2281	2.9
Flowable Concentration	996	1.2
Liquid Concentration	38.1	0
Dust / Powder	35.1	0
Pressurized Liquid / Sprays / Foggers	1.58	0
Solution / Liquid (Ready to use)	0.103	0
Total	79,990	100%

ai = active ingredient

Of the top four formulations used in Orange County, only the granular / flake formulation would act to slowly release the active ingredient into the water, while the other formulations would enhance mobility. The lower release rate would result in lower concentrations over time.

Dissipation of chlorpyrifos from water takes place through sorption, volatilization, and photolysis. Chemical breakdown (hydrolysis) rates increase with increasing temperature and pH. Adsorbed chlorpyrifos is subject to degradation by UV light, chemical hydrolysis, and biodegradation.

II. Pesticide Usage

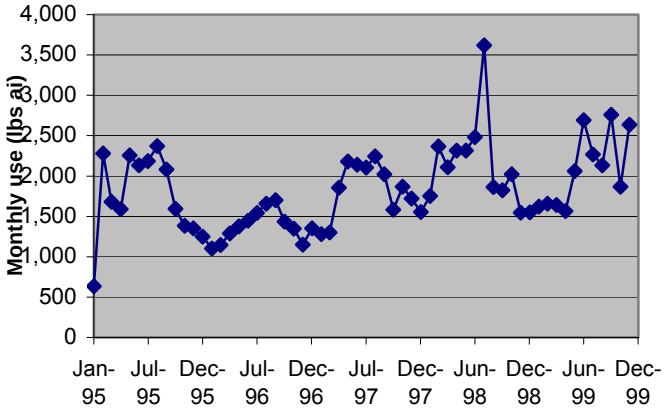
The CDPR requires records of all pesticide applications except for residential use by homeowners. These records are compiled and reported on a county-by-county basis. The Newport Bay watershed occupies 20% of Orange County, and it is assumed here that 20% of the pesticide use reported for Orange County occurred within the Newport Bay watershed.

Diazinon

As shown in Figure C-1, reported diazinon use in Orange County has remained fairly steady over the past five years. Seasonally correlated increases in diazinon use are apparent in the summer months in response to increased pest activity.

As noted above, residential use by homeowners is not reported in the CDPR database. Information on national pesticide usage by homeowners is available from the USEPA Pesticide Industry Sales and Usage Market Estimates report. On a national basis, 75% of the diazinon used in the US each year is for non-agricultural purposes, with 39% used by homeowners outdoors and 3% used by homeowners indoors (USEPA 1999b). Total homeowner use is therefore about 42% on a national basis.

Figure C-1: Reported Diazinon Use
Orange County: 1995-1999



In Orange County, the total agricultural use is likely less than the national average due to urbanization of the watershed. Thus homeowner uses probably account for more than the 42% reported nationally. A more specific estimate of the unreported homeowner use can be obtained by assuming the national ratio of homeowner use to total non-agricultural use (42/75, or 56%) is applicable to Orange County. Since data on the total non-agricultural diazinon use in Orange County is reported to the CDPR on a yearly basis, the national ratio can be used to estimate the unreported homeowner use in Orange County. Estimating the unreported homeowner use at 56% of total non-agricultural use results in a figure of 29,119 lbs. active ingredient (ai) for 1999. This would amount to 54% of total use (including agricultural use) in Orange County; somewhat higher than the national figure of 42% reported by USEPA.

Tables C-4 and C-5 present the reported and estimated unreported diazinon use in Orange County. For 1999, the total diazinon use in the Newport Bay watershed would be one-fifth of the Orange County total, or approximately 10,714 lbs. ai, while the estimated residential use would be about 5,824 lbs. ai.

Table C-5 indicates that urban uses accounted for over 97% of diazinon use, while agricultural uses (including nurseries) accounted for the remainder. Data from the Sales and Use Survey in the Newport Bay watershed (Wilen 2001) indicate that unreported residential diazinon use in 2000 was about 7,864 lbs. ai; about 32% larger than the estimate of 5,919 lbs. presented above using separate national data. This would suggest that total urban uses account for more than the 97% indicated in Table C-5.

Table C-4: Reported and Estimated Diazinon Use
Orange County: 1995-1999 (lbs. ai)

Use	1995	1996	1997	1998	1999
Structural	17,463	14,046	18,892	23,076	22,085
Nursery	1,037	839	803	1,212	1,144
Agriculture	2,004	746	1,363	865	429
Landscape	1,030	762	595	612	789
Other non-residential	9.8	46.2	1.6	1.7	5.3
Reported subtotal	21,543	16,439	21,655	25,766	24,452
Estimated Unreported Residential Use	23,548	18,905	24,804	30,150	29,119
Total	45,092	35,344	46,458	55,915	53,571

ai = active ingredient

Tables C-4 and C-5 show a decline in agriculture use from 1995 to 1999, both in absolute and percentage terms. The land use data also show a similar pattern, and the decline in agricultural diazinon usage may be a reflection of the continuing conversion of agricultural land to urban uses in Orange County and the Newport Bay watershed.

Table C-5: Reported and Estimated Diazinon Use
Orange County: 1995-1999 (percent)

Use	1995	1996	1997	1998	1999
Structural	38.7%	39.7%	40.7%	41.3%	41.2%
Nursery	2.3%	2.4%	1.7%	2.2%	2.1%
Agriculture	4.4%	2.1%	2.9%	1.5%	0.8%
Landscape	2.3%	2.2%	1.3%	1.1%	1.5%
Other non-residential	0.0%	0.1%	0.0%	0.0%	0.0%
Estimated Residential	52%	53%	53%	54%	54%
Total	100%	100%	100%	100%	100%

USEPA Phaseout of Certain Diazinon Uses

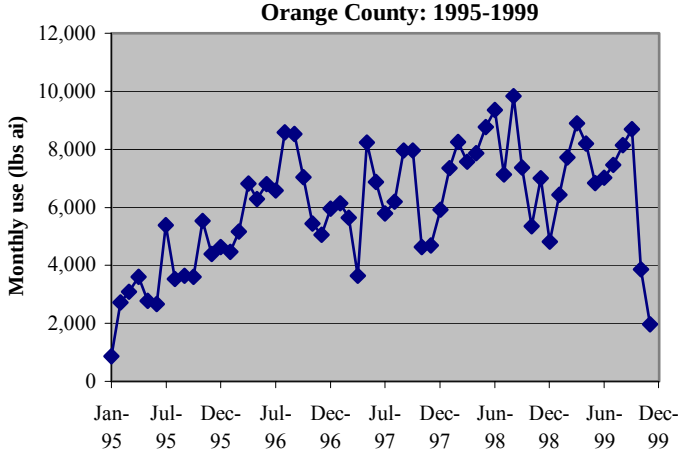
In January 2001, USEPA released a revised risk assessment and an agreement with registrants to phase out most diazinon uses (USEPA 2001b). Under the agreement, all indoor uses will be terminated, and all outdoor non-agricultural uses will be phased out over the next few years. Indoor uses will be banned after December 31, 2002. The EPA expects that these actions will end about 75% of the current use of diazinon. In addition, on a national basis, about one-third of the agricultural crop uses will be removed. For the San Diego Creek / Newport Bay watershed, the percentage reduction in agricultural usage will be higher (ca. 55%) due to the particular crops that are grown in the watershed.

The usage data in Table C-5 show that non-agricultural and non-nursery uses account for over 90% of the diazinon use in Orange County. It is thus likely that the EPA agreement will result in the cessation of most diazinon use in the Newport Bay watershed soon after the outdoor non-agricultural use registration expires on December 31, 2004.

Chlorpyrifos

Figure C-2 shows the reported chlorpyrifos use in Orange County from 1995 to 1999. As with diazinon, higher use tends to occur in the dry season, and is likely correlated with increased pest activity during warmer weather. An increasing trend from 1995 to 1998 is apparent followed by a sharp drop in 1999. This drop may be due to the agreement between EPA and the manufacturers to begin phasing out certain uses of chlorpyrifos (see below).

Fig C-2: Reported Chlorpyrifos Use
Orange County: 1995-1999



Tables C-6 and C-7 show the reported and estimated unreported chlorpyrifos use in Orange County. While overall chlorpyrifos use declined in 1999, nursery use increased by 300 percent. The significant increase in chlorpyrifos use by nurseries is likely due to the requirements imposed by the CDFA under the RIFA program. Runoff of the solution from the treatment area is not permitted (CDFA 1999).

Table C-6: Reported and Estimated Chlorpyrifos Use
Orange County: 1995-1999 (lbs. ai)

Use	1995	1996	1997	1998	1999
Structural	38,263	72,174	69,865	88,985	74,904
Nursery	652	772	971	994	2,913
Agriculture	1,414	952	1,450	645	1,132
Landscape	1,446	1,230	1,374	1,082	1,005
Other non-residential	7	268.5	1.6	1.6	35.3
Reported subtotal	41,782	75,396	73,662	91,707	79,990
Estimated Residential	21,663	40,185	38,859	49,128	41,424
Total	63,445	115,580	112,520	140,835	121,414

ai = active ingredient

Unreported (residential) chlorpyrifos use can be estimated by determining the national ratio of unreported home use to licensed (non-agricultural) use as reported in the USEPA Market Estimates Report (USEPA 1999b). Nationally, in 1995/96, the residential use was estimated at 2-4 million lbs. ai, while the licensed (non-agricultural) use was estimated at 4-7 million lbs. ai. Using the midpoints of these ranges, the ratio of residential use to licensed non-agricultural use is 0.545 on a national basis. Applying this ratio to the licensed non-agricultural use in Orange County reported to the CDPR for 1999 (75,944 lbs. ai) yields an estimate of 41,424 lbs. ai unreported residential use (Table C-6). This indicates that the unreported residential use was roughly 34% of the total use in 1999 (Table C-7). Total chlorpyrifos use in the Newport Bay watershed for 1999 would be approximately 24,300 lbs. ai (one-fifth of the Orange County total).

Data from the Sales and Use Survey (Wilen 2001) indicates that retail sales of chlorpyrifos in the Newport Bay watershed may have declined to as little as 546 lbs. ai on an annual basis in 2000. This compares to the estimated residential use of 8,285 lbs. ai (one-fifth of the Orange County total) presented in Table C-6 for 1999. The decline in chlorpyrifos use appears to be a continuation of the trend shown in Figure C-2 toward the end of 1999, and is likely related to the re-registration agreement for chlorpyrifos (see below).

Table C-7: Reported and Estimated Chlorpyrifos Use
Orange County: 1995-1999 (percent)

Use	1995	1996	1997	1998	1999
Structural	59.2%	61.9%	61.3%	62.7%	60.6%
Nursery	1.0%	0.7%	0.9%	0.7%	2.4%
Agriculture	2.2%	0.8%	1.3%	0.5%	0.9%
Landscape	2.2%	1.1%	1.2%	0.8%	0.8%
Other non-residential	0.0%	0.2%	0.0%	0.0%	0.0%
Reported subtotal	66%	65%	65%	65%	66%
Estimated Unreported Residential Use	34%	35%	35%	35%	34%
Total	100%	100%	100%	100%	100%

An analysis of chlorpyrifos sales data provided by Dow AgroSciences indicates that treatment for wood protection accounts for 70% of urban use (Giesy et al. 1998). Typical applications involve subsurface injection of chlorpyrifos at relatively high concentrations. Another 14% of urban use was categorized as home use (indoor pests, pet collars, lawns and gardens, building foundations, and other structural applications), while non-residential turf applications accounted for 7% of urban use.

USEPA Phaseout of Certain Chlorpyrifos Uses

In June 2000, the EPA published its revised risk assessment and agreement with registrants for chlorpyrifos (USEPA 2000b). The agreement imposes new restrictions on chlorpyrifos use in agriculture, cancels or phases out nearly all indoor and outdoor residential uses, and also cancels non-residential uses where children may be exposed. Application rates for non-residential areas where children will not be exposed (golf courses, road medians, industrial plant sites) will be reduced. Public health use for fire ant eradication and mosquito control will be restricted to professionals. Non-structural wood treatments will continue at current rates. Since the EPA estimates that about 50% of the chlorpyrifos use (both licensed and unreported) takes place at residential sites, the agreement is likely to result in at least a 50% decrease in chlorpyrifos use.

In Orange County, residential use (reported and unreported) likely accounts for over 90% of total chlorpyrifos use (most of the reported use is for structural protection applied in and around homes). Thus, it appears that over 90% of the current chlorpyrifos use in the Newport Bay watershed will be eliminated by the EPA agreement. Retail sales are scheduled to stop by December 31, 2001, and structural uses will be phased out by December 31, 2005.

As noted above, the CDPR data, and the Sales and Use Survey data (Wilen 2001) indicate that chlorpyrifos use has been declining sharply within the last two years. This is likely due to the warning from EPA that retailers should not purchase stock unless they were able to sell it by December 31, 2001. A survey conducted in northern California in late 2000 noted, “Chlorpyrifos products have become increasingly difficult to find” (TDC Environmental 2001). It should be noted that the available water-quality data for the Newport Bay watershed, is largely from 1996-2000, and not directly correlated to the latest usage data from 2000-2001.

III. Source Analysis

This section presents an analysis of the sources of diazinon and chlorpyrifos in the Newport Bay Watershed. Each chemical summary includes monitoring data and a discussion of diazinon and chlorpyrifos sources categorized by land use. Point sources and non-point sources are also discussed in a separate section.

Diazinon Data Summary

Table C-8 summarizes the results of diazinon sampling in the Newport Bay watershed. The sampling programs are described in Section 2. The table shows the high diazinon detection frequency, particularly during stormflow. The observed diazinon concentrations are similar to those observed in urban watersheds elsewhere in California. The mean values for both baseflow and stormflow exceeded the chonic numeric target, while 86% of the diazinon concentrations observed in the watershed drainage channels exceeded the acute numeric target.

Table C-8. Summary of Diazinon Sampling Results

Source	Count	# of Detects	Det. Freq.	Min.	Max.	Mean	Median
Water Samples (ng/L)							
Drainage Channels (All Flows)	198	185	93%	<40	10,000	471	220
Baseflow	104	93	89%	<40	10,000	473	160
Stormflow	94	92	98%	<50	7990	451	357
Upper Newport Bay	26	26	100%	197	720	386	357
Rainfall	1	1	--	--	13	--	--
Sediment Samples (ug/kg)							
Drainage Channels	98	2	2%	<10	49	--	--
Newport Bay	64	2	3%	<0.4	60	--	--

Freshwater Numeric Targets: acute = 80 ng/L; chronic = 50 ng/L (CDFG 2000a)

For comparison, the median diazinon concentration in the Santa Ana River downstream of Prado dam was 100 ng/L (USGS 2000), and the detection frequency was 99% (72 of 73 samples). The USGS also reported stormflow concentrations as significantly elevated relative to baseflow concentrations.

The low detection frequency for the sediment samples is in accordance with the moderately low diazinon adsorption coefficient, and its relatively high solubility. All the sediment detections were reported from samples collected in 1994, and diazinon has not been detected in subsequent semi-annual sediment sampling.

Table C-9 presents the data summarized by waterbody group. Highest concentrations occur in the upstream tributary channels to San Diego Creek. The maximum concentrations collected in 1998 from Hines Channel (which drains to Peters Canyon Channel) were three baseflow samples with concentration ranging from 2,500 to 10,000 ng/L. The maximum concentration of six baseflow samples collected in Hines channel during 2000, was 323 ng/L, indicating either a decrease in usage or more effective runoff control.

Table C-9: Diazinon Results by Waterbody Group

Waterbody	Count	Results (ng/L)				Exceedances	
		Min	Max	Mean	Median	Above acute	Above chronic
Tributaries to SDC Reach 2	24	40	7,990	817	256	96%	92%
Tributaries to SDC Reach 1	21	49	628	226	134	86%	67%
Tributaries to P CC	41	40	10,000	791	271	83%	78%
Peters Canyon Channel	15	170	820	390	367	100%	100%
SDC Reach 1	59	50	960	301	215	95%	92%
Tributaries to UNB	35	40	2,250	357	202	94%	91%

SDC=San Diego Creek; PCC=Peters Canyon Channel; UNB=Upper Newport Bay
Freshwater Numeric Targets: acute = 80 ng/L; chronic = 50 ng/L

The similarity in median concentrations indicates that there are no clearly dominant areas of the watershed with regard to diazinon loading to San Diego Creek and Upper Newport Bay. Concentrations in Peters Canyon Channel are somewhat elevated relative to the other segments of the drainage network. This was also a conclusion of the 319h study (Lee and Taylor 2001a)

San Diego Creek Reach 2: There were no sampling stations within Reach 2 of San Diego Creek. However, 24 samples were collected from tributary channels (Bee Canyon and Marshburn Slough). These samples were collected several miles upstream of where these channels join San Diego Creek and were mainly targeted at monitoring nursery discharges. The median concentration for these samples was 256 ng/L, with maximum concentrations of 7,990 ng/L during stormflow and 2,320 ng/L during baseflow. Over 90% of the observed concentrations exceeded the acute and chronic numeric targets.

San Diego Creek Reach 1: The main tributary to San Diego Creek Reach 1, (aside from Reach 2), is Peters Canyon Channel. Median diazinon concentrations in Peters Canyon Channel (367 ng/L) were higher than in San Diego Creek (208 ng/L). The median concentration for other tributaries to San Diego Creek was 143 ng/L. All 15 samples collected within Peters Canyon Channel exceeded both the acute and chronic numeric targets, while in the tributaries to Peters Canyon Channel, the percentages exceeding the acute and chronic numeric targets were lower, 78% and 83% respectively. Over 90% of the observed concentrations within Reach 1 exceeded the acute and chronic numeric targets.

Upper Newport Bay: The median concentration for drainage channels discharging directly to Upper Newport Bay (East Costa Mesa, Westcliff Park, Santa Ana Delhi) was 202 ng/L. The CDFG has not recommended criteria for diazinon in saltwater, however, the LC-50 for the commonly used test species (*Mysidopsis bahia*) is 4,200 ng/L, and the observed diazinon concentrations were all below this level, with a maximum of 720 ng/L. The USEPA (2000a) has published draft recommended acute and chronic criteria for diazinon in saltwater (820 ng/L and 400 ng/L respectively). The maximum and average results from Upper Newport Bay were below the respective draft USEPA saltwater CMC and CCC.

Diazinon Sources Categorized by Land Use

Tables C-10a and C-10b present the diazinon results by sampling location along with the land use pattern in the monitored sub-watershed. The locations in Table C-10a are sorted according to median stormwater runoff concentration, while in Table C-10b, they are sorted according to median baseflow concentration. Several of the locations were sampled for only baseflow or only stormflow conditions.

Table C-10a: Land Use and Diazinon Stormflow Concentrations
Newport Bay Watershed: 1996-2000

Station	Land Use	Count	Stormflow Results (ng/L)			
			Min	Max	Avg.	Median
Westcliff Park	residential	7	174	1,079	692	678
Drain at Bee Canyon and Portola Pkwy.	nursery	7	126	7,990	1,625	599
Central Irvine Channel – Monroe	ag (nursery)-residential	2	90	810	545	545
Peters Canyon Channel – Walnut	mixed	1	520	520	520	520
East Costa Mesa Channel – Highland Dr.	residential	2	370	560	465	465
Bonita Creek at San Diego Creek	residential	7	69	628	424	456
San Diego Creek - Campus Dr.	mixed	25	96	960	445	375
El Modena-Irvine Channel upstream of Peters Canyon Channel	residential	1	330	330	330	330
Hines Channel - Irvine Blvd.	nursery	9	199	810	455	324
Peters Canyon Channel – Barranca	mixed	10	202	426	321	309
San Diego Creek – Harvard Av.	mixed	2	200	280	240	240
Santa Ana Delhi Channel – Mesa Dr.	residential-urban	10	64	375	171	174
Marshburn Slough – Irvine Blvd.	Nursery	7	96	291	168	136
Sand Canyon Ave - NE corner Irvine Blvd.	agricultural	2	70	110	90	90
San Joaquin Creek - Univ Dr.	agricultural-open	2	<50	<50	<50	<50

At virtually all the locations, the median stormflow concentration is significantly higher than the median baseflow concentration. Since stormwater runoff constitutes about 80% of the volume of water discharged to Newport Bay on an annual basis, this would indicate that the overwhelming majority of the pesticide load would derive from stormflow rather than baseflow. The average concentration is actually higher for baseflow, but this is biased by a few very high detections from 1998 near nurseries. These results have not been observed in later sampling and the nurseries have subsequently instituted measures targeted at reducing pesticide runoff.

Although the sampling network is not detailed enough to identify individual sources (aside from nurseries), two conclusions are apparent:

(1) Stormflow concentrations are virtually always higher than baseflow concentrations. This is particularly the case in the non-agricultural areas.
(2) Residential areas tend to yield the highest stormwater runoff concentrations while the nursery areas tend to yield the higher baseflow concentrations.

Studies reported in the literature indicate that residential hotspots (individual homes) can account for most of the diazinon runoff from a neighborhood. Samples collected from the near vicinity of these residential hotspots (prior to dilution in the storm drain), showed concentrations above 10,000 ng/L (Scanlin and Feng 1997). Such detailed sampling and analysis for pesticides has not been completed in residential areas of the Newport Bay watershed. The residential run-off reduction study is currently in progress but results were not available for these TMDLs.

Table C-10b: Land Use and Diazinon Baseflow Concentrations
Newport Bay Watershed: 1996-2000

Station	Land Use	Count	Baseflow Results (ng/L)			
			Min	Max	Avg.	Median
Hines Channel - Irvine Blvd.	Nursery	10	47	10,000	2,129	862
Drain at Bee Canyon and Portola Pkwy.	Nursery	7	93	2,320	977	637
Central Irvine Channel – Bryan St	agricultural-residential	5	117	1,940	722	570
Peters Canyon Channel – Barranca	Mixed	4	170	820	533	570
Central Irvine Channel – Monroe	ag (nursery)-residential	2	90	840	465	465
San Diego Creek - Coronado St.	Mixed	2	94	365	230	230
Westcliff Park	Residential	9	<40	2,250	432	215
East Costa Mesa Channel – Highland Dr.	Residential	1	210	210	210	210
El Modena-Irvine Channel upstream of PCC	Residential	1	180	180	180	180
San Diego Creek - Campus Dr.	Mixed	28	<50	570	200	160
Santa Ana Delhi Channel - Mesa Dr.	Residential-urban	6	<50	340	149	125
Bonita Creek at San Diego Creek	Residential	12	49	332	139	114
El Modena	Nursery	3	<40	310	146	87
San Diego Creek - Harvard Av.	Mixed	2	<50	<50	<50	<50
Marshburn Slough - Irvine Blvd.	Nursery	1	<40	<40	<40	<40
Hines at Weir	Nursery	5	<40	45	41	<40

Chlorpyrifos Data Summary

Table C-11 summarizes the chlorpyrifos results. The detection frequency is lower than for diazinon. This is due in part, to the lower solubility of chlorpyrifos, and its greater affinity for sediment (Table C-1). As discussed in Section I, the lower mobility of chlorpyrifos results in lower concentrations in the drainage channels, despite the fact that over twice as much chlorpyrifos is applied as compared to diazinon (lbs. ai) (Tables C-4 and C-6),

The average values for stormflow and baseflow exceed the chronic numeric targets. Within the drainage channels, 44% of the chlorpyrifos results exceeded the freshwater chronic target (14 ng/L), while 92% of the samples collected in Upper Newport Bay were over the saltwater chronic target (9 ng/L).

Table C-11. Summary of Chlorpyrifos Sampling Results

Source	Count	# of Detects	Det. Freq	Min.	Max.	Mean	Median
Water (ng/L)							
Drainage Channels (All flows)	198	89	45%	ND	770	139	<50
Baseflow	104	36	35%	ND	670	162	<40
Stormflow	94	53	56%	ND	770	123	50
Upper Newport Bay	24	24	100%	2	132	43.3	41.5
Rainfall	1	1	--	--	23	--	--
Sediment (ug/kg)							
Drainage Channels	2	2	100%	17	29	--	--

Freshwater Numeric Targets: acute = 20 ng/L; chronic = 14 ng/L (CDFG 2000a)
Saltwater Numeric Targets: acute = 20 ng/L; chronic = 9 ng/L (CDFG 2000a)

The sediment data for chlorpyrifos is reflective of the higher soil adsorption coefficient relative to diazinon. Although chlorpyrifos analyses were not presented in the OCPFRD data, chlorpyrifos was detected in both sediment samples collected by the CDFG (2000b).

Table C-12 presents the chlorpyrifos data summarized by waterbody group. Detection frequencies were low, particularly in the upper reaches of the watershed. Detection frequencies were higher in Peters Canyon Channel and its tributaries, where a large proportion of the samples were from undiluted nursery discharges. Comparison to the acute and chronic numeric targets is difficult because they are set at levels below the analytical reporting limit used for most of the sampling/monitoring programs. In Table C-12, all detections exceeded the acute and chronic targets. In Upper n

Table C-12. Chlorpyrifos Results by Waterbody Group

Waterbody	Count	Results (ng/L)			Exceedances*	
		Max	Mean	Median	Above acute	Above chronic
Tributaries to SDC Reach 2	24	121	51	<40	33%	33%
Tributaries to SDC Reach 1	21	770	95	<40	10%	10%
Tributaries to P CC	41	670	108	50	54%	54%
Peters Canyon Channel	15	420	83	57	60%	60%
SDC Reach 1	59	580	102	57	59%	59%
Tributaries to UNB	35	231	47	<40	37%	37%
Upper Newport Bay	24	132	43.3	41.5	80%	92%

SDC = San Diego Creek; PCC = Peters Canyon Channel; UNB=Upper Newport Bay
* The reporting limit for chlorpyrifos in freshwater was above the acute and chronic numeric targets, therefore all detected concentrations exceeded the numeric targets.

San Diego Creek Reach 2: There were no samples collected from within Reach 2, however, samples collected from tributary channels discharging into Reach 2 had a low detection frequency (33%) and a maximum concentration of 121 ng/L.

San Diego Creek Reach 1: Samples collected from locations in Reach 1 of San Diego Creek (at Campus, Coronado, and Harvard streets) had a relatively high detection frequency and the highest median concentration, along with Peters Canyon Channel. This may indicate that the greater part of the chlorpyrifos loading is derived from Peters Canyon Channel and its sampled tributaries (Hines, Central

Irvine). However, the maximum chlorpyrifos concentrations occurred in two samples collected from San Joaquin Creek, which discharges directly into Reach 1 of San Diego Creek.

Upper Newport Bay: Chlorpyrifos was detected in all samples collected in Upper Newport Bay, where a lower detection limit was employed. The samples were collected over several days during a storm event in January 1999. The chlorpyrifos concentration that saltwater organisms are exposed to is largely dependent on the degree of mixing between saltwater and freshwater in the upper bay. In the case of the storm sampled in January 1999, a freshwater lens persisted for several days in the upper bay. Chlorpyrifos concentrations were inversely correlated with salinity. Overall, the observed concentrations were lower in Upper Newport Bay than in San Diego Creek.

Chlorpyrifos Sources Categorized by Land Use

Tables C-13a and C-13b present the chlorpyrifos results by sampling location along with the land use pattern in the monitored sub-watershed. The locations in Table C-13a are sorted according to median stormwater runoff concentration, while in Table C-13b, they are sorted according to median baseflow concentration.

Stations sampling runoff derived from mixed land use areas tended to have the highest chlorpyrifos concentrations under both baseflow and stormflow conditions. A major exception was the data from San Joaquin Creek. This creek was sampled during two separate storm events in February, 2000. (Baseflow samples were not collected). The results were the two highest chlorpyrifos concentrations (770 ng/L and 470 ng/L) in the entire dataset. This sample was also associated with very high concentrations of carbaryl that were determined to originate from agricultural fields planted with strawberries that were treated with pesticides immediately prior to a rainfall event.

Chlorpyrifos was not detected in the two stormflow samples collected at the second non-nursery agricultural location (Sand Canyon Ave - NE corner Irvine Blvd). Therefore, it may be prudent to avoid assigning a median concentration to the entire watershed for non-nursery agriculture based on this limited data set.

It is difficult to draw strong conclusions from the data in Tables C-13a and C-13b due to the limited number of samples at most of the locations, and the large number of non-detect results. The chlorpyrifos results also do not correlate well with the diazinon results; the locations with the higher diazinon concentrations do not generally yield the higher chlorpyrifos concentrations. The sampling locations at Westcliff Park and the Central Irvine Channel at Monroe were the only locations among the top seven stormflow results for both chlorpyrifos and diazinon. The baseflow results had a somewhat better correlation, but overall the data suggest differing usage patterns for chlorpyrifos and diazinon.

Sample locations monitoring residential areas tended to have lower chlorpyrifos concentrations. Chlorpyrifos was not detected at three of the residential locations under either baseflow or stormflow conditions. The detection frequency, and maximum concentrations detected at another partly residential location (Santa Ana Delhi Channel) were low. The only residential site with relatively high chlorpyrifos concentrations was Westcliff Park (stormflow), but the baseflow concentrations were relatively low.

Although it appears that some of the nursery/agricultural locations yield higher chlorpyrifos concentrations than the residential areas, it should be noted that the nursery monitoring locations are selected to monitor undiluted nursery discharge, very close to where the chlorpyrifos is used. In contrast, runoff water quality data from individual homes or from distinct residential neighborhoods were not available. Rather data were collected from drainage channels receiving mixed/diluted runoff from many residential neighborhoods. In addition, because of the relative immobility of chlorpyrifos, and its tendency to adsorb to sediment, higher chlorpyrifos concentrations are most likely to be encountered

only near areas where it is applied, before it partitions out of the aqueous phase and settles out along with the sediment.

Table C-13a: Land Use and Stormflow Chlorpyrifos Concentrations
Newport Bay Watershed: 1996-2000

Station	Land Use	Count	Results (ng/L)			
			Min	Max	Avg	Median
San Joaquin Creek – Univ Dr.	agricultural-open	2	470	770	620	620
San Diego Creek – Harvard Av.	Mixed	2	190	310	250	250
Central Irvine Channel - Monroe	ag(nursery)-residential	2	70	150	110	110
Westcliff Park	Residential	9	<40	231	97	94
Peters Canyon Channel - Barranca	Mixed	10	<40	102	72	69
Marshburn Slough – Irvine Blvd.	Nursery	7	45	121	74	62
San Diego Creek – Campus Dr.	Mixed	25	<40	260	87	57
Hines Channel - Irvine Blvd.	Nursery	9	<40	349	98	<50
Santa Ana Delhi Channel - Mesa Dr.	residential-urban	10	<40	55	48	<40
Drain at Bee Canyon and Portola Pkwy.	Nursery	7	<40	60	43	<40
Sand Canyon Ave - NE corner Irvine Blvd.	Agricultural	2	<50	<50	<50	<50
East Costa Mesa Channel - Highland Dr.	Residential	2	<50	<50	<50	<50
El Modena-Irvine Channel upstream of Peters Canyon Channel	Residential	1	<50	<50	<50	<50
Bonita Creek at San Diego Creek	Residential	7	<40	<40	<40	<40

Table C-13b: Land Use and Baseflow Chlorpyrifos Concentrations
Newport Bay Watershed: 1996-2000

Station	Land Use	Count	Results (ng/L)			
			Min	Max	Avg	Median
San Diego Creek – Harvard Av.	mixed	2	50	400	225	225
Central Irvine Channel – Monroe	ag(nursery)-residential	2	<50	281	166	166
Peters Canyon Channel – Walnut	mixed	1	150	150	150	150
Central Irvine Channel – Bryan St	agricultural-residential	5	<40	315	164	117
Hines Channel - Irvine Blvd.	nursery	10	40	670	158	88
San Diego Creek – Campus Dr.	mixed	28	<40	580	111	56
Peters Canyon Channel – Barranca	mixed	4	50	420	144	54
El Modena	nursery	3	<40	57	49	49
Santa Ana Delhi Channel - Mesa Dr.	residential-urban	6	<40	50	37	<40
East Costa Mesa Channel - Highland Dr.	residential	1	<50	<50	<50	<50
El Modena-Irvine Channel upstream of Peters Canyon Channel	residential	1	<50	<50	<50	<50
Westcliff Park	residential	7	<40	129	51	<40
Marshburn Slough - Irvine Blvd.	nursery	1	<40	<40	<40	<40
Hines at Weir	nursery	5	<40	63	45	<40
Drain at Bee Canyon and Portola Pkwy.	nursery	7	<40	<40	<40	<40
San Diego Creek – Coronado St.	mixed	2	<40	<40	<40	<40
Bonita Creek at San Diego Creek	residential	12	<40	<40	<40	<40

Point Sources

There are over fifteen waste discharge requirement (WDR) and NPDES permit holders in the Newport Bay watershed. In addition, three general NPDES permit exist within the San Diego Creek watershed. Some of these permits are in the process of being rescinded.

NPDES

Most of the NPDES permits are minor permits for discharge of extracted groundwater. These are not expected to be sources of diazinon and chlorpyrifos loads to the watershed (groundwater is discussed further below), and the dischargers are not required to monitor for OP pesticides. Two NPDES permits are classified as major permits and are discussed below.

NPDES - Stormwater Runoff:

Stormwater runoff in the Newport Bay watershed is regulated by an NPDES permit for Orange County. As discussed in Section 2, the OCPFRD monitoring program does not include analysis for organophosphate pesticides. However, considerable data have been collected from stormwater runoff channels as part of the 205j, 319h, and CDPR investigations.

NPDES - Sewage Treatment Plants:

Diazinon has been found in effluent from sewage treatment plants (USEPA 1999a). This may be dues to improper disposal of surplus pesticides into sewer drains, or to indoor diazinon usage in urban areas (TDC Environmental 2001). The Newport Bay Watershed residential use survey has indicated a lack of knowledge among homeowners concerning proper disposal procedures (Wilen 2001). There are no sewage treatment plants in the Newport Bay Watershed that discharge effluent to the drainage channels or Newport Bay.

General Permits:

Three general permits have dischargers enrolled within the watershed. Two of the general permits, (groundwater cleanup, and dewatering) are for groundwater discharge. Discharges associated with these permits are not expected to be a source of diazinon or chlorpyrifos (see groundwater discussion below). The third general permit is for boatyards, and includes six enrollees located in Newport Beach. Diazinon/chlorpyrifos usage at boatyards is not expected to differ significantly from general urban uses. The permit prohibits discharge of water to Newport Bay with the exception of stormwater runoff after the first $1/10^{th}$ inch of precipitation. In short, the boatyards are not regarded as a significant source of OP pesticide runoff.

Santa Ana RWQCB permits:

Nursery Waste Discharge Requirements (WDR):

There are three commercial nurseries in the Newport Bay watershed that are regulated under WDRs. WDRs are being prepared for an additional two nurseries. Together, these nurseries account for less than two percent of the area in the Newport Bay Watershed. As part of the nutrient TMDL for Newport Bay (1999) nurseries greater than five acres and discharging to tributaries that enter Newport Bay were required to institute a regular monitoring program. The monitoring program includes bi-monthly monitoring for toxicity, however, there is no requirement for analysis of OP pesticides. Several of the sampling locations for the 205j, 319h and DPR-RIFA studies were chosen to monitor discharges from nurseries to the drainage channel network. The highest diazinon results occurred in Hines channel and the Drain at Bee Canyon and Portola Parkway sampling station. These results reflect relatively undiluted discharge from agricultural (mostly nursery) areas.

Other WDRs:
Several other facilities (including three landfills) have WDRs but none are required to monitor for OP pesticides, and they are not considered to be significant sources of OP pesticide load

Groundwater

Although there are no currently available groundwater data for diazinon and chlorpyrifos in the Newport Bay watershed, groundwater does not appear to be contributing diazinon and chlorpyrifos loads to the drainage system. Diazinon and chlorpyrifos concentrations are lower downstream of areas where groundwater seeps into the drainage channels. This indicates that the groundwater serves to dilute the concentrations.

In general, diazinon and chlorpyrifos tend to dissipate from the ground surface or in the upper soil layers before percolating to groundwater. Diazinon and chlorpyrifos have not been detected in groundwater sampling conducted by the USGS in the lower Santa Ana River Basin.

Sediment Remobilization

As discussed in the fate and transport section, diazinon has a relatively low potential to adsorb to sediment while chlorpyrifos has a greater adsorption coefficient (Table C-1). Chlorpyrifos could accumulate in sediment and be gradually released into the water through desorption. This would require stability of the adsorbed chlorpyrifos, but adsorbed chlorpyrifos is still subject to chemical hydrolysis and biodegradation.

The available sediment data demonstrate that diazinon is not being bound to sediment. As shown in Table C-8, the detection frequency for diazinon in sediment samples is less than two percent.

Two sediment samples were collected by the CDFG in July / August 2000. Chlorpyrifos was detected in sediment from Hines channel (29 ng / g) and in sediment collected nine miles downstream from the nurseries in San Diego Creek (17 ng / g) (CDFG 2000b). Diazinon was not detected at either location (reporting limit of 10 ng / g dry weight)

As part of the semi-annual sampling program, the OCPFRD collected 96 sediment samples from the Newport Bay watershed and 54 sediment samples from the Bay itself from 1994-1999. Only four diazinon detections were reported. All the detections occurred in 1994, at concentrations of 40 ug / kg to 60 ug / kg. Reporting limits ranged from 35 ug / kg to 400 ug / kg. OCPFRD does not currently monitor sediment for chlorpyrifos.

Atmospheric Deposition

Diazinon is one of the most frequently detected pesticides in air, rain, and fog (USEPA 1999a). In sampling conducted in California in 1988, diazinon was detected in approximately 90% of the sites sampled. Chlorpyrifos has a vapor pressure in the same range as diazinon, and can be expected to volatilize from treated areas. It is not as commonly detected in the atmosphere however.

A rainwater sample collected in the Newport Bay watershed during the 205j studies (December 1997) was reported to have a diazinon concentration of 13 ng / L and a chlorpyrifos concentration of 23 ng / L (Lee and Taylor 2001b). For comparison, eight rainwater samples collected in the Castro Valley Creek

watershed, an urban watershed in northern California, had a mean diazinon detected concentration of 58 ng/L with a maximum of concentration of 88 ng/L (Katznelson and Mumley 1997).

Higher diazinon concentrations in rainwater have been detected in agricultural areas (over 5,000 ng/L in 1994-95, and ranging from 418 ng/L to 5,463 ng/L in 14 cities located in the Central Valley) but these are likely related to aerial spray applications to orchards – a type of use that is negligible in the Newport Bay Watershed. Rainfall collected in the winter of 1992-93 in the San Joaquin basin contained up to 1,900 ng/L diazinon. The source of this diazinon is "presumed to be droplets from dormant spray applications (not volatilization from treated crops)" (Novartis 1997).

Assuming the measured rainfall concentration is representative for all storm events, and assuming no degradation during runoff, the annual diazinon load derived from rainfall would be approximately 0.7 lbs. This would be about 2% of the mean annual load at the San Diego Creek – Campus station. For chlorpyrifos, the load would be 1.3 lbs., or about 15% of the mean annual load.

It is uncertain whether this contribution is from volatilization from use within the watershed, or from aerial transport from sources outside the watershed. For estimating loads, the contribution from rainfall is already taken into account by the runoff sampling in the watershed. Direct deposition (rainfall falling directly into Upper Newport Bay) would be negligible since the area of the bay relative to the watershed is less than one percent. The diazinon load would be less than 0.0072 lbs., or less than 0.02% of the annual load to the Bay. For chlorpyrifos the load would be 0.0127 lbs. or about 0.15% of the total annual load.

IV. Approach to calculating current loads

This section presents calculations of estimated diazinon and chlorpyrifos loads to San Diego Creek and Upper Newport Bay. Because the TMDL is concentration based, the load information is presented for information purposes only and is not used as a basis for assigning allocations.

Mean annual loads were calculated using mean water column concentrations from the SDC-Campus Station. Mean annual baseflow and stormflow volumes were calculated using the flow data for the SDC-Campus station presented in Part B (Freshwater flow and seasonal variation). Baseflows are defined in Part B as flow rates less than or equal to 20 cfs at the SDC-Campus station. For the purposes of the diazinon and chlorpyrifos TMDL, stormflows are defined as flows greater than 20 cfs at the SDC-Campus station. Using these definitions, mean annual baseflow and stormflow volumes were calculated using the 19 years of flow data summarized in Part B. Loads were then determined by multiplying the mean concentrations with the mean flows. As the SDC-Campus station represents over 95% of the flow in the watershed, loads were not calculated for the other tributaries.

Diazinon

The estimated mean annual diazinon load at the San Diego Creek- Campus station is about 32 lbs (Table C-14). This amounts to about 0.3% of the estimated 10,800 lbs of diazinon (ai) that was used within the watershed in 1999. This finding is similar to the results of a recent study in the Castro Valley (urban) watershed. That study found that 0.3% of the applied diazinon (ai) was discharged into Castro Valley Creek with 90% of the load delivered by storm runoff (Scanlin and Feng 1997).

Table C-14: Estimated Mean Annual Diazinon Load
San Diego Creek – Campus Station

Flow	Mean Annual Flow (acre-feet)	Mean Conc. (ng/L)	Load (lbs.)	Load (%)
Base flow	6,323	200	3.43	10
Storm flow	26,950	445	32.6	90
Total	33,273	--	36.0	100

Table C-15 presents summary diazinon results categorized by land use, and estimates of the annual load for baseflow and stormflow. Only samples from locations where either urban or non-urban (agriculture, nursery) land use predominated were included in generating the table; about 40% of the samples in the data set were excluded.

Table C-15: Diazinon Concentrations and Loads by Land Use

			Results (ng/L)			Area		Load		Load
Condition	LandUse	Count	Max	Avg	Median	(acres)	(%)	(lbs)	(%)	(lbs/acre)
Baseflow	Urban	27	2,250	236	140	66,507	68%	2.4	88.4%	3.61E-05
	Agriculture	27	10,000	1,002	131	9,286	10%	0.31	11.6%	3.38E-05
	Open	---	---	---	---	21,948	22%	0.0	0.0%	0.00E+00
	Total					97,741	100%	2.7	100%	2.78E-05
Stormflow	Urban	27	1,079	400	370	66,507	68%	24.1	96.3%	3.63E-04
	Agriculture	27	7,990	627	271	9,286	10%	2.47	2.1%	2.66E-04
	Open	---	---	---	---	21,948	22%	0.0	0.0%	0.00E+00
	Total					97,741	100%	26.6	100%	2.72E-04

The total diazinon load estimated from Table C-15 is not directly comparable with the total load calculated using the average data from San Diego Creek (Table C-14) because the data sets are different. The table is simply intended to compare export rates from urban and agricultural areas. On a per-acre basis, diazinon export rates appear to be slightly higher for urban areas than for agricultural areas.

The intensive residential investigation in the Castro Valley Creek watershed (Scanlin and Feng 1997) revealed that a small number of individual residential hotspots (2% to 4% of the homes) produced the bulk of the diazinon loading to the Creek. Controlled experiments to evaluate diazinon runoff from individual homes demonstrated that even when diazinon was used properly, very high levels of diazinon would still be found in the runoff. Highest source areas were patios and driveways, followed by roof drains. These results are probably due to the lower rates of dissipation from these surfaces as compared to lawns or soil, where biodegradation would be much more significant.

Chlorpyrifos

Table C-16 presents an estimate of the annual chlorpyrifos loading to San Diego Creek and Upper Newport Bay. The total annual mass of chlorpyrifos entering Upper Newport Bay is about 8 pounds. This is about 0.03% of the estimated 24,300 lbs. ai of chlorpyrifos applied in the watershed in 1999 (one-fifth of the Orange County total given in Table C-6). This load is based on a conservative estimate of chlorpyrifos concentrations in tributaries to Upper Newport Bay. Actual concentrations in Upper Newport Bay would be reduced due to mixing and dilution.

Table C-16. Estimated Mean Annual Chlorpyrifos Load
San Diego Creek – Campus Station

Flow	Annual Flow (acre ft.)	Mean Conc. (ng / L)	Load (lbs.)	Load (%)
Baseflow	6,323	111	1.91	23
Stormflow	26,950	86.8	6.36	77
Total	33,273	--	8.27	100

Table C-17 presents chlorpyrifos concentrations and loads categorized by land use for the baseflow and stormflow conditions. Compared to diazinon, urban areas contribute a lesser percentage of the stormflow chlorpyrifos load. On a per-acre basis, export rates for urban and agricultural areas are similar. The total chlorpyrifos load estimated from Table C-17 is not directly comparable with the total load calculated using the data from San Diego Creek (Table C-16). The discrepancy between the two methods results from the differing data sets.

Table C-17: Chlorpyrifos Concentrations and Loads by Land Use

		Results				Area		Load		Load
Condition	**Land Use**	**Count**	**Max**	**Det Freq.**	**Median**	**(acres)**	**(%)**	**(lbs)**	**(%)**	**(lbs/acre)**
Baseflow	Urban	27	129	14%	<40	66,507	68%	0.69	87.7%	1.03E-05
	Agriculture	27	670	35%	<40	9,286	10%	0.10	12.3%	1.03E-05
	Open	---	---	---	---	21,948	22%	0.00	0.0%	0.00E+00
	Total					97,741	100%	**0.78**	100%	8.01E-06
Stormflow	Urban	27	231	33%	<40	66,507	68%	2.61	85.1%	3.92E-05
	Agriculture	27	770	56%	50	9,286	10%	0.46	14.9%	4.90E-05
	Open	---	---	---	---	21,948	22%	0.00	0.0%	0.00E+00
	Total					97,741	100%	**3.06**	100%	3.13E-05

V. Summary and conclusions

The following conclusions are based on data collected in Newport Bay watershed prior to implementation of EPA re-registration agreements for chlorpyrifos and diazinon:

Reported and unreported urban uses account for over 90% of total chlorpyrifos and diazinon use in Orange County and in the Newport Bay Watershed.

About 36 pounds of diazinon is discharged annually to San Diego Creek, mostly during storm events. This amounts to about 0.34% of the applied diazinon mass in the watershed. About 8 pounds of chlorpyrifos are annually discharged to Upper Newport Bay, with 77% of the load delivered during storm events. This amounts to about 0.03% of the applied chlorpyrifos mass.

Surface runoff is the source of virtually all the loadings. Contributions from sediment remobilization and groundwater are negligible, however, loading from atmospheric deposition to Upper Newport Bay is potentially significant, though not well-quantified.

On a per acre basis, different land uses contribute diazinon and chlorpyrifos runoff at fairly equal rates within the watershed. Runoff derived from urban land uses accounts for about 88% of the diazinon baseflow load, and 96% of the stormflow load. Agricultural sources (including nurseries) account for the remainder of the load. For chlorpyrifos, runoff derived from urban land uses accounts for about 85% to 88% of the baseflow and stormflow loads, while agriculture (including nurseries) accounts for about 12% to 15% of the load.

Average diazinon concentrations in San Diego Creek exceeded the chronic numeric target, and 95% of the observed concentrations were also above the acute numeric target.

Average chlorpyrifos concentrations in San Diego Creek exceeded the chronic numeric target, and at least 59% of the observed concentrations exceeded the acute numeric target. The average chlorpyrifos concentration observed in Upper Newport Bay during a storm event exceeded the saltwater chronic numeric target, and 80% of the concentrations exceeded the acute numeric target.

The diazinon re-registration agreement by EPA will likely end over 90% of current diazinon use in the Newport Bay watershed. If runoff concentrations show a corresponding decline, diazinon concentrations in San Diego Creek could decrease below the chronic numeric target (50 ng/L).

The chlorpyrifos re-registration agreement by EPA will likely end over 90% of current chlorpyrifos use in the Newport Bay watershed. If runoff concentrations show a corresponding decline, chlorpyrifos concentrations in San Diego Creek and Upper Newport Bay could decline below the respective chronic numeric targets for freshwater and saltwater.

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Part D—Selenium (Se)

Introduction

Selenium (Se) is a natural trace element in the environment that has chemical and physical properties that are intermediate between those of metals and non-metals. It is an essential nutrient for fish, birds, animals, and humans. One of the most important features of selenium is the very narrow margin between nutritionally optimal and potentially toxic dietary exposures for vertebrate animals (Wilber 1980). Excessive amounts of selenium are found to cause toxicity in wildlife. Toxicological effects of selenium on wildlife include lowered reproduction rates, shortened life spans, and stunted growth. Many of these effects are not readily observable and detailed biological studies are required to determine whether or not selenium is negatively impacting biota in a watershed.

This Technical Support Document presents an analysis of the major sources of selenium to San Diego Creek and Upper Newport Bay. Monitoring results and preliminary data on potential sources of selenium in the watershed are reviewed. These studies were not detailed enough to identify all sources, but it is largely recognized that one of the primary sources of selenium in the watershed is from shallow groundwater that enters San Diego Creek through seeps, springs, and weepholes.

Most of the information presented in this Technical Support Document was selected from the DRAFT Selenium TMDL written by Regional Board staff (2001a).

I. Physicochemical description of chemical toxicant

Selenium exists in different environmental compartments that are atmospheric, marine, and terrestrial in nature. Heterogeneity in its distribution results in movement of selenium among those compartments (Nriagu 1989). Parent materials having the highest selenium concentrations are black shales (around 600 mg / kg dry) and phosphate rocks (1-300 mg / kg dry); both of which can potentially give rise to seleniferous soils and food chain selenium toxicity. Selenium can become mobilized and concentrated by weathering and evaporation in the process of soil formation and alluvial fan deposition in arid and semiarid climates (Presser 1994), and through leaching of irrigated agricultural soils and remobilization in irrigation water (Presser and Ohlendorf, 1987; Seiler *et al.* 1999). Selenium contamination of aquatic ecosystems is of special concern in large parts of California, and other semi-arid regions of western North America (Seiler *et al.* 1999).

Chemical Forms/ Speciation

The chemical speciation of selenium is a critical consideration in assessing selenium contamination in that the bioavailability and toxicity of selenium are greatly affected by its chemical forms. Selenium can occur in four different oxidation states: selenide (–2), elemental selenium (0), selenite (+4), and selenate (+6). In general, selenate (Se^{6+}) has a high solubility and is the most mobile in water. Selenite (Se^{4+}) is soluble in water but its strong affinity to be adsorbed to soil particles greatly reduces its mobility. Elemental selenium (Se^{0}) exists in a crystalline form and is usually incorporated in soil particles. In most surface waters, selenate and selenite are the most common chemical forms. Selenite is the most bioavailable of the dissolved phase inorganic species (Maider *et al.* 1993; Skorupa 1998). Though some data suggests that selenite is more toxic than selenate, selenate toxicity data are scant (Nagpal and Howell, 2001). A decrease in cell division and growth rates of some species of algae exposed to selenate have been shown by several studies (Davis et al., 1988; Dobbs et al., 1996; Richter, 1982). Selenate is also readily taken up by plants and thereby enters the food chain (pers. comm., D. Lemly). Organo-selenide was also found to

be very bioavailable and hence potentially toxic to algae, invertebrates, and fish (Maider *et al.* 1993).

Selenium is also found with particulate matter, which may include primary producers (*e.g.*, phytoplankton), bacteria, detritus, suspended inorganic material, and sediments. Interactions and transformation of selenium between dissolved and particulate phases could be biological, chemical, and/or physical in nature. Those reactions play an important role in selenium toxicity (Luoma and Presser 2000). Since all forms of selenium may interconvert however, they should all be considered toxicologically important (T.Fan and G.Cutter, commun. 1998)

Bioaccumulation
Selenium tends to bioaccumulate in bio-tissues and causes toxicological effects. There is strong evidence that the major selenium uptake route into fish is not accumulation from water, but rather via the food chain (Fowler and Benayoun 1976; Wilber 1980; Luoma *et al*. 1992). Bioaccumulation of selenium in lower trophic level invertebrates (*e.g.*, zooplankton and bivalves) is a critical step in determining the effects of selenium since higher trophic level predators such as fish and birds feed on invertebrates. Studies have shown that uptake of dissolved selenium by invertebrates is not as important as uptake from diet (Luoma *et al.* 1992; Lemly 1993). Luoma and Presser (2000) suggested that direct uptake of particulate selenium by invertebrates via filter-feeding or deposit feeding is the primary route for selenium to enter the food web. In laboratory studies of the mussel *Mytilus edulis*, dissolved selenite (+4) is the most bioavailable form of inorganic selenium taken up from solution (Wang *et al.* 1996). However, Luoma *et al.* (1992) showed that the uptake rate of dissolved selenite explained less than 5% of the tissue concentrations of selenium accumulated by the clam *Macoma balthica* at concentrations typical of the San Francisco Bay-Delta. The role of dissolved organic selenides in selenium bioaccumulation is not as well understood as availability of inorganic selenium, but it is unlikely that its uptake rate is greater than uptake rates from food (Luoma and Presser 2000).

II. Monitoring Results

Surface Waters and Groundwater
IRWD monthly monitoring data from 12/1997 to 3/1999 (Figure D-1) indicate consistent violation of the numeric target (5 µg/L) in San Diego Creek at Campus Drive. Figure D-1 shows selenium concentrations in relation to flow rate. No strong correlation is found. However, daily loads estimated from concentrations and flow data seem to exhibit a pattern when plotted as a function of flow rate (Figure D-2). In general, the estimated daily load shows an increasing trend with flow rate at the low end of the flow spectrum. There are too few data points to determine the load pattern at high flow rates.

The monitoring data at Campus Drive provides an estimation of loading to Newport Bay. This estimate uses a statistical method to calculate annual load. The calculation methodology is summarized in Section IV of this document. As discussed in the TMDL summary document, the annual load of selenium is estimated to be 2,443 lbs/year (4/1/98 - 3/31/99) with a dry season load of 1,196 lbs (4/1/98 - 9/30/98) and a wet season load of 1,247 lbs (10/1/98 – 3/31/99). Detailed calculations and data used are shown in Section IV of this TSD (see Table D-3).

III. Source Analysis

Selenium Source Identification Study
Hibbs and Lee (2000) investigated sources of selenium in the Newport Bay/San Diego Creek watershed. The study area is shown in Figure D-3. The study presents convincing evidence that groundwater is a significant source of selenium to San Diego Creek and Newport Bay. At the watershed scale, the study

shows that selenium concentrations exceed the numeric target in most of the surface and groundwater samples collected, and that they exhibit spatial heterogeneity (Figure D-4). Concentrations in groundwater range from below 4 µg/L (method detection limit) to 478 µg/L. A statistical analysis shows that selenium concentrations in groundwater samples were generally found to be higher within the boundaries of a historical marsh ("Swamp of the Frogs" or "La Cienega de las Ranas") than in other areas. Radioisotope analysis on the water samples suggest that high selenium concentrations in groundwater result from oxidation and leaching of subsurface soils in the saturated zone underlying the old marsh area.

Monitoring of nursery discharge shows selenium concentrations in most runoff samples (6 out of 7) were below detection limits (*i.e.*, < 4 µg/L). One sample was detected at 7 µg/L from Bordiers Nursery. Surface water monitoring shows that discharges containing less than 10 µg/L selenium were mostly urban and agricultural runoff. Surface channels and drains with particularly high concentrations coincide with areas where high selenium groundwater samples were collected. Those channels include Como Channel (38 to 42 µg/L), Valencia Drain at Moffett Drive (25 to 40 µg/L), Warner Drain (24 to 33 µg/L), and the circular drains at Irvine Center Drive (141 to 162 µg/L) and at Barranca Parkway (107 µg/L). Channel inspection and chemical composition analysis indicate that those drainage channels collect considerable amounts of groundwater.

Three drainage channels (San Diego Creek above the confluence with Peters Canyon Wash, Como Channel, and Santa Fe Channel) were selected for detailed flow and chemical investigation. In these three channels, stream flows were measured at upstream and downstream gage stations. Results indicated that these channels are gaining streams in the reaches studied. Namely, the increases in flow rates result from seepage of groundwater into the surface channels.

An analysis of the flow and concentration data indicates the significance of groundwater as a source of selenium. The total selenium load from groundwater in these three reaches is approximately 0.36 lbs/day. The surface water loading of selenium at Campus Drive falls in the range of 1.6 to 4 lbs/day at low flow conditions (see Figure D-1). The comparison shows that groundwater inputs to these three reaches alone represent a significant portion (9 to 22%) of the total selenium load to Newport Bay, indicating the significance of groundwater inputs of selenium to surface water. Selenium loads from groundwater may account for up to 70% of the total selenium load in the creek under base flow conditions (pers. comm., B. Hibbs). Detailed calculations are summarized in Table D-6 (Appendix B).

Results of the study suggest that discharges from groundwater cleanup projects and shallow groundwater dewatering activities are potential sources of selenium and could be significant depending on the locations of these activities. However, selenium information is not yet available for these discharges.

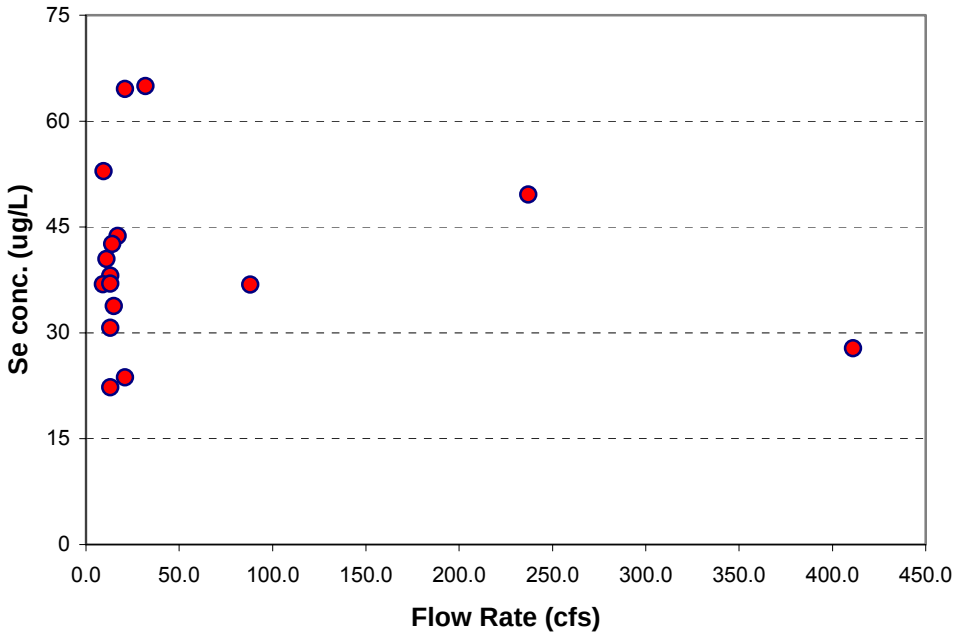

Figure D-1. Relationships between dissolved selenium concentration and flow rate at Campus Drive in San Diego Creek for March 1997 to March 1998 (selenium data: IRWD, flow data: OCPFRD).

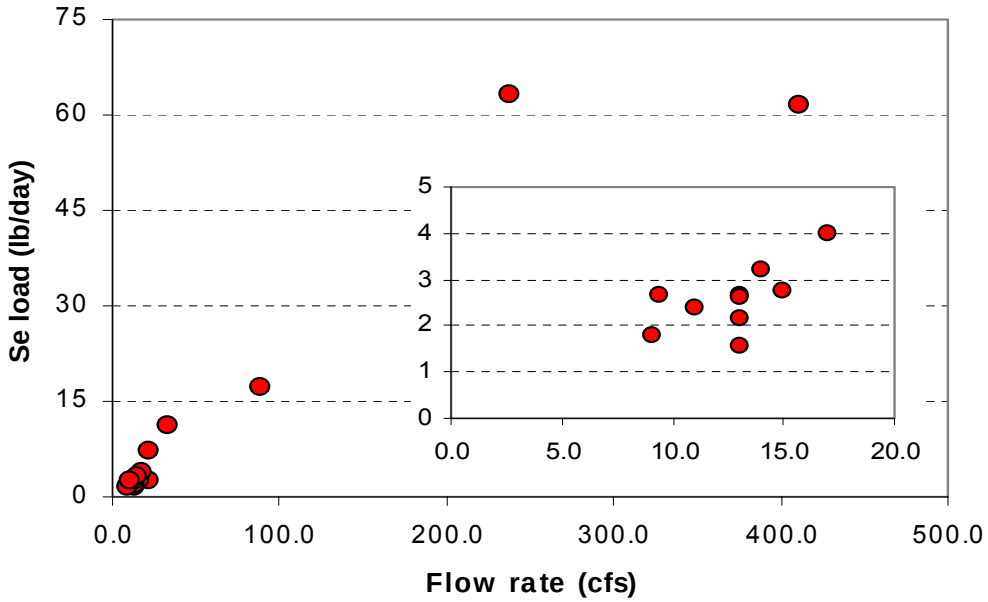

Figure D-2. Estimated selenium daily load (lbs / day) as a function of flow rate (cfs) at Campus Drive in San Diego Creek for March 1997 to March 1998 (selenium data: IRWD, flow data: OCPFRD).

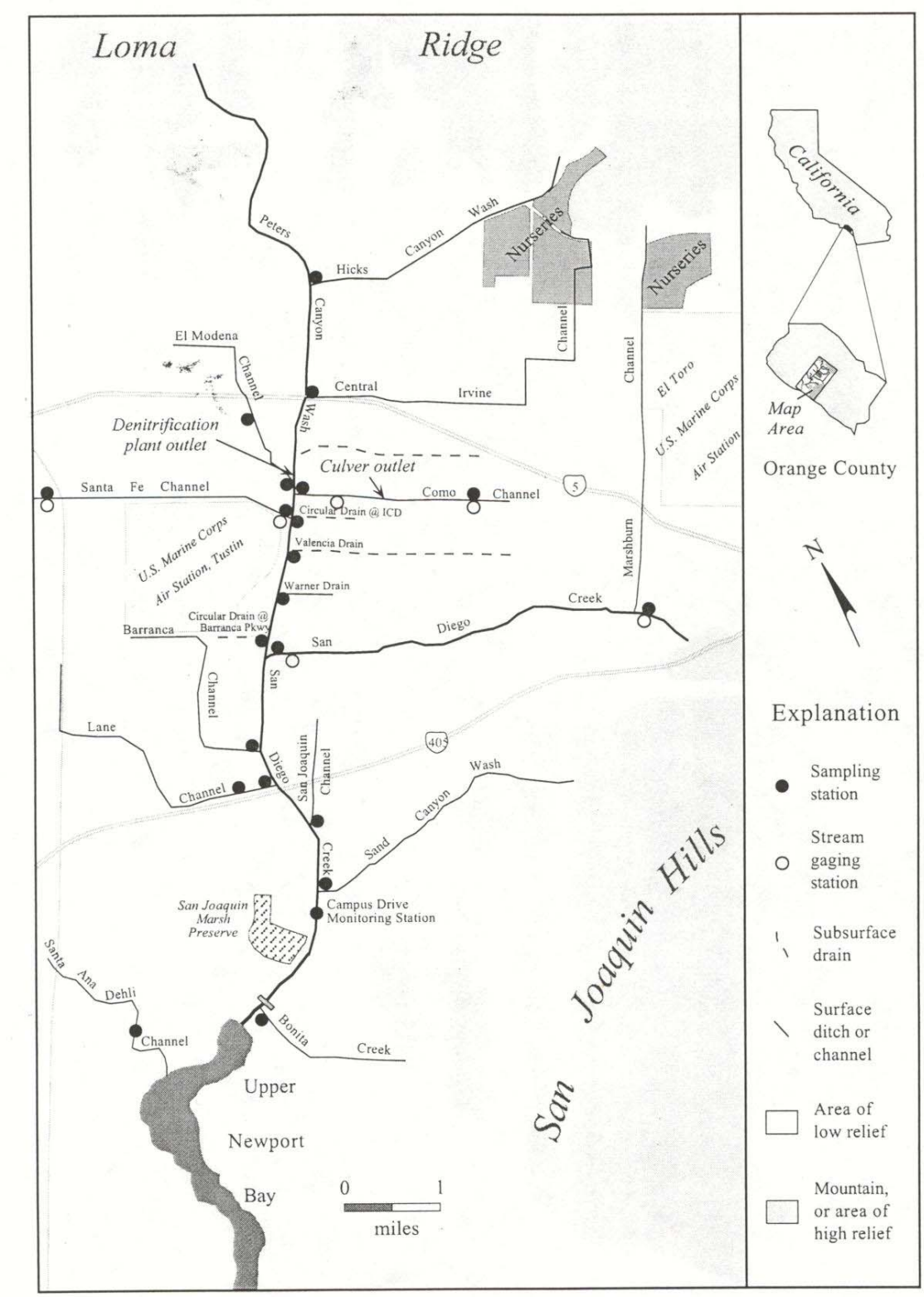

Figure D-3. Map of study area, showing the locations of water sampling stations and stream gage stations on important channels and creeks (source: Hibbs and Lee 2000).

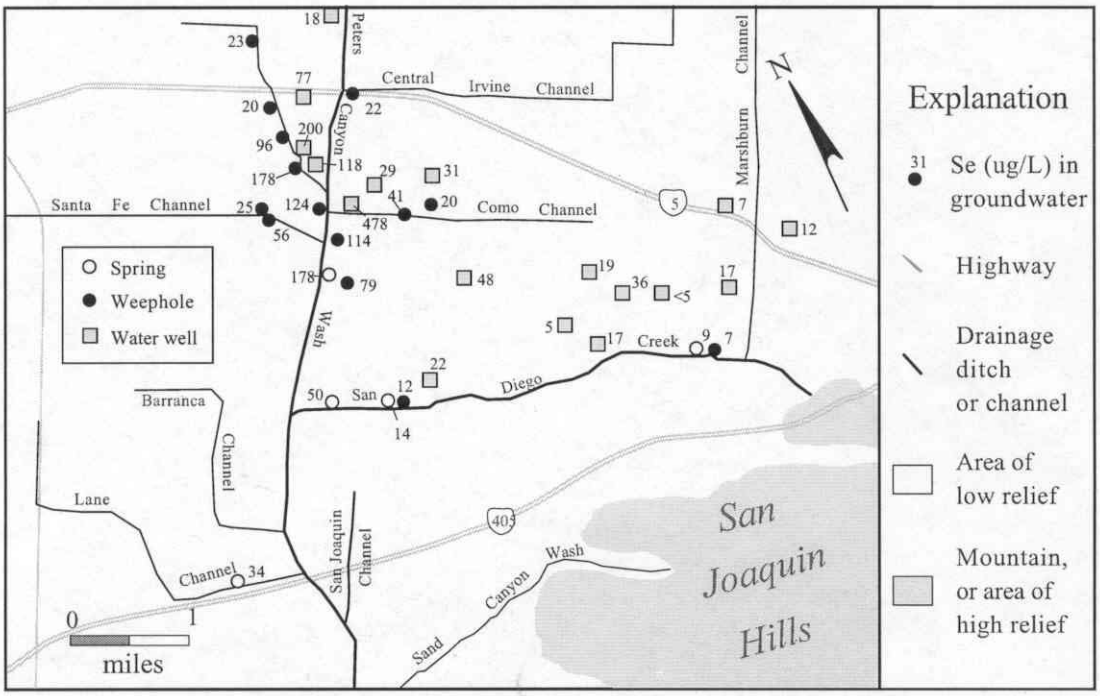

Figure D-4. Selenium concentrations in groundwater (µg/L). Sample points include water wells, weepholes, and springs (data source: Hibbs and Lee 2000).

OCPFRD Sept.1999 Peters Canyon Wash/San Diego Creek Nutrient Study

As part of the investigation of nutrient sources in the San Diego Creek watershed, OCPFRD conducted a one-week program of measurements of flow rate in tributaries of Peters Canyon Wash and reaches 1 and 2 of San Diego Creek in September 1999. The flow information allows estimation of groundwater flow inputs to surface channels at the watershed scale. Results show that the net increase in flow at Barranca Parkway in Peters Canyon Wash was approximately 0.36 cfs in the reach studied. Increases in San Diego Creek were 1.32 and 0.79 cfs for reach 1 and reach 2, respectively. These net flow increases, calculated by subtracting measured creek flow from its tributary flows, are believed to be contributions from groundwater via seepage and weepholes. The net flow increases a total of 2.47 cfs, which represents a significant portion of the Creek at Campus Drive. It should be noted that the overall contribution of groundwater to surface flow is expected to be larger since inputs of groundwater to the tributaries (*e.g.*, Como and Santa Fe Channels, Table D-6, Appendix B) are not included in the calculation.

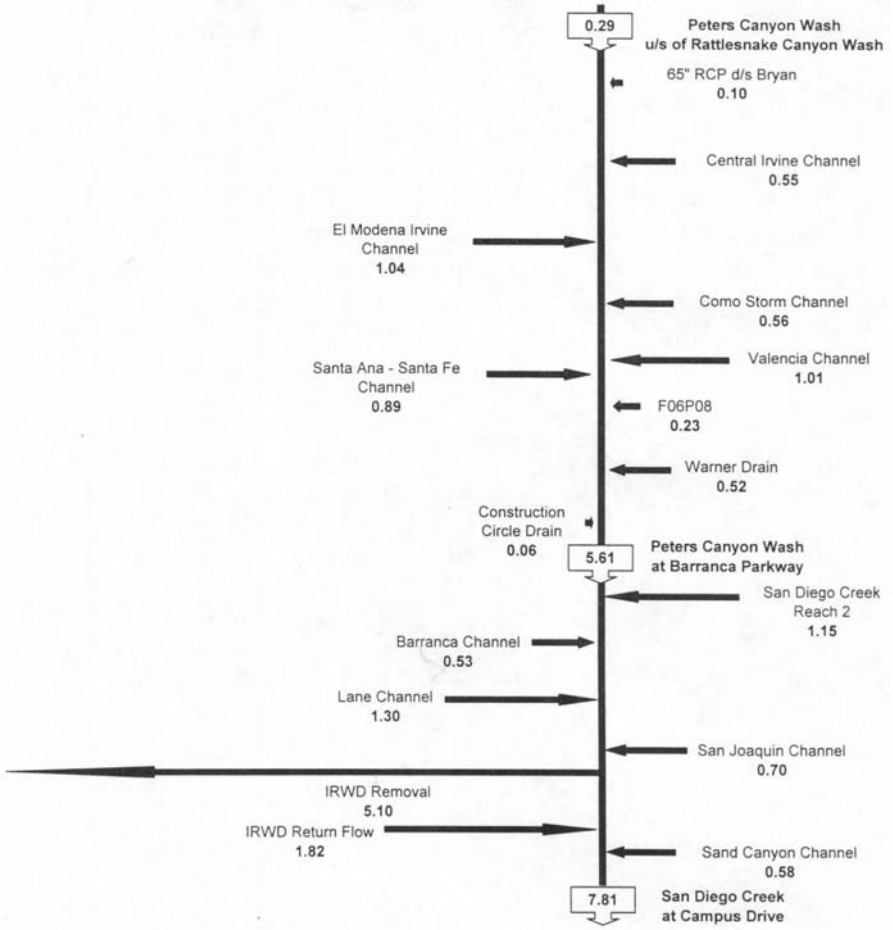

Figure D-5. Average daily flow rates (cfs) in tributaries to Peters Canyon Wash and Reaches 1 and 2 of San Diego Creek, September 12-20, 1999 (data: OCPFRD 2000).

Aquatic Toxicity Study (Lee & Taylor 2001a)

As part of the 319(h)study, Lee and Taylor (2001a) investigated sources of acute toxicity in the San Diego Creek watershed. Samples were collected on four days in 2000 – 01/25, 02/12, 02/21, and 05/31. The sampling in January and February occurred during storm events and the January sampling represents a "first-flush" event, according to flow records. The May sampling provides information under base flow conditions. Chemical analysis allows differentiation of dissolved and particulate selenium. Sampling stations and selenium concentrations are summarized in Table D-5, Appendix B. The results suggest that water-borne selenium mostly existed in dissolved forms under low flow conditions. Particulate fractions (*i.e.*, total minus dissolved) of selenium during rain events fall in a wider range than those found in dry weather (5/31/00 samples). Consistent with other monitoring data, the measured concentrations exceed the numeric target at most of the locations.

There was only one sample collected on January 25, 2000 and the total selenium concentration was 15.6 µg/L at Campus Drive. Total selenium concentrations for the rest of the sampling days are shown in Figures D-6 – D-8. These figures show spatial distributions of selenium concentrations in the watershed and allow comparisons of loading from different tributaries. Table D-1 lists estimated loads at four locations in the watershed. Several observations concerning selenium sources are summarized below:

- During rain events, high concentrations were found at Hines Channel and Sand Canyon Channel during storms (Figures D-6 and D-7), suggesting that selenium sources exist upstream of the sampling locations when rain events occur. These sources may include runoff from hillside, open fields, agricultural lands, and nurseries. The high concentrations were diluted downstream as flows increased.

- The dry weather sample collected in May (Figure D-8) from Hines Channel shows a low concentration, which is consistent with the findings in Hibbs' study. This suggests that contributions from nursery channels to the watershed are small under base flow conditions.

- The estimated loads indicate that San Diego Creek contributes a substantially higher selenium load to the Bay than Santa Ana-Delhi channel. Of the load at Campus Drive, Peters Canyon Wash is the biggest contributor of selenium in the San Diego Creek watershed in dry weather. As noted in section III of this TSD, the contribution is attributable to inputs of groundwater to Peters Canyon Wash.

- Selenium loads at Barranca Parkway in Peters Canyon Wash did not change considerably between base flow conditions and rain events. The drainage area consists of mostly urban land uses, suggesting that urban selenium loads are not significant.

- Loading at Harvard Avenue in San Diego Creek increases substantially during rain events compared to that in base flow conditions. Estimated loads (Table D-1) are comparable to those from Peters Canyon Wash. The drainage area for Harvard Avenue in SDC covers more open space than that in Peters Canyon Wash drainage area (see Figure A-2, TSD Part A, for land uses). The seasonal variation in loading suggests that open space runoff is a potential source of selenium during rain events.

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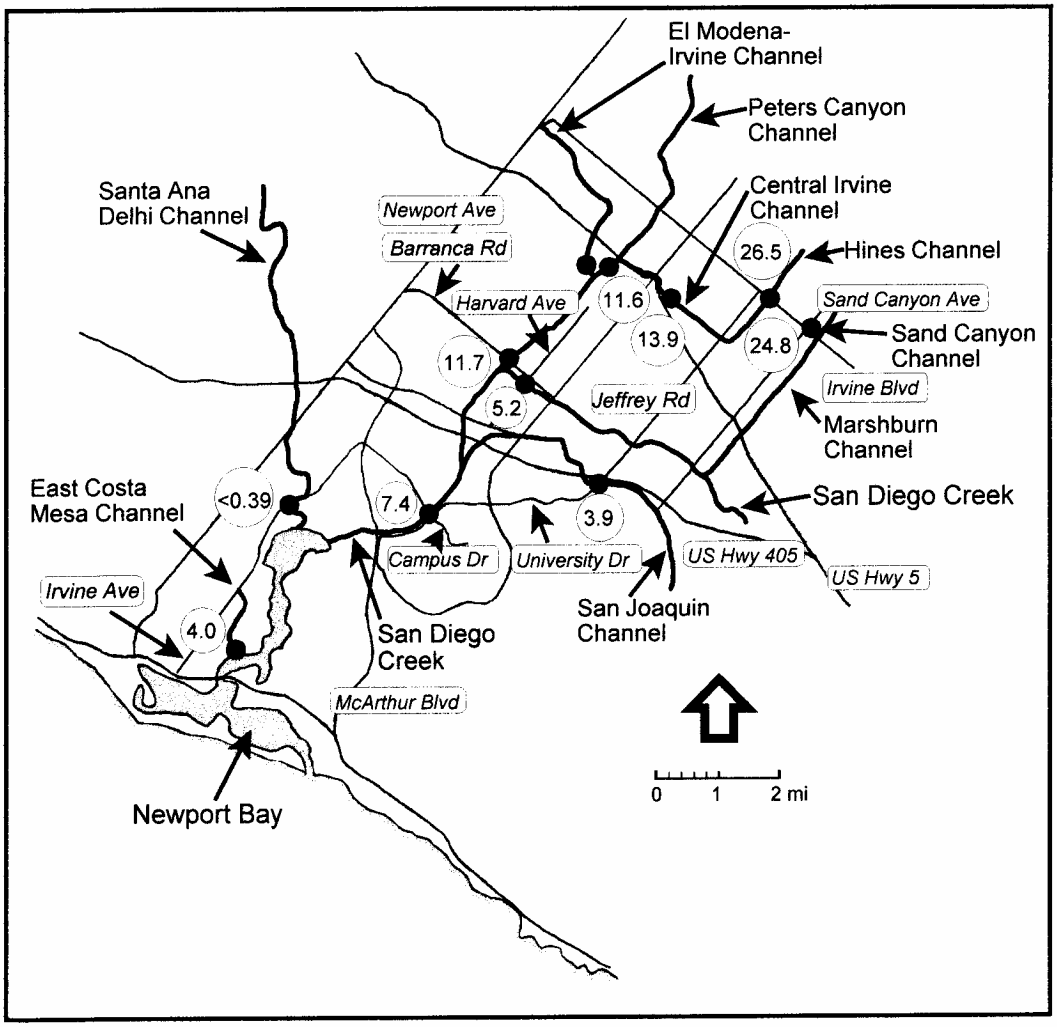
Table D-1. Calculated selenium loads from major tributaries in Newport Bay/San Diego Creek watershed

	SDC[a] @ Campus	SDC @ Harvard	PCC[b] @ Barranca	Santa Ana-Delhi
2/12/00				
Conc. (µg/L)	7.4	5.2	11.7	<0.39
Flow[c] (cfs)	96.5	49.9	30.8	23.7
Load (lbs/day)	**3.86**	**1.40**	**1.95**	**<0.05**
2/21/00				
Conc. (µg/L)	5.4	5.4	8.2	3.4
Flow[c] (cfs)	96.5	49.9	30.8	23.7
Load (lbs/day)	**2.81**	**1.45**	**1.36**	**0.44**
5/31/00				
Conc. (µg/L)	22.1	10.1	31	11.9
Flow[c] (cfs)	14.6	3.62	8.21	3.29
Load (lbs/day)	**1.74**	**0.20**	**1.37**	**0.21**

[a]San Diego Creek, [b]Peters Canyon Wash, [c]Monthly average flow rate

(Conc. * Flow * conversion factor = lbs/day or µg/L * ft^3/sec * 0.0054 = lbs/day)



Total Selenium Concentrations (µg/L)
February 12, 2000
(Wet Weather Sampling)

Figure D-6. Spatial distribution of total selenium concentrations during a storm on February 12, 2000 (from Lee and Taylor 2001a).

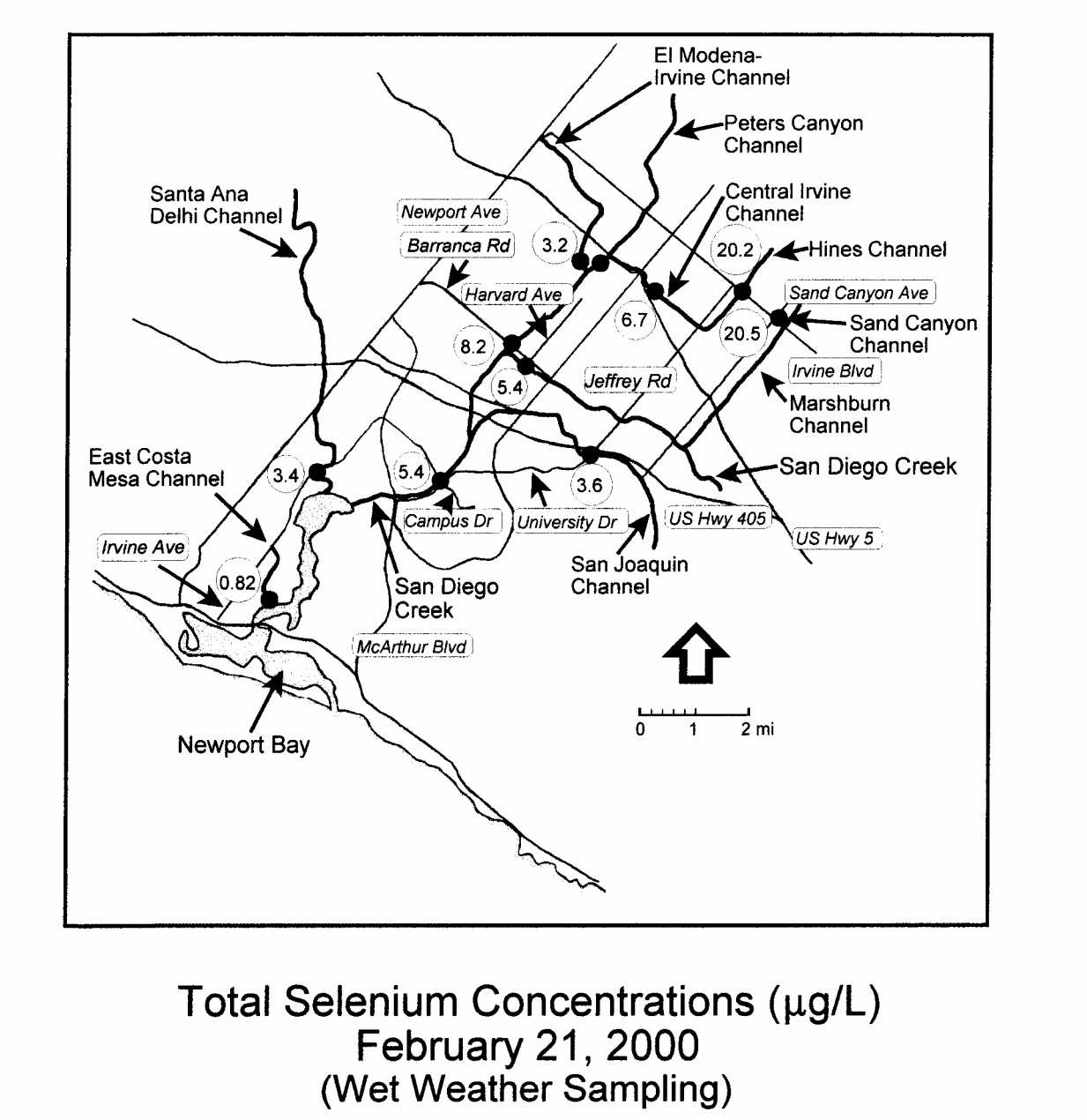
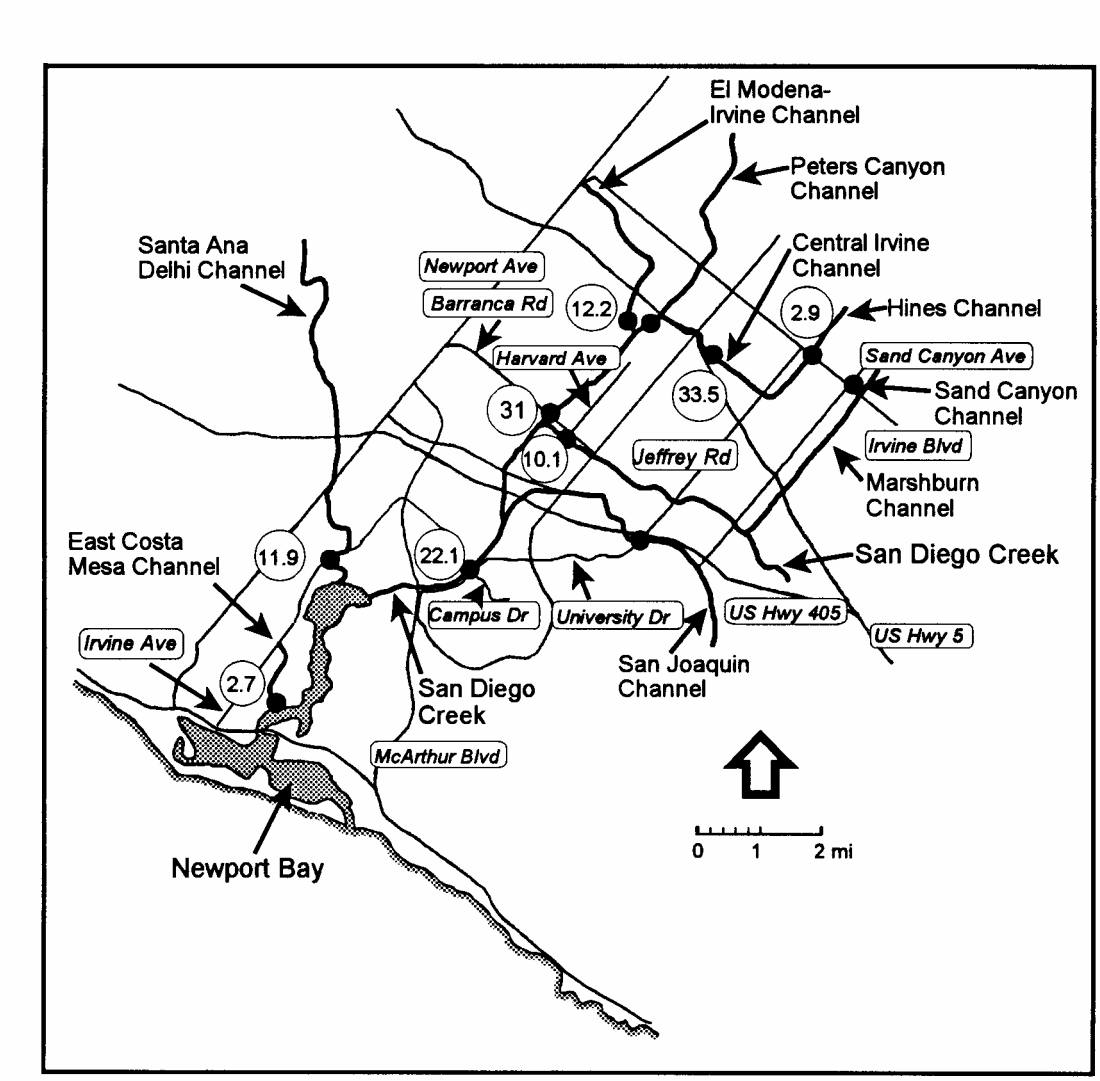


Figure D-7. Spatial distribution of total selenium concentrations during a storm on February 21, 2000 (from Lee and Taylor 2001a).



Total Selenium Concentrations (µg/L)
May 31, 2000
(Dry Weather Sampling)

Figure D-8. Spatial distribution of total selenium concentrations on May 31, 2000 (from Lee and Taylor 2001a)

Residential Runoff Reduction (R3) Study

The R3 study was initiated in 2000 by a multi-agency workgroup to reduce the impact of urban residential runoff and conserve domestic and reclaimed water resources. The workgroup includes the Southern California Coastal Water Research Project (SCCWRP), the Municipal Water District of Orange County (MWDOC), National Water Research Institute (NWRI), Department of Pesticide Regulations (DPR), the Irvine Ranch Water District (IRWD), and Santa Ana Regional Water Quality Control Board (SARWQCB). The study identified five isolated residential communities to allow investigation of pollutant loading strictly from residential areas. As a part of the baseline monitoring, selenium concentrations in the runoff samples collected from 11/28/00 to 7/3/01 were measured. Results show that all samples were below detection limits of the analytical methods used (1.5 µg/L and 5 µg/L). This suggests that urban runoff is not a significant source for selenium.

Background concentrations

Studies are currently in progress to more accurately assess the extent of selenium levels in various sources in the watershed. No monitoring data are available to determine the extent of selenium sources within the Bay. This might be attributed to very low selenium concentrations in seawater. On the global scale, average seawater dissolved selenium concentrations are 0.03 µg/L and 0.095 µg/L in the surface mixed layer of oceans and in deep oceans, respectively (Nriagu, 1989). In Northern California, dissolved selenium was reported to be 0.1 µg/L at Golden Gate in San Francisco Bay (San Francisco Estuary Institute 1997). These reported levels of selenium fall below the chronic seawater numeric target value (71 µg/L). Therefore, selenium input from seawater is not expected to be significant.

Atmospheric Deposition

Deposition of selenium from the atmosphere is a part of the global cycling of selenium and it represents a source to the watershed. The physical constituents of atmospheric selenium are the particle phases, predominantly less than 1 µm in diameter (Duce *et al.* 1976), and gaseous forms (Mosher and Duce 1983). Gaseous atmospheric selenium can bond to particulate material for long-range transport. Deposition of selenium from the atmosphere to the global surface occurs in both wet and dry forms. Dry deposition accounts for the exchange of particulate and gaseous material between the atmosphere and the global surface. It is usually insignificant compared to wet deposition. Wet deposition refers to rainout and washout of all forms of atmospheric selenium. It is the most important removal mechanism for selenium from the atmosphere to the earth surface. Reported rain concentrations in urban areas are in the range of 0.1 to 0.4 µg/L (Mosher and Duce 1989). Selenium load due to rainfall is then estimated to be 1.43 lbs/year to the Bay (1,363.6 acres, open water area) assuming rainfall concentration of 0.4 µg/L and annual rainfall of 11.6 in (historical average at Newport Beach Harbor Master station, OCPFRD). Therefore, atmospheric deposition is insignificant compared to the load at Campus Drive in San Diego Creek.

Summary of source analysis

In summary, existing data are limited for a thorough study and investigation of the sources and impacts of selenium to Newport Bay/San Diego Creek watershed. The data available allow preliminary assessment of the problem. Conclusions of the analysis in this report are summarized as follows:

- IRWD monitoring data provide analysis of the relationship between concentration, load, and flow rates. The monthly monitoring data at Campus Drive shows no apparent trend between concentration and flow rate. Daily load increases with flow rate and seems to reach a plateau at high flow rates during large storms. However, there were only two data points greater than 100 cfs and they are not sufficient to determine a trend at the high end of the flow spectrum. Statistical analysis of the data estimates that the annual selenium load was 2,443 lbs. from 4/1/98 to 3/31/99.

- Hibbs and Lee's study (2000) provides convincing evidence that shallow groundwater is a significant source of selenium to surface waters in the San Diego Creek watershed. Flow increases in three drainage channels selected were attributable to contributions from groundwater. (See Table D-5 in Appendix B of this TSD.) Measurements of selenium concentrations were found to be substantially higher downstream in these channels than upstream as a result of groundwater inputs. Surface channels associated with high selenium concentrations coincide with areas where high groundwater water concentrations of selenium were found, namely, the general area of Peters Canyon Wash and its tributaries. High selenium concentrations are also found in deeper groundwater in the watershed (IRWD, comment letter, May 2002). This suggests that groundwater cleanup and dewatering operations could be significant sources of selenium to the watershed.

- The OCPFRD investigation of nutrient sources reveals the magnitude of groundwater flow input to surface water. Three major reaches (Peters Canyon Wash, both reaches of San Diego Creek) all contain significant amounts of groundwater in the channel flows.

- The 319(h) study for identifying toxicity source in San Diego Creek watershed (Lee and Taylor 2001a) provides spatial distributions of selenium concentrations in the watershed. San Diego Creek contributes the largest load of selenium to Newport Bay. Of the load from San Diego Creek, Peters Canyon Wash, which collects selenium from selenium-laden shallow groundwater, represents the major source. Nursery channels showed low concentrations during base flow conditions. However, high concentrations were found in the channels during rain events (large flows), suggesting sources existing upstream of the channels. These sources may include runoff from hillsides, open spaces, agricultural lands, and commercial nursery sites. Further studies are needed to identify the sources. During rain events, the selenium load from San Diego Creek-Reach 2 was comparable to that from Peters Canyon Wash, suggesting runoff from open space is a potential source during rain events.

- Atmospheric deposition of selenium is not significant compared to loading from San Diego Creek and other tributaries. Natural selenium concentrations in seawater are unlikely to cause ecological impacts.

Figure D-9 shows sources of selenium in the watershed. The significance of these sources varies, in part depending on the location of discharges and the season of the year (see discussion in Section III, Source Analysis). In general, groundwater seepage / infiltration represents a significant and constant source. Runoff from open space, hillsides, and agricultural lands could be significant sources during rain events. Nursery runoff contains relatively low concentrations of selenium (< 7 µg / L) in dry weather yet are potential sources during storms.

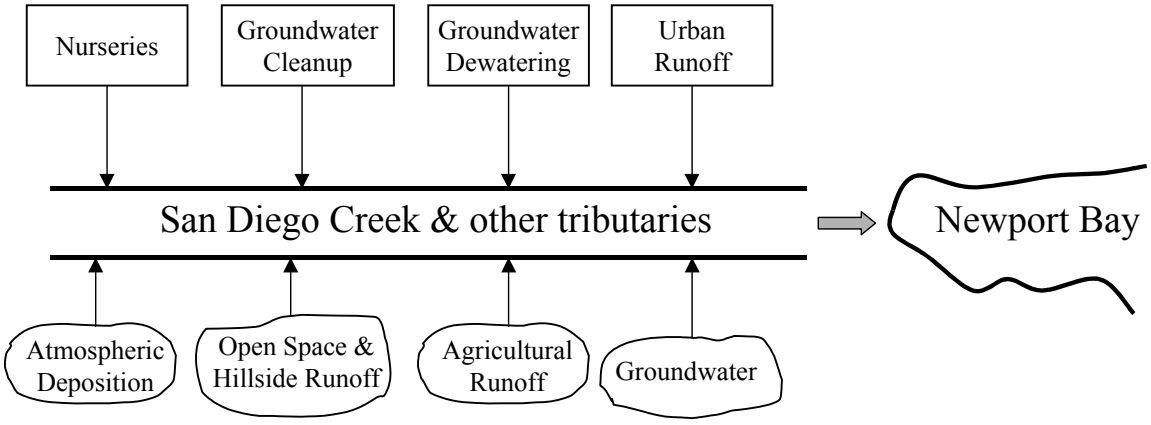


Figure D-9. Sources of selenium in the Newport Bay / San Diego Creek watershed. Sources in boxes are point sources, others are non-point sources.

IV. Approach to Calculating Loads

In southern California, a Mediterranean climate prevails, with dry summer and wet winter seasons. As a result, water bodies typically experience distinctly different seasonal flows and pollutants loads. In the dry season, surface channels in the watershed are mostly at their base flow conditions except those days when rain events take place. In the wet season, rain events occur more frequently than in the dry season. Contributions of selenium from different sources vary under different flow conditions, resulting in variations in water quality (see Section III, Source Analysis). For this reason, flow-based load allocations are developed to achieve the calculated TMDL. Specifically, the annual flow spectrum at Campus Drive in SDC is divided into four flow tiers and loading capacities for each flow tier are allocated to identified pollutant sources. The breakpoints of the flow tiers are based on a statistical analysis of flow records in San Diego Creek at Campus Drive (see TSD—Part B for freshwater flow analysis).

Computation Methodology
The following is the step-by-step procedure used in estimating the current annual and seasonal selenium loads to Newport Bay. Step *a* defines the dry and wet seasons.

a. Use IRWD monthly data for selenium concentrations at Campus Drive in San Diego Creek. The one-year window, 4/1/98 – 3/31/99, is selected for estimating annual load. **Selenium load from 4/1/98 to 9/30/98 is termed dry season load and the remainder (10/1/98 – 3/31/99) is wet season load**. Annual load is then the combination of the dry season and wet season loads.

b. Use OCPFRD daily flow record for the same time period of analysis as in step *a*.

c. Take natural log of the concentration data from step *a*.

d. Calculate means (μ) and variances (s^2) of the natural logs obtained from step *c*.

e. Use the following formula to calculate expected values *ev* (also known as mean of the concentrations) for dry and wet seasons.

$$ev = e^{\left(\mu + \frac{s^2}{2}\right)}$$

Calculate upper and lower confidence limits, x_{hi} and x_{lo} from μ, s, and standardized normal deviate, z.

$$x_{hi} = e^{(\mu + zs)}, \qquad x_{lo} = e^{(\mu - zs)}$$

The value of z corresponds to a given probability of exceedence, which can be converted to a confidence level. For a confidence level of 90%, the z value corresponding to 0.90 is 1.28 (obtained from a standard normal distribution table).

f. Calculate expected selenium loads by multiplying the expected values (mean of concentrations) from step *e* by flow volumes from step *b* for both dry and wet seasons. Expected selenium loads are converted to pounds (lbs) using conversion factor 1 µg/L*cfs = 0.0054 lbs/day.

g. Repeat step *g* to obtain 90% confidence limits for expected selenium loads for dry and wet seasons by substituting the expected values with the confidence limits from step *f*.

Table D-2. IRWD monthly monitoring data and calculated daily load based on OCPFRD flow records from April 1998 to March 1999.

Date	Flow (cfs)	Se Conc. (ug/L)	Daily Load (lbs/day)
04/16/98	20	64.57	6.97
05/21/98	18	23.68	2.30
06/16/98	24	38.12	4.94
07/07/98	9.5	40.49	2.08
08/12/98	16	33.82	2.92
09/01/98	14	30.72	2.32
10/27/98	13	43.74	3.07
11/18/98	7.7	49.61	2.06
12/15/98	3.8	36.87	0.76
01/07/99	15	36.97	2.99
02/23/99	15	42.59	3.45
03/30/99	9.4	52.91	2.69

1 µg/L*cfs = 0.0054 lbs/day.
Complete set of daily flow records for this time period are shown in Appendix A.
Samples for selenium analysis were only collected during base flow and small storm events; therefore, the calculated daily selenium loads do not reflect selenium loading during medium and large storm flows.

Table D-3. Calculations of seasonal and annual loads of selenium using IRWD monitoring data and OCPFRD flow records from April 1998 to March 1999.

Date	**Conc. (ug/L)**	**Nat. log(conc.)**		**Dry 4/1/98-9/30/98**	**Wet 10/1/98-3/31/99**	**Total 4/1/98-3/31/99**
04/16/98	64.57	4.17	Mean	3.60	3.77	
05/21/98	23.68	3.16	Variance, s^2	0.11	0.02	
06/16/98	38.12	3.64	s	0.33	0.15	
07/07/98	40.49	3.70	ev	38.84	43.86	
08/12/98	33.82	3.52	Total flow (cfs)	5704.5	5264.1	
09/01/98	30.72	3.42	**Total Load (lbs)**	**1196.40**	**1246.79**	**2443.18**
10/27/98	43.74	3.78				
11/18/98	49.61	3.90	x_{hi} (90%)	56.37	52.44	
12/15/98	36.87	3.61	x_{lo} (90%)	23.92	35.88	
01/07/99	36.97	3.61	Load for x_{hi} (lbs)	1736.46	1490.80	3227.26
02/23/99	42.59	3.75	Load for x_{lo} (lbs)	736.88	1020.05	1756.93
03/30/99	52.91	3.97				

s = Standard Deviation
ev = Expected Value
x_{hi} = Upper Confidence Limit
x_{lo} = Lower Confidence Limit

Table D-4. Waste Load and Load Allocation Calculations for San Diego Creek Watershed.
(This table provides additional information regarding the allocations defined in Table 4.5 of the summary document.)

Source	4/98-3/99 Loading (lbs/year)	Allocations (lbs/year)					% ALLOCATION†† (for individual line items in box to left)			
		Tier 1	Tier 2	Tier 3	Tier 4	Annual Total	Tier 1	Tier 2	Tier 3	Tier 4
Wasteload Allocations (WLA)										
MCAS - Tustin		1.55	1.95	1.76	7.90	**13.16**	2.0%	2.0%	1.8%	1.5%
GW Cleanup		6.19	7.81	7.54	36.88	**58.4**	8.0%	8.0%	7.5%	7.0%
Silverado GTF		3.09	3.91	4.02	21.07	**32.1**	4.0%	4.0%	4.0%	4.0%
GW Dewatering		3.87	4.88	4.52	21.07	**34.3**	5.0%	5.0%	4.5%	4.0%
other GW facilities		0.39	0.49	0.50	2.63	**4.0**	0.5%	0.5%	0.5%	0.5%
Stormwater permit (MS4)		0.39	0.98	1.00	5.27	**7.6**	0.5%	1.0%	1.0%	1.0%
WLA Sub-total		15.47	20.01	19.34	94.83	**149.66**				
Load Allocations (LA)										
Hines Nursery		1.1	1.4	1.5	7.8	**11.9**	4.0%	4.0%	4.0%	4.0%
Bordiers Nursery		0.6	0.7	0.7	3.9	**5.9**	4.0%	4.0%	4.0%	4.0%
El Modeno Gardens		0.2	0.3	0.3	1.6	**2.5**	4.0%	4.0%	4.0%	4.0%
Nakase Nursery		0.4	0.4	0.5	2.4	**3.7**	4.0%	4.0%	4.0%	4.0%
AKI		0.1	0.1	0.1	0.5	**0.8**	4.0%	4.0%	4.0%	4.0%
Unpermitted nurseries		0.7	0.9	0.9	4.9	**7.4**	4.0%	4.0%	4.0%	4.0%
Nursery Sub-total		3.1	3.9	4.0	21.1	**32.1**				
Agriculture Runoff		5.4	7.3	8.0	44.8	**65.6**	7.0%	7.5%	8.0%	8.5%
Undefined Sources[1]		53.4	66.4	69.1	366.2	**555.0**	69.0%	68.0%	68.8%	69.5%
LA Sub-total		61.9	77.6	81.1	432.0	**652.6**				
Total allocations[2]	**2443[3]**	**77.4**	**97.6**	**100.5**	**526.8**	**802.3**				

Cutoff flow	Load %†
0 (cfs)	5 & 20¥ (µg / L)
20	9.6%
181	12.2%
814	12.5%
> 814	65.7%

¥The NTR acute criterion of 20 ug / L is only applied to large flows (>814 cfs) with an average annual duration of 3 days.

[1] Undefined Sources: Open space and hillside runoff, shallow GW, in-bay selenium. Atmospheric deposition has NOT been included as data indicates that this contribution is negligible.
[2] The flow tier total allocations are based on percentages shown in upper right hand corner (see †). Individual allocations per tier are further calculated using values in %allocations columns (see ††).

89.145 MOS

891.45 TMDL

SARB_001345

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Appendix A — Daily flow records for San Diego Creek at Campus Dr. (OCPFRD data, March 1998 to April 1999) used for calculating current selenium load estimates in Table D-2

Date	Flow (cfs)	Date	Flow (cfs)	Date	Flow (cfs)	Date	Flow (cfs)
03/01/98	88	04/20/98	22	06/09/98	20	07/29/98	18
03/02/98	75	04/21/98	22	06/10/98	19	07/30/98	15
03/03/98	80	04/22/98	22	06/11/98	32	07/31/98	16
03/04/98	65	04/23/98	22	06/12/98	45	08/01/98	15
03/05/98	37	04/24/98	22	06/13/98	21	08/02/98	15
03/06/98	38.5	04/25/98	22	06/14/98	18	08/03/98	14
03/07/98	40	04/26/98	21.5	06/15/98	17	08/04/98	15
03/08/98	34	04/27/98	21	06/16/98	19	08/05/98	14
03/09/98	33	04/28/98	21	06/17/98	21	08/06/98	15
03/10/98	31	04/29/98	22	06/18/98	19	08/07/98	16
03/11/98	31.5	04/30/98	23	06/19/98	18	08/08/98	16
03/12/98	32	05/01/98	20	06/20/98	19	08/09/98	16
03/13/98	114	05/02/98	21	06/21/98	15.5	08/10/98	15
03/14/98	465	05/03/98	21	06/22/98	12	08/11/98	15
03/15/98	42	05/04/98	24	06/23/98	16	08/12/98	16
03/16/98	39.5	05/05/98	484	06/24/98	13	08/13/98	15
03/17/98	37	05/06/98	255	06/25/98	13	08/14/98	16
03/18/98	33	05/07/98	26	06/26/98	13.5	08/15/98	14
03/19/98	31	05/08/98	26	06/27/98	14	08/16/98	13
03/20/98	32	05/09/98	19	06/28/98	13	08/17/98	14
03/21/98	31.5	05/10/98	17	06/29/98	14	08/18/98	13
03/22/98	31	05/11/98	233.5	06/30/98	12	08/19/98	14
03/23/98	26	05/12/98	450	07/01/98	12	08/20/98	12
03/24/98	24	05/13/98	678	07/02/98	9.4	08/21/98	15
03/25/98	1110	05/14/98	46	07/03/98	9.7	08/22/98	15
03/26/98	582.5	05/15/98	30	07/04/98	10	08/23/98	14
03/27/98	55	05/16/98	24.5	07/05/98	9.5	08/24/98	13
03/28/98	322	05/17/98	19	07/06/98	11	08/25/98	13
03/29/98	60	05/18/98	17	07/07/98	9.5	08/26/98	16
03/30/98	41	05/19/98	17	07/08/98	7.8	08/27/98	15
03/31/98	475	05/20/98	18	07/09/98	9.6	08/28/98	16
04/01/98	373	05/21/98	17.5	07/10/98	14	08/29/98	11
04/02/98	75	05/22/98	17	07/11/98	11	08/30/98	11
04/03/98	40	05/23/98	18	07/12/98	10	08/31/98	11
04/04/98	40	05/24/98	18	07/13/98	10	09/01/98	14
04/05/98	35	05/25/98	17	07/14/98	11	09/02/98	16
04/06/98	35.5	05/26/98	18	07/15/98	9.4	09/03/98	18
04/07/98	36	05/27/98	19	07/16/98	9.6	09/04/98	28
04/08/98	55	05/28/98	18	07/17/98	11	09/05/98	17
04/09/98	54	05/29/98	22	07/18/98	11	09/06/98	11
04/10/98	30	05/30/98	20	07/19/98	10	09/07/98	11
04/11/98	57.5	05/31/98	21	07/20/98	11	09/08/98	11
04/12/98	85	06/01/98	22	07/21/98	12	09/09/98	12
04/13/98	31	06/02/98	21	07/22/98	15	09/10/98	12
04/14/98	26	06/03/98	22	07/23/98	13	09/11/98	13
04/15/98	24	06/04/98	20	07/24/98	16	09/12/98	13
04/16/98	31.5	06/05/98	20	07/25/98	17	09/13/98	14
04/17/98	19	06/06/98	20.5	07/26/98	16	09/14/98	14
04/18/98	21	06/07/98	21	07/27/98	14	09/15/98	14
04/19/98	20	06/08/98	20	07/28/98	16	09/16/98	14

Date	Flow (cfs)	Date	Flow (cfs)	Date	Flow (cfs)	Date	Flow (cfs)
09/17/98	15	11/06/98	17	12/26/98	4.4	02/14/99	15
09/18/98	18	11/07/98	15	12/27/98	4.3	02/15/99	16
09/19/98	18	11/08/98	452	12/28/98	4.5	02/16/99	16
09/20/98	17	11/09/98	11	12/29/98	4.3	02/17/99	16
09/21/98	17	11/10/98	7.8	12/30/98	9.7	02/18/99	16
09/22/98	19	11/11/98	8.8	12/31/98	12	02/19/99	16
09/23/98	19	11/12/98	7.7	01/01/99	12	02/20/99	16
09/24/98	19	11/13/98	7.2	01/02/99	12	02/21/99	17
09/25/98	19	11/14/98	7.3	01/03/99	15	02/22/99	15
09/26/98	18	11/15/98	7.4	01/04/99	13	02/23/99	15
09/27/98	18	11/16/98	7.7	01/05/99	13	02/24/99	16
09/28/98	18	11/17/98	7.5	01/06/99	13	02/25/99	16
09/29/98	17	11/18/98	7.7	01/07/99	15	02/26/99	16
09/30/98	20	11/19/98	7.9	01/08/99	14	02/27/99	15
10/01/98	16	11/20/98	5.5	01/09/99	13	02/28/99	14
10/02/98	15	11/21/98	3.7	01/10/99	13	03/01/99	88
10/03/98	17	11/22/98	4	01/11/99	14	03/02/99	75
10/04/98	16	11/23/98	4.1	01/12/99	14	03/03/99	80
10/05/98	15	11/24/98	4.1	01/13/99	13	03/04/99	65
10/06/98	14	11/25/98	4.1	01/14/99	14	03/05/99	37
10/07/98	15	11/26/98	4	01/15/99	14	03/06/99	38.5
10/08/98	18	11/27/98	3.9	01/16/99	13	03/07/99	40
10/09/98	16	11/28/98	237	01/17/99	13	03/08/99	34
10/10/98	18	11/29/98	7.9	01/18/99	12	03/09/99	33
10/11/98	17	11/30/98	3.9	01/19/99	11	03/10/99	31
10/12/98	16	12/01/98	348	01/20/99	44	03/11/99	31.5
10/13/98	17	12/02/98	36	01/21/99	21	03/12/99	32
10/14/98	19	12/03/98	7.4	01/22/99	15	03/13/99	114
10/15/98	19	12/04/98	20	01/23/99	13	03/14/99	465
10/16/98	17	12/05/98	71	01/24/99	12	03/15/99	42
10/17/98	17	12/06/98	211	01/25/99	284	03/16/99	39.5
10/18/98	17	12/07/98	6.1	01/26/99	361	03/17/99	37
10/19/98	16	12/08/98	4.8	01/27/99	302	03/18/99	33
10/20/98	16	12/09/98	4	01/28/99	19	03/19/99	31
10/21/98	16	12/10/98	3.7	01/29/99	16	03/20/99	32
10/22/98	15	12/11/98	3.5	01/30/99	14	03/21/99	31.5
10/23/98	16	12/12/98	3.6	01/31/99	243	03/22/99	31
10/24/98	16	12/13/98	3.5	02/01/99	21	03/23/99	26
10/25/98	24	12/14/98	3.6	02/02/99	14	03/24/99	24
10/26/98	14	12/15/98	3.8	02/03/99	13	03/25/99	1110
10/27/98	13	12/16/98	3.9	02/04/99	28	03/26/99	582.5
10/28/98	14	12/17/98	3.9	02/05/99	58	03/27/99	55
10/29/98	13	12/18/98	4.1	02/06/99	16	03/28/99	322
10/30/98	13	12/19/98	14	02/07/99	14	03/29/99	60
10/31/98	12	12/20/98	24	02/08/99	13	03/30/99	41
11/01/98	13	12/21/98	5	02/09/99	38	03/31/99	475
11/02/98	13	12/22/98	5.1	02/10/99	35		
11/03/98	13	12/23/98	6.4	02/11/99	15		
11/04/98	13	12/24/98	8.8	02/12/99	14		
11/05/98	14	12/25/98	9.1	02/13/99	15		

Appendix B—Surface Channel Selenium Data (4/15/99—5/1/00)

Table D-5. Selenium concentrations in tributaries, creeks, and drains of San Diego Creek (Hibbs and Lee 2000)

Sampling Location	Date	Conc. (ug/L)
Hicks Canyon Wash at confluence with Peters Canyon Wash	05/28/99	6
Central Irvine Channel at confluence with Peters Canyon Wash	05/28/99	11
El Modena Channel at Michelle Dr	04/15/99	<4
El Modena Channel at Michelle Dr	05/25/99	5
El Modena Channel at Michelle Dr	05/28/99	9
El Modena Channel at Michelle Dr	06/21/99	7
El Modena Chanel at confluence with Peters Canyon Wash	08/01/99	11
Como Channel at confluence with PCW	05/28/99	42
Como Channel at confluence with PCW	05/01/00	38
Santa Fe Channel at confluence with PCW	06/21/99	16
Santa Fe Channel at confluence with PCW	09/12/99	15
Santa Fe Channel at confluence with PCW	05/01/00	32
Circ. Drain at Irvine Center Dr at confluence with PCW	08/01/99	162
Circ. Drain at Irvine Center Dr at confluence with PCW	10/31/99	141
Valencia (Moffett) Drain at confluence with PCW	08/01/99	25
Valencia (Moffett) Drain at confluence with PCW	10/31/99	40
Warner Drain at confluence with Peters Canyon Wash	06/21/99	33
Warner Drain at confluence with Peters Canyon Wash	08/01/99	28
Warner Drain at confluence with Peters Canyon Wash	10/31/99	24
Circ. Drain at Barranca Pkwy at confluence with PCW	07/05/99	107
San Diego Creek at confluence with PCW	04/15/99	39
San Diego Creek at confluence with PCW	04/15/99	15
San Diego Creek at confluence with PCW	04/15/99	18
Barranca Channel at confluence with SDC	06/21/99	13
Barranca Channel at confluence with SDC	10/02/99	12
Lane Channel at confluence with SDC	07/05/99	25
Lane Channel at McCabe	10/02/99	21
Lane Channel at McCabe	11/08/99	18
San Joaquin Channel at confluence with SDC	07/05/99	11
San Joaquin Channel at confluence with SDC	10/31/99	9
Sand Canyon Wash at confluence with SDC	10/31/99	5
Bonita Canyon at confluence with SDC	07/05/99	14
Santa Ana Delhi Channel at Irvine Ave	07/05/99	18
San Diego Creek at Campus Dr	10/31/99	19

Table D-6. Selenium load from groundwater in three drainage channels based on upstream and downstream flow and selenium concentration measurements. (Hibbs and Lee 2000)

Channel	Date	Upstream		Downstream		Load from groundwater (lb/day)
		Flow (cfs)	Conc. (µg/L)	Flow (cfs)	Conc. (µg/L)	
San Diego Creek Reach 2	08/28/99	1.63	4	2.32	18	0.19
Como Channel	05/01/00	0.0004	<4	0.44	38	0.09
Santa Fe Channel	05/01/00	0.019	<4	0.46	32	0.08

Note: Daily loads of selenium from groundwater are calculated by the differences in loads between downstream and upstream.

Part E—Metals (Cadmium, Copper, Lead and Zinc)

Introduction

This section of the TMDL presents an analysis of the major sources of heavy metals to water bodies of Newport Bay. Information is compiled to develop TMDLs for cadmium in San Diego Creek and Upper Bay only, and for copper, lead and zinc in all waterbodies of Newport Bay including Rhine Channel. The source analysis summarizes monitoring results to provide a preliminary assessment of metal distribution relevant to water quality problems. Although many metals analyses have been completed in all media (water, soil and fish tissue), including toxicity tests which implicate metals as toxicants, no study has been completed to date that clearly establishes the source of any specific metal. Heavy metals are generally attributed to surface runoff from open space and urban areas; yet some metal inputs come from other sources such as nurseries and other agricultural applications within the watershed as well as recreational boat hulls (for copper).

This technical support document (TSD) begins by describing the chemical characteristics of each heavy metal, including aqueous behavior in natural waters. Next monitoring results for each metal in all waterbodies are reviewed and where feasible conclusions are included. Unfortunately, water column sampling methods were not consistent and quality control and quality assurance measures not uniformly completed, so there are some limitations in comparing and interpreting these surface water results. Descriptions and estimates of background sources (natural runoff and ambient seawater) and miscellaneous sources (e.g., copper from boat hulls, nursery applications and direct atmospheric deposition) are included.

The final section of this TSD explains methods used for calculating dissolved metal loads for each water body. This includes methods for determining dissolved metal loadings via the flow-based approach for San Diego Creek as well as the approach for approximating the Newport Bay loading capacity.

I. Physicochemical description of metal toxicants

Copper and Zinc are essential elements for all living organisms but elevated levels may cause adverse effects in all biological species. Cadmium and Lead are presumed to be non-essential elements for life; more importantly, even at extremely low environmental concentrations these elements may create adverse impacts on biota. In fact molecular biology studies have demonstrated that Cd and Pb atoms may substitute for other divalent metals such as Cu and Zn within enzyme binding sites. Biochemical similarities between these atoms suggest that Cd and Pb may also compete with cell surface uptake sites or bind to sulfur and nitrogen donor atoms of various functional groups within the cell. This is more likely to occur in freshwater systems (where dissolved calcium can be low) than in saline water since calcium ameliorates divalent metal toxicity (Playle and Dixon 1993).

Dissolved metals are directly taken up by bacteria, algae, plants, and planktonic and benthic organisms. Dissolved metals can also adsorb to particulate matter in water column and enter aquatic organisms through various routes. Cadmium, copper, lead and zinc may bioaccumulate within lower organisms, yet they do not biomagnify up the food chain as do mercury and selenium (Moore and Ramamoorthy 1984). Of all of these metals, copper is considered the most potent toxin at environmentally relevant aqueous concentrations. Copper is generally more toxic to lower aquatic organisms such as phytoplankton, copepods and ciliates than to birds or mammals because the higher animals seem capable of regulating copper concentrations in tissues (USF&W 1998). Copper is more commonly found in herbivorous fish than carnivorous fish from the same location (USF&W 1998). Copper is used as an aquatic herbicide to reduce algae growth in reservoirs and also applied (via antifouling paints) to boat hulls in marinas.

Importance of speciation in natural waters

The fate and transport of metals in natural waters is influenced by the physical state and chemical complexation of each element. Physical separation methods (i.e., filters) define metals associated with the particulate, colloidal or dissolved phases. Unfiltered or "total" metal samples represent the sum of all size fractions; whereas filtered or "dissolved" samples yield metals in solution. As a general rule, particulate metal concentrations are higher than those in dissolved phase for all metals in these TMDLs. This is based in part on the inherent reactivity of negatively charged particulate matter and positively charged metal ions (Buffle 1989). As outlined in the California Toxics Rule, EPA has defined aquatic life water quality criteria for these metals based on the dissolved fraction of aqueous samples (EPA 2000a); these serve as numeric targets for these TMDLs.

Within the dissolved fraction, metals exist in various chemical forms or species (Buffle 1989). Each divalent metal may exist by itself as the free metal ion (e.g., Cu^{++}) or it may combine with other elements to form inorganic complexes such as other hydroxyl or chloride chemical species (e.g., $CuOH^{+}$ and $Cu(OH)_2$ or $CuCl^{+}$ or $CuCl_2$). Metal-organic forms may also exist dependent on presence of soluble matter such as synthetic chelators, phytoplankton exudates, humic and fulvic acids and other forms of dissolved organic carbon. Metals change chemical forms in freshwater based on pH, temperature, oxygen, organic matter, and biological activity; toxicity is affected likewise. In general, acidic soft freshwaters demonstrate high toxicity to aquatic organisms due to elevated concentrations of free metal ions (e.g., Cu^{++}), the most bioavailable forms. By contrast, slightly alkaline hard freshwaters contain free calcium (Ca^{++}) and magnesium (Mg^{++}) ions to ameliorate divalent metal toxicity. In seawater systems, aquatic chemists have discovered much more metal bound up in organic complexes as compared to inorganic complexes (Bruland *et al.* 1994). For example within estuarine systems dissolved copper results appear to contain 90 to 99% organic complexes, consequently free copper ion concentrations are ca. 100 fold lower than dissolved copper concentrations (Donat *et al.* 1994). Similar results have been estimated for Pb (70 to 95%), Zn (50 to 97%) and Cd (70 to 80%) (Muller 1996, Kozelka and Bruland 1997). Organic complexation in freshwater systems exists and presumably at lower levels in flowing systems than relatively static ones. For primary producers such as phytoplankton, ciliates, copepods, and crab larvae, bioavailability is generally correlated to the free metal ion concentration, thus toxicity is much lower in seawater systems than in freshwater bodies (Sunda et al. 1987).

Sediments contain particulate sorbed metals, often referred to as bulk sediment concentrations. Interstitial porewaters of sediments also contain metals. Such porewaters may contain acid-volatile sulfides in concentrations higher than the combination of certain metals (Cd, Cu, Pb, Ni, Zn) and render that portion unavailable and non-toxic to biota (Di Toro et al. 1992).

II. Monitoring Results

Surface waters

In the past five years, three separate studies have compiled heavy metals monitoring data for freshwater bodies of Newport Bay. Below is a brief review of each study and some comments about sampling techniques relevant to comparisons to water quality standards. As previously noted, it is difficult to make direct comparison of water measurements since quality assurance and quality control was not consistent across each study. A summary of monitoring results for each dissolved metal by waterbody is provided in Tables E -- 1(a - d).

IRWD monitoring data

From Dec. 1997 to March 1999, Irvine Ranch Water District monitored 2 stations on bi-monthly basis. In general results include both wet weather and dry weather conditions, although sampling plan did not target to collect runoff from individual storms. Individual grab samples were collected using trace metal clean techniques and filtered in the laboratory prior to analysis. Thus results are best interpreted as single snap shots of water quality in San Diego Creek and can be compared only to acute (hardness dependent) water quality standards.

319(h) monitoring data

Lee and Taylor (2001a) collected grab samples at 10 sites covering San Diego Creek and Santa Ana-Delhi Channel during three storms and one dry weather event in 2000. Trace metal clean techniques were used; however, hydrographs with indicated collection times (figures A2-8, A3-8, A3-9 therein) reveal samplers missed peak flow conditions. This study provides a decent spatial assessment of metal inputs during slightly elevated flows (ca. 200 cfs). Maximum concentrations for all three metals occur in Santa Ana-Delhi Channel, followed by Costa Mesa Channel and Hines Channel. The authors suggest that elevated concentrations in Hines Channel relative to concentrations measured downstream in San Diego Creek at Campus can be attributed to dilution as more water enters the tributary system from various channels.

OCPFRD monitoring data

Orange County Public Facilities Resource Division (OCPFRD), part of Orange County Environmental Management Agency, has been collecting water samples in the watershed for more than 15 years. For the purposes of developing this TMDL, EPA focused on recent results (past five years), which included monitoring data representing a wide range of flow conditions (i.e., 1998 was an exceptionally high water year due to El Nino conditions and 1999 was a normal water year as discussed more in Technical Support Document - Part B). Total and dissolved results, along with hardness values, for each sampling event were reported in the annual report for the NPDES stormwater permit (OCPFRD 2000). OCPFRD monitoring plans require several (minimum of five) composite samples collected each day over the course of each storm event; as well as grab samples collected throughout the hydrograph during the first flush event of each water year. Dry weather samples are individual grabs. OCPFRD staff to date has not used trace metal clean sampling techniques. Paired data from unfiltered (total metals) and filtered (dissolved metals) provides preliminary evaluation of metal translator values. These translator values were close to 1.2 and therefore we assumed dissolved metals are 80% of the total recoverable results. In addition to summary results presented in Tables E-1(a - d), noteworthy results include: elevated Cu in Lane Channel, Bonita Canyon Channel and Costa Mesa Channel, high Pb in Lane Channel and high Zn in Costa Mesa Channel.

Table E-1a. Dissolved Copper Monitoring Results by Waterbody (ug/L)

Waterbody	Collection dates	Org.	n	Min	Max	Mean	Median
San Diego Creek	1996-00	OCPFRD	91	2.1	100	16.4 ± 14	14.0
	1997-99	IRWD	32	1.7	35.8	13.0 ± 10	12.8
	2000	Lee and Taylor	4	2.4	5.5	3.8	3.5
Santa Ana Delhi	1996-00	OCPFRD	65	9.3	74	22.2 ± 12	18.1
	2000	Lee and Taylor	3	5.0	6.3	6.4	6.3
Upper Bay	1996-00	OCPFRD	83	3.4	29.0	11.0	11.0
	1997-99	IRWD	10	1.2	2.3	1.7 ± 0.4	1.7
Lower Bay	1996-00	OCPFRD	25	8.2	26.3	15.9	16.1
	1997-99	IRWD	6	0.6	3.4	2.3 ± 0.9	2.3

Table E-1b. Dissolved Lead Monitoring Results by Waterbody (ug/L)

Waterbody	Collection dates	Org.	n	Min	Max	Mean	Median
San Diego Creek	1996-00	OCPFRD	90	1.0	70	4.9 ± 10.6	2.0
	1997-99	IRWD	26	0.01	5.1	1.01	0.18
	2000	Lee and Taylor	4	0.05	0.35	0.19 ± ? ?	0.11
Santa Ana Delhi	1996-00	OCPFRD	64	1.0	45	5.3 ± 7.4	2.0
	2000	Lee and Taylor	3	0.03	0.95	0.63	0.90
Upper Bay	1996-00	OCPFRD	83	<2	<20	3.1	2.0
	1997-99	IRWD	10	0.023	0.96	0.44	0.29
Lower Bay	1996-00	OCPFRD	25	<2	<2	<2	<2
	1997-99	IRWD	6	0.03	0.89	0.45 ± 045	0.43

Table E-1c. Dissolved Zinc Monitoring Results by Waterbody (ug/L)

Waterbody	Collection dates	Org.	n	Min	Max	Mean	Median
San Diego Creek	1996-00	OCPFRD	86	5.2	640	46.6 ± 81.9	16.5
	1997-99	IRWD	38	3.5	106	13.7 ± 16.7	12.0
	2000	Lee and Taylor	4	2.6	23.1	13.1	8.2
Santa Ana Delhi	1996-00	OCPFRD	59	10.0	532	95.0 ± 102	57.4
	2000	Lee and Taylor	3	5.4	35.9	31.8	27.7
Upper Bay	1996-00	OCPFRD	83	10	100	19.9	14.5
	1997-99	IRWD	23	2.5	11.5	6.8± 3.1	5.5
Lower Bay	1996-00	OCPFRD	25	8.2	29.5	17.3	16.3
	1997-99	IRWD	13	1.1	44.4	10.6 ± 10.1	7.5

Table E-1d. Dissolved Cadmium Monitoring Results by Waterbody (ug/L)

Waterbody	Collection dates	Org.	n	Min	Max	Mean	Median
San Diego Creek	1996-00	OCPFRD	88	0.5	18	1.7 ± 2.7	1.0
	1997-99	IRWD	32	0.13	0.65	0.31 ± 0.12	0.30
	2000	Lee and Taylor	4	0.13	0.27	0.22	0.20
Santa Ana Delhi	1996-00	OCPFRD	63	<1.0	10.0	1.6 ± 2.9	1.0
	2000	Lee and Taylor	3	0.08	0.14	0.12	0.10
Upper Bay	1996-00	OCPFRD	83	<1.0	<10	1.6 ± 2.2	1.0
	1997-99	IRWD	10	0.095	0.22	0.14 ± 0.04	0.13

Sediments

Sediment monitoring results for both fresh and saltwater bodies are summarized in Tables E-2(a - d). Individual results were compared with sediment quality guidelines appropriate for each water body type; freshwater and saltwater threshold effect levels (TEL) and saltwater probable effect levels (PEL). These TEL and PEL values are from Florida Dept. of Environmental Protection study (MacDonald et al. 1996). Some freshwater sediment metal results within San Diego Creek are above TEL values, most notably Cd. But rarely, if ever, do the sediment metal levels exceed PEL values (OCPFRD 2000). No doubt during heavy storm events, Cd, Cu, Pb and Zn contaminated sediments are transported from freshwater bodies to saltwater bodies in Newport Bay; however, we do not anticipate much dissolved metal fluxes from these freshwater sediments into the San Diego Creek water column.

In saltwater bodies of Newport Bay, some sediment metal concentrations are elevated relative to TEL values. The higher frequencies of exceedances of TEL values occur in Lower Newport Bay and Rhine Channel. Maximum values always occur in Rhine Channel, especially for copper, which frequently (80%) exceeds the PEL value. This observation supports the theory that fluvial transport along the freshwater / saltwater gradient produces higher sediment metal concentrations where sediment deposition is most likely to occur.

Within each water body, sediment metal concentrations fluctuate widely and there is no systematic increase or decrease from long-term trend analyses. Part of this may be attributed to the patchy nature of sampling sediments via grabs as well as the presumption that sediments and associated contaminants shift during major storms. Based on spatial distribution of these bulk sediment chemistry results, one can generalize that metal concentrations are low in freshwater bodies and systematically increase along the saltwater gradient. (Cadmium appears to have contrasting distribution between fresh and saltwater.) Another pattern does exist within Lower Bay, metal sediment concentrations decrease along the west to east gradient. That is, the lowest values occur near Newport Jetty closest to open ocean waters. Maximum levels exist in Rhine Channel, which is not surprising given poor tidal flushing and long residence times (up to 9 days) within this dead-end reach (RMA 2001).

AVS/SEM and porewater results

Two other studies -- BPTCP (1997) and Bight '98 (SCCWRP in prep.) assessed relevant sediment metal parameters. In 1996, BPTCP measured acid-volatile sulfides (AVS) and simultaneously extracted metals (SEM) at one site in Rhine Channel. The SEM total was greater than AVS total (6.80 vs. 4.65) with SEMCu about 68% of SEM total value. As part of Bight '98, AVS / SEM and interstitial porewater concentrations were measured at 11 Lower Bay sites, excluding Rhine Channel. Since all 11 sites showed consistent results -- AVS totals were greater than SEM totals, one could assume the metals were bound to acid-volatile sulfides. However at half the sites, individual porewater concentrations showed elevated Cu concentrations relative to saltwater chronic CTR value (3.1 ppb), with two sites showing 33.3 ppb and 65.9 ppb. Porewater concentrations for Pb and Zn were below saltwater chronic values, 8.1 ppb and 81 ppb respectively.

In summary, San Diego Creek and Upper Bay sediment metals are not frequently above TEL values, except for Cd. We presume these sediments do not release metals into the water column, rather these sediments are a trap for particulate metals from the water column, thus acting as a sink. This appears to be true for Cd, Pb and Zn in Lower Bay, where porewater concentrations are low. However in the case of copper both sediment bulk levels and interstitial porewater concentrations are elevated. Therefore, benthic fluxes, both resuspension of contaminated particles and porewater releases to sediment / water interface, may be important for copper but not for other metals.

Table E-2a. Copper Sediment Monitoring Results by Waterbody (mg/ dry kg)

Waterbody	Collection dates	Org.	n	Min	Max	Mean	Median	% above TEL/PEL
San Diego Creek	91-99	OCPFRD	172	0.2	53.0	8.5	4.4	4%>TEL
	97-98	IRWD	2	1.0	2.5	--	--	
Upper Bay	91-99	OCPFRD	66	3.0	190.0	23.6	17.0	17%>TEL
	94 & 96	BPTCP	7	5.8	40.80	26.91	35.40	
	00-01	SCCWRP	10	11	58	30.9	25.5	
Lower Bay	91-99	OCPFRD	20	5.0	49.0	25.8	29.5	33%>TEL
	94	BPTCP	11	29.5	240.0	83.7	75.2	
	98	BIGHT	11	10.5	157.4	52.3	39.9	
	99	OGDEN	12	9.5	83	30.8	24	
	00-01	SCCWRP	8	9	130	64.4	63.5	
Porewater	98	BIGHT	9	1.53 ug/L	65.6 ug/L	13.03 ug/L	6.63 ug/L	
Rhine Channel	91-99	OCPFRD	18	29	530	316.5	330	**82%>PEL**
	94 & 96	BPTCP	2	479	505	--	--	
	00	Coastkeeper	2	170	270	--	--	
	00-01	SCCWRP	2	607	634	--	--	

Freshwater Sediment TEL value for Cu is 36 mg/dry kg.
Saltwater Sediment TEL value for Cu is 19 mg/dry /kg; PEL value is 108 mg/dry kg.

Table E-2b. Lead Sediment Monitoring Results by Waterbody (mg/ dry kg)

Waterbody	Collection dates	Org.	n	Min	Max	Mean	Median	% above TEL
San Diego Creek	91-99	OCPFRD	172	0.8	330	11.3	6.6	6%>TEL
	97-98	IRWD	2	<10	--	--	--	
Upper Bay	91-99	OCPFRD	66	3.3	47	16.8	12.8	5%>TEL
	94 & 96	BPTCP	7	14.2	29.6	20.1	20.4	
	00-01	SCCWRP	10	7	37	18.6	17.5	
Lower Bay	91-99	OCPFRD	20	5.0	36	18.5	18.1	11%>TEL
	94	BPTCP	11	14.8	114	42.6	33.3	
	98	BIGHT	11	7.1	97	37.3	19.8	
	99	OGDEN	12	9.5	51	19.6	13.5	
	00-01	SCCWRP	8	5	30	32.3	22.5	
Porewater	98	BIGHT	9	0.32 ug/L	5.13 ug/L	0.95 ug/L	0.52 ug/L	
Rhine Channel	91-99	OCPFRD	18	26	140	78.5	87.5	54%>TEL
	94 & 96	BPTCP	2	78.1	95	--	--	
	00	Coastkeeper	2	28	58	--	--	
	00-01	SCCWRP	2	72	87	--	--	

Freshwater sediment TEL value for Pb is 35 mg/dry kg.
Saltwater sediment TEL value for Pb is 30 mg/dry /kg; PEL value is 112 mg/dry kg.

Table E-2c. Zinc Sediment Monitoring Results by Waterbody (mg/ dry kg)

Waterbody	Collection dates	Org.	n	Min	Max	Mean	Median	% above TEL
San Diego Creek	91-99	OCPFRD	173	1.0	200	36.2	22.5	4%>TEL
	97-98	IRWD	2	7.4	12	--	--	
Upper Bay	91-99	OCPFRD	66	4.2	210	79.4	67.2	17%>TEL
	94 & 96	BPTCP	7	46.4	171.0	115.3	136.0	
	00-01	SCCWRP	10	48	169	115	108.5	
Lower Bay	91-99	OCPFRD	20	18.0	130.0	82.3	73.5	37%>TEL
	94	BPTCP	11	86.5	460	219.5	209.0	
	98	BIGHT	11	44.5	260	145	149	
	99	OGDEN	12	30	160	75.5	64	
	00-01	SCCWRP	8	31	248	148	152	
Porewater	98	BIGHT	9	3.85 ug/L	10.9 ug/L	6.06 ug/L	6.11 ug/L	
Rhine Channel	91-99	OCPFRD	18	86	340	198	195	38%>TEL
	94 & 96	BPTCP	2	236	303	--	--	
	00	Coastkeeper	2	77	120	--	--	
	00-01	SCCWRP	2	288	366	--	--	

Freshwater Sediment TEL value for Zn is 123 mg/dry kg.
Saltwater Sediment TEL value for Zn is 124 mg/dry /kg; PEL value is 271 mg/dry kg.

Table E-2d. Cadmium Sediment Monitoring Results by Waterbody (mg/ dry kg)

Waterbody	Collection dates	Org.	n	Min	Max	Mean	Median	% above TEL
San Diego Creek	91-99	OCPFRD	170	0.2	7.4	1.0	0.7	46%>TEL
	97-98	IRWD	2	<0.5	--	--	--	
Upper Bay	91-99	OCPFRD	66	0.2	17.0	2.4	1.4	20%>TEL
	94 & 96	BPTCP	7	0.23	1.17	0.75	0.76	
	00-01	SCCWRP	10	1	2	1.3	1	

Freshwater Sediment TEL value for Cd is 0.6 mg/dry kg.
Saltwater Sediment TEL value for Cd is 0.7 mg/dry /kg; PEL value is 4.2 mg/dry kg

Toxicity

Bay Protection Toxic Cleanup Program
The 1994 State Water Board Bay Protection and Toxic Cleanup Program (BPTCP) results showed Upper Bay, Lower Bay and Rhine Channel sediments were toxic to some forms of aquatic life (two amphipods and fertilization and embryo development of sea urchins). Toxicity was highly significant in both bulk sediments and interstitial porewater at some locations. Direct cause of toxicity was not assessed but statistical correlation was found between toxicity to two amphipod species and sea urchin larvae and elevated levels of numerous chemicals, including copper, lead, and zinc. Benthic organism degradation was also assessed in this study and there was correlation between lower infaunal index and elevated levels of copper (and other organic compounds).

Bight '98

The Southern California Bight Regional Monitoring Project (Bight '98, coordinated by SCCWRP) provides an integrated assessment of Southern California coastal estuaries. Sediments were highly or moderately toxic at 9 of 11 sites in Lower Newport Bay, with no toxicity at two sites close to Newport jetty. Sediment elutriate results yielded toxicity at 7 of 11 sites (Bay et al. 2000). Cause of toxicity was not determined in this study. Benthic degradation was evident at 7 of 11 sites. Correlation of toxicity and chemistry results has also not been completed, in part because some chemistry results are being validated. Nonetheless, bulk sediment metal results (discussed above) indicate elevated levels of copper, lead and zinc at some Lower Bay stations.

Southern California Coastal Water Research Project

Recently, the Southern California Coastal Water Research Project (SCCWRP) has been contracted by Regional Board to complete toxicity identification evaluations (TIEs) of salt waterbodies, including Rhine Channel. Results of this two-year project (still in progress) have consistently detected toxicity (to amphipods and sea urchin larvae) at 8 of 10 sites during September 2000 and May 2001 sampling events (SCCWRP 2001a). Bulk chemistry results are included in these Toxics TMDLs (see Tables E-2 (a -- d) above). Thorough TIE studies in Upper Bay and Rhine Channel are currently in progress and will investigate if metals and / or priority organics are possible causes.

Background

Metals are associated with open-hillside, soils, groundwater, seawater and atmospheric deposition, therefore input of metals via background sources must be evaluated and included in the development of these TMDLs.

Background metals in surface runoff

To date, the best available data for estimating the contribution from runoff of open hillside soils comes from the 319(h) study (Lee and Taylor 2001a). EPA selected dissolved metal results for San Joaquin Channel to provide metal concentrations associated with open spaces. This site was described as 90% open space and 10% agriculture (see Table E-7). No samples were collected during dry weather conditions from this site or any other viable open space site. The range and mean values from this site for two wet weather sampling events are provided in Table E-3. We acknowledge the preliminary nature of these results, yet for lack of other data, we have utilized the mean wet weather values to estimate freshwater (dissolved) loads for medium and high flow tiers.

Table E-3. Metal concentrations in natural soil runoff at San Joaquin Channel

Metal	Range (ug/L)	Mean (ug/L)
Dissolved Cd	0.13 – 0.22	0.17
Dissolved Cu	6.3 – 8.0	7.2
Dissolved Pb	0.097 – 0.13	0.11
Dissolved Zn	7.5 – 16.4	12.0

(source: Lee and Taylor 2001a)

In the summary TMDL document, EPA adjusted OCPFRD estimates of total metals stormwater loads for San Diego Creek and Santa Ana-Delhi Channel using literature values of natural versus anthropogenic contributions. This adjustment was based on information reported by Schiff and Tiefenthaler (2000) who recorded freshwater flows and measured total metals in storm runoff of Santa Ana Watershed, which neighbors the Newport Bay watershed. [This study is the best proxy since no reliable direct measurements of soil runoff within Newport Bay watershed exist to date.] This report provides an assessment of anthropogenic versus natural emissions of metals within surface runoff during the 1998 water year. Using an iron normalization technique, the authors state that Cd, Cu, Pb and Zn were most enriched (33-63%), whereas Cr and Ni were the least enriched (0.5 to 0.7%) due to anthropogenic contributions. Anthropogenic contributions of metals in surface runoff were estimated to be these amounts: 63% (Cd); 42% (Cu); 38% (Pb); 33% (Zn). Percent natural contributions, event mean concentrations (EMC) and median EMCs are summarized in Table E-4.

Table E-4. Total metal results from stormwater monitoring in Santa Ana River Basin in 1998

Metal	Estimate natural (%)	Minimum EMC (ug/L)	Median EMC (ug/L)
Total Cd	37	0.07	0.37
Total Cu	58	7.02	23.3
Total Pb	62	4.07	14.99
Total Zn	67	29.03	93.78

(source: Schiff and Tiefenthaler 2000)

These percent natural contributions have *not* been utilized for developing these dissolved metals TMDLs, since the results were derived from total metals samples.

Groundwater

Remedial Investigation/Feasibility Studies completed at El Toro MACS provide concentration ranges of background contributions of heavy metals in local groundwater. Results range from <2 ug/L for Pb, 4 ug/L for Cd, 21 ug/L for Cu, and 88 ug/L for Zn. Unfortunately these background levels are for unfiltered samples (total metals) collected without using trace metal clean techniques and therefore these results are not reliable for use for these dissolved metals Toxics TMDLs.

Other sources of groundwater data for dissolved metals from shallow (<50 bgs) monitoring wells have yet to be identified within the Newport Bay watershed.

Background metals in ambient seawater

Surface seawater contains metals due to several sources: coastal runoff, ocean upwelling, atmospheric deposition to sea surface, etc. [EPA has designated ambient surface seawater as source of metals but has opted to not differentiate between natural and anthropogenic contributions to surface seawater.] Dissolved metal concentrations in ambient surface seawater are generally quite low (either ppb or less). The range of dissolved metal concentrations in various coastal systems has been reported by Cutter (1991), with more local data supplied from samples collected offshore the Southern California Bight (pers. comm., R. Gossett). Table E-5 that summarizes dissolved metal concentrations in various seawater samples and mean results for Upper Newport Bay water column samples (IRWD 1999) are included for comparison.

Table E-5. Dissolved metal concentrations in saline waters (ug/L)

metal	Calif. Coastal seawater (CRG Lab)	Upper Newport Bay Mean value (IRWD 1999)	Range in Coastal waters (Cutter 1991)
Dissolved Cd	0.1	0.14	0.002 – 0.095
Dissolved Cu	1.4	1.7	0.3 – 3.8
Dissolved Pb	0.1	0.44	0.004 – 0.19
Dissolved Zn	4.1	6.8	0.3 – 30

see text for references

Obviously, inputs of metals from ambient seawater need to be included when determining the background contributions of metals to saline waterbodies of Newport Bay. These inputs are contingent on tidal influences and freshwater flows from San Diego Creek, Santa Ana Delhi Channel and other drainages. During high tides and low freshwater flows, surface seawater contributions would be at their highest levels, whereas during low tides concurrent with storm events would yield much lower contributions from ambient seawater. EPA has used coastal seawater results (CRG Lab) results to approximate inputs from ambient seawater.

III. Source Analysis

OCPFRD estimates

In the 2000 *NPDES Annual Report*, OCPFRD included estimates of total metal stormwater loading from Santa Ana-Delhi Channel, San Diego Creek and two of its tributaries. These estimates are based on monitoring results of unfiltered (composite) water samples and flow measurements at each sampling station collected during wet weather events in each water year. Unfortunately, these total load results do not represent annual loads since not all storm events were samples in the water year. Estimates for 1998 are considered exceptionally high due to El Nino conditions (38.4 inches of rain); whereas 1999 is a slightly dry year (8.8 inches) in comparison to average annual rainfall (13.3 inches) at Tustin / Irvine Ranch site. Table E-6 summarizes these total stormwater load estimates, gives the mean and includes adjustments to display the man-made inputs (Zn = 33.3%, Cu = 41.5%, Pb = 38.3%) as determined by Schiff and Tiefenthaler (2000). No estimates of Cd loading are included in OCPFRD *Annual Report*.

Table E-6. OCPFRD estimates of total metal stormwater loads for San Diego Creek and Santa Ana-Delhi Channel.

Element/ Stn Name	1998 Water year (lbs)	1999 water year (lbs)	2001 water year (lbs)	mean total load (lbs)	Adjusted total load (man-made input) (lbs)
Zn @ PCW	21,575	1306	2964	8615	2869
Zn @ WYL	18,790	1582	3937	8103	2698
Zn @ SDC	63,021	3784	7900	29,908	9957
Zn @ SAD	7031	805	2175	3337	1111
Cu @ PCW	5059	332	862	2084	865
Cu @ WYL	4519	402	956	1959	813
Cu @ SDC	15,087	1643	2020	6250	2594
Cu @ SAD	1643	185	492	770	320
Pb @ PCW	2924	169	356	1150	440
Pb @ WYL	2184	166	407	919	352
Pb @ SDC	10,385	449	1188	12,022	4604
Pb @ SAD	1297	124	369	1790	686

PCW = Peter's Canyon Wash; WYL = San Diego Creek @ Culver;
SDC = San Diego Creek@ Campus; SAD = Santa Ana-Delhi Channel
All results in represent total metals in lbs; for sampled wet weather events only
Adjusted mean = reported mean – % natural calculated from Schiff and Tiefenthaler (2000)

319(h) report

As part of the 319(h) report, Lee and Taylor (2001a) provide estimates of copper loadings based on grab sampling results during two separate storm events in 2000. The authors state that in general the metals data exhibit the highest contributions from "urban stations" and agriculture / open space exhibiting the lowest loadings. They acknowledge the impracticality of making load calculations using grab samples [their methods] as opposed to composite samples [OCPFRD methods], stating "rigorous total load calculations would include the use of constituent concentrations calculated from flow-weighted composite samples taken over the entire runoff hydrograph...Copper loads may be better characterized by OCPFRD NPDES permit stormwater runoff data than the limited single grab sample analysis performed here." Nonetheless, using copper data from Feb. 21, 2000 storm event and corresponding flow data from OCPFRD, the authors estimate metal loadings from specific areas of the watershed. More intriguing are the approximations of total copper loads per acre of tributary drainage area; these provide an estimate of the relative contributions of land uses that are represented at each sampling site. Table E-7 summarizes the dissolved and total copper loads as well as the dominant land use associated with each sampling station.

Table E-7. Land Uses and Total Copper loads for One Storm Event (Feb. 21, 2000)

Sampling station	Dissolved Cu Load (lbs.)	Total Cu load (lbs.)	Total Copper per acre (lbs./acre x 10^{-5})	Dominant land use
San Diego Creek @ Campus	16	159	234	Mixed residential, agricultural, nursery
San Diego Creek @ Harvard	10	169	629	Mixed residential, agricultural, nursery
Peters Canyon Wash @ Barranca	7	39	136	Mixed residential, agricultural, nursery
Hines Channel @ Irvine Blvd	0.2	0.6	94	Nursery, agricultural
San Joaquin Channel @ University	0.2	1.2	136	Agricultural, open space
Santa Ana Delhi	8	28	252	Residential, commercial
El Modena-Irvine Channel	4	8	104	Residential, commercial
Sand Canyon Avenue	N / a	N / a	59	Agricultural
East Costa Mesa @ Highland	N / a		91	Residential, commercial
Central Irvine Channel	N / a	N / a	101	Agricultural, residential, nursery

(Source: Lee and Taylor 2001a)

For the purposes of these *dissolved* metal TMDLs, it is possible to convey dry weather load estimates provided by Lee and Taylor as part of the same 319(h) study (2001a). These dry weather results are based on one filtered grab sample collected during one sampling event and extrapolated use of stream flow volumes (OCPFRD data) recorded during the entire dry season. Table E-8 summarizes the dissolved copper results and for comparison, we include our estimates of dissolved Cu load from the baseflow and small flow tiers as calculated in section IV of this TSD.

Table E-8. Dissolved Copper loads within Newport Bay watershed

Sampling station	Estimated dry weather Dissolved Cu load* (lbs.)	Baseflow and small flow tier Dissolved Cu Load # (lbs.)
San Diego Creek @ Campus	122.5	1031
San Diego Creek @ Harvard	N / a	--
PetersCynWash @ Barranca	77.65	--
Santa Ana Delhi	238.4	163

*estimated (based on one dry season sample and dry flow records for entire year), source Lee and Taylor 2001a);
#value approximated from chronic targets for base and small flow tiers multiplied by associated flow volumes used in these TMDLs

Metal inputs from Point Sources vs. Non-point sources

Within the Newport Bay watershed, one can reasonably assume the vast majority of metals contributed to fresh and saltwater bodies arise from non-point sources. There are no direct discharges from wastewater treatment plants into San Diego Creek and Newport Bay as is typically true for other waterbodies. There are some discharges of groundwater treatment (cleanup or dewatering) facilities. One study performed in Santa Clara California, identified some of the (non-point) sources of heavy metals from an urban watershed – Lower San Francisco Bay (Woodward-Clyde 1998). Urban road runoff from roads is believed to be the largest contributor of cadmium (tires), copper (brakes and tires), lead (brakes, tires, fuels and oils) and zinc (tires, brakes, auto frame). Secondary contributions come from contaminated sediments, atmospheric deposition and miscellaneous sources, such as antifouling paints from recreational boats. All of these are likely to exist in the Newport Bay watershed.

The possibility remains that individual sites with elevated metal levels may contribute metals to neighboring surface waters, via surface runoff or contaminated groundwater flows. To unveil such contaminated sites EPA has conducted a comprehensive survey of existing databases listing contaminated sites within the Newport Bay watershed. Databases included USEPA National Priority List (NPL), Comprehensive Environment Responsibility, Compensation, and Liability System (CERCLIS), California Department of Toxic Substances Control (DTSC) Calsites and Orange County hazardous material or incidental spill sites (E&I sites). A complete list of sites and associated toxicants is presented in Appendix A. Discussion below narrows the complete survey to information relevant only to metal (Cd, Cu, Pb, Zn) contamination. Information is presented for future exploration / verification of possible metal contaminated runoff from these sites.

Of the Federal sites (NPL and CERCLIS), where preliminary investigations have been completed, only two, Orange Coast Plating and El Toro Military Base, have been shown to have metal contamination. The Orange Coast Plating facility (in Santa Ana) was remediated via soil excavation and surface paving in 1987. It is currently under State regulation and seems unlikely to release trace metals into surface runoff.

Review of RI/FS documents pertaining to El Toro MCAS identified several "hot spots" for heavy metal contamination. Three sites in particular have soil samples with levels in excess (as high as 60x) of background levels. Battery disposal area had high Pb (923 mg/kg dry) and Zn (288 mg/kg dry); Drop Tank Drainage area had high Zn (1760 mg/kg dry) and Cu (548 mg/kg dry) and Materials Management area had high Zn (507 mg/kg dry). No excessive levels of Cd existed in these results. Remediation has either occurred or is planned (pers. comm., M. Smits). To establish if these or other heavy metal hot spots at El Toro are indeed sources one would have to investigate surface runoff during various storm conditions from MCAS base into Marshburn Channel, Borrego Canyon Wash and Agua Chinon Wash. Therefore uncertainty exists if heavy rainfall and subsequent runoff from El Toro sites would transport dissolved and particulate metals into nearby channels, and eventually flow into San Diego Creek.

Tustin Marine Corp Air Station has already remediated metal hotspots (Pb soils); therefore, heavy metal releases into surface runoff and San Diego Creek waterways are believed to be minimal.

Thirty two California DTSC Calsite facilities are located within the watershed, three of which are associated with metal contamination (Appendix A). Two Calsites have very small quantities (Pb soils in planter boxes) and have undergone voluntary cleanups.

Three of twenty four County E&I sites – emergency incidents and industrial clean-ups – were listed for metal contamination; however, these sites (Appendix A) have been remediated or cited that small quantities of surface runoff contamination is likely.

Atmospheric deposition

Deposition of airborne particles may be responsible for contributing specific heavy metals to Newport Bay. Deposition can occur directly as particles settle onto the wet surface or indirectly as they settle on land and are subsequently washed or blown into Upper and Lower Bay. These toxic chemicals are then added to the burden of chemicals in water surface microlayer (a 50 micron boundary layer between atmosphere and water), the water column and/or the sediments. The resultant increase in toxicity may affect aquatic life in Newport Bay. For these TMDLs we have included direct deposition of metal—via both dry and wet processes to surface waters of Upper and Lower Bay, including Rhine Channel. We have not included indirect deposition (fallout or washout to watershed land and subsequent fluvial transport) since it is included in surface runoff concentrations which have already been measured and corrected by background levels.

Average rainfall at Tustin/Irvine weather station is 13 inches per year. EPA used literature cited values from metal deposition studies of San Francisco Bay (Tsai et al. 2001) and Santa Monica Bay (Stolzenbach, et al. 2001). Those studies provide mean dry and wet deposition results for Cu, Pb and Zn. Other studies have included assessments for Cd (Sweet et al. 1997; Golomb et al.1997) which were very small corresponding values so we have disregarded air deposition of Cd for this TMDL. In short this contribution is minimal relative to Cd inputs from other sources, e.g., tributary loading and sediment remobilization.

Saltwater body surface area estimates included mean tidal area of Upper Bay (372.5 acres = 1.5 million sq. meters), Lower Bay (790.2 acres = 3.2 million sq. meters) and Rhine Channel (15.2 acres = 61,000 sq. meters) (GIS data, City of Newport Beach).

Table E-9 Direct Deposition of Metals to surface of Newport Bay

Metal	Dry Dep (ug/m2/day)	Wet Dep (ug/L)	Total air dep. (lbs/yr)
Cd	0.061*	0.4*	3.5
Cu	0.29	2.16	100.7
Pb	0.16	1.47	68.4
Zn	53.57	8.7	606.1

(source: *Tsai et al. 2001; all other values from Stoltzenbach et al. 2001)

Recreational Boats (for Cu)

EPA has utilized information from San Diego RWQCB Dissolved Copper TMDL (for Shelter Island Yacht Basin) to estimate copper inputs from recreational boats to Newport Bay. The San Diego TMDL, currently in draft status, provides dissolved copper loading equations for both passive leaching from wetted hull surfaces and from underwater hull cleaning (i.e., wiping down the wetted surface to remove marine growth). Briefly, EPA has applied local conditions (number of moored boats) for Newport Bay, assumed similar mean boat length and wetted surface area and used equations from the San Diego TMDL to give preliminary estimates of dissolved copper loads per year. Passive leaching contributes approximately 35,000g / day (77 lbs / day) and hull cleaning about 27,279 g / day (60 lbs / day). More explicit details for these calculations are provided in Section IV of this TSD.

Summary of Monitoring results and Source analysis

- In freshwater bodies, water column measurements of dissolved metals exceed water quality standards during wet weather events. Sediment metal concentrations rarely exceed TEL values in freshwater bodies, except for Cadmium. Sediment metal levels generally increase along the freshwater to saltwater gradient, with maximum levels found in Rhine Channel. Porewater results indicate fluxes of dissolved copper may occur at levels of concern within Lower Bay, but this is unlikely for other metals. Transport of metals from fresh to saline systems may contribute to toxicity problems observed in Newport Bay sediments.
- OCPFRD loading estimates, uncorrected for anthropogenic inputs and based on unfiltered composite samples collected during storm events, demonstrate direct relationship with flow conditions; i.e., heavy storm years yield high metal loads in surface runoff. Inputs from San Diego Creek (90%) far outweigh those from Santa Ana-Delhi Channel (10%). For two tributaries of San Diego Creek, Peters Canyon Wash (54%) contributes slightly more heavy metals than those from waters upstream of San Diego Creek at Culver (46%).
- Lee and Taylor (2001a) estimates of metal loading are generally lower than OCPFRD's, however there are differences in sampling techniques and collection approach (grabs versus composites). Dissolved metal levels are much lower than those measured in total (unfiltered) metals samples. It is difficult to utilize the 319(h) results to approximate stormwater loads of dissolved metals due to lack of adequate monitoring during peak flows (Lee and Taylor 2001a). Nonetheless, dramatic decreases in metal concentrations during all weather conditions may occur if trace metal clean sampling methods are utilized by all those sampling for metals in surface or groundwaters with Newport Bay and the surrounding watershed.
- Assessment has included ambient surface seawater results as well as approximate open space runoff contributions. Based on unfiltered samples, total metal results may be adjusted to demonstrate anthropogenic contributions, Zn = 33%, Pb = 38%, Cu = 42%, Cd = 63% (Schiff and Tiefenthaler 2000). To date, no useful groundwater results exist within the San Diego Creek watershed. Air deposition and ambient seawater sources are deemed to be minor sources to Newport Bay.
- Using TMDL studies nearly completed in San Diego Bay, recreational boat hulls may be the single largest contributor of dissolved copper in saltwater bodies of Newport Bay. Our extrapolation of methods presented in the San Diego yacht harbor for passive leaching and underwater hull cleaning suggest as much as 80% of all copper inputs to Newport Bay. These preliminary results suggest that dissolved copper from boat hulls is a significant non-point source in Lower Bay and may be carried into Upper Bay with tidal flows.

Table E-10. Summary of (estimated) metal inputs to San Diego Creek (lbs/yr)

	Cd	Cu	Pb	Zn	
Stormwater[1]	N/a	6250	12,022	29,908	
Groundwater[2]	Unknown	Unknown	Unknown	Unknown	
Nurseries/ Other ag.[3]		214		4	
Open space runoff[4]	221	622	335	12,392	
Total	>221	>7086	>12,357	>42,304	

[1] total metal loads from stormwater samples -- not adjusted (OCPFRD 2000)
[2] inputs from groundwater could be significant although reliable monitoring data from numerous sites in the watershed are required for assessment
[3] value is approximation of total metals applied to all agriculture crops in watershed, equivalent to twice the value of total metals applied by three nurseries in 1996 (Lee and Taylor 2001b)
[4] dissolved metals, based on San Joaquin Channel mean concentration reported in 319 (h) study (Lee and Taylor 2001a) multiplied by medium and large flow tier volumes.

Table E-11. Summary of Total metal inputs to Newport Bay (lbs/yr)

	Cd	Cu	Pb	Zn	
freshwater[1]	N/a	7020	13,812	33,245	
Recreational Boats[2]	negligible	50,114	negligible	Unknown	
Air deposition[3]	3.5	101	68.4	606	
Ambient seawater[4]	389	777	233	9330	
Porewater[5]	negligible	Unknown	negligible	negligible	
Total	393	58,002	14,113	43,181	

[1] sum of total metal loads from stormwater samples collected in 2000 from San Diego Creek and Santa Ana-Delhi (OCPFRD)
[2] preliminary estimate of dissolved copper from passive leaching and hull cleaning (see TSD section IV)
[3] estimate for direct deposition of metal to surface waters of Newport Bay only (see TSD section IV)
[4] estimate of dissolved metal inputs from ocean based on local data (pers. comm. R. Gossett) and approximate ocean volume into Newport Bay (see section IV on Newport Bay "bathtub model")
[5] porewater results from Bight '98 study (SCCWRP in prep)

IV. Approach to calculating mass-based Loading Capacity

Freshwater loads of dissolved metals

In the DRAFT summary TMDL document, EPA selected to use the flow based approach to determine mass based dissolved metal loads in freshwater bodies. In this approach, the continuous range of river flow that occurs at each target site is broken down into ranges or tiers. Target dissolved metal concentration multiplied by volume associated with each tier gives the dissolved metal load per flow tier; the sum equals the loading capacity. The applicable allocation for a given source does not depend on the time of year, rather on the actual creek flow at the time of discharge and associated hardness value. So flow rate determines hardness which in turn dictates the appropriate metals criteria or target. Complete discussion of freshwater flows in San Diego Creek and Santa Ana Delhi are presented in TSD Part B – Flow.

Here is an explanation of the sequence of steps to determine metals criteria associated with each flow tier. We use small flow tier and dissolved copper target as an example.

1. Range of flow is 21 to 181 cfs. Choose highest flow rate within the tier = 181 cfs.
2. Use linear equation to find corresponding hardness value….start with natural log (flow rate)
3. For San Diego DCreek, hardness = -57.742 (ln [flow])+ 622.5
4. Use this hardness value (322 mg/L as $CaCO_3$) in CTR equations to determine acute and chronic criteria for each metal.
5. Dissolved chronic Copper criteria = e(0.8545[ln(hardness)]-1.702)*0.96 =24.3 ug/L

Table E-12. Calculation of dissolved metal loading capacity for San Diego Creek (at Campus)

Copper	**Range of Flow rates** (Q)	**Hardness applied** (mg/L)	**Flow volume** (ft3)	**Target metal conc.** (mg/L)	**loading per tier (lbs)**	**% total**
baseflow	Q <20	400	275,411,823	0.0293	503.78	23%
Small flow	20<Q<181	322	347,504,437	0.0243	527.18	24%
Medium flow	181<Q<814	236	357,632,336	0.0187	417.51	19%
Large flow	Q > 815	197	468,824,589	0.0255	746.35	34%
			1449,373,185 Total volume		2194.83 **lbs/yr**	

Flow volume per tier is based on 19 water year average: 1977/78, 1984/85 to 2000/01
Target metal concentration is hardness dependent.

This methodology was utilized for calculating dissolved metal load estimates from Santa Ana-Delhi Channel too. Chronic conditions applied to base, small and medium flows, acute conditions applied to large flows. Daily flow records for Santa Ana-Delhi Channel covered six water years: 1995/96 – 2000/01. Using method outlined in Table E-12, dissolved copper inputs from Santa Ana-Delhi Channel would be approximately 303 lbs/yr. Thus total freshwater inputs from SAD and SDC would be less than 2499 lbs/yr. This is a conservative estimate based on chronic concentrations for much of the year, whereas higher concentrations may exist and be tolerated by freshwater organisms during short term (acute) exposures.

Dissolved metal loads in Newport Bay via "bathtub model"

The following information and equations were used to evaluate loading capacities in Newport Bay. We did not differentiate between Upper & Lower Bay & Rhine Channel since these water bodies are inherently intertwined when considering dissolved constituents. As you can see this "bathtub model" incorporates data for dissolved and total metal concentrations, freshwater flows, ebb and flood tides, and the volume of the Bay

The mass balance of water and pollutant can be written as follows:

$$\frac{dV}{dt} = (Q_0 - Q_b + Q_f)$$

$$\frac{dVC}{dt} = Q_0 C_0 - Q_b C + L_f + L_l - A v_s F_d C_T$$

where
C = dissolved pollutant concentration (mg / L)
C_T = total pollutant concentration (mg / L)
Qf = freshwater inflow
Q_0 = the quantity of water that enters the bay on the flood tide through the ocean boundary that did not flow out of the bay on the previous ebb tide (m^3 / T)
Q_b = the quantity of water leaving the bay on the ebb tide that did not enter the bay on the previous flood tide (m^3 / T)
V = volume of the bay
T = period of dominant tidal period (day)
L_f = loading from upstream (g / day)
L_l = loading from local area (additional sources within the bay; e.g., boats) (g / day)
A = surface area of the bay
v_s =net settling velocity (m / day)
F_p = fraction of particulate pollutant

At steady state

$$Q_b = Q_0 + Q_f$$

$$Q_b C + A v_s F_p C_T = Q_0 C_0 + L_f + L_l$$

The volume of new ocean water entering the bay on the flood tide can be determined by using ocean tidal exchange ratio (R_0) as

$$Q_0 = R_0 Q_T$$

where R_0 = exchange ratio and Q_T = total volume of ocean water entering the bay on the flood tide. The exchange ratio can be estimated from salinity data (Fischer et al. 1979)

$$R_0 = \frac{S_f - S_e}{S_0 - S_e}$$

Where S_f = average salinity of ocean water entering the bay; S_e =average salinity of bay water leaving the bay; and S_0 = Salinity at ocean side. The volume of mixed bay water Q_b leaving the bay on the ebb tide can be determined by using tidal exchange ratio (R_b)

$$R_b = \frac{S_f - S_e}{S_f - S_b}$$

where S_b is salinity of mixed bay water.

The flushing time (residence time) T_L can be calculated as follows:

$$T_L = \frac{V_b}{Q_b}$$

Where V_b = mean volume of the bay (19 million m^3 from RMA 2001). The exchange ratio R_0 can be estimated from the salinity observation data (RMA 1999). The ratio varies from 0.20 to 0.30. It can also be estimated through model calibration. The ratio used in the model is 0.25. Use median freshwater input of 16cfs, Q_b can be estimated.

Assume 0.80 as dissolved fraction of copper. ($C+0.2\ C_T = C_T$, $C_T = 1/0.8C$.)
Therefore, C_T =1.25 C and the pollutant concentration in the bay can calculated as follows:

$$C = \frac{Q_0 C_0 + L_f + L_l}{Q_b + 1.25 A v_s F_p}$$

Let C_c be the criteria of Cu in the Bay, the loading capacity can be estimated as

$$Load = C_c (Q_b + 1.25 A v_s F_p) - Q_0 C_0$$

The results are listed in Table E-13.

Table E-13 "Bathtub" Model Results for dissolved copper

Bay volume (m^3)	Con. at ocean side (ug/L)	Exchange ratio	Volume entering Bay_0 (m^3/day)	Freshwater Cu Loading (lbs/yr)*	Estimated concentration (ug/L)	Criteria (ug/L)	Loading capacity (lbs/yr)
19000000	1.4	0.25	4,830,918	2499	3.03	3.1	11646

* This estimate assumes substantial reductions (>five fold) in copper loading from hull leaching and boat maintenance.

Calculations of direst atmospheric deposition load to Newport Bay

For these TMDLs, atmospheric concentrations reported in scientific literature were utilized for each metal to estimate the overall mass deposition into the Bay, F. There are two types of direct deposition: dry and wet. Dry deposition involve the transport and surface accumulation of particulate air contaminants during periods without precipitation. Wet deposition involves the removal of pollutant from the atmosphere via various precipitation processes ("washout"). Both dry and wet deposition are considered in this general equation.

$$F = C * V * S$$

Where

C = ambient air concentration ($ug/m^2/day$ or ug/L)
V = deposition velocity (m/yr)
S = total surface area for deposition (m^2)

Table E-14. Direct Air Deposition of metals to Newport Bay surface waters

	dry (ug/m2/day)	wet (ug/L)	total dry (g/yr)	total wet (g/yr)	total air load (g/yr)	total air load (lbs/yr)
Cd	0.061	0.11	3.34E+01	1574.85	1.61E+03	3.5
Cu	0.29	2.16	5.04E+02	45153.29	4.57E+04	100.7
Pb	0.16	1.47	2.78E+02	30729.32	3.10E+04	68.4
Zn	53.57	8.7	9.31E+04	181867.42	2.75E+05	606.1

Pesticide Use Reports

Pesticide Use Reports for three nurseries (Bordier's, El Modeno, and Hines) show relatively small amounts of copper (about 20, 15, and 72 lbs. respectively) per year and even smaller amounts of zinc (2 lbs. or less). (source: Lee and Taylor 2001b)

Methods to estimate Cu loads from boat hulls

EPA has utilized information compiled by San Diego RWQCB as part of the Dissolved Copper TMDL for Shelter Island Yacht Basin (SD RWQCB 2001 and references therein). The Shelter Island TMDL is nearly complete and has relatively robust data to support their estimates of leaching off boat hulls. Typically owners rely on copper-based antifouling paints to minimize algae growth on boat hulls, thus both passive leaching and underwater hull cleaning result in release of dissolved copper into Newport Bay. Common maintenance practices involve underwater hull cleaning about once per month, with much less frequent removal for dry-dock repainting. [Above water hull cleaning or dry-docking occurs within boatyards and discharges containing copper from antifouling paints are regulated by diversion into pre-treatment systems and then sewer drains or into local sumps.]

EPA has assumed that similar boat maintenance practices occur in Newport Bay harbors. Further we use the same assumptions about mean boat length and wetted surface area as presented in the Shelter Island Yacht Basin Dissolved Copper TMDL. One difference is applied--approximately 10,000 boats are moored in Newport Harbor (pers. comm., T. Melum). We recognize this extrapolation of methods and values from one location to another may not be construed as exact science; however, it does serve as first approximation until further site specific data has been accomplished.

The Shelter Island Dissolved Copper Draft TMDL includes information from boat studies performed in 1994 and 1995. Additional studies are currently in progress to refine these preliminary studies and establish more substantial data sets for hull cleaning and passive leaching. Results from these additional studies were not available for these Newport Bay Toxics TMDLs. References included below are from the Shelter Island Dissolved Copper TMDL. Adjustments for *data applicable to Newport Bay are in italics.*

Passive Leaching

In San Diego Bay, the majority of recreational vessels are sailboats that range in length from 30 to 40 feet (9.1 to 12.2 meters) (Conway and Locke 1994, Southwestern Yacht Club 2000). In the SIYB, the average size recreational vessel is 40 feet in length (12.2 meters), with a beam width of 11 feet (3.4 meters) (Bay Club 2000, Half Moon Marina 2000, Southwestern Yacht Club 2000, Conway and Locke 1994). Average wetted hull surface area is calculated based on this average size vessel, which is then used to calculate the amount of passive leaching over time per vessel. Wetted hull surface area is calculated using the following equation: Wetted hull surface area = (Overall length)*(Beam height)*(0.85) (Interlux 1999).

Dissolved copper loading from all of the recreational vessels in the SIYB is calculated from the average number of vessels known to reside there. Copper loading from passive leaching is calculated as follows:

Annual copper load (kg / yr.) = P*S*N, and S = L*B*0.85

Where:
P = Passive leaching rate
N = Number of boats
S = Wetted hull surface area = Overall length*Beam*0.85
L = Average length
B = Average beam height
Given:
P = 10 $\mu g / cm^2 / day$
N = 10,000 (number of boats moored in Newport Bay)
L = 12.2 m (= 40 ft)
B = 3.4 m
Wetted hull surface area = (Overall length)*(Beam height)*(0.85)
Wetted hull surface area = (12.2 m)*(3.4 m)*(0.85) = 35.3 m^2
Annual load = (10 $\mu g / cm^2 / day$)*(35 m^2)*(*10,000* vessels)*(10,000 cm^2 / m^2)*($kg / 10^9 \mu g$)(365 day / yr.)

Estimates of Copper load from passive leaching in Newport Bay= 12,775 kg / year (35,000 g / day).

Hull Cleaning

Underwater hull cleaning (hull cleaning) is a common maintenance practice designed to prevent buildup of marine organisms on a ship's hull. Although antifouling paints are effective at halting growth, some growth does occur which will build up over time. This growth may be removed from recreational vessel hulls either through haul-out at a boatyard, or manually while the boat is in-water using underwater hull cleaning techniques (SCCWRP 2000). It has been estimated that almost all of the pleasure crafts in the Shelter Island Yacht Harbor undergo periodic underwater hull cleaning (SCCWRP 2000).

The physical process of removing marine growth on a ship's hull underwater results in a release of dissolved copper from the paints. The amount of copper released from hull cleaning is dependent on cleaning frequency, method of cleaning, type of paint, and frequency of painting. It was been estimated that underwater hull cleaning takes place in San Diego Bay about ten times a year for regularly maintained recreational boats (Conway and Locke 1994). (*this rate is also assumed to apply to boats in Newport Bay)* In addition, it was determined that painting frequency varies from one to three years, with most vessels being repainted every two years (Johnson et al 1998, Conway and Locke 1994). However, there are no known published studies that quantitatively compare release rates based on paint age, paint type, or method of cleaning. It is reasonable to assume that those frequently painted vessels with higher copper content paints will release more copper during hull cleanings. It is also reasonable to assume that more abrasive cleaning techniques tend to release more copper. However, published studies that provide quantitative estimates of copper loading from underwater hull cleaning are limited, particularly for recreational vessels.

Prior to the hull cleaning, dissolved copper concentrations in the vicinity of the boat averaged 12 μg/L. During the hull cleaning, average concentrations increased from 12 μg/L to 56 μg/L. Concentration levels decreased to 17 μg/L within five minutes after the cleaning ended, and levels returned to background within ten minutes. Researchers found that the copper contaminant plume moved with the current, and that the degree of plume contamination was dependent upon fouling extent and exertion by the diver (McPherson and Peters 1995). Based on the results, the authors concluded that underwater hull cleaning generates elevated concentrations in the vicinity of the operation, which return to background levels in a short time (within minutes).

More studies are needed to fully evaluate the environmental impacts of underwater hull cleaning over a range of environmental conditions and cleaning techniques. The Southern California Coastal Water Research Project Authority (SCCWRP), in collaboration with the Regional Board, is currently investigating environmental effects of antifouling paints and underwater hull cleaning activities in San Diego Bay as part of a two-year research grant. Funding for this research was provided by the State Water Resources Control Board (SWRCB) through the USEPA 319(h) Nonpoint Source Implementation Grant Program. Results from this study should provide greater information about the environmental impacts from underwater hull cleaning.

<u>Calculations</u>

Copper loading from hull cleaning was calculated from information provided in the studies by PRC (1997) and McPherson and Peters (1995). In the McPherson and Peters study, an underwater hull-cleaning event was monitored for dissolved copper concentrations in the resulting plume. Plume concentrations ranged from 40 μg/L to 83 μg/L, with a mean of 56 μg/L. Prior to the hull-cleaning event, concentrations in the SIYB averaged 12 μg/L (McPherson and Peters 1995). Equations for the determination of plume and copper concentration in the plume were provided by PRC (1997).

Plume concentration (P_c) = (Total plume concentration) – (Background concentration)

P_c = (56 μg/L) – (12 μg/L) = 44 μg/L

Plume volume (P_v) = L_p*W_p*D_p

P_v = (L_b + 6 m + 6 m)*(W_b + 6 m + 6 m)*(6 m)

P_v = (24.2 m)*(15.4 m)*(6 m) = 2236 m^3 per cleaning event

Where:
P_c = Plume concentration
P_v = Plume volume
L_p = Average plume length
W_p = Average plume width
D_p = Average plume depth
L_b = Average boat length
W_b = Average boat width
D_p = Average plume depth

Given:
L_b = 12.2 m
W_b = 3.4 m

Annual copper load = N_h*P_v*P_c*N_v
= (10 / yr.)*(2236 m^3)*(44 µg / L)*(*10,000* vessels)*(kg / 10^9 µg)*(1000 L / m^3)

Where:
N_h= Number of hull cleaning events / year
P_v = Plume volume
P_c = Plume concentration
N_v = Number vessels

Given:
N_h = 10 / year
P_v = 2236 m^3
P_c = 44 µg / L
N_v =10,000 estimated occupancy

Estimates of Copper load from hull cleaning in Newport Bay = 9838 kg / year (27,279 g / day)

New Cd criteria:

EPA has recently issued a revised ambient water quality criteria for dissolved cadmium (EPA 2001a). While the State of California has yet to adopt this criteria, it is useful to provide the equations to determine the freshwater dissolved criteria as well as the corresponding revised concentration based allocations for San Diego Creek.

Dissolved acute Cadmium criteria = e*(1.0166[ln(hardness)]-3.924)*0.908

Dissolved chronic Cadmium criteria = e*(.7409[ln(hardness)]-4.719)*0.873

Table E-15. Current dissolved Cd Numeric Targets (ug/L) based on flow tiers for San Diego Creek.

Dissolved Metal	Base Flows (<20 cfs) hardness @ 400 mg/L		Small Flows (21 - 181 cfs) hardness @ 322 mg/L		Medium Flows (182 -815 cfs) hardness @ 236 mg/L		Large Flows (>815 cfs) @ 197 mg/L
	Acute	Chronic	Acute	Chronic	Acute	Chronic	Acute
Current Cd	19.1	6.2	15.1	5.3	10.8	4.2	8.9
Proposed Cd	7.7	0.64	6.3	0.55	4.6	0.45	3.9

Proposed Cd targets based on recently revised ambient water quality criteria (EPA 2001a)

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Appendix A: DTSC Calsite facilities within Newport Bay watershed

Site ID number	Facility Name	Address	City	Chemicals of concern	Comment
30970007	Tustin Parcel	Corner of Edinger Ave. And Harvard Ave.	Tustin	Pesticides near housing project; Elevated As in shallow soil samples	Nfa for pesticides (1994); As area under investigation (2001)
Same (?)	Tustin Parcel	Corner of Barranca Pkwy and Harvard Ave.	Tustin		Maybe same site as above
30970004	Costa Mesa Air National Guard	South of Presidio Dr.	Costa Mesa	Waste fuel, paint, oil, solvents	Active site; Sampling plan submitted 6/01
30970002	Tustin Marine Corps Air Station	Edinger Avenue	Tustin	Numerous chemicals have been remediated, MTBE plume, As soil	DTSC active site
30790003	Orange County International Raceway	15000 Sand Canyon Avenue	Irvine	Waste oils	Converted to commercial sites (1991) Nfa by DTSC (1994)
30750008	G & H Radiator Service	120 S. Main Street	Santa Ana	Auto radiator waste	Nfa by DTSC (1994)
30510001	Avalon Chemical Company Incorporated	1230 Saint Gertrude Place	Santa Ana	Solvents, acids, bases	Referred to RCRA (1995)
30490110	Edison/Santa Ana II	N.W. of 2nd St. and Sycamore St.	Santa Ana	PAHs, VOCs, heavy metals	DTSC approved RI/FS in 2001, vol. cleanup
30490108	Southern California Gas/Santa Ana I	Corner of Minnie St. and E. Walnut	Irvine	PAHs and Pb	Preliminary endangerment assess. in 1997, still DTSC site
30490008	Coyote Canyon Sanitary	South of Bonita	Irvine	On-site disposal	Referred to County and RWQCB (1989)

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Site ID number	Facility Name	Address	City	Chemicals of concern	Comment
	Landfill	Canyon on Coyote Canyon			
30370015	Ford Aerospace Corporation	1000 Ford Road	Newport Beach	Haz. Material handlers, TSD facility	Referred to RCRA (1995)
30360252	Universal Circuits	1800 Newport Circle	Santa Ana	VOCs, heavy metals in soil	Referred to County (1995)
30360188	Engineered Electronics Company	1441 E. Chestnut	Santa Ana	TSD large facility generator	Nfa by DTSC (1996)
30360052	Hughes, Connecting Devices Division	17150 Van Karman	Irvine	(Poor drum storage)	Nfa by DTSC (1982); Referred to RCRA (1995)
30360008	Metropolitan Circuits Inc.	1261 Logan Avenue	Costa Mesa	Cu and metals in soil	Soil remediation in 1995, Nfa by DTSC
30350177	B & D Metal Finishing	1901 Westminister Avenue	Garden Grove	Solvents	Referred to County (1984)
30350014	Audio Magnetics	2602 Michelson	Irvine	VOCspill (1976)	Nfa by DTSC (1984)
30340301	Rheem Metals	1722 S. Santa Fe Street	Santa Ana	Uncertain	Soil removed 1982, certified clean by DTSC (1982)
30340300	Circuit One	2101 Grand Ave.	Santa Ana	Pb, sludge waste, acids, bases	PEA complete (1984); Nfa by DTSC (1994)
30340067	Smith Tool Company	17871 Von Karman	Irvine	Waste oil and metals	Referred toRWQCB (1995); Nfa by EPA and DTSC
30340061	Rockford Aerospace Products	17300 Redhill	Irvine	Waste oil, cyanides, acids, solvents	Referred to County (1991)
30340054	Orange Coast Plating	2515 S. Birch St.	Santa Ana	Metal sludge, acids, cyanide	Site inspection approved by EPA (1997); Nfa by

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Site ID number	Facility Name	Address	City	Chemicals of concern	Comment
					RWQCB (1999)
30340013	Embee Plating	2144 South Hathaway	Santa Ana	VOCs, metals, solvents, acids	Referred to RWQCB (1995)
30330070	Aluminum Forge	502 E. Alton	Santa Ana	Waste oil and mixed oil	Referred to County after EPA and DTSC deem Nfa (1991)
30300129	Newport Adhesives Composites	1822 Reynolds Avenue	Irvine	TCE, PCE, TPHs,	PA completed (1996), no action since
30280534	Extruded Plastics Company	2201 S. Standard	Santa Ana	Unspecified liquids	Referred to RWQCB (1982)
30280530	Exotic Material, Inc.	2930 Bristol St.	Costa Mesa	Wate oil, solvents, acids	Nfa (1994)
30280469	Holchem DBA Service Chemical	1341 E. Maywood St.	Santa Ana	Uncertain	Site is residential area (1982)
30280370	Zeus Manufacturing	2970 Airway Avenue	Costa Mesa	Solvents, metals, acids	PA done by EPA (1988) Nfa by DTSC (1995)
30280149	McKesson Chemical	1302 Industrial Drive	Tustin	Pseticides and solvents in drums	Nfa by DTSC (1994); referred to County
30280073	Tibbetts Newport Company	2337 Birch St.	Santa Ana	Pesticide containers, paint sludge	Referred to County (1987)
30280006	Consolidated Thermoplastics	2520 S. Birch St.	Santa Ana	Pb, Cr, waste oil, solvents	Nfa by EPA (1989); Nfa by DTSC (1989)

Nfa = no further action; PEA = preliminary endangerment assessment
DTSC contact, Carole Mah, (916) 323-3397

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Appendix A (cont.): Orange County Health Care Agency comments on DTSC Calsites.

SITE NUMBER	SITE NAME	OCHCA INFORMATION
30970007	Tustin parcel	No information
30970004	National Guard	Clean up closed 6-93, clean operation
30970002	MCAS	DTSC clean up no HCA involvement
30790003	O C Raceway	No info, not a current site
30750008	G&H Radiator	No info, not a current site
30510001	Avalon chemical	No info, not a current site
30490110	Edison	No info, not a current site
30490108	SC Gas	No info, not a current site
30490008	Coyote landfill	Landfill closed 1991, regular LEA monitoring
303700015	Ford Aerospace	Facility closed 1998
30360252	Engineered Electronic	No info, not a current site
30360052	Hughes	Clean operation
30360008	Metro Circuits	Velie Circuits, clean site
30350177	B&D metal	No info, not a current site
30350014	Audio magnetics	No info,not a current site
30340301	Rheem Metals	No info, not a current site
30340300	Circuit One	Active clean up, no problems
30340067	Smith Tool	Clean up closed 4-86
30340061	Rockford Products	No info, not a current site
30340054	Orange Coast Plate	Clean up referred to DTSC 11-95
30340013	Embee Plating	Clean up referred to DTSC 5-96, clean opera
30330070	Aluminum Forge	Clean up closed 10-87
30300129	Newport Composites	Clean facility
30280534	Extruded Plastics	No info, not current site
30280530	Exotic Material	No info, not current site
30280469	Holchem	No info, not current site
30280370	Zeus	Chart Industries, clean site
30280149	McKesson	No info, not current site
30280073	Tibbetts Newport	No info, not current site
30280006	Consolidated Therm	No info, not current site

PART F. Organochlorine (OC) Compounds

This support document provides the technical details of the accompanying TMDL document and has been provided for readers interested in the approach, the assumptions, and the data used to develop the organochlorine TMDLs. The organization of this document is as follows:

Section I Pollutant Properties, outlines the chemical and physical properties of the organochlorine compounds for which TMDLs have been developed. Because of the persistent nature of these pollutants and their known impact on the environment, there is a substantial body of literature available that describes their properties. This section provides a summary of the values used to characterize the pollutant properties used in the TMDL analysis.

Section II Calculation of Loading Capacities and Existing Loads, outlines the process and scientific rationale used to calculate the loading capacities and existing loads and presents the calculations for each of the organochlorine compounds. For each compound, all equations, input parameters, and assumptions have been included, along with text that describes how the information was used in the analysis.

Section III References, includes complete citations for each of the references included in the document.

Appendix 1, Data Analysis and Source Assessment, includes the data used to support the organochlorine TMDL analysis.

I. Pollutant Properties

The organochlorine compound TMDLs have been presented in a single document because, as a class of compounds, they possess unique physical and chemical properties that influence their persistence, fate, and transport in the environment. Although these properties differ among the organochlorine compounds, they all exhibit an ability to resist degradation, associate with sediments or other solids, and to accumulate in the tissue of invertebrates, fish, and mammals. In fact, it is their unique properties that have contributed to both their efficacy as pesticides and industrial products and their persistence and accumulation in the environment. Because these unique properties are important factors in identifying and applying the technical procedures used to calculate the TMDLs, this section has been included to provide a better understanding of each of the compounds. The summaries have been developed by reviewing published reports and are focused on the properties that influence their behavior in the environment. This information provides a better understanding of these compounds and supports the TMDL analysis through the selection of values to represent environmental processes.

Polychlorinated biphenyls

Polychlorinated biphenyls (PCBs) are mixtures of up to 209 individual chlorinated compounds (known as congeners). An important property of PCBs is their general inertness; they resist both acids and alkalis and have thermal stability. This made them useful in a wide variety of applications, including dielectric fluids in transformers and capacitors, heat transfer fluids, and lubricants. In general, PCBs are relatively insoluble in water, and the solubility decreases with increased chlorination. Photolysis is the more significant process of degradation than hydrolysis or oxidation. Degradation can occur under both aerobic and anaerobic conditions. The greater the chlorine content of the PCB, the longer the half-life, ranging from days to years (ATSDR

Although it is now illegal to manufacture, distribute, or use PCBs, these synthetic oils were used for many years as insulating fluids in electrical transformers and in other products such as cutting oils (GE, 1999). In 1976, the manufacture of PCBs was prohibited because of evidence they build up in the environment and can cause harmful health effects. Products made before 1977 that may contain PCBs include old fluorescent lighting fixtures and electrical devices containing PCB capacitors, and old microscope and hydraulic oils. Historically, PCBs have been introduced into the environment through discharges from point sources and through spills and accidental releases. Although point source contributions are now controlled, nonpoint sources may still exist. For example, refuse sites and abandoned facilities may still contribute PCBs to the environment. Once in a waterbody, PCBs become associated with solid particles and typically enter sediments (Wisconsin DNR, 1997).

DDT

DDT (1,1,1-trichloro-2,2-bis(p-chlorophenyl)ethane) is an insecticide that was once widely used on agricultural crops and to control disease-carrying insects. Because of potential harm to wildlife and human health, the use of DDT was banned in the United States in 1972, except for public health emergencies. One pesticide, Dicofol, is a currently registered pesticide and an

active source of DDT. Dicofol was permitted to contain up to 15% DDT until 1987, afterwards only 0.015% DDT is allowed as the active ingredient. DDT is still used in some other countries.

DDT degrades into two metabolites: DDD and DDE. DDD was also historically used as a pesticide, but its use has also been banned. One form of it has been used medically to treat cancer of the adrenal gland. DDE has no commercial use. DDT has a half-life in air of less than 2 days and does not dissolve easily in water. Other characteristics include:

- DDT adheres strongly to soil particles and does not move quickly to ground water—its half-life in soil ranges from 2–15 years.
- DDT will evaporate from soil and surface water into the air and is broken down by sunlight or by microorganisms in soil or surface water.
- DDT in soil usually breaks down to form DDE or DDD.
- DDT accumulates in plants and in the fatty tissues of fish, birds, and animals.

Chlordane

Chlordane was used as a pesticide in the United States from 1948 to 1988. Because of concern about environmental and human health impacts, EPA banned the use of chlordane in 1983 except to control termites; all uses have been banned since 1988. Until 1983, chlordane was used as a pesticide on crops such as corn and citrus and on home lawns and gardens. The following characteristics of chlordane affect its fate in the environment:

- Chlordane adheres strongly to soil particles at the surface and is not likely to enter groundwater.
- Chlordane has the ability to stay in the soil for over 20 years.
- Chlordane can leave soil by evaporation to the air.
- Chlordane does not dissolve easily in water.
- Chlordane accumulates in the tissues of fish, birds, and mammals.

Dieldrin

Dieldrin is an insecticide that was used from 1950 to 1970 on crops such as corn and cotton. Because of concerns about damage to the environment and the potential harm to human health, EPA banned all uses of dieldrin in 1974 except to control termites. In 1987, EPA banned all uses. Characteristics of dieldrin that affect its fate in the environment include:

- Dieldrin binds tightly to soil and slowly evaporates to the air.
- Dieldrin breaks down very slowly.
- Dieldrin in soil can accumulate in plants.
- The pesticide, Aldrin, rapidly changes to Dieldrin in plants and animals.
- Dieldrin is stored in body fat and leaves the body very slowly.

Toxaphene

The insecticide Toxaphene contains over 670 chemicals and was one of the most heavily used insecticides in the United States until 1982, when it was banned for most uses. All uses were banned in 1990. It was used primarily in the southern U.S. to control insect pests on cotton and other crops. It was also used to control insect pests on livestock and to kill unwanted fish in lakes. Toxaphene may enter the environment from hazardous waste sites or by evaporation. Other characteristics that affect its fate in the environment include the following:

- Toxaphene does not dissolve well in water, so it is more likely to be found in air, soil, or sediment at the bottom of lakes or streams, than in surface water.
- Toxaphene breaks down very slowly in the environment.
- Toxaphene accumulates in fish and mammals.

Summary of Organochlorine Compound Properties

All organochlorine compounds addressed in this analysis have properties that contribute to their ability to concentrate in biota and magnify in the food chain. These chemicals also have considerable persistence in soils and sediment. Although information on exactly how long these chemicals persist in the environment varies depending on the environmental conditions, they are all found in several media in Newport Bay and San Diego Creek despite the lack of active sources. Consistent with their physical properties, these chemicals are typically not observed in the water column but instead are observed in sediment and fish and mussel samples, as indicated by data collected as part of the CA State Mussel Watch program (SMW 1993 - 2000). Data collected over 20 years shows evidence of declining fish tissue concentrations for these compounds; however, this trend is uncertain in freshwater and saltwater sediments.

The three key properties of the organochlorine compounds used to calculate the TMDLs include:

- Octanol-water partition coefficients (Kow) are a laboratory-measured property that provides a measure of the tendency of a substance to prefer non-aqueous or oily environments rather than water and is used as an indicator of the degree to which a substance will bioaccumulate.
- Organic carbon/water partition coefficients (Koc) describe the ratio of a compound adsorbed to solids and in solution, normalized for organic carbon content.
- Bioconcentration factors (BCF) the ratio between the concentration of the chemical in an organism's tissues to the concentration in the surrounding water.

Appropriate values for the TMDL analyses were identified through a search of local, regional, and national values presented in the literature. For this TMDL the following values were selected as shown in Table F-1 and associated references below.

Table F-1. Summary of Properties of the Organochlorine Compounds

	Total PCBs	Total DDT	Chlordane	Dieldrin	Toxaphene
Log Kow	6.261[a]	p,p' DDT = 6.610[b] p,p, DDE = 6.956[c] p,p DDD = 6.217[d]	6.32[e]	5.401[d]	5.5[e]
Log Koc[g]	6.15	p,p' DDT = 6.498 p,p DDE = 6.838 p,p DDD = 6.111 **Mean DDT = 6.48**	6.21	5.31	5.4
BCF[f]	270,000	363,000	37,800	2,993	52,000

[a] Mean of 20 congener values cited for PCB cited in de Bruijn et al. (1989)
[b] mean of two values cited in USGS (2001) One value from de Bruijn et al. (1989) and one value from Brooke et al. (1990)
[c] USGS (2001) from de Bruijn et al. (1989)
[d] de Bruijn et al. (1989)
[e] "Southerland" EPA report
[f] references for the BCF values are presented in Table F-4.
[g]The following general equation was used for converting Log Kow to Log Koc.
Log Koc = 0.00028 + log Kow (0.983) (Hoke et al. 1994).

Review of Sediment Targets

As discussed in the TMDL document, the Santa Ana Regional Board Basin Plan (1995) includes narrative water quality objectives for each of the pollutants addressed in this document (see section II in the summary document). However, to calculate the loading capacities, it was necessary to select a numeric endpoint protective of the narrative standards. The rationale for selecting the numeric endpoints is presented in section VI of the summary document. The endpoints are listed in Table F-2.

Table F-2. Sediment Targets Used in the TMDL Analyses

	PCBs (µg/kg)*	DDT (µg/kg)*	Chlordane (µg/kg)*	Dieldrin (µg/kg)*	Toxaphene (µg/kg)*
San Diego Creek	34.1	6.98	4.5	2.85	0.1
Upper Newport Bay	21.5	3.89	2.26	NR	NR
Lower Newport Bay	21.5	3.89	2.26	0.71	NR
Rhine Channel	21.5	3.89	2.26	0.71	NR

NR: TMDL not required for these pollutant-waterbody combinations
* dry weight

II. Calculation of Loading Capacities and Estimate of Existing Loadings

General Conceptual Approach

The loading capacity for each pollutant represents the maximum loading that a waterbody can assimilate and still meet and maintain water quality standards. For the organochlorine compounds addressed in these TMDLs, long-term loadings at or below the loading capacities should eventually result in reduction in concentrations of these compounds in bottom sediment to levels protective of the standards. A review of available data (see Appendix 1 for a summary of the data used in the TMDL analysis) indicates that bottom sediments currently exhibit elevated organochlorine compound concentrations and it is believed that these elevated levels are primarily associated with the past use and disposal of products containing these compounds. The higher the current concentrations in bottom sediments, the longer it will take to meet standards, even if external sources are reduced.

The approach to determining the loading capacities for each of the organochlorine compounds was similar and was based on an understanding of the sources of these compounds (past, present, and future) and the transport and ultimate fate of these compounds in various environmental media. Based on a review of literature sources, it was observed that organochlorine compound environmental persistence and affinity for adsorbing to sediment and accumulating in biota generally limits their presence in the water column, at least relative to sediment and biota. Additionally, because these compounds are no longer used in the watershed (with the exception of small amounts of DDT associated with Dicofol applications) the primary sources are assumed to be sediment loading associated with watershed runoff and resuspension and transport of previously deposited in-stream sediments. The loading capacities were determined by "back-calculating" the allowable load from the selected sediment target (Table F-2) and the associated estimates of sediment loads.

The calculation of existing organochlorine compound loads, which are not required components of the TMDLs, allows for a relative comparison the estimated current loading to the calculated loading capacity. In contrast to the calculation of the loading capacities, which was accomplished through back calculation from the sediment targets, the existing loadings were based on review and analysis of available multi-media data.

The methodologies used to calculate the loading capacities and existing loads for San Diego Creek and Newport Bay are discussed the following section with separate subsections for each methodology.

Calculation of San Diego Creek Loading Capacity and Existing Loads

Figure F-1 presents a schematic of the approach used to calculate the loading capacity and existing loads for San Diego Creek. The approach relies on the following key information:

- Flow data from gaging station at Campus Drive (USGS and OCPFRD data)
- Suspended sediment concentrations from the RMA modeling study regression analysis (RMA 1997)

- Sediment targets (see Table F-2)
- Partition coefficients (see Table F-1)
- Acute and chronic criteria from the California Toxics Rule (EPA 2000a)
- Fish tissue concentrations (for calculating existing loads)
- Pollutant-specific bioconcentration factors (BCFs)

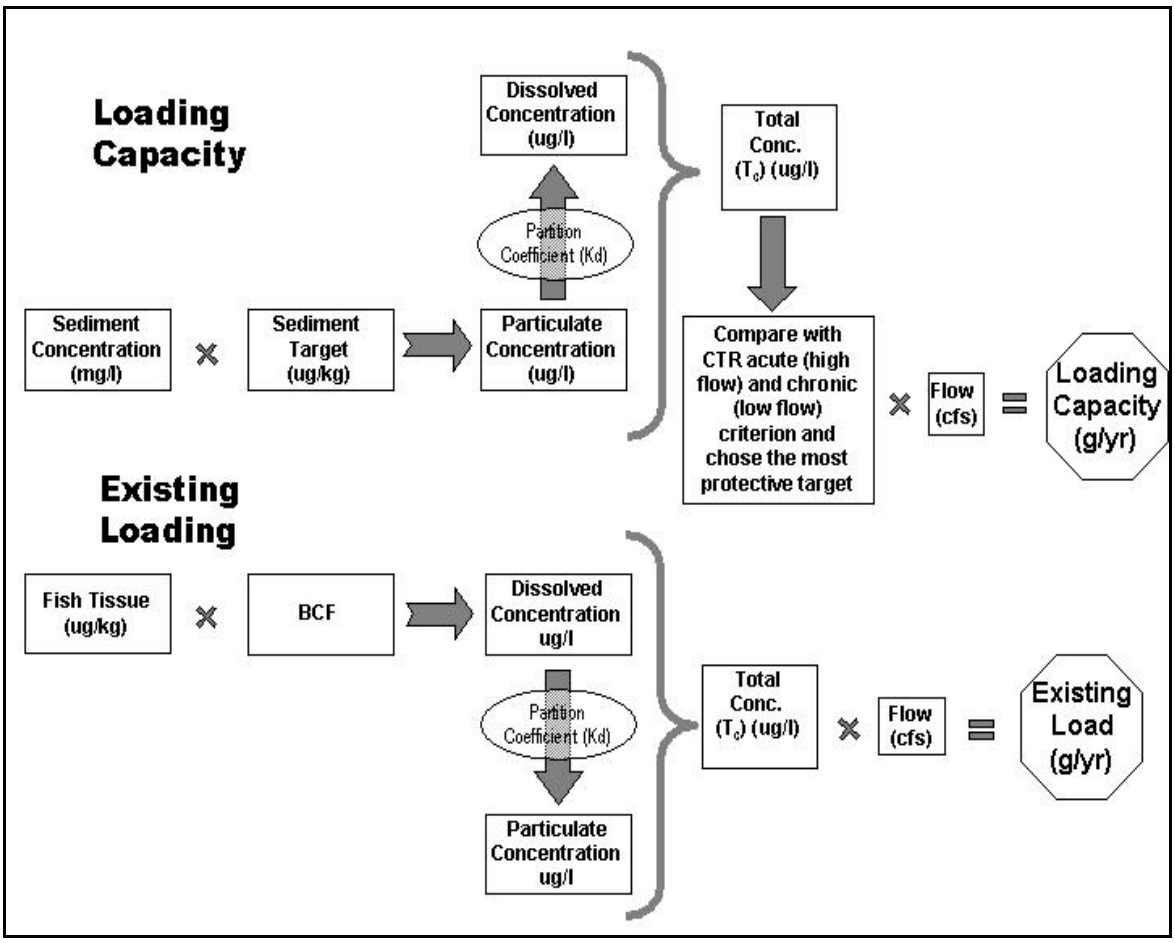

Figure F-1. Approach to Developing Loading Capacities and Existing Loads in San Diego Creek

The analyses for the loading capacity and the existing loads were based on the same general procedures but the availability of data dictated several differences, notably the use of available fish tissue data and bioconcentration factors in the calculation of existing loads. The remainder of this section outlines the procedures, parameters, and values used in the calculation of loading capacities and existing loads.

Loading Capacity

The loading capacity represents the maximum amount of a pollutant a waterbody can assimilate and still meet applicable water quality objectives. For the organochlorine compound TMDLs, sediment targets protective of the objectives were identified and formed the basis for the calculation of the loading capacity. The first step involved using the sediment targets and calculating particulate pollutant concentrations using information on the suspended sediment concentrations in the creek under three flow tiers. Daily flow records available at Campus Drive (USGS 1977-1997) were analyzed and categorized into the following flow tiers:

- Base and low flows: median (15 cfs) for 352 days
- Medium flows: median (365 cfs) for 10 days
- High flows: median (1,595 cfs) for 3 days

The suspended sediment concentration corresponding to each of the flow tiers was calculated based on the observation data and regression results from the Feasibility Report for Upper Newport Bay (RMA 1997). The values are 97, 1,730, and 5,011 mg/L for the base and small, medium, and high flow tiers, respectively. The following is the regression equation used in the analysis:

$$\log(y) = -0.09(\log(x)\text{^}2 + 2.24(\log(x)) - 1.96$$

where: x = flow (cfs)
y = sediment (tons/day)

Because the organochlorine compounds have a strong affinity for sediment, partition coefficients, which describe the ratio of a compound adsorbed to solids and in solution, were identified and used with the particulate concentrations to estimate the dissolved concentration. The sum of the particulate and dissolved concentrations represented the total concentration of the pollutant in the water column.

The total water column concentrations for each flow tier were than compared to either the acute (Criterion Maximum Concentration [CMC]) or the chronic (Criterion Continuous Concentration [CCC]) criterion. The concentrations for each flow tier that were most protective of water quality objectives were summed used with flow data to calculate the loading capacity. The base and low flow and medium flow concentrations were compared to the chronic criteria and the high flow concentrations were compared to the acute criteria. The acute and chronic values were obtained from the California Toxics Rule (USEPA 2000a) and are presented in Table F-3.

The following equations provide the approach for calculating the loading capacities presented in Table F-5.

$$\text{Load (g/yr)} = Cw \times Q \times 28.31 \times 86{,}400 \times Qd \times 0.000001$$

where: Cw = water concentration (µg/L)
Q = flow (cfs)

28.31	=	cubic feet to liter
86,400	=	conversion factor for days per year
Qd	=	number of days of flow (3, 10, or 362)
0.000001	=	conversion factor from μg to g

The values for Cw were calculated using the following equation:

$$Cw = Ct \times Cs \times 1/F_p \times CF$$

where:	Ct	=	pollutant target concentration in sediment (μg/kg)
	Cs	=	sediment concentration (mg/L)
	F_p	=	particulate fraction
	CF	=	conversion factor from mg to kg

The values for F_p were calculated using the following equation:

$$F_p = 1 - F_d$$

$$F_d = \frac{1}{1 + K_d \cdot Cs}$$

where:	K_d	=	pollutant-specific partition coefficient (m^3/g)

Table F-3. CCC (chronic) and CMC (acute) values.

Pollutant	CCC (chronic) (μg/L)	CMC (acute) (μg/L)
PCB	0.014	0.0140
DDT (total)	0.001	1.1000
Chlordane	0.0043	2.4000
Dieldrin	0.056	0.2400
Toxaphene	0.0002	0.7300

Source: EPA (2000a): California Toxics Rule

Existing Loads

The calculation of existing loads (see Figure F-1) was accomplished using the same general procedure outlined above for the loading capacity. The primary differences include:

- Recent fish tissue data were used with BCFs to back calculate the dissolved pollutant concentrations.
- Partition coefficients were used with the dissolved concentrations to estimate the particulate fraction.
- The total concentration and flow were used to calculate existing loads—no comparison to water quality criterion was conducted.

The analysis of existing loads was conducted using fish tissue (red shiner) data collected in June 1998 as part of the Toxic Substances Monitoring Program at the following three locations:

- San Diego Creek/Michelson Drive
- Peters Canyon Channel
- San Diego Creek/Barranca Parkway

The geometric mean of the fish tissue data (Appendix 1) from this source were used because they represented the best available recent data on the accumulation of the organochlorine compounds in aquatic biota.

The next step in the analysis required using the fish tissue concentrations with BCF values for each of the organochlorine compounds to calculate a dissolved pollutant concentration. The selection of appropriate BCF values, which have published values spanning several orders of magnitude, was conducted. Species-specific (i.e., Red Shiner) BCF values were not available therefore values for similar small bottom feeding fish such as the fat head minnow were used (Table F-4).

Table F-4. Bioconcentration factors used in the analysis of existing loadings.

Name	BCF	Reference
PCBs	270,000	EPA Ambient Water Quality Criteria - PCB (Aroclor 1260 - Fathead minnow (female) *Pimehales promelas*)
Dieldrin	2,993	EPA Ambient Water Quality Criteria - Channel catfish (*Ictalurus punctatus*)
DDT	363,000	EPA Ambient Water Quality Criteria - DDT (Common Shiner - *Notropis Cornutus*)
Toxaphene	52,000	EPA Bioaccumulation Testing And Interpretation For The Purpose of Sediment Quality Assessment (Fathead minnow *Pimehales promelas*)
Chlordane	37,800	EPA Ambient Water Quality Criteria - Chlordane (Fathead minnow - *Pimehales promelas*)

Once appropriate BCFs were determined, they were used with the fish tissue concentrations to calculate the dissolved pollutant concentration. In contrast to the approach used to calculate the loading capacity, partition coefficients were used to determine the pollutant concentration in the particulate fraction. The dissolved and particulate concentrations were then summed into a total concentration, which was used with flow data to calculate the existing loads for each pollutant. All of the equations presented above for the calculation of the loading capacity were also used to calculate existing loads. In addition, the following equation was used to calculate the dissolved concentration using the fish tissue concentrations and BCF values.

$$c_w = \frac{TC}{BCF}$$

where: TC = tissue Concentration in µg/kg
BCF = EPA Bioconcentration Factor in L/kg
c_w = dissolved concentration (estimated) in µg/L

Table F-5 presents the loading capacities and existing loadings of the organochlorine compounds for San Diego Creek.

Table F-5. Summary of San Diego Creek Existing Loads and Loading Capacities

	Existing Load (g/year)	Loading Capacity (g/year)
PCB	282.1	2,226.3
DDT	3,733.8	432.6
Chlordane	615.7	314.7
Dieldrin	381.8	261.5
Toxaphene	582.1	8.8

Calculation of Newport Bay Loading Capacity and Existing Loads

The major source of the organochlorine compounds into Newport Bay is upstream loadings from San Diego Creek (88 percent), local drainages, and redistribution of historically deposited sediments within the Bay system. Previous modeling studies, completed by RMA for the U.S. Army Corps of Engineers (USACE) have examined the circulation patterns, and transport and deposition of sediments in Newport Bay (RMA 1998). By examining model calibration results (RMA 1998) for Newport Bay from 1985-1997, the sediment deposition in each region of Newport Bay was estimated. Historic pollutant loads to the bottom sediment were estimated by using observed pollutant concentrations in bottom sediments and net sedimentation rates. Sediment volume was converted to dry weight using an estimated porosity of 0.65.

Figure F-2 presents a schematic of the approach used to calculate the loading capacity and existing loads for Newport Bay. The approach relies on the following key information:

- Sediment deposition rates (from the RMA (1997) model)
- Sediment deposition patterns (from the RMA (1997) model)
- Sediment pollutant targets (used for loading capacity) (see Table F-2)
- Sediment organochlorine concentrations from observation data (used for existing loads)

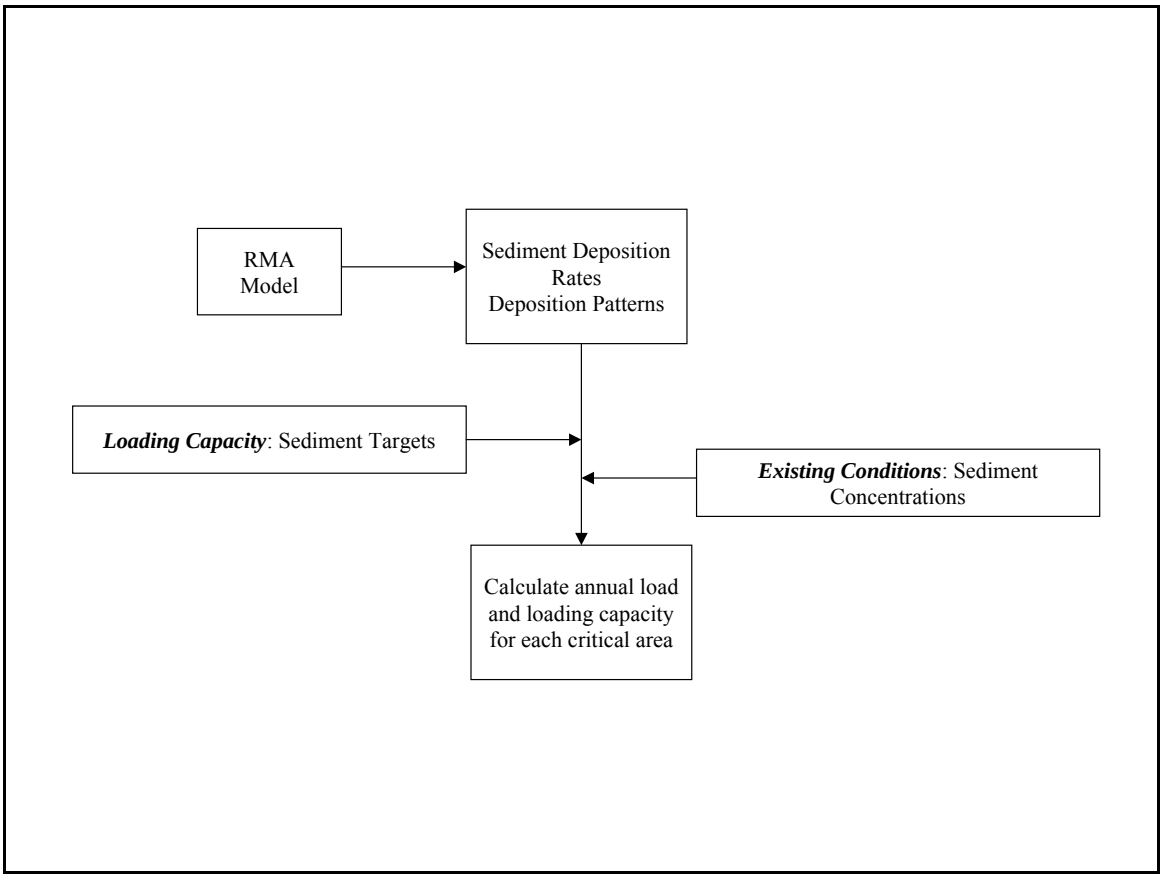

Figure F-2. Approach to Developing Loading Capacities and Existing Loads in Newport Bay

The remainder of this section presents the loading capacity calculations for each of the organochlorine compounds. For each compound, all equations, values applied, and references used in the calculation are included.

Summary of Approach for Calculating Loading Capacities and Existing Loads of Organochlorine Compounds for Newport Bay

The following equation was used with sediment target concentrations (Cs) (Table F-6) to calculate the loading capacities. For existing loadings, the same equation was used with concentrations from existing data substituted for the sediment targets.

$$\text{Load (g/yr)} = Cs \times Ds \times \rho s \times (1 - Ps) \times CF$$

where:

Cs	=	sediment concentration (µg/kg dry)
Ds	=	sediment deposition (m^3/yr)
ρs	=	sediment density (kg/m^3)
Ps	=	sediment porosity
CF	=	conversion factor from µg to g

The values for all parameters used in the analysis for Newport Bay and Rhine Channel are presented in Table F-6.

Table F-6. Parameter values used in the Newport Bay TMDL Analysis.

	Sediment conc. (ug/kg dry)				ρs (kg/m^3)	Ps	CF
	Target Concentration	Observed Concentrations*					
		UNB	LNB	RC			
PCB	21.5	42.8	40.8	93.1	2,500	0.65	0.000001
DDT	3.89	58.7	74.5	7.45			
Chlordane	2.26	12.8	8.94	0.44			
Dieldrin	0.71	1.0	1.0	5.0			

*UNB: Upper Newport Bay; LNB: Lower Newport Bay; and RC: Rhine Channel
Ds (m^3/year): Upper Newport Bay: 81,233.95; Lower Newport Bay: 29,924.01; Rhine Channel: 859.23

Calculations

PCB

Loading Capacity

$$\text{Upper NB Loading Capacity (g/yr)} = 21.5 \times 81{,}234 \times 2{,}500 \times (1 - 0.65) \times 0.000001$$
$$\text{Lower NB Loading Capacity (g/yr)} = 21.5 \times 29{,}924 \times 2{,}500 \times (1 - 0.65) \times 0.000001$$
$$\text{Rhine Channel Loading Capacity (g/yr)} = 21.5 \times 859.23 \times 2{,}500 \times (1 - 0.65) \times 0.000001$$

Existing Loading

$$\text{Upper NB Existing Loading (g/yr)} = 42.8 \times 81{,}234 \times 2{,}500 \times (1 - 0.65) \times 0.000001$$
$$\text{Lower NB Existing Loading (g/yr)} = 40.8 \times 29{,}924 \times 2{,}500 \times (1 - 0.65) \times 0.000001$$
$$\text{Rhine Channel Existing Loading (g/yr)} = 93.1 \times 859.23 \times 2{,}500 \times (1 - 0.65) \times 0.000001$$

PCB	Existing Load (g/year)	Loading Capacity (g/year)
Upper Newport Bay	858.7	1528
Lower Newport Bay	409.8	563.0
Rhine Channel	70.02	16.16

DDT

Loading Capacity

$$\text{Upper NB Loading Capacity (g/yr)} = 3.89 \times 81{,}234 \times 2{,}500 \times (1 - 0.65) \times 0.000001$$
$$\text{Lower NB Loading Capacity (g/yr)} = 3.89 \times 29{,}924 \times 2{,}500 \times (1 - 0.65) \times 0.000001$$
$$\text{Rhine Channel Loading Capacity (g/yr)} = 3.89 \times 859.23 \times 2{,}500 \times (1 - 0.65) \times 0.000001$$

Existing Loading

$$\text{Upper NB Existing Loading (g/yr)} = 58.7 \times 81{,}234 \times 2{,}500 \times (1 - 0.65) \times 0.000001$$
$$\text{Lower NB Existing Loading (g/yr)} = 74.5 \times 29{,}924 \times 2{,}500 \times (1 - 0.65) \times 0.000001$$
$$\text{Rhine Channel Existing Loading (g/yr)} = 7.45 \times 859.23 \times 2{,}500 \times (1 - 0.65) \times 0.000001$$

DDT	Existing Load (g/year)	Loading Capacity (g/year)
Upper Newport Bay	1080	276.5
Lower Newport Bay	438.4	101.9
Rhine Channel	5.60	2.92

Chlordane

Loading Capacity

$$\text{Upper NB Loading Capacity (g/yr)} = 2.26 \times 81{,}234 \times 2{,}500 \times (1 - 0.65) \times 0.000001$$
$$\text{Lower NB Loading Capacity (g/yr)} = 2.26 \times 29{,}924 \times 2{,}500 \times (1 - 0.65) \times 0.000001$$
$$\text{Rhine Channel Loading Capacity (g/yr)} = 2.26 \times 859.23 \times 2{,}500 \times (1 - 0.65) \times 0.000001$$

Existing Loading

$$\text{Upper NB Existing Loading (g/yr)} = 12.8 \times 81{,}234 \times 2{,}500 \times (1 - 0.65) \times 0.000001$$
$$\text{Lower NB Existing Loading (g/yr)} = 8.94 \times 29{,}924 \times 2{,}500 \times (1 - 0.65) \times 0.000001$$
$$\text{Rhine Channel Existing Loading (g/yr)} = 0.44 \times 859.23 \times 2{,}500 \times (1 - 0.65) \times 0.000001$$

Chlordane	Existing Load (g/year)	Loading Capacity (g/year)
Upper Newport Bay	290.7	160.6
Lower Newport Bay	50.20	59.17
Rhine Channel	0.33	1.70

Dieldrin

Loading Capacity

$$\text{Lower NB Loading Capacity (g/yr)} = 0.71 \times 29{,}924 \times 2{,}500 \times (1 - 0.65) \times 0.000001$$
$$\text{Rhine Channel Loading Capacity (g/yr)} = 0.71 \times 859.23 \times 2{,}500 \times (1 - 0.65) \times 0.000001$$

Existing Loading

$$\text{Lower NB Existing Loading (g/yr)} = 1.0 \times 29{,}924 \times 2{,}500 \times (1 - 0.65) \times 0.000001$$
$$\text{Rhine Channel Existing Loading (g/yr)} = 5.0 \times 859.23 \times 2{,}500 \times (1 - 0.65) \times 0.000001$$

Dieldrin	Existing Load (g/year)	Loading Capacity (g/year)
Lower Newport Bay	5.93	18.59
Rhine Channel	3.76	0.53

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Appendix 1: Data Analysis and Assessment

This appendix presents the data available to characterize the level of contamination by organochlorine compounds in the Newport Bay watershed. Monitoring data are available for three media: water, sediment, and tissue. The following data summaries are organized by the source/agency.

Orange County Public Facilities and Resources Department (OCPFRD): Sediment data results were available for three DDT compounds and two PCB Aroclors; no data results were available for Chlordane, Dieldrin and Toxaphene. Data were available from 1999 to 2000 for some freshwater tributaries and several sites in Upper and Lower Bay. OCPFRD results (1999/00) for PCBs were used in the analysis of existing loads. Results reported below the MDL were assumed equal to half that value. No data for organics in the water column were available.

***Irvine Ranch Water District (IRWD*):** Limited data were available for 1997 and 1998. All water monitoring data were reported as not detected. One sediment sample was reported as 1 µg/kg for p-p' DDE in October of 1998. This data was not used in the analysis.

Toxic Substance Monitoring Program(TSMP): Species specific fish tissue data was available for organic compounds from 1993 to 1998. The most recent fish tissue data (1998) from three locations in San Diego Creek (San Diego Creek/Michelson Drive, Peters Canyon Channel and San Diego Creek/Barranca Parkway) was used. Results were reported for all organochlorine pollutants in these TMDLs.

Bay Protection and Toxic Cleanup Program Data (BPTCP): This study reports sediment concentrations at various locations in the Newport Bay for PCB, DDT, Chlordane, Toxaphene, and Dieldrin. Sediment sample data in µg/kg was available from two sampling events that took place in 1994 and 1998. This data was used to supplement the most recent sediment sampling data when it was not available (i.e., Dieldrin in Newport Bay).

Newport Bay Sediment Toxicity Studies (SCCWRP 2001a): Sediment samples collected at 10 Newport Bay stations in May 2001 was available. Sediment data in µg/kg for PCB, DDT, Chlordane, and Dieldrin at selected locations was used to estimate the existing loading capacity.

Resource Management Associates report (USACE, 1997 - RMA model):
Estimates of the sediment distribution for the Upper Bay, Lower Bay and Rhine Channel were made using the results of sediment transport model developed by RMA. The model simulates wet and dry conditions as well as the largest storm event from 1985-1997. Because most sediment entering Upper Newport Bay occurs during the storm events, mean daily stream discharge records for San Diego Creek were used to develop a five-day hydrograph that were used to simulate storm event for RMA model. The peak flows for each model simulation years are shown in Table 2 below. A detailed description can be found in the RMA report (RMA, 1997). The sediment deposition rates for Newport Bay were derived from 12-year model simulation results. Although the mean values are used to estimate the sediment budget for the Newport Bay, the sediment deposition rates represents a net deposition over the years.

The following tables list data from different sources by the various sources used in the analysis.

The most recent sediment data (May 2001) was used from the Newport Bay Sediment Toxicity Studies Report, October 23, 2001 (Tables 8, 9 and 10). Where data were not available (dieldrin only), it was supplemented with sampling studies done in 9/19/1994 and from the Orange County Public Facilities and Research Department (OCPFRD 1991 – 2000). Supplemented data are footnoted.

Table 1 Sediment Chemistry Toxicity Data used in the TMDL

Location	Total DDT	Chlordane[a]	Total PCB	Dieldrin
	ug/kg dry	ug/kg dry	ug/kg dry	Ug/kg dry
Unit I basin (NB10)	17.43	3.52	18.00[b]	0.00
Unit II basin (NB9)	14.97	6.41	6.76[c]	1.00[d]
South of Unit II (NB7)	7.1	1.25	18.00[a]	0.00
Downstream to PCH Bridge(NB6)	19.18	1.6	0.00	0.00
Lower Bay (NB1)	1.91	0.00	18.00[b]	0.00
Turning Basin (NB4)	49.81	5.93	22.76	1.00[d]
Newport channel (NB2)	22.8	3.01	0.00	0.00
Rhine Channel (NB3)	7.45	0.44	93.13	5.00[d]

All non-detects were taken as zero

[a]sum of gamma-Chlordane, alpha-Chlordane, trans-Nonachlor, and cis-achlor reported in the Newport Bay Sediment Toxicity Studies Report, October 23, 2001 at each location.

[b]OCPFRD 1999 – 2000 data.

[c]NB8 sediment concentration for Total PCB was used as NB9 was not available.

[d]9/19/1994 Bay Protection and Toxic Cleanup Program data (BPTCP)

Table 2. Peak storm flows USACE, 1997 (RMA model)

	Mean Daily Flow (cfs)					
Water Year	Day 0	Day1	Day2	Day3	Day4	Day5
1985-1986	18	268	530	1589	106	71
1986-1987	24	659	205	69	48	48
1987-1988	13	649	201	17	14	14
1988-1989	10	512	828	15	15	15
1989-1990	13	1772	175	38	18	18
1990-1991	10	1030	2370	1700	47	18
1991-1992	175	2020	2350	712	60	60
1992-1993	410	1950	2979	625	60	40
1993-1994	12	835	200	15	13	13
1994-1995	71	4509	437	397	70	53
1995-1996	24	1600	978	89	24	18
1996-1997	24	1600	978	89	24	18

Table 3. Sediment Deposition rates in Newport Bay – Estimated from the USACE 1997 (RMA model)

Location	Sediment Deposition (m3/year)
Unit I basin	31474.17
Unit II basin	30327.34
South of Unit II	11659.46
Downstream to PCH Bridge	7772.97
Upper Newport Bay Total	**81233.95**
Lower Bay	17444.29
Turning Basin	6782.52
Newport channel	5697.20
Lower Newport Bay Total	**29924.01**
Rhine Channel	859.23

Table 4. Fish Tissue Data in San Diego Creek – Toxic Substance Monitoring Plan (TSMP, 1983 –1998)

Station	Species	Date	Chlordane	Total DDT	Dieldrin	Total PCB	Toxaphene
San Diego Creek/Michelson Drive	Red Shiner	6/9/1998	8.1	203.5	5.7	ND	83.0
Peters Canyon Channel	Red Shiner	6/9/1998	54.8	2168.2	12.5	79.4	330.0
San Diego Creek/Barranca Parkway	Red Shiner	6/9/1998	13.8	458.8	3.2	60.7	91.6
Value used in calc.			**18.3**	**587.2**	**6.1**	**69.4**	**135.9**

Other information reviewed to identify potential sources and to characterize contributions is summarized blow.

Toxic Substance Control Act Facility Database—Federal
Congress enacted the Toxic Substances Control Act (TSCA) of 1976 to protect human health and the environment from the effects of chemicals and other substances that have not undergone appropriate risk screening. To implement its responsibilities under TSCA, EPA maintains the Toxic Substances Control Act database, which tracks the thousands of new chemicals developed by industries each year. A review of the TSCA facility database indicated that no facilities in the watershed handle DDT, Dieldrin, Toxaphene, Chlordane, or PCBs.

Resource Conservation and Recovery Act Information System—Federal
The Resource Conservation and Recovery Act of 1976 (RCRA) gave EPA the authority to control hazardous waste "cradle to grave." This control includes the generation, transportation, treatment, storage, and disposal of hazardous waste. The 1986 amendments to RCRA enabled EPA to address environmental problems that could result from underground tanks storing petroleum and other hazardous substances. RCRA focuses only on active and future facilities and does not address abandoned or historical sites.

According to the EPA RCRA Information System (RCRIS) records, the Newport Bay and San Diego Creek watersheds contain about 1,000 RCRA facilities. However, none of these facilities were found to be a possible source of DDT, Dieldrin, Toxaphene, Chlordane, or PCBs.

Comprehensive Environmental Response, Compensation, and Liability Act Information System—Federal
The Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) provides for a federal “Superfund” to clean up uncontrolled or abandoned hazardous waste sites, as well as accidents, spills, and other emergency releases of pollutants and contaminants into the environment. The Comprehensive Environmental Response, Compensation, and Liability Information System (CERCLIS) supports the identification and management of Superfund sites.

EPA Permit Compliance System and Industrial Facility Discharge
A review of the EPA Permit Compliance System (PCS) shows 14 permitted facilities in the watershed. None of these 14 facilities were permitted to discharge DDT, PCBs, Dieldrin, Toxaphene, or Chlordane. The Industrial Facility Discharge (IFD) database was also reviewed for facilities within the watershed. The facilities identified in IFD are permitted surface water discharges that have a small flow and are not expected to significantly affect the waters. No other potential point sources were identified based on review of the IFD database.

DTSC sites—State of California
Thirty-two facilities in the watershed were listed under the California Department of Toxic Substance Control (DTSC) CALSITE database (pers. commun. C. Mah). Only three of those facilities (Table F-2) were found to have the chemicals of concern for this TMDL. There is not enough information available to quantify pesticide loads from these three sites.

Table 4. DTSC Calsite facilities within Newport Bay watershed

Site ID number	Facility Name	City	Chemicals of concern	Comments (from database)	Comments (from OCHCA)
30970007	Tustin Parcel	Tustin	Pesticides near housing project;	Nfa for pesticides (1994);	No information
30280149	McKesson Chemical	Tustin	Pesticides and solvents in drums	Nfa by DTSC (1994); referred to County	No information, not a current site
30280073	Tibbetts Newport Company	Santa Ana	Pesticide containers, paint sludge	Referred to County (1987)	No information, not a current site

Source: DTSC database; Nfa = no further action; PEA = preliminary endangerment assessment; OCHCA=Orange County Health Care Agency

Part G— Chromium (Cr) and Mercury (Hg) TMDLs

This support document provides the technical details of the accompanying TMDL document and has been provided for readers interested in the approach, the assumptions, and the data used to develop the mercury and chromium TMDLs. The organization of this document is as follows:

Section I, Pollutant Properties, outlines the chemical and physical properties of mercury and chromium for which TMDLs have been developed. Because of the persistent nature of these pollutants and their known impact on the environment, there is a substantial body of literature available that describes their properties. This section also provides a summary of the possible sources of mercury and chromium to the Rhine Channel.

Section II, Calculation of Loading Capacities and Existing Loads, outlines the process and scientific rationale used to calculate the loading capacities and existing loads and presents the calculations for mercury and chromium. For each compound, all equations, input parameters, and assumptions have been included, along with text that describes how the information was used in the analysis.

Section III, References, includes complete citations for each of the references included in the document.

Appendix 1, Data Analysis and Source Assessment, includes the data used to support the mercury and chromium TMDL analysis.

I. Pollutant Properties

The mercury and chromium TMDLs have been presented in a single document because they are similar in physical and chemical properties and are identified as needing TMDLs in Rhine Channel only. Although these properties differ for the two compounds, they both exhibit an ability to associate with sediments or other solids, and to accumulate in the tissue of invertebrates, fish, and mammals.

The summaries have been developed by reviewing published reports and are focused on the properties that influence their behavior in the environment. This information provides a better understanding of these compounds and supports the TMDL analysis through the selection of values to represent environmental processes.

Mercury (Hg)

Mercury is naturally occurring metal that has several chemical forms: Hg(0), Hg(I) and Hg(II). It may enter the water or soil from natural mineral deposits and volcanic activity. Mercury combines with other elements, such as chlorine, sulfur or oxygen to form inorganic mercury salts, which are usually white powders or crystals. Metallic mercury is used to produce chlorine gas and caustic soda, and is sometimes used in thermometer, dental fillings, and batteries. Inorganic mercury enters the air from mining ore deposits, coal-fired power plants, chlor-alkali plants, cement manufacturing. Cinnabar (HgS) is the most common ore of mercury. Mercury is also used in seed dressings, fungicides, paints, and slimicides. Mercury laden soils or sediments may be a source of mercury in various chemical species.

Mercury also combines with carbon to make organic mercury compounds. Methylmercury (CH_3Hg^+) is produced primarily by microscopic organisms in the water or soil. The formation of methylmercury is the most significant transformation because methylmercury is far more toxic than any other form of mercury. Most scientists observe that anaerobic conditions are required for conversion of inorganic mercury to methylmercury. Organic forms of mercury build up in animal tissues; methylmercury is the prominent chemical species. Since mercury bioaccumulates in tissues, animals at higher trophic levels, such as larger and older fish or birds, tend to have the highest levels of mercury.

The human nervous system is very sensitive to all forms of mercury. Exposure to high levels of metallic, inorganic, or organic mercury can permanently damage the kidneys and brain. Effects on brain functioning may result in irritability, shyness, tremors, changes in vision or hearing, and memory problems. Short-term exposure to high levels of metallic mercury vapors may cause effects including lung damage, nausea, vomiting, diarrhea, increases in blood pressure or heart rate, skin rashes and eye irritation. Mercury's harmful effects may be passed from mother to nursing infant via breast milk. Developmental problems may result such as brain damage, mental retardation, incoordination, blindness, seizures, and inability to speak (ATSDR 2001).

Possible Mercury Sources

Most sources of mercury to the Rhine Channel are anthropogenic. Monitoring results suggest that existing sediments in Rhine Channel are the largest source of mercury. The Regional Board technical report (1998) defines the Rhine Channel as a toxic hot spot and states that historical uses of ship anti-fouling paints containing mercury and other metals may be responsible for elevated sediment levels. However, no investigation has been completed to explain the elevated (total) mercury sediment concentrations within Rhine Channel.

Orange County Coastkeeper (1999) measured mercury concentrations in one sediment core and the results provide a historical perspective. The highest concentrations of total mercury (11 mg/kg dry) were found at the bottom of the core and the lowest concentrations (3.4 mg/kg dry) were found at the top of the core. Other researchers have found similar sediment concentrations in Rhine Channel; the most recent data reported by SCCWRP (2001) reports 5.8 mg/kg dry and SARWQCB (1998) reports (8.7 mg/kg dry). However, these levels are still high enough to contribute to the degradation of benthic organisms. Mercury exceeds the Effects Range-Median (ERM) guidelines in the Rhine Channel (SARWQCB 1998). Table G-1 summarizes observations of mercury and chromium levels in the Rhine Channel sediments.

Table G-1. Chromium and Mercury Sediment Monitoring Results for Rhine Channel

Organization (cite)	Collection dates	Location	Cr conc. (mg/ kg dry)	Hg conc. (mg/ kg dry)	
SCCWRP (2001)	5/01	Boatyard launch	44.0	5.80	
	9/00	See above	26.0	5.30	
OCPFRD (2000)	4/96 -- 6/00	Rhine -- bend	13.3 – 60	N/a*	Mean = 24.4 Median = 17
BPTCP (1997)	1996	N/A	69.6	8.74	
	1994	N/A	51.5	7.62	
Coastkeeper (1999)	1999	Rhine -- middle	13	4.4	
Coastkeeper Sediment core (1999)	1999	Rhine -- bend Top	16	3.4	
	1999	Top-middle	15	7.6	
	1999	Mid-bottom	13	9.8	
	1999	Bottom	12	18	

*currently, OCPFRD does not monitor for mercury; mean and median values are for chromium.
N/A= not available

Mercury-containing sediments may also have been transported from the San Diego Creek watershed into the Rhine Channel. Historic records show mercury mining occurred at Red Hill mine between 1880 and 1939 (CA Division of Mines 1976). According to this report, 130 seventy-six pound flasks of mercury were produced between 1927 and 1929. Minor mercury production is also reported for 1932-33 and 1939. Insufficient information is available to accurately interpret sediment transport from this historic mining site.

Atmospheric deposition is believed to be an active source of mercury; however, compared to inputs from existing sediments and contributions from freshwater sediment deposition, atmospheric deposition of mercury is considered negligible. In addition, ambient seawater concentrations of mercury are extremely low, typically less than 1 ng/L, indicating that seawater is an insignificant source of mercury in the Rhine Channel.

Chromium (Cr)

Chromium is a naturally occurring element found in plants, rocks, soils, and volcanic dust and gases. Chromium is present in the environment in several different forms. The most common forms are chromium (0), chromium (III), chromium (VI). Metallic chromium (0) is used for making steel. Chromium (III) and (VI) are used for chrome plating, dyes and pigments, leather tanning, and wood preserving.

Chromium can strongly attach to soil and only a small amount can dissolve in water and move deeper in the soil to underground water. Fish do not accumulate much chromium in their tissues from water. Chromium (III) is an essential nutrient that helps humans metabolize sugar, protein and fat. Chromium (VI) is classified as human carcinogen by the World Health Organization. Ingesting large amounts of chromium (VI) can cause stomach upsets and ulcers, convulsions, kidney and liver damage, and even death. Skin contact with certain chromium (VI) compounds can cause skin ulcers. Some people are extremely sensitive to chromium (III) or chromium (VI). Allergic reactions consisting of severe redness and swelling of the skin have been noted (ATSDR 2001).

Possible Chromium Sources

A wide range of information was accessed to identify potential sources of chromium and mercury and to characterize contributions, including monitoring data, data from national, state and local databases, and scientific literature. The source analysis section focused on possible point, nonpoint, and tributary sources. Sources of chromium in the Rhine Channel include existing sediments in Newport Bay, historic deposits in the San Diego Creek watershed, and possibly atmospheric deposition. Sources of chromium may include paint chips, dust, and grit from shipyard operations, leaching of anti-fouling paints from boat hulls, and storm water runoff from industrial areas. Chromium may also be leaching from treated wood pylons in marine areas (Warner and Solomon 1990). Recently reported levels of chromium in Rhine Channel sediments are shown in Table G-1.

According to Regional Board records, a potential source of chromium inputs to the Rhine Channel is the former Newport Plating facility located at 2810 Villa Way in Newport Beach (see Figure A-7, TSD Part A). Chromium has been found at excessive levels both in soil samples (maximum concentrations of 8,160 mg/kg total chromium and 34.7 mg/kg Cr^6) and in groundwater (0.03 – 1.98 mg/L as total Cr) beneath the facility (Petroleum Industry Consultants, Inc., 1987; Remedial Action Corporation, 1988). (Other contaminants identified in borings and groundwater monitoring wells at the facility include cadmium, copper, nickel, and zinc.) On March 19, 1987, Orange County cited (Notice to Correct) the operator of the plating facility for leaking of finishing wastewater (OCHCA, 1987). The facility was the site of several spills during its period of operation (approximately 20 years) and many of the solutions used in the plating process were disposed to a floor drain that discharged directly to the soils beneath the facility (SARWQCB facility investigation reports, March 25 and April 7, 1987). A Cleanup and Abatement Order (CAO No. 87-83) was issued to the property owner and the operator of Newport Plating on May 18, 1997. On December 11, 1987, the operator discharged wastewater to City of Newport Beach surface drains in violation of the CAO (SARWQCB staff report, February 11, 1988). A storm drain that connects directly to the Rhine Channel is located at the southern end of the plating facility property (Figure A-7, TSD Part A).

The plating facility closed in March 1988 after the owner evicted the operator of the facility. In 1990 the case was referred to the Attorney General for collection of ACL assessments (Resolution No. 90-100). It appears that the site has not yet been remediated based on a visit to the facility on February 7, 2002, by Regional Board staff (the facility and property did not appear to have been disturbed). OCHCA staff indicated that the plating waste inside the facility was cleaned and disposed of on March 3, 1988, but they have no records indicating that the soils and groundwater beneath the facility were cleaned up or remediated (pers. comm., B. Pepki). Therefore, soils and groundwater beneath the facility are likely continuing to contribute to the pollutant loading in the Rhine Channel.

Currently, there is not sufficient information to estimate chromium atmospheric deposition rates in the Newport Bay watershed.

Review of Sediment Targets

As discussed in the TMDL document, two targets have been identified for each chemical, one for sediment and one for tissue levels. The primary target value (sediment) is for TMDL development, whereas the alternate target (tissue) is designed to provide another means of assessing desired water quality conditions of Rhine Channel.

There are several available screening values for mercury concentrations in sediment and fish tissue. For mercury in Rhine Channel, EPA applied the sediment numeric target, 0.13 mg/dry kg, as the most appropriate indicator of desired water quality. This threshold effect level (TEL) is associated with no observed effect on benthic organisms as part of a study by MacDonald et al. 1996 and cited in NOAA SQuiRTs (Buchman 1999). For comparison, the TEL value is much lower than the probable effects level (PEL = 0.696 mg/kg dry). The NOAA Effects Range-Low (ERL) value for mercury (ERL = 0.15 mg/kg dry) is close to the TEL target value.

EPA has also evaluated the available water quality criteria and levels for sediments and fish tissue to determine the appropriate numeric target for chromium TMDL in Rhine Channel. EPA selected the sediment target (52 mg/kg dry, Buchman 1999) as the best available target to protect both wildlife predators and benthic organisms.

Table G-2. Sediment Targets Used in the TMDL Analyses

	Mercury (mg/kg)*	Chromium (mg/kg)*
Rhine Channel	0.13	52

* dry weight

II. Calculation of Loading Capacities and Estimate of Existing Loadings

General Conceptual Approach

The loading capacity for each pollutant represents the maximum loading that a waterbody can assimilate and still meet and maintain water quality standards. For the mercury and chromium addressed in these TMDLs, long-term loadings at or below the loading capacities should eventually result in reduction in concentrations of these compounds in bottom sediment to levels protective of the standards. A review of available data (see Appendix 1 for a summary of the data used in the TMDL analysis) indicates that bottom sediments currently exhibit elevated mercury and chromium concentrations. The higher the current concentrations in bottom sediments, the longer it will take to meet standards, even if external sources are reduced.

The approach to determining the loading capacities for mercury and chromium is similar to the approach used for the organochlorine compounds (TSD – Part F) and was based on an understanding of the sources of these compounds (past, present, and future) and the transport and ultimate fate of these compounds in various environmental media. Based on a review of literature sources, it was observed that mercury and chromium environmental persistence and affinity for adsorbing to sediment and accumulating in biota generally limits their presence in the water column, at least relative to sediment and biota. The loading capacities were determined by "back-calculating" the allowable load from the selected sediment target (Table G-2) and the associated estimates of sediment loads.

The calculation of existing mercury and chromium compound loads, which are not required components

of the TMDLs, allows for a relative comparison the estimated current loading to the calculated loading capacity. In contrast to the calculation of the loading capacities, which was accomplished through back calculation from the sediment targets, the existing loadings were based on review and analysis of available sediment data.

Calculation of Newport Bay Loading Capacity and Existing Loads

Previous modeling studies, completed by RMA for the U.S. Army Corps of Engineers (USACE) have examined the circulation patterns, and transport and deposition of sediments in Newport Bay (RMA 1998, 1997). By examining model calibration results (RMA 1997) for Newport Bay from 1985-1997, the sediment deposition in Rhine Channel was estimated. Historic pollutant loads to the bottom sediment were estimated by using observed pollutant concentrations in bottom sediments and net sedimentation rates. Sediment volume was converted to dry weight using an estimated porosity of 0.65.

Figure G-1 presents a schematic of the approach used to calculate the loading capacity and existing loads for Mercury and Chromium for Rhine Channel.

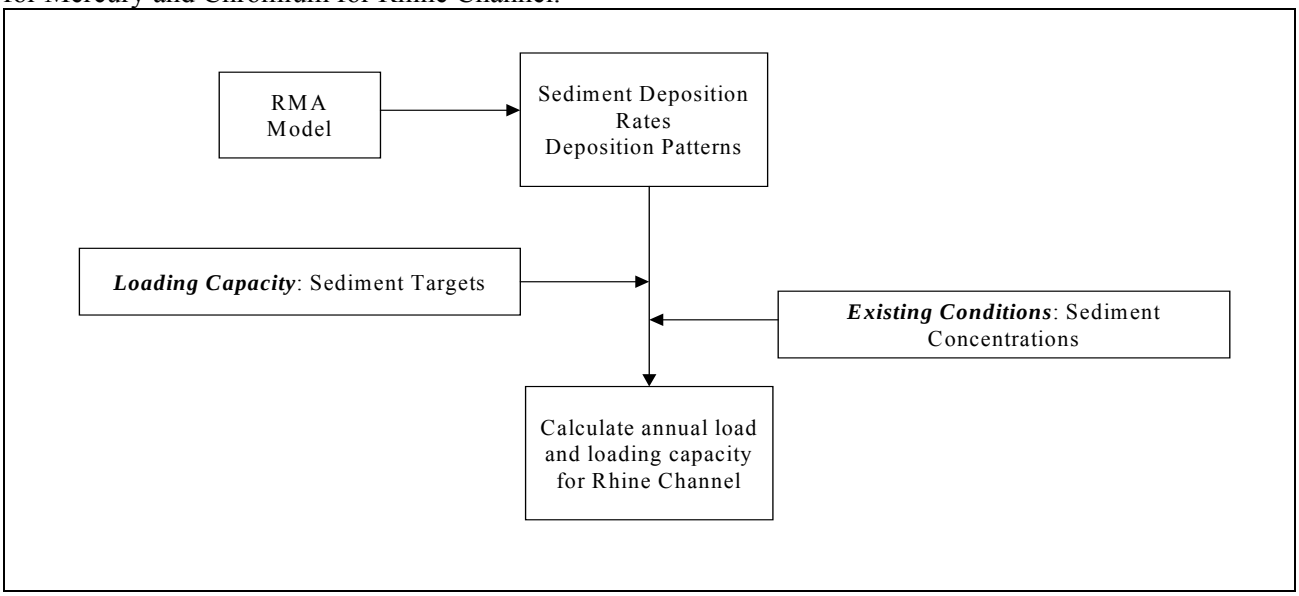

Figure G-1. Schematic of Loading Calculation Steps

The approach relies on the following key information:
Sediment deposition rates (from the RMA (1997) model)
Sediment deposition patterns (from the RMA (1997) model)
Sediment pollutant targets (used for loading capacity) (see Table G-2)
Sediment mercury and chromium concentrations from observation data (used for existing loads) (see Table G-1 and Appendix 1)

The remainder of this section presents the loading capacity calculations for mercury and chromium. For each compound, all equations, values applied, and references used in the calculations are included.

Summary of Approach for Calculating Loading Capacities and Existing Loads of Mercury and Chromium Compounds for Rhine Channel

The following equation was used with sediment target concentrations (Cs) (Table G-2) to calculate the

loading capacities. For existing loadings, the same equation was used with concentrations from existing sediment data substituted for the sediment targets.

$$\text{Load (g/yr)} = Cs \times Ds \times \rho s \times (1 - Ps) \times CF$$

where:

Cs	=	sediment concentration (mg/kg dry)
Ds	=	sediment deposition (m^3/yr)
ρs	=	sediment density (kg/m^3)
Ps	=	sediment porosity
CF	=	conversion factor from mg to kg

The values for all parameters used in the analysis for Newport Bay and Rhine Channel are presented in Table G-3.

Table G-3. Parameter values used in the Rhine Channel TMDL analysis.

	Sediment conc. (mg/kg dry)		ρs (kg/m^3)	Ps	CF
	Target Concentration	Observed Concentrations*			
Mercury	0.13	5.8	2,500	0.65	0.000001
Chromium	52	44			

Ds (m^3/year): Rhine Channel: 859.23
*SCCWRP (2001), 2001 sampling data

Calculations

Mercury

Loading Capacity

$$\text{Rhine Channel Loading Capacity (kg/yr)} = 0.13 \times 859.23 \times 2{,}500 \times (1 - 0.65) \times 0.000001$$

Existing Loading

$$\text{Rhine Channel Existing Loading (kg/yr)} = 5.8 \times 859.23 \times 2{,}500 \times (1 - 0.65) \times 0.000001$$

Table G-4. Existing and Loading Capacity for Rhine Channel for Mercury

Mercury	Existing Load (kg/year)	Loading Capacity (kg/year)
Rhine Channel	4.39	0.10

Chromium

Loading Capacity

$$\text{Rhine Channel Loading Capacity (kg/yr)} = 52 \times 859.23 \times 2{,}500 \times (1 - 0.65) \times 0.000001$$

Existing Loading

$$\text{Rhine Channel Existing Loading (kg/yr)} = 44 \times 859.23 \times 2{,}500 \times (1 - 0.65) \times 0.000001$$

Table G-5. Existing Loading and Loading Capacity for Rhine Channel for Chromium

Chromium	Existing Load (kg/year)	Loading Capacity (kg/year)
Rhine Channel	33.1	39.10

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Appendix 1: Data Analysis and Assessment

This appendix presents the data available to characterize the level of contamination by chromium and mercury in Rhine Channel. Monitoring data are available for three media: water, sediment, and tissue. The following data summaries are organized by the source/agency.

Bay Protection and Toxic Cleanup Program Data (BPTCP): This study reports sediment concentrations at various locations in the Newport Bay for Mercury and Chromium. Sediment sample data in mg/kg was available from two sampling events that took place in 1994 and 1996. This data was not used in the analysis but is reported in Table G-1.

Newport Bay Sediment Toxicity Studies (SCCWRD, 2001): Sediment samples collected at 10 Newport Bay stations in May 2001 were available. Sediment data in mg/kg for Cr and Hg at selected locations in Rhine Channel was used to estimate the existing loading capacity.

Resource Management Associates report (RMA, 1997): Estimates of the sediment distribution for the Upper Bay, Lower Bay and Rhine Channel were made using the results of sediment transport model developed by RMA. The model simulates wet and dry conditions as well as the largest storm event from 1985-1997. Because most sediment entering Upper Newport Bay occurs during the storm events, mean daily stream discharge records for San Diego Creek were used to develop a five-day hydrograph which were used to simulate storm event for RMA model. The peak flows for each model simulation years are shown in Table 2 below. A detailed description can be found in the RMA report (RMA, 1997). The sediment deposition rates for Newport Bay were derived from 12-year model simulation results. Although the mean values are used to estimate the sediment budget for the Newport Bay, the sediment deposition rates represents a net deposition over the years.

The following tables list data from different sources by the various sources used in the analysis. The most recent sediment data (May 2001) was used from the Newport Bay Sediment Toxicity Studies Report, October 23, 2001 (Tables 8, 9 and 10) (SCCWRD, 2001).

Table 1. Sediment Chemistry Toxicity Data used in the TMDL

Location	Chromium	Mercury
	mg/kg dry	mg/kg dry
Rhine Channel (NB3)	44	5.8

All non-detects were taken as zero

Table 2. Sediment Deposition rates in Newport Bay – Estimated from the RMA (1997)

Location	**Sediment Deposition (m3/year)**
Unit I basin	31474.17
Unit II basin	30327.34
South of Unit II	11659.46
Downstream to PCH Bridge	7772.97
Upper Newport Bay Total	81233.95
Lower Bay	17444.29
Turning Basin	6782.52
Newport channel	5697.20
Lower Newport Bay Total	29924.01
Rhine Channel*	859.23

*Rhine Channel deposition rates used for this analysis.

Part H. Decision Document of Water Quality Assessment for San Diego Creek and Newport Bay

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I. TMDL Overview

EPA Region 9 is required by a consent decree to ensure completion of Total Maximum Daily Loads (TMDLs) for certain toxic pollutants in Newport Bay by June 2002. The chemicals of concern are specific to three water bodies and are identified in the consent decree. Although the consent decree included a list of chemicals for which TMDLs would be prepared, it specifically provided that EPA was under no obligation to establish TMDLs for any pollutants that EPA determined did not need TMDLs consistent with Clean Water Act Sec. 303(d). This document summarizes EPA's analysis supporting our determinations of which pollutants need TMDLs. This document was originally drafted in May 2001 but has been revised based on some additional data and analysis.

Santa Ana Regional Water Quality Control Board staff prepared a problem statement (Dec. 2000) that includes their determination of which chemicals warrant preparation of TMDLs based on their assessment of which chemicals appear to be creating toxicity in the water bodies at issue. This report recommends a significant number of chemicals identified in the consent decree not receive TMDLs. The report also recommends preparing TMDLs for some water body segments in the Newport Bay watershed and specific chemicals not identified in the consent decree.

EPA Region 9 independently evaluated all readily available data for San Diego Creek and Upper and Lower Newport Bay to determine which chemicals warrant TMDLs. We did not evaluate chemicals beyond those identified in the consent decree or by Santa Ana Regional Board. Column 1 of Table 1 lists specific chemicals for each affected water body identified in the consent decree. Column 2 of Table 1 identifies the specific chemicals for each affected water body for which EPA has determined that TMDLs need to be prepared. As part of our analysis, we determined the Rhine Channel should be treated as a separate water body. Therefore, Table 1 identifies chemicals for the three water bodies set forth in the consent decree, plus Rhine Channel.

EPA Region 9 has agreed to gather monitoring data for those constituents not determined to be appropriate for TMDL development, e.g., Endosulfan, Silver and other chemicals in Column 3 of Table 1. EPA Region 9 will compile analytical results of water column, sediment and fish tissue samples collected in 2001, 2002 and 2003. This monitoring report (and accompanying data) will be submitted to Santa Ana Regional Board in April 2003. This report will supply additional information to the Regional Board as part of future water quality assessment and planning activities.

Watershed description

Newport Bay is about 4 miles long by three to one-half mile wide with one ocean inlet. The watershed (150 sq. miles) consists of two regions of freshwater tributaries flowing into San Diego Creek, which flows into Upper Newport Bay. Santa Ana Regional Board has divided San Diego Creek (**SDC**) into two Reaches, upstream (Reach 1) and downstream (Reach 2) of Jeffrey Road. San Diego Creek has a mean base flow of about 8 cfs with significant increases (1000 to 4000 cfs) during storm events. SDC is influenced by slightly saline water table (less than 1 or 2% salinity) and approximate mean hardness of about 400 ppm. SDC is the primary tributary and flows into Upper Newport Bay.

Upper Newport Bay (**UNB**) is defined by Jamboree Road to the North and Pacific Coast Highway (PCH) Bridge to the south. There are two main freshwater inputs—San Diego Creek and Santa Ana / Delhi Channel—as well as tidal influxes, so salinity is about 15 ppt. It has estuarine wetlands and is designated a State Ecological reserve in the upper areas with more small boat marinas (including a boat painter's yard) near PCH Bridge. Periodically it has been dredged to remove trapped sediment. There is a storm drain just above PCH Bridge coming from the PCH Bridge overpass and immediate vicinity.

Lower Newport Bay (**LNB**) is defined as below PCH bridge to the outer harbor, so salinity is about 30--35 ppt. Surrounding shores and two islands are highly urbanized with nine boatyards and about 10,000 small boats. In the western area of Lower Newport Bay, two isolated areas have less tidal flushing: Turning Basin and Rhine Channel.

Santa Ana Regional Board has designated **Rhine** Channel as toxic hotspot. The land use history in the area immediately adjacent to Rhine Channel suggests that local pollutant source may be significantly different from the pollutant sources that have discharged to the rest of the watershed. Given the different levels of sediment contamination observed in Rhine Channel as compared to other areas of Newport Bay and the likely association of toxic hotspots in Rhine Channel with local pollutant sources, EPA has determined that is appropriate to develop separate TMDLs for that reach of Lower Newport Bay rather than simply addressing it as part of the TMDLs for Lower Newport Bay. We believe this approach will facilitate more effective planning and implementation of pollutant control strategies by the State.

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Table 1.

Consent Decree	**TMDL Development**	More monitoring
San Diego Creek: Cd, Cr, Cu, Pb, Zn	**Cd, Cu, Pb, Zn, Se**	Cr
Endosulfan, DDT, PCBs, Toxaphene, Chlorpyrifos	**Chlordane, Dieldrin, DDT, PCBs, Toxaphene** **Chlorpyrifos, Diazinon**	Endosulfan
Upper Newport Bay: Cd, Cr, Cu, Pb, Hg, Ag, Zn	**Cd, Cu, Pb, Zn, Se, As**	Cr, Hg, Ag
Endosulfan, DDT	**Chlordane, DDT, PCBs, Chlorpyrifos**	Endosulfan
Lower Newport Bay: As, Cd, Cu, Pb, Se, Ag, Hg, Zn	**Cu, Pb, Zn, Se, As**	Ag, Cd, Hg
Chlorbenside, Chlordane, Chlorpyrifos, Dieldrin, Endosulfan, DDT, PCBs, Toxaphene,	**Chlordane, Dieldrin, DDT, PCBs**	Chlorbenside, Chlorpyrifos, Endosulfan, Toxaphene
Rhine Channel:	**Cu, Pb, Zn, Se, As, Cr, Hg**	Ag, Cd
	Chlordane, Dieldrin, DDT, PCBs	Chlorbenside Chlorpyrifos, Endosulfan, Toxaphene

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III. Weight of Evidence Approach

EPA Region 9 assessed several types of available toxicity and chemical data to assess the need for TMDLs: water column data, sediment quality data, and fish/shellfish tissue data. We applied a two-tiered approach whereby data were analyzed to determine whether there is clear evidence of impairment with probable adverse effects (TIER 1) or incomplete evidence and/or evidence of possible adverse effects or potential for future impairment (TIER 2). Table 2 provides a diagram of EPA's assessment criteria for determining whether a constituent would be placed in TIER 1 or TIER 2 with respect to each data category.

If a chemical exceeded the screening criteria in TIER 1 with respect to any of the three categories, we determined that a TMDL would be completed for that chemical in the affected water body.

TIER 2 addresses the "gray area" where exceedences of standards or screening guidelines are less frequent or less extreme, where data sets are incomplete for particular categories, or where there is concern about potential water quality standards violations in a segment based on conditions in the adjacent segments. EPA developed two methods for determining whether TMDLs were needed based on TIER 2 considerations.

First, if a chemical exceeded the screening criteria in TIER 2 with respect to two or more data categories, we determined that a TMDL is needed. This determination was based on a conclusion that the weight of available evidence indicates applicable numeric and/or narrative water quality standards are being exceeded and that designated beneficial uses may not be fully supported.

Second, we also considered as part of the TIER 2 analysis whether a TMDL is warranted for an individual water segment based on the considerations that TMDLs were determined to be needed for adjoining water segments and that some evidence of impairment was present for the individual segment. All the water segments in the watershed are hydrologically connected, and in many cases pollutants may move freely between different segments. Therefore, EPA carefully evaluated situations where a specific water segment did not meet the criteria for a TMDL determination based on the data analysis criteria described above, but one or more adjoining segments did meet the data analysis criteria and were found to need TMDLs. If there was some evidence for the specific segment indicating potential impairment and the impairment evidence for the adjacent segment was very strong, we determined TMDLs may be needed for the specific water segments in order to ensure that TMDLs would be developed where needed despite uncertainties about the degree of local impairment. For the toxic pollutants of potential concern in the watershed, this approach was warranted because many of these pollutants remain in and move through the aquatic environment for long periods of time. Because Newport Bay is tidally influenced, water, sediments, and pollutants may move back and forth in the Bay over time. EPA concluded that it is appropriate to take a "watershed approach" to TMDL development for many pollutants rather than simply excluding individual segments from consideration because TIER 1 and TIER 2 data analysis thresholds were not fully met when adjacent segments did meet those thresholds. This watershed approach enabled EPA to look holistically at pollutant discharges and transport through the watershed in developing TMDL approaches. The sections below that present analysis for specific pollutants describe the basis for EPA's judgments in conducting the adjacent waters analysis.

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In a few situations, however, EPA determined it was not appropriate to develop TMDLs for specific segments despite the fact that an adjacent segment was determined to need a TMDL. TMDL development is not appropriate in these situations because the evidence of impairment in the adjacent segment, or evidence of potential impairment in the specific segment, was not strong enough to support such a determination. The basis for these determinations is described below where the individual pollutant assessments are discussed.

We have applied this tiered system to assess water, sediment and tissue monitoring data in four water body segments: San Diego Creek, Upper Newport Bay, Lower Newport Bay and Rhine Channel (see Table 5 for data sources). To maximize the relevance of this analysis to present conditions of water quality and to ensure the analysis is based on reliable data, we concentrate on most recent results (since 1995) and apply quality control (QC) measures outlined in Section V.

Tier 1 Sufficient evidence in *one category* establishes impairment and triggers a TMDL

Water Column

Dissolved water column concentrations were compared to acute and chronic California Toxic Rule (CTR) water quality criteria (WQC). EPA 305(b) guidance (EPA, 1997) suggests that if greater than 10% of sample results exceed either acute or chronic values then the aquatic life beneficial uses of the water body are not fully supported. If water toxicity tests showed a chemical caused toxicity, then we concluded a TMDL was needed for this chemical. In our best professional judgment, we assumed that toxicant identification evaluations (TIE) should be completed for at least two organisms or three or more separate sampling events to clearly demonstrate impairment associated with water column toxicity tests. This frequency is based on the often-transient nature of water column contamination and associated toxicity.

Sediment

Sediment TIE studies and triad studies determine if one or more chemicals are present at levels which do not support beneficial uses. Triad studies require three measurements: sediment toxicity, infaunal analysis and sediment chemistry to evaluate sediment effects on aquatic life. If two of the three portions of triad study indicate benthic community degradation (e.g., defined as a negative value by Bay Protection Toxic Clean-up Program) then impairment was established but additional analysis was needed to clarify which pollutants were causing the degradation. To identify chemicals associated with impairment, we compared sediment concentrations to higher sediment quality guidelines (SQGs) or equilibrium partitioning guidelines (ESG) and if greater than 25% of sample results exceed higher SQGs then we concluded a TMDL was necessary.

Tissue

Two types of tests were applied. First, if a fish consumption advisory was posted *and* based on analysis of local data, then TMDL development was determined to be necessary. Second, sportfish and shellfish tissue concentrations were compared to screening values, primarily those established by EPA or California Office of Environmental Health Hazard Assessment (OEHHA). For chemicals for which neither EPA or OEHHA have established

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screening values, we also considered tissue screening values from other sources: maximum tissue residue levels (MTRLs), United Nations Median International Standards (MIS), and wildlife risk values (US Fish and Wildlife, 1998). We compared the lowest or most protective screening value to results of total tissue concentrations, except for arsenic as discussed in section IV below. If greater than 25% of sample results exceeded this screening value then we concluded a TMDL is necessary for this pollutant.

We determined that a minimum of ten samples were needed in order to make a TIER 1 determination of TMDL necessity. Because TIER 1 determinations were based on a single line of evidence, we concluded that it was reasonable to expect a minimum number of samples in order to increase the level of confidence in the determination. The EPA 305(b) guidance (EPA, 1997) recommends a minimum of 10 water samples in three years in assessing potential exceedences of water quality standards for toxic pollutants. We assumed that ten sediment or fish tissue sediments were required for clear evidence of impairment. For each pollutant and data category, if 10 samples do not exist then available data were considered through the TIER 2 assessment methods described below. We consider our reliance on a minimum of ten samples for an assessment based on a single data type to be reasonable and prudent given the variability and uncertainty associated with environmental monitoring. In addition, our reliance on a minimum sample size was reasonable for the Newport Bay watershed for which relatively plentiful data are available compared to most waters in the region.

<u>Tier 2</u> Requires evidence in *two out of three categories* or information from adjacent segments to trigger a TMDL

Water Column

Dissolved water column concentrations were compared to applicable acute and chronic CTR values. EPA 305(b) guidance states if chemical results exceeded either acute or chronic values more than once in three years then the chemical partially supports beneficial uses of the water body. Limited toxicity tests were also considered reasonable indicators of possible adverse effects. Either case warranted further convincing evidence from other categories (sediment or tissue results). Prudent evaluation includes consideration of the frequency and magnitude of these exceedences as well as the analytical error for these results relative to the CTR values. (See Data QA / QC in section V.)

Sediment

Sediment concentrations were compared to low sediment quality guidelines (e.g., effects range low (ERL) and threshold effect levels (TELs)) and if greater than 10% sample results exceed *both* of those lower SQGs then the chemical was found to partially support aquatic life use. Whenever feasible specific freshwater SQGs were used for San Diego Creek sediment data. In sediment triad studies (as described above in Tier 1), when only two of three legs have been completed, at least one part must be for chemistry data in order to identify the pollutant(s) of concern. Again, evidence from water or tissue studies was also required to trigger TMDL development.

Tissue

Tissue concentrations were compared to the lowest or most protective screening values. Total concentrations were used except for arsenic as discussed in section IV below. If

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greater than 10% of sample results exceed the screening value, then we reviewed results of water and sediment assessments to determine additional evidence and possibly trigger TMDL. EPA or OEHHA values were preferred, yet if value for chemical was unavailable (e.g., Ag, Cd, Cr, Pb, Zn), then MTRLs, MIS, FDA, or wildlife risk values were used.

Adjacent Segments Analysis

As discussed above, we also considered as part of the TIER 2 analysis whether a TMDL is warranted for an individual water segment based on the considerations that:

- TMDLs were determined to be needed for adjacent water segments, and
- some evidence of impairment (e.g., one potential exceedence based on TIER 2 analysis) was present for the individual segment.

If there was some evidence for the specific segment indicating potential impairment and the impairment evidence for the adjacent segment was very strong, we determined TMDLs may be needed for the specific water segments in order to ensure that TMDLs would be developed where needed despite uncertainties about the degree of local impairment

Table 2.

Two–tiered approach to assessment of monitoring data for Newport Bay and its watershed			
	Water Quality	Sediment Quality	Tissue Results
Tier 1 Impairment to Aquatic Life or Probable Adverse Human Health effects	>10% samples* exceed CTR values OR water TIEs clearly demonstrate toxicant	sediment triad or TIE studies clearly demonstrate toxicant OR >25% samples# exceed high SQGs (or ESG values)	posted consumption advisory$^{\delta}$ OR >25% samples# above tissue screening values
Tier 2 Possible Effects to Aquatic Life or Human Health	two or more samples* exceed applicable CTR values within six years	>10% samples above *both* low SQGs OR toxicity evident and sediment chemistry results provided, but no TIEs	>10% samples above fish tissue OR Shellfish values
Comment TMDL can triggered by one category in Tier 1 but needs two categories in Tier 2	see CTR for full discussion of acute and chronic values; Freshwater metals values are hardness dependent	ESGs from EPA (draft 2001a) High SQGs = PELs / ERMs / AETs; low SQGs = ERLs / TELS	Use lowest value of EPA, OEHHA, US F&W, MTRL or MIS.

NOTE: For TIER 1 requires minimum number of 10 samples within each category. If insufficient data exist then assessment defaults into TIER 2 or inconclusive.
*10% and "two or more" from EPA 305(b) guidance (1997), section 3.2.4 on toxics in water samples.
#25% from Consolidated Assessment and Listing Methodology guidance (EPA draft report 2001b).
$^{\delta}$based on local data in comparison to criteria equal to or more stringent than water quality standard
Acronyms explained in text of Sections III & IV.

Trend Analysis

EPA guidance provides that threatened waters (waters currently meeting standards but expected to exceed standards within the next two years) should be considered for TMDL development (EPA, 1997). EPA regulations, as interpreted in EPA guidance (1997) also provides that TMDLs may not be needed for impaired waters if other control mechanisms will

result in attainment of standards within the next two years. Therefore, EPA evaluated whether there appeared to be water quality trends in the different water segments in the watershed that would indicate either:

- waters currently meeting standards appear to have declining trends and may not meet standards in the future or
- waters currently exceeding standards appear to have improving trends and may meet standards in the future.

We plotted available water chemistry, sediment, and tissue data to evaluate whether chemical concentrations are decreasing or increasing relative to the numeric criteria or screening value in that category. Such graphs were generated *if* and *only if* there is sufficient data (using consistent sampling and analytical methods) covering more than five years of results; e.g., State Mussel Watch program. If trends were apparent based on visual observation of the graphs, we applied statistical methods (e.g. regression analysis and Mann-Kendall test (Gilbert, 1987) to evaluate the apparent trends were statistically significant.

Some potential trends were observed based on this analysis. Tissue levels of chromium, selenium, zinc in tissue samples appeared to be increasing over time in some segments of Newport Bay. On the other hand, tissue levels of organic chemical pollutants and sediment levels of copper and lead appeared to be declining over time in some segments of Newport Bay.

However the available data were too limited and the apparent trends insufficiently clear to conclude either that:

- waters which now exceed standards will meet standards within the next two years or
- waters that now meet standards will exceed standards within the next two years.

Therefore, EPA concluded that no adjustments to the determinations of TMDL necessity were warranted based on the trend analysis.

IV. Discussion of numeric screening values used in decision process

Table 3 provides a compilation of screening values used in our decision process. Here we provide further explanation on selection of these values.

Water

Water quality criteria values are from California Toxics Rule (CTR), promulgated by EPA (2000a). As appropriate for certain metals, we have adjusted freshwater values to assume hardness equals 400 ppm (average conc. in San Diego Creek). Monitoring data for chromium (Cr) results in water samples are reported in two different ways, depending upon whether the available data identified valence states of chromium. First, Irvine Ranch Water District (IRWD) and Orange County Public Facilities Resources Department (OCPFRD) report dissolved Chromium results, so we have combined chromium CTR values (added Cr (3+) and Cr (6+)) to make the appropriate comparison with the OCPFRD data. This is reasonable based upon the analytical method to determine dissolved chromium in aqueous samples. Second, Lee and Taylor (2001a) report chromium speciation results so separate Cr (3+) and Cr (6+) data were interpreted against those individual CTR values.

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Sediments

There are no *promulgated* sediment quality criteria, so we have chosen to use values from National Oceanic Atmospheric Association (NOAA) Sediment Quality Reference Tables (September 1999). According to NOAA, these numeric values are "intended for preliminary screening purposes only...to initially identify substances which may threaten resources of concern. [These multiple SQGs]… help portray the entire spectrum of [environmental] concentrations which have been associated with various probabilities of adverse biological effects." We recognize these NOAA values have been derived by associating nationwide sediment chemistry data sets with benthic toxicity results and there is no direct cause and effect relationship. Nonetheless, we have concluded that these values provide reasonable evidence of potential adverse aquatic life effects and therefore apply them as sediment quality guidelines (SQGs) to provide comparison for trace metals and organic compounds. Low SQGs (e.g., threshold effect levels (TELs) and effects range low (ERLs)) are presumed to be non-toxic levels and pose with a high degree of confidence no potential threat. High SQGs (e.g., probable effects levels (PELs) and effects range median (ERMs)) identify pollutants that are more probably elevated to toxic levels. SQG values for some pollutants do not exist; e.g., silver (in freshwater) and toxaphene.

We use freshwater SQGs for comparison to San Diego Creek sediment results and saltwater SQGs for the three saline segments of Newport Bay. Based upon methods explained by Long, *et al*. (1998), we have opted to use low SQG levels (TELs and ERLs) as protective levels for aquatic life. In that study, the authors determined that if sediment concentrations did not exceed *both* TELs and ERLs then one could reasonably predict non-toxicity in those sediments. We believe it is appropriate to apply these lower threshold values in TIER 2, when evaluating "gray area" data. When evaluating heavily contaminated sediments, we use the higher SQGs to indicate probable impairment (TIER1) since adverse effects are (nearly) always expected when PELs or ERMs are exceeded. Adverse effect threshold (AET) values were used only if other SQGs do not exist, since these values were derived from site-specific studies in Puget Sound.

EPA has drafted (2001a) equilibrium partitioning sediment guidelines (ESGs) for a limited group of pollutants-- six metals and two organic compounds. These ESGs are based upon a different approach than NOAA's screening guidelines and ESGs rely on considerably more data than is typically generated in sediment studies. In short, measurements of total organic carbon (for organic compounds) and acid volatile sulfides (for metals) are required to calculate ESGs for those sediment sites. To date, only one study (Bight '98/SCCWRP) has sufficient data to use ESG values, and these results apply only to sediments in Lower Newport Bay. We have included assessment of acid volatile sulfide and simultaneously extracted metal results for five metals at ten Lower Newport Bay sites. We have also evaluated metal porewater concentrations relative to interstitial water guidelines for those same Lower Bay sties. We were unable to perform ESG assessments for organic compounds but Bight '98 results for organic compounds were incomplete.

Tissue

Both EPA (2000b,c) and OEHHA (1999) have issued guidance for issuing fish consumption advisories to protect human health via sportfish and shellfish consumption. Tissue screening values (SVs) were determined for noncarcinogens and some carcinogens

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using a risk-based approach, assuming a risk level of 1 in 100,000. This risk based approach included assumptions on human body weight, reference dose and daily consumption rates. EPA has evaluated numerous fish consumption surveys and recommended that risk assessments assume consumption values of 17.5 grams per day for the general adult population and recreational fishers and 142.2 grams / day for subsistence fishers (2000d). OEHHA assumes recreational fishers consume 21 grams per day. We have found no data that a large number of anglers are subsistence fishers in Newport Bay, thus we have utilized screening values from EPA and OEHHA for recreational fishers and the general adult population.

For some metals for which EPA or OEHHA tissue SVs do not exist, we have opted to use either MTRLs or MIS values. California State Water Board's Mussel Watch Program developed MTRLs using a different approach than EPA and OEHHA. MTRLs are calculated by multiplying the applicable water quality objective by a bioconcentration factor specific for each chemical. State Water Board applies MTRLs to fish and shellfish results for Enclosed Bays and Estuaries. Median International Standards (MIS) values arise from a survey of international standards and legal limits by Food and Agriculture Organization of United Nations (1983). We acknowledge that MIS values were not developed in the United States; however, we have used them because fore certain pollutants values (Ag, Cr, Pb, Se, and Zn) have not been established by EPA, OEHHA or the State Water Board. Separate MIS values exist for freshwater fish and shellfish, thus we have applied them with respect to fish tissue results in San Diego Creek and shellfish results throughout Newport Bay. Total concentrations were compared to the lowest (or most protective) screening value provided by EPA, OEHHA, State Water Board, or MIS.

For arsenic in tissue results we have formulated a side-by-side comparison to examine both total arsenic and inorganic arsenic concentrations. The goal was to evaluate the relative contribution from inorganic arsenic, the carcinogenic form of arsenic. We used updated EPA guidance (2000b) to provide an inorganic arsenic screening value, whereas OEHHA (1999) used total arsenic concentrations. Our comparison uses reported total arsenic results and calculated inorganic arsenic data (from the total results) using 4% in finfish and 60% in shellfish. These percentages arise from conclusions in scientific literature. Donohue and Abernathy (1996) completed a broad literature review of total and inorganic arsenic results in both types of tissue and Schoof, *et al.* (1999) performed a market basket survey of inorganic arsenic in food, including finfish. Estimates of inorganic arsenic results in shellfish are provided by Francesconi and Edmonds (1994) and Creed (pers. commun.).

To address protection of aquatic wildlife and aquatic dependent species as well as human health, we have reviewed available literature and selected the lowest screening value from several sources. (Again, there are no promulgated wildlife criteria fish tissue values.) For example, National Academy of Sciences *recommended* maximum concentrations of organic chemicals in animals in freshwater systems (NAS Blue Book 1973). These NAS values were designed to protect aquatic organisms themselves as well as wildlife predators. US Fish and Wildlife (1998) have compiled scientific information to provide guidelines for interpreting biological effects of some chemicals in biota, water and sediment. For most chemicals of concern, the EPA or OEHHA tissue screening values are both the most protective tissue value; copper is one exception (see Table 4). Moreover, EPA and OEHHA values are based upon the most recent scientific information.

Table 4. Fish tissue values: Human Health vs. Wildlife protection

	EPA (2000a) Human health	OEHHA (1999) Human health	NAS (1973) Aquatic Wildlife	U.S Fish & Wildlife (1998) Biological Effects
Arsenic (As)	1.2	1.0	--	0.25
Copper	--	--	--	15
Mercury	0.3*	0.3	--	0.3#
Chlordane	114	30	50	--
Dieldrin	2.5	2.0	5	--
DDT (total)	117	100	50¥	wide range
PCB (total)	20	20	500	--

all values expressed in wet weight: total metal in ppm; organic in ppb; -- means no data available)
*0.3 mg/kg wet wt. for methylmercury conc in fish tissue
#from Canadian study on bird reproduction
¥another DDT value is 150 ppb ww from EPA water quality criteria (1980)
[*EPA (1995) defined aquatic freshwater wildlife criteria for three analytes: DDT, PCBs and mercury based upon studies in Great Lakes Region. Those aquatic wildlife criteria apply only to water bodies within the Great Lakes Region, due to site-specific bioaccumulation factors, and were not used in this assessment of Newport Bay watershed.*]

Table 3. Overview of numeric screening values for METALS

	WATER (ppb)						**SEDIMENT** (ppm dry wt.)							**TISSUE** (ppm wet)		
	fresh acute	fresh chronic	salt acute	Salt Chronic	Water & org.	Org. only	Fresh TEL	Fresh PEL	Salt TEL	Salt ERL	Salt PEL	Salt ERM	Salt AET	EPA	OEHHA	MTRL or MIS
As	340	150	69	36			5.9	17	7.24	8.2	41.6	70	35	1.2	1.0	1.4
Cd	19	6.2	42	9.3			0.596	3.53	0.67	1.2	4.2	9.6	3.0	4.0	3.0	0.3 / 1
Cr-tot	1724	565	1100	50			37.3	90	52.3	81	160.4	370	260			1.0
Cr6+	16	11	1100	50												
Cu	50	29	4.8	3.1	1300		35.7	197	18.7	34	108	270	390			15@
Pb	281	11	210	8.1			35	91.3	30.2	46.7	112	218	400			2.0
Hg	1.4	0.77	1.8	0.94	0.050*	0.051*	0.174	0.486	0.13	0.15	0.696	0.71	0.41	0.3	0.3	0.37#
Ag	37		1.9						0.73	1	1.77	3.7	3.1			
Se	20	5	300	71									1	20	20	2 / 0.3
Zn	380	380	90	81	1.7	6.3	123.1	315	124	150	271	410	410			45 / 70

Blank space indicates no value available

Water values from CTR (EPA 2000a) , freshwater values calculated at 400 ppm hardness
*mercury CTR values (for human health consumption of water and / or organisms) do not reflect most current fish bioconcentration factor, thus EPA fish tissue value (0.3 ppm wet wt. MeHg as determined in 2000b) is most appropriate.

Sediment values from NOAA SQuiRTS (1999)
TEL = threshold effects level; PEL = probable effects level; ERL = effects range low; ERM = effects range median; AET = apparent effects threshold

Tissue values from EPA (2000b), OEHHA (1999)
¥most recent available inorganic arsenic value is 1.2 ppm (EPA 2000b)
#MTRL value from State Mussel Watch (2000), @Copper value from US Fish & Wildlife (1998)
MIS values from Median International Standards from United Nations survey (1983); first value presented for freshwater fish and second for shellfish

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Table 3. (cont'd) Overview of numeric screening values for ORGANICS

	WATER (ppb)						**SEDIMENT** (ppb dry wt.)							**TISSUE** (ppb wet)		
	fresh acute	fresh chronic	salt acute	Salt chronic	Water & org.	Org. only	fresh TEL	fresh PEL	Salt TEL	Salt ERL	Salt PEL	Salt ERM	Salt AET	EPA	OEHHA	MTRL
Chlorbenside																
Chlordane	2.4	0.0043	0.09	0.004	.00057	.00059	4.5	8.9	2.26	0.5	4.79	6	2.8	114	30	8.3
Dieldrin	0.24	0.056	0.71	0.0019	.00014	.00014	2.85	6.67	0.715	0.02	4.3	8	1.9	2.5	2.0	0.7
DDT-tot	1.1	0.001	0.13	0.001	.0059	.0059	6.98	572*	3.89	1.58	51.7	46.1	11	117	100	109
Endosulfan-tot#	0.44	0.112	0.068	0.0174	220	480								24 (ppm)	20 (ppm)	64.8 (ppm)
PCBs-tot	2	0.014	10	0.03	.00017	.00017	34.1#	277	21.5	22.7	189	180	130	20	20	5.3
Toxaphene	0.73	0.0002	0.21	0.0002	.00073	.00075								36.3	30	9.8

Blank space indicates no value available

Water values from CTR (EPA 2000a) ; #sum of endosulfan α & β values
"water & org." and "org. only" refer to human health criteria for consuming water and / or organisms from same waterbody

Sediment values from NOAA SQuiRTS (1999)
TEL = threshold effects level; PEL = probable effects level; ERL = effects range low; ERM = effects range median; AET = apparent effects threshold
*freshwater PEC (probable effects concentration) from Ingersoll, et al. (2000), range of values cited therein: SEL = 120, ERM = 350, PEL = 4450
#freshwater TEL from NOAA, MacDonald et al. (2000) have reviewed the range of total PCB values for freshwater and saltwater (see values cited therein) and provide threshold effects concentrations (TEC) determined by consensus: freshwater TEC = 35 ppb and saltwater TEC = 48 ppb

Tissue values from EPA (2000b), OEHHA (1999), MTRL values from State Mussel Watch (2000) for Enclosed Bays and Estuaries

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V. Data QA/QC issues

Sound scientific practice calls for applying quality assurance and quality control measures when assessing sampling design and analytical results. Relevant issues are presented below. We applied QA / QC issues to monitoring data as part of the two-tier decision scheme. Best professional judgment was also required as each project and data set has unique nuances.

a. To determine present day water quality condition and support of aquatic uses, recent data (past 5 years) was given more significance than older data (past ten years). Data greater than 10 years old was not used in the evaluation process except to generate trend analyses.

b. Ideal monitoring studies supply robust data sets, which address spatial and temporal variability and include relevant speciation or congener data. However, robust data sets are not always available so we used the best of data available.

c. Only dissolved (<0.45 um filter) water data were used for comparison to CTR values, since the dissolved fraction best approximates bioavailable metals and organics. Metals are hardness dependent and CTR values were adjusted to appropriate water hardness measurements.

d. Results generated from best sampling and analysis protocols were preferred over those studies that use inappropriate or outdated practices. (Historical evidence has demonstrated that sampling, storage and analytical protocols have yielded contaminated water column samples and consequently high bias data for aqueous mercury and other priority pollutant metals.) Representative ambient water samples are best collected via trace metal clean techniques (EPA Method 1669), handled carefully to minimize contamination within the laboratory (Method 1669), and analyzed by optimal analytical methods (EPA 1600 series). Also, accurate detection of metals in seawater requires specific preparation methods to remove and account for salt matrix interferences (EPA Methods 1638, 1639 and 1640). Simple dilution of seawater samples is not sufficient for accurate detection of aqueous metals in comparison to marine CTR values.

e. Water--Four (consecutive) day composite samples were computed using OCPFRD data for San Diego Creek and tributaries and we made comparisons to CTR chronic water values (assuming mean hardness value of 400 ppm).

f. Tissue–Data from fish fillets were compared to human health screening values, whereas whole fish data were based against ecological criteria if they exist. Ideally, fish tissue data include arsenic speciation results; that is, inorganic values are measured directly and compared to EPA's inorganic arsenic tissue values. In this assessment, finfish inorganic values were calculated as 4% of total arsenic values. For shellfish, total arsenic data and inorganic data (60% of total) were compared to MTRL values.

g. If method detection limits were insufficiently low then we found it difficult to make definitive evaluations with data relative to water quality criteria, sediment guidelines

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or tissue screening values. If datum was stated "<x" or "-x" then datum was interpreted as "x/2" for numerical value in comparisons or statistical calculations.

h. If datum was reported "~~yy~~" then datum was not used in numerical comparisons or statistical calculations. Presumably this datum was considered suspect by laboratory or sampling staff and required further verification prior to use in comparisons or calculations.

i. Trend analyses were applied to program results using consistent sampling and analytical protocol; e.g., State Mussel Watch Program. If a change in protocol was made to comply with improved methods or techniques then trend analyses clearly identified the date(s) and the distinction.

j. "Hits" were defined as data above WQC, SQG or tissue screening levels. EPA Region 9 evaluated frequency of hits and magnitude of hits. Two important considerations were applied.

    a. Extreme magnitude exceedences were heavily weighted with regard to frequency of exceedence and minimum sample size. For example, if sample results were more than 20fold higher than the appropriate WQS, SQG or tissue screening value and sufficient samples existed (>five) then this was viewed as evidence of impairment similar to TIER 1 decisions. See mercury sediment concentrations in Rhine Channel.

    b. We also evaluated the magnitude of these exceedences by considering the analytical error for monitoring results relative to the screening criteria/values. For example, two "hits" at levels three times the CTR acute value were valid exceedences and deserved recognition of possible adverse effects. Whereas two "hits" at levels very close to the CTR value (within analytical error, ±20%) were considered borderline cases and warranted further convincing evidence from other categories. Both of these examples are TIER 2 type decisions.

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Monitoring Data for San Diego Creek and Newport Bay

EPA has considered all readily available and most recent data (as of March 2002) in our assessment. Since Santa Ana Regional Board staff issued their Problem Statement (December 2000), we have added three new data sets (cited by name here): Lee report, City dredge report, and Bight '98. We have also updated three data sets: OCPFRD, Toxic Substances Monitoring Program (TSMP) and State Mussel Watch to include more recent (still preliminary) results. Two Southern California Coastal Research Water Project (SCCWRP) studies are still pending and results are currently unavailable.

Table 5. Overview of monitoring data

Attach-ment	**Title** / org.	Data dates	Type	Comments
J	**Lee & Taylor** / 319(h) report to Santa Ana RWQCB	'99-'00	Water chem. & tox test	Metals and OP pesticides in watershed, Draft report provided Feb. 2001
K	IRWD WWSP Report	'97-'99	Water & Sediment	metals and organics measured using APPROPRIATE sampling and analytical techniques, one day composites, year round, NO storm events
L	**OCPFRD** Stormwater	'95-'00	Water	seven metals, year round sampling, includes dry and wet weather events; four consecutive day sampling data can be used for chronic comparisons; most dissolved samples in 1996—'00 (one dissolved sample in 1995 for SDC)
M	OCPFRD	'91-'00	Sediment	semi-annual sediment data for same metals and some organics
N	**Ogden Environ.** / for City of Newport Beach	'99	Sediment	Metals and few organics in dredge studies of only four sites, most in LNB
O	BPTCP / SWRCB / NOAA / EPA	'94 & '96	Sediment triad study	metals and organics measured, some porewater results, toxicity on six organisms, and benthic community index, APPROPRIATE sampling and analytical techniques, only two sites in '96
P	Bight '98 / Coordinated by SCCWRP	'98	Sediment chemistry	Metals and few organics at 11 LNB sites, AVS & SEM data, interstitial porewater data for SEM; no Rhine Channel site
Q	Orange County Coastkeeper / MEC Consultants	'99	Sediment chemistry	Metals at two Rhine sites and one in Turning Basin; two surface sediment samples and one sediment core sample
R	Calif. Fish Contam. Study (SWRCB & OEHHA)	'99–'00	Sport fish Tissue	Total As, Cd, Se, Hg and organics in fish fillets of UNB & LNB
S	**SMW** / SWCRB	'80-'00	Shellfish Tissue	Total metals and organics in resident or transplanted mussels, no recent data in SDC, useful for trends analysis
T	**TSMP** / SWRCB	'83–'98	Fish Tissue	Total metals and organics in whole fish
U	Fish Bioaccumulation / SCCWRP	pending	Tissue	sportfish samples for two seasons, some data available in Summer 2001
V	Sediment Toxicity / SCCWRP	pending	sed & water Toxicity	sediments and water in UNB & LNB, some data available in Summer 2001

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VII. Question sequence for weight of evidence approach:

- Does **water (dissolved) monitoring data** exist in past 5 years?
- Were appropriate sampling and analysis techniques used for ambient surface waters?
- Compare data to CTR values, using hardness adjustments for freshwater samples.
- Per chemical parameter, do data exceed CTR value (either chronic or acute) more than 10% frequency in 5 years?
- Are there at least 10 water samples? If yes, TIER 1 = develop TMDL (If less than ten samples then default into TIER 2.)

- Per chemical parameter, do four day composite data exceed chronic CTR value twice or more in 5 years? If yes, then TIER 2; i.e., examine sediment and tissue data for additional exceedances.
- Per chemical parameter, do grab sample data exceed acute CTR value twice or more in 5 years? If yes, then TIER 2.
- Any water TIE studies available for this waterbody in past 5 years? Were water TIE studies completed for more than one sampling event to evaluate "representative" conditions of waterbody? If yes, then develop TMDL for identified pollutants.

- Does **sediment monitoring data** exist in past 5 years?
- Were samples composited or individually analyzed in study? If composites were used then proceed. Whereas if grabs were analyzed, then consider use median (in lieu of mean) to evaluate data skewed by individual data.
- Compare chemistry data to NOAA sediment quality guidelines.
  (If AVS and SEM results exist, determine ESG values.)
- Per chemical parameter, do data exceed PEL or ERM or ESG values more than 25% frequency in 5 years?
- Are there at least ten samples? If yes, TIER 1 = develop TMDL (If less than ten samples then default into TIER 2.)

- Per chemical parameter, do data exceed *both* ERLs *and* TELs values more than 10% frequency in 5 years? If yes then TIER 2; i.e., examine water and tissue data for additional exceedances.
- Any sediment TIE studies for this waterbody in past five years? Do sediment triad studies establish impairment of benthic organisms? Are there chemistry results to make correlations with high or low SQGs?
- If porewater concentration results exist, convert them to interstitial water guideline units and compare them to (total) chronic saltwater CTR values (as in water data above).

- Do **finfish or shellfish tissue** monitoring data exist in past 5 years?
- Were samples composited or individually analyzed in study? If mixture of results provided then consider use median (in lieu of mean) to evaluate data skewed by individual data.
- Fish filet results are best compared to human health SVs; whole fish data to predator tissue values.
- Compare total concentrations to various tissue screening values. For arsenic, compare

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both total and inorganic arsenic concentrations to tissue screening values.

- Per chemical parameter, do data exceed lowest screening value more than 25% frequency in 5 years?
- Are there at least ten samples? If yes, TIER 1 = develop TMDL (If less than ten samples then default into TIER 2.)

- Per chemical parameter, do data exceed lowest screening value more than 10% frequency in 5 years?
- If yes, then TIER 2; i.e., examine water and sediment data for additional exceedances.
- Use MTRL or MIS values only if no EPA or OEHHA value exists.

- Are **trends** evident in any of the above monitoring data? Be sure to compare "apples to apples" and create graphs from data collected over longer than five-year timeframe, preferably ten or twenty years at the same site. If graphs indicate expected impairment or "threatened water bodies" based upon increasing concentrations soon above screening values, then perform statistical tests to elucidate confidence in such a comparison. If graphs indicate improving water quality and presently below screening levels, then no TMDL is required.

- How does impairment information for subject segment related to impairment information for **adjacent segments?**
- Is evidence of potential impairment . available for the subject segment (e.g. exceeds one TIER 2 criterion or potential water quality threat indicated based on other data or studies) ? If yes, proceed to next question.
- Is there impairment evidence for one or more adjacent segments that is very strong e.g., very high frequency or magnitude exceedence of objectives or screening values)? If yes, TMDL development is warranted.

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VIII. Assessment Summary

This section discusses how the weight of evidence decision rules were applied for individual pollutants and waterbody segments in the Newport Bay watershed. In general, TMDLs are warranted in cases where one TIER 1 criterion is met, two TIER 2 criteria are met, or where there is TIER 2 evidence in a segment and very strong evidence of impairment in an adjacent segment.

Arsenic (As)

San Diego Creek — Determination: no TMDL
No (0/62) water quality criteria exceedances
Sediment results (2/2) inconclusive vs. freshwater SQGs
7% (1/15) tissue exceedances vs. inorganic As screening value in past five years = TIER 2

Upper Newport Bay — Determination: no TMDL
No (0/6) water quality criteria exceedances
12% (1/8) sediment results above low SQGs = TIER 2
0% (0/9) tissue exceedances vs. inorganic As value (1.2 ppm) in past five years

Lower Newport Bay — Determination: no TMDL
no (0/3) water quality criteria exceedances
68% (17/25) sediment results above low SQGs. = TIER 2
0% (0/22) tissue exceedances vs. inorganic As value (1.2 ppm)in past five years

Rhine Channel — Determination: no TMDL
no water column data
(2/2) sediment results above low SQGs = TIER 2
0% (0/11) shellfish exceedances vs. inorganic As (0.026 ppm)in past five years

Cadmium (Cd)

San Diego Creek — Determination: yes TMDL
no water quality criteria exceedances -- (1/347 acute; 0/90 chronic) based on CTR std.
Many water quality criteria exceedances (6/347 acute; 23/23 chronic) based on more recent EPA criteria value; therefore threatened waterbody = TIER 2
46% (12/26) sediment results above low freshwater SQGs = TIER 2
No (0/15) tissue exceedances in past five years

Upper Newport Bay — Determination: yes TMDL
no (0/10) water quality criteria exceedances
21% (8/42) sediment results above low SQGs = TIER 2
No (0/15) tissue exceedances in past five years
Sediment data indicate potential threat to UNB, and substantial evidence of impairment in San Diego Creek, therefore TMDL warranted based on adjacent waters analysis.

Lower Newport Bay — Determination: no TMDL
no (0/6) water quality criteria exceedances
no porewater results above saltwater chronic CTR values
30% (8/27) sediment samples above low SQGs = TIER 2
acid volatile sulfide and porewater results indicate no problem
No (0/20) tissue exceedances in past five years

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Rhine Channel Determination: no TMDL
no reliable water column data
15% (2/15) sediment results above low SQGs = TIER 2
acid volatile sulfide and porewater results indicate no problem
No (0/13) shellfish tissue exceedances in past five years

Chromium (Cr) Assessment Summary

San Diego Creek Determination: no TMDL
no water quality criteria exceedances—(0/269 for Cr-tot and 0/30 for Cr(VI) and Cr(III))
[OCPFRD field screening data of Cr(VI) in SDC tributaries showed false positives results (26%) due to interferences with analytical technique.]
1% (3/94) sediment results above freshwater SQGs
No (0/15) tissue exceedances in past five years

Upper Newport Bay Determination: no TMDL
no (0/10) water quality criteria exceedances
no (0/42) sediment results above low SQGs
10% (1/10) tissue exceedance in past five years = TIER 2

Lower Newport Bay Determination: no TMDL
no (0/6) water quality criteria exceedances
4% (1/27) sediment results above low SQGs
20% (2/10) tissue exceedances in past five years = TIER 2

Rhine Channel Determination: yes TMDL
no reliable water column data
8% (1/13) sediment results above low SQGs
31% (4/13) shellfish tissue exceedances in past five years = TIER 1

Potential increasing trends in tissue data since 1980s.

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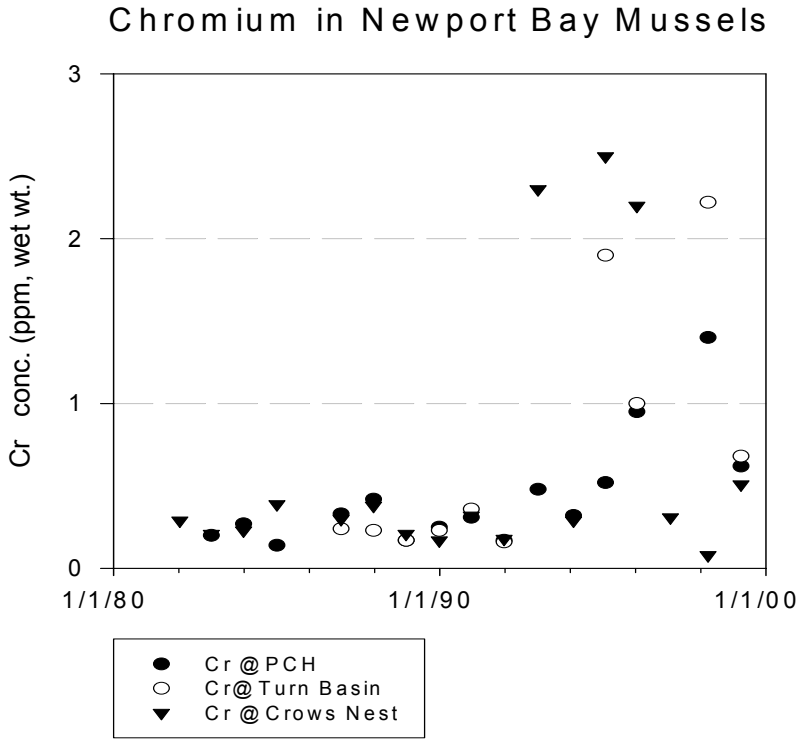

Figure H-1. Cr in Newport Bay Mussels (SMW database). Screening value is 1.0 ppm ww.

Copper (Cu) **Assessment Summary**

San Diego Creek Determination: yes TMDL

5.6% (21/347) acute water exceedances; 25% (7/28) chronic water exceedances based upon OCPFRD data = TIER 1
3% (1/30) acute water exceedances based on Lee (00-01) report, no exceedances in IRWD data
4% (4/92) sediment results above freshwater SQGs
No (0/15) tissue exceedances in past five years

Upper Newport Bay Determination: yes TMDL

Numerous water quality exceedances based on OCPFRD monitoring data = TIER 2
no (0/10) water quality criteria exceedances based on IRWD data
17% (7/42) sediment results above low SQGs = TIER 2
No (0/10) tissue exceedances in past five years

Lower Newport Bay Determination: yes TMDL

no (0/6) water colunm criteria exceedances, based on IRWD data but some values close to saltwater CTR std; many OCPFRD exceedances
33 (9/27) sediment results above low SQGs = TIER 2
acid volatile sulfide results indicate no problem
(5/10) sites have elevated Cu conc. in porewaters based on Bight '98 data = TIER 2
No (0/10) tissue exceedances in past five years

Rhine Channel Determination: yes TMDL

no reliable water column data
82% (9/11) sediment samples above *higher* SQGs = TIER 1
acid volatile sulfide and porewater results indicate problem =TIER 2
15% (2/13) shellfish tissue exceedances in past five years = TIER 2

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Potentially increasing trends in mussel tissue in Newport Bay

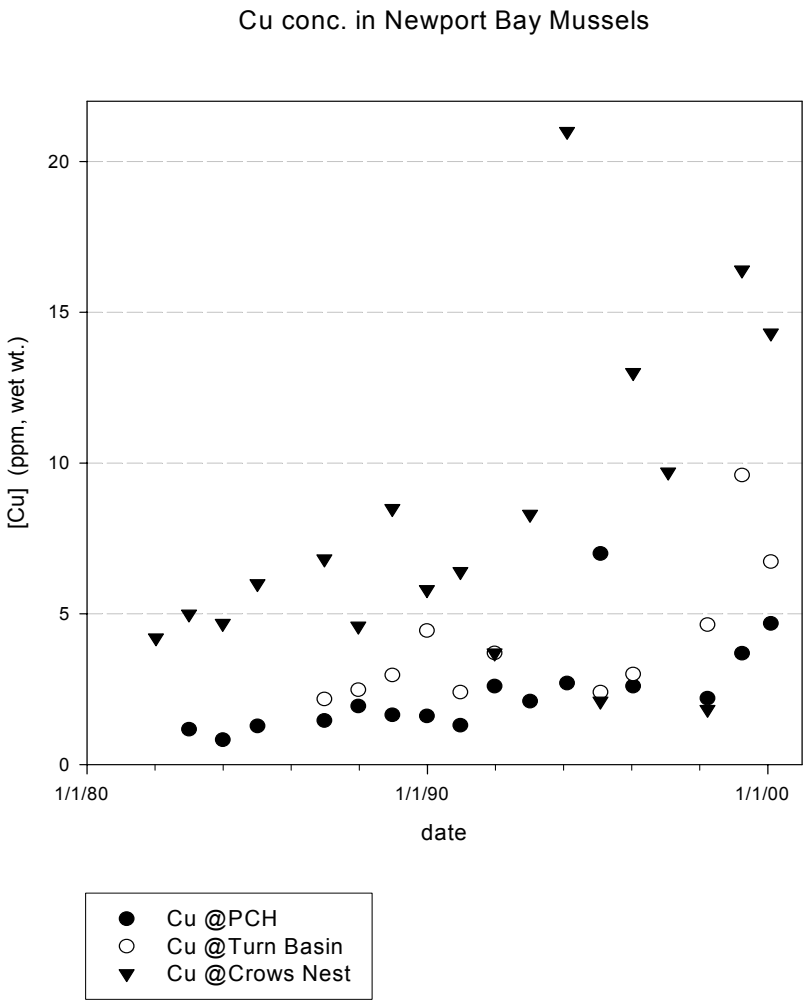

Figure H-2. Copper in Newport Bay mussels (SMW database). Screening value is 15 ppm

Lead (Pb) Assessment Summary

San Diego Creek Determination: yes TMDL

7% (2/28) chronic water exceedances based on OCPFRD data = TIER 2
no (0/371) acute water exceedances
6% (4/72) sediment results above low freshwater SQGs
No (0/15) tissue exceedances in past five years
Water column and sediment data indicate potential threat to SDC, and substantial evidence of impairment in Rhine Channel, therefore TMDL warranted based on adjacent waters analysis.

Upper Newport Bay Determination: yes TMDL

no (0/10) water quality criteria exceedances
5% (2/42) sediment results above low SQGs
No (0/10) tissue exceedances in past five years
Sediment data indicate potential threat to UNB, and substantial evidence of impairment in Rhine Channel, therefore TMDL warranted based on adjacent waters analysis.

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Lower Newport Bay Determination: yes TMDL
no (0/6) water quality criteria exceedances
12% (2/42) sediment results above low SQGs = TIER 2
acid volatile sulfide and porewater results indicate no problem
No (0/10) tissue exceedances in past five years
Sediment data indicate potential threat to LNB, and substantial evidence of impairment in Rhine Channel, therefore TMDL warranted based on adjacent waters analysis.

Rhine Channel Determination: yes TMDL
no reliable water column data
54% (7/13) sediment results *above high* ERMs = TIER 1
acid volatile sulfide and porewater results indicate no problem
No (0/13) shellfish tissue exceedances in past five years; and trend analysis shows declining conc. below SV

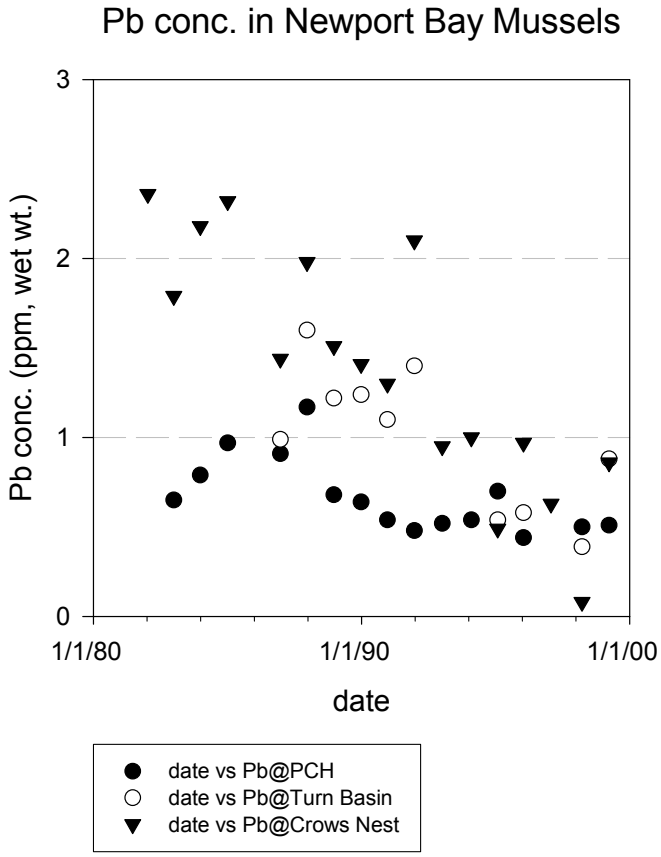

Figure H-3. Lead in Newport Bay mussels (SMW database) Screening value is 2.0 ppm ww.

Mercury (Hg) Assessment Summary

San Diego Creek Determination: no TMDL
no (0/62) water quality criteria exceedances
no (0/2) sediment results above freshwater SQGs
No (0/15) tissue exceedances in past five years

Upper Newport Bay Determination: no TMDL
no water column data available
no (0/2) sediment results above low SQGs
10% (1/10) tissue exceedances in past five years = TIER 2

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Lower Newport Bay Determination: no TMDL
no water column data available
36% (5/14) sediment exceedances above low SQGs = TIER 2
No (0/23) tissue exceedances in past five years

Rhine Channel Determination: yes TMDL
no water column data available
(5/5) sediment results *above high* SQGs = TIER 2 or TIER 1 based on magnitude of exceedences
all values show very high exceedances (>3.4 ppm) vs. ERM value (0.71 ppm), indicating substantial threat. TMDL warranted based on observed magnitude of sediment levels which are at least 5 times higher than screening values
No (0/12) shellfish tissue exceedances in past five years

Selenium Assessment Summary

San Diego Creek Determination: yes TMDL
97% (30/31) water quality criteria exceedances = TIER 1
(3) sediment results inconclusive since no freshwater SQG
no (0/15) tissue exceedances in past five years

Upper Newport Bay Determination: yes TMDL
no water quality data
all sediment results were non-detect, but no saltwater SQG
no (0/9) tissue exceedances in past five years
Due to substantial evidence of exceedences in SDC, appearance of increasing Se trend in Newport Bay mussel tissue, and concerns about protection of aquatic and aquatic dependent species in Ecological Reserve in UNB, TMDL warranted based on adjacent waters analysis. Implementation of TMDLs for SDC should be sufficient to attain TMDLs for Newport Bay segments; establishment of the Bay TMDLs will assist in ensuring that aquatic life uses of concern in the Bay are fully maintained in the future.

Lower Newport Bay Determination: yes TMDL
all (0/11) sediment results were detects, but no saltwater SQG
no (0/9) tissue exceedances in past five years, but trend analysis shows increase in mussels
Due to substantial evidence of exceedences in SDC, and increasing Se trend in Newport Bay mussel tissue, TMDL warranted based on adjacent waters analysis. Implementation of TMDLs for SDC should be sufficient to attain TMDLs for Newport Bay segments; establishment of the Bay TMDLs will assist in ensuring that aquatic life uses of concern in the Bay are fully maintained in the future.

Rhine Channel Determination: yes TMDL
(2) sediment results were detects, but no saltwater SQG
no (0/10) tissue exceedances in past five years
Due to substantial evidence of exceedences in SDC, and increasing Se trend in Newport Bay mussel tissue, TMDL warranted based on adjacent waters analysis. Implementation of TMDLs for SDC should be sufficient to attain TMDLs for Newport Bay segments; establishment of the Bay TMDLs will assist in ensuring that aquatic life uses of concern in the Bay are fully maintained in the future.

Silver (Ag) Assessment Summary

San Diego Creek Determination: no TMDL
(1/338) acute water exceedance but no chronic exceedences
Virtually all sediment results below detection limits and inconclusive since no freshwater SQG
No tissue screening value for comparison

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Upper Newport Bay Determination: no TMDL
no (0/7) water quality criteria exceedances
9% (4/42) sediment result above low saltwater SQGs
No tissue screening value for comparison

Lower Newport Bay Determination: no TMDL
no (0/3) water quality criteria exceedances
no (0/27) sediment results above low saltwater SQGs
no acid volatile sulfide results for silver; porewater results show no problem
No tissue screening value for comparison

Rhine Channel Determination: no TMDL
no reliable water column data
31% (4/13) sediment results above low saltwater SQGs = TIER 2
no acid volatile sulfide results for silver; porewater results show no problem
No tissue screening value for comparison

Zinc (Zn) Assessment Summary

San Diego Creek Determination: yes TMDL
no (0/62) acute exceedances based on IRWD dataset and Lee report
1% (5/370) acute water quality criteria exceedances based upon OCPFRD data = TIER 2
4% (4/94) sediment results above low freshwater SQGs
20% (3/15) tissue exceedances in past five years = TIER 2

Upper Newport Bay Determination: yes TMDL
no (0/25) water quality criteria exceedances based solely on IRWD data, but many exceedences found if OCPFRD data are considered= probably TIER 2
17% (8/48) sediment results above low SQGs = TIER 2
10% (1/10) tissue exceedances in past five years =TIER 2

Lower Newport Bay Determination: yes TMDL
no (0/15) water quality criteria exceedances exceedances based solely on IRWD data, but many exceedences found if OCPFRD data are considered= probably TIER 2
37% (14/38) sediment results above low SQGs = TIER 2
acid volatile sulfide and porewater results indicate no problem
No (0/10) tissue exceedances in past five years

Rhine Channel Determination: yes TMDL
no reliable water column data
38% (5/13) sediment results above low SQGs; 15% results above high SQGs = TIER 2
acid volatile sulfide and porewater results indicate no problem
69% (9/13) shellfish tissue exceedances in past five years = TIER 1

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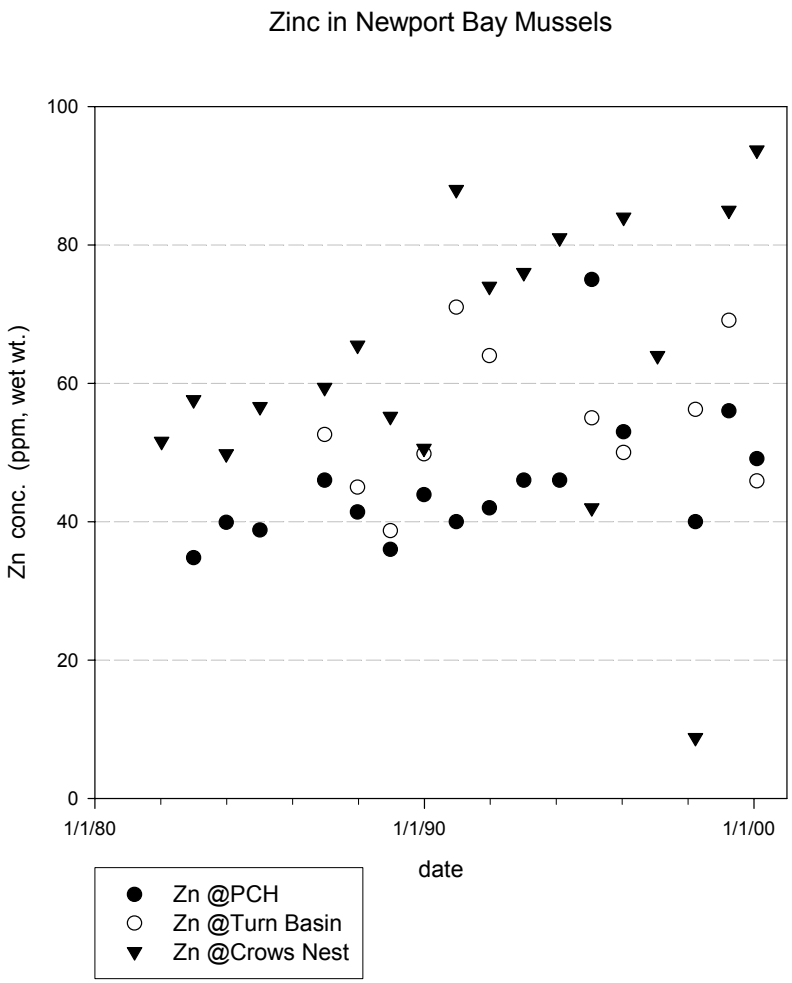

Figure H-4. Zinc in Newport Bay Mussels (SMW database) Screening value is 70 ppm ww.

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Chlorbenside Assessment Summary

San Diego Creek Determination: no TMDL
no water quality data
no sediment data
no shellfish tissue detections in 1983—'93

Upper Newport Bay Determination: no TMDL
no water quality data
no sediment data
no tissue detections in 1982—'94

Lower Newport Bay Determination: no TMDL
no water quality data
no sediment data
two shellfish tissue detections in 1982 & 1983; no detections in 1984—'90

Rhine Channel Determination: no TMDL
no water quality data
no sediment data
one shellfish tissue detections in 1982; no detections in 1983—'94

Chlorpyrifos Assessment Summary

San Diego Creek Determination: yes TMDL
Water Quality: 44% (34/78) exceed acute freshwater numeric target of 20 ng/L = TIER 1
(this includes some non-detects with MDL = 40 ng/L) (2/2) detections but results inconclusive, no sediment criteria guidelines available
no (0/34) tissue exceedances of OEHHA screening value (10,000 ppb)

Upper Newport Bay Determination: yes TMDL
Water Quality: 92% (22/24) exceed acute saltwater numeric target of 11 ng/L = TIER 1
No sediment data
Tissue: (0/14) tissue exceedance of OEHHA screening value (10,000 ppb)

Lower Newport Bay Determination: no TMDL
no data

Rhine Channel Determination: no TMDL
no data

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Diazinon **Assessment Summary**

San Diego Creek Determination: yes TMDL

Water Quality: 87% (68/78) exceed acute freshwater numeric target of 80 ng/L = TIER 1
(Seventy-eight water samples from San Diego Creek)
(2/98) sediment detections, but no sediment criteria guidelines available
3% (1/34) tissue exceedances of OEHHA screening value (300 ppb)

Upper Newport Bay Determination: no TMDL

Water Quality: 0% (0/26) exceed *Americamysis bahia* LC-50 of 4,500 ng/L
(lowest LC50 available in literature for diazinon in saltwater; no other numeric targets available)
(2/64) sediment detections, no sediment criteria guidelines available
no (0/14) tissue exceedance of OEHHA screening value (300 ppb)

Lower Newport Bay Determination: no TMDL

no data

Rhine Channel Determination: no TMDL

no data

Chlordane (total) **Assessment Summary**

San Diego Creek Determination: yes TMDL

no (0/6) water quality criteria exceedances
sediment results (2) inconclusive vs. freshwater SQG
40% (6/15) tissue exceedances in past five years = TIER 1

Upper Newport Bay Determination: yes TMDL

no water column data
56% (13/23) above high SQGs = TIER 1
(see Masters and Inman data)
No (0/6) tissue exceedances in past five years

Lower Newport Bay Determination: yes TMDL

no water column data
36% (8/22) sediment results *above high* SQGs = TIER 1
no (0/19) tissue exceedances in past five years

Rhine Channel Determination: yes TMDL

no water quality data
2/2 sediment results above low SQGs = TIER 2
no (0/10) shellfish tissue exceedances in past five years
Sediment data indicate potential threat to Rhine Channel, and substantial evidence of impairment in LNB, therefore TMDL warranted based on adjacent waters analysis.
Potentially declining tissue trends in San Diego Creek but still above screening values.

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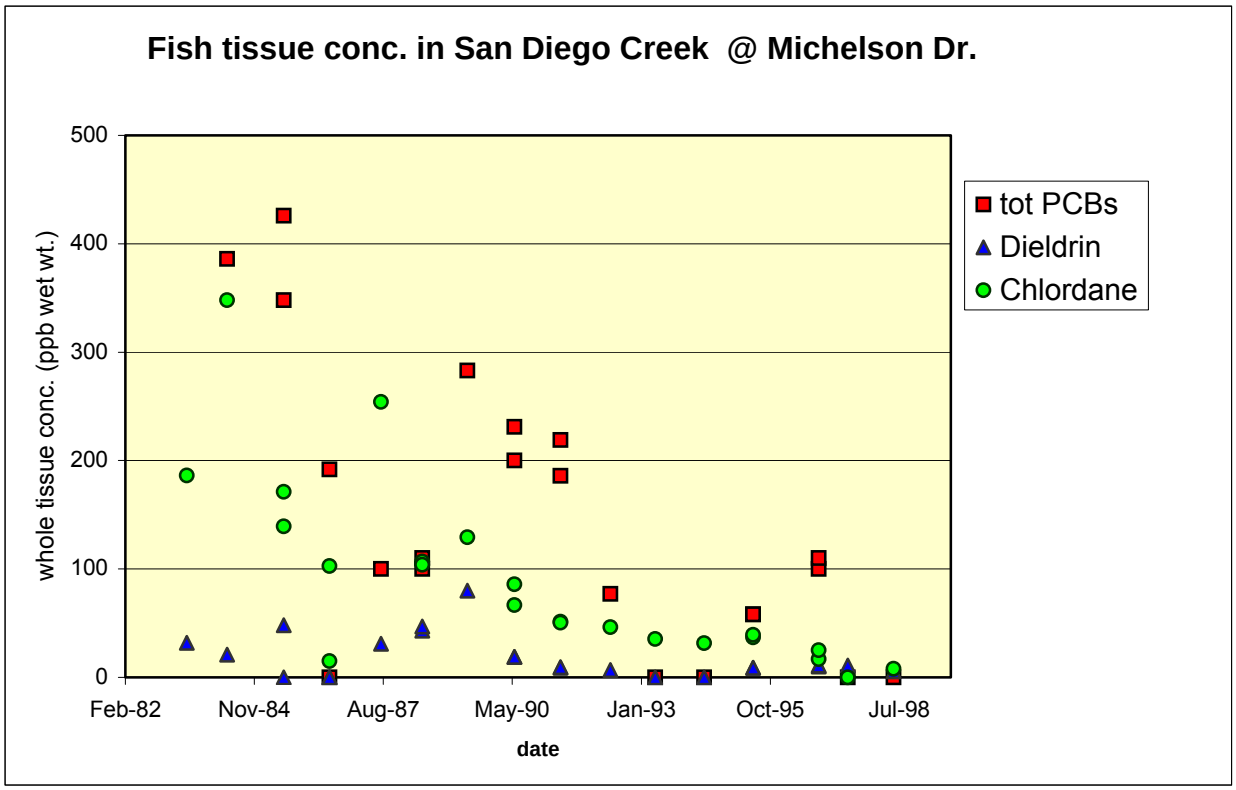

Figure H-5. Chlordane, Dieldrin and total PCBs in fish tissue at San Diego Creek. (TSMP database) Chlordane screening value is 30 ppb; Dieldrin value is 2.0 ppb; total PCBs value is 20 ppb wet wt.

Dieldrin **Assessment Summary**

San Diego Creek — Determination: yes TMDL

no water quality criteria exceedances
no (0/2) sediment results above freshwater SQG
93% (13/14) tissue exceedances in past five years = TIER 1

Upper Newport Bay — Determination: no TMDL

no water quality data
37% (3/8) sediment results above low SQGs = TIER 2
(see Masters and Inman for additional data of non-detects for Dieldrin)
No (0/6) tissue exceedances in past five years
EPA concluded that the evidence of impacts in the adjacent segments was not strong enough to warrant a conclusion that a TMDL is needed for Upper Newport Bay.

Lower Newport Bay — Determination: yes TMDL

no water quality data
27% (3/11) sediment results above low SQGs = TIER 2
5% (1/21) tissue exceedances in past five years
Sediment data indicate potential threat to LNB, and substantial evidence of impairment in Rhine Channel, therefore TMDL warranted based on adjacent waters analysis.

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Rhine Channel Determination: yes TMDL
no water quality data
(1/2) sediment result *above high* SQG = TIER 2
60% (6/10) shellfish tissue exceedances in past five years= TIER 1
trend analysis shows decline in mussels but not below screening value as of 1999

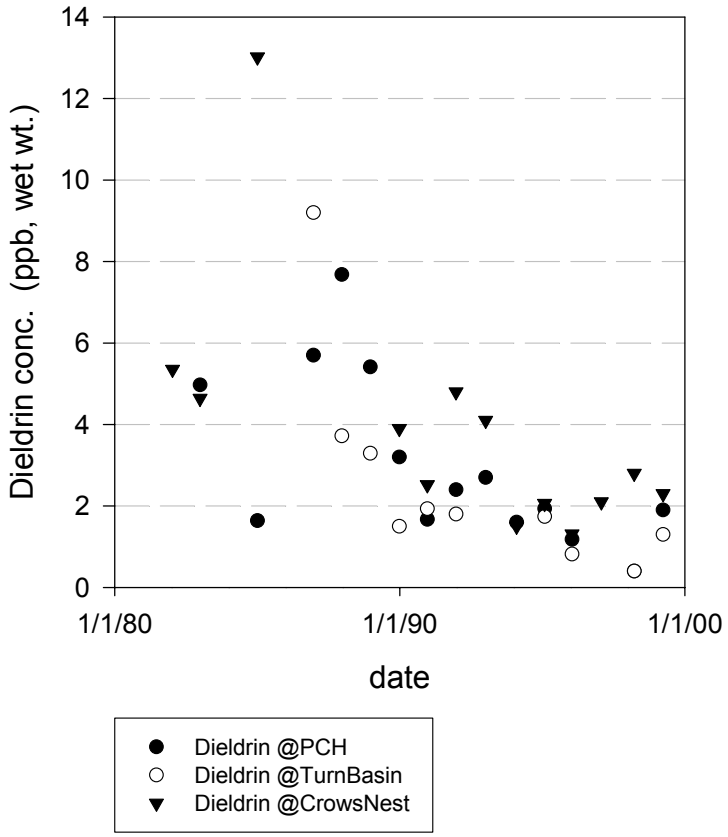

Figure H-6. Dieldrin in Newport Bay mussels. (SMW database) Tissue screening value is 2.0 ppb.

DDT (total) Assessment Summary

San Diego Creek Determination: yes TMDL
no water quality criteria exceedances
(0/2) sediment results above freshwater SQG
93% (14/15) tissue exceedances in past five years = TIER 1

Upper Newport Bay Determination: yes TMDL
no water quality data
37% (20/21) sediment results *above low* saltwater SQGs = TIER 2
50% (3/6) tissue exceedances in past five years = TIER 2

Lower Newport Bay Determination: yes TMDL
no water quality data
91% (10/11) sediment results *above high* saltwater SQGs = TIER 1
14% (3/21) tissue exceedances in past five years = TIER 2

Rhine Channel Determination: yes TMDL
no water data

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(2 / 2) sediment results *above high* saltwater SQGs = TIER 2
10% (1 / 10) tissue exceedances in past five years = TIER 2
trend analysis shows decline in mussels but not below screening value as of 1999

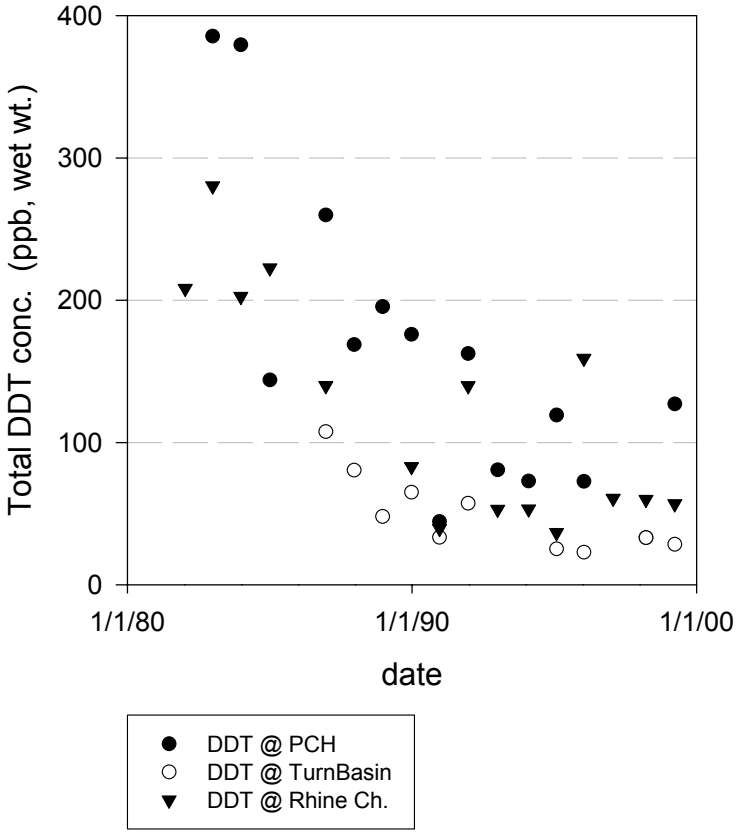

Figure H-7a. DDT in Newport Bay Mussels (SMW database). Tissue screening value is 100 ppb.

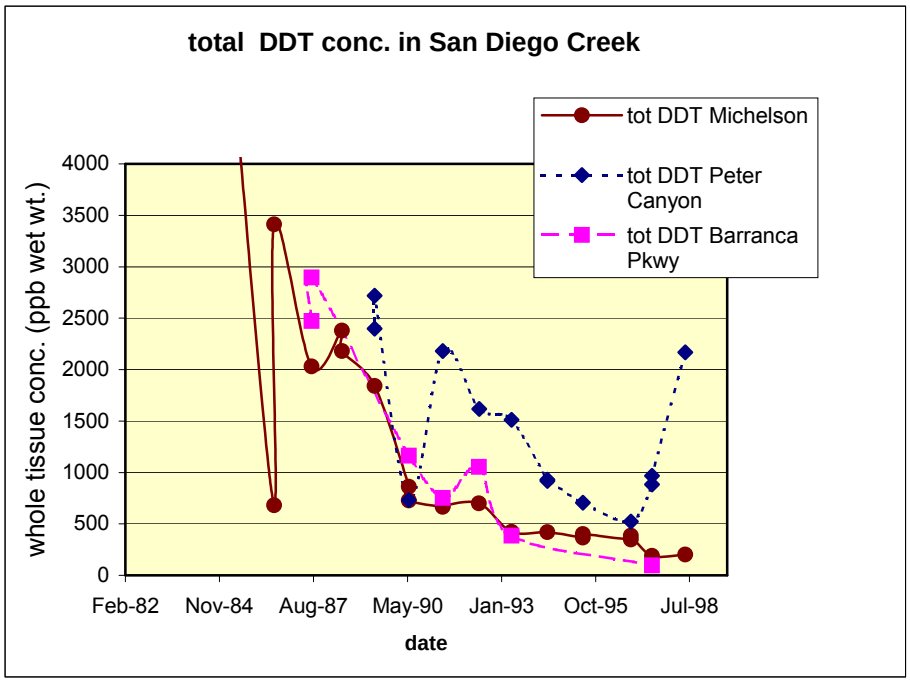

Figure H-7b. Total DDT fish tissue conc. in San Diego Creek (TSMP database).
Total DDT screening value is 100 ppb wet wt.

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Endosulfan (total) **Assessment Summary**

San Diego Creek Determination: no TMDL
no water quality criteria exceedances of endosulfan α and β, nor endosulfate
6% (5/84) sediment results maybe detection, yet inconclusive since no freshwater SQG
no (0/15) tissue exceedances in past five years

Upper Newport Bay Determination: no TMDL
no water quality data
(3/36) sediment results maybe detection, yet inconclusive since no saltwater SQG
No (0/6) tissue exceedances in past five years

Lower Newport Bay Determination: no TMDL
no water quality data
no (0/12) sediment results above detection limit and inconclusive since no saltwater SQG
no (0/19) tissue exceedances in past five years

Rhine Channel Determination: no TMDL
no water data
no (0/10) sediment results above detection limit and inconclusive since no saltwater SQG
no (0/10) tissue exceedances in past five years

PCBs (total) **Assessment Summary**

San Diego Creek Determination: yes TMDL
no water quality data
(1/2) sediment results non-detect vs. freshwater SQG, inconclusive
67% (10/15) tissue exceedances in past five years = TIER 1

Upper Newport Bay Determination: yes TMDL
no water quality data
no (0/8) sediment results above low SQGs, (max = 530 ppb in 1995)
17% (1/6) tissue exceedances in past five years = TIER 2
Tissue data indicate potential threat to UNB, and substantial evidence of impairment in SCD and LNB, therefore TMDL warranted based on adjacent waters analysis.

Lower Newport Bay Determination: yes TMDL
no water quality data
14% (2/14) sediment results above low SQGs = TIER 2
33% (7/21) tissue exceedances in past five years = TIER 1

Rhine Channel Determination: yes TMDL
no water quality data
(2/2) sediment results were above low SQGs; one sample above high SQG = TIER 2
100% (13/13) shellfish tissue exceedances in past five years = TIER 1
trend analysis shows decline in mussels but not below screening value in 1999

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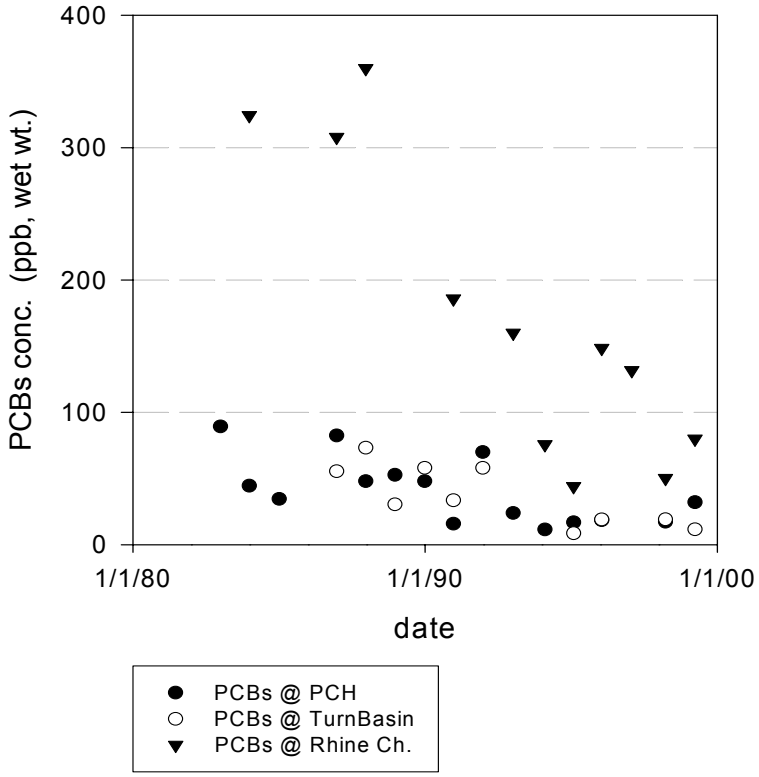

Figure H-8. PCBs in Newport Bay mussels (SMW database). Tissue screening value is 20 ppb.

Toxaphene Assessment Summary

San Diego Creek — Determination: yes TMDL
no water quality criteria exceedances
(2 / 2) sediment results inconclusive vs. freshwater SQG
87% (13 / 15) tissue exceedances in past five years = TIER 1

Upper Newport Bay — Determination: no TMDL
no water quality data
all (0 / 6) sediment results were non-detect, but no saltwater SQG
17% (1 / 6) tissue exceedances in past five years = TIER 2

Lower Newport Bay — Determination: no TMDL
no water quality data
all (0 / 10) sediment results were non-detect, but no saltwater SQG
no (0 / 23) tissue exceedances in past five years

Rhine Channel — Determination: no TMDL
no water quality data
(0 / 2) sediment results were non-detect, but no saltwater SQG
20% (2 / 10) tissue exceedances in past five years = TIER 2

SARB_001450

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SARB_001432

Part I. RESPONSIVENESS SUMMARY

NEWPORT BAY & SAN DIEGO CREEK TMDLS FOR TOXIC POLLUTANTS

Prepared by USEPA, Region 9

June 14, 2002

INTRODUCTION

This document summarizes the comments that were submitted, identifies the commentor, and responds to those comments. They are arranged by topic wherever possible. When multiple comments were received on a single topic, the multiple commentors are grouped under one comment number. Changes to the TMDLs made in response to a comment are generally summarized in the response to that comment.

Comments were received from the following organizations and individuals:

- The Irvine Co./Latham & Watkins
- California Dept. of Pesticide Regulation
- Bordier=s Nursery
- Irvine Ranch Water District (IRWD)
- California Farm Bureau Federation
- Orange County Integrated Waste Management Department/GeoSyntec Consultant
- California Regional Water Quality Control Board, Santa Ana Region
- National Resources Defense Council/Defend the Bay/Limmo-Tech, Inc.
- City of Irvine Public Works Department
- City of Costa Mesa
- City of Irvine
- Orange County PFRD
- MANA (Makhteshim-Agan of North America, Inc.)
- Dr. John Skinner

GENERAL LEGAL COMMENTS

L1. *Comment:* TMDLs should not be based on narrative standards when there are numeric standards which have been subject to notice and comment rulemaking. It is arbitrary and capricious to ignore the specific CTR numerical standards that are just two years old, and instead base the TMDLs on outdated, vague, ambiguous, less reliable narrative criteria. EPA oversteps its authority by establishing numeric targets that are more restrictive than the adopted numeric WQS.

Commentor(s): Irvine Co./Latham&Watkins, California Farm Bureau Federation

Comment: One source of uncertainty concerns interpretation of the narrative Basin Plan objectives pertaining to toxic substances when numeric objectives are either not available or there may be debate about their relevance, given the nature of the impairment. We support the application of appropriate data, including sediment and tissue data (fish or other organisms), to interpret and implement the narrative objectives. *Commentor:* Santa Ana Regional Water Quality Control Board.

Response: EPA regulations provide that TMDLs shall be established Aat levels necessary to attain and maintain the applicable narrative and numerical WQS....@ 40 C.F.R. 130.7(c)(1). It is incorrect to say

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that in developing these TMDLs, EPA ignored any CTR numeric standards. Rather, EPA took into consideration, and developed TMDLs designed to achieve, both the CTR numeric criteria (for those pollutants having CTR numeric criteria) and also the narrative bioaccumulation and toxicity criteria.

As discussed in the TMDLs, the metals and selenium TMDLs are based explicitly on the CTR numeric criteria or equations, and for the OP pesticides there are no promulgated numeric criteria. The comment that EPA ignored the CTR criteria, therefore, appears to be addressing the TMDLs for the OC compounds, mercury and chromium. EPA did in fact calculate the numeric targets for the OC, mercury and chromium TMDLs based on tissue or sediment screening criteria which we considered the best indicators of achieving the narrative criteria; however, we emphasize, as noted above, that our analysis indicated that attaining the sediment or tissue targets would also result in attainment of the CTR water column numeric criteria.

EPA regulations provide that in developing TMDLs, site-specific information should be used whenever possible. 40 C.F.R. 130.7(c)(1)(i). For the OC compounds, mercury and chromium, the available data were primarily sediment and tissue data. When we compared this data with screening criteria developed by various organizations, it appeared that these pollutants are having an adverse impact on the environment in this particular watershed such that the beneficial uses, e.g. RARE and WILD, and the narrative standards designed to protect those beneficial uses, were not being achieved. As discussed in the Overview section of the TMDLs, the narrative objectives considered for these TMDLs are (1) toxic substances shall not be discharged at levels that will bioaccumulate in aquatic resources to levels which are harmful to human health, and (b) the concentrations of toxic substances in the water column, sediments or biota shall not adversely affect beneficial uses. As discussed in the TMDL, all the water bodies in this watershed are designated for wildlife habitat and recreational beneficial uses, and other beneficial uses (e.g. uses related to fishing and preservation of biological habitats) apply to specific portions of the watershed.

Based on our analysis of the available data along with relevant screening criteria (discussed generally in the Overview section of the TMDLs and more particularly in the TMDL for each group of pollutants), we determined that it was necessary to develop sediment and fish tissue targets to protect the beneficial uses and to achieve the narrative criteria designed to protect those beneficial uses B in general, to protect against pollutant bioaccumulation in the food chain and resultant human health or aquatic life impacts from consumption of contaminated organisms. Additionally, EPA determined that these pollutants, as present in this particular watershed, are more likely to be associated with particulate matter sorbed to bottom sediments, rather than occurring in the dissolved phase in the water column; therefore, setting sediment and tissue targets most closely relates to the actual way in which the pollutants exist in the environment in this particular watershed. EPA determined that developing such targets was more appropriate than simply applying the CTR criteria, which apply to the water column.

We acknowledge that the CTR numeric criteria would generally be the applicable target, and, as noted above, we are in fact basing the metals and selenium targets on the CTR criteria and equations. EPA-s decision regarding the appropriate targets for the OC, mercury and chromium TMDLs in this particular watershed does not reflect a determination that the statewide CTR numeric criteria are no longer applicable. Rather, based on the our review of site-specific data for those specific pollutants, we determined that establishing the TMDLs based on the statewide CTR numeric criteria alone would not be sufficient to protect the designated uses and attain the narrative criteria in this particular watershed. In order to protect the applicable uses and meet the narrative criteria, the most appropriate approach, for these particular pollutants in this particular watershed, was to develop TMDLs designed to meet narrative as well as numeric criteria.

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L2. *Comment:* EPA=s inclusion of numeric targets into any TMDL is unacceptable because the statute and regulations don=t mention numeric targets. Establishing numeric targets is tantamount to creating a new water quality standard.

Commentor: California Farm Bureau Federation

Response: EPA disagrees. Since a TMDL is an inherently quantitative analysis, it is necessary to develop appropriate quantitative indicators of any applicable narrative criteria in order to calculate the pollutant level that can be present in the water and attain the applicable criteria, and the appropriate loads (see EPA Region 9, 2000). The TMDL process provides a mechanism for identifying quantitative targets as necessary to interpret and apply existing, applicable numeric or narrative water quality standards for different pollutants. Establishing numeric targets, or a numeric interpretation of a narrative criterion, is not establishing a water quality standard but rather is a necessary step in the implementation of a narrative criterion.

L3. *Comment:* EPA cannot base TMDLs for priority toxic pollutants listed pursuant to CWA 307(a) on narrative criteria. CWA 303(c)(2)(B) provides that water quality criteria for these pollutants Ashall be specific numerical criteria.@ It is contrary to law to rely instead on the less reliable narrative criteria. The commentor cites the case of *City of Los Angeles v. U.S. EPA*, No. CV-00-08919 (C.D. Cal. 2001).

Commentor: Irvine Co./Latham&Watkins

Response: See response to comment L1. CWA 303(c)(2)(B) requires that states adopt numeric water quality criteria for certain toxic pollutants. EPA satisfied this requirement with promulgation of the California Toxics Rule (CTR). Neither the Clean Water Act nor the *City of Los Angeles* decision precludes the State from also adopting narrative criteria as well as numeric criteria for toxic pollutants. EPA developed these TMDLs to meet both numeric and narrative water quality criteria.

L4. *Comment:* The narrative criteria upon which EPA is relying are without specific procedures to translate them into numerical criteria and therefore cannot be used as the basis of a TMDL. EPA=s Dec. 12, 1988 guidance on water quality standards under CWA 303(c)(2)(B) provides that narrative standards for toxic pollutants must include a procedure to translate the narrative standards into numerical standards. Because California has not adopted such a translation procedure, EPA cannot apply narrative standards to toxic pollutants and cannot base a TMDL on the State=s narrative standards.

Commentor: Irvine Co./Latham&Watkins

Response: EPA=s 1988 guidance was designed to identify options a State could follow in meeting the requirement of CWA 303(c)(2)(B) that there be numeric criteria for toxic pollutants. Under EPA=s guidance, if a state does not adopt numeric criteria for toxic pollutants, the state is allowed to satisfy Sec. 303(c)(2)(B) by adopting a translator procedure to translate narrative criteria for priority toxic pollutants. The EPA guidance does not preclude a State from adopting narrative criteria in addition to numerical criteria, and does not invalidate the narrative criteria at issue in these TMDLs. As noted in response to Comment L3, CWA 303(c)(2)(B) has been complied with through the California Toxics Rule. (CWA 303(c)(2)(B) does not apply to chlorpyrifos and diazinon because they are not listed pursuant to CWA 307(a); see 40 C.F.R. 401.15.)

L5. *Comment:* EPA cannot rely on non-regulatory sediment or fish tissue values to establish a TMDL for priority toxic pollutants unless those values have been the subject of notice and comment rulemaking. EPA is trying to perform an Aend-run@ around the requirement that numerical criteria or a Atranslator@ procedure for priority toxic pollutants go through notice-and-comment rulemaking. This is especially a problem when there are numeric criteria which are not being used and which have gone through

rulemaking. EPA cannot promulgate a regulation establishing sediment and biota criteria through the establishment of a TMDL.

Commentor: Irvine Co./Latham&Watkins

Response: See response to Comment L4. In these TMDLs, EPA is using sediment and fish tissue values in interpreting the State=s narrative criteria. EPA=s interpretation is included in the TMDLs, which have been subject to a 45-day public review and comment period. Thus, commentors have had full opportunity to comment on EPA=s interpretation of the narrative criteria. In these TMDLs, EPA is not establishing sediment and biota criteria. Rather, EPA is using the best information available to set TMDLs which meet both the numeric water quality criteria and also the narrative bioaccumulation and toxicity criteria.

L6. *Comment:* EPA cannot base TMDLs on narrative criteria that give the public no explanation as to how they will be applied. EPA regulations at 40 C.F.R. 131.11(a)(2) provide that when a state adopts narrative criteria for toxic pollutants, it must provide information identifying the method by which it intends to regulate point sources. The Basin Plan does not contain such information.

Commentor: Irvine Co./Latham&Watkins

Response: 40 C.F.R. 131.11(a)(2) requires the State to provide information identifying the method by which the State intends to regulate point source discharges of toxic pollutants on water quality-limited segments based on the State=s narrative criteria. Thus, this requirement becomes an issue when the State takes regulatory action. EPA=s action in establishing these TMDLs does not directly regulate point source discharges. No NPDES permittee must directly comply with this TMDL. Pursuant to 40 CFR 122.44(d)(1)(vii)(B), when permits are issued, the permits must include conditions consistent with wasteload allocations in TMDLs. That is not to say, however, that TMDLs themselves are a permit or a regulation of point sources, nor that their only function is permit-related. TMDLs are used by States in a variety of ways, including addressing nonpoint source pollution, and general watershed planning.

The State has been closely involved in the development of these TMDLs and supports EPA=s interpretation of the State=s narrative criteria and use of site-specific data. Some of the screening values which EPA used in developing the numeric targets were values established by the State, e.g. the OEHHA tissue concentration screening values and the Department of Fish and Game aquatic life criteria values for chlorpyrifos and diazinon. Additionally, these TMDLs themselves provide abundant information that the State may use in implementing its narrative criteria. The State may consider the methods used to derive the acceptable pollutant loads in these TMDLs as a method (or a major component of a method) for regulating point source discharges based on the narrative criteria in this particular watershed.

The State intends to revisit these TMDLs and develop implementation plans for them as part of their Basin Plan amendment process. In developing the implementation plans, the State will be determining how to regulate point source discharges which may need to be reduced based on the calculations and wasteload allocations in these TMDLs. If the State identifies additional methods pursuant to 40 C.F.R. 131.11(a)(2), in addition to those set forth in these TMDLs, those will be identified during the Basin Plan amendment process. Additionally, if the State obtains new information which it can use in interpreting the narrative standards through numeric targets, or if the methods ultimately identified by the State lead to a different interpretation of the State=s narrative, the State may revise the TMDLs as appropriate and submit the revised TMDLs to EPA for approval.

L7. *Comment:* EPA cannot establish a TMDL for any pollutant without first demonstrating that the watershed at issue is in violation of an applicable water quality standard for that pollutant. EPA has not

demonstrated through monitoring data that any of the watersheds are in violation of applicable numeric standards for many of the pollutants in these TMDLs.

Commentor: Irvine Co./Latham&Watkins

Response: The commentor=s assertions concerning the limits on when a TMDL may be developed are not correct. TMDLs are developed for Awater quality limited segments,@ and EPA defines Awater quality limited segments@ as including both waters which are not meeting water quality standards, and also waters which are not expected to meet standards. 40 C.F.R. 130.2(j). Additionally, in determining which segments are water quality-limited, States consider whether narrative criteria as well as numeric criteria are being achieved In determining which segments in this watershed needed TMDLs for which pollutants, EPA assessed available toxicity and chemical data in three water-quality categoriesBwater column quality, sediment quality, and tissue levels. EPA used a two-tiered weight-of-evidence approach, set forth in detail in EPA=s *Decision Document of Water Quality Assessment for San Diego Creek and Newport Bay* (ADecision Document@) (2002), to determine which TMDLs were appropriate.

L8. *Comment:* EPA cannot establish a TMDL for any pollutant without first demonstrating that the TMDL will render the watershed in compliance with an applicable water quality standards. For several of the pollutants, EPA has not demonstrated that implementation of the TMDL will bring the watersheds in compliance. [Comments regarding specific TMDLs are discussed separately in the sections on those TMDLs.]

Commentor: Irvine Co./Latham&Watkins

Response: EPA agrees that under Clean Water Act 303(d), TMDLs are to be established at levels necessary to implement the applicable water quality standards. However, if a TMDL is not stringent enough to meet a water quality standard, then the remedy is not to determine that no TMDL is appropriate, as the commentor seems to be suggesting, but instead to make the TMDL more stringent. EPA has calculated these TMDLs at levels necessary to meet all applicable water quality standards, as is discussed in the specific TMDLs. However, we acknowledge that there are many uncertainties in these analyses, and we strongly support the Regional Board=s plans to monitor implementation of these TMDLs and, if warranted, revise the TMDLs.

L9. *Comment:* The toxics TMDL is invalid to the extent it proposes to regulate nonpoint source pollutant. Because the TMDLs propose allocations for nonpoint sources, they exceed EPA jurisdiction. Pollutants only deal with discharge from point sources.

Commentor: Irvine Co./Latham&Watkins

Response: The TMDL program applies to both point source and nonpoint source pollution. This was recently reaffirmed by the Federal Court of Appeals for the Ninth Circuit. See *Pronsolino v. Marcus*, 91 F.Supp. 2d 1337 (N.D. Cal. 2000), affirmed by *Pronsolino v. Nastri*, No. 00-16026 (9th Cir. May 31, 2002).

L10. *Comment:* U.S. EPA=s resort to a narrative toxicity standard which does not itself identify a single compound is a concern.

Commentor: Irvine Co.

Response: These TMDLs are intended to meet all applicable water quality standards, narrative or numeric. Because all the pollutants at issue in these TMDLs are considered to be toxic substances, EPA considers the toxicity and bioaccumulation narrative standards to be applicable.

L11. *Comment:* None of the compounds which are the subjects of these TMDLs are included in the 1998 303(d) list, even though the consent decree requiring establishment of these TMDLs was signed in 1997. The List specifies broad categories of compounds and Aunknown toxicity, but does not identify specific compounds. EPA should not deny the public the opportunity to participate in the process of determining which specific pollutants are responsible for the impairment. EPA knew the pollutants of concern in 1997 when it entered into the consent decree, but did not require California to notify the public of these pollutants in the 1998 List.

Commentor: Irvine Co./Latham&Watkins

Response: While EPA prefers that States identify specific pollutants in their 303(d) Lists, we recognize that sometimes States are only able to identify general classes of pollutants or broader problems such as Aunknown toxicity.@ The pollutants identified in the 1997 consent decree were EPA=s best understanding of the probable pollutants for which TMDLs needed to be developed. The consent decree itself, however, specifically noted that the list of pollutants was subject to change by the State, and that EPA could also determine that TMDLs were not needed. In fact, the TMDLs being established by EPA in this action differ somewhat from the list in the consent decree, as explained in EPA=s *Decision Document* (2002). Given the uncertainties regarding the specific pollutants, EPA determined that the State=s identification of general categories in its 1998 303(d) list was adequate to meet the requirements of the Clean Water Act and its implementing regulations

L12. *Comment:* The technical work is arbitrary and capricious because it is based on compound assumptions and extrapolations and Ablack box@ science. There is too much uncertainty, subjectivity, and error. The materials are too hard to understand, do not satisfy minimum scientific standards, and do not give the public a meaningful opportunity to comment. Affected parties have not been afforded due process because they have not been given a full and fair opportunity to participate in TMDL development.
Commentor(s): Irvine Co./Latham & Watkins

Comment: The conclusions in the proposed toxics TMDLs are presented without detailed backup data. Potential concerns relating to data validation, sampling procedures, sample preparation, use of appropriate laboratory procedures, establishment of dose-response, seasonal variability, biological population evaluation, etc., could not be evaluated. *Commentor:* Orange Integrated Waste Management Department/GeoSyntec Consultant

Response: EPA acknowledges that the scientific issues involved in these TMDLs are complicated, and for that reason we included the Technical Support Documents (TSDs) in the materials available for public review and afforded the public a 45-day public comment period. There were also opportunities for public input at EPA and State workshops and meetings, as discussed under APublic Participation@ in the TMDL document. The fact that there is uncertainty does not preclude development of a TMDL. Indeed, Congress fully anticipated that there would be uncertainty, and for that reason incorporated the margin of safety requirement in the TMDL statute. EPA acknowledges that there were some errors in the draft analysis and appreciates the complete review provided by commentors. The final TMDLs have been revised to correct errors which EPA and others found during the public review period. These revisions are discussed in the final TMDLs and/or in responses to specific comments.

With respect to the comment that Apotential concerns@ about the technical basis for the TMDLs could not be evaluated, the comment did not identify any specific concerns about the approaches used to calculate the TMDLs. As noted above, the TSDs, as well as the TMDLs, were available for public review during the comment period. Although EPA is not required to include every aspect of a TMDL analysis in the decision document, EPA did attempt to fully explain the analytical basis for the TMDL decisions in

the TMDL summary document and TSDs. Many commentors did review and comment in detail on the technical approaches used for these TMDLs. The general comment about Apotential concerns@ does not provide a basis for modifying any specific aspect of the TMDL decisions or underlying technical analysis.

L13. *Comment:* The promulgation of a new TMDL is a rulemaking, as it will have a future binding effect and limit administrative discretion. EPA should publish the draft TMDL it in the Federal Register or give actual notice to Apersons subject to the rule@ to allow for public comment, citing 5 U.S.C. 553(b)(3) (Administrative Procedure Act). The supporting data for the TMDL should also be available for public comment. Among other things, the partitioning information is missing from the chemical description, the water values used are unavailable, the model used to calculate loading capacity is not comprehensible, and the basis for water column concentrations is not sufficiently explained to assess the accuracy of the approach.

Commentor: Irvine Co./Latham & Watkins

Response: EPA disagrees with the commentor=s assertion that establishment of TMDLs constitutes Arulemaking@ under the Administrative Procedure Act. These TMDLs are specific factual determinations B calculations of the loads these particular water bodies can receive and still achieve the water quality standards applicable to the water bodies. They have no application nationwide, nor even statewide. Furthermore, we submit that if Congress had intended to require EPA to use rulemaking procedures, it would have given EPA more than the 30 days in which EPA is expected to establish TMDLs after disapproving State TMDLs under CWA 303(d)(2). Indeed, the fact that Congress explicitly established a rulemaking procedure for other actions, e.g. establishing water quality standards in CWA 303(c), indicates that such a procedure is not required for actions such as TMDL establishment under CWA 303(d), where the statute does not specify any type of public participation at all, much less rulemaking procedures.

Although the CWA does not require any type of public notice prior to establishment of TMDLs by either EPA or the State, EPA regulations do require some public review when TMDLs are established under certain circumstances; for example, 40 C.F.R. 130.7 provides that when EPA establishes a TMDL after disapproving a State TMDL, EPA must Aissue a public notice seeking comment@ and consider the public comments received. There is no requirement, however, for publication in the Federal Register.

For the toxics TMDLs, EPA determined that the most effective way of providing notice and soliciting public comment was through the local newspaper of general circulation. Thus, EPA public-noticed the draft TMDLs in the Orange County Register. Copies of the public notice were mailed to the Basin Plan distribution list provided by the Regional Board and posted on the EPA Region 9 TMDL website. Public meetings and workshops were also held, as discussed in the APublic Participation@ section of the TMDL document. Copies of the TMDLs and TSDs were available at the public meetings, on the EPA REgion 9 TMDL workshop, and in the EPA and Regional Board offices.

As noted previously, EPA acknowledges that the scientific issues in these TMDLs are quite complicated, and for that reason made the more detailed TSDs available in the website postings, at the Regional Board and EPA offices, through mailings, and at the public meeting held during the comment period. EPA staff, EPA=s technical consultant, and all supporting data and information used to develop the TMDLs were also available to commentors via email, conference calls, and in person during the public comment period. The TMDLs were revised in several places in response to technical issues raised by commentors, as is discussed in responses to specific comments and/or in the final TMDLs. As sufficient level of detail was provided in the draft TMDLs and administrative record to facilitate a technical review of the TMDLs by interested commentors. The commentor=s consultants submitted extensive technical comments which express the commentor=s views concerning the technical approaches

used in the TMDLs. Therefore, we disagree that insufficient information was provided in the TMDL documents and supporting information to enable the commenter to assess the TMDL methods.

L14. *Comment:* EPA used unreliable scientific methodologies to establish the TMDLs. EPA translated narrative standards into numeric standards using techniques that have not been subject to peer or public review, ignored well-established numerical data for the watersheds at issue, and produced a largely unintelligible explanatory document. (Commentor includes specific examples, which are addressed separately in this Response to Comments in the Technical Comments section.)

Commentor: Irvine Co./Latham&Watkins

Response: EPA based this TMDL on the best scientific data and methods which were available to us. In some cases, it was necessary to devise new methods of analysis specifically for these TMDLs. EPA=s reasons for considering narrative as well as numeric water quality criteria and data are set forth in our Response to Comment L1. While these TMDLs have not been subject to a formal peer review process, they have been subject to comprehensive public review, including workshops during and after development of the draft TMDL and the formal public comment period. EPA also worked closely with scientists at the Regional Board and with EPA=s consultant, Tetra Tech. We acknowledge that there were some errors in our original analysis, which have been corrected in the final TMDLs and are discussed in response to specific comments and/or in the final TMDLs.

L15. *Comment:* EPA must ensure that allocations for all point and non-point sources are included in the TMDLs. In some cases, EPA either does not include a potential source in the allocations or does not set an adequate allocation for that source. (Commentor includes several examples, which are addressed separately in this Response to Comments in the sections regarding the individual TMDLs.) Each individual point source should be assigned its own individual wasteload allocation, not grouped together under a catch-all loading (specifically noting the metals TMDLs) so that the WLAs may be implemented through the individual NPDES permits. All of the allocations should be transparent when reading the TMDL so that everyone is fully informed of what is being covered and so that dischargers are aware of which allocations apply to them.

Commentor: Natural Resources Defense Fund (NRDC)

Response: As noted above, comments regarding allocations in specific TMDLs are addressed in the specific TMDL sections of this Response to Comments. EPA agrees that TMDLs should if possible establish individual wasteload allocations for individual point sources. Given time constraints and the data available, however, we were not able to do this for some point sources in some of the TMDLs. We have identified the specific permitted discharges to which the grouped allocations apply and specified how these allocations should apply to individual dischargers in the future. For metals, we established concentration based wasteload allocations which apply to each NPDES permitted facility. More specific allocations within the general allocations will be determined by the Regional Board when it develops implementation measures for these TMDLs and revises permits consistent with these TMDLs.

L16. *Comment:* Where there is significant uncertainty and/or lack of data to support the source analysis, we believe a larger explicit margin of safety must be provided. EPA should clarify which loadings, if any, are encompassed by the explicit margin of safety.

Commentor: NRDC

Response: The explicit margin of safety was included to account for uncertainties in the analysis but was generally not intended to comprise an unallocated reserve or account for loadings not addressed in the source analysis. We do consider the MOS for the selenium TMDLs to encompass loading from

atmospheric deposition, although this source is not considered to be significant. EPA considers the 20% explicit margin of safety for metals and the 10% MOS for the other pollutants, combined with conservative assumptions used throughout development of the TMDLs, to provide an adequate margin of safety. See also response to comments OP17, M11, and OC 37.

L17. *Comment:* The Regional Board has adopted a phased approach in establishing TMDLs for other pollutants (nutrients, sediments) in this watershed. The phased approach includes a schedule whereby final compliance with the TMDLs is to be achieved, and also includes interim implementation steps, including additional monitoring and investigation, and revision/refinement of the TMDLs if warranted. We expect the Board will take a similar approach in the adoption of the toxics TMDLs, given limited data and the difficulties anticipated in achieving compliance. We would welcome a discussion of EPA=s implementation recommendations for these TMDLs. The implementation recommendations section might be the appropriate vehicle to express EPA=s position that no discharge rights or obligations are changed directly by TMDL promulgation. Rather, any such changes would occur in the process of implementing the TMDL through NPDES permit/WDR modifications and other implementation actions identified by the Regional Board in the implementation plan in the basin plan. This is a position with which we agree, as reflected in the recently reissued Orange County MS4 permit. The Regional Board=s TMDL implementation approach to date has been to request that the responsible parties submit plans and schedules for achieving compliance with the requirements of the TMDLs. We urge EPA to endorse this approach.

Commentor: Santa Ana Regional Water Quality Control Board

Response: EPA supports the Regional Board=s phased approach. Additionally, the Regional Board=s interpretation of EPA=s position concerning the obligations of dischargers is correct. As recommended by the Regional Board, we are including an implementation recommendations section in the final TMDLs.

L18. *Comment:* The ambiguities in the TMDL preclude clear notice to the City of its obligations. Compliance with the TMDLs is unrealistic and an undue burden on the City. The City is not a major contributor of the pollutants and should not have to undergo tremendous cost to prove this.

Commentor: City of Costa Mesa.

Response: The commentor did not provide specifics concerning the cost which it envisions incurring, nor is the comment clear with regard to ambiguities and the City=s obligations. As discussed in Comment L17, the City=s discharge rights and obligations are not changed directly by the TMDL. Rather, such changes will occur, if necessary, in the process of implementing the TMDL by the Regional Board through permits or possibly other means.

L19. *Comment:* There are no time-for-compliance provisions in the TMDL. The TMDL will immediately place many stakeholders in a position of violating the TMDL. The TMDL should contain provisions for a phased-in approach for eventual compliance.

Commentor: City of Costa Mesa

Response: See Comments L17 and L18.

L20. *Comment:* A re-opener clause should be incorporated into the TMDL that allows the load allocations to be re-evaluated and revised. This will provide the ability to take into account any new

scientific data that is developed or to revise the proposed load allocations in the event that stakeholders are unable to meet the load allocations as currently proposed.

Commentor: City of Costa Mesa

Response: EPA declines to include a mandatory reopener clause in the TMDLs; however, we note that the State is always free to revise a TMDL and submit the revised TMDL to EPA for approval, and we encourage States to do this when new information becomes available. In this regard, we note the Regional Board=s intent to develop a phased implementation approach, including additional monitoring, investigation, and revisions of the TMDLs if warranted. If commentors are concerned with implementability of the TMDLs, we urge them to submit comments and recommendations to the Regional Board when it develops implementation measures for the TMDLs.

L21. *Comment:* The TMDLs may result in regulatory requirements that are unattainable and subject stakeholders to third party lawsuits and possible criminal proceedings by regulatory agencies.

Commentor: Irvine Public Works Dept.

Comment: I believe that a forced TMDL for toxics will be counter productive and logistically unenforceable. How can the EPA hold liable the vast majority of permit holders and those businesses that have demonstrated continuous support and improvements of this watershed=s water quality? My hope is that EPA will not actively enforce these TMDLs and instead work with the Regional Board to develop an implementation plan that will satisfy the consent decree and reward stakeholders for their continued efforts to protect this watershed=s water quality. *Commentor:* Bordier=s Nursery.

Response: See Response to Comments L17-20. As discussed in Comment L17, discharge rights and obligations are not changed directly by the TMDL. Rather, such changes will occur, if necessary, in the process of implementing the TMDL by the Regional Board through permits or possibly other means. If commentors are concerned with implementability of the TMDLs, we urge them to submit comments and recommendations to the Regional Board when it develops implementation measures for the TMDLs.

L22. *Comment:* Further monitoring and analysis has been, and will continue to be, an important part of our TMDL implementation efforts, both to assess the effectiveness of control measures and to assist us in refining the TMDLs. In addition to implementation of a routine monitoring program, which will be coordinated with the local stakeholders, a number of special investigations are being conducted to forward the TMDL work. These include studies in the Rhine Channel area, an identified Toxic Hot Spot. The Regional Board has already approved a general cleanup plan for that area and the studies underway will help us to refine it. We expect that implementation of a detailed cleanup plan will be the key remediation vehicle for the Rhine Channel.

Commentor: Santa Ana Regional Water Quality Control Board.

Response: EPA applauds the Regional Board=s commitment to future monitoring, analysis, and refinement of these TMDLs, and the Regional Board=s efforts to coordinate this work with local stakeholders. We also commend the Regional Board for its work on the general Rhine Channel cleanup plan, and note that this is an positive example of combining the results of TMDL analyses with overall watershed planning.

L23. *Comment:* In order to manage the Irvine Groundwater Basin, IRWD will need to construct, operate and maintain water wells and desalters. These activities will require discharge to surface waters, because they will discharge large quantifies of water for short periods of time. IRWD requests that discharges associated with the management of the Irvine Groundwater Basin be included in any waste load allocations included in the TMDL.

Commentor: Irvine Ranch Water District (IRWD).

Response: The grouped wasteload allocation for groundwater dewatering and groundwater treatment operations is designed to apply to the type of discharge described by the commenter. As discussed in the implementation section, we will urge the State to work with dischargers to collect data and conduct analysis necessary to support more specific delineation of wasteload allocations for individual dischargers of pumped groundwater. Meanwhile, the grouped allocation is intended to ensure that the sum of all discharges from this class of discharge does not contribute to TMDL exceedences.

L24. *Comment:* We request that EPA stay the promulgation and implementation of the proposed TMDLs pending further investigation, and allow further opportunity for public comment. *Commentor:* Latham & Watkins.

Comment: We suggest extending the deadline for comments by 90 days. *Commentor:* City of Irvine Public Works Department.

Comment: We encourage EPA to defer approval of the TMDLs in question until they can be revised and subjected to additional public review. *Commentor:* California Farm Bureau Federation.

Response: EPA has already negotiated an extension of the consent decree deadline for establishing these TMDLs (to June 15, 2002), has provided for a 45-day public comment period, and does not consider an additional extension to be appropriate. We agree that the issues are technically very complicated, and applaud the Regional Board=s commitment to including monitoring and further analysis as it implements these TMDLs (see Comment L17, 20). As the Regional Board develops implementation measures for these TMDLs, there will be additional opportunity to both submit formal comments to the Regional Board, and also to work with Regional Board staff in developing the implementation measures.

L25. *Comment:* It is stated that TMDLs are required for toxic substances that are shown to cause probable adverse effects. However, it is not clearly stated how Aadverse effects@ are defined. The TMDL states, AEvidence of adverse impacts to aquatic life as a result of direct or indirect exposures to these toxic pollutants is limited.@ This lack of evidence is significant. It appears that based on these statements and the lack of definition of a problem statement that further study and data gathering may be required before a determination of Aadverse effect@ can be made.

Commentor: Orange County IWMD/GeoSyntec Consultant

Response: The Commentor is referred to EPA=s 2002 *Decision Document*, in which we document our criteria for determining which TMDLs needed to be developed. We have revised the language in the TMDL to indicate that although water quality standards have been exceeded for the subject pollutants, the degree to which beneficial uses have actually experienced adverse effects is unknown. Water quality standards and TMDLs are designed to be protective, and the TMDLs are intended to identify maximum allowable pollutant loads and concentrations that can be discharged without exceeding water quality standards and harming beneficial uses.

EPA agrees that further study and data gathering is desirable for the implementation phase of these TMDLs, and concurs with the Regional Board=s plans to increase data gathering and analysis and, if necessary, revise these TMDLs.

L26: *Comment:* It is difficult to comment on a draft TMDL that has no implementation plan.

Commentor: Irvine Co.

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Response: EPA is not establishing implementation plans for these TMDLs as it is the State, not EPA, which is responsible for developing implementation measures necessary to attain TMDLs, In its comments concerning the EPA TMDLs, the Regional Board signaled its commitment to adopt TMDLs and implementation plans for these toxic pollutants in a timely manner. The Regional Board will do this through the Basin Plan amendment process, which involves extensive public participation. At the request of the Regional Board, EPA has included general recommendations of implementation actions in a new section of the TMDL summary document (AImplementation Recommendations@). As discussed in that section, these implementation and monitoring recommendations are not required and are not part of the TMDL decisions being made by EPA at this time; rather, they are included with the TMDLs to assist followup planning and implementation work by the State and local stakeholders.

Organophosphate (OP) TMDLs

OP1. *Comment:* I am concerned that the banning of diazinon and chlorpyrifos from products available to the general public may not be enough to reduce the levels of the organophosphates in the waters of San Diego Creek to an acceptable level in a reasonable length of time. It may be necessary to also restrict commercial use of these compounds in order to protect the biota in creek water.

Commentor(s): John F. Skinner MD

Response: The EPA re-registration agreements phase out various diazinon and chlorpyrifos uses over a five-year period. The uses that will be discontinued include many of the commercial applications as well. Overall, it is our best estimate that more than ninety percent of diazinon and chlorpyrifos use (as of 1999-2000) will be discontinued over the next five years. The implementation recommendations in the final TMDL suggest that if reductions associated with the phase-out of these pesticides are insufficient to implement the TMDL, then additional actions to reduce discharges of these pesticides may be necessary.

OP2. *Comment:* Overall, the draft OP pesticide TMDL and the interpretation of supporting data are reasonable. Instead of specific technical comments, DPR would like to inform you of the recent availability of documents addressing urban pesticide use and water quality.

Commentor(s): California Department of Pesticide Regulation (CDPR)

Response: Three of the documents listed were reviewed during development of the TMDL. The additional studies will be reviewed and may be used by the Regional Board for developing the implementation plan for the TMDL.

OP3. *Comment:* The TMDL is worded to include all Organophosphate products not just the currently identified products Diazinon and chlorpyrifos.

Commentor(s): George Gutman, Bordiers Nursery

Response: The TMDL is for chlorpyrifos and diazinon only. TMDLs for other organophosphates are not being developed at this time. The term Aorganophosphates@ is used to distinguish these two pesticides from the organochlorine pesticides.

OP4. *Comment:* (A) There are state and federal regulations that require nurseries to maintain our stock and our facilities in Acommercially clean@ condition all the time. This requires pesticides. We are also in some case to be Afree from@ pests. This is the case for the federal quarantine on the Red Imported Fire Ant (RIFA). How will EPA work this issue out with USDA? (B) Ironically, to comply with protocols for

protecting against the transport of red imported fire ants, the nurseries are directed to use diazinon on the nursery stock before it can be shipped from the nursery.

Commentor(s): (A) George Gutman, Bordiers Nursery, (B) Kathy Nakase, California Farm Bureau

Response: We are informed by the Regional Board that the implementation plan will address the issue of diazinon and chlorpyrifos use for the RIFA plan. Strategies to achieve the TMDL goals while taking into account the requirements of the RIFA program will be developed. In this regard, the Regional Board anticipates working with the stakeholders and building on the cooperative work being undertaken by the DPR, USDA, and UC Cooperative Extension to address potential water quality impacts from the RIFA program.

We also note that the USDA requires mitigation measures to minimize impact of quarantine treatment on the environment and human health. See, e.g. USDA *Imported Fire Ant Quarantine Treatments for Nursery Stock and Other Regulated Article*s, Program Aid No. 1653 (1999).

OP5. *Comment:* The OP pesticide TMDL creates a number of concerns for the agricultural community of Orange County. First, the OP pesticides, diazinon and chlorpyrifos, are important broad-spectrum pesticides for California agriculture. In reality, the ability of OPs to control a number of pests results in less pesticide use by the industry. When a farmer is forced to forego using OP, the farmer is usually forced to use two or more other pesticides that are designed to address a single pest. We state these concerns because of the statement on page 28, which indicates that additional measures will be necessary to achieve the reductions set forth in the TMDL. We are concerned that the allocations established by the TMDL will not be able to be implemented in an economically effective manner by the state and the Regional Board. If the set allocation is not implementable the impact to the Orange County agricultural community could be devastating.

Commentor(s): Kathy Nakase, California Farm Bureau

Response: Additional measures may be necessary to achieve the reductions in OP concentrations in San Diego Creek.. However, this does not mean that additional usage reductions are necessarily needed. Less than one percent of the applied diazinon and chlorpyrifos mass reaches San Diego Creek on an annual basis. Physical and chemical processes breakdown the pesticides before they reach the drainage channels. The Regional Board anticipates that the TMDL implementation plan will include a component focused on development and application of effective management practices that reduce pesticide concentrations in runoff.

OP6. *Comment:* Proposed application of the CDFG numeric targets is inconsistent with the NRC approach. EPA admitted that the methodology underlying the CDFG numeric targets would have to be updated when it was created seventeen years ago. The CDFG targets are excessively conservative. If the targets are to be used, they should reflect the results of PERA and Mesocosm/Microcosm studies. MANA recommends that EPA discontinue use of the numeric targets developed by the CDFG and revise the TMDL for diazinon and chlorpyrifos.

Commentor(s): Makhtashim Agan of North America Inc (MANA)

Response: The validity of the USEPA methodology (AGuidelines for Deriving Numerical National Water Quality Criteria for the Protection of Aquatic Organisms and their Uses@) was affirmed recently with the promulgation of the California Toxics Rule (CTR) in May 2000 (40 CFR Part 131, page 31689). This is the methodology used by the California Department of Fish and Game (CDFG). The NRC approach, while it appears worthwhile to consider, is not yet reflected in relevant TMDL regulations.

OP7. *Comment:* The saltwater chronic numeric target for chlorpyrifos in Upper Newport Bay is based on the National water chronic criterion of 5.6 pptr (EPA 1986). The criterion is based on 8 chronic bioassays in marine organisms. One of these bioassays was done by Chuck Mckenney at the EPA Gulf Breeze Laboratory and reported in 1981. The bioassay was a 28 day study in *Mysidopsis bahia*.

I discussed the study with Chuck Mckenney. He said the 42,000 pptr data point was in error in the National water criterion document and should be 42 pptr. He said 4 pptr and 10 pptr concentrations were estimated and not analyzed. The National water criteria are guidance and not standards unless adopted by local agencies for specific watersheds. Considering the lack of analytical verification and a questionable technique for assessing growth inhibition for the 4 pptr and 10 pptr concentrations, the effect level of 42 pptr is the lowest concentration verified by analysis and having effects on survival, reproduction, and growth. Adoption of this effect level would raise the chronic criterion above the California freshwater chronic criterion of 14 pptr.

Using a freshwater chronic criterion for chlorpyrifos in Upper Newport Bay seems appropriate since the period of concern is the during storm flows when the Upper Bay is dominated by freshwater. Therefore, whether the standard is considered to be a reinterpretation of the National chronic saltwater criterion (corrected from 5.6 pptr to 14 pptr or higher) or a CDFG recommended freshwater chronic guideline, the TMDL for chlorpyrifos in the Upper Newport Bay should be based on a maximum chronic concentration of 14 pptr.

Commentor(s): James Byard, (Irvine Co)

Response: Chuck Mckenny, the scientist who performed the study has expressed his confidence in the results, and that effects were present at the 4 pptr level (personal communication with EPA). The typographical error in the reporting of the bioassay did not affect calculation of the chronic criterion.

However, the numeric targets in the TMDL have been revised to use the recommended CDFG (2000) criteria, 9 ng/L(chronic) and 20 ng/L (acute), as these represent the latest scientific evaluation of available data. The study performed by Chuck Mckenny was reviewed by the CDFG and included in the data set used to derive the chronic numeric target.

OP8. *Comment:* There is no evidence of real-world, field toxicity in the waters that are subject of TMDLs.

Commentor(s): Latham & Watkins (Irvine Co)

Response: Numerous toxicity tests have demonstrated the occurrence of toxicity in the watershed. Cited references in the TMDL include:

Bailey, HC DiGiorgia, C and DE Hinton. 1993. *Newport Bay Watershed Toxicity Study*

Lee, GF and S Taylor. 2001a. Results of Aquatic Life Toxicity Testing Conducted During 1999-2000 in the Upper Newport Bay Watersheds.

Lee, GF and S Taylor. 2001a. Results of Aquatic Life Toxicity Testing Conducted During 1997-1999 in the Upper Newport Bay Watershed and Review of Existing Water Quality Characteristics of Upper Newport Bay and its Watershed.

CDPR 1999-2000. Preliminary Results of Pesticide Analysis and Acute Toxicity Testing of Monthly Surface Water Monitoring for RIFA Project in Orange County. (Monthly monitoring memos)

OP9. *Comment:* A simple mixing calculation indicates that if San Diego Creek contributes more than 40 percent of the volume in the Bay, Upper Newport Bay will not meet its target. Please provide an analysis of the relative proportion of the volume that San Diego Creek can contribute to the Upper Bay under

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storm conditions that demonstrates that the numeric targets for Upper Newport Bay will be met under the range of storm conditions.

Commentor(s): Limno-Tech (NRDC/Defend the Bay)

Response: The concentration-based TMDLs apply under all flow conditions to San Diego Creek and Upper Newport Bay and are sufficient to ensure that the numeric targets will be met under storm conditions. The Regional Board anticipates that the implementation plan will include a task to evaluate the degree of mixing and proportion of San Diego Creek flow volumes in Upper Newport Bay during storm conditions, and that the TMDL will be refined/revised as necessary.

OP10. *Comment:* The typical detection limit for chlorpyrifos water samples appears to be between 40-50 ng/L. Please provide guidance on how non-detect data for chlorpyrifos will be interpreted with respect to the numeric targets. Discuss the availability and use of sampling and analytical methods that will result in detection limits less than or near the numeric targets. This issue should be incorporated into the implementation plan.

Commentor(s): Limno-Tech (NRDC/Defend the Bay)

Response: Some of the data summarized in the TMDL were collected using sampling and analytical methods with detection limits below the numeric targets. The Regional Board anticipates that the implementation plan for the TMDL will include a monitoring and reporting program that specifies appropriate detection/reporting limits for chlorpyrifos and diazinon.

OP11. *Comment:* Source Analysis: The TMDL provides text describing how the available data compare to the chronic numeric criteria for each waterbody and compound. Please provide the same information with respect to the acute criteria.

Commentor(s): Limno-Tech (NRDC/Defend the Bay)

Response: Additional discussion of the data with respect to the acute criteria has been included in the TMDL and the TSD.

OP12. *Comment:* We cannot evaluate the current loadings in the analysis presented in the TSD. Please clarify how the mean base and storm flow concentration used in Tables C-14 and C-16 were determined. The concentrations in these tables are not consistent with the base and storm flow concentrations presented in Tables C-8 and C-11.

Commentor(s): Limno-Tech (NRDC/Defend the Bay); (B) James H. Eldridge, City of Irvine

Response: Tables C-8 and C-11 are data summaries for all 398 diazinon and chlorpyrifos samples collected from the various drainage channels in the watershed. Tables C-14 and C-16 refer to 28 samples collected at the San Diego Creek at Campus station (SDC-Campus). For purposes of estimating loads, the data from the SDC-Campus station are appropriate as the station is representative of flow from over 95% of the watershed (Tables C-14 and C-16).

The loads on page 25 of the Summary Document were determined using median concentrations from the data at the SDC-Campus station. The loads in Tables C-14 and C-16 of the TSD were determined using the mean concentrations. For consistency, the loads on page 25 have been edited to reflect the loads determined based on the mean concentrations as in the TSD.

It should be noted that the estimated loads are provided in the TMDL for information purposes only, as the TMDL is concentration based.

OP13. *Comment:* Please reconcile the various existing load estimates.
Commentor(s): Limno-Tech (NRDC/Defend the Bay)

Response: The load estimates in the TMDL were made using median concentrations from the SDC-Campus station while the load estimates in the TSD were made using mean concentrations. These concentrations were multiplied with mean annual base and storm flow rates. The text has now been revised to use mean concentrations in both the summary and the TSD, and the mean annual base and storm flow rates are based on the flow analysis from the TSD Part B.

OP14. *Comment:* The calculation of the percent contribution of indirect deposition from rainfall appears to be incorrect on page 17 of the TSD.
Commentor(s): Limno-Tech (NRDC/Defend the Bay)

Response: The atmospheric deposition percentage calculations have been redone using the new loads calculated as described above (OP13).

OP15. *Comment:* The language in the TMDL contradicts the analysis of loadings from atmospheric deposition presented in the TSD. We recommend that the TMDL be changed to more accurately reflect the analysis presented in the TSD by rephrasing the second full paragraph on page 25. We suggest the following language be inserted into the TMDL. ALoadings from atmospheric deposition are potentially significant, though not well-quantified. Because the origin and magnitude of these loadings are not well understood, their potential contribution is factored into the margin of safety.@
Commentor(s): Limno-Tech (NRDC/Defend the Bay)

Response: The text has been modified to include the language similar to the suggested text. See also response to OP17 concerning margin of safety.

OP16. *Comment:* (A) Why are there two calculations for Reach 1 in Table C-16? (B) Please correct the following errata:

- On page 24 of the TMDL there is a reference to Table 3.2,which does not appear in the document with the content described in the paragraph.
- The last paragraph in the chlorpyrifos section on page 24 lists the saltwater chronic numeric target as 9 ng/L. This should be changed to 5.6 ng/L.
- In Table C-16 in the TSD, ASD Creek Reach 1@ is listed twice. The second entry was likely meant to be AUpper Newport Bay.@

Commentor(s): (A) James H. Eldridge, City of Irvine; (B) Limno-Tech (NRDC/Defend the Bay);

Response: The sentence referring to Table 3.2 has been removed. The saltwater numeric targets have been changed to reflect the latest scientific evaluation published by the CDFG in 2000. The saltwater chronic numeric target has thus been revised from 5.6 ng/L to 9 ng/L. See also the response to comment OP7. Table C-16 has been revised to simply provide the estimated load at the San Diego Creek-Campus station.

OP17. *Comment:* Given the uncertainty regarding the origin and magnitude of loadings from atmospheric deposition, we suggest increasing the margin of safety to 20 percent for chlorpyrifos for both water bodies to encompass this uncertainty.
Commentor(s): Limno-Tech (NRDC/Defend the Bay)

SARB_001468

Response: As the TMDL is concentration-based, the uncertainty in the contribution from the atmosphere will not affect establishment of the TMDLs and allocations. Regional Board staff have indicated that the uncertainty may require targeted actions during the implementation period to ensure that the criteria are met in the watershed. These actions could include additional monitoring to better assess the significance of rainfall as a separate source, and a thorough investigation of potential sources and transport pathways to the watershed.

OP18. *Comment:* We suggest adding language to the text in the Allocations section that specifically states what sources are covered in each allocation.

Commentor(s): Limno-Tech (NRDC/Defend the Bay)

Response: The TMDL has been revised to include the suggested information.

OP19. *Comment:* The storm average concentrations presented in Table 3-4 are not consistent with the mean concentrations presented in Tables C-8, C-11, C-14, and C-16. Please explain how the values in Table 3-4 were derived.

Commentor(s): Limno-Tech (NRDC/Defend the Bay)

Response: Multiple samples are available from five separate storm events in the watershed from 1997-2000. The storm average concentrations in Table 3-4 are the maximum single storm averages at the SDC-Campus station. These are the best data available for comparison to the chronic criterion (4-day average). For chlorpyrifos the data are six samples from January 25-26, 2000. For diazinon, the data are four samples from January 25-27, 1999.

The averages in Tables C-8, C-11, C-14, and C-15, are for all sampled storms from 1996-2000. The diazinon and chlorpyrifos averages for the entire watershed are presented in Tables C-8 and C-11 respectively (data summary), while the averages for the SDC-Campus station are used in Tables C-14 and C-16 (load calculation).

OP20. *Comment:* On pages 22 and 23 of the document it states that there is no evidence of bioaccumulation. Yet further down, the TMDL concludes by saying that adverse impacts may be affecting fish survival and reproduction. There does not appear to be any evidence to support the claim of adverse impacts to fish survival. Without supporting evidence, the statement should be stricken and the conclusion of acute and chronic toxicity should be reexamined.

Commentor(s): Kathy Nakase (California Farm Bureau Federation)

Response: The sentence concerning potential impacts on fish survival and reproduction has been deleted. However, the document notes that the presence of acute and chronic toxicity has been well documented using the standard test species *Ceriodaphnia dubia*.

The commentor is referred to EPA=s 2002 *Decision Document* for a discussion of EPA=s method for determining which TMDLs are needed. As indicated in that document, there is sufficient water-column evidence of toxicity that EPA has concluded that a TMDL is warranted.

OP21. *Comment:* As mentioned above, on page 28 the document discusses the phase out agreements and then concludes that additional measures will be necessary to achieve reductions. The document fails to provide information on why the phase-outs will not be protective and why additional measures will be necessary. Based upon the small percentage of land use related to agriculture in this highly urban

environment, it is hard to believe that additional agricultural reductions will be necessary once the phase-outs are implemented.

Commentor(s): Kathy Nakase (California Farm Bureau Federation)

Response: The TSD describes the estimated load contribution from agriculture as around 10 percent. However, the re-registration agreements, which target urban uses to a greater extent than agricultural uses, may result in a higher proportion of agriculture use remaining. Only a miniscule fraction (<1%) of the annually applied diazinon and chlorpyrifos mass reaches San Diego Creek. Regional Board staff expect that the TMDL implementation plan will not be focused on further reducing the remaining diazinon and chlorpyrifos uses in the watershed. Instead, the implementation plan will address development and application of BMPs to ensure that runoff to San Diego Creek meets the numeric targets.

OP22. *Comment:* The allocation of 20 percent of Orange County pesticide usage to the Newport Bay watershed because it represents 20 percent of Orange County land may not be appropriate. If the ratio of agricultural to nonagricultural uses is used for analysis differences in the ratio between the Newport Bay watershed and Orange County as a whole may affect the apportionment of use for the watershed.

Commentor(s): James H. Eldridge, City of Irvine

Response: Estimation of pesticide usage in the watershed from records kept on a county-wide basis can be performed several different ways. As noted by the comment, pesticide usage patterns may not be uniform across Orange County; thus a simple approach using proportion of total area may result in some degree of inaccuracy. Pesticide usage rates are also affected by a large number of factors such as income, landscaping, lot sizes, population, and the presence or absence of pest infestations. Detailed evaluation of all these factors was not necessary given that the usage rates were only used to estimate the general magnitude (>90 percent) of the decline in usage expected from the EPA re-registration agreements.

OP23. *Comment:* There should be a description of the analysis of the impacts associated with expected reductions in loadings from the re-registration of both pesticides.

Commentor(s): James H. Eldridge, City of Irvine

Response: The Regional Board indicates that this analysis will be performed for the TMDL implementation plan. The TMDL analysis discusses the prospective reductions in loads associated with scheduled phase-outs of these pesticides in urban uses.

OP24. *Comment:* There is an inconsistency between the TMDL and the TSD. The conclusions of the TSD state that re-registration agreements with EPA will result in a 90 percent decline in use in Newport Bay and if there are corresponding declines in runoff concentrations, chronic numeric targets should be met for both substances. However, the conclusion in the draft TMDL states that AWhile these agreements should result in significant decreases in OP pesticide use and the resulting discharge concentrations to the water bodies, additional measures appear to be necessary to achieve the reductions set forth above.@ Since there is no analysis presented, no conclusions should be drawn.

Commentor(s): James H. Eldridge, City of Irvine

Response: The text has been revised to state Aadditional measures may be necessary@ rather than Aadditional measures appear to be necessary.@

Achievement of the numeric targets through the re-registration agreements is dependent on the assumption of a linear relationship between usage and pesticide concentrations in runoff. While this might be the case, there is also some evidence that certain pesticide use practices may be responsible for a large part of the runoff load. Thus additional measures may be necessary.

OP25. *Comment:* There are no water quality standards for chlorpyrifos and diazinon. It is inappropriate to translate the narrative toxicity standard into numeric TMDLs using non-regulatory guidance values.
Commentor: Latham&Watkins.

Response: While at present there are no promulgated numeric water quality criteria for chlorpyrifos and diazinon, the narrative criteria for toxicity and bioaccumulation apply. See Responses to comments L1, L2 and L4.

OP26. *Comment:* We fully support EPA=s commitment to promulgate a TMDL for diazinon, even though this TMDL is not required by the consent decree. Available data demonstrates that diazinon is a source of water column toxicity in San Diego Creek. This toxicity is appropriately addressed by the development and implementation of a TMDL.
Commentor: Santa Ana Regional Water Quality Control Board.

Response: EPA appreciates the comment.

Selenium TMDLs

S1. *Comment:* The Regional Board concluded (RB 2000 Problem Statement) that there are no data for selenium indicating any water quality toxicity in Newport Bay and no evidence that concentrations of selenium are impairing beneficial uses or exceeding water quality standards in the Bay. Selenium concentrations in the Bay do not exceed the CTR saltwater criterion of 71 ppb.
Commentor: Irvine Co./Latham&Watkins

Response: Though there have been no measurements to date of dissolved selenium concentrations in Newport Bay that exceed the CTR saltwater criterion (71 ug/L), recent tissue data indicate that selenium is bioaccumulating to levels that pose a concern about potential toxicological/reproductive effects. Thus, there is evidence that the concentrations of toxic substances in the biota may be adversely affecting wildlife-related beneficial uses, in violation of the Regional Board=s narrative toxics objective. Combined with substantial evidence of water quality standards violations in San Diego Creek, Upper Newport Bay satisfies the decision criteria utilized in EPA=s Decision Document for identifying waters needing TMDL development.

Regional Board staff indicates that implementation of this TMDL is expected to be accomplished largely through the implementation of the selenium TMDL for San Diego Creek and other tributaries to the Bay, and that additional monitoring of selenium bioaccumulation in fish and mussels in Newport Bay will be conducted as part of the selenium TMDL implementation plan.

S2. *Comment:* Regulating selenium is not appropriate because selenium is naturally occurring in the watershed and there is little anthropogenic selenium. The Clean Water Act does not require cleanup of naturally occurring conditions. EPA can only regulate pollution, which is defined in the CWA as man-

made alterations to water. The TMDL acknowledged that selenium loadings come largely from natural runoff and discharges of shallow groundwater, and that it would be difficult to estimate naturally occurring selenium discharge levels. While acknowledging the selenium is present naturally, EPA is proposing to regulate *all* selenium, without distinguishing natural from anthropogenic. This approach will require a cleanup that will never end, as nature will keep producing selenium. EPA should look at other TMDLs in the region where natural conditions are used as a benchmark, at which TMDL compliance is achieved.

Commentor: Irvine Co./Latham&Watkins**;** IRWD

Response: TMDLs need to analyze all sources of a pollutant, natural and anthropogenic. The commentors did not provide specific examples of TMDLs where natural conditions are used as a benchmark and how those TMDLs provide a useful model for the selenium TMDLs, so it is not possible to ascertain exactly what the commentors are proposing.

Moreover, EPA disagrees with the commentors= premise that the selenium in the surface water bodies of Newport Bay and its watershed is naturally occurring. Though selenium in the groundwater is naturally occurring, the selenium in the San Diego Creek watershed and Newport Bay is primarily the result of anthropogenic processes. Agricultural practices conducted in the early 20th century resulted in the rerouting of the drainage patterns in the San Diego Creek and Newport Bay watersheds. Swamps and marshes were drained (most notably the historical Swamp of the Frogs [La Cienega de las Ranas]), irrigation channels were constructed, and the drainage net was artificially extended downstream to Newport Bay (Trimble 1998). Prior to these changes, the San Diego Creek watershed did not have integrated drainage and did not regularly drain to the Bay. Large storm flows from the watershed ponded in the Swamp of the Frogs and an ephemeral lake located along the southwestern margin of the swamp between Upper Newport Bay and the present route of the Santa Ana River (Trimble 1998).

Though seleniferous water and sediments may have existed in the Swamp of the Frogs and the ephemeral lake, that selenium has now been re-mobilized and artificially rerouted into the watershed tributaries via groundwater discharge. As a result, the high selenium flows in San Diego Creek and its tributaries, which at one time did not except on very rare occasions reach Newport Bay, now flow directly to the Bay. It may be noted also that according to Trimble (1998), on those rare occasions when storm water overflowed from the ephemeral lake, it flowed westward into the Santa Ana River and directly into the Lower Bay, thereby completely bypassing the Upper Bay. The historical basis for selenium concentrations in the San Diego Creek Watershed has been described briefly by Dr. James Byard in his comments on the selenium TMDL (Irvine Co.). Dr. Byard notes that though seleniferous water and sediments may have accumulated in the inland lentic water bodies that existed on the Tustin Plain, selenium associated with these swamp and lake deposits has now been re-mobilized in the shallow groundwater. The shallow (perched) groundwater discharges through springs, seeps and weepholes to San Diego Creek, which has been artificially extended to Upper Newport Bay.

S3. *Comment:* Although natural in origin, selenium is an undesirable contaminant, and communities may as a result of selenium removal show some improvement. Because of the widespread presence of selenium in the surface and subsurface environment, it will be necessary to disturb the environment in order to remove the selenium. Consequently, programs instituted to remove selenium may cause some short term increases in selenium in the surface environment. The USEPA and other regulatory agencies need to recognize that minor excursions of the adopted selenium standard do not constitute a violation of the standard. Since selenium is neither created or destroyed, the only alternative to lessen selenium toxicity is to move excessively high concentrations of selenium to an environment which is less susceptible to selenium toxicity. IRWD recommends that selenium removal implementation plans require

as a goal the net export of selenium from the Irvine Basin to ocean waters which would not be affected by minor increases in their selenium load.

Commentor: IRWD

Response: Many of the comments on these TMDLs concern implementation issues. All comments will be forwarded to the Regional Board for its consideration in implementing these TMDLs. The Regional Board has indicated that in developing the implementation plan for the selenium TMDL, a variety of remedial options for treating or removing the selenium in the surface flows and/or groundwater in the watershed will be considered.

S4. *Comment:* The naturally-occurring selenium in the creek exceeds the CTR criteria; thus, the Creek is likely to be well adapted to this naturally-occurring substance. The environment has adapted well to the natural selenium. EPA erroneously assumed that naturally-occurring selenium is toxic, when the local ecosystem is adapted to background levels exceeding the regulatory standard.

Commentor: Irvine Co/Latham&Watkins**;** Byard, IRWD

Response: Though selenium in the groundwater is naturally occurring, the presence of selenium in San Diego Creek as it now exists is the result of anthropogenic processes. See Response to Comment S2.

Additionally, the commentors have not produced any evidence to support the argument that the ecosystem is likely well adapted to existing selenium concentrations, which, as discussed above, are not naturally occurring. Selenium concentrations in San Diego Creek at Campus Drive consistently exceed the CTR criterion for fresh waters (5 ug/L). These concentrations are well above the level that Engberg et al (1998) characterized as certain to cause toxicological and reproductive effects. Selenium concentrations in fish tissues collected from San Diego Creek fall in the range of levels of concern for fish. This suggests that selenium is likely to cause ecological impacts in San Diego Creek.

Since selenium biomagnifies up the food chain, toxicological impacts from selenium in primary producers such as birds may not show up immediately. Toxicological effects of selenium on wildlife include lowered reproduction rates, shortened life spans, and stunted growth. Many of these effects are not readily observable and detailed biological studies will be needed to determine whether or not selenium is negatively impacting biota in the watershed and the Bay. We understand that several extensive investigations of selenium and its role in the San Diego Creek watershed are planned or are in the data collection stage. While these investigations may yield data on which the Regional Board may base a determination that revisions to the TMDLs are warranted, at this time EPA does not consider it prudent to postpone this TMDL analysis until a time when these toxicological and reproductive effects are more apparent or when additional data is gathered.

S5. *Comment:* EPA cannot establish a TMDL for any pollutant without first demonstrating that the TMDL will render the watershed in compliance with applicable water quality standards. EPA can=t show this for selenium because naturally occurring selenium exceeds the CTR criteria, so reducing anthropogenic selenium will not achieve water quality standards.

Commentor: Irvine Co./Latham&Watkins

Response: It appears that this comment is directed to the freshwater selenium TMDLs. Regarding compliance with applicable water quality standards, see our general response to comment L8. Regarding the commentor=s inference that Anatural@ sources of selenium are causing the observed exceedences of water quality standards in San Diego Creek, see response to comment S2.

The selenium TMDLs and allocations do not specifically distinguish between apparently natural and anthropogenic sources of selenium discharge associated with rising or pumped groundwater because, as discussed above, basin land uses and hydrology have been substantially altered over time. We have set allocations which, upon implementation, would result in attainment of water quality standards for selenium. If the State later determines that it is infeasible to reduce selenium loadings to levels which result in attainment of standards, potentially because it finds that a significant portion of selenium loadings are truly natural in origin, the State may be able to carry out a use attainability analysis and revise the water quality standards accordingly.

S6. *Comment:* The agencies should take into consideration the unique characteristics of San Diego Creek watershed prior to implementing a TMDL based on the national standard for selenium of 5 ppb. The national standard is based on studies of a lake in North Carolina. Selenium in San Diego Creek is less likely to bioaccumulate.

Commentor: Irvine Co., Latham& Watkins; California Farm Bureau Federation.

Response: The 5 ppb standard has been adopted for California through the CTR and is considered the applicable standard in this watershed; therefore, it is necessary for these TMDLs to meet that standard.

Regarding the commentor=s technical concerns, bioaccumulation of selenium has been found in both lotic (running water) and lentic (standing water) systems. High instream selenium levels will also affect offstream linkages such as backwaters, marshes, reservoirs, and estuaries (Hamilton and Lemly, 1999). In addition, given the low flow regime that predominates in San Diego Creek (mean flow rate = 13 cfs), the presence of small pools, stagnant ponds, and in-stream sedimentation basins likely results in localized reducing conditions that could cause accumulation of the more bioavailable forms of selenium.

Though some data suggests that selenite is more toxic than selenate, selenate toxicity data are scant (Nagpal and Howell, 2001). Some organisms appear to be sensitive to selenate. A decrease in cell division and growth rates of some species of algae exposed to selenate have been shown by several studies (Davis et al., 1988; Dobbs et al., 1996; Richter, 1982). Selenate is also readily taken up and accumulated by plants and enters the food chain via this route (Dr. Lemly, USFS, personal communication, June 10, 2002). Since all forms of selenium may interconvert, they should all be considered toxicologically important (Drs. Teresa Fan and Gregory Cutter, comments at EPA Peer Consultation Workshop on Selenium Aquatic Toxicity and Bioaccumulation, EPA, 1998).

Studies of selenium have been conducted in various watersheds throughout the United States, including the western states. Chronic toxicological effects associated with selenium range from less than 2 ug/L (Skorupa and Ohlendorf, 1991) to 6.8 ug/L (Adams et al. 1998) depending on which endpoint is chosen to be protected and the models used by the investigators (Nagpal and Howell, 2001). Though the 5 ug/L CTR standard was based predominantly on a study of Belews Lake in North Carolina it falls within this range of values. Additionally, Skorupa (1998) reviewed 12 examples of selenium poisoning. Five of the sites (42%) were in California (Kesterson Reservoir, Richmond Chevron Marsh, Tulare Basin, Salton Sea, and Red Rock Ranch) and concluded that a national water-based criterion of less than 5ug/L was easily justified (Hamilton and Lemly, 1999). EPA is currently engaged in the process of reviewing its national criteria for selenium. Until this process is complete, it is appropriate to base the selenium TMDLs on the established CTR objectives. If these objectives are revised, or if a site-specific objective for selenium is developed and approved for the Newport Bay watershed, the TMDL must be revised accordingly.

SARB_001474

S7. *Comment:* Regional Board staff had proposed that the selenium TMDL be based on 2 ppb, based on the recommendations of US Fish & Wildlife Service. However, we recognize that the law requires the TMDL to meet the established CTR objective, and support basing the selenium freshwater TMDLs on the CTR objective. *Commentor:* Santa Ana Regional Water Quality Control Board.

Comment: Defend the Bay and NRDC believe that the chronic CTR criterion of 5 ug/l is not adequately protective. Rather, we believe that a 2 ug/l target for all flow conditions is required. A recent USGS study on the effects and fate of selenium in the San Francisco Bay and Delta found that a target of 5 ug/l is not adequately protective. In addition, US Fish & Wildlife Service has also suggested that a 2 ug/l target for selenium is necessary for adequate protection of fish and wildlife. If EPA does not use the 2 ug/l criterion, then a much larger margin of safety is required. *Commentor:* NRDC.

Comment: Targets for selenium must mirror the currently adopted water quality objectives, not objectives that may be adopted in the future. *Commentor:* California Farm Bureau Federation.

Response: EPA agrees with the Regional Board that the target should be based on the CTR criterion of 5 ppb. Commentors noted information from various studies which could support selenium targets which are either higher or lower than the currently applicable CTR standard. No evidence of current selenium bioaccumulation effects in San Diego Creek or Newport Bay biota was identified during the TMDL development process. Sufficient water column data were available to develop the initial TMDLs and allocations. In light of the uncertainty over, and disagreements about, the appropriate levels of protection from selenium exposures, the fact that criteria revision is currently underway, and the fact that we had sufficient water column data to develop TMDLs based on ambient criteria, EPA determined that it is most prudent to establish the TMDLs based on the existing CTR standard. However, we note that if the CTR in fact is altered and a lower criterion is adopted, the Regional Board will very probably need to revise the TMDL to ensure that the revised CTR criteria can be achieved.

As discussed in responses for other pollutants and in the general response to comment L1, EPA determined that in some other cases it is most appropriate to establish TMDLs for the watershed based on narrative standards due to the availability of data for sediment and/or fish tissue, the behavior of the pollutants following discharge, and the processes through which they potentially cause adverse effects to human or ecological health. However, those considerations were not applicable to the selenium TMDLs.

S8. *Comment:* A phased approach is recommended for the selenium TMDLs. We believe that a phased TMDL approach is particularly appropriate in dealing with selenium, given that the challenge of meeting the TMDL will be very significant, and given that we have relatively limited data on which to base management decisions. A number of studies are or will be underway shortly to assist us in filling those data gaps. One basic question is whether selenium is posing the ecological threat suggested by the findings of freshwater concentrations in excess of the CTR objective. Implementation of the selenium TMDL will also be difficult given that native groundwater is the major source.

Commentor: Santa Ana Regional Water Quality Control Board.

Response: EPA has not specifically developed these TMDLs as phased TMDLs. However, we acknowledge the problems noted by the Regional Board, and fully support the Regional Board=s plan to develop a phased implementation program for these TMDLs. As noted in comments and responses no. L17 and L18, no discharge rights or obligations are changed directly by promulgation of these TMDLs. Rather, such changes will occur, if necessary, in the process of

implementing the TMDL by the Regional Board through permits or possibly other means.

S9. *Comment:* TMDLs are proposed even though existing loads are not well understood. For example, in the analysis of selenium, a total of 408 pounds per year is estimated to be from Aundefined sources.@ Leaving the source Aundefined@ makes subsequent implementation phases of the TMDL process unmanageable. Establishing a TMDL for this compound without better defining the sources in inappropriate.

Commentor: Orange County IWMD/GeoSyntec Consultant

Response: EPA acknowledges the uncertainties and supports the Regional Board=s phased approach as described in the previous comment. Uncertainties in TMDL development are not uncommon, and for that reason both the Clean Water Act and EPA=s implementing regulations specifically require a margin of safety.

S10. *Comment:* The Watershed is a flowing creek that terminates in an estuary. The flow-through nature of the Watershed limits the ability of selenium in the water column to equilibrate with sediments and the aquatic food chain

Commentor(s): Irvine Co./Byard

Response: Bioaccumulation of selenium has been found in both lotic (running water) and lentic (standing water) systems. High instream selenium levels will also effect offstream linkages such as backwaters, marshes, reservoirs, detention/sedimentation basins, and estuaries (Hamilton and Lemly, 1998). In addition, the low flow conditions (0-20 cfs) that predominates in San Diego Creek much of the year results in the presence of small pools and stagnant ponds. In-channel sedimentation basins are located in the creek directly above Newport Bay. These areas may result in localized reducing conditions that could provide conditions for accumulation of selenium in plants, sediment, and detritus and therefore, increase the concentrations of selenium in the food web.

S11. *Comment:* Other factors reducing the impact of selenium in the San Diego Creek are the predominance of selenate as the chemical form of selenium and the presence of high sulfate. Selenate is not as readily taken up by sediments and the aquatic food chain as selenite. Sulfate competes for the uptake of selenate into phytoplankton, reducing the bioaccumulation process.

Commentor(s): Irvine Co./Byard

Response: Since all forms of selenium may interconvert, they should all be considered toxicologically important. Though some data suggests that selenite is more toxic than selenate, selenate toxicity data are scant (Nagpal and Howell, 2001). Some organisms appear to be sensitive to selenate. A decrease in cell division and growth rates of some species of algae exposed to selenate have been shown by several studies (Davis et al., 1988; Dobbs et al., 1996; Richter, 1982). In addition, selenate is readily taken up and accumulated by plants, thereby entering the food chain (Dr. Lemly, USFS, personal communication, June 10, 2002). Sulfate does not appear to be important in terms of the expression of chronic toxicity except potentially for primary producers (USEPA, 1998).

S12. *Comment:* The EPA is considering lowering the selenium standard to 2 ppb. The high selenate, high sulfate, and flow-through characteristics of the San Diego Creek Watershed indicate that a 2 ppb standard would be unnecessarily overprotective. Even 5 ppb would likely be overprotective. A level of 10 ppb would most likely result in fish residue levels below 4 ppm. A reasonable approach would be a several year period at a watershed specific standard of 10 ppb_In the unlikely event that the levels of selenium in

biota did not regress sufficiently to be below levels of concern, then a lower standard could be put in place. This titration approach to establishing a selenium standard for the Watershed would be the most efficient way to achieve protection of wildlife.

Commentor(s): Irvine Co./Byard

Response: The 5 ppb standard is the applicable numeric standard based on the CTR. This comment addresses potential revision of the selenium standards and is therefore beyond the scope of the TMDL establishment action.

S13. *Comment:* [T]he potential impacts to the Creek from high loads associated with storm events are much less than the smaller loads associated with dry flows. For this reason, an acute standard for selenium should be applied to storm flows_resulting from major storm events.

Commentor(s): Irvine Co./Byard

Response: Based on revision of the flow data (see revised TSD Part B), an acute standard of 20 ug/L for storm events exceeding 814 cfs (new flow tier 4), has been applied and the loads calculated accordingly.

S14. *Comment:* Selenium is present not only in surface soils but is also present to a substantial depth in the Irvine Basin. Based on the results of water analysis performed by the Orange County Water District, selenium is present at 32 ug/L at a depth of 100 feet and present at 5 ug/L to a depth of 360 feet.

Commentor(s): IRWD

Response: We are aware that selenium in the deeper groundwater aquifers often exceeds the levels in San Diego Creek., There appears to be little connectivity of these deeper aquifers with the surface flow in San Diego Creek, except as the result of man=s activities. The aquifer located at 100 feet is a confined aquifer and the communication between this aquifer and the shallow perched aquifer has not been investigated. Regional Board anticipates that the selenium TMDL implementation plan will include studies to investigate the connection between these aquifers.

Selenium from these aquifers can enter surface flows in San Diego Creek through construction dewatering, well construction, purging, and maintenance, and groundwater remediation (pump and treat) operations. Regional Board anticipates that as part of the implementation plan, these inputs will be evaluated and considered prior to revising existing NPDES discharge limits.

S15. *Comment:* I believe the major threat of selenium is coming from dry weather flows originating from groundwater sources that are purposefully drained from shallow aquifers in central Irvine_I believe that selenium reduction efforts should target dry weather flows in San Diego Creek instead of wet weather flows.

Commentor(s): Dr. Jack Skinner

Response: We agree. This has been discussed with Dr. Barry Hibbs, who is of the opinion that as much as 70% of the selenium in San Diego Creek is likely coming from the shallow groundwater aquifer (personal communication, June 10, 2002). However, though construction dewatering, well construction, maintenance and purging, and groundwater remediation operations may periodically contribute to the surface flows in San Diego Creek, perched groundwater is predominantly getting into the creek via seeps, springs, and weepholes, as a result of the hydraulic gradient, not due to purposeful drainage. Ongoing studies by Dr. Hibbs, and Dr. Tom Meixner of UCR, are investigating the sources of the selenium in the San Diego Creek watershed.

Because of their relative infrequency, large volume of water, and high flow velocities, large storm events likely do not contribute to selenium in San Diego Creek itself, except for sediment that may be deposited in the creek in the inline sedimentation basins located just above Upper Newport Bay. The role these storm events play in contributing selenium to the Bay has not yet been determined. However, since the dry weather flows in San Diego Creek are currently dominated by groundwater inputs, treatment of these flows (and/or the shallow groundwater) will be an important step in removing a major source of selenium from the watershed.

S16. *Comment:* It is important to do the remediation of the groundwater selenium inputs near the source rather than just prior to entering Newport Bay.

Commentor(s): Dr. Jack Skinner

Response: We concur. Regional Board informs us that any remediation of selenium sources will be located as close to the sources as possible and upgradient of the Bay and tidally-influenced areas of the creek to ensure that the selenium is removed before it can reach sensitive estuarine habitats.

S17. *Comment:* _[W]ith regard to selenium, a 10% margin of safety will not be adequate if the TMDL is set at 5 ug/L instead of 2ug/L_As EPA has noted, there is considerable uncertainty and a lack of data to quantify loadings from various sources_For this reason, we recommend a larger margin of safety_In addition, the uncertainty regarding selenium sources to Newport Bay requires an additional MOS unless a thorough analysis indicates that compliance with the freshwater TMDLs will also ensure compliance with objectives in Newport Bay.

Commentor(s): Defend the Bay/NRDC/Limno-Tech

Response: There are ongoing investigations of the sources of selenium in the San Diego Creek/Newport Bay watershed. However, as much as 70% of the selenium in San Diego Creek is likely coming from the shallow groundwater aquifer (Dr. Barry Hibbs, personal communication, June 10, 2002). Since San Diego Creek is by far the largest freshwater contributor (>95%) to Upper Newport Bay and it drains over three-quarters of the entire Newport Bay watershed, reductions of selenium in the creek should also result in reductions in the Bay. Therefore, the level of uncertainty about selenium sources does not warrant an additional margin of safety.

As noted previously, EPA is reviewing the 5 ppb selenium criterion, and investigations of selenium in this watershed are on going. If warranted by this review or site-specific studies, the TMDL, including the margin of safety, can be modified as appropriate.

S18. *Comment:* The Regional Board=s suggested approach of using different criteria for the base/small flows (2 ug/L) and medium/high flows (10 ug/L) is not sufficiently protective. Using a criterion of 10 ug/L is likely to cause toxicity to organisms in San Diego Creek.

Commentor(s): Defend the Bay/NRDC/Limno-Tech

Response: Based on revised flow data (see Revised TSD Part B), the chronic CTR criterion of 5 ug/L will be applied to all flow tiers that exceed an annual average of 4 days (see Table 2, TSD Part B). This includes base flows (Q = $\leq$20cfs), small flows (20>Q$\leq$181cfs), and medium flows (181>Q$\leq$814cfs). The national acute criterion of 20 ug/L will only be applied to the large flows (Q>814cfs) which did not exceed 3 days in duration during the period of record examined for the TMDLs (Table 2, TSD Part B). The NTR value for acute conditions has been applied, as the CTR does not specify an acute criterion for selenium.

SARB_001478

The selenium numeric targets in these TMDLs are expected to be protective of the wildlife in San Diego Creek and Upper Newport Bay. Site specific studies of the role selenium plays in the watershed are currently being planned or conducted. Regional Board anticipates that the results of these studies will be used to refine or revise the selenium TMDL during the implementation process.

S19. *Comment:* We are concerned that the numeric target selected for Newport Bay (the CTR saltwater criterion) will not be sufficiently protective of wildlife.

Commentor(s): Defend the Bay/NRDC/Limno-Tech

Response: The USFWS concurred with this saltwater value (71 ug/L) in its review of the CTR. This target is expected to result in protection of all designated uses in Newport Bay. Also, since San Diego Creek is the major contributor of freshwater flows to Newport Bay, reductions of selenium in the creek should also result in reductions in the Bay. Regional Board anticipates that additional monitoring of selenium bioaccumulation in fish and mussels in Newport Bay will be conducted as part of the selenium TMDL implementation plan.

S20. *Comment:* We recommend using a longer, more representative period to determine flow volumes for the loading capacity calculations, to ensure that the resulting calculated loading capacities are representative of actual conditions.

Commentor(s): Defend the Bay/NRDC/Limno-Tech

Response: The TMDL now reflects evaluation of daily flow records for 19 water years at San Diego Creek at Campus. These data have been used to determine the flow tiers for developing selenium (and metals) TMDLs. The rainfall-runoff information outlined by OCPFRD (in their comments on the proposed TMDLs) has been used and the analysis has been extended to include all available complete water year records; i.e., water years 1977/78, 1983/1984, 1984/85 and so on up to 2000/01. Flow volumes associated with each tier were calculated by summation of daily flow rates with each tier for all 19 water years. (See Table B-2 in the TSD Part B).

S21. *Comment:* Allocations were combined for all of the Newport Bay water bodies_we recommend that the San Diego Creek TMDL Allocation be separate from allocation for Santa Ana-Delhi Channel...

Commentor(s): Defend the Bay/NRDC/Limno-Tech

Response: This has been done. See revised tables in TSD Part D.

S22. *Comment:* We are concerned that the allocations for San Diego Creek and Santa Ana-Delhi Channel might not result in compliance with targets for Newport Bay.

Commentor(s): Defend the Bay/NRDC/Limno-Tech

Response: Since San Diego Creek is the major contributor of freshwater flows to Newport Bay (>95%), reductions of selenium in the creek should also result in reductions in the Bay. Regional Board anticipates that additional monitoring of selenium water column concentrations and bioaccumulation in fish and mussels in Newport Bay will be conducted as part of the selenium TMDL implementation plan.

S23. *Comment:* We are concerned that it will be difficult to implement the tiered allocations. Therefore, implementation of the TMDLs should be closely monitored by the EPA.

Commentor(s): Defend the Bay/NRDC/Limno-Tech

Response: We agree that implementation of these TMDLs will be challenging; the EPA will be providing feedback to Regional Board staff on all of the Toxics TMDL implementation plans.

S24. *Comment:* There are a great number of qualifiers describing loading pathways_If there is no methodology for quantifying existing loads by source, then that should be stated.

Commentor(s): City of Irvine

Response: Comment noted. The TSD explains the source analysis method used. We acknowledge that insufficient data and information were available to precisely characterize all loading sources. An investigation into potential sources of selenium in the San Diego Creek watershed is currently in progress. This study should help to quantify the unidentified sources of selenium in the watershed, and the Regional Board can revise the TMDL if necessary.

S25. *Comment:* For selenium, Figure 4-1 in the summary document (Figure D-9 in the TSD) is useful_, but should be expanded to give estimates of the existing loads from each source is these are available or is there a methodology to calculate them?

Commentor(s): City of Irvine

Response: A table has been added to the TSD (Table D-4) illustrating how the waste load and load allocations for selenium were calculated using the revised flow tiers.

S26. *Comment:* Additional explanation is needed for how the source allocations were made. If they are based on existing loads, the absence of source data in Table 4-5 should be rectified. If they are based on land use, the analysis should be explained. As it stands, it us unclear how the allocations are derived.

Commentor(s): City of Irvine

Response: Please see Table D-4 which has been added in response to the previous comment. Table D-4 presents a more detailed breakdown of the estimated waste load and load allocations.

S27. *Comment:* Page D-3 B Source Analysis - The report does not reference historical selenium data collected by the County prior to the NPDES program. From 1973 to 1987, the Orange County Environmental Management Agency (now PFRD) collected samples for selenium analyses from San Diego Creek at Campus Drive. In all, 26 samples were collected including three influenced by stormwater runoff. Although the data are limited, they show that levels above the CTR chronic freshwater criterion and proposed TMDL numeric target of 5 micro g/L, were present in San Diego Creek 20-30 years ago.

Commentor(s): County of Orange, Public Facilities and Resource Department

Response: We appreciate the submittal of the additional data but do not believe it supports revisions to the TMDLs.

S28. *Comment:* Page D-18 B Tables D-2 and D-3 B The daily average discharges (cfs) shown in Table D-2 are incorrect. This has resulted in substantial inaccuracies in the daily load calculations. The total flows (cfs) in Table D-3 for both dry and wet weather events for the periods 4-98 thru 9-98 and 10-98 thru 3-99,

respectively are incorrect.

Commentor(s): County of Orange, Public Facilities and Resource Department

Response: We have revised Tables D-2 and D-3 accordingly, and recalculated the total flow volumes for the wet and dry seasons.

S29. *Comment:* Appendix A - The title references Table D-5. This should be changed to Table D-2 as there is no Table D-5 found in the text.

Commentor(s): County of Orange, Public Facilities and Resource Department

Response: Correction made.

Metals TMDLs

M1. *Comment:* It is not necessary to reduce metals loading through a TMDL because most of the metals, on average, are below the CTR standards. According to the Regional Board (Problem Statement 2000), dissolved cadmium, chromium, lead, nickel, silver and zinc Aare probably not causing, or contributing to, toxicity to aquatic life in Newport Bay and San Diego Creek.@ It appears that EPA has inflated the exceedences by assuming that the heavy metals readily dissolve in water, contrary to reality and common knowledge.

Commentor: Irvine Co./Latham&Watkins

Response: In preparing these TMDLs, EPA independently evaluated all readily available data for this watershed, including new and updated data since the Regional Board issued its 2000 Problem Statement, to determine which of the chemicals identified in the consent decree and by the Regional Board warranted TMDLs. The reasons EPA has determined that specific TMDLs should be prepared are discussed for each chemical in EPA=s *Decision Document* (2002). As discussed in that document, EPA assessed not only water column data, but also sediment quality data and fish/shellfish tissue data.

See response to comment L1 regarding our use of narrative as well as numeric criteria in developing these TMDLs. We disagree that the methods used in these TMDLs inflate water body exceedences and we did not assume that heavy metals readily dissolve in water. EPA=s methods for associating total and dissolved metals in the analysis are discussed in the TSD. On average, we found that dissolved metal and total metals concentrations were relatively close to each other.

M2. *Comment:* The TMDL does not contain a proposed methodology for allocating responsibility for any exceedence. For example, the copper TMDL includes allocations for urban runoff and for Aother NPDES permittees@. There are no provisions for distributing loads among the various stakeholders. What criteria will be used to assign limits?

Commentor: City of Costa Mesa

Response: EPA has provided additional information in final TMDLs to explain allocations. Section II of the Summary Document lists the NPDES discharge sources covered by the Aother NPDES permittees@ category. According to Regional Board staff, little monitoring data exists

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for these facilities and therefore it is not feasible to precisely estimate metals inputs from these sources. EPA has utilized best professional judgment to make an allocation to this source, rather than provide an allocation equal to zero.

M3. *Comment:* The summary tables E-10 and E-11 in the TSD need to be clarified. The totals for Pb and Zn do not reflect the sum of the sources. There is no explanation of whether the unknowns are significant.

Commentor: City of Costa Mesa

Response: EPA has reviewed and rectified summary tables E-10 and E-11 in TSD Part E. Insufficient data were available to support a precise assessment of the significance of the unknown sources. For example, groundwater inputs of these dissolved metals to could be significant in localized areas of San Diego Creek. In Newport Bay, zinc anodes are used on recreational boats, although they do not cover large surface areas as compared to wetted boat hulls, and are not likely to be nearly as significant a source of Zn as boat hulls are for Cu. Our review of available data and information yielded no evidence that Cd and Pb loads from unknown sources are significant.

M4. *Comment:* Explain the allocations for loading capacity. The correlation of allocations to existing loads is unclear except for ambient levels and air deposition.

Commentor: City of Costa Mesa

Response: EPA has included an explanation of allocations in the final summary document.

Comment: Clarify allocation categories for metals.

Commenter: Irvine Company/Geosyntec

Response: EPA categories are defined by either known inputs to water bodies, such as urban stormwater and NPDES permittees (e.g, CalTrans) or non-point sources such as agricultural runoff from nurseries or open fields. Undefined includes natural runoff and possible inputs (very small) from contaminated sediments existing in the waterbody. Boats refers to all wetted surfaces of recreational boat hulls in Newport Bay.

M5. *Comment:* It is unclear which OCPFRD data were used to calculate metals translator values. EPA=s translator average was 1.2, but analysis of SDC data from 1996-2000 yielded a translator closer to 3.0. It appears EPA included many pairs of data that were at the detection limit, which would yield translators of 1.0. Translators should be calculated for each metal on a site specific basis. Natural channels transporting greater sediment loads would have greater translators compared to concrete lined channels.

Commentor: County of Orange

Comment: The 80% dissolved to total metals ratio used for the TMDLs is a good estimate for nonstorm flows but the dissolved fraction in stormwater is about 40%. Use of the 80% translator could overestimate metals loads during storm flows.

Commentor: Irvine Company/Geosyntec

Response: EPA has used stormwater data (provided by OCPFRD) to estimate the ratio of dissolved to total metals. EPA concluded that it was reasonable to use a single translator based on average metals conditions since the mass-based TMDLs are expressed on an annual average basis and the concentration based TMDLs are expressed on an acute and chronic basis, but are

not dependent upon the translator value(s) selected to be implemented.

M6. *Comment:* There is a large range of data shown in the TSD tables and the confidence interval brackets the CTR values for all parameters. The extreme values likely radically skew the data. Dry and wet weather data should be evaluated separately.

Commentor: Irvine Company/Geosyntec

Response: EPA synthesized considerable data collected by several groups in the TSD tables. The goal was to provide an overview of results from all data sources. Extreme results may skew the data, and it would be helpful to define dry vs. wet weather separately. However, there is no evidence that apparent outlier data are unreliable, and EPA guidance cautions against excluding apparent outliers without a sound rationale. We note that CTR values are not based on comparisons with means data values. Instead, most toxic pollutant standards are based on the assumptions that they are to be exceeded very rarely (i.e. once in 3 years on average). If the commenter intends to infer that the data indicate that the CTR standards are being met, we disagree.

M7. *Comment:* The margin of safety may be unreasonably stringent because (1) there are safety factors inherent to the CTR values, (2) unnecessarily conservative hardness values were applied, and (2) chronic standards were inappropriately applied. Expressing a margin of safety as a percent of the average concentration in the runoff has no scientific basis. The safety factor should be expressed as an upper or lower limit based on research on the pollutant of concern.

Commentor: Irvine Company/Geosyntec

Response: EPA applied the margin of safety based on uncertainty in several aspects of the source analysis; e.g., the dissolved to total metals ratio and the flow based approach. TMDLs are required to be set at levels necessary to meet applicable water quality standards with a margin of safety. This does not mean that a TMDL can simply rely upon a margin of safety considered in establishing the water quality standards. The commenter provided no evidence that the hardness values applied are Aunnecessarily conservative.@ The hardness values applied are consistent with the CTR assumptions and are based on moderate hardness values for each flow tier. The commenter provides no basis for concluding that chronic standards were inappropriately applied. EPA carefully evaluated the recurrence frequencies of flows in different flow tiers in comparison with the flow recurrence frequencies assumed in the CTR. Finally, the commenter provides no analysis supporting the assertion that expressing a margin of safety as a percentage of the concentration or mass based TMDLs is scientifically invalid. This approach is commonly used in TMDL calculations.

M8. *Comment:* The metals TMDLs are based on relatively wet years, which could result in an overestimate of loading capacities.

Commentor: NRDC

Response: EPA and Regional Board staff have revised flow records pertinent to these TMDLs. Analysis of nearly 20 water year records will provide more representative conditions in San Diego Creek; consequently this will yield more realistic estimates of loading capacities.

M9: *Comment:* Metals TMDLs for San Diego Creek should be concentration based and for Newport Bay should be mass based.

Commentor: NRDC

Response: EPA has revised the final TMDLs to include concentration-based TMDLs for San Diego Creek and mass-based TMDLs for Newport Bay, as discussed in the TMDLs. Concentration based targets for Newport Bay have also been included to assure compliance with CTR standards, should the mass based allocations require verification of compliance.

M10. *Comment:* EPA does not include several potential sources in the metals allocations, including sediment porewater (for copper), Aundefined natural sources@, and nurseries (for copper).
Commentor: NRDC

Response: EPA has identified that dissolved copper concentrations in porewaters exceed chronic saltwater targets; however, this data was produced in 1998 and only for Lower Bay (not including Rhine Channel). Further monitoring results, preferably from Rhine Channel and maybe from Upper Bay, would be useful to assist with defining the contributions of dissolved copper from sediments. For now, Aundefined natural sources@ may represent porewater inputs. Allocations for nurseries were included in Aag runoff@ in allocations for Newport Bay.

M11. *Comment:* The metals TMDL implicit margins of safety are insufficient to account for uncertainty and should be increased another 5-10%.
Commentor: NRDC

Response: EPA has defined the margin of safety for both San Diego Creek and Newport Bay as 20%. This value arises from dissolved to totals metals ratios determined for copper in stormwaters. It is also consistent with the copper translator value defined for saltwaters in CTR (USEPA 2000a). No additional increase in margin of safety is warranted at this time.

M12. *Comment*: The hardness assumptions for high flow conditions are not stringent enough and are inconsistent with observed hardness levels under high flows. A low range hardness, perhaps at the 10th percentile for the flow tier, should be used in determining the numeric targets.
Commentor: NRDC

Response: EPA has reviewed both high flow and low flow conditions to develop an indirect relationship between flow and hardness. Given that flow conditions vary widely as well as the individual hardness values, this was the best approach. The commentor does not provide convincing rationale for selecting the 10th percentile.

M13. *Comment:* We disagree that chronic targets will always be protective due to variability during a 4 day averaging period. The acute targets should also apply.
Commentor: NRDC

Response: EPA has modified the metals TMDLs to include acute and chronic concentration based targets for base, small and medium flows. During large flows, and to be consistent with the short term duration of these elevated flow rate, only acute concentration targets apply.

M14. *Comment:* It is unclear whether EPA has verified that water column targets will be protective of sediments, which is a concern because the primary problem in Newport Bay is sediment toxicity.
Commentor: NRDC

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Response: EPA has considered this problem and defined both water column targets and sediment targets (Table 5-3) to define desired water quality conditions. Sediment targets are designed to protect benthic organisms and alleviate toxicity attributable to these metals.

M15. *Comment:* We would like to review any revised flows used to calculate the TMDLs. The calculations must be based on actual flow data covering a representative period.

Commentor: NRDC

Response: EPA and Regional Board staff have revised flow records pertinent to these TMDLs. Analysis of nearly 20 water year records will provide more representative conditions in San Diego Creek; consequently calculations from this revised analysis yield more realistic estimates of loading capacities.

M16. *Comment:* EPA should correct several errors in the loading capacity calculation method, which appears technically appropriate, and clarify the procedures and values used in the calculations.

Commentor: NRDC

Response: EPA has corrected the errors in Newport Bay loading capacity. See TSD Part E B Metals.

17. *Comment:* The allocations for copper show poor correspondence between San Diego Creek and Newport Bay for sources including CalTrans and nurseries. Allocations for Newport Bay should account for upstream loads and allocations from San Diego Creek, and allocations for other sources to the Bay need to be reduced accordingly.

Commentor: NRDC

Response: EPA has revised the mass-based allocations for Newport Bay to account for the considerations raised in this comment. San Diego Creek allocations are now concentration based and therefore they are not defined in mass per year. The allocations for Newport Bay are expressed as net allowable loads for each segment, not cumulative allowable loads for each source. Total allocations for individual sources can be calculated by summing individual allocations for individual water segments.

M18. *Comment:* Undefined (natural) LAs are much lower than source assessment indicates is contributed by natural sources. The natural source LAs should be increase to reflect this discrepancy, and the other allocations decreased accordingly.

Commentor: NRDC

Response: Values for undefined natural sources in Table 5-6a are consistent with contributions defined by natural sources as outlined in Table E-10 in TSD.

M19. *Comment:* The TMDLs do not adequately address seasonality and critical conditions because they do not carry through the flow tier approach to the mass-based allocations. The TMDLs and allocations should be adjusted to avoid lumping allowable loads for each flow tier into a single annual number.

Commentor: NRDC

Response: EPA has revised the allocations in San Diego Creek to be concentration based for each flow tier. Three out of four of those flow tiers have chronic targets; this

amount to 362 days of the year. In Newport Bay, mass-based allocations are still defined as a single annual number. Given that sediment toxicity is the major impairment in this waterbody, a single annual number is reasonable to address the long term loading of metals which may contribute to sediment toxicity.

M20. *Comment:* We support the 20% margin of safety, but believe a larger margin of safety is warranted to reflect uncertainty about whether the water column target concentrations will be protective of sediment toxicity. Commenter disagrees that some factors characterized by EPA as providing an implicit margin of safety actually do so.

Commentor: NRDC

Response: EPA has defined a 20% margin of safety as described above. Commenter does not provide sufficient rationale to support a larger margin of safety. See also responses to Comments M11 and L16.

Organochlorine Compound TMDLs

OC1. *Comment:* EPA is proposing TMDLs for DDT, chlordane, dieldrin, toxaphene, and PCBs despite the fact that none of these compounds have been detected at all in the waters of Newport Bay and San Diego Creek. A TMDL is inappropriate because EPA has not demonstrated through monitoring data that any of the watersheds are in violations of applicable numeric standards. Also, DDT is not bioaccumulating in the watersheds to a level that is harmful to human health or the environment. Concentrations of DDT are declining. Current concentrations are not causing harm to human health or the environment. There is no indication that wildlife or humans are being harmed.

Commentors: Irvine Co.,/Latham&Watkins; City of Costa Mesa; Irvine Ranch Water District

Response: See response to comment L1 regarding use of narrative criteria and data. EPA determined that TMDLs should be prepared for these pollutants based on exceedences of tissue and/or sediment data, as set forth in EPA=s *Decision Document* (2002). The *Decision Document* explains EPA=s general approach to determining whether there were probable adverse effects to beneficial uses (and thus nonattainment of the narrative criteria), including EPA=s consideration of impairment in adjoining water segments. The basis for developing a TMDL for each specific segment and each specific pollutant is set forth in the Assessment Summary portion of the *Decision Document*. With regard to the comment that there is no indication that wildlife or humans are being harmed, we note that the Basin Plan provides that Aan adverse effect or impact on a beneficial use occurs where there is an actual or threatened loss or impairment of that beneficial use.@ EPA considers current data to warrant preparation of TMDLs, and does not consider it prudent to postpone TMDL analysis until a time when adverse effects on wildlife or humans may be more apparent.

OC2: *Comment:* EPA cannot rely on non-regulatory sediment or fish tissue values to establish a TMDL unless those values have been the subject of notice and comment rulemaking. EPA has proposed sediment quality criteria for dieldrin and other compounds but has not finalized them. EPA cannot promulgate a regulation establishing sediment and biota criteria through the establishment of a TMDL.

Commentor: Irvine Co./Latham&Watkins

Response: EPA is not establishing water quality criteria in this TMDL. See response to Comment L2 regarding numeric targets.

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OC3: *Comment:* Studies show that legacy pesticide levels are decreasing naturally.
Commentor: Bordier=s Nursery.

Response: EPA=s determination that these TMDLs are warranted is based on sediment and tissue exceedences and is documented in the *Decision Document* (2002). We agree that levels of the OC pollutants appear to be decreasing over time; however, the best recent data indicate that the sediment and tissue screening levels continue to be exceeded.

OC4. *Comment:* EPA cannot establish a TMDL for any pollutant without first demonstrating that the TMDL will render the watershed in compliance with applicable water quality standards. EPA can=t show this for organochlorines because of the legacy residues. There is no nexus between the loadings for DDT and the achievement of any applicable water quality standards. In light of the 37 kilograms of DDT already present in Newport Bay sediments, it is not plausible to expect to be able to even detect any change in the concentration that might be associated with an annual reduction of 0.23 kilograms entering the Bay. Achieving the proposed TMDL for DDT, and probably the other legacy pollutants, is unlikely to make any difference in Newport Bay.
Commentor: Irvine Co./Latham&Watkins

Response: See response to Comment L7. We agree that legacy pollutants present serious challenges in TMDL development and implementation, but these challenges in no way lead to the conclusion that TMDLs should not be developed. The Clean Water Act does not specify timeframes for restoration of impaired waters. We acknowledge that improvement of the situation in the Bay will be incremental and not immediate; however, reducing the input of legacy pollutants to the Bay will keep the problems from worsening, and will accelerate the pace of recovery. Moreover, given ample evidence that organochlorine pollutants can cause significant adverse effects even at very low levels, we believe it is reasonable and necessary to establish TMDLs that address the ongoing estimated loadings of these pollutants.
If the State determines, based on followup monitoring, that the pace of recovery is too slow or that the TMDLs are ineffective, they may consider tightening allocations and controls and/or investigate the feasibility of remediating contaminated sediment sources in the Bay.

OC5. *Comment:* Legacy pesticides should not be included in the TMDL because they don=t have a source nor are they background. Fixing this problem should happen outside the TMDL process. There is no purpose served by setting discharge limits on discharges that no longer occur. *Commentor:* City of Costa Mesa, IRWD
Comment: TMDLs for legacy pollutants create confusion and uncertainty since there is no responsible party for control or clean up of the legacy problem. *Commentor:* California Farm Bureau Federation.

Response: TMDLs must consider all sources of a pollutant in a waterbody, including natural background and legacy pollution. We disagree that there are no ongoing discharges of these pollutants. Ongoing loadings are associated with erosion of sediments to which OC pollutants may adhered, transport of sediments already in watercourses, and (potentially) discharges from localized hot spots or spill events. TMDLs can help determine whether additional pollutant source control or remedial actions are needed. TMDLs are but one tool available to the Regional Board, other agencies, and private entities for use in dealing with these problems, and EPA supports efforts in addition to the TMDL process to solve these problems. We hope, moreover, that the calculations and analyses in these TMDLs will assist planning

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agencies and entities in addressing these problems in a variety of ways.

OC6. *Comment:* Agricultural soils are more friable than urban soils and therefore more subject to erosion and mobilization of DDT into the aquatic environment. Therefore, the current process of converting land from agricultural use to urban use will reduce erosion and the transport of DDT into the aquatic environment. The Irvine Basin has in place extensive controls or Best Management Practices (BMPs) to minimize erosion of land under conversion to urban development. Rather than implement a standard that would be beyond current abilities to measure and then develop implementation strategies and BMPs to achieve the unmeasurable, IRWD feels that DDT control would be more successful by improving BMPs for contaminated soils than to set an unachievable numerical standard. *Commentor:* IRWD

Comment: The levels as outlined are too low for compliance at this time. There is no available technology for use in compliance. *Commentor:* Bordier=s Nursery.

Response: TMDLs are inherently quantitative, and it is necessary to set numeric loads. However, EPA acknowledges the challenges of implementing these TMDLs. All comments are being forwarded to the Regional Board for their use in developing implementation strategies for these TMDLs, and commentors are encouraged to work with the Regional Board in developing implementation measures. EPA=s implementation recommendations suggest that sediment control plans currently in place may result in sufficient OC pollutant reductions and that additional controls may not even be necessary. We note, however, that no commenter provided evidence to support assertions that TMDL compliance is infeasible in this case.

OC7. *Comment:* We urge you to specifically endorse, as the first phase of implementation for the organochlorine TMDLs, full implementation of the sediment TMDL reductions, coupled with monitoring to determine whether sediment TMDL implementation is sufficient to meet the organochlorine allocations.

Commentor: Santa Ana Regional Water Quality Control Board

Response: EPA recognizes the link between sediment and OC contamination, and fully supports full implementation of the Newport Bay sediment TMDL as the first step in the implementation of the OC TMDLs.

OC8. *Comment:* Partition coefficients used in Draft TMDLs were not identified. Kow and Koc values for DDT were too low and based on out-dated information in ATSDR.

Commentor: Irvine Co/R.Tjeerdema/J. Byard/S. Paulsen

Response: EPA has reviewed the Koc values used in the organochlorine TMDL analysis and has revised the numbers to reflect more recent values published in the literature. The values used in the analysis have been included and referenced in the revised Technical Support Document.

OC9. *Comment:* BCF values are inappropriate; there is no such thing as general BCF factor. BCFs should be [biological] species specific.

Commentor: Irvine Co/R.Tjeerdema

Response: EPA has reviewed the relevant literature on available BCF values and has determined that the BCF values used in the original analysis did not appropriately reflect values expected in the indicator species. Because tissue data were available for several fish species, updated BCF values that

are more representative of a family of fish, for which data are available, have been used in the analysis. The BCF values are included and referenced in the Technical Support Document.

OC10. *Comment:* Use of mean values of mussel data is potentially inaccurate especially for San Diego Creek which has old data from 1984 to 1993.

Commentor: Irvine Co/R.Tjeerdema

Response: EPA agrees that the use of mussel data that does not coincide with available sediment data should be revised with a different approach to better represent existing conditions. The analysis has been modified to take advantage of more recently collected fish tissue data that are available for San Diego Creek. The revised analysis uses the available fish tissue data along with appropriate BCF values to support the calculation of existing loadings.

OC11. *Comment:* There is confusion about the DDT sediment target...if it pertains to 4,4'-DDT or total DDT, which is sum of DDT, DDE and DDE. Per conversations with EPA staff, new freshwater sediment targets for organochlorine compounds were identified. The new target would be 6.89 ug/kg dry for total DDT.

Commentor: Irvine Co/R.Tjeerdema/J. Byard/S. Paulsen

Response: EPA agrees that the sediment criteria used in the original TMDL analysis was incorrect for total DDT. The revised analysis uses the Total DDT sediment targets of 6.98 ug/kg for San Diego Creek and 3.89 ug/kg for Newport Bay.

OC12. *Comment:* Error in Tables F-5 and F-6 regarding units for fish tissue concentrations. The units should be ppb and not ppt. The fish data for Newport Bay in part F are in error and when corrected from ppt to ppb were still below the fish level that is the basis for the national water quality criteria and below the fish target level in the TMDL. Therefore, a TMDL for DDT is not needed.

Commentor: Irvine Co/R.Tjeerdema/J. Byard/S. Paulsen

Response: EPA has confirmed that the units in the original reference were incorrect and has made the corrections to the tables. Regarding the need for DDT TMDLs, see responses to comments L1 regarding narrative criteria, OC1 regarding the OC TMDLs in general, and OC15 regarding the DDT TMDLs. As noted in the response to Comment OC15 and in EPA=s 2002 *Decision Document*, we have determined that a TMDL for the Upper Bay is warranted based on both tissue and sediment exceedences, and that a TMDL for Lower Bay is warranted based on sediment exceedences. This remains true following adjustment of some methods and values applied in the final TMDL analysis.

OC13. *Comment:* Modeling approach used by EPA/Tetra Tech should recognize the declining trend in DDT concentrations in mussel tissue.

Commentor: Irvine Co/R.Tjeerdema/J. Byard/S. Paulsen

Response: EPA has acknowledged that available mussel data indicate a decreasing trend in DDT concentrations.

OC14. *Comment:* Model should more accurately capture DDT loading during wet and dry periods.

Commentor: Irvine Co/ S. Paulsen

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Response: EPA has revised the flow regimes used to calculate DDT loading in the final TMDL.

OC15. *Comment:* Draft TMDL shows the revised DDT sediment target (6.98 ug/kg dry) is being met, therefore no TMDL is required.

Commentor: Irvine Co/ S. Paulsen

Response: EPA has determined that the sediment criteria used in the original TMDL analysis was incorrect for total DDT. The revised analysis uses the correct sediment targets of 6.98 ug/kg for San Diego Creek and 3.89 ug/kg for Newport Bay (based in part on comments from commentors), and the analysis conducted using these targets does not indicate that DDT is meeting the criteria in either San Diego Creek or Newport Bay. EPA=s decision to develop DDT TMDLs is set forth in the *Decision Document* (2002). We have concluded that a TMDL is warranted for San Diego Creek based on tissue exceedences; for Lower Newport Bay based on sediment exceedences, and for Rhine Channel and Upper Newport Bay based on both tissue and sediment exceedences, as set forth in more detail in the *Decision Document.* See response to comment OC11.

OC16. *Comment:* Table 6-5 must contain typo errors. For DDT, the table states that the existing load already meets the numeric target, when the numeric values show otherwise. This table has similar inconsistencies for other constituents.

Commentor: Irvine Co/ S. Paulsen

Response: EPA appreciates the identification of the errors in Table 6-5, which are corrected in the final TMDLs.

OC17. *Comment:* The lack of accuracy, abundance of errors and absence of rationales in the TMDL modeling (for DDT) is frustrating. The technical analysis was not adequately explained, continually changed during the comment period, and it was never clear on what proposal one was commenting. Despite your efforts to facilitate our understanding, there have been too many major errors, too many changes in approach and explanation, poor technical analysis and poor technical writing. The TMDL conclusions are not based on a solid scientific foundation. This does not provide a fair and full opportunity to comment on the organochlorine TMDL. EPA is encouraged to allow a longer time for TMDL development and review. The commentor requests the opportunity to provide comments on any revised analysis.

Commentor: Irvine Co/R.Tjeerdema/J. Byard/S. Paulsen

Response: EPA appreciates the time and effort put forth to review and comment on these TMDLs. EPA has made every effort to improve the clarity of the document and has strived to ensure all pertinent details and references are included in the current version of the TMDL and technical support document. See responses to Comments L11 and L12 regarding the public review process.

We disagree with the characterization that the draft TMDL was not based on a sound scientific foundation, While some errors were identified and corrected in the final TMDLs, the basic methods used were sound. Several commentors indicated their endorsement of the technical methods used to calculate the TMDLs.

During the comment period, we attempted to address technical questions posed by commentors and participated in several meetings and telephone calls to explain our approaches. We did not change our proposal during the comment period, but several staff at EPA and our contractors were involved in these meetings and calls, which may have contributed to delivery of inconsistent oral answers to technical questions. We regret any confusion that may have occurred as a result. However, several commentors

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provided detailed technical comments, which EPA carefully considered in our final decisions. We believe the public was afforded a sufficient opportunity to review the decision documents and calculation methods.

OC18. *Comment:* Comment: A fundamental concern is with the modeled estimates of DDT in sediment in the future. It is incorrect to hold c-s and c-w constant, given that the mass of DDT must decline over time.

Commentor: Irvine Co.

Response: We note the comment concerning future declines in DDT concentrations, but do not believe it would affect the definition of the current DDT loading capacity, which provides the basis for the TMDL calculations.

OC19. *Comment:* Given that the draft TMDL shows that the sediment target of 6.98 ug/kg is likely being met, even considering the flaws in the modeling approach which overestimate future concentrations, it is unclear that a TMDL is required for DDT.

Commentor: Irvine Co.

Response: See response to comment OC15.

OC20: *Comment:* There is a related liability question of what would happen if the load allocations are being met and yet the target sediment and/or biota concentrations remain above levels deemed appropriate by EPA.

Commentor: Irvine Co.

Response: As discussed in the final TMDL summary document, load allocations are not self-implementing and do not create any direct liability for allocation holders. See response to comment OC4.

OC21: *Comment:* I was quickly struck by what seemed to be unusually low sediment targets for DDT and other organochlorines.

Commentor: Irvine Co.

Response: See response to comment OC15.

OC22: *Comment:* The commentor reports much confusion regarding the use of a MacDonald South Florida reference. The commentor points out several problems with using the South Florida reference: 1) a recent workshop concluded the approach is not adequate, alone, for setting regulatory targets, 2) MacDonald uses different sediment targets for sum DDT versus the TMDL report refers to DDT (the parent compound.) 3) MacDonald southern California approach of using bioassay data could be used and result in effects levels higher than the Canadian approach; 4) The log K-oc used by MacDonald could result in a sediment TMDL of 53 ppb, this can be compared to the highest level of DDT reported in sediment of 15 ppb (Masters and Inman.)

Commentor: Irvine Co.

Response: See responses to comments OC1, 12, and 15.

OC23: *Comment:* Fish data from the Creek is higher than the Bay, however the creek is a small and infrequent source of dietary fish.

Commentor: Irvine Co.

Response: The commenter provides no evidence to support this assertion. In any event, fish consumption is a protected beneficial use of San Diego Creek, and it would not be reasonable to ignore evidence of OC pollutant bioaccumulation in San Diego Creek fish.

OC24: *Comment*: The 1.9 ppb for total DDT used is actually the TEL for DDT alone. AThe real total TEL for marine systems is 3.89 ppb.@ The commentor also states that a freshwater total DDT value of 6.98 ppb was discussed.
Commentor: Irvine Co.
Response: See response to comment OC15.

OC25: *Comment:* The commentor states that using different sediment target values would result in target water concentration values (now 6 pptr and 3 pptr) and indicate that a TMDL is not necessary.
Commentor: Irvine Co.

Response: See response to comments OC12 and 15.

OC26: *Comment:* Arguing against the need to develop a total DDT TMDL, the commentor refers to graphs in Figure F-4. AFor San Diego Creek, raising the sediment standard to 3.89 - 6.98 ppb would indicate that current projected total DDT concentrations are currently below it.
Commentor: Irvine Co.

Response: See response to comment OC 15.

OC27: *Comment:* The commentor states that using a regression approach with the mussel watch data A would have better estimated current total DDT loads as well as what they would likely be at the time of predicted TMDL implementation. This would have further supported the contention the total DDT in sediments and water is currently below concentrations requiring the development of a TMDL.@
Commentor: Irvine Co.

Response: EPA is not required to extrapolate the data as suggested by the commenter. Instead, we relied upon actual data results, based on relatively extensive monitoring, to identify the need to complete TMDLs for DDT. We did not detect statistically significant trends indicating that total DDT levels are currently below the screening levels.

OC28: *Comment:* Information regarding DDT in agricultural and nursery effluents in outdated and reflective of singular events, not long-term monitoring... total DDT are described as relatively high when they are clearly in the low ppb range.
Commentor: Irvine Co.

Response: EPA used all available data in the analysis. We have clarified our characterization of local DDT levels in the text to reflect the comment; however, we note that DDT levels in the low ppb range may contribute to adverse ecological effects over time.

OC30: *Comment:* The assumption that DDT (in dicofol) is present at 0.015% is clearly unsupported speculation.
Commentor: Irvine Co.

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Response: The text was modified to clarify the basis for the concern about potential DDT content in dicofol. The registered formulation of dicofol indicates that DDT may be present in the formulation as an impurity.

OC 31: *Comment:* The commentor disagrees that atmospheric deposition or trace impurities of DDT in other registered pesticides are likely. The draft TMDL provides no local information in support of these sources.

Commentor: Irvine Co.

Response: The text was modified to reflect this comment.

OC32: *Comment:* The commentor provides a citation for DDT in sediment in Upper Newport Bay which shows that concentrations of chlorinated hydrocarbons are declining to near detection limits.

Commentor: Irvine Co.

Response: See response to comment OC15.

OC33: *Comment:* Information on pesticide... clean-up sites is presented for the period 1988-94, but the ... pesticide involved is absent. It is unlikely that DDT or related chlorinated organics were involved, as their use was discontinued prior to 1988.

Commentor: Irvine Co.

Response: The comment is noted. Although DDT and most other OC pollutants addressed in these TMDLs were banned prior to 1988, this does not mean that their use from existing pesticide stocks or discharge from spills could not have occurred during the 1988-94 period. EPA was attempting to present all potentially useful information about potential OC pollutant sources in the analysis.

OC34: *Comment:* Sediment data for total DDT and 2 PCB arochlors are reported... the report describes the MDL as Arelatively high@ without either the specific analyte or actual value.

Commentor: Irvine Co.

Response: The comment is noted. Text in the final TMDLs was edited to clarify our analysis.

OC 35: *Comment:* The commentor states that the method for specifying water column concentrations (based on available monitoring data and best professional judgment) is not explained sufficiently to provide an assessment of the accuracy of the approach.

Commentor: Irvine Co.

Response: The text was clarified to address this comment.

OC36: *Comment:* Targets selected are not fully protective of designated uses. Targets should be revised as per Limmo-Tech (NRDC/Defend the Bay consultant) comments.

Commentor: NRDC

Response: EPA considers the targets to be protective, based on the analysis presented in the TMDL. Specific technical comments are responded to below.

OC37: *Comment:* There should be a margin of safety of 20%. There is a lack of detail in the source

analysis, and where there is a lack of data to support the source analysis there should be a larger explicit margin of safety. Additionally, the TMDL should recognize the cumulative degree of uncertainty in the estimation of numerous parameters of the model, which is another reason for a larger margin of safety.
Commentor: NRDC

Response: Regarding the source analysis, EPA has developed the TMDL using the available source characterization data to support the analysis. Although the data to quantify existing sources is limited, we believe that the TMDLs provide the means to identify allowable loadings for the water bodies of concern. Further data gathering during the implementation of the TMDL will help to target restoration efforts.

EPA does not believe that any increase in the MOS is warranted at this time. EPA recognizes the range of values available for several of the key variables used in the analysis including Koc, partition coefficients, and estimates of sediment concentrations. EPA believes that 10% represents a reasonable margin of safety for the TMDLs in combination with the implicit margin of safety provided by the conservative analytical assumptions used in EPA=s calculation approach. Since the reduction of the loading of OC compounds will rely largely on natural attenuation, and current trends identify a decline in loading over time, a larger margin of safety is currently not supported. Should future monitoring and implementation suggest that the allocation is not sufficiently protective, the State may consider appropriate revisions.

OC38: *Comment:* Flow analysis used by EPA is based on relative wet (higher flow) years. This may not represent actual conditions and result in an overestimation of loading capacity.
Commentor: NRDC

Response: The final TMDLs were modified based on a longer, more representative flow record.

OC39: *Comment:* The commenter recommends additional detail and specific allocations to potential sources in the allocations.
Commentor: NRDC

Response: EPA believes the current level of allocations is consistent with the available information for the pollutants evaluated in these TMDLs. Additional source specific information can be addressed in the implementation phase of the TMDL.

OC40: *Comment:* The use of flow tiers is proposed by EPA to address seasonality and critical conditions. However, the use of flow tiers will be adequate only if those tiers carry through to the wasteload and load allocations.
Commentor: NRDC

Response: The environmental mechanisms through which OC pollutants cause ecological hard operate over relatively long timeframes; therefore, EPA concluded that it was unnecessary to develop the TMDLs based on short term pollutant loading and control timeframes. We found no evidence of seasonal variability in loading capacities that would warrant setting TMDLs based on shorter timeframes.

OC41: *Comment:* The numeric targets presented in Table 6-1 should be normalized to organic carbon rather than being solids-based. Organic carbon content varies significantly within and across media. Since these compounds will preferentially adsorb to organic carbon, these targets will be more meaningful if they are based on that fraction within each media (sediments and tissue). This may change the media that

is most restrictive. The loading capacity calculations should be repeated to reflect these changes in the selected endpoints.

Commentor: Limno Tech/NRDC/Defend the Bay

Response: The comment provides an insufficient rationale to warrant changes in the TMDL.

OC42: *Comment:* We suggest that if alternative sediment target values are considered for any compounds (e.g. Swartz et al., *Environ. Toxicol. Chem*. 13:949-962 for DDT), they be compared to the numeric targets proposed in the Draft TMDL and the lower of the two values be used to be most protective. Both values need to be based on the same media in order to be compared. We concur with EPA=s approach for developing numeric targets. Given the high historical loadings, the toxicity associated with these compounds, and their tendency to accumulate in sediment and tissue, setting sediment and tissue targets will be more protective than water column numeric targets.

Commentor: Limno Tech/NRDC/Defend the Bay

Response: EPA verified that sediment and water column targets are the most protective available indicators.

OC43: *Comment:* The Source Analysis introduction in the TMDL is poorly worded when it suggests that DDT and PCB are the only chemicals still being discharged in the watershed. This wording should be changed or supplemented with text explaining that the basis for this statement is that these are the only compounds in this TMDL that are still detected at quantifiable levels in soil samples collected in the watershed.

Commentor: Limno Tech/NRDC/Defend the Bay

Response: EPA has revised to wording in the final TMDL report to clarify that other sources might be present but data are available to support the presence of DDT and PCBs.

OC44: *Comment:* Adding flow charts or decision trees explaining the process used for the analysis of San Diego Creek and Upper Newport Bay loadings and allocations would be very helpful in understanding the analyses.

Commentor: Limno Tech/NRDC/Defend the Bay

Response: The revised TMDL includes additional flowcharts describing the analyses performed for San Diego Creek and Newport Bay.

OC45: *Comment:* Neither the TMDL nor the TSD explains why the odd choice of flow tiers used in the San Diego Creek analysis can represent annual loads in the creek. The four tier approach used in the Metals TMDL provides a better characterization of annual flow conditions in the Creek and should be used in this TMDL for calculating the existing load and the loading capacity.

Commentor: Limno Tech/NRDC/Defend the Bay

Response: The flow tiers used in the final TMDLs were modified based on a longer, more representative flow record.

OC46: *Comment:* The Total Suspended Solids (TSS) concentrations associated with each flow tier presented in Tables F-7 and F-8 for San Diego Creek seem to be at least an order of magnitude higher than what one might reasonably expect. Are there any characteristics in the watershed that would lead one

to expect such high concentrations? Use of these concentrations allows a finite amount pollutant mass to be Aspread@ over a larger mass of solids, essentially diluting the chemical concentration when measured on a solids basis. The net result is an increase, likely an overestimate, of the loading capacity of San Diego Creek. No information is provided in the TMDL or TSD regarding the source and analyses that were performed to determine these TSS concentrations. No information is provided on the source and analyses that were performed on the TSS concentrations. Analysis of the tiered TSS data should be performed to select an appropriate concentration for each tier used in the loading analysis. Details should be included in the TSD.

Commentor: Limno Tech/NRDC/Defend the Bay

Response: Additional information is provided in the TSD to describe the TSS analysis and sources of supporting information. The TSS concentration is derived based on a regression of RMA data for the flow tiers.

OC47: The fraction of organic carbon in the sediments is typically much different that the fraction of organic carbon in the solids entering the water column. The EPA approach appears to assume that they are the same. The analysis should be refined to account for differences in organic carbon content between the in-stream sediments and solids in the water column.

Commentor: Limno Tech/NRDC/Defend the Bay

Response: Insufficient monitoring information and literature values are available to distinguish from in-stream and water column solids for this analysis.

OC48: *Comment:* The amount of DDT in dicofol can be a significant source to Newport Bay. The relative use of dicofol by land use should be factored into the allocations of load and wasteload categories. Control of the use of dicofol should be addressed in the implementation plan.

Commentor: Limno Tech/NRDC/Defend the Bay

Response: Dicofol as a source of DDT is cited in the source analysis of the TSD and in the TMDL document. The source allocation includes sources with potential for dicofol application.

Implementation measures for this TMDL will be developed by the Regional Board. Many of the comments submitted on these TMDLs raise implementation issues and will be forwarded to the Regional Board for its use in developing implementation measures.

OC49: *Comment:* To clarify the TMDL the following items should be added. 1. Description of total suspended solids, fraction organic carbon for each media (water, sediment and tissue) and lipid content data sources. 2. The BCFs and partition coefficients (and their units) used to compute water column concentrations in Tables F-7, F-8, F-10, F-11 and F-17. 3. Equations, assumptions and input data used to compute values presented in Tables F-7, F-8, F-10, F-11, and F-17. 4. Units for the partition coefficient column presented in Table F-8.

Commentor: Limno Tech/NRDC/Defend the Bay.

Response: Revisions have been made to the TSD to include flowcharts, more detailed descriptions of approach, and updated tables and references of supporting materials.

OC50: *Comment:* The commenter requests confirmation of the use of net sedimentation rates in the analysis. They recommend that the analysis be redone using burial rates.

Commentor: Limno Tech/NRDC/Defend the Bay

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Response: The final TMDL TSD clarifies the sediment model approach.

OC51. *Comment:* Page 17 of TMDL provides summary of allocation strategy. More detail is requested.
Commentor: Limno Tech/NRDC/Defend the Bay

Response: EPA believes that the current level of allocation is consistent with the available information for development of this TMDL. The basis for the allocations is described in greater detail in the final TMDLs.

OC52: *Comment:* EPA should adjust scenario of allocation to make sure that sources outside San Diego Creek cannot increase from current load levels.
Commentor: Limno Tech/NRDC/Defend the Bay

Response: The allocation and TMDL loading capacities are designed to ensure protection of water quality standards. The TMDL allocation process selects existing loading if less than loading capacity to ensure that no additional discharges are allowed for the OC compounds. The final allocation was checked for San Diego Creek and Newport Bay to ensure that they are separately and collectively protective for all the water bodies of concern.

OC53: *Comment:* Clarify steps in section 6 of the TSD. Clarify which steps were applied to Newport Bay.
Commentor: Limno Tech/NRDC/Defend the Bay

Response: The revised TSD provides clarification of the approach taken for San Diego Creek and Newport Bay. The analysis and decision process have been further described using flowcharts.

OC54: *Comment:* Change equation 5 to equation 6 in Section 6 of the TSD.
Commentor: Limno Tech/NRDC/Defend the Bay

Response: The revised TSD correctly references the equations used and associated steps.

OC55. *Comment:* How was the RMA model used for San Diego Creek?
Commentor: Limno Tech/NRDC/Defend the Bay
Response: RMA modeling data was only used to derive suspended sediment concentrations for the flow tiers used in the San Diego Creek TMDL.

OC56: *Comment:* The Aundefined@ category of the Load Allocation in vague. The reviewer request that text be added to the TMDL describing the sources covered under Aundefined@.
Commentor: Limno Tech/NRDC/Defend the Bay

Response: EPA believes that the current source allocation is consistent with the available information for development of the TMDL. This category is intended to include sediment resuspension, atmospheric deposition, localized hot spots that have not been identified, and other uncharacterized sources. Further specific source information can be provided as part of the implementation process.

OC57: *Comment:* Presuming the Aundefined@ includes sediments and atmospheric deposition, the reviewer recommends that the undefined category remain unchanged and remaining sources be reduced

sufficient to meet a 30% MOS.

Commentor: Limno Tech/NRDC/Defend the Bay

Response: For reasons discussed in previous comments, EPA does not consider a larger margin of safety to be warranted.

Chromium and Mercury TMDLs

CM1. *Comment:* According to the Regional Board (Problem Statement 2000), the data show that concentrations of chromium do not exceed CTR water quality objectives, and thus this chemical is Aprobably not causing, or contributing to, toxicity to aquatic life in Newport Bay and San Diego Creek.@

Commentor: Latham&Watkins

Response: EPA determined that a chromium TMDL was warranted for the Rhine Channel based on shellfish tissue exceedences, as set forth in EPA=s *Decision Document* (2002). The draft Problem Statement prepared by Regional Board staff recommended Cr TMDL in Rhine based on shellfish tissue exceedences.

CM2. *Comment:* The rationale for using the two tier flow system for chromium and mercury is not adequately explained.

Commenter: County of Orange

Response: EPA used a two tier flow system for chromium and mercury to define inputs of metal laden sediment from San Diego Creek. Two tiers represent dry and wet weather inputs as described in the TSD.

CM3. *Comment:* Explain why the chromium and mercury TMDLs are based on 15 years of runoff data when the report previously states that conditions have changed significantly during this time period.

Commenter: County of Orange

Response: EPA has explained in TSD Part B that flow conditions for San Diego Creek have changed over the past 15 years due to significant changes in land use (urbanization and loss of agricultural lands). The final TMDL is based on nearly 20 years of daily flow records for San Diego Creek to provide a more representative data set for these TMDLs. This decision recognizes the changes in land use as well as widely varying annual precipitation.

CM4. *Comment:* Mercury contamination may be a naturally occurring artifact rather than occurring from human causes based on the fact that mercury was mined in the Red Hill area. Mercury contamination in Rhine Channel could be from use of mercury-containing boat paints which are no longer used. Because this mercury pollution was episodic and is unlikely to reoccur, a mercury TMDL is not warranted.

Commenter: IRWD

Response: When developing TMDLs, EPA needs to consider all sources of the pollutant-- natural historical, as well as anthropogenic. As noted in the final TMDL, we considered the Red Hill site but do not believe it is likely to be a significant historical source of mercury loads to Rhine Channel. See response to comment OC4.

CM5. *Comment*: The use of modeling approaches for the mercury and chromium TMDLs introduces substantial uncertainty into the TMDL results, necessitating a higher margin of safety than provided in the draft TMDLs.

Commenter: NRDC

Response: EPA does not find sufficient rationale in the comment to increase the margin of safety. On-going studies, conducted under review by EPA and Regional Board staff, will supply more relevant data to provide better interpretation of current conditions of these and many other toxic pollutants in the Rhine.

CM6. *Comment:* EPA should translate sediment and tissue target concentrations to values that can be directly compared, and use the most stringent of the resulting targets.

Commentor: NRDC

Response: EPA acknowledges the value of comment although this Atranslation@ is much like comparing apples to oranges. EPA believes the sediment target will also be protective of bioaccumulation of mercury and minimize build up of chromium in shellfish tissue.

CM7. *Comment:* Estimated loads from San Diego Creek are inconsistent between the Summary Document and TSD.

Commentor: NRDC

Response: EPA has rectified this inconsistency.

CM8. *Comment:* The fact that chromium levels in tissue are elevated but less so in sediment indicates there are likely sources besides existing sediment.

Commentor: NRDC

Response: EPA and Regional Board have included information pertaining to Newport Plating facility in vicinity of Rhine Channel. Two investigations of this facility in 1986 showed extremely high values of chromium and other metals in soil boring samples and groundwater. Regional Board have no indication that remediation has occurred at this facility (not operating for nearly 20 years). See TSD Part G.

CM9. *Comment:* Atmospheric deposition and mining operations have not been adequately considered as potential sources.

Commentor: NRDC

Response: EPA recognizes that atmospheric deposition could be contributing mercury to Rhine Channel although this waterbody has an extremely small surface area as to suggest negligible inputs. Any assessment to address inputs from mining operations would require further monitoring data from upstream non-point sources.

CM10. *Comment:* Partitioning coefficients are acknowledged as not well documented, and it is unclear which partition coefficients were selected for TMDL calculation. EPA must use the most conservative available value.

Commentor: NRDC

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Response: EPA has provided more information in the TSD for mercury and chromium to define partitioning coefficient and other values used.

CM11. *Comment:* Additional information must be provided describing the BCFs, partition coefficients, and other methods used to estimate loads and calculate loading capacities.
Commentor: NRDC

Response: EPA has provided more information in the TSD for mercury and chromium to define partitioning coefficient and other values used.

CM12. *Comment:* There is insufficient description of how the loading capacities for Rhine Channel were determined.
Commentor: NRDC

Response: EPA has included additional information to describe determination of allocations in the final TMDL.

CM13. *Comment:* There are many potential sources of chromium (e.g. atmospheric deposition and mining) discussed but not specifically allocated in the TMDL. These sources should be properly assessed and allocations identified. Failure to allocate to these sources may result in other allocations being too high.
Commentor: NRDC

Response: EPA believes the sources of chromium are best defined by the categories outlined in the TMDL. Atmospheric deposition and mining would be included in the category of Aother sources@.

Arsenic

A1. *Comment:* There should be a TMDL for arsenic because EPA agreed to do so under the consent decree.
Commentor: NRDC

Response: The pollutants identified in the 1997 consent decree were EPA=s best understanding of the probable pollutants for which TMDLs needed to be developed. However, the consent decree specifically noted that the list of pollutants was subject to change by the State, and that EPA could also determine that TMDLs were not needed. EPA has concluded that the most recent information does not justify establishing a TMDL for arsenic, as summarized in EPA=s 2002 *Decision Document* and in the Arsenic Analysis in the TMDL summary document.

A2. *Comment:* The new EPA screening value is not protective enough because it does not consider carcinogenic effects.
Commentor: NRDC/LTI

Response: EPA utilized the most reliable screening factor available for inorganic arsenic. Due to

EPA=s concerns about the scientific validity of previously proposed screening values for assessment of potential carcinogenic effects, EPA believes it is inappropriate to apply it for TMDL screening purposes. The commentors provided no evidence to persuade EPA to reconsider this decision.

A3. *Comment:* EPA should account for weaknesses in its selected screening value by increasing the assumed fish consumption rate and redoing its risk analysis based on a higher fish consumption rate.
Commentor: NRDC/LTI

Response: The commentor provided no evidence of higher than average fish consumption rates by a significant portion of anglers in the Newport Bay area; therefore, EPA has no basis for reanalyzing arsenic-related risk based on a higher fish consumption value. EPA believes that absent evidence to the contrary, it is reasonable to apply national fish consumption rates recommended for criteria development in applying toxic pollutant screening values.

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OFFICE OF
WATER

MEMORANDUM

SUBJECT: Establishing Total Maximum Daily Load (TMDL) Wasteload Allocations (WLAs) for Storm Water Sources and NPDES Permit Requirements Based on Those WLAs

FROM: Robert H. Wayland, III, Director
Office of Wetlands, Oceans and Watersheds

James A. Hanlon, Director
Office of Wastewater Management

TO: Water Division Directors
Regions 1 - 10

This memorandum clarifies existing EPA regulatory requirements for, and provides guidance on, establishing wasteload allocations (WLAs) for storm water discharges in total maximum daily loads (TMDLs) approved or established by EPA. It also addresses the establishment of water quality-based effluent limits (WQBELs) and conditions in National Pollutant Discharge Elimination System (NPDES) permits based on the WLAs for storm water discharges in TMDLs. The key points presented in this memorandum are as follows:

NPDES-regulated storm water discharges must be addressed by the wasteload allocation component of a TMDL. See 40 C.F.R. § 130.2(h).

NPDES-regulated storm water discharges may not be addressed by the load allocation (LA) component of a TMDL. See 40 C.F.R. § 130.2 (g) & (h).

Storm water discharges from sources that are not currently subject to NPDES regulation may be addressed by the load allocation component of a TMDL. See 40 C.F.R. § 130.2(g).

It may be reasonable to express allocations for NPDES-regulated storm water discharges from multiple point sources as a single categorical wasteload allocation when data and information are insufficient to assign each source or outfall individual WLAs. See 40 C.F.R. § 130.2(i). In cases where wasteload allocations

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are developed for categories of discharges, these categories should be defined as narrowly as available information allows.

The WLAs and LAs are to be expressed in numeric form in the TMDL. See 40 C.F.R. § 130.2(h) & (i). EPA expects TMDL authorities to make separate allocations to NPDES- regulated storm water discharges (in the form of WLAs) and unregulated storm water (in the form of LAs). EPA recognizes that these allocations might be fairly rudimentary because of data limitations and variability in the system.

NPDES permit conditions must be consistent with the assumptions and requirements of available WLAs. See 40 C.F.R. § 122.44(d)(1)(vii)(B).

WQBELs for NPDES-regulated storm water discharges that implement WLAs in TMDLs may be expressed in the form of best management practices (BMPs) under specified circumstances. See 33 U.S.C. §1342(p)(3)(B)(iii); 40 C.F.R. §122.44(k)(2)&(3). If BMPs alone adequately implement the WLAs, then additional controls are not necessary.

EPA expects that most WQBELs for NPDES-regulated municipal and small construction storm water discharges will be in the form of BMPs, and that numeric limits will be used only in rare instances.

When a non-numeric water quality-based effluent limit is imposed, the permit's administrative record, including the fact sheet when one is required, needs to support that the BMPs are expected to be sufficient to implement the WLA in the TMDL. See 40 C.F.R. §§ 124.8, 124.9 & 124.18.

The NPDES permit must also specify the monitoring necessary to determine compliance with effluent limitations. See 40 C.F.R. § 122.44(i). Where effluent limits are specified as BMPs, the permit should also specify the monitoring necessary to assess if the expected load reductions attributed to BMP implementation are achieved (e.g., BMP performance data).

The permit should also provide a mechanism to make adjustments to the required BMPs as necessary to ensure their adequate performance.

This memorandum is organized as follows:

(I). Regulatory basis for including NPDES-regulated storm water discharges in WLAs in TMDLs;

(II). Options for addressing storm water in TMDLs; and

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(III). Determining effluent limits in NPDES permits for storm water discharges consistent with the WLA

(I). Regulatory Basis for Including NPDES-regulated Storm Water Discharges in WLAs in TMDLs

As part of the 1987 amendments to the CWA, Congress added Section 402(p) to the Act to cover discharges composed entirely of storm water. Section 402(p)(2) of the Act requires permit coverage for discharges associated with industrial activity and discharges from large and medium municipal separate storm sewer systems (MS4), i.e., systems serving a population over 250,000 or systems serving a population between 100,000 and 250,000, respectively. These discharges are referred to as Phase I MS4 discharges.

In addition, the Administrator was directed to study and issue regulations that designate additional storm water discharges, other than those regulated under Phase I, to be regulated in order to protect water quality. EPA issued regulations on December 8, 1999 (64 FR 68722), expanding the NPDES storm water program to include discharges from smaller MS4s (including all systems within "urbanized areas" and other systems serving populations less than 100,000) and storm water discharges from construction sites that disturb one to five acres, with opportunities for area-specific exclusions. This program expansion is referred to as Phase II.

Section 402(p) also specifies the levels of control to be incorporated into NPDES storm water permits depending on the source (industrial versus municipal storm water). Permits for storm water discharges associated with industrial activity are to require compliance with all applicable provisions of Sections 301 and 402 of the CWA, i.e., all technology-based and water quality-based requirements. See 33 U.S.C. §1342(p)(3)(A). Permits for discharges from MS4s, however, "shall require controls to reduce the discharge of pollutants to the maximum extent practicable ... and such other provisions as the Administrator or the State determines appropriate for the control of such pollutants." See 33 U.S.C. §1342(p)(3)(B)(iii).

Storm water discharges that are regulated under Phase I or Phase II of the NPDES storm water program are point sources that must be included in the WLA portion of a TMDL. See 40 C.F.R. § 130.2(h). Storm water discharges that are not currently subject to Phase I or Phase II of the NPDES storm water program are not required to obtain NPDES permits. 33 U.S.C. §1342(p)(1) & (p)(6). Therefore, for regulatory purposes, they are analogous to nonpoint sources and may be included in the LA portion of a TMDL. See 40 C.F.R. § 130.2(g).

(II). Options for Addressing Storm Water in TMDLs

Decisions about allocations of pollutant loads within a TMDL are driven by the quantity and quality of existing and readily available water quality data. The amount of storm water data available for a TMDL varies from location to location. Nevertheless, EPA expects TMDL authorities will make separate aggregate allocations to NPDES-regulated storm water discharges

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(in the form of WLAs) and unregulated storm water (in the form of LAs). It may be reasonable to quantify the allocations through estimates or extrapolations, based either on knowledge of land use patterns and associated literature values for pollutant loadings or on actual, albeit limited, loading information. EPA recognizes that these allocations might be fairly rudimentary because of data limitations.

EPA also recognizes that the available data and information usually are not detailed enough to determine waste load allocations for NPDES-regulated storm water discharges on an outfall-specific basis. In this situation, EPA recommends expressing the wasteload allocation in the TMDL as either a single number for all NPDES-regulated storm water discharges, or when information allows, as different WLAs for different identifiable categories, e.g., municipal storm water as distinguished from storm water discharges from construction sites or municipal storm water discharges from City A as distinguished from City B. These categories should be defined as narrowly as available information allows (e.g., for municipalities, separate WLAs for each municipality and for industrial sources, separate WLAs for different types of industrial storm water sources or dischargers).

(III). Determining Effluent Limits in NPDES Permits for Storm Water Discharges Consistent with the WLA

Where a TMDL has been approved, NPDES permits must contain effluent limits and conditions consistent with the requirements and assumptions of the wasteload allocations in the TMDL. See 40 CFR § 122.44(d)(1)(vii)(B). Effluent limitations to control the discharge of pollutants generally are expressed in numerical form. However, in light of 33 U.S.C. §1342(p)(3)(B)(iii), EPA recommends that for NPDES-regulated municipal and small construction storm water discharges effluent limits should be expressed as best management practices (BMPs) or other similar requirements, rather than as numeric effluent limits. See *Interim Permitting Approach for Water Quality-Based Effluent Limitations in Storm Water Permits*, 61 FR 43761 (Aug. 26, 1996). The Interim Permitting Approach Policy recognizes the need for an iterative approach to control pollutants in storm water discharges. Specifically, the policy anticipates that a suite of BMPs will be used in the initial rounds of permits and that these BMPs will be tailored in subsequent rounds.

EPA's policy recognizes that because storm water discharges are due to storm events that are highly variable in frequency and duration and are not easily characterized, only in rare cases will it be feasible or appropriate to establish numeric limits for municipal and small construction storm water discharges. The variability in the system and minimal data generally available make it difficult to determine with precision or certainty actual and projected loadings for individual dischargers or groups of dischargers. Therefore, EPA believes that in these situations, permit limits typically can be expressed as BMPs, and that numeric limits will be used only in rare instances.

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Under certain circumstances, BMPs are an appropriate form of effluent limits to control pollutants in storm water. See 40 CFR § 122.44(k)(2) & (3). If it is determined that a BMP approach (including an iterative BMP approach) is appropriate to meet the storm water component of the TMDL, EPA recommends that the TMDL reflect this.

EPA expects that the NPDES permitting authority will review the information provided by the TMDL, see 40 C.F.R. § 122.44(d)(1)(vii)(B), and determine whether the effluent limit is appropriately expressed using a BMP approach (including an iterative BMP approach) or a numeric limit. Where BMPs are used, EPA recommends that the permit provide a mechanism to require use of expanded or better-tailored BMPs when monitoring demonstrates they are necessary to implement the WLA and protect water quality.

Where the NPDES permitting authority allows for a choice of BMPs, a discussion of the BMP selection and assumptions needs to be included in the permit's administrative record, including the fact sheet when one is required. 40 C.F.R.§§ 124.8, 124.9 & 124.18. For general permits, this may be included in the storm water pollution prevention plan required by the permit. See 40 C.F.R. § 122.28. Permitting authorities may require the permittee to provide supporting information, such as how the permittee designed its management plan to address the WLA(s). See 40 C.F.R. § 122.28. The NPDES permit must require the monitoring necessary to assure compliance with permit limitations, although the permitting authority has the discretion under EPA's regulations to decide the frequency of such monitoring. See 40 CFR § 122.44(i). EPA recommends that such permits require collecting data on the actual performance of the BMPs. These additional data may provide a basis for revised management measures. The monitoring data are likely to have other uses as well. For example, the monitoring data might indicate if it is necessary to adjust the BMPs. Any monitoring for storm water required as part of the permit should be consistent with the state's overall assessment and monitoring strategy.

The policy outlined in this memorandum affirms the appropriateness of an iterative, adaptive management BMP approach, whereby permits include effluent limits (e.g., a combination of structural and non-structural BMPs) that address storm water discharges, implement mechanisms to evaluate the performance of such controls, and make adjustments (i.e., more stringent controls or specific BMPs) as necessary to protect water quality. This approach is further supported by the recent report from the National Research Council (NRC), *Assessing the TMDL Approach to Water Quality Management* (National Academy Press, 2001). The NRC report recommends an approach that includes "adaptive implementation," i.e., "a cyclical process in which TMDL plans are periodically assessed for their achievement of water quality standards" . . . and adjustments made as necessary. *NRC Report* at ES-5.

This memorandum discusses existing requirements of the Clean Water Act (CWA) and codified in the TMDL and NPDES implementing regulations. Those CWA provisions and regulations contain legally binding requirements. This document describes these requirements; it does not substitute for those provisions or regulations. The recommendations in this memorandum are not binding; indeed, there may be other approaches that would be appropriate

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in particular situations. When EPA makes a TMDL or permitting decision, it will make each decision on a case-by-case basis and will be guided by the applicable requirements of the CWA and implementing regulations, taking into account comments and information presented at that time by interested persons regarding the appropriateness of applying these recommendations to the particular situation. EPA may change this guidance in the future.

If you have any questions please feel free to contact us or Linda Boornazian, Director of the Water Permits Division or Charles Sutfin, Director of the Assessment and Watershed Protection Division.

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Managing Mosquitoes in Stormwater Treatment Devices

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The federal Clean Water Act, as amended in 1987, requires states to develop and implement nonpoint source pollution management programs (see Copeland 1999, 2003). These mandated programs require that certain measures be taken to abate pollutants carried by rainwater and urban (i.e., dry weather) runoff, herein collectively referred to as stormwater runoff. A principal component of stormwater programs is the implementation of Best Management Practices (BMPs), a term first adopted in the 1970s to represent actions and practices used to reduce the flow rates and the constituent concentrations in runoff (WEF and ASCE 1998).

The regulatory pressure to achieve increasingly higher levels of pollution abatement gave birth to a burgeoning industry that specializes in developing stormwater treatment devices based on the latest available technologies. These "treatment" BMPs are engineered to maximize the capture and removal of target pollutants from stormwater, often with the added benefit of reducing excessive downstream flows. Hundreds of designs have been developed across the United States, including many proprietary devices, and in some cases existing structures such as flood-control basins and constructed wetlands may be modified to function as treatment BMPs to satisfy local needs. Unfortunately, although "best" for managing runoff, these devices often provide aquatic habitats suitable for mosquitoes and other vector species as an unintended consequence of their implementation (see CH2M Hill 1999; Chanda and Shisler 1980; Dorothy and Staker 1990; Florida Coordinating Council on Mosquito Control 1998; Kluh et al. 2002; McLean 2000; Metzger et al. 2002, 2003; O'Carroll 1978; Santana et al. 1994; Schimmenti 1979; Schmidt 1980; Smith and Shisler 1981). In this publication, "treatment BMP" and "treatment device" are used interchangeably.

Public health and safety is a major component of all stormwater management programs. Flood control and the reduction of waterborne pathogens are high priorities, yet mosquito management is often overlooked. Mosquito management is essential to prevent disease transmission and maintain quality of life and must be integrated into every stormwater program. This publication provides basic guidelines for mosquito management that are relevant to the location, design, and operation of proprietary and nonproprietary stormwater treatment devices. Unfortunately, the rapid growth and evolution of stormwater programs and BMP designs combined with the tremendous number of local factors that may influence mosquito production at any given site preclude any "cure-all" recommendations or solutions. Careful implementation of these guidelines will help suppress mosquito breeding while reducing health risks and discomfort, lowering costs associated with mosquito abatement, and lessening legal liability.

MOSQUITOES AND MOSQUITO CONTROL

Mosquitoes are regarded as undesirable in both rural and urban areas throughout most of the United States. Not only is their biting activity a nuisance, mosquitoes also vector (transmit) pathogens that cause human and animal diseases. The recent threat of West Nile virus compounds concerns and reinforces the need for effective mosquito control.

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There are approximately 3,000 species of mosquitoes worldwide (about 200 in the United States) and all require water to complete their life cycle (fig. 1). Mosquito control is most effective when directed at immature stages in standing water rather than at adults and is best conducted using a combination of techniques including biological, physical, chemical, and in states such as California, legal control (California Health & Safety Code [H&S Code], §§2060-2067, 100170, 100175). Biological control uses or enhances natural enemies of mosquitoes such as fish; physical control makes habitats less suitable for mosquito production; chemical control uses insecticides that target immatures or adults; and legal control can force uncooperative parties to eliminate breeding habitats on their property or face financial penalties.

Despite advances in mosquito management, the importance and need for careful preventative design and maintenance plans is paramount. This becomes apparent especially when faced with the limitations imposed by certain treatment BMPs as a result of their design, location, or accessibility. For example, underground treatment devices that hold permanent sources of water and produce mosquitoes are unlikely to support commonly used biological control agents, and physical controls such as exclusion

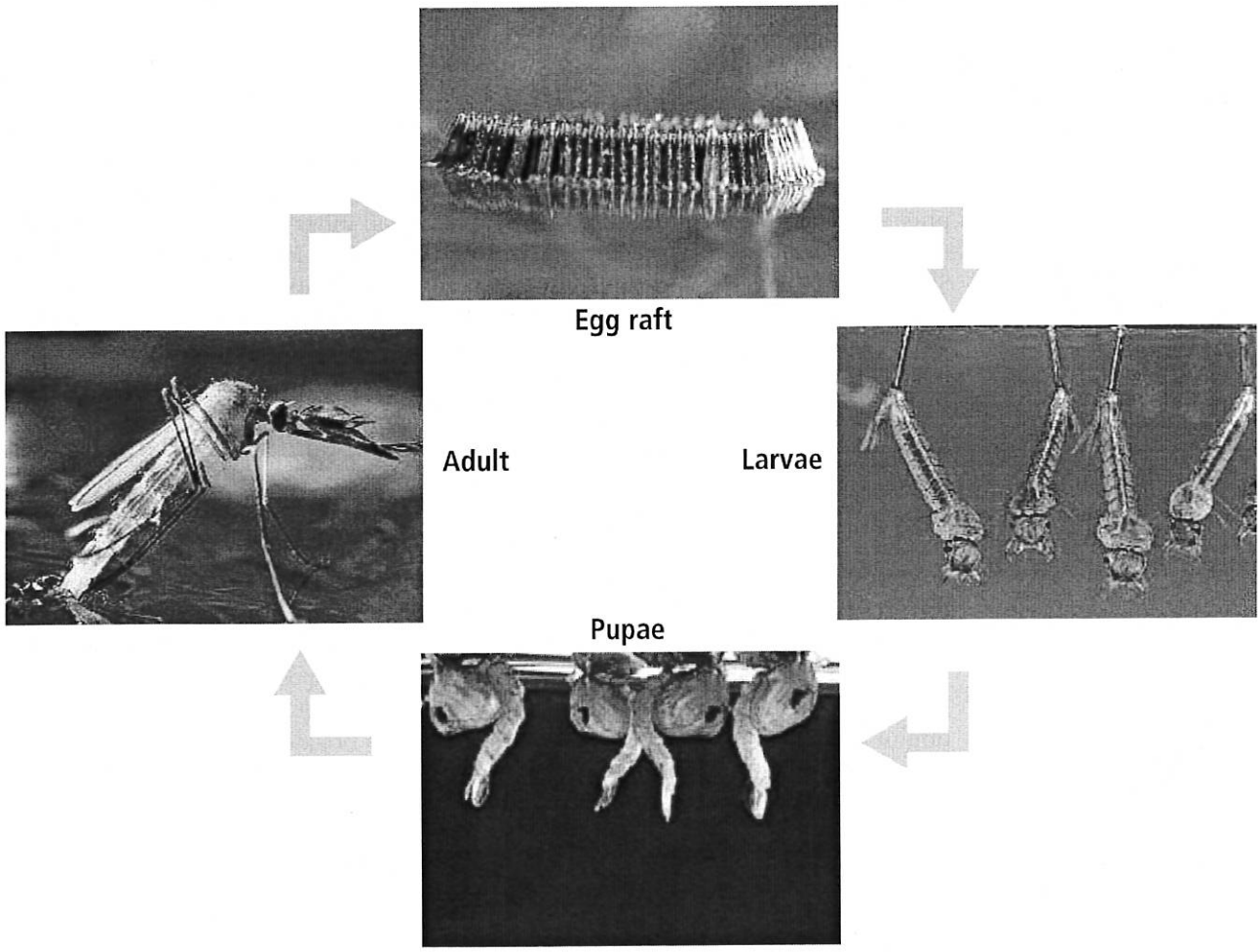

Figure 1. The mosquito life cycle consists of four stages: egg, larva, pupa, and adult. Female mosquitoes lay eggs on or near water. Eggs hatch into aquatic larvae that feed on organic material and grow through four stages before becoming pupae. Winged adults emerge from pupae, mate, and begin the cycle again. Only female mosquitoes feed on blood, which provides the nutrients needed for the development of eggs. Males are more short-lived and feed on plant juices. *Photos courtesy of Marin/Sonoma Mosquito and Vector Control District.*

(e.g., valves and covers) can be difficult to implement without affecting the devices' intended function. In these situations, chemical treatment, and legal abatement in some states, are the only remaining options. Note that in this publication, "chemical treatment" refers to the use of registered pesticides to control the aquatic stages of mosquitoes (larvicides), including bacteria, hormone mimics, and oils.

LARVICIDING VERSUS PREVENTATIVE ENGINEERING

As more and more stormwater programs recognize the importance of integrating mosquito control into their lists of public health priorities, the dilemma of how to effectively manage mosquitoes in designs that favor mosquito breeding becomes obvious. Larvicide treatments are increasingly considered as long-term solutions for mosquito control in lieu of costly retrofits, replacements, or redesigns. However, sole reliance on larvicides is *not* a long-term solution for preventing mosquito production. Every possible effort should be made to "design the bugs out" during preconstruction planning or via postconstruction retrofits to avoid creating a possible public health hazard. When all else fails, registered pesticides should be applied only by certified professionals due to the risk of establishing pesticide resistance in target organisms, as well as potential liability issues from misuse.

TYPE AND LOCATION OF TREATMENT BMPS

When selecting and installing stormwater treatment devices, agencies consider factors such as the projected runoff for a given area, the available or allocated space, cost, and local pollutants of concern. Structural designs can range from simple to elaborate and appear to be limited only by funding and the imagination of engineers. The most common processes used for pollution management in treatment BMPs that may be used singly or in combination include trash capture, settling and sedimentation, media filtration, and infiltration. Typical urban and suburban treatment devices include vegetated channels (swales), dry detention basins, wet retention ponds or constructed wetlands, media filtration devices, and belowground sumps, vaults, and basins. Of concern to public health officials is that an alarming number of these devices hold nutrient-rich stagnant water that provides breeding places for mosquitoes (fig. 2).

Figure 2. Waters rich in accumulations of organic materials created by some treatment BMPs provide ideal larval habitats for many species of mosquitoes, including those that can transmit human diseases. The standing water in this small roadside stormwater basin harbored hundreds of mosquito larvae and illustrates the reproductive potential of mosquitoes when provided with suitable habitat. *Photo: Marco Metzger.*

Location can greatly affect whether a treatment BMP becomes a significant source of mosquitoes. For example, identical structures in different locations may vary widely in potential mosquito production due to the number of mosquitoes present in the area, the species composition, and the duration of breeding activity. Elements that may influence the mosquito breeding potential in any given location may include a variety of environmental, construction, and local factors operating singly or in combination (table 1). Because of their propensity to breed mosquitoes, *all* treatment BMPs, regardless of their design, should be monitored periodically by vector control professionals with knowledge of the biology and ecology of local mosquito species. A more proactive approach would be to include vector

Table 1. Factors that may influence mosquito production potential in treatment BMPs.

Elevation
Installation above or below ground
Local climate
Local fauna (i.e., potential predators)
Nonstormwater runoff quantity, quality, and event frequency (e.g., residential and commercial)
Proximity to existing mosquito sources
Stormwater runoff quantity, quality, and event frequency
Surrounding host animals (wild and domestic) potentially available for female mosquitoes to feed upon
Surrounding land use, both present and future
Surrounding structural refuges for adult mosquitoes (e.g., trees, shrubs, storm sewers)
Surrounding vegetation, both native and exotic

Note: This list is incomplete. Other local factors may also be conducive to mosquito production.

control professionals in preconstruction planning. This type of collaborative effort could help prevent costly future retrofits or replacements necessary to meet mosquito management goals.

MOSQUITO SUPPRESSION THROUGH DESIGN AND MAINTENANCE

The majority of treatment BMPs operate as "passive" systems, meaning that they do not require active operational control or adjustment beyond routine maintenance. As a result, most installations remain unsupervised for extended periods, and if conditions are favorable, mosquito breeding could occur unobserved and uncontrolled. Conscientious planning that emphasizes mosquito habitat reduction or elimination in both design and maintenance plans can prevent these problems (Metzger et al. 2002; O'Carroll 1978; Schimmenti 1979). Minimizing the mosquito production potential of treatment BMPs requires that standing water not be available for sufficient time to permit emergence of adult mosquitoes. This can be achieved in one of three ways:

- Rapid discharge of all captured water.
- Denying mosquitoes access to standing water (e.g., tight-fitting covers).
- Making the habitat less suitable for breeding (e.g., vegetation management, mosquitofish).

Mosquito development from egg to adult varies by species and is influenced primarily by temperature and food availability. Certain species can complete the aquatic stages of development and emerge as adults in less than 1 week under ideal conditions. Because of this, a 72-hour maximum residence time for captured water in treatment BMPs is recommended in California and elsewhere as a conservative safeguard to prevent emergence of adult mosquitoes (Florida Coordinating Council on Mosquito Control 1998; Metzger et al. 2003; Santana et al. 1994). In reality, many treatment BMPs hold water for over 72 hours, sometimes due to their outdated designs, and more recently in order to meet stringent effluent water quality requirements. To ensure that public health and safety is maintained, the following suggestions should be considered for any structure that holds water for over 72 hours.

- Select or design an alternative (or modified) device that provides adequate constituent removal and complete drainage in 72 hours. *This is the most reliable and cost-effective choice.*
- Contact state or local public health or vector control agencies to determine whether local mosquito species and local factors (e.g., high elevation) may preclude rapid mosquito emergence, thus safely allowing water residence times to exceed 72 hours. In some areas this may require a detailed study that should be funded by the soliciting party.
- Provide adequate funds necessary to support routine mosquito monitoring and control.

Possibly the most overlooked aspect of treatment BMP implementation is the long-term commitment of funds necessary for proper maintenance of structures. Routine and timely maintenance is critical for suppressing mosquito breeding as well as for meeting local water quality goals. If maintenance is neglected or inappropriate for a given site, even structures designed to be the least "mosquito friendly" may

become significant breeding sites. Table 2 lists conditions that may increase the probability of breeding mosquitoes over time in various treatment BMPs. Maintenance guidelines for individual BMPs are often site-specific and are beyond the scope of this publication.

Table 2. Postconstruction conditions that may increase the probability of mosquito production in treatment BMPs.

Clogging (e.g., effluent pipes, media filters, infiltration basins)
Establishment of invasive or exotic vegetation
Groundwater fluctuations
Nonstormwater runoff (i.e., increases in runoff frequency, residence time, and/or volume)
Scouring and erosion
Structural damage (e.g., shifting or settling, roots)
Trash and sediment accumulation (e.g., formation of pools, clogging, redirected water flows)
Vandalism
Vegetation overgrowth

Note: This list may be incomplete. Other conditions favorable to mosquito production may become apparent as structures age.

BASIC GUIDELINES FOR MOSQUITO MANAGEMENT

Dry Systems

This category includes all stormwater treatment devices that are designed to drain completely following a storm event and remain dry. Examples include extended detention (dry detention) basins, vegetated swales, infiltration devices, and media filters.

- Design structures so they do not hold standing water for more than 72 hours. Special attention to groundwater depth is essential.
- Incorporate features that prevent or reduce the possibility of clogged discharge orifices (e.g., debris screens). The use of weep holes is not recommended due to rapid clogging.
- Use the hydraulic grade line of the site to select a treatment BMP that allows water to flow by gravity through the structure. Pumps are not recommended because they are subject to failure and often require sumps that hold water.
- Design distribution piping and containment basins with adequate slopes to drain fully and prevent standing water. The design slope should take into consideration buildup of sediment between maintenance periods. Compaction during grading may also be needed to avoid slumping and settling.
- Avoid the use of loose riprap or concrete depressions that may hold standing water (fig. 3).

Figure 3. The use of loose rocks (riprap) to dissipate the energy of incoming runoff encourages mosquito production. Inevitably, standing water collects between the rocks, providing habitat for mosquitoes and making monitoring and control very difficult. A low-maintenance sloped concrete slab with imbedded rocks or concrete blocks is recommended as an alternative. *Photo: Marco Metzger.*

- Avoid barriers, diversions, or flow spreaders that may retain standing water.

Systems with Sumps, Vaults, or Basins

This category includes all stormwater treatment devices, except ponds and wetlands, that incorporate features that hold permanent or semipermanent standing water. Sumps, vaults, and basins may be located both above and below ground, but they are particularly common features of belowground proprietary and nonproprietary treatment devices that tie into existing storm sewers. Examples include above- and belowground media filters, oil-water separators, vortex separators, and vault-type devices (fig. 4).

- Completely seal structures that retain water permanently or longer than 72 hours to prevent entry of adult mosquitoes. Adult female mosquitoes may

Figure 4. Stormwater treatment BMPs that hold permanent sources of standing water, especially belowground devices, pose a difficult challenge to mosquito exclusion efforts. A cooperative effort between stormwater professionals, municipal planners, public health officials, vector control agencies, and others is crucial to developing novel techniques that eliminate or deny mosquitoes access to standing water. Contact the state or local public health or vector control agency to discuss local vector issues and provide input and consultation on siting, design, and maintenance of proposed treatment BMPs. *Photo: Marco Metzger.*

Figure 5. Mosquitoes can access underground sources of water in treatment BMPs from many places, including inlet and outlet pipes, loose-fitting covers, and vent holes. As a general rule, any gap 1/16 inch (2 mm) or greater is large enough to allow egg-laying females to enter. The hole in this manhole cover is more than large enough to allow mosquito entry. *Photo: Marco Metzger.*

penetrate openings as small as 1/16 inch (2 mm) to gain access to water for egg laying (fig. 5). Screening can exclude mosquitoes, but it is subject to damage and is not a method of choice.

- If using covers, they should be tight fitting with maximum allowable gaps or holes of 1/16 inch (2 mm) to exclude entry of adult mosquitoes. The use of gaskets can provide a much more effective barrier when used properly.
- If the sump, vault, or basin is sealed against mosquitoes, with the exception of the inlet and outlet, submerge the inlet and outlet completely to reduce the available surface area of water for mosquito egg-laying (female mosquitoes can fly through pipes). Alternatively, creative use of flapper or pinch valves, collapsible tubes (Mulligan and Schaefer 1982), and "brush curtains" might be effective for mosquito exclusion in certain designs.
- Design structures with the appropriate pumping, piping, valves, or other necessary equipment to allow for easy dewatering of the unit if necessary.

Stormwater Ponds and Wetlands

Stormwater ponds and constructed, modified, or restored wetlands that receive runoff and provide stormwater treatment pose a difficult challenge for mosquito control because nearly all produce mosquitoes to some degree (fig. 6). Over time, emergent and shoreline vegetation create habitats conducive to mosquito breeding that may be difficult or even hazardous for mosquito control professionals to access. Hazards increase significantly if proper access (see below) is not provided. If these kinds of structures must be built, it is crucial that appropriate and adequate funds be allocated to support long-term site maintenance as well as routine monitoring and management of mosquitoes by a qualified agency. The long-term costs, jurisdictional and maintenance conflicts associated with establishment of protected species (United States Fish and Wildlife Service 1999), and legal liability (e.g., H&S Code) associated with

Figure 6. Stormwater treatment ponds and constructed wetlands form complex biological systems in which mosquitoes can be difficult to control. Effective mosquito management in these habitats requires careful planning before, during, and after construction. Mosquito suppression in this stormwater pond was achieved by following guidelines provided in this publication, i.e., weekly larval monitoring, annual removal of emergent vegetation, and maintenance of a healthy mosquitofish population. Additional guidelines for managing mosquitoes in surface-flow constructed wetlands are available and should be consulted (see Walton 2003). *Photo: Marco Metzger.*

these kinds of projects must be evaluated; if any doubt exists, consider alternate treatment devices. For example, feasibility studies of subsurface flow treatment wetlands are currently under investigation and may provide excellent mosquito-free alternatives (see Anonymous 2002).

Long-term management of mosquitoes in stormwater ponds and wetlands should integrate biological control, vegetation management and other physical practices, and chemical control as appropriate. Also, a provision for regular inspection of sites for detection of developing mosquito populations should be included. Some general guidelines are listed below. Local factors may influence the overall effectiveness of certain approaches for mosquito reduction. Additional information and guidelines are available for surface-flow constructed treatment wetlands and should be consulted (Walton 2003) to ensure that mosquito populations are minimized.

Mosquito Predators and Biological Control

- Stormwater ponds and wetlands should maintain water quality sufficient to support surface-feeding fish such as mosquitofish *(Gambusia affinis)*, which feed on immature mosquitoes and can aid significantly in mosquito control.
- If large predatory fish are present (e.g., perch and bass), mosquitofish populations may be negatively impacted or eradicated. In this case, careful vegetation management remains the only nonchemical mosquito control measure.
- Where mosquitofish are not allowed, careful vegetation management remains the only nonchemical mosquito control measure.
- Other opportunistic predators such as dragonflies, diving beetles, birds, and bats feed on mosquitoes when available, but their effects are generally not sufficient to preclude chemical treatment. Despite popular beliefs, control of adult mosquitoes by birds (e.g., purple martins) and bats cannot be relied on in lieu of habitat maintenance and chemical control (Kale 1968; Tuttle 2000).

Vegetation

- Emergent vegetation provides mosquito larvae with refuge from predators, protection from surface disturbances, and increased nutrient availability while interfering with monitoring and control efforts.
- Perform routine maintenance to reduce emergent plant densities to facilitate the ability of mosquito predators (i.e., fish) to move throughout vegetated areas.
- Whenever possible, maintain stormwater ponds and wetlands at depths in excess of 4 feet (1.2 m) to limit the spread of invasive emergent vegetation such as cattails (*Typha* spp.). Deep, open areas of exposed water are typically unsuitable for mosquito immatures due to surface disturbances and predation. Deep zones also provide refuge areas for fish and beneficial macroinvertebrates should the densely vegetated emergent zones be drained.

- Build shoreline perimeters as steep and uniform as practicable to discourage dense plant growth.
- Use concrete or liners in shallow areas to discourage unwanted plant growth where vegetation is not necessary.
- Eliminate floating vegetation conducive to mosquito production (i.e., water hyacinth [*Eichhornia* spp.], duckweed [*Lemna* and *Spirodela* spp.], and filamentous algal mats).

Miscellaneous

- Make shorelines accessible to maintenance and vector control crews for periodic maintenance, control, and removal of emergent vegetation, as well as for routine mosquito monitoring and abatement procedures, if necessary.
- Design and obtain necessary approvals for all stormwater ponds and wetlands to allow for complete draining when needed.

General Access Requirements

Providing adequate and safe access for maintenance activities and for mosquito monitoring and management in stormwater treatment devices cannot be over emphasized (fig. 7). An alarmingly high number of treatment BMPs already exist that were constructed with little or no regard to reasonable access and safety. Examples include basins with 1:1 perimeter slopes, devices with deep sumps or vaults, and covered devices with heavy lids or grates.

- All stormwater treatment devices should be easily and safely accessible without the need for special requirements (e.g., OSHA requirements for "confined space"). This allows vector control personnel to effectively monitor and, if necessary, abate vectors.
- If utilizing covers, the design should include spring-loaded or lightweight access hatches that can be opened easily for inspection.
- Mosquito larvicides are applied with handheld equipment at small sites and with backpack or truck-mounted high-pressure sprayers at large sites. The effective swath width of most backpack or truck-mounted larvicide sprayers is approximately 20 feet (6 m) on a windless day. Because of these equipment limitations, all-weather road access (with provisions for turning a full-size work vehicle) should be provided along at least one side of large above-ground structures that are less than 25 feet (7.5 m) wide. Structures that have shoreline-to-shoreline distances in excess of 25 feet should have a perimeter road for access to all sides.

Figure 7. An example of a well-designed perimeter road and access ramp to the basin floor. Adequate access in and around BMP devices such as this large extended detention basin are critical for maintenance activities and vector control. *Photo: Marco Metzger.*

- Access roads should be built as close to the shoreline as possible. Vegetation or other obstacles should not be permitted between the access road and the stormwater treatment device that might obstruct the path of larvicides to the water.
- Vegetation should be controlled (by removal, thinning, or mowing) periodically to prevent barriers to access.

CONCLUSION

Stormwater treatment devices, especially those that hold permanent sources of standing water by design, create a difficult challenge for public health officials and vector control agencies and may pose a legal liability in states such as California (H&S Code). The best solution to managing mosquito populations in stormwater structures lies in fostering interdisciplinary cooperation among stormwater professionals, municipal planners, public health officials, vector control agencies, and others. Existing and future treatment BMPs must incorporate features and follow guidelines to minimize or eliminate mosquitoes. Contact state or local public health or vector control agencies to discuss local vector issues and provide input and consultation into siting, design, and maintenance of proposed treatment BMPs. Ultimately, a proactive rather than reactive approach saves money, time, effort, and most importantly, ensures the public's health.

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FOR MORE INFORMATION

You'll find more information on mosquito control in the following ANR Communication Services publications

Aquatic Pest Control, Publication 3337, 2001.

Managing Mosquitoes in Surface-Flow Constructed Treatment Wetlands, Publication 8117, 2003, available for free downloading at http://anrcatalog.ucdavis.edu/pdf/8117.pdf

Mosquitoes: Pest Notes for Home and Landscape, Publication 7451, 1998.

Mosquitoes of California, 3rd edition, Publication 4084, 1978.

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Evaluation of the Landscape Performance Certification Program

Prepared for
The Municipal Water District of Orange County and
The Metropolitan Water District of Southern California
The U.S. Bureau of Reclamation, Southern California Area Office

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Executive Summary

This report documents an evaluation of a water conservation program in Orange County California that targeted large landscape water use through dedicated landscape meters—seeking to close the gap between effort (water management) and result (efficient water use.) The Landscape Performance Certification Program (LPCP) was pioneered by the Municipal Water District of Orange County (MWDOC) with significant funding assistance from The Metropolitan Water District of Southern California (Metropolitan) for large landscape customers in Orange County. The US Bureau of Reclamation contributed financial and staff resources toward this evaluation.

Evaluation Approach

There are three parts of the evaluation:

1. **Process Evaluation**—How was the program implemented and what worked and what did not work?
2. **Impact Evaluation**—What were the water savings produced by the program and how cost effective was the effort and how cost effective could it be in the future?
3. **Recommendations**—How can the program be made more successful? Can the program be replicated by other water agencies, and if so, how easy or difficult will this be?

Findings of the Process Evaluation

The process evaluation conducted numerous interviews to obtain perceptions of the program from each of the LPCP's stakeholders—the Metropolitan Water District of Southern California (Metropolitan), the Municipal Water District of Orange County (MWDOC), the retail water agencies, participating customers, property managers, and landscape maintenance contractors. Stakeholders were queried about ease of process, reasons for participation, value of the program to them, and aspects of the program they would like to see improved. While the detailed findings by each category of stakeholder are provided in Chapter 4, the findings are best summarized by theme as follows.

What's Working?

- **The Water Budget:** The water budgeting process is soundly meeting its intended purpose for providing the necessary information base for informed water use management. The program is perceived by participants as changing both their attitudes and actions.

- **Program Operation:** The program operates smoothly and the participating customers give the program overall high ratings. Customers state that the website and the reports are easy to access, straightforward and contain valuable information.

- **Loop of Accountability:** Typically, landscape programs struggle to get the HOA, the property management company, and the landscape contractors working together to oversee landscape maintenance in a water efficient manner. The Landscape Performance Certification Program effectively pulls the three stakeholders into the process and creates a "loop of accountability."

What is Not Working as Well?

- **Customer Participation**: The major finding of the process analysis is that, for a number of reasons that are detailed in this report, customer participation levels are far below their potential. Increased participation will deliver a higher volume of water savings to Metropolitan, MWDOC, and water agencies at a lower overall unit cost.

- **Agency Data Limitations:** Unfortunately, data limitations have prevented a number of agencies from participating in the program. The data issues fall into three categories:

    1. Several water agencies in North County have very small numbers of dedicated irrigation meters. Due to their large number of non-dedicated, mixed use meters, these agencies find the program less attractive despite having a large number of large landscape sites.

2. A number of agencies cannot locate existing dedicated irrigation meters within their agency's information systems, again making access to the program more difficult.

3. The most far reaching data issue is the inability for numerous agencies to automatically run monthly data transfers of customer usage data to the program vendor (ConserVision). Some agencies with older billing systems forgo the program because of this problem.

- **Site Measurement Data:** A major stumbling block to participation is the task of gathering site measurement data. Presently this responsibility lies solely on the shoulders of the customer. Typically, customers simply do not have the time or resources to initiate the data gathering process. As a result the customer elects not to participate.

- **Current Marketing Strategy:** Over the past several years, the program has relied heavily upon letter mailing campaigns and word of mouth to solicit participation. This current marketing approach is not enough to bring in the desired volume of customers for the participating water agencies.

- **Advertising Frequency of Top Performing Customers:** The program advertises the names of the most water efficient customers once a year. This inexpensive marketing vehicle needs to be increased dramatically in order to heighten program awareness and provide better motivation to strive for the bronze, silver, or gold medal status.

Findings of the Impact Evaluation

- **Average Water Savings:** Customers participating in the recent Phases 3 and 4 of the Landscape Performance Certification Program (that is, after November 2001) were found to save approximately 765 gallons per day on average (540 gpd – 991 gpd bound the 95 percent confidence interval). Customers participating in early Phases 1 and 2 of the Landscape Performance Certification Program (that is, before November 2001) were found to save approximately 367 gallons per day on

average (251 gpd – 512 gpd is the 95 percent confidence level). This sample compared 393 Phase 1 and 2 participants and 498 Phase 3 and 4 participants to 5,381 nonparticipating customers.

- **Effect on Peak Demand**: A secondary finding in this sample related to seasonal shape in this average savings effect. For the consumption data within our sample, the water savings were not constant throughout the year. The Landscape Performance Certification Program saved considerably more water in the peak summer period, up to 1300 gallons per day on the maximum day demand.

- **Cost-effectiveness of the Program:** The comparison of historically incurred direct program costs with the steam of benefits attributable to the program (net water savings times the avoided cost of additional water supply) paints a healthy picture--the present value benefits well exceed the present value costs, resulting in a positive $1.3 million net present value. Translating this cost benefit result into the commonly used cost-effectiveness metric for water supply results in an estimated cost per nominal acre-foot of 165 $/AF. These results suggest that the LPCP currently produces water savings in a fashion that is very cost-competitive with other water resource alternatives. The prospective analysis suggests that this cost effectiveness can be further improved by increasing the program scale. Chapter 6 discusses the additional indirect costs and benefits that were not included in this valuation exercise. For example, the water savings can reasonably be expected to reduce the "urban runoff" often associated with urban landscape irrigation, as confirmed by empirical measurements of urban runoff documented by MWDOC's award winning *Residential Runoff Reduction Study.*

Recommendations

Given the impact evaluation findings of significant and cost-effective water savings, the key focus of the recommendations is ***how to increase the number of water agencies and retail customers participating in the program to make it even more cost effective.*** Increased participation will deliver a higher volume of water savings to Metropolitan,

MWDOC, and water agencies at a lower overall unit cost. Recommendations for increasing participation fall into two categories:

1) ***Expand the number of participating agencies by:***

   a) Opening the program to all Metropolitan member agencies.

   b) Maximizing the number of participating agencies within the MWDOC region.

2) ***Expand the number of program participants by:***

   a) ***Creating a solution for the area measurement problem***-Currently this burden for customers causes many to forgo participation in the program. Stakeholders need to create a short-term solution (staff assistance, sufficiently accurate approximations, etc.) until more consistent and universal solutions (such as aerial or satellite measurement) can be worked out.

   b) ***Resolving data issues that block agency participation***

      i) Some agencies cannot identify dedicated irrigation meters within their territory; and/or

      ii) Agencies are incapable of performing, or leery of attempting to perform, regular monthly data transfers of customer water usage. Overcoming this hurdle may require direct assistance from Metropolitan/MWDOC and/or the assignment of this task as a priority by upper management of the retail agency.

   c) ***Creating a production-based, one-on-one sales and marketing initiative***- Take marketing from an intermittent activity to a standard and continuous component of the program. Program staff resources should be increased to make one-on-one sales/marketing a program priority. Increased investment of resources in marketing is warranted by the value of potential program benefits.

   d) ***Open the program to mixed use meter customers***- Expand beyond the limited universe of dedicated irrigation meter customers to increase the pool of potential participants.

To build on existing program success, each stakeholder has a role to play in continuing to improve overall program performance. Chapter 6 lists more detailed recommendations for each implementation stakeholder—Metropolitan, MWDOC, Retail Agencies, and the Implementation Contractor.

Chapter 1 - Introduction

In the past, attempts to improve large landscape water use efficiency have met with mixed success. Programs targeting landscape water use tread on sensitive ground. Residential landscaping has often been thought of as an integral part of customers' lifestyles and outdoor programs were difficult to implement because they required behavioral change to be successful.

Many retail water agencies have had difficulty identifying large landscape customers in need of the information that targeted conservation programs can provide. Yet other retail water agencies struggle with their billing systems to try to provide near real-time (i.e. monthly) information on water consumption for improved tracking of water management performance.

Also, homeowner associations and property management companies viewed conservation programs as a potential threat to property values. Furthermore, because the tasks of water use management are often contracted out, the incentives to follow through on recommended efficiency improvements remain indirect at best.

This report documents an evaluation of a water conservation program in Orange County California that targeted large landscape water users with dedicated landscape meters—seeking to close the gap between effort (water management) and result (efficient water use.) The Landscape Performance Certification Program (LPCP program) was pioneered by MWDOC with funding assistance from Metropolitan for large landscape customers in Orange County.

This report documents three components of a broad and thorough evaluation of the LPC Program that seek to answers to three different types of questions.

1. **Process Evaluation**—how was the program implemented and what worked and what did not work?
2. **Impact Evaluation**—what were the water savings produced by the program and how cost effective was the effort?
3. **Expectations, Recommendations, and Replication**—how can the program be made more successful? Can the program be replicated by other water agencies, and if so, how easy or difficult will this be?

Study Design

The Landscape Performance Certification Program evaluation documented in this report employs multiple data collection efforts and analytical methods to address each of the questions identified above. Table 1.1 below depicts the connections between the focus, data, and analytical methods.

Table 1.1 - Study Focuses, Data, and Methods

Study Objective	Focus	Data Sources	Analytical Methods
1. Process Evaluation	Program Design and Implementation	• Agency documents • Structured interviews • Contractor/Customer interviews	• Description • Qualitative assessment • Summary
2. Impact Evaluation	Water Savings	• Customer billing records • Weather data	• Descriptive statistics • Statistical modeling
	Cost-Effectiveness	• Program cost estimates • Water savings analysis	• CUWCC Guidelines for Cost-Effectiveness Analyses
3. Recommendations	How to improve the program	• Structured interviews • Customer survey • Water savings analysis • Cost-effectiveness analysis	• All the above

The three main study components used to evaluate the LCP Program were:

- **Structured interviews**. In-person and telephone interviews were held with a broad range of stakeholders—the interviewees included water agency personnel, implementing staff, water customers and irrigation management contractors, green industry professionals, and other interested parties..

- **Water use analysis**. For participating agencies, the research team analyzed historical account-level water use records. Careful data analysis was conducted to compare raw water use before and after implementation of the LPCP program. To control for potential biasing effects—including changing climatic conditions and varying customer characteristics— a sophisticated statistical analysis was conducted. Both the average daily water savings and the seasonal pattern of water savings was formally estimated and graphically depicted.

- **Cost-effectiveness analysis**. Results from the water use analysis and program cost data from the structured interviews were utilized to conduct a cost-effectiveness analysis. The cost-effectiveness analysis focuses on recent participants and examines the prospect question of how the program cost effectiveness is a critical function of program scale. As per CUWCC guidelines on cost-effectiveness, multiple perspectives were considered, including the customer, the retail agency, the wholesale agency service area, and the total society.

Report Overview

The remaining chapters of this report are overviewed below:

Chapter 2 - Program Description describes the LPC Program. It then evaluates the process by which this program was created, implemented, and adapted. This process evaluation includes:

- A discussion of the impetus for creation of the program;
- A description of how the program was initially designed and implemented; and
- A description of how the program evolved and was adapted through the history of the program.

Chapter3 – Impact Evaluation: Estimated Water Savings describes the results of the analysis of historical water use data collected from agency billing systems. The impact analysis documents how the water use patterns of participating customers have changed.

Readers interested in the technical details of data, methods, and complete statistical results should refer to *Appendix A*. Though much of this material is necessarily technical, this appendix takes pains to clearly communicate the problems and processes of a water use impact evaluation.

Chapter 4 – Process Evaluation describes the results of the interviews with program stakeholders—agency staff, customers, and green industry professionals. The process evaluation seeks to identify what worked, what did not work, and what could be improved.

Chapter 5 - Cost-Effectiveness Analysis, identifies and analyzes the costs and benefits of the LPCP program. The analysis conducts a prospective analysis to show how program cost effectiveness changes with the scale of the program. This information is critical to depict the value of program expansion.

Chapter 6 - Recommendations summarizes the findings of the process and impact evaluations. The qualifications and caveats to these findings are documented. Also included are recommendations that target the key impediments to program expansion—customer identification, inclusion of mixed meters, area measurements, and information management hurdles.

Appendix A -- Impact Evaluation: Data, Methods, Statistical Results contains more detailed information related to the data, methods, and statistical results of the impact evaluation. *Appendix B — Interview Protocols* contains the two interview protocols used in the process evaluation for conducting the in-person and telephone interviews.

Chapter 2 - Program Description

Overview

The Municipal Water District of Orange County offers its member agencies a Landscape Performance Certification Program (LPCP) for dedicated irrigation meter customers in an effort to save valuable water supplies and comply with Best Management Practice No. 5 Large Landscape water use efficiency. MWDOC's member agencies can elect to participate at their discretion.

Personnel for the LPCP work with dedicated landscape irrigation meter customers to create water budgets for their landscape areas and teach customers to maintain their schedules over time. Customers are motivated to participate in order to save money through a reduction in their water/sewer bills while MWDOC and its member agencies reduce their need for expensive imported water. Property managers, Homeowner Associations (HOAs), and landscape contractors are the primary targets for participation in the program.

The program receives funding from two primary sources:

- MWDOC
- Metropolitan Water District of Southern California

Additional Program Partners have included:

- Orange County Integrated Waste Management Department
- State Integrated Waste Management Board

Who Participated?

Today the program has 9 of 31 retail water agencies in Orange County on board and operating to serve a collective total of 47 HOA customers equating to 1,489 dedicated irrigation meters. Many of the retail agencies that do not participate feel that they have no immediate and critical need to conserve at this time. As a result conservation is not a priority and many do not have the necessary staff to implement a program such as this.

Other retail agencies that do not participate lack the data billing systems capability needed to identify dedicated meters. Participating agencies are required to submit, on a monthly basis, their customers' dedicated irrigation meter usage. Many non-participating agencies feel that the ability to regularly transfer customer usage data is beyond their capability. This key hurdle must be overcome for the program to be able to reach all of its targeted customers.

Table 2.1 – Participating Retail Agencies

Agency	No. of Dedicated Irrigation Meters	Participant (yes or no)	No. of Active Accounts	% of Active Accounts vs Dedicated Meters
Anaheim, City of	Unknown	*Yes but not currently active	0	Unknown
Brea, City of	184	No	0	0
Buena Park, City of	300	No	0	0
Capistrano Valley Water District	448	Yes	47	9%
East Orange County Water District	0	No	0	0
El Toro Water District	878	Yes	63	7%
Fountain Valley, City of	287	No	0	0
Fullerton, City of	252	No	0	0
Garden Grove, City of	310	No	0	0
Huntington Beach, City of	1026	No	0	0
Irvine Ranch Water District	3856	Yes	187	6%
Laguna Beach Water District	0	No	0	0
La Habra, City of	71	No	0	0
La Palma, City of	35	No	0	0
Mesa Consolidated Water District	853	Yes	184	22%
Moulton Niguel Water District	2299	Yes	189	13%

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Agency	No. of Dedicated Irrigation Meters	Participant (yes or no)	No. of Active Accounts	% of Active Accounts vs Dedicated Meters
Newport Beach, City of	1135	Yes	48	Not available
Orange. City of	671	No	0	0
Orange Park Acres Water Company	0	No	0	0
San Clemente, City of	584	Yes	151	26%
Santa Ana, City of	375	No	0	0
Santa Margarita Water District	1712	Yes	558	33%
Santiago County Water District	0	No	0	0
Seal Beach, City of	0	No	0	0
Serrano Water District	0	No	0	0
South Coast Water District	494	Yes	62	22%
Southern California Water Company	0	No	0	0
Trabuco Canyon Water District	128	No	0	0
Tustin	193	No	0	0
Westminster	181	No	0	0
Yorba Linda Water District	692	No	0	0
	16964		**1489**	**9%**

Table 2.2 - Summary of Activation Levels

Agency	Date of Activation	Activated as of 12/31/01	Activated as of 4/30/02	Activated as of 8/31/02	Activated as of 12/31/02	Activated as of 4/30/02	Activated as of 8/31/03	Total
Capistrano Valley Water District	11/01/01	42	0	1	4	0	0	47
El Toro Water District	11/15/02	0	0	0	2	51	10	63
Irvine Ranch Water District	11/1/01	80	22	20	32	5	28	187
Mesa Consolidated Water District	4/15/02	4	2	109	0	30	39	184
Moulton Niguel Water District	11/1/01	161	14	6	0	2	6	189
Newport Beach	11/15/02	9	38	0	1	0	0	48
Santa Margarita Water District	11/1/01	333	1	20	17	0	187	558
San Clemente	5/15/02	0	7	31	28	39	46	151
South Coast Water District	2/15/03	0	0	0	0	62	0	62
Total		**629**	**84**	**187**	**84**	**189**	**316**	**1489**

Marketing

Industry professionals look at customer response as one of the key indicators of a program's viability. The response to this program hovers at a low level of successful activation; with participation from 1,489 meters of the estimated 17,000 dedicated irrigation meters available in MWDOC territory. This equates to an 8.7% response rate within the nine agency territory. The program has had phases where there were marketing pushes and large clusters of customers were brought on board the program. At other times, little to no marketing was performed relying solely on word of mouth and the addition of new program participants dropped to low levels.

Over the past several years, the program has relied heavily upon two outreach methods to solicit participation:

1. Letter mailing campaigns
2. One-on-one presentations
3. Workshops

Customers with existing site measurement data respond favorably to program solicitations via letter campaigns. When program solicitation letters were sent to Santa Margarita customers they found high customer receptivity. The reason for the high response – customers were drawn in by personalized information contained within the letter. The data included in the letter makes the offer credible to the customer.

The problem lies in that this group is only a small portion of the dedicated irrigation meter customer population. Generic letters sent to other customers failed to solicit a meaningful response. Additionally, the letter campaigns often reach the property management firms instead of the primary decision maker; the Homeowner Associations (HOAs) and property owners. With less direct tie-in to the payment of the water bill, the property management firms generally were generally less responsive than the HOAs.

The most persuasive of three outreach methods was the one-on-one presentations. The program offer is complex and this forum allows for full exchange of program information and benefits. Customers can ask and have questions answered about participation and water savings. Many customers interviewed stated that they signed up because of one-on-one presentations. These have been the highest response category by far, but the number of overall presentations has been minimal and sporadic.

Training Workshops

All customers or their representatives must attend a training session in order to become certified for program participation. Technical training sessions are designed to help both the landscape contractor and the property manager to:

- Manage sites efficiently
- Explain evapotranspiration and water budgets
- Review runoff and its implications
- Demonstrate the website and reports
- Learn how to market water use efficiency to prospective customers
- Learn how to incorporate water and green waste efficiency into standard business practices for business retention, new business services and/or increasing business profits

The information is unavailable as to how many training sessions occurred under the initial contractor, CTSI. Seven workshops were conducted by ConserVision in 2002. The balance of customers now attends the Protector Del Aqua (PDA) training offered through Metropolitan. Metropolitan does not pass along the cost of PDA to MWDOC. By routing customers through the PDA program, dollars can be spent in areas other than technical training.

Landscape Performance Certification Program Workshops

Date	Place	Companies Attending	No. of Attendants	Presenters
5/24/2002	El Toro WD	8	16	Ash, Sánchez, Berg
3/22/2002	IRWD	27	60	Ash, Sánchez, Berg
4/4/2002	Santa Margarita WD	6	7	Sánchez, Berg
4/18/2002	City of San Clemente Offices	2	6	Sánchez
6/6/2002	San Clemente City Hall	16	19	Ash, Sánchez

Landscape Performance Certification Program Workshops

11/13/2002	City of Orange	17	41	Ash, Sánchez
11/26/2002	City of Huntington Beach	6	16	Ash, Sánchez
	Total	82	165	

At this time the total number of trainees that have become program participants is unknown due to missing data from the early days of the program when records of this nature were not maintained.

Site Measurement Process

One of the key topics of discussion regarding this program is the difficulty of obtaining timely and accurate site measurement data. This data is used to establish the baseline water budget utilized throughout the program. The process of gathering the data requires the customer to walk the property, measure the landscape area and identify plant type valve- by -valve to establish the total area measurement for each meter.

Customers are given data collection forms and training during the technical training session. They are solely responsible for completing the forms and returning the information to ConserVision. This task is an obstacle for the customer and the program, causing time delays and lack of participation.

Copies of the site measurement forms are available as an attachment.

Customer Reports and Website

During the second phase of the program, one of the primary activities was to create a reliable internet based tool to allow simultaneous and timely assess to program data for landscape contractors, property managers and owners. It also eliminated an unwieldy volume of faxing.

ConserVision designed and implemented the website. Estimated development costs were $170,000 for completion of the website as it exists today. As with database and website development there were glitches, though minor in nature. The system is now stable, user

friendly and well received by customers. In the chart below is an example of a typical customer report available on the website. Should this program roll out to other water agencies areas outside of MWDOC's territory, these agencies could consider utilizing the MWDOC website developed by ConserVision instead of attempting to recreate it. The website would be available to other water agencies at no charge because it was developed with public funds

Customers are sent a monthly e-mail notification letting them know their reports are available for preview on the website. This e-mail notification also includes a program newsletter containing seasonally appropriate landscape maintenance suggestions. Copies of newsletters are provided as an attachment. When interviewed, customers stated they were generally satisfied with the website and reports. Their only recommendations would be to change the sender of the e-mail from ConserVision to the local water agency's name and to better label some of the column headings.

Account:	237685	**Area:**	35,719
Meter:	001377943	**% Turf:**	5%
Site Name:	Vista Norte	**Meter Type:**	Dedicated
Agency:	Santa Margarita WD	**Microclimate:**	Foothill
Landscaper:	W. B. Starr, Inc.	**Grass cycling:**	No
Property Mgr.:	Merit Property Mgmt. Inc.	**Mulch:**	Yes
HOA:	Vista Norte	**Divert/Recycle:**	Yes
Waste Hauler:	Not Available	**Controller Type:**	Real Time

The certification process was designed to provide motivation for a customer, both property managers and landscape contractors, to attain a desirable performance status ranking of bronze, silver or gold. The intent of the certification aspect of the program is to give companies that manage their sites with a high level of water use efficiency recognition and prestige coupled with a competitive business advantage over non-participants.

Certification is based on 1) collecting appropriate site data, 2) monthly performance of efficient water use and 3) green waste management. The more efficiency achieved at the customer site, the higher the performance status ranking. The list of certified companies is posted on MWDOC web site and is continually updated. Additionally, these top performing customers are listed in local newspapers each year.
Described below are descriptions of the three performance status ranks:

Level 1 Certification: (Bronze)

- Data collected and received on sites managed in Orange County
- Attend scheduled training classes
- Up to 50% of sites meet 100% water budget
- Use mulch onsite

Level 2 Certification: (Silver)

- Data collected and received on sites managed in Orange County
- Attend scheduled training sessions
- Up to 75% of sites meet 100% water budget
- Use mulch onsite

Level 3 Certification: (Gold)

- Data collected and received on sites managed in Orange County
- Attend scheduled training sessions
- *More than* 75% of sites meet 100% water budget
- Use mulch and divert other green waste to recycling or composting facility

At this stage in the program, no customer has moved beyond the Bronze Level. During the customer interviews, only one customer stated that it was leveraging its certification status and using it in business marketing materials. Other customers never raised the certification as a program benefit. In order to make performance certification more meaningful, focus needs to be given to a more well-developed advertising campaign along with a strategy to move customers to the silver and gold levels.

Program Evolution

The evolution of the Landscape Performance Certification Program spans four distinct phases. Phase I required the development of a landscape curriculum, program materials and training; Phase II initiated the development of databases, Internet capabilities and the inception of a focused outreach program; Phase III aimed to expand participation to those customers who would most benefit from the Landscape Certification Program. In Phase IV, which is currently underway, additional funding was secured to allow Program implementation to continue and to evaluate the program's effectiveness.

Historical Background

In 1991, the District became a signatory to the Memorandum of Understanding (MOU) Regarding Best Management Practices (BMP) for Urban Conservation in California. BMP 5 targets large landscape water-use efficiency and requires the implementation of water budgets and performance reporting for dedicated irrigation meters. BMP 10 includes provisions for wholesale agencies, such as MWDOC and Metropolitan, to assist their retail agencies with implementation of the MOU.

The Landscape Performance Certification Program was conceived in order to implement BMP 5 throughout Orange County. This regional implementation approach would not only offer a consistent program to the public but would encourage the development of higher quality materials, programs and systems. Agencies would pool their efforts in order to achieve economies of scale.

In the mid 1990s, MWDOC, Metropolitan and Moulton Niguel Water District conducted a landscape area measurement study to evaluate the accuracy and cost of four landscape area measurement methodologies. The objective was to determine the most appropriate methodology for use in the development of Landscape Irrigation Budgets (LIBs), which are generated based upon the irrigated area served by a dedicated landscape water meter,

the various plant materials irrigated and the local climate. LIBs fluctuate monthly as the weather changes.

Area measurement methodologies evaluated included the following: aerial photography and GIS-based parcel boundary overlays; parcel data; mail-out surveys; and on-site measurement.

The study revealed both aerial photography and on-site measurement methods were highly accurate, but also expensive when performed by the water agency. The parcel data approach was deemed unacceptable due to incomplete data. The mail-out survey method was reasonably accurate when performed by a landscape contractor and relatively inexpensive, but suffered from inaccuracies when performed by homeowners. As a result of this study, area measurements performed by landscape contractors became the basis of the LPCP.

Phase I (March 1999-March 2000): Landscape Conservation Curriculum

In March of 1999, the Landscape Performance Certification Pilot Program was initiated. Education materials were developed and workshops conducted. A comprehensive irrigation management-training program was developed independently and went beyond the scope of the existing *Protector del Aqua* program to train landscape contractors. The newly developed program materials included the following:

- Irrigation management principles;
- Irrigation technologies;
- Area measurement and data collection;
- Water budget calculations.

Early reporting methodology relied on a hands-on approach. The program vendor collected names and fax numbers and manually calculated water budgets. Fax numbers were used to communicate reports to participating customers. This early phase also

included the development of effective data collection forms, which would eventually be incorporated into a database.

"Certification" consisted of attending workshops, which were organized and presented to participants with detailed information on budgets, landscape horticulture and irrigation methods. The Program team educated customers on the costs of over-watering and under-watering. The level of detail presented in the workshops was appropriate for some participants while overwhelming for others who needed basic, practical information. The Program team developed and used a training manual with steps to calculate a water budget and manage landscape sites. A copy of this training manual is available upon request.

Later in Phase I, measurement data collection increased rapidly after area measurement data was determined to exist in the billing system databases of Santa Margarita and Moulten Niguel water districts. These area measurements were developed during the housing development process for reclaimed water supply and distribution system planning purposes.

In addition, during this time, the program received a grant from the state and county Integrated Waste Management Boards to combine efforts in the area of managing green waste to meet the Integrated Waste Management Act (AB939) waste reduction goals. Data collection efforts were combined for the added capability to assess mulching and grass cycling practices.

Phase II (April 2000 –March 2001): Information Technology

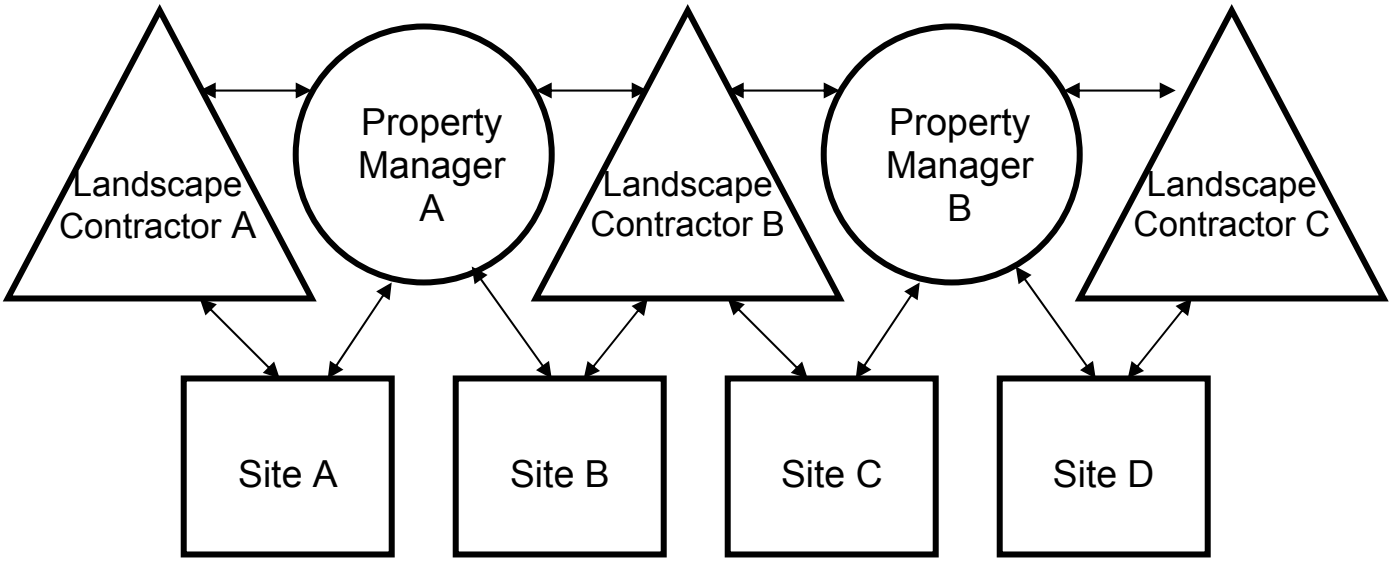
As the number of participants in the Program increased during Phase II, the method of faxing budget reports proved inefficient. As a result, project contractors developed an internet-based tool in order to allow access to program data and to expand database

capabilities. Although the data system was now available on-line, budget reports were still faxed. However, once e-mail capability was established, participants received notification via e-mail and obtained their landscape budget information from the website.

Phase II also marked the development of the Program's website, which contained large amounts of poor quality data and insufficient contact information. Hence, much of the effort in Phase II focused on transforming the data system and website into efficient tools. Efforts were made to increase the amount of contact information related to the meters in the database. Much of the data initially input into the database was later deemed to have questionable reliability

In addition to Internet capabilities, a "loop of accountability" was developed to promote the effective use of data and water budgets (See Figure 2.1). The concept consists of contacts between landscape contractors, property owners, and property managers. Emails would be sent to all three groups to foster communication and interaction. This allowed all the players involved to view the same report and information at the same time.

Figure 2.1: Loop of Accountability



During this phase, the notion of participant "activation" developed into two forms. First, activation meant that all data were obtained for the customer, including contact information and meter numbers. Second, full "activation" occurred when the water agency's consumption data was acquired for those meters. Once activation was completed, the loop of accountability became effective and all groups shared the same information.

Presentations and outreach continued during Phase II. Tom Ash continued to give talks and disseminated flyers and site data forms. The presentations were given directly to homeowners associations, landscaper maintenance contractors, city landscape maintenance staff and the County's Harbors, Beaches and Parks staff.

Phase II ended abruptly when the Program's vendor declared bankruptcy.

Program Hiatus (April 2001 – December 2001)

During the program hiatus, the program was maintained at a minimal level of operation until a new Program vendor could be selected. ConserVision was signed on as the replacement program vendor in December 2001.

Phase III (December 2001-March 2003): Marketing the Program

With a new program vendor under contract, marketing efforts for the Landscape Performance Certification Program resumed and were refocused. Workshops were redesigned to be more succinct and concise for practical implementation and limited to two-four hours. They were also conducted countywide to make the program more accessible. The program also continued to expand its outreach to include property managers, HOA board members and other landscape decision makers. Efforts were focused to bring together these groups and to obtain their contact information for future follow up. The program worked more actively and directly with water districts.

Phase III saw the development of greater electronic capabilities. More data could now be transferred electronically to databases, spreadsheets, and PDF files. For example, irrigated area data exists for three or four agencies. The program was (and continues) making an effort to obtain these data, merge them with mail records and send out customized notices to these potential participants, thereby facilitating program signup more efficiently. This process was completed with Santa Margarita Water District and continues to be worked on with other water agencies. All the customer is required to do is sign up. The customer incurs no participation charge. However, this process can take several months as the notices are first sent to the HOA board of directors care of the property management company for discussion and a vote at the regular Board meetings. Thus far, responses from HOAs have been positive.

Although occasionally the acreage data is unreliable, the performance focus is on the pattern of irrigation changes over the course of a year versus total irrigation. For cases in which the measurement is systematically too high or low, the changing patterns still demonstrate whether timers are being adequately adjusted.

Not all water districts within Orange County that want to participate have the data billing system capabilities needed to identify dedicated meters. In such cases, the program was (and continues) making efforts to collect contact information and dedicated meter number information from the customer before requesting consumption data from these districts. Although this involves more effort, the acceptance rate is significantly high when compared to mass mailings.

Phase IV (April 2003 – present): Program Implementation and Evaluation

Additional funding was secured to allow Program implementation to continue until March 31, 2004. In addition, an evaluation of the program's effectiveness by A & N Technical, Services, Inc., is currently underway.

Chapter 3 - Impact Evaluation: Estimated Water Savings

A Model Based Definition of Water Savings

Appendix A documents a careful statistical analysis of historical water consumption data to derive estimates of the net water savings from this program. The "net" water savings is the estimate of how much *more* participating customers saved than nonparticipants. The reader should note that this is a different construct than some estimate of "gross" water savings—the total amount of water saved. The water use analysis derived its estimate of net water savings by estimating water savings among 393 early participants (Phases I and II) and 498 later participants (Phases III and IV) defined relative to 5381 nonparticipating customers. The explanatory variables in these models include:

- The seasonal shape of demand
- Weather conditions
- Measures of air temperature
- Meter-specific mean water consumption per billing period
- "Intervention" measures of the date of participation and the program phase

Data and Methods

Of the 1465 activated meters (661 early participants and 804 later participants) approximately 144 accounts were excluded from the sample based upon prior participation in other landscape conservation programs such as computer controlled irrigation system retrofits and weather based irrigation timer retrofits. Accounts could also be excluded if the consumption records were of insufficient length or quality. Thus, meter reads containing a negative number of days in the meter read or more than 120 days were omitted. To keep other data inconsistencies from corrupting statistical estimates of model parameters, this modeling effort employed a sophisticated range of

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outlier-detection methods and models. Appendix A documents the technical background on the data and methods used to estimate the landscape customer water demand model. Table A.1 of Appendix A presents the descriptive statistics of the sample used for modeling.

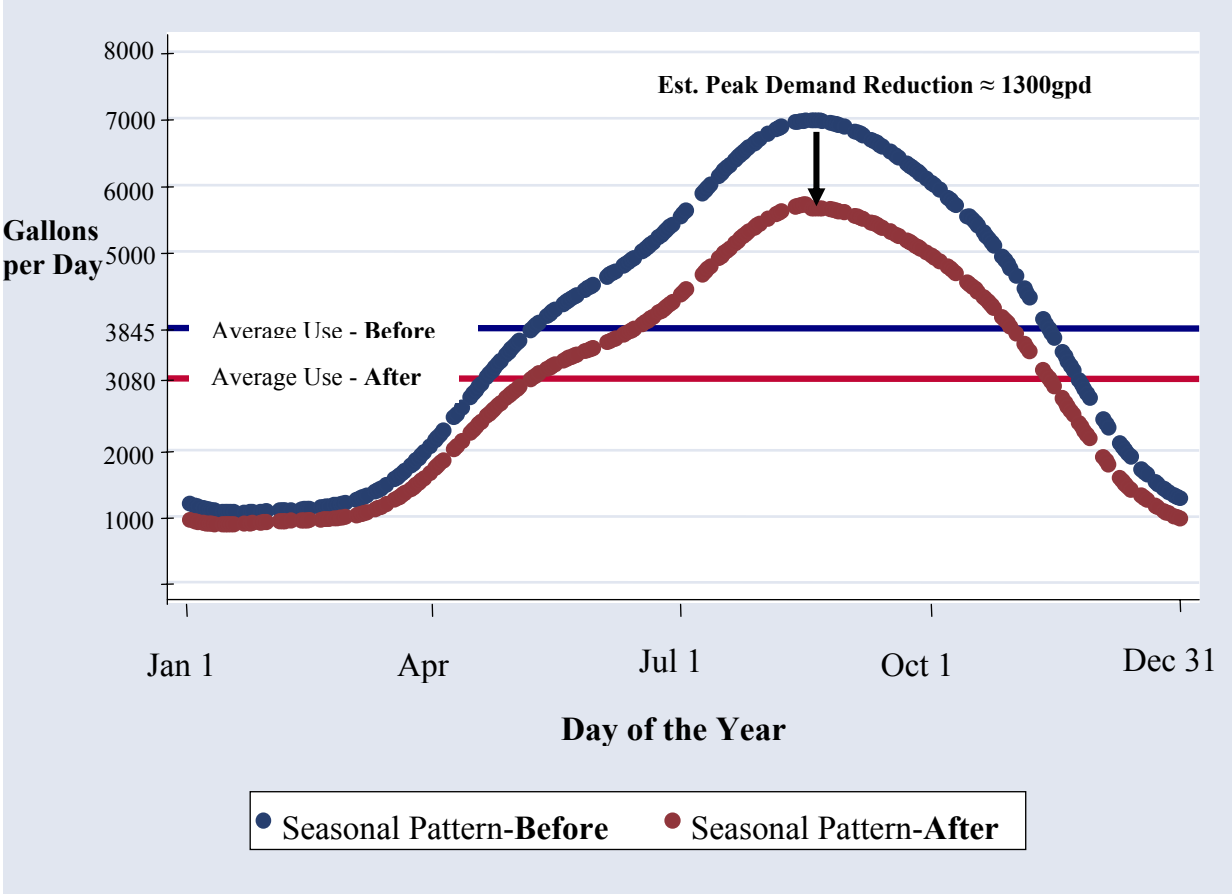
Estimated Average Water Savings

The estimated parameter for average water savings among Phase III and IV participants implied a mean change in water consumption of -765 gallons per day (-540 gpd to -991 gpd bound the 95 percent confidence interval)., approximately 20 percent of the pre-intervention water use. The parameter for Phase I and II participants implied a mean change in water consumption of -367 gallons per day (-251 gpd to -512 gpd bound the 95 percent confidence level), approximately 9 percent of mean water use. The reader is urged to note that these results summarize the findings that can be inferred within the sample of customers analyzed. The same program, implemented in other water agencies or areas, may produce different levels of water savings. For example, inland water agencies or water agencies with a lower retail water rate could experience higher net water savings. Contrariwise, coastal water agencies or water agencies with a higher retail water rate could experience lower net water savings. Your mileage may vary.

How Program Participation Affects Peak Demand

The estimated water demand model in Appendix A was also used to infer the seasonal shape of demand before and after participation in the Landscape Performance Certification Program. Figure 1, on the following page, graphically depicts the change in water demand for recent participating customers (Phases III and IV).

Figure 3.1 Load Shaping Effect of Performance Certification on Large Landscape Demand



For the consumption data within our sample, the water savings were not constant. The Landscape Performance Certification Program saved considerably more water in the peak summer period, about 1307 gallons per day (18.7%) of the maximum day demand (August 18th within the observed sample).

Caveats and Conclusions

This modeling effort focused on developing the best depiction of net changes in water consumption due to participation in the Landscape Performance Certification Program. The empirical effort has quantified the change in mean water consumption and the shift

in seasonal consumption. The models have not been extended to document how water savings vary across customers.

- How do savings change across customers of lower or higher water use?
- How do water savings vary as a function of landscape area?
- Since the sample only contains limited post participation data, the statistical models can say little about the persistence of water savings.
- The error component of the estimated models could be improved by specifying a function form to explain the variance.

Customers participating in these programs saved significant amounts of water. Participation in the program changed both the level and shape of water demand.

Chapter 4 - Process Evaluation: Implementation Assessment

The impact evaluation seeks to measure the program impacts—in this case the net water savings produced by the Landscape Performance Certification Program (LPCP). The process evaluation of this chapter seeks to define *how* the LPCP produced its impacts. In order to increase the benefits produced by the LPCP, one needs to understand these processes, define what works, and point to areas that need improvement.

Process Evaluation - How did the Program Succeed or Fail?

A summary measure of a program's success or a failure is its cost effectiveness. However to improve a program's overall value, the program design and operation must be thoroughly analyzed. Key performance indicators for this program are summarized in *Table 4.1 – Performance Indicators* on the following page.

The key methods of this process evaluation—an assessment of program processes, review of the program website and reports, and interviews with key stakeholders—there were clear indications regarding successes and weaknesses in the program. As with many qualitative projects, the reader is cautioned that these findings are subject to limitations. The relatively small sample of individuals interviewed was necessarily nonrandom. The interview method sought to exhaust the population of potential respondents. Snowball sampling methods were also employed—"Who else could speak knowledgably about this program?" Even with a small sample size of interviewees, program strengths and areas of opportunity were consistently identified with surprising regularity.

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Table 4.1 – Performance Indicators:

Agency Participation:	*How do the agencies perceive the program? Why did an agency choose to participate? What is the reason for other agencies to forego participation? What would cause these agencies to change their decision?*
Customer Participation:	*Is the marketing effort effective at attracting customers to participate? How was the customer approached and what motivated it to participate? Why did other targeted customers fail to enroll?*
Customer Services and Ease of Process:	*Is it easy for customers to get started with the program? How demanding is it for them to participate over time? Do they like the design of the program and the web services? What caused some customers to drop out of the program?*
Transferability of the Program:	*Can this program be easily replicated by other non-MWDOC water agencies? What are the major hurdles to overcome? What types of costs must these agencies budget? Does the program have value to the industry?*

The research team developed several quantitative and qualitative methods to assess these performance indicators. These include the following methods and tasks:

1. Created questionnaires for each stakeholder: water agency, participating customer and non-participants
2. Conducted telephone interviews with each stakeholder
3. Reviewed customer reports, program web site, progress reports, and marketing pieces
4. Summarized and assessed results
5. Identified major program issues and developed recommendations

Interview Results by Stakeholder Category

Interviews were conducted in order to obtain each stakeholder's overall perception of the program. Stakeholders were queried about ease of process, reasons for participation, value of the program to them, and aspects of the program they would like to see improved. Prior to conducting interviews an interview protocol was developed to

improve consistency across interviews. One of the questions asked of all interviewees was a general question… "How would you rank the program on a scale of 1 – 10 with 10 being the highest?" Though the response to this question reflects the subjective assessments of the interviewees, a summary of their responses is provided to convey differences in responses across interviewee types. (Copies of the questionnaires have been provided to the sponsors.)

Although the sample size in each category is small attitudes and recommendations tracked consistently forming strong conclusions. Described below are summary results of the interviews broken out by stakeholder category.

Metropolitan

Metropolitan has been funding the program year after year without a precise sense of the actual water savings. As a result, Metropolitan has been hesitant to fully support the program let alone endorse an expansion plan. This evaluation is considered critical to determine the cost effectiveness of the LPCP. Since this study includes a defensible savings analysis that shows considerable savings, this missing information hurdle has been addressed to permit Metropolitan's Board of Directors to make sound decisions regarding future funding. Below are highlights from the interviews with Metropolitan staff.

2 Interviews Conducted
Overall Rating: **5**

Pros	Cons
▪ Water budgets are helpful tools to improve water efficiency and landscape health	▪ Was not sure if it was cost effective
▪ Gets information simultaneously to all stakeholders; HOAs, property managers and landscape contractors on a timely (monthly) basis	▪ Level of service (web site, monthly e-mails) may come at too high a cost…might be able to get same results with less service and less cost.
▪ Program is meeting the objective of water budgets and BMP 5	▪ Volume of customers is too low

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Pros	Cons
	▪ Not enough one-on-one marketing ▪ Haven't been able to get any contractors out of bronze certification ▪ Certification process has not created the competitive market it was intended to create

MWDOC

1 Interview Conducted
Overall Rating: **8**

MWDOC strongly supports this program and believes that the program will evolve into a highly valuable foundation for future landscape initiatives. Below is an assessment of the program from MWDOC's perspective:

Pros	Cons
▪ Program created "loop of accountability" for all three parties: HOA's, property managers, and landscape contractors	▪ Needs more one-on-one marketing to HOA boards
▪ Regional design provides for best quality	▪ Cost and difficulty of getting accurate area measurements
▪ Service level and program design is right	▪ Needs additional promotion of certified companies
▪ Believes water budgets are required as a foundation of all landscape programs. Program educates customers on the "bell shaped curve" for landscape irrigation	▪ Needs landscape and irrigation performance based contract language for customers to use
▪ Program can meet objective of BMP 5	
▪ Good education platform of watershed management	

Participating Water Agencies

5 Interviews Conducted
Overall Rating: **7.7**

The participating water agencies are highly supportive of the program. They participated because of the regional design, to meet BMP #5, and because of the potential water savings. They especially like the regional design because without the support of MWDOC and Metropolitan they would be unable to provide this program to their customers. They believe that the retail agencies and MWDOC receive excellent public relations in that the customer is given a valuable service and all parties are saving water. Below is a snapshot of participating water agencies' feedback:

Pros	Cons
▪ The program design is on target	▪ Want more marketing
▪ Like it because once it's in place, it's automatic	▪ Customers having to get area measurements on their own is a barrier to participation
▪ Access to data on the web for all parties	▪ Getting customer data to contractor (ConserVision) on a consistent basis has been difficult
▪ Like regional design	▪ There is no regular assessment of landscape contractor's performance
▪ Like that program certification specifically recognizes landscape contractors' performance "without recommending" contractors	▪ Want more summary information on number of customers over budget
	▪ Want more consistent program meetings to sustain program momentum

Non-participating Water Agencies

3 Interviews Conducted
Overall Rating: **8**

Initially these water agencies had a strong desire to participate but lost their enthusiasm as program barriers and operational interruptions occurred. They like it in theory and would participate if program barriers were removed. Below are interview findings:

Pros	Cons
▪ Like it in theory	▪ Don't have many dedicated irrigation meters ▪ Can't get data out of billing system ▪ Not sure if it saves water

Customers: HOAs

4 Interviews Conducted
Overall Rating: **7.25**

With the water bill as their second largest line item, the HOAs elected to participate in order to save money. All interviewees heard about LPCP through one-on-one contact. All stated their water bills had gone down. Two of the four interviewees planned to overhaul their landscape and irrigation systems to further maximize water savings. They found the site measurement process cumbersome; however, all other aspects of the program are user-friendly. Below are summary findings from HOA interviews:

Pros	Cons
▪ Water bill has gone down significantly ▪ Finds program invaluable	▪ Area measurement data gathering is burdensome and most customers won't do it ▪ Took a while to educate everyone on HOA board

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- Came up with three year plan to make landscape changes (1 customer)
- Web site is easy
- Everyone has access to information
- Wants more tangible (installation) programs

Customers: Property Managers

6 Interviews Conducted
Overall Rating: **8.3**

Property managers gave the program an overall high rating. They participated to save money and show their HOA client an ability to better manage the HOAs water usage. A couple of the interviewees led the participation process and directed their HOA clients to the program. Three property managers stated that the program information aided them in their request to the client for landscape improvements. All respondents heard about program through one-on-one contact. Below are highlights of property manager interviews:

Pros	Cons
▪ Used information to justify landscape and irrigation improvements (3 customers)	▪ Obtaining area measurements is costly and cumbersome
▪ Saved water and money	▪ Data can be intimidating to landscapers
▪ Used certification list to hire landscape contractor	

Landscape Contractors

5 Interviews Conducted
Overall Rating: **8.5**

Three of the five interviewees were landscape contractors with a higher than average level of landscape design and water efficiency knowledge. They personally championed participation in the program. Many felt that obtaining area measurements was a costly and time-consuming process. From the interviews it was unclear how often monthly reports reached the field worker. Again all

respondents heard about the program through one-on-one contact. Below is a summary of the Landscape Contractor interviews:

Pros	Cons
▪ Likes it because once it's in place, its automatic	▪ Obtaining area measurements is a problem
▪ Helps clients	▪ We were already irrigation and ET experts
▪ Boost image	
▪ Provides budget which should be the first thing you do otherwise it's like an open checkbook	

Customers: Non-participants

3 Interviews Conducted

The non-participants interviewed reacted favorably when the program was explained to them. They felt the services were valuable however they would not pay for these services if this were a requirement of the program. The interviewees stated they had the means to conduct the site measurements, but it was cost prohibitive. It appears this measurement constraint, coupled with the lack of a direct marketing approach are major obstacles to participation.

Pros	Cons
▪ Likes program	▪ Didn't know about program
▪ Would use reports	▪ Sort of understand program
	▪ Not willing to pay

What's Working?

The Water Budget

The water budget was intended to:

1. Educate customers about the irrigation "bell curve" seasonal pattern of water need
2. Show them where they presently are on this curve
3. On a monthly basis influence them to operate at the appropriate point on the curve
4. Save significant water for both the customer and the water agency

The water budgeting process is soundly meeting its intended purpose. Customers have seen a large reduction in their water bills and are pleased with the monetary savings. Customers are not only using this information to save water today, but are utilizing this as a resource tool for future landscape planning. As a direct result of this program, several customers stated they have plans in place to retrofit their entire landscapes and irrigation systems to further optimize efficiency. The program is truly changing customers' attitudes and actions.

Program Operation

The program operates smoothly and the participating customers give the program overall high ratings. Customers state that the website and the reports are easy to access, straightforward and contain valuable information

Loop of Accountability

Typically, landscape programs struggle to get the HOA, the property management company, and the landscape contractors working together to oversee landscape maintenance in a water efficient manner. The Landscape Performance Certification Program effectively pulls the 3 stakeholders into the process and creates a "loop of accountability."

This is achieved by the inclusion of all three parties in the marketing, training, certification, and water budgeting process. More importantly, all three parties are given

access to the monthly irrigation performance reports. The program strives to position the property owners as the drivers since they pay the water bills and have the ultimate authority over the property managers and landscape contractors.

Despite the strengths of the overall program process and the loop of accountability the program creates, there are several impediments, hurdles and barriers affecting the overall quality of the program.

Agency Data Limitations

Unfortunately, data limitations have removed a number of agencies from participating in the program. The data issues fall into three categories:

1. Several water agencies in north Orange County have very small numbers of dedicated irrigation meters. Due to their large number of non-dedicated, mixed use meters, these agencies find the program less attractive despite a high number of large landscape sites.
2. A number of agencies cannot locate existing dedicated irrigation meters within their agency's information systems, again making access to the program more difficult.
3. The most far reaching data issue is the ability for an agency to automatically run monthly data transfers of customer usage data to ConserVision. Some agencies with older billing systems forgo the program because of this problem.

Site Measurement Data

A major stumbling block to participation is the task of gathering site measurement data. Presently this responsibility lies solely with the customer. Typically, customers simply do not have the time or resources to initiate the data gathering process. As a result, the data is often wrong or the customer elects not to participate.

Current Marketing Strategy

Over the past several of years, the program has relied heavily upon letter mailing campaigns and word of mouth to solicit participation. This current marketing approach is not enough to bring in the desired volume of customers for the participating water agencies.

Advertising Frequency of Top Performing Customers

The program advertises the names of the most water efficient customers, the Bronze Level customers, once a year. This inexpensive marketing vehicle needs to be increased dramatically in order to heighten program awareness and provide better motivation to strive for the bronze, silver, or gold medal status.

These top-performing customers should be printed in the local papers on a monthly basis with highlight stories placed on an alternating basis for various companies including HOAs, property management firms and landscape contractors.

Top Customer Performance Stuck at Bronze Level

The bronze, silver, gold certification program is intended to create incentives for customers to reach for higher efficiency and, hence achieve a more prestigious medal ranking. To date, without one customer earning higher than a bronze rating, the rating system fails to drive performance higher. Program staff needs to work with clients and aid them in achieving higher certification levels. Once there are customers in the higher performance silver and gold levels, the certification program will provide better motivation for the overall pool of participating customers.

Additional Benefits

The Landscape Performance Certification Program comes at the beginning of our industry's landscape efficiency evolution. Its true economic value will not be known for some years to come because too many other landscape efficiency solutions have yet to be developed. Dedicated irrigation meters; internal data issues; weather sensitive controllers; and plant retrofit programs are all in the early stages of implementation at this time. This program will become one step in a series of actions (equipment upgrades, plant upgrades and behavioral change) that will finally allow the industry to effectively deal with the elusive customer landscape and irrigation market. When this occurs, the cost effectiveness of this customer education program will increase because the bundled

services will show significant and cost effective savings for the customer and water agencies.

Weather Sensitive Controllers

When Weather Sensitive Controller technology becomes available via rebate and grant programs for mass the market, the Landscape Performance Certification Program is a good gateway to controller installations. This sister program relationship could help to defray the cost burden of both programs (landscape performance certification and controller distribution) by providing shared overheads and reduced marketing expenses. An additional benefit of a sister program is that the water savings from the Weather Sensitive Controllers will be higher than if the Weather Sensitive Controllers were offered as a stand alone program with minimal customer education.

Run-off/Non-point Source Pollution Reduction

Run-off or non-point source pollution has recently become a heightened environmental issue. Improving the efficiency of outdoor irrigation often results in significantly less water running off landscapes and down through the storm drains. As this environmental issue escalates in importance, this program can provide more value to additional parties. Cities are now required to police non-point source pollution and could become potential funding and marketing partners.

Chapter 5 - Cost-Effectiveness Analysis: Retrospective and Prospective

Introduction

The impact evaluation of Chapter 3 empirically estimated the additional water savings attributable to participation in the LPCP. The magnitude of net water savings was statistically and practically significant. Further, the process evaluation of Chapter 4 documented the generally positive response to the program. This chapter systematically compares the costs of the program to its benefits—this can help determine whether the program makes sense to implement from an economic point of view.

The economic methods used in this chapter include standard methods of cost-benefit and cost-effective analysis.[1] With cost-effectiveness analysis, the focus of the analysis is on estimating the cost of the program per volumetric unit of savings. This is also known as the "unit cost" of the program and will be denominated in dollars per acre foot ($/AF). This metric allows comparison of the cost-effectiveness of the LPCP program to the cost-effectiveness of other conservation programs. With cost-benefit analysis, the costs of the program (in dollars) are compared to the benefits of the program (water savings and other benefits measured in dollars). The cost-benefit analysis expresses its results in net present value (NPV) terms--the present value of benefits minus the present value of costs.

Both NPV and cost per acre-foot are calculated in this chapter for both retrospective and prospective analyses. The *retrospective* analysis looks back at the costs already incurred and at the stream of benefits that will result from this expenditure. In this way, the retrospective analysis supports the body of this document in its primary role in program evaluation.

[1] See, for example, Pekelney, D. and T. Chesnutt, *A Guide to Data and Methods for Cost-Effectiveness Analyses of Urban Water Conservation Best Management Practices*, A report for the California Urban Water Conservation Council, March 1999

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In contrast, the *prospective* analysis looks forward to ask questions such as: "Will the program be cost effective moving forward?" "How can the cost effectiveness be extended or improved?" The prospective economic analysis supports the secondary role in this study by estimating the costs and benefits of the recommendations, including ongoing program support.

Savings

Table 5.1 summarizes the estimated average water savings determined from the sample of meters analyzed in Chapter 3. Each of the early participants averaged 365 gallons per day (gpd) savings or .41 acre-feet per year (AFY) equivalently. Summing across the entire sample of 393 early participants, total annual net savings are 161 AF. For the 498 later participants, the net water savings total 427 AFY based on the average daily savings of 765 gpd. The table also reports the average peak savings for the later participants.

Table 5.1 - Sample Water Savings

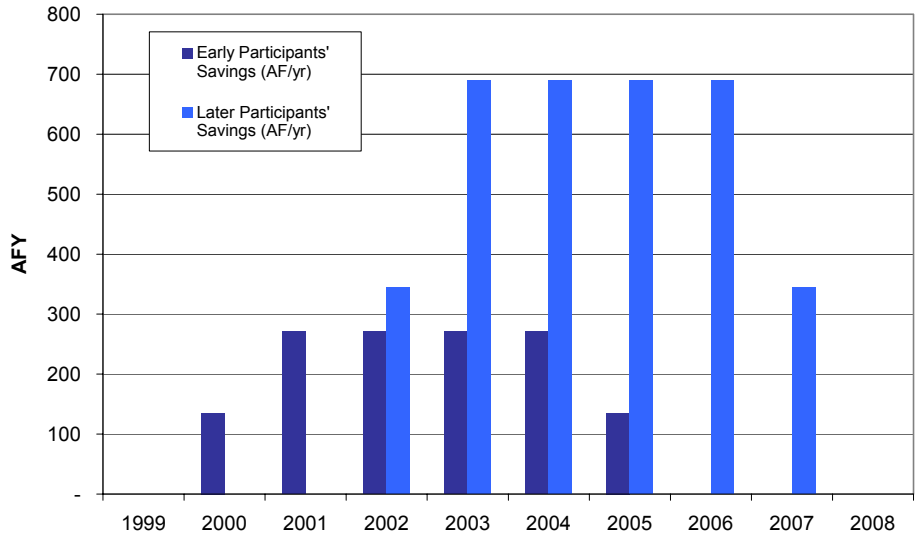
Statistical Sample	Sample Size (n)	Average Savings per Meter (gpd)	Annual Savings per Meter (AFY)	Sample Annual Savings (AFY)	Average Peak Savings (gpd)	Sample Peak Savings (cfs)
Early Participants	393	365	0.41	161		
Later Participants	498	765	0.86	427	1,300	1.00
Total	891			588		

Table 5.2 shows the net water savings for the whole population of participating meters, if all participants share the average water savings observed within the sample. Thus, the total program savings is estimated as 960 AFY. Peak savings are 1,300 gpd per meter, which is equivalent to 1.62 cubic feet per second (or 1.05 million gallons per day) peak capacity.

Table 5.2 - Population Water Savings

Program Population	Population Size (n)	Average Savings per Meter (gpd)	Annual Savings per Meter (AFY)	Population Annual Savings (AFY)	Average Peak Savings (gpd)	Population Peak Savings (cfs)
Early Participants	661	365	0.41	270		
Later Participants	804	765	0.86	689	1,300	1.62
Program Total	1,465			960		

Figure 5.1 - Water Savings Over Time



To estimate the total lifetime water savings expected from the LPCP activated meters, assumptions are needed regarding the life span of savings and the decay in savings over time. Given the dearth of research results on the persistence of large landscape conservation savings, and that the results from this study are from a program just now in full operation, this chapter uses the simplifying assumption that average annual savings last 5 years. (Note that the area under rectangle of five years of constant savings is equivalent to an assumption of a more gradual decay over a longer period—e.g., a 20 percent savings decay over 20 year life.) We believe the assumption of a 5-year water

savings lifetime is conservative, especially for the LPCP that is characterized by ongoing information feedback. Given this assumption and the estimated annual savings volume, the total water savings yield from the LPCP is shown in Figure 5.1. The graphs shows the average annual water savings expected based solely on the existing set of activated meters.

Benefits

The approach used to value the water savings — that is, the dollar benefits of the program — involves estimating the avoided costs of water to Orange County. Table 5.3 shows the current wholesale water rates for Tier 2 water purchased from MWDSC.

Table 5.3 - Avoidable Water Rates

Category		Rates
Tier 2 Supply $/AF	$	154
System Access $/AF	$	141
System Power $/AF	$	89
Water Stewardship $/AF	$	23
Treated Surcharge $/AF	$	82
Total $/AF	$	489

The analysis uses these current rates and their projected increases for the near future from the Metropolitan Draft Long-Range Financial Plan. Likewise for the estimation of the additional peaking benefit, the analysis defines peaking benefit in dollar terms as the reduction in the Capacity Reserve Charge, currently set at $6,100 per cfs. Table 5.4 contains a sample calculation of peak capacity rate savings for a recent year.

Table 5.4 - Peak Capacity Rate Savings

Summer conservation (gpd per meter)		1,300
Summer conservation (cfs per meter)		0.002
Number of landscape meters in program		1,465
Summer peak savings for program (cfs)		2.95
Capacity Reservation Charge ($/cfs peak, annual)	$	6,100
Rate savings for program ($/year) [1]	$	17,975
Savings per meter ($/year)	$	12.27

(1) Potential savings to agency if summer peaking reduced 1 to 1 with landscape reduction

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Costs

Table 5.5 shows the costs incurred by agencies to develop and support the program to date. A total of $785,000 has been invested in the program over time. Considerable amounts of these funds have gone to development of the curriculum materials for the workshops, development of the database, and other start-up costs.

Table 5.5 Budgeted Program Costs To Date

Program	Program Implementation				Proposed Phase IV		Totals
Phase	Phase I	Phase II	Program Hiatus	Phase III	Implement-ation	Evaluation	Phases I – IV
Period	3/15/99 - 3/15/00	3/15/00 - 3/15/01	3/15/01 - 12/01/01	12/1/01- 3/31/03	03/31/03 - 03/31/04		Total
Totals	$179,000	$175,778	$ 7,000	$160,222	$ 141,000	$ 85,900	$ 748,940
These figures are take from a budget summary report (Agr No 19140 - Chronological Summary.xls) with a slightly different labeling of program Phases consistent with Chapter 2. Phase IV evaluation budget has been revised upward from the original spreadsheet value.							

These direct program costs were annualized according to historical budget estimates and combined with the direct annual costs of the Protector del Agua (PDA) program in the MWDOC service area[2]. Table 5.6 depicts these annual program costs.

Table 5.6 Total Annualized Direct Costs To Date

Year	Direct LPCP Program Cost	Protector del Agua Program Costs	Total Annual Program Costs
1999	$179,000	N/A	$179,000
2000	$175,778	N/A	$175,778
2001[1]	$18,444	$20,691	$39,135
2002	$148,778	$36,485	$185,263
2003[2]	$226,940	$41,114	$268,054

(1) Includes hiatus period plus one month of Phase 3.
(2) Includes $85,940 in evaluation costs that are not ongoing program costs.

[2] Though we include all costs of the PDA program in the total costs, a strong case could be made that the LPCP should not bear all these costs. It should be noted that the inclusion of PDA costs in the LPCP cost analysis also illustrates an interesting phenomena on the benefit analysis—the case of spillover benefits. This is conceptually the opposite of a "Free-rider effect. Training of landscape contractors in the PDA program conveys knowledge and skills that benefit customers that do not participate in the LPCP program. The training of contractors through the PDA can increase the level of ongoing conservation, even among customers not participating in the LPCP.

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Future costs are most likely to involve ongoing programmatic costs with relatively less database development and more routing maintenance—potentially reducing the unit cost of implementation. At the same time, future costs are likely to increase as the market becomes more saturated and search costs begin to rise for new customers. Thus, for the *prospective analysis*, we assume three program years at costs similar to the total annual cost of the most recent year of the program including PDA—$182,000 per year.

Cost-Benefit Analysis

Table 5.7 summarizes the main results of the cost-benefit and cost-effectiveness calculations. For the retrospective analysis, the present value benefits well exceed the present value costs, resulting in a positive $1.3 million net present value. The cost per nominal acre-foot of water is $165. The hypothetical prospective analysis also has a positive net present value. The cost per nominal acre-foot of water is $178.

Table 5.7 - Economic Results

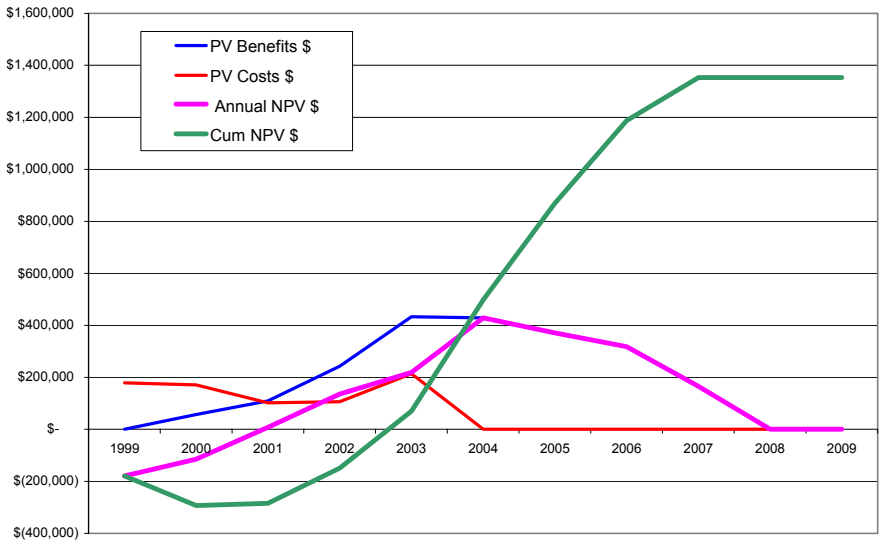
Item	PV Costs $	PV Benefits $	NPV $	Cost PV$/AF
Retrospective Analysis	$ 794,251	$ 2,125,040	$1,330,788	$ 165 /AF
Prospective Analysis (1)	$ 457,400	$ 1,191,933	$ 734,533	$ 178 /AF

(1) Prospective analysis includes $182,000 per year for three years and savings the same as the later participants, but no increased marketing costs. Clearly the cost-effectiveness would support an increase in marketing costs.
(2) The assumed annual discount rate is three percent.

Figure 5.2 shows the NPV results graphically. Their respective lines indicate the streams of costs and benefits over the period of analysis. Note that the costs are incurred in the early years, and benefits accrue beyond the end of the cost items due to the savings life span. The "Annual NPV" line is determined by subtracting costs from benefits. The "Cum. NPV" line indicates a primary result of the cost-benefit analysis — that after the first few years, the program not only pays for itself, but it results in significant economic savings.

Note that these results are based on the assumption that no additional costs are incurred—an assumption which clearly delineates the retrospective analysis. In practice, the program is likely to continue with ongoing costs that will help maintain the program and its savings for all participants, including early participants, for years into the future. Likewise, savings are likely to continue indefinitely as long as the program is maintained, rather than the assumed 5 years savings duration. In other terms, our retrospective analysis has answered the question, "Has the program benefits exceeded costs so far." The prospective analysis answers the question, "Will the benefits of continuing the program exceed the costs of continuing the program."

Figure 5.2 - Net Present Value Over Time



Conclusions and Caveats

The cost-benefit analysis indicates that the economic benefits outweigh the economic costs of the LPCP. This is indicated for both retrospective and prospective analyses.

Caveats to the analysis include:

- All of the direct costs to agencies so far have been included in the cost items, even though a considerable part of those costs went to start up and development.
- Some indirect costs have not been estimated — water agency staff time to monitor and market the program, incremental water agency costs to transfer consumption data, and any other category of water agency general and administrative cost or overhead. These indirect costs were not estimated because these costs are not, in general, estimated for other water resource alternatives.

- Customer costs have not been estimated because this analysis is specific to the agency involved.

- Uncertainty exists in economic parameters such as the discount rate and the future value of the benefit stream.

- The only benefits that have been included are the direct benefit of water savings. Benefit categories not addressed include urban runoff reduction benefits, wastewater benefits, and any esthetic improvements brought about by better irrigation management.

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Chapter 6 – Recommendations for the LPCP

This report finds that the existing program delivers cost-effective water savings among existing participants. As a result, the key focus of the recommendations is ***how to increase the number of water agencies and retail customers participating in the program to make it even more cost effective.*** Increased participation will deliver a higher volume of water savings to Metropolitan, MWDOC, and water agencies at a lower overall unit cost.

Overall Recommendations

Recommendations for increasing participation fall into two categories:

1) ***Expand the number of participating agencies***- This can be accomplished in two ways:

    a) Open the program to all Metropolitan member agencies.

    b) Maximize the number of participating agencies within the MWDOC region.

3) ***Expand the number of program participants*** – This can be accomplished in four ways:

    a) ***Create a solution for the area measurement problem***- Currently this burden for customers causes many to forgo participation in the program. Stakeholders need to create a short-term solution (staff assistance, sufficiently accurate approximations, etc.) until more consistent and universal solutions (such as aerial and/or satellite measurement) can be worked out.

    b) ***Resolve the data issues blocking agency participation***- There are two major data obstacles:

        i) Many agencies have difficulty identifying irrigation meters within their territory; and/or

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ii) Agencies are incapable of performing, or leery of attempting to perform, regular monthly data transfers of customer water usage. Overcoming this hurdle may require direct assistance from Metropolitan/MWDOC or the assignment of this task as a priority by upper management of the retail agency. Staff championing upgrades in the information system capability required to provide monthly consumption reports should point to the avoided costs of additional purchased water and investments to handle peaking requirements. This will be easier for some agencies to tackle than others depending upon their information management capabilities, the degree of data limitations, and the priorities of upper management.

c) ***Create a production-based, one-on-one sales and marketing initiative***- take marketing from an intermittent activity to a standard and continuous component of the program. Presently the program relies heavily on a direct mail campaign with periodic one-on-one sales. This strategy should be reversed: because of its past success, the one-on-one sales approach should be the foundation of the customer outreach campaign. Program staff resources should be increased to make one-on-one sales/marketing a program priority.

d) ***Open the program to mixed use meter customers***- Expand beyond the limited universe of dedicated irrigation meter customers to increase the pool of potential participants.

To build on existing program success, each stakeholder has a role to play in continuing to improve overall program performance. As such, the recommendations are listed accordingly.

Recommendations for Metropolitan

1) **Fully support the program.** Now that the existing program has demonstrated cost-effective water savings, this program can become a foundation to augment existing and create future landscape water initiatives. The success of Weather Sensitive

Controllers, irrigation system upgrade programs, and landscape plant material retrofit programs all depend upon monthly customer interaction and maintenance. This program establishes that essential link with the customer and can be used to empirically evaluate and monitor incremental savings associated with additional incentive investments from Weather Sensitive Controllers, other system upgrades and plant replacement incentives.

2) **Communicate the message of demonstrated program success and potential to Metropolitan management.** It is important that the internal audience of decision-makers at Metropolitan be fully informed of the rigorously measured water savings of the existing program, its cost-effectiveness and its potential for scalable, high value water savings. This information is necessary for rational investment decisions in the future evolution of this program. (This program is complementary to other landscape programs promoted by Metropolitan including the Southern California Heritage Gardening campaign for native/arid climate plants, Irrigation Schedule Calculator and Irrigation Index.)

3) **Aggressively expand the program.** The first step in program expansion is to offer the program to all agencies including ongoing Conservation Credits Program funding. Newer communities (planned communities and water agency development standards) tend to have a higher percentage of dedicated irrigation meters, and would represent the "lowest hanging fruit." In some cases, requiring an area measurement when new service is established (i.e. for reclaimed planning purposes) could ensure the highest accuracy and lowest costs.

4) **Solve the "area measurement problem."** As the leading regional water agency, MWD should continue its leadership role by identifying and implementing a feasible solution to this major program obstacle. Any consistent technical solution—such as that offered through satellite or aerial measurement—lays the groundwork for rapid customer response and more rapid adoption of this program.

5) **Open the program to customers with mixed-use meters,** thereby allowing more agencies to participate in the program. This will require development of a feasible plan for implementing mixed meter water budgets.

6) **Solicit watershed agencies for program co-funding and cross advertising.** Agencies responsible for watershed management would receive direct benefit from reduced irrigation since reduced irrigation results in reduced run-off.

Assuming Metropolitan's Board of Directors approves a recommendation for continued funding and expanding this program there are a number of design and operational decisions that need to occur. Below are listed the major critical decision points to review:

1) **Consider how Metropolitan will pay agencies for landscape certification/water budget programs.** It's recommended that Metropolitan consider a payment plan based upon performance; either 50% of project cost, or contributions per meter or per acre. This choice is possible now that the cost effectiveness has been determined. For the long term Metropolitan should evaluate a market-based approach for implementation contractor compensation based on realized water savings. There are several different options on how to do this. These options must be analyzed in greater detail before the most viable option can be identified and selected.

2) **Determine best method for expansion of program web site and software to support multiple agencies**. In order for this program to maintain and improve overall cost effectiveness, economies of scale need to be maintained. The program web site and software costs can be shared beneficially by multiple agencies driving down per unit costs. There are several possibilities on how to accomplish this:

   a) MWDOC/ConserVision could provide Metropolitan with operational software and codes. Metropolitan could provide program disks to participating agencies. Agencies would then install system and customize the program to their agency

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needs. Customer data entry and routine support and maintenance would be the responsibility of the local agency. The limitations of this option are that customized software is complicated and difficult for another company to further develop and maintain. Many agencies may not be able to support the software effectively, thereby compromising program performance.

b) Another option is that ConserVision could create a licensing agreement to be offered to participating agencies along with a menu of services from which to select those items that are most appropriate for them. Services would range from the minimum set-up and support to data entry and customer reporting. Agencies would pay ConserVision directly depending on the level of service selected. This is a highly practical option if Metropolitan wants limited involvement. There may be a sole source issue with this approach, but it would be the most cost effective and is readily available.

c) A third option is that Metropolitan hire ConserVision to provide centralized program support. Participating agencies would use the centralized web site and system under the umbrella of their own program. Again there could be different levels of service such as ConserVision providing set-up and on-going maintenance and agencies doing their own data entry and reporting or ConserVision providing all computer related services. This is a practical option if Metropolitan is willing to provide direct involvement and a turnkey program for its agencies.

3) **Decide upon level of Metropolitan involvement and support for program roll out**. As with the software system Metropolitan must determine their level of involvement in regards to the field aspects of the program, i.e. marketing and sales, site measurement and general administration. There are essentially three options for Metropolitan to consider:

a) Metropolitan could remain hands-off on the program implementation, providing funds and computer software only.

b) Metropolitan could provide limited centralized services, i.e. web site and support.

c) Metropolitan could carry responsibility for full program implementation similar to the Region-wide CII Rebate Program

4) **Metropolitan should present findings of this program at the next member agency meeting and informally solicit agency feedback** and attitudes towards further expansion and format of this program. Feedback can be utilized in the refinement of Metropolitan's plan.

5) **Future Water Use Efficiency funding from the state creates a role for Metropolitan in defining appropriate regional solutions**. Statewide WUE funding creates an opportunity for Metropolitan to define regionally effective solutions to some of the practical constraints on expansion of WUE programs targeting landscapes. Such solutions might include (1) satellite-based area measurements of landscape that build on the recent experiences of other water agencies or (2) development of a regional database that builds on county-level public information on parcels to attach identifiers for landscape water end-uses.

Recommendations for MWDOC

With the Landscape Certification Program well underway and Metropolitan's support solidified MWDOC has the opportunity to further maximize program performance and cost effectiveness. The following are recommendations for MWDOC's consideration.

1) **Renegotiate program funding with Metropolitan**. Metropolitan could provide funding based on participating meters or acres. Extensions of the estimated empirical model measuring water savings are both possible and germane to this question.

2) **Renegotiate contract with ConserVision**. Contract would include new payment structure possibly aligned with Metropolitan funding structure. New price should include costs for direct salesperson. Contract could include performance criteria such as number of sales visits conducted per month, number of customers enrolled per month, number of customers that utilized site measurement service, timeframe for uploading water agency data and e-mailing customer reports.

2) **Hold annual but separate kick- off meetings for all MWDOC agencies, landscape contractors, and property managers for each successive phase of the program.** The purpose of the meeting would be to re-energize the program by showcasing certified companies; solicit additional agency (etc) participation, and assist in gaining momentum on local marketing.

3) **Oversee monthly agency/ consultant meetings during the re-initiation period.** The agencies lack a forum to discuss program problems and exchange ideas or solutions. A monthly meeting would open up the channels of communication between regional players and help to maintain or even increase program momentum.

4) **Support agency staff in selling program to agency management**. This could be done most effectively now that program performance is documented in a report/presentation. Steps or requirements for participation along with anticipated benefits could be clearly defined and presented to agency management creating a

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clear path for participation. Whenever possible, MWDOC should participate in a joint presentation (MWDOC and agency staff) to agency upper management. This would show strong regional support and help to validate the program and its value to that agency. (Could also include presentations to elected officials at appropriate forums focusing on water use efficiency and watershed management benefits)

5) **Require that ConserVision hire and train a high level salesperson**. This salesperson should be given performance objectives that would regularly be reviewed with ConserVision and MWDOC managers. This person would promote participation from all parties including HOAs, property managers, and landscape contractors.

6) **Establish the site measurement support service.** There are two options for MWDOC to consider. MWDOC could select one or both of the following options:

   a) Require that ConserVision hire and train a Site Measurement Specialist. This Specialist would be available "for hire" by customers needing assistance. The customer billing rates should be affordable It will also be necessary to create an accounting process for customer collections and reporting.

   b) Develop an incentive for irrigation consultants to promote the program and provide area measurement data to the program. Several program participants were brought into the program by irrigation consultants. These individuals have already had the "ear" of their client and are a valuable marketing avenue to bring on new customers. With their high level of landscape knowledge these firms could provide the program with quality measurement information.

7) **Work with ConserVision to develop model landscape maintenance contract language** to facilitate performance based irrigation management. This language would be provided to HOAs in order to aid the customer in establishing an incentive for their landscape contractors and property managers to use water more efficiently.

Utilizing the program resources (web site and reports) the HOA, property manager and landscape contractor would have established water use goals with monetary awards for meeting or exceeding those goals and penalties for failing to achieve them.

8) **Elevate the importance of the bronze, silver, gold certification program** by providing meaningful promotion of those customers that attain a metal status. Creating a strong advertising campaign can do this. MWDOC should require ConserVision to develop a more dynamic and detailed advertising plan. This plan should include a more comprehensive list of advertising outlets and a monthly calendar. In addition to increased advertising frequency the ads themselves need to be eye-catching and contain a strong message.

9) **Keep delivering the message to the landscape professionals and customers**. Most of the companies and customers that were interviewed under this evaluation stated that they were sold on the program by one-on-one discussions with MWDOC staff. MWDOC's marketing initiative is highly effective and directly feeds the program response.

10) **On a regional and local level, solicit watershed agencies for program co-funding and cross advertising.**

Recommendations for Participating Agencies

1) **Provide as much one-on-one marketing as possible**. The retail agency name provides a formidable marketing impact on a local customer. Agencies need to aid the marketing initiative with breakfast seminars; association networking and other direct contact opportunities with their customers. (Agencies could require participation for all new connections as service is requested and for existing connections by a date certain)

2) **Resolve data and staffing issues** that are causing the time lag in getting customers real-time reports on their water management performance. This area has seen tremendous improvement but still needs advancement. Consider possible new resources for solutions such as billing system software companies and consultants.

3) **On a local level, solicit watershed agencies (specifically municipalities) for program co-funding and cross advertising.** At a minimum, customers that violate watershed restrictions could be fed into the program.

Non-Participating Agencies

1) **Work to resolve the internal data issues that are blocking program participation.** Non-participating agencies that want to participate need to escalate the internal data issues to the attention of upper management. Staff should present the successes of their sister agencies to upper management in order to redirect internal resources to overcome this problem and gain access to the program.

2) **Inform Metropolitan and MWDOC on the types of assistance that is most needed.** Staff at the water wholesalers find it easier to deliver assistance when it is requested.

3) **Work with Metropolitan and MWDOC on opening the program to mixed-use meters.**

Recommendations for the Program Consultant (ConserVision)

1) **Add a dedicated field sales person.** A one-on-one sale is the most effective method of gaining response. The program offer is complicated and not conducive to a direct mail format. The industry is beginning to understand that the commercial marketplace requires a direct sales dialog with the customer to build program response. This new individual would be an experienced salesperson spending 80% of their time in the field pitching the program one-on-one to all potential customers. They would be required to follow a production schedule and be paid on an incentive or commission basis.

Overcome the area measurement barrier by providing a field specialist for the customer to hire at a reasonable rate. The area measurement process can be tackled by a mid level field specialist who is appropriately trained. For less than $25 an hour, the customer could hire the area measurement specialist to complete this portion of the work on their behalf. The customer would be relieved of this burden and the program would receive higher quality information than typically seen.

3) **Design and implement incentive system for irrigation consultants to promote the program and provide area measurement data.**

4) **Work with MWDOC to develop model landscape maintenance contract language** to facilitate performance based irrigation management.

5) Implement revised marketing campaign for bronze, silver, gold certification program.

Appendix A—Impact Evaluation: Data, Methods, Statistical Results

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Introduction

The purpose of this work is a statistical analysis of water savings among large-landscape customers who participated in the Landscaper Performance Certification Program in Orange County, California. This report documents a careful statistical analysis of historical water consumption data to derive estimates of the net water savings from this program.

Approach

Historical water consumption records (July 1999 to August 2002) for a sample of participants and for a sample of nonparticipating customers were examined statistically. The hypothesis was that better management of existing equipment would reduce the observed water consumption of customers participating in this program. This study empirically estimates the water savings that resulted from the initial implementation of this program (Phases 1 and 2, before November 2001) and the more recent implementation (Phases 3 and 4, after November 2001).

Since participation in this program required the voluntary agreement of the customer to participate, this sample of customers can be termed "self-selected." While this analysis does quantitatively estimate the reduction of participant's water consumption, one may not directly extrapolate this finding to nonparticipants. This is because self-selected participants can differ from customers who decided not to participate.

The explanatory variables in these models include

- Deterministic functions of calendar time, including
    - The seasonal shape of demand
- Weather conditions
    - measures of air temperature
    - measures of precipitation, contemporaneous and lagged
- Meter-specific mean water consumption per billing period
- "Intervention" measures of the date of participation and the program phase

Data and Methods

Consumption records were compiled from the customer billing system by the implementing vendor for all landscape customers in the study areas. Billing histories were obtained from meter reads between January 1999 and July 2003. The current implementing vendor also attached the data at which participating meters were activated in the program. This "meter activation date" was not available for the early participants in Phase 1 and 2 of the program. Though the specific activation date for Phase 1 and 2 participants is not known, it is known that these meters were active and participating after November 2001. This study will not be able to conduct formal tests on the "pre-intervention" water use of Phase 1 and 2 participants since the pre-intervention period cannot be identified.

To get a cleaner definition of "nonparticipants," records were complied of accounts that participated in other regional landscape water conservation programs. Of the 1465 activated meters (661 early participants and 804 Phase 3 and 4 participants) approximately 144 accounts were excluded from the sample based upon prior participation in other landscape conservation programs. Accounts could also be excluded if the consumption records were of insufficient length or quality. Thus, meter reads

containing a negative number of days in the meter read or more than 120 days were omitted. Table A.1 presents descriptive statistics—mean water use per year, activated meter count per agency, and the total irrigated area per meter—on the remaining sample containing usable consumption records.

Table A.1: Landscape Accounts Descriptive Statistics

	Early Participant, Phase 1, 2 (Before 11/2001)	**Recent Participant, Phase 3, 4** (After 11/2001)	**Non-Participant** (in known conservation programs)
Annual Average Water Consumption (in gallons per day)			
Calendar Year 1999	5208	4890	4448
Calendar Year 2000	4839	5463	4500
Calendar Year 2001	4018	4017	3919
Calendar Year 2002	4779	3917	4326
Number of Meters by Participating Agency			
Mesa Consolidated WD	0	120	9
Mouton Niguel WD	85	25	2461
Newport Beach	0	38	654
San Clemente	0	127	524
Santa Margarita WD	308	188	1733
Total Number of Usable Meters	393	498	5381
Mean Area Irrigated by Meter(sq. ft)			
Mesa Consolidated WD		34,408	N.A.
Mouton Niguel WD	91,948	75,375	N.A.
Newport Beach		62,342	N.A.
San Clemente		77,262	N.A.
Santa Margarita WD	88,642	99,436	N.A.
Overall Mean Irrigated Area	89,126	86,924	N.A.

Daily weather measurements—daily precipitation, maximum air temperature, and evapotranspiration—were collected from the CIMIS weather station No. 75 located in Irvine. The daily weather histories were collected as far back as were available (January 1, 1948) to provide the best possible estimates for "normal" weather through the year.

Thus we have at least 55 observations upon which to judge what "normal" rainfall and temperature for January 1^{rst} of any given year.

The first major issue with using meter-read consumption data is the level and magnitude of noise in the data. The second major issue is that records of metered water consumption can also embed non-ignorable meter mis-measurement. To keep either type of data inconsistencies from corrupting statistical estimates of model parameters, this modeling effort employed a sophisticated range of outlier-detection methods and models. These are described next.

Robust regression techniques were used to detect which observations are potentially data quality errors. This methodology determines the relative level of inconsistency of each observation with a given model form. A measure is constructed to depict the level of inconsistency between zero and one; this measure is then used as a weight in subsequent regressions. Less consistent observations are down-weighted. Other model-based outlier diagnostics were also employed to screen the data for any egregious data quality issues.

Specification

A Model of Water Demand

The model for customer water demand seeks to separate several important driving forces. In the short run, changes in weather can make demand increase or decrease in a given year. These models are estimated at a meter level and, as such, should be interpreted as a

condensation of many types of relationships—meteorological, physical, behavioral, managerial, and chronological. Nonetheless, these models depict key short-run and long-run relationships and should serve as a solid baseline for estimating the delta change induced by participation in the Landscape Performance Certification Program.

Systematic Effects

This section specifies a water demand function that has several unique features. First, it models seasonal and climatic effects as continuous (as opposed to discrete monthly, semi-annual, or annual) function of time. Thus, the seasonal component in the water demand model can be specified on a continuous basis, and then aggregated to a level comparable to measured water use (e.g. monthly or bimonthly). Second, the climatic component is specified in difference form as a similar continuous function of time. The weather measures are thereby made independent of the seasonal component. Third, the model permits interactions of the seasonal component and the climatic component. Thus, the season-specific response of water demand can be specific to the season of the year.

The general form of the model[1] is:

Equation 1

$$Use_{i,t} = \mu_i + S_t + W_t + E_{i,t}$$

where $\boldsymbol{Use_{i,t}}$ is the quantity of water demand for meter i within time t, the parameter $\boldsymbol{\mu_i}$ represents mean water consumption per meter i, $\boldsymbol{S_t}$ is the seasonal component, $\boldsymbol{W_t}$ is the

[1] The general form of this continuous time model was developed and explained further in Chesnutt et al., *Continuous-Time Error Components Models of Residential Water Demand*, A report for the Metropolitan Water District of Southern California, June 1992.

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weather component, $\boldsymbol{E_{i,t}}$ is the effect the landscape interventions for meter *i* at time period *t*. Each of these components is described below.

Seasonal Component : A monthly seasonal component can be formed using monthly dummy variables to represent a seasonal step function. Equivalently, one may form a combination of sine and cosine terms in a Fourier series to define the seasonal component as a continuous function of time.[1] The following harmonics are defined for a given day *T*, ignoring the slight complication of leap years:

Equation 2

$$S_t \equiv \sum_{1}^{6}\left[\beta_{i,j}\cdot\sin\left(\frac{2\pi\cdot jT}{365}\right)+\beta_{i,j}\cdot\cos\left(\frac{2\pi\cdot jT}{365}\right)\right]=Z\cdot\beta_S$$

where $T = (1,...365)$ and *j* represents the frequency of each harmonic.[2] Because the lower frequencies tend to explain most of the seasonal fluctuation, the higher frequencies can often be omitted with little predictive loss.

[1] The use of a harmonic representation for a seasonal component in a regression context dates back to *Hannan* [1960]. *Jorgenson* [1964] extended these results to include least squares estimation of both trend and seasonal components.

[2] If measures of water demand are available on a daily basis, the harmonics defined by Equation 2 can be directly applied. When measures of water demand are only observed on a monthly basis, two steps must be taken to ensure comparability. First, water demand should be divided by the number of days in the month to give a measure of average daily use. Otherwise, the estimated seasonal component will be distorted by the differing number of days in a month. The comparable

To compute the entire seasonal effect, one simply sums the multiplication of each seasonal coefficient with its respective value. This seasonal effect will explain how demand changes due to seasonal fluctuations. The model will also be used to test for possible changes to the seasonal shape of demand.

Weather Component: The model incorporates two types of weather measures into the weather component–maximum daily air temperature and rainfall.[3] The measures of temperature and rainfall are then logarithmically transformed to yield:

Equation 3

$$R_t \equiv \ln\left[1 + \sum_{t=T}^{T_d} Rain_t\right], A_t \equiv \ln\left[\sum_{t=T}^{T_d} \frac{AirTemp_t}{d}\right]$$

where *d* is the number of days in the time period. For monthly aggregations, *d* takes on the values 31, 30, or 28, ignoring leap years; for daily models, *d* takes on the value of one. Because weather exhibits strong seasonal patterns, climatic measures are strongly correlated with the seasonal measures. In addition, the occurrence of rainfall can reduce expected air temperatures. To obtain valid estimates of a constant seasonal effect, the seasonal component is removed from the weather measures by construction.

Specifically, the weather measures are constructed as a departure from their "normal" or expected value at a given time of the year. The expected value for rainfall during the

---

measures of the seasonal component are given by averaging each harmonic measure for the number of days in a given time period.

[3] Specifically it uses the maximum daily air temperature and the total daily precipitation at the Irvine weather station. This station was selected due to its proximity to the study area.

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year, for example, is derived from regression against the seasonal harmonics. The expected value of the weather measures ($\hat{\boldsymbol{A}}=\boldsymbol{Z}\hat{\boldsymbol{\alpha}}$) is subtracted from the original weather measures:

Equation 4

$$W_t \equiv (R_t - \hat{R}_t) \cdot \beta_R + (A_t - \hat{A}_t) \cdot \beta_A$$

The weather measures in this deviation-from-mean form are thereby separated from the constant seasonal effect. Thus, the seasonal component of the model captures all constant seasonal effects, as it should, even if these constant effects are due to normal weather conditions. The remaining weather measures capture the effect of weather departing from its normal pattern.

The model can also specify a richer texture in the temporal effect of weather than the usual fixed contemporaneous effect. Seasonally-varying weather effects can be created by interacting the weather measures with the harmonic terms. In addition, the measures can be constructed to detect lagged effects of weather, such as the effect of rainfall one month ago on this month's water demand.

Effect of Landscape Interventions: Information was compiled on the timing of customer participation. The account numbers from these data were matched to meter consumption histories going back to 1999. All raw meter reads were converted to average daily consumption by dividing by the number of days in the read cycle. Using these data,

relatively simple "intervention analysis" models[2] were statistically estimated where, in this case, the intervention is participation in the Landscape Performance Certification program. The form of the intervention is:

Equation 5

$$E_{i,t} \equiv I_{1,2} \cdot \beta_{1,2} + I_{3,4} \cdot \beta_{3,4}$$

The indicator variable $I_{1,2}$ takes on the value one to indicate participation in Phase 1 or 2 and is zero otherwise. The indicator variable $I_{3,4}$ takes on the value one to indicate participation in Phase 3 or 4 and is zero otherwise.

The parameter $\hat{\beta}_{1,2}$ represents the mean effect participating in Phase 1 or 2 and is expected to be negative (participation reduces water consumption.) The parameter $\hat{\beta}_{3,4}$ has a similar interpretation for Phase 3 and 4 participants.

This formulation also permits formal testing of the hypothesis that landscape interventions can affect the seasonal shape of water consumption within the year. The formal test is enacted by interacting the participation indicators with the sine and cosine harmonics.

Stochastic Effects

To complete the model, we must account for the fact that not every data point will lie on the plane defined by **Equation 1**. This fundamental characteristic of all systematic

[4]See Box and Tiao, "Intervention Analysis with Applications to Economic and Environmental Problems" *Journal of the American Statistical Association*, Vol 70, No. 349, March 1975, pp. 70-70.

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models can impose large inferential costs if ignored. Misspecification of this "error component" can lead to inefficient estimation of the coefficients defining the systematic forces, incorrect estimates of coefficient standard errors, and an invalid basis for inference about forecast uncertainty. The specification of the error component involves defining what departures from pure randomness are allowed. What is the functional form of model error? Just as the model of systematic forces can be thought of as an estimate of a function for the "mean" or expected value, so too can a model be developed to explain departures from the mean—i.e., a "variance function" If the vertical distance from any observation to the plane defined by **Equation 1** is the quantity **ε**, then the error component is added to **Equation 1**:

Equation 6

$$Use = \mathbf{f}(\mathbf{S}_t, \mathbf{C}_t, \mathbf{T}_t) + \varepsilon$$

The error structure is assumed to be of the form:

Equation 7

$$\varepsilon_{it} = \mu_i + \xi_{it}$$
where
$$\mu_i \sim N(0, \sigma_\mu^2)$$
$$\xi_{it} \sim N(0, \sigma_\xi^2)$$

Note: Once again, I'd suggest including a footnote that refers people to earlier work in which decomposition of the error term is discussed in greater detail.

The X and ξ are assumed to be independent of each other and of μ. The individual component μ represents the effects of unmeasured household characteristics on household

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water use. An example of such an unmeasured characteristic might be the water use behavior of household members. This effect is assumed to persist over the estimation period. The second component ξ represents random error. Because μ and ξ are independent, the error variance can be decomposed into two components:

Equation 8

$$\sigma_{\varepsilon}^2 = T \cdot \sigma_{\mu}^2 + \sigma_{\xi}^2$$

This model specification is accordingly called an error components or variance components model. The model was estimated using maximum likelihood methods.

Estimation Results

Estimated Landscape Customer Water Demand Model

Table A.2 presents the estimation results for the model of landscape (irrigation-only) customer water demand in the participating MWDOC member agencies. This sample represents water consumption among 6272 accounts between January 1999 and July 2003. This sample contains 498 water meters that were activated in Phases 3 and 4 (after November 2001), 393 water meters that were activated in Phases 1 and 2 (prior to November 2001), and 5381 unactivated water meters (non-participants).

The constant term (1) describes the intercept for this equation. (A separate intercept is estimated for each of the 6272 meters but these are not displayed in Table 2 for reasons of brevity.) The independent variables 2 to 8—made up of the sines and cosines of the Fourier series described in Equation 2—are used to depict the seasonal shape of water demand. The predicted seasonal effect (that is, $Z \cdot \widehat{\beta}_S$) is the shape of demand in a normal

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weather year. This seasonal shape is important in that it represents the point of departure for the estimated weather effects (expressed as departure from normal). We will also test to see if the landscape interventions have any effect on this seasonal shape.

The estimated weather effect is specified in "departure-from-normal" form. Variable 10 is the departure of monthly temperature from the average temperature for that month in the season. (Average seasonal temperature is derived from a regression of daily temperature on the seasonal harmonics.) The reader should also note that the contemporaneous temperature effect is interacted with the harmonics to capture any seasonal shape to the temperature elasticity (Variables 11 and 12). Thus, departures of temperature from normal produce the largest percentage effect in the spring growing season. Rainfall is specified analogously in "departure from normal" form (Variable 13). One month lagged rainfall deviation is also included in the model (Variables 14).

The effect of the landscape conservation program interventions is captured in the following rows. The parameter on the indicator for Phase 3 and 4 participants (15) suggests that the mean change in water consumption is -765 gallons per day, approximately 20 percent of the pre-intervention water use. The variable testing for differences in pre-intervention use cannot distinguish any differences between the recent Phase 3 and 4 participants and nonparticipants (Variable 21).

The parameter on the indicator for Phase 1 and 2 participants (18) suggests that the mean change in water consumption is -367 gallons per day, approximately 9 percent of mean

water use. Because we cannot cleanly distinguish pre-intervention use for the early Phase 1 and 2 participants, we cannot perform this formal test for preexisting differences. Thus, one should be careful in interpreting the estimated mean change in water consumption for Phase 1 and 2. Specifically, it is incorrect to interpret 9 percent as the long term water savings of the current implementation of the Landscape Performance Certification program. The early participants may differ from the more recent participants, the implementation of the program differed, and there were different implanting agencies. Even though the interpretation of the water savings of early participants must proceed with more caveats, it is an encouraging sign to observe meaningful water savings even among these very early participants.

Table A.2: Landscape Customer Water Demand Model
Dependent Variable: Average Daily Metered Water Consumption
(in gallons per day)

Independent Variable	Coefficient	Std. Error
1. Constant (Mean intercept)	3938.5990	43.8258
2. First Sine harmonic, 12 month (annual) frequency	-1374.2230	18.3938
3. First Cosine harmonic, 12 month (annual) frequency	-2625.8170	16.7367
4. Second Sine harmonic, 6 month (semi-annual)frequency	239.5262	13.0504
5. Second Cosine harmonic, 6 month (semi-annual) frequency	-281.5594	13.5826
6. Third Sine harmonic, 4 month frequency	-83.0898	14.7469
7. Third Cosine harmonic, 4 month frequency	69.4731	15.4047
8. Fourth Sine harmonic, 3 month (quarterly) frequency	202.0835	17.1809
9. Fourth Cosine harmonic, 3 month (quarterly) frequency	38.0282	16.9349
10. Deviation from logarithm of 31 or 61 day moving average of maximum daily air temperature	10073.170	280.6154
11. Interaction of contemporaneous temperature with annual sine harmonic	1242.9110	355.6203
12. Interaction of contemporaneous temperature with annual cosine harmonic	1284.9020	426.5038
13. Deviation from logarithm of 31 or 61 day moving sum of rainfall	-897.2015	24.4000
14. Monthly lag from rain deviation	-397.4304	21.6044

15. Average effect for recent Phase 3,4 participants in the post Nov. 2001 period (498 activated meters)	-765.4730	115.2420
16. Interaction of Phase 3,4 participation with annual sine harmonic	191.7932	122.2208
17. Interaction of Phase 3,4 participation with annual cosine harmonic	528.6346	114.0177
18. Average effect for Phase 1,2 participants in the post Nov. 2001 period (393 activated meters)	-366.8083	61.16293
19. Interaction of Phase 1,2 participation with annual sine harmonic	-202.0787	73.60319
20. Interaction of Phase 1,2 participation with annual cosine harmonic	-383.6452	67.57704
21. Recent participants, test for difference in pre-intervention use	-93.7152	155.2680
Number of observations		204,144
Number of customer accounts		6,272
Standard Error of Individual Constant Terms		3054.05
Standard Error of White Noise Error		3646.77
Time period of Consumption	January 1999 - July 2002	

How Program Participation Affects Peak Demand

The question of how this program affected the seasonal shape of water demand can be interpreted from the remaining interactive effects—the indicators interacted with the first sine and cosine harmonics. For example, the seasonal shape of demand can be derived before and after participation in the Landscape Performance Certification Program:

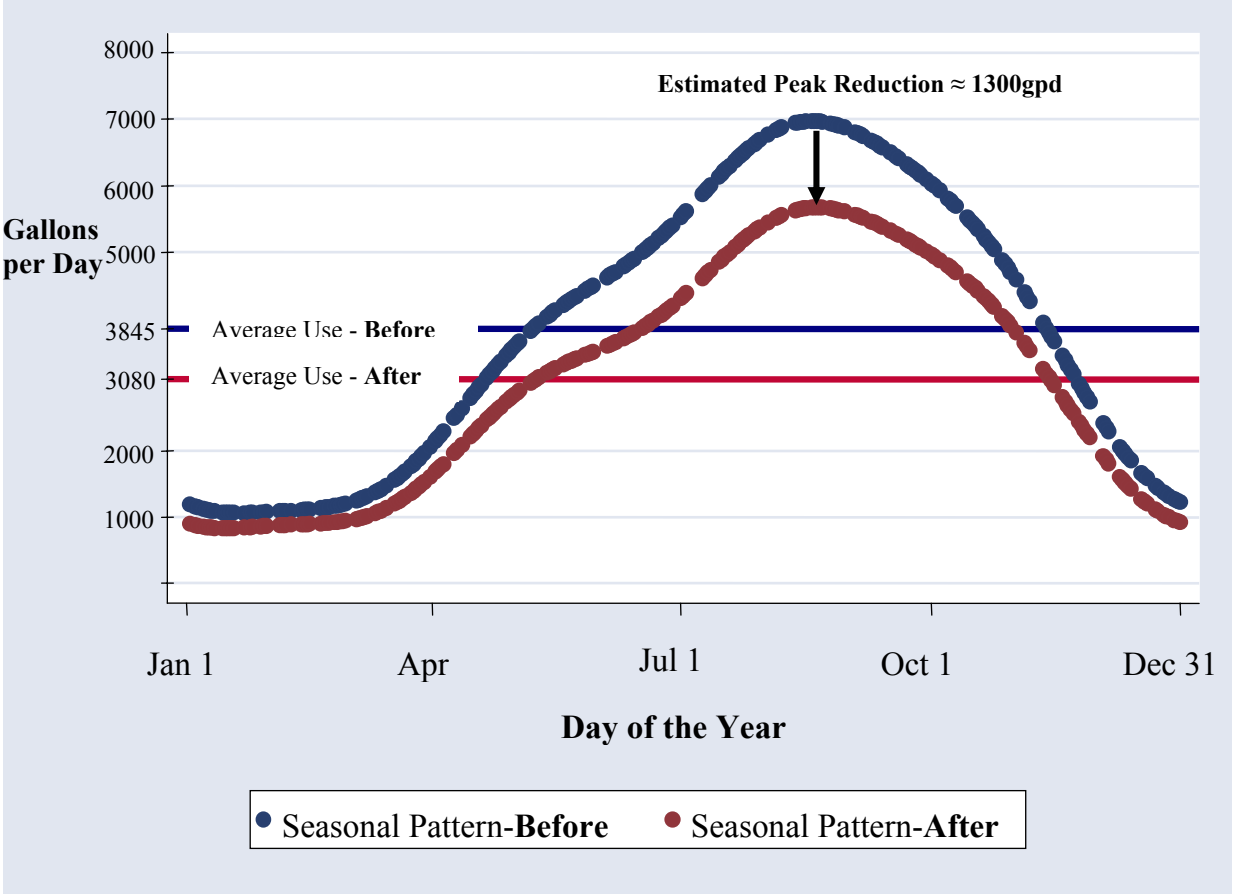
$$\text{Pre_Intervention}: S_t = Z \cdot \hat{\beta}_S \approx -1374 \cdot \sin_1 - 2625 \cdot \cos_1 + 239.5 \cdot \sin_2 + \ldots + 38 \cos_4$$

$$\text{Post_Intervention}: S_t^{'} = Z \cdot \hat{\beta}_S + 191.8 \cdot I_{3,4} \cdot \sin_1 + 528.6 \cdot I_{3,4} \cdot \cos_1$$

When the pre/post seasonal patterns are combined with their pre/post mean water consumption, the following before and after picture can be seen throughout the year

In Figure A.1, several observations should be made. First, the difference between the two horizontal lines corresponds to the estimated mean reduction of approximately 765 gallons per day. Second, the assumption of a constant 765 gallon per day effect does not hold true throughout the year. The reduction is much larger during the peak summer period.

Figure A.1 Load Shaping Effect of Performance Certification on Large Landscape Demand



The reduction in peak demand—though dependent upon how the seasonal peak is defined[3]—is greater than the average reduction.

[3] This is the issues of "coincident" versus "noncoincident" peak demand: the extent to which the peak load of a customer coincides with the system peak. Water systems by

The estimated peak day demand, occurring on August 18, is reduced by approximately 1300 gallons. This "load-shaping" effect of the ET controller intervention can translate into an additional benefit to water agencies. The benefits from peak reduction derive from the avoided costs of those water system costs driven by peak load and not average load—the costs for new treatment, conveyance, and distribution all contain cost components driven by peak capacity requirements.

Caveats and Additional Work

This modeling effort focused on developing the best depiction of net changes in water consumption due to participation in the Landscape Performance Certification program. Much of the modeling effort was expended on data cleaning, diagnosis, and validation. We believe that the most serious data issues were identified and appropriately handled. To the extent that future data quality can be improved, future work could provide several statistical refinements in model specification:

- The empirical effort has quantified the change in mean water consumption and the shift in seasonal consumption. The models have not been extended to document how water savings vary across customers.
    1. Is there remaining conservation potential among participants?
    2. How do savings change across customers of lower or higher water use?
    3. How do savings vary across climate zones?
    4. How do water savings vary as a function of landscape area?
    5. How do savings change across agencies with lower and higher water rates?

---

their nature have a strong and predictable tendency to peak seasonally—for Southern California, this occurs in the summer. Given the predictability of system peaks, and the attendant costs, the empirical case for the contribution of load shaping to the reduction of systems cost is relatively straightforward. The additional value of peak reduction--over and beyond reductions in average consumption--requires careful specification of the additional incremental costs necessitated by peak flow requirements.

- Since the sample only contains limited post participation data, the statistical models can say little about the persistence of water savings. Additional follow-up quantification of water savings in subsequent years would yield critical information about the long term water savings.
- The modeling effort to date has *not* attempted to estimate the effect of self-selection. Thus, we make no attempt to extend the inference from the existing sample of participants to (1) the remainder of the nonparticipating accounts in these service areas or (2) to other service areas.
- The error component of the estimated models could be improved by specifying a function form to explain the variance. This should only be attempted after all major data issues have been resolved.

Conclusion

This report documents the shape of water savings achieved by participation in the Landscape Performance Certification program. Customers participating in these programs saved significant amounts of water. Participation in the program changed both the level and shape of water demand.

Appendix B—Interview Protocols

Landscape Service Providers, Property Managers and Owners, and Home Owner Associations Interview Protocol

Interviewee Name:	☐ Landscape Service Provider ☐ Property Manager ☐ Property Owner ☐ HOA ☐ Other
Service Address:	City and Zip:
Company Name:	Day Phone
Water Agency:	Evening Phone

1. How did you hear or learn about (or get involved with) the program?

2. Why did you choose to participate?

3. When did you participate?

4. How do you typically receive new product/program information? How would you like to receive information on program like this in the future? Where do you think this program should be advertised?

5. Was the participation process easy to understand and straightforward? If it wasn't, how could it be improved?

6. Who from your organization attended the training? When? Is that person still with your organization? Was the information on the program and your organization's responsibilities for participation in the program transferred to another person? (consider breaking into two 1) marketing workshops and 2) irrigation management training workshops for questions 6-10)

7. Was the training valuable? If "Yes", in what ways was it valuable. If "No", why was it not valuable. (need to make sure the person who attended the workshops answers this question)

8. Was it hard to commit to the training time requirements?

9. Did the training help in calculating the area measurement for each landscape meter for implementation of the Landscape Irrigation Budget? Managing your landscape? Implementing your water saving strategy? If "Yes", how did it help?

10. Training improvement recommendations…

11. When did you receive your first Landscape Irrigation Budget report update notice and produce/print/review your first budget report?

12. Is the Landscape Irrigation Budgeting website easy to use, access and the information easy to understand?

13. How would you rate the value of the initial report? On-going reports? (1-10, 10 being highest)

14. Who from your organization has access to the reports? Who uses the reports? How do they use the reports?

15. Do all necessary parties in your organization have access to a computer?

16. Was the budget helpful in making decisions about how to implement a water saving strategy?

17. Do you feel the budgeted amount was reasonable?

18. How was your initial performance vs. budget? How is it now? If it has not changed significantly, what are the limiting factors that are making it difficult to increase performance (i.e., watering closer to budget)?

19. Did you take steps to implement a water saving strategy? If so, what did you do and when did you do it?

20. How much did you pay to make the improvements?

21. Who performed the improvements? Was the process easy?

22. Are you getting reports consistently? Monthly? Bimonthly? Quarterly? Every once in a while? Not at all?

23. Are you using the information to manage your irrigation usage? How?

24. Are you giving the information to anyone else in your organization?

25. Is the newsletter informative and useful?

26. Is e-mail the best communication method? If no, what method would be best?

27. *(property owner, manager, or home owners association)* Do you have a written agreement with your landscape service contractor? Did you have one before this program? Did you put it in place because of this program? Has it been useful? What terms of the contract relate to water use versus water budget?

or

27. *(landscape contractor*) Do you have a written agreement with the property owner or manager? Did you have one before this program? Did you put it in place because of this program? If so, has the contract been altered because of the program objectives? Has it been useful?

28. Who pays the water bill?

29. Are you incentivized or penalized based on the amount of water used?

30. Have you seen a reduction in your water bill?

31. Have you seen any changes in your landscape aesthetics/health?

32. Do you feel the recognition and rewards offered through the program are sufficient?

33. Did you gain additional business because of the recognition?

34. Did your customer's appreciate your efforts?

35. Are there any other improvements to the program you would recommend?

36. If you had it to do all over again would you participate in this program again?

37. Overall how would you rate this program (1-10, 10 being highest)

38. Currently, this program is provided at no cost as a result of grant funding from the Municipal Water District of Orange County and Metropolitan Water District of Southern California. Should that grant funding no longer exist, would you be willing to pay a monthly fee for this service and how much?

Water Agency Interview Protocol

Interviewee Name:	Title:
Address:	City and Zip:
Water Agency::	Day Phone
Number of Dedicated Irrigation Meters:	Number of Total Customers:

1. Why does your agency participate/not participate in the program?

2. What benefits does this program provide your agency and the local community you serve?

3. What was your general marketing campaign?

4. How did you determine which customers/sites to target for participation?

5. Did you market to customers, property management companies, or landscape service providers?

6. How did you obtain or generate your target lists?

7. Which group yielded the highest success or participation rates? Why?

8. Which marketing method yielded the highest success (direct mail, telephone, one-on-one direct visits)?

9. Do you have sample materials to distribute to potential participants in your service area?

10. How long was the marketing/sales cycle to get a customer, property management company or landscape service provider to participate?

11. Marketing improvement recommendations…

12. How well did you feel the program contractor (Conservision/CTSI) implemented the program?

13. What improvements would you recommend for the program contractor?

14. Which training option was the most valuable (Protector del Agua classes) or /Conservision/CTSI presentations)?

15. Training improvement recommendations…

16. Did you provide all of the data on your dedicated irrigation accounts?

17. What method was used to provide landscape area measurements? Direct measurements? Site plans? Estimates, customer provided data?

18. What process do you utilize for transferring data to the contractor? Did it work?

19. What process did you implement for meter changes and notifying the contractor? Did it work?

20. Data transfer improvement recommendations…

21. Do you use the Landscape Irrigation Budget reporting web-site?

22. Do you think the Landscape Irrigation Budget reporting web-site works adequately (excellent, good, fair, poor)?

23. Have you had problems with the web-site? If so, have those problems been resolved and how?

24. Is overall program and web-site user friendly from an agency perspective? From a customer, property manager, landscape service provider perspective?

25. Web-site improvement recommendations..

26. Do you think the actual Landscape Irrigation Budget allotments are fair to the customer?

27. Are the Landscape Irrigation Performance reports readable, valuable, customer friendly?

28. Once the customer is in the system receiving updates does the process work? (*What does this mean?)*

29. How would you rate the value of the initial report? On-going reports?

30. Do you think customers use the reports? The customer/HOA, property manager, or landscape service provider?

31. Do you think the communication with the customer is consistent enough?

32. Do you think e-mail is the best communication method?

33. Budget, report and communication improvement recommendations…

34. Do you believe/observe that customers are changing their water use habits as a result of this program?

35. Who is driving that change? The customer/HOA, property manager, or landscape service provider?

36. What changes are you seeing being made?

37. If you had it to do all over again would you participate in this program again?

38. Overall, how would you rate this program (1-10, 10 being highest)

39. What is the biggest success of this program?

40. What is the biggest failure?

41. Currently, this program is provided at no cost as a result of grant funding from the Municipal Water District of Orange County and Metropolitan Water District of Southern California. Should that grant funding no longer exist, would your agency be willing to pay for this program?

The Residential Runoff Reduction Study

Municipal Water District of Orange County

Irvine Ranch Water District

July 2004

Study Participants

A & N Technical Services

CalFed Bay-Delta Progam

California Department of Pesticide Regulation

California Environmental Protection Agency

California Regional Water Quality Control Board

HydroPoint Data Systems, Inc.

Irvine Ranch Water District

Metropolitan Water District of Southern California

Montgomery Watson Labs

Municipal Water District of Orange County

National Water Research Institute

County of Orange

Southern California Coastal Water Research Project

State Water Resources Control Board

United States Department of the Interior Bureau of Reclamation

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Executive Summary

Study Background and Rationale

In 2001, the Irvine Ranch Water District (IRWD), the Municipal Water District of Orange County (MWDOC), and the Metropolitan Water District of Southern California (MWD) completed a small-scale study of weather-based evapotranspiration (ET) irrigation controllers. This study, known as the "Westpark Study," tested the effectiveness of ET controller technology in residential applications. After 40 such controllers were installed in the Westpark neighborhood of Irvine, California, water demand and runoff in the study area were measured. The resulting average water savings for this study were 37 gallons per day, or 7 percent of total household water use and 18 percent of irrigation water use.

Based upon the findings of the Westpark Study, IRWD and MWDOC partnered on new research, the Residential Runoff Reduction (R3) Study, in which the number of sites studied was increased, a baseline area where no changes were made was included, and an "education only" area where printed educational materials were distributed was also included. This made the R3 Study one of the first studies to attempt to quantify the effectiveness of public education alone versus a technology-based plus education approach to reducing residential irrigation water usage. Figure ES-1 presents the study participants and their respective roles within the R3 Study.

The R3 Study had four primary purposes:

1) To test the use of weather-based irrigation technology, also known as ET controllers, to manage irrigation water for residential homes and large landscape areas;
2) To evaluate the effectiveness of a targeted education program on residential homeowners;
3) To determine the correlation between proper water application in landscape irrigation and the quantity and quality of urban dry-season runoff; and
4) To gauge the acceptance of water management via the controller technology.

Study Methodology

The R3 Study area included five similar neighborhoods (Sites 1001 through 1005) in Irvine, California, each with its own single point of discharge into the urban storm drain system. The five sites are shown on Figure ES-2. At these points of discharge from each study area, the runoff volume was monitored and water quality samples were taken. The five sites were divided into three separate areas. The first area, Site 1001 (retrofit group), used ET controller technology and public education. The second area, Site 1005 (education group), received educational materials, but did not receive controllers. The third area (control group) consisted of three separate neighborhoods (Sites 1002, 1003, and 1004), which received neither ET controllers nor educational materials.

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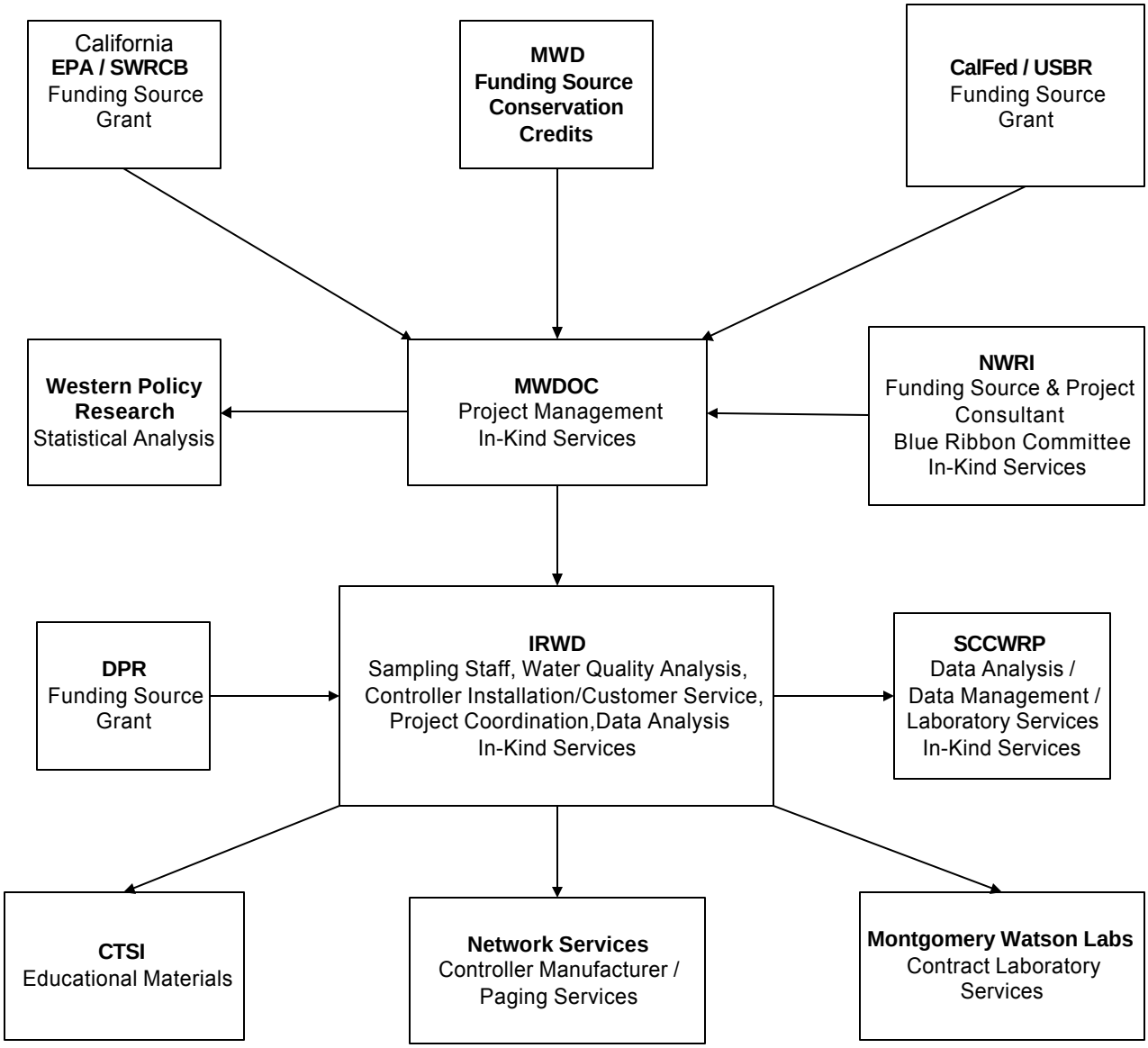
Figure ES -1
R3 Study Participants



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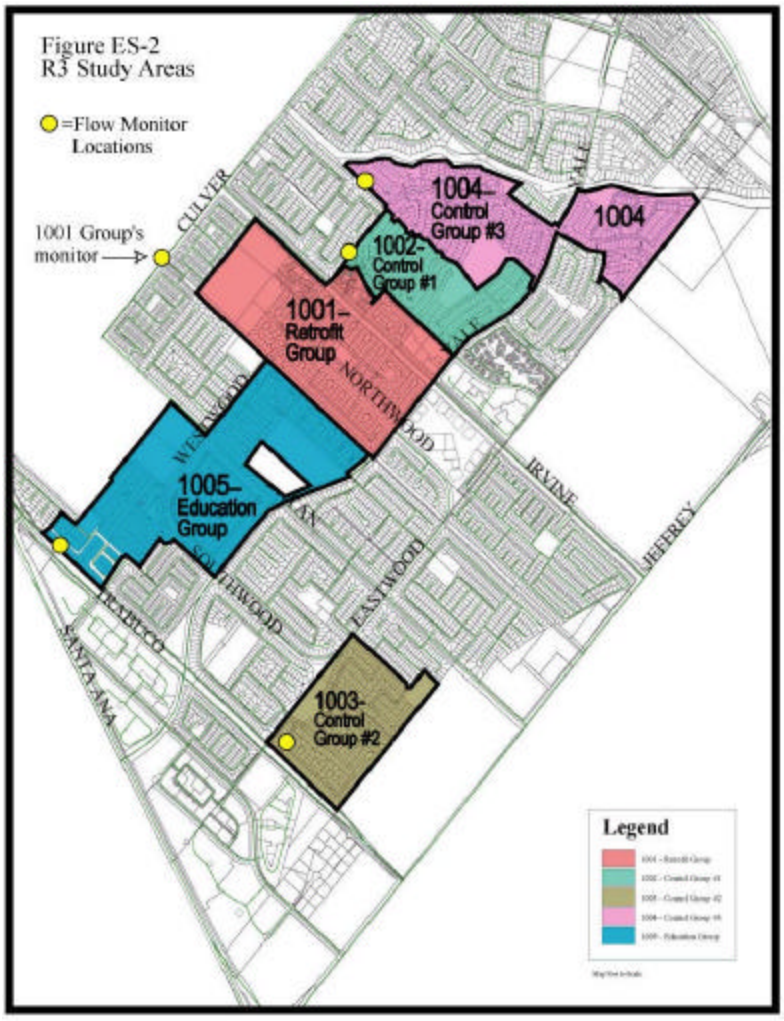

Evaluation Results

After the initial 18-month study period was completed, the data was compiled and evaluated for water conservation savings, dry season runoff changes, and changes in the quality of the dry season runoff water. The following summarizes the results:

a) Water Conservation Savings

Water conservation savings from the typical participant in the retrofit group were 41 gpd, or approximately 10 percent of total household water use. The bulk of the savings occurred in the summer and fall (Figure ES-3. Residential Water Savings: Technology + Education). The education group residential customers saved 26 gpd, or about 6 percent of total water use. The savings from this group were more uniform throughout the year (Figure ES-4, Residential Water Savings, Education Only). The retrofit group also included 15 dedicated landscape accounts (ranging in size from 0.14 acres to 1.92 acres), which showed average water savings of 545 gpd. The net result was eight times more water savings than with the single-family residential controller, strongly indicating that the larger the landscape, the better the savings per controller.

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Figure ES -3
Residential Water Savings: Technology + Education

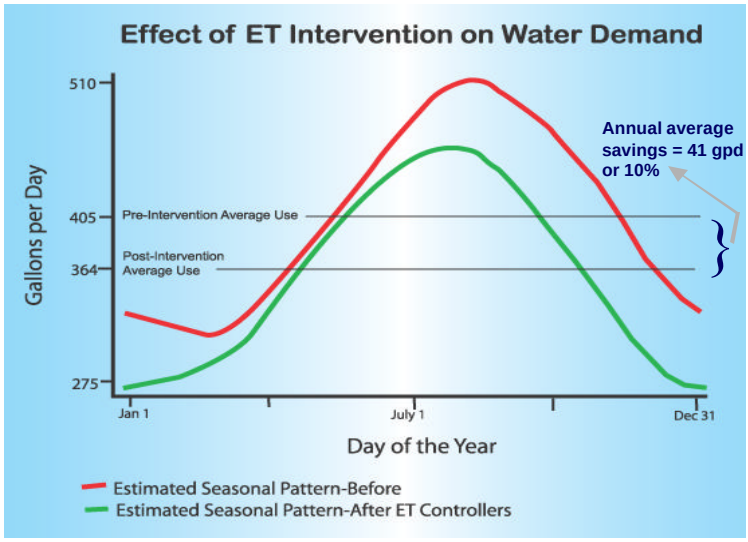

Figure ES -4
Residential Water Savings: Education Only

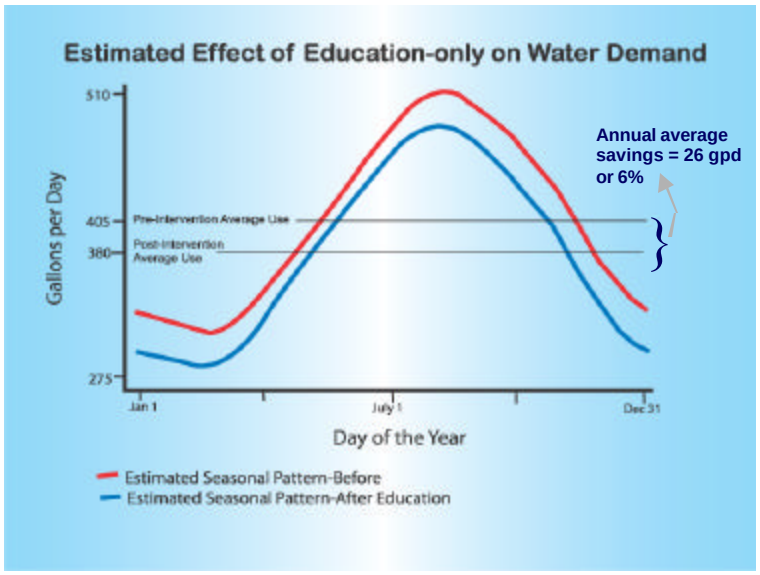

Figure ES -5
Changes in Runoff Within Each Site

b) Dry Season Runoff Changes

The retrofit group experienced a 50 percent direct reduction in water runoff (pre-intervention runoff compared to post-intervention runoff) during dry season periods. When the retrofit group is compared to the control group, the dry season runoff shows a statistical reduction of approximately 71 percent. In contrast, a comparison of direct pre-intervention and post-intervention runoff from the education group increased 37 percent, while runoff increased 70 percent within the control group. Other than the presence of an

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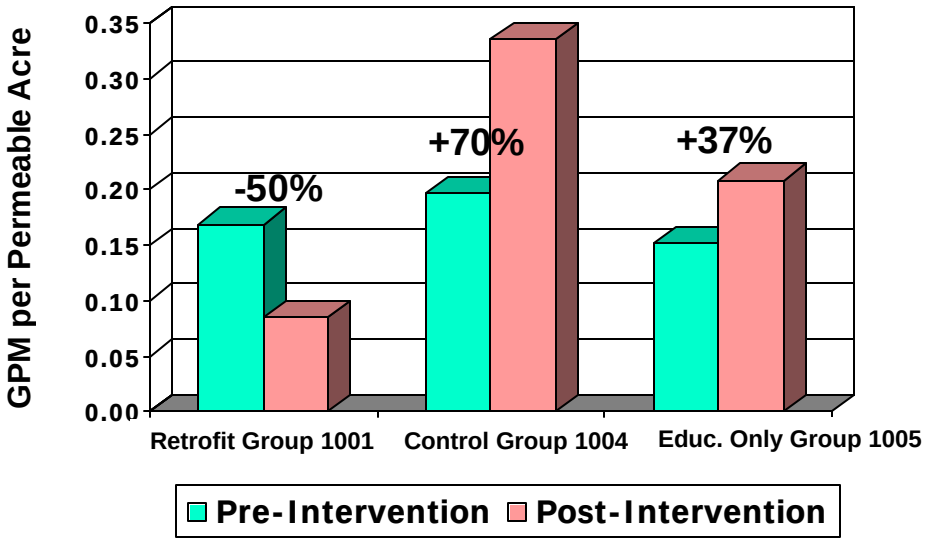
ET controller, the primary difference between these groups is the participation of the 15 landscape accounts in the retrofit group. These accounts irrigated approximately 12 acres of landscape versus between 4 to 5 acres of total irrigated area for the 112 residential homes. Figure ES-5 presents R3 Study changes in runoff within sites.

Figure ES -5
Changes is Runoff Within Each Site



Note: It is also possible to compare post-intervention runoff *between* the study sites. These comparisons suggest a higher reduction in runoff for Site 1001 (between 64 and 71 percent) than was observed for the "within site" pre and post comparison, and a reduction in runoff of 21 percent for Site 1005. However, as described more fully in the text, these comparisons are less reliable than the "within site" pre and post comparisons shown here.

c) Changes in Runoff Water Quality

The study gathered a great deal of information on the water quality constituents present in urban runoff. In almost all cases, the data showed no changes in the concentration of these constituents in the runoff. The most significant fact to come out of the urban runoff water quality data is that the decrease in runoff volume from the retrofit group did not appear to result in an increase in the concentration of pollutants in the runoff. Thus, it is probable that a reduction in total pollutant migration could be achieved by reducing total dry season urban runoff.

d) Public Acceptance of Water Management

While there were some customer service-related issues, the retrofit group had a generally positive response to the ET controller, with 72 percent of participants indicating that they liked the controllers. The retrofit group also found that the controller irrigation either maintained or improved the appearance of the landscape. This has very positive implications. The water district customers receive a desired benefit of a healthy landscape, and the community receives several important environmental benefits from

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the conservation of valuable and limited water resources and the reduction in dry season urban runoff.

Findings, Conclusions, and Recommendations

The R3 Study showed that weather-based irrigation controllers, which provide proper landscape water management, resulted in water savings of 41 gpd in typical residential settings and 545 gpd for larger dedicated landscape irrigation accounts. The observed reduction in runoff from the retrofit test area was 50 percent when comparing pre-intervention and post-intervention periods and 71 percent in comparison to the control group. The education group saw reductions in water use of 28 gpd, and a reduction in runoff of 21 percent in comparison to the control group. Water quality parameters in both study areas were highly variable, and very few differences in the level of monitored constituents were detected. In terms of water savings per controller (and cost-effectiveness), the study clearly indicated that larger landscape areas (parks and street medians) should provide the initial targets for the expansion of similar programs.

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Chapter 1: Introduction

1.1 Overview

Weather-based evapotranspiration (ET) irrigation control has long been a tool of large agricultural operations, maximizing crop yields through pinpoint management of crop watering. The Residential Runoff Reduction (R3) Study was conducted to evaluate the applicability of ET technology for other uses. This chapter of the study report presents the following:

- Background information on study rationale;
- Specific study goals and objectives;
- Identification of study partners and their roles/contributions to the study.

The organization of this report is also described, and commonly-used abbreviations and acronyms are listed. References used during the study are presented in Appendix A.

1.2 Background

Approximately 58 percent of residential water demand is used for outdoor purposes, primarily for home landscape irrigation (AWWARF Residential End Uses of Water, 1999). Excess irrigation results in inefficient use of valuable water supplies and increased runoff that is the transport mechanism of pollutants that enter natural waterways and, ultimately, the Pacific Ocean for areas along the west coast.

Landscape water use efficiency/water conservation and watershed management in the urban sector are linked. Water agencies throughout the state are implementing 14 Best Management Practices (BMPs) to increase the efficient use of urban water supplies including landscape irrigation efficiency. Cities and counties are also implementing National Pollutant Discharge Elimination System (NPDES) permit requirements containing BMPs for watershed management focused on runoff reduction.

Recent studies in Orange County have had promising results. In 1998-1999, Irvine Ranch Water District (IRWD), Municipal Water District of Orange County (MWDOC), and the Metropolitan Water District of Southern California (MWD) conducted a study that evaluated the use of weather-based ET irrigation control technology at 40 residential homes in the Westpark area of Irvine. The report from this research, entitled "Residential Weather-Based Irrigation Scheduling: Evidence from the Irvine 'ET Controller' Study," showed water savings that translated to 37 gallons per day (gpd), or 7 percent of total household water use/16 percent of irrigation water use.

In April 2001, water savings from the ET Controller study in Westpark were evaluated through September 2000, or the second post-retrofit year. This evaluation confirmed the persistence of water savings observed during the initial evaluation. More specifically, this evaluation concluded that ET Controllers were able to reduce total household water consumption by roughly 41 gallons per household per day, representing an 8 percent reduction in total household use, or an 18 percent reduction in estimated landscape water use.

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The R3 Study represents the next phase of research associated with the new irrigation control technology linking benefits to watershed management.

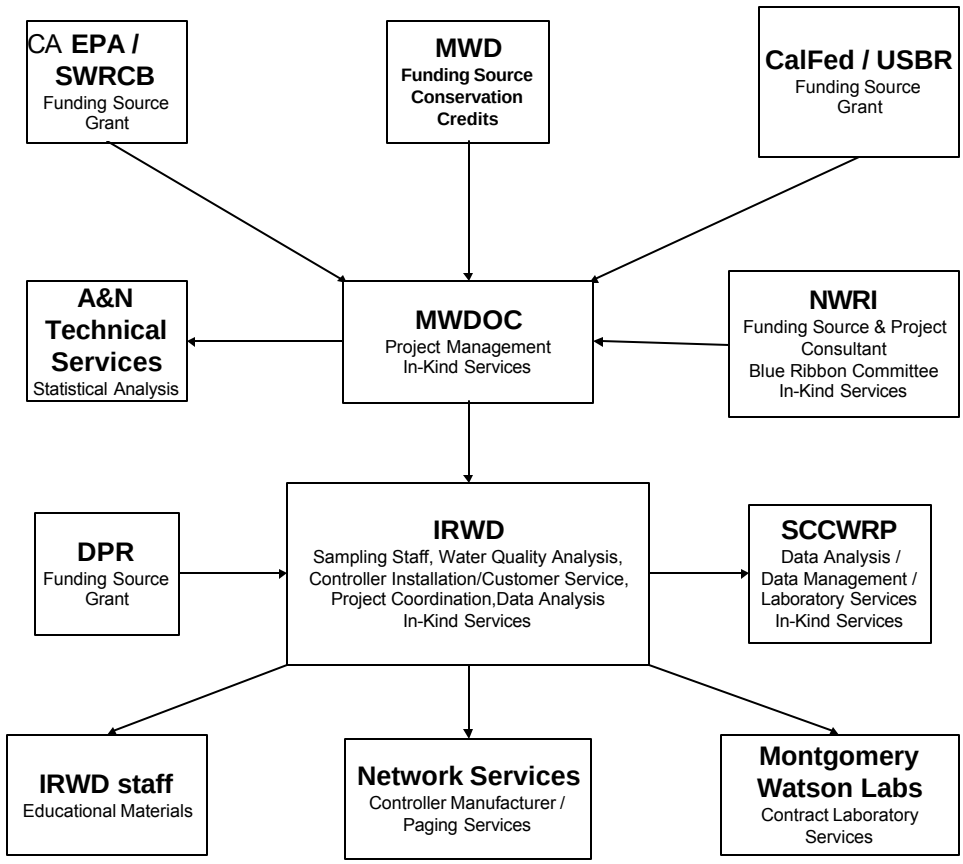
1.3 Study Goal and Objectives

The goal of the R3 Study was to quantify ET Controller savings for single-family residences and large landscape users. The study had four primary purposes: 1) to develop and expand the application and use of pager-signal (electronic controller) technology to manage irrigation water for residential homes and large landscape areas; 2) to evaluate the effectiveness of a targeted education program; 3) to determine the connection between proper water use in the landscape and the quantity and quality of dry weather runoff; and 4) to gauge the acceptance of water management via the controller technology.

1.4 Study Partners

The R3 Study was made possible through a partnership of agencies and organizations committed to improved water use efficiency and watershed management. The members of the partnership are shown on Figure 1-1. The figure also indicates the roles played by each study partner.

Figure 1-1
R3 Study Partners



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As shown on Figure 1-1, the R3 Study involved a diverse mix of study participants and funding agencies bringing equally diverse interests and visions to the project. In general, the study was based on the premise that runoff from poor irrigation practices from urban areas in the San Diego Creek watershed constitutes non-point source pollution and contributes to water quality problems both in the Creek and in Newport Bay, the receiving water for the Creek. Although water quality problems in the Creek and Bay have been well documented, data on the specific sources of these pollutants is limited.

The R3 Study was intended to focus on and analyze both the quality and quantity of runoff from relatively small sub-areas of the watershed to provide insight into the sources of pollution in the Creek and Bay. In addition to providing this baseline information, the study was intended to evaluate the effectiveness of two methods of reducing runoff and improving water quality: 1) education; and 2) education combined with ET controller technology. Furthermore, since irrigation runoff is 100 percent water waste, the water agency participants were very interested in the ability of the study intervention methods to reduce customer water usage.

The R3 Study presented a good opportunity to develop valuable information about the relative effectiveness of structural (retrofit) versus non-structural (public education) controls. A technology + education (retrofit group) BMP was applied in one neighborhood, an education-only BMP was applied in a second neighborhood, and a control was established through three additional neighborhoods.

A more detailed discussion of the study participants is provided below. For purposes of simplicity, the organizations are categorized as agencies responsible for water quality, agencies responsible for water supply, and "supporting participants." However, in many cases, these objectives are overlapping and are not mutually exclusive.

1.4.1 Agencies Responsible for Water Quality

Study participants whose major area of responsibility is water quality include the California Environmental Protection Agency (CAEPA), the State Water Resources Control Board (SWRCB), the Regional Water Quality Control Board (RWQCB), the California Department of Pesticide Regulation (DPR), the County of Orange, and the Southern California Coastal Water Research Project (SCCWRP). These agencies are charged with regulating, enforcing, implementing, or researching and monitoring federal and state laws pertaining to water quality and the control of constituents which may degrade water quality. For example, the RWQCB is responsible for establishing limits on the amount of pollutants that can be discharged to Newport Bay. These limits are defined as "Total Maximum Daily Load" (TMDL). The County of Orange, which provided indirect funding to the study through DPR, is the primary permittee on the Municipal Separate Storm Sewer System (MS4) Permit issued by the RWQCB. The County's primary interest in the study relates to their efforts to implement a comprehensive program of BMPs to meet the TMDLs as required by the MS4 permit. In addition to providing improved baseline water quality and runoff information, these agencies focus on gauging the

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effectiveness of the two study intervention methods in reducing the quantity of runoff and improving the quality of the water that does run off.

1.4.2 Water Agencies

IRWD and MWDOC are water districts whose primary mission is to provide safe and reliable water service to customers within their respective service areas. The reliability of water service, in particular, is directly related to the efficiency of water use. In other words, since supplies of reasonably priced water are essentially fixed, increases in efficiency can result in additional supplies being available for storage until they are needed during periods of supply shortages.

Both IRWD and MWDOC, as well as MWDOC's "parent" agency, MWD, operate various water efficiency/conservation programs within their service areas. Some progress has been made on increasing water use efficiency from programs targeting outside use for landscape irrigation (which generally accounts for about 50 percent of total urban water use). However, water use in this sector remains closely linked to the ability and responsiveness of landscape personnel with responsibility for controlling and adjusting irrigation control timers.

Two basic issues are associated with this "people to water use efficiency" link. First, there is a wide variation in the abilities of personnel to properly set baseline irrigation schedules based on site factors (type of plant material, soil, exposure, slope, irrigation equipment, etc.). Second, for various reasons, it is believed that very few of these timers are adjusted on a sufficient frequency to promote optimum water use efficiency. Consequently, the water agencies are very interested in technologies such as the irrigation controller tested as a part of the R3 study. This technology allows irrigation schedules to be automatically adjusted based on real-time weather conditions. Equally important, the technology provides the ability to set appropriate base irrigation schedules by site conditions, particularly the soil type (infiltration capacity) and slope. This capability is critical to reducing runoff.

In addition to the potential effectiveness of the water management/irrigation controller program, IRWD and MWDOC were also very interested in determining if the focused educational and communication efforts tested in the study could yield customer water savings. This is particularly important since these efforts can be a very cost-effective way to achieve water savings.

In addition to water conservation, water agencies are becoming increasingly aware of their role as providers of water which, if not used efficiently, may ultimately become a nuisance or source/carrier of non-point source pollution. Consistent with its vision to optimize the use of resources as demonstrated by its globally-recognized recycled water reuse program, IRWD in particular has taken a leadership role in addressing irrigation runoff/non-point source pollution within its service area, which covers a majority of the San Diego Creek watershed. In addition to the current study focusing on potential source control measures, IRWD has prepared a master plan outlining a system of constructed wetlands which will capture and treat runoff and improve water quality in the watershed and Newport Bay.

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1.4.3 Supporting Participants

The remaining study participants provided vital support for various aspects of the study. Network Services Corporation (now HydroPoint Data Systems, Inc.) manufactured the ET controllers used in the study and was responsible for compiling weather data and transmitting this information to the controllers. The National Water Research Institute (NWRI) provided input on the study design and evaluation, and A&N Technical Services prepared the detailed analysis of water savings and runoff reduction under a contract. Similarly, a portion of the water quality analysis was conducted under a contract by Montgomery Watson.

1.5 Report Organization

The R3 Study report is organized into two main parts: a body, consisting of seven chapters, followed by eight Appendices containing references and the analyses prepared by the study partners and presented in their entirety.

The first two sections of this report (Chapters 1 and 2) present general information about study goals and methodology. Chapter 1 presents study rationale, goals and objectives, and participating organizations. Chapter 2 describes how the study area was developed and presents the methodology used to develop information on the four main study areas: water conservation savings, dry season runoff/reduction savings, water quality impacts, and customer acceptance/public education.

Chapters 3 through 6 present the evaluations for the four main study areas, respectively, water conservation, dry season runoff, water quality, and customer acceptance. Each chapter provides an overview, summarizes the evaluation approach, presents results, and summarizes major conclusions. More detailed information on the evaluations is presented in the Appendices.

The final section of this report (Chapters 7) integrates study results and describes relevance for future planning and policy. Key findings, conclusions, and recommendations are presented.

The Appendices to this report contain eight sections. Appendix A, References, lists reports, articles, and other documents utilized during the R3 Study. Appendix B, Study Design, provides support information for Chapter 2, Study Methodology, and provides details on the techniques and methods used for data collection, sampling, and analysis. Appendix C, Water Conservation, presents the detailed water conservation evaluation conducted by A&N Technical Services, Inc., and includes detailed information on data models developed for the analysis. Appendix D1, Statistical Analysis of Urban Runoff Reduction, and Appendix D2, 2003 Runoff Data, present the detailed statistical analysis of runoff reduction. These analyses were also prepared by A&N Technical Services, Inc., and include detailed information on the data collection and analysis approach. Appendix E1 and E2 present Water Quality information. E1 was prepared by SCCWRP, and E2 was prepared by GeoSyntec Consultants. Finally, Appendix F, Public Education, presents information on customer acceptance and public involvement.

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1.6 Abbreviations and Acronyms

The following abbreviations and acronyms are used in this report:

ADP	antecedent dry period
ANOVA	analysis of variance between groups
AWWA	American Water Works Association
AWWARF	American Water Works Association Research Foundation
BACI	before-after control impact
BMPs	Best Management Practices
CAEPA	California Environmental Protection Agency
Calfed	consortium of state and federal agencies who address California and San Francisco Bay-Delta water issues
cfs	cubic feet per second
CIMIS	California Irrigation Management Information System
CTR	California Toxic Rule
DPR	California Department of Pesticide Regulation
ET	evapotranspiration
fps	feet per second
GIS	geographic information system
gpd	gallons per day
HOA	homeowners association
IRWD	Irvine Ranch Water District
K-W	Kruskal-Wallis
mgd	million gallons per day
mg/acre/day	milligrams per acre per day
mg/L	milligrams per liter
mL	milliliters
MPN	most probable number
MS4	Multiple Separate Storm Sewer System
MWD	Metropolitan Water District of Southern California
MWDOC	Municipal Water District of Orange County
NPDES	National Pollutant Discharge Elimination System
NWRI	National Water Research Institute
OCPFRD	Orange County Public Facilities and Resources Department
OP	organophosphorus
ng/L	nanograms per liter
PCF	pressure control facility
R3	Residential Runoff Reduction Study
RWQCB	Regional Water Quality Control Board
SCCWRP	Southern California Coastal Water Research Project
SWRCB	State Water Resources Control Board
TIN	total inorganic nitrogen
TKN	total Kjeldahl nitrogen
TMDL	total maximum daily load
TN	total nitrogen

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TP	total phosphorous
ug/L	micrograms per liter
USBR	United States Bureau of Reclamation
USEPA	Untied States Environmental Protection Agency

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Chapter 2: Study Methodology

2.1 Overview

Historically, water agencies have utilized educational programs and in some cases allocation-based rate structures to achieve improved irrigation efficiency in urban landscapes. With the introduction of "smart" weather-based irrigation controller technology, which in early studies generated quantifiable and reliable irrigation water savings over time, water agencies may now have a new and effective management tool to introduce to residential and other customers. The R3 Study compared, in a controlled setting, water savings and watershed management benefits of a remote, weather-based "ET" automated irrigation controller technology. This chapter of the report presents information on the methodology used in the following areas:

- Study design, including study area development, flow monitoring and water quality sampling procedures, and determination of a viable ET irrigation controller operation and selection process.
- Evaluation of water conservation savings.
- Quantification of dry season runoff reduction savings.
- Assessment of water quality impacts.
- Approach to public acceptance/public education.

More information on study design is presented in Appendix B. Evaluation-specific information on study design, data collection/analysis, and results is presented in Chapters 3 through 6 for water conservation, dry season runoff reduction, water quality, and public education, respectively. Additional details are provided in Appendices C through F.

2.2 Study Design

Study design included developing a viable study area, which provided for accurate data collection and comparison. Identifying appropriate flow monitoring equipment and determining an effective ET irrigation controller operation and selection were also important.

The goal of this study is to compare the effectiveness of technological BMPs versus public education for reducing the volume, concentrations, and mass emissions of potential pollutants in dry weather runoff from irrigated landscapes. The technological BMP consisted of ET controllers that communicate with irrigation systems of individual households and selected large landscapes, such as street medians, parks, etc. This technology is designed to optimize watering times for landscaped areas, hence reducing over-watering and resultant runoff. (See Section 2.2.3.) The public education campaign focused both on appropriate watering times and on the correct application of pesticides, herbicides, and fertilizers. (See Section 2.3.4.) These two types of BMPs were tested in residential neighborhoods, typically the most common land use in urban watersheds (Wong et al.1997). The goal was to determine if technology or education provides more pollutant reduction so that urban runoff managers can select optimal runoff pollutant minimization strategies.

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2.2.1 Development of the Study Area

When developing the R3 Study area, the study partners focused on identifying watersheds with similar characteristics that would enable them to confirm water savings identified in the previous "Westpark" study, a water conservation evaluation (IRWD, MWDOC and MWD, 200l). Because a parallel purpose was to expand upon the findings of the Westpark study by measuring changes in dry weather volume (dry season runoff evaluation) and pollutant content of residential runoff (water quality evaluation) associated with improved irrigation management practices, both single-family residences and medium-size landscapes were considered. The R3 Study area is located within IRWD's service area as shown on Figure 2-1.

The R3 Study involved data collection and evaluation not previously attempted at such a large scale. In order to ensure reliable and accurate results, the study team sought to minimize the effects of outside variables that might produce "skewed" results. The team designated a study area that included five similar neighborhoods in Irvine, California. The study area was configured so that meaningful data could be provided for the water conservation, dry weather runoff reduction, and water quality evaluations. Runoff from each of the neighborhoods could be isolated and sampled at a single point from within the municipal sewer system, enabling each neighborhood to be treated individually. At these points of drainage, the runoff volume was monitored, and water quality samples were taken. The five neighborhoods are summarized in Table 2-1 and depicted graphically on Figure 2-2.

Table 2-1
Summary of Neighborhoods

Name	Description/Purpose	Comments
Site 1001 Retrofit Group	The homes in this group were retrofitted with an ET controller and also received education information.	The Retrofit Group area consisted of: • 112 residential landscapes • 12 City of Irvine streets • 2 condominium associations • 1 homeowners association
Sites 1002 – 1004 Control Groups	The homes in this group were monitored as experimental control groups and received no ET controller and no public education materials.	The Control Group area had evaluation-specific variations in size and configuration. In addition, some evaluations assessed "matched" and "unmatched" controls from within and outside of the study area.
Site 1005 Education Group	The homes in this group received information materials only (the same education information as supplied to the Retrofit Group).	The Education Group consisted of 225 homes identified by visual selection. This area also included one large school site.

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Figure 2-1
Location of R3 Study Area Within Southern California

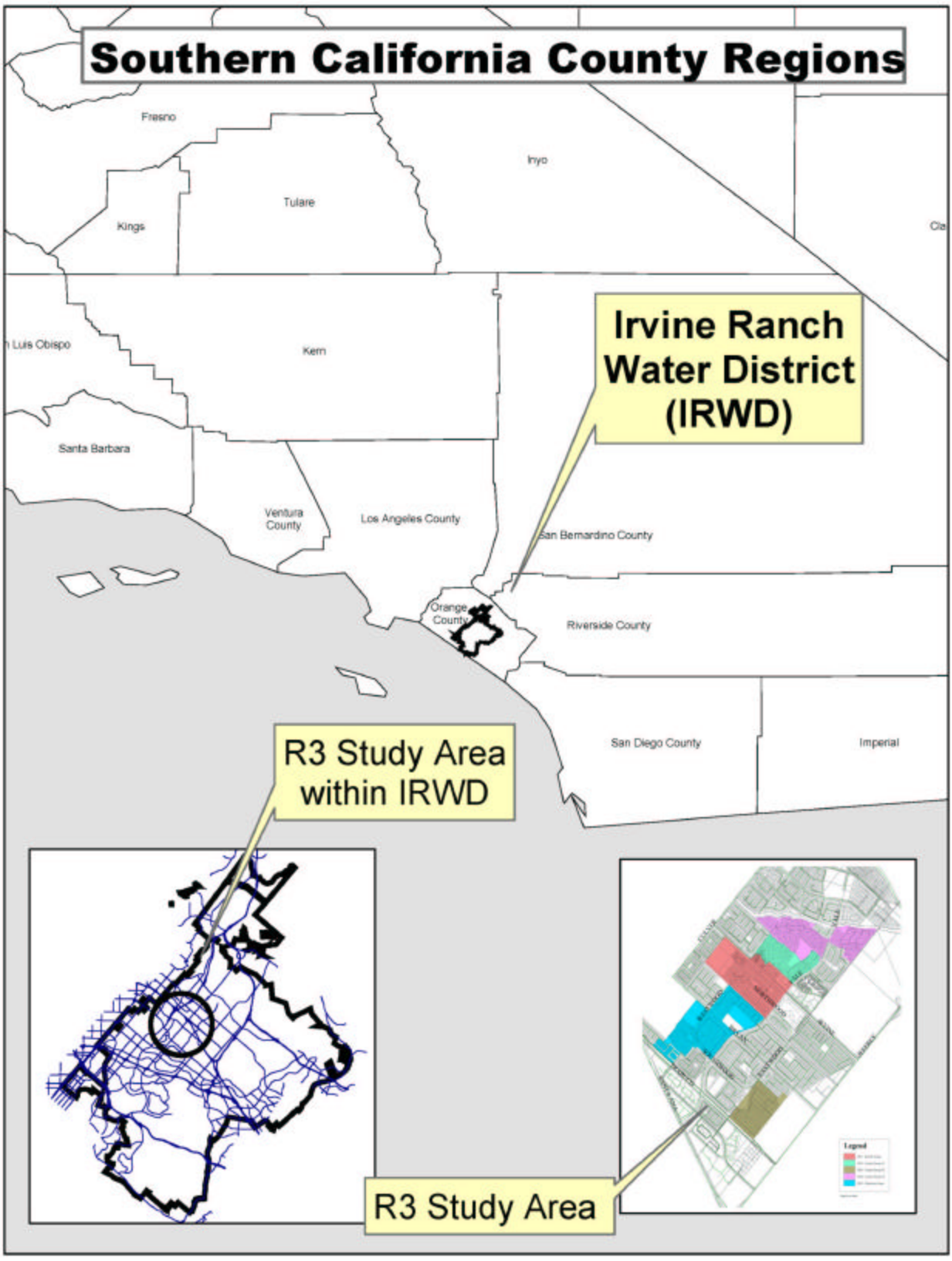
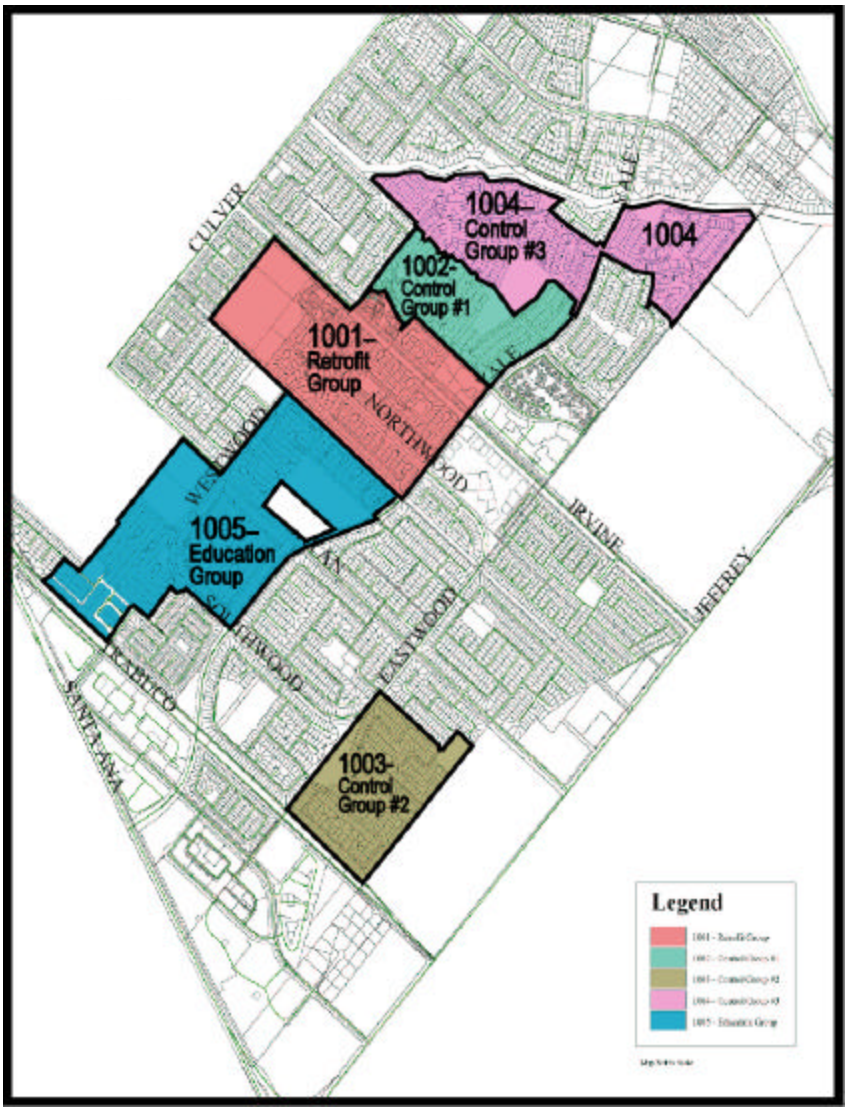


Figure 2-2
R3 Study Neighborhood Areas



In the first of the neighborhoods (Site 1001 or retrofit group), participating homes received a site evaluation and installation of an ET controller to automatically adjust irrigation schedules. Additionally, the residents at these homes received information regarding environmentally-sensitive landscape maintenance practices. The controllers were installed in 112 residential homes, 12 city street landscapes in the City of Irvine, two condominium associations' landscapes, and one homeowners association (HOA) landscape. The HOA landscape had three distinctive sites: 1) pool/park/tennis courts, 2) park, and 3) streetscapes.

The second neighborhood (Site 1005, or education group) received the same environmentally-sensitive landscape maintenance information as the first group, as well as a suggested irrigation schedule.

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The three remaining neighborhoods (Sites 1002 – 1004, or control group) did not receive ET controllers and were not provided educational materials. Residents in the control groups had no knowledge of the study and were used only for comparison purposes. The make-up of the control group varied depending upon the evaluation. In the water conservation evaluation, "matched controls" were used in addition to the control group sites. In the water conservation and the dry weather runoff evaluations, only data from Site 1004 was used, as discussed in Sections 2.3.1 and 2.3.2. Data from all three sites was used in the water quality evaluation.

The five neighborhoods were selected based on the following criteria: 1) isolation from other neighborhood watersheds, 2) climate, 3) land use, 4) development age, and 5) irrigation water management techniques. These parameters are described in greater detail in Appendix B.

2.2.2 Flow Monitoring / Water Quality Sampling

This section summarizes the approach to flow monitoring and water quality sampling.

2.2.2.1 Flow Monitoring

Two main criteria were established for the study's flow monitoring equipment. First, the monitor could not alter the pipe or channel. Second, the monitoring had to be sufficiently accurate to distinguish seasonal flow changes and any flow change that resulted from the two study treatments (retrofit and education). Because the storm drain systems used for flow monitoring are designed to convey peak storm flows, and the focus of the R3 study was on changes in dry season (low flow) runoff associated with the treatments, the flow monitors had to be able to detect relatively small differences in low volume flows in large diameter storm drains. This situation was exacerbated by the fact that only a portion of each tributary neighborhood received the study treatments. Two flow monitoring technologies were determined to meet these criteria:

- Manning's equation plus a level sensor
- Velocity sensor and level monitor (area-velocity)

The area-velocity method was chosen due to lack of slope information for the storm drain system. The selected equipment was an American Sigma 950, which is battery-operated and can record data every minute. The equipment has an ultrasonic transmitter and a velocity sensor, both of which were installed in the storm drain. The ultrasonic transmitter establishes the water surface level and area, while the velocity sensor determines the velocity of the water in the pipe. Flow is calculated by the equation:

- Flow = Area x Velocity

Because four of the five monitoring locations were in a pipe, several variations on the ultrasonic transmitter / velocity sensor were tested before the combination of sonic and velocity wafer were finalized.

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The accuracy of the flow monitoring equipment was tested at all study sites. This was accomplished by metering flow (at three different levels) from a fire hydrant within each tributary watershed and comparing these metered flows to flows measured at the flow monitoring locations. As expected, the accuracy of the flow monitors varied from site to site depending on the nature and condition of each storm drain. For example, some settling of the storm drain was noted near the flow monitor for Site 1002, resulting in an accumulation of sediment. This physical "anomaly" altered the hydraulic characteristics of the pipe and affected the accuracy of flow measurements. However, based on the flow test results, it was believed that these issues were manageable. The subsequent analysis of flow data as presented in Chapter 4 of this report suggests that this belief was partially correct; although flow monitoring problems required data from two of the three control sites to be discarded, the data from the other three sites (two treatments and one control) was sufficiently accurate to allow for the determination of meaningful statistical results.

2.2.2.2 Water Quality Sampling

The water quality sampling program quantified constituents found in residential runoff flows. This program consisted of two phases: 1) pre-study and 2) dry weather sampling. More information about water quality sampling and analysis is provided in Section 2.3.3, Chapter 5 and Appendices B and E.

2.2.3 ET Irrigation Controller Operation and Selection Process

The technology-based BMP consisted of an ET controller + education. The ET controller selected was similar to most automatic sprinkler timers available at home improvement stores and nurseries, but with the capacity to receive radio signals that will alter sprinkler timing based on current weather conditions. If the weather is hot and dry, the radio signal calls for longer or more frequent irrigation. If the weather is cool and moist, such as recent precipitation, the radio signals call for shorter or less frequent irrigation. For the R3 Study, the existing sprinkler timers that are set manually by the homeowner were replaced with the radio-controlled ET controller systems. Trained technicians were used to ensure successful installation because the ET controller requires programming for each valve including area (size of yard or planter per valve), soil type (clay, sand, etc.), and landscape type (turfgrass, shrubbery, etc.). The remaining irrigation system was unchanged, including piping and sprinkler head configuration.

Since residential areas include landscapes other than the homeowners, these "common area" and streetscape landscape areas ("medium-size" landscapes) were included in the water management component of the R3 Study. As shown in Table 2-2, the medium-size landscapes accounted for an estimated 70 percent of the total landscape area treated in the retrofit group (Site 1001). The installation process for both residential and medium-size landscapes is described in Appendix B.

2.2.3.1 Controller Installation

The study evaluated the performance of the engineering of irrigation management techniques to reduce the consumption and residential runoff while maintaining the quality of the landscape. A typical irrigation controller is difficult to program and limited in the scope of the scheduling

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ability. Proper scheduling requires calculations based on real time ET data, landscape topography, and plant type, which are beyond the capabilities of typical controllers. The landscaper in the field is left to guess or rely on past experience as to the correct amount of water, the correct runtime to prevent runoff, and the correct number of days of the week to water.

The controllers were installed following the general principle that an ET controller is a water management tool and that professional operation should result in conservation and reduction of runoff. A picture of the controller is shown on Figure 2-3. More information is provided in Appendix B.

Figure 2-3
ET Controller

2.2.3.2 ET Controller Operation

The operation of the ET controller in this study was optimized by proper irrigation scheduling. As discussed further in Chapter 4 and Appendices B, D1 and D2, the ET controller must meet three key criteria: cost, ease of operation, and ability to conserve water and reduce runoff.

2.3 Study Evaluations

This section summarizes the water conservation evaluation, the quantification of changes in dry season runoff reduction savings, the analysis of water quality impacts, and the approach to customer acceptance / public education.

Table 2-2
Study Sites Land Use and Treatment Summary

Site 1001

Land Use	No. of Lots	Acres	Treatment Sites	Treatment Acreage*	No. of Controllers
SFR	565	66.8	112	6.6	112
Condo	109	10.3	2	1.9	8
HOA	4	5.9	1	0.9	3
School	2	4.6			
Landscape	10	19.4	12	11.2	15
Street	97	49.7			
Unmetered	64	11.5			
Total	**851**	**168.1**	**127**	**20.5**	**138**

***Note: All acreage except SFR were considered "medium-size" landscapes.**

Site 1002

Land Use	No. of Lots	Acres	Treatment Sites	Treatment Acreage	No. of Controllers
SFR	-	-	control	control	control
Condo	-	-	control	control	control
HOA	-	-	control	control	control
School	-	-	control	control	control
Landscape	-	-	control	control	control
Street	-	-	control	control	control
Unmetered	-	-	control	control	control
Total	-	-			

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Table 2-2 (continued)
Study Sites Land Use and Treatment Summary

Site 1003

Land Use	No. of Lots	Acres	Treatment Sites	Treatment Acreage	No. of Controllers
SFR	-	-	control	control	control
Condo	-	-	control	control	control
HOA	-	-	control	control	control
School	-	-	control	control	control
Landscape	-	-	control	control	control
Street	-	-	control	control	control
Unmetered	-	-	control	control	control
Total	**-**	**-**			

Site 1004

Land Use	No. of Lots	Acres	Treatment Sites	Treatment Acreage	No. of Controllers
SFR	417	47.8	control	control	control
Condo	-	-	control	control	control
HOA	1	0.9	control	control	control
School	1	8.0	control	control	control
Landscape	2	0.0	control	control	control
Street	42	25.0	control	control	control
Unmetered	61	7.1	control	control	control
Total	**524**	**88.8**			

Site 1005

Land Use	No. of Lots	Acres	Treatment Sites	Treatment Acreage	No. of Controllers
SFR	559	67.9	225	13.0	n/a
Condo	-	-	-	-	n/a
HOA	1	1.5	-	-	n/a
School	2	12.1	-	-	n/a
Landscape	2	0.0	-	-	n/a
Street	45	0.0	-	-	n/a
Unmetered	8	2.7	-	-	n/a
Total	**617**	**84.2**	**225**	**13.0**	**0**

2.3.1 Water Conservation Evaluation

The water conservation evaluation was conducted by A&N Technical Services, Inc. The firm performed a statistical analysis of historical water consumption records from, roughly, July 1997 to August 2002. Two main types of water use were reviewed: single-family residences and medium-size landscapes. For the single-family residences, data was compared among the retrofit group, the education group, and the control group. For the medium-size landscape accounts, a slightly different approach was used. Accounts within the study area were compared to "matched" and "unmatched" controls in the City of Irvine, both within and outside of the study

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area. Matched controls were similar in sun exposure, irrigation type, soil type, etc. Unmatched controls were areas not similar enough to be used for direct comparison but areas that could be used for weather normalization. A detailed description of the methods used to evaluate water savings for the single-family residence and medium-size landscape sites is provided in Chapter 3 and Appendix C of this report.

2.3.2 Dry Season Runoff Reduction Savings Quantification

In addition to the water conservation evaluation, A&N Technical Services, Inc., performed a statistical analysis of the reduction of runoff induced by ET controller and irrigation education. With the assistance of IRWD staff, who collected runoff data, A&N developed regression models to estimate mean runoff by site.

Two of the control sites (1002 and 1003) had recurring measurements issues that produced generally unreliable data. Site 1002 was found to have a physical hydraulic jump, which caused sediments to build in such a way that flows avoided the monitor. At Site 1003, there was an occurrence of illegal dumping of cement into the storm drain. This event reshaped the monitoring area, led to continuous collection of debris, and caused the monitor to perform erratically. Thus, it was only possible to use data from Site 1004. More details are provided in Chapter 4 and Appendices D1 and D2.

2.3.3 Water Quality Impacts Assessment

As described in Section 2.2.2.2, the water quality sampling program quantified constituents found in residential runoff flows. Two independent reviews of the water quality data were performed. The initial review, conducted by SCCWRP, used parametric statistical techniques (t-test; analysis of variance [ANOVA]), which provide a good descriptive review of the study. However, these techniques are generally considered to have less power for detecting differences in data than other statistical tests. A subsequent statistical overview was performed by Geosyntec Consultants to review alternative and possibly more "robust" data analysis techniques. This work, which included the review of only a portion of the data set, focused on additional descriptive techniques (time series plots; box plots; probability distributions) and the use of non-parametric statistical techniques (rank-sum test; Kruskal-Wallis [K-W]). The SCCWRP and Geosyntec Consultants reports are presented in Appendix E-1 and E-2, respectively.

2.3.4 Public Acceptance / Public Education Approach

The public acceptance evaluation was conducted to compare the effectiveness of proposed BMPs for ET controller technology + education and education only. The participating ET technology retrofit group homes received a site evaluation and installation of an ET controller to manage the irrigation system. Additionally, the residents of these homes received information regarding environmentally-sensitive landscape practices. The education-only group received an initial informational packet containing three items: an introductory letter, an informational booklet, and a soil probe to measure the water content of landscaped soils.

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In addition to the initial packet, monthly reminders were mailed to each homeowner that included tips for maintaining the irrigation system. Suggested sprinkler run times (for the non-ET controller neighborhood) and tips on fertilizer or pesticide application usage, including non-toxic alternatives, were also provided in the monthly newsletter. A telephone log was kept to monitor incoming customer calls relating to the R3 Study, and a pre- and post-program survey was developed to measure customer impact of the study. More details are provided in Chapter 6 and Appendix F.

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Chapter 3: Water Conservation

3.1 Overview

This chapter describes the statistical analysis of water savings (water conservation) among customers who installed ET controllers and customers given irrigation education in the study area. Specific information includes:

- A summary of study methods and evaluation approach.
- Evaluation results for large landscape customers and for single-family residences.
- Effect of ET controllers on seasonal peak demand.

More detailed information is provided in Appendix C.

3.2 Evaluation Approach

This section summarizes the overall evaluation approach, the records, review process, and data assessment techniques.

3.2.1 Overall Evaluation Approach

Historical water consumption records for a sample of participants and for a sample of nonparticipating customers were examined statistically. The hypothesis was that installation of new irrigation technology or better management of existing equipment would reduce the observed water consumption of customers participating in this program. This study empirically estimates the water savings that resulted from two types of "interventions"—1) customers receiving both ET controllers and follow-up education and 2) customers receiving an education-only intervention. Both single-family residences and medium-size landscapes were evaluated. (See Tables 3-1 and 3-2.)

Table 3-1
Summary of Water Conservation Evaluation Approach for Single-family Residences

Site	Number of Usable Accounts	
Site 1001 Retrofit Group	Retrofit Non Participants	97* 213
Site 1004 Control Group		264
Site 1005 Education Group	Education Non Participants	192* 346

*Note: These sample numbers are smaller than the total number of original participants in each group due to changes in tenants, anomalous data, and other data quality issues.

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Table 3-2
Summary of Water Conservation Approach for Medium-size Landscapes

Type	Number of Usable Accounts	Average Acres Per Account
Participating Landscapes	15*	0.93
Matched Controls	76	0.92
Unmatched Controls	895	0.96

Note: This sample number is smaller than the total number of original study participants due anomalous data, and other data quality issues .

Since installation of ET controllers required the voluntary agreement of the customer to participate, this sample of customers can be termed "self-selected." Customers in the education–only group were initially approached by mail about their interest in participating in the study. 137 customers initially expressing interest were included in the study group. However, because sufficient interest in the study was not generated through this mailing to meet the study saturation goals for this group, the remaining 112 participants self selected. While this analysis does quantitatively estimate the reduction of participant's water consumption, one may not directly extrapolate this finding to nonparticipants. This is because self-selected participants can differ from customers who decided not to participate.

The explanatory variables in these models include:

- Deterministic functions of calendar time, including
    - the seasonal shape of demand
- Weather conditions
    - measures of air temperature
    - measures of precipitation, contemporaneous and lagged
- Customer-specific mean water consumption
- "Intervention" measures of the date of participation and the type of intervention

3.2.2 Records Review Process

Consumption records were compiled from IRWD's customer billing system for customers in the study areas. Billing histories were obtained from meter reads between July 1997 and August 2002. It is important to note that a meter read on August 1 will largely represent water consumption in July. Since the ET controllers were installed in May and June of 2001, the derived sample contained slightly more than one year of data for each participant. More information is presented in Appendix C.

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The landscape-only customers (15 accounts) were handled separately. Two control groups were developed for these irrigation accounts: A matched control group was selected by IRWD staff by visual inspection, finding three-to-five similar control sites for each participating site. Similarity was judged by irrigated area and type of use (HOA, median, park, or streetscape). Since the City of Irvine was improving irrigation efficiency on the City-owned sites during the post-intervention period, this matched control group also had potential water savings. A second control group was developed where the selection was done solely based on geographic area. In this way, the statistical models could separately estimate the water savings effects for each group. (See Appendix C.)

3.2.3 Data Assessment Techniques

The first major issue with using meter-read consumption data is the level and magnitude of noise in the data. The second major issue is that records of metered water consumption can also embed non-ignorable meter mis-measurement. To keep either type of data inconsistencies from corrupting statistical estimates of model parameters, the modeling effort employed a sophisticated range of outlier-detection methods and models. These are described in Appendix C.

Daily weather measurements—daily precipitation, maximum air temperature, and evapotranspiration—were collected from the California Irrigation Management Information System (CIMIS) weather station located in Irvine. Daily weather histories were collected as far back as were available (January 1, 1948) to provide the best possible estimates for "normal" weather through the year. Thus, 54 observations were available upon which to judge "normal" rainfall and temperature for January 1^{rst} of any given year.

Robust regression techniques were used to detect which observations were potentially data quality errors. This methodology determines the relative level of inconsistency of each observation with a given model form. A measure is constructed to depict the level of inconsistency between zero and one; this measure is then used as a weight in subsequent regressions. Less consistent observations are down-weighted. Other model-based outlier diagnostics were also employed to screen the data for any egregious data quality issues.

3.3 Evaluation Results

This section presents evaluation results for single-family residences and landscape-only customers. The effect of ET controllers on peak demand is also discussed.

3.3.1 Estimated Single-family Residential Water Demand

Table 3-3 presents the estimation results for the model of single-family water demand in the R3 study sites. Twenty-one variables are listed. This sample represents water consumption among 1,525 single-family households between June 1997 and July 2002. This sample contains 97 ET controller/education participants (in Site 1001) and 192 education-only participants (in Site 1005). This sample is smaller than the total number of participants in each group due to changes in tenants and anomalous data.

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The constant term (1) describes the mean intercept for this equation. (A separate intercept is estimated for each of the 1,525 households, but these are not displayed in Table 3-3 for reasons of brevity.) The independent variables 2 to 8—made up of the sines and cosines of the Fourier series described in Appendix C (Equation 2)—are used to depict the seasonal shape of water demand.

Table 3-3
Single-family Residential Water Demand Model

Dependent Variable: Average Daily Metered Water Consumption in gallons per day (gpd)		
Independent Variable	**Coefficient**	**Std. Error**
1. Constant (Mean intercept)	405.6593	3.1660
2. First Sine harmonic, 12 month (annual) frequency	-45.4215	0.9636
3. First Cosine harmonic, 12 month (annual) frequency	-89.1494	0.9629
4. Second Sine harmonic, 6 month (semi-annual) frequency	3.6549	0.6798
5. Second Cosine harmonic, 6 month (semi-annual) frequency	1.0709	0.6733
6. Third Cosine harmonic, 4 month frequency	1.7312	0.7151
7. Fourth Sine harmonic, 3 month (quarterly) frequency	4.4016	0.7403
8. Fourth Cosine harmonic, 3 month (quarterly) frequency	3.3491	0.7865
9. Interaction of contemporaneous temperature with annual sine harmonic	48.7897	17.1559
10. Interaction of contemporaneous temperature with annual cosine harmonic	-72.4672	22.3626
11. Deviation from logarithm of 31 or 61 day moving average of maximum daily air temperature	284.7163	13.542
12. Interaction of contemporaneous rain with annual sine harmonic	10.1102	1.8546
13. Interaction of contemporaneous rain with annual cosine harmonic	5.9969	2.6904
14. Deviation from logarithm of 31 or 61 day moving sum of rainfall	-34.0117	1.8931
15. Monthly lag from rain deviation	-13.3173	1.0549
16. Average Effect of ET controller/Education (97 participants)	**-41.2266**	**4.0772**
17. Interaction of ET intervention with annual sine harmonic	38.9989	5.3327
18. Interaction of ET intervention with annual cosine harmonic	-6.3723	4.8980
19. Average Effect of Education-only intervention (192 participants)	**-25.5878**	**2.8081**
20. Interaction of Ed.-only intervention with annual sine harmonic	6.0357	3.5870
21. Interaction of Ed.-only intervention with annual cosine harmonic	-3.0703	3.3826
Number of observations	94,655	
Number of customer accounts	1,525	
Standard Error of Individual Constant Terms		120.85
Standard Error of White Noise Error		129.81
Time period of Consumption	June 1997 - July 2002	

The predicted seasonal effect is the shape of demand in a normal weather year. This seasonal shape is important because it represents the point of departure for the estimated weather effects (expressed as departure from normal). The effect of the landscape interventions on this seasonal shape was also tested.

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The estimated weather effect is specified in "departure-from-normal" form. Variable 11 is the departure of monthly temperature from the average temperature for that month in the season. (Average seasonal temperature is derived from a regression of daily temperature on the seasonal harmonics.) Rainfall is treated in an analogous fashion (Variable 14). One month lagged rainfall deviation is also included in the model (Variable 15). It is also noted that the contemporaneous weather effect is interacted with the harmonics to capture any seasonal shape to both the rainfall (Variables 12 and 13) and the temperature (Variables 9 and 10) elasticities. Thus, departures of temperature from normal produce the largest percentage effect in the spring growing season. Similarly, an inch of rainfall produces a larger effect upon demand in the summer than in the winter.

The effect of the landscape conservation program interventions is captured in the following rows. The parameter on the indicator for ET controllers/education (Variable16) suggests that the mean change in water consumption is 41.2 gpd (reduction) while the education only participants (Variable 19) saved approximately 25.6 gpd. Because residential meters serve both outdoor and indoor demand, the model cannot say whether education-only participants saved this water through improved irrigation management or by also reducing indoor water consumption. Since the sample includes only one year of post-intervention data, the model cannot say how persistent either effect will be in future years.

3.3.2 Estimated Landscape Customer Water Demand

Table 3-4 presents the estimation results for the model of medium-size landscape (irrigation-only) customer water demand in the R3 study sites. Seventeen variables are listed. This sample represents water consumption among 992 accounts between June 1997 and August 2002 and contains 21 ET controller accounts, 76 matched control accounts, and 895 unmatched control accounts.

The constant term (1) describes the intercept for this equation. The independent variables 2 to 9—made up of the sines and cosines of the Fourier series described in Appendix C (Equation 2)—are used to depict the seasonal shape of water demand. The estimated weather effect is specified in "departure-from-normal" form. Variable 10 is the departure of monthly temperature from the average temperature for that month in the season. (Average seasonal temperature is derived from a regression of daily temperature on the seasonal harmonics.) Rainfall is treated similarly (Variable 11). One month lagged rainfall deviation is also included in the model (Variable 12). The next variable accounts for the amount of irrigated acreage on the site. (Note that while measured acreage is available for all irrigation-only accounts, this is not true for single-family accounts.)

The effect of the landscape conservation program interventions is captured in the following rows. The parameter on the indicator for ET controllers (Variable 14) suggests that the mean change in water consumption is 545 gpd (reduction), approximately 21 percent of the pre-intervention water use. The matched control group (Variable 16) did experience water savings, approximately 241 gpd or 8.7 percent of their pre-intervention water use. As noted previously, this group included City of Irvine landscape accounts for which a parallel water efficiency program was

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conducted. The variables testing for differences in pre-intervention use cannot distinguish any differences between the different types of accounts.

Table 3-4
Landscape Customer Water Demand Model

Dependent Variable: Average Daily Metered Water Consumption (in gallons per day)		
Independent Variable	**Coefficient**	**Std. Error**
1 Constant (Mean intercept)	2624.0890	235.5602
2. First Sine harmonic, 12 month (annual) frequency	-810.6712	26.4690
3. First Cosine harmonic, 12 month (annual) frequency	-1979.1650	26.1149
4. Second Sine harmonic, 6 month (semi-annual) frequency	103.7890	26.7195
5. Second Cosine harmonic, 6 month (semi-annual) frequency	-18.6126	27.1067
6. Third Sine harmonic, 4 month frequency	-123.5511	28.2926
7. Third Cosine harmonic, 4 month frequency	106.4412	28.6328
8. Fourth Sine harmonic, 3 month (quarterly) frequency	38.3819	30.6999
9. Fourth Cosine harmonic, 3 month (quarterly) frequency	-61.4848	30.9128
10. Deviation from logarithm of 31 or 61 day moving average of maximum daily air temperature	6293.6890	565.6084
11. Deviation from logarithm of 31 or 61 day moving sum of rainfall	-748.2235	52.1792
12. Monthly lag from rain deviation	-209.9027	46.5477
13. Irrigated Acreage (in acres)	485.1284	140.1746
14. ET controller sites, test for difference in pre-intervention use	-327.6321	1511.6870
15. Average Effect of ET controller (21 accounts)	-545.3841	330.3669
16. Matched accounts, test for difference in pre-intervention use	-166.6455	693.9447
17. Average Effect of city efficiency improvements (76 accounts)	-240.4067	148.4015
Number of observations		56666
Number of customer accounts		977
Standard Error of Individual Constant Terms		5766.8
Standard Error of White Noise Error		4189.5
Time period of Consumption	June 1997 - July 2002	

3.3.3 Effect of ET Controllers on Seasonal Peak Demand (Single-family Residential)

The question of how these programs affected the seasonal shape of water demand can be interpreted from the remaining interactive effects—the indicators interacted with the first sine and cosine harmonics.

When the pre / post seasonal patterns are combined with their pre / post mean water consumption, the following before and after picture can be seen throughout the year.

On Figure 3-1, several observations should be made. First, the difference between the two horizontal lines corresponds to the estimated mean reduction of approximately 41 gpd. Second,

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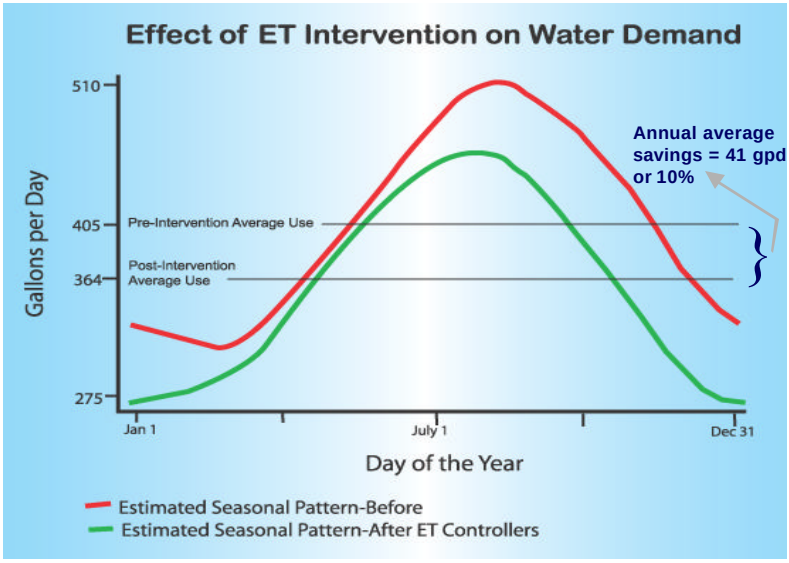
the assumption of a constant 41 gpd effect does not hold true throughout the year. The reduction is barely noticeable in the spring growing season and is much larger in the fall.

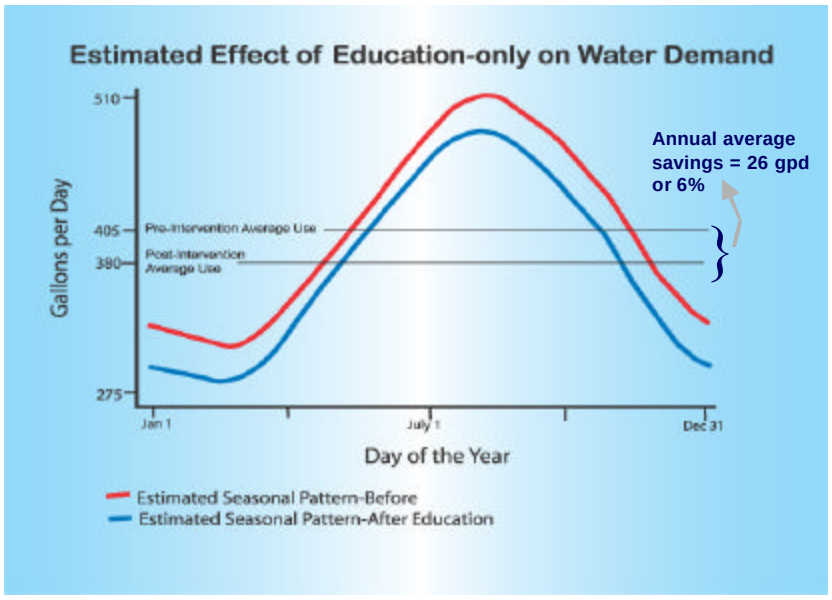
Figure 3-1
Effect of ET Intervention on Seasonal Water Demand for Single-family Residential



The reduction in peak demand—though dependent upon how the seasonal peak is defined—is greater than the average reduction. The estimated peak day demand, occurring on August 8, is reduced by approximately 51 gallons. This "load-shaping" effect of the ET controller intervention can translate into an additional benefit to water agencies. The benefits from peak reduction derive from the avoided costs of those water system costs driven by peak load and not average load—the costs for new treatment, conveyance, and distribution all contain cost components driven by peak capacity requirements

Figure 3-2 plots the corresponding estimates for the education-only intervention. The reduction in average demand is less—approximately 25 gpd. The effect upon the estimated seasonal shape of demand is much more muted. In fact, the change to the estimated seasonal shape of demand induced by the education-only intervention is not significantly different from zero at classical levels of significance.

Figure 3-2
Estimated Effect of Education-only on Seasonal Water Demand for Single-family Residential



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3.4 Conclusions

This modeling effort focused on developing the best depiction of net changes in water consumption due to the landscape interventions of ET controllers and / or education. Much of the modeling effort was expended on data cleaning, diagnosis, and validation. The most serious data issues were identified and appropriately handled. To the extent that future data quality can be improved, future work could provide several statistical refinements in model specification. These are described in Appendix C.

The documentation provided in this report describes the shape of water savings achieved by the landscape interventions of ET controllers and / or education. Households participating in these programs saved significant amounts of water. Savings for the education-only program were less than for the retrofit group, but were still significant. The ET controller / education program changed both the level and shape of water demand.

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Chapter 4: Runoff

4.1 Overview

This chapter presents the statistical analysis of the reduction of runoff induced by ET controllers and irrigation education. Specific information includes:

- Description of flow meters used and the data collection approach
- Discussion of the runoff analysis and analytical methods
- Presentation of evaluation results

More detailed information is provided in Appendices D1 and D2.

4.2. Evaluation Approach

The evaluation approach is summarized in Table 4-1 and discussed in more detail below.

Table 4-1
Summary of Dry Weather Runoff Evaluation Approach

Site	Description/Purpose	Controllers	Measuring Points
Site 1001 Retrofit Group	The study site contained 565 single-family residences. Of these, 112 participated in the ET/education program. In addition, 15 medium-size landscape sites also received ET controllers.	The accounts listed in Table 2-1 were allocated controllers as follows: • 112 for residential landscapes • 15 for 12 City of Irvine streets • 8 for the condominium associations • 3 for the HOA	1
Sites 1004 Control Group	This site contained 417 single-family residences and 44 large landscapes.	Not Applicable	1
Site 1005 Education Group	At this site, 225 residential customers participated in the irrigation education program.	Not Applicable	1

4.2.1 Data Collection

To measure dry weather runoff, flow monitors were installed at the five locations shown on Figure 4-1. The study used Sigma 950 flow monitors manufactured by Hach. The flow monitor applies an area-velocity calculation. The basic formula for flow is: flow (Q) equals the velocity (V) of the water multiplied by the area (A) of the water (Q=VA).

The first variable in the equation, velocity, was measured by velocity wafers placed below the surface of the runoff stream to measure the velocity of the water. These electronic devices were attached to metal plates positioned at the bottom of the concrete pipes that carried runoff. Each velocity wafer was centered to the width of the water flowing in the pipe. Once it is correctly

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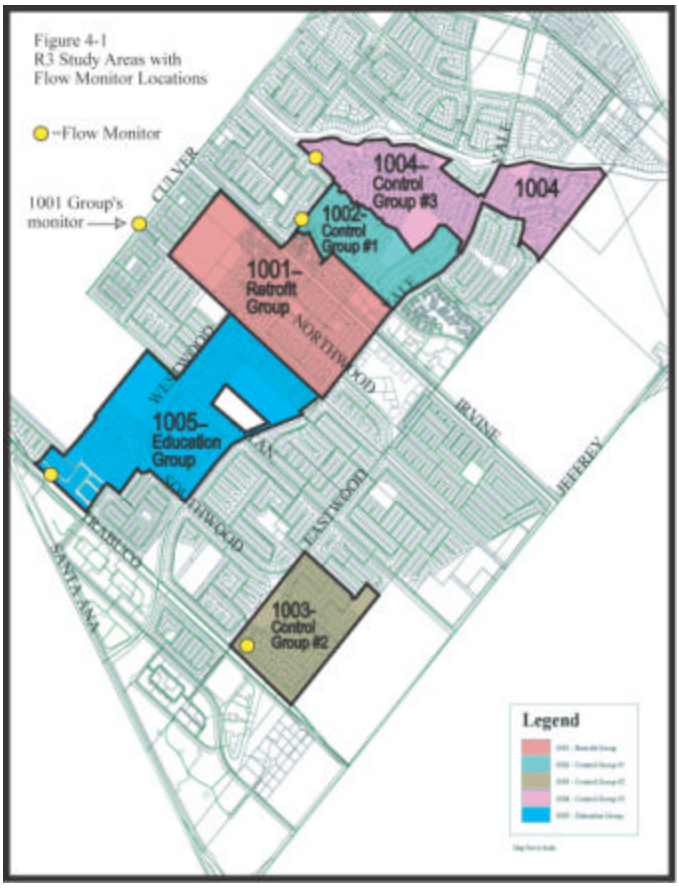
positioned, the wafer measures the velocity of the water by measuring the speed of the particles in the water. This information is then transmitted via cable to the Sigma 950.

The second variable in the water flow equation, the area of the water, also referred to as the cross sectional area, was obtained by multiplying the depth of the water by its width. This calculation is based on geometry, the diameter of the pipe, and the depth of the water. Since the geometry of the area is the arc of a circular pipe of known diameter, the Sigma 950 was able to internally calculate this measurement using data from a sonic sensor. The sonic sensor measures the depth of the water by hanging above the water surface and sending out a sonic pulse that reflects off the surface of the water.

The Sigma 950 contains a central processing unit that recorded the time, water depth, water velocity, and flow every five minutes.

Maintaining the flow monitors in good working order required an R3 Study field staff member to visit each of the five data collection locations twice per week. At each site, staff would open the manhole and lift out the monitor. Then, the storm drainpipe would be inspected for any obstruction or interference with the flow or with the devices (velocity wafer and sonic sensor) used to measure flow.

Figure 4-1
Flow Monitor Locations



Next, staff would measure the depth of the water with a tape measure and recalibrate the flow monitor to this measurement. The velocity wafers could not be calibrated. They were adjusted for accuracy, however, during low flow and low velocity periods. To accomplish this, staff would observe an object on the surface of the water. As the object moved with the flow, staff would estimate its speed as feet per second (fps). This speed was compared to the value simultaneously registered on the flow monitor. If the observed velocity was much slower than that recorded by the monitor, staff would disconnect the velocity wafer. This action would usually reset the velocity wafer. If the problem persisted, the wafer would be replaced.

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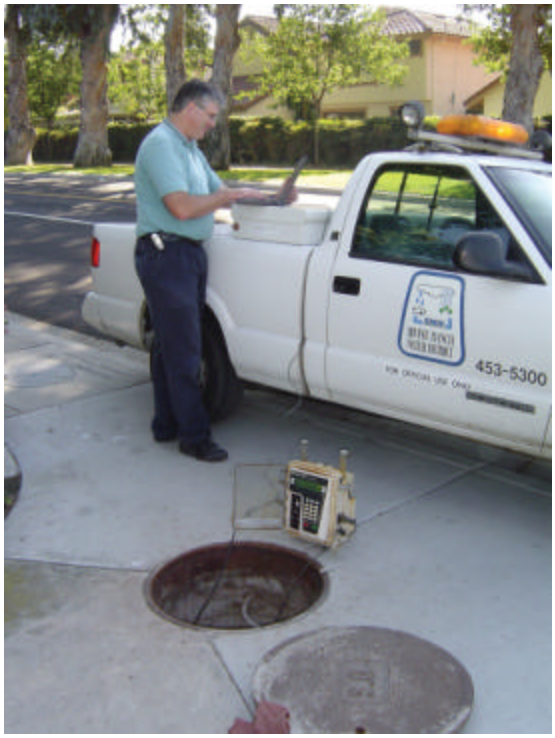
Figure 4-2:
Downloading Data from Sigma 950 Flow Monitor to Laptop



4.2.2 Ranking Collected Data

Twice per week during each site visit, data was downloaded from the flow monitor to a laptop computer. This process is depicted on the adjacent figure (Figure 4-2). When staff returned to IRWD's operations building, the data was downloaded to the District's central computer. Here the data was transferred from a text file to an excel file. At this point, staff would rank the data for each download of each site. After observing the site, recalibrating the flow monitor, and reviewing the data graphs, staff would add ranking to each site's data. The following process assigned these ranks: a) if staff observed nothing unusual and had no reason to suspect any data collection problems, the flow, depth and velocity received a ranking of "zero," b) if one of these factors was suspect or the data graph had an unusual jump in value, the rank indicator was a "one," c) if staff noted a problem which may have affected the data and changed its values beyond the tolerances of the equipment, the data was ranked with a "two."

4.2.2 Data Methods

Robust regressions techniques were used to detect which observations were potentially data quality errors. This methodology determines the relative level of inconsistency of each observation with a given model form. A measure is constructed to depict the level of inconsistency between zero and one; this measure is then used as a weight in subsequent regressions. Less consistent observations are down-weighted. Other model-based outlier diagnostics (Cook's distance, DFBETA statistics, and residual diagnostics) were also employed to screen the data for any egregious data quality issues

After screening for the known data quality problems, using the "rank" indicator, all raw meter reads were first converted to average hourly values. These were then aggregated by date to convert to daily runoff, available in both mean hourly flow and total daily volume.

Precipitation taken from the Irvine weather station was matched to the daily data and used to separate wet from dry days. It should be noted that wet weather flows were monitored and evaluated in a parallel study that assessed pesticide contributors from residential land use during dry and wet weather (SCCWRP, 2003). However, the focus of the R3 study was runoff reduction during the peak irrigation season (i.e., dry weather).

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Wet weather storm flow can be a more complicated phenomenon to predict, as it depends on the timing and magnitude of the rainfall event, the moisture deficit of soils, and other factors. The relative lack of large storm events in the post-intervention period precluded examination of these more complicated forces and the effect that the landscape interventions might have on wet day runoff.

Area-standardized measures of site runoff were also created for dry/wet days, where total daily volume was divided by the estimated permeable/total area. Estimates of area for the study sites were derived from the IRWD geographic information system (GIS) system. The GIS system was queried to produce estimates of the number of lots and total area for the different land use classifications (single family residence, condo, HOA, school, landscape, street, and unknown). The GIS system also provided an estimate of the number of buildings, and building area. The area taken up by buildings is treated as impermeable. The remaining area was separated into permeable and impermeable area using a land use classification-specific assumption of impermeability. Table 4-2 provides the raw data used to construct the estimated site area. (Due to lack of usable flow measures, Sites 1002 and 1003 are not separately reported.) Table 4-3 aggregates the data by site.

Table 4-2
Estimated Area of Study Sites by Land Use

R3 GROUP	#Lots	Classification	Total Area in square feet. (sq. ft.)	Building Area in sq. ft.	Assumed Impermeable Coefficient %	Estimated Impermeable Area in sq. ft.	Estimated Permeable Area in sq. ft.
1001	64	Unmetered	499885		0	0	499885
1001	565	SFR	2911227	976574	0.5	1943900	967326
1001	109	Condo	447096	189721	0.9	421358	25738
1001	4	HOA	255208		0.75	191406	63802
1001	2	School	198676		0.9	178808	19868
1001	10	Landscape	845529		0	0	845529
1001	97	Street	2163105		1	2163104	0
1004	61	Unmetered	307556		0.0	0	307556
1004	417	SFR	2081636	719485	0.5	1400560	681076
1004	1	HOA	40165		0.8	30123	10041
1004	1	School	348739		0.9	313865	34874
1004	2	Landscape	1136		0.0	0	1136
1004	42	Street	1089143		1.0	1089143	0
1005	8	Unmetered	118370		0.0	0	118370
1005	559	SFR	2957363	1033197	0.5	1995280	962083
1005	1	HOA	66421		0.8	49816	16605
1005	1	School	264236		0.9	237812	26424
1005	1	School	261089		0.9	234980	26109
1005	2	Landscape	773206		0.0	0	773206
1005	45	Street	1736098		1.0	1736098	0

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Table 4-3
Estimated Area of Study Sites

R3 Group	Estimated Impermeable Area sq.ft.	acres	Estimated Permeable Area sq. ft.	acres	Total Area sq. ft.	acres
1001	4,898,578	112.5	2,422,148	55.6	7,320,724	168.1
1004	2,833,691	65.1	1,034,683	23.8	3,868,374	88.9
1005	4,253,986	97.7	1,194,553	44.1	6,176,783	141.8

4.3 Evaluation Results

Table 4-4 presents the robust regression estimation results for the model of dry day runoff in R3 study Site 1001 (containing some customers receiving the ET controller/education intervention), Site 1004 (whose customers received no treatment), and Site 1005 (containing some customers receiving the education-only treatment). This sample represents metered dry day runoff, standardized by estimated site permeable area, between February 2001 and June 2002.

The changes in runoff estimated during the R3 study are summarized on Figure 4-3 and described in more detail below. Additional descriptions of the regression models are presented in Appendices D1 and D2.

Table 4-4
Robust Regression Estimates of Mean Dry Day Runoff

Dependent Variable: Dry Day Runoff Height (in hundredths inches per unit area)
(Height=Runoff Volume/Site Area)

Variable	Coefficient	Std. Error	t	Prob.>|t|
Mean Runoff: Feb-May 2001				
1. Intercept (1001 mean runoff)	0.898563	0.120838	7.44	0
2. Difference of Site1004 in pre-period	0.143721	0.157245	0.91	0.361
3. Difference of Site1005 in pre-period	-0.092260	0.151479	-0.61	0.543
Change in Runoff: June 2001-June2002				
4. Change of Site 1001 in post-period	-0.445390	0.134540	-3.31	0.001
5. Change of Site 1004 in post period	0.878089	0.113737	7.72	0
6. Change of Site 1005 in post period	0.202553	0.106973	1.89	0.059
Number of observations	950			
F (5, 944)	74.92			
Prob. > F	0			
Quasi-R-Squared	0.35			

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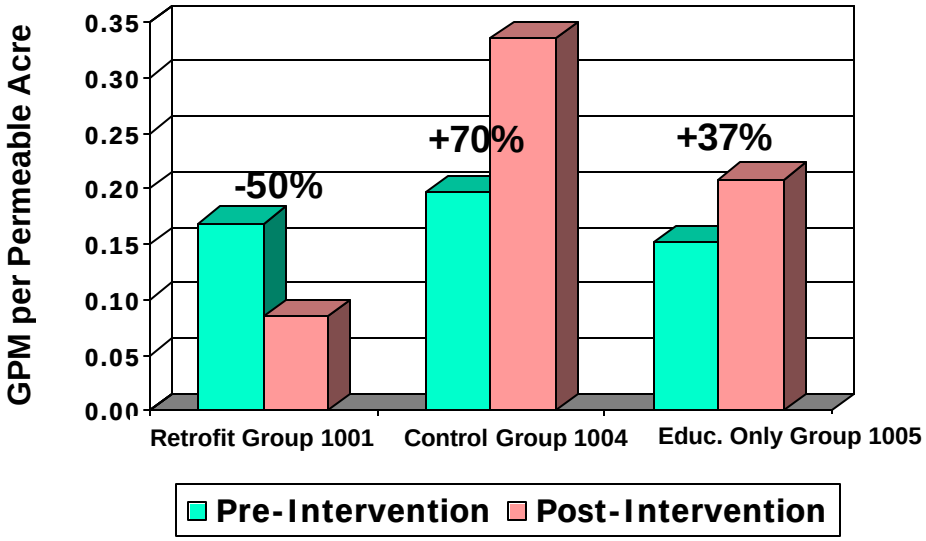
Figure 4-3
R3 Study's Changes in Runoff (Within Sites)



4.3.1 Pre-intervention Period

The constant term (Variable 1) in Table 4-4 defines the intercept for the model equation and can be interpreted as the mean daily runoff in Site 1001—about 0.898 hundredths of an inch per permeable acre (equal to 0.00898 inches). Variables 2 and 3, the indicators for Sites 1004 and 1005 in the pre-period, suggest that estimated difference in mean runoff is not statistically distinguishable from zero (standard error > coefficient). The estimated pre-period site mean runoff for these sites can also be inferred from these coefficients:

$$m_{4,\mathrm{Pre}} \equiv m_1 + d_{4,\mathrm{Pre}} \approx 0.899 + 0.144 = 1.042 \text{ hundredths of an inch and}$$

$$m_{5,\mathrm{Pre}} \equiv m_1 + d_{5,\mathrm{Pre}} \approx 0.899 - 0.092 = 0.806 \text{ (See Table 4-5.)}$$

Table 4-5
Study Site Comparisons of Pre Period Flow vs. Post Period Flow

	1001 Pre	1001 Post	1004 Pre	1004 Post	1005 Pre	1005 Post
Permeable Square feet	2,422,148	2,422,148	1,034,683	1,034,683	1,922,797	1,922,797
Permeable Acres (Table 4-3)	55.6	55.6	23.8	23.8	44.1	44.1
Coefficient from Table 4-4 (Hundredths of in/day/perm acre)	0.899	-0.445	0.144	0.878	-0.092	0.203

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Table 4-5 (continued)

	1001 Pre	1001 Post	1004 Pre	1004 Post	1005 Pre	1005 Post
Hundredths of in/day/perm acre flow	0.899	0.453	1.042	1.777	0.806	1.101
in/day/perm acre flow	0.0090	0.0045	0.0104	0.0178	0.0081	0.0110
feet/day	0.04164	0.02063	0.0081	0.0178	0.0081	0.0110
Raw GPM	9.42	4.75	4.67	7.96	6.71	9.71
GPM/perm acre	0.169	0.085	0.197	0.335	0.152	0.208
Percent change in flow (Pre to Post)	**-50%**		**+70%**		**+37%**	

4.3.2 Post-intervention Period

The formal test for the change in runoff in the post-intervention period (June 2001-June 2002) can be found in the following three terms: variables 4, 5 and 6 as shown in Table 4-4. The estimated change in dry day runoff for Site 1001 (Variable 4 in Table 4-4), is -0.44 hundredths of an inch. In relative terms, this works out to approximately a 50 percent reduction. The implied mean post-intervention dry day runoff for Site 1001, is 0.89-0.44˜0.45 hundredths of an inch. This reduction in runoff is statistically distinguishable from zero at classical levels of confidence.

It should be noted that the pre- and post- periods are not comparable. The post-intervention period, June 2001 to June 2002, includes 13 months, but would be fairly close to an annual average. The period of time covered by the pre-intervention period for all sites, February to May 2001, includes at most four months. For Site 1001, the pre-intervention period only includes the months of April and May in 2001 because the flow meter produced enough invalid reads in February and March to necessitate its relocation to a new site in April. Since these are not the highest months for urban runoff, it would be reasonable to expect runoff in the post-intervention period to increase. For this reason, the reduction of 50 percent from the pre-intervention period would be a lower bound on the true estimate of runoff reduction. An examination of the other two valid sites would provide insight into how much runoff would have increased in the post-intervention period.

The estimated change in dry day runoff for Site 1004 (Variable 5 in Table 4-4) is +0.88 hundredths of an inch. This increase in runoff is statistically distinguishable from zero at classical levels of confidence. The implied mean post-intervention dry day runoff for Site 1004, is (0.89+0.88˜) 1.77 hundredths of an inch. In relative terms, this works out to a fairly large (1-{1.77-1.03}/1.03˜) 70 percent increase in the post-intervention period.

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The estimated change in dry day runoff for Site 1005 (Variable 6 in Table 4-4) is +0.20 hundredths of an inch. This increase in runoff is statistically distinguishable from zero at close to classical levels of confidence. The implied mean post-intervention dry day runoff for Site 1005, is (0.89+0.20~) 1.09 hundredths of an inch. In relative terms, this works out to a more modest (1-{1.09-0.80}/0.80=) 37 percent increase in the post-intervention period.

4.3.3 Comparison Across Sites

The last and potentially most vulnerable inference compares the time change in runoff across sites. If Site 1001 had experienced the same change in runoff as its neighbor sites 1005 or 1004, then dry day runoff would have increased from 37 to 70 percent in the post-intervention period. In absolute terms, this would imply a prediction of non-intervention runoff of 1.24 to 1.53 hundredths of inches per acre. Compared to the realized 0.45 hundredths of inches of runoff in the post-intervention period, this reduction would translate to reduction in runoff from 64 to 71 percent.

A similar counterfactual exercise for Site 1005 would require assuming that Site 1004 is a good matched control site. Then dry weather runoff in Site 1005 would have increased by 72 percent in the post-intervention period, a level of 1.38 hundredths of inches per acre. Compared to the realized 1.09 hundredths of inches of runoff in the post-intervention period, the reduction would translate into a modest but non-ignorable 21 percent decrease in runoff.

Both of these exercises require use of Site 1004 as a control site. While the unadjusted flow measures for Sites 1001 and 1005 are fairly close in the pre-intervention period, the same cannot be said for the flow measures from Site 1004. There are uncertainties as to which of the three estimates of reduction runoff for Site 1001 should be used. The direct within-site estimate of a 50 percent runoff reduction is likely biased low; runoff in the post-intervention period should have increased. The estimate of 64 percent, based on Site 1005 as a control site, may also be biased on the low side. Though Site 1005 did have pre-intervention runoff that reasonably matched Site 1001, Site 1005 also contained more than 200 homes that participated in the education-only intervention with monthly follow-up. These homes did have quantified water savings, some of which is likely to have resulted from reduced runoff. Site 1004 did not receive any treatment, but did have measurement issues. Thus, the estimate of a 71 percent reduction, using Site 1004 as a control site, has an unknown bias.

The bigger inferential uncertainties lie in how these conservation interventions will work as they are scaled in a larger program or in how implementations of these programs would work in other areas.

4.4 Conclusions

The difficulties encountered in calibrating custom configured equipment to measure dry season / low flow runoff limited the amount of pre-intervention data. This in turn precluded simple before and after comparisons of mean runoff flow. Nonetheless, a sufficient length of baseline data was collected to allow quantitative estimates of runoff reduction. If additional flow data can be collected, additional analysis would be possible: 1) the runoff reduction under wet conditions

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could be examined, and 2) an estimate of the seasonal shape of runoff could be included in the models to improve the precision of the estimated runoff reduction.

Because the runoff measurement is not at a customer level, it was not possible to distinguish the relative contribution of different customers to urban runoff reduction. Thus, for Site 1001, it was not possible to determine how much the single-family ET controller/education contributed relative to the ET controller intervention with medium-size landscape customers.

However, because the medium-size landscapes accounted for an estimated 70 percent of the area "treated" with ET controllers (Table 2-2), on strictly a proportional basis it is likely that the medium-size landscapes contributed to the majority of the observed runoff reduction for Site 1001.

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Chapter 5 Water Quality and Watershed Implications

5.1 Overview

This chapter describes the water quality evaluations conducted as a part of the R3 Study and outlines the potential implications of these evaluations on the San Diego Creek Watershed. Specific information includes:

- A discussion of two approaches to the evaluation of water quality
- A summary of the study methods relating to water quality
- Development of "before and after" assessments of water quality to evaluate the effectiveness of ET technology and public education
- Detailed discussions of the evaluation approaches and findings based on these approaches
- A discussion of the implications of the findings for water quality in the San Diego Creek Watershed, focusing on TMDL constituents

More detailed information is provided in Appendices E1 and E2.

5.2 Introduction

Two independent reviews of water quality measurements were conducted as a part of this study. The initial review was conducted by SCCWRP as a part of its participation in the R3 Study and is included in its entirety as Appendix E1. This review used parametric statistical techniques (t-test; ANOVA), which provide a good descriptive review of the study data, but are generally considered to have less statistical power for detecting differences in data than other statistical tests. In general, because of the variability of the data and limitations in sample quantities, this review concluded that there was virtually no difference in either the concentration or "flux" (concentration times flow) of pollutants over time or between study treatments.

A subsequent statistical overview by Geosyntec Consultants was commissioned by IRWD to review alternative and possibly more "robust" data analysis techniques that might identify differences in study data not uncovered during the initial review. This work, which included the review of only a portion of the data set, focused on additional descriptive techniques (time series plots; box plots; probability distributions) and the use of non-parametric statistical techniques (rank-sum test; K-W). For some of the parameters reviewed, these techniques suggest that differences in measured water quality did occur across time and between study treatments. The entire Geosyntec report is provided in Appendix E2.

As noted above, both of the completed statistical reviews of the study data are included in the Appendices of this report. The remainder of this chapter of the report discusses the key findings of each review.

5.3 SCCWRP Water Quality Review

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This section describes the SCCWRP evaluation approach, sampling and laboratory analysis, data analysis, and interpretations of the results. Watershed implications are also discussed.

5.3.1 Evaluation Approach

A before-after, control-impact (BACI) design was used to evaluate the effectiveness of both the sprinkler technology and public education. Each neighborhood was sampled every other week between December 2000 and June 2001. In June 2001, homes in one of the neighborhoods were outfitted with the ET controllers. Since homeowners with the retrofitted ET controllers were simultaneously being educated, a well-defined public education campaign was also begun with these homeowners. To ascertain the difference between education and ET technology, homeowners in a second neighborhood were targeted with an identical public education campaign, but without effect of the ET retrofit technology. There was no education or technology intervention in the remaining three neighborhoods, which served as control neighborhoods to document the effect of no treatment. Sampling at the five neighborhoods continued every other week from June 2001 to June 2002.

5.3.2 Sampling and Laboratory Analysis

Each neighborhood was hydrologically self-contained and drained to a single underground pipe. At each of these five locations, samples were collected for flow and water quality. Stage (water depth) and velocity were recorded at 5-minute intervals using an ultrasonic height sensor mounted at the pipe invert and a velocity sensor mounted on the floor of the pipe. Flow was calculated as the product of velocity and wetted cross-sectional area as defined by the stage and pipe circumference. Despite the relatively continuous measurement of flow, many of the flow measurements were excluded due to faulty readings. Synoptic flow and water quality measurements were only available for two sites over the course of the entire study (i.e. before and after intervention), including the ET controller + education and education only sites. Flow measurements at the time of water quality sampling for the three control sites were considered faulty and discarded.

Grab samples for water quality were collected just downstream of the flow sensors in the early morning using peristaltic pumps and pre-cleaned Teflon tubing. Samples were placed in individual pre-cleaned jars, placed on ice, and transported to the laboratory within one hour. Each sample was analyzed for 19 target analytes, five microbiological parameters, and four toxicity endpoints (Table 5-1). Target analytes included trace metals, nutrients, and organophosphorus (OP) pesticides. Microbiological parameters included fecal indicator bacteria and bacteriophage. Toxicity was evaluated using two marine species, the purple sea urchin *Strongylocentrotus purpuratus* and the mysid *Americamysis bahia*. All of the laboratory methodologies followed standard protocols developed by the USEPA or Standard Methods.

5.3.3 Data Analysis

Data analysis consisted of five steps: 1) comparison of water quality among the five neighborhoods prior to intervention; 2) comparison of water quality concentrations over time by neighborhood; 3) comparison of water quality concentrations before and after intervention by

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treatment type; 4) comparison of pollutant flux before and after intervention by treatment type; and 5) correlation of toxicity measures with potential toxicants in dry weather runoff.

Comparison of water quality concentrations among the five neighborhoods prior to intervention was conducted to assess if there were inherent differences among treatment sites for each

Table 5-1
Reporting Level and Method for Target Parameters

	Reporting Level	Method
Metals (ug/L)		
Antimony	0.2	EPA 200.8
Arsenic	1.5	EPA 200.8
Barium	0.2	EPA 200.8
Cadmium	0.2	EPA 200.8
Chromium	0.3	EPA 200.8
Cobalt	0.1	EPA 200.8
Copper	1.5	EPA 200.8
Lead	0.3	EPA 200.8
Nickel	0.2	EPA 200.8
Selenium	5.0	EPA 200.8
Silver	0.4	EPA 200.8
Zinc	5.0	EPA 200.8
Nutrients (mg/L)		
Ammonia as N	5.0	EPA 350.1
Nitrate/Nitrite as N	5.0	EPA 353.2
Total Kjeldahl Nitrogen	10.0	EPA 351.2
Ortho-Phosphate as P	0.5	EPA 365.1
Total Phosphorus	1.0	EPA 365.4
OP Pesticides (ng/L)		
Chlorpyrifos	20.0	IonTrap GCMS
Diazinon	20.0	IonTrap GCMS
Microbiology		
Enterococcus (MPN/100 mL)	2	SM9230B
Fecal Coliform (MPN/100 mL)	2	SM9221B
Total Coliform (MPN/100 mL)	2	SM9221B
MS2 Phage (PFU/100 mL)	2	EPA 1602
Somatic Phage (PFU/100 mL)	2	EPA 1602
Toxicity (% effluent)		
Sea Urching Fertilization EC50	NA	EPA 1995
Sea Urching Fertilization NOEC	NA	EPA 1995
Mysid EC50	NA	EPA 1993
Mysid NOEC	NA	EPA 1993

Note: ug/L = micrograms per liter; MPN/100 mL=most probable number per 100 milliliters; PFU/100mL=plaque forming units per 100 milliliters; mg/L=milligrams per liter; ng/L=nanograms per liter.

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constituent. This analysis was conducted using ANOVA using Tukey's post hoc test for identifying the significantly different neighborhoods. All data was tested for normality and homogeneous variance prior to testing. Only the microbiological data was determined to be non-normally distributed, so these results were log transformed prior to data analysis.

Comparison of water quality concentrations over time was accomplished by creating temporal plots of monthly mean concentration. Comparisons of water quality concentration before and after intervention by treatment type were accomplished using a standard t-test of the mean concentration before versus mean concentration after intervention. The mean concentrations for ET controller + education, education only, and ET controller + education – education only for each sampling event were normalized by the grand mean of the control sites for the same sampling event.

Pollutant flux estimates were calculated by the product of the concentration and volume at the time of sampling and then normalized to the area of the sampled neighborhood. Pollutant flux before and after treatment was compared somewhat differently since the lack of flow data at the control sites did not permit an estimate of flux for these neighborhoods. Mean pollutant flux before and after intervention was compared using standard t-tests at the ET controller + education and education only neighborhoods without normalization to control values.

Correlation of toxicity with toxicant concentrations was accomplished using a Pearson product moment correlation. These correlations are inferential only and do not presume resulting correlations automatically identify the responsible toxicants. In order to help identify potential causative toxic agents, concentrations of the correlated constituents were compared to concentrations known to induce toxicity in the respective test organisms.

5.3.4 Evaluation Results

There were significant differences in water quality among sites prior to intervention (Appendix E1, Table WQ3). Site 1004, the control site, had the greatest mean concentrations for 15 of the 24 constituents evaluated prior to the ET controller intervention. In particular, all of the mean nutrient concentrations were greater at Site 1004 than the other sites. On the other hand, Sites 1001 and 1002 generally had the lowest average concentrations prior to the ET controller intervention. Cumulatively, these sites had the lowest mean concentrations for 17 of the 24 constituents evaluated. Site 1002 also had the least toxicity, on average, of all five sites. Finally, Site 1003 had an intermediate status. Mean concentrations of enterococcus and fecal coliforms at this site were greater than any other site (fecal coliforms significantly greater than Sites 1001 and 1002), but the mean concentrations of five trace metals (chromium, copper, cobalt, nickel, selenium) were lowest at this site.

Water quality concentrations and toxicity were highly variable over time during the study period. Temporal plots of concentrations and toxicity for each site demonstrated that there was no seasonal trend and no overall trend with time. There were, however, occasional spikes in concentrations for many constituents that appeared to fall into one of two categories. The first

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category was recurring spikes in concentration that were unpredictable in timing and location. The second category of concentration spike was single or infrequent peaks. Occasionally these spikes would occur across multiple sites, without commensurate changes in concentration at the treatment sites (1001 or 1005). More often, infrequent spikes were isolated to a single site. For example, concentrations of chlorpyrifos climbed to over 10,000 ng/L in July 2001, but averaged near 50 ng/L the remainder of the year at site 1005. Similarly, concentrations of ammonia and total phosphorus spiked 10 and 25-fold prior to June 2001 at the control site (1004) with less variability and overall lower concentrations the remainder of the study.

There were few significant differences that resulted from the intervention of education, ET controller + education, or ET controller + education – education only, relative to control sites (Table 5-2). Only six of the 24 constituents evaluated showed a significant difference between pre and post-intervention concentrations after normalizing to mean control values. These significant differences were a net increase in concentrations of ammonia, nitrate/nitrite, total phosphorus, chlorpyrifos, diazinon, and fecal coliforms. These statistical analyses were the result of one of two circumstances. In the first circumstance, there were individual large spikes in concentration at treatment sites, but not at control sites following intervention. Therefore, the net difference in concentrations between controls and treatments increased following the intervention. In these cases, removal of the outlier samples resulted in no significant difference among treatment effects relative to controls before intervention compared to after intervention. In the second circumstance, there were large spikes in concentrations at control site(s) prior to the intervention that later subsided, while treatment site concentrations and variability remained steady. Therefore, the difference between treatments and controls changed following interventions, although it was not a result of the education or technology.

Although there were no significant differences in pollutant flux as a result of the intervention, significant differences were noted in pollutant flux among sites prior to intervention. Site 1001, the ET controller + education site, had the greatest mean flux for 22 of the 24 constituents evaluated prior to the ET controller intervention. The mean flux for 20 of these 22 constituents was significantly greater at Site 1001 than the mean flux at Site 1005 (t-test, $p<0.05$). Site 1005 had greater mean fluxes only for MS2 phage and ammonia. The differences among the fluxes prior to (and after) intervention were the result of two factors: greater flow and, at times, greater concentrations at Site 1001 compared to Site 1005. Mean dry weather flow at the time of water quality sampling was nearly three times greater at Site 1001 than Site 1005.

Toxicity was inconsistently found at all five of the sampling sites, and there was no change in toxicity as a result of the intervention (Table 5-3). The two species tested did not respond similarly either among sites, among treatments, or over time. Correlation of toxicity with constituent concentrations yielded few significant relationships for either species (Table 5-3). Mysid toxicity was correlated with diazinon and several trace metals, but the strongest relationship was with diazinon concentration. Moreover, the concentrations of diazinon were well above the levels known to cause adverse effects in mysid, while trace metals were not. Sea urchin fertilization toxicity was only correlated with concentrations of zinc. The concentrations of zinc were well above the level known to induce adverse effects in this species.

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Table 5-2
Significance of ANOVA Results for the Effect of ET Controller + Education, Education Alone, and the Difference Between ET Controller + Education and Education Alone Relative to Control Concentrations. (No data indicates p > 0.05)

	Effect of ET Controller + Education	Effect of Education Alone	Difference Between ET Controller + Education and Education Alone
Metals			
Antimony			
Arsenic			
Barium			
Cadmium			
Chromium			
Cobalt			
Copper			
Lead			
Nickel			
Selenium			
Silver			
Zinc			
Nutrients			
Ammonia as N	0.03	0.02	
Nitrate/Nitrite as N	0.02		
Total Kjeldahl Nitrogen			
Ortho-Phosphate as P			
Total Phosphorus		0.03	
OP Pesticides			
Chlorpyrifos	<0.01	<0.01	<0.01
Diazinon		<0.01	
Microbiology			
Enterococcus			
Fecal Coliform	0.04		
Total Coliform			
MS2 Phage			
Somatic Phage			
Toxicity			
Fertilization EC50			
Fertilization NOEC			
Mysid EC50			
Mysid NOEC			

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Table 5-3
Correlation Coefficients (and p value) of Constituent Concentrations with Toxicity Endpoints (No Observed Effect Concentration, NOEC and Median Effect Concentration, EC50) in Dry Weather Discharges from Residential Neighborhoods in Orange County, CA. (No data indicates p > 0.05)

	Sea Urchin Fertilization NOEC	Mysid Survival NOEC	Sea Urchin Fertilization EC50	Mysid Survival EC50
Antimony		-0.273 (0.009)		
Arsenic		-0.3396 (0.001)		
Barium				
Cadmium				
Chromium		-0.244 (0.021)		-0.219 (0.044)
Cobalt		-0.330 (0.002)		-0.279 (0.010)
Copper				
Lead		-0.215 (0.042)		
Nickel				
Silver		-0.260 (0.013)		-0.229 (0.035)
Zinc	-0.277 (0.005)		-0.274 (0.006)	
Chlorpyrifos				
Diazinon		-0.426 (0.001)		-0.468 (0.001)
Ammonia				

5.3.5 Interpretation of Results

The evaluation was unable to find large, significant reductions in concentration or pollutant flux as a result of education and/or ET controller retrofit technology. This may indicate that the technology and/or education are inefficient for improvements in water quality. Equally as important, however, was the absence of meaningful increases in concentrations. Of the small number of concentrations that showed significant increases, most could be explained by highly variable spikes in concentrations reminiscent of isolated entries to the storm drain system, as opposed to ongoing chronic inputs or the effects of best management practices evaluated in this study.

If significant changes did occur, the evaluation design may not have detected these changes due to two factors. First, the variability in concentrations within and between sites is naturally high and the evaluation simply collected too few samples. After taking into account the variability and relative differences in mean concentrations, zinc was used as an example constituent to determine what sample sizes would be required to detect meaningful differences. Assuming that the sampling yielded the true mean and variance structure that actually existed at the five sites, power analysis indicated that a minimum sample size of no less than five-fold would have been required to detect the differences observed in zinc concentrations during this study.

The second factor that could have hindered the ability to detect meaningful differences in water quality is that the technology and education treatments were applied at the spatial scale of individual homes, while the evaluation design sampled at the neighborhood scale. This problem was exacerbated because only a fraction (approximately one-third) of the homes within the

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neighborhoods sampled had the technological or educational treatments. Therefore, the treatments were effectively diluted, decreasing the ability to detect differences in water quality.

5.3.6 Watershed Implications

It appears that residential dry weather flows measured in the R3 Study may contribute significant proportions of some constituents to overall watershed discharges. The study sites were located within the San Diego Creek watershed, the largest tributary to Newport Bay. The Orange County Public Facilities and Resources Department (OCPFRD) publishes monitoring data on San Diego Creek to provide environmental managers the information they need to properly manage the Bay (OCPFRD 2002). The dry weather monitoring data was compiled at the mouth of San Diego Creek from OCPFRD during 2001-2002 and compared the concentrations to our results from residential neighborhoods (Table 5-4). Mean concentrations of chlorpyrifos, diazinon, copper and zinc were much higher in upstream residential neighborhoods than concentrations measured at the mouth of San Diego Creek. These residential dry weather contributions were amplified by the fact that the San Diego Creek watershed is primarily composed of residential land uses. In contrast, concentrations of selenium, arsenic, and total phosphorus in the residential dry weather discharges were much lower than the cumulative dry weather discharges from San Diego Creek, indicating that residential areas may not be the primary source of these constituents.

Table 5-4
Comparison of Mean Concentrations (95% Confidence Intervals) in Residential Dry Weather Discharges from this Study Compared to Concentrations in Dry Weather Discharges from San Diego Creek at Campus Drive During 2001-2002. (Data from OCPFRD)

	San Diego Creek	Residential
Parameter	**Mean (95% CI)**	**Mean (95% CI)**
Nitrate	5.16 (0.72)	4.76 (1.96)
Phosphate	1.98 (0.07)	1.16 (0.20)
Diazinon	0.13 (0.07)	1.52 (0.52)
Chlorpyrifos	0.05 (0.01)	0.35 (0.44)
Copper	11.59 (2.83)	23.59 (5.65)
Arsenic	6.58 (0.40)	2.68 (0.26)
Selenium	21.22 (2.65)	2.46 (0.03)
Zinc	22.08 (2.75)	60.09 (8.26)

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5.4 Geosyntec Water Quality Review

This section presents examples of alternative approaches to data analysis, data analysis methods, example results, and watershed implications.

5.4.1 Examples of Alternative Approaches to Data Analysis

These example analyses focus on TMDL constituents: nutrients (total nitrogen [TN] and total phosphorus [TP]), metals (copper, lead, zinc, cadmium), pesticides, and pathogens (fecal coliform). The analyses also focus on dry weather flows, as reduction of these flows was a major objective of the R3 Study.

5.4.2 Data Analysis Methods

Exploratory Data Analysis
Visual inspection of data and exploration of factors that could potentially influence data (e.g. seasonal trends, rain events)

1. Divide data into pre and post- intervention groups.
2. Construct time series plots to visually inspect data and visually examine for seasonal trends. Overlay storm event markers to identify any relation to rainfall volume or antecedent dry period (ADP).
3. Investigate normality or log normality of data sets. Select appropriate statistical tests.
4. Construct probability plots for pre-intervention and post-intervention periods.
5. Prepare quantile plots.
6. Prepare side-by-side box plots.
7. Calculate descriptive statistics

Hypothesis Testing
Test data for skewness, normality, and statistically significant differences. Skewness and normality tests are only needed if parametric approaches are conducted. Use of non-parametric approaches is recommended for consistency because normality will not be met in all cases. Nonetheless, examples are provided to show that several of the data sets do not come from a normal distribution.

1. Skewness hypothesis test for symmetry.
2. Shipiro-Wilkes normality test.
3. Mann-Whitney rank-sum test.
4. For the data sets that have greater than 50 percent censored data (i.e., data only known to be less than the detection limit), hypothesis tests for differences in proportions.

5.4.3 Example Results

The first step in the data analysis was to construct individual time-series plots for each site to identify seasonal periodicity, step-trends, and monotonic trends. Plotting each site individually reveals more information than plotting all sites together. Also, by overlaying storm events, the role of rainfall volumes and the ADP may be more apparent and may indicate whether additional analyses are warranted (e.g., correlating ADP with concentration). Figure 5-1 is an example

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time-series plot with storm event markers overlain for TP for Site 1001. As shown on the figure, the pre-intervention period had much more rainfall, which likely added to the variability in runoff concentrations and fluxes. However, it is apparent that the winter and spring concentrations appear to be lower and less variable during the post-intervention period. The irrigation controllers may have had an effect on the runoff concentrations by reducing the amount of irrigation during moister weather conditions (i.e., high soil moisture). A similar effect for TN is shown on Figure 5-2. Additional time-series plots are provided in Appendix E2.

Figure 5-1
Example Time-series Plot of Total Phosphorus with Storm Event Markers.

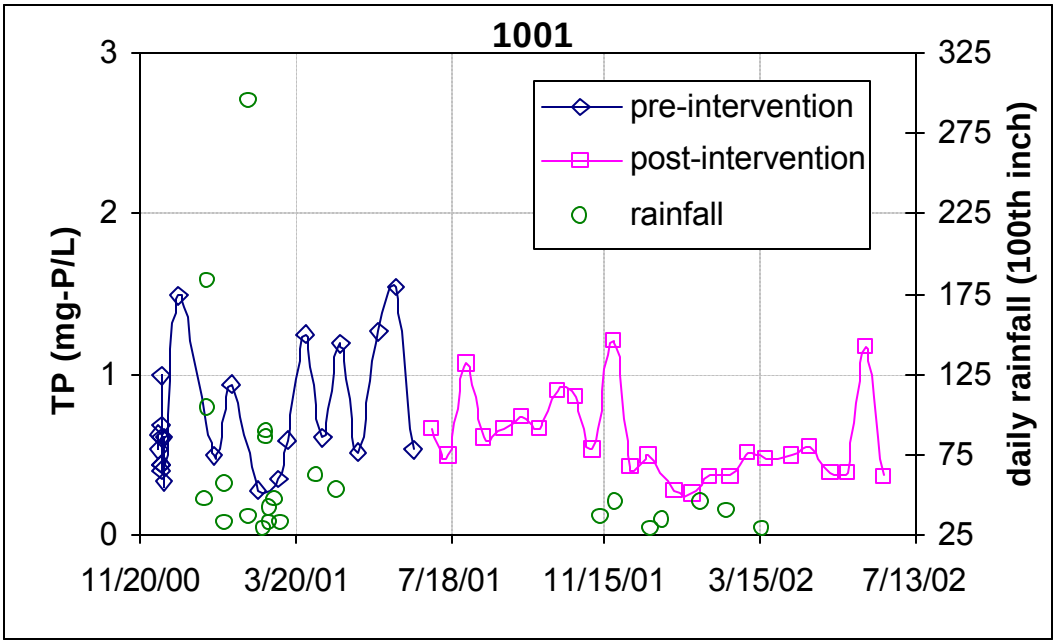
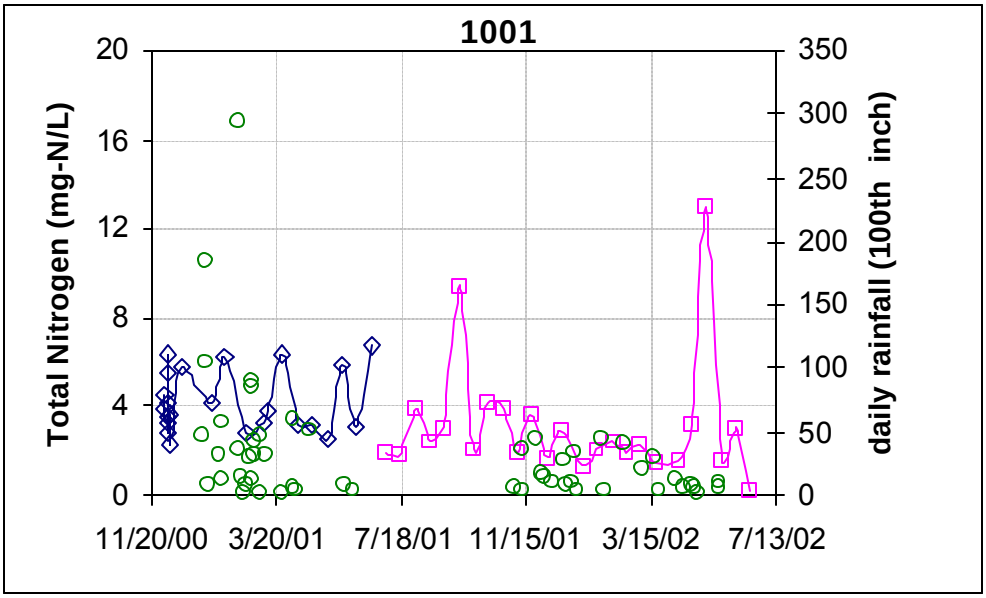


Figure 5-2
Example Time-series Plot of Total Nitrogen with Storm Event Markers.



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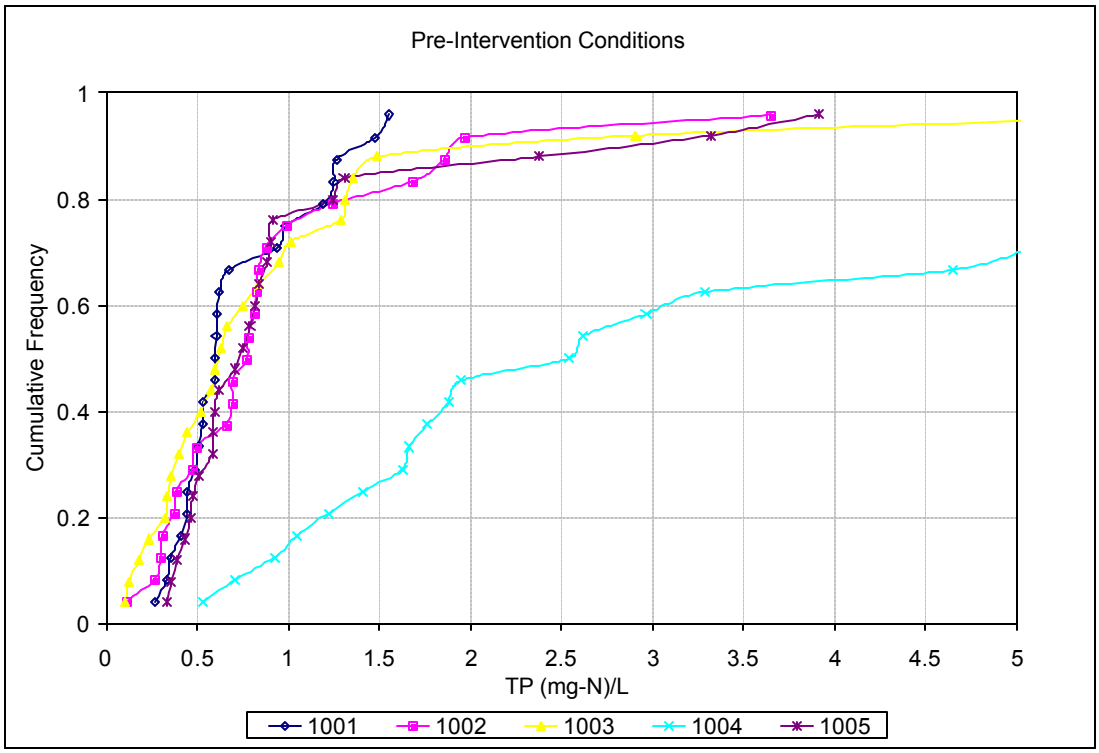
5.4.3.1 Comparison of Water Quality Data Prior to Intervention

To visually investigate whether the test sites have similar runoff characteristics, probability plots were constructed. Figure 5-3 is an example of a probability plot for TP for all of the test sites. The figure shows that all of the sites have a similar distribution except for Site 1004.

Figure 5-3
Example Probability Plot of Total Phosphorus for All Sites Prior to Intervention.



The next step in the data analysis was to calculate parametric and non-parametric descriptive statistics. Table 5-5 is an example table of descriptive statistics for TN for all sites for both the pre- and post-intervention periods. (Additional descriptive statistics are included in Appendix E2). Table 5-5 includes the number of data points (n), the detection percent (%>MDL/RL), the mean, median, 25 percent trimmed mean, min, max, 25th percentile, 75th percentile, standard deviation, interquartile range (IQR), and the coefficient of skewness (g_s). Also included in the table are critical skewness coefficients (g_{cr}), which are readily available in statistics texts. If the coefficients of skewness are less than these critical values, then the data is symmetric. It should be noted that the measures of central tendency (mean and median) and variability (standard deviation) of the sites during the pre-intervention period are quite different, indicating the data arises from different distributions. The median values are consistently smaller than the mean (in some cases substantially smaller), demonstrating the influence of the outliers on the measure of central tendency. Only three pre-intervention data sets are symmetric, and none of the post-intervention data sets are. Failure to pass the symmetry test indicates the data is not normal. However, passing the symmetry test does not indicate the data is normal; this requires a normality test. The symmetry test, which is easier to conduct than normality tests, serves as an initial screen for normality to reduce the number of data sets needing further investigation.

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Table 5-5
Example Table of Descriptive Statistics for Total Nitrogen for Each Site for Pre- and Post-intervention.

Parameter	Statistic	1001		1002		1003		1004		1005	
		Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post
TN (calculated)	n	23	25	23	25	23	25	23	25	23	25
	% > MDL/RL	100%	80%	98%	90%	98%	96%	98%	96%	100%	98%
(mg-N/L)	Mean	4.24	3.09	5.31	3.44	3.66	4.42	48.00	10.18	6.89	7.74
	Median	3.84	2.27	3.95	2.55	2.66	2.50	19.01	5.57	5.06	4.36
	Trimmed mean	3.94	2.40	4.53	2.76	2.93	3.01	33.11	6.47	5.08	4.42
	min	2.30	0.30	1.50	0.78	1.46	0.45	3.28	0.74	2.48	1.07
	max	6.76	12.99	13.83	11.40	12.12	19.91	141.06	40.80	20.41	67.12
	25th percentile	3.20	1.79	2.27	2.10	2.11	2.04	9.05	2.71	3.52	3.47
	75th percentile	5.68	3.13	8.02	4.36	4.81	5.17	94.79	19.18	7.07	5.62
	St Dev	1.41	2.67	3.56	2.51	2.48	4.39	49.17	10.73	5.29	12.85
	IQR	2.48	1.34	5.75	2.26	2.70	3.13	85.74	16.47	3.55	2.15
	Skewness, g_s	0.55	2.82	0.84	1.87	2.13	2.27	0.74	1.37	1.88	4.46
	g_{cr}	0.96	0.92	0.96	0.92	0.94	0.92	0.96	0.92	0.94	0.92
	Symmetric ($g_s < g_{cr}$)?	Y	N	Y	N	N	N	Y	N	N	N

The non-parametric equivalent to the ANOVA test is the K-W test, which tests for a difference between the medians of independent data groups. The K-W test will also test whether the datasets are derived from the same distribution.

Comparison of the mean ranks in Table 5-6 provides an indication of whether the data groups are derived from the same distribution. A p values < 0.05 indicates that two or more of the data groups have different distributions. Examination of the mean ranks in Table 5-6 shows that Sites 1001, 1002, and 1005 have somewhat similar mean ranks, and Sites 1003 and 1004 have somewhat different mean ranks. This suggests that Sites 1003 and 1004 have a different distribution than the other sites. Thus, the K-W test was performed on just Sites 1001, 1002, and 1005. These results are shown in Table 5-7. The p-value is now greater than 0.05, so the distributions of the TN data are not significantly different. Based on this analysis, Site 1002 was determined to be the only control site for comparison of TN data. Furthermore, it is clear that Site 1004 should not be considered as a control site for TN, and Site 1003 should be used with caution.

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Table 5-6
Example of Kruskal-Wallis Test Results for Total Nitrogen at the Test Sites Prior to Intervention.

Test:	**Kruskal-Wallis ANOVA**		
Comparison:	**Total Nitrogen: 1001, 1002, 1003, 1004, 1005**		
Performed by:	**GeoSyntec Consultants**		
n	115		
Total Nitrogen	**n**	**Rank sum**	**Mean rank**
1001	23	1128.0	49.04
1002	23	1162.0	50.52
1003	23	774.0	33.65
1004	23	2150.0	93.48
1005	23	1456.0	63.30
Kruskal-Wallis statistic	41.71		
p	<0.0001	(chisqr approximation)	

Table 5-7
Example of Kruskal-Wallis Test Results for Total Nitrogen at Sites 1001, 1002, and 1005 Prior to Intervention.

Test:	**Kruskal-Wallis ANOVA**		
Comparison:	**Total Nitrogen: 1001, 1002, 1005**		
Performed by:	**GeoSyntec Consultants**		
n	69		
Total Nitrogen	**n**	**Rank sum**	**Mean rank**
1001	23	710.0	30.87
1002	23	761.0	33.09
1005	23	944.0	41.04
Kruskal-Wallis statistic	3.27		
p	0.1948	(chisqr approximation)	

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5.4.3.2 Comparison of Water Quality Data Before and After Intervention

Side-by-side box plots and probability plot comparisons of pre-intervention and post-intervention were constructed to identify any apparent differences in the central tendency and concentration distributions between the two data sets. Figure 5-4 shows side-by-side box plots of total nitrogen at all of the test sites. Site 1004 was omitted due to its high variability. The figure shows that Site 1001 has a distinct decrease in TN while the other sites do not. However, other sites do show a decreasing trend in median concentration and inter-quartile ranges.

Figure 5-4
Side-by-side Box Plots of Pre- versus Post-Intervention for Total Nitrogen at All Sites.

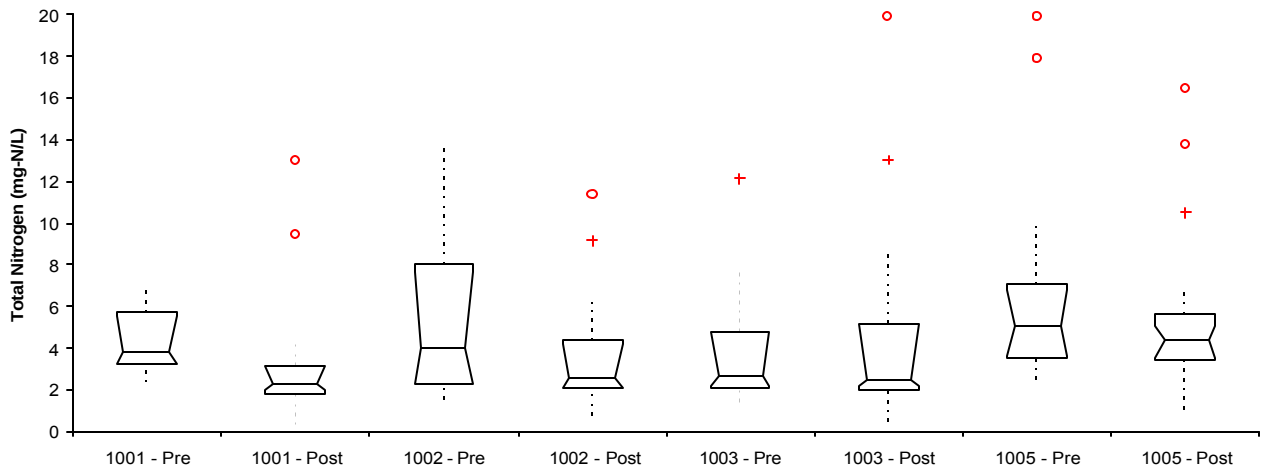
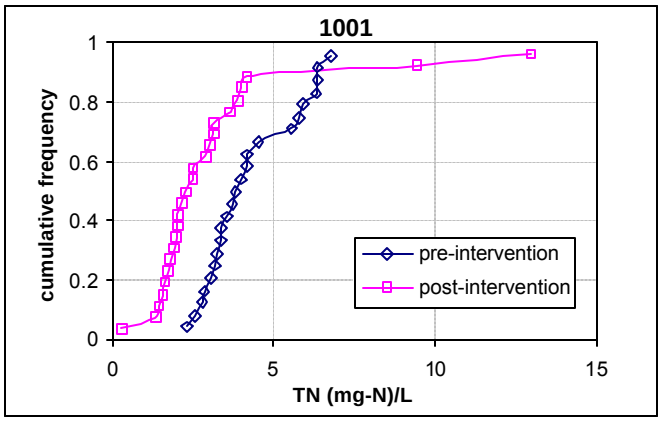


Figure 5-5 is a probability plot of TN for Site 1001 before and after intervention. (Additional probability plot comparisons are included in Appendix E2.) This figure shows a distinct reduction in TN at the site. However, since the data is from different time-periods, this difference could be related to temporal variability.

Figure 5-5
Example Probability Plot of Pre- versus Post-intervention for Total Nitrogen at Site 1001.



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To evaluate if temporal variability caused by the different monitoring periods has anything to do with the difference in TN concentrations, the probability plots of the pre- and post-intervention period for Site 1001 were plotted with those for Site 1002 and Site 1005 (as these were determined to be the only valid control sites). These comparison plots are shown on Figure 5-6 and Figure 5-7. For pre-intervention, the distribution of Site 1001 more closely follows the distribution of Site 1005 than that of Site 1002, and for post-intervention the opposite is true. This indicates that the year-to-year variability alone cannot explain the reduction in TN at Site 1001.

Figure 5-6
Example Probability Plot for Total Nitrogen of Site 1001 versus Site 1002 for the Pre- and Post-Intervention Periods.

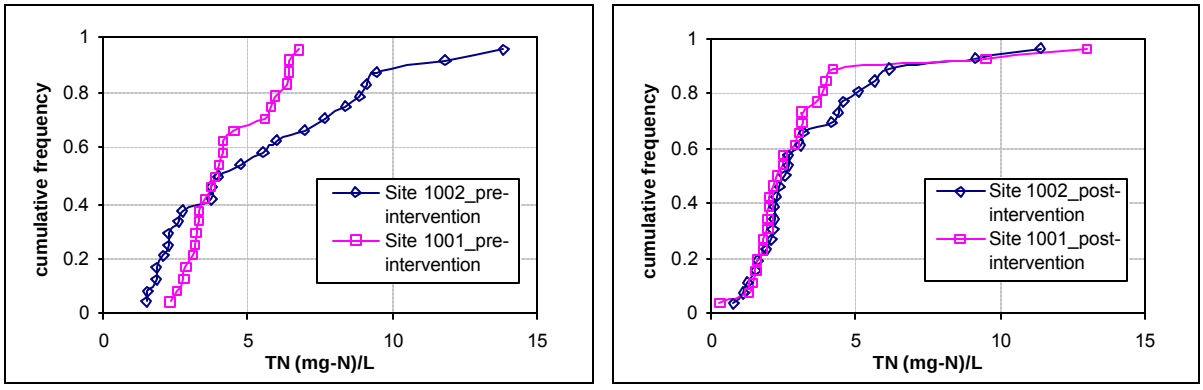
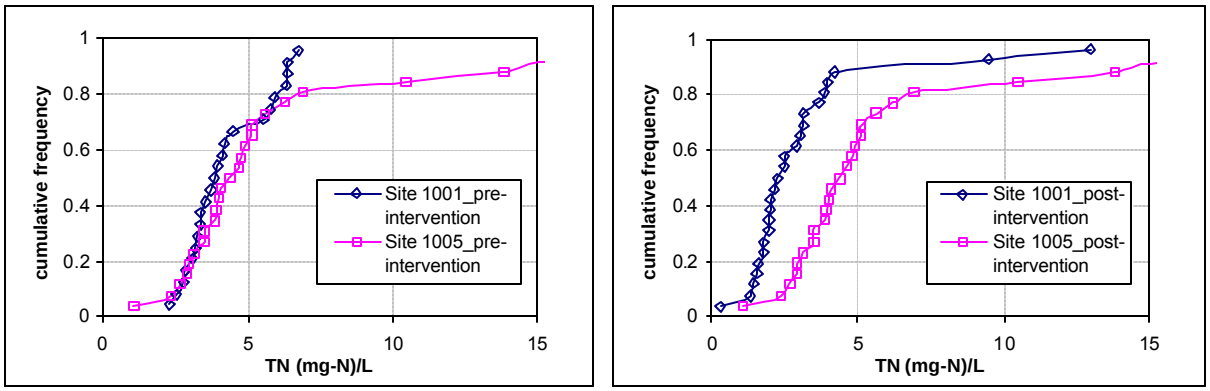


Figure 5-7
Example Probability Plot for Total Nitrogen of Site 1001 versus Site 1005 for the Pre- and Post-Intervention Periods.



The Mann-Whitney test (rank-sum) was used to determine if there is a statistical difference in the median values of two independent data sets (by rejecting the hypothesis that they are the same). Tables 5-8 through 5-10 show the output of the Mann-Whitney tests on Sites 1001, 1002, and 1005, respectively. The tables show a statistically significant difference ($p<0.05$) in the medians between the pre- versus post-intervention TN data at both Sites 1001 and 1002, but not at Site 1005. Furthermore, the difference in the medians at Site 1001 is at a higher level of confidence (more statistically significant) than the difference at Site 1002 (i.e., greater than 99 percent

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significant compared to about 96 percent significant). The magnitudes of these differences (Hodges-Lehmann estimator) are about 1.5 and 1.3 milligrams of nitrogen per liter (mg-N/L) for Sites 1001 and 1002, respectively. These tests indicate that the difference in the TN medians at Site 1001 from pre-intervention to post-intervention cannot be explained by the year-to-year variation alone (e.g., the intervention appears to have had an effect). It also indicates that the public education applied to Site 1005 did not appear to make a significant difference.

Table 5-8
Example Mann-Whitney Test for Difference in Medians for Total Nitrogen at Site 1001 from Pre- Versus Post-intervention.

Test :	**Mann-Whitney test**			
Alternative hypothesis	**1001: Pre versus Post**			
Performed by:	**GeoSyntec Consultants**			
n	48			
1001	**n**	**Rank sum**	**Mean rank**	**U**
Pre	23	736.0	32.00	115.0
Post	25	440.0	17.60	460.0
Difference between medians	1.497			
95.2% CI	0.883	to +?	(normal approximation)	
Mann-Whitney U statistic	115			
1-tailed p	0.0002	(normal approximation)		

Table 5-9
Example Mann-Whitney Test for Difference in Medians for Total Nitrogen at Site 1002 from Pre- Versus Post-Intervention.

Test:	**Mann-Whitney test**			
Alternative hypothesis:	**1002: Pre versus Post**			
Performed by:	**GeoSyntec Consultants**			
n	48			
1002	**n**	**Rank sum**	**Mean rank**	**U**
Pre	23	651.0	28.30	200.0
Post	25	525.0	21.00	375.0
Difference between medians	1.289			
95.2% CI	0.065	to +?	(normal approximation)	
Mann-Whitney U statistic	200			
1-tailed p	0.0355	(normal approximation)		

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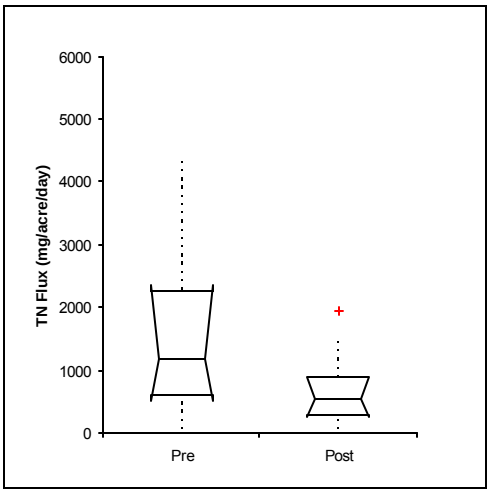
Table 5-10
Example Mann-Whitney Test for Difference in Medians for Total Nitrogen at Site 1005 from Pre- Versus Post-intervention.

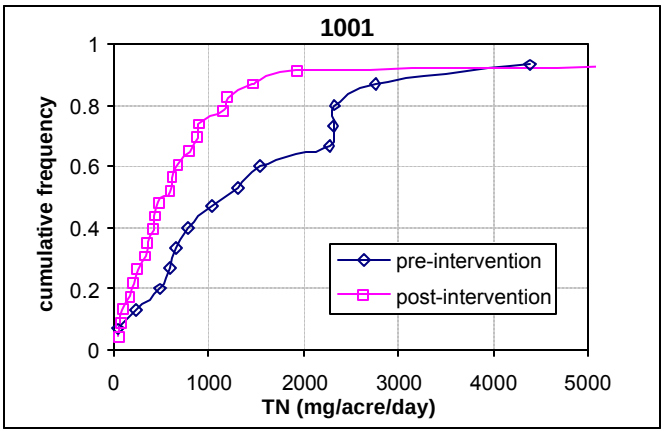
Test:	**Mann-Whitney test**			
Alternative hypothesis:	**1005: Pre versus Post**			
Performed by:	**GeoSyntec Consultants**			
n	48			
1005	**n**	**Rank sum**	**Mean rank**	**U**
Pre	23	610.0	26.52	241.0
Post	25	566.0	22.64	334.0
Difference between medians	0.530			
95.2% CI	-0.446	to +?	(normal approximation)	
Mann-Whitney U statistic	241			
1-tailed p	0.1686	(normal approximation, corrected for ties)		

5.4.3.3 Comparison of Constituent Fluxes Before and After Intervention

The statistical procedures applied to the concentrations examples above were also applied to the constituent fluxes (mass loadings). For completeness, an abridged example analysis is provided here. Figure 5-8 includes side-by-side box plots and probability plots of total nitrogen flux data milligrams per acre per day (mg/acre/day) for Site 1001 at pre- and post-intervention. There appears to be a significant decrease in the median, as well as an overall reduction in the distribution of values.

Figure 5-8
Side-by-side Box Plot and Probability Plots of Pre- Versus Post-Intervention for Total Nitrogen Flues at Site 1001.





Table

Table 5-11 shows the results of the Mann-Whitney test (rank-sum) for the total nitrogen flux at Site 1001. The medians from pre- to post-intervention are statistically significantly different at the 95 percent confidence level ($p<0.05$). The magnitude of the difference (the Hodges-Lehmann estimator) is approximately 530 mg/acre/day, indicating a relatively large reduction in total nitrogen loads from the neighborhood. However, as discussed below, the extent to which the ET controllers contributed to this reduction is unclear.

The nitrogen fluxes used in this analysis were computed as the product of the measured concentration and the average daily flow. Therefore, the reduction in TN flux could be due to a reduction in flow, a reduction in concentration, or a combination of both. Analyses presented earlier showed a statistically significant reduction in median TN concentration at Site 1001 between the pre- and post-intervention periods. Similarly, analyses discussed elsewhere in this report indicate that there was a statistically significant reduction in flow at Site 1001 between the pre- to post-intervention periods; however, it was cautioned that the pre- and post-intervention periods are not comparable due to seasonal differences in the data collection period. Thus, observed reductions in flow in 1001 could be influenced by seasonal factors. Therefore, the extent to which the ET controllers contributed to a reduction in flow is unknown. Consequently, reductions in TN flux could be attributed to a combination of TN reduction, flow reduction, and/or seasonal factors.

Table 5-11
Example Mann-Whitney Test for Difference in Medians for Total Nitrogen Flux at Site 1001 from Pre- Versus Post-intervention.

Test :	**Mann-Whitney test**			
Alternative hypothesis	**1001 flux (mg/acre/day): Pre vs. Post**			
Performed by:	**GeoSyntec Consultants**			
n	36			
1001_flux (mg/acre/day)	**n**	**Rank sum**	**Mean rank**	**U**
Pre	14	320.0	22.86	93.0
Post	22	346.0	15.73	215.0
Difference between medians	529.389			
95.1% CI	115.985	to +?	(normal approximation)	
Mann-Whitney U statistic	93			
1-tailed p	0.0239	(normal approximation)		

The above results suggest that it would be valuable to complete a more robust statistical evaluation of the data because some significant management implications could be determined.

5.4.4 Watershed Implications

The water quality evaluation results were examined in the context of existing TMDLs in the San Diego Watershed. Most of the existing TMDLs are reviewed below, and possible inferences and implications of the R3 Study data for TMDL compliance are discussed. The sediment and organophosphorus pesticide TMDLs were not reviewed because sediment data was not collected

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(the vast majority of sediments are transported by storm flows) and because Schiff and Tiefenthaler (SCCWRP, 2003) have previously conducted an extensive analysis of the OP pesticide data.

5.4.4.1 Comparisons with Regulatory Requirements

Mean dry-season concentrations for nutrients, toxics, metals, and pathogens at the R3 Study Sites were compared with regulatory objectives including TMDL's, California Toxics Rule (CTR) criteria, and Basin Plan objectives in Tables 5-12 and 5-13. These comparisons are strictly descriptive and provide a rough sense of dry-season residential water quality in comparison to regional water quality objectives. This comparison shows substantial variability between neighborhoods and among constituents.

Table 5-12
Comparison of Dry Season Concentrations of Nutrients and Toxics at R3 Study Sites with Regulatory Objectives

Parameter/Location	Objective	Site 1001	Site 1002	Site 1003	Site 1004	Site 1005
TIN (San Diego Creek Reach 1 / Reach 2)	13 mg/L / 5 mg/L (RWQCB-TMDL)	4.079 mg/L	0.464 mg/L	2.18 mg/L	18.16 mg/L	4 mg/L
		Percent of Samples above Toxics TMDL				
		Site 1001	**Site 1002**	**Site 1003**	**Site 1004**	**Site 1005**
Chlorpyriphos -Acute (San Diego Creek Reach 1)	18 ug/L (RWQCB-TMDL)	36.59	N/A	N/A	22.76	43.9
Chlorpyriphos - Chronic- (San Diego Creek Reach 1)	12.6 ug/L (RWQCB-TMDL)	46.34	N/A	N/A	26.02	49.59
Diazinon - Acute- (San Diego Creek Reach 1)	72 ug/L (RWQCB-TMDL)	70.73	N/A	N/A	69.11	73.17
Diazinon - Chronic- (San Diego Creek Reach 1)	45 ug/L (RWQCB-TMDL)	74.80	N/A	N/A	75.61	77.24

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Table 5-13
Comparison of Dry Season Concentrations of Metals and Pathogens at R3 Study Sites with Regulatory Objectives

		Percent of Samples above CTR Criteria				
Parameter	**Objective**	**Site 1001**	**Site 1002**	**Site 1003**	**Site 1004**	**Site 1005**
Copper -Acute	13 ug/L (CTR Criteria for Metal Toxicity*)	43.59	43.59	46.14	46.15	71.79
Copper - Chronic	9 ug/L (CTR Criteria for Metal Toxicity*)	74.36	56.41	76.92	74.36	87.18
Lead -Acute	65 ug/L (CTR Criteria for Metal Toxicity*)	0	0	0	0	0
Lead -Chronic	2.5 ug/L (CTR Criteria for Metal Toxicity*)	10.26	28.21	10.26	12.82	28.21
Zinc -Acute	120 ug/L (CTR Criteria for Metal Toxicity*)	0	7.69	5.13	7.69	15.38
Zinc -Chronic	120 ug/L (CTR Criteria for Metal Toxicity*)	0	7.69	5.13	7.69	15.38
		Median Dry Season Fecal Coliform				
Parameter	**Objective**	**Site 1001**	**Site 1002**	**Site 1003**	**Site 1004**	**Site 1005**
Fecal Coliform	200 MPN/100 mL (RWQCB Basin Plan)	1400 MPN/100 mL	3000 MPN/100 mL	5000 MPN/100 mL	13000 MPN/100 mL	65000 MPN/100 mL

5.4.4.2 Nitrogen

Nitrogen Water Quality Objectives and TMDLs – The Basin Plan water quality objectives for nitrogen in San Diego Creek are 13 milligrams per liter (mg/L) Total Inorganic Nitrogen (TIN) in Reach 1, and 5 mg/L TIN in Reach 2 (RWQCB, 1995). Reach 1 extends from Newport Bay to Jeffrey Road, and Reach 2 extends from Jeffrey Road to the headwaters. There is no numeric standard for nitrogen in Upper Newport Bay in the Basin Plan.

The nitrogen TMDL for Upper Newport Bay is based on the general goal of reducing nutrient loads to Newport Bay by 50 percent, to levels observed in the early 1970s (USEPA, 1998b). The nitrogen TMDL sets phase-in limits on TN loads to Newport Bay (see Table 5-14). Separate loads are established for the dry and wet seasons (dry season is from April 1 to September 30). In addition, the winter load is exclusive of storm flows with an average daily flow greater than 50 cubic feet per second (cfs) in San Diego Creek at Campus Drive.

There is no TMDL for nitrogen loads in San Diego Creek, Reach 1 because it was reasoned that attainment of the 50 percent reduction in nitrogen loads to Newport Bay would result in compliance with the Basin Plan in-stream water quality standard for Reach 1 (13 mg/L TIN). However, for Reach 2, it was determined that the average in-stream nitrogen concentrations would likely remain close to or above the Basin Plan in-stream water quality standard (5 mg/L TIN), even with attainment of the Newport Bay TMDLs. Therefore a TMDL of 14 lbs/day TN

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was established for Reach 2 (see Table 5-14) and is applicable for all flows exclusive of storm flows greater than an average daily flow of 25 cfs in San Diego Creek at Culver Drive.

Table 5-14
Summary of Nutrient TMDLs for Upper Newport Bay and San Diego Creek

TMDL	Dec 31, 2002	Dec 31, 2007	Dec 31, 2012
Newport Bay Watershed, TN – Summer load (4/1 to 9/30)	200,097 lbs	153,861 lbs	
Newport Bay Watershed, TN – Winter load (10/1 to 3/31; non-storm)			144,364 lbs
Newport Bay Watershed, Total Phosphorus – Annual Load	86,912 lbs	62,080 lbs	
San Diego Creek, Reach 2, daily load			14 lbs/day
Urban Runoff Allocation for the Newport Bay Watershed Summer load Winter load	22,963	11,481	 38,283

Study Data Comparison with Nitrogen Water Quality Objective – The Basin Plan water quality objectives are expressed in terms of TIN, which is comprised of nitrate/nitrite nitrogen and ammonia. By far the majority of the TIN in San Diego Creek is comprised of nitrate/nitrite nitrogen, as measured ammonia concentrations were typically quite low with a majority below the detection limit. For this reason, only the nitrate/nitrate concentration data is compared to the Basin Plan objectives in this report.

Table 5-15 shows the mean and median nitrate/nitrite concentrations measured in the five study sites. The mean and median nitrate/nitrite concentration of all sites except 1004 was below the Reach 2 Basin Plan objective of 5 mg/L TIN. As discussed previously, Site 1004 may not be a representative control site because the underlying distribution of pre-intervention nitrogen data appears to be different from the other sites. Similar arguments may also be true for Site 1003. With the exception of Site 1004, mean nitrate/nitrite concentrations suggest that, on average, residential runoff from these sites does not contribute to the exceedance of Basin Plan standards for TIN in receiving waters in San Diego Creek, Reach 1 and 2. The Reach 2 water quality objective was occasionally exceeded in all sites, except for the post intervention conditions in 1001 and 1002.

Table 5-15
Mean and Median Nitrate/Nitrite Concentration (mg/l) by Site (all data).

	1001		1002		1003		1004		1005	
	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post
n	23	25	23	25	24	25	23	25	24	25
Mean	2.56	1.47	2.57	1.07	2.13	1.71	36.50	6.61	2.61	4.13
Median	2.32	1.38	1.56	0.93	1.68	0.94	16.88	2.29	2.45	1.48
n>5 mg/L	1	0	4	0	1	2	18	8	2	1
n>13 mgL	0	0	0	0	0	0	12	4	0	1

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The mean and median nitrate/nitrate concentrations in Sites 1004 and 1005 exhibit exceedances of the 5 mg/L standard during pre- and/or post intervention conditions. Site 1004, in particular, had high levels of measured nitrate/nitrite concentrations, especially during the pre-intervention period. A number of these high readings exceed the Reach 1 water quality objective of 13 mg/L TIN. The results from Site 1004 are not consistent with those from the other four study sites, and the source of the high readings is unknown. Localized conditions involving excessive fertilizer usage by a few users could possibly be a factor in these elevated readings. In particular, the R3 Study mentions an unknown connection to a neighboring watershed, which could explain the source of elevated nutrient levels.

The Mann-Whitney (rank-sum) test was performed to compare the statistical difference between median concentrations during pre- and post-intervention periods. The median nitrate/nitrite in the post-intervention period was lower at all sites, and the difference was statistically significant at the 0.05 confidence level. As the control stations exhibited this trend, the data (i.e. entire data sets with unequal seasonal coverage) cannot be used to ascertain if the structural and educational BMPs were effective in reducing the runoff concentrations of nitrate/nitrite.

Clearly another factor is contributing to reduced concentrations in the post-intervention period. One possibility that was investigated is differences in seasons, year-to-year variability, and sampling times of the pre- and post-intervention data. Table 5-16 presents mean and median concentrations for comparable seasons and sampling times. The table shows that there are still noticeable reductions in all of the median concentrations, except Site 1005. Applying the Mann-Whitney (rank-sum) test to the data, it was found that statistically significant differences between median nitrate/nitrite concentrations in the pre- and post-intervention periods occurred only at Sites 1001 and 1004, as compared to all sites when all data is considered. These results indicate that seasonal effects are present in the data and should be considered in the study evaluation. It may be inferred from these results that there were significant reductions in the nitrate/nitrite concentration in the intervention site during the wet season that may, in part, be attributable to the structural BMPs. It is unknown whether similar reductions would occur in dry weather runoff during the dry season because such data was not collected during the pre-intervention period.

Table 5-16
Mean and Median Nitrate/Nitrite Concentration (mg/l) by Site for Comparable Seasons and Sampling Times[1]

	1001		1002		1003		1004		1005	
	Pre	**Post**	**Pre**	**Post**	**Pre**	**Post**	**Pre**	**Post**	**Pre**	**Post**
n	18	14	18	14	19	14	18	14	19	14
Mean	2.38	1.43	1.95	0.95	2.17	1.66	26.24	6.57	2.24	6.27
Median	2.22	1.48	1.16	0.96	1.50	1.02	8.94	2.06	2.03	1.96
n>5 mg/L	0	0	2	0	1	1	13	4	1	1
n>13 mg/L	0	0	0	0	0	0	7	3	0	1

1 – evening samples were deleted from the pre-intervention data. The post-intervention data include only those data collected in months identical to the pre-intervention period.

Study Data Comparison with Nitrogen TMDLs - The nitrogen TMDL is expressed in terms of total nitrogen TN loads. TN concentrations were calculated from the monitoring data as the sum

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of the nitrate/nitrite nitrogen and total Kjeldahl nitrogen (TKN) nitrogen. Table 5-17 shows the mean and median TN concentrations measured in the five study sites. The mean and median TN concentration in dry weather runoff are generally in the range of 2 to 5 mg/L, with the exception of Site 1004 where substantially higher concentrations were measured. The rank sum tests indicated that median TN concentrations were significantly lower (in a statistical sense) in the post-intervention period in Site 1001 (structural BMPs, see Table 5-8), and at Site 1002 (control, see Table 5-9). Based on the probability plots in Appendix E2, Site 1004 is expected to as well. However, Sites 1003 and 1005 did not show statistically significant reductions. These results did not change when only subsets of the data were used to consider possible effects stemming from the sampling time and sampling months.

Table 5-17
Mean and Median TN Concentration (mg/l) by Site

	1001		1002		1003		1004		1005	
	Pre	**Post**	**Pre**	**Post**	**Pre**	**Post**	**Pre**	**Post**	**Pre**	**Post**
All Data										
n	23	25	23	25	23	25	23	25	23	25
Mean	4.24	3.09	5.31	3.44	3.66	4.42	48.00	10.18	6.89	7.74
Median	3.84	2.27	3.95	2.55	2.66	2.50	19.01	5.57	5.06	4.36
Subsets[1]										
n	18	14	18	14	18	14	18	14	18	14
Mean	4.18	2.78	4.51	2.63	3.71	3.71	33.99	8.91	6.98	9.91
Median	3.62	2.02	3.22	2.21	2.51	2.47	12.14	3.74	4.17	3.96

1 – Data subsets with comparable sampling time and seasons. Evening samples were deleted from the pre-intervention data. The post-intervention data include only those data collected in months identical to the pre-intervention period.

TN flux estimates were calculated for Sites 1001 and 1005 (Table 5-18). The flow measurements at Sites 1002 to1004 are not reliable. Therefore, flux estimates were not calculated for these sites. Flux estimates were calculated as the product of the constituent concentration and the average daily flow occurring on the day of the sample collection. The flux estimates were found to be quite variable as they depend on both flow and concentration measurements. Table 5-18 shows that median TN flux estimates decreased from the pre- to post-intervention periods for both sites. Mann-Whitney (rank sum) tests show the reductions to be statistically significant (Table 5-11). Because comparable data is not available for the control sites, it is not possible to infer whether these reductions are influenced by the ET controllers in the intervention site (1001). Also, as previously discussed, the reduction in TN flux may be attributable to a reduction in flow, a reduction in concentration, seasonal factors, or a combination of these.

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Table 5-18
Mean and Median TN Flux (mg-N/acre/day) by Site

	1001		1005	
	Pre	**Post**	**Pre**	**Post**
All data				
n	14	22	10	21
Mean	1476	1667	2104	6537
Median	1164	530	1568	1177
Subset[1]				
n	12	14	10*	8
Mean	1384	587	2104	1716
Median	902	497	1568	960

1 – Data subsets with comparable sampling time and seasons. Evening samples were deleted from the pre-intervention data. The post-intervention data include only those data collected in months identical to the pre-intervention period.
* – Same as the all data case

Although the flux estimates in Table 5-18 are limited in number, duration, and location, they can be used to speculate about the magnitude of the urban area contribution of TN loads to Newport Bay and the potential reduction in loads from structural and nonstructural BMPs. Based on the limited flux data, the annual TN load to Newport Bay in dry weather runoff from urban areas in the San Diego Creek Watershed is estimated to range between 37,000 to 50,000 lbs per year under existing land-use conditions (see Table 5-19). This is for the most part below the 2012 urban runoff allocation of 49,764 lbs. The annual TN load is estimated to increase to 50,000-67,000 lbs per year under build-out conditions.

According to the 2001 report on the nutrient TMDL (OCPFRD, 2001), the average daily TN load in San Diego Creek at Campus Drive was 540 lbs/day between July 2000 and June 2001. This converts to an annual load of about 197,000 lbs, which is below the 2007 TMDL (note: San Diego Creek is the majority but not sole contributor of TN loads to Newport Bay). Estimates in Table 5-19 suggest that dry weather runoff from urban areas account for about 20 to 25 percent of the annual TN in the San Diego Creek Watershed. If it is assumed that flux reductions observed in the post intervention period are attributable to the structural and nonstructural BMPs, and if similar interventions could hypothetically be implemented on a watershed-wide basis, then the potential reduction in annual dry weather TN loads is estimated to range between 12,500-20,000 lbs. This would represent a reduction of about 6-10 percent of the current TN loads and about 30-40 percent of the estimated current dry weather urban loads. These estimates are based on few data collected in a limited area and should therefore be considered preliminary in nature.

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Table 5-19
Estimated Annual TN Loads in Dry Weather Runoff from Urban Areas in the San Diego Creek Watershed

	TN flux (mg-N/acre/d)	Annual TN Load to Newport Bay (lbs) Existing land-use[1]	Annual TN Load to Newport Bay (lbs) Built-out land-use[2]
Pre-intervention conditions	1160 – 1560	37,300 – 50,500	50,000 – 67,000
Post-intervention conditions	530 – 1180	17,000 – 38,000	23,000 – 51,000
Potential reduction		~12,500 – 20,000	~16,000 – 27,000

1 –Used 40000 acres or about 53% of the San Diego Creek Watershed area (IRWD, 2003). For comparison, urban land use in 1999 use was estimated at 35,500 acres of the watershed area at Campus Drive (Tetra-Tech, 2000).
2 – Used 53500 acres or about 71% of the San Diego Creek Watershed area (IRWD, 2003).

The following conclusion can be made based on the analyses above:

- Average and median nitrate/nitrite concentrations in dry weather runoff are below the Reach 2 water quality objective (5 mg/L), for most but not all study sites.
- Occasional exceedance of the Reach 2 water quality objective occurred in all study sites.
- The majority of measured nitrate/nitrite concentrations at Site 1004 during the pre-intervention period were greater than the Reach 2 water quality objective of 5 mg/L. The data is not consistent with those from the other sites. The cause is unknown, but could possibly be related to the unknown connection to the neighboring nursery discussed in the R3 report.
- Sampling periods (months) and sampling time (morning versus evening) were found to affect the statistical significance of differences between pre- and post- intervention median nitrate/nitrate concentration in some of the sites. The sampling period and sampling time did not affect the statistical significance of differences between pre- and post-intervention median TN concentrations.
- Median TN fluxes at Sites 1001 and 1005 were statistically smaller in the post-intervention period. The extent to which the structural and nonstructural BMPs contributed to these reductions cannot be determined due to the lack of reliable flow data in the control sites.
- Preliminary estimates of annual TN loads to Newport Bay in dry weather runoff from urban sources range between 37,000 to 50,000 lbs per year, or about 20 to 25 percent of the current TN loads.
- The potential reductions in annual dry weather TN loads due to implementation of BMPs on a watershed basis is estimated to range between 12,500-20,000 pounds per year. This would represent a reduction of about 6-10 percent of the current TN loads and 30-40 percent of the urban loads.

5.4.4.3 Phosphorus

The majority of the annual TP load in the San Diego Creek Watershed occurs in the wet season, and has been correlated with sediment loads generated by storm events (USEPA, 1998b). This

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correlation suggests that a majority of phosphorus occurs in particulate form attached to sediments. The main sources of the TP are in Peters Canyon Wash and San Diego Creek above Culver Drive (USEPA, 1998b).

Phosphorus TMDL – There is no numeric objective for phosphorus for San Diego Creek in the Basin Plan. Because measured TP and sediment loads are correlated, it was determined in the TMDL that a 50 percent reduction in TP loads would be achieved through compliance with the sediment TMDL (USEPA, 1998a). Accordingly, the TMDL for TP was based on a 50 percent reduction of average annual load estimated at 124,160 lbs (USEPA, 1998b). The TMDLs are applicable for all flow conditions. The target compliance date was set for December 31, 2007.

The annual TP load allocation for urban areas is 4102 lbs by 2002, reducing to 2960 lbs by 2007. According to the USEPA (1998b), the TP is allocated in the same proportion as sediments. The annual urban area (stabilized vs. construction) sediment allocation for the Newport Bay Watershed is 50 tons distributed over 95.3 square miles (see Table 5 in USEPA, 1998a). This is a very small allocation over a large area. By contrast, the annual construction allocation is 6500 tons distributed over the assumed 3.0 square miles under construction in any one year. Using the same proportions of sediment load allocations, the TP load rate based on the 2007 urban allocation is 2960 lbs/95.3 square miles = 0.0485 lbs/acre/yr. If the construction and urban allocations are combined, the TP load rate based on the combined 2007 urban and construction allocations is (2960+12810) lbs/(95.3+3.0) square miles = 0.251 lbs/acre/yr.

Study Data Comparison with TMDLs – Similar to the nitrogen TMDL, the phosphorus TMDL is expressed in terms of total annual TP loads. Table 5-20 shows the mean and median TP concentrations measured in the five study sites. The mean and median TP concentrations in dry weather runoff are below 1.2 mg/L in all sites, with the exception of Site 1004, where substantially higher concentrations were measured. Comparison of the pre- and post-intervention median TP concentrations in all data (Table 5-20) reveals an increase in the median TP concentration during the post-intervention period for all sites except the intervention Site 1001 and Site 1004. In contrast, when subsets of the data with similar seasons and sampling times are considered (Table 5-20), there is a decrease in the median TP concentration at all sites except 1005. This indicates that there are seasonal influences in the data, which presumably are related to rainfall. Unfortunately, no data is available to permit comparison of pre- and post-intervention concentrations for dry weather flows during the dry season.

Table 5-20 Mean and Median TP Concentration (mg/l) by Site

	1001		**1002**		**1003**		**1004**		**1005**	
	Pre	**Post**	**Pre**	**Post**	**Pre**	**Post**	**Pre**	**Post**	**Pre**	**Post**
All Data										
n	23	25	23	25	24	25	23	24	24	25
Mean	0.73	0.60	0.92	0.84	0.98	1.21	3.33	1.50	1.01	1.19
Median	0.60	0.51	0.77	0.82	0.62	0.67	2.54	1.05	0.73	0.85
Subsets[1]										
n	18	14	18	14	19	14	18	13	19	14
Mean	0.78	0.47	0.91	0.67	1.13	0.57	2.62	1.33	0.93	1.24
Median	0.61	0.41	0.73	0.56	0.75	0.58	1.82	1.07	0.75	0.83

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1 – Data subsets with comparable sampling time and seasons. Evening samples were deleted from the pre-intervention data. The post-intervention data include only those data collected in months identical to the pre-intervention period.

TP flux estimates were calculated for Sites 1001 and 1005 using the approach discussed in the nitrogen section above. Table 5-21 shows that median TP flux estimates decrease from the pre- to post-intervention periods at the intervention site (1001), but not in the education only site (1005). Mean fluxes increased at both sites. However, as discussed earlier, the mean values are strongly influenced by outliers and do not provide a good measure of central tendency for the data. Application of the Mann-Whitney (rank sum) test shows the reduction in median TP flux at Site 1001 is statistically significant. This suggests that the structural BMPs had a positive influence in reducing the TP fluxes. However, because comparable data is not available for the control sites, it is not possible to ascertain the extent to which the ET controllers contributed to these reductions. Also, as discussed previously, reductions in flux could be influenced by several factors: reduction in concentration, reduction in flow, and/or seasonal variability.

Table 5-21
Mean and Median TP Flux (mg-P/acre/day) by Site (all data)

	1001		**1005**	
	Pre	**Post**	**Pre**	**Post**
All data				
n	14	22	10	21
Mean	265	370	473	1327
Median	164	109	219	219

Similar to the previous analyses of TN loads, the TP flux estimates in Table 5-21 can be used to speculate about the magnitude of the urban area contribution of TP loads to Newport Bay and the potential reduction in loads from structural BMPs. Based on the limited flux data, the annual TP load to Newport Bay in dry weather runoff from urban areas in the Newport Bay Watershed is estimated to range between about 5,000 to 11,000 lbs per year (see Table 5-22), assuming a total urban area of 95.3 square miles obtained from Table 5 of the sediment TMDL (USEPA, 1998a). These estimated annual TP loads are greater than the urban allocation (for both dry and wet weather) and are less than the combined urban and construction allocations (Table 5-22). However, these estimates are based on dry weather data only, and it is expected that a major portion of the TP loads will occur in runoff from winter storms. Therefore, actual annual TP loads would be expected to be greater. If it is hypothesized that flux reductions observed at the intervention site (1001) could be realized over the entire watershed, then the potential reduction in annual dry weather TP loads from urban areas is estimated at 2700 lbs. As stated previously, these estimates are based on few data collected in a limited area and should therefore be considered preliminary in nature.

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Table 5-22
Estimated Annual TP Loads in Dry Weather Runoff from Urban Areas in the San Diego Creek Watershed

	TP flux (mg-P/acre/d)	Annual TP Load Rate to Newport Bay (lbs/acre/year)[1]	Annual TP Load to Newport Bay (lbs/year)
2007 Urban Area Allocation for Newport Bay		0.0485	2960
2007 Combined Urban and Construction Area Allocation for Newport Bay		0.251	15770
Pre-intervention conditions (median fluxes)	164 – 219	0.132 – 0.176	8049 – 10748
Post-intervention conditions (median fluxes)	109 – 219	0.088 – 0.176	5350 – 10748
Potential reduction			2700

1 - urban area is 95.3 square miles and the construction area is 3.0 square miles based on Table 5 in USEPA,1998a

5.4.4.4 Metals

Metals TMDLs – The USEPA (June 2002) determined that TMDLs are required for dissolved copper, lead, and zinc in San Diego Creek, Upper Newport Bay, and Lower Newport Bay, and that TMDLs are required for cadmium in San Diego Creek and the Upper Newport Bay. The TMDLs for San Diego Creek are expressed as concentration limits, based on the California Toxic Rule (CTR) criteria at various hardness values that are associated with different flow regimes (Table 5-23). The flow regimes are based on 19 years of flow measurements in San Diego Creek at Campus Drive. The concentration-based TMDLs apply to all freshwater discharges to San Diego Creek, including discharges from agricultural, urban, and residential lands, and storm flow discharges. The applicable flow regime at any location in the entire watershed is determined on the basis of discharge at Campus Drive.

Table 5-23
Summary of Dissolved Metal TMDLs for San Diego Creek

Dissolved Metal (?g/l)	Base flow (0–20 cfs) hardness @ 400 mg/L		Small flows (21-181 cfs) hardness @ 322 mg/L		Medium flows (182-814 cfs) hardness @ 236 mg/L		Large flows (>814 cfs) hardness @ 197 mg/L
	Acute	Chronic	Acute	Chronic	Acute	Chronic	Acute
Cadmium	19.1	6.2	15.1	5.3	10.8	4.2	8.9
Copper	50	29.3	40	24.3	30.2	18.7	25.5
Lead	281	10.9	224	8.8	162	6.3	134
Zinc	379	382	316	318	243	244	208

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Metals Sources – The USEPA (June 2002) conducted a source analysis as part of the TMDL preparation. Surface runoff is the largest contributor of metals loads in the San Diego Creek watershed, which includes natural and man made sources (USEPA, June 2002). Much of the metals loads are from natural sources. The estimated anthropogenic contributions are metal specific and range from about 33 percent for zinc to 63 percent for cadmium (USEPA, June 2002). A primary anthropogenic source of heavy metals is runoff from urban roads, which contributes to sources of cadmium (tire wear), copper (brakes, tires), lead (brakes, tires, fuels and oils), and zinc (tires, brakes, galvanized metals). Use of copper sulfate by nurseries may also be a minor source of copper loads. Other copper and zinc uses in building materials (roofing and roof drains) may be another source.

The USEPA found that metal inputs were heavily influenced by rainfall and stream flow rates. Monitoring results were reported to be highly variable due to different rainfall amounts and flows during each water year. The USEPA estimated that base flows account for 25 percent of the total metal loadings, with the remainder from low, medium and large flows caused by storms.

The USEPA's preliminary analyses suggest that: 1) a primary source of metals in dry weather runoff in the study watershed is from roads (i.e. wash off of metals in driveways, parking lots, streets, gutters, etc.); 2) the runoff concentrations will be influenced by rainfall which result in wash off of accumulated metals; and 3) the concentrations can be variable depending on the amount of rainfall.

Study Data Comparison with Base Flow TMDLs – The metals TMDLs for base flow conditions are based on meeting the CTR criteria at a total hardness of 400 mg/L. The CTR criteria express maximum allowable concentrations in receiving waters for acute (short term) and chronic (4-day) exposure periods. The acute and chronic criteria are expressed as values that cannot be exceeded more that once in three years. Although the criteria are applicable in the receiving waters and not in the urban runoff per se (i.e. the measured dry weather discharge), exceedance of the CTR in the urban discharge would suggest a potential for the discharge to contribute to an exceedance in the receiving waters.

Table 5-24 shows the mean and median heavy metal concentrations in the five study sites. With the exception of mean copper concentrations in some of the sites, all mean and median concentrations were below the chronic and acute CTR criteria. Copper, lead, and zinc concentrations occasionally exceeded the chronic CTR criteria, and copper and zinc concentrations occasionally exceeded the acute criteria. These exceedances suggest that the dry weather runoff can potentially contribute to an exceedance in the receiving waters. However, if intervention is determined to be effective in reducing runoff flows, then the BMPs would help to reduce impacts of these potential exceedances by allowing for greater dilution with the in-stream flows.

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Table 5-24
Mean and Median Metal Concentrations (mg/L) by Site (all data)

	1001		1002		1003		1004		1005	
	Pre	**Post**	**Pre**	**Post**	**Pre**	**Post**	**Pre**	**Post**	**Pre**	**Post**
Cadmium										
n	23	25	23	25	24	25	23	25	24	25
Mean	0.26	0.14	0.47	0.44	0.27	0.17	0.64	0.22	0.21	0.29
Median	0.27	0.10	0.24	0.10	0.10	0.10	0.36	0.10	0.10	0.10
n>6.2 ? g/l	0	0	0	0	0	0	0	0	0	0
n>19.1 ? g/l	0	0	0	0	0	0	0	0	0	0
Copper										
n	23	25	23	25	24	25	23	25	24	25
Mean	13.5	16.9	27.3	30.3	11.5	26.6	21.8	17.7	32.1	30.8
Median	11.5	11.4	10.9	14.0	11.1	14.3	12.7	11.4	12.3	20.4
n>29.3 ? g/l	2	2	3	7	0	2	5	4	3	5
n>50 ? g/l	0	1	3	3	0	2	2	3	3	2
Lead										
n	23	25	23	25	24	25	23	25	24	25
Mean	0.8	1.6	5.9	4.7	0.8	1.6	3.5	1.5	1.0	3.2
Median	0.6	0.6	0.9	1.2	0.6	0.8	0.7	0.7	0.7	1.3
n>10.9 ? g/l	2	1	2	3	0	0	2	0	0	1
n>281 ? g/l	0	0	0	0	0	0	0	0	0	0
Zinc										
n	23	25	23	25	24	25	23	25	24	25
Mean	58.7	37.2	115.2	86.3	56.3	56.8	83.6	40.9	74.0	75.0
Median	56.0	50.2	53.4	57.2	50.7	53.9	50.8	43.8	52.4	54.5
n>382 ? g/l	0	0	1	2	0	0	1	0	0	0
n>379 ? g/l	0	0	1	2	0	0	1	0	0	0

Dry weather metals monitoring information in the Central Irvine Channel, the immediate receiving water of the study watersheds, was unavailable. OCPFRD dry weather monitoring data is available in San Diego Creek at Campus Drive, which is quite a way downstream from the study sites. Data collected between December 2001 and June 2002 (Table 5-25) shows that average dry weather concentrations at Campus Drive are well below mean and median concentrations measured in dry weather runoff from the study watershed. Similar comparisons cannot be made for lead and cadmium because the method detection limits in the OCPFRD data are greater than those in the R3 data. None of the OCPFRD dry weather data exceeded the chronic or acute criteria.

Table 5-25
Summary of OCPFRD Dry Weather Monitoring Data of San Diego Creek at Campus Drive (12/01 to 6/02)

	Cadmium	**Copper**	**Lead**	**Zinc**
Sample number	24	24	24	24
Range	All < 1 ?g/l	<2 – 16 ?g/l	<2-2.4 ?g/l	<10-16
Mean		7.4 ?g/l	most <2 ?g/l	most <10
Median-		6.8?g/l		

These comparisons suggest that metal loads in dry weather runoff from the study (urban) watersheds could be a contributing factor to dry weather copper and zinc loads measured at Campus Drive. These dry weather discharges do not result in non-compliance of the base flow metal TMDL at Campus (based on the reviewed data only). It is unknown if the elevated

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concentrations measured in the dry weather urban runoff result in exceedance of the CTR criteria in the immediate receiving waters. If flow reductions observed in the intervention watershed are attributable to the ET controllers, then these controllers would help to reduce impacts from any potential exceedances of the TMDL because the discharges would be subject to greater dilution by the in-stream flows.

5.4.4.5 Pathogens

Pathogens are agents or organisms that can cause diseases or illnesses, such as bacteria and viruses. Fecal coliform bacteria are typically used as an indicator organism because direct monitoring of human pathogens is generally not practical. Fecal coliform are a group of bacteria that are present in large numbers in the feces and intestinal tracts of humans and animals, and can enter water bodies from human and animal waste. The presence of fecal coliform bacteria implies the water body is potentially contaminated with human and/or animal waste, suggesting the potential presence of associated pathogenic organisms.

Fecal Coliform TMDL – The RWQCB has adopted phased TMDL criteria for pathogens, with the initial focus on additional monitoring and assessment to address areas of uncertainty. The goal of the Newport Bay TMDL is compliance with water contact recreational standards by 2014:

- Fecal coliform concentration of not less than five samples per 30 days shall have a geometric mean less than 200 MPN/100 ml, and not more than 10 percent of the samples shall exceed 400 MPN/100ml for any 30-day period.

A second goal is to achieve the shellfish harvesting standards by 2020:

- The monthly median fecal coliform concentration shall be less than 14 MPN/100 ml, and not more than 10 percent of the samples shall exceed 43 MPN/100 ml.

The TMDLs are applicable for all flow regimes.

Study Data Comparison with Fecal Coliform TMDLs – Table 5-26 shows the mean and median fecal coliform concentrations measured in the five study watersheds. From 70 percent to 100 percent of all fecal coliform measurements were greater than 400 MPN/ml in all study watersheds. This level of exceedance is substantially greater than the allowable 10 percent. The mean and median fecal coliform concentrations also exceed the 400 MPN/100ml criterion in all study watersheds. There was insufficient data to calculate the 30-day geometric mean (a minimum of 5 samples per 30 days needed). However, the TMDL criterion (30-day geometric < 200 MPN/100 ml) would likely be exceeded, assuming that any additional data would be of the same magnitude as those collected. Exceedance of the TMDL criteria in all study watersheds suggests that urban dry weather runoff is likely a contributing factor to any dry weather exceedance of the TMDL in the receiving waters.

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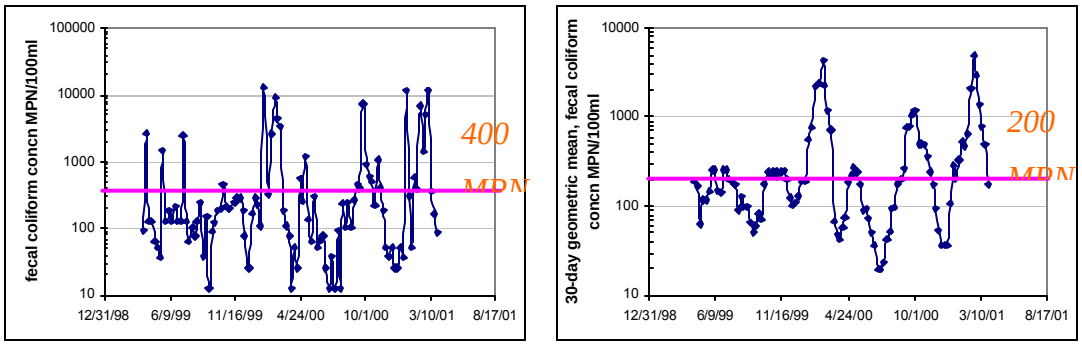
Table 5-26
Mean and Median Fecal Coliform Concentration (MPN/100ml) by Site

	1001		1002		1003		1004		1005	
	Pre	**Post**	**Pre**	**Post**	**Pre**	**Post**	**Pre**	**Post**	**Pre**	**Post**
All Data										
n	22	24	21	24	23	24	21	24	23	24
Mean	4921	3003	5582	128193	34526	28980	28205	34185	17976	10326
Median	2300	1400	1700	3000	13000	4000	13000	13000	8000	8000
% > 400 MPN/100ml	82%	67%	86%	79%	100%	88%	95%	83%	92%	93%
Subsets[1]										
n	17	14	17	14	18	14	17	14	18	14
Mean	2545	3054	3090	5074	13783	37479	23312	20166	8524	6109
Median	2200	950	1400	1400	8000	2650	8000	6500	4000	2900
% > 400 MPN/100ml	100%	71%	82%	79%	100%	86%	94%	79%	100%	93%

1 – Data subsets with comparable sampling time and seasons. Evening samples were deleted from the pre-intervention data. The post-intervention data include only those data collected in months identical to the pre-intervention period.

Dry weather coliform monitoring information in the Central Irvine Channel was not available. Therefore, it is unknown if elevated fecal coliform concentrations measured in the study watershed contribute to an exceedance of the TMDL in the immediate receiving waters. The OCPFRD has collected dry and wet weather *E. coli* monitoring information in San Diego Creek at Campus Drive (OCPFRD, September 2001), which is considerably downstream from the study watersheds. A plot of the equivalent fecal coliform concentration (assuming an 80 percent *E. coli* content) shows exceedance of the TMDL occurs primarily during the wet season, although dry season exceedances are also evident (see Figure 5-9). This suggests that dry weather urban runoff is potentially a contributing factor to exceedance of the TMDL in dry weather flows at Campus Drive. The ET controllers would reduce the impacts from these potential exceedances if they were determined to be effective in reducing the dry weather runoff volumes.

Figure 5-9
Time Series of Fecal Coliform Levels of San Diego Creek at Campus Drive (converted from measured E. *coli* concentrations)



Median fecal coliform concentrations presented in Table 5-26 may be used to evaluate the influence of the structural and non-structural BMPs. When all monitoring data sets are

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considered, the median fecal coliform concentrations are equivalent or increase from pre- to post- intervention conditions in all sites except the 1001 (intervention site) and 1003 (a control site). Based on the Mann-Whitney (rank-sum) test, the reduction in median concentrations at Site 1001 and 1003 is significant at the 95 percent confidence level. Thus the site with the irrigation controllers corresponded to a significant reduction in median fecal coliform concentrations, in comparison to two of the three control sites, while the education only watershed exhibited no discernable reduction in median concentrations.

When subsets of the data with similar seasons and sampling times are considered (Table 5-26), there is a decrease in the median fecal coliform concentration at all sites except 1002. However, because of the smaller sample sizes, the decrease is median concentration is statistically significant only at Site 1003. This suggests that there could be seasonal influences in the monitoring data, but the data is not sufficient to determine if there are statistically significant differences in the median concentrations.

5.5 Conclusions

The initial review of water quality data from the study found virtually no difference in concentrations or pollutant flux over time. The technological and education treatments provided essentially no detectable increase or decrease in water quality following the intervention.

The follow-up review utilizing more robust statistical methods on a sample of study data suggests that the interventions did result in changes in water quality. TN levels in the retrofit neighborhood following intervention were found to be significantly lower than levels before intervention, whereas no detectable differences were noted before and after intervention in the education neighborhood. Relatively large observed reductions in TN flux in the retrofit neighborhood could be influenced by seasonal factors, and the extent to which the ET controller contributed to the reduction is unknown. Similarly, although reductions in TP flux were observed in the retrofit neighborhood, the effect of the ET controllers cannot be determined.

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Chapter 6: Public Education

6.1 Overview

This chapter discusses issues pertaining to public acceptance of water conservation and runoff reduction measures. Specific information is provided on:

- Evaluation approach, including development of ET controller + education and education-only BMPs
- Customer interaction
- Evaluation results, as measured through responses to pre- and post-intervention customer surveys

More detailed information is provided in Appendix F.

6.2 Evaluation Approach

The public acceptance evaluation was conducted to compare the effectiveness of proposed BMPs for ET controller technology + education and education only. There were three groups of R3 Study participants: 1) participants who had their home irrigation controllers replaced with an ET controller and who received educational materials, 2) participants who received educational materials only, and 3) control groups, who received no interventions. The retrofit participants were selected through random "cold knocking" and through letter solicitations that explained the study. The education group was self and randomly selected. Some of the education group participants voluntarily chose to participate in the study by replying to a letter. However, the majority was randomly selected through a door-to-door campaign.

6.2.1 ET Technology + Education (Retrofit Group)

For the R3 Study, existing sprinkler timers that are set manually by the homeowner were replaced with the radio controlled ET controller systems. Trained technicians were used to ensure successful installation because ET controllers require programming for each valve including area (size of yard or planter per valve), soil type (clay, sand, etc.), and landscape type (turfgrass, shrubbery, etc.). The remaining irrigation system was unchanged, including piping and sprinkler head configuration.

The participating ET technology retrofit group homes received a site evaluation and installation of an ET controller to manage the irrigation system. Additionally, the residents of these homes received information regarding environmentally sensitive landscape practices. The controllers were installed in 112 residential homes, two condominium associations' landscapes, two HOA landscapes, one pool/park setting, and 12 city street landscapes.

Public education materials were also provided, as described in Section 6.2.2.

6.2.2 Education Only

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Educational materials were provided to both the retrofit and education-only groups. Public education consisted of an initial informational packet containing three items. The first item was an introductory letter that described the purpose of the packet. The second item was a booklet with irrigation, fertilization, and weed and pest control information. The centerfold of the booklet was a month-by-month guide to irrigating, fertilizing, and pesticide application suitable for posting near the sprinkler timer. Third, each homeowner was supplied a soil probe for measuring the water content of the landscaped soils. In addition to the initial packet, monthly reminders were mailed to each homeowner including landscape maintenance tips about irrigation system, watering schedule, fertilizing, and weed and insect control. Suggested sprinkler run times (for the non-ET sprinkler neighborhood) and fertilizer or pesticide application usage, including non-toxic alternatives, were also provided in the monthly newsletter. A representative collection of the public information tools used for the R3 Study is provided in Exhibits A through D at the end of this section.

6.2.3 Customer Interaction

Home residents were advised that if they had any problems with the controller or if the controller required any adjustments, they should call the water district for assistance. IRWD's customer service department telephone number was left on a sticker on the ET controller. All calls related to the ET controller were logged in separately and routed to the appropriate staff member for assistance. Table 6-1 shows the number of calls that were received from residential residents during the R3 study period.

Table 6-1
Calls from Residential Customers in R3 Study

April 2001	1	August 2001	13	December 2001	1	April 2002	2
May 2001	12	September 2001	4	January 2002	4	May 2002	3
June 2001	7	October 2001	5	February 2002	9	June 2002	6
July 2001	13	November 2001	3	March 2002	4	July 2002	2

Generally, there were four common types of calls: 1) customer misunderstanding the way the ET controllers were supposed to operate, 2) installation-related issues, 3) maintenance or system design issues, and 4) ET controller malfunctioning. These issues were addressed and resolved. (See Appendix F.)

.

6.3 Customer Surveys

This section describes pre-and post-intervention surveys developed to measure public acceptance.

6.3.1 Pre-survey

The purpose of the pre-survey was to determine if the retrofit group and the education group had similar irrigation practices and attitudes. The pre-survey was distributed to the retrofit group while installation of the controller was taking place. Retrofit study participants were asked to fill

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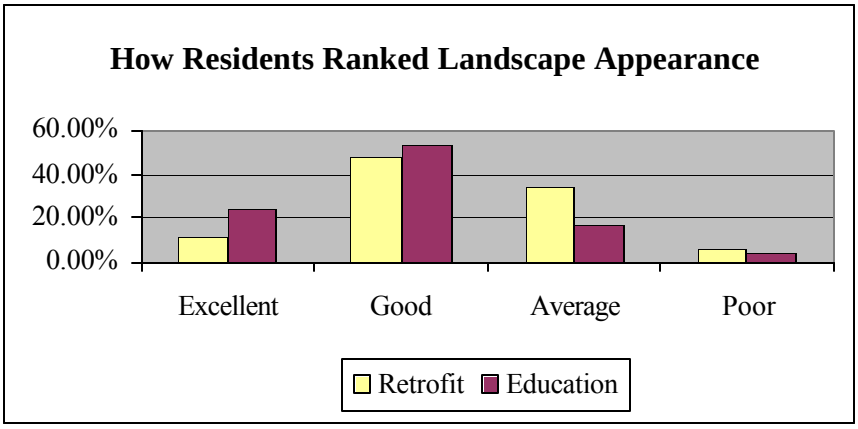
out the survey while staff was installing the controller. The education group received their survey as part of the initial educational packet that was randomly distributed to residents. Education group participants were provided a stamped addressed envelope to return their survey to the IRWD. Ninety-seven percent (109/112) of those that received a survey from the retrofit group mailed the survey back. Twenty-four percent (53/225) of residents in the education group mailed back a survey. Pre-survey results are tabulated in Appendix F and summarized below.

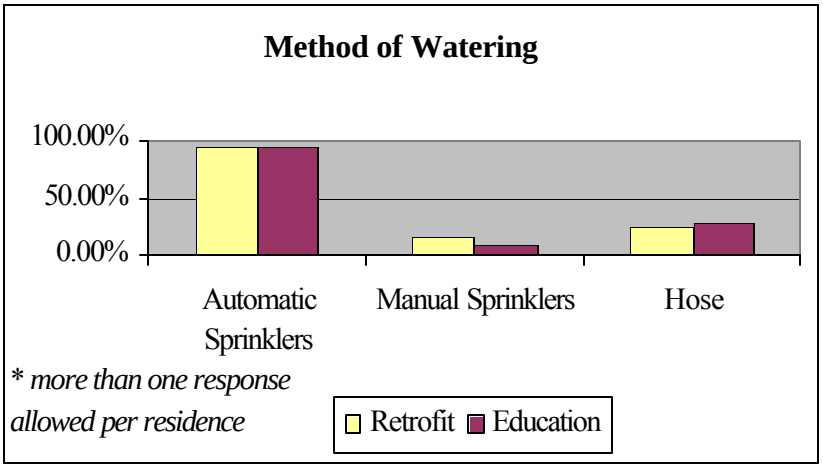
Figure 6-1 shows the responses of both of the groups. Similar responses were given. A majority of the residents in both groups believed that the appearance of the yard is average to good. It should be noted that the "excellent" response was selected by more of the education group than the retrofit group. One possible explanation for this response is that the staff was on-site while people were filling out their survey in the retrofit group.

Figure 6-1



When residents were asked how they watered their lawn, the responses across groups were very similar. The percentage of people in the retrofit and education group that use automatic sprinklers, manual sprinklers, or a hose are similar. The survey shows that the retrofit and education groups have similar watering behaviors. As shown on Figure 6-2, the majority of the participants used automatic sprinklers. This is important because the R3 Study focuses on retrofitting the automatic irrigation controllers as a water management tool.

Figure 6-2



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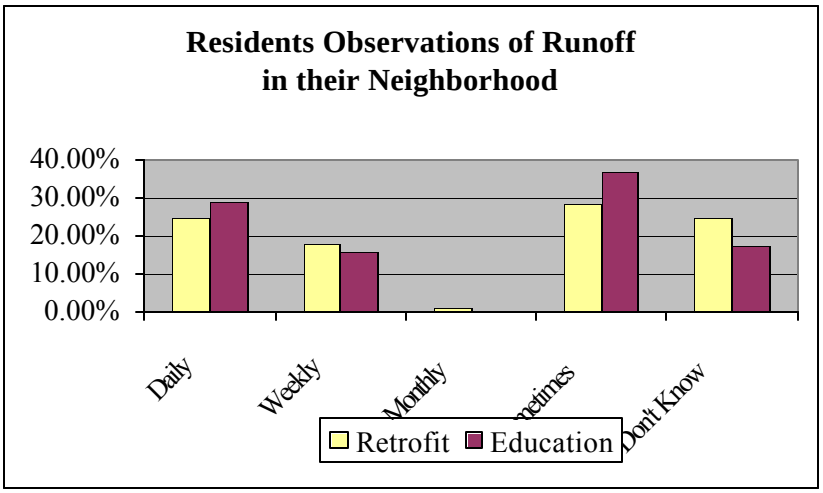
Residents were asked how often they observed runoff in their neighborhood. As presented on Figure 6-3, the data shows that residents in both groups have similar attitudes and views of urban runoff.

Figure 6-3



Residents were asked if they used fertilizers in their landscape, and chemicals to control pests or weeds. As shown on Figure 6-4, fertilizer use in both groups is almost the same. Results for chemical use were also similar for both groups. (See Figure 6-5.)

Figure 6-4

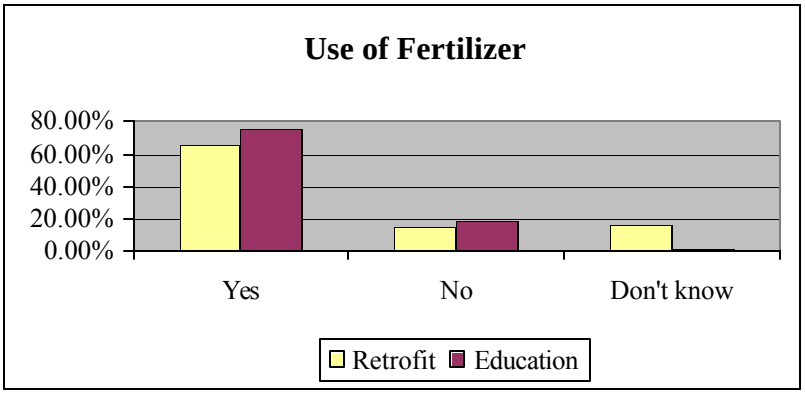
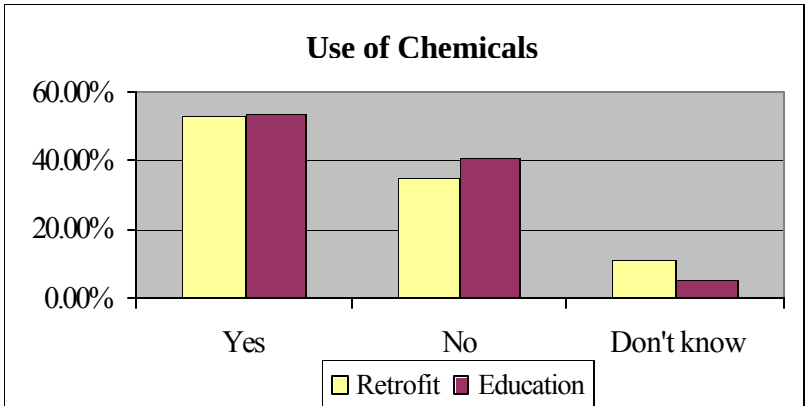


Figure 6-5



The purpose of the post-survey was to determine the attitudes of the study participants towards the ET controller and to determine if the education material had an impact on modifying behavior of the recipients. The post-survey was distributed to both of the groups through the mail. Twenty-three percent (52/225) of the education group participants responded to the survey, and forty-five percent (50/112) of the retrofit group participants responded. Post survey results are tabulated in Appendix F and summarized in the tables and text below.

6.3.2 Post-survey

Table 6-1 summarizes responses of the retrofit group compared to responses from the education group. The majority of the retrofit households acknowledged their satisfaction with the ET controller's performance and agreed that they would recommend the ET controller to their friends. It appears that the residents liked the controller and did not mind having someone else manage their irrigation-watering schedule. Data shows that households accepted the controller as a method of saving water, reducing runoff, and watering their landscapes. The survey shows that twice the number of retrofit households observed a decrease in their water bill than the education households did. A majority of the education households did not observe a change in their water bills. Data appears to show that the appearances of the retrofit landscapes were ranked equally with those landscapes that were part of the education group. It can therefore be concluded that the survey showed that the lower use of water did not create landscapes that were inferior to the education group. The customer's perception of a lower bill is important for the success of any long-term conservation program.

The retrofit and education group were asked if they were willing to pay for an ET controller signal. A majority of the households in both of the groups would not be willing to pay for an ET signal. The ET controller costs approximately $150.00 and the signal fee is $48 per year. The ET controller would be able to save less than 2 ccfs per month, which is a savings of about $14 per year. It appears that the savings in water use per year is not large enough for the water customer to pay for an ET signal.

Table 6-2
ET Controller Selected Responses

Responses to select survey questions	Retrofit group	Education group
Were satisfied with the ET controller	72 percent	n/a
Would recommend use of the ET controller to others	70 percent	n/a
Ranked the appearance of their yard as good to excellent	70 percent	69 percent
Not willing to pay for an ET signal	58 percent	69 percent
Saw decrease in water bills	44 percent	23 percent
Saw water bills unchanged	38 percent	63 percent

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6.3.3 Education Only and Retrofit Group Responses

Table 6-3 summarizes the responses to the educational material by the retrofit group compared to the responses by the education group. Samples of these educational materials provided for participants in the R3 Study are presented on the following pages as Exhibit A through Exhibit D. Only half of the education households acknowledged that they sometimes or most of the time would change the settings on their controller according to ET via the monthly letter's (Exhibits A and B) suggested schedule. Monthly mailings also provided monthly landscape maintenance tips (Exhibits C and D). Here, the majority of the households in both of the groups liked the tips on the irrigation checks and fertilization sections. Although most people read these sections, a vast majority (80 percent) of households in both of the groups did not change their use of pesticides, herbicides, or fertilizers.

In addition to the education materials, a soil probe was given to both groups at the beginning of the study. A soil probe is a tool that takes a soil sample and enables the user to see the amount of moisture available to the plants and its depth. This allows the user of the soil probe to determine if the plants require more or less irrigation. More than half of the households in both groups only used the soil probe once or not at all. The majority of the people never used the soil probe at all. From a program point of view, people enjoy the education materials, but they appear to have little effect on modifying behavior.

Table 6-3
Education Material Selected Responses

Responses to select survey questions	Retrofit group	Education group
Have not changed their use of pesticides and herbicides	82 percent	81 percent
Have not changed their use of fertilizers	80 percent	73 percent
Did not use the soil probe or used it only once	76 percent	62 percent
Believed fertilization checks (part of monthly tips) were helpful	58 percent	44 percent
Believed irrigation checks (part of monthly tips) were helpful	42 percent	58 percent

6.4 Conclusions

While there were some customer service-related issues, the response to the ET controller was generally positive with 72 percent of participants indicating that they liked the controllers. This group also found that the controller irrigation either maintained or improved the appearance of their landscape. This is a classic win-win situation. The water district customers receive a desired benefit of a healthy landscape, and the community receives several important environmental benefits from the conservation of valuable and limited water resources and the reduction in dry season urban runoff.

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Exhibit A
Monthly Landscape Maintenance Tips Letter Sent to "retrofit" customers in group 1001

May Landscape Maintenance Tips

The weather is getting warmer, the days are longer, and most of your plants are well into their growth stage. This is also the season for weeds and garden pests.

Irrigation System

- Watch for grass or plant growth that blocks sprinkler heads.
- Look for overspray onto streets and sidewalks and realign the sprinkler head.
- Look for dry spots and find the sprinkler problem to fix, such as a clogged head.
- Look for wet spots and potential sprinkler problems, such as a broken head.

Watering Schedule

- The Run-off Study Controller will adjust watering times as the weather changes.

Fertilizing

- Time to apply a slow release Nitrogen fertilizer to turf (apply only as directed on the bag or container).
- Keep fertilizer off of sidewalks, patio and streets.
- Do not wash fertilizer into drains or gutters.

Weed and Insect Control

- Watch for aphids and whiteflies. Wash insects off of leaves with a hard spray of water or spray with diluted soap solution.
- Apply mulch to control weeds, improve moisture retention and restore nutrients to the soil.
- Pick weeds now while they're still small.
- Use weed and insect chemicals only as directed on the containers.

This is a guide only. This guide does not hold public agencies responsible for the health and appearance of your home landscape.

Exhibit B
Monthly Landscape Maintenance Tips Letter (Sent to "education only" customers in group 1005)

May Landscape Maintenance Tips

The weather is getting warmer, the days are longer, and most of your plants are well into their growth stage. This is also the season for weeds and garden pests.

Irrigation System

- Watch for grass or plant growth that blocks sprinkler heads.
- Look for overspray onto streets and sidewalks and realign the sprinkler head.
- Look for dry spots and find the sprinkler problem to fix, such as a clogged head.
- Look for wet spots and potential sprinkler problems, such as a broken head.

Watering Schedule

- Start with this suggested schedule:
  Turf: 3 days per week, 3 cycles* of 3 minutes
  Shrubs and groundcover: 2 days per week, 3 cycles* of 3 minutes
- Reduce this amount in shaded areas.
- Use the soil probe to check the level of moisture beneath the surface before you water. If the soil is still moist 2 or more inches below the surface, wait another day to water.

Fertilizing

- Time to apply a slow release Nitrogen fertilizer to turf (apply only as directed on the bag or container).
- Keep fertilizer off of sidewalks, patio and streets.
- Do not wash fertilizer into drains or gutters.

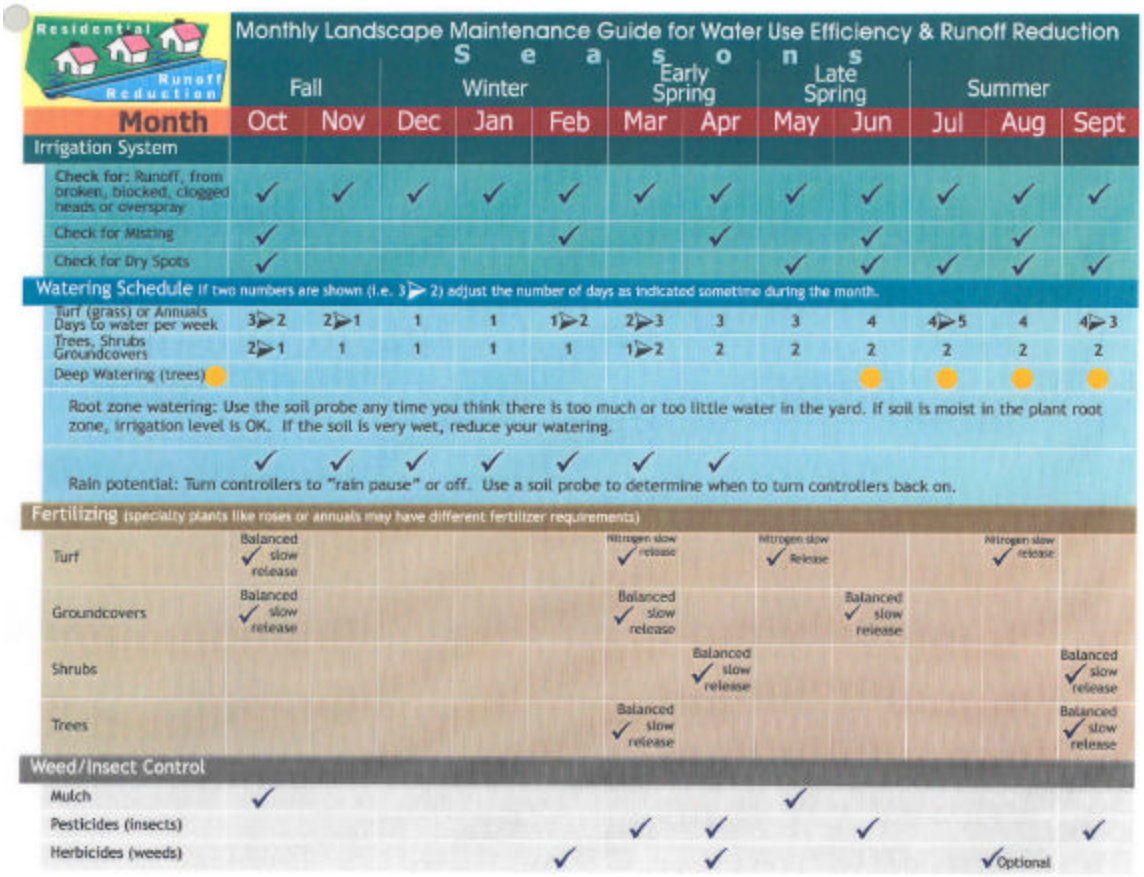
Weed and Insect Control

- Watch for aphids and whiteflies. Wash insects off of leaves with a hard spray of water or spray with diluted soap solution.
- Apply mulch to control weeds, improve moisture retention and restore nutrients to the soil.
- Pick weeds now while they're still small.
- Use weed and insect chemicals only as directed on the containers.

This is a guide only. This guide does not hold public agencies responsible for the health and appearance of your home landscape.

*By "cycling" your irrigation timer to turn on for the suggested number of minutes about an hour apart, you reduce runoff and gain deeper watering and healthier root growth.

Exhibit C
Monthly Landscape Maintenance Calendar (Provided for "retrofit" and "education only" customers)
(Actual size: 8.5 in. x 11in.)



Monthly Landscape Maintenance Guide for Water Use Efficiency & Runoff Reduction

Seasons	Fall		Winter			Early Spring		Late Spring		Summer		
Month	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept
Irrigation System												
Check for: Runoff, from broken, blocked, clogged heads or overspray	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Check for Misting	✓				✓		✓		✓		✓	
Check for Dry Spots	✓							✓	✓	✓	✓	✓
Watering Schedule If two numbers are shown (i.e. 3▶2) adjust the number of days as indicated sometime during the month.												
Turf (grass) or Annuals Days to water per week	3▶2	2▶1	1	1	1▶2	2▶3	3	3	4	4▶5	4	4▶3
Trees, Shrubs Groundcovers	2▶1	1	1	1	1	1▶2	2	2	2	2	2	2
Deep Watering (trees)									●	●	●	●
Root zone watering: Use the soil probe any time you think there is too much or too little water in the yard. If soil is moist in the plant root zone, irrigation level is OK. If the soil is very wet, reduce your watering.												
Rain potential: Turn controllers to "rain pause" or off. Use a soil probe to determine when to turn controllers back on.	✓	✓	✓	✓	✓	✓	✓					
Fertilizing (specialty plants like roses or annuals may have different fertilizer requirements)												
Turf	✓ Balanced slow release					✓ Nitrogen slow release		✓ Nitrogen slow Release			✓ Nitrogen slow release	
Groundcovers	✓ Balanced slow release					✓ Balanced slow release			✓ Balanced slow release			
Shrubs							✓ Balanced slow release					✓ Balanced slow release
Trees						✓ Balanced slow release						✓ Balanced slow release
Weed/Insect Control												
Mulch	✓							✓				
Pesticides (insects)						✓	✓		✓			✓
Herbicides (weeds)					✓		✓				✓ Optional	

Exhibit D
Monthly Landscape Maintenance Guide
Provided for "retrofit" and
"education only" customers
(Actual size 5.5 in. x 8.5 in)

Chapter 7: Findings, Conclusions, and Recommendations

7.1 Overview

The previous chapters of this report evaluate changes in water usage, dry weather runoff, water quality, and customer attitudes and awareness related to irrigation practices associated with the R3 Study. The intent of this chapter is to "integrate" these findings and outline their context as they relate to the interests and goals of the study participants and provide guidance for future efforts to improve water quality in the San Diego Creek watershed and in other areas of the county and state. Information is provided on:

- Findings and conclusions related to study methods for the water conservation, runoff reduction, water quality, and customer acceptance evaluations
- Findings and conclusions related to key results from the four study evaluations
- Recommendations related to future planning and policy

7.2 Study Methods

As noted in Chapters 3 through 6 of this report, study assumptions and methods demonstrated varying degrees of success. This section presents findings and conclusions regarding the degree of reliability of certain evaluation approaches and provides a foundation for future studies to build upon.

7.2.1 Water Conservation

Findings and conclusions regarding the study method for the water conservation evaluation portion of the R3 Study focused on three major areas.

First, the empirical effort used in the study quantified the change in mean water consumption and the shift in seasonal consumption. The models were not extended to document how water savings vary across households, for example, how savings are decreased/increased among lower/higher water use households. Such information could be useful in future studies.

Second, the study evaluated only about one year of post installation data. Thus, the statistical models can say little about the persistence of water savings. Additional follow-up quantification of water savings in subsequent years would be desirable.

Third, the modeling effort did not estimate the effect of self-selection by the participants in the education-only group. Thus, no attempt was made to extend the inference from the existing sample of participants to: 1) the rest of the service area; or 2) other service areas. The error component of the estimated models could be improved by specifying a function form to explain the variance. This should only be attempted after all major data issues have been resolved.

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7.2.2 Runoff Reduction

As discussed in Chapters 2 and 4, significant measurement and data quality issues were associated with the enacted real-time measurement of urban runoff. The technology employed involved custom configurations and numerous needed calibration adjustments. Debris build-up was an early, ongoing, and possibly unavoidable issue that interfered with the calibration of the flow meters. Some of the original locations selected were more prone to this type of problem, and the flow meters were necessarily relocated. Although flow-monitoring problems required data from two of the three control sites to be discarded, the data from the other three sites (two treatments and one control) was sufficiently accurate to allow for the determination of meaningful statistical results.

To minimize the data collection issues experienced during the R3 Study, it would be helpful to install a V-notch weir in the storm drain. (See figure 7-1.) This would enable low flows to be captured and measured more precisely. It should be noted, however, that installation in an underground drain (as opposed to the surface drain shown on the figure) would require protective gear to be worn by the data collectors. Full gear (breathing apparatus) could become cost prohibitive for an aggressive (bi-weekly) monitoring program.

Figure 7-1
Detail of Diversion V-notch Design of Weir Installed in Large Drainage Pipe
(Note: Black sonic sensor hanging directly over V-notch to measure water flow levels.)

7.2.3 Water Quality

As discussed in Chapter 5, two independent reviews of water quality measurements were conducted as part of the R3 Study. Because of the variability of the data and limitations in sample quantities, the first review, which used parametric statistical techniques, provided less definitive results that the second review, which used more robust data analysis techniques. For

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some of the parameters reviewed, the robust analytical techniques were able to identify and measure differences in water quality across time and between study treatments.

7.2.4 Public Acceptance

As discussed in Chapter 6, pre- and post- intervention surveys were given to both the retrofit group and the education group. The pre-intervention survey was given to assess and document the prevailing landscape maintenance attitudes and behaviors of both participating groups. The post- intervention survey was given to determine 1) whether or not there was an acceptance of the ET controller as a way of managing landscape irrigation and 2) if exposure to the educational materials and monthly landscape maintenance tips had led to a change in irrigation practices and landscape management behaviors in either study group.

The survey responses indicate that, while 82 to 90 percent of the retrofit and education-only group reported to have read the educational materials, reading these materials did not cause their landscape maintenance habits to change. These responses suggest that future surveys should be designed to capture a measurement of the changes in the study subjects' consumer attitudes and behaviors in greater detail.

Future projects could benefit from using a marketing research firm specializing in the use of polls and surveys to measure residential consumers' attitudes and behaviors. The wording of each pre- and post- intervention survey question can be very carefully crafted in order to target, capture, and quantify each specific pre- and post- intervention behavioral change that is being measured. Identical or one-to-one correspondence between the pre- and post- survey questions is another effective marketing research technique. By documenting customers' changing responses, over time, to identical questions, behavioral shifts can be tracked and quantified.

7.3 Study Results

Key results of the four R3 Study evaluations are summarized below. Because the water conservation and runoff reduction evaluations were interrelated, the results from these evaluations are discussed together below.

7.3.1 Water Conservation and Runoff Reduction

As discussed in Chapter 3, water consumption by residential customers in the retrofit group was reduced by 41.2 gallons per day per household, with a reduction for the education group of 25.6 gallons per day per household. In contrast, whereas the runoff flows for the retrofit group were reduced during the study, flows in the education group increased (Chapter 4). There are three related explanations for this dichotomy: 1) the inclusion of small to medium size "common area" landscapes in the retrofit group and the exclusion of this group from the education group; 2) differences in irrigation scheduling between the residential homes in the two groups; and 3) proximity and relative flow volumes of the landscapes to the storm drain system.

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7.3.1.1 Dedicated Landscapes

The retrofit group common areas averaged 0.8 acres in size and encompassed 15 sites/irrigation controllers including city landscape medians, HOA greenbelts, and a park. It is estimated that these sites account for more than 75 percent of the total area under treatment in the Site 1001 area. More specifically, these 15 sites totaled about 12 acres. The remaining 112 irrigation controllers installed on single-family residential lots are estimated to encompass 3.5 to 4 acres. The proportion of residences receiving educational materials including irrigation scheduling information was chosen to match the number receiving retrofit treatment. However, the total treated acres for the two groups varied considerably.

As was the protocol for all retrofit sites, irrigation schedules for these sites were established based on valve-by-valve evaluations of plant, soil, and irrigation system parameters. These schedules resulted in significantly more start times and shorter run times than that observed in these areas prior to the study.

More specifically, prior to installation of the retrofit treatment, each valve was turned on for two minutes to determine the flow. In this brief period, runoff was observed for many of the valves. This relates to the predominant clay soils, where runoff can exceed 90 percent of applied water after short periods due to the low infiltration rates. It is believed that the more frequent, short duration irrigation schedules developed by the treatment irrigation technology is the primary mechanism to reduce runoff from irrigation sites. In addition, these sites were closely monitored and incorporated suggested BMPs such as weekly meter readings. These sites were also used to develop the protocol for the midweek scheduling changes for all of the retrofit area and when to terminate a rain pause for the region.

In contrast to the retrofit group, the controllers on comparable common area landscapes in the education group are assumed to have continued with typical irrigation schedules that likely result in higher levels of runoff. If this is the case, and the common areas account for a similar percentage of irrigated area, this could explain the observed differences in runoff between the retrofit and education groups.

7.3.1.2 Differences in Irrigation Schedules

In addition to the runoff differences likely stemming from the inclusion of the nonresidential landscapes in the retrofit group, irrigation scheduling differences also existed for the residential homes between the retrofit and education groups. The education group households received a suggested irrigation schedule that provided the number of days per week to run the irrigation system, the number of minutes per cycle (start time), and a maximum of three start times. As noted above, short run times and multiple start times are believed to be the key element in reducing irrigation runoff.

Although the post-study survey indicated that about 60 percent of those in the education group changed their controller's irrigation schedule at least "sometimes," it is not clear how closely they followed the suggested schedule, including the recommendation on start times. Inasmuch as programming many controllers for multiple start times can be challenging, it is possible these

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instructions were generally overlooked. In contrast, the weather-based irrigation controller used on the retrofit homes automatically reduced the run time for slope, soil, and sprinkler precipitation rate. This will likely reduce runoff even in the absence of direct water savings. This difference may also be a consideration in the dissimilar runoff results in the two treatment sites.

7.3.1.3 Proximity to Storm Drains and Flow Volumes

The final consideration is the location and relative flow volumes of the common area landscapes relative to location and flow volumes of the residences. The common area landscapes were typically located closer to storm drain catch basins (and the study flow monitors) than most residential lots and also had much higher flow volumes on the individual irrigation valves. Runoff from most residential lots had to travel a signficant distance through surface street gutters before reaching catch basins and were subject to both evaporation and seepage in route. In addition, the limited drainage associated with many residential back yards could have further reduced the quantity of water reaching the storm drain from these areas in both the retrofit and education groups. Consequently, the reduction in runoff from treated retrofit common area landscapes and the presumed lack of similar reductions for the education group common areas, combined with the high valve flow volumes, likely explain the differences in observed runoff for the two treatment groups.

7.3.2 Water Quality

As described in Chapter 5, water quality samples were taken twice per month, resulting in a total of 39 samples over an 18-month period. One of the simplest and most straightforward methods to review these samples is to compare them to established water quality objectives for the San Diego Creek watershed. The subsections below address water quality and flow, and runoff water quality.

7.3.2.1 Water Quality and Flow

Chapter 5 of this report also describes issues with the reliability of study flow data during certain study periods and with certain monitoring locations. Because of the temporal relationship of these issues, integrating the water quality and flow data to determine changes in the mass loading of water quality constituents is difficult from a statistical standpoint. However, certainly, the water quality and flow data from the study provide some useful qualitative insight into the impacts of the interventions and may be instructive for future water quality improvement efforts.

7.3.2.2 Runoff Water Quality

Analyses utilizing ore robust statistical methods suggest that the intervention did result in changes in water quality. TN levels in the retrofit neighborhood following intervention were found to be significantly lower than levels before intervention, whereas no detectable differences were noted before and after intervention in the education neighborhood. Relatively large observed reduction in TN flux in the retrofit neighborhood could be influenced by seasonal factors, and the extent to which the ET controller contributed to the reduction is unknown.

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7.3.3 Public Education

Data issues discussed previously make it difficult to quantify the impact of public education on reduced water usage and reduced dry season runoff. However, pre- and post-surveys of the retrofit + education and education only groups showed a positive response to the concepts of the irrigation tips. More than 70 percent of the retrofit group participants indicated that they liked the ET controllers, and the group also found that controller irrigation either maintained or improved the landscape. However, it appears that the savings in water use per year is not large enough for the water customers to be willing to pay for an ET signal.

7.4 Recommendations

The application of data from this study will influence future programs and efforts to improve water quality. The application of the irrigation management program focusing on using automatic real-time weather-based irrigation scheduling not only resulted in reductions in onsite/customer water use, but also reduced runoff. With the quality of runoff essentially unchanged, this reduction in runoff should result in a decrease in the total mass of non-point source pollutant loading to the watershed. The relative cost-effectiveness of this program should be evaluated in comparison to other existing or proposed BMPs to improve watershed water quality.

Although not directly determined from the study, the results suggest that the common area landscape sites will provide the most cost-effective application of the water management program. Additional empirical verification of this relative cost-effectiveness supposition is likely warranted.

An additional issue related to the water management program is the availability and viability of the irrigation controllers tested as a part of the study. Although the tested controllers operated reasonably well, occasionally glitches occurred, which necessitated either telephone or onsite intervention by study personnel. For the number of controllers installed for the study, these maintenance issues were manageable. However, the wide-scale use of these controllers would require a significant commitment from the water purveyor or the controller manufacturer to address maintenance issues. At this time, it is not believed that the controller manufacturer has established infrastructure to support a large number of controllers. In addition, the viability of the tested water management program is completely dependent on the regular transmission of data signals from the controller manufacturer to adjust irrigation schedules. Assurances on the long-term viability of signal transmission are imperative to the expansion of the tested program.

In contrast to the water management program, the educational program implemented as a part of the R3 Study reduced customer water use, but did not reduce measured runoff from the study area. Consequently, again assuming no change in runoff quality, this treatment would not appear to provide pollutant mass loading benefits to the watershed. However, the relationship between the observed water savings for the treated portion of the study area and increased runoff for the entire study area is unclear. Because of the clear relative cost advantages of educational programs, additional and more focused studies should be conducted to more fully understand this

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relationship and determine the viability of educational programs in reducing non-point source pollution.

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Appendix A: References

The Residential Runoff Reduction Study

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Appendix A: References

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Appendix B: Study Design

The Residential Runoff Reduction Study

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Appendix B: Study Design

Introduction

In 1999, the Municipal Water District of Orange County (MWDOC) and Irvine Ranch Water District (IRWD), in partnership with other national, state, and local agencies and organizations began developing a project to accomplish two goals:

1) Measure changes in the dry weather volume and pollutant content of residential runoff associated with improved irrigation management practices.
2) Confirm residential irrigation water savings identified in a previous study evaluating an automated residential irrigation controller system (the "Westpark Study").

This Appendix presents detailed information on the general study design framework described in Chapter 2. Subjects discussed include watershed selection, flow monitoring, water quality sampling, ET controller operation and selection process, and controller installation and operation.

Watershed Selection

Five watersheds were selected for the study area, based on five criteria: 1) Isolation from other watersheds, 2) climate, 3) land use, 4) development age, 5) irrigation water management techniques.

Isolation from Other Watersheds:

A watershed consists of a region of land, which drains through a single point. The five study watersheds were located in the Northwood Village subdivision in the IRWD service area. Each watershed drains through a single point and is isolated from other sources of runoff. This enabled the runoff flow and water quality to be free of interference from other sources.

Climate

While most of Southern California and Northwood Village have a similar climate, the five watersheds share the same ET zone. They are located within 5 miles of CIMIS station #75, which provides local ET_o information. The ET_o (reference evapotranspiration, the amount of water utilized by plants and lost to evaporation) is the same throughout the Northwood region and most of the central section of the IRWD service area. The plant water requirements of ET_g, which is the standard of turfgrass for cool season turfgrass and is often referred to as simply ET, are the same for all five watersheds.

Due to the close proximity of the all the homes and the lack of any physical or geographical separation of the five watersheds, the study team relied on the CIMIS station #75 for ET_o data.

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Land Use

The Northwood section of IRWD's service area was selected because the predominant land use is single-family residence. There are also local parks, common city streetscapes, two condominium associations and one homeowners association (HOA). Several of the watersheds contained townhouses, apartments or condominiums. However, these types of multi-family units were limited in each of the watersheds; no single watershed had a large number of multi-family units.

Development Age

Northwood's neighborhoods were created during two distinct periods of home development. The first phase of development began in the late 1970s and finished in the early 1980s. The second phase started in 2000 and continues to the present. The study excluded the newer section of Northwood for two reasons. First, the newer homes and their HOA are not typical of Southern California. Second, IRWD has monthly water bill information dating back to the late 1980s on homes in the older section of Northwood.

Irrigation Water Management Factors

In addition to ET_o, other basic factors of irrigation water management are precipitation rate, soil type, and plant type. This study implemented real time ET scheduling through a commercially-available signal and distributed educational material to improve water management. Other water management factors are described below.

Precipitation rates vary from irrigation valve to irrigation valve, and most of the homes applied the water with spray heads operating off the pressure provided by IRWD. The individual homeowners installed most of the irrigation systems after the purchase of their houses. The technology used in these irrigation systems was of the same approximate age and featured similar types of equipment. The irrigation systems installed in the study area were also representative of a common irrigation set-up presently in use in Southern California. .

The soil type in the study area is not typical of Southern California and consists of heavy clay. Clay has the lowest infiltration rate and requires the highest level of water management.

The landscapes have sufficiently similar plant material. Although there was no data available to perform a numerical comparison, the study team field surveyed each of the potential watersheds. The majority of landscaping of all homes in the study area consisted of turfgrass. To varying extent, the outside edges, fence, building and walkways areas were lined with shrubs and plant materials other than turfgrass. The best estimate of the ratio of turfgrass to other landscaping is approximately 70 percent. While some of the homes in each of the watersheds may not have followed this construct, the vast majority of landscapes were laid out in this fashion, which allowed the study team to determine which plant materials were mostly consistently found throughout the five watersheds.

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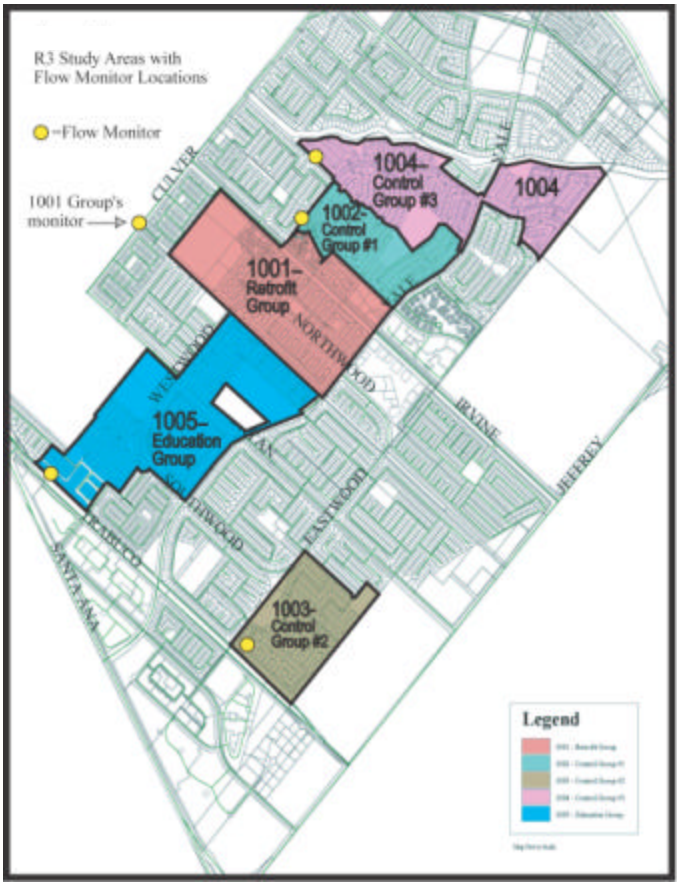
Results

After determining that large sections of Northwood were similar and after locating safe monitoring sites, the study team traced the storm drains. The selection of the monitoring site determined the shape and contents of the watershed. The study was able to isolate five watersheds with similar characteristics. The areas of the five watersheds are outlined and labeled in Figure B-1 below.

Figure B-1
Five watershed areas and their corresponding Control groups



Flow Monitoring

The two main criteria for the study's flow monitoring equipment were: 1) the monitor could not alter the pipe or channel and 2) the monitoring must be able to distinguish the seasonal flow changes and any flow change that resulted from the three different treatments (i.e., retrofit group treatment, education-only group treatment, and control group treatment).

Two technologies were suitable for this application: Manning's equation plus a level sensor, or velocity sensor and level monitor (area-velocity). The area-velocity method was chosen due to lack of slope information for the storm drain system. The selected equipment was a Sigma 950, manufactured by Hach. The equipment was battery operated, could record data every minute, and included an ultrasonic transmitter and a velocity sensor located in the storm drain. The ultrasonic transmitter established the water surface level and area, while the velocity sensor determined the velocity of the water in the pipe.

Flow was calculated by the equation: Flow = Area x Velocity. Because four of the five monitoring locations (see Figure B-1 above) were located in pipes, several variations on the ultrasonic transmitter / velocity sensor were tested before the combination of sonic and velocity wafer were selected.

Water Quality Sampling

The water quality sampling program quantified constituents found in residential runoff flows. Because a typical residential neighbor includes more than single-family lots, the concept of water management through an ET signal technology expanded to include common area landscapes.

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The water quality sampling program consisted of two phases: 1) pre-study and 2) dry weather sampling.

Pre-study

Based on water level elevation provided by the flow monitors, the study team developed a plan for sampling water quality during dry weather runoff periods. In the early evening (7 to 10 pm) and again in the early morning (3 to 6 am), the water level would rise, indicating an increase in runoff flow. While the amount of change varied by location and date, the pattern was common to all of the watersheds.

The study team performed a weeklong test to determine the most representative sampling time. The team sampled all five study areas every day at 4 am and 7 pm. The constituents sampled were fecal coliform, nutrients, and trace metals.

The test results showed neither differences nor patterns in concentrations between sites, days, and sample times.

Dry Weather Sampling Duration

The final sampling program consisted of bi-weekly sampling of all five sites. During sampling weeks, all five sites were sampled for all analyses listed in Table B-1 on Tuesday, and three sites were sampled for pesticides two additional days. Toxicity samples were collected once per month at all five sites.

Table B-1
Routine Water Quality Analysis Responsibilities

Responsible Lab	Water Quality Parameter	Bottle Type
IRWD	NO_2, NO_3, NH_3, T-PO_4, TKN, O-PO_4, EC, pH, Trace Metals, Total / Fecal Coliform	(2) 1-L Cubitainer (1) 250 ml Sterile
SCCWRP	Toxicity (Sea Urchin Fertilization)	
SCCWRP	Pesticides	
MWL	MS-2 Phage	(1) 1-L (from MWL)
MWL	Enterococcus	(1) 250 mL (from MWL)

The study team collected the biweekly Tuesday samples beginning in January of 2001 and continuing through the next 18 months. The first months of sampling occurred before or during the installation of the ET controllers in the residences and the common landscape. The last 12 months, starting in July 2001 and finishing in June 2002, became the post retrofit samplings. The pesticide sampling continued for an additional six months through December 2002. Table B-2 provides outlines the water quality and data collection schedule for each group in the study.

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Table B-2. Water Quality and Data Collection Schedule					
Sample Site	**Site ID**	**Cross Streets**	**Atlas Page**	**Parameter**	**Frequency**
Group A Education Site Control Site	 1005 1003	 Shadwell/Westmoreland Carver/Carver	 84w – C1 105w – A1	Flow WQ	Weekly Bi-weekly
Group B Control Site Control Site Retrofit Site	 1004 1002 1001	 Hicks Canyon/Park Place La Paloma/Park Place Culver/Florence	 83w – D2 83w - D1 84n – A3	Flow WQ	Weekly Bi-weekly

ET Irrigation Controller Operation and Selection Process

To meet the R3 Study objectives, it was necessary to install as many ET controllers as possible in the retrofit group. Providing the fullest coverage of the watershed with proper irrigation water management generated the best chance of changing the runoff flows. Since residential areas include landscapes other than those of the homeowners, these landscape areas were included in the water management component of the R3 Study. This represents a 3 to 1 ratio of medium-size landscapes to residential landscapes. A description of the installation process for both residential and medium-size landscapes follows:

Residential Landscapes

The IRWD staff attempted to reach as many of the 334 residences in the retrofit watershed as possible. These targeted residents received three letters which informed them of the following:

1) If selected to participate in the study, they would receive a free controller that would automatically adjust the landscape watering.
2) Their participation would be part of an environmental study aimed at preventing runoff from reaching the ocean.
3) They would be saving water without having to program an irrigation controller.
4) They were provided instructions for participating in the study along with a phone number to call to sign-up, as well as a form with a stamped and addressed envelope (for returning the form).

Additionally, IRWD staff hosted a function for the HOA in which staff demonstrated the ET controller to the residents and helped them to complete the sign-up form. Lastly, IRWD staff walked the Northwood neighborhood and hung flyers on the study candidates' front doors. These flyers contained statements from the homeowners in Westpark that had participated in the original ET Controller study. The flyers also described the ET controllers' overall customer satisfaction and ease with which the irrigation system worked.

In all, 137 residents responded to the various communication efforts by agreeing to participate in the study and installing the ET controller on their property. Of the 137 positive responses, 112 homes were equipped with proper automatic valves.

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The installation of controllers began in April 2001 and continued through June 2001. A full team of IRWD staff worked weekdays, Saturdays and evenings to complete the installations. Additionally, educational materials were distributed to the retrofit group during installations.

Medium-size Landscapes

In addition to the single-family residences, the retrofit watershed contains 2 condominium complexes, and one HOA with three distinct land use types. The area also contained 12 city streetscapes. The City of Irvine agreed to change out the existing manual controllers with the ET controllers. All of the HOAs agreed to change out their controllers for the ET controllers.

The only major landscape not replacing its existing controller with an ET controller was the park-playground area of the school. The school landscape area consisted of a single meter with two separate controllers and more than 50 valves. This would require at least six ET controllers. Given the limitation in the controller and the high number of cycles that would be required to correctly irrigate the school site, IRWD was not confident that the ET controllers could be programmed in a manner that would avoid conflicting runtimes.

Controller Installation and Operation

The study evaluated the performance of the engineering of irrigation management techniques to reduce the consumption and residential runoff while maintaining the quality of the landscape. A typical irrigation controller is difficult to program and limited in the scope of the scheduling ability. Proper scheduling requires calculations based on real time ET data, landscape topography, and plant type, which are beyond the capabilities of typical controllers. The landscaper in the field is left to guess or rely on past experience as to the correct amount of water, the correct runtime to prevent runoff, and the correct days of the week to water.

The operation of the ET controller in this study was optimized by: 1) weekly maintenance, and 2) proper irrigation scheduling. IRWD staff programmed the controllers, which were operated by a combination of IRWD staff and HydroPoint consultants. (HydroPoint Data Systems, also known as HydroPoint, developed and supplied the ET controllers used in the R3 Study.)

During the prior study in Westpark, the programming was calculated based on a design precipitation rate suggested for spray heads. That study received numerous complaints that too much water was being applied and an effort was undertaken to conduct an area/flow measurement to determine the actual precipitation rate. These measurements indicated an average precipitation rate of 3.98 inches per hour while the design precipitation rate for the spray heads was 1.80 inches per hour. The measured rates varied from as low as 1.4 inches per hour to as high as 9 inches per hour. This suggested that standard settings in which a homeowner would program the controller are unlikely to efficiently run the irrigation. Because of this and other important factors, trained staff preformed the installations

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Appendix C: Statistical Analysis of Water Savings

The Residential Runoff Reduction Study

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Appendix C - Statistical Analysis of Water Savings

Prepared for
Municipal Water District of Orange County and
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Summary

Findings

$ **Single Family Residences:** Households receiving an evapotranspiration (ET) controller and education were found to save approximately 41.2 gallons per day on average (33.2 gpd – 49.2 gpd is the 95 percent confidence level). Households receiving the education treatment alone were found to save approximately 25.6 gallons per day on average (20.1 gpd – 31.1 gpd is the 95 percent confidence level). This sample compared 93 ET controller/education participants and 192 education-only participants to 1236 nonparticipating single family customers.

A secondary finding in this sample related to seasonal shape in this average savings effect. For the one year of post-intervention consumption data within our sample, the water savings was not constant. The ET controller/education intervention, in particular, saved more water in the autumn and less in the spring growing season.

$ **Landscape-Only Accounts:** Among a smaller sample of 21 landscape-only accounts, significant water savings (16 percent) were obtained from the use of ET controllers. A sample of 76 matched sites (similar in landscaped area and type of use) also showed the effects of City water efficiency improvements. Since both of these samples contain a large number of medians and streetscapes, it is possible that each gallon saved from irrigation-only sites contributes more to runoff

reduction than a gallon saved at a single family site. Since the runoff reduction was not measured by customer account, this study will not be able to confirm or deny this hypothesis.

SARB_001722

Introduction

The purpose of this work is a statistical analysis of water savings among customers who installed evapotranspiration (ET) controllers and customers given irrigation education in the Irvine Ranch Water District. This report documents a careful statistical analysis of historical water consumption data to derive estimates of the net water savings from these interventions.

Approach

Historical water consumption records (July 1997 to August 2002) for a sample of participants and for a sample of nonparticipating customers were examined statistically. The hypothesis was that installation of new irrigation technology or better management of existing equipment would reduce the observed water consumption of customers participating in this program. This study empirically estimates the water savings that resulted from both types of interventions—(1) customers receiving both ET controllers and follow-up education and (2) customers receiving an education-only intervention.

Since installation of ET controllers required the voluntary agreement of the customer to participate, this sample of customers can be termed "self-selected." Customers were randomly chosen to receive the education-only treatment. While this analysis does quantitatively estimate the reduction of participant's water consumption, one may not directly extrapolate this finding to nonparticipants. This is because self-selected participant can differ from customers that decided not to participate.

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The explanatory variables in these models include

- Deterministic functions of calendar time, including
  - The seasonal shape of demand
- Weather conditions
  - measures of air temperature
  - measures of precipitation, contemporaneous and lagged
- Customer-specific mean water consumption
- "Intervention" measures of the date of participation and the type of intervention

Data and Methods

Consumption records were compiled from the IRWD customer billing system for customers in the study areas. Billing histories were obtained from meter reads between July 1997 and August 2002. It is important to note that a meter read on August 1 will largely represent water consumption in July. Since the ET controllers were installed in May and June of 2001, the derived sample will only contain slightly more than one year of data for each participant. Table 1 presents descriptive statistics on the sample.

Table 1: Single Family Residential Sample Descriptive Statistics

	Site 1001		Site 1004	Site 1005	
	ET Controller Participant	Non-Participant	Control	Education Participant	Non-Participant
Number of Usable Accounts	97	213	264	196	346
Pre-period: July 1997-May 2001					
Mean Use (gpd)	375	371	405	390	418
No. of observations	4,504	9,860	12,452	9,251	16,364
Post-period: June 2001-August2002					
Mean Use (gpd)	366	379	427	395	421
No. of observations	1,358	2,982	3,694	2,744	4,856

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The landscape-only customers (21 accounts) were handled separately. Two control groups were developed for these irrigation accounts: A matched control group was selected by IRWD staff by visual inspection, finding 3-5 similar control sites for each participating site. Similarity was judged by irrigated area and type of use (Home Owner Association, Median, Park, or Streetscape). Since the City of Irvine was improving irrigation efficiency on the City-owned sites during the post-intervention period, this matched control group also had potential water savings. A second control group was developed where the selection was done solely located by geographic area. In this way, the statistical models can separately estimate the water savings effects for each group.

Table 2: Landscape Accounts Descriptive Statistics

	Participant	Matched Control	Unmatched Control
Number of Usable Accounts	21	76	895
Acres per Account	0.93	0.92	0.96
Type of Account (if known)			
HOA	3	13	
Median	3	11	
Park	1	6	
Streetscape	14	47	
Pre-period: July 1997-June 2001			
Mean Use (gpd)	2,948	2,768	3,042
Mean Use per Acre (inches/day)	0.11702	0.11823	0.12893
No. of observations	967	3,503	39,352
Post-period: July 2001-August2002			
Mean Use (gpd)	2,845	2,990	3,271
Mean Use per Acre (inches/day)	0.10813	0.12012	0.13013
No. of observations	293	1,052	12,121

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The first major issue with using meter-read consumption data is the level and magnitude of noise in the data. The second major issue is that records of metered water consumption can also embed non-ignorable meter mis-measurement. To keep either type of data inconsistencies from corrupting statistical estimates of model parameters, this modeling effort employed a sophisticated range of outlier-detection methods and models. These are described in the next section.

Daily weather measurements—daily precipitation, maximum air temperature, and evapotranspiration—were collected from the CIMIS weather station located in Irvine. The daily weather histories were collected as far back as were available (January 1, 1948) to provide the best possible estimates for "normal" weather through the year. Thus we have at least 54 observations upon which to judge what "normal" rainfall and temperature for January 1^{rst} of any given year.

Robust regression techniques were used to detect which observations are potentially data quality errors. This methodology determines the relative level of inconsistency of each observation with a given model form. A measure is constructed to depict the level of inconsistency between zero and one; this measure is then used as a weight in subsequent regressions. Less consistent observations are down-weighted. Other model-based outlier diagnostics were also employed to screen the data for any egregious data quality issues.

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Specification

A Model of Water Demand

The model for customer water demand seeks to separate several important driving forces. In the short run, changes in weather can make demand increase or decrease in a given year. These models are estimated at a household level and, as such, should be interpreted as a condensation of many types of relationships—meteorological, physical, behavioral, managerial, legal, and chronological. Nonetheless, these models depict key short-run and long-run relationships and should serve as a solid point of departure for improved quantification of these linkages.

Systematic Effects

This section specifies a water demand function that has several unique features. First, it models seasonal and climatic effects as continuous (as opposed to discrete monthly, semi-annual, or annual) function of time. Thus, the seasonal component in the water demand model can be specified on a continuous basis, then aggregated to a level comparable to measured water use (e.g. monthly). Second, the climatic component is specified in different form as a similar continuous function of time. The weather measures are thereby made independent of the seasonal component. Third, the model permits interactions of the seasonal component and the climatic component. Thus, the season-specific response of water demand can be specific to the season of the year.

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The general form of the model is:

Equation 1

$$Use = m_i + S_t + W_t + E_{i,t}$$

where ***Use*** is the quantity of water demand within time t, the parameter $\boldsymbol{\mu_i}$ represents mean water consumption per meter i, $\boldsymbol{S_t}$ is a seasonal component, $\boldsymbol{W_t}$ is the weather component, $\boldsymbol{E_{i,t}}$ is the effect the landscape interventions for meter i at time period t. Each of these components is described below.

Seasonal Component : A monthly seasonal component can be formed using monthly dummy variables to represent a seasonal step function. Equivalently, one may form a combination of sine and cosine terms in a Fourier series to define the seasonal component as a continuous function of time.[1] The following harmonics are defined for a given day T, ignoring the slight complication of leap years:

Equation 2

$$S_t \equiv \sum_{1}^{6}\left[b_{i,j} \cdot \sin\left(\frac{2p \cdot jT}{365}\right) + b_{i,j} \cdot \cos\left(\frac{2p \cdot jT}{365}\right)\right] = Z \cdot b_S$$

[1] The use of a harmonic representation for a seasonal component in a regression context dates back to *Hannan* [1960]. *Jorgenson* [1964] extended these results to include least squares estimation of both trend and seasonal components.

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where $T = (1,...365)$ and j represents the frequency of each harmonic.[2] Because the lower frequencies tend to explain most of the seasonal fluctuation, the higher frequencies can often be omitted with little predictive loss.

To compute the seasonal component one simply sums the multiplication of the seasonal coefficient with its respective value. This number will explain how demand changes due to seasonal fluctuation.

Weather Component: The model incorporates two types of weather measures into the weather component–maximum daily air temperature and rainfall.[3] The measures of temperature and rainfall are then logarithmically transformed to yield:

Equation 3

$$R_t \equiv \ln\left[1 + \sum_{t=T}^{T_d} Rain_t\right], A_t \equiv \ln\left[\sum_{t=T}^{T_d} \frac{AirTemp_t}{d}\right]$$

where d is the number of days in the time period. For monthly aggregations, d takes on the values 31, 30, or 28, ignoring leap years; for daily models, d takes on the value of one. Because weather exhibits strong seasonal patterns, climatic measures are strongly correlated with the seasonal measures. In addition, the occurrence of rainfall can reduce expected air temperatures. To obtain valid estimates of a constant seasonal effect, the seasonal component is removed from the weather measures by construction.

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[2] If measures of water demand are available on a daily basis, the harmonics defined by Equation 2 can be directly applied. When measures of water demand are only observed on a monthly basis, two steps must be taken to ensure comparability. First, water demand should be divided by the number of days in the month to give a measure of average daily use. Otherwise, the estimated seasonal component will be distorted by the differing number of days in a month. The comparable measures of the seasonal component are given by averaging each harmonic measure for the number of days in a given time period.

[3] Specifically it uses the maximum daily air temperature and the total daily precipitation at the Irvine weather station. This station was selected due to its proximity to the study area.

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Specifically, the weather measures are constructed as a departure from their "normal" or expected value at a given time of the year. The expected value for rainfall during the year, for example, is derived from regression against the seasonal harmonics. The expected value of the weather measures ($\hat{\boldsymbol{A}}=\boldsymbol{Z}\bullet$) is subtracted from the original weather measures:

Equation 4

$$W_t \equiv (R_t - \hat{R}_t) \cdot b_R + (A_t - \hat{A}_t) \cdot b_A$$

The weather measures in this deviation-from-mean form are thereby separated from the constant seasonal effect. Thus, the seasonal component of the model captures all constant seasonal effects, as it should, even if these constant effects are due to normal weather conditions. The remaining weather measures capture the effect of weather departing from its normal pattern.

The model can also specify a richer texture in the temporal effect of weather than the usual fixed contemporaneous effect. Seasonally-varying weather effects can be created by interacting the weather measures with the harmonic terms. In addition, the measures can be constructed to detect lagged effects of weather, such as the effect of rainfall one month ago on this month's water demand.

Effect of Landscape Interventions: Information was compiled on the timing and location of each ET controller installation and education-only customer participation. The account numbers from these data were matched to meter consumption histories going back to 1997. All raw meter reads were converted to average daily consumption by dividing by the number of days in the read cycle. Using these data, relatively simple

"intervention analysis" models[4] were statistically estimated where, in this case, the intervention is ET controller installation and/or participation in the landscape education program. The form of the intervention is:

Equation 5

$$E_{i,t} \equiv I_{ET} \cdot b_{ET} + I_{Ed} \cdot b_{Ed}$$

The indicator variable I_{ET} takes on the value one to indicate the presence of a working ET controller and is zero otherwise. The indicator variable I_{Ed} takes on the value one if a household agreed to participate in the education program and is zero otherwise. The parameter $\hat{b}_{ET}$ represents the mean effect of installing an ET controller and is expected to be negative (installing an ET controller reduces water consumption.) The parameter $\hat{b}_{Ed}$ has a similar interpretation for the education-only participants.

This formulation also permits formal testing of the hypothesis that landscape interventions can affect the seasonal shape of water consumption within the year. Since numerous studies have identified a tendency of customers to irrigate more than ET requirements in the fall and somewhat less in the spring, it will be informative to examine the effect of ET controllers designed to irrigate in accord with ET requirements. The formal test is enacted by interacting the participation indicators with the sine and cosine harmonics.

[4]See Box and Tiao, "Intervention Analysis with Applications to Economic and Environmental Problems" *Journal of the American Statistical Association*, Vol 70,No. 349, March 1975, pp. 70-70.

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Stochastic Effects

To complete the model, we must account for the fact that not every data point will lie on the plane defined by **Equation 1**. This fundamental characteristic of all systematic models can impose large inferential costs if ignored. Misspecification of this "error component" can lead to inefficient estimation of the coefficients defining the systematic forces, incorrect estimates of coefficient standard errors, and an invalid basis for inference about forecast uncertainty. The specification of the error component involves defining what departures from pure randomness are allowed. What is the functional form of model error? Just as the model of systematic forces can be thought of as an estimate of a function for the "mean" or expected value, so too can a model be developed to explain departures from the mean—i.e., a "variance function" If the vertical distance from any observation to the plane defined by **Equation 1** is the quantity **e**, then the error component is added to **Equation 1**:

Equation 6

$$Use = \mathbf{f}(\mathbf{S}_t, \mathbf{C}_t, \mathbf{T}_t) + e$$

The error structure is assumed to be of the form:

Equation 7

$$e_{it} = m_i + x_{it}$$
$$where$$
$$m_i \sim N(0, s_m^2)$$
$$x_{it} \sim N(0, s_x^2)$$

The X and $?$ are assumed to be independent of each other and of μ. The individual component μ represents the effects of unmeasured household characteristics on household water use. An example of such an unmeasured characteristic might be the water use behavior of household members. This effect is assumed to persist over the estimation period. The second component $?$ represents random error. Because μ and $?$ are independent, the error variance can be decomposed into two components:

Equation 8

$$s_e^2 = T \cdot s_m^2 + s_x^2$$

This model specification is accordingly called an error components or variance components model. The model was estimated using maximum likelihood methods.

Estimation Results

Estimated Landscape Customer Water Demand Model

Table 3 presents the estimation results for the model of landscape (irrigation-only) customer water demand in the R3 study sites. This sample represents water consumption among 992 accounts between June 1997 and August 2002. This sample contains 21 ET controller accounts, 76 matched control accounts, and 895 unmatched control accounts.

The constant term (1) describes the intercept for this equation. The independent variables 2 to 9—made up of the sines and cosines of the Fourier series described in Equation 2—are used to depict the seasonal shape of water demand. The estimated weather effect is specified in "departure-from-normal" form. Variable 10 is the departure of monthly temperature from the average temperature for that month in the season. (Average seasonal temperature is derived from a regression of daily temperature on the seasonal harmonics.) Rainfall is treated similarly (Variable 11). One month lagged rainfall deviation is also included in the model (Variables 12). The next variable accounts for the amount of irrigated acreage on the site. (Note that while measured acreage is available for all irrigation-only accounts, this is not true for single family accounts.)

The effect of the landscape conservation program interventions is captured in the following rows. The parameter on the indicator for ET controllers (15) suggests that the mean change in water consumption is 472 gallons per day, approximately 16 percent of the pre-intervention water use. The matched control group (17) did experience water savings, approximately 241 gallons per day or 8.7 percent of their pre-intervention water use. The variables testing for differences in pre-intervention use cannot distinguish any differences between the different types of accounts.

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Table 3: Landscape Customer Water Demand Model Dependent Variable: Average Daily Metered Water Consumption (in gallons per day)		
Independent Variable	**Coefficient**	**Std. Error**
1. Constant (Mean intercept)	2619.0670	234.8112
2. First Sine harmonic, 12 month (annual) frequency	-811.6864	26.3271
3. First Cosine harmonic, 12 month (annual) frequency	-1984.6310	25.9776
4. Second Sine harmonic, 6 month (semi-annual) frequency	104.1141	26.5769
5. Second Cosine harmonic, 6 month (semi-annual) frequency	-18.5088	26.9614
6. Third Sine harmonic, 4 month frequency	-124.1069	28.1396
7. Third Cosine harmonic, 4 month frequency	107.1129	28.4812
8. Fourth Sine harmonic, 3 month (quarterly) frequency	39.5420	30.5372
9. Fourth Cosine harmonic, 3 month (quarterly) frequency	-62.1012	30.7453
10. Deviation from logarithm of 31 or 61 day moving average of maximum daily air temperature	6306.4130	562.5547
11. Deviation from logarithm of 31 or 61 day moving sum of rainfall	-747.0860	51.9108
12. Monthly lag from rain deviation	-209.8997	46.2994
13. Irrigated Acreage (in acres)	490.5891	139.6673
14. ET controller sites, test for difference in pre-intervention use	-46.2624	1278.0470
15. Average Effect of ET controller (21 accounts)	-472.1763	279.4630
16. Matched accounts, test for difference in pre-intervention use	-166.3042	691.8883
17. Average Effect of city efficiency improvements (76 accounts)	-240.9208	148.0551
Number of observations		57017
Number of customer accounts		983
Standard Error of Individual Constant Terms		5749.64
Standard Error of White Noise Error		4179.81
Time period of Consumption	June 1997 - July 2002	

Estimated Single Family Residential Water Demand Model

Table 4 presents the estimation results for the model of single family water demand in the R3 study sites. This sample represents water consumption among 1,525 single family households between June 1997 and July 2002. This sample contains 97 ET

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controller/education participants (in Site 1001) and 192 education-only participants (in Site 1005).

The constant term (1) describes the mean intercept for this equation. (A separate intercept is estimated for each of the 1,525 households but these are not displayed in Table 4 for reasons of brevity.) The independent variables 2 to 8—made up of the sines and cosines of the Fourier series described in Equation 2—are used to depict the seasonal shape of water demand. The predicted seasonal effect (that is, $Z \cdot \hat{b}_S$) is the shape of demand in a normal weather year. This seasonal shape is important in that it represents the point of departure for the estimated weather effects (expressed as departure from normal). We will also test to see if the landscape interventions have any effect on this seasonal shape.

The estimated weather effect is specified in "departure-from-normal" form. Variable 11 is the departure of monthly temperature from the average temperature for that month in the season. (Average seasonal temperature is derived from a regression of daily temperature on the seasonal harmonics.) Rainfall is treated in an analogous fashion (Variable 14). One month lagged rainfall deviation is also included in the model (Variables 15). The reader should also note that the contemporaneous weather effect is interacted with the harmonics to capture any seasonal shape to both the rainfall (Variables 12 and 13) and the temperature (Variables 9 and 10) elasticities. Thus, departures of temperature from normal produce the largest percentage effect in the spring growing season. Similarly, an inch of rainfall produces a larger effect upon demand in the summer than in the winter.

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The effect of the landscape conservation program interventions is captured in the following rows. The parameter on the indicator for ET controllers/education (16) suggests that the mean change in water consumption is 41.2 gallons per day while the education only participants (19) saved approximately 25.6 gallons per day. The model cannot say whether education-only participants saved this water through improved irrigation management or by also reducing indoor water consumption. Since the sample includes only one year of post-intervention date, the model cannot say how persistent either effect will be in future years.

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Table 4: Single Family Residential Water Demand Model
Dependent Variable: Average Daily Metered Water Consumption (in gallons per day)

Independent Variable	Coefficient	Std. Error
1. Constant (Mean intercept)	405.6593	3.1660
2. First Sine harmonic, 12 month (annual) frequency	-45.4215	0.9636
3. First Cosine harmonic, 12 month (annual) frequency	-89.1494	0.9629
4. Second Sine harmonic, 6 month (semi-annual) frequency	3.6549	0.6798
5. Second Cosine harmonic, 6 month (semi-annual) frequency	1.0709	0.6733
6. Third Cosine harmonic, 4 month frequency	1.7312	0.7151
7. Fourth Sine harmonic, 3 month (quarterly) frequency	4.4016	0.7403
8. Fourth Cosine harmonic, 3 month (quarterly) frequency	3.3491	0.7865
9. Interaction of contemporaneous temperature with annual sine harmonic	48.7897	17.1559
10. Interaction of contemporaneous temperature with annual cosine harmonic	-72.4672	22.3626
11. Deviation from logarithm of 31 or 61 day moving average of maximum daily air temperature	284.7163	13.542
12. Interaction of contemporaneous rain with annual sine harmonic	10.1102	1.8546
13. Interaction of contemporaneous rain with annual cosine harmonic	5.9969	2.6904
14. Deviation from logarithm of 31 or 61 day moving sum of rainfall	-34.0117	1.8931
15. Monthly lag from rain deviation	-13.3173	1.0549
16. Average Effect of ET controller/Education (97 participants)	-41.2266	4.0772
17. Interaction of ET intervention with annual sine harmonic	38.9989	5.3327
18. Interaction of ET intervention with annual cosine harmonic	-6.3723	4.8980
19. Average Effect of Education-only intervention (192 participants)	-25.5878	2.8081
20. Interaction of Ed.-only intervention with annual sine harmonic	6.0357	3.5870
21. Interaction of Ed.-only intervention with annual cosine harmonic	-3.0703	3.3826
Number of observations	94,655	
Number of customer accounts	1,525	
Standard Error of Individual Constant Terms		120.85
Standard Error of White Noise Error		129.81
Time period of Consumption	June 1997 - July 2002	

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How ET Controllers Affect Peak Demand

The question of how these programs affected the seasonal shape of water demand can be interpreted from the remaining interactive effects—the indicators interacted with the first sine and cosine harmonics. For example, the seasonal shape of demand can be derived before and after ET controller/education participation:

$$\text{Pre_Intervention}: S_t = Z \cdot \hat{b}_S \approx -45.4 \cdot \sin_1 - 89.1 \cdot \cos_1 + 3.6 \cdot \sin_2 + 1.1 \cdot \cos_2 + ... + 3.4 \cos_4$$

$$\text{Post_ETIntervention}: S_t' \approx Z \cdot \hat{b}_S + 39 \cdot I_{ET} \cdot \sin_1 - 6.4 \cdot I_{ET} \cdot \cos_1$$

When the pre/post seasonal patterns are combined with their pre/post mean water consumption, the following before and after picture can be seen throughout the year.

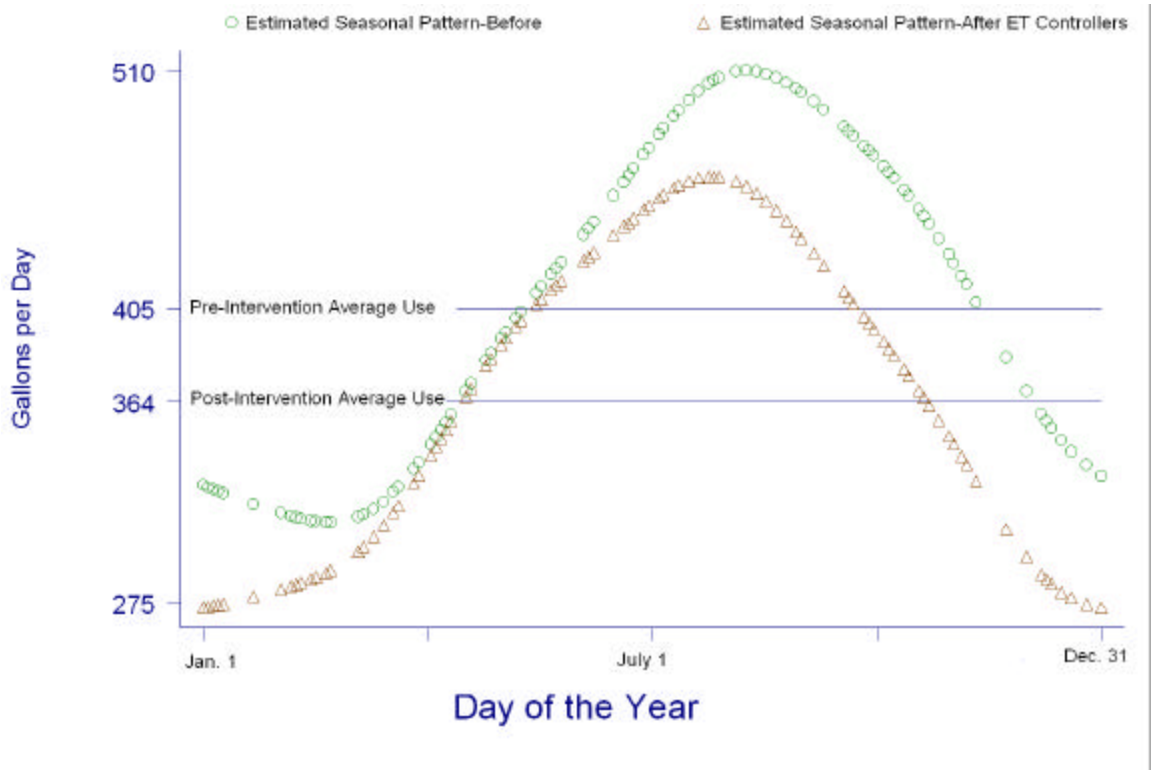

Figure 1-Effect of ET intervention on Water Demand

In Figure 1, several observations should be made. First, the difference between the two horizontal lines corresponds to the estimated mean reduction of approximately 41 gallons

per day. Second, the assumption of a constant 41 gallon per day effect does not hold true throughout the year. The reduction is barely noticeable in the spring growing season and is much larger in the fall.

The reduction in peak demand—though dependent upon how the seasonal peak is defined[5]—is greater than the average reduction. The estimated peak day demand, occurring on August 8, is reduced by approximately 51 gallons. This "load-shaping" effect of the ET controller intervention can translate into an additional benefit to water agencies. The benefits from peak reduction derive from the avoided costs of those water system costs driven by peak load and not average load—the costs for new treatment, conveyance, and distribution all contain cost components driven by peak capacity requirements.

Figure 2 plots the corresponding estimates for the Education-only intervention. The reduction in average demand is less—approximately 25 gallons per day. The effect upon the estimated seasonal shape of demand is much more muted. In fact, the change to the estimated seasonal shape of demand induced by the education-only intervention is not significantly different from zero at classical levels of significance.

[5] This is the issues of "coincident" versus "noncoincident" peak demand: the extent to which the peak load of a customer coincides with the system peak. Water systems by their nature have a strong and predictable tendency to peak seasonally—for Southern California, this occurs in the summer. Given the predictability of system peaks, and the attendant costs, the empirical case for the contribution of ET controller load shaping to the reduction of systems cost is relatively straightforward. The additional value of peak reduction--over and beyond reductions in average consumption--require careful specification of the additional incremental costs necessitated by peak flow requirements.

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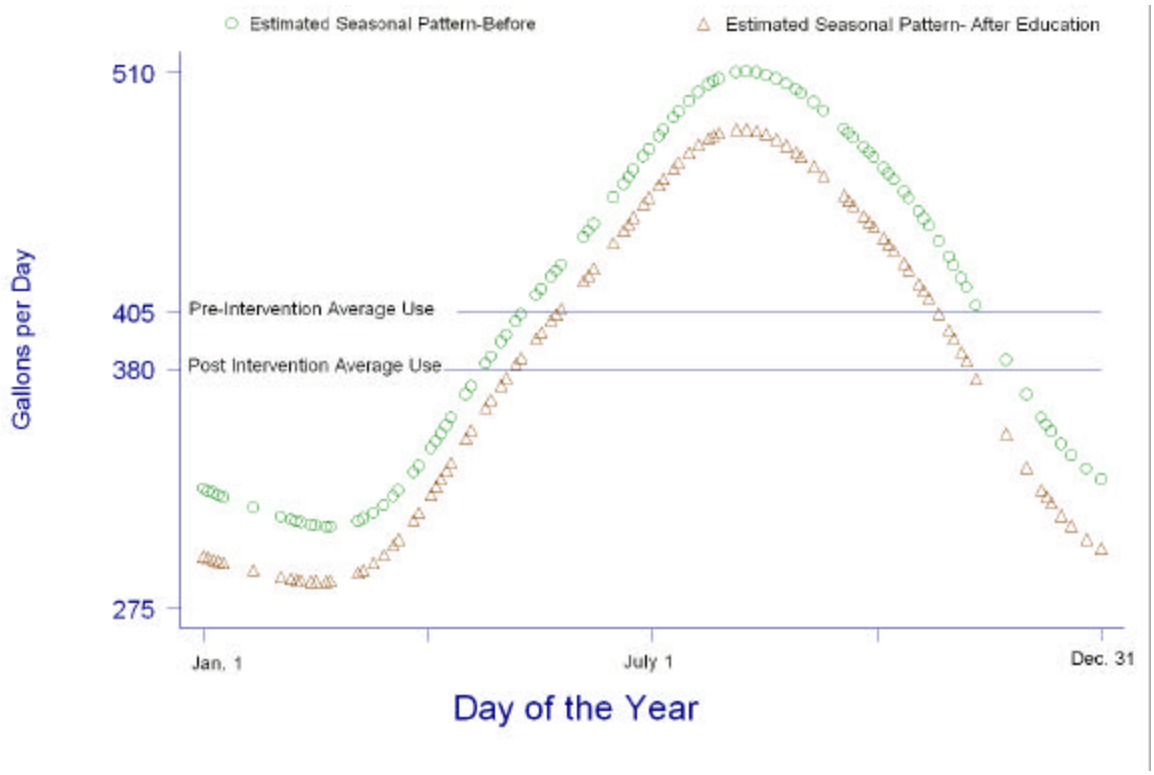

Figure 2-Estimated Effect of Education-only on Water Demand

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Caveats and Additional Work

This modeling effort focused on developing the best depiction of net changes in water consumption due to the landscape interventions of ET controllers and/or education. Much of the modeling effort was expended on data cleaning, diagnosis, and validation. We believe that the most serious data issues were identified and appropriately handled. To the extent that future data quality can be improved, future work could provide several statistical refinements in model specification:

- The empirical effort has quantified the change in mean water consumption and the shift in seasonal consumption. The models have not been extended to document how water savings vary across households—how are savings decreased/increased among lower/higher water use households?
- Since the sample only contains about one year of post installation data, the statistical models can say little about the persistence of water savings. Additional follow-up quantification of water savings in subsequent years is required.
- The modeling effort to date has *not* attempted to estimate the effect of self-selection. Thus, we make no attempt to extend the inference from the existing sample of participants to (1) the rest of the service area or (2) to other service areas.
- The error component of the estimated models could be improved by specifying a function form to explain the variance. This should only be attempted after all major data issues have been resolved.

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Conclusion

This report documents the shape of water savings achieved by the landscape interventions of ET controllers and/or education. Households participating in these programs saved significant amounts of water. The education-only program showed less water savings than the ET controller/education program, but were still significant. The ET controller/education program changed both the level and shape of water demand.

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Appendix D1: Statistical Analysis of Urban Runoff Reduction

The Residential Runoff Reduction Study

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Appendix D1 - Statistical Analysis of Urban Runoff Reduction

Prepared for
Municipal Water District of Orange County and
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Summary

$ **Data Reliability and Validity:** There were significant measurement and data quality issues with the enacted real-time measurement of urban runoff. The technology employed involved custom configurations and numerous needed calibration adjustments. Debris build-up was an early, ongoing, and possibly unavoidable issue that interfered with the calibration of the flow meters. Some of the original locations selected were more prone to this type of problem and the flow meters were necessarily relocated. Careful attention was paid to documenting data quality issues in ways that did allow for quantitative evaluation of runoff. Nonetheless, the intrinsic data reliability constrain the inference that can be drawn.

$ Control Study Sites 1002 and 1003: The measured runoff for the study sites 1002 and 1003—potential control sites—had recurring measurement issues that produced generally unreliable runoff data. We were unable to use the runoff data from either of these sites to serve as a match to either of the sites receiving landscape interventions (ET controllers and/or education).

$ **Control Site (1004):** The unadjusted runoff flow at Site 1004 contained some elevated and likely invalid flow recordings in the pre-intervention period; that is prior to May 2001. Using robust statistical modeling methods, the spurious flow observations were identified and "quarantined." It is possible that these high flow

measures were completely accurate measures of real runoff within Site 1004; perhaps one or more customers experienced undetected leaks. If this is the case, then Site 1004 could not serve as a good "matched" control site. The runoff in the post-intervention period for the Control Site 1004 increased 63 percent from the pre-intervention period.

$ **Effect of Education-only Intervention (Site 1005):** Study site 1005 contained approximately 565 single family residences. Of these, 225 residential customers agreed to participate in the irrigation education program. Study site 1005 was found to have post-intervention runoff (after May 2001) that was 36 percent higher than pre-intervention runoff (May 2001 and before). The question of how much higher runoff might have been without the education intervention necessitates comparisons to comparable sites that did not receive any intervention.

Comparison across sites can, in theory, control for time-varying covariance in runoff. That is, measured runoff from a matched control group could be used to estimate how runoff increases in the summer period. Comparing across sites, however, will also require standardizing for the different areas across sites and testing for how well matched the sites are in the pre-intervention period. These results are presented in the body of this chapter. If one is willing to accept the Control Site as a matched control, Site 1005's post-intervention runoff is 21 percent less than expected.

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$ **Effect of Evapotranspiration Controller/Education Intervention:** Study site 1001 contained 565 single family residences. Of these, 114 agreed to participate in the evapotranspiration (ET) controller/education program. In addition, approximately 26 landscape sites (HOA, City median, parks, and school sites) also received ET controllers.

Study site 1001 was found to have post-intervention runoff (after May 2001) that was approximately 49 percent less than pre-intervention runoff (May 2001 and before). These two time periods are not equivalent as valid pre-intervention measures include less than four months of data. Since urban runoff derives from outdoor water use, it generally increases in the spring and summer and declines in the autumn and winter. Hence, the 49 percent runoff reduction is likely to be an underestimate of the level of runoff reduction that would be estimated on comparable time periods.

Using either Site 1005 or 1004 as matched controls implies that the observed post-intervention runoff was 64 to 71 percent less than expected.

SARB_001749

Introduction

The purpose of this work is a statistical analysis of the reduction of runoff induced by Evapotranspiration (ET) controllers and irrigation education in the Irvine Ranch Water District. This report documents a careful statistical analysis of measured runoff in residential areas to derive estimates of the runoff reduction from these interventions.

Data and Methods *THIS INFO NEEDS TO BE ADDED BY IRWD STAFF*

Data collection (by IRWD staff)

Description of flow meters and how they work
Description of staff meter checking
Description of QA/QC on data (flagging suspect data through "rank" indicator)
Description of calibration tests - measurement issues at high (wet day) flow rates

Methods

Robust regressions techniques were used to detect which observations are potentially data quality errors. This methodology determines the relative level of inconsistency of each observation with a given model form. A measure is constructed to depict the level of inconsistency between zero and one; this measure is then used as a weight in subsequent regressions. Less consistent observations are down-weighted. Other model-based outlier diagnostics (Cook's distance, DFBETA statistics, and residual diagnostics) were also employed to screen the data for any egregious data quality issues.

Results

Descriptive Statistics

Raw flow rates

After screening for the known data quality problems, using the "rank" indicator, all raw meter reads were first converted to average hourly values. These were then aggregated by date to convert to daily runoff—the runoff measures are available in both mean hourly flow and total daily volume. Precipitation taken from the Irvine weather station was matched to the daily data and used to separate wet from dry days. Wet weather storm flow can be a more complicated phenomenon to predict, as it depends on the timing and magnitude of the rainfall event, the moisture deficit of soils, and other factors. The relative lack of large storm events in the post-intervention period precluded examination of these more complicated forces and the effect that the landscape interventions might have on wet day runoff.

Standardizing for area

Area-standardized measures of site runoff were also created for dry/wet days, where total daily volume was divided by the estimated permeable/total area. Estimates of area for the study sites were derived from the IRWD GIS system. The GIS system was queried to produce estimates of the number of lots and total area for the different land use classifications (single family residence, condo, HOA, school, landscape, street, and unknown). The GIS system also provided an estimate of the number of buildings, and building area. The area taken up by buildings is treated as impermeable. The remaining area was separated into permeable and impermeable area using a land use classification-specific assumption of impermeability. Table 1 provides the raw data used to construct the estimated site area. (Due to lack of usable flow measures, Sites 1002 and 1003 are not separately reported.) Table 2 aggregates these data by site.

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Table 1: Estimated Area of Study Sites by Land Use

R3 GROUP	#Lots	Classification	Total Area	Building Area	Assumed Impermeable Coefficient	Estimated Impermeable Area	Estimated Permeable Area
1001	64	?	499885		0	0	499885
1001	565	SFR	2911227	976574	0.5	1943900	967326
1001	109	Condo	447096	189721	0.9	421358	25738
1001	4	HOA	255208		0.75	191406	63802
1001	2	School	198676		0.9	178808	19868
1001	10	Landscape	845529		0	0	845529
1001	97	Street	2163105		1	2163104	0
1004	61	?	307556		0.0	0	307556
1004	417	SFR	2081636	719485	0.5	1400560	681076
1004	1	HOA	40165		0.8	30123	10041
1004	1	School	348739		0.9	313865	34874
1004	2	Landscape	1136		0.0	0	1136
1004	42	Street	1089143		1.0	1089143	0
1005	8	?	118370		0.0	0	118370
1005	559	SFR	2957363	1033197	0.5	1995280	962083
1005	1	HOA	66421		0.8	49816	16605
1005	1	School	264236		0.9	237812	26424
1005	1	School	261089		0.9	234980	26109
1005	2	Landscape	773206		0.0	0	773206
1005	45	Street	1736098		1.0	1736098	0

Table 2: Estimated Area of Study Sites (in sq. ft.)

R3 Group	Estimated Impermeable Area	Estimated Permeable Area	Total Area
1001	4,898,578	4,246,905	7,320,726
1004	2,833,692	572,686	3,868,375
1005	4,253,986	1,194,553	6,176,782

Robust Analysis of Runoff

Form of the Model

Using the runoff flow data, regression models were used to estimate mean runoff by site. A regression framework allows for (1) hypothesis testing within or across sites and (2) use of robust modeling techniques to identify and minimize the influence of spurious or outlying observations. Sites 1002 and 1003 contained too few valid observations to be included in this analysis. The form of the model is specified to have a single pre-intervention mean (μ_1) and to allow for tests of changes in this mean over time and across sites:

Equation 1

$$\frac{RunoffVolume_{i,t}}{SiteArea_i} \equiv m_1 + I_{4,\mathrm{Pre}} \cdot d_{4,\mathrm{Pre}} + I_{5,\mathrm{Pre}} \cdot d_{5,\mathrm{Pre}} + I_{1,Post} \cdot d_{1,Post} + I_{4,Post} \cdot d_{4,Post} + I_{5,Post} \cdot d_{5,Post}$$

The indicator variable $I_{i,\,t}$ takes on the value one to indicate that an observation comes from site i and the time period t (pre/post). Thus, the indicator variable $I_{4,Pre}$ takes on the value one for Site 1004 in the pre-period (Feb.2001-May 2001) and is zero otherwise. The parameter $d_{4,\mathrm{Pre}}$ is the estimate of how runoff in Site 1004 differs from the common mean μ_1 in the pre-period. The parameter $d_{5,\mathrm{Pre}}$ has a similar interpretation for Site 1005. The common intercept will, by construction, pick up the estimate of Site 1001 pre-period mean runoff, since the parameters $d_{4,\mathrm{Pre}}$ and $d_{5,\mathrm{Pre}}$ absorb any differences in the other sites.[1] The indicator variable $I_{,1Post}$ takes on the value one for Site 1001 in the post-period

[1] The choice of Site 1001 as the reference site—implied by excluding a Site 1001 change indicator—is not required. Choosing another site would generate an essentially

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(June 2001 -June 2002); its parameter is interpreted as the estimated change to the pre-period mean runoff. The parameters $d_{4,Post}$ and $d_{5,Post}$ have similar interpretations for Site 1004 and Site 1005.

Table 3: Robust Regression Estimates of Mean Dry Day Runoff

Dependent Variable: Dry Day Runoff Height (in inches per unit area) (Height=Runoff Volume/Site Area)

Variable	Coefficient	Std. Error	t	Prob.>|t|
Mean Runoff: Feb-May 2001				
1. Intercept (1001 mean runoff)	0.898563	0.120838	7.44	0
2. Difference of Site1004 in pre-period	0.143721	0.157245	0.91	0.361
3. Difference of Site1005 in pre-period	-0.092260	0.151479	-0.61	0.543
Change in Runoff: June 2001-June2002				
4. Change of Site 1001 in post-period	-0.445390	0.134540	-3.31	0.001
5. Change of Site 1004 in post period	0.878089	0.113737	7.72	0
6. Change of Site 1005 in post period	0.202553	0.106973	1.89	0.059
Number of observations	950			
F(5, 944)	74.92			
Prob. > F	0			
Quasi-R-Squared	0.35			

Robust Regression Results

Table 2 presents the robust regression estimation results for the model of dry day runoff in R3 study Site 1001 (containing some customers receiving the ET controller/education intervention), Site 1004 (whose customers received no treatment), and Site 1005 (containing some customers receiving the education-only treatment). This sample represents metered dry day runoff, standardized by estimated site permeable area, between Feb. 2001 and June 2002.

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equivalent model that is one that generates identical predictions, but would change the interpretation of the coefficients.

Differences among Sites in the Pre-Intervention Period. The constant term (1) defines the intercept for this equation and can be interpreted as the mean daily runoff in Site 1001—about 0.898 hundredths of an inch per permeable acre. The following two variables (2) and (3), the indicators for Sites 1004 and 1005 in the pre-period, suggest that estimated difference in mean runoff is not statistically distinguishable from zero; The standard errors of the estimated coefficients are larger than the estimated coefficients. The estimated pre-period site mean runoff for these sites can also be inferred from these coefficients: $m_{4,\mathrm{Pre}} \equiv m_1 + d_{4,\mathrm{Pre}} \approx 0.89 + 0.14 = 1.03$ hundredths of an inch and $m_{5,\mathrm{Pre}} \equiv m_1 + d_{5,\mathrm{Pre}} \approx 0.89 - 0.09 = 0.80$.

Change in Runoff in the Post-Intervention Period: The formal test for the change in runoff in the post-intervention period (June 2001-June 2002) can be found in the following three site-specific terms: variables 4, 5 and 6 as shown in Table 3. The estimated change in dry day runoff for Site 1001 (4), is -0.44 hundredths of an inch. In relative terms, this works out to approximately a 49 percent reduction. The implied mean post-intervention dry day runoff for Site 1001, is 0.89-0.44˜0.45 hundredths of an inch. This reduction in runoff is statistically distinguishable from zero at classical levels of confidence.

The reader should be careful in interpreting this result as the pre- and post- periods are not comparable. The post-intervention period, June 2001 to June 2002, includes 13

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months but would be fairly close to an annual average. The period of time covered by the pre-intervention period for all sites, February to May 2001, includes at most 4 months. For Site 1001, the pre-intervention period only includes the months of April and May in 2001, because the flow meter produced enough invalid reads in February and March to necessitate its relocation to a new site in April. Since these are not the highest months for urban runoff, it would be reasonable to expect runoff in the post-intervention period to increase. For this reason, the reduction of 49 percent from the pre-intervention period would be a lower bound on the true estimate of runoff reduction. We can examine the other two valid sites for insight into how much runoff would have increased in the post-intervention period.

The estimated change in dry day runoff for Site 1004 (5), is +0.88 hundredths of an inch. This increase in runoff is statistically distinguishable from zero at classical levels of confidence. The implied mean post-intervention dry day runoff for Site 1004, is (0.89+0.88˜) 1.77 hundredths of an inch. In relative terms, this works out to a fairly large (1-{1.77-1.03}/1.03=) 72 percent increase in the post-intervention period.

The estimated change in dry day runoff for Site 1005 (6), is +0.20 hundredths of an inch. This increase in runoff is statistically distinguishable from zero at close to classical levels of confidence. The implied mean post-intervention dry day runoff for Site 1005, is (0.89+0.20˜) 1.09 hundredths of an inch. In relative terms, this works out to a more modest (1-{1.09-0.80}/0.80=) 36 percent increase in the post-intervention period.

Comparing Post-Intervention Change in Runoff across Sites. The last and potentially most vulnerable inference compares the time change in runoff across sites. If Site 1001 had experienced the same change in runoff as its neighbor sites 1005 or 1004, then dry day runoff would have increased from 36 to 72 percent in the post-intervention period. In absolute terms, this would imply a prediction of non-intervention runoff of 1.24 to 1.53 inches per acre. Compared to the realized 0.45 inches of runoff in the post-intervention period, this reduction would translate to 64 to 71 percent reduction in runoff.

A similar counterfactual exercise for Site 1005, would require assuming that Site 1004 is a good matched control site. Then dry weather runoff in Site 1005 would have increased by 72 percent in the post-intervention period, a level of 1.38 inches per acre. Compared to the realized 01.09 inches of runoff in the post-intervention period, the reduction would translate into a modest but non-ignorable 21 percent decrease in runoff.

Both of these exercises require use of Site 1004 as a control site. While the unadjusted flow measures for Sites 1001 and 1005 are fairly close in the pre-intervention period, the same cannot be said for the flow measures from Site 1004. Perhaps the question would be best put, "Given the three estimates of reduction runoff for Site 1001, which should be used?" The direct within-site estimate of a 49 percent runoff reduction is likely biased low; runoff in the post-intervention period should have increased. The estimate of 64 percent, based on Site 1005 as a control site, may also be biased on the low side. Though Site 1005 did have pre-intervention runoff that reasonably matched Site 1001, Site 1005 also contained more than 200 homes who participated in the education-only intervention

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with monthly follow-up. These homes did have quantified water savings, some of which is likely to have resulted from reduced runoff. Site 1004 did not receive any treatment but did have measurement issues. Thus the estimate of a 71 percent reduction, using Site 1004 as a control site, has an unknown bias.

The bigger inferential uncertainties lie in how these conservation interventions will work as they are scaled in a larger program or in how other implementations of these programs would work in other areas.

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Caveats and Additional Work

- The difficulties encountered in calibrating custom configured equipment to measure runoff limited the amount of pre-intervention data. This in turn precluded simple before and after comparisons of mean runoff flow. Nonetheless, a sufficient length of baseline data was collected to allow quantitative estimates of runoff reduction. If additional flow data can be collected, additional analysis would be possible: (1) the runoff reduction under wet conditions could be examined and (2) an estimate of the seasonal shape of runoff could be included in the models to improve the precision of the estimated runoff reduction.

- Because the runoff measurement is not at a customer level, we cannot distinguish the relative contribution of different customers to urban runoff reduction. Thus, for Site 1001, we cannot state how much the single family ET controller/education contributed relative to the ET controller intervention with landscape customers.

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Appendix D2: Residential Runoff Reduction Study Update – 2003 Runoff Data

The Residential Runoff Reduction Study

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Memorandum

To: Dick Diamond, IRWD

From: Thomas W. Chesnutt, Ph.D.

Date: August 31, 2004

Re: Residential Runoff Reduction Study Update – 2003 Runoff Data

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Finding

The 2003 measures of runoff from the Residential Runoff Reduction Sites 1001, 1004, 1005 support the findings of the earlier data: Site 1001 has a consistently lower mean level of urban runoff *and* a smaller variation in runoff.

Approach

A & N Technical Services performed data manipulation, collation, and validation on 2003 flow data collected in the R3 Study. The raw flow measures were provided in spreadsheet form. First, the spreadsheets of flow data from three study sites were incorporated into database form. This entailed the writing of a program for each site to convert the spreadsheets that also accounted for variations of form. Second, we performed validation checks on the estimated flow rates to check for consistency problems. Where correctable, revisions will be performed to the flow estimates. Last, these raw data exhibit an inconsistent time step, varying from 5-30 minutes. The raw data for each site was converted into their consistent daily basis—mean flow and total daily volume. The consistent time series version of flow data in the three study sites was then combined into a single consistent database with a consistent time series across sites. A consistent time-step, in term, allows valid comparisons across sites.

An attached spreadsheet contains the raw estimated daily runoff data–mean daily flow, total daily volume, and an indicator measure of data quality. As was experienced with the earlier data, there were considerable measurement issues that the IRWD team had to overcome to obtain consistent measures of flow. The project team coded a data quality indicator ("rank") for each subcomponent of the flow measure—instantaneous velocity and flow height. A combined indicator was also developed. The data quality indictor was set to 2 for measures that were known to be bad (rank=2). The data quality indictor was set to 1 for measures of questionable data quality (rank=1). Thus, the data quality indicator rank would take on the value 222 if all three measures (velocity, height, and estimated flow) were known to be bad and would take on the value 111 if all three were of questionable data quality. A value of zero was assigned to measures having no known or suspected data quality issues.

The data are summarized in two ways. First, the descriptive statistics of the mean daily flow volume (adjusted by site area) at each of the three sites in this post-installation period are examined. The

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estimated mean daily runoff flow is expressed in inches per acre. Second, a graph of 2003 runoff data is developed for each site that displays the raw data and a lowess-smoothed line of central tendency. (Lowess smoothers are a robust data analytic technique that can convey a sense of the level of runoff.)

Table 1 provides the descriptive statistics of mean dry day runoff height at the three sites. (Note that the number of observations per site are reduced due to the exclusion of flow measures on wet days and exclusion of flow measures due to data quality concerns.) The 2003 flow data were also graphed for the three sites. These figures follow. Site 1001 that received the ET controller and education intervention consistently displays both lower levels of runoff and lower variability in runoff. Site 1004 displays very large variability in runoff; this level of variability is the norm rather than the exception. The months of May and June in 2003 did experience wetter than normal (May) and cooler than normal (June) weather patterns.

Table 1: Estimated Mean Dry Day Runoff Height

January 2003 – August 2003

(in inches per unit area)

(Height=Runoff Volume/Site Permeable Area)

Site	Obs	Mean	Std. Dev.	Min	Max
Site 1001 (ET controllers +ed.) Runoff Height	136	1.03	0.72	0	3.90
Site 1005 (Education only) Runoff Height	160	1.79	2.75	0	27.29
Site 1004 ("Control") Runoff Height	136	2.29	2.83	0	14.25

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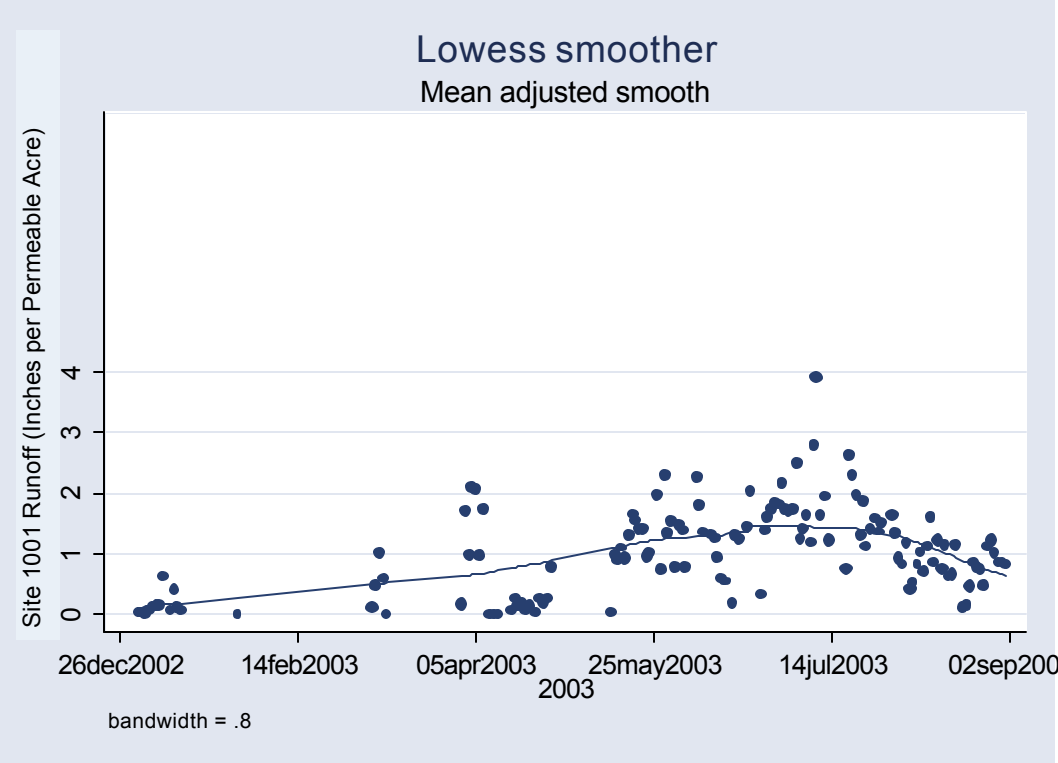

Figure 1: Site 1001 ET Control and Education Intervention

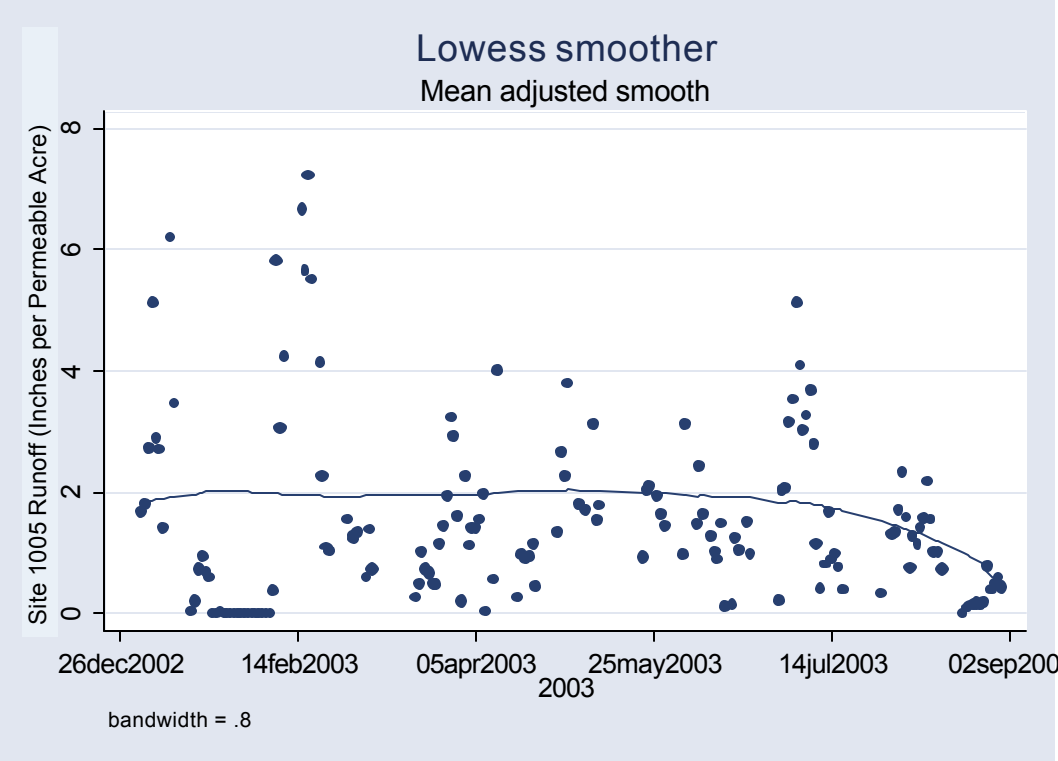

Figure 2: Site 1005 Education Only Site

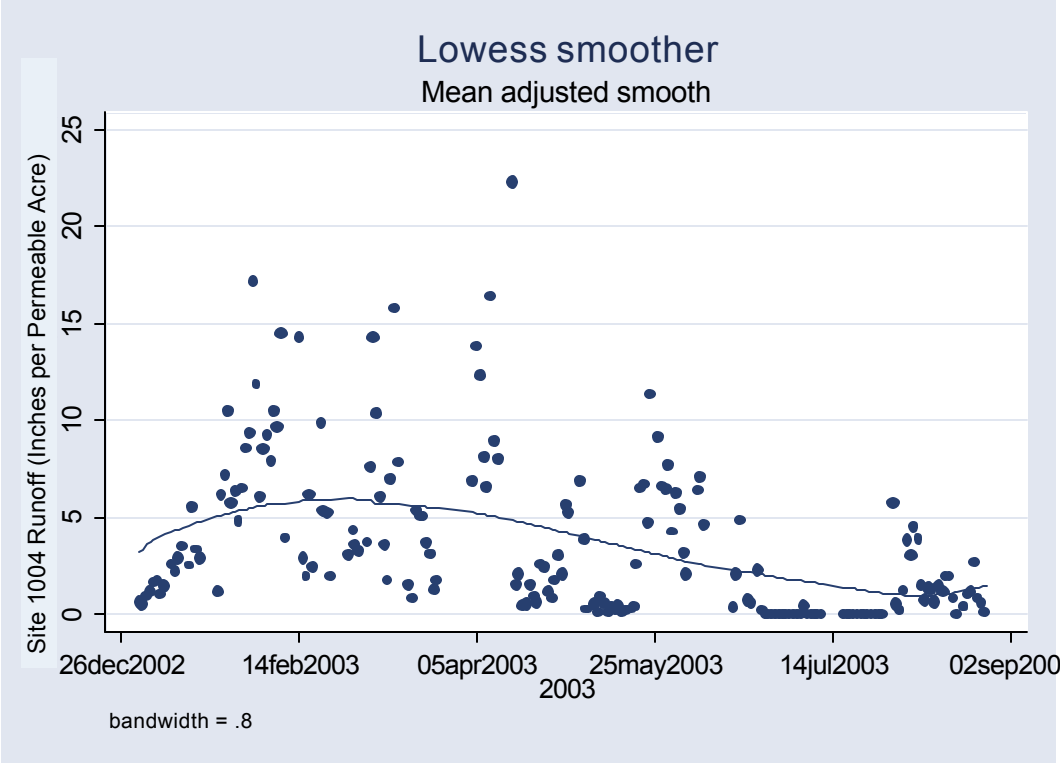

Figure 3: Site 1004 "Control" site

Appendix E1: The Effect of Technology and Public Education on the Water Quality of Dry Weather Runoff from Residential Neighborhoods

The Residential Runoff Reduction Study

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Appendix E1

The Effect of Technology and Public Education on the Water Quality of Dry Weather Runoff from Residential Neighborhoods

Prepared by Kenneth C. Schiff,
Southern California Coastal Water Research Project

May 2003

ABSTRACT

Urban runoff is one of the largest contributors of pollutants to impaired surface waters in the United States, however little is known about effectiveness of potential best management actions (BMPs) to improve water quality. The goal of this study was to quantify the effectiveness of a technological BMP compared to public education as a BMP. The technological BMP consisted of a new evapotranspiration (ET) sprinkler controller that automatically changes sprinkler timing based on weather conditions using remotely controlled radio signals at a nearby weather station. Water quality (nutrients, trace metals, bacteria, pesticides, toxicity) was measured every two weeks for six months at five similar residential neighborhoods, then the technology plus education or education only treatments were applied to one neighborhood each, and measurements continued for another year. At the end of one year post intervention, there was virtually no difference in concentrations or pollutant flux over time. The technological and education treatments provided essentially no detectable increase or decrease in water quality following the intervention. The lack of detectable differences in water quality was a result of a combination of factors including large variability among measurements within a neighborhood and insufficient sample sizes to detect small changes in concentration or pollutant flux.

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INTRODUCTION

Urban runoff has been identified as a major contributor to water quality problems throughout the United States (EPA 2000). Runoff from urban areas contains numerous potential pollutants including nutrients, trace metals, pesticides, and/or bacteria (US EPA 1987, Wong et al 1997, Smullen et al 1999, Ackerman and Schiff in press). These discharges have resulted in water quality impairments such as excessive blooms of algae (Bricker et al 1999), toxicity to aquatic organisms (deVlaming et al 2000, Bay et al 1996, closures of recreational shoreline for protection of human health (Noble et al 2000).

As managers become aware of the environmental concerns resulting from discharges of urban runoff, they are seeking methods and technologies for reducing or eliminating these discharges. Best management practices (BMPs) come in a variety of forms, including structural and non-structural control measures. Structural BMPs typically include technologically driven management actions that either reduce or eliminate runoff volume and/or attempt treatment of runoff prior to discharge. Non-structural BMPs typically are aimed at changing peoples attitudes or behavior that reduce the use of potential pollutants or limit their entry into the storm drainage systems. The most commonly cited form of non-structural BMPs is public education, which often consists of advertising campaigns, mailers, and other widely distributed educational materials.

The problem with both structural and nonstructural BMPs is that the efficiency and effectiveness of these BMPs are largely unknown. There is no uniform manner or standard method for independently testing these BMPs. Manufacturer information is occasionally available for some structural BMPs, but these data are looked upon suspiciously by most urban runoff managers as a result of their potential conflict of interest. Nonstructural BMPs, such as public education, are almost entirely without rigorous evaluation of their effectiveness. Hence, managers struggle with which BMPs to select, and in which environmental application, to achieve the greatest reduction in pollutant concentrations or mass emissions. At the same time, regulatory mechanisms like National Pollutant Discharge Elimination System (NPDES) Permits for municipal

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separate storm sewer systems or total maximum daily loads (TMDLs) continue to push the regulatory obligation of urban runoff managers to reduce concentrations and mass emissions of many potential pollutants.

The goal of this study is to compare the effectiveness of technological BMPs versus public education for reducing concentrations or mass emissions of potential pollutants in dry weather discharges. The technological BMP consisted of evapotranspiration (ET) controllers that communicate with landscape irrigation systems of individual households. This technology is designed to optimize watering times for landscaped areas, hence reducing overwatering and resultant runoff. The public education campaign focused on not just appropriate watering times, but also minimization of pesticide, herbicide, and fertilizer usage. These two types of BMPs were tested in residential neighborhoods, typically the most common land use in urban watersheds (Wong et al. 1997). Our goal was to determine if technology or education provides more pollutant reduction so that urban runoff managers can select optimal runoff pollutant minimization strategies.

METHODS

We used a before-after, control-impact (BACI) design for evaluating the effectiveness of both the sprinkler technology and public education. Each neighborhood was sampled every other week between December 2000 and June 2001. In June 2001, homes in one of the neighborhoods were outfitted with the ET sprinkler controllers. Since homeowners with the retrofitted sprinkler controllers were simultaneously being educated, a well-defined public education campaign was also begun with these homeowners. To ascertain the difference between education and ET sprinkler technology, homeowners in a second neighborhood were targeted with an identical public education campaign, but without effect of the ET sprinkler retrofit technology. There was no education or technology intervention in the remaining three neighborhoods, which served as control neighborhoods to document the effect of no treatment. Sampling at the five neighborhoods continued every other week from June 2001 to June 2002.

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ET Sprinkler Controller and Public Education

The ET controller is described in detail elsewhere (*see Chapter 2 – Study Methods*). It is similar to any automatic sprinkler timer available at most home improvement stores and nurseries, but with the capacity to receive radio signals that will alter sprinkler timing based on current weather conditions. If weather is hot and dry, the radio signals call for longer or more frequent irrigation. If the weather is cool and moist, such as recent precipitation, the radio signals call for shorter or less frequent irrigation. For this study, the existing sprinkler timers that are set manually by the homeowner were replaced with the radio controlled ET controller systems. Trained technicians were used to ensure successful installation; ET controller requires programming for each valve including area (size of yard or planter per valve), soil type (clay, sand, etc.), and landscape type (turfgrass, shrubbery, etc.). The remaining irrigation system was unchanged, including piping and sprinkler head configuration.

Public education consisted of an initial informational packet containing three items. The first item was an introductory letter that described the purpose of the packet. The second item was a booklet with irrigation, fertilization and weed and pest control information. The centerfold of the booklet was a month-by-month guide to irrigating, fertilizing and pesticide application suitable for posting near their sprinkler timer. Third, each homeowner was supplied a soil probe for measuring the water content of their landscaped soils. In addition to the initial packet, monthly reminders were mailed to each homeowner including landscape maintenance tips such as irrigation system, water schedule, fertilizing, and weed and insect control. Suggested sprinkler run times (for the non-ET sprinkler neighborhood) and fertilizer or pesticide application usage, including non-toxic alternatives, were also provided in the monthly newsletter.

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Treatment Neighborhoods

The five neighborhoods were located within a three mile radius in Irvine, CA. The selection criteria for the neighborhoods included similarity in: 1) age of neighborhood (approximately 20 years old); 2) primary land use (single family residential); 3) irrigation management factors (precipitation rate, soil type, plant type, slope and sun exposure); 4) proximity to radio signal for ET controller (all neighborhoods used the same signal). The five neighborhoods were designated 1001 (sprinkler retrofit + education), 1002 (control), 1003 (control), 1004 (control), and 1005 (education only). Although each of the five neighborhoods met the selection criteria, there were some differences worth noting (Table WQ1). First, the two treatment neighborhoods were larger, up to twice as large as the control neighborhoods. Second, the two treatment neighborhoods were more impervious, up to two twice as much impervious area, as the control neighborhoods. Third, the two treatment neighborhoods had greater proportions of landscaped common areas than any of the control neighborhoods.

The treatments were not uniformly applied to all homeowners in either the 1001 or 1005 neighborhoods. In the case of sprinkler + retrofit neighborhood (1001), roughly one third of the pervious area actually retrofit their sprinkler systems. These homeowners, condominium complexes, school and city landscaped areas were recruited by trained personnel. In order to keep the relative percentages approximately the same between treatment neighborhoods, homeowners representing roughly 30% of the pervious area were selected to receive the education materials in the education only neighborhood (1005). These homeowners were selected at random.

Sampling and Laboratory Analysis

Each of the five neighborhoods were hydrologically self-contained and drained to a single underground pipe unique to each neighborhood. At each of these five locations, samples were collected for flow and water quality. Stage (water depth) and velocity were recorded at 5 min intervals using an ultrasonic height sensor mounted at the pipe invert and a velocity sensor mounted on the floor of the pipe. Flow was calculated as the

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product of velocity and wetted cross-sectional area as defined by the stage and pipe circumference. Despite the relatively continuous measurement of flow, many of the flow measurements were excluded due to faulty readings. Synoptic flow and water quality measurements were only available for two sites over the course of the entire study (i.e. before and after intervention), including the sprinkler + education and education only sites. Flow measurements at the time of water quality sampling for the three control sites were considered faulty and discarded.

Grab samples for water quality, collected just downstream of the flow sensors in the early morning, were collected using peristaltic pumps and pre-cleaned Teflon tubing. Samples were placed in individual pre-cleaned jars, placed on ice, and transported to the laboratory within one hour. Each sample was analyzed for 19 target analytes, five microbiological parameters, and four toxicity endpoints (Table WQ2). Target analytes included trace metals, nutrients, and organophosphorus (OP) pesticides. Microbiological parameters included fecal indicator bacteria and bacteriophage. Toxicity was evaluated using two marine species, the purple sea urchin *Strongylocentrotus purpuratus* and the mysid *Americamysis bahia*. Toxicity endpoints included the median effects concentration that estimates the concentration at which 50% of the sample population is affected (EC50) and the no effect concentration that estimates the highest concentration at which no effect is observed (NOEC). All of the laboratory methodologies followed standard protocols developed by the US EPA (1995, 1993, 1983) or Standard Methods (APHA 2001).

Data Analysis

Data analysis consisted of five steps. These steps included: 1) comparison of water quality among the five neighborhoods prior to intervention; 2) comparison of water quality concentrations over time by neighborhood; 3) comparison of water quality concentrations before and after intervention by treatment type; 4) comparison of pollutant flux before and after intervention by treatment type; and 5) correlation of toxicity measures with potential toxicants in dry weather runoff.

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Comparison of water quality concentrations among the five neighborhoods prior to intervention was conducted to assess if there were inherent differences among treatment sites for each constituent. This analysis was conducted using an analysis of variance (ANOVA) using Tukey's post hoc test for identifying the significantly different neighborhoods. All data were tested for normality and homogeneous variance prior to testing. Only the microbiological data were determined to be non-normally distributed, so these results were log transformed prior to data analysis

Comparison of water quality concentrations over time was accomplished by creating temporal plots of monthly mean concentration. Comparisons of water quality concentration before and after intervention by treatment type were accomplished using a standard t-test of the mean concentration before versus mean concentration after intervention. The mean concentrations for sprinkler+education, education only, and sprinkler+education – education only for each sampling event were normalized by the grand mean of the control sites for the same sampling event.

Pollutant flux estimates were calculated by the product of the concentration and volume at the time of sampling and then normalized to the area of the sampled neighborhood. Pollutant flux before and after treatment was compared somewhat differently since the lack of flow data at the control sites did not permit an estimate of flux for these neighborhoods. Mean pollutant flux before and after intervention was compared using standard t-tests at the sprinkler+education and education only neighborhoods without normalization to control values.

Correlation of toxicity with toxicant concentrations was accomplished using a Pearson product moment correlation. These correlations are inferential only and do not presume resulting correlations automatically identify the responsible toxicants. In order to help identify potential causative toxic agents, concentrations of the correlated constituents were compared to concentrations known to induce toxicity in the respective test organisms.

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RESULTS

There were significant differences in water quality among sites prior to intervention (Table WQ3). Site 1004, the control site, had the greatest mean concentrations for 15 of the 24 constituents evaluated prior to the sprinkler intervention. Mean concentrations for seven of the 15 constituents were significantly greater at site 1004 than mean concentrations at least one other site (ANOVA, $p<0.05$). In particular, all of the mean nutrient concentrations were greater at site 1004 than the other sites. Mean ammonia, nitrate/nitrite, and TKN were a factor of 13, 11, and 2.5-fold greater at site 1004 than the mean concentrations at the next greatest site, respectively. On the other hand, sites 1001 and 1002 generally had the lowest average concentrations prior to the sprinkler intervention. Cumulatively, these sites had the lowest mean concentrations for 17 of the 24 constituents evaluated. Site 1002 also had the least toxicity, on average, of all five sites. Finally, site 1003 had an intermediate status. Mean concentrations of enterococcus and fecal coliforms at this site were greater than any other site (fecal coliforms significantly greater than sites 1001 and 1002), but the mean concentrations of five trace metals (chromium, copper, cobalt, nickel, selenium) were lowest at this site.

Water quality concentrations and toxicity were highly variable over time during the study period (Figure WQ1). Temporal plots of concentrations and toxicity for each site demonstrated that there was no seasonal trend and no overall trend with time. There were, however, occasional spikes in concentrations for many constituents that appeared to fall into one of two categories. The first category was recurring spikes in concentration that were unpredictable in timing and location. For example, both fecal coliform and enterococcus consistently varied by more than an order of magnitude from month to month during the study period and there was no similarity in pattern between the sites. The second category of concentration spike was single or infrequent peaks. Occasionally these spikes would occur across multiple sites, such as the peak in both lead and zinc at all three control sites (1002, 1003, and 1004) in October 2001, without

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commensurate changes in concentration at the treatment sites (1001 or 1005). More often, infrequent spikes were isolated to a single site. For example, concentrations of chlorpyrifos climbed to over 10,000 ng/L in July 2001, but averaged near 50 ng/L the remainder of the year at site 1005. Similarly, concentrations of ammonia and total phosphorus spiked 10 and 25-fold prior to June 2001 at the control site (1004) with less variability and overall lower concentrations the remainder of the study.

There were few significant differences that resulted from the intervention of education, sprinkler retrofit and education, or sprinkler retrofit minus education, relative to control sites (Table WQ4). Only six of the 24 constituents evaluated showed a significant difference between pre and post-intervention concentrations after normalizing to mean control values. These significant differences were a net increase in concentrations of ammonia, nitrate/nitrite, total phosphorus, chlorpyrifos, diazinon, and fecal coliforms. These statistical analyses were the result of one of two circumstances. In the first circumstance, there were individual large spikes in concentration at treatment sites, but not at control sites following intervention (i.e. chlorpyrifos and diazinon at sites 1001 and 1005). Therefore, the net difference in concentrations between controls and treatments increased following the intervention. In these cases, removal of the outlier samples resulted in no significant difference among treatment effects relative to controls before intervention compared to after intervention. In the second circumstance, there were large spikes in concentrations at control site(s) prior to the intervention (i.e. ammonia, nitrate/nitrite, and total phosphorus at site 1004) that later subsided while treatment site concentrations and variability remained steady. Therefore, the difference between treatments and controls changed following interventions, although it was not a result of the education or technology.

Although there were no significant differences in pollutant flux as a result of the intervention, there were significant differences in pollutant flux among sites prior to intervention (Table W5). Mean flux did not change at either site from before to after the installation of technology or initiation of education. Site 1001 however, the sprinkler+education site, had the greatest mean flux for 22 of the 24 constituents

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evaluated prior to the sprinkler intervention. The mean flux for 20 of these 22 constituents was significantly greater at site 1001 than the mean flux at site 1005 (t-test, $p<0.05$). Site 1005 had greater mean fluxes only for MS2 phage and ammonia. The differences among the fluxes prior to (and after) intervention was the result of two factors; greater flow and, at times, greater concentrations at site 1001 compared to site 1005. Mean dry weather flow at the time of water quality sampling was nearly three times greater at site 1001 than 1005.

Toxicity was inconsistently found at all five of the sampling sites (Table WQ3, Figure WQ4) and there was no change in toxicity as a result of the intervention (Table WQ4). The two species tested did not respond similarly either among sites, among treatments, or over time. Correlation of toxicity with constituent concentrations yielded few significant relationships for either species (Table WQ6). Mysid toxicity was correlated with diazinon and several trace metals, but the strongest relationship was with diazinon concentration. Moreover, the concentrations of diazinon were well above the levels known to cause adverse effects in this species while trace metals were not (Table WQ7). Sea urchin fertilization toxicity was only correlated with concentrations of zinc. The concentrations of zinc were well above the level known to induce adverse effects in this species (Table WQ7).

DISCUSSION

This study was unable to find large, significant reductions in concentration or pollutant flux as a result of education and/or sprinkler retrofit technology. This may indicate that the technology and/or education are inefficient for improvements in water quality. Equally as important, however, was the absence of meaningful increases in concentrations. Of the small number of concentrations that showed significant increases, most could be explained by highly variable spikes in concentrations reminiscent of

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isolated entries to the storm drain system as opposed to ongoing chronic inputs or the effects of best management practices evaluated in this study.

If significant changes did occur, our study design may not have detected these changes due to two factors. First, the variability in concentrations within and between sites are naturally high and our study simply collected too few samples. After taking into account the variability and relative differences in mean concentrations, we used zinc as an example constituent to determine what sample sizes would be required to detect meaningful differences. Assuming that our sampling yielded the true mean and variance structure that actually existed at the five sites, power analysis indicated that a minimum sample size of no less than five-fold would have been required to detect the differences we observed in zinc concentrations during this study.

The second factor that could have hindered our ability to detect meaningful differences in water quality is that the technology and education treatments were applied at the spatial scale of individual homes, while our study design sampled at the neighborhood scale. This problem was exacerbated in this study because only a fraction (approximately one-third) of the homes within the neighborhoods we sampled had the technological or educational treatments. Therefore, the treatments were effectively diluted, decreasing our ability to detect differences in water quality.

It appears that residential dry weather flows measured in our study may contribute significant proportions of some constituents to overall watershed discharges. Our study sites were located within the San Diego Creek watershed, the largest tributary to Newport Bay. San Diego Creek is routinely monitored to provide environmental managers the information they need to properly manage the Bay (OCPFRD 2002). We compiled the dry weather monitoring data at the mouth of San Diego Creek from OCPFRD during 2001-2002 and compared the concentrations to our results from residential neighborhoods (Table wq5). Mean concentrations of chlorpyrifos, diazinon, copper and zinc were much higher in upstream residential neighborhoods, than concentrations measured at the mouth of San Diego Creek. These residential dry weather contributions

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are amplified by the fact that the San Diego Creek watershed is primarily composed of residential land uses. In contrast, concentrations of selenium, arsenic, and total phosphorus in the residential dry weather discharges were much lower than the cumulative dry weather discharges from San Diego Creek, indicating that residential areas may not be the primary source of these constituents.

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Table WQ1. Characteristics of the five treatment[a] study neighborhoods.

	Neighborhood				
	1001	1002	1003	1004	1005
Total Area (ft^2)	5,174,861	2,145,864	2,426,731	3,868,375	6,176,782
Impervious Area (%)	64.3	30.3	33.6	54.8	82.2
Land Use (%)					
Single Family Res	34.4	52.8	65.4	53.8	47.9
Condo	7.7	2.2	0.0	0.0	1.1
Homeowners Assoc	1.6	8.1	0.0	1.0	4.3
School	3.8	0.0	0.0	9.0	4.2
Landscape	16.3	0.1	6.6	0.0	12.5
Street	29.2	30.4	28.1	28.2	28.1
Unknown	7.0	6.5	0.0	8.0	1.9

[a] 1002, 1003, 1004=control, 1005=education, 1001=education + sprinkler retrofit

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Table WQ2. Reporting level and method for target analytes.

	Reporting Level	Method
Metals (ug/L)		
Antimony	0.2	EPA 200.8
Arsenic	1.5	EPA 200.8
Barium	0.2	EPA 200.8
Cadmium	0.2	EPA 200.8
Chromium	0.3	EPA 200.8
Cobalt	0.1	EPA 200.8
Copper	1.5	EPA 200.8
Lead	0.3	EPA 200.8
Nickel	0.2	EPA 200.8
Selenium	5.0	EPA 200.8
Silver	0.4	EPA 200.8
Zinc	5.0	EPA 200.8
Microbiology		
Enterococcus (MPN/100 mL)	2	SM9230B
Fecal Coliform (MPN/100 mL)	2	SM9221B
Total Coliform (MPN/100 mL)	2	SM9221B
MS2 Phage (PFU/100 mL)	2	EPA 1602
Somatic Phage (PFU/100 mL)	2	EPA 1602
Nutrients (mg/L)		
Ammonia as N	5.0	EPA 350.1
Nitrate/Nitrite as N	5.0	EPA 353.2
Total Kjeldahl Nitrogen	10.0	EPA 351.2
Ortho-Phosphate as P	0.5	EPA 365.1
Total Phosphorus	1.0	EPA 365.4
OP Pesticides (ng/L)		
Chlorpyrifos	20.0	IonTrap GCMS
Diazinon	20.0	IonTrap GCMS
Toxicity (% effluent)		
Sea Urchin Fertilization EC50	NA	EPA 1995
Sea Urchin Fertilization NOEC	NA	EPA 1995
Mysid EC50	NA	EPA 1993
Mysid NOEC	NA	EPA 1993

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Table WQ3. Mean concentration (and 95% confidence interval) of constituents in dry weather discharges collected before and after intervention[a] at five residential neighborhoods in Orange County, CA.

Parameter	Site 1001				Site 1002				Site 1003				Site 1004				Site 1005			
	Pre-Intervention		Post-Intervention		Pre-Intervention		Post-Intervention		Pre-Intervention		Post-Intervention		Pre-Intervention		Post-Inter vention		Pre-Intervention		Post-Intervention	
	Mean	95% CI	Mean	95% CI	Mean	95% CI	Mean	95% CI	Mean	95% CI	Mean	95% CI	Mean	95% CI	Mean	95% CI	Mean	95% CI	Mean	95% CI
Metals (ug/L)																				
Antimony	3.28	0.52	3.09	0.51	2.90	0.29	3.49	0.73	3.33	0.60	3.71	0.72	2.98	0.33	3.46	0.51	2.66	0.30	3.11	0.58
Arsenic	2.19	0.64	2.61	0.95	1.99	0.41	2.87	1.25	1.58	0.35	2.38	0.94	4.06	0.85	3.07	0.95	2.44	0.60	3.02	0.97
Barium	80.91	11.61	93.04	10.97	87.39	9.00	105.12	23.99	88.34	6.09	80.12	11.72	79.22	21.23	82.01	13.16	94.36	13.93	104.55	17.74
Cadmium	0.26	0.09	0.15	0.07	0.26	0.11	0.42	0.38	0.25	0.12	0.23	0.18	0.37	0.14	0.21	0.12	0.28	0.12	0.28	0.18
Chromium	2.49	0.98	1.97	0.59	3.74	1.53	4.72	3.35	1.96	0.41	2.70	1.25	3.31	1.41	2.44	0.82	4.01	2.79	3.89	2.01
Cobalt	0.43	0.11	0.50	0.21	0.65	0.28	1.19	0.81	0.40	0.11	0.53	0.26	0.97	0.49	0.73	0.25	0.64	0.19	1.08	0.54
Copper	13.91	4.31	16.14	7.27	31.50	30.24	27.12	17.30	11.82	2.57	24.30	15.41	24.02	12.64	16.81	6.71	33.98	39.62	29.67	14.38
Lead	0.57	0.18	1.63	1.15	6.95	9.32	4.23	2.90	0.88	0.40	1.45	0.88	4.09	4.84	1.34	0.69	0.79	0.23	3.09	1.98
Nickel	9.28	0.91	9.32	1.87	9.40	1.58	10.94	4.14	7.76	0.72	7.87	2.06	11.18	1.94	9.11	1.60	9.97	1.46	10.23	2.33
Selenium	2.43	0.13	2.50	0.00	2.43	0.13	2.50	0.00	2.30	0.26	2.50	0.00	2.43	0.13	2.50	0.00	2.30	0.26	2.50	0.00
Silver	0.13	0.05	0.14	0.07	0.11	0.02	0.18	0.10	0.17	0.09	0.17	0.15	0.12	0.03	0.16	0.17	0.16	0.09	0.17	0.15
Zinc	58.75	7.13	40.57	10.49	130.25	115.77	65.28	29.77	59.33	14.92	53.58	16.10	93.40	50.30	40.80	12.22	73.08	31.52	75.74	35.18
Microbiology (Log)																				
Enterococcus (MPN/100 mL)	3.95	0.43	3.24	0.18	3.80	0.38	4.16	0.35	4.36	0.68	4.22	0.24	4.49	0.61	4.35	0.25	4.34	0.31	4.37	0.29
Fecal Coliform (MPN/100 mL)	3.45	0.31	2.94	0.27	3.15	0.37	3.50	0.45	4.13	0.33	3.67	0.32	4.08	0.35	3.84	0.32	3.88	0.33	3.67	0.23
Total Coliform (MPN/100 mL)	4.16	0.27	3.82	0.24	4.30	0.30	4.51	0.46	4.70	0.33	4.36	0.26	5.04	0.39	4.50	0.27	4.53	0.34	4.51	0.24
MS2 Phage (PFU/100 mL)	-0.30	0.00	0.02	0.55	-0.30	0.00	-0.09	0.52	-0.19	0.14	0.02	0.53	0.30	0.44	0.05	0.52	0.05	0.43	0.33	0.54
Somatic Phage (PFU/100 mL)	2.00	0.35	2.02	0.49	1.84	0.42	1.81	0.69	2.59	0.40	2.24	0.62	2.88	0.32	2.52	0.54	2.16	0.46	2.37	0.47
Nutrients (mg/L)																				
Ammonia as N	0.17	0.15	0.08	0.03	0.17	0.07	0.39	0.51	0.23	0.11	0.28	0.23	7.32	4.93	0.31	0.26	0.65	0.32	0.42	0.24
Nitrate/Nitrite as N	2.72	0.50	1.48	0.28	3.00	1.14	1.00	0.33	2.35	0.96	1.63	0.78	38.71	18.21	9.29	6.58	2.94	0.61	3.70	4.48
Total Kjeldahl Nitrogen	1.62	0.51	1.87	1.20	1.75	0.62	2.38	0.92	1.96	1.33	2.61	1.75	11.18	5.71	3.60	2.03	4.49	2.64	3.51	1.65
Ortho-Phosphate as P	0.65	0.15	0.64	0.12	0.80	0.25	0.73	0.14	0.79	0.39	1.21	0.75	2.93	0.90	1.55	0.57	0.87	0.25	1.00	0.22
Total Phosphorus	0.79	0.21	0.63	0.16	0.78	0.25	0.82	0.23	1.22	0.83	1.19	1.07	3.30	1.37	1.46	0.73	0.96	0.39	1.16	0.40
OP Pesticides (ng/L)																				
Chlorpyrifos	22.66	9.27	442.78	827.29									45.54	33.48	11.34	6.31	75.27	64.41	803.44	1433.34
Diazinon	1680.45	1379.39	829.56	338.72									3265.38	3277.20	1650.50	1540.87	1159.12	553.01	1738.58	721.44
Toxicity (% effluent)																				
Fertilization EC50	47.26	8.89	53.73	6.17	57.37	3.48	51.94	9.85	41.60	8.94	49.58	10.17	49.79	8.96	55.91	6.48	43.81	9.26	58.35	2.98
Fertilization NOEC	25.36	8.61	44.62	10.32	35.00	8.54	46.23	11.11	32.07	13.27	37.69	11.15	32.50	9.66	51.92	7.67	22.00	9.31	42.88	9.76
Mysid EC50	46.76	25.04	60.00	0.00	56.32	10.22	39.04	35.71	39.10	24.16	51.94	22.38	54.28	15.88	49.36	25.33	39.32	25.25	60.00	0.00
Mysid NOEC	90.71	17.23	104.00	9.49	82.14	18.13	95.00	16.20	95.71	12.20	77.50	17.53	64.29	16.73	68.50	22.30	53.86	14.81	83.00	17.96

[a] 1002, 1003, 1004=control, 1005=education, 1001=education + sprinkler retrofit

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Table WQ4. Significance of ANOVA results for the effect of sprinkler + education, education alone, and the difference between sprinkler + education and education alone relative to control concentrations. No data indicates $p > 0.05$

	Effect of Sprinkler + Education	Effect of Education Alone	Difference Between Sprinkler + Education and Education Alone
Metals			
Antimony			
Arsenic			
Barium			
Cadmium			
Chromium			
Cobalt			
Copper			
Lead			
Nickel			
Selenium			
Silver			
Zinc			
Microbiology			
Enterococcus			
Fecal Coliform	0.04		
Total Coliform			
MS2 Phage			
Somatic Phage			
Nutrients			
Ammonia as N	0.03	0.02	
Nitrate/Nitrite as N	0.02		
Total Kjeldahl Nitrogen			
Ortho-Phosphate as P			
Total Phosphorus		0.03	
OP Pesticides			
Chlorpyrifos	<0.01	<0.01	<0.01
Diazinon		<0.01	
Toxicity			
Fertilization EC50			
Fertilization NOEC			
Mysid EC50			
Mysid NOEC			

SARB_001782

Table WQ5. Mean flux (and 95% confidence interval) of constituents in dry weather discharges collected before and after intervention[a] at two residential neighborhoods in Orange County, CA.

Parameter	Site 1001				Site 1005			
	Pre-Intervention		Post-Intervention		Pre-Intervention		Post-Intervention	
	Mean Flux	95% CI	Mean Flux	95% CI	Mean Flux	95% CI	Mean Flux	95% CI
Metals (ug/hr/km^2)								
Antimony	1564	740	920	410	167	99	1756	1666
Arsenic	1476	1006	741	427	164	107	2610	2425
Barium	41644	18423	29241	11384	6537	4624	83266	71121
Beryllium	43	17	36	15	7	5	94	79
Cadmium	157	97	40	17	13	5	207	189
Chromium	880	474	562	264	155	86	3199	2810
Cobalt	273	166	131	57	41	21	958	854
Copper	4738	2383	3600	1587	2233	1178	13717	11137
Lead	1149	861	253	133	81	52	1475	1270
Nickel	4287	2096	2743	1249	636	465	7319	6221
Selenium	1075	420	910	367	177	132	2045	1894
Silver	58	19	49	35	13	8	64	73
Zinc	28968	13481	11264	9171	5589	3276	39966	39179
Microbiology (Log)								
Enterococcus (MPN/hr/km^2)	1771	768	1437	624	281	208	1822	1464
Fecal Coliform (MPN/hr/km^2))	1254	567	955	418	234	170	3393	3251
Total Coliform (MPN/hr/km^2)	1628	607	1264	489	284	193	3902	3687
Somatic Phage (PFU/hr/km^2)	976	480	650	282	57	32	748	550
Nutrients (mg/hr/km^2)								
Ammonia as N	584	324	339	260	1145	1236	2466	2475
Nitrate/Nitrite as N	12981	6366	4316	2174	1849	1706	12102	9812
Total Kjeldahl Nitrogen	8144	4881	3621	1893	3083	2614	18149	13628
Ortho-Phosphate as P	4822	2535	1516	679	504	279	6735	6634
Total Phosphorus	4875	2573	1645	657	477	308	7782	8007
Pesticides (ng/hr/km^2)								
Chlorpyrifos	8	8	7	4	3	5	26	20
Diazinon	467	606	234	185	56	36	822	579

[a] 1005=education, 1001=education + sprinkler retrofit

SARB_001783

Table WQ6. Correlation coefficients (and p value) of constituent concentrations with toxicity endpoints (No Observed Effect Concentration, NOEC and Median Effect Concentration, EC50) in dry weather discharges from residential neighborhoods in Orange County, CA. No data indicates $p > 0.05$

	Sea Urchin Fertilization NOEC	Mysid Survival NOEC	Sea Urchin Fertilization EC50	Mysid Survival EC50
Antimony		-0.273 (0.009)		
Arsenic		-0.3396 (0.001)		
Barium				
Cadmium				
Chromium		-0.244 (0.021)		-0.219 (0.044)
Cobalt		-0.330 (0.002)		-0.279 (0.010)
Copper				
Lead		-0.215 (0.042)		
Nickel				
Silver		-0.260 (0.013)		-0.229 (0.035)
Zinc	-0.277 (0.005)		-0.274 (0.006)	
Chlorpyrifos				
Diazinon		-0.426 (0.001)		-0.468 (0.001)
Ammonia				

SARB_001784

Table WQ7. Comparison of median effect concentrations for the mysid survival (*Americamysis bahia*) and sea urchin (*Strongylocentrotus purpuratus*) fertilization tests.

Constituent (µg/L)	Mysid Survival (EC50)	Sea Urchin Fertilization (EC50)
Antimony	>4150	-
Arsenic	1390-2725	-
Barium	>500,000	>1500
Cadmium	16.5-90.2	1,272
Chromium	1560-2450	-
Cobalt	-	-
Copper	267	30
Lead	3130	>4,000
Nickel	387-635	-
Silver	220-283	-
Zinc	400	29
Chlorpyrifos	0.04	-
Diazinon	4.5	>1,000
Ammonia	-	69

- indicates no data available

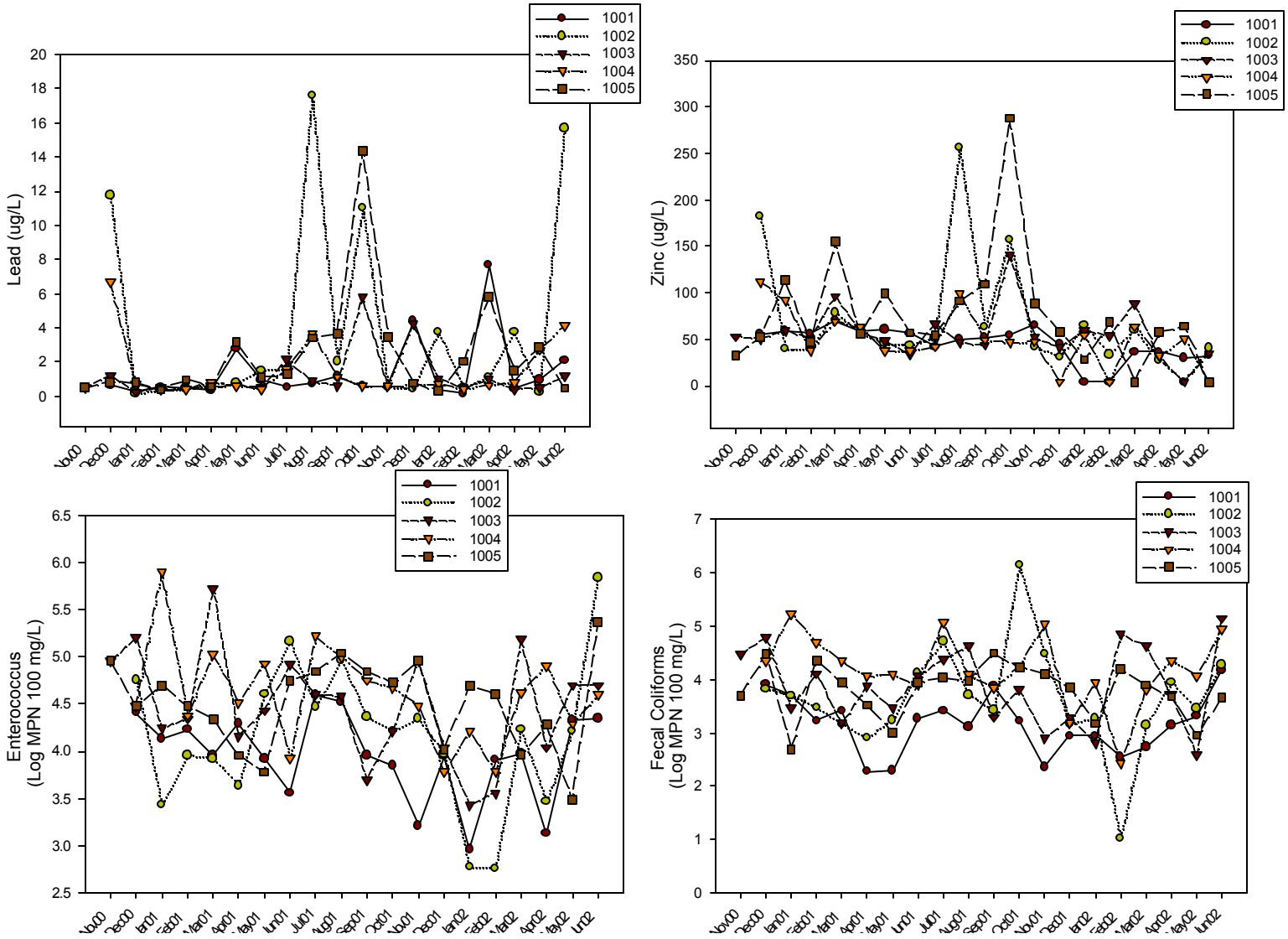
SARB_001785

Table WQ8. Comparison of mean concentrations (95% confidence intervals) in residential dry weather discharges from this study compared to concentrations in dry weather discharges from San Diego Creek at Campus during 2001-2002 (Data from OCPFRD).

	San Diego Creek	Residential
Parameter	Mean(95% CI)	Mean(95% CI)
Nitrate	5.16(0.72)	4.76(1.96)
Phosphate	1.98(0.07)	1.16(0.20)
Diazinon	0.13(0.07)	1.52(0.52)
Chlorpyrifos	0.05(0.01)	0.35(0.44)
Copper	11.59(2.83)	23.59(5.65)
Arsenic	6.58(0.40)	2.68(0.26)
Selenium	21.22(2.65)	2.46(0.03)
Zinc	22.08(2.75)	60.09(8.26)

SARB_001786

Figure WQ1. Monthly average concentrations in dry weather discharges from five residential neighborhoods in Orange ounty, CA.



SARB_001787

Figure WQ1 continued.

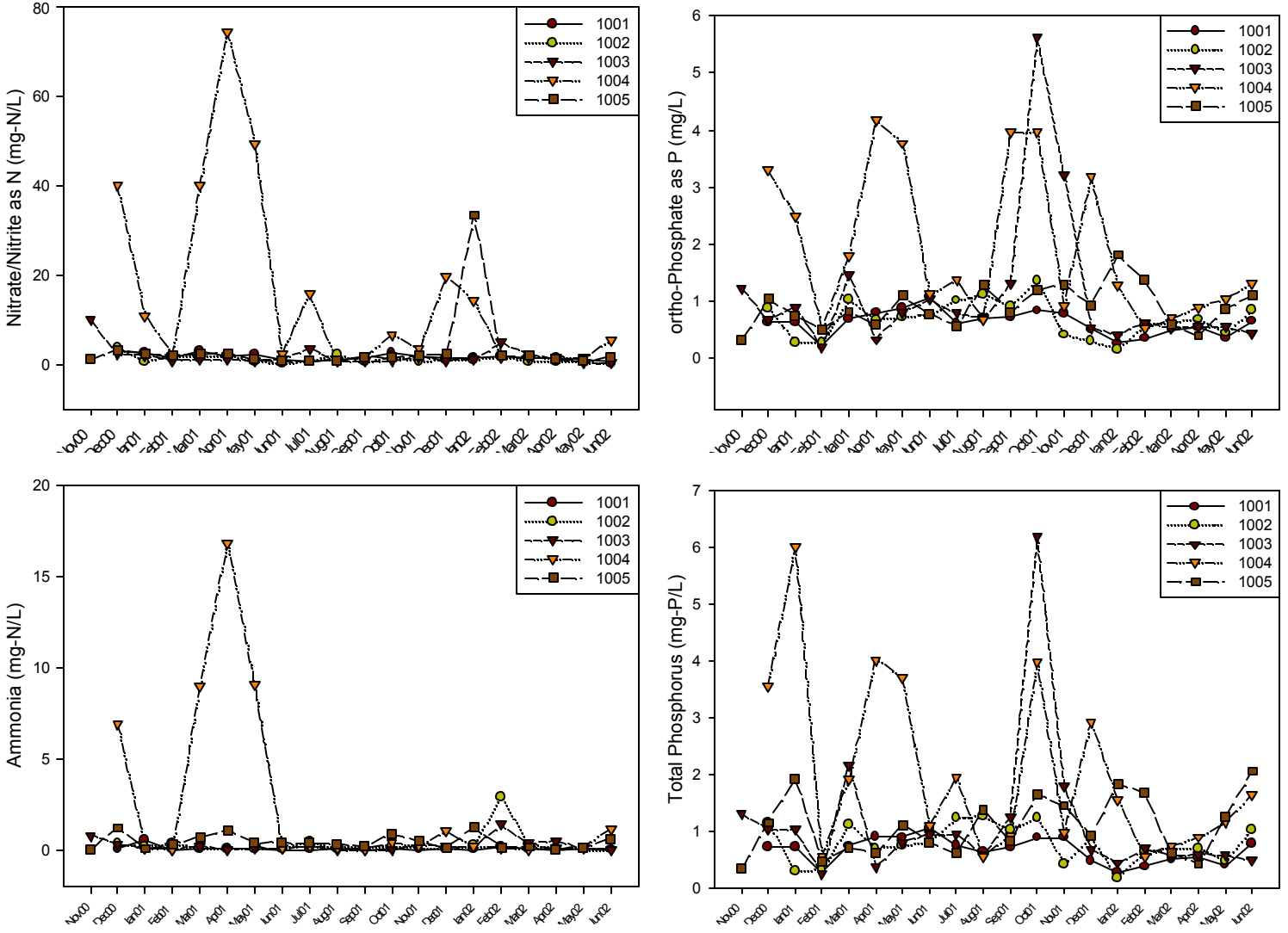
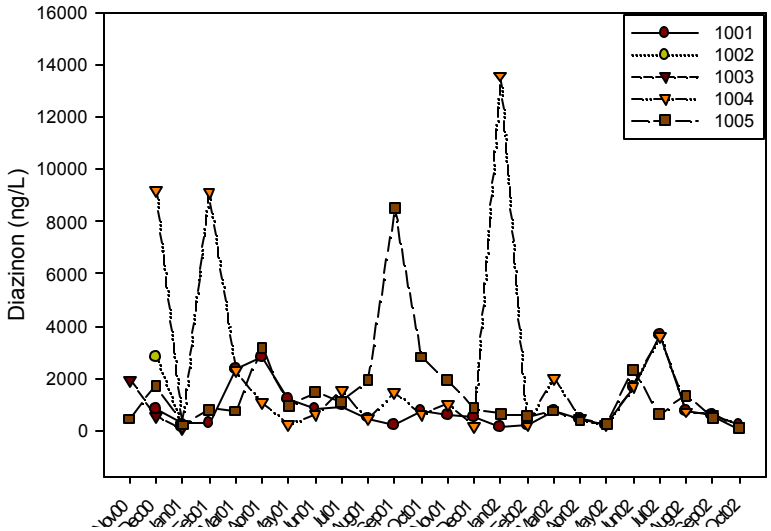


Figure WQ1 continued



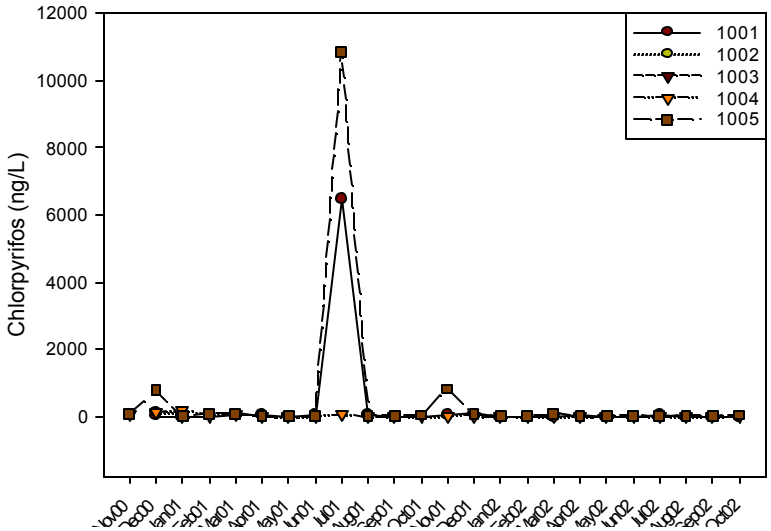


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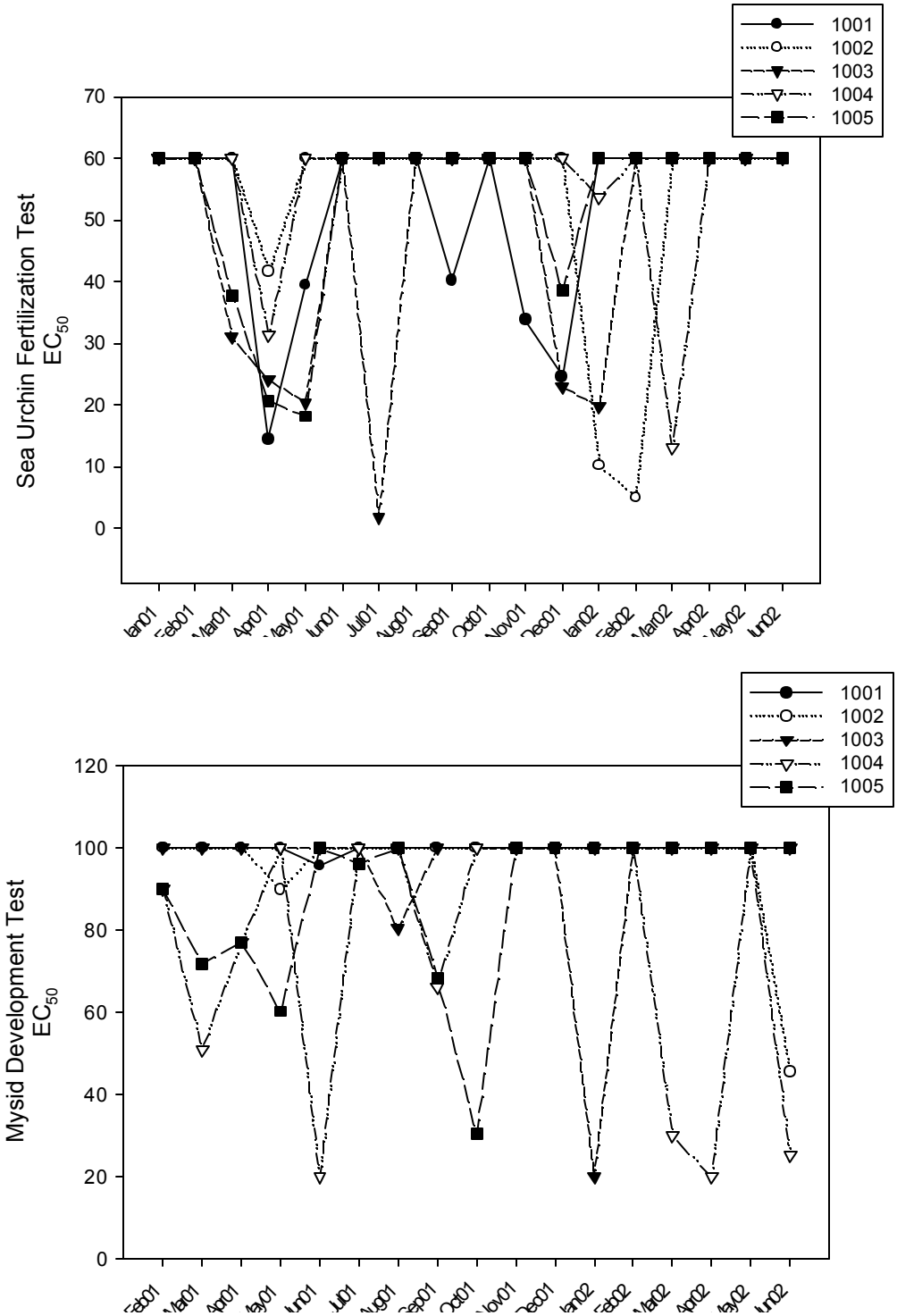
Figure WQ2. Toxicity of dry weather discharges from five residential neighborhoods in Orange County, CA



SARB_001790

Appendix E2: Technical Assistance

The Residential Runoff Reduction Study

SARB_001791

Appendix E2: Technical Assistance for the Residential Runoff Reduction (R3) Report

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SARB_001792

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1. Introduction

This report describes analyses and results of work conducted by GeoSyntec Consultants for the Irvine Ranch Water District (IRWD) to assist in the completion of the Residential Reduction Runoff (R3) Study. The R3 Study is an ambitious investigation to quantify the effectiveness of BMPs in reducing dry weather discharges and associated pollutants.

GeoSyntec Consultants completed the following tasks:

1. Review and Analysis of Water Quality Data. We reviewed the analyses described in Chapter 5 of the R3 report and conducted additional analyses of the water quality data and flux calculations to explore and potentially enhance the interpretation of the monitoring results.
2. Evaluation of Possible Implications on TMDL Compliance. We reviewed and summarized applicable TMDLs in the San Diego Creek Watershed. Results from Task 1 were compared with the TMDLs to evaluate whether the BMPs are beneficial to achieving the TMDL objectives.

2. GeoSyntec Review of Section 5 of the R3 Study Report

Section 5 in the R3 report describes the water quality monitoring data and analyses. The following are GeoSyntec review comments of Section 5.

- **Abstract and Introduction**. The abstract and introduction section provides a recap of the entire study, including a description of the study motivation and objectives. This suggests that this section of the report was originally written as a stand-alone report. In the final report we recommend that most of this information should be integrated into an earlier overall report introductory chapter. The introduction of Section 5 should be limited to a recap of the water quality and flow data, and to present the purpose/goals of the data analysis described in this section.
- **Methods**. The methods section similarly presents much of the study details (watershed descriptions, intervention description-BMPs applied-, etc). We recommend this information be presented in an earlier chapter in the report that describes the study design and procedures in a high degree of detail. This study description chapter could then be referenced as needed throughout the report.
- **Data Analysis and Results**. The 5 data analysis steps are logical and reasonable, however, the procedures, assumptions made, and results are, in some cases, unclear as discussed below. Additional details of the procedures and assumptions made, as well as the use of alternative, possibly more appropriate statistical procedures could enhance the interpretation and usefulness of the monitoring data. Some specific suggestions and comments are discussed below:

1. **Comparison of water quality data prior to intervention**. ANOVA tests were used to test for differences among the treatment sites for each constituent prior to intervention. ANOVA is a parametric test, which is identical to the t-test when comparing only two groups of data. This test assumes that all data sets are normally distributed and have equal variance. The t-test has limitedpower todetect small differences among data sets if they are not normally distributed. Currently the report states that the "data were tested for normality and homogeneous variance prior to testing...[and] only the microbiological data were determined to be non-normally distributed..." However, the results of the normality tests were not included, nor were any descriptive statistics that may indicate normality. Our analyses suggest that many of the data groups are not normally distributed. In addition the mean is not considered a good measure of central tendency for many of R3 data, because mean values can be strongly influenced by outlier values, which were frequently observed. Much of our analyses, therefore, are based on the evaluation of median concentrations. Median values are resistant to the influence of outlier values, and may therefore be a more appropriate measure of central tendency in the R3 data.

   Table WQ3 includes means and 95% confidence intervals for the water quality data before and after intervention (BMPs applied). These descriptive statistics only show part of the story. At the very least, other parametric descriptive statistics, such as the standard deviation and the coefficient of skewness should be included, as well as non-parametric (i.e., resistant to outliers) descriptive statistics, such as the median, interquartile range, and the quartile skew. These will aid in interpreting the central tendency, variation, and skewness of the data. A test on the coefficient of skewness will indicate whether the data are symmetric or not. If the null hypothesis that the data are symmetric cannot be rejected, normality tests are warranted. Otherwise, it can be safely assumed that the data do not come from a normal distribution and alternative non-parametric statistical procedures that do not require normality should to be used.

   The standard methods for calculating the 95% confidence interval about the mean (based on t-distribution) are symmetric confidence intervals that require normality, especially with small data sets. While the report does not state the method used for calculating the 95% confidence intervals, it is likely that the standard method was employed since normality was assumed for the ANOVA analysis. When data are non-normal, alternative methods for calculating the 95% confidence intervals could be used, such as the non-parametric interval estimate for the median (no specific data distribution assumed) or an asymmetric confidence interval about the mean (a specific distribution is assumed, such as the lognormal distribution). However, it should be noted that 95% confidence intervals, are appropriate, but not necessary for testing whether there are significant differences between data sets. Hypothesis tests can be used to detect differences. It is recommended that confidence intervals be reserved for showing the uncertainty in an estimate of central tendency (e.g. mean or median) to determine the likelihood for a threshold to be exceeded, such as a water quality criterion.

If one or more of the pre-intervention data sets are determined to be non-normal or unequal in variance, alternatives to the single-factor ANOVA test can be used, such as the Kruskal-Wallis (K-W) test. The K-W test will determine if all of the data sets have the same distribution and if the medians are equivalent within a specified level of confidence.

2. **Comparison of water quality concentrations over time.** Monthly mean concentrations over time were included in the report. While this is a valid approach to analyzing data, it has a tendency to mask the data's true variability, and since there were generally only two samples per month, there is no apparent advantage to averaging for this exploratory data analysis. Also, Site 1004 had large spikes in the nutrient values that when plotted on the same graph as the other sites tends to dampen and make less apparent the variability in monitoring results from the other sites. It is recommended that all data are initially plotted on separate time-series graphs to identify seasonal periodicity, step-trends, or monotonic trends for each sampling site. Time series plots are an excellent approach for presenting the data and an appropriate first step for understanding the characteristics of the data. Note that unless there are obvious trends (step or monotonic), the time-series plots should probably be placed in an appendix rather than the main body of the report, as there will be a number of them and the information provided is primarily to aid the investigator in determining the next step in the analysis.

   In addition to time series plots, other plotting procedures are available that can be useful in the visual inspection of the data. Plots that should be considered for inclusion in the report include box plots that show side-by-side comparisons of central tendency and variability, and side-by-side quantile (cumulative probability distribution) plots that give an indication of the underlying distribution and any apparent differences in those distributions. These should be included in the main body of the report.

3. **Comparison of water quality data before and after intervention**. Standard t-tests were used to compare mean concentrations before and after intervention. The report states that only 6 out of 24 constituents showed significant differences, and the differences showed a net increase from pre- to post treatment. Removing the outlier points did not affect this result. As stated above, the t-test assumes that both groups of data are normally distributed about their respective means and that they have constant variance. There is no indication that the data meet these strict requirements (water resources data rarely do). The report also states that the data were "normalized" to the grand mean of the control sites, but there is no justifiable reason for doing so, especially since the control sites varied greatly amongst themselves.

   A limitation in the comparison of mean concentrations, such as through the use of the t-test, is that the mean of the concentration data is heavily influenced by outlier values. Given that outlier values were identified and recognized to influence the results, alternative measures of central tendency that are more resistant to the influence of the outliers (e.g. median) should be investigated and presented in the report. The rank-sum test, or Mann-Whitney test, is a non-parametric test that tests whether the median of one

group is significantly different from the median of another group. The rank-sum test does not assume any particular distribution or even that the two data sets come from the same distribution. Also, it has the power to detect small differences among data sets and will even work on censored data (data only known to be below the detection limit) as long as less than 50% of the data are censored. The rank-sum test is equivalent to the Kruskal-Wallis test discussed above, but applied to only two data sets. Based on the relative strengths of the rank-sum test as compared to the t-test, and for consistency in the data analysis (as it is highly unlikely the assumptions of the t-test could be met for all, if any of the data sets), it is recommended that the rank-sum (or Krsuskal-Wallis) tests be performed on all data sets.

Once it is determined that a significant difference in the medians exists, the magnitude of the difference can be calculated using the Hodges-Lehmann estimator, which is the median of all possible pair-wise differences between the two data sets. Note that this is often significantly different than the simple difference in medians. A confidence interval about the Hodges-Lehmann estimator can then be calculated to illustrate the variability of the estimate.

4. **Comparison of constituent fluxes (Mass loadings per time) before and after intervention**. Similar to the analysis of concentration data discussed above, mean fluxes for the pre- and post-intervention cases were compared using standard t-tests (for 2 sites only). In general, no difference in the mean flux was found between the pre- and post-intervention data.

   Similar to the analysis of the concentration data, the mean of the flux data is heavily influenced by outliers. Therefore, alternative measures of the central tendency should be calculated and compared. The rank-sum test could be used here as well.

5. **Correlation of toxicity measures with potential toxicants in dry weather runoff**. Correlations between toxicity data and concentration data were investigated using a Pearson product moment correlation. Based on this analysis, no correlations were found to be significant. The first and foremost step in investigating whether one variable is associated with another is to plot the two variables on opposite axes (scatterplot). This step was presented in the report and should be included. A scatterplot matrix helps to identify the nature of the correlation between several variables in one concise graph. A scatterplot will also indicate whether the use of Pearson's correlation coefficient is even appropriate, as it only tests whether there is a linear association between two variables. Due to the nature and complexity of biotic systems, the relationship between toxicity and constituent concentration are likely to be nonlinear. Therefore, an alternative measure of association should be used such as Kendall's Tau or Spearmans Rho. Both of these statistics measure the strength of the monotonic relationship between two variables.

- **Discussion and General Review Comments**. The primary conclusions drawn from the investigation were that there is no statistically significant reductions in pollutant concentration or flux (loadings) as a result of the education and/or sprinkler retrofit

technology. While this may be the case, the data analysis described and presented may have had limited ability to detect differences for the particular data sets. The discussion section included two possible explanations for not being able to detect changes between pre- and post-intervention: 1) the data had too much variability and not enough samples were taken, and 2) the treatments were applied at only about one-third of the individual homes within the test watersheds, which effectively diluted the effects of the intervention. Both of these are logical explanations and should be considered in the design of future studies. A helpful assessment would be to evaluate how much data would be needed to detect levels of differences desired to be detected. This information would be valuable for planning of future studies.

Another possible explanation for having difficulty in detecting differences that was not mentioned in the report is the difference in time periods for the pre-intervention and the post-intervention. The pre-intervention period was from December 2000 to June 2001 and the post-intervention period was from July 2001 to June 2002. In other words, the post-intervention period includes summer and fall data, while the pre-intervention period does not. Moreover, there was considerably more rainfall during the pre-intervention wet season than the post intervention wet season (see Table 1).

Based on this it may be desirable to analyze differences using a truncated post-intervention data set with only winter and spring data. The downside of this approach is that it reduces the number of data points to include in the analysis. However, it is justifiable in that in the summer and fall the observed dry-weather flows are likely more associated with irrigation practices and in the winter and spring the observed dry-weather flows are likely more associated with the leaching of saturated soils. We recommend that the use of a truncated data set should be considered if additional analyses of the data using the approaches recommended above do not reveal statistically significant differences.

Table 1: Daily Rainfall Data at the Tustin-Irvine Rain Gauge (100th of inches)

	2001												2002												
	Dec 00	Jan 01	Feb 01	Mar 01	Apr 01	May 01	Jun 01	Jul 01	Aug 01	Sep 01	Oct 01	Nov 01	Dec 01	Jan 02	Feb 03	Mar 02	Apr 02	May 02	Jun 02	Jul 02	Aug 02	Sep 02	Oct 02	Nov 02	Dec 02
1																									
2							5						15												
3																									
4				47	7							6		5											
5																									
6				3	61												12								
7																22									
8		47																							
9				33	5																				
10													10											163	
11		184										4													
12		105	36									36													
13		8	295																						
14			14																						
15																	7								
16																									99
17															40	29									8
18			3																						
19																		7							
20			9															10							85
21					52								28												
22													8												
23			29													4									9
24		32	12									46					9								
25			85																						
26		57	90	3		8											7						5		
27		13	42											46			3								
28			32											5										3	
29												18	10												13
30													35											54	
31																									
total	0	446	647	86	125	8	5	0	0	0	0	110	106	56	40	55	38	17	0	0	0	0	5	220	214

Pre-intervention period (13.2 inches from12/00-6/01) Post-intervention period (3.1 inches from12/01-6/02)

3. Examples of Recommended Approaches to Data Analysis for Chapter 5

These example analyses focus on TMDL constituents: nutrients (total nitrogen and total phosphorus), metals (copper, lead, zinc, cadmium), pesticides, and pathogens (fecal coliform). The analyses also focus on dry weather flows, as reduction of these flows was the objective of the R3 study.

Recommended Data Analysis Methods

Exploratory Data Analysis

Visual inspection of data and exploration of factors that could potentially influence data (e.g. seasonal trends, rain events)

1. Divide data into pre and post- intervention groups.
2. Construct time series plots to visually inspect data and visually examine for seasonal trends. Overlay storm event markers to identify any relation to rainfall volume or antecedent dry period (ADP).
3. Investigate normality or log normality of data sets. Select appropriate statistical tests.
4. Construct probability plots for pre-intervention and post-intervention periods.
5. Prepare quantile plots.
6. Prepare side-by-side box plots.
7. Calculate descriptive statistics

Hypothesis Testing

Test data for skewness, normality, and statistically significant differences. Note that the skewness and normality tests are only needed if parametric approaches are conducted. It is our recommendation to use non-parametric approaches for consistency because normality will not be met in all cases. Nonetheless examples have been provided to show that several of the data sets do not come from a normal distribution.

1. Skewness hypothesis test for symmetry.
2. Shipiro-Wilkes normality test.
3. Mann-Whitney rank-sum test.
4. For the data sets that have greater than 50% censored data (i.e. data only known to be less than the detection limit), hypothesis tests for differences in proportions.

Example Results

The first step in the data analysis is to construct time-series plots. Time-series plots are constructed to identify seasonal periodicity, step-trends, and monotonic trends. The original report included monthly average time-series plots with all sites included per plot. The authors noted that periodicity and trends were not apparent. However, plotting all sites on one graph tends to hide much of the information. For instance, Site 1004 had much higher nutrient concentrations than the other sites, so by including this site, the minor fluctuations in data from

the other stations are less apparent. Individually plotting the time-series plots reveals more information. Also, by overlaying storm events the role of rainfall volumes and the antecedent dry period (ADP) may be more apparent and may indicate whether additional analyses are warranted (e.g., correlating ADP with concentration). Figure 1 is an example time-series plot with storm event markers overlain for total phosphorus for Site 1001. Notice the pre-intervention period had much more rainfall, which likely added to the variability in runoff concentrations and fluxes. However, it is apparent that the winter and spring concentrations appear to be lower and less variable during the post-intervention period. The irrigation controllers may have had an affect on the runoff concentrations by reducing the amount of irrigation during moister weather conditions (i.e. high soil moisture). Notice a similar effect for total nitrogen in Figure 2. Additional time-series plots are provided in Appendix A.

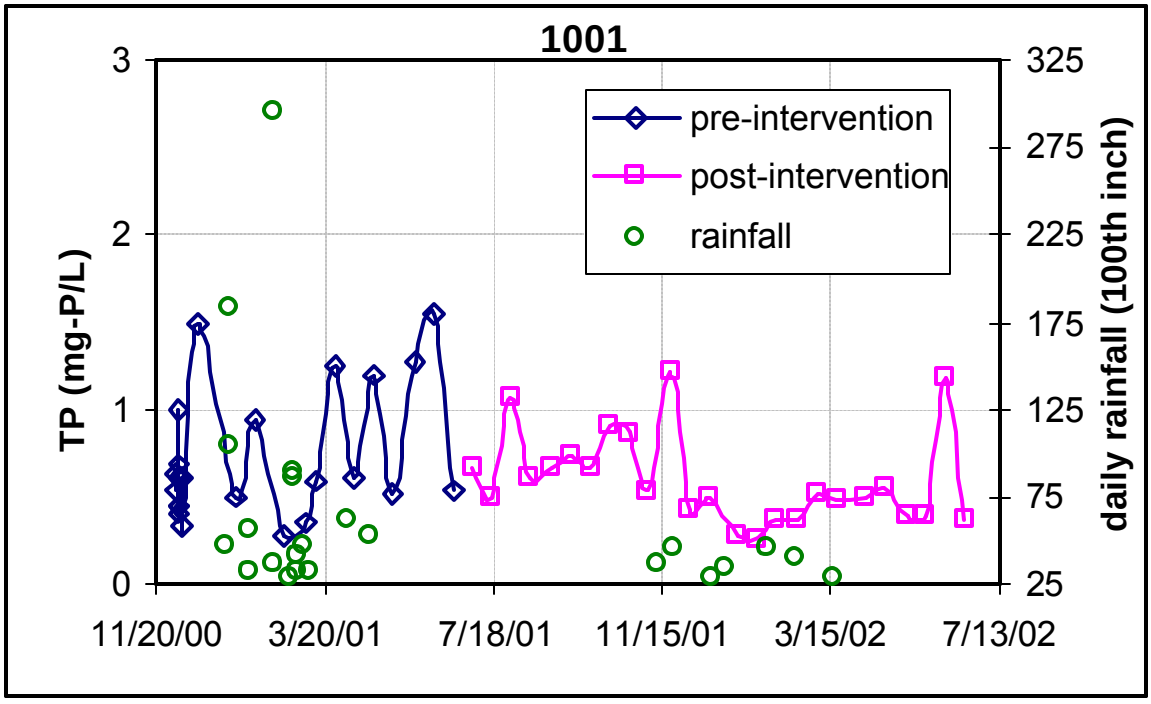


Figure 1. Example time-series plot of total phosphorus with storm event markers.

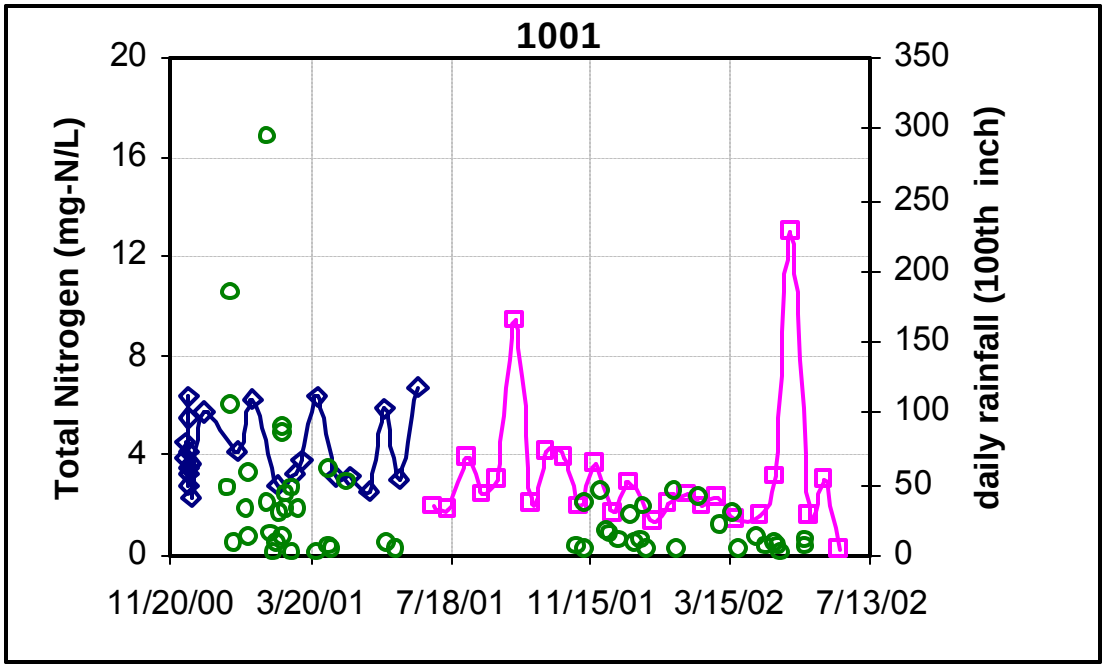


Figure 2. Example time-series plot of total nitrogen with storm event markers.

Comparison of Water Quality Data Prior to Intervention

To visually investigate whether the test sites have similar runoff characteristics, probability plots should be constructed. Figure 3 is an example of a probability plot for total phosphorus for all of the test sites. Notice that all of the sites have a similar distribution except for Site 1004. This suggests that Site 1004 should not be used for "normalizing" of the intervention sites (other information in the report indicating an unknown connection to a nursery further suggests the exclusion of site 1004). However, as mentioned above there is no advantage to normalizing the data using the control sites even if all of the sites had similar distributions.

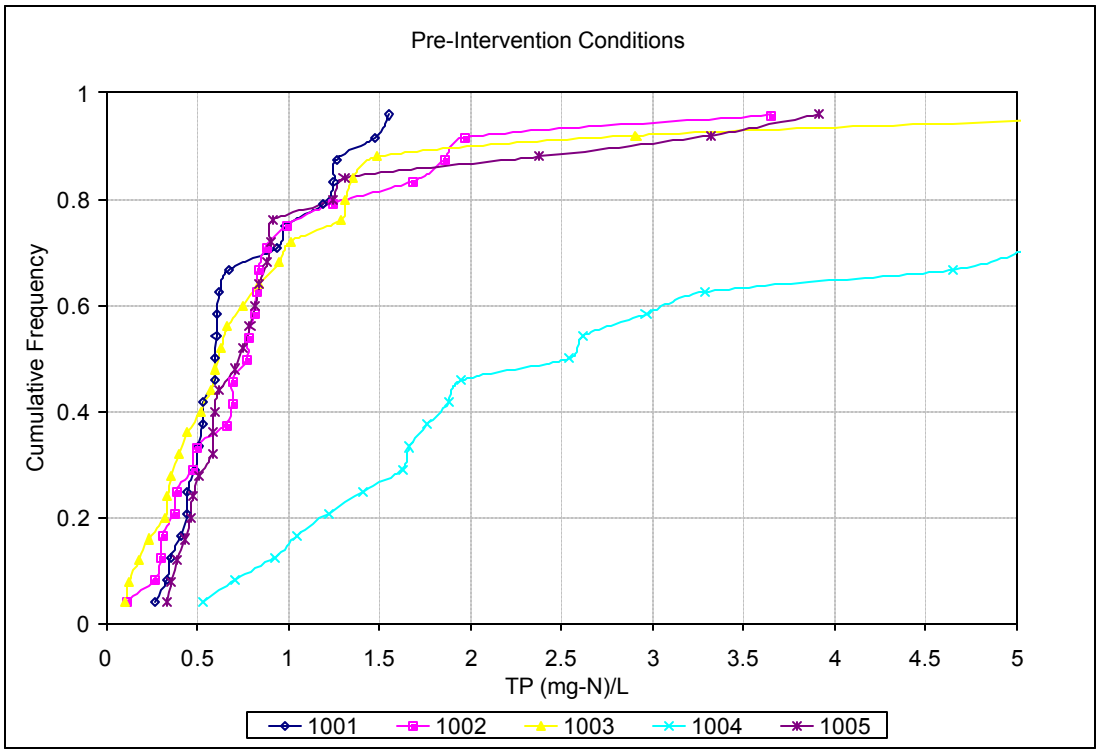


Figure 3. Example probability plot of total phosphorus for all sites prior to intervention.

The next step in the data analysis is to calculate parametric and non-parametric descriptive statistics. Table 2 is an example table of descriptive statistics for total nitrogen for all sites for both the pre- and post-intervention periods. (Additional descriptive statistics are included in Appendix B.) Table 2 includes the number of data points (n), the detection percent (%>MDL/RL), the mean, median, 25% trimmed mean, min, max, 25th percentile, 75th percentile, standard deviation, interquartile range (IQR), and the coefficient of skewness (g_s). Also included in the table are critical skewness coefficients (g_{cr}), which are readily available in statistics texts. If the coefficients of skewness are less than these critical values, then the data are symmetric. Notice that the measures of central tendency (mean and median) and variability (standard deviation) of the sites during the pre-intervention period are quite different, indicating the data arise from different distributions. The median values are consistently smaller than the mean (in some cases substantially smaller) demonstrating the influence of the outliers on the measure of central tendency. Also note that only three pre-intervention data sets are symmetric and none of the post-intervention data sets are. Failure to pass the symmetry test indicates the data are not normal. However, passing the symmetry test does not indicate the data are normal; this requires a normality test. The symmetry test, which is easier to conduct than normality tests, serves as an initial screen for normality to reduce the number of data sets needing further investigation.

Table 2. Example table of descriptive statistics for total nitrogen for each site for pre- and post-intervention.

		1001		1002		1003		1004		1005	
Parameter	**Statistic**	**Pre**	**Post**	**Pre**	**Post**	**Pre**	**Post**	**Pre**	**Post**	**Pre**	**Post**
TN (calculated) (mg-N/L)	**n**	23	25	23	25	23	25	23	25	23	25
	% > MDL/RL	100%	80%	98%	90%	98%	96%	98%	96%	100%	98%
	Mean	4.24	3.09	5.31	3.44	3.66	4.42	48.00	10.18	6.89	7.74
	Median	3.84	2.27	3.95	2.55	2.66	2.50	19.01	5.57	5.06	4.36
	Trimmed mean	3.94	2.40	4.53	2.76	2.93	3.01	33.11	6.47	5.08	4.42
	min	2.30	0.30	1.50	0.78	1.46	0.45	3.28	0.74	2.48	1.07
	max	6.76	12.99	13.83	11.40	12.12	19.91	141.06	40.80	20.41	67.12
	25th percentile	3.20	1.79	2.27	2.10	2.11	2.04	9.05	2.71	3.52	3.47
	75th percentile	5.68	3.13	8.02	4.36	4.81	5.17	94.79	19.18	7.07	5.62
	St Dev	1.41	2.67	3.56	2.51	2.48	4.39	49.17	10.73	5.29	12.85
	IQR	2.48	1.34	5.75	2.26	2.70	3.13	85.74	16.47	3.55	2.15
	Skewness, g_s	0.55	2.82	0.84	1.87	2.13	2.27	0.74	1.37	1.88	4.46
	g_{cr}	0.96	0.92	0.96	0.92	0.94	0.92	0.96	0.92	0.94	0.92
	Symmetric ($g_s < g_{cr}$)?	Y	N	Y	N	N	N	Y	N	N	N

Non-parametric tests are recommended for all data analyses for consistency since all data sets do not meet the required assumptions for parametric tests (i.e. normality and constant variance). Non-parametric tests are not based on the assumption of normally distribution; therefore, normality tests were not warranted. It is important to note that if the data sets that passed the initial symmetry screening (Sites 1001, 1002, and 1004 in the table above) also passed a normality test, it does not indicate the data follow a normal distribution, especially for small data sets. The test simply indicates that normality cannot be rejected for the data.

As mentioned above, the non-parametric equivalent to the ANOVA test is the Kruskal-Wallis test, which tests for a difference between the medians of independent data groups. The K-W test will also test whether the datasets are derived from the same distribution. Several statistical packages will perform this test. Results of the K-W test shown in Table 3 was generated from a statistical add-on to Microsoft Excel® called Analyse-It™.

Comparison of the mean ranks in Table 3 provides an indication of whether the data groups are derived from the same distribution. A p values < 0.05 indicates that two or more the data groups have different distributions. Examination of the mean ranks in Table 3 shows that Sites 1001, 1002, and 1005 have somewhat similar mean ranks and Sites 1003 and 1004 have somewhat different mean ranks. This suggests that Sites 1003, 1004 have a different distribution than the other sites. Therefore, it is determined that the K-W test should be performed on just Sites 1001,

1002, and 1005. These results are shown in Table 4. Notice that the p-value is now greater than 0.05, so the distributions of the total nitrogen data are not significantly different. Based on this analysis, Site 1002 should be used as the only control site for comparison of total nitrogen data. These analyses will need to be repeated for the other water quality constituents.

Table 3. Example of Kruskal-Wallis test results for total nitrogen at the test sites prior to intervention.

Test	**Kruskal-Wallis ANOVA**
Comparison	Total Nitrogen: 1001, 1002, 1003, 1004, 1005
Performed by	GeoSyntec Consultants
n	115

Total Nitrogen	n	Rank sum	Mean rank
1001	23	1128.0	49.04
1002	23	1162.0	50.52
1003	23	774.0	33.65
1004	23	2150.0	93.48
1005	23	1456.0	63.30

Kruskal-Wallis statistic	41.71	
p	<0.0001	(chisqr approximation)

Table 4: Example of Kruskal-Wallis test results for total nitrogen at the Site 1001, 1002, and 1005 prior to intervention.

Test	**Kruskal-Wallis ANOVA**
Comparison	Total Nitrogen: 1001, 1002, 1005
Performed by	GeoSyntec Consultants
n	69

Total Nitrogen	n	Rank sum	Mean rank
1001	23	710.0	30.87
1002	23	761.0	33.09
1005	23	944.0	41.04

Kruskal-Wallis statistic	3.27	
p	0.1948	(chisqr approximation)

Based on these example analyses of the pre-intervention TN data, it is clear that Site 1004 should not be considered as a control site for total nitrogen, and Site 1003 should be used with caution.

Comparison of Water Quality Data Before and After Intervention

Side-by-side box plots and probability plot comparisons of pre-intervention and post-intervention were constructed to identify any apparent differences in the central tendency and concentration distributions between the two data sets. Figure 4 shows side-by-side box plots of total nitrogen at all of the test sites. Site 1004 was omitted due to its high variability. Notice that Site 1001 shows a distinct decrease in total nitrogen, while the other sites do not. However, other sites do show a decreasing trend in median concentration and inter-quartile ranges.

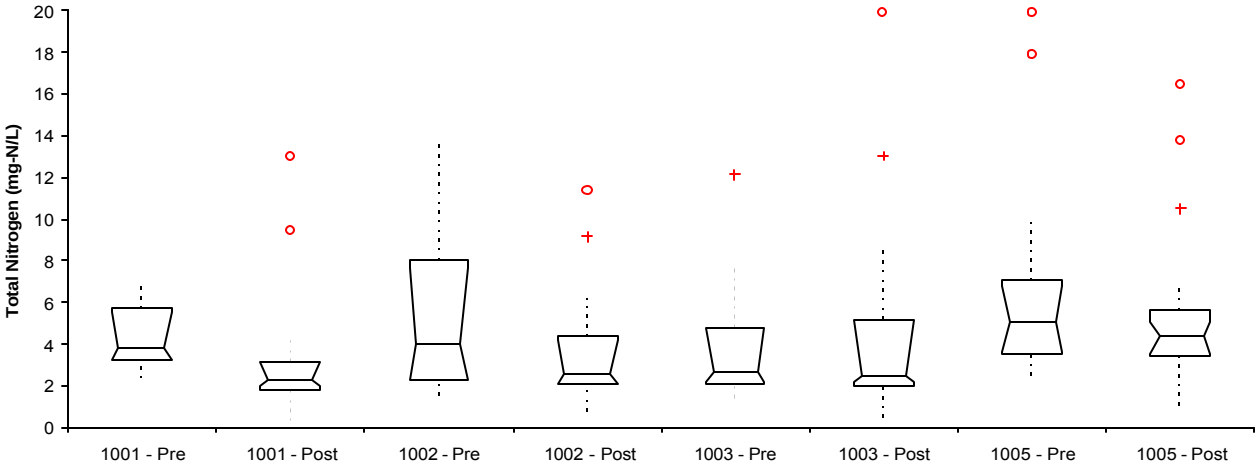


Figure 4. Side-by-side box plots of pre- versus post-intervention for total nitrogen at all sites.

Figure 5 is a probability plot of total nitrogen for Site 1001 before and after intervention. (Additional probability plot comparisons are included in Appendix C.) Notice that there is a distinct reduction in total nitrogen at the site. However, since these data are from different time-periods, this difference could be related to temporal variability.

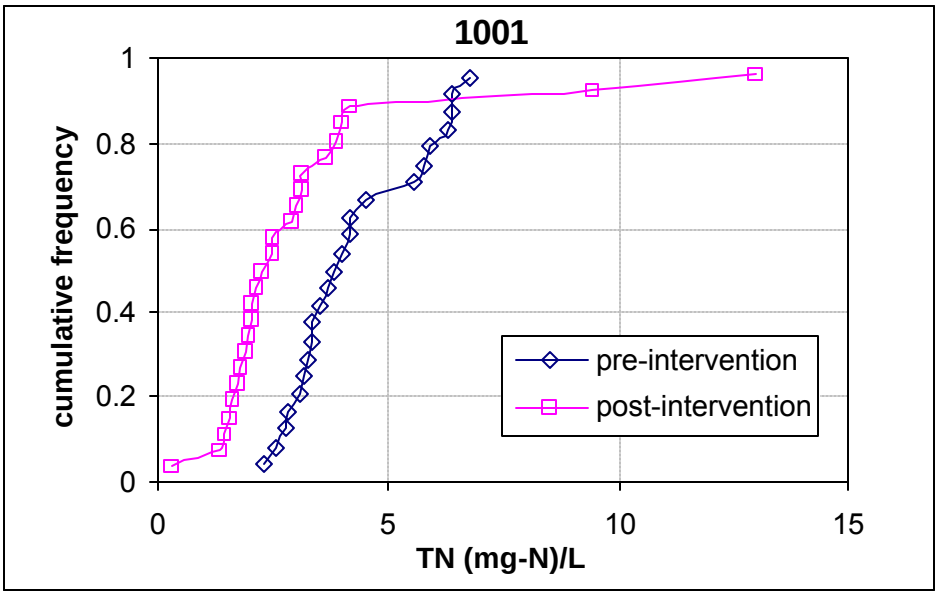


Figure 5. Example probability plot of pre- versus post-intervention at Site 1001 for total nitrogen.

To evaluate if temporal variability caused by the different monitoring periods has anything to do with the difference in total nitrogen concentrations, the probability plot of the pre- and post-intervention period for Site 1001 is plotted with those for Site 1002 and Site 1005 (as these were determined to be the only valid control sites). These comparison plots are shown in Figure 6 and Figure 7. Notice that for pre-intervention, the distribution of Site 1001 more closely follows the distribution of Site 1005 than that of Site 1002, and for post-intervention the opposite is true. This indicates that the year-to-year variability alone cannot explain the reduction in total nitrogen at Site 1001. However, this would need to be statistically verified.

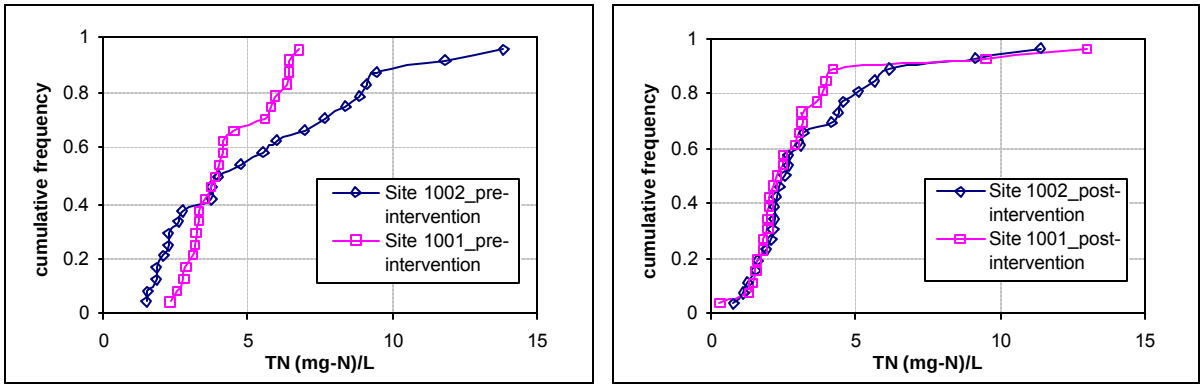


Figure 6. Example probability plot for total nitrogen of Site 1001 versus Site 1002 for the pre- and post-intervention periods.

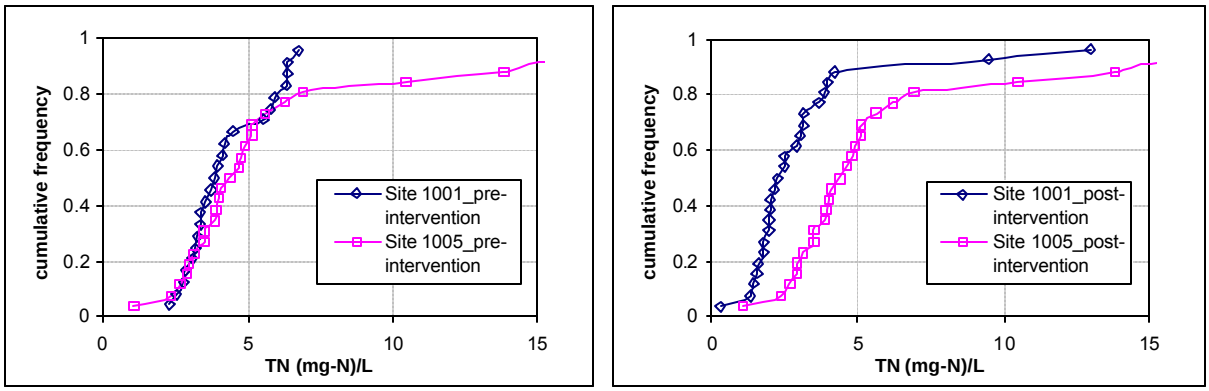


Figure 7. Example probability plot for total nitrogen of Site 1001 versus Site 1005 for the pre- and post-intervention periods.

As mentioned earlier, the Mann-Whitney test (rank-sum) can be used to determine if there is a statistical difference in the median values of two independent data sets (by rejecting the hypothesis that they are the same). Table 5, Table 6, and Table 7 show the output of the Mann-Whitney tests from the Analyse-It™ statistical package on Sites 1001, 1002, and 1005, respectively. Notice that there is a statistically significant difference ($p<0.05$) in the medians between the pre- versus post-intervention total nitrogen data at both Sites 1001 and 1002, but not at Site 1005. Furthermore, the difference in the medians at Site 1001 is at a higher level of confidence (more statistically significant) than the difference at Site 1002 (i.e., greater than 99% significant compared to about 96% significant). The magnitudes of these differences (Hodges-Lehmann estimator) are about 1.5 and 1.3 mg-N/L for Sites 1001 and 1002, respectively. These tests indicate that the difference in the total nitrogen medians at Site 1001 from pre-intervention to post-intervention cannot be explained by the year-to-year variation alone (e.g., the intervention appears to have had an effect). It also indicates that the public education applied to Site 1005 did not appear to make a significant difference.

Table 5: Example Mann-Whitney test for difference in medians for total nitrogen at Site 1001 from pre- versus post-intervention.

Test	Mann-Whitney test			
Alternative hypothesis	1001: Pre ≥ Post			
Performed by	GeoSyntec Consultants			
n	48			
1001	**n**	**Rank sum**	**Mean rank**	**U**
Pre	23	736.0	32.00	115.0
Post	25	440.0	17.60	460.0
Difference between medians	1.497			
95.2% CI	0.883	to +∞	(normal approximation)	
Mann-Whitney U statistic	115			
1-tailed p	0.0002	(normal approximation)		

Table 6. Example Mann-Whitney test for difference in medians for total nitrogen at Site 1002 from pre- versus post-intervention.

Test	Mann-Whitney test			
Alternative hypothesis	1002: Pre ≥ Post			
Performed by	GeoSyntec Consultants			
n	48			
1002	**n**	**Rank sum**	**Mean rank**	**U**
Pre	23	651.0	28.30	200.0
Post	25	525.0	21.00	375.0
Difference between medians	1.289			
95.2% CI	0.065	to +∞	(normal approximation)	
Mann-Whitney U statistic	200			
1-tailed p	0.0355	(normal approximation)		

Table 7. Example Mann-Whitney test for difference in medians for total nitrogen at Site 10052 from pre- versus post-intervention.

Test	Mann-Whitney test			
Alternative hypothesis	1005: Pre ≥ Post			
Performed by	GeoSyntec Consultants			
n	48			
1005	**n**	**Rank sum**	**Mean rank**	**U**
Pre	23	610.0	26.52	241.0
Post	25	566.0	22.64	334.0
Difference between medians	0.530			
95.2% CI	-0.446	to +∞	(normal approximation)	
Mann-Whitney U statistic	241			
1-tailed p	0.1686	(normal approximation, corrected for ties)		

Comparison of Constituent Fluxes Before and After Intervention

The statistical procedures applied to the concentrations examples above should also be applied to the constituent fluxes (mass loadings). For completeness, an abridged example analysis will be provided here. Figure 8 includes side-by-side box plots and probability plots of total nitrogen flux data (mg/acre/day) for Site 1001 at pre- and post-intervention. Note there appears to be a significant decrease in the median, as well as an overall reduction in the distribution of values.

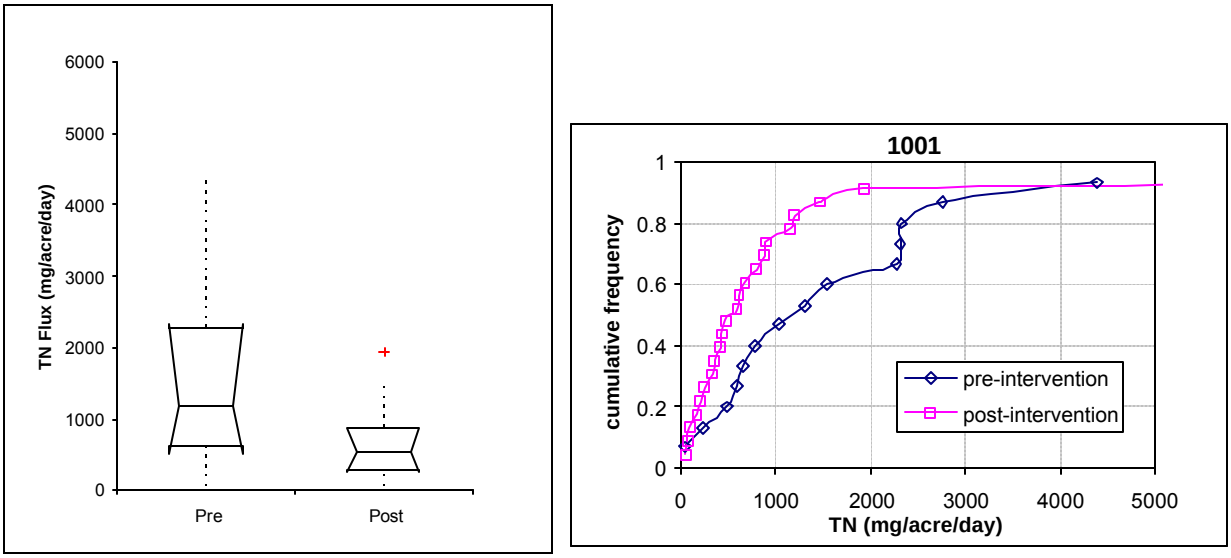


Figure 8. Side-by-side box plot and probability plots of pre- versus post-intervention for total nitrogen flues at Site 1001.

Table 8 shows the results of the Mann-Whitney test (rank-sum) for the total nitrogen flux at Site 1001. Notice the difference in the medians from pre- to post-intervention are statistically significantly different at the 95% confidence level ($p<0.05$). The magnitude of the difference (the Hodges-Lehmann estimator) is approximately 530 mg/acre/day, indicating a relatively large reduction in total nitrogen loads from the neighborhood. However, as discussed below, the extent to which the ET controllers contributed to this reduction is unclear.

The nitrogen fluxes used in this analysis were computed as the product of the measured concentration and the average daily flow. Therefore, the reduction in TN flux could be due to a reduction in flow, a reduction in concentration, or a combination of both. Analyses presented earlier showed a statistically significant reduction in median TN concentration at site 1001 between the pre- and post-intervention periods. Similarly, analyses discussed in the R3 report indicate that there was a statistically significant reduction in flow at site 1001 between the pre- to post-intervention periods; however, it was cautioned that the pre- and post-intervention periods are not comparable due to seasonal differences in the data collection period. Thus, observed reductions in flow in 1001 could be influenced by seasonal factors, and therefore the extent to which the ET controllers contributed to a reduction in flow is unknown. Consequently, reductions in TN flux could be attributed to a combination of TN reduction, flow reduction, and/or seasonal factors.

Table 8. Example Mann-Whitney test for difference in medians for total nitrogen flux at Site 1001 from pre- versus post-intervention.

Test	Mann-Whitney test			
Alternative hypothesis	1001_flux (mg/acre/day): Pre ≥ Post			
Performed by	GeoSyntec Consultants			
n	36			
1001_flux (mg/acre/day)	**n**	**Rank sum**	**Mean rank**	**U**
Pre	14	320.0	22.86	93.0
Post	22	346.0	15.73	215.0
Difference between medians	529.389			
95.1% CI	115.985	to +∞	(normal approximation)	
Mann-Whitney U statistic	93			
1-tailed p	0.0239	(normal approximation)		

Based upon the above results, we believe that it would be valuable to complete a more robust statistical evaluation of the data, as we believe that some significant management implications could be determined.

4. Possible Implications for TMDL Compliance.

The R3 Study results were examined in the context of existing TMDLs in the San Diego Watershed. Most of the existing TMDLs are reviewed below and possible inferences and implications of the R3 Study data for TMDL compliance are discussed. The sediment and organophosphorus pesticide TMDLs were not reviewed because sediment data were not collected (the vast majority of sediments are transported by storm flows) and because Schiff and Tiefenthaler (2003) have previously conducted an extensive analysis of the organophosphorus pesticide data.

4.1. Nitrogen

Nitrogen Water Quality Objectives and TMDLs – The Basin Plan water quality objectives for nitrogen in San Diego Creek are 13 mg/L Total Inorganic Nitrogen (TIN) in Reach 1, and 5 mg/L TIN in Reach 2 (RWQCB, 1995). Reach 1 extends from Newport Bay to Jefferey Road, and Reach 2 extends from Jefferey Road to the headwaters. There is no numeric standard for nitrogen in Upper Newport Bay in the Basin Plan.

The nitrogen TMDL for Upper Newport Bay is based on the general goal of reducing nutrient loads to Newport Bay by 50 percent, to levels observed in the early 1970's (USEPA, 1998b). The nitrogen TMDL sets phase-in limits on total nitrogen (TN) loads to Newport Bay (see Table 9). Separate loads are established for the dry and wet seasons (dry season is from April 1 to September 30). In addition, the winter load is exclusive of storm flows with an average daily flow greater than 50 cfs in San Diego Creek at Campus Drive.

There is no TMDL for nitrogen loads in San Diego Creek, Reach 1 because it was reasoned that attainment of the 50 percent reduction in nitrogen loads to Newport Bay would result in compliance with the Basin Plan in-stream water quality standard for Reach 1 (13 mg/l TIN). However, for Reach 2 it was determined that the average in-stream nitrogen concentrations would likely remain close to or above the Basin Plan in-stream water quality standard (5 mg/L TIN), even with attainment of the Newport Bay TMDLs. Therefore a TMDL of 14 lbs/day TN was established for Reach 2 (see Table 9) and is applicable for all flows exclusive of storm flows greater than an average daily flow of 25 cfs in San Diego Creek at Culver Drive.

Table 9: Summary of Nutrient TMDLs for Upper Newport Bay and San Diego Creek

TMDL	Dec 31, 2002	Dec 31, 2007	Dec 31, 2012
Newport Bay Watershed, TN – Summer load (4/1 to 9/30)	200,097 lbs	153,861 lbs	
Newport Bay Watershed, TN – Winter load (10/1 to 3/31; non-storm)			144,364 lbs
Newport Bay Watershed, Total Phosphorus – Annual Load	86,912 lbs	62,080 lbs	
San Diego Creek, Reach 2, daily load			14 lbs/day
Urban Runoff Allocation for the Newport Bay Watershed Summer load Winter load	22,963	11,481	 38,283

Study Data Comparison with Nitrogen Water Quality Objective – The Basin Plan water quality objectives are expressed in terms of total inorganic nitrogen (TIN), which is comprised of nitrate/nitrite nitrogen and ammonia. By far the majority of the TIN in San Diego Creek is comprised of nitrate/nitrite nitrogen, as measured ammonia concentrations were typically quite low with a majority below the detection limit. For this reason, only the nitrate/nitrate concentration data are compared to the Basin Plan objectives in this report.

Table 10 shows the mean and median nitrate/nitrite concentrations measured in the five study watersheds. The mean and median nitrate/nitrite concentration in all watersheds except 1004 are below the Reach 2 Basin Plan objective of 5 mg/l TIN. As discussed previously, Site 1004 may not be a representative control site because the underlying distribution of pre-intervention nitrogen data appears to be different from the other sites. Similar arguments may also be true Site 1003. With exception of Site 1004, mean nitrate/nitrite concentrations suggests that, on average, residential runoff from these watersheds do not contribute to the exceedance of Basin Plan standards for TIN in receiving waters in San Diego Creek, Reach 1 and 2. The Reach 2 water quality objective was occasionally exceeded in the all watersheds, except for the post intervention conditions in 1001 and 1002.

The mean and median nitrate/nitrate concentrations in watershed 1004, and 1005 exhibit exceedances of the 5 mg/l standard during pre- and/or post intervention conditions. Watershed 1004, in particular, had high levels of measured nitrate/nitrite concentrations, especially during the pre-intervention period. A number of these high readings exceed the Reach 1 water quality objective of 13 mg/l TIC. The results from watershed 1004 are not consistent with those from the other four study watersheds, and the source of the high readings is unknown. Localized conditions involving excessive fertilizer usage by a few users could possibly be a factor in these elevated readings. In particular, the R3 mentions an unknown connection to a neighboring watershed, which could explain the source of elevated nutrient levels.

Table 10: Mean and Median Nitrate/Nitrite Concentration (mg/l) by Watershed (all data)

	1001		1002		1003		1004		1005	
	Pre	**Post**	**Pre**	**Post**	**Pre**	**Post**	**Pre**	**Post**	**Pre**	**Post**
n	23	25	23	25	24	25	23	25	24	25
Mean	2.56	1.47	2.57	1.07	2.13	1.71	36.50	6.61	2.61	4.13
Median	2.32	1.38	1.56	0.93	1.68	0.94	16.88	2.29	2.45	1.48
n>5 mg/l	1	0	4	0	1	2	18	8	2	1
n>13 mg/l	0	0	0	0	0	0	12	4	0	1

The Mann-Whitney (rank-sum) test was performed to compare the statistical difference between median concentrations during pre- and post-intervention periods (see example in Section 3 above). The median nitrate/nitrite in the post-intervention period was lower in all watersheds, and the difference was statistically significant at the 0.05 confidence level. As the control stations exhibited this trend, these data (i.e. entire data sets with unequal seasonal coverage) cannot be used to ascertain if the structural and educational BMPs were effective in reducing the runoff concentrations of nitrate/nitrite.

Clearly there is another factor contributing to reduced concentrations in the post intervention period. One possibility that was investigated is differences in seasons, year-to-year variability, and sampling times of the pre- and post-intervention data. Table 11 shows mean and median concentrations for comparable seasons and sampling times. Note there are still noticeable reductions in all of the median concentrations, except Site 1005. Applying the Mann-Whitney (rank-sum) test to these data it was found that statistically significant differences between median nitrate/nitrite concentrations in the pre- and post-intervention periods occurred only in watersheds 1001 and 1004, as compared to all watershed when all data are considered. These results indicate that seasonal effects are present in these data and should be considered in the study evaluation. It may be inferred from these result that there were significant reductions in the nitrate/nitrite concentration in the intervention watershed during the wet season that may, in part, be attributable to the structural BMPs. It is unknown whether similar reductions would occur in dry weather runoff during the dry season because such data were not collected during the pre-intervention period.

Table 11: Mean and Median Nitrate/Nitrite Concentration (mg/l) by Watershed for Comparable Seasons and Sampling Times[1]

	1001		1002		1003		1004		1005	
	Pre	**Post**	**Pre**	**Post**	**Pre**	**Post**	**Pre**	**Post**	**Pre**	**Post**
n	18	14	18	14	19	14	18	14	19	14
Mean	2.38	1.43	1.95	0.95	2.17	1.66	26.24	6.57	2.24	6.27
Median	2.22	1.48	1.16	0.96	1.50	1.02	8.94	2.06	2.03	1.96
n>5 mg/l	0	0	2	0	1	1	13	4	1	1
n>13 mg/l	0	0	0	0	0	0	7	3	0	1

1 – evening samples were deleted from the pre-intervention data. The post-intervention data include only those data collected in months identical to the pre-intervention period.

Study Data Comparison with Nitrogen TMDLs - The nitrogen TMDL is expressed in terms of total nitrogen (TN) loads. TN concentrations were calculated from the monitoring data as the sum of the nitrate/nitrite nitrogen and TKN nitrogen. Table 12 shows the mean and median TN concentrations measured in the five study watersheds. The mean and median TN concentration in dry weather runoff are generally in the range of 2 to 5 mg/l, with the exception of watershed 1004 where substantially higher concentrations were measured. The rank sum tests indicated that median TN concentrations are significantly lower (in a statistically sense) in the post-intervention period in watershed 1001 (structural BMPs, see Table 5), and in watershed 1002 (control, see Table 6), and based on the probability plots in Appendix C, Site 1004 is expected to as well. However, sites 1003 and 1005 did not show statistically significant reductions. These results did not change when only subsets of the data were used to consider possible affects stemming from the sampling time and sampling months.

Table 12: Mean and Median TN Concentration (mg/l) by Watershed

	1001		1002		1003		1004		1005	
	Pre	**Post**	**Pre**	**Post**	**Pre**	**Post**	**Pre**	**Post**	**Pre**	**Post**
All Data										
n	23	25	23	25	23	25	23	25	23	25
Mean	4.24	3.09	5.31	3.44	3.66	4.42	48.00	10.18	6.89	7.74
Median	3.84	2.27	3.95	2.55	2.66	2.50	19.01	5.57	5.06	4.36
Subsets[1]										
n	18	14	18	14	18	14	18	14	18	14
Mean	4.18	2.78	4.51	2.63	3.71	3.71	33.99	8.91	6.98	9.91
Median	3.62	2.02	3.22	2.21	2.51	2.47	12.14	3.74	4.17	3.96

1 – Data subsets with comparable sampling time and seasons. Evening samples were deleted from the pre-intervention data. The post-intervention data include only those data collected in months identical to the pre-intervention period.

TN flux estimates were calculated for watersheds 1001 and 1005 (Table 13). The draft R3 report indicates that the flow measurements in watershed 1002-1004 are not reliable and therefore flux estimates were not calculated for these watersheds. Flux estimates were calculated as the product of the constituent concentration and the average daily flow occurring on the day of the sample collection. The flux estimates were found to be quite variable as they depend on both flow and concentration measurements. Table 13 shows that median TN flux estimates decrease from the pre- to post-intervention periods for both watersheds. Mann-Whitney (rank sum) tests show the reductions to be statistically significant (Table 8). Because comparable data are not available for the control sites, it is not possible to infer whether these reductions are influenced by the ET controllers in the intervention watershed (1001). Also, as previously discussed, the reduction in TN flux may be attributable to a reduction in flow, a reduction in concentration, seasonal factors, or a combination of these.

Table 13: Mean and Median TN Flux (mg-N/acre/day) by Watershed

	1001		1005	
	Pre	**Post**	**Pre**	**Post**
All data				
n	14	22	10	21
Mean	1476	1667	2104	6537
Median	1164	530	1568	1177
Subset[1]				
n	12	14	10*	8
Mean	1384	587	2104	1716
Median	902	497	1568	960

1 – Data subsets with comparable sampling time and seasons. Evening samples were deleted from the pre-intervention data. The post-intervention data include only those data collected in months identical to the pre-intervention period.
* – Same as the all data case

Although the flux estimates in Table 13 are limited in number, duration, and location, they can be used to speculate about the magnitude of the urban area contribution of TN loads to Newport Bay and the potential reduction in loads from structural and nonstructural BMPs. Based on the limited flux data, the annual TN load to Newport Bay in dry weather runoff from urban areas in the San Diego Creek Watershed is estimated to range between 37,000 to 50,000 lbs per year under existing land-use conditions (see Table 14). This is for the most part below the 2012 urban runoff allocation of 49,764 lbs. The annual TN load is estimated to increase to 50,000-67,000 lbs per year under built-out conditions.

According to the 2001 report on the nutrient TMDL (OCPFED, 2001), the average daily TN load in San Diego Creek at Campus Drive was 540 lbs/day between July 2000 and June 2001. This converts to an annual load of about 197000 lbs, which is below the 2007 TMDL (note: San Diego Creek is the majority but not sole contributor of TN loads to Newport Bay). Estimates in Table 14 suggest that dry weather runoff from urban areas account for about 20 to 25% of the annual TN in the San Diego Creek Watershed. If it is assumed that flux reductions observed in the post intervention period are attributable to the structural and nonstructural BMPs, and if similar interventions could hypothetically be implemented on a watershed-wide basis, then the potential reduction in annual dry weather TN loads is estimated to range between 12,500-20,000. This would represent a reduction of about 6-10% of the current TN loads and about 30-40% of the estimated current dry weather urban loads. Note these estimates are based on few data collected in a limited area, and should therefore be considered preliminary in nature.

Table 14: Estimated Annual TN Loads in Dry Weather Runoff from Urban Areas in the San Diego Creek Watershed

	TN flux (mg-N/acre/d)	Annual TN Load to Newport Bay (lbs) Existing land-use[1]	Annual TN Load to Newport Bay (lbs) Built-out land-use[2]
Pre-intervention conditions	1160 – 1560	37,300 – 50,500	50,000 – 67,000
Post-intervention conditions	530 – 1180	17,000 – 38,000	23,000 – 51,000
Potential reduction		~12,500 – 20,000	~16,000 – 27,000

1 –Used 40000 acres or about 53% of the San Diego Creek Watershed area (IRWD, 2003). For comparison, urban land use in 1999 use was estimated at 35,500 acres of the watershed area at Campus Drive (Tetra-Tech, 2000).
2 – Used 53500 acres or about 71% of the San Diego Creek Watershed area (IRWD, 2003).

The following conclusion can be made based on the analyses above:

- Average and median nitrate/nitrite concentrations in dry weather runoff are below the Reach 2 water quality objective (5 mg/l), for most but not all study watersheds.
- Occasional exceedance of the Reach 2 water quality objective occurred in all study watersheds
- The majority of measured nitrate/nitrite concentrations in watershed 1004 during the pre-intervention period were greater than the Reach 2 water quality objective of 5 mg/l. These data are not consistent with those from the other watersheds. The cause is unknown, but could possibly be related to the unknown connection to neighboring nursery discussed in the R3 report.
- Sampling periods (months) and sampling time (morning versus evening) was found to affect the statistical significance of differences between pre- and post- intervention median nitrate/nitrate concentration in some of the watersheds. The sampling period and sampling time did not affect the statistical significance of differences between pre- and post-intervention median TN concentrations.
- Median TN fluxes in watershed 1001 and 1005 were statistically smaller in the post-intervention period. The extent to which the structural and nonstructural BMPs contributed to these reductions cannot be determined due to the lack of reliable flow data in the control sites.
- Preliminary estimates of annual TN loads to Newport Bay in dry weather runoff from urban sources range between 37,000 to 50,000 lbs per year, or about 20 to 25% of the current TN loads.
- The potential reductions in annual dry weather TN loads due implementation of BMPs on a watershed basis is estimated to range between 12,500-20,000 pounds per year. This would represent a reduction of about 6-10% of the current TN loads and 30-40% of the urban loads.

4.2. Phosphorus

The majority of the annual TP load in the San Diego Creek Watershed occurs in the wet season, and has been correlated with sediment loads generated by storm events (USEPA, 1998b). This correlation suggests that a majority of phosphorus occurs in particulate form attached to sediments. The main sources of the total phosphorus (TP) are in Peters Canyon Wash and San Diego Creek above Culver Drive (USEPA, 1998b).

Phosphorus TMDL – There is no numeric objective for phosphorus for San Diego Creek in the Basin Plan. Because measured TP and sediment loads are correlated, it was determined in the TMDL that a 50 percent reduction in TP loads would be achieved through compliance with the sediment TMDL (USEPA, 1998a). Accordingly, the TMDL for TP was based on a 50 percent reduction of average annual load estimated at 124,160 lbs (USEPA, 1998b). The TMDLs are applicable for all flow conditions. The target compliance date was set for December 31, 2007.

The annual TP load allocation for urban areas is 4102 lbs by 2002, reducing to 2960 lbs by 2007. According to the USEPA (1998b) the TP is allocated in the same proportion as sediments. The annual urban area (stabilized vs. construction) sediment allocation for the Newport Bay Watershed is 50 tons distributed over 95.3 square miles (see Table 5 in USEPA, 1998a). This is a very small allocation over a large area. By contrast, note that the annual construction allocation is 6500 tons distributed over the assumed 3.0 square miles under construction in any one year. Using the same proportions of sediment load allocations, the TP load rate based on the 2007 urban allocation is 2960 lbs/95.3 square miles = 0.0485 lbs/acre/yr. If the construction and urban allocations are combined, the TP load rate based on the combined 2007 urban and construction allocations is (2960+12810) lbs/(95.3+3.0) square miles = 0.251 lbs/acre/yr.

Study Data Comparison with TMDLs – Similar to the nitrogen TMDL, the phosphorus TMDL is expressed in terms of total annual (TP) loads. Table 15 shows the mean and median TP concentrations measured in the five study watersheds. The mean and median TP concentrations in dry weather runoff are below 1.2 mg/l in all watersheds, with the exception of watershed 1004 where substantially higher concentrations were measured. Comparison of the pre- and post-intervention median TP concentrations in all data (Table 15) reveals an increase in the median TP concentration during the post-intervention period for all watersheds except the intervention watershed 1001 and 1004. In contrast, when subsets of the data with similar seasons and sampling times are considered (Table 15), there is a decrease in the median TP concentration in all watersheds except 1005. This indicates that there are seasonal influences in the data, which presumably are related to rainfall. Unfortunately there are no data available to permit comparison of pre- and post-intervention concentrations for dry weather flows during the dry season.

Table 15: Mean and Median TP Concentration (mg/l) by Watershed

	1001		1002		1003		1004		1005	
	Pre	**Post**	**Pre**	**Post**	**Pre**	**Post**	**Pre**	**Post**	**Pre**	**Post**
All Data										
n	23	25	23	25	24	25	23	24	24	25
Mean	0.73	0.60	0.92	0.84	0.98	1.21	3.33	1.50	1.01	1.19
Median	0.60	0.51	0.77	0.82	0.62	0.67	2.54	1.05	0.73	0.85
Subsets[1]										
n	18	14	18	14	19	14	18	13	19	14
Mean	0.78	0.47	0.91	0.67	1.13	0.57	2.62	1.33	0.93	1.24
Median	0.61	0.41	0.73	0.56	0.75	0.58	1.82	1.07	0.75	0.83

1 – Data subsets with comparable sampling time and seasons. Evening samples were deleted from the pre-intervention data. The post-intervention data include only those data collected in months identical to the pre-intervention period.

TP flux estimates were calculated for watersheds 1001 and 1005 using the approach discussed in the nitrogen section above. Table 16 shows that median TP flux estimates decrease from the pre- to post-intervention periods in the intervention watershed (1001) but not in the education only watershed. Mean fluxes increase in both watersheds, but as discussed earlier, the mean values are strongly influenced by outliers and do not provide a good measure of central tendency for these data. Application of the Mann-Whitney (rank sum) test shows the reduction in median TP flux in 1001 is statistically significant. This suggests that the structural BMPs had a positive influence in reducing the TP fluxes, but because comparable data are not available for the control sites, it is not possible to ascertain the extent to which the ET controllers contributed to these reductions. Also, as discussed previously, reductions in flux could be influenced by several factors: reduction in concentration, reduction in flow, and/or seasonal variability.

Table 16: Mean and Median TP Flux (mg-P/acre/day) by Watershed (all data)

	1001		1005	
	Pre	**Post**	**Pre**	**Post**
All data				
n	14	22	10	21
Mean	265	370	473	1327
Median	164	109	219	219

Similar to the previous analyses of TN loads, the TP flux estimates in Table 16 can be used to speculate about the magnitude of the urban area contribution of TP loads to Newport Bay and the potential reduction in loads from structural BMPs. Based on the limited flux data, the annual TP load to Newport Bay in dry weather runoff from urban areas in the Newport Bay Watershed is estimated to range between about 5,000 to 11,000 lbs per year (see Table 17) based on a total urban area of 95.3 square miles obtained from Table 5 of the sediment TMDL (USEPA, 1998a). These estimated annual TP loads are greater than the urban allocation (for both dry and wet weather) and are less than the combined urban and construction allocations (Table 17). Note,

however, that these estimates are based on dry weather data only, and it is expected that a major portion of the TP loads will occur in runoff from winter storms. Therefore, actual annual TP loads would be expected to be greater. If it hypothesized that flux reductions observed in the intervention watershed 1001 could be realized over the entire watershed, then the potential reduction in annual dry weather TP loads from urban areas is estimated at 2700 lbs. As stated previously, these estimates are based on few data collected in a limited area, and should therefore be considered preliminary in nature.

Table 17: Estimated Annual TP Loads in Dry Weather Runoff from Urban Areas in the San Diego Creek Watershed

	TP flux (mg-P/acre/d)	Annual TP Load Rate to Newport Bay (lbs/acre/year)[1]	Annual TP Load to Newport Bay (lbs/year)
2007 Urban Area Allocatoion for Newport Bay		0.0485	2960
2007 Combined Urban and Construction Area Allocatoion for Newport Bay		0.251	15770
Pre-intervention conditions (median fluxes)	164 – 219	0.132 – 0.176	8049 – 10748
Post-intervention conditions (median fluxes)	109 – 219	0.088 – 0.176	5350 – 10748
Potential reduction			2700

1 - urban area is 95.3 square miles and the construction area is 3.0 square miles based on Table 5 in USEPA, 1998a

4.3. Metals

Metals TMDLs – The USEPA (June 2002) determined that TMDLs are required for dissolved copper, lead, and zinc in San Diego Creek, Upper Newport Bay, and Lower Newport Bay, and that TMDLs are required for cadmium in San Diego Creek and the Upper Newport Bay. The TMDLs for San Diego Creek are expressed as concentration limits, based on the CTR criteria at various hardness values that are associated with different flow regimes (Table 18). The flow regimes are based on 19 years of flow measurements in San Diego Creek at Campus Drive. The concentration-based TMDLs apply to all freshwater discharges to San Diego Creek, including discharges from agricultural, urban, and residential lands, and storm flow discharges. The

applicable flow regime at any location in the entire watershed is determined on the basis of discharge at Campus Drive.

Table 18: Summary of Dissolved Metal TMDLs for San Diego Creek

Dissolved Metal (mg/l)	Base flow (0–20 cfs) hardness @ 400 mg/L		Small flows (21-181 cfs) hardness @ 322 mg/L		Medium flows (182-814 cfs) hardness @ 236 mg/L		Large flows (>814 cfs) hardness @ 197 mg/L
	Acute	Chronic	Acute	Chronic	Acute	Chronic	Acute
Cadmium	19.1	6.2	15.1	5.3	10.8	4.2	8.9
Copper	50	29.3	40	24.3	30.2	18.7	25.5
Lead	281	10.9	224	8.8	162	6.3	134
Zinc	379	382	316	318	243	244	208

Metals Sources – The USEPA (June 2002) conducted a source analysis as part of the TMDL preparation. Surface runoff is the largest contributor of metals loads in the San Diego Creek Watershed, which includes natural and man made source (USEPA , June 2002). Much of the metals loads are from natural sources. The estimated anthropogenic contributions are metal specific and range from about 33% for zinc to 63% for cadmium (USEPA, June 2002). A primary anthropogenic source of heavy metals is runoff from urban roads, which contributes to sources of cadmium (tire wear), copper (brakes, tires), lead (brakes, tires, fuels and oils), and zinc (tires, brakes, galvanized metals). Use of copper sulfate by nurseries may also be a minor source of copper loads. Other copper and zinc uses in building materials (roofing and roof drains) may be another source.

The USEPA found that metal inputs were heavily influenced by rainfall and stream flow rates. Monitoring results were reported to be highly variable due to different rainfall amounts and flows during each water year. The EPA estimated that base flows account for 25% of the total metal loadings, with the remainder from low, medium and large flows caused by storms.

The EPA's preliminary analyses suggest that: 1) a primary source of metals in dry weather runoff in the study watershed is from roads (i.e. wash off of metals in driveways, parking lots, streets, gutters, etc.); 2) the runoff concentrations will be influenced by rainfall which result in wash off of accumulated metals; and 3) the concentrations can be variable depending on the amount of rainfall.

Study Data Comparison with Base Flow TMDLs – The metals TMDLs for base flow conditions are based on meeting the CTR criteria at a total hardness of 400 mg/l. The CTR criteria express maximum allowable concentrations in receiving waters for acute (short term) and chronic (4-day) exposure periods. The acute and chronic criteria are expressed as values that cannot be exceeded more that once in three years. Although the criteria are applicable in the

receiving waters and not in the urban runoff per se (i.e. the measured dry weather discharge), exceedance of the CTR in the urban discharge would suggest a potential for the discharge to contribute to an exceedance in the receiving waters.

Table 19 shows the mean and median heavy metal concentrations in the five study watersheds. (*Note to IRWD reviewer: we assumed that the analytical results are for dissolved metals based on guidance from IRWD, but this is not clearly indicated in the data base or draft report; it is likely the case as base flows are typically low in suspended sediments.*) With the exception of mean copper concentrations in some of the watersheds, all mean and median concentrations were below the chronic and acute CTR criteria. Copper, lead, and zinc concentrations occasionally exceeded the chronic CTR criteria, and copper and zinc concentrations occasionally exceeded the acute criteria. These exceedances suggest that the dry weather runoff can potentially contribute to an exceedance in the receiving waters. However, if intervention is determined to be effective in reducing runoff flows, then the BMPs would help to reduce impacts of these potential exceedances by allowing for greater dilution with the in-stream flows.

Table 19: Mean and Median Metal Concentrations (µg/l) by Watershed (all data)

	1001		1002		1003		1004		1005	
	Pre	**Post**	**Pre**	**Post**	**Pre**	**Post**	**Pre**	**Post**	**Pre**	**Post**
Cadmium										
n	23	25	23	25	24	25	23	25	24	25
Mean	0.26	0.14	0.47	0.44	0.27	0.17	0.64	0.22	0.21	0.29
Median	0.27	0.10	0.24	0.10	0.10	0.10	0.36	0.10	0.10	0.10
n>6.2 µg/l	0	0	0	0	0	0	0	0	0	0
n>19.1 µg/l	0	0	0	0	0	0	0	0	0	0
Copper										
n	23	25	23	25	24	25	23	25	24	25
Mean	13.5	16.9	27.3	30.3	11.5	26.6	21.8	17.7	32.1	30.8
Median	11.5	11.4	10.9	14.0	11.1	14.3	12.7	11.4	12.3	20.4
n>29.3 µg/l	2	2	3	7	0	2	5	4	3	5
n>50 µg/l	0	1	3	3	0	2	2	3	3	2
Lead										
n	23	25	23	25	24	25	23	25	24	25
Mean	0.8	1.6	5.9	4.7	0.8	1.6	3.5	1.5	1.0	3.2
Median	0.6	0.6	0.9	1.2	0.6	0.8	0.7	0.7	0.7	1.3
n>10.9 µg/l	2	1	2	3	0	0	2	0	0	1
n>281 µg/l	0	0	0	0	0	0	0	0	0	0
Zinc										
n	23	25	23	25	24	25	23	25	24	25
Mean	58.7	37.2	115.2	86.3	56.3	56.8	83.6	40.9	74.0	75.0
Median	56.0	50.2	53.4	57.2	50.7	53.9	50.8	43.8	52.4	54.5
n>382 µg/l	0	0	1	2	0	0	1	0	0	0
n>379 µg/l	0	0	1	2	0	0	1	0	0	0

We were unable to locate dry weather metals monitoring information in the Central Irvine Channel, which is the immediate receiving water of the study watersheds (*IRWD please confirm*). OCPFRD dry weather monitoring data are available in San Diego Creek at Campus Drive, which is quite a ways downstream from the study watersheds. Data collected between 12/01 and 6/02 (Table 20) show that average dry weather concentrations at Campus Drive are well below mean and median concentrations measured in dry weather runoff from the study watersheds. Similar comparisons cannot be made for lead and cadmium because the method detection limits in the OCPFRD data are greater than those in the R3 data. None of the OCPFRD dry weather data exceed the chronic or acute criteria.

These comparisons suggest that metal loads in dry weather runoff from the study (urban) watersheds could be a contributing factor to dry weather copper and zinc loads measured at Campus Drive. These dry weather discharges do not result in non-compliance of the base flow metal TMDL at Campus (based on the reviewed data only). It is unknown if the elevated concentrations measured in the dry weather urban runoff result in exceedance of the CTR criteria in the immediate receiving waters. Note that if flow reductions observed in the intervention watershed are attributable to the ET controllers, then these controllers would help to reduce impacts from any potential exceedances of the TMDL because the discharges would be subject to greater dilution by the in-stream flows.

Table 20: Summary of OCPFRD Dry Weather Monitoring Data in San Diego Creek at Campus Drive (12/01 to 6/02)

	Cadmium	Copper	Lead	Zinc
Sample number	24	24	24	24
Range	All < 1 µg/l	<2 – 16 µg/l	<2-2.4 µg/l	<10-16
Mean		7.4 µg/l	most <2 µg/l	most <10
Median-		6.8 µg/l		

4.4. Pathogens

Pathogens are agents or organisms that can cause diseases or illnesses, such as bacteria and viruses. Fecal coliform bacteria are typically used as an indicator organism because direct monitoring of human pathogens is generally not practical. Fecal coliform are a group of bacteria that are present in large numbers in the feces and intestinal tracts of humans and animals, and can enter water bodies from human and animal waste. The presence of fecal coliform bacteria implies the water body is potentially contaminated with human and/or animal waste, suggesting the potential presence of associated pathogenic organisms.

Fecal Coliform TMDL – The RWQCB has adopted phased TMDL criteria for pathogens, with the initial focus on additional monitoring and assessment to address areas of uncertainty. The

goal of the Newport Bay TMDL is compliance with water contact recreational standards by 2014:

> Fecal coliform concentration of not less than five samples per 30 days shall have a geometric mean less than 200 most probable number (MPN)/100ml, and not more than 10 percent of the samples shall exceed 400 MPN/100ml for any 30-day period.

A second goal is to achieve the shellfish harvesting standards by 2020:

> The monthly median fecal coliform concentration shall be less than 14 MPN/100 mL, and not more than 10 percent of the samples shall exceed 43 MPN/100 mL.

The TMDLs are applicable for all flow regimes.

Study Data Comparison with Fecal Coliform TMDLs – Table 21 shows the mean and median fecal coliform concentrations measured in the five study watersheds. 70% to 100% percent of all fecal coliform measurements were greater than 400 MPN/ml in all study watersheds. This level of exceedance is substantially greater than the allowable 10%. The mean and median fecal coliform concentrations also exceed the 400 MPN/100ml criterion in all study watersheds. There was insufficient data to calculate the 30-day geometric mean (a minimum of 5 samples per 30 days needed), however, the TMDL criterion (30-day geometric < 200 MPN/100 ml) would likely be exceeded, assuming that any additional data would be of the same magnitude as those collected. Exceedance of the TMDL criteria in all study watersheds suggests that urban dry weather runoff is likely a contributing factor to any dry weather exceedance of the TMDL in the receiving waters.

Table 21: Mean and Median Fecal Coliform Concentration (MPN/100ml) by Watershed

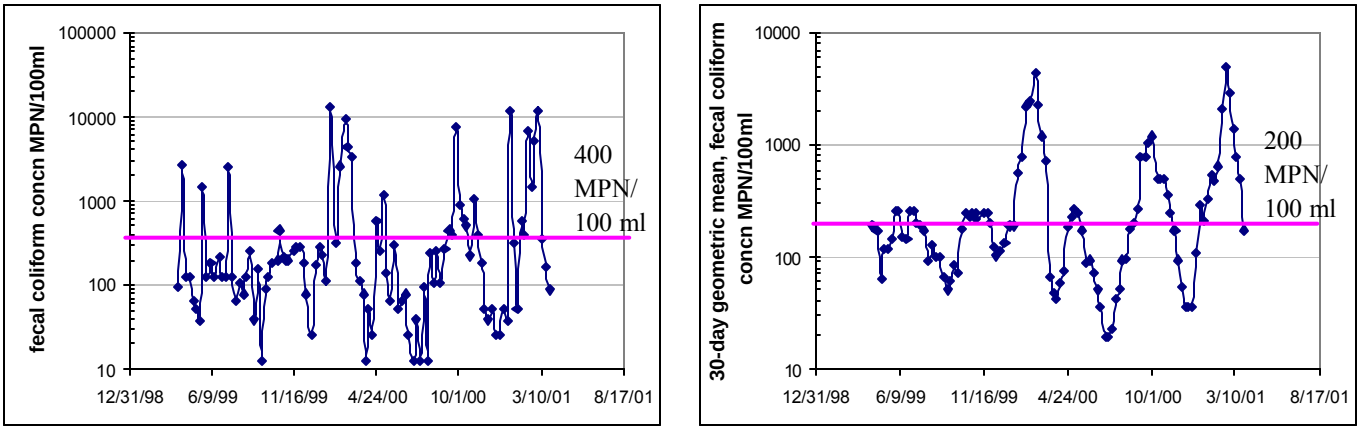
	1001		1002		1003		1004		1005	
	Pre	**Post**	**Pre**	**Post**	**Pre**	**Post**	**Pre**	**Post**	**Pre**	**Post**
All Data										
n	22	24	21	24	23	24	21	24	23	24
Mean	4921	3003	5582	128193	34526	28980	28205	34185	17976	10326
Median	2300	1400	1700	3000	13000	4000	13000	13000	8000	8000
% > 400 MPN/100ml	82%	67%	86%	79%	100%	88%	95%	83%	92%	93%
Subsets [1]										
n	17	14	17	14	18	14	17	14	18	14
Mean	2545	3054	3090	5074	13783	37479	23312	20166	8524	6109
Median	2200	950	1400	1400	8000	2650	8000	6500	4000	2900
% > 400 MPN/100ml	100%	71%	82%	79%	100%	86%	94%	79%	100%	93%

1 – Data subsets with comparable sampling time and seasons. Evening samples were deleted from the pre-intervention data. The post-intervention data include only those data collected in months identical to the pre-intervention period.

We were unable to locate dry weather coliform monitoring information in the Central Irvine Channel, which is the immediate receiving water of the study watersheds (*IRWD please confirm*). Therefore it is unknown if elevated fecal coliform concentrations measured in the

study watershed contribute to an exceedance of the TMDL in the immediate receiving waters. The OCPFRD has collected dry and wet weather *E. coli* monitoring information in San Diego Creek at Campus Drive (OCPFRD, September 2001), which is considerably downstream from the study watersheds. A plot of the equivalent fecal coliform concentration (assuming an 80% *E. coli* content) shows exceedance of the TMDL occurs primarily during the wet season, although dry season exceedances are also evident (see Figure 9). This suggests that dry weather urban runoff is potentially a contributing factor to exceedance of the TMDL in dry weather flows at Campus Drive. The ET controllers would reduce the impacts from these potential exceedances if they were determined to be effective reducing the dry weather runoff volumes.

Figure 9: Time Series of Fecal Coliform Levels San Diego Creek at Campus Drive (converted from measured E. coli concentrations)



Median fecal coliform concentrations presented in Table 21 may be used to evaluate the influence of the structural and non-structural BMPs. When all monitoring dataset is considered, the median fecal coliform concentrations are equivalent or increase from pre- to post-intervention conditions in all watersheds except the 1001 (intervention watershed) and 1003 (a control watershed). Based on the Mann-Whitney (rank-sum) test, the reduction in median concentrations in 1001 and 1003 is significantly significant at the 95% confidence level. Thus the watershed with the irrigation controllers corresponded to a significant reduction in median fecal coliform concentrations, in comparison to 2 of the 3 control sites, while the education only watershed exhibited no discernable reduction in median concentrations.

When subsets of the data with similar seasons and sampling times are considered (Table 21), there is a decrease in the median fecal coliform concentration in all watersheds except 1002. However, because of the smaller sample sizes, the decrease is median concentration is statistically significant only in watershed 1003. This suggests that there could be seasonal influences in the monitoring data, but the data are not sufficient to determine if there are statistically significant differences in the median concentrations.

5. References

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OCPFRD, 2001. County of Orange Public Facilities and Resources Department, NPDE Annual Progress Report.

OCPFRD, September 2001. Newport Bay Fecal Coliform TMDL Annual Data Report.

RWQCB, 1995. Water Quality Control Plan, Santa Ana River Basin (8).

Schiff, K.C. and L.L.Tiefenthaler, June 2003. Contributions of organophosphorus pesticides from residential land uses during dry and wet weather. Technical Report 406, Southern California Coastal Water Research Project.

USEPA (Region 9), 1998a. *Total Maximum Daily Loads for Sediment and Monitoring and Implementation Recommendations; San Diego Creek and Newport Bay, California*

USEPA (Region 9), 1998b. *Total Maximum Daily Loads for Nutrients; San Diego Creek and Newport Bay, California*

USEPA, June 2002. Total Maximum Daily Loads for Toxic Pollutants – San Diego Creek and Newport Bay, California, June 14, 2002.

Tetra Tech, Inc., July 2000c. Newport Bay Watershed Urban Nutrient TMDL Compliance Evaluation.

Appendix A - Time-Series Plots

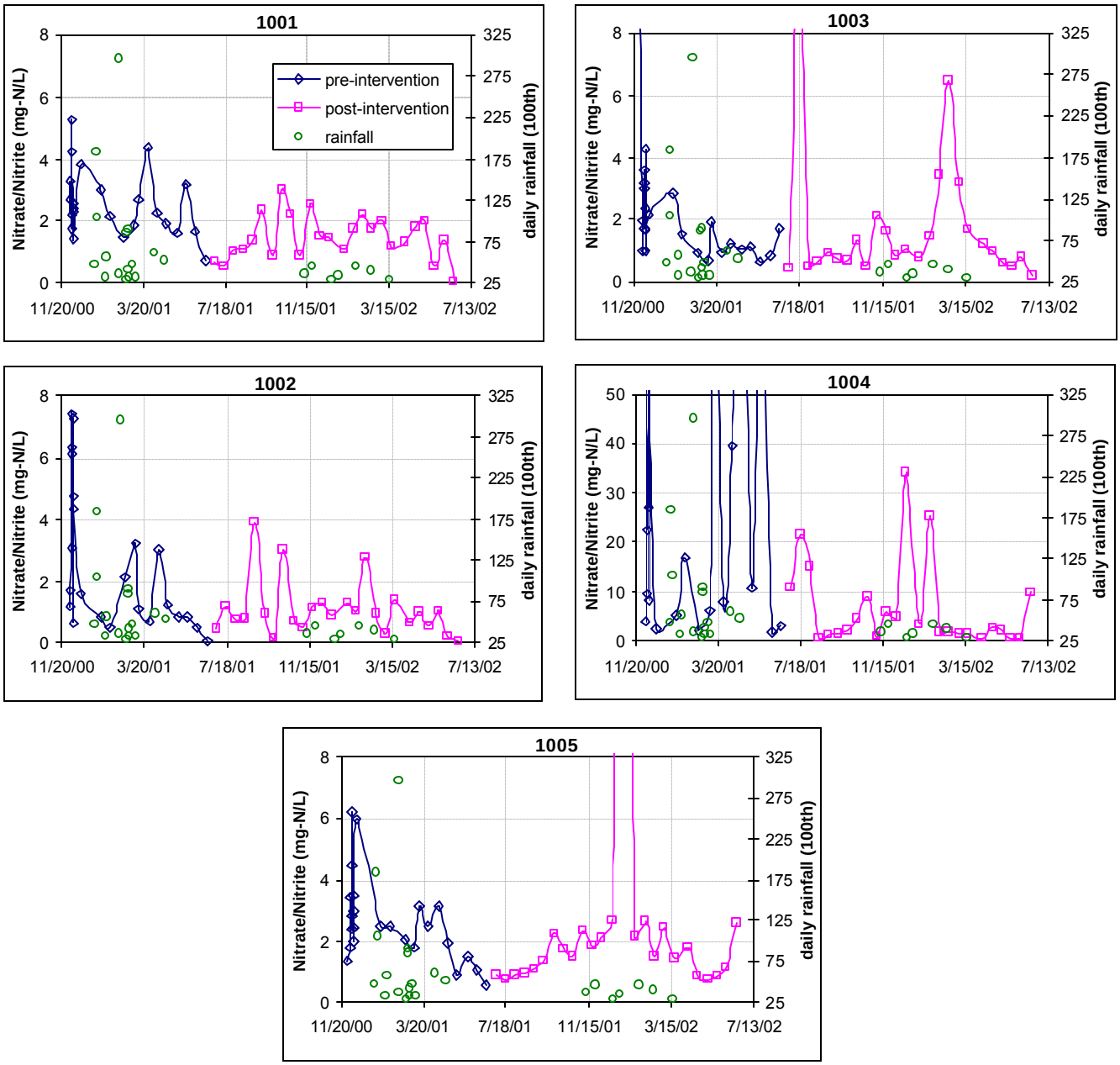

Figure A-1: Time Series of Nitrate/Nitrite in Dry Weather Samples (all data)

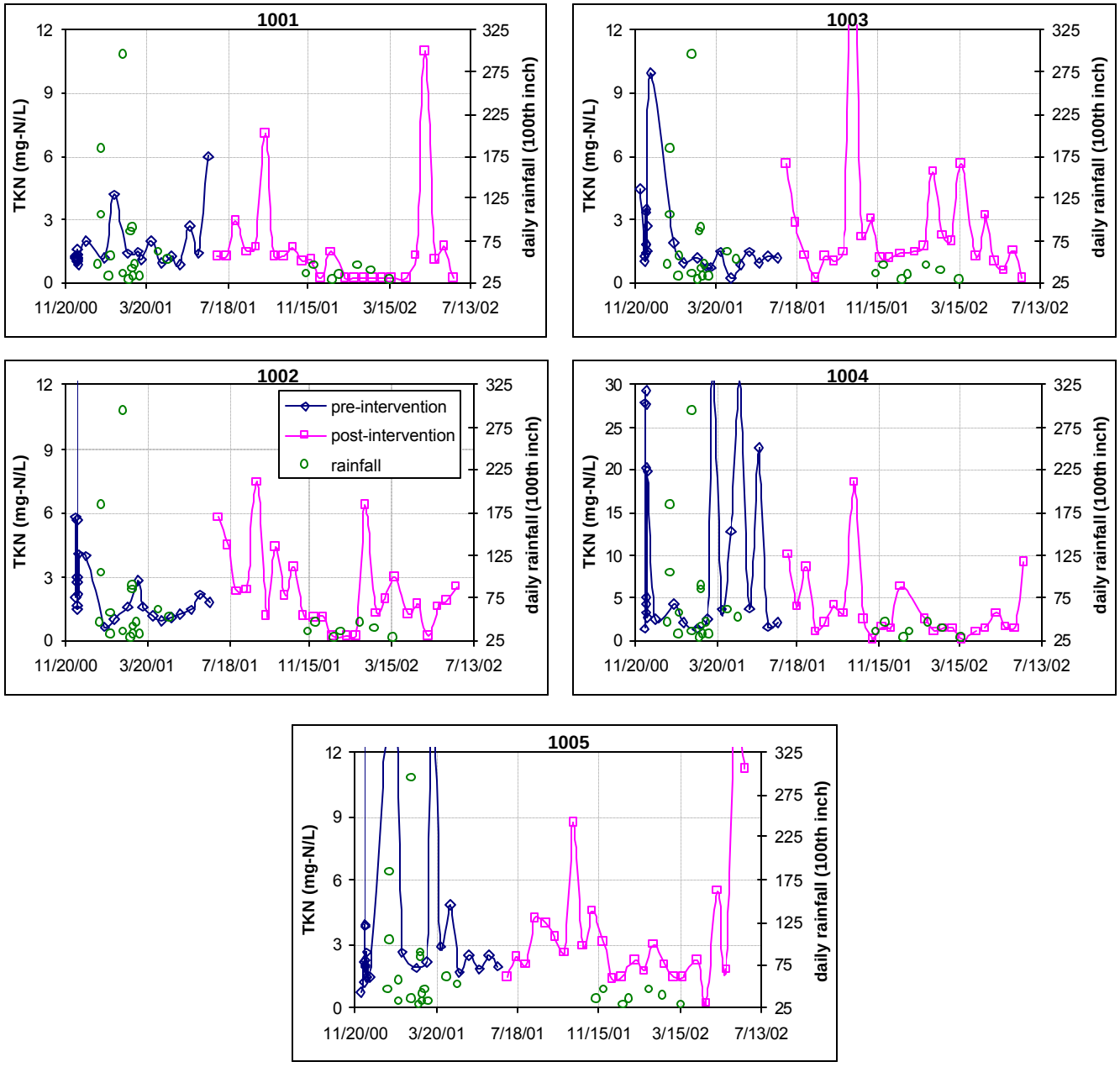

Figure A-2: Time Series of TKN in Dry Weather Samples (all data)

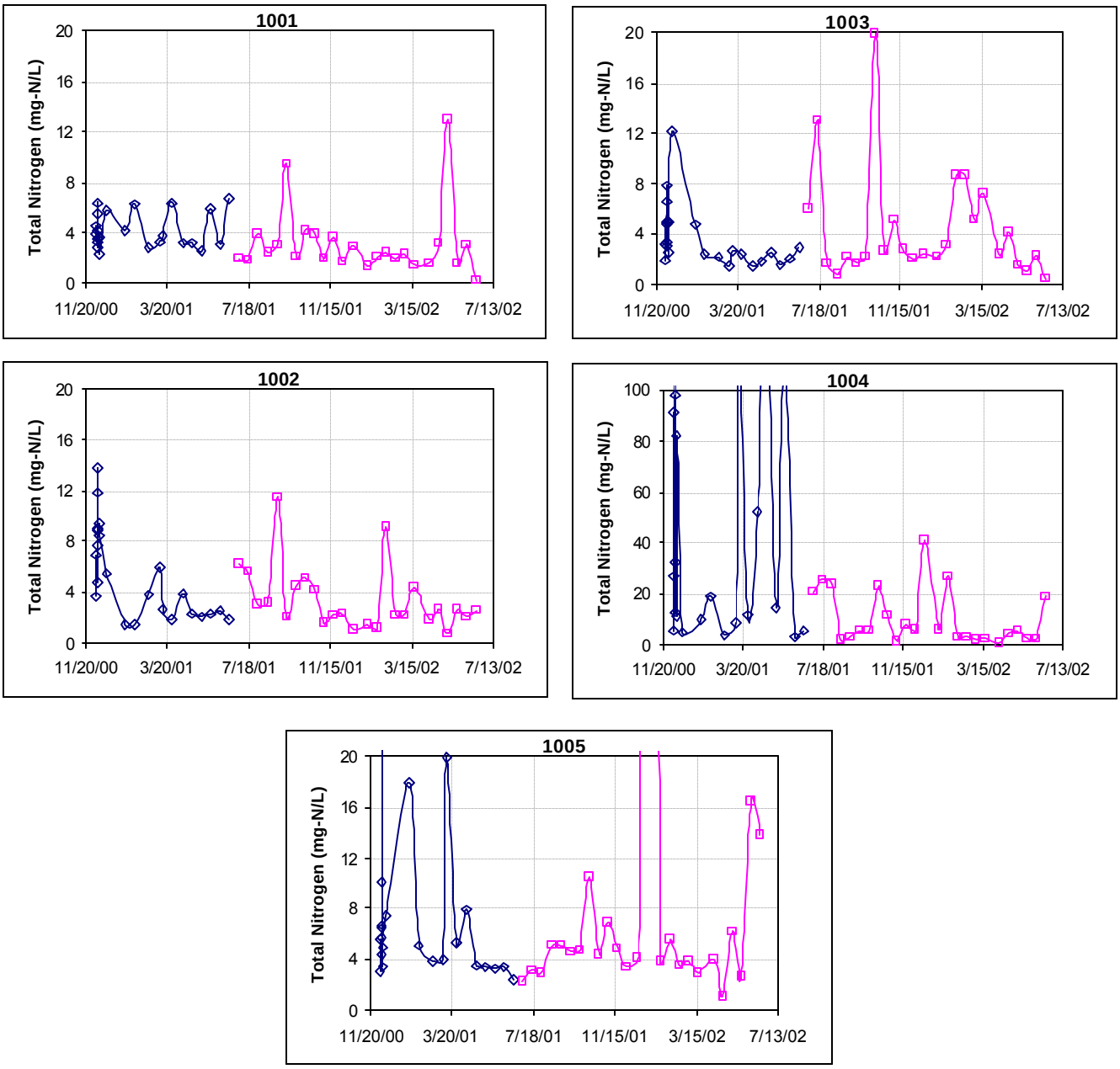

Figure A-3: Time Series of TN (Calculated) in Dry Weather Samples (all data)

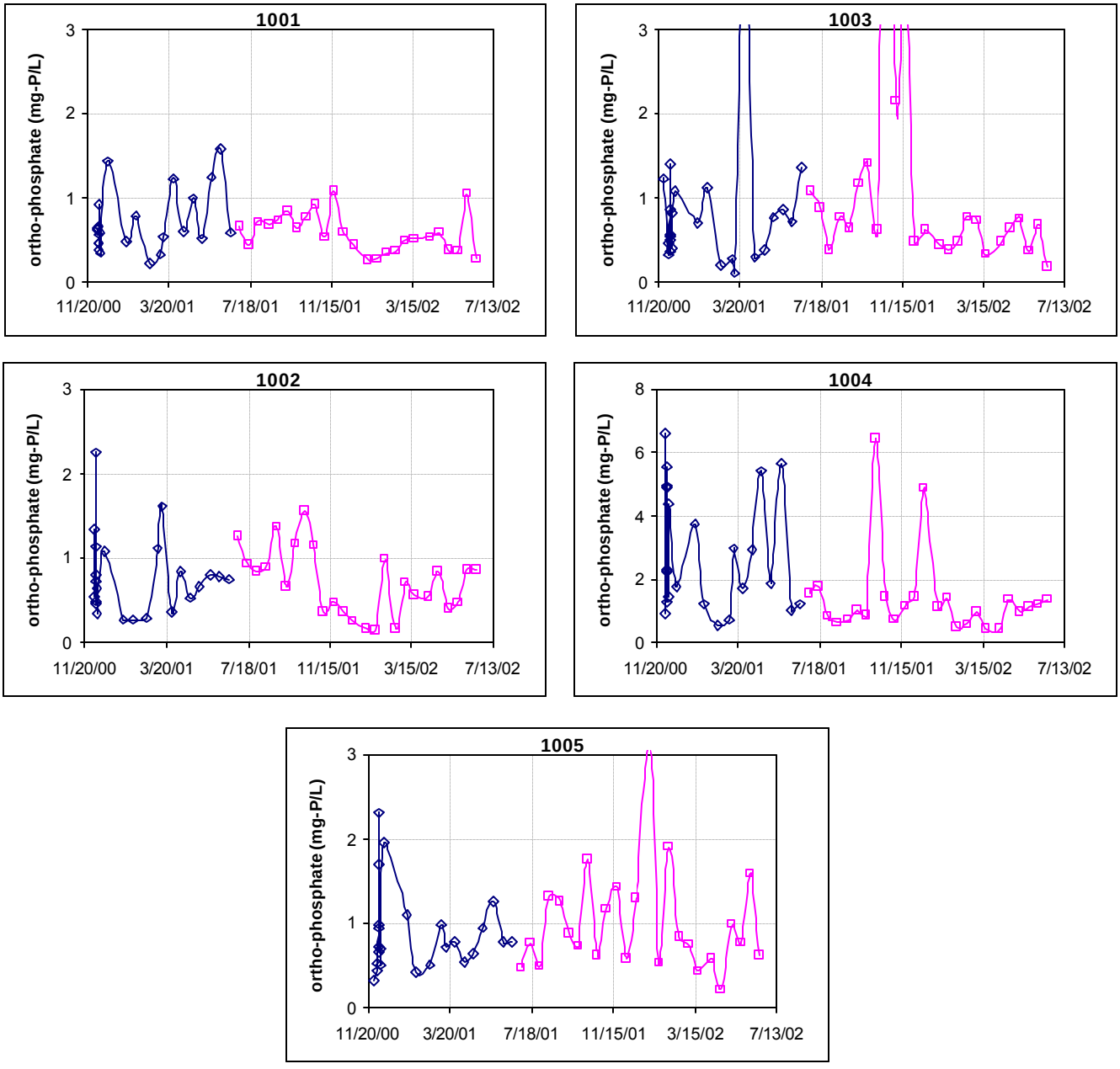

Figure A-4: Time Series of Ortho-Phosphate in Dry Weather Samples (all data)

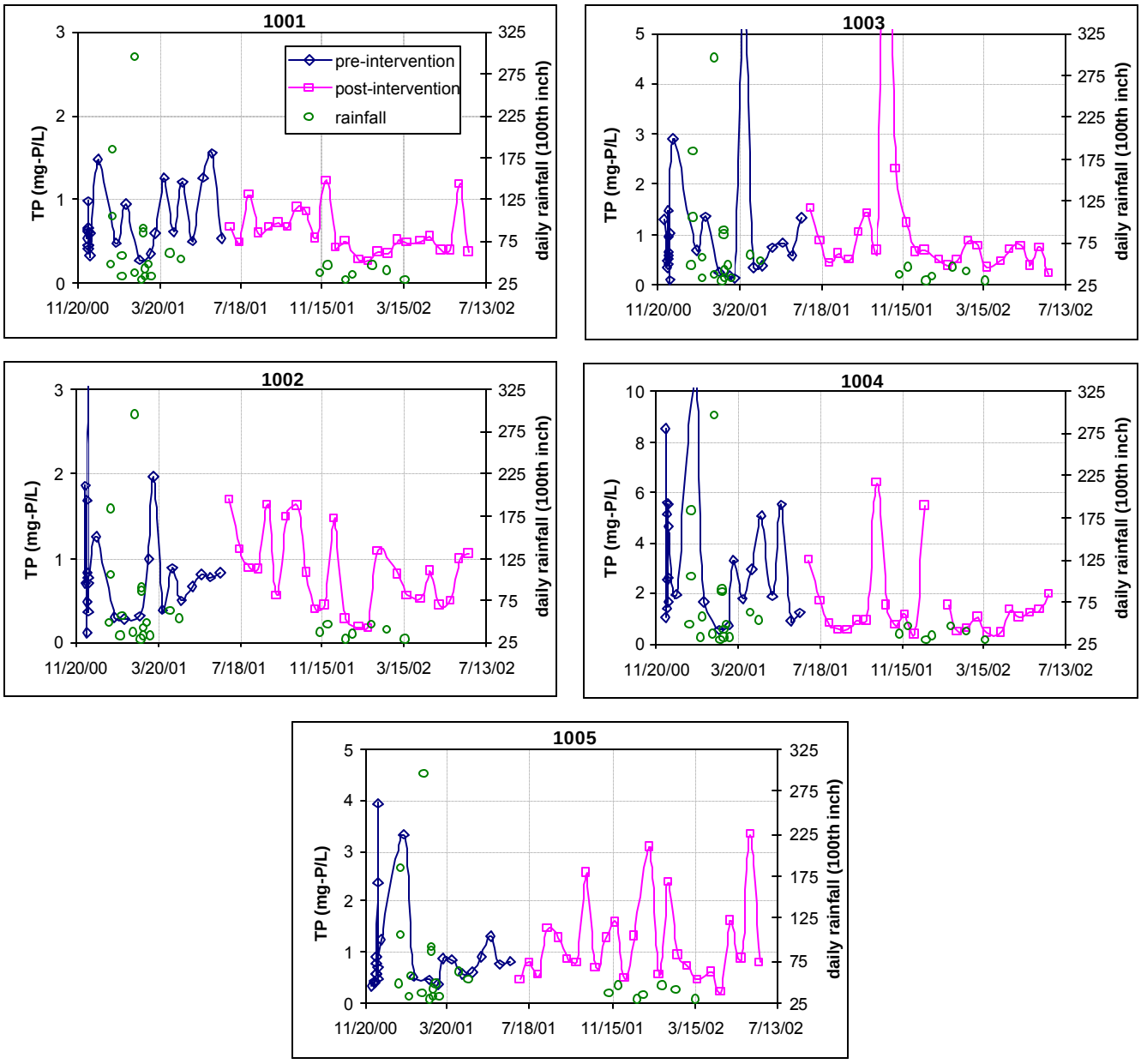

Figure A-5: Time Series of Total-Phosphorus in Dry Weather Samples (all data)

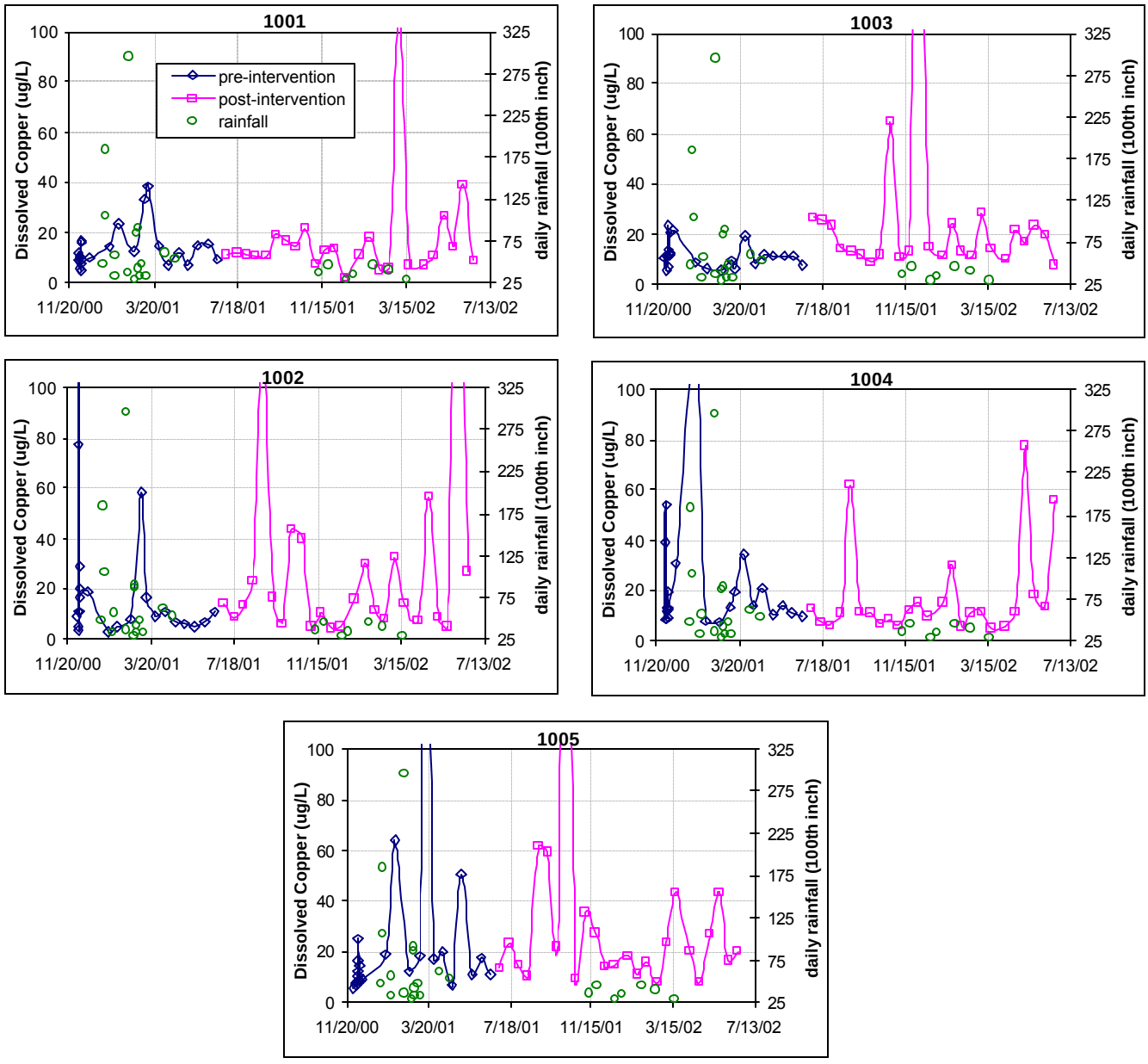

Figure A-6: Time Series of Dissolved Copper in Dry Weather Samples (all data)

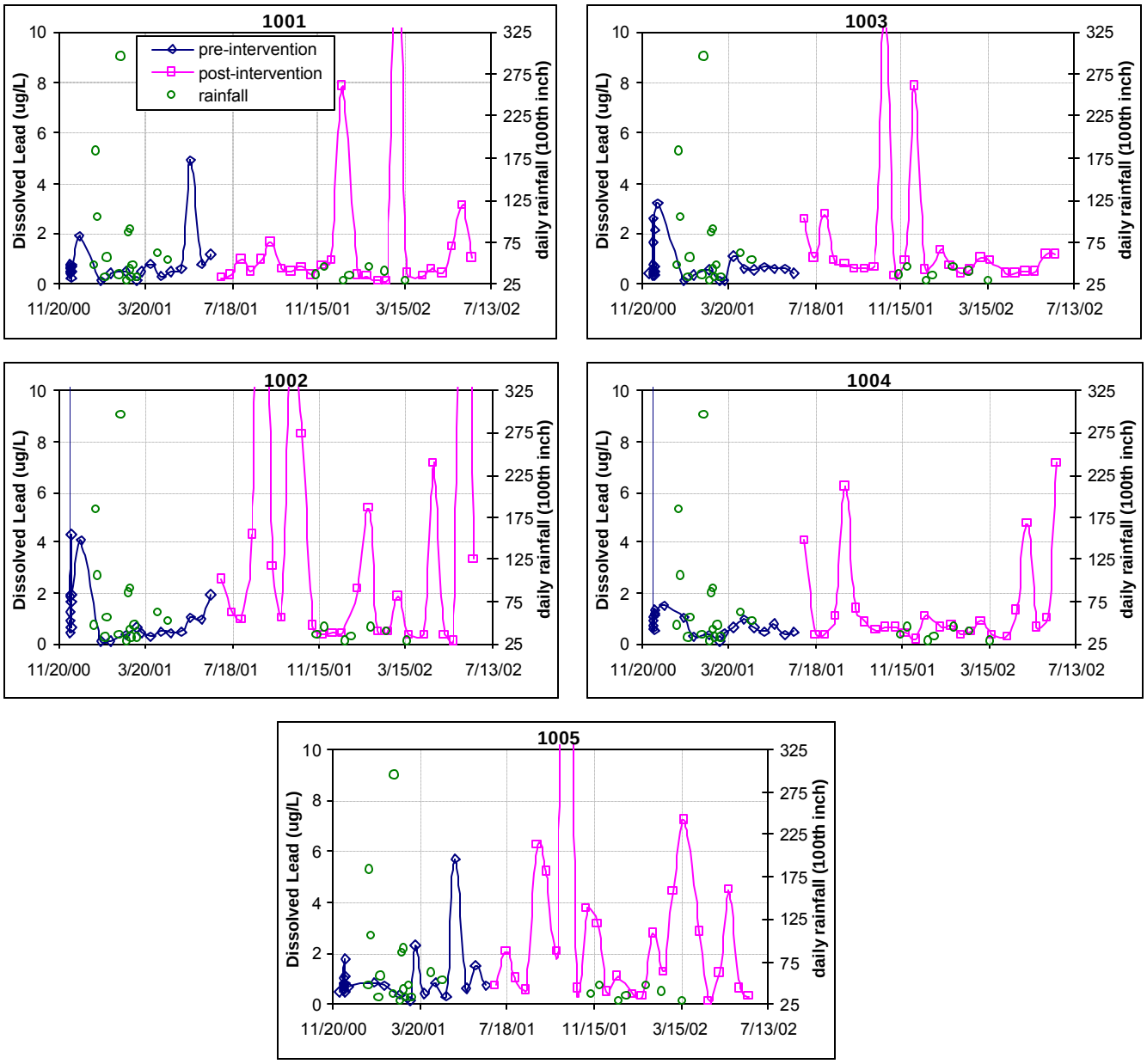

Figure A-7: Time Series of Dissolved Lead in Dry Weather Samples (all data)

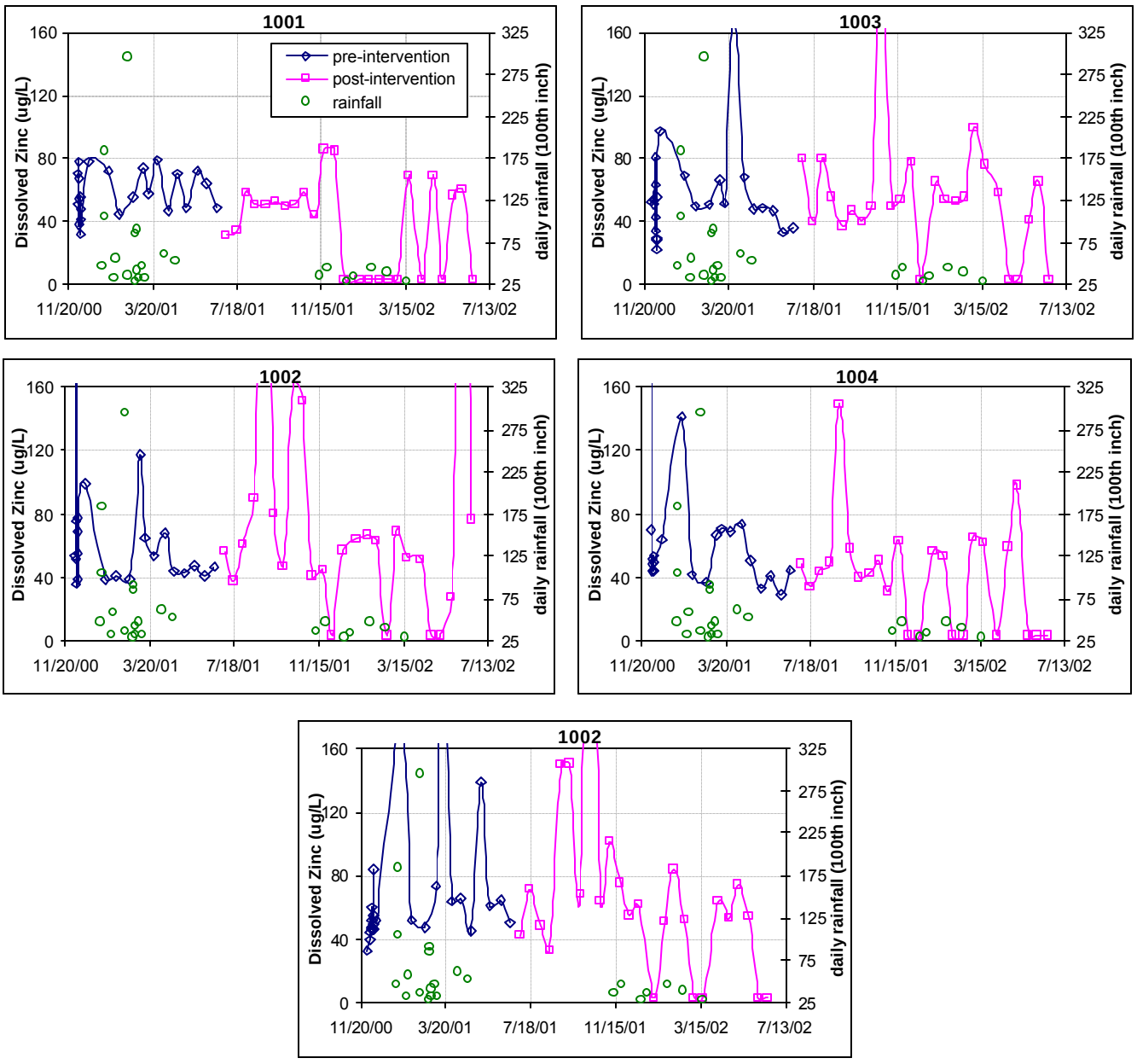

Figure A-8: Time Series of Dissolved Zinc in Dry Weather Samples (all data)

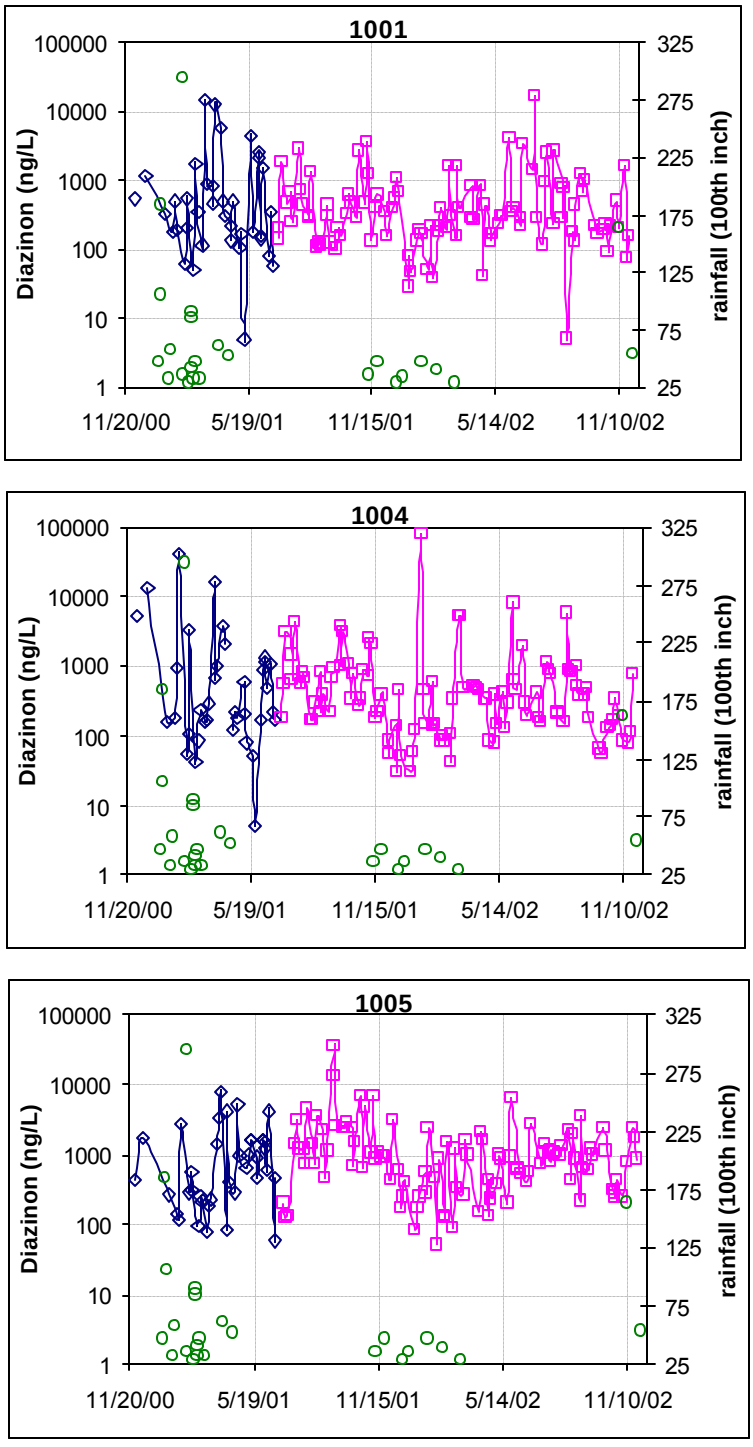

Figure A-9: Time Series of Diazinon in Dry Weather Samples (all data)

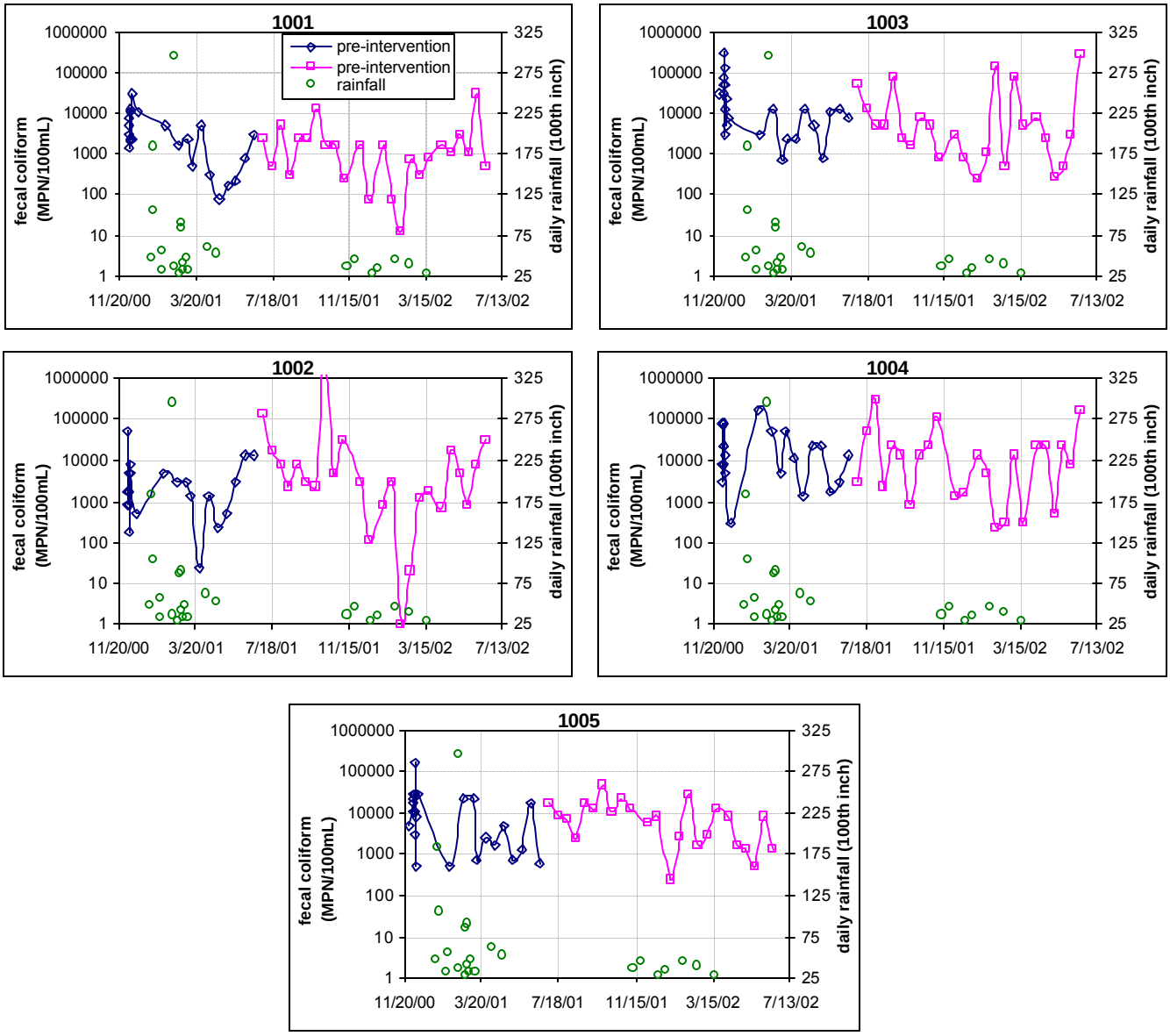

Figure A-10: Time Series of Fecal Coliform in Dry Weather Samples (all data)

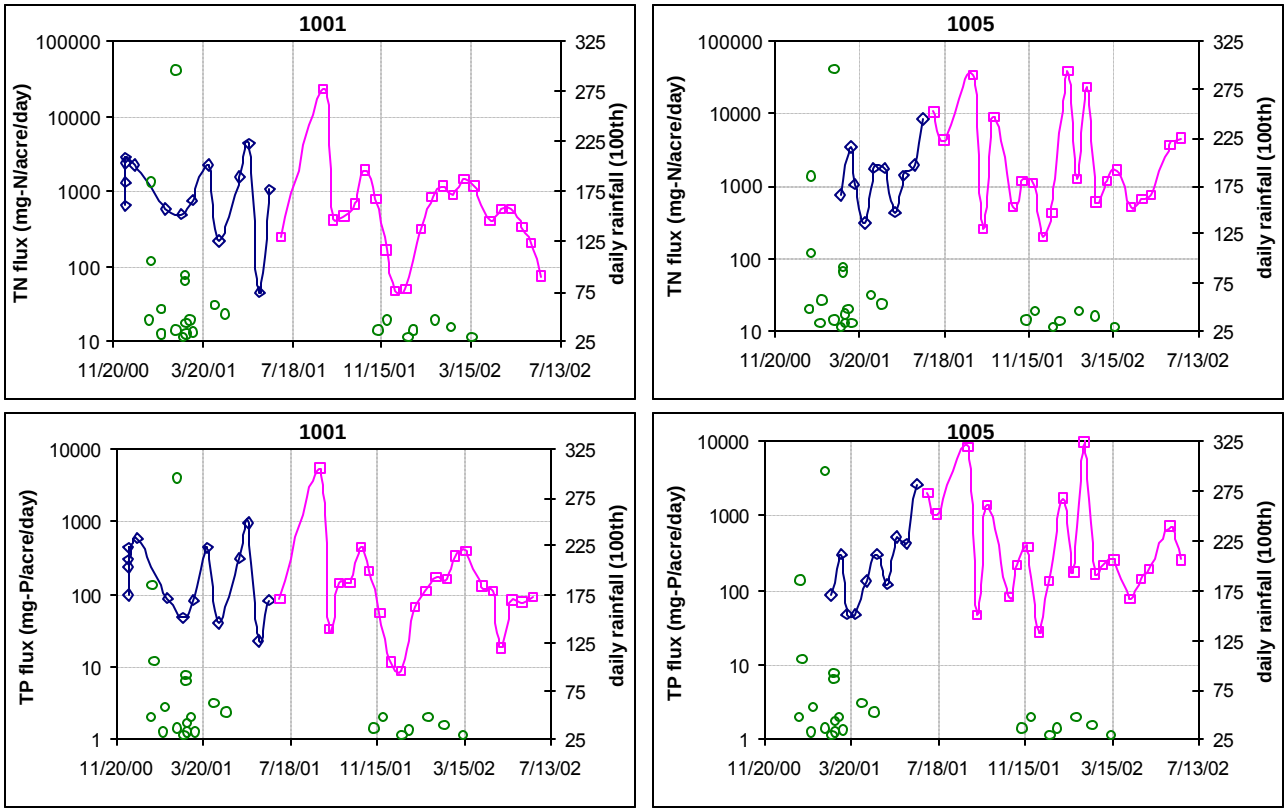

Figure A-11: Time Series of Nutrient Fluxes in Dry Weather Samples (all data)

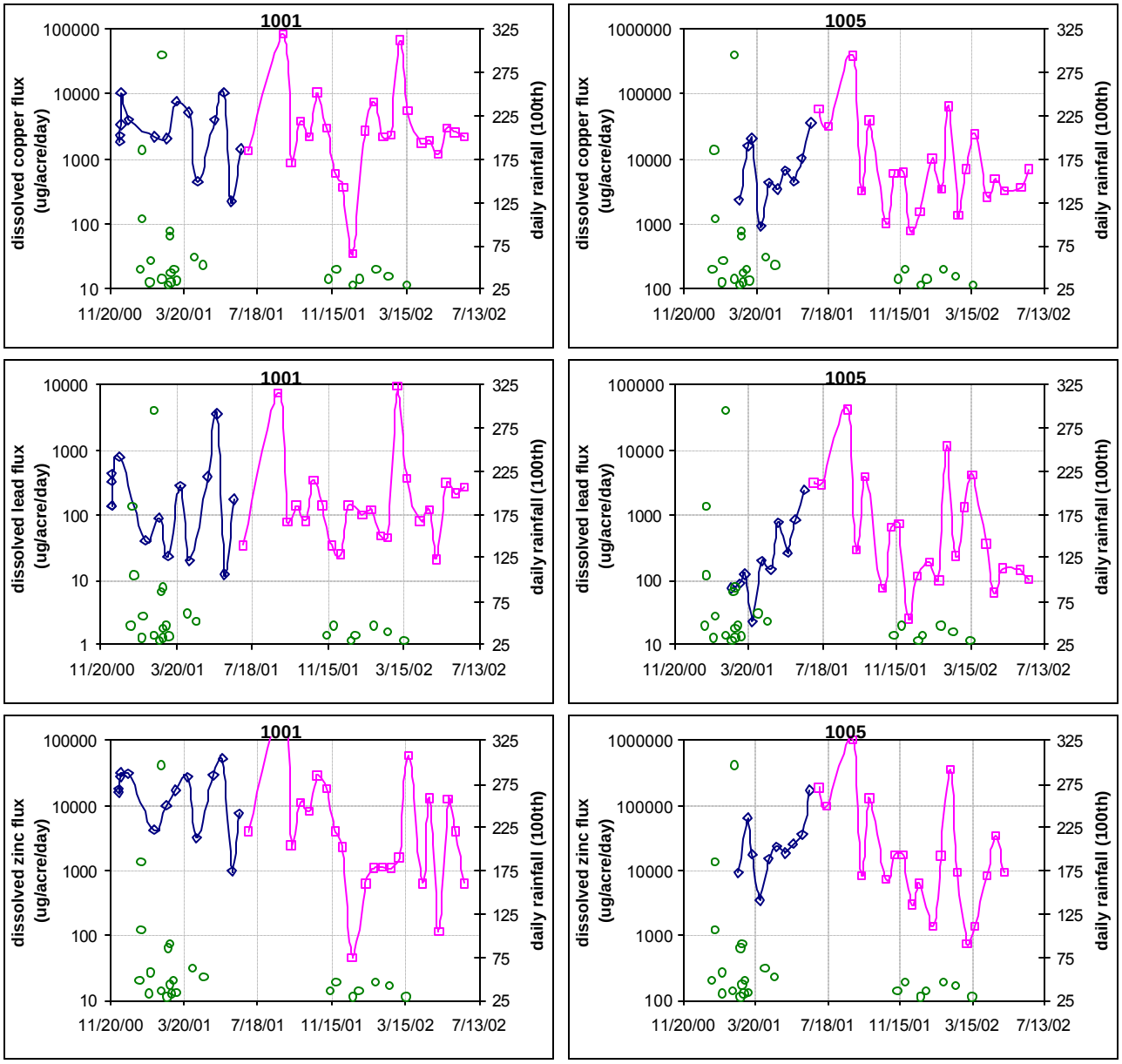

Figure A-12: Time Series of Dissolved Metal Fluxes in Dry Weather Samples (all data)

Appendix B – Summary Statistics

Table B-1: Descriptive Statistics

		1001		1002		1003		1004		1005	
Parameter	**Statistic**	**Pre**	**Post**	**Pre**	**Post**	**Pre**	**Post**	**Pre**	**Post**	**Pre**	**Post**
Nitrate/Nitrite as N	**n**	23	25	23	25	24	25	23	25	24	25
(mg-N/L)	**% > MDL/RL**	100%	96%	96%	96%	100%	100%	100%	100%	100%	100%
	Mean	2.56	1.47	2.57	1.07	2.13	1.71	36.50	6.61	2.61	4.13
	Median	2.32	1.38	1.56	0.93	1.68	0.94	16.88	2.29	2.45	1.48
	Trimmed mean	2.37	1.44	1.80	0.89	1.61	1.01	25.04	3.33	2.41	1.60
	min	0.74	0.05	0.05	0.05	0.65	0.20	1.70	0.60	0.54	0.73
	max	5.26	2.97	7.42	3.92	9.96	10.16	109.90	34.40	6.21	64.90
	25th percentile	1.81	1.05	0.82	0.53	0.98	0.64	5.62	1.43	1.79	0.96
	75th percentile	3.10	1.99	3.77	1.18	2.49	1.60	70.76	8.95	3.11	2.22
	St Dev	1.08	0.70	2.34	0.91	1.94	2.21	37.82	8.78	1.40	12.68
	IQR	1.29	0.94	2.95	0.65	1.51	0.96	65.14	7.52	1.32	1.26
	Skewness, gs	0.84	0.14	1.00	1.89	3.11	2.96	0.76	2.01	1.19	4.98
	gcr	0.96	0.92	0.96	0.92	0.94	0.92	0.96	0.92	0.94	0.92
	symmetric?	Y	Y	N	N	N	N	Y	N	N	N
TKN	**n**	23	25	23	25	24	25	23	24	24	25
(mg-N/L)	**% > MDL/RL**	100%	64%	100%	84%	96%	92%	96%	92%	100%	96%
	Mean	1.68	1.63	2.74	2.37	1.97	2.71	11.50	3.72	4.08	3.61
	Median	1.27	1.21	1.78	1.90	1.38	1.46	4.26	1.91	2.23	2.39
	Trimmed mean	1.29	0.77	1.95	1.87	1.40	1.69	7.51	2.23	2.29	2.57
	min	0.88	0.25	0.68	0.25	0.25	0.25	1.44	0.25	0.76	0.25
	max	6.02	11.00	13.20	7.48	9.97	18.60	31.81	18.60	17.43	15.30
	25th percentile	1.13	0.25	1.33	1.13	1.01	1.20	2.55	1.41	1.88	1.71
	75th percentile	1.57	1.46	2.86	2.98	1.85	2.87	21.46	4.03	3.15	4.01
	St Dev	1.19	2.40	2.68	1.96	1.97	3.64	11.61	4.21	4.90	3.41
	IQR	0.44	1.21	1.53	1.85	0.84	1.67	18.90	2.62	1.26	2.30
	Skewness	2.84	3.16	3.00	1.23	3.24	3.77	0.75	2.31	2.29	2.34
	Gcr	0.96	0.92	0.96	0.92	0.94	0.92	0.96	0.92	0.94	0.92
	symmetric?	N	N	N	N	N	N	Y	N	N	N
Ammonia as N	**n**	23	25	23	25	24	25	23	24	24	25

		1001		1002		1003		1004		1005	
Parameter	**Statistic**	**Pre**	**Post**	**Pre**	**Post**	**Pre**	**Post**	**Pre**	**Post**	**Pre**	**Post**
	% >										
(mg-N/L)	**MDL/RL**	30%	20%	74%	64%	75%	52%	87%	71%	92%	96%
	Mean	0.13	0.08	0.25	0.42	0.26	0.29	7.05	0.25	0.85	0.42
	Median	0.05	0.05	0.18	0.20	0.17	0.10	0.71	0.14	0.43	0.22
	Trimmed mean	0.05	0.05	0.19	0.13	0.19	0.11	3.43	0.12	0.50	0.24
	min	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
	max	1.12	0.36	0.90	5.45	1.06	2.29	26.34	2.03	6.92	2.41
	25th percentile	0.05	0.05	0.08	0.05	0.09	0.05	0.24	0.05	0.24	0.15
	75th percentile	0.12	0.05	0.30	0.28	0.29	0.36	13.69	0.28	0.94	0.42
	St Dev	0.23	0.07	0.22	1.06	0.26	0.48	9.14	0.40	1.39	0.50
	IQR	0.07	0.00	0.22	0.23	0.20	0.31	13.45	0.23	0.70	0.27
	Skewness	4.04	3.08	1.66	4.78	1.98	3.40	0.93	4.09	3.95	3.01
	gcr	0.96	0.92	0.96	0.92	0.94	0.92	0.96	0.92	0.94	0.92
	symmetric?	N	N	N	N	N	N	Y	N	N	N
TN (calculated)	**n**	23	25	23	25	23	25	23	25	23	25
	% >										
(mg-N/L)	**MDL/RL**	100%	80%	98%	90%	98%	96%	98%	96%	100%	98%
	Mean	4.24	3.09	5.31	3.44	3.66	4.42	48.00	10.18	6.89	7.74
	Median	3.84	2.27	3.95	2.55	2.66	2.50	19.01	5.57	5.06	4.36
	Trimmed mean	3.94	2.40	4.53	2.76	2.93	3.01	33.11	6.47	5.08	4.42
	min	2.30	0.30	1.50	0.78	1.46	0.45	3.28	0.74	2.48	1.07
	max	6.76	12.99	13.83	11.40	12.12	19.91	141.06	40.80	20.41	67.12
	25th percentile	3.20	1.79	2.27	2.10	2.11	2.04	9.05	2.71	3.52	3.47
	75th percentile	5.68	3.13	8.02	4.36	4.81	5.17	94.79	19.18	7.07	5.62
	St Dev	1.41	2.67	3.56	2.51	2.48	4.39	49.17	10.73	5.29	12.85
	IQR	2.48	1.34	5.75	2.26	2.70	3.13	85.74	16.47	3.55	2.15
	Skewness	0.55	2.82	0.84	1.87	2.13	2.27	0.74	1.37	1.88	4.46
	gcr	0.96	0.92	0.96	0.92	0.94	0.92	0.96	0.92	0.94	0.92
	symmetric?	Y	N	Y	N	N	N	Y	N	N	N
ortho-phosphate	**n**	23	25	23	25	24	25	23	25	24	25
	% >										
(mg-P/L)	**MDL/RL**	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
	Mean	0.71	0.58	0.79	0.72	0.81	1.26	2.84	1.40	0.89	1.00
	Median	0.58	0.53	0.73	0.72	0.64	0.64	2.23	1.10	0.76	0.77
	Trimmed mean	0.60	0.56	0.69	0.70	0.63	0.66	2.42	1.10	0.77	0.87
	min	0.23	0.26	0.28	0.15	0.11	0.19	0.52	0.43	0.33	0.22
	max	1.58	1.08	2.25	1.56	4.01	10.60	6.57	6.45	2.31	3.11
	25th percentile	0.47	0.38	0.48	0.41	0.38	0.47	1.25	0.75	0.55	0.59
	75th	0.86	0.72	0.96	0.93	0.92	0.89	4.63	1.42	0.98	1.29

		1001		1002		1003		1004		1005	
Parameter	**Statistic percentile**	**Pre**	**Post**	**Pre**	**Post**	**Pre**	**Post**	**Pre**	**Post**	**Pre**	**Post**
	St Dev	0.37	0.23	0.47	0.39	0.77	2.11	1.89	1.35	0.49	0.62
	IQR	0.39	0.34	0.48	0.52	0.54	0.42	3.38	0.67	0.44	0.70
	Skewness	1.13	0.60	1.55	0.32	3.27	4.03	0.60	3.03	1.66	1.79
	gcr	0.96	0.92	0.96	0.92	0.94	0.92	0.96	0.92	0.94	0.92
	symmetric?	N	Y	N	Y	N	N	Y	N	N	N
TP	**n**	23	25	23	25	24	25	23	24	24	25
	% >										
(mg-P/L)	**MDL/RL**	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
	Mean	0.73	0.60	0.92	0.84	0.98	1.21	3.33	1.50	1.01	1.19
	Median	0.60	0.51	0.77	0.82	0.62	0.67	2.54	1.05	0.73	0.85
	Trimmed mean	0.61	0.53	0.72	0.77	0.65	0.68	2.73	1.06	0.72	0.95
	min	0.27	0.26	0.11	0.16	0.11	0.23	0.53	0.34	0.33	0.22
	max	1.55	1.22	3.65	1.69	6.18	11.70	10.37	6.38	3.92	3.32
	25th percentile	0.47	0.39	0.43	0.49	0.35	0.49	1.52	0.60	0.50	0.60
	75th percentile	0.97	0.67	0.94	1.08	1.08	0.87	5.11	1.55	0.91	1.46
	St Dev	0.38	0.27	0.77	0.47	1.26	2.23	2.58	1.51	0.92	0.83
	IQR	0.50	0.28	0.51	0.59	0.73	0.38	3.59	0.96	0.40	0.86
	Skewness	1.00	1.07	2.27	0.49	3.39	4.68	1.26	2.41	2.35	1.38
	gcr	0.96	0.92	0.96	0.92	0.94	0.92	0.96	0.92	0.94	0.92
	symmetric?	N	N	N	Y	N	N	N	N	N	N
Cadmium	**n**	23	25	23	25	24	25	23	25	24	25
	% >										
(ug/L)	**MDL/RL**	61%	12%	61%	36%	38%	16%	74%	36%	38%	44%
	Mean	0.26	0.14	0.47	0.44	0.27	0.17	0.64	0.22	0.21	0.29
	Median	0.27	0.10	0.24	0.10	0.10	0.10	0.36	0.10	0.10	0.10
	Trimmed mean	0.20	0.10	0.20	0.12	0.12	0.10	0.33	0.12	0.12	0.15
	min	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10
	max	0.56	0.79	3.40	3.50	1.77	0.92	4.54	1.22	0.92	1.89
	25th percentile	0.10	0.10	0.10	0.10	0.10	0.10	0.16	0.10	0.10	0.10
	75th percentile	0.39	0.10	0.40	0.26	0.26	0.10	0.42	0.23	0.25	0.45
	St Dev	0.15	0.15	0.78	0.79	0.37	0.20	1.15	0.25	0.20	0.37
	IQR	0.29	0.00	0.30	0.16	0.16	0.00	0.27	0.13	0.15	0.35
	Skewness	0.29	4.04	3.21	3.06	3.37	3.08	3.09	3.05	2.56	3.47
	gcr	0.96	0.92	0.96	0.92	0.94	0.92	0.96	0.92	0.94	0.92
	symmetric?	Y	N	N	N	N	N	N	N	N	N
Copper	**n**	23	25	23	25	24	25	23	25	24	25
	% >										
(ug/L)	**MDL/RL**	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
	Mean	13.5	16.9	27.3	30.3	11.5	26.6	21.8	17.7	32.1	30.8
	Median	11.5	11.4	10.9	14.0	11.1	14.3	12.7	11.4	12.3	20.4

Parameter	Statistic	1001 Pre	1001 Post	1002 Pre	1002 Post	1003 Pre	1003 Post	1004 Pre	1004 Post	1005 Pre	1005 Post
	Trimmed mean	11.6	12.1	10.7	15.4	10.7	16.2	13.9	11.3	13.2	19.8
	min	5.2	1.9	3.2	4.6	5.6	7.2	7.3	5.1	5.4	7.9
	max	38.4	108.0	278.4	226.6	23.4	227.0	119.3	77.4	389.6	210.0
	25th percentile	8.4	8.8	6.2	8.0	8.0	11.6	10.0	7.5	8.7	14.2
	75th percentile	15.0	16.9	17.9	29.8	12.3	23.4	20.5	15.2	18.6	27.5
	St Dev	8.3	20.5	57.5	48.2	5.1	43.3	24.2	18.9	77.4	40.2
	IQR	6.7	8.1	11.8	21.8	4.2	11.8	10.5	7.7	9.9	13.3
	Skewness	1.9	4.0	4.1	3.3	1.1	4.5	3.3	2.3	4.7	4.0
	gcr	0.96	0.92	0.96	0.92	0.94	0.92	0.96	0.92	0.94	0.92
	symmetric?	N	N	N	N	N	N	N	N	N	N
Lead	n	23	25	23	25	24	25	23	25	24	25
(ug/L)	% > MDL/RL	91%	92%	91%	96%	88%	100%	96%	100%	96%	96%
	Mean	0.79	1.59	5.93	4.72	0.82	1.59	3.47	1.47	1.01	3.24
	Median	0.60	0.60	0.89	1.20	0.59	0.81	0.72	0.69	0.74	1.30
	Trimmed mean	0.57	0.62	0.94	1.65	0.56	0.81	0.77	0.76	0.72	1.79
	min	0.10	0.10	0.10	0.10	0.10	0.28	0.10	0.21	0.10	0.10
	max	4.91	14.90	81.70	30.87	3.19	10.90	37.74	7.16	5.70	28.10
	25th percentile	0.46	0.38	0.41	0.40	0.42	0.53	0.48	0.44	0.52	0.62
	75th percentile	0.74	0.97	1.91	4.30	0.71	1.14	1.13	1.09	0.92	3.77
	St Dev	0.97	3.18	17.63	8.10	0.79	2.46	9.19	1.91	1.11	5.56
	IQR	0.28	0.59	1.50	3.90	0.29	0.61	0.65	0.65	0.40	3.15
	Skewness	3.81	3.63	4.06	2.58	1.95	3.16	3.32	2.14	3.62	4.02
	gcr	0.96	0.92	0.96	0.92	0.94	0.92	0.96	0.92	0.94	0.92
	symmetric?	N	N	N	N	N	N	N	N	N	N
Zinc	n	23	25	23	25	24	25	23	25	24	25
(ug/L)	% > MDL/RL	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
	Mean	58.7	37.2	115.2	86.3	56.3	56.8	83.6	40.9	74.0	75.0
	Median	56.0	50.2	53.4	57.2	50.7	53.9	50.8	43.8	52.4	54.5
	Trimmed mean	58.6	26.4	54.2	57.6	51.2	53.1	53.2	27.7	54.5	58.3
	min	32.5	2.5	35.4	2.5	22.1	2.5	29.5	2.5	32.3	2.5
	max	79.2	86.2	1069.7	429.6	171.0	231.0	429.0	149.0	330.0	512.0
	25th percentile	48.1	2.5	41.7	40.4	40.9	40.2	43.3	2.5	46.9	42.8
	75th percentile	71.4	58.2	72.1	76.9	63.9	65.5	69.0	58.6	64.6	74.5
	St Dev	14.1	29.1	219.7	109.1	29.9	44.4	97.0	35.1	63.0	99.1
	IQR	23.2	55.7	30.4	36.5	23.0	25.3	25.7	56.1	17.7	31.7
	Skewness	-0.1	-0.1	4.1	2.6	2.6	2.4	3.0	1.1	3.4	3.8
	gcr	0.96	0.92	0.96	0.92	0.94	0.92	0.96	0.92	0.94	0.92

		1001		1002		1003		1004		1005	
Parameter	**Statistic**	**Pre**	**Post**	**Pre**	**Post**	**Pre**	**Post**	**Pre**	**Post**	**Pre**	**Post**
	symmetric?	Y	Y	N	N	N	N	N	N	N	N
Diazinon	**n**	37	104					36	104	39	104
(ng/L)	**% > MDL/RL**	97%	99%					97%	100%	100%	100%
	Mean	1457	748					2694	1556	1295	1711
	Median	345	291					231	346	614	884
	Trimmed mean	420	352					442	369	783	902
	min	5	5					5	29	60	53
	max	14465	16590					41402	80969	7910	34838
	25th percentile	156.8	166.6					157.6	150.2	262.8	415.8
	75th percentile	890.4	641.6					1119.2	791.3	1601.5	1609.8
	St Dev	3140.5	1753.2					7505.6	7977.2	1655.4	3741.7
	IQR	733.6	475.0					961.6	641.1	1338.7	1194.0
	Skewness	3.4	7.5					4.4	9.8	2.3	7.2
	gcr	0.77	0.47					0.78	0.47	0.75	0.47
	symmetric?	N	N					N	N	N	N
Chlorpyrifos	**n**	37	104								
(ng/L)	**% > MDL/RL**	57%	40%								
	Mean	38.3	456.4								
	Median	25.0	10.0								
	Trimmed mean	18.9	10.0								
	min	5.0	5.0								
	max	213.7	45094.0								
	25th percentile	10.0	5.0								
	75th percentile	42.2	28.7								
	St Dev	51.1	4419.7								
	IQR	32.2	23.7								
	Skewness	2.5	10.2								
	gcr	0.77	0.47								
	symmetric?	N	N								

Appendix C – Probability Plot Comparisons

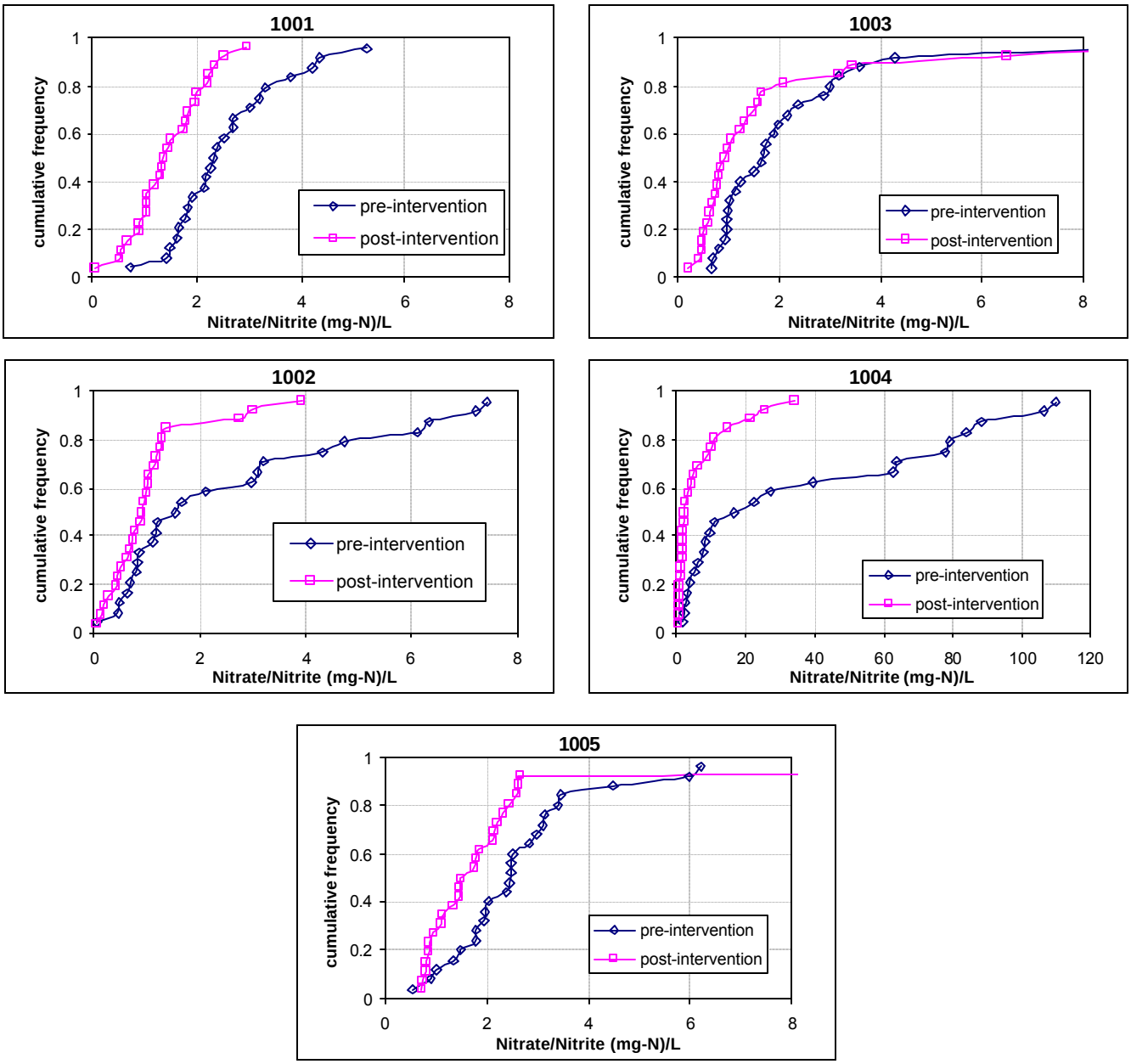

Figure C-1: Cumulative Frequency of Nitrate/Nitrite in Dry Weather Samples (all data)

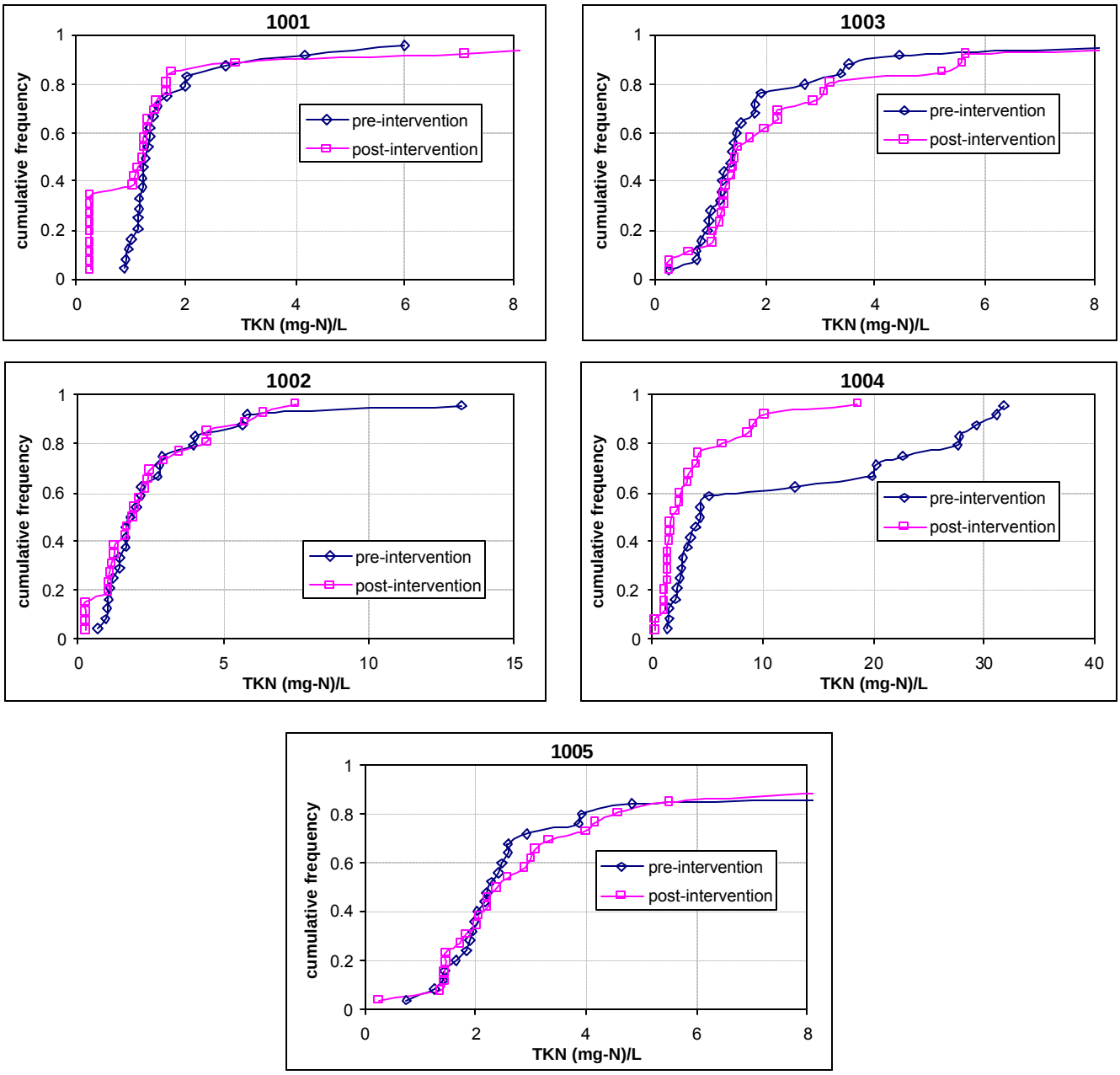

Figure C-2: Cumulative Distribution of TKN in Dry Weather Samples (all data)

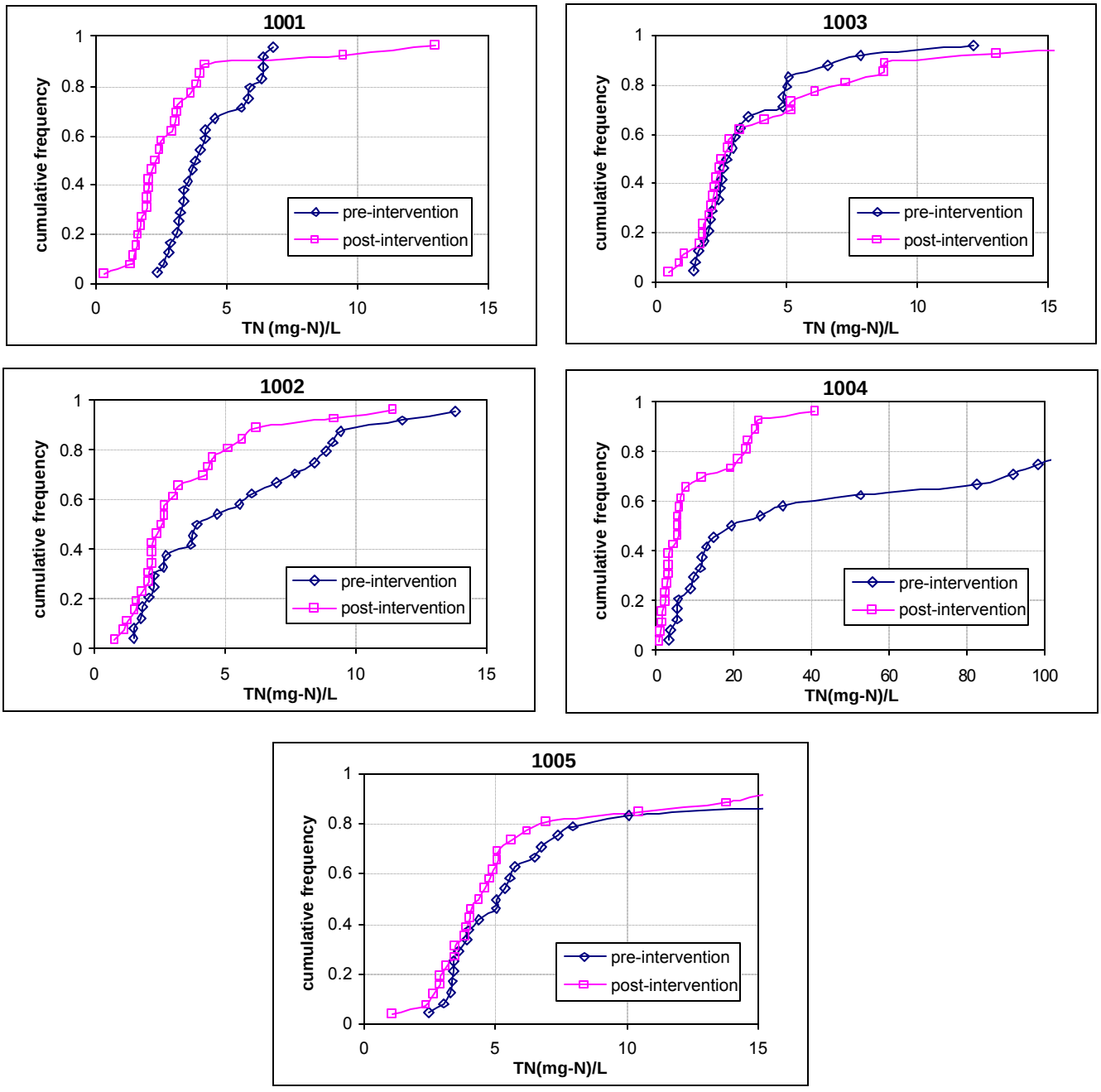

Figure C-3: Cumulative Distribution of TN (Calculated) in Dry Weather Samples (all data)

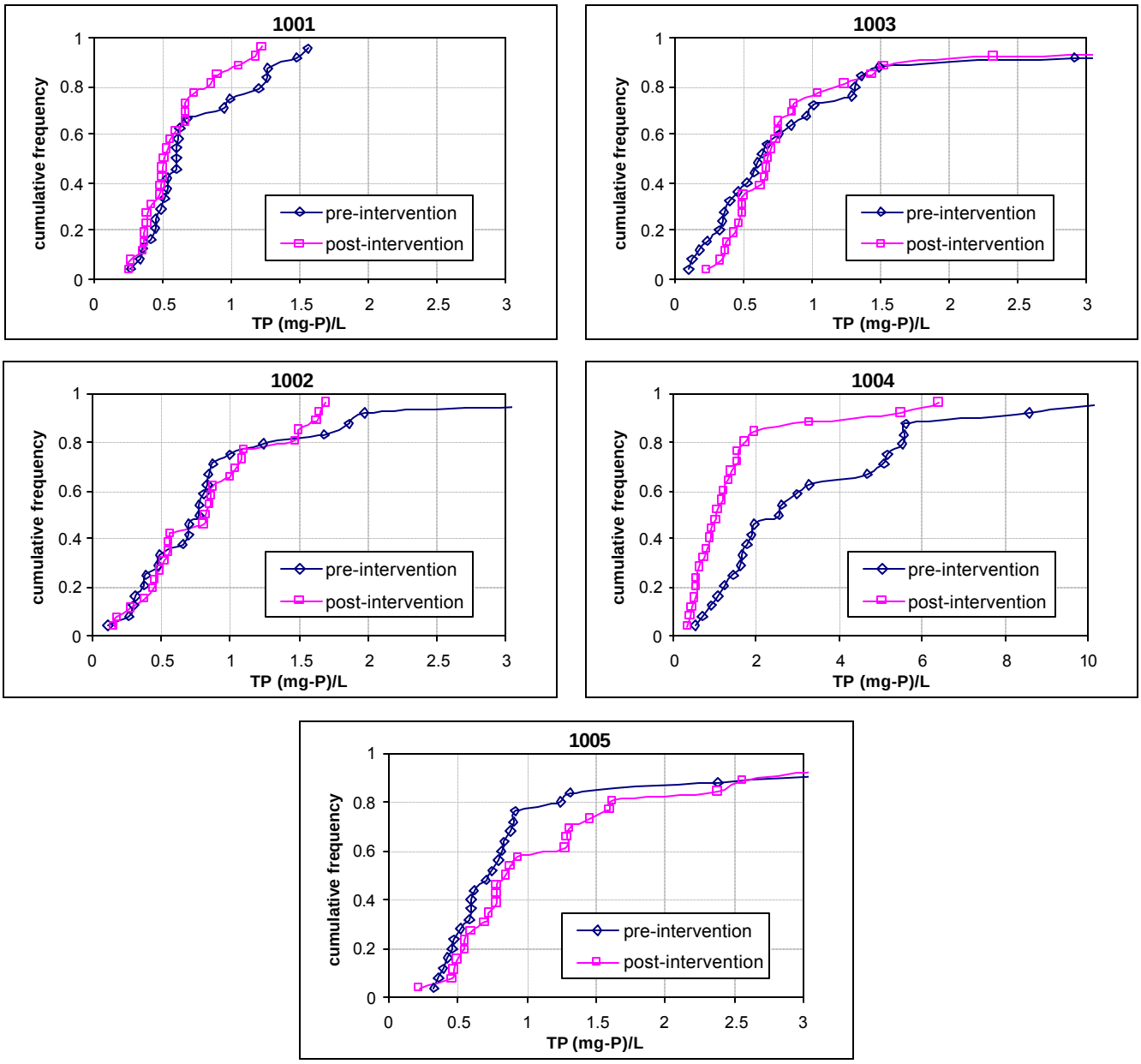

Figure C-4: Cumulative Distribution of TP in Dry Weather Samples (all data)

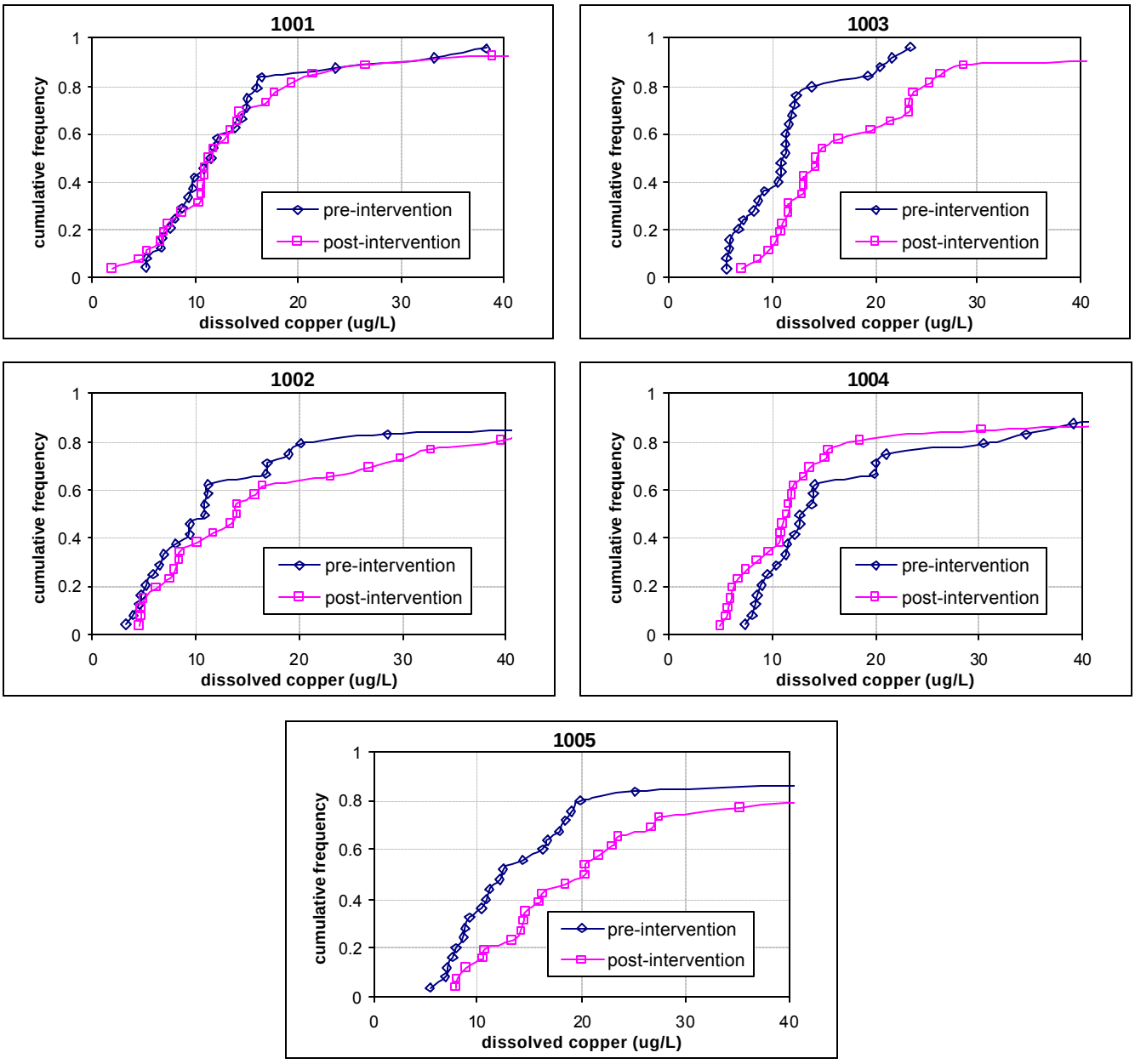

Figure C-5: Cumulative Distribution of Dissolved Copper in Dry Weather Samples (all data)

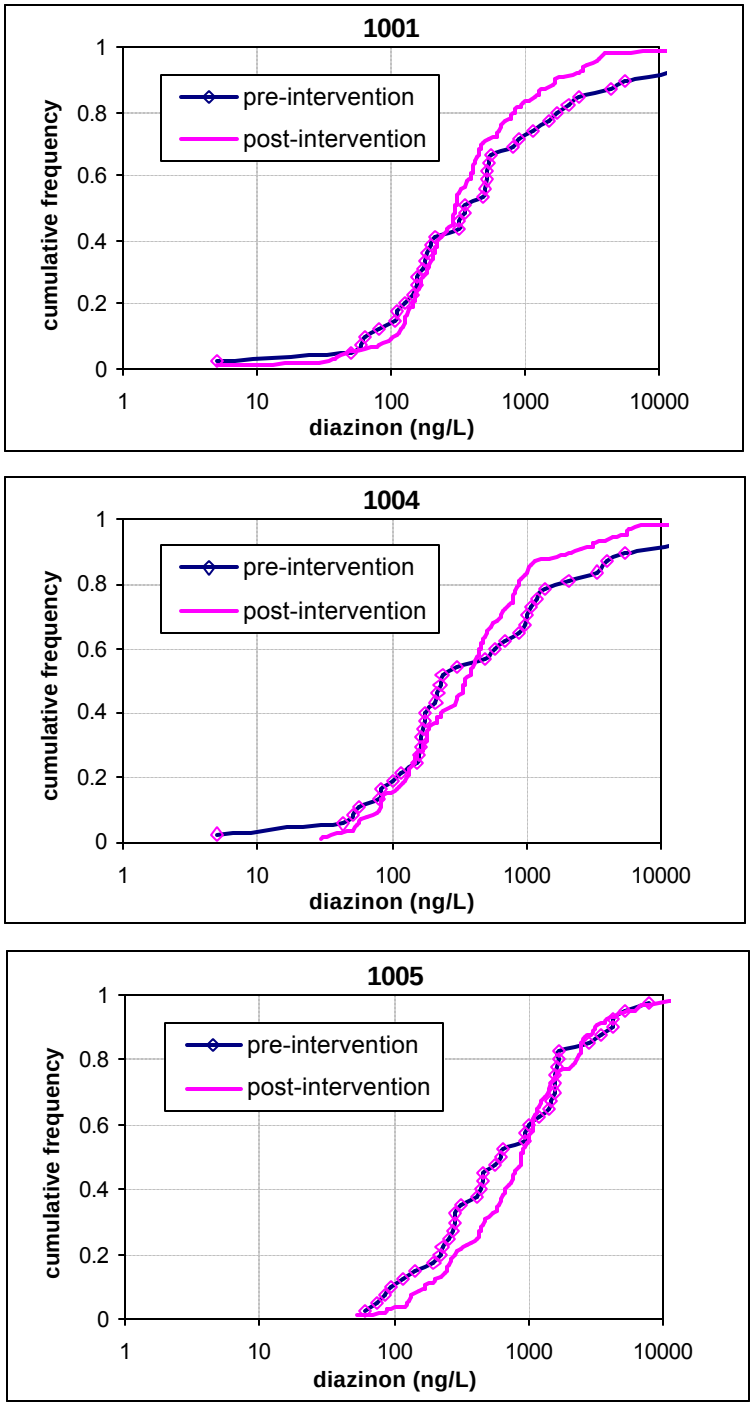

Figure C-6: Cumulative Distribution of Diazinon in Dry Weather Samples (all data)

Appendix F: Public Acceptance

The Residential Runoff Reduction Study

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Appendix F: Public Acceptance

This appendix is divided into two parts. The first section describes the customer service program during the R3 Study time period and includes results of pre- and post-intervention surveys. The second part provides a representative sampling of public education materials distributed during the study. There were three groups of R3 study participants. The first group was the education group and the second group was the participants who had their home irrigation controllers replaced with an ET controller and lastly the control groups that received no treatment. The education group was self and randomly selected. Some of the education group participants voluntarily choose to participate in the study by replying to a letter. However, the majority of the education group was randomly selected through a door-to door campaign. The retrofit participants were selected through random "cold knocking" and through letter solicitations that explained the study.

Customer Interactions

ET Controller Installation Overview

ET Controllers were installed in two phases. The first phase was the installation of controllers at residences. The controllers were installed on the weekends between April and June 2001. The second phase of the installation process was the retrofit of City of Irvine and HOA sites. The retrofitted HOA sites watered the common areas of condominium and the City of Irvine sites watered the medians and streetscapes. Both of these two groups were all in the same watershed as the residential homes that were retrofitted. Initially, the time per installation was approximately one to one and one-half hours, depending on the number of valves. However, as

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the IRWD staff became familiar with the process, which most had never done before, the time dropped to approximately one-half hour.

Residential post-installation concerns and problems

Home residents were advised that if they had any problems with the controller or if the controller required any adjustments, they should call the water district for assistance. IRWD's customer service department telephone number was left on the ET controller on a sticker. All calls related to the ET controller were logged in separately and routed to the appropriate staff member for assistance. Table 1 presents a summary of calls received from residential residents during the R3 study period. Generally, there were four common types of calls: 1) customer misunderstanding ("no problem" category), 2) installation-related issues, 3) system flaws, and 4) ET controller malfunctions.

Table 1: Telephone Log Summary

April 2001	1	August 2001	13	December 2001	1	April 2002	2
May 2001	12	September 2001	4	January 2002	4	May 2002	3
June 2001	7	October 2001	5	February 2002	9	June 2002	6
July 2001	13	November 2001	3	March 2002	4	July 2002	2

The first type were calls where the customer had a misunderstanding on the way the ET controllers were supposed to operate. In this type of call there was a "problem, where no problem actually existed". A common example was when a resident called to say that the sprinklers were not turning on every night. The staff member would then explain to the resident that with proper irrigation management it is normal if the irrigation sprinklers do not turn on every night.

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The second types of calls received were either related to programming or installation-related mistakes. These usually occurred when the installation staff entered an incorrect value in the programming process. In other cases, a landscape contractor for the City of Irvine or HOA sites had incorrectly programmed the controller. Both groups were instructed at the beginning of the study to call IRWD to meet with a staff member who would adjust the ET controller for them.

The third category of calls included problems that were a result of a lack of irrigation system maintenance or a flaw in the design of the system. These problems were the responsibility of the homeowner to fix and were not related to the actual malfunctioning of the ET controller. For example, a customer called customer service and said that his lawn was turning brown because it was not being watered correctly. A site visit by staff would discover that the controller was set correctly, but the problem was that overgrown plant material was interfering with the normal spray pattern of the nozzle. It was this obstruction by plant material that caused the brown spot and not the settings on the ET controller.

The fourth category of calls was related to the ET controller malfunctioning. The calls from study participants were that the controller had stopped responding and the display was frozen, incorrect date or time display, or a signal dropout caused by a faulty program version. If resetting the unit or resending the ET signal could not correct the problem, the ET controllers were often changed out with a new controller with the latest version of the program. City of Irvine and HOA controllers with older versions of the controller were upgraded by uploading a new version of the program from a device provided by the manufacturer.

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Tracking of Water Consumption of the City of Irvine and HOA Sites

In addition to responding to CSR calls, weekly meter reads were incorporated into the study as part of irrigation water management in order to monitor each site for excessive water usage. One ET controller installed for selected City of Irvine street landscapes was able to cover a larger area than the same controller installed in a residence. In addition, each of the City of Irvine retrofit sites had dedicated landscape irrigation water. Because of this, it was easier to track weekly water consumption of 18 meters instead of monitoring 112 residential meters. Weekly meter reads was a convenient way for staff to monitor water usage and to evaluate the performance of the ET controllers. Study staff periodically met with City of Irvine landscape staff to discuss the condition of the landscape and to discuss any other concerns. The landscape supervisor said that the appearance of the landscapes with the ET controllers were equal to similar city sites that did not have the ET controller.

One of the advantages of the ET controller is that it was able to receive a new ET signal if there was an unexpected change in weather conditions after a weekly signal had already been sent out. The controllers were grouped by water district zone, ET zone, and Zip code. Changes in weather conditions warranted staff to either increase the ETo or decrease the ET_o. During the rainy weeks, a signal would be sent to the all of the controllers that would pause the watering schedule for the appropriate number of days, this was referred to as a "rain pause signal". Additionally, the controllers had a feature that allowed each valve to be micro-managed without having to adjust the entire watering schedule.

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City of Irvine and Home Owner Associations

There are numerous benefits that can result from the installation of the ET controllers in a City environment as a water management tool. Costs that are associated with maintaining a city streetscape are labor hours and equipment. During the rainy season, city staff shuts off irrigation controllers for a given number of days that is determined by the amount of rainfall. This process is completed by manually having a city employee drive to each controller and turn the controllers off. This can be a very time intensive activity. In comparison the ET controllers are able to receive a rain pause signal and all the controllers in an area can be turned off within minutes. Hence, the ET controller can provide potential savings in labor and equipment required for programming each individual controller. It eliminates the guesswork as to whether or not to turn off the controllers. This savings in time and labor can be very substantial when the system needs to be shut down and then turned back on due to rain. With this system the city can allocate their resources more efficiently by focusing on landscape system maintenance instead of spending time on those tasks that can be performed with the ET controller technology. In addition, city staff will be able to cover a larger area. The water management features of the technology can maintain healthy landscapes and can help the city avoid penalty charges.

City and HOA controllers could be installed during regular business hours and no overtime was required for staff. These two groups were flexible about the installation times. In future programs or implementation of this technology it may be possible to train the local landscaper or contractor to install and monitor the controller. Monitoring the controller includes inspections of the irrigated area and meter reads. The local landscapers are probably the most familiar with irrigation controllers and could be cost effective to have them install the ET controller.

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Customer Surveys

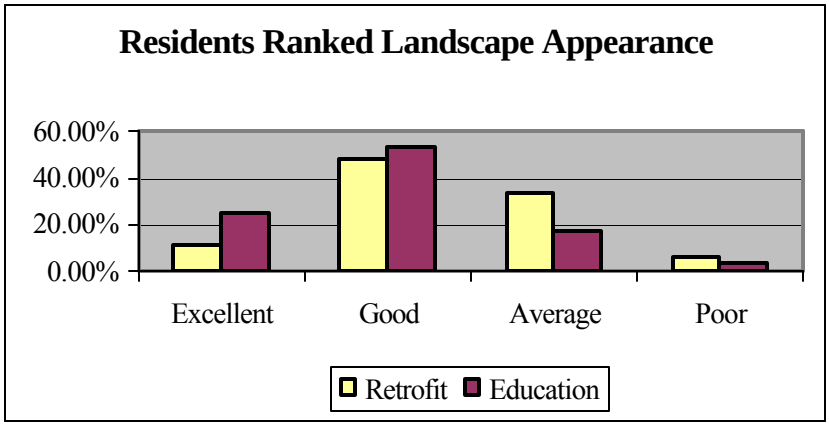
Pre-Survey Goal

The purpose of the pre-survey was to determine if the retrofit group and the education had similar irrigation practices and attitudes.

Survey Distribution

The pre-survey was distributed to the retrofit group while installation of the controller was taking place. Retrofit study participants were asked to fill-out the survey while staff was installing the controller. The education group received their survey as part of the initial educational packet that was randomly distributed to residents. Education group participants were provided a stamped addressed envelope to return their survey to the Irvine Ranch Water District. Ninety-seven (109/112) percent of those that received a survey from the retrofit group mailed the survey back. Twenty-four percent (53/225) of residents in the education group mailed back a survey.

Figure 1: Landscape Appearance

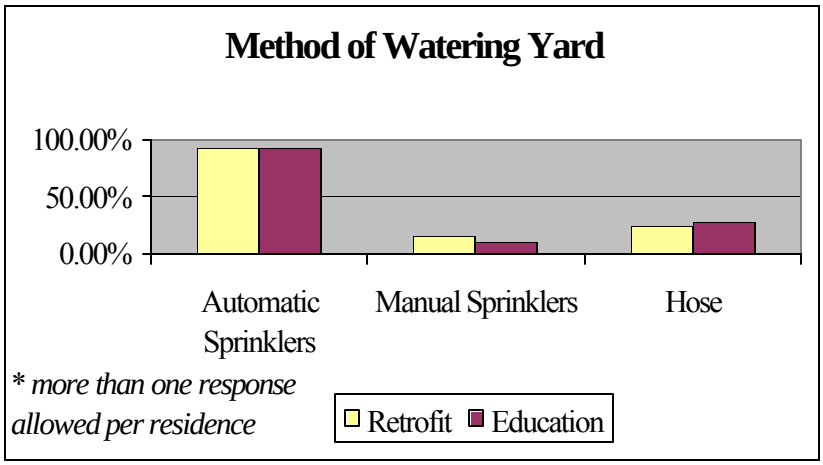


Selected Responses

A look at Figure 1 to the right shows the responses of both of the groups. Both groups gave similar responses. A majority of the residents in both groups believe that the appearance of the yard is average to good. Notice that the "excellent" response was selected by more of the education group that the retrofit group. One possible explanation for

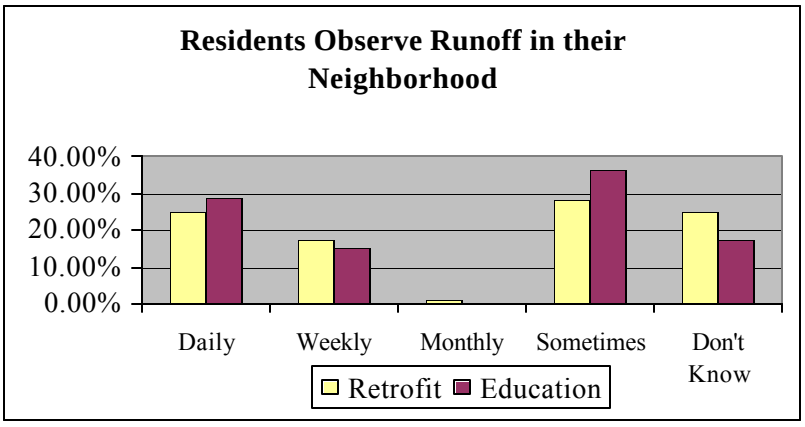
this response is that the staff was on-site while people were filling out their survey in the retrofit group.

Figure 2: Watering Methods



Residents were asked how they watered their lawn. Figure 2 shows responses across groups were very similar. The percentage of people in the retrofit and education group that use automatic sprinklers, manual sprinklers, or a hose are similar. The survey shows that the retrofit and education groups have similar watering behaviors. A majority of the participants used automatic sprinklers. This is important because the R3 study focuses on retrofitting the automatic irrigation controllers as a water management tool.

Figure 3: Runoff Observed



Residents were asked how often they observed runoff in their neighborhood. The data presented in Figure 3 shows that residents in both groups have similar attitudes and views of urban runoff.

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Residents were asked if they used fertilizers in their landscape. As shown Figure 4 at right, fertilizer use in both groups is almost the same. Their behavior when it comes to applying fertilizers is also the same.

Figure 4: Use of Fertilizers

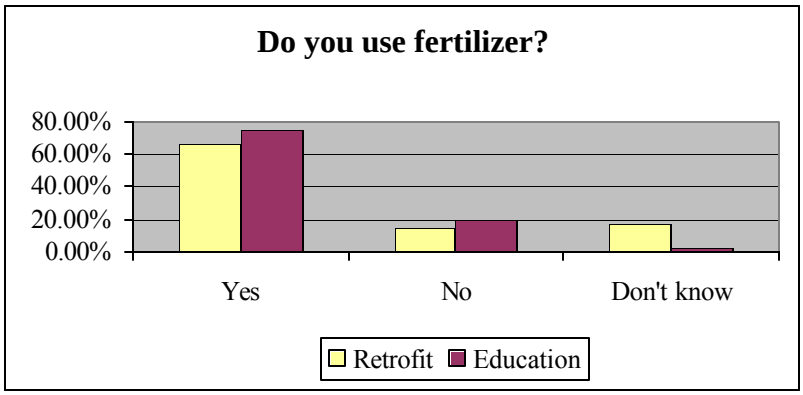

Figure 5: Use of Chemicals

Residents were also asked if they used chemicals to control pests or weeds in their yard. Figure 5 shows their responses.

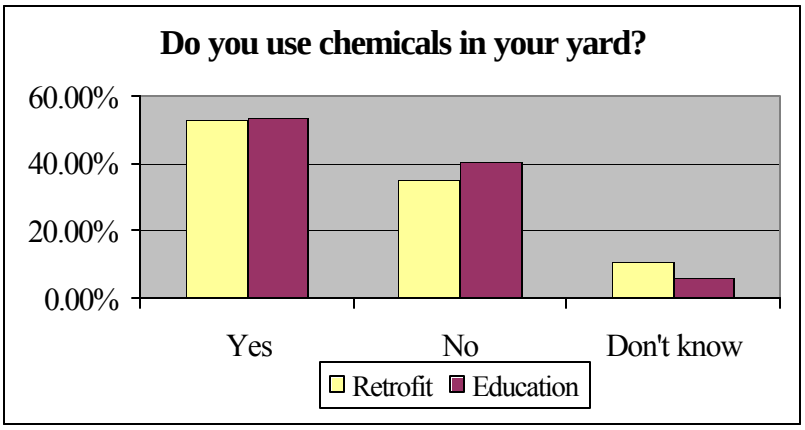

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Table 2: Pre-Survey Responses

R3 Study Pre-Survey Results		
	Retro	Education
Who is responsible for yard maintenance at your home?		
Adult	68.81%	76.92%
Children	3.67%	3.85%
Yard Service	49.54%	40.38%
How is your yard watered?		
Automatic Sprinklers	92.66%	92.31%
Manual Sprinklers	14.68%	9.62%
Hose	23.85%	26.92%
How often is your yard watered?		
Summer- Days Per Week	RV	RV
Summer-Minutes Per Day	RV	RV
Summer-Don't Know	10.09%	5.77%
Winter - Days Per Week	RV	RV
Winter - Minutes Per Day	RV	RV
Winter-Don't Know	10.09%	9.62%
Controller Times Changed	RV	RV
How often do you see water runoff in your neighborhood?		
Runoff in Neighborhood-Daily	24.77%	28.85%
Runoff in Neighborhood-Weekly	17.43%	15.38%
Runoff in Neighborhood-Monthly	0.92%	0.00%
Runoff in Neighborhood-Sometimes	28.44%	36.54%
Runoff in Neighborhood-Don't Know	24.77%	17.31%
How often are patios, sidewalks, and driveways cleaned at your home?		
Driveways are cleaned-Daily	0.00%	1.92%
Driveways are cleaned-Weekly	39.45%	40.38%
Driveways are cleaned-Monthly	24.77%	21.15%
Driveways are cleaned-Sometimes	33.03%	34.62%
Driveways are cleaned-Other	RV	RV
How do you clean driveways	RV	RV
Who is responsible for pest and weed control in your yard?		
I am - Responsible for Weed/Pest Control	59.63%	67.31%
Yard Service- Responsible for Weed/Pest Control	30.28%	17.31%
Pest Control Service - Responsible for Weed/Pest Control	15.60%	25.00%
Dont Use Weed or Pest Control Service	6.42%	11.54%
Other - Responsible for Weed/Pest Control	0.00%	0.00%
Do you use chemicals to control pests or weeds in your yard?		
Chemicals are used to control pests/weeds	53.21%	53.85%
Chemicals are not used to control pests/weeds	34.86%	40.38%
Don't know if chemicals are used	11.01%	5.77%
Chemicals used are	RV	RV
Chemicals used, How often?	RV	RV

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Do you use fertilizer in your yard?		
Fertilizer is used	66.06%	75.00%
Fertilizer is NOT used	14.68%	19.23%
Don't know if fertilizer is used	16.51%	1.92%
If Fertilizer used, which ones?	RV	RV
If Fertilizer used,how often?	RV	RV
Who is responsible for dispocal of unused landscape chemicals?		
I am - Responsible for disposal of unused chems	48.62%	63.46%
Pest Control - Responsible for disposal of unused chems	8.26%	5.77%
Yard Service - Responsible for disposal of unused chems	0.00%	0.00%
Don't know who - Responsible for disposal of unused chems	11.93%	7.69%
How are chems disposed of?	RV	RV
Rank the overall appearance of your yard?		
Appearance of yard-Excellent	11.93%	25.00%
Appearance of yard-Good	48.62%	53.85%
Appearance of yard-Average	33.94%	17.31%
Appearance of yard-Poor	6.42%	3.85%
Appearance of yard-Very Poor	0.00%	0.00%
How serious do you consider urban ruoff?		
Neighborhood Urban Runoff = Very Serious	6.42%	15.38%
Neighborhood Urban Runoff = Serious	16.51%	17.31%
Neighborhood Urban Runoff = Needs Improvement	46.79%	38.46%
Neighborhood Urban Runoff = No Problem	22.02%	23.08%
Irvine Urban Runoff = Very Serious	5.50%	15.38%
Irvine Urban Runoff = Serious	15.60%	11.54%
Irvine Urban Runoff = Needs Improvement	39.45%	42.31%
Irvine Urban Runoff = No Problem	18.35%	11.54%
Orange Co Urban Runoff = Very Serious	7.34%	15.38%
Orange Co Urban Runoff = Serious	21.10%	25.00%
Orange Co Urban Runoff = Needs Improvement	44.95%	34.62%
Orange Co Urban Runoff = No Problem	4.59%	1.92%
California Urban Runoff = Very Serious	13.76%	19.23%
California Urban Runoff = Serious	19.27%	21.15%
California Urban Runoff = Needs Improvement	40.37%	36.54%
California Urban Runoff = No Problem	3.67%	1.92%
Is there animal waste that gets left in you yard?		
Animal Waste is left in yard	35.78%	26.92%
Animal Wate is NOT left in yard	63.30%	69.23%
If Animal Waste is left in yard, then what type of animal	RV	RV
How many people live in your home?		
Household Adults	RV	RV
Household Children	RV	RV
*(RV) Responses Varied		

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Post-Survey Goal

The purpose of the post-survey was to determine the attitudes of the study participants towards the ET controller and to determine if the education material had an impact on modifying behavior of the recipients. Specifically, determining whether or not there was an acceptance of the ET controller as a way of managing their landscape and was there a change in irrigation practices and behaviors because of the education material.

Survey Distribution

The post-survey was distributed to both of the groups through the mail. Twenty-three (52/225) percent of the education group participants responded to the survey and forty-five percent (50/112) of the retrofit group participants responded.

ET Controller

The majority of the retrofit households acknowledged their satisfaction with the ET controller's performance and agreed that they would recommend the ET controller to their friends. It appears that the residents liked the controller and did not mind having someone else manage their irrigation-watering schedule. Data shows that households accepted the controller as a method of saving water, reducing runoff, and watering their landscape. The survey shows that twice the number of retrofit households observed a decrease in their water bill than the education households did. A majority of the education households did not observe a change in their water bills. Data appears to show that the appearances of the retrofit landscapes were ranked equally with those landscapes that were part of the education group. It can therefore be concluded that the survey showed that the lower use of water did not create landscaped that were inferior to the

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education group. The customer's perception of a lower bill is important for the success of any long-term conservation program.

The retrofit and education group were asked if they were willing to pay for an ET controller signal. A majority of the households in both of the groups would not be willing to pay for an ET signal. The ET controller costs approximately $150.00 and the signal fee is $48 per year. The ET controller would be able to save less than 2 ccfs per month, which is a savings of about $14 per year. It appears that the savings in water use per year is not large enough for the water customer to pay for an ET signal.

ET Controller Selected Responses

- 72% of the retrofit households were satisfied with the ET Controller.
- 70% of the retrofit households would recommend the ET Controller to others.
- 44% of the retrofit households saw a decrease in their water bill,
- 38% saw their bill as unchanged.
- 23% of the education households saw a decrease in their water bill,
- 63% saw their water bills as unchanged.
- 69% of the education households ranked the appearance of their yard as good to excellent.
- 70% of the retrofit households ranked the appearance of their yard as good to excellent.
- 69% of the education households would not be willing to pay for an ET signal.
- 58% of the retrofit households would not be willing to pay for an ET signal.

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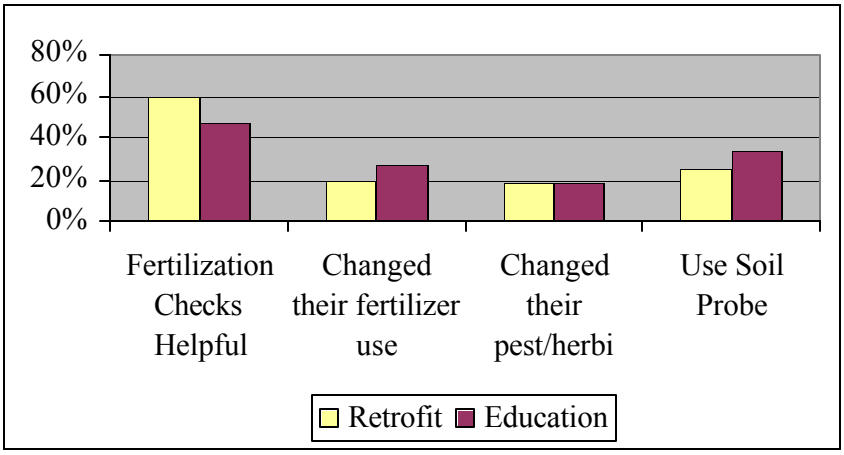
Education Program

Figure 6: Impacts on Education Program



The results of the education program are summarized on Figure 6. More than half of the education households acknowledged that they sometimes or most of the time would change the settings on their controller according to ET via the monthly letter's suggested schedule. Monthly letters provided monthly landscape maintenance tips. Here, the majority of the households in both of the groups liked the tips on the irrigation checks, and fertilization sections. Although most people read these sections, a vast majority (80%) of households in both of the groups did not change their use of pesticides, herbicides, or fertilizers. In addition to the education materials, a soil probe was given to both groups at the beginning of the study. A soil probe is a tool that takes a soil sample and allows the user to see the depth and amount of moisture available to the plants. This allows the user of the soil probe to determine if the plants require more or less irrigation. More than half of the households in both groups only used the soil probe once or not at all. The majority of the people never used the soil probe at all. From a program point of view, people enjoy the education materials but they appear to have little effect on modifying behavior.

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Education Material Selected Responses

- 54% of the education households changed their irrigation controller schedule (based on the recommendations included in the monthly tips) most of the time or sometimes.
- 58% of the education households and 42% of the retrofit households believed that the irrigation checks (part of the monthly tips) were helpful.
- 44% of the education households and 58% of the retrofit households believed that the fertilization checks (part of the monthly tips) were helpful.
- 81% of the education and 82% of the retrofit households have not changed their use of pesticides and herbicides.
- 73% of the education households and 80% of the retrofit households have not changed their use of fertilizer.
- 62% of the education households and 76% of retrofit households did not use the soil probe or they only used it once.

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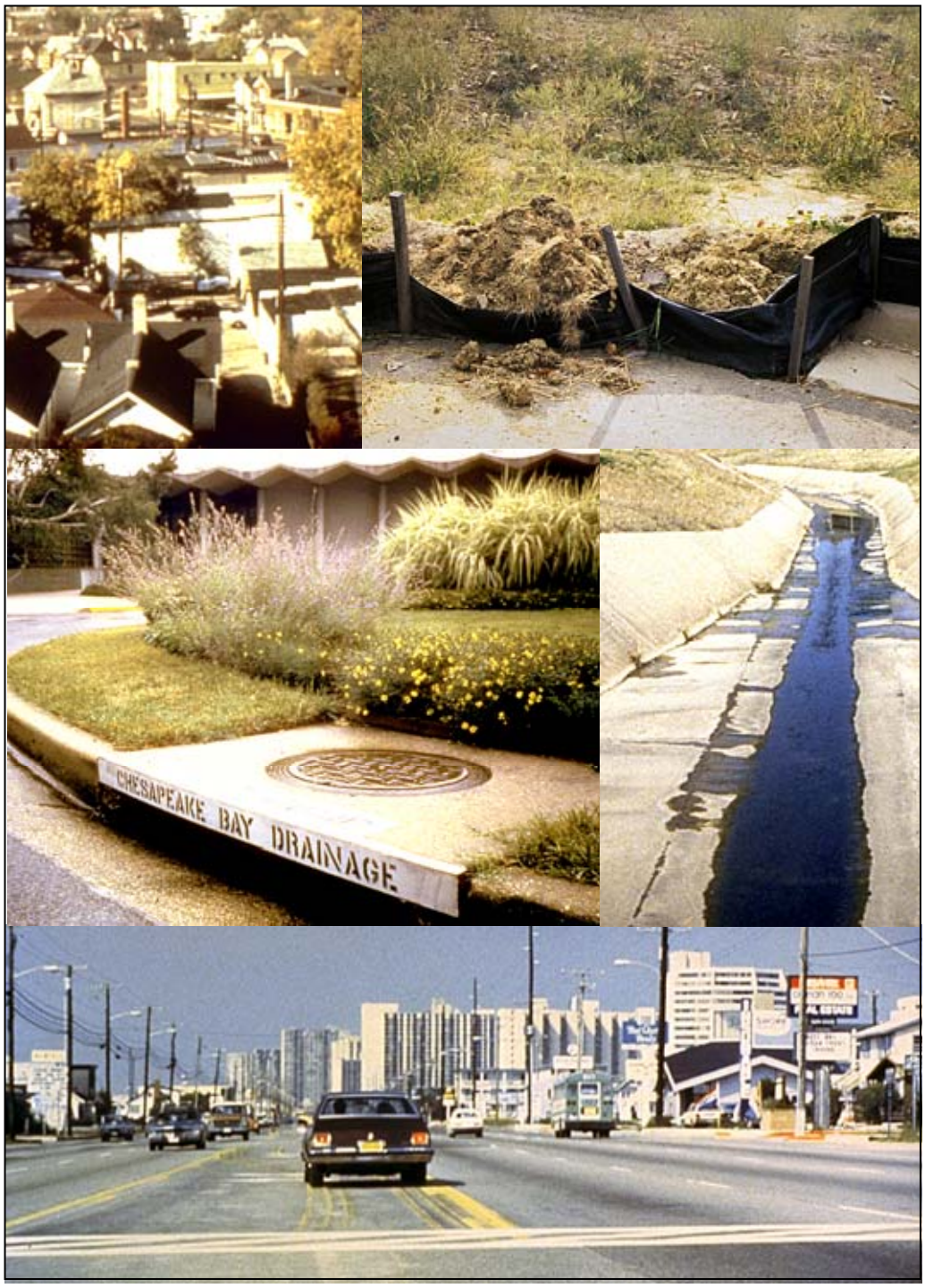
Table 3: Post-Survey Results

R3 Study Post-Survey Results						
1. Rank the overall appearance of your yard.						
	Excellent	Good	Average	Poor	Very Poor	
Education	9.62%	59.62%	30.77%	1.92%	0.00%	
Retrofit	16.00%	54.00%	24.00%	4.00%	2.00%	
2. Have you seen any change in your water bill in the past 12 months?						
	Increase	Decrease	Unchanged			
Education	9.62%	23.08%	63.46%			
Retrofit	14.00%	44.00%	38.00%			
3. Which monthly monthly tips were helpful to you?						
	Irrigation Checks	Watching for Runoff	Pest& Weed Control	Fertilization	None were Helpful	Dd Not Read
Education	57.69%	28.85%	23.08%	44.23%	1.92%	9.62%
Retrofit	42.00%	30.00%	46.00%	58.00%	2.00%	18.00%
4. How often did you use the soil probe?						
	Once	2 to 6 times	More than 6 times	Only for the Rain	Did Not Use	
Education	11.54%	30.77%	1.92%	3.85%	50.00%	
Retrofit	12.00%	16.00%	6.00%	0.00%	64.00%	
5. How often do you see water runoff in your neighborhood? (choose one)						
	Daily	Weekly	Monthly	Sometimes	Don't Know	
Education	25.00%	32.69%	5.77%	26.92%	11.54%	
Retrofit	10.00%	36.00%	2.00%	40.00%	16.00%	
6. How often are patios, sidewalks and driveways cleaned at your home? (choose						
	Daily	Weekly	Monthly	Sometimes	Never	
Education	0.00%	46.15%	21.15%	30.77%	3.85%	
Retrofit	2.00%	48.00%	16.00%	32.00%	4.00%	
7. How do you clean patios, sidewalks and driveways at your home?						
	Hose	Broom	Blower	Other		
Education	44.23%	63.46%	30.77%	RV		
Retrofit	48.00%	58.00%	36.00%	RV		
8. Have you changed your use of pesticides and herbicides in the yard in the past 12 months?						
	Yes	No	How?			
Education	15.38%	80.77%	RV			
Retrofit	16.00%	82.00%	RV			
9. Have you changed the use of fertilizer in your yard in the past 12 months?						
	Yes	No	How?			
Education	23.08%	73.08%	RV			
Retrofit	18.00%	80.00%	RV			
10. Is there animal waste that gets left in your yard?						
	Yes	No	What type of animal			
Education	21.15%	75.00%	RV			
Retrofit	36.00%	64.00%	RV			
11. How serious a problem do you consider urban runoff? (choose one)						
	Very Serious	Serious	Needs Improvement	No Problem		
Education	3.85%	38.46%	46.15%	9.62%		
Retrofit	12.00%	28.00%	52.00%	10.00%		
12. Were you satisfied with the test irrigation controller installed to manage the landscape water?						
	YES	NO	Why			
Retrofit	72.00%	24.00%	RV			
13. Would you recommend this irrigation controller to others?						
	YES	NO	Why			
Retrofit	70.00%	24.00%	RV			
14. Would you pay a monthly fee to have signal sent to the controller for landscape water management as tested in this study						
	YES	NO	How Much?			
Education	26.92%	69.23%	RV			
Retrofit	38.00%	58.00%	RV			
15. How often did you change your irrigation controller to the times provided in the monthly tips?						
	Every Month	Most of the Time	Sometimes	Once or Twice	Never	
Education	5.77%	28.85%	25.00%	23.08%	15.38%	

SARB_001866

National Management Measures to Control Nonpoint Source Pollution from Urban Areas



SARB_001867

United States Environmental Protection Agency
Office of Water
Washington, DC 20460
(4503F)

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November 2005

Disclaimer

This document provides guidance to States, Territories, authorized Tribes, and the public regarding management measures that may be used to reduce nonpoint source pollution from urban areas. This document refers to statutory and regulatory provisions which contain legally binding requirements. This document does not substitute for those provisions or regulations, nor is it a regulation itself. Thus, it does not impose legally-binding requirements on EPA, States, Territories, authorized Tribes, or the public and may not apply to a particular situation based upon the circumstances. EPA, State, Territory, and authorized Tribe decision makers retain the discretion to adopt approaches on a case-by-case basis that differ from this guidance where appropriate. Interested parties are free to raise questions and objections about the appropriateness of the application of the guidance to a particular situation, and EPA will consider whether or not the recommendations in this guidance are appropriate in that situation. EPA may change this guidance in the future.

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INTRODUCTION

The nation's aquatic resources are among its most valuable assets. Although environmental protection programs in the United States have improved water quality during the past several decades, many challenges remain. Of special concern are the problems in our urban streams, lakes, estuaries, aquifers, and other water bodies caused by runoff that is inadequately controlled or treated. These problems include changes in flow, increased sedimentation, higher water temperature, lower dissolved oxygen, degradation of aquatic habitat structure, loss of fish and other aquatic populations, and decreased water quality due to increased levels of nutrients, metals, hydrocarbons, bacteria, and other constituents.

The *National Water Quality Inventory: 2000 Report to Congress* identified urban runoff as one of the leading sources of water quality impairment in surface waters (USEPA, 2002b). Of the 11 pollution source categories listed in the report, "urban runoff/storm sewers" was ranked as the fourth leading source of impairment in rivers, third in lakes, and second in estuaries (Table 0.1).

Table 0.1: Leading sources[b] of water quality impairment related to human activities for rivers, lakes, and estuaries (USEPA, 2002b).

Rivers and Streams	Lakes, Ponds, and Reservoirs	Estuaries
Agriculture (48%) [a]	Agriculture (41%) [a]	Municipal point sources (37%)[a]
Hydrologic modifications (20%)	Hydrologic modifications (18%)	Urban runoff/storm sewers (32%)
Habitat modifications (14%)	Urban runoff/storm sewers (18%)	Industrial discharges (26%)
Urban runoff/storm sewers (13%)	Misc. nonpoint source pollution (14%)	Atmospheric deposition (24%)

[a]Values in parentheses represent the percentage of assessed river miles, lake acres, or estuary square miles that are classified as impaired. States assessed 19% of stream miles, 43% of lakes, ponds, and reservoirs, and 36% of square mileage of estuaries.
[b] Excluding unknown, natural, and "other" sources.

0.1 Purpose and Scope of the Guidance

National summaries, such as those shown in Table 0.1, are useful in providing an overview of the magnitude of the problems associated with urban runoff. Solutions, however, are usually applied at the local level. State and local elected officials and agencies, landowners, developers, environmental and conservation groups, and others play a crucial role in protecting, maintaining, and restoring water resources. Their efforts, in aggregate, form the basis for changing the status of urban runoff from a local problem to a national problem.

This document provides guidance to states, territories, authorized tribes, and the public regarding management measures that can be used to reduce nonpoint source pollution from urban activities. This document refers to statutory and regulatory provisions that contain legally binding requirements. This document does not substitute for those provisions or regulations, nor is it a regulation itself. Thus, it does not impose legally binding requirements on the U.S. Environmental Protection Agency (EPA), states, territories, authorized tribes, or the public and may not apply to a particular situation based upon the circumstances. EPA, state, territory, and

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authorized tribe decision-makers retain the discretion to adopt approaches that differ from this guidance on a case-by-case basis. Interested parties are free to raise questions and objections about the appropriateness of the application of the guidance to a situation, and EPA will consider whether or not the recommendations in this guidance are appropriate in that situation. EPA may change this guidance in the future.

This guidance document *is* intended to provide technical assistance to state and local program managers and other practitioners on the best available, most economically achievable means of managing urban runoff and reducing nonpoint source pollution of surface and ground waters from urban sources. It describes how to develop a comprehensive runoff management program that deals with all phases of development—from predevelopment watershed planning and site design, through the construction phase of development, to the operation and maintenance of structural controls. It also provides information for other situations such as retrofitting existing development, implementing nonstructural controls, and reevaluating the runoff management program. Figure 0.1 presents the components of a comprehensive runoff management program.

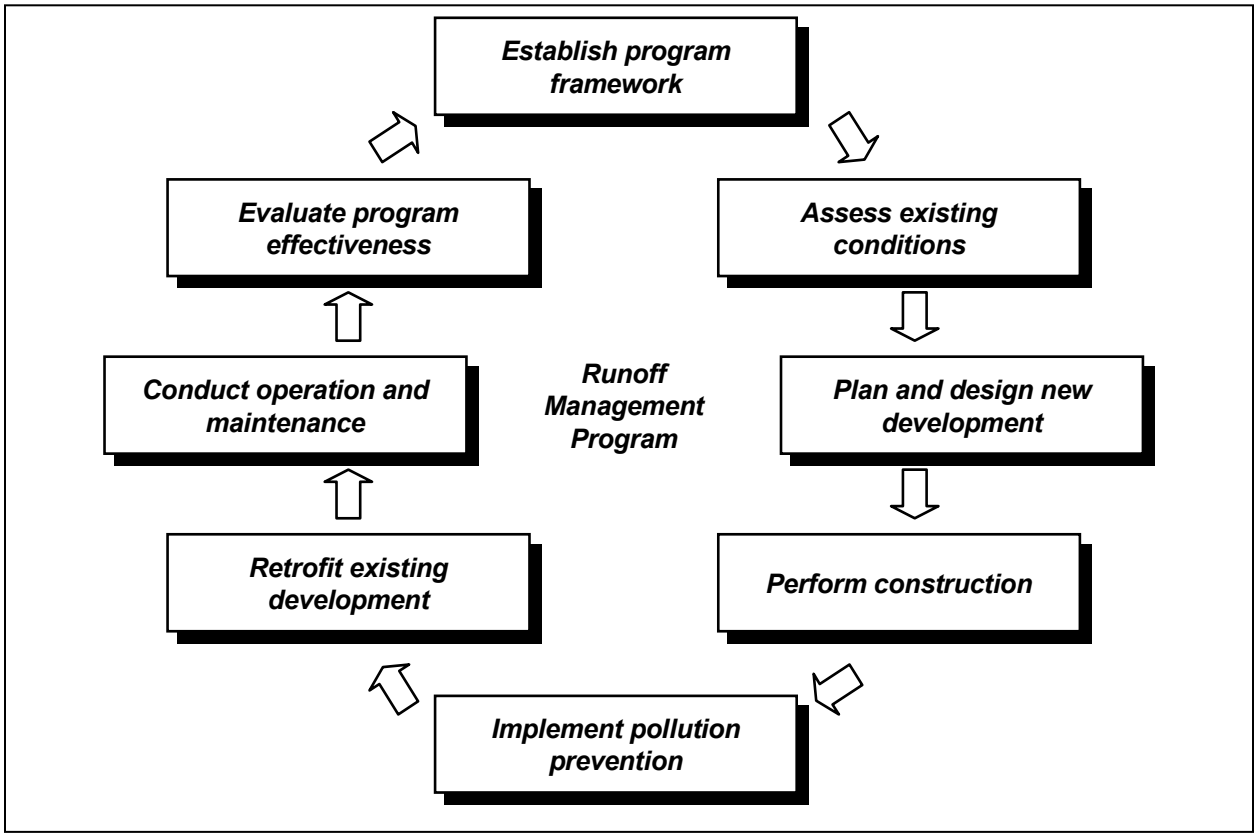

Figure 0.1: Components of a comprehensive runoff management program.

This document is intended to provide guidance for all urban areas, not just those covered by National Pollutant Discharge Elimination System (NPDES) phase II requirements. While the document can serve as a resource for meeting NPDES phase II requirements, there are still a number of smaller jurisdictions that are not regulated by the NPDES program and that can benefit from guidance in developing an urban runoff program.

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0.1.1 Management Measures

Management measures can be used to guide the development of a runoff management program. They establish performance expectations and, in many cases, specify actions that can be taken to prevent or minimize nonpoint source pollution or other negative impacts associated with uncontrolled and untreated urban runoff. Twelve management measures have been included in this guidance. Figure 0.2 groups these measures within the context of the runoff management program cycle.

Each management measure listed in Figure 0.2 deals with an important aspect of the runoff management cycle. For example, Management Measure 8 focuses on construction site erosion, sediment, and chemical control. Local officials and developers should address these issues because if exposed soils are allowed to erode and move off construction sites as sediment, they can clog storm drains, streams, and other water bodies, harm habitat, and impair water quality.

This management measure has four elements:

- Prior to land disturbance, prepare and implement an approved erosion and sediment control plan or similar administrative document that contains erosion and sediment control provisions.
- Reduce erosion and, to the extent practicable, retain sediment on-site during and after construction.
- Use good housekeeping practices to prevent off-site transport of waste material and chemicals.
- Minimize application and generation of potential pollutants, including chemicals.

Note that specific actions or practices for achieving the performance expectations are not included in the management measure statement. This is by design. Local officials and other practitioners need the flexibility to choose management practices that best achieve the management measure's performance expectations given their own unique circumstances. To aid in their decision, however, this guidance presents several management practices that can potentially be used to achieve each management measure.

The components of the runoff management program shown in Figure 0.2 are organized in a cycle that can be followed stepwise if desired. The elements are meant to work together, but each can stand alone. The elements of the cycle do not have to be implemented consecutively.

The cycle begins with establishing a program framework that provides legal authority, funding, and staffing for watershed initiatives (Management Measure 1). Once this framework is established, watershed managers can commence an assessment of existing conditions (Management Measure 2) to identify areas in need of protection or restoration. This assessment also provides stream channel and water quality baselines (i.e., environmental indicators) against which the success of watershed initiatives can be compared (Management Measure 12: Evaluate Program Effectiveness).

Management Measures 3 through 7 address issues associated with new development. The watershed protection management measure (3) focuses on siting development and establishing

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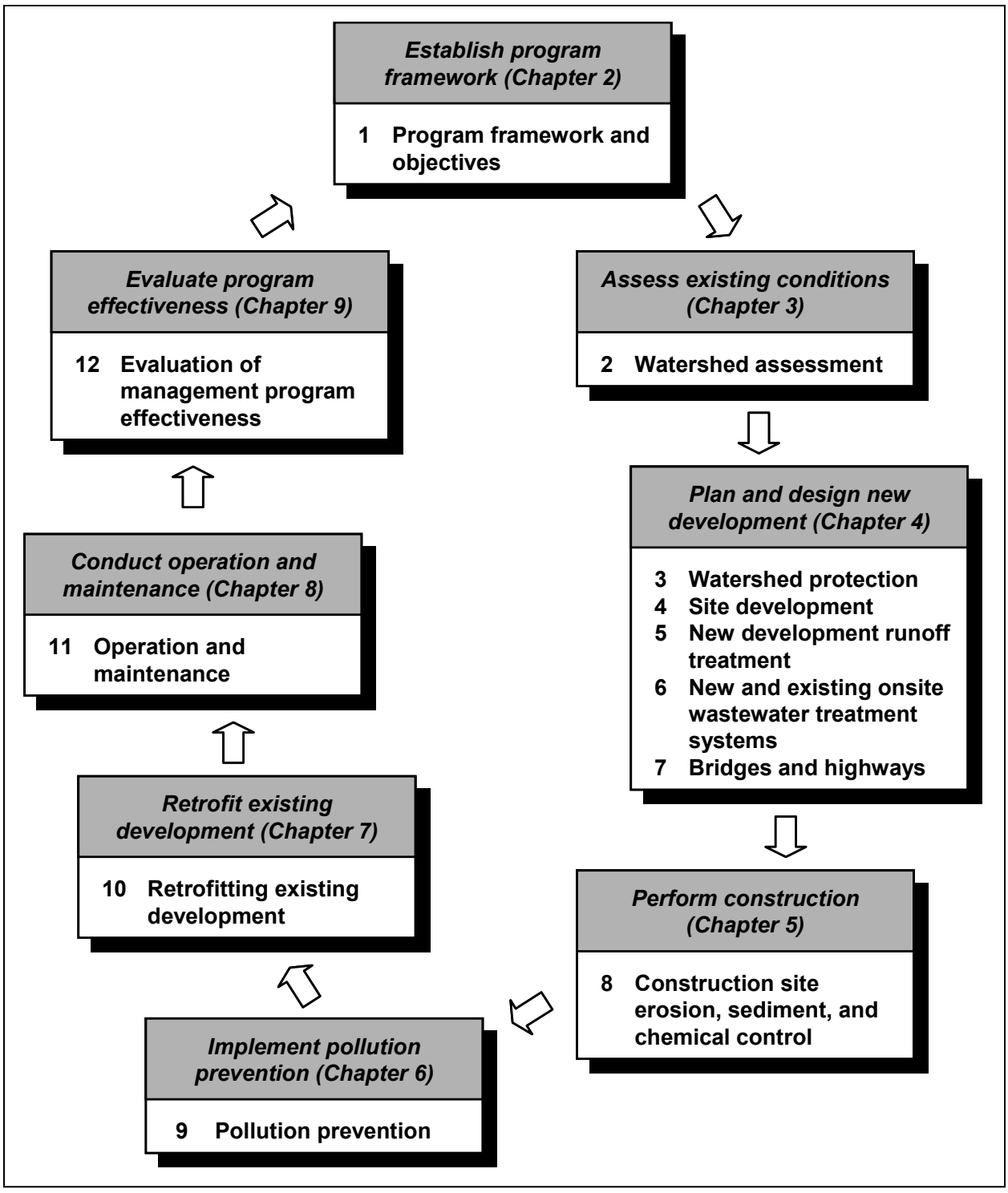

Figure 0.2: Twelve management measures associated with the runoff management program cycle.

actions to protect areas identified as sensitive or ecologically valuable. The Site Development Management Measure (4) provides guidance for planning development on the site scale with alternative, low-impact site layouts and infrastructure options that protect sensitive areas and

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reduce the quantity of runoff leaving the site. The New Development Runoff Treatment Management Measure (5) details practices that can be identified to prevent pollutants in runoff generated from newly developed areas. The onsite wastewater treatment systems management measure (6) provides guidance on how to reduce pollutant loadings from both new and existing on-site systems. Finally, the Highways and Bridges Management Measure (7) addresses pollutants generated from activities related to new and existing transportation infrastructure.

Once development plans have been made, watershed managers can refer to Management Measure 8: Construction Site Erosion, Sediment, and Chemical Control. This measure presents practices that reduce pollutant loadings from land-disturbing activities.

Throughout the runoff management program cycle, watershed managers can use the Pollution Prevention Management Measure (9) to target municipalities, businesses, and individual citizens with education and awareness programs to reduce pollutants generated from day-to-day activities. Managers also can use the practices presented in the Existing Development Management Measure (10) to address areas in need of restoration or retrofitting of existing management practices. Additionally, the Operation and Maintenance Management Measure (11) describes activities needed to maintain and extend the life of new and existing management practices.

Once programs have been established and management practices implemented, managers can evaluate their effectiveness using program and administrative indicators (Management Measure 12). This evaluation involves reassessing conditions in the watershed to determine whether the implemented practices effectively reduced nonpoint source pollution. This evaluation also identifies areas where additional restoration or preservation activities are needed, guiding future watershed initiatives and thereby restarting the management cycle.

North Branch of the Chicago River Demonstration Project

Through the North Branch of the Chicago River Demonstration Project, the Friends of the Chicago River, and the Lake County Storm Water Management Commission joined to develop a plan to address NPS pollution and flooding while educating and involving citizens and community leaders in the process (USEPA, 2000a). The result was an urban watershed planning model, similar to the one presented in this guidance, that any city can use to protect its water resources.

This 96-square-mile watershed was affected by storm water runoff from two counties and 24 towns. The partners in the North Branch of the Chicago River Demonstration Project divided the project into four tasks—developing a watershed plan, conducting an information and education campaign, developing a handbook to guide them through the process, and conducting a series of demonstration projects. For more information, contact Friends of the Chicago River (http://www.chicagoriver.org).

0.1.2 Document Organization

Chapters 2 through 9 of this document consecutively focus on the eight components of the runoff management program cycle (Figure 0.2). Each chapter describes a component, introduces one or more management measures that define the performance expectation(s) for that component, and presents a range of management practices that potentially can be implemented to achieve the management measure(s). When available, information concerning effectiveness and costs of

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practices is included in the discussion, as are case studies that illustrate how select management practices have been implemented within communities.

0.2 Origin and Regulatory Context

0.2.1 Origin of This Guidance

This document is an update of the urban management measures and practices provided in Chapter 4 of an EPA manual entitled *Guidance Specifying Management Measures for Sources of Nonpoint Pollution in Coastal Waters* (USEPA, 1993). That document, referred to hereafter as the Coastal Management Measures Guidance, was published in January 1993 for the specific purpose of providing state and territorial officials with management measures to incorporate into their coastal nonpoint source (NPS) pollution control programs.

Through the Coastal Zone Act Reauthorization Amendments of 1990 (CZARA), Congress mandated that EPA develop the Coastal Management Measures Guidance, and that every state and territory with an approved coastal zone management program develop an NPS pollution control program, including enforceable policies and mechanisms to implement all of the specified management measures. The programs were submitted to EPA and the National Oceanic and Atmospheric Administration (NOAA) for approval. All were subsequently approved, some with conditions. The Coastal Management Measures Guidance functions as a blueprint for the coastal states and territories in their efforts to put together their NPS control programs.

The Coastal Management Measures Guidance included management measures for urban areas (Chapter 4), agriculture (Chapter 2), silviculture (Chapter 3), marinas (Chapter 5), and hydromodification (Chapter 6). It also addressed protection of wetlands and riparian areas from NPS pollution impacts and the use of vegetative treatment systems, such as constructed wetlands, as management practices to control runoff (Chapter 7).

Of all the NPS pollution sources identified in the Coastal Management Measures Guidance, none has experienced the rapid technical advancement that has occurred in the areas of urban NPS pollution control. Many communities have set their sights beyond simple NPS pollutant reduction targets and are now seeking ways to achieve balance and integration of many quality-of-life factors, including economic growth, community livability, and environmental protection.

Based on these changes, EPA perceived a need to update and expand the information in Chapter 4 of the Coastal Management Measures Guidance to help local urban officials in both coastal and inland areas remain current with state-of-the-art management measures and practices. Readers should note, however, that this guidance does *not* supplement or replace the 1993 *Guidance Specifying Management Measures for Sources of Nonpoint Pollution in Coastal Waters* for the purpose of implementing programs under CZARA. It simply serves as an additional resource guide for local officials seeking to develop or improve their urban runoff management programs.

Fundamental differences between this guidance and the Coastal Management Measures Guidance are presented in Table 0.2.

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Table 0.2: Key differences between the *Guidance Specifying Management Measures for Sources of Nonpoint Pollution in Coastal Waters* (USEPA, 1993) and *National Management Measures to Control Nonpoint Source Pollution from Urban Areas*.

	Guidance Specifying Management Measures for Sources of Nonpoint Pollution in Coastal Waters	National Management Measures to Control Nonpoint Source Pollution from Urban Areas
Date	1993	2005
Target audience	*Primary:* state and territory officials *Secondary:* all others interested in NPS pollution	All persons interested in urban NPS pollution and control practices
Focus	NPS management measures and control practices in coastal areas	NPS management measures and control practices in coastal and inland areas
Use	Required under CZARA	Voluntary
Organization	Management measures and practices presented by source category	Management measures and practices presented in the context of a comprehensive watershed program

0.2.2 Regulatory Context

During the first 15 years (1972–1987) of the national program to abate and control water pollution, EPA and the states focused most of their activities on traditional point sources. These point sources have been regulated by EPA and the states through the NPDES permit program established by Section 402 of the Clean Water Act. The NPDES program functions as the primary regulatory tool for ensuring compliance with water quality standards. NPDES permits, issued by either EPA or an authorized state, contain discharge limits designed to meet water quality standards and national technology-based effluent regulations.

In 1987, in view of the progress achieved in controlling point sources and growing national awareness of the increasingly dominant influence of NPS pollution on water quality, Congress amended the Clean Water Act to focus greater national efforts on nonpoint sources. Under this amended version, referred to as the 1987 Water Quality Act, Congress revised Section 101, "Declaration of Goals and Policy," to add the following fundamental principle:

> It is the national policy that programs for the control of nonpoint sources of pollution be developed and implemented in an expeditious manner so as to enable the goals of this Act to be met through the control of both point and nonpoint sources of pollution.

The Water Quality Act of 1987 also included language that required comprehensive storm water regulation using a two-phased approach. (Detailed information on both phases of the NPDES Storm Water Program is available at http://www.epa.gov/npdes/stormwater.) Phase I, in place since 1990, required operators of medium and large municipal separate storm sewer systems (MS4s) located in incorporated areas and counties with populations of more than 100,000, certain industrial activities, and construction activities disturbing 5 acres or more to obtain an NPDES permit to discharge storm water runoff. In October 1999 EPA expanded the federal storm water program with the promulgation of the Phase II rule.

Phase II requires operators of small MS4s (non-Phase I regulated MS4s) in "urbanized areas" (as defined by the Bureau of the Census) and small construction activities disturbing between 1 and

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5 acres of land to obtain an NPDES permit. Further, the NPDES permitting authority may require operators of small MS4s not in urbanized areas and small construction activities disturbing less than 1 acre to obtain an NPDES permit based on the potential for contribution to a violation of a water quality standard. NPDES permitting authorities are required under the rule to assess for potential designation all small MS4s located outside an urbanized area that are in areas with a population of at least 10,000 and a population density of 1,000 per square mile. The Phase II rule also includes a revised conditional no-exposure provision for industrial facilities, which provides for a waiver from the permit program if the storm water pollutant sources at a facility can be demonstrated to be isolated from precipitation and runoff.

For small MS4 permits, Phase II prescribes a set of six minimum control measures, as well as requirements for evaluation and assessment efforts. The minimum measures are: (1) public education and outreach on storm water impacts; (2) public involvement/participation; (3) illicit discharge detection and elimination; (4) construction site runoff control; (5) postconstruction storm water management in new development and redevelopment; and (6) pollution prevention/good housekeeping for municipal operations. The regulated operators must choose and implement appropriate best management practices (BMPs) and define measurable goals for each measure. The operators must also periodically evaluate and assess program compliance, the appropriateness and effectiveness of their chosen BMPs, and progress toward achieving their identified measurable goals. This guidance is expected to be consistent with any guidance issued for regulated small MS4 operators to meet the requirements of Phase II NPDES storm water discharge permits. Therefore, the management measures and practices herein can serve as a resource in developing a community's storm water management program. It is important to note, however, that additional requirements not addressed in this guidance may be imposed under an NPDES storm water permit. Table 0.3 specifies how the management measures relate to each of the six minimum control measures.

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Table 0.3: Comparison of management measures to the six minimum control measures of NPDES Phase II.

	Public Education	Public Involvement	Illicit Discharge	Construction Site ESC	Post Construction	Pollution Prevention
Program Framework and Objectives						
Establish Legal Authority			✓	✓	✓	✓
Develop an Institutional Structure						
Provide Adequate Funding and Staffing						
Foster Input From Technical Experts, Citizens, and Stakeholders		✓				
Establish Intergovernmental Coordination		✓				
Develop Training and Education Programs and Materials	✓	✓				
Watershed Assessment						
Characterize Watershed Conditions	Measurable Goals					
Assess Cumulative Effects						
Estimate the Effectiveness of Treatment Programs						
Establish a Set of Watershed Indicators						
Establish Water Quality Indicators						
Establish Physical and Hydrological Indicators						
Establish Biological Indicators						
Establish Programmatic Indicators						
Develop a Suite of Social Indicators						
Watershed Protection						
Resource Inventory and Information Analysis					✓	
Development of Watershed Management Plan					✓	
Implement the Plan					✓	
Land or Development Rights Acquisition Practices					✓	
Site Development						
Site Planning Practices					✓	
On-Lot Impervious Surfaces					✓	
Residential Street and Right-of-Way Impervious Surfaces					✓	
Parking Lot Impervious Surfaces					✓	
Xeriscaping Techniques					✓	
New Development Runoff Treatment						
Infiltration Practices					✓	
Vegetated Open Channel Practices					✓	
Filtering Practices					✓	
Detention and Retention Practices					✓	
Other Practices					✓	
New and Existing Onsite Wastewater Treatment Systems						
Permitting and Installation Programs			✓			✓
Operation and Maintenance Programs			✓			✓

Table 0.3 (continued).

	Public Education	Public Involvement	Illicit Discharge	Construction Site ESC	Post Construction	Pollution Prevention
Bridges and Highways						
Site Planning and Design Practices					✓	
Soil Bioengineering and Other Runoff Controls for Highways					✓	
Structural Runoff Controls for Bridges					✓	
Bridge Operation and Maintenance Controls						✓
Nonstructural Runoff Control Practices						✓
Construction Site Erosion, Sediment, and Chemical Control						
Erosion and Sediment Control Programs				✓		
Erosion Control Practices				✓		
Sediment Control Practices				✓		
Develop and Implement Programs to Control Chemicals and Other Construction Materials				✓		
Pollution Prevention						
Household Chemicals	✓	✓				✓
Lawn, Garden, and Landscape Activities	✓	✓				✓
Commercial Activities	✓	✓	✓			✓
Trash	✓	✓				✓
Nonpoint Source Pollution Education for Citizens	✓	✓				
Existing Development						
Identify, Prioritize, and Schedule Retrofit Opportunities					✓	
Implement Retrofit Projects as Scheduled					✓	
Restore and Limit the Destruction of Natural Runoff Conveyance Systems					✓	
Restore Natural Streams					✓	
Preserve, Enhance, or Establish Buffers					✓	
Redevelop Urban Areas to Decrease Runoff-Related Impacts					✓	
Operation and Maintenance						
Establishing an Operation and Maintenance Program					✓	✓
Source Control Operation and Maintenance					✓	✓
Treatment Control Operation and Maintenance					✓	✓
Evaluate Program Effectiveness						
Assess the Runoff Management Program Framework	Measurable Goals					
Track Management Practice Implementation						
Gauge Improvements in Water Quality Resulting from Management Practice Implementation						
Develop and Implement a Schedule to Improve the Management Program Framework						

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The Clean Water Act establishes several reporting, funding, and regulatory programs that address pollutants carried in runoff that is not subject to confinement or treatment. These programs relate to watershed management and urban NPS control. Readers are encouraged to use the information contained in this guidance to develop nonpoint source management programs/plans that comprehensively address the following EPA reports and programs:

- *Section 303(d) Lists and TMDLs*. Under section 303(d) of the Clean Water Act, states are required to compile a list of impaired waters that fail to meet any of their applicable water quality standards or cannot support their designated or existing uses. This list, called a "303(d) list," is submitted to Congress every two years, and states are required to develop a Total Maximum Daily Load (TMDL) for each pollutant causing impairment for water bodies on the list. More information on the TMDL program and 303(d) lists is provided at http://www.epa.gov/owow/tmdl.
- *Section 305(b) and the National Water Quality Inventory: Report to Congress*. Every two years, states are required to submit a report to Congress detailing the health of their waters. These periodic reports allow Congress to gauge progress toward meeting the goals of the Clean Water Act and to help identify priorities for future pollution control funding and activities. More information on the 305(b) program and the National Water Quality Inventory is provided at http://www.epa.gov/owow/305b.
- *Section 319 Grant Program*. Under Section 319 of the Clean Water Act, EPA awards funds to states and eligible tribes to implement NPS management programs. These funds can be used for projects that address urban sources of pollution. More information about the Section 319 program is provided at http://www.epa.gov/owow/nps/cwact.html.
- *Section 404 Discharge of Dredged and Fill Material*. Under Section 404 of the Clean Water Act, persons planning to discharge dredged or fill material to wetlands or other waters of the United States generally must obtain authorization for the discharge from the U.S. Army Corps of Engineers (Corps), or a state approved to administer the Section 404 program. Such authorization can be through issuance of an individual permit, or may be subject to a general permit, which applies to certain categories of activities having minimal adverse environmental effects. Implementation of Section 404 is shared between the Corps and EPA. The Corps is responsible for reviewing permit applications and deciding whether to issue or deny permits. EPA, in consultation with the Corps, develops the Section 404(b)(1) Guidelines, which are the environmental criteria that the Corps applies when deciding whether to issue permits. EPA also has authority under Section 404(c) to "veto" Corps issuance of a permit in certain cases. More information about the 404 program is provided at http://www.epa.gov/owow/wetlands.
- *Clean Water State Revolving Fund*. EPA established the Clean Water State Revolving Fund (CWSRF) to provide states with low- or no-interest loans for projects that improve water resources. These funds can be used to support urban NPS pollution programs and projects. To receive CWSRF loans from EPA for water quality projects, states must develop annual Intended Use Plans that outline the expected use of these funds. More information on the CWSRF program is provided at http://www.epa.gov/OWM/finan.htm.
- *National Estuary Program.* Under the National Estuary Program, states work together to evaluate water quality problems and their sources, collect and compile water quality data,

and integrate management efforts to improve conditions in estuaries. So far 28 estuaries have been accepted into the program. Estuary programs can be an excellent source of water quality data and can provide information on management practices. More information on the National Estuary Program is provided at http://www.epa.gov/owow/estuaries/nep.html.

Two excellent resources for learning more about the Clean Water Act and the many programs established under it are *The Clean Water Act: An Owner's Manual* (Elder et al., 1999) and *The Clean Water Act Desk Reference* (WEF, 1997).

Safe Drinking Water Act. Many urban areas, especially urban fringe areas, need to maintain or improve the quality of surface and ground waters that are used as drinking water sources. This act requires states, among other things, to develop Source Water Assessment Reports and implement Source Water Protection Programs. Low- or no-interest loans are available under the Drinking Water State Revolving Fund Program. More information about the Safe Drinking Water Act and Source Water Protection Programs can be found at http://www.epa.gov/safewater/protect.html.

0.3 Key Concepts

0.3.1 Watershed Approach

Since 1991, EPA has promoted the watershed approach as the key framework for dealing with problems caused by urban runoff and other sources that impair surface and ground waters (USEPA, 1998). Five principles guide the watershed approach:

- *Place-based focus*. Activities are directed within specific geographic areas known as management units. When surface runoff is the primary issue, these management units are defined by watershed boundaries. Other types of boundaries can also be used to define management units in special circumstances. If ground water is an issue, for example, ground water recharge areas might be a logical designation.

- *Stakeholder involvement and partnerships*. The people most affected by management decisions are involved throughout the process. Stakeholder participation helps to ensure that local quality of life, economic stability, and other important community issues are incorporated into planning and implementation activities. Partnerships among public agencies and private groups at all levels are also crucial for long-term success.

- *Environmental goals and objectives*. The success of watershed initiatives is measured by improvements of the water resource rather than by programmatic objectives. For example, reestablishing the pool and riffle structure in a stream channel to increase aquatic insect and fish populations might be an objective. Local goals and objectives need to be consistent with all applicable state, tribal, and federal statutes and regulations, including water quality standards.

- *Problem identification and prioritization*. Sound scientific data and methods are used to identify and prioritize threats to human and ecosystem health. This process usually begins

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with the assessment and characterization of current natural resource and community conditions within the management unit(s). Problems, including their causes and sources, are also documented. Stakeholders and partners then work jointly to set priorities among the various water resource concerns, taking into account priorities already established at scales above and below the management unit.

– *Integration of actions*. Stakeholders and partners take actions in a comprehensive and integrated manner. Results are then evaluated and actions are adjusted as needed.

A key attribute of the watershed approach is that it can be applied with equal success to large- and small-scale watersheds. Federal agencies, states, interstate commissions, and tribes usually apply the approach on watersheds of approximately 100 square miles. Local agencies and urban communities, however, can apply the approach to watersheds as small as 1 square mile. Although specific objectives, priorities, actions, timing, and resources might vary from large scale to small scale, the basic goals of the watershed approach remain the same—protecting, maintaining, and restoring water resources.

Local runoff management program officials must be especially conscious of watershed scale when planning and implementing specific management practices. Nonstructural practices, such as stream protection ordinances and public education campaigns, are usually applied community-wide. Consequently, the results benefit many small watersheds. In contrast, structural practices, such as infiltration basins and sand filters, usually provide direct benefits to a single stream. Regional structural management practices such as retention ponds for larger watersheds can be used, but they do not protect smaller contributing streams. Given limited resources, runoff program officials must often analyze costs and benefits and choose between large- and small-scale practices. Often, a combination of nonstructural and structural practices is the most cost-effective approach.

British Columbia's Watershed Approach

The Province of British Columbia has taken a watershed approach in planning for water quality protection through runoff volume management. Program officials have recognized the link between surface water volume and watershed health, and are incorporating land use planning into urban runoff management efforts. The Water Balance Model is a decision support tool developed to assist in the integration of land use planning and urban runoff management by simulating the effects of source controls within the watershed. This tool allows the province to establish priorities and efficiently evaluate the potential effectiveness of management efforts (Stephens et al., 2003).

0.3.2 Stream Network

The size of a watershed is closely related to the network of streams contained within its borders. Streams with no upstream tributaries are designated as first-order streams down to their first confluence. A second-order stream is formed when two first-order streams meet. A third-order stream is created by the confluence of two second-order streams, and so on.

Headwater streams are defined as first- and second-order streams. What they lack in individual size and length, they make up through sheer numbers. Headwater streams dominate the landscape, accounting for roughly 75 percent of the total stream and river mileage in the United

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States (Table 0.4). Because they are the dominant drainage feature, headwater streams also directly receive the bulk of runoff from construction sites, developments, parking lots, highways, and other features of the urban landscape. In most communities, runoff is collected by a storm sewer system and discharged with no treatment. Increases in the volume and rate of storm water runoff have historically resulted in construction of concrete channels and drainage pipes, eliminating many headwater streams.

Table 0.4: National stream order statistics (Leopold et al., 1964).

Stream Order	Number of Streams	Total Length of Stream Miles	Mean Drainage Area (square miles)
1	1,570,000	1,570,000	1
2	350,000	810,000	4.7
3	80,000	420,000	23
4	18,000	220,000	109
5	4,200	116,000	518
6	950	61,000	2,460
7	200	30,000	11,700
8	41	14,000	55,600
9	8	6,200	264,000
10	1	1,800	1,250,000

0.3.2.1 Watershed scales

Any number of watersheds can be defined by the streams within the network. Larger watersheds encompass progressively smaller watersheds in a hierarchical manner. Larger watershed scales, or national scales, are classified using the Hydrologic Unit Code (HUC), a system of hierarchical codes used by federal agencies, states, interstate commissions, tribes, and others to identify watersheds at the national level. Smaller local watersheds, existing at scales below the smallest HUC scale, are identified more informally.

The U.S. Geological Survey (USGS) has developed the National Hydrography Dataset (NHD), which is a comprehensive set of digital spatial data derived from USGS digital line graphs and EPA's reach file 3 that contains information about surface water features such as lakes, ponds, streams, rivers, springs, and wells. Within the NHD, surface water features are combined to form "reaches," which provide the framework for linking water-related data to the NHD surface water drainage network. These linkages enable the analysis and display of these water-related data in upstream and downstream order. More information about the NHD is provided at http://nhd.usgs.gov.

0.3.2.2 National-level scales

USGS developed the HUC system for the purpose of inventorying all "national scale" watersheds in the United States. To accomplish this objective the agency first divided the country into 21 regions that account for the watersheds of 21 major river basins. Within those major river basins the agency identified a total of 222 watershed subregions. The subregions, in turn, were classified as 352 accounting units. The accounting units were further broken down into 2,262 smaller watersheds called cataloging units.

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Each level, or scale, in the watershed hierarchy is identified by a numerical code. The cataloging unit, the smallest scale in the hierarchy, has an eight-digit code that uniquely identifies its location. The region where the cataloging unit resides is designated by the first two digits of the code, the subregion by the second two digits, and so on until the four scales are identified. For example, the watershed of the Upper Mississippi River at Hasting, Minnesota, has a HUC code of 07010206. This code breaks down as follows:

Major River Basin ID	07
Subbasin ID	0701
Accounting Unit ID	070102
Catalog Unit ID	07010206

0.3.2.3 Local-level scales

The hierarchy established by the HUC system identifies scales useful for watershed planning and management by national, regional, state, and multi-state jurisdictions. In many instances, a municipality or urban community is part of a larger team and undertakes activities in a large-scale context. However, because even the smallest scale, the cataloging unit, usually describes watersheds of 100 to 1,000 square miles, local practitioners of runoff management typically find the HUC-designated scales simply too large to be of practical use. This is especially true when designing and implementing runoff control practices for individual developments and sites. Consequently, the watershed hierarchy must be extended to include smaller-scale management units. A national effort is under way to designate 14-digit HUCs.

The Center for Watershed Protection (Caraco et al., 1998) proposed three progressively smaller scales in the watershed hierarchy below the subbasin cataloging unit (Figure 0.3):

- *Watershed*. The scale encompassed by the cataloging unit. Generally, this is the largest management unit that falls within the local land use planning authority. A community might have one or more watersheds within its borders, depending on its size.

- *Subwatershed*. The scale encompassed by the watershed. Its boundaries include all the land area draining to the point where two second-order streams come together to form a third-order stream. In most regions, subwatersheds are a few square miles in area and are drained by a stream several feet in width.

- *Catchment*. The smallest scale in the hierarchy. The Center for Watershed Protection defines it as the area that drains an individual development site to its first intersection with a stream. In some cases this intersection is in the form of a pipe outfall. Depending on the size of the development site, the catchment might also include some off-site drainage.

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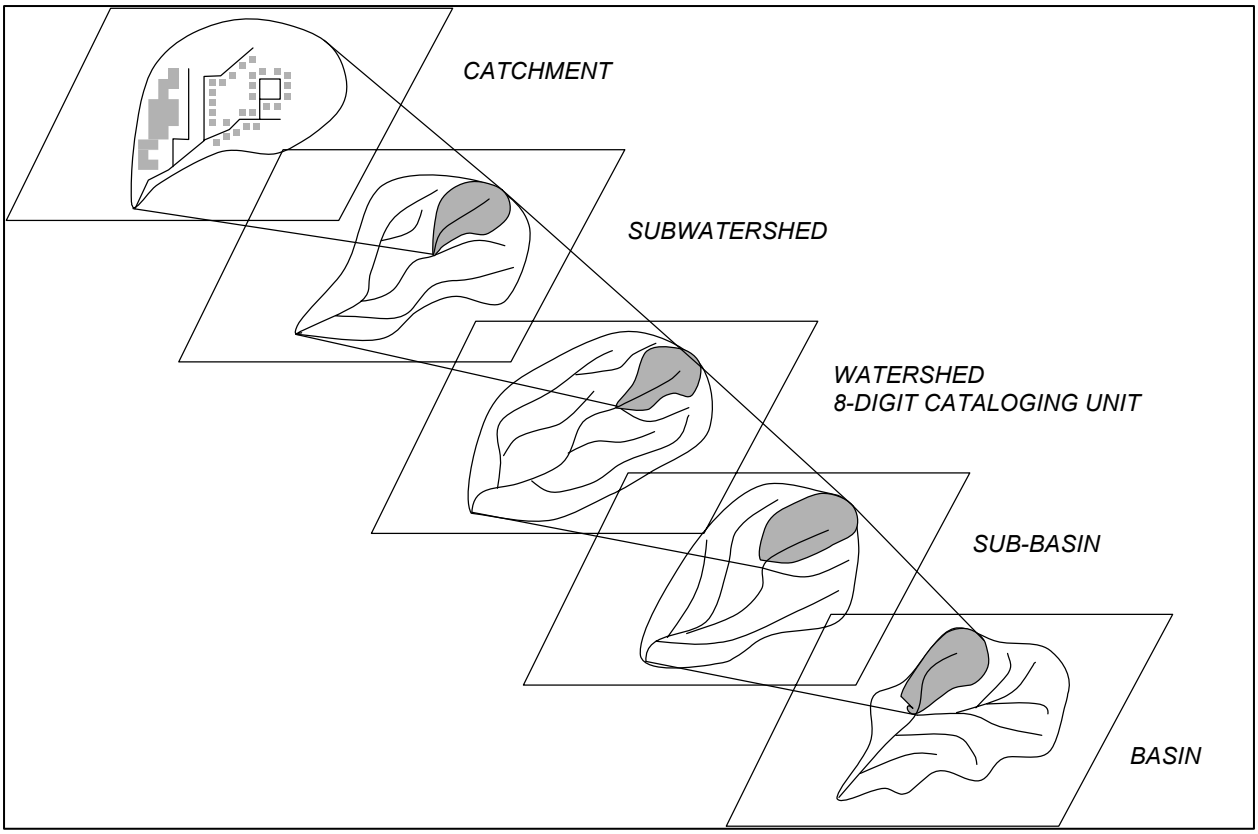

Figure 0.3: Scales of watershed management units (Schueler, 1995).

0.3.3 Impervious and Pervious Surfaces in the Urban Landscape

The term impervious surface refers to land cover, both natural and human-made, that cannot be penetrated by water. Consequently, precipitation that falls on impervious surfaces does not infiltrate into the soil. Instead, it runs off to a pervious area where all or a portion infiltrates into the soil, or it continues to travel down-slope on impervious surfaces including saturated soils until it is eventually conveyed to a ditch, a storm drain network, a stream, a lake, a wetland, an estuary, or some other type of surface receiving water. For additional discussion on the water quality impacts of imperviousness, see Section 1.3.5, Changes in the Watershed Due to Increased Imperviousness.

Most of the impervious cover in an urban watershed or subwatershed can be organized into three main categories:

- *Rooftops*. Impervious cover created by buildings, homes, garages, stores, warehouses, and other structures with roofs.

- *Transport systems*. Impervious cover created by structures such as roads, sidewalks, driveways, and parking lots. Most of these structures are associated with transportation of people or materials, hence the name transport systems.

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- *Recreational facilities*. Impervious cover created by tennis and basketball courts, playgrounds, decks, and swimming pools.

In most areas the transport systems component covers a larger percentage of land than the rooftops component. A study in the city of Olympia, Washington, for example, revealed that transport system imperviousness constituted 63 to 70 percent of the total impervious cover at 11 sites of varying land use, including residential, multifamily, and commercial areas (City of Olympia, 1995).

0.3.3.1 Total and effective impervious surface

The amount of impervious cover in a watershed or subwatershed is reported in two basic ways:

- *Total (or mapped) impervious area*. Includes all impervious cover in a watershed or subwatershed—rooftops, transport systems, and recreational facilities. It is usually expressed as a percentage of the total watershed or subwatershed area. It can be calculated by direct measurement or by percentage estimation based on land use, road density, population density, or another indicator.

- *Effective impervious area (EIA)*. The portion of total impervious cover that is directly connected to the storm drain network (Sutherland, 1995). These surfaces usually include street surfaces and paved driveways and sidewalks connected to or immediately adjacent to them, parking lots, and rooftops that are hydraulically connected to the drainage network (e.g., downspouts running directly to gutters or driveways). EIA also is usually expressed as a percentage of the total watershed or subwatershed area. It is the preferred statistic for use when estimating runoff volumes because it is the portion of the impervious cover that generates direct runoff.

Subtracting EIA from the total impervious area yields the amount of impervious area that is not directly connected to the storm drain network, or the ineffective impervious area. Residential rooftops are an example of possible ineffective impervious areas because downspouts can direct runoff to yards and other pervious landscaping areas, where a portion of the water can infiltrate the ground. Rooftops in some residential and most commercial areas, however, will likely be classified as effective impervious areas because their downspouts typically will be tied directly to the storm drain network. Filtration, infiltration, evaporation, and biological uptake of pollutants can substantially reduce runoff volume and improve water quality when runoff is directed over vegetated areas. For further discussion on downspout disconnection, see Management Measure 4: Site Development and Management Measure 10: Existing Development.

Both the amount of impervious area and the relationship between total and effective impervious areas varies according to land use (Caraco et al., 1998). For example, work in the Puget Sound area revealed that total impervious area in low-density residential sites averaged approximately 10 percent, with an effective impervious area of only 4 percent. In commercial and industrial areas, however, total impervious area averaged about 90 percent. Almost all of the total impervious area is also effective impervious area because of the lack of pervious areas to break up direct connections.

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0.3.3.2 Pervious surfaces

The urban and suburban landscape has a variety of pervious surfaces, including

- Forests and wetlands
- Lawns and other private turf
- Public turf
- Intensively landscaped areas
- Vacant lands
- Runoff treatment areas

Although most of these areas are green, it would be a mistake to think of them as hydrologically equivalent to an undisturbed meadow, forest, or other natural pervious area, especially in terms of their ability to allow runoff to infiltrate. Soils in urban landscapes are usually highly disturbed and compacted, poor in structure, and low in permeability. In addition, they often receive runoff from adjacent impervious areas, resulting in water inputs many times greater than normal. These factors and others tend to decrease the ability of pervious urban areas to infiltrate runoff, which means an increased fraction of water moves off these areas to impervious areas and storm drainage networks. In extreme cases, the amount of runoff generated is close in volume to that generated from impervious surfaces. Consequently, some "pervious" areas function as impervious areas and cause analysts to underestimate peak flow, runoff volumes, and time of concentration. Refer to Management Measure 9: Pollution Prevention, for more information on runoff from lawns.

0.3.4 Impervious Cover Model

A simple tool, the *Impervious Cover Model*, can be used to project the current and future quality of streams and other water resources at the subwatershed scale based on impervious cover (Caraco et al., 1998). The objective of this model is to assist local officials and other watershed practitioners in devising realistic goals and objectives given present and future levels of development. The impervious cover model is a simple urban stream classification system that contains three stream categories based on the percentage of impervious cover present in the subwatershed. It is intended to help managers decide how to adapt and refine management measures given the intensity of urban development in their watersheds. The impervious cover model has some limitations. These are (Caraco et al., 1998):

- *Reference condition*. The model predicts potential, not actual, stream quality, so in some cases stream reaches might depart from the model's predictions.

- *Scale effect*. The model should be applied only to small, first- to third-order streams because the influence of impervious cover is strongest at these spatial scales.

- *Statistical variability*. There is a moderate degree of scatter exhibited in individual impervious cover/stream quality indicator relationships, although the indicators show a general downward trend as imperviousness increases. The model predicts the average behavior of multiple indicators over a range of imperviousness, and the impervious cover thresholds are not sharp breakpoints but transitions.

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- *Measuring and projecting impervious cover*. Accurately quantifying actual and projected impervious cover is important for the model. However, there is no standardized method for measuring total or effective imperviousness.

- *Regional adaptability*. The model has been tested mostly in the mid-Atlantic and Puget Sound ecoregions but little research has been conducted to determine the applicability of the model in western, midwestern, and mountain streams.

- *Defining thresholds for nonsupporting streams*. More sampling and study are needed to more firmly establish the threshold for the transition between impacted streams and nonsupporting streams, projected to occur at 25 percent impervious cover for small urban streams.

- *Influence of management practices in extending thresholds*. The changes in hydraulic and pollutant loadings, and their effects on receiving streams, should be carefully considered when practices are used to extend the threshold of imperviousness.

- *Influence of riparian cover in extending thresholds*. Conservation or restoration of a riparian zone has been shown to extend the impervious cover threshold.

- *Pervious area*. Urban landscapes contain pervious areas, but many of them are highly disturbed and do not resemble pervious areas in non-urban landscapes. However, planners can integrate pervious and impervious areas to greatly reduce effective impervious area and reduce the impact of imperviousness on stream quality.

0.3.4.1 Subwatersheds as the primary management unit

The impervious cover model relies on the subwatershed as the primary management unit. Table 0.5 displays the influence of impervious cover in the context of a hierarchy of watershed-based management units. The subwatershed scale is ideal for planning purposes at the local level for many reasons, including:

- The influence of impervious cover on hydrology, channel stability, water quality, and biodiversity is most evident at the subwatershed scale because the receiving water body is typically a headwater stream.

- The smaller scale helps local officials more easily identify impacts of individual development projects and sources of pollutants.

- Subwatersheds are typically small enough to be within the borders of one or two jurisdictions. This eases the burden of establishing regulatory authority as well as keeping the number of stakeholders to a manageable number.

- Assessments and evaluations can be conducted more easily because most subwatersheds can be mapped on a standard 24-inch by 36-inch sheet with sufficient detail to provide useful management information. The smaller scale also allows assessments and evaluations to be completed more rapidly than similar efforts at larger scales. This creates the opportunity for phasing the development of subwatershed plans (or focusing on areas

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needing priority attention), making the best use of limited resources. Officials and local citizens can more easily recognize progress as plans are completed and implemented over a coordinated cycle.

Table 0.5: Idealized characteristics of five watershed management units with respect to size and the influence of impervious cover (adapted from Caraco et al., 1998).

Watershed Management Unit	Typical Area (square miles)	Influence of Impervious Cover
Catchment	0.05–0.50	Very strong
Subwatershed	1–10	Strong
Watershed	10–100	Moderate
Subbasin	100–1,000	Weak
Basin	1,000–10,000	Very weak

0.3.4.2 Classification levels

The impervious cover model designates three levels of classification based on impervious cover:

- *Sensitive subwatersheds*, which have less than 10 percent impervious cover. Streams found in sensitive subwatersheds are at, or close to, predevelopment conditions. Urban runoff management strategies, therefore, should focus on maintaining these conditions. New development and redevelopment should be discouraged or designed to have no impact to prevent any increase of impervious cover in subwatersheds of this type.

- *Degrading subwatersheds*, which have 11 to 25 percent impervious cover. Degrading subwatersheds have crossed the 10 percent imperviousness threshold, and have experienced degradation of key stream attributes or can be expected to experience such degradation over time. Some of the more sensitive organisms probably have disappeared or will disappear. Resource objectives consequently should focus more on maintaining or restoring key conditions than on resource protection as a whole. Structural and nonstructural practices that deal with, or counteract, increased urban runoff are recommended.

- *Nonsupporting subwatersheds*, which have more than 25 percent impervious cover. Streams in nonsupporting subwatersheds are well beyond the impervious cover thresholds and may never recover predevelopment conditions no matter how many management practices are implemented. Resource objectives are primarily aimed at reducing peak flows and preventing and removing urban pollutants so they will not be carried downstream. Limited restoration of some attributes such as increased biodiversity can sometimes be achieved given the right circumstances. Pollution prevention and retrofitting in existing urban areas are the most frequently used practices.

Table 0.6 describes channel stability, water quality, and biodiversity attributes, as well as general resource and water quality objectives associated with each category.

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Table 0.6: Characteristics of aquatic integrity in urban watersheds.

Integrity Rating	Low	Moderate	High
Riparian Habitat Characteristics	– Riparian zone greatly reduced – Increased sediment deposition – Completely bare/exposed banks – Deeply incised and widened channel cross-section 	– Riparian zone partly cleared – Moderate sediment deposition, sand bar formation – Banks slightly exposed – Steep banks and widened channel cross-section 	– Mature riparian zone – Decreased sediment deposition, mostly rocky substrates – Bank well-vegetated and forested – Floodplain terrace channel cross-section
Macroinvertebrate Community Characteristics	– Pollution-tolerant species – Tolerant of low dissolved oxygen (DO) levels – Reduced feeding and life history requirements – Decreased diversity and number of species	– Moderately pollution-tolerant species – Tolerant of moderate DO levels – Some general reduction in life history and feeding requirements	– Pollution-intolerant species – Intolerant of low DO levels – Unaltered life history and feeding requirements – Increased number and diversity of species
Fish Assemblage Characteristics	– Pollution-tolerant species – Exotic/introduced species – Reduced feeding and life history requirements – Decreased diversity and number of species	– Moderately pollution-tolerant species – Intermediate number of individuals and species – Some general reduction in life history and feeding requirements	– Pollution-intolerant species – Unaltered life history and feeding requirements – Increased number and diversity of species
Rehabilitation Process	Degraded		Improved

0.3.5 Changes in the Watershed Due to Increased Imperviousness

Watershed imperviousness plays an important role in determining the conditions in streams and other bodies of water. Impervious cover, however, is an inescapable attribute of development and a permanent part of the urban/suburban landscape. Figure 0.4 illustrates how four important components in the water cycle are affected by increasing levels of imperviousness (FISRWG, 1998). In natural landscapes, there is usually very little or no surface runoff. Water either percolates into the ground or is returned to the atmosphere by evaporation and transpiration. As imperviousness increases:

– Runoff increases because the surface area of rooftops and transportation systems is increased.

– Soil percolation decreases because pervious areas are reduced.

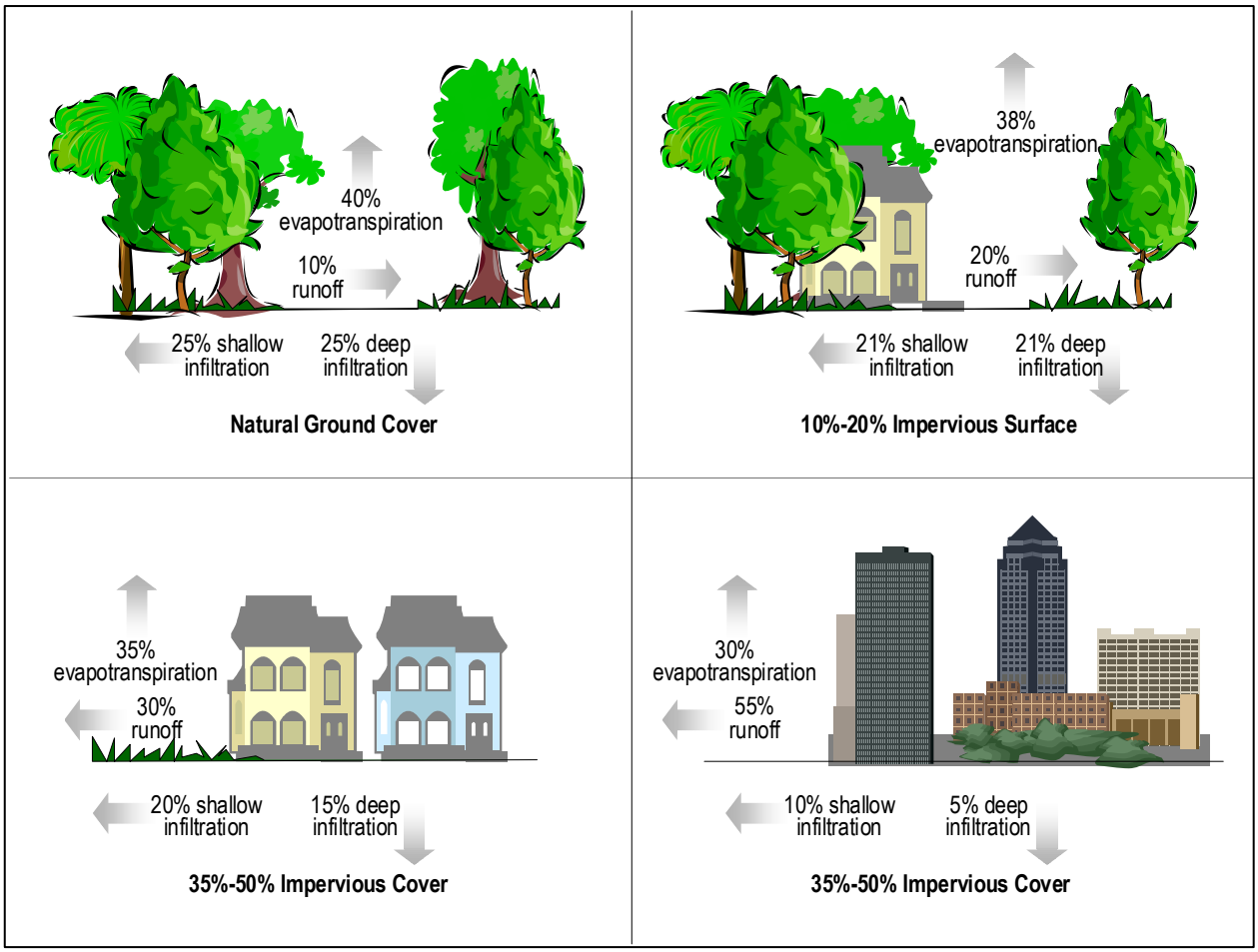

Figure 0.4: Impacts of urbanization on the water cycle (Adapted from FIRSWG, 1998).

- Evaporation decreases because there is less time for it to occur when runoff moves quickly off impervious surfaces.

- Transpiration decreases because vegetation has been removed.

As might be expected, there is a linear relationship between the amount of impervious surfaces in a given area and the amount of runoff generated. What is unexpected is what this means in terms of both the volume of water generated and the rate at which it exits the surface. Depending on the degree of impervious cover, the annual volume of storm water runoff can increase to anywhere from 2 to 16 times the predevelopment amount (Schueler, 1994). Impervious surface coverage as low as 10 percent can destabilize a stream channel, raise water temperature, and reduce water quality and biodiversity (Schueler, 1995). One recent study found that connected imperviousness levels between 8 and 12 percent represented a threshold region where minor changes in urbanization could result in major changes in stream condition (Wang et al., 2001).

Figure 0.5 shows a hydrograph comparing stream flow rates before, during, and after a storm under pre- and postdevelopment conditions (Schueler, 1987). As indicated, streams with developed watersheds have substantially higher peak flows, and these peak flows occur more quickly than under predevelopment conditions. This is reflective of typical urban conditions, where runoff moves quickly over impervious surfaces and drains into a channel.

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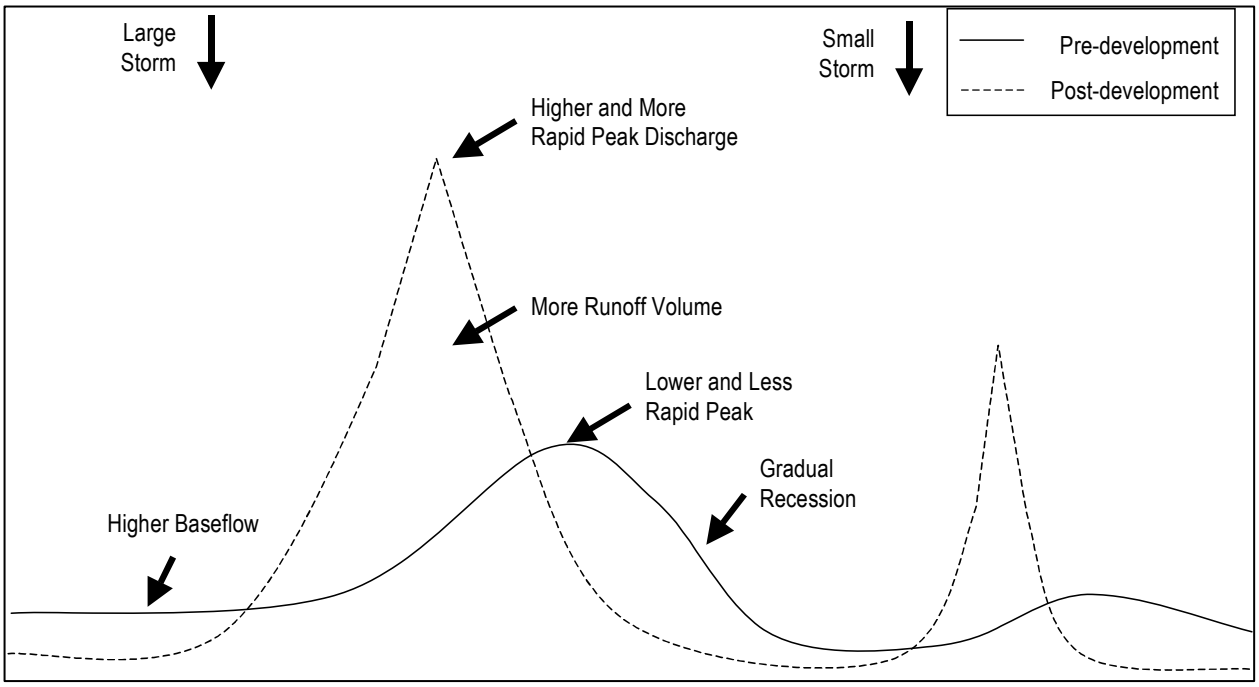

Figure 0.5: Changes in stream flow hydrograph as a result of urbanization (Schueler, 1987).

Development and increased impervious cover also lead to erosion and undercutting of streambanks, widening of channels, and depositing of in-channel sediment. In addition, decreased base flow occurs in dry weather because a greater portion of runoff flows off the

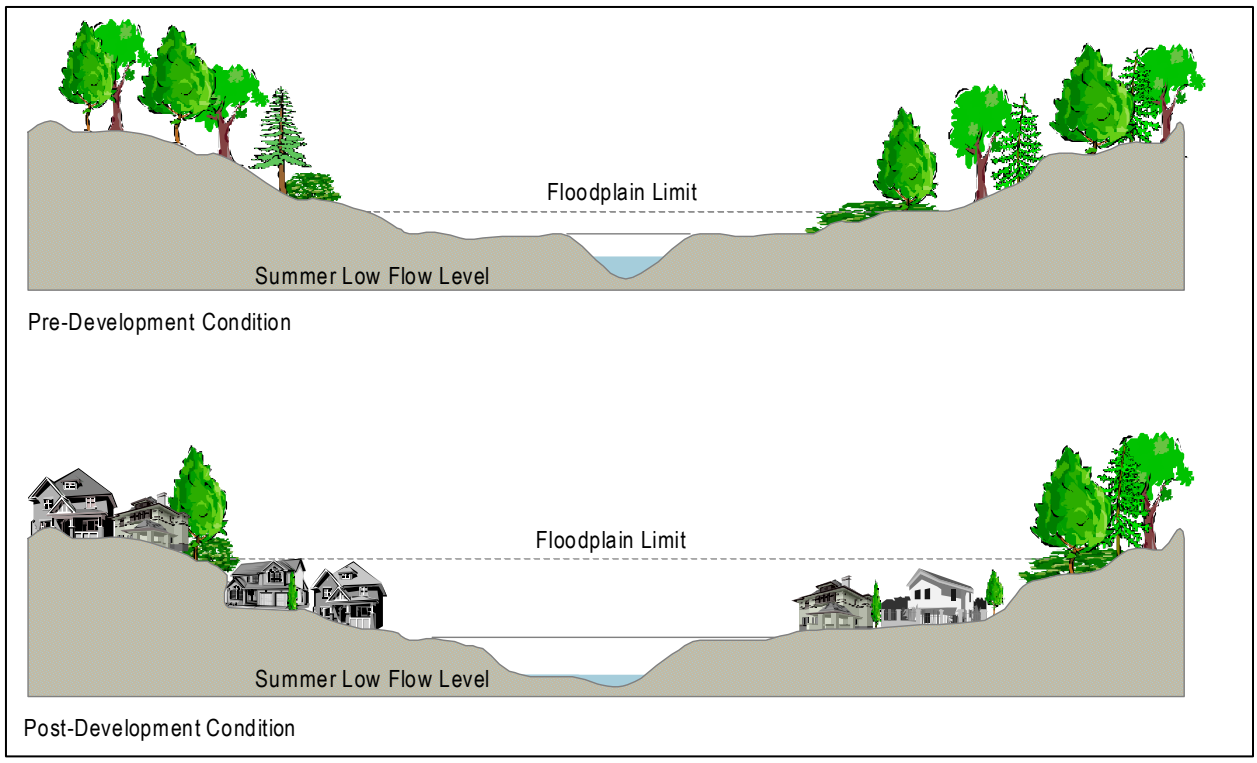

Figure 0.6: Response of stream geometry to urbanization (Schueler, 1987).

surface, resulting in less infiltration to ground water reserves that normally provide base flow to streams. Figure 0.6 shows changes to stream geometry in response to urbanization (Schueler, 1987).

EPA (1997) reviewed the literature for case studies that quantitatively examined the relationship between increased impervious surfaces and stream impacts. Table 0.7 lists these relationships, and Table 0.8 summarizes the case studies used to derive the relationships.

Table 0.7: Impacts from increases in impervious surfaces (USEPA, 1997).

Increased Imperviousness Leads to:	Resulting Impacts				
	Flooding	Habitat Loss	Erosion	Channel Widening	Streambed Alteration
Increased Volume	✓	✓	✓	✓	✓
Increased Peak Flow	✓	✓	✓	✓	✓
Increased Peak Duration	✓	✓	✓	✓	✓
Increased Stream Temperature		✓			
Decreased Base Flow		✓			
Sediment Loading Changes	✓	✓	✓	✓	✓

Table 0.8: Summary of case studies linking urbanization to hydrological impacts on streams (USEPA, 1997).

Case Study	Location	Documented Impacts	Inferred Impacts
East Meadow Brook	Nassau County, NY	– Increased peak flows	Flooding, habitat loss, erosion, channel widening, streambed alteration
Holmes Run Watershed	Fairfax, VA	– Frequent flooding – Severe streambank erosion – Sedimentation	Flooding, habitat loss, erosion, channel widening, streambed alteration
Kelsey Creek	Bellvue, WA	– Degradation of designated uses – Decreased base flow – Loss of fish populations	Habitat loss, channel widening
Patuxent River System	Maryland	– Increased instream sediment load – Changes in morphology of urban channels	Habitat loss, erosion, channel widening
Peachtree Creek	Atlanta, GA	– Increased bankfull events – Decreased base flow	Flooding, habitat loss, erosion, channel widening, streambed alteration
Pheasant Branch Basin	Middleton, WI	– Stream incision – Increase in bankfull events – Sedimentation	Flooding, habitat loss, erosion, channel widening, streambed alteration
Pipers Creek	Seattle, WA	– Increased peak flows – Loss of fish populations – Aesthetic degradation	Flooding, habitat loss, erosion, channel widening, streambed alteration
Several creeks	Dekalb County, GA	– Stream enlargement – Stream incision – Increased sediment transport	Habitat loss, erosion, channel widening, streambed alteration
Valley Stream, Pines Brook, Bellmore Creek, and Massapequa Creek	Nassau County, NY	– Decreased base flow	Habitat loss

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Recent research has shown that streams in urban watersheds have a fundamentally different character from that of streams in forested, rural, or even agricultural watersheds. The amount of impervious cover in the watershed can be used as an indicator to predict how severe these differences might be. In many regions of the country, as little as 10 percent watershed impervious cover has been linked to stream degradation, with the degradation becoming more severe as impervious cover increases (Schueler, 1995).

Some key changes in urban streams that merit special attention are detailed below:

- *Bankfull and subbankfull floods increase in magnitude and frequency.* The peak discharge associated with the bankfull flow (the 1.5- to 2-year return storm) increases sharply in magnitude in urban streams. In addition, channels experience more bankfull and subbankfull flood events each year and are exposed to critical erosive velocities for longer intervals (Booth et al., 1996; Hollis, 1975; and MaCrae, 1996).

- *Dimensions of the stream channel are no longer in equilibrium with its hydrologic regime*. The hydrologic regime that defined the geometry of the predevelopment stream channel irreversibly changes, and the stream experiences higher flow rates on a more frequent basis. The higher-flow events of the urban stream are capable of moving more sediment than before.

- *Channels enlarge.* The customary response of an urban stream is to increase its cross-sectional area to accommodate the higher flows. This is done by streambed downcutting, channel widening, or a combination of both. Urban stream channels often enlarge their cross-sectional area by a factor of 2 to 5 depending on the degree of impervious cover in the upland watershed and the age of development (Arnold et al., 1982; Gregory et al., 1992; and Macrae, 1996).

- *Stream channels are highly modified by human activity.* Urban stream channels are extensively modified in an effort to protect adjacent property from streambank erosion or flooding. Headwater streams are frequently enclosed within storm drains, while other streams are channelized, lined, and/or “armored” by heavy stone. Another modification unique to many urban streams is the installation of sanitary sewers underneath or parallel to the stream channel.

- *Upstream channel erosion contributes greater sediment load to the stream*. The prodigious rate of channel erosion coupled with sediment erosion from active construction sites increases sediment discharge to urban streams. Researchers have documented that channel erosion constitutes as much as 75 percent of the total sediment budget of urban streams (Crawford and Lenat, 1989; Trimble, 1997). Urban streams also tend to have a higher sediment discharge than non-urban streams, at least during the initial period of active channel enlargement.

- *Dry weather flow in the stream declines*. Because impervious cover prevents rainfall from infiltrating the soil, less flow is available to recharge ground water. Consequently, during extended periods without rainfall, baseflow levels are often reduced (Simmons and Reynolds, 1982).

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- *Wetted perimeter of the stream declines*. The wetted perimeter of a stream is the proportion of the total cross-sectional area of the channel that is covered by flowing water during dry weather, and it is an important indicator of habitat degradation in urban streams. Given that urban streams develop a larger channel cross-section at the same time that their base flow rates decline, it follows that the wetted perimeter will become smaller. Thus, for many urban streams, this results in a very shallow, low-flow channel that "wanders" across a very wide streambed, often changing its lateral position in response to storms.

- *Instream habitat structure degrades*. Urban streams are routinely scored as having poor instream habitat quality, regardless of the specific metric or method employed. Habitat degradation is often exemplified by loss of pool and riffle structure, embedding of streambed sediments, shallow depths of flow, eroding and unstable banks, and frequent streambed turnover.

- *Large woody debris (LWD) is reduced*. LWD is an important structural component of many low-order stream systems because it creates complex habitat structure and generally makes the stream carry more water. In urban streams, the quantity of LWD found in stream channels declines sharply because of the loss of riparian forest cover, storm washout, and channel maintenance practices (Booth et al. 1996; May et al., 1997).

- *Stream crossings and potential fish barriers increase*. Many forms of urban development are linear in nature (e.g., roads, sewers, and pipelines) and cross stream channels. The number of stream crossings increases in direct proportion to impervious cover (May et al., 1997), and many crossings can become partial or total barriers to upstream fish migration, particularly if the streambed erodes below the fixed elevation of a culvert or pipeline.

- *Riparian forests become fragmented, narrower, and less diverse.* The important role that riparian forests play in stream ecology is often diminished in urban watersheds as tree cover is often partially or totally removed along the stream as a consequence of development (May et al., 1997). Even when stream buffers are preserved, encroachment often reduces their effective width and native species are supplanted by exotic trees, vines, and ground covers.

- *Water quality declines*. The water quality of urban streams during storms is consistently poor. Urban storm water runoff contains moderate to high concentrations of sediment, carbon, nutrients, trace metals, hydrocarbons, chlorides, and bacteria (Schueler, 1987). Although considerable debate exists as to whether storm water pollutant concentrations are actually toxic to aquatic organisms, researchers agree that pollutants deposited in the streambed exert an undesirable impact on the stream community.

- *Summer stream temperatures increase*. The impervious surfaces, ponds, and poor riparian cover in urban watersheds can increase mean summer stream temperatures by 2 ºF to 10 ºF (Galli, 1991). Because temperature plays a central role in the rate and timing of instream biotic and abiotic reactions, such increases have an adverse impact on streams. In some regions, summer stream warming can irreversibly shift a cold-water

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stream to a cool-water or even warm-water stream, resulting in deleterious effects on salmonids and other temperature-sensitive organisms.

– *Reduced aquatic diversity*. Urban streams are typified by fair to poor fish and macroinvertebrate diversity, even at relatively low levels of watershed impervious cover or population density (Couch, 1997; Crawford and Lenat, 1989; May et al., 1997; Miltner, 2003; Schueler, 1995; Shaver et al., 1994). Declines in sensitive species have been observed at levels of impervious cover as low as 4 percent. Impervious cover in highly urbanized areas comprising greater than 25 percent of a watershed may even preclude the Clean Water Act goal of "fishable" waters (Miltner, 2003). The ability to restore predevelopment fish assemblages or aquatic diversity is constrained by a host of factors, including irreversible changes in carbon supply, temperature, hydrology, lack of instream habitat structure, and barriers that limit natural recolonization.

Figure 0.7 shows the relationship between impervious cover and aquatic insect diversity; Figure 0.8 shows the relationship between imperviousness and fish diversity. Both studies were conducted in Maryland streams (Schueler and Galli, 1992, as cited in Schueler, 1995).

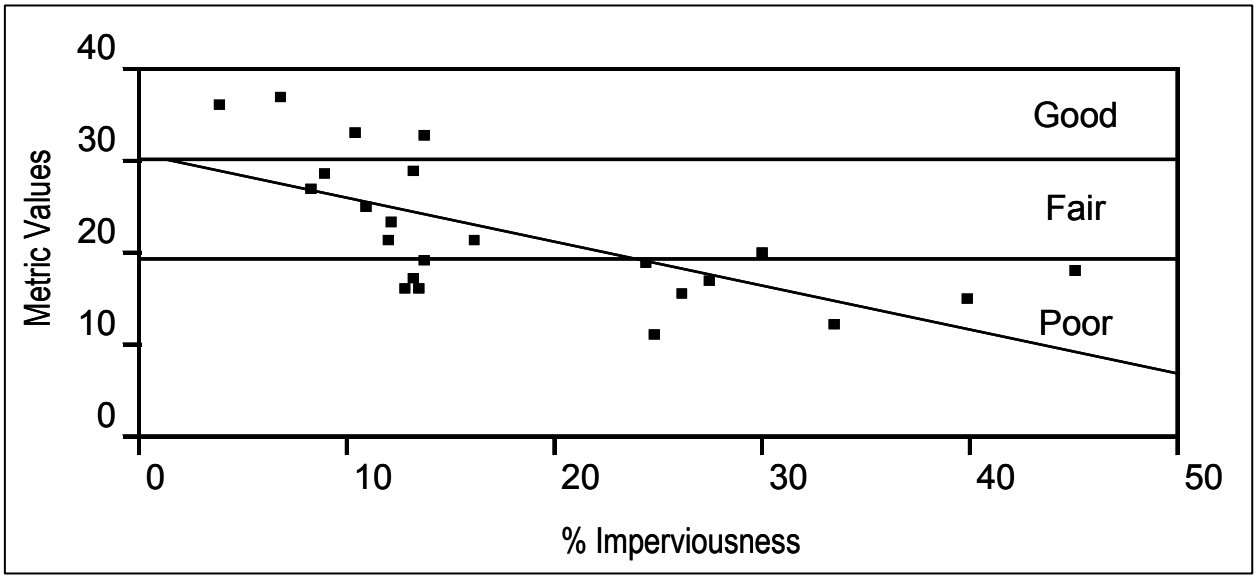

Figure 0.7: Relationship between impervious cover and aquatic insect diversity in Anacostia River subwatersheds (Schueler and Galli, 1992, as cited in Schueler, 1995).

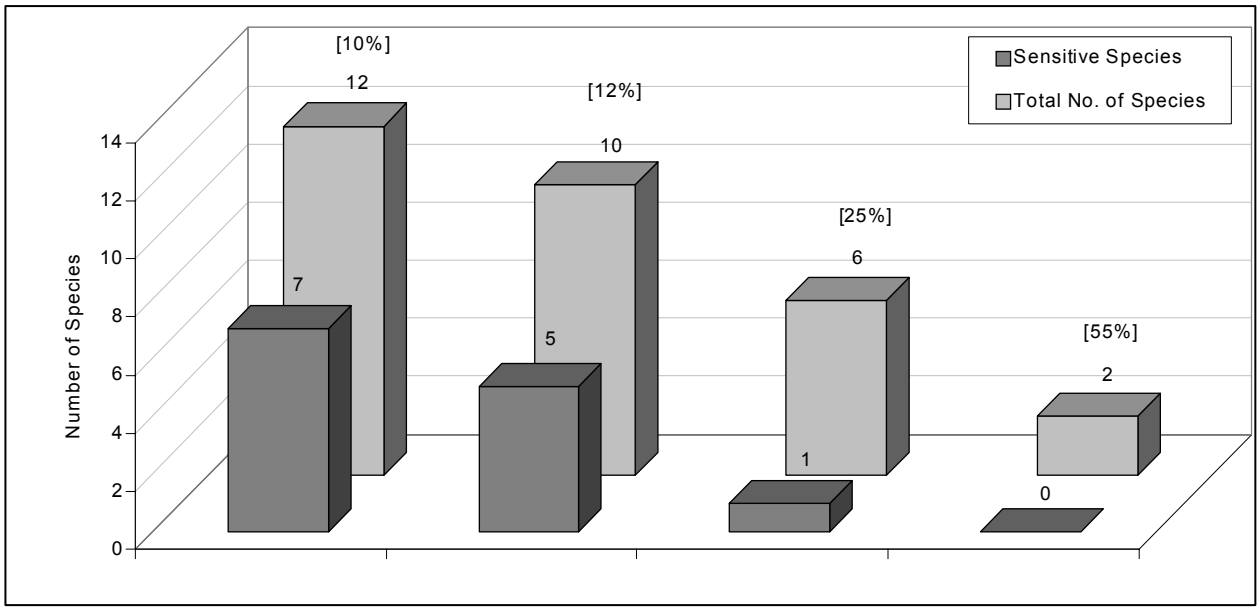

Figure 0.8: Fish diversity in four subwatersheds of different impervious cover in the Maryland Piedmont (Schueler and Galli, 1992, as cited in Schueler, 1995).

0.3.6 Nonpoint Source Pollutants and Their Impacts

Urban areas are a source for many different types of pollutants. Table 0.9 shows typical pollutant concentrations found in storm water. The following discussion identifies the principal types of pollutants found in urban runoff and describes their potential adverse effects:

0.3.6.1 Sediment

Excessive erosion, transport, and deposition of sediment in surface waters are significant sources of pollution in the United States, resulting in major water quality problems. Sediment imbalances impair waters' designated uses. Excessive sediment can impair aquatic life by filling interstitial spaces of spawning gravels, impairing sources of fish food, filling rearing pools, and reducing beneficial habitat structure in stream channels. In addition, excessive sediment can cause taste and odor problems in drinking water supplies and block water intake structures.

According to the *National Water Quality Inventory: 2000 Report to Congress* (required under section 305(b) of the Clean Water Act), states, tribes, and other jurisdictions surveyed water quality conditions in 19 percent of the nation's 3.6 million miles of rivers and streams (USEPA, 2002b). Some 39 percent of these surveyed waters were impaired by various pollution sources. Sediment was the second-leading cause of impairment, accounting for 31 percent of the impaired waters. Furthermore, sediment, especially its fine fractions, is the primary carrier of other pollutants such as organic components, metals, ammonium ions, phosphates, and toxic organic compounds.

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Table 0.9: Typical pollutant concentrations found in urban storm water (adapted from MDE, 1999, and Terrene Institute, 1994).

Typical Pollutants Found in Storm Water Runoff	Units	Residential[a]	Mixed[a]	Commercial[a]	General Urban[b]
Total suspended solids	mg/L	101	67	69	80[c]
Total phosphorus	mg/L	383	263	201	0.30[c]
Total nitrogen	mg/L	–	–	–	2.0[c]
Total Kjeldahl nitrogen	mg/L	1.9	1.3	1.2	–
Nitrate + Nitrite	µg/L	736	558	572	–
Total organic carbon	mg/L	–	–	–	12.7[c]
Biological oxygen demand	mg/L	10	7.8	9.3	–
Chemical oxygen demand	mg/L	73	65	57	–
Fecal coliform bacteria	MPN/100 mL	–	–	–	3,600[c]
E. coli bacteria	MPN/100 mL	–	–	–	1,450[c]
Petroleum hydrocarbons	mg/L	–	–	–	3.5[c]
Oil and grease	mg/L	–	–	–	2 to 10[d]
Cadmium	µg/L	–	–	–	2[c]
Copper	µg/L	33	27	29	10[c]
Lead	µg/L	144	114	104	18[c]
Zinc	µg/L	135	154	226	140[c]
Chlorides (winter only)	mg/L	–	–	–	230[c]
Insecticides	µg/L	–	–	–	0.1 to 2.0[c]
Herbicides	µg/L	–	–	–	1 to 5.0[c]

[a] Source: USEPA, 1983.
[b] These concentrations represent mean or median storm concentrations measured at typical sites and may be greater during individual storms. Also note that mean or median runoff concentrations from storm water "hotspots" are 2 to 10 times higher than those shown here. Units: mg/L = milligrams/liter, µg/L = micrograms/l, MPN = most probable number.
[c] Source: MDE, 1999.
[d] Source: Terrene Institute, 1994.

A recent study of the economic impact of excessive erosion and transport of sediment in surface water systems estimates the annual cost of damage due to sediment pollution in North America at approximately $16 billion (Osterkamp et al., 1998). Sediment pollution costs can be measured in physical damages, chemical damages, and biological damages. Physical damages include harm to water conveyance, treatment, and storage facilities, and interference with recreational and navigational use. Chemical damages include deposition and storage of nutrients, metals, and pesticides associated with eroded sediments. Biological damages include harm to aquatic habitat from the movement and storage of sediment.

Potential sources of sediment pollution include agricultural erosion, deforestation, overgrazing, silvicultural erosion, urban runoff, construction activities, and mining activities. Sediments can also be dislodged and transported directly from the water body's shoreline, bank, or bottom. Atmospheric sources might also be a factor. In an informal study of atmospheric deposition of dust, Urbonas and Doerfer (2004) found that each 100 ft^2 of impervious surface can yield up to 1 to 1.2 pounds of solids in runoff on an average annual basis. Assuming that all of this dust enters storm water and that 30 percent of impervious surfaces are directly connected to the storm drain system, the authors estimate that 1 square mile of mixed-use urban development could yield 40 to 50 tons of total suspended solids in storm water each year.

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The following is a summary of impacts of suspended and deposited sediments on the aquatic environment (adapted from Schueler, 1997):

Suspended sediments

- Abrasion of and damage to fish gills, increasing risk of infection and disease
- Scouring of periphyton from stream
- Loss of sensitive or threatened fish species when turbidity exceeds 25 nephelometric turbidity units (NTU)
- Shifts in fish community toward less-diverse, more sediment-tolerant species
- Decline in sunfish, bass, chum, and catfish when average monthly turbidity exceeds 100 NTU
- Reduction in sight distance for trout, with reduction in feeding efficiency
- Reduction in light penetration, resulting in a reduction in plankton and aquatic plant growth
- Reduction in filtering efficiency of zooplankton in lakes and estuaries
- Adverse impacts on aquatic insects, which are the base of the food chain
- Slight increases in stream temperature in summer
- Particles are a major vector for transport of nutrients and metals
- Turbidity, which increases probability of boating, swimming, and diving accidents
- Increased water treatment costs to meet drinking water standards of 5 NTU
- Increased wear and tear on hydroelectric and water intake equipment
- Reduction of anglers' chances of catching fish
- Diminishing quality of direct and indirect recreational experience of receiving waters
- Decreased submerged aquatic vegetation (SAV) populations

Deposited sediments

- Physical smothering of benthic aquatic insect community
- Reduced survival rates for fish eggs
- Destruction of fish spawning areas and redds

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- Imbedding of stream bottom, which reduces fish and macroinvertebrate habitat value
- Loss of trout habitat when fine sediments are deposited in spawning habitat or riffle-runs
- Potential for elimination of sensitive or threatened darters and dace from fish community
- Increase in sediment oxygen demand, which can deplete dissolved oxygen in lakes or streams
- Significant contributing factor in the rapid decline of freshwater mussels
- Reduced channel capacity, exacerbating downstream bank erosion and flooding
- Reduced flood transport capacity under bridges and through culverts
- Loss of storage and lower design life for reservoirs, impoundments, and ponds
- Dredging costs to maintain navigable channels and reservoir capacity
- Spoiling of sand beaches
- Changes in the composition of bottom substrate
- Coral reef degradation in tropical and subtropical coastal areas
- Deposits that diminish the scenic and recreational value of waterways

Additional chronic effects may occur where sediments rich in organic matter or clay are present. These enriched depositional sediments may present a continued risk to aquatic and benthic life, especially where the sediments are disturbed and resuspended.

Although most concerns are due to excessive sedimentation, some ecological problems can result from insufficient sediment in a water body caused by hydrological modifications. Too little sediment can lead to channel scour and destruction of habitat dependent on an optimum level of sediment. In lakes, reservoirs, and estuaries, insufficient total suspended sediments can lead to increased light levels, resulting in the growth of nuisance algae.

The term *sediment* is broadly used to describe a problem associated with suspended solids, siltation, erosion, weathering, sedimentation, and other factors. Erosion, sediment transport, and deposition are natural processes caused by stresses placed on the earth's surface. Sediment movement is the result of water and air moving against the sediment (gravitation stresses) and natural weathering (molecular and chemical stresses). Because erosion is a natural process and significant quantities of sediments are being moved as a result of natural denudation, it would be unrealistic to expect complete control or elimination of sediment loads to receiving waters. However, it is feasible to control or manage excessive sediment loadings that have resulted from various land use activities and would be detrimental to the quality of the receiving bodies of water and to the aquatic and terrestrial habitat.

0.3.6.2 Nutrients

Nutrient overenrichment is especially prevalent in agricultural areas where manure and fertilizer inputs to crops significantly contribute to nitrogen and phosphorus levels in streams and other receiving waters. Urban streams have been shown to have the second-highest nitrate and total phosphorus levels, second only to agricultural streams (Barth, 1995). There are several nonpoint sources of nutrients in urban areas, mainly fertilizers in runoff from lawns, pet wastes, failing septic systems, and atmospheric deposition from industry and automobile emissions. Deposition of airborne pollutants is beyond the scope of this guidance. More information can be found at North Carolina State University's Web site, http://h2osparc.wq.ncsu.edu/wetland/aqlife/atmosdep.html.

Excessive nutrient levels in receiving waters can lead to exceedance of drinking water criteria (10 mg/L for nitrate-nitrogen), although monitoring data suggest that urban sources of nitrate are not high enough to pose a human health risk. However, moderately high concentrations of nutrients can result in eutrophication of sensitive receiving waters. These sensitive waters include oligotrophic or mesotrophic lakes where phosphorus is a limiting nutrient, or coastal or estuarine areas where nitrogen is limiting. Eutrophication can lead to changes in periphyton, benthic, and fish communities; extreme eutrophication can cause hypoxia or anoxia, resulting in fish kills. Surface algal scum, water discoloration, and the release of toxins from sediment can also occur.

0.3.6.3 Oxygen-demanding substances

Proper levels of dissolved oxygen (DO) are critical to maintaining water quality and aquatic life. Decomposition of organic matter by microorganisms may deplete DO and result in the impairment of the water body. Data have shown that urban runoff with high concentrations of decaying organic matter can severely depress DO levels after storms. The Nationwide Urban Runoff Program (NURP) study (USEPA, 1983) found that oxygen-demanding substances can be present in urban runoff at concentrations similar to those in secondary wastewater treatment discharges.

0.3.6.4 Pathogens

Urban runoff typically contains elevated levels of pathogenic organisms, including bacteria, viruses, and protozoa. The bacteria standard is one of the most commonly violated water quality standards in terms of both the number of water bodies and stream miles impaired. Approximately 50 percent of stream miles in Virginia are impaired due to bacteria contamination (Waye, 2002).

The presence of pathogens in runoff may result in water body impairments such as closed beaches and shellfish beds, and contaminated drinking water sources. Pathogen contamination related to onsite wastewater treatment systems (OWTSs) has been implicated in a number of shellfish bed closings. This problem may be especially prevalent in areas with porous or sandy soils and/or shoreline areas with a high concentration of OWTSs. Epidemiological studies have shown that pathogens can have significant effects on human health in contaminated marine swimming areas (Haile et al., 1999). While the most common effects of bathing in contaminated

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water are gastrointestinal illnesses, other conditions affecting the upper respiratory tract, ear, eye, and skin may also be contracted (USEPA, 2002a).

Indicator organisms have long been used to determine the level of risk for contracting illnesses from recreational activities in surface waters contaminated by fecal pollution. These organisms often do not cause illness directly, but have demonstrated characteristics that make them good indicators of harmful pathogens in water bodies. Until 1986, EPA recommended the use of fecal coliforms as an indicator for bacteria. However, after conducting epidemiological studies, EPA published *Ambient Water Quality Criteria for Bacteria*, which recommends that states use *Escherichia coli* (*E. coli*) for fresh recreational waters and enterococci for fresh and marine recreational waters because they are better predictors of acute gastrointestinal illness than fecal coliforms (USEPA, 1986). Some states and tribes have replaced their fecal coliform criteria with water quality criteria for *E. coli* or enterococci, but many other states and tribes have not yet made this transition (USEPA, 2002a).

Two protozoa of major concern as waterborne pathogens are *Giardia lamblia* and *Cryptosporidium parvum*. *Cryptosporidium* has become an increasingly serious pathogen problem in urban areas since the 1993 outbreak in Milwaukee, Wisconsin, when pathogens passed through a water treatment plant and left 400,000 people ill and almost 100 dead. Three major sources of pathogens in urban areas are human waste, pet waste, and anthropogenic wildlife. Anthropogenic wildlife includes raccoons, geese, pigeons, seagulls, and rats (Waye, 2002). Human waste can contaminate urban runoff through illicit connections of sanitary sewers with storm water systems, resulting in high bacterial counts and human health risks. These non-storm water sources are often a major contributor of pathogens to discharges from storm drain systems (Pitt et al., 2001).

While some types of waste can be treated before entering water bodies, others, such as feces from pets, should be disposed of properly. When pet waste is not properly disposed of, it can wash into nearby water bodies or be carried by runoff into storm drains. Since most urban storm drains do not connect to treatment facilities, but rather drain directly into lakes and streams, untreated animal feces can become a significant source of pathogens in surface waters.

As pet waste decays in a water body, it uses up oxygen, sometimes releasing ammonia. Low oxygen levels and ammonia combined with warm temperatures can be detrimental to fish and aquatic life. Pet waste also contains nutrients that promote weed and algae growth, which can cause eutrophication. Perhaps most importantly, pet waste carries bacteria, viruses, and other parasites that can pose health risks to humans and wildlife. For more information, refer to the discussion of microbial contamination in Management Measure 2: Watershed Assessment, and the discussion of pet waste in Management Measure 9: Pollution Prevention.

0.3.6.5 Road salts

According to a study by the Department of the Interior and USGS (1996), road salt has become a problem for both surface water and ground water quality, especially in the Northeast and Midwest. Nationally, an estimated $10 million are spent annually by state and local governments to remedy road salt contamination. The Northeastern Illinois Planning Commission (undated) estimates that 18 million tons of deicing salt, primarily sodium and calcium chlorides, are used

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each year in the United States. When the dissolved salts in runoff from highways and bridges enter soils, ground water, and surface waters, salinity levels increase and can become toxic to plants, fish, and other aquatic organisms. These impacts are especially pronounced in smaller water bodies adjacent to salted areas. Additionally, salt is corrosive and may cause damage to roadways, bridges, and vehicles. Deicing is very important for pedestrian and driver safety, and there are a number of new technologies available for reducing the threat to water quality from this activity. For a discussion of management practices to minimize the environmental impact of road salt application, see Management Measure 7: Bridges and Highways.

0.3.6.6 Hydrocarbons

The sources of oil, grease, and other petroleum hydrocarbons in urban areas include spillage and seepage of fossil fuels, discharge of domestic and industrial wastes, atmospheric deposition, and runoff. Atmospheric deposition is beyond the scope of this guidance (see North Carolina State University's Web site, http://h2osparc.wq.ncsu.edu/wetland/aqlife/atmosdep.html).

Runoff can be contaminated by leachate from asphalt roads, wearing of tires, deposition from automobile exhaust, and oiling of roadsides and unpaved roadways with crankcase oil (USEPA, 2000b). Also, many do-it-yourself auto mechanics dump used oil and other automobile-related fluids directly into storm drains (Klein, 1985). Petroleum hydrocarbons, such as polycyclic aromatic hydrocarbons (PAHs), can accumulate in aquatic organisms from contaminated water, sediments, and food, and are known to be toxic to aquatic life at low concentrations (USEPA, 2000b). Hydrocarbons can persist in sediments for long periods and result in adverse impacts on the diversity and abundance of benthic communities.

Hydrocarbons can be measured as total petroleum hydrocarbons (TPH), as oil and grease, or as individual groups of hydrocarbons, such as PAHs (see Management Measure 7).

0.3.6.7 Heavy metals

Heavy metals are typically found in urban runoff, with automobiles suspected to be the leading source (CWP, 1994). For example, Klein (1985) reported in a study of the Chesapeake Bay that designated urban runoff was the source for 6 percent of the cadmium, 1 percent of the chromium, 1percent of the copper, 19 percent of the lead, and 2 percent of the zinc.

Heavy metals are of concern because of toxic effects on aquatic life and the potential for ground water contamination. Copper, lead, and zinc are the most prevalent NPS pollutants found in urban runoff. High metal concentrations can bioaccumulate in fish and shellfish, and affect beneficial uses of a water body.

0.3.6.8 Toxic pollutants

Many different toxic compounds (priority pollutants) have been associated with urban runoff. The NURP studies (USEPA, 1983) indicated that at least 10 percent of urban runoff samples contained toxic pollutants. Methylene chloride and bis (2-ethylhexyl) phthalate were the most commonly reported and detected organic constituents in an ongoing evaluation of stormwater data from NPDES Phase 1 Municipal Separate Storm Sewer System permit holders. PAHs were also found in several hundred storm events (Pitt, 2004).

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0.3.6.9 Temperature

Temperature changes result from increased flows, removal of vegetative cover, and increases in impervious surfaces. Impervious surfaces act as heat collectors, which heat urban runoff as it passes over them. Data indicate that intensive urbanization can increase stream temperature by as much as 5 to 10ºC during storms (Galli and Dubose, 1990). Elevated temperatures can be caused when streambeds become wider and shallower due to higher flows, removal of riparian vegetation along streambanks, and detaining water in runoff management facilities during warm weather. Elevated temperatures disrupt aquatic organisms that have finely tuned temperature limits, such as trout, salmon, and the aquatic insects on which they feed, by decreasing the amount of dissolved oxygen in the water column. Increased water temperatures can also lead to a shift in the algal community, disrupting the aquatic food chain (Galli, 1991).

0.3.7 Nonpoint Source Pollutant Loading

Nonpoint source pollution has been associated with water quality standard violations and the impairment of designated uses of surface waters. The *National Water Quality Inventory: 2000 Report to Congress* (USEPA, 2002b) reported the following:

Siltation, pathogens, oxygen-depleting substances, and nutrients are leading causes of water quality impairments in the nation's rivers and streams; and agriculture, hydromodification, habitat alteration, and urban runoff/storm sewers, all of which are nonpoint sources, were the leading sources of impairment.

The pollutants described previously can have a variety of impacts on coastal resources. Examples of water bodies that have been adversely affected by nonpoint source pollution are varied. The Miami River and Biscayne Bay in Florida have experienced loss of habitat, loss of recreational and commercial fisheries, and decrease in productivity partly as the result of urban runoff (SFWMD, 1988). Additionally, shellfish beds in Port Susan, Puget Sound, Washington, have been declared unsafe for the commercial harvest of shellfish in part because of bacterial contamination from OWTSs (USEPA, 1991). Also, impairment due to toxic pollution from urban runoff continues to be a problem in the southern part of San Francisco Bay (USEPA, 1992). Finally, nonpoint sources of pollution have been implicated in degradation of water quality in Westport River, Massachusetts, which discharges to Buzzards Bay. High concentrations of coliform bacteria have been observed after rainfall, and shellfish bed closures in the river have been attributed to loadings from surface runoff and OWTSs (USEPA, 1992).

0.3.8 Other Impacts of Urban Runoff

Other impacts not related to a specific pollutant can also occur as a result of urbanization. Salinity can be affected by urbanization. Freshwater inflows due to increased runoff can affect estuaries, especially if they occur in pulses, disrupting the natural salinity of an area. Increased impervious surface area and the presence of storm water conveyance systems commonly result in elevated peak flows in streams during and after storms. These rapid pulses or influxes of fresh water into saline receiving waters (i.e., bays, estuaries, and oceans) may be 2 to 10 times greater than normal (ABAG, 1991) This may lead to a decrease in the number of aquatic organisms living in the receiving waters (McLusky, 1989).

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The alteration of natural hydrology due to urbanization and accompanying runoff diversion, channelization, and destruction of natural drainage systems have resulted in riparian and tidal wetland degradation or destruction. Deltaic wetlands have also been adversely affected by changes in historic sediment deposition rates and patterns. Hydromodification projects designed to prevent flooding can reduce sedimentation rates and decrease the marsh aggradation that would normally offset erosion and apparent changes in sea level within the delta (Cahoon et al., 1983).

0.3.9 Management Practices

Management practices are specific actions taken to achieve, or aid in the achievement of, a management measure. A more familiar term might be *best management practice* (BMP). The word "best" has been dropped for the purposes of this guidance (as it was in the Coastal Management Measures Guidance) because the adjective is too subjective. The “best” practice in one area or situation might be entirely inappropriate in another area or situation.

Four major runoff management themes dominate the management practices presented in this guidance document:

- Minimize the amount of impervious land coverage and disconnect impervious areas.
- Promote infiltration.
- Prevent polluted runoff by not allowing pollutants and runoff to mix.
- Remove pollutants from runoff before allowing it to flow into natural receiving waters.

The management practices can be grouped into two basic categories:

- *Nonstructural practices*. Nonstructural practices prevent or reduce urban runoff problems in receiving waters by reducing potential pollutants or managing runoff at the source. These practices can take the form of regulatory controls (e.g., codes, ordinances, regulations, standards, or rules) or voluntary pollution prevention practices. Nonstructural controls can be further subdivided:

    - *Land use practices*. Land use practices are aimed at reducing impacts on receiving waters resulting from runoff from new development by controlling or preventing land use in sensitive areas of the watershed. They can also be used to minimize total land used for development while accommodating growth.

    - *Source control practices.* Source control practices are aimed at preventing or reducing potential pollutants at their source before they come into contact with runoff or aquifers. Some source controls are associated with new development. Others are implemented after development occurs and include pollution prevention activities that attempt to modify aspects of human behavior, such as educating citizens about the proper disposal of used motor oil and application of lawn fertilizers and pesticides.

- *Structural practices*. Structural practices are engineered to manage or alter the flow, velocity, duration, and other characteristics of runoff by physical means (USEPA, 1993).

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In doing so they can control storm water volume and peak discharge rates and, in some cases, improve water quality. They can also have ancillary benefits such as reducing downstream erosion, providing flood control, and promoting ground water recharge.

0.4 Information Resources

The Center for Watershed Protection is a non-profit organization that provides information concerning watershed restoration, planning, research, and training, storm water management, better site design, education, and outreach. Among other achievements, the Center has completed 20 plans to protect or restore local watersheds and 30 watershed research projects, responded to 5,000 requests for watershed advice, and trained more than 15,000 individuals through workshops. The Center for Watershed Protection's Web site (http://www.cwp.org) provides links to upcoming workshops, current and ongoing projects, surveys, and publications. Example publications available electronically include *Stormwater BMP Design for Cold Climates*, *Codes and Ordinances Worksheet*, and *Site Planning for Urban Stream Protection*. The Center for Watershed Protection also manages the Stormwater Manager's Resource Center Web site, which is designed to provide technical information to storm water managers.

Coordinated through the European Rivers Network, Rivernet is a multilingual service providing information concerning river ecological projects, river basins, and organizations currently working on problems associated with rivers. Access to newsletters, water policy and river management information, educational materials, international news related to rivers, and regional river basin news are available at the Rivernet homepage (http://www.rivernet.org/welcome.htm).

The Natural Resources Defense Council (NRDC), an organization with more than 500,000 members nationwide, seeks to protect and restore the natural environment. Information relevant to storm water management and pollution can be accessed at their Web site (http://www.nrdc.org/water/pollution). An example is *Stormwater Strategies*, which is a publication intended for municipal officials, local decision-makers, citizens, and environmental activists that provides examples of effective storm water management programs employed across the U.S. *Stormwater Strategies* can be downloaded at http://www.nrdc.org/water/pollution/storm/stoinx.asp.

The U.S. Geological Survey's Web site offers water quality and use data; publications, products, and technical resources; and links to water resource-related programs. Individual USGS case studies and reports of grants related to urban runoff programs are available through this site, which is located at http://water.usgs.gov.

Part of EPA's Office of Wetlands, Oceans, and Watersheds, the Nonpoint Source Control Branch provides information on many aspects of nonpoint source pollution. Resources include introductory information about nonpoint source pollution, nonpoint source publications and information resources, funding, information on the Clean Water Act and Coastal Zone Act Reauthorization Amendments, and educational information. More information and access to a full list of available resources can be found at http://www.epa.gov/OWOW/NPS/index.html.

EPA's Office of Wastewater Management (OWM), in cooperation with state and local agencies, administers the NPDES permit program, which includes regulating storm water discharges from municipal separate storm sewer systems. The OWM Web site provides technical and regulatory information on the NPDES Storm Water program as well as publications dealing with urban runoff. The OWM Web site can be accessed at http://www.epa.gov/npdes and information specific to the Storm Water program can be accessed at http://www.epa.gov/npdes/stormwater.

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The Water Environment Federation (WEF) is a nonprofit technical and educational organization dedicated to the preservation and enhancement of the global water environment. The Water Environment Federation Web site contains a search engine for periodicals, newsletters, technical magazines, and other publications related to wastewater treatment and water quality protection. Members of the organization provide technical expertise and training on issues, including nonpoint source pollution, hazardous waste, residuals management, and groundwater; sponsor conferences and other special events around the world; and review, testify, and comment on environmental regulations and legislation. More information on WEF is available at http://www.wef.org.

The Sierra Club and American Rivers sponsored the publication of *Where Rivers Are Born: The Scientific Imperative for Defending Small Streams and Wetlands*, which provides an argument for protecting small, intermittent or "headwater" streams and wetlands based on the numerous environmental functions of these systems and their close connectivity with activities on land. The authors detail such functions as flood control, maintenance of water supplies, sediment trapping, and maintenance of biological diversity. The document can be downloaded in PDF format at http://iowa.sierraclub.org/Steve-Sierra%20web%20docs0526/WhereRiversAreBorn.pdf.

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MANAGEMENT MEASURE 1
PROGRAM FRAMEWORK AND OBJECTIVES

1.1 Management Measure

Develop, implement, and enhance a runoff management program framework that

- Has adequate legal authority to implement the program effectively;
- Has an effective institutional structure;
- Has adequate funding and staffing;
- Incorporates comprehensive watershed planning, including watershed/subwatershed goals and objectives; and
- Fosters input from citizens, stakeholders, and technical experts, and coordinates with other agencies.

1.2 Management Measure Description and Selection

1.2.1 Description

The goal of this management measure is to ensure that urban runoff management programs are developed and implemented with a solid institutional foundation. Federal, state, regional, and local governments all play important roles in establishing and maintaining programs. Consequently, a team approach must be taken to avoid overlap of key responsibilities and authorities, and to ensure that the appropriate levels of government function cooperatively.

1.2.1.1 Role of federal government

Because nonpoint source runoff management programs are within the purview of state and local governments, the federal government's primary role in nonpoint source runoff management programs is to develop broad urban runoff control guidance with participation of state, regional, and local governments, and to provide technical and financial assistance to support the implementation of effective programs and practices.

1.2.1.2 Role of state government

State programs play an especially important role in establishing the team approach to runoff management. State officials interpret and coordinate federal mandates for implementation at the local level, establish state performance standards, and design criteria for runoff control. States also typically take the lead in conducting research, providing technical assistance, developing public education programs, running training and certification programs for practitioners of runoff management, and implementing monitoring programs to help evaluate the effectiveness of management practices (WMI, 1997a).

Many states allow runoff management programs to be delegated to local jurisdictions while the states retain important oversight and enforcement responsibilities to ensure statewide

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consistency. States should maintain the authority to intervene if necessary. The following is a list of regulatory elements that might be included in a state's runoff legislation, or in rules and regulations to help guide local program implementation (WMI, 1997b):

- Criteria for local program implementation or delegation
- Types of activities that require runoff control
- Waivers, exemptions, and variances
- Plan approval and inspection fees, including construction or maintenance performance bonds
- Authority for a local storm water utility
- Specific design criteria
- Permit application and approval process
- Operation permit requirements and time frames
- Development and implementation of mandated educational programs related to site inspection of active and completed storm water management systems
- Requirements for any other educational programs
- Inspection requirements, including certification of inspectors
- Maintenance requirements for postconstruction runoff control facilities
- Penalty provisions in the event of noncompliance with requirements for the design, construction, or operation of storm water management systems

1.2.1.3 Role of regional authorities

Regional authorities often share some of the duties of state agencies but customize their services to fit the needs and attributes of the region. They provide a link between local communities and the state, and often work with state officials to establish region-based performance standards and design criteria for runoff controls. They also serve as a focal point for coordinating issues and interests among communities in the region, especially in terms of implementing the watershed approach, developing watershed plans, ensuring consistency of storm water runoff master planning, and resolving situations that affect downstream communities.

1.2.1.4 Role of local government

Counties and municipalities integrate local runoff management planning with land use and regional watershed management plans, floodplain management, wastewater planning, and other programs that affect the management of urban runoff. They are involved with the day-to-day administrative, operational, and technical aspects of runoff management and are responsible for performing inspections, enforcing compliance, performing operation and maintenance, identifying and removing illicit connections, and coordinating program funding.

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Wisconsin DNR Revisits their Approach to Watershed Programs

The Wisconsin Department of Natural Resources (WDNR) recognized a need for a more holistic approach to watershed programs (Nemke, 1997). They recognized the following problems associated with planning, coordination, cooperation, funding, and implementation of watershed initiatives:

- Although money is available for implementing watershed initiatives, no formal mechanisms exist to raise and allocate money needed to carry plans forward.
- There is no single agency or organization that has regulatory authority over all of the resources that are involved in watershed initiatives, which sometimes results in conflicting priorities.
- Groups that plan and implement watershed initiatives typically are made up of a diverse group of stakeholders with different leadership abilities, motivations and priorities, and technical backgrounds. This diversity makes it difficult to keep the group moving in a consistent direction and becomes problematic when a consensus is needed to allocate funding for implementation.
- Rules and guidance documents often dictate inflexible solutions for dischargers and discourage more creative, innovative, or cost-effective solutions that could be equally or more beneficial to the watershed initiative.

WDNR presented the following recommendations for watershed districts to help overcome logistical problems associated with watershed programs:

- Staff should stay current on watershed issues and initiatives by attending conferences and keeping abreast of relevant journal articles and reports to get a better idea of what practices and policies work best.
- Staff should take a leadership role on technical issues relating to evaluation of watershed problems and solutions.
- The district should avoid taking an expanded role in solving watershed problems unless this role is clearly defined in their statutory authority and other government bodies agree that this role is appropriate and prudent.
- The district should only commit funds to initiatives that are clearly tied to potential benefits for the district's users.
- The district should encourage and participate in evaluations of legislative initiatives that will provide adequate authority to implement watershed-based solutions.
- The district should critically evaluate proposed solutions to watershed problems to ensure they will adequately and sensibly address these problems.

All runoff management programs share common needs, including the legal authority to create, adopt, and enforce ordinances; an institutional structure designed to carry out the goals and objectives of the program; and adequate funding for staff and program activities. Planning serves as the foundation for runoff programs; it establishes management measures and determines how and where management practices will be applied. The program framework should also include the input of citizens and other stakeholders, technical experts, and other agencies in the program

planning and implementation. Communities will need to balance stakeholder concerns for the environment and the economy. Community groups must work together as they develop their own sustainable development concepts to contribute to the betterment of the environment and the residents of the watershed. Finally, ongoing program evaluation and feedback are critical (see Management Measure 12: Evaluate Program Effectiveness).

1.2.2 Management Measure Selection

This management measure was selected because successful runoff management programs require an established program framework and objectives. The measure is intended to provide general guidance on the common aspects of a program framework that should be considered and addressed when developing a runoff management program. Examples are provided to illustrate how the practices can be used to implement the management measure.

1.3 Management Practices

1.3.1 Establish Legal Authority

A successful urban runoff program must have the legal authority to accomplish its goals and objectives. State-level programs derive their legal authority from various laws, codes, and regulations enacted by the state legislature. Only a few states have passed comprehensive statewide runoff management legislation. States whose laws often serve as models include Delaware, Florida, Maryland, New Jersey, and Washington.

The language in state runoff legislation is usually general and might include the runoff program's goals, procedures, and general requirements for maintenance. Details concerning design, construction, operation, and maintenance of runoff management practices are established by the program's implementing regulations and guidance materials (runoff management manual).

If authorized by state law, the state can delegate program implementation authority to local entities. Delegation is usually beneficial to local governments because they have a direct interest in seeing that practices are installed, operated, and maintained correctly. Delegation also provides them the flexibility to implement the program based on the needs of the community. To aid local communities in this endeavor and to ensure statewide consistency in runoff management, state program officials typically develop a state manual that presents design criteria and guidance for implementing specific management practices. State and local regulation writers typically adopt the state manual by reference into their regulations wherever appropriate to ensure that the information contained in the document is used and applied correctly.

EPA's Office of Wetlands, Oceans, and Watersheds has developed a Web site that has examples of model ordinances that address issues such as aquatic buffers, erosion and sediment control, open space development, storm water control operation and maintenance, illicit discharges, and postconstruction controls (USEPA, 1999b). The Web site, http://www.epa.gov/owow/nps/ordinance, also has materials that support particular ordinances, such as maintenance agreements and inspection checklists. Additionally, the Center for Watershed Protection's Stormwater Manager's Resource Center Web site has a collection of model ordinances, which can be accessed at http://www.stormwatercenter.net/.

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The primary focus of the management practices discussed below is on how local governments can increase their ability to manage runoff by developing new ordinances or regulations, or modifying existing ones. It should be noted that many of these practices could also be adopted at the state level to ensure statewide consistency of runoff management practices.

1.3.1.1 Examine existing laws and regulations

The first step in crafting ordinances to improve runoff management controls at the local level is to examine all the existing mandates, authorities, laws, regulations, codes, ordinances, review processes, and so forth that pertain to environmental review in the community. By comparing current rules and practices with the rules needed to achieve the goals and objectives of the runoff management program, a community can identify gaps and weaknesses that need to be addressed.

Frederick County, Maryland, Site Planning Roundtable

The Frederick County Department of Planning and Zoning and the Center for Watershed Protection facilitated a local site planning roundtable in Frederick County, Maryland. The roundtable worked to review the county's current subdivision and zoning codes, define the local hurdles that impede the implementation of more innovative site planning techniques, and hammer out changes to local codes and ordinances that would foster more environmentally friendly development. By January 2000 the diverse group of planners, developers, watershed planners, and other community professionals arrived at a consensus on the modifications necessary to achieve widespread implementation for more environmentally sensitive site designs. The changes the group recommended are designed to guide future site development in the county toward the goals of reducing impervious cover, conserving natural areas, and minimizing storm water pollution.

The resulting document, Fred*erick County Roundtable Recommendations: A Consensus Agreement*, was presented to the Frederick County Commissioners in February 2000. While certainly fostering better site design in Frederick County, the successful Frederick County roundtable also is an important example for other communities interested in implementing similar projects. In addition, this project complements other ongoing regional, state, and local growth management efforts occurring throughout Maryland.

For more information on the Frederick County Site Planning Roundtable's recommendations, contact the Center for Watershed Protection, 8391 Main Street, Ellicott City, Maryland 21043; phone 410-461-8323; fax 410-461-8324; e-mail: mailto:center@cwp.org.

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Revision of Development Rules for the City of High Point, North Carolina

The state of North Carolina plans to build a reservoir, called Randleman Lake, to meet the growing need for water in North Carolina's Piedmont Triad region (Brewer et al., 2000). Recognizing that the watershed has one of the highest rates of urbanization in the region, the state has developed a set of rules, called the Randleman Lake Water Supply Watershed Protection Rules, to establish requirements for wastewater dischargers, protect and maintain riparian areas, and provide for urban runoff management in areas draining to Randleman Lake. The City of High Point was charged with developing a watershed protection ordinance to comply with the Randleman Lake Rules, which require strict development limitations for areas within the watershed (Table 1.1).

Table 1.1: Summary of the Randleman Lake water supply watershed protection rules.

Development Option	1.1.1.1.1 Description
Critical area low density	– 6% impervious surface limit or 1 dwelling unit per 2 acres. – 50-foot stream buffers around perennial and intermittent streams.
Critical area high density	– 30 percent impervious surface limit. – 100-ft and 50-ft buffers for perennial and intermittent streams, respectively. – Structural controls required for developments with 6 to 30% imperviousness.
General watershed area—low density	– 12% impervious surface limit or 1 dwelling unit per acre. – 50-foot stream buffers around perennial and intermittent streams.
General watershed area—high density	– 50% impervious surface limit. – 100-ft and 50-ft buffers for perennial and intermittent streams, respectively. – Structural controls required for developments with 12 to 50% imperviousness.

The city undertook a two-part study to facilitate development of an ordinance that protects water quality while providing flexibility to accommodate projected growth. The first part of the study involved a committee of stakeholders charged with identifying and evaluating different strategies for watershed protection. The city used an iterative approach to involve the stakeholder groups with an important "feedback loop" and key checkpoints throughout the process to gauge and document each stakeholder group's buy-in and formal approval. The second part of the study involved a comparative analysis of impacts of different protection strategies for the watershed. The comparative analysis focused on phosphorus as an indicator of water quality impacts on Randleman Lake. The analysis involved establishing a baseline of phosphorus loading that is not to be exceeded by alternative strategies for new development. It also involved identifying and estimating additional loadings from areas that are expected to be developed more intensely and are expected to exceed the baseline phosphorus loading. Strategies for offsetting these loadings elsewhere in the watershed or mitigating them with more protective on-site management practices were then developed and evaluated.

The plan (see Figure 1.1) and ordinance adopted as a result of this study were based on a phosphorus banking principle and included the following elements:

- Maintenance of a 6.4-square-mile critical area, which is larger and more restrictive than that required in the Randleman Lake Rules and yields a phosphorus loading reduction/offset of approximately 800 lb/yr.
- Use of 440 lb/yr, or approximately 55 percent of the phosphorus offset, to allow increased imperviousness for planned higher-density nonresidential development.
- Use of the remaining offset as a phosphorus reduction reserve.
- Revision of ordinance(s) and engineering specifications to encourage low-impact design and alternatives to traditional storm water ponds.

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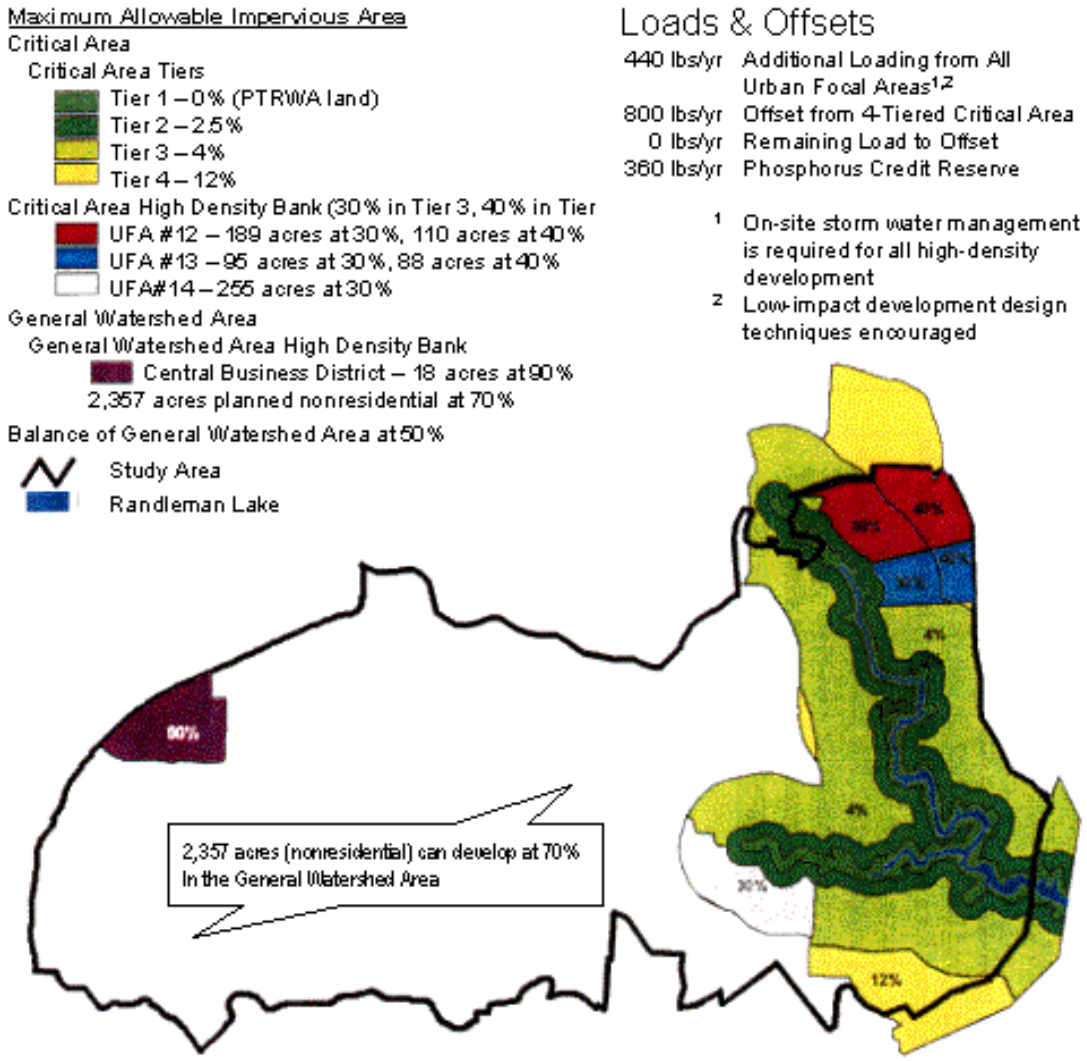

Figure 1.1: Adopted watershed protection plan for the City of High Point, North Carolina.

The city has adopted a watershed protection ordinance for the Deep River 1 watershed that incorporates the strategies listed above and has modified its engineering specifications to allow bioretention facilities and to provide guidance for their design. In the coming year, the city will work to:

- Review local monitoring data and recommend additional monitoring protocols that can track the effectiveness of best management practices used, including new low-impact development design techniques. Possible funding sources for monitoring will be identified.
- Review and revise the city's development ordinance and engineering specifications to further allow and encourage low-impact design techniques.
- Plan and host a spring 2000 low-impact development design workshop for city staff, local contractors, and engineers.

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1.3.1.2 Develop or improve ordinances for water quality enhancement

(1) *Aquatic buffer ordinance*. Aquatic buffers serve as natural boundaries between local waterways and existing development. They help protect water quality by filtering pollutants, sediment, and nutrients from runoff. Some other benefits of buffers are flood control, streambank stabilization, controlling stream temperature, and providing room for lateral movement of the stream channel. Good aquatic buffer ordinances specify the size and management of the stream buffer and are a specific planning tool to protect stream quality and aquatic habitat.

Effective buffer ordinances provide guidelines for buffer creation and maintenance and should require:

- Buffer boundaries that are clearly marked on local planning maps;
- Maintenance language that restricts vegetation and soil disturbance;
- Tables that illustrate buffer width adjustment by percent slope and type of stream; and
- Direction on allowable uses and public education.

(2) *Erosion and sediment control ordinance*. A basic goal of erosion and sediment control programs should be to minimize off-site impacts by first preventing erosion and then maximizing control of sedimentation on-site (WMI, 1997a). A key tool for accomplishing this goal is an effective erosion and sediment control (ESC) ordinance.

An ESC ordinance typically requires developers to submit an ESC plan to a state or local regulatory agency for approval prior to initiating construction activities. This plan contains specific practices to prevent erosion and control sediment, as well as information concerning phasing of clearing and grading activities. Once the plan is approved by the regulatory agency, the developer and contractor are responsible for following the plan and implementing the management practices. If follow-up inspection reveals a lack of

Residents' Willingness to Pay for Riparian Buffers

In St. Charles County, Missouri, rapid growth has resulted in serious threats to the environment such as flooding, water pollution, and habitat loss for aquatic organisms and wildlife. To combat these problems, the St. Charles "Natural Watercourse Protection Ordinance" was passed, and requires 50-foot riparian buffer along major streams and a 25-foot buffer along tributaries when adjacent land is being developed for residential or other non-agricultural uses. In anticipation of potential increases in development costs and home prices resulting from the ordinance, a study was conducted in the Dardenne Creek watershed to evaluate the residents' willingness to pay for adopting buffers in newly developed residential communities. Survey respondents identified wildlife, environmental benefits, and natural appearance and sounds as the primary values of Dardenne Creek. Respondents were concerned about the damaging impacts of flooding, erosion, and safety of children on property values. 43.7 percent of the respondents were willing to pay a median value of $1000 for community-owned and open accessible buffers. The study indicates that residents generally recognize the potential environmental benefits of the buffer ordinance, but outreach efforts should focus on informing homeowners that the ordinance may result in increased construction costs and higher home prices. The study's author concludes that the residents' willingness to pay indicates that the real estate market can absorb the possible increases in the construction costs due to implementing the ordinance (Qiu, 2003).

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compliance, the inspector may issue a permit violation, stop-work order, or fine, or take other steps to compel action.

Whether program authority is implemented at the state level or delegated to a local government, the ordinance should include goals, performance standards, and design criteria for both erosion prevention and sedimentation control. At a minimum, the ordinance should define the following erosion prevention design criteria:

- The threshold for disturbed areas at which regulatory action/compliance is required; and
- The maximum time frame for permanent site stabilization after final grading or temporary stabilization if construction ceases and the site is left dormant.

(3) *Open space ordinance*. Open space development, also known as "cluster development," is a planning technique that concentrates dwelling units in a compact area and leaves the balance of the site as natural, open space. Lot sizes, setbacks, and frontage distances are minimized, thereby reducing the amount of impervious cover on-site. Open space development reduces the need for clearing and grading by 35 to 60 percent, and increases opportunities for using the reserved land for a variety of purposes such as conservation, recreation, habitat preserves, and storm water management. Table 1.2 shows a summary of studies that contrasted conventional and open space designs in terms of impervious cover and storm water runoff (CWP, 1998a). Specific recommendations on how to limit imperviousness and maximize pervious areas can be found in Management Measure 4: Site Development.

Table 1.2: Redesign analyses comparing impervious cover and storm water runoff from conventional and open space subdivisions (CWP, adapted 1998a).

Residential Subdivisions	Conventional Zoning for Subdivision	Impervious Cover at the Site			Percent Reduction in Runoff
		Conventional Design	Open Space Design	Net Change	
Remlik Hall	5-acre lots	5.4%	3.7%	-31%	20%
Duck Crossing	3- to 5-acre lots	8.3%	5.4%	-35%	23%
Tharpe Knoll	1-acre lots	13%	7%	-46%	44%
Chapel Run	½-acre lots	29%	17%	-41%	31%
Pleasant Hill	½-acre lots	26%	11%	-58%	54%
Prairie Crossing	½- to ⅓-acre lots	20%	18%	-10%	66%
Rapahannock	⅓-acre lots	27%	20%	-24%	25%
Buckingham Greene	⅛-acre lots	23%	21%	-7%	8%
Belle-Hall	High density	35%	20%	-43%	31%

For open space development to be successful, the ordinance needs to be crafted to foster development that is both marketable and environmentally sensitive. The ordinance also needs to effectively address issues such as maintenance, liability, and access by emergency vehicles. In addition, the community needs to be prepared to manage the space or to dedicate open space to a responsible organization.

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The Center for Watershed Protection and EPA Present Model Ordinances on the Web

Communities can strengthen the language of their regulations and ordinances to better protect environmental resources by referring to examples of exemplary ordinances from across the country. The following is a list of ordinances available for download from http://www.epa.gov/owow/nps/ordinance.

Aquatic Buffers
- Language from Baltimore County, MD
- Coastal Zone Program, RI (an example of a buffer ordinance in a coastal region)
- Ordinance on Riparian Habitat Areas, Napa, CA
- Portland Metro Floodplain Preservation Ordinance
- Model Land Trust Agreement from the Natural Lands Trust

Erosion and Sediment Control
- Erosion and Sediment Control Ordinance from Minneapolis, MN
- Clearing and Grading Ordinance from Olympia, WA
- Erosion and Sediment Control Inspection Checklist from the Lower Platte South Natural Resources District, NE
- Small Site Design Guideline from the Indiana Department of Natural Resources
- Preconstruction Meeting Notice from Montgomery County, MD

Open Space Development
- Open Space Development Ordinance from Calvert County, MD
- Land Preservation District Model Zoning from Montgomery County, PA
- Open Space Ordinance from Hamburg Township, MI

Storm Water Operation and Maintenance
- Ordinance Language from Grand Traverse County, MI
- Example Maintenance Agreement from Albemarle County, VA
- Easement and Right-of-Way Agreement from Montgomery County, MD
- Inspection Checklist from Anne Arundel County, MD
- Performance Bond from Colorado

Illicit Discharges
- Fort Worth, TX, Environmental Code: Storm Water Protection
- Washentaw County, MI, Regulation for Inspection of Residential Onsite Disposal Systems at Property Transfer
- Metro. St. Louis Sewer District Sewer Use
- City of Monterey, CA, Storm Water Ordinance
- Montgomery County, MD, Illicit Discharge Ordinance

Postconstruction Controls
- Maryland Department of the Environment Proposed Storm Water Management Regulations
- Grand Traverse County, MI, Soil Erosion and Storm Water Runoff Control Ordinance
- City of Seattle Storm Water, Grading, and Drainage Control Code
- St. Johns River Water Management District, FL: Environmental Resource Permits
- City of Santa Monica, CA, Municipal Code of Ordinances: Urban Runoff Pollution

Source Water Protection: Ground Water Ordinances
- Aquifer Protection District Ordinance from Stratham, NH
- Ground Water Protection and Siting Ordinance from Hernando County, FL
- Ground Water Source Protection Overlay District Ordinance from Salt Lake City, UT
- Sinkhole Ordinance from Lexington, KY
- Wellhead Protection District Ordinance from Weston, WI

Source Water Protection: Surface Water Ordinances
- Tahoe Regional Planning Agency Source Water Protection Ordinance
- Shoreland Management Overlay District Ordinance from Buffalo, MN
- Water Supply Watershed District Overlay Ordinance from Greensboro, NC
- Watershed Management and Protection Area Overlay District Ordinance from County of York, VA
- Town of Skaneateles Lake Watershed District Ordinance, NY

Miscellaneous Ordinances
- Lake Travis Nonpoint Source Ordinance
- Storm Water Utility Ordinance from Takoma Park, MD
- Transfer of Development Rights Ordinance from Sarasota, FL
- Golf Course Management Guidelines from Baltimore County, MD
- Wetlands and Watercourses Ordinance from Croton-on-Hudson, NY
- Forest Conservation Ordinance from Frederick County, MD

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(4) *Storm water operation and maintenance ordinance*. The expense of maintaining most storm water management practices is relatively small compared to the original construction cost. Too frequently, however, maintenance is not completed, particularly when the practice is privately owned. Improper maintenance decreases the efficiency of management practices and can also detract from the aesthetics of the practices. The operation and maintenance language within a storm water ordinance can ensure that designs facilitate easy maintenance and that regular maintenance activities are completed.

(5) *Illicit discharge ordinance*. An illicit discharge is defined as any discharge to the municipal separate storm sewer system that is not composed entirely of storm water, except for discharges allowed under an National Pollutant Discharge Elimination System permit or waters used for firefighting operations. These non-storm water discharges occur because of illegal connections to the storm drain system from residential, business, or commercial establishments. As a result of these illicit connections, contaminated wastewater enters storm drains or directly enters local waters before it receives treatment at a wastewater treatment plant. Illicit connections might be intentional or can be unknown to the business owner; often they are the result of connection of floor drains to the storm sewer system. Additional sources of illicit discharges include improperly connected sanitary sewer lines, failing septic systems, illegal dumping practices, and the improper disposal of sewage from recreational activities like boating and camping.

Illicit discharge detection and elimination programs are designed to prevent contamination of ground and surface waters by monitoring, inspection, and removal of these illegal non-storm water discharges. An essential element of these programs is an ordinance granting the authority to inspect properties suspected of releasing contaminated discharges into storm drain systems. Another important factor is the establishment of enforcement actions for those properties that are found to be in noncompliance or refuse to allow access to their facilities.

(6) *Postconstruction runoff control*. The management of runoff from sites after the construction phase is vital to controlling the adverse effects of development on urban water quality. The increase in impervious surfaces such as rooftops, roads, parking lots, and sidewalks due to land development can have a detrimental effect on aquatic systems. High amounts of impervious cover have been associated with stream warming, habitat alteration, and decreased aquatic integrity in urban areas (Karr, 1991; May et al., 1997; Schueler, 1995; Shaver et al., 1994). Runoff from impervious areas can also contain a variety of pollutants that are detrimental to water quality, such as sediment, nutrients, road deicers, heavy metals, pathogenic bacteria, and petroleum hydrocarbons.

The main goal of a runoff management ordinance for existing development is to limit surface runoff volumes and reduce runoff pollutant loadings. For example, the ordinance could specify which nonstructural and structural storm water practices are allowed in the community. Communities might also wish to add language pertaining to on-site runoff requirements, and should identify whether off-site treatment is an option. Example ordinances can be found on EPA's Model Ordinances to Protect Local Resources Web site at http://www.epa.gov/owow/nps/ordinance/index.htm.

(7) *Source water protection ordinances*. Source water protection involves preventing the pollution of the ground water, lakes, rivers, and streams that serve as sources of drinking water for local communities. Source water protection ordinances help safeguard community health and reduce the risk of water supply contamination. When drafting an ordinance aimed at protecting these sources, drinking water supplies can be divided into two general sources: ground water (aquifers and wells) and surface water (lakes and reservoirs). Wellhead Protection Zones and Aquifer Protection Areas are two examples of source water protection ordinances that seek to protect ground water sources. Water Supply Watershed Districts and Lake Watershed Overlay Districts are examples of local management tools that provide protection of surface water supplies by restricting land uses around a reservoir used for drinking water.

(8) *Runoff management ordinances/regulations*. The primary purpose of runoff regulations is to ensure that runoff management systems (within the area of jurisdiction) are properly designed, constructed, inspected, operated, and maintained. A comprehensive ordinance should incorporate the issues addressed below (WMI, 1997b).

(a) *Design and review requirements*. Runoff management systems must be properly designed and constructed to function efficiently. A design manual tailored to local topographic, geologic, and climatic conditions and local regulations should be developed to accompany a runoff management ordinance. National and regional guidance is available to assist local governments in developing technical guidance. For example, the National Association of Homebuilders (NAHB, 1995) has produced a guidance manual entitled *Storm Water Runoff and Nonpoint Source Pollution Control Guide for Builders and Developers* that can be used to develop a technical design manual. The design manual is typically referenced in the ordinance to direct users to technical support for their runoff management projects.

(b) *Construction requirements*. Runoff management facilities can fail prematurely if they are poorly constructed or if sediments and other pollutants are not carefully managed during the construction phase. Techniques for protecting structural practices from construction-related pollution are usually addressed in the state runoff management manual and incorporated by reference into the ordinance. Specific practices to mitigate construction site erosion and control sediment are discussed in Chapter 5 under the construction site erosion and sediment control management measure (8).

To ensure that a facility is constructed properly, a runoff management ordinance should include the following:

- *Financial assurances*. A guarantee, usually in the form of a surety or cash bond, should be made that the completed runoff management facility functions properly. The amount typically should not be less than 50 percent of the estimated construction cost of the system (WMI, 1997b).
- *Inspections*. Inspectors should maintain a presence throughout the construction phase and conduct inspections at specified stages of construction, not at assigned time intervals (WMI, 1997b).

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- *As-built certifications and record drawings*. Completed facilities should have official documentation prepared and sealed by a professional engineer or other qualified design professional (WMI, 1997b).
- *Allowances for damage to temporary practices*. Funds should be set aside specifically to repair damage to erosion and sediment controls (e.g., silt fences) at temporary construction sites caused by severe storm flows, high winds, or fallen trees. Funds may be used only if documented inspections show erosion and sediment controls are installed and maintained as required. This allowance helps to ensure 100 percent compliance by contractors (Deering, 1999).

(c) *Operation and maintenance requirements*. Ensuring that runoff management facilities are properly operated and maintained, both in the short term and the long term, is another critical element that should be addressed in the design phase. For the short term, the ordinance should stipulate a warranty period (perhaps one or two years) during which the original developer must retain all operation and maintenance responsibilities. The developer should be required to post a bond or other security to ensure that costs will be covered if any design defects or construction failures are discovered during the warranty period.

Several techniques can be used to ensure longevity of management practices, including warranties, operating permits, and maintenance bonds. Specific requirements for operation and maintenance to be set forth in an ordinance might include the following:

- An easement that provides an access road for maintenance equipment
- Ownership of the system and maintenance access road by those who use the system
- Inspection by a certified site inspector at defined intervals
- Land set aside for disposal of sediments removed during maintenance
- Clear documentation of maintenance responsibilities and maintenance schedule
- A written maintenance agreement

When the initial warranty period is over, long-term operation and maintenance responsibilities typically revert to a property owners' association. Unfortunately, in many instances these types of groups do not perform important operation and maintenance tasks because they lack the financial, legal, and/or administrative capability. Very often, this neglect results in failed systems and problems for downstream property owners. The ordinance needs to incorporate specific elements to ensure that a system is in place for collecting fees, contracting for services, and establishing rules and regulations before a property owners' association is granted authority for long-term maintenance. In some cases, it is more prudent for an alternative entity such as local government, special taxing district, or public utility to be responsible for long-term operation and maintenance functions.

(d) *Maintenance inspection requirements*. Periodic inspections and certifications are necessary to ensure that the legal operation and maintenance entity is keeping the storm water system in good working order and making all necessary repairs. An ordinance needs to include language that identifies the inspectors and specifies how often the inspections are to be conducted. Depending on the framework, inspections could be done by the permitting authority or some other public agency. Alternatively, private inspectors might be used. In

either case, inspectors should be required to complete a state-sponsored course and receive certification.

The frequency of inspection depends on the type of management practices employed at the site. Some types of facilities (e.g., a wet pond) might need to be inspected only annually. A sand filter, in contrast, might need to be inspected once a month or even more frequently during the wet season. The entity responsible for maintenance inspections should maintain inspection and maintenance records on file. In addition, procedures need to be established to ensure that problems identified during the inspection process are fixed in a timely manner and that reinspection occurs as soon as practicable.

(9) *Wetlands protection ordinance*. Local governments can protect wetlands by adopting a wetland protection ordinance that supplements the permitting program established under Section 404 of the Clean Water Act (for more information on Section 404, see the Introduction (section 1.2.2 Regulatory Context) or http://www.epa.gov/owow/wetlands/facts/fact10.html). Section 404 does not cover all wetlands, nor does it cover all activities that may infringe on a wetland. A local regulatory program can be used to provide additional protection. A local ordinance should, however, be compatible with, supplement, and/or streamline the Section 404 program while tailoring wetland protection plans to meet local conditions and circumstances (Patton et al., 2000).

Following are some of the important components of a wetlands ordinance (Cowles et al., 1991).

- The applicant should be required to submit a detailed wetland analysis, performed by a trained wetland ecologist, of the subject property, including a professional survey of the wetland edge.
- A wetland should be protected by an adequate undisturbed buffer and placed within a permanent open space or protective easement tract to preclude future subdivision of the wetland.
- Wetlands should not be used as surrogate runoff detention structures. Any runoff directed into a wetland should be pretreated.
- Construction near wetland areas should utilize management practices, including proper placement and installation of sedimentation control and clearly marked limits of construction to avoid inadvertent wetland impacts.
- Non-wetland field staff such as building inspectors, grading inspectors, or any other appropriate staff should be trained to recognize wetlands and to ensure management practices are used and enforced during the construction process.

(9) *Miscellaneous ordinances*. Other ordinances capture issues that are important for protection of water resources but do not fall into a single category. The following are examples of miscellaneous ordinances:

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- The Nonpoint Source Ordinance for Lake Travis, which is located along the lower Colorado River near Austin, Texas, addresses techniques required to control nonpoint source pollution from permitted and unpermitted activities.
- The Transfer of Development Rights Ordinance of Sarasota, Florida, allows for the transfer of development rights to protect environmentally sensitive areas from impacts caused by new development by directing new development to less-sensitive areas.

1.3.1.3 Explore market-based regulatory approaches

Water quality trading is a market-based approach to improving and preserving water quality. Trading allows one pollution source to meet its regulatory obligation by purchasing pollutant reductions created by another source that reduces pollution below levels required by federal and state regulations. Trading is a cost-effective solution because pollution control is achieved where the cost is lowest.

EPA is currently targeting water quality trading and providing guidance and procedures. Trading is a possibility in all watersheds, even where water quality is not impaired, but the focus is on watersheds with approved TMDLs. Water quality trading is encouraged for nutrients and sediments. For pollutants other than nutrients or sediment, a higher level of scrutiny would be applied. EPA does not support the trading of persistent bioaccumlative toxic pollutants, or trading where water quality standards would be exceeded.

Water quality programs should include the following provisions for trading:

- Permits under Sections 402 and 404.
- For NPDES permits, information on how trading baselines and conditions have been established and how they are consistent with water quality standards.
- Standard methods for measuring compliance.
- Designated uses to be protected (e.g. the antidegradation policy will be upheld).

Credible trading programs generally include:

- Legal authority and mechanisms
- Clearly defined units of trade
- Creation and duration of credits
- Protocols for quantifying credits and addressing uncertainty
- Provisions for compliance and enforcement
- Public participation and access to information
- Periodic program evaluations

This box is intentionally left empty.

EPA's trading Web site (http://www.epa.gov/owow/watershed/trading.htm) provides a number of resources related to the current policy, new developments, case studies, and links to other trading programs.

1.3.2 Develop an Institutional Structure

The following practices follow the approach presented by the Center for Watershed Protection in the *Rapid Watershed Planning Handbook* (CWP, 1998c). This approach applies mainly to local efforts in small watersheds. State and regional agencies might need to conduct their efforts on a larger scale. Other resources that address establishing a watershed planning framework on a larger scales include *Framework for a Watershed Management Program* (Clements et al., 1996) and *Know Your Watershed* (CTIC, 2000).

1.3.2.1 Establish a watershed baseline

The first step in a watershed assessment process is to gather basic background information about the watershed and subwatersheds. This process can be used as a foundation for developing the rest of the watershed plan.

(1) *Define watershed and subwatershed boundaries*. Watershed and subwatershed boundaries need to be mapped on a good topographic map such as those produced by the U.S. Geological Survey. These maps, an example of which is shown in Figure 1.2, can help in identifying the political jurisdictions and citizens that should participate in the watershed planning effort, and the land use patterns in the watershed and each subwatershed (CWP, 1998c).

(2) *Identify "embedded" agricultural areas*. Livestock waste management is typically not considered an issue in urban areas. However, the urban/suburban landscape can build up around an existing agricultural area, or property owners can board animals on residential property, making animal waste management an important component of maintaining water

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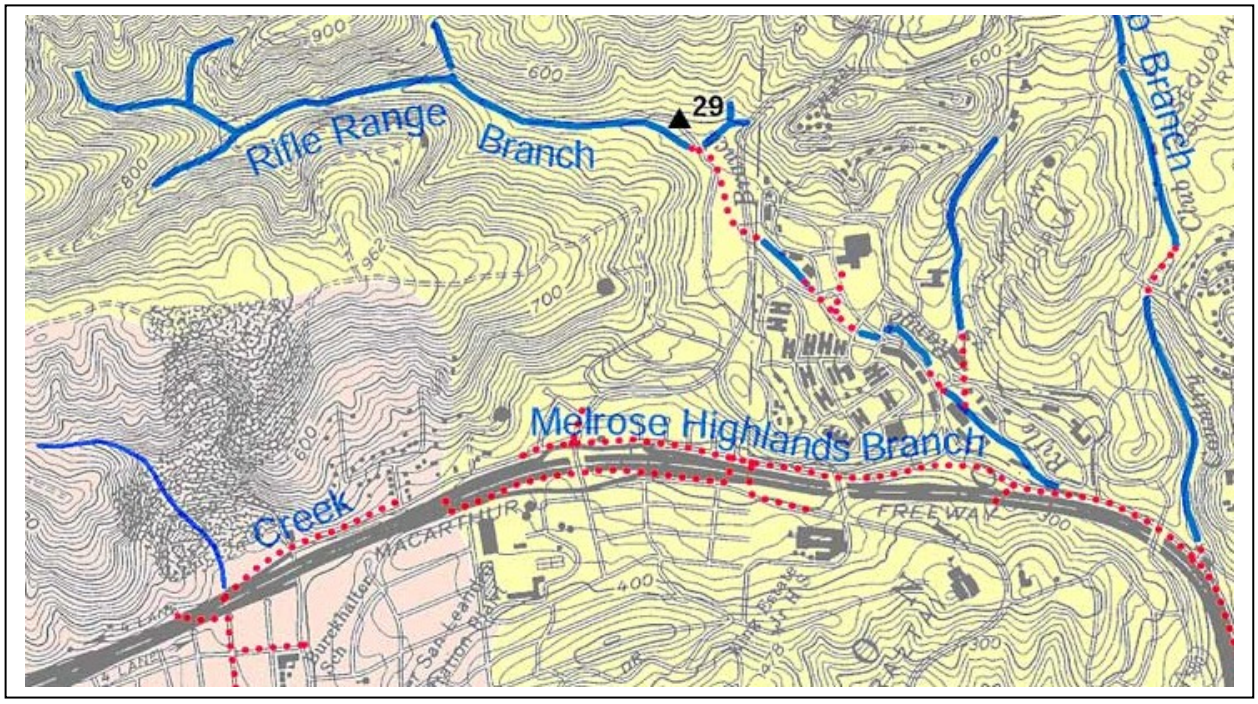

Figure 1.2: Example of part of a subwatershed base map (Oakland Museum of California, No date).

quality in urban areas. Animal wastes from stables or backyard pens contribute nutrients and pathogens to runoff and ground water. Manure can also be a nuisance because of odors and flies, and animals can contribute to the destruction of vegetation through trampling and overgrazing.

Water quality problems can be associated with stables and backyard livestock pens. Management techniques to address these agricultural nonpoint sources include (Terrene Institute, 1994):

- Siting animal areas to drain away from water bodies
- Planting or maintaining as much vegetation as possible between animal areas and water bodies
- Establishing diversions upslope from a high-use area to divert clean water away from bare soils and manure
- Establishing berms or diversions downslope of high-use areas to collect contaminated runoff for treatment
- Establishing fenced areas for animal use to protect vegetation
- Collecting manure and bedding regularly and protecting stored manure from rainfall and runoff

Good Horse Keeping

Horse owners in Massachusetts and the Patriot Resource Conservation and Development (RC & D) Council have launched the Horse Manure Management Initiative (HMMI). The Initiative involves collaboration between horse owners, the Massachusetts Farm Bureau, the Massachusetts Stable Owners, and the Operators and Instructors Association to improve and protect water quality in Essex, Middlesex, Norfolk, and Suffolk counties. The HMMI is focused on education, outreach, and policy initiatives to promote good horse keeping practices and manure management. The Patriot RC&D Council plans to release a *Good Horse Keeping* video and a *Horse Owner Directory and Resource Guidebook* in 2003. For more information, visit http://patriotrcd.org/horse_manure_management.html.

- Applying animal wastes as fertilizer for pastures, croplands, lawns, gardens, nurseries, and greenhouses at rates dictated by soil analyses
- Composting raw manure to reduce bulk, odors, and bacteria

Sources of information for managing pollution from livestock areas include local cooperative extension service offices, soil and water conservation district offices, and U.S. Department of Agriculture (USDA) Natural Resources Conservation Service (NRCS) offices. NRCS published the *Agricultural Waste Management Field Handbook*, which is a comprehensive guide for livestock operators that provides detailed technical information about practices to properly manage animal wastes (USDA NRCS, 1992). This document can be accessed online at http://www.wcc.nrcs.usda.gov/awm/awmfh.html. Additionally, EPA published *National Management Measures to Control Nonpoint Source Pollution from Agriculture*. This document is available for download from the Office of Wetlands, Oceans, and Watersheds' Web site at http://www.epa.gov/owow.

(3) *Identify possible stakeholders*. Stakeholder participation in planning for watershed management is crucial. Stakeholders have power and a variety of insights that will play a large role in whether the plan succeeds or fails. Stakeholders are affected by the outcome of the watershed plan, have a responsibility for implementing the plan, or have the ability to impede or assist the plan's implementation. See below for a list of organizations and people that might be stakeholders. This group is not limited to people living or working in the watershed or subwatershed delineated on the watershed map. Because several local management units can be encompassed by a single watershed**,** state, tribal, interstate, and federal officials often are considered stakeholders in a local watershed initiative. In addition to identifying the stakeholders, the planning process should include developing a technical advisory team or committee to assist with the scientific aspects of the watershed program.

Federal Agencies
- Environmental Protection Agency
- Army Corps of Engineers
- Fish and Wildlife Service (Department of the Interior)
- Federal Emergency Management Agency

Nonprofit Organizations
- Greenways coalitions
- "Friends of …" groups
- Watershed coalitions or foundations
- Anglers' groups
- Volunteer organizations
- Recreation/hiking groups

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State/Local Agencies
- Environmental or wildlife agency
- Flood control district
- Water rights agency (primarily in the southwestern United States)
- Public works department
- Planning/zoning department or board
- State department of transportation
- Local conservation commissions
- Extension services from land grant universities

Private Sector
- Consulting engineers
- Local businesses
- Real estate companies
- Builders/developers
- Trade associations

Other Citizens
- Local residents
- Schools/teachers
- "Downstream" users (i.e., drinking water consumers)

(4) *Measure existing impervious cover*. The amount of impervious cover is a key attribute of watersheds. The impervious cover model (CWP, 1998a) directly links imperviousness levels to the quality of water resources at the subwatershed scale. Crucial to the use of the model is an estimation of the percentage of the subwatershed covered by impervious surfaces. A number of practices can be used to make this estimate, ranging from measuring cover directly using aerial photographs to predicting cover based on the relationship between imperviousness and population or road density statistics.

(5) *Assemble historical monitoring data*. Most water resources in urban and suburban areas have been monitored at one time or another. The challenge is to identify who has collected data and whether the data are in an accessible and usable form. Often the people that collect data in a particular watershed are also stakeholders or members of the technical committee. Whatever the source, watershed data need to be assessed in terms of quality and usefulness. The technical advisory team plays an important role in this endeavor. Once organized, historical data provide the background knowledge necessary for guiding the other steps of the local watershed planning process.

(6) *Assess existing mapping resources*. Resource maps are used to present many aspects of the watershed management plan in a clear, reader-friendly format. Natural and cultural features that can be included on a resource map are:

- Floodplain boundaries
- Stream corridors
- Soils and geologic features
- Current and future land use
- Transportation routes
- Buffers
- Wetlands
- Detention/retention ponds
- Direction of drainage

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(7) *Conduct an audit of local watershed protection capabilities*. A sometimes overlooked but very important task associated with baseline assessment is a critical evaluation of local capabilities to implement watershed practices. The audit should be as complete as possible and should include examination of local programs, regulations, ordinances, master plans, staff resources, and funding. If deficiencies or potential problems are found, the audit can be used as a basis for making changes.

Watershed Assessment, Tracking, and Environmental Results

EPA has developed an integrated information system for the nation's surface waters that combines data from various EPA Office of Water programs into one large framework. Data from the information system, Watershed Assessment, Tracking and Environmental Results (WATERS), is available online through interactive Web-based applications and mapping tools. The following is a list of programs that are incorporated or scheduled to be incorporated into the database:

- *Water Quality Standards*: The Water Quality Standards Database contains information on designated uses for waterbodies
- *Water Quality Inventory 305(b) Report*: The National Assessment Database includes information on the attainment of water quality standards. Waterbodies are classified as Fully Supported, Threatened or Not Supporting these designated uses.
- *Total Maximum Daily Load 303(d) List*: The TMDL Tracking System provides information on waterbodies that are designated as Not Supporting. These waterbodies are required by law to have TMDLs developed, and the database tracks the status of those TMDLs.
- *Water Quality Monitoring*: The STORET database contains water quality, biological and physical data.
- *NPDES Permits*: The Permit Compliance System stores data on NPDES facilities, permits, compliance status, and enforcement activities for up to six years.
- *Safe Drinking Water*: The Safe Drinking Water Information System contains information on public water systems and drinking water standard violations.
- *Fish Consumption Advisories*: The National Listing of Fish and Wildlife Advisories database includes information on fish consumption advisories issued by states, tribes, and the federal government.
- *Nonpoint Source Pollution*: The Section 319 Grants Reporting and Tracking System is a compilation of information on projects and activities funded by CWA Section 319(h) funds.
- *Nutrient Criteria*: The Nutrient Criteria Database stores and analyzes nutrient water quality data.
- *The BEACH Program*: The Beaches Environmental Assessment, Closure & Health (BEACH) Watch database provides information on whether a specific beach is being monitored for water quality, the party responsible for the monitoring, the pollutants that are being monitored, and advisories or closures that have been issued.
- *Vessel Sewage Discharge*: Vessel sewage discharge is regulated under Clean Water Act Section 312, which mandates the use of marine sanitation devices (on-board equipment for treating and discharging or storing sewage) on all commercial and recreational vessels that are equipped with installed toilets. Under Section 312 States may request a No-Discharge Zone designation that prohibits the discharge of sewage from all vessels into defined waters.

The WATERS database can be accessed online at http://www.epa.gov/waters.

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1.3.2.2 Set up an institutional structure

A successful runoff management program requires a strong institutional structure (CWP, 1998c). A typical institution carries out many functions, including:

- Setting goals for the watershed and subwatersheds
- Identifying gaps in monitoring data and taking steps to acquire needed information
- Operating as a forum for stakeholder input
- Reviewing and prioritizing management strategies to achieve maximum watershed protection
- Establishing links with other groups and agencies
- Encouraging cooperative exchanges of information
- Providing funding for planning actions and exploring funding options for management practice implementation
- Ensuring long-term implementation of the runoff management plan

Key attributes needed to perform these functions are:

- Adequate permanent staff to perform facilitation and administrative duties
- A consistent, long-term funding source to ensure a sustainable organization
- Inclusion of all stakeholders in planning efforts
- A core group of dedicated people that have the support of local governmental agencies
- Local ownership of the runoff management plan throughout the process
- A process for monitoring and evaluating implementation strategies
- Open communication channels to increase cooperation among organization members

There are three types of runoff management institution models:

- Government-directed model
- Citizen-directed model
- Hybrid model

The primary difference among the three management options is the authority that is ultimately responsible for directing the watershed plan. In the government-directed model, local or regional agencies assume responsibility for making decisions about how the watershed is managed. The citizen-directed model is driven by citizen activists or grassroots organizations, and the hybrid model combines the best of both models and is recommended for most watersheds. Each paradigm has particular strengths and weaknesses, but whatever form the model takes, the framers of the institution must define its goals and carefully lay out the responsibilities and contributions that will be made by each element. Table 1.3 compares the typical components of the three models, lists advantages and disadvantages associated with each model, and specifies conditions where each model might best be applied.

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Table 1.3: Elements of three watershed management structures (CWP, 1998c).

Element	Government-Directed Model	Citizen-Directed Model	Hybrid Model
Formation	Created by legislative authority.	Created at grassroots level by citizens or other interested parties.	Created with some governmental authority and support from citizens.
Membership	Organization membership appointed by governmental authority.	Stakeholder participation is voluntary.	Some members are required to participate, but many are volunteers.
Authority	Structure has regulatory authority over land use and other permits.	Advisory capacity with no regulatory authority over land use or permits.	Some members of the structure have regulatory authority; others act in a volunteer or advisory capacity.
Funding	Funding is through taxes or levied fees.	Funding is by grant, donations, or sometimes local government contributions.	Much of the funding is through a steady source, such as an agreement with a local government, but grants might also compose a significant portion of the budget.
Implementa-tion	Government agencies at the state, local, and federal levels implement the plan.	Local governments implement the plan.	Local governments implement the plan with some assistance from state and federal agencies.
Advantages	Has legal authority to influence development. Has a secure funding source. Consistent staff are available.	Local community has ownership in the plan. No stakeholders are forced to participate. Residents are less intimidated by other citizens than by the government.	Has some authority to implement the plan. Incorporates stakeholders from the public and the government. Usually has some stable funding source and permanent staff. Technical expertise from many sectors can be used to formulate the plan.
Disadvan-tages	Might not incorporate all interests. Citizens and local governments might not have a sense of ownership in the process.	Might be difficult to secure a stable funding source. Implementation might be difficult without legal authority. Because most members are volunteers, it might be difficult to complete the plan quickly. The most vocal groups might be over-represented.	Demands significant input from citizens and government.
Where best applied	Where the plan will require extensive regulations and land use rules to implement. Where the local community cannot raise the funds to develop and implement a plan. Where the community is not strongly mobilized to take the initiative.	Where the local community has a very strong interest in the water resource. Where the local government has an excellent relationship with local citizens' groups and developers. Where some external funding source, or a steady supply from local governments, can support the citizen groups. Where disagreements between different interests are not expected to slow the group's progress.	Most watersheds.

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(1) *Government-directed model*. In this model, an agency of government takes on the responsibility for determining the goals of the runoff management program and directing the means by which those goals are met. Such a structure can consist of one agency vested with regulatory responsibility or a coalition of agencies from the local, state, and federal levels.

The program framework under the government model is strong because of its legal authority and consistent funding, whether required by legislation or instituted as a reflection of an administrative priority. Government involvement ensures that the management process draws on broad public goals and balances the utility of various courses of action. However, government-directed programs often do little to raise public awareness of the need for resource protection, and if a government-led watershed management plan makes inadequate provisions for public input, feelings of disenfranchisement can result. In addition, interagency rivalry can hamper the effectiveness of a government-led management structure.

The government-directed model is frequently employed when a government agency is best positioned to address a particular problem, or when public interest and awareness are not sufficient to motivate citizen participation in the runoff management process.

(2) *Citizen-directed model*. This type of framework is highly legitimate in the public eye because it concentrates heavily on co-opting public involvement throughout the management process and gives the public a strong sense of ownership of the plan. Management recommendations coming solely from the community have no legal authority, however, and community leaders must rely on their ability to engage and motivate governmental entities to accomplish their goals. For that reason, the citizen model usually is effective only where there is a healthy relationship between community leaders and local government.

(3) *Hybrid model*. A quasi-governmental structure, a hybrid runoff management institution is designed to combine legislative authority with technical advice, allowing additionally for stakeholder and citizen input. By representing both government and citizen interests, the model usually provides the most effective means of incorporating public opinion and activity into the needs of the locality and watershed. The specific form that a hybrid management structure takes depends on a variety of factors, but it will usually concentrate heavily on incorporating as many stakeholders as possible into the watershed planning process. Hybrid structures are not vested with regulatory authority but use one of several structures to recommend courses of action to the governing body and plan and implement runoff management practices.

1.3.2.3 Determine budgetary resources available for watershed planning

One of the most important challenges confronting a watershed manager is how to develop watershed and subwatershed plans within existing budget constraints. The manager needs to identify what sources of funding are available and develop budgets for the subwatershed and watershed plans. The cost of a watershed plan varies depending on choices the watershed manager makes regarding mapping, monitoring, modeling, and ongoing management. The budget also depends on the area and complexity of the watershed and its subwatersheds.

1.3.2.4 Project future land use change in the watershed/subwatershed

Land use in a watershed and individual subwatersheds has a strong influence on aquatic ecosystems. Current impervious cover should have been measured as a part of the watershed baseline analysis. The watershed manager needs to forecast the future impervious cover based on available land use planning information, such as existing zoning or master plans.

Impervious cover projection helps watershed managers determine if aquatic resources will degrade from current conditions (see Section 6 of the Introduction for more information about impervious cover). If the analysis indicates that impervious cover will increase to such an extent that it will cause subwatershed quality to decline, a watershed manager should consider shifting impervious cover to another watershed or limiting development.

Southeastern Delaware Whole Basin Management

The Delaware Department of Natural Resources and Environmental Control (DNREC) and Sussex County officials developed a phased process to manage the Inland Bays Basin that combines an assessment program with an implementation plan to solve water quality problems affecting Rehoboth, Indian River, and Little Assawoman Bays (Delaware DNREC, 2000). They identified excessive nitrogen and phosphorus as the most pressing water quality problems in the basin. They attributed the elevated nutrient levels to both urban and agricultural sources, including

- Failing or inadequate septic systems.
- Sewage treatment plant effluent.
- Fertilizer application for residential and commercial landscaping.
- Construction site sediment export.
- Exhaust emissions.
- Open burning.
- Field application of manure to crops.

They also assessed biological populations and identified priority communities and species that warrant special protection.

To begin implementing a whole basin management program, the Delaware legislature established the Center for the Inland Bays in 1994. In 1998 the Center initiated a Tributary Strategy Program that organized stakeholders into three Tributary Action Teams, which assist the Center in reducing nutrient inputs to the bays and restoring habitat. They are also assisting DNREC in developing pollution control strategies to meet TMDLs for nutrients. In 1999 the Delaware House of Representatives passed Resolution 32, which established a multijurisdictional committee to

- Assess progress toward implementation of the Land-Use Action Plan of the Inland Bays Comprehensive Conservation and Management Plan.
- To identify areas where implementation has not been achieved.
- To recommend changes to Sussex County's Comprehensive Plan and implement zoning and subdivision ordinances.

Finally, in 1999 the Delaware Legislature passed the Delaware Nutrient Management Law, which established the Delaware Nutrient Management Commission. The purpose of the Commission is to develop a program to address nutrient inputs from both agricultural sources and urban sources such as golf course landscape operations, residential inputs, and residential and commercial fertilizers.

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Regardless of the forecasting option chosen to estimate future impervious cover, it is important to verify and adjust the estimate periodically. This adjustment helps ensure that land use planning tools for the watershed result in the desired level of impervious cover needed to maintain the management strategy of each subwatershed.

1.3.2.5 Develop subwatershed plan

Based on the information obtained in the preceding steps, the watershed manager should determine what goals and objectives are appropriate in the watershed and its individual subwatersheds. Goal-setting is among the most important steps in watershed planning, and the management structure should ensure full involvement from stakeholders at this stage.

A subwatershed plan is a detailed blueprint to achieve the established subwatershed objectives. A typical plan may include revised zoning, management practice regulations, proposed management practice locations, description of proposed new programs, estimates of budget and staff needed to implement the plan, stream buffer widths, or monitoring protocols.

The plan should target the subwatershed objectives with the combination of management practices that is most economical, effective, and feasible. Implementing management practices by planning on the subwatershed scale can increase cost-effectiveness and water quality benefits. A combination of nonstructural, on-site, regional, and channel stabilization practices specifically tailored to the subwatershed will help to maximize these benefits. Pollution prevention and nonstructural practices are key, as they can reduce the generation of pollution and its exposure to rainfall and runoff. In addition, implementing site-dispersed, low-impact development practices can help to control both runoff quality and quantity at the site level. Ensuring that drainage channels and floodplains are stable will provide protection against flooding and serve to buffer receiving waters. Finally, regional runoff control and treatment practices are a last line of defense to control flooding and reduce pollution. The following are descriptions of each type of practice and how they can meet water quality objectives in a subwatershed:

- *Nonstructural practices*. Pollution prevention and nonstructural practices are effective in reducing the generation of pollution and its exposure to rainfall and runoff. These practices help to increase public awareness, and can reduce the need for pollutant removal capacity in runoff treatment controls and the burden of maintaining those controls. Used alone, however, nonstructural practices do not provide a comprehensive solution for runoff management. While various techniques have been developed to qualitatively measure the effectiveness of nonstructural practices, it is difficult to gauge their direct water quality benefits.
- *Site-dispersed (on-site) practices*. Site-dispersed, low-impact development practices control runoff quality and quantity at the site level and reduce the flow volume and pollutant load that reaches drainage channels. In addition to these benefits, infiltration practices can be a source of ground water recharge and reduce the frequency of combined sewer overflows (CSOs). They require less land area and can provide aesthetic benefits. These practices can also provide cost savings from both reduced construction costs and lower maintenance requirements. On the other hand, responsibility might fall on the property owner to inspect and maintain the practices. In addition, on-site treatment

practices only treat the first ½ inch to 1 inch of runoff, and the rest is bypassed. They are, however, good first practices in a system of storm water management practices.

- *Regional (off-site) practices*. Regional runoff control and treatment practices act as a last line of defense to control flooding and reduce pollution. The advantages of regional controls are that they are easier to maintain and do not require the actions of the property owner; they can provide aesthetic and recreational benefits; and they can be cost-effective due to the economy of scale. However, a regional pond offers no protection to upstream tributaries, and placement in low-lying areas may hurt natural wetlands. Communities may also have to address safety and liability considerations.
- *Stable drainage channels*. Stable drainage channels and floodplains are important for protection against flooding and as buffers for receiving waters by filtering pollutants and preventing erosion. Riparian areas can provide aesthetic and recreational benefits as well as wildlife habitat. Restoring stream channels and riparian areas can, however, be expensive, and is not feasible when development exists along drainage channels or restoration conflicts with landowner use of streamside property.

Regional vs. On-Site Development Regulations

In anticipation of dramatic growth in the next decade or two, the city of Seattle, Washington is considering the development of an integrated drainage plan to address storm water at the subwatershed level rather than on a project-by-project basis. One of the options being considered is the establishment of off-site mitigation programs in urban jurisdictions. These programs allow developers to meet on-site development requirements relating to storm water by compensating the municipality to provide equivalent mitigation in an off-site public facility. In a case study, Maupin and Wagner (2003) explore the costs and benefits of regional and onsite management practices. The authors determine that an offsite mitigation program might be beneficial if the municipality has storm water management obligations, has the authority to regulate development, requires on-site storm water management on new development or redevelopment projects, and cost, water quality, or community benefits may result from off-site treatment. Because it shifts the maintenance burden to the municipality, it may not be appropriate in all cases (Maupin and Wagner, 2003).

Targeting Runoff Treatment Practices for Temperature Control

In the Token Creek Watershed in Dane County Wisconsin, a proposed 492-acre development for single-family homes posed concern for regulators regarding Token Creek, a cold water stream that is a major tributary to Lake Mendota. Managers identified three major goals for the watershed: reduce overall sediment and nutrient flows to Lake Mendota; protect the water quality in Token Creek, primarily regarding sediment and water temperature; and implement practices that will be aesthetically pleasing and increase property values. Managers recognized that traditional treatment practices such as storm water ponds and wetlands (for more information, see Management Measure 5) would not protect the stream from the potential thermal impacts of runoff from a highly developed area. Instead, the channel was lined with rock to provide infiltration, heat dissipation, and erosion control, and rock-filled gabion dams were installed. The Temperature Urban Runoff Model (TURM) was used to estimate water quality benefits. Modeling results predicted a 10.7 degree Fahrenheit increase in water temperature with the practices installed, as opposed to a predicted 21.6 degree increase without the practices (Dorava et al., 2003).

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1.3.2.6 Adopt and implement the watershed plan

The best way to ensure that a plan is implemented is to incorporate the right stakeholders, realistically assess budgetary resources, develop a scientifically and economically sound plan, and mandate the plan's use and implementation. During and after plan development, watershed managers need to ensure that local governments have both the regulatory authority and the resources to implement the plan.

Watershed managers need to identify funding sources to support plan implementation. One of the greatest costs of watershed implementation is the staff resources needed to continue monitoring in the watershed, design and build retrofits and new management practices, and enforce the ordinance and laws called for in the plan.

1.3.2.7 Revisit and update the watershed and subwatershed plan

A one-time watershed study only identifies the problems that exist in a watershed. Many local governments, for one reason or another, take on watershed planning without realizing that it is a process rather than a report. Watershed and subwatershed plans should continue to be updated and revised as the watershed management process evolves and problems are identified.

1.3.3 Provide Adequate Funding and Staffing

Implementing an urban runoff control program requires funding to support programs and provide staff. Local and state governments can provide revenue from the tax base, but environmental programs often come up short when they compete with other municipally funded projects. Alternative borrowing and fundraising techniques can be used to provide additional money for water quality projects.

A variety of resources for financing information are available. The Environmental Finance Center, sponsored by EPA and the University of Maryland Sea Grant College, was created to assist local communities in finding creative ways to pay for environmental projects. The Center promotes alternative and innovative ways to manage the cost of environmental activities, provides training and development opportunities in environmental management, and works to increase awareness of the benefits associated with sound environmental management policies. In addition, the Center serves as a national repository and clearinghouse for environmental finance-related information, including information from EPA, the Environmental Financial Advisory Board (EFAB), and the Environmental Financing Information Network (EFIN), as well as other Environmental Finance Centers (EFCs) across the nation. More information about the technical assistance and support the Center provides, such as workshop and conference sessions, problem-solving roundtables for communities, watershed management training sessions, and utility rate design assistance, is provided at http://www.mdsg.umd.edu/EFC (EFC, 2000).

Another source of financing information is the Florida Stormwater Association (FSA), which was formed to assist professionals in both the public and private sectors who work in the storm water management and finance areas. FSA provides online services to its members, including a newsletter, storm water utility survey, access to local ordinances, and the FSA membership directory. For more information about FSA, refer to http://www.florida-stormwater.org/ (FSA, 2000).

City of Lenexa, Kansas, Sales Tax Increase

The City of Lenexa, Kansas, passed a 1/8-cent sales tax to help fund a new storm water program. The initiative includes the construction of multipurpose lakes and other storm water facilities to reduce flooding, improve water quality, and provide recreation for the citizens of Lenexa. The program differs from conventional storm water programs in that it also focuses on water quality and recreational opportunities. Most storm water programs focus only on preventing flooding. Revenue from the sales tax will be used to

- Construct lakes, detention basins, and sport fields.
- Acquire land in key locations before development occurs.
- Address existing problems in developed areas.

Other sources of revenue for the program include an annual $30 per home utility charge, a new development charge, and existing revenue sources such as a mill levy and Johnson County storm water funds.

The city's watershed management program will be implemented by constructing new facilities, improving the management of existing facilities, establishing development policies and processes, and implementing activities to ensure compliance with new regulations associated with the Clean Water Act. Lenexa has recently inventoried critical natural areas in the city to provide guidance for conserving, protecting, and restoring natural resources. Stream restoration opportunities in developed areas of the city will be identified, along with measures to address flooding. Lenexa encourages citizens to participate in the Watershed Management Program and offers tips for improving the quality of urban storm water runoff.

For more information about the Lenexa Storm Water Management Plan, contact Lenexa Public Works at 913-477-7680 or refer to http://www.ci.lenexa.ks.us/Stormwater/intro.html (Lenexa, No date).

Finally, the Center for Urban Policy and the Environment at Indiana University–Purdue University Indianapolis (2001) developed *An Internet Guide to Financing Stormwater Management*. This guide, located at http://stormwaterfinance.urbancenter.iupui.edu, is designed to help communities find ways to pay for storm water management projects. The site includes an annotated bibliography of existing storm water finance materials, an archive that contains selected previously published materials concerning storm water finance, a manual that discusses the financing options available to communities for storm water management programs, a set of case studies that describe successful finance mechanisms that have been used in seven communities around the country, and a group of links to other useful Web sites about storm water management.

Several mechanisms that watershed managers can use to secure funding for their storm water programs are described below.

1.3.3.1 Taxes and fees

Municipalities often use taxes to fund environmental programs, but the taxes are not dedicated for a specific purpose and may be allocated to other, non-environmental programs. Fees are another method that can generate money for environmental programs. Table 1.4 outlines several kinds of taxes and fees that are appropriate for financing storm water management programs.

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Table 1.4: Types of taxes and fees that can be used to raise money for storm water management programs (adapted from USEPA, 1994).

Tax or Fee	Description
Property and sales taxes	Charged as a percentage of property value or gross sales.
Real estate transfer taxes	Assessed as a percentage of property values when property is sold.
Commodity taxes	Charged on specific items such as gasoline and hunting and fishing equipment.
Tax surcharges	Added to established tax rates.
Tax incentives	Offer tax reductions as state tax credits, deductions, or rebates.
Tax disincentives	Fees, taxes, or price increases to discourage the use of an inefficient product.
Tax differentiation	Tax charged on an inefficient product to encourage the use of an efficient substitute.
Selective sales tax	In the form of a retail tax or an inspection fee.
Tax increment	Financing incremental increases in real estate taxes to repay the original investment in improved public facilities that resulted in increased real estate values.
Plan review fees	Collected to conduct development plan reviews to ensure they meet requirements.
Storm water utility fees	Imposed on property owners based on amount of runoff generated, impervious area on the property, or the assessed value of the property.
Impact fees	The cost of infrastructure services is paid up-front by fees collected from developers or property owners.
Inspection fees	Collected to ensure that development plans are properly implemented.
User fees	Directly tied to the use of a resource or facility and especially useful at the local level where user groups are easily identified.
Capacity credits	Private interests guarantee future capacity in a public facility and provide additional funding to local governments for project completion.
Effluent discharge fees	Levied on an industrial facility based on the volume of pollutants discharged. Can be used to meet water quality objectives, to cover costs of pollution abatement, or to meet effluent standards. Provides economic incentive to reduce pollution output and is an equitable method for funding pollution control projects.

1.3.3.2 Bonds

Several kinds of bonds can be used to fund projects over the long or short term. Long-term bonds provide funding for the duration or life expectancy of the project and can be paid back all at once at the end of the project or little by little until the end of the project. Short-term bonds provide interim funding for long-term projects that have not yet been financed. There are also general obligation bonds, which are issued by state or local governments and are repaid using taxes and other revenues. Revenue bonds are also issued by state or local governments, but they are repaid using income or funds generated by the project itself. Finally, state revolving funds, which are long-term, low-interest loans to local governments or individuals for capital investments, can be used to fund storm water projects. Repayment allows the fund to revolve its lending ability continuously. The fund is intended to provide a permanent source of financing for state and local water quality projects and can be used for many different projects, including:

- Construction of wastewater treatment plants
- Implementation of approved state nonpoint source management programs and ground water protection strategies under section 319 of the Clean Water Act

- Development and implementation of estuary comprehensive conservation and management plans under section 320 of the Clean Water Act

1.3.3.3 Leases

A municipal lease grants the lessee the option of applying lease payments to the purchase of the facility. The lessee is responsible for paying taxes on the property. Leases can be used to finance the purchase of environmentally sensitive areas, land for wetland restoration, or other projects. A sale/lease-back arrangement allows the owner of a facility to sell it to another entity and subsequently lease it back from the new owner. This arrangement can provide alternative financing for a facility and may limit a government's liability.

1.3.3.4 Intergovernmental transfers and assistance

Grants are awarded to state or local governments for assistance in meeting national environmental quality goals. EPA establishes the criteria that must be met before receiving funds, while section 319 of the Clean Water Act allocates federal funds to states for implementing approved nonpoint source management programs. The grant money can also be used for postimplementation monitoring and groundwater assessment as part of an approved NPS pollution control program.

The conservation districts in Delaware have a conservation cost-share program that is funded by the state. Each of the three districts currently receives approximately $300,000, plus an additional $175,000 for nutrient management program practices. Most of the urban management practices involve backyard drainage projects, streambank erosion control, rehabilitation of storm water management ponds, urban flood control projects, tree plantings in community open space, conservation windbreaks, and debris pit remediation, and they can include assisting a community with an engineering study to determine solutions for a problem. Each conservation district determines the priority areas for the conservation funding, with the most urban BMPs implemented in New Castle County. Depending on the practice, the landowner pays 25 to 50 percent of the costs (Mickowski, 2004).

Using Clean Water Act Funds for Water Quality Improvements

The Delaware Department of Natural Resources and Environmental Control (DNREC) is using the Clean Water State Revolving Fund to effect water quality improvements. Practices implemented with the funds include wastewater collection to eliminate 300 failing onsite wastewater treatment systems and prevent 594 new systems; replacement of failing onsite wastewater treatment systems; sediment and storm water management practices; water body restoration practices such as stream bank stabilization, wetland restoration, and riparian buffer installations; land purchases and conservation easements for water quality protection; and implementation of Comprehensive Conservation and Management Plans for the Delaware Estuary and Delaware Inland Bays. For more information on the Clean Water State Revolving Fund, see http://www.epa.gov/owmitnet/cwfinance/cwsrf.

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1.3.3.5 Public-private partnerships

The private sector can invest in public-sector facilities. This approach reduces the financial burden for the public sector through cost sharing and is especially appropriate when neither the public nor private entities can fund the projects themselves. However, there might be political opposition from government workers or negative public opinion due to private ownership and operation of a public facility, even though private operations are often more cost-efficient, provide a higher level of service, and require less implementation time than public operations.

1.3.4 Foster Input from Technical Experts, Citizens, and Stakeholders

Most runoff management institutions require input from three groups of people—technical experts, citizens, and stakeholders—to plan and implement successful runoff management practices. Technical committees are often set up to provide expertise on scientific issues, while citizen advisory and stakeholder committees afford the public a chance to include their opinions in the management process.

1.3.4.1 Technical committees

The central principle of technical committees is that proactive involvement of all stakeholders will result in greater watershed improvements because actions will have the approval of all interests. Ideally, members of the technical committee are also agency representatives in the larger management institution. Members may include representatives from the state and county natural resources, environment, planning, health, and water resources management entities. In addition, federal agency representatives and individual citizens with expertise in scientific fields or engineering may participate. The technical committee evaluates monitoring data and identifies data gaps, coordinates monitoring efforts within the watershed to obtain missing data, evaluates proposed regulatory or land use changes with respect to their potential impact on the watershed resource, interprets scientific data for the watershed management institution, and assesses and coordinates currently approved implementation projects.

1.3.4.2 Citizen committees

A citizen committee is open to all citizens and provides direct feedback to the management institution on public sentiments regarding the planning process. The review of citizen concerns in a comprehensive process is critical in gaining community support. Some of the possible functions of a citizen committee include organizing public outreach and community awareness projects, such as tree planting days, stream cleanups, storm drain system stenciling, watershed awareness days, and volunteer activities, and exploring funding sources and grant-writing. In addition, such a committee might organize media relations and publicity programs such as press releases, informational flyers, and watershed awareness campaigns; act as a liaison between citizen groups and government agencies; and establish early stakeholder and public involvement.

Creating Quality Places Program, Kansas City, Missouri

The "Creating Quality Places: Successful Communities by Design" is a program of the Mid-America Regional Council (MARC), which represents city and county governments in the bistate Kansas City metropolitan area. The program, which is partially supported with resources from EPA's Sustainable Communities Challenge Grant Program, is aimed at developing a better quality of life in neighborhoods throughout the Kansas City region. Creating Quality Places is divided into two phases. In the first phase, 20 quality principles were identified to guide future development. These principles offer the best means for the region to grow, while also preserving and enhancing the quality of life enjoyed by residents. The second phase of the program focuses on the means for implementing these principles.

Creating Quality Places was a coordinated effort between multiple stakeholders. In the first phase, a steering committee and three advisory committees were convened by MARC to ensure broad stakeholder representation. The steering committee, which included elected officials, developers, civic leaders, citizens, planners, and representatives of other stakeholder groups, provided input and direction throughout the proceedings. The three advisory committees provided specific and technical input during deliberations. These committees each represented a specific sector of the development arena and included mayors, city council members, county commissioners, planning commissioners, city managers, planning directors, park professionals, public works professionals, developers, builders, architects, and engineers.

The initial quality principles were developed by merging the principles devised by each of the four committees. At a joint session of the four committees, the combined principles were reviewed, strengths and weaknesses of each were identified, and the principles were edited. The edited principles were then reviewed through a questionnaire, which was administered at public forums conducted for each topic area. The steering committee and advisory committees conducted a final review, and the quality principles were finalized. This development and review process allowed stakeholders to be involved throughout the entire process.

MARC also ensured stakeholder involvement by organizing public forums to establish dialogue on quality development issues and to raise awareness about land use and development practices. The forums consisted of two parts. The first part was a session at which national speakers and local panels discussed issues, and the second was a workshop that provided steering and advisory committee members with an opportunity to ask questions and discuss concerns.

For more information about the quality principles, including specifics of the final 20 quality principles, resources for implementing the principles, and case studies of how other communities are using the principles, refer to *www.qualityplaces.marc.org* (MARC, 2000).

1.3.4.3 Stakeholder committees

Stakeholder committees address the goals and opinions of the agencies, organizations, or individuals directly affected by management activities in the watershed. The incorporation of stakeholder views into the development of the watershed plan is crucial to building consensus and gaining support for future implementation. Typical stakeholders involved in the watershed planning process include:

- Conservation groups (e.g., Trout Unlimited, Save our Streams, Bass Masters)
- Developers
- Homeowners
- Citizen associations

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- Farmers
- Industrial and commercial business interests
- Utility companies

Other groups, such as trade associations, research and academic institutions, sporting groups, and individual citizens, might also wish to be involved in the process. When planning occurs at the watershed level or higher, local and regional offices of federal agencies will also often decide to become involved. By placing the emphasis for watershed management on the subwatershed level, the number of stakeholders guiding plan development will be much more manageable.

Early and frequent involvement of stakeholders is a key ingredient in building support for the subwatershed management process. Stakeholders should be given a meaningful and well-defined role in the formulation of management plans. Sharing data and mapping, establishing goals, setting priorities, developing management criteria, measuring success, and reviewing and approving subwatershed plans will strengthen stakeholder ownership in the plan.

1.3.5 Establish Intergovernmental Coordination

The watershed management institution's primary responsibility is to oversee the execution of a watershed management plan. The management institution focuses the diverse stakeholders in a watershed into a viable group capable of guiding implementation. The institution is also responsible for the timely preparation and implementation of the watershed plan and its revision as project goals are achieved or changed. Communities might elect to create a single authority for an entire watershed, or a series of smaller authorities at the subwatershed level. The effectiveness of the management institution is dependent upon its ability to forge all interagency or multi-jurisdictional partnerships and agreements necessary to support the organization over the life of the planning process.

Intergovernmental coordination is essential when establishing a watershed management program, especially when the watershed extends over more than one political jurisdiction. Without the participation of a broad spectrum of local, state, and federal agencies, most watershed planning endeavors will not have the financial or information-gathering resources required to continue beyond initial start-up efforts. Interagency coordination requires sharing of resources and data, joint development and endorsement of a watershed management plan, and continued participation of all agencies. Care must be taken to avoid interagency rivalries or miscommunication.

The first step in fostering interagency coordination is the establishment of a watershed management institution. One instrument that has been used to steer this process is the Memorandum of Understanding (MOU). An MOU is an agreement by government agencies and local stakeholder representatives to work together in the creation of a watershed planning strategy. MOUs are widely used because agencies can enter into these agreements while retaining their jurisdictional and budgetary appropriation authority. MOUs are not legally binding contracts. Instead, the points in an MOU are presented in a broad manner to facilitate consensus. Typically short (one or two pages), these agreements outline the goals and objectives for the watershed management institution. The basic contents of an MOU are:

- Identification of the parties involved in the process
- Vision statement
- Purpose of the MOU (issues to be addressed by the agreement)
- Pact to provide assistance to the partnership for coordination of planning efforts under a central management organization
- Resolution to use the watershed plan as guidance in future land use or water management decisions
- Signatures of all partners involved

Philadelphia's Office of Watersheds

In 1998, the Office of Watersheds was created within the Philadelphia Office of Water. The new department is charged with administering a watershed management program that integrates combined sewer overflow, storm water management, and drinking water source protection. The watershed approach focuses on regional and local partnerships and supports watershed initiatives at the local level through innovations and demonstrations, and by facilitating cooperation between stakeholders. The Office of Water's "watershed technology center" is a central repository of technical support such as Geographic Information Systems, information technology, and model development for the various watershed programs. The office is working with local watershed organizations, academic institutions, and other agencies to pursue funding for demonstration projects, streambank restorations, and information collection for regional watersheds (Neukrug, 2003; WERF, 2000).

1.3.6 Develop Training and Education Programs and Materials

Training programs and educational materials designed for people directly involved in the design and implementation of a runoff management program are essential. Most states and many local governments have developed guidance manuals, workshops, and other educational opportunities to assist developers, site designers, contractors, plan reviewers, consultants, inspectors, and others in understanding and complying with runoff management goals and objectives.

Most states make education and training voluntary. A few states, however, including Delaware, Florida, Maryland, South Carolina, and Virginia, have made professional educational programs mandatory by law or regulation. Delaware, for example, requires that "all responsible personnel involved in a construction project will have a certificate of attendance at a Department-sponsored or approved training course for the control of sediment and storm water before initiation of land disturbing activity." The state provides personnel training and educational opportunities for contractors to meet this requirement, and has delegated program elements to conservation districts, counties, and other agencies.

In addition to professional audiences, the public can greatly benefit from runoff management education and training. Public awareness of program goals leads to greater support. Awareness can be achieved in many ways, including workshops, brochures, meetings, and media campaigns, as well as hands-on projects like storm drain stenciling and stream clean-ups.

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Watershed citizens can and do play an important role in controlling nonpoint source pollution. Consequently, they need to acknowledge and be educated on pollution prevention issues and activities. Management practices concerning this topic are discussed in greater detail under the Management Measure 9: Pollution Prevention.

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1.4 Information Resources

An Internet Guide to Financing Stormwater Management is a Web site presented by the Center for Urban Policy and the Environment (2001) at Indiana University-Purdue University Indianapolis. The site includes an annotated bibliography of existing storm water finance materials, an archive that contains selected previously published materials concerning storm water finance, a manual that discusses the financing options available to communities for storm water management programs, a set of case studies that describe successful finance mechanisms that have been used in seven communities around the country, and a group of links to other useful Web sites about storm water management. The site can be accessed at http://stormwaterfinance.urbancenter.iupui.edu.

The Center for Watershed Protection's *Rapid Watershed Planning Handbook* (CWP, 1998) describes techniques communities can use to more effectively protect and restore water resources. This document is available for purchase from the Center for Watershed Protection's Web site (http://www.cwp.org).

Framework for a Watershed Management Program (Clements, 1996) develops a specific watershed management protocol to increase the understanding of the critical components in watershed management programs. The publication is available for purchase from the Water Environment Research Foundation by calling 800-666-0206 and specifying publication order number D53016.

Building Local Partnerships, an Internet brochure published by the Conservation Technology Information Center (no date), provides an overview of local partnerships, including the types of partnerships that can be made, a how-to guide for forming partnerships, and caveats, as well as links to other resources pertaining to partnership-building. The publication can be accessed at http://www.ctic.purdue.edu/KYW/Brochures/BuildingLocal.html.

The Environmental Finance Center (2000) was created to assist local communities in finding creative ways to pay for environmental projects. The Center promotes alternative and innovative ways to manage the cost of environmental activities, provides training and development opportunities in environmental management, and works to increase the public and private sector's awareness of the benefits associated with sound environmental management policies. The site includes *Creative Financing Techniques for Establishing Riparian Forest Buffers* (or other land protection efforts), which describes methods such as notification, recognition, and nonbinding agreement programs; management agreements and leases; financing arrangements, such as agreements tied to loans; easements; and land acquisition to encourage conservation and stewardship of ecologically significant properties. The site also includes *Financing Stream Corridor Protection with a Community Quilt*, which describes a method for financing environmental protection and restoration efforts using a "community quilt" of financing techniques that has the potential to cover the variety of activities within the watershed. The Environmental Finance Center is located at http://www.mdsg.umd.edu/EFC.

The Florida Stormwater Association (2000) Web site contains information for storm water managers and stakeholders, including a manual entitled *Establishing a Stormwater Utility in*

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Florida, storm water utility surveys, articles, news, and activities, and links to storm water management resources. The site can be accessed at http://www.florida-stormwater.org/.

The National Association of Counties (1999) has assembled a comprehensive kit that provides counties a host of tools for beginning and strengthening programs that favor purchase of products that are energy-efficient, contain recycled materials, and are less hazardous to the environment and human health. The kit includes case studies, a model purchasing resolution, a sample press release, and a comprehensive list of resources. It can be ordered (free for members, $10 for nonmembers) from the National Association of Counties' Web site at http://www.naco.org/Template.cfm?Section=Publications&Template=/cffiles/pubs/publications.cfm&PubCat=EPP.

The *State and Local Government Guide to Environmental Program Funding Alternatives* (USEPA, 1994) provides an overview of traditional (nongovernmental) funding mechanisms and innovative approaches for funding environmental programs. The document can be downloaded from http://www.epa.gov/owow/nps/MMGI/funding.html.

The *Catalog of Federal Funding Sources for Watershed Protection* (USEPA, 1999a) provides a guide for watershed practitioners on federal funds that might be available to support a variety of watershed protection projects. The catalog presents information on 69 federal funding sources (grants and loans) that can be used to fund watershed projects. The information on funding sources is organized into categories including coastal waters, conservation, economic development, education and research, environmental justice, forestry, Indian tribes, mining, pollution prevention, and wetlands. The catalog also includes key words that can be used to search for funding programs for particular subject areas. The document is available in HTML format at http://www.epa.gov/owow/watershed/wacademy/fund.html.

Model Ordinances to Protect Local Resources (USEPA, 1999b), located at http://www.epa.gov/owow/nps/ordinance, is a Web site of model ordinances that can serve as a template for those charged with making decisions concerning growth and environmental protection. For each model ordinance listed, there are several real-life examples of ordinances used by local and state governments around the nation. The ordinances address matters that are often forgotten in many local codes, including aquatic buffers, erosion and sediment control, open space development, storm water control operation and maintenance, illicit discharges, and postconstruction controls. There is also a miscellaneous category containing ordinances that don't fit into these sections. In addition, this Web site has materials that support particular ordinances, such as maintenance agreements and inspection checklists.

EPA's Office of Wastewater Management (USEPA, 2001) has a financing Web site (http://www.epa.gov/OWM/finan.htm) that provides an overview of the many types of assistance they provide to national, state, and local programs to abate and prevent municipal water pollution. Included is guidance information such as *Paying For Water Quality: Managing Funding Programs to Achieve the Greatest Environmental Benefit* and *Guide to Using EPA's Automated Clearing House For the Drinking Water State Revolving Fund Program* as well as information on programs such as the Clean Water State Revolving Fund (SRF), Construction Grants Programs, Section 106 Water Pollution Control Program Grants, Section 104(b)(3) Water Quality Cooperative Agreements, and Indian Set-Aside Grants.

The Watershed Management Institute, Inc. (1997a) printed a book entitled *Institutional Aspects of Urban Runoff Management: A Guide for Program Development and Implementation*. This book presents a comprehensive review of the institutional frameworks of successful urban runoff management programs. It was developed to assist individuals responsible for developing and implementing urban erosion, sediment control, and storm water management programs. The book is available for purchase ($10 for Storm Water Phase II communities, $27 for others) using an order form that can be downloaded at http://www.naco.org/Template.cfm?Section=Publications&Template=/cffiles/pubs/publications.cfm&PubCat=EPP.

The Southeast Michigan Council of Governments (SEMCOG) is a regional planning partnership that supports local planning efforts through technical support, the facilitation of intergovernmental coordination, and the adoption of region-wide plans and policies. SEMCOG partnered with six local communities to assemble a workbook, *Opportunities for Water Resource Protection in Local Plans, Ordinances, and Programs: A Workbook for Local Governments*, which provides guidance on planning to protect water resources. SEMCOG's approach is not prescriptive, but rather provides various options for planners, outlining key programmatic and regulatory components for a range of watershed protection approaches. The workbook emphasizes the need to address the protection of water resources through planning and prevention, and is meant to serve as a basis for local governments to customize their individual plans based on the needs and resources of the community. The book is available for download at http://www.stormwater.ucf.edu/publications/urban_runoff.pdf.

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MANAGEMENT MEASURE 2
WATERSHED ASSESSMENT

2.1 Management Measure

Develop and implement a watershed assessment program to:

- Characterize watershed conditions
- Establish a set of watershed indicators

2.2 Management Measure Description and Selection

2.2.1 Description

Watershed assessment and monitoring are tools used to characterize water quality and to identify trends in water quality over time (USEPA, 1998c). This management measure describes methods that can be used to determine the health of water bodies by using watershed indicators that measure physical, chemical, and biological conditions.

2.2.2 Management Measure Selection

2.2.2.1 Overview

Watershed assessment is a critical component of a watershed-based approach to managing receiving waters. Watershed assessment is needed to develop both protection and restoration strategies, identify priorities, and adjust management prescriptions based on trend analyses. Both rapid and extensive assessments can be performed to determine water body status and trends. Numerous metrics, such as EPA's *Rapid Bioassessment Protocols for Use in Wadeable Streams and Rivers: Periphyton, Benthic Macroinvertebrates, and Fish*; *Lake and Reservoir Bioassessment and Biocriteria*; and *Estuarine and Coastal Marine Waters:Bioassessment and Biocriteria Guidance,* are available for determining water body status. In general, the objectives, available funding, and expertise of the assessors will determine the level of assessment conducted.

An assessment and monitoring program is important for effective watershed management because it provides a basis for decisions and actions, and allows managers to continually reassess progress and redefine goals and priorities. Monitoring enables water quality managers to identify existing or emerging problems. Monitoring also facilitates responses to emergencies such as spills and floods, and helps water quality managers target specific pollution prevention or remediation programs to address these problems. Assessment and monitoring can be used to determine whether program goals, such as compliance with pollution regulations and implementation of effective pollution control actions, are being met. Monitoring programs should be established based on indicators of human health and aquatic life. A large number of

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documents and case studies are available to use as resources (see Information Resources at the end of this chapter).

2.2.2.2 Examples of monitoring and assessment programs and methodologies

State pollution control agencies, Indian tribes, local governments, and federal agencies typically are responsible for watershed assessment and monitoring activities. These entities monitor water quality and identify waters and watersheds that do not meet clean water goals through various programs, which include the following:

- Unified Watershed Assessments (UWAs), developed by states in 1999 to assess the health of watersheds and identify watersheds in need of restoration (i.e., watersheds that do not currently meet clean water and other natural resource goals). UWAs also identified watersheds that need preventive action to sustain water quality using ongoing state, tribal, and federal programs, as well as pristine or sensitive watersheds on federal lands that need an extra measure of protection. The results of these assessments can be obtained from state environmental protection departments.

- Water Quality Reporting Program, established under CWA section 305(b), which mandates the collection of water quality information and reporting on the condition of waters every two years.

- 303(d) program, established under CWA section 303(d), which mandates the use of monitoring and other water quality information to develop lists of waters that do not meet water quality standards.

- Nonpoint Source Program, established under CWA section 319, which involves identifying waterbodies that are impaired by nonpoint sources.

- Source Water Protection Program, established under the Safe Drinking Water Act, which involves assessments of drinking water sources that form a basis for actions to protect such sources.

- State Revolving Fund (SRF) Program, which involves developing and prioritizing clean water projects.

- Federal Emergency Management Agency's National Flood Insurance Program, which involves conducting floodplain studies and developing mitigation plans.

- Marine pollution control programs, which include identification of coastal water quality problem areas as part of efforts to reduce polluted runoff to coastal waters.

- Wetlands Program, which involves developing assessments of wetland areas that need special attention or protection.

One example of a state assessment program comes from the Commonwealth of Pennsylvania. The state's Act 167 requires that watershed assessments consider the following objectives (Pennsylvania DEP, 1999):

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- Implement nonpoint source pollutant removal methodologies
- Maintain ground water recharge
- Reduce channel erosion
- Manage overbank flood events
- Manage extreme flood events

The state established four subtasks to achieve these objectives:

- Determine the water quality design storm
- Determine the runoff capture design storm (recharge/retention)
- Establish streambank erosion requirements
- Establish overbank/extreme event requirements (release rates)

To accomplish these subtasks, Pennsylvania developed a process that will ultimately lead to the development of standards for stream bank erosion, infiltration, water quality, overbank flooding, and extreme storm events. The assessment fits into a larger framework for integrated watershed resource management, which includes the following steps:

- Watershed assessment/prioritization
- Watershed evaluation
- Restoration/protection plan development
- Financial resources secured
- Restoration/protection plan implementation
- Results compared to goals

2.3 Management Practices

2.3.1 Characterize Watershed Conditions

2.3.1.1 Establish a reference condition

It is important to establish a reference that characterizes the relatively unimpaired condition of the water body. The reference condition establishes a basis for making comparisons between sites, and is essential for detecting impairment. Conversely, if a water body is found to be impaired, it is important to have an understanding of natural background concentrations before undergoing costly efforts to mitigate anthropogenic inputs.

There are two types of reference conditions—site-specific and regional. Site-specific reference conditions are determined from one or more sites in a watershed or stream from a point where discharges (nonpoint source, point source, or a combination) are occurring. Regional reference conditions typically are established from a population of relatively unimpaired sites within a relatively homogeneous region and habitat type. An ecoregional framework based on land surface form, soil, potential natural vegetation, and land use has been developed by Omerink (1987) to interpret spatial patterns in data (USEPA, 1999); these ecoregions can be used to help develop a reference condition for a relatively homogeneous region. Regional reference conditions are often preferable to site-specific conditions because they are more widely

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applicable, they produce a larger sample of unimpaired sites, and they allow more robust statistical comparisons.

The U.S. Geological Survey (USGS) developed a model for determining ecoregional background concentrations of nitrogen and phosphorus as a function of annual runoff, basin size, atmospheric nitrogen deposition rate, and region-specific factors. Background total nitrogen (TN) concentrations ranged from 0.02 mg/L in the western United States to more than 0.5 mg/L in the southeastern United States. Background total phosphorus concentrations ranged from less than 0.0006 mg/L in the western United States to more than 0.08 mg/L in the Great Plains (Smith et al., 2003).

2.3.1.2 Model pollutant sources and loads

Watershed managers can use models to estimate storm water pollutant loads in receiving waterbodies. Modeling of pollutant loadings can help watershed managers target specific areas for nonpoint source control. More specifically, runoff models can accomplish one or more of the following:

- Simulate the generation and movement of water and pollutants from their point of origin to a place of treatment or disposal into receiving waters
- Perform frequency analyses on water quality parameters to determine the return periods of concentrations or loads
- Provide input for an analysis of receiving water quality
- Determine the relative effects of pollution control options
- Determine optimal locations and combinations of management practices
- Provide input to cost-benefit analyses

Selecting the model that is most appropriate to fulfill watershed management goals requires careful consideration of trade-offs with respect to level of detail, data requirements, cost, and accuracy. For example, a high level of detail requires a more complex model. Data requirements are also important: a complex model might require more data than one has or is willing to collect. Sometimes published data can be substituted for field-collected data. The advantage of using published data is avoidance of costly, labor-intensive fieldwork. A major data source is the USEPA National Urban Runoff Program (NURP) database, which contains concentration values measured for 30 cities (USEPA, 1983). Information generally required for models includes the following:

Quantity Parameters

- Rainfall information
- Catchment area

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- Imperviousness
- Runoff coefficient

Quality Parameters

- Constant concentrations (event mean concentrations or EMCs)
- Constituent median and coefficient of variation (CV)
- Regression relationships
- Buildup and wash-off parameters

Calibration/Verification Parameters

- Measured rainfall
- Measured runoff
- Water quality samples

While model calibration is beneficial, models generally used for watershed assessments do not strictly require calibration and precision to determine compliance with permit requirements or Clean Water Act requirements. Therefore, these models can be simpler and less expensive, while still providing watershed managers with information on pollutant loadings and sources.

Another consideration when choosing a model is its reputation. Watershed managers should become familiar with the model's concepts, assumptions, and limitations, as well as the experiences of other users. In choosing the most appropriate model, watershed managers should:

- Use the simplest model that will satisfy the project's objectives
- Use a model that is consistent with available data
- Predict only the water quality parameters of interest
- Make predictions over the broadest time scale that will satisfy the objectives
- Become familiar with the characteristics and assumptions of the model

Using pollutant loading models has advantages and disadvantages. Measured data are preferable to simulated data, especially when characterizing the magnitude of a pollution problem, because accurate concentration values are important. Models cannot substitute for good field-sampling programs, but they can be used to extrapolate and to augment field-sampling results.

To ensure quality results from a modeling effort, sensitivity analyses should be performed when uncertainty exists regarding data quality or model assumptions. Also, if possible, models should be calibrated and validated using measured values (field monitoring). This process is labor-intensive and can add to the expense of the modeling effort, but it is worthwhile to ensure accuracy when making management decisions.

A detailed description of water quality models of all types can be found in the *Compendium of Tools for Watershed Assessment and TMDL Development* (USEPA, 1997a). In general, watershed managers can choose from several different methodologies depending on the specific goals of the modeling effort, including the following:

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- *Constant concentration or published yield values*. This method involves calculating loads as the product of the proportion of land area in a particular land use and the published loading rates for that land use. A disadvantage is that the catchments from which the published values are derived may not represent the catchment of interest. However, the calculations are very simple and easy to use for general loading assessments. Options include coupling constant concentrations with a hydrologic model so that loading will vary with flow, or calculating a confidence interval for loading to determine the level of uncertainty that can be tolerated before conclusions change. This method might be robust enough to answer straightforward management questions despite assumptions.

- *Unit loads*. This method involves calculation of the mass of the pollutant of interest per area of watershed per unit of time. It is site-specific (demographic and hydrologic factors are important determinants) and is based on average runoff volume (not coupled to a hydrologic model). Also, loading rates are variable and difficult to extrapolate from one area to another. This is a relatively simple method that does not require a great deal of data collection. Published values can be used at the expense of some accuracy.

- *Simple empirical model*. This method uses spreadsheet calculations to combine precipitation data with a runoff coefficient and land use-specific constant concentrations. This method easily simulates a mixture of land uses, allowing the study area to extend over a large area without compromising the quality of results. The model can quantify relative contributions from different land uses, and can be expanded readily to incorporate more complex calculations. The hydrologic modeling is very simple, however, and the model does not necessarily work well for short-term predictions. Also, using published constant concentrations in the model introduces errors; locally measured concentrations would greatly improve the model's performance.

- *Statistical method*. The statistical method uses a derived, usually lognormal frequency distribution of estimated mean concentrations (EMCs) of pollutants. This method is useful for assessing the frequency of exceedance of water quality standards, but it has weak hydrologic assumptions. The model can be coupled with stream flow, storage, and treatment data to improve accuracy and estimate the effects of management practices on water quality. Estimates can be improved by using measured EMC values rather than published ones. EMCs can vary widely because of seasonal and watershed land use variations, and might require at least one year and often two years of field verification to be statistically significant.

- *Regression equations.* Regression equations are published equations from the U.S. Geological Survey (USGS) (Driver and Tasker, 1990) that relate loads and EMCs to catchment, demographic, and hydrologic characteristics. They usually incorporate total storm loads and runoff flows or volumes. They require neither preliminary estimates of EMCs nor local monitoring data, and standard errors are provided for a measure of uncertainty. They are more or less accurate depending on the pollutant of interest and the level of precipitation (arid vs. humid). The equations predict only the mean rather than a frequency distribution of EMCs or loads, and they are subject to error when extrapolating to conditions that are different from those used to derive the equations. A related

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approach uses rating curves to relate pollutant loads or EMCs to flow rates or volumes, thereby allowing quantification of intra-storm variations in these measures.

- *Buildup and washoff*. This method is used to determine loadings by estimating the buildup of pollutants during dry weather and estimating washoff during rainfall events. This method quantifies intra-storm variations in pollutant loading and is good for comparing the relative effects of management practices. However, processes of sediment transport and erosion that are fundamental to this method are still poorly understood. Moreover, this method requires averaging the extent of pollutant buildup on heterogeneous urban surfaces. This averaging can result in erroneous predictions because actual values vary widely over relatively small areas. Assumptions include linear buildup and generic washoff coefficients that might or might not represent actual conditions. Estimates can be improved by using local monitoring data such as site-specific buildup and washoff estimates for model calibration.

- *Mechanistic models*. Mechanistic models contain hydrologic and water quality components and use mathematical algorithms to represent the mechanisms that generate and transport runoff and contaminants. They are the most comprehensive models in that they incorporate many variables to produce the best estimations of the numerous mechanisms that affect pollutant loading. However, they require substantial local data to set and verify parameters, and they demand both skill and commitment from staff. Users must ensure that the models are documented, supported, and proven through the experience of other users. There are several commercially available mechanistic models, including STORM by the U.S. Army Corps of Engineers and SWMM and HSPF by EPA. (See Web references and resources below.)

The confounding factors for load estimation models are:

- Inputs from atmospheric deposition (H_2SO_4, NO_3, etc.)
- Ground water inputs
- Pervious surfaces that confound runoff estimates
- Sediment transport and erosion
- Pollutants adsorbed to solids. These pollutants, namely metals and organics, can be estimated as a proportion of the total suspended solids concentration or annual load.
- Point sources in the watershed (e.g., industrial and commercial sources and publicly owned treatment works)

All of these factors can be included in the surface runoff model at the expense of time and simplicity and can improve the accuracy of loading estimates. Before they are included, consideration should be given to the level of detail needed for the analysis.

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Application of a GIS Decision Support Tool to Urban Watershed Management in Fulton County, Georgia

The high density of development in Sandy Springs, a suburban area northwest of Atlanta, reduces the opportunities for new, areawide management practices such as regional detention ponds. Instead, multiple on-site or local management practices are recommended. In response to the need for developing storm water and water quality plans, a GIS application called LORELEI was developed (Slawecki et al., no date). LORELEI allows users to rapidly develop and compare watershed management alternatives for catchments with hundreds of management practices. It was developed to

- Keep track of hundreds of candidate management practice sites.
- Develop management scenarios using different combinations of management practices.
- Evaluate the practices' impact on water quality.
- Compare scenario results.
- Present the information to a wide range of people.

LORELEI provides decision support through data management, scenario development and evaluation, and enhanced involvement in and understanding of the watershed management process. LORELEI stores data about potential management practice locations and associated costs, practice types, and effectiveness data, as well as standard geographic information such as natural features, watershed delineations, and property ownership. Through scenario development, the program allows for rapid selection of individual projects and entire categories of management practices to build various scenarios. LORELEI then evaluates the scenarios to estimate and compare their costs and benefits. Finally, with enhanced involvement and understanding, LORELEI uses GIS to give decision makers an opportunity to participate directly in the watershed management process and to clearly understand issues, components, and cost and benefit implications of different management scenarios. GIS linkages allow for fine-tuning of the scenarios to determine the cost and performance effects of different suggestions made by participants at public meetings.

2.3.1.3 Model receiving water quality

Receiving water quality models identify impacts from runoff inputs and help watershed managers determine whether receiving waters meet water quality standards. Usually, computer models are used because of the complexity of calculations. Models are available for streams, lakes, reservoirs, estuaries, bays, and coastal segments. Most models couple quantity (hydrodynamic) and quality parameters, but some consider these parameters separately.

A useful water resource impact model is the Long-Term Hydrologic Impact Assessment (L-THIA), which was developed by Purdue University (2000) for land use planners to provide site-specific estimates of changes in runoff, recharge, and nonpoint source pollution resulting from past or proposed land use changes. The model uses regional climate data and user-provided location, land use, and soil group data for up to three different scenarios (past, present, and future). The results are in the form of tables, bar charts, and pie charts. The model is available at http://danpatch.ecn.purdue.edu/~sprawl/LTHIA7.

The best sources of information for receiving water quality models are either government agencies or product vendors. The following is a list of government agencies that can provide the information needed to choose the most appropriate model:

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- USEPA Center for Exposure Assessment Modeling, Athens, Georgia
- US Army Corps of Engineers, Waterways Experiment Station, Vicksburg, Mississippi
- US Army Corps of Engineers, Hydrologic Engineering Center, Davis, California
- USGS, Reston, Virginia
- National Oceanic and Atmospheric Administration (NOAA), Silver Spring, Maryland—estuaries and bays
- Tennessee Valley Authority (TVA), Knoxville, Tennessee—rivers and reservoirs

Additional guidance regarding load estimation and receiving water quality modeling is provided in *Compendium of Tools for Watershed Assessment and TMDL Development* (USEPA, 1997a), which supports the watershed approach by summarizing available techniques and models that assess and predict physical, chemical, and biological conditions in water bodies. This document is intended to provide watershed managers and other users with information helpful for selecting models appropriate to their needs and resources. The *Compendium* includes information on the following:

- A wide range of watershed-scale loading models
- Field-scale loading models
- Receiving water models, including eutrophication/water quality models, toxics models, and hydrodynamic models
- Integrated modeling systems that, for example, link watershed-scale loading with receiving water processes
- Ecological techniques and models that can be used to assess and/or predict the status of habitat, single species, or biological communities

An additional modeling resource is *Modeling of Nonpoint Source Water Quality in Urban and Non-Urban Areas*, which is a major nonpoint source model review effort published by EPA in 1991. It focuses on nonpoint source assessment procedures and modeling techniques for both urban and non-urban land areas (Donigian and Huber, 1991). The report provides detailed reviews of specific methodologies and models, as well as overview discussions and model comparison tables. Simple procedures, such as regression and loading function approaches, are also described in the report, along with complex models like SWMM, HSPF, STORM, CREAMS/GLEAMS, SWRRB, AGNPS, and others. Brief case studies of modeling efforts are summarized, with emphasis on the use of nonpoint and comprehensive watershed models for watershed management activities. This publication can be found at http://yosemite.epa.gov/water/owrccatalog.nsf/0/b28aec046488178585256fc700700b24?OpenDocument.

EPA has assembled a Web site with information about and links to water quality models. This site includes basic information, EPA-supported models, other federal government-supported models, technical guidance for models, and model training and meetings. The Web site can be accessed at http://www.epa.gov/waterscience/wqm/.

2.3.2 Assess Cumulative Effects

A watershed assessment should include an evaluation of cumulative effects, which are combined effects of multiple activities over space or time. Such effects can be difficult to assess because a large number of resources can be affected and often there are multiple pathways through which these effects can occur. In addition, the appropriate spatial and temporal scales for the analysis usually are uncertain. Because many environmental assessments do not take cumulative effects into account, most likely because there is no explicit process for analyzing them, MacDonald (2000) developed a conceptual process to guide their assessment and management. The process is divided into three phases: the scoping phase, the analysis phase, and the implementation and management phase. Within each phase are a group of interrelated steps that, if followed, typically lead to a complete analysis of the cumulative effects on a watershed. The three phases and their steps are shown in Figure 2.1.

2.3.3 Estimate the Effectiveness of Treatment Programs

A useful tool to estimate the effectiveness of treatment practices on water quality is the Watershed Treatment Model (WTM), which was developed by the Center for Watershed Protection (Caraco, 2001). The WTM is a simple model for rapidly assessing how various management programs influence pollutant loadings and/or habitat quality in urban watersheds. It incorporates many simplifying assumptions that allow watershed managers to assess various programs and sources that are not typically tracked in more complex models. The WTM consists of two basic components: pollutant sources and treatment options. The pollutant sources component estimates the load from a watershed without treatment measures in place. It assesses two broad categories of pollutant sources: primary land uses and secondary sources. The treatment options component estimates the reduction in the uncontrolled load resulting from a wide range of treatment measures. Treatment options are broadly defined in the model as storm water treatment practices and storm water management programs. The most current version of the WTM, version 3.0, can track sediment, nutrients, and bacteria. The WTM can be a useful tool for managers who are analyzing the effectiveness of current watershed restoration programs, preparing Total Maximum Daily Loads (TMDLs), or evaluating the watershed benefit of National Pollutant Discharge Elimination System (NPDES) storm water programs. For more information about the WTM, contact the Center by e-mailing center@cwp.org or visit their Web site at http://www.cwp.org.

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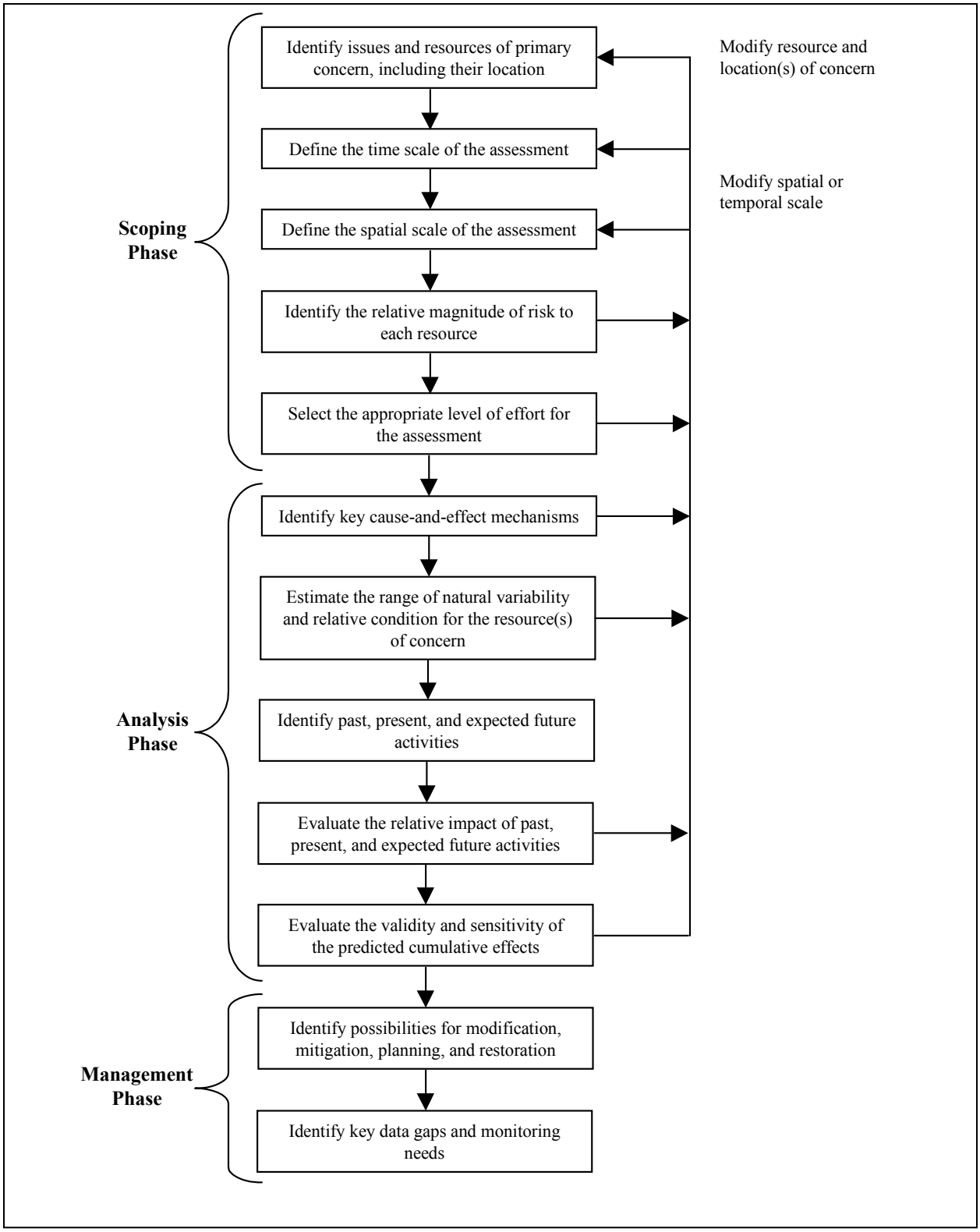

Figure 2.1: Conceptual process for assessing cumulative effects (MacDonald, 2000).

Indicators of Storm Water Program Effectiveness

The Hampton Roads Planning District Commission in Chesapeake, Virginia, has developed a database to track and evaluate various indicators of the effectiveness of the storm water program. The indicators fall into four basic categories: water quality, physical & hydrological, socioeconomic, and programmatic. This database tracks the indicators as listed below (Hillegass, 2003):

- *Water quality*: pollutant loadings for nutrients
- *Physical and hydrological*: acres of open space land protected from development
- *Socioeconomic*: inventory of public education efforts, such as number of publications produced and distributed, Web site hits, media campaigns, stream cleanup activities
- *Programmatic*: the following are programmatic indicators:
  - Number of approved erosion and sediment control plans and disturbed acreage
  - Number of inspections and enforcement actions for erosion and sediment controls
  - Number of citizen calls about flooding and drainage problems, and number of responses
  - Cost and number of flooding and drainage projects
  - Investigative and corrective actions for illicit discharge detection and elimination
  - Operation and maintenance activities
  - Number of approved site and subdivision plans, and acreage served
  - Number and type of BMPs installed, the number of acres served by each BMP, and installation and maintenance information

Under the Phase II Storm Water Rule, communities are required to go beyond chemical pollutant monitoring to track the implementation of storm water management programs. This database can serve as a useful tool in fulfilling this requirement and can be used as a model for the development of varied indicators of program success (Hillegass, 2003).

2.3.4 Establish a Set of Watershed Indicators

Watershed indicators are monitoring parameters or techniques used to measure the effectiveness of management practices in meeting watershed and subwatershed goals and objectives. Indicators range from complex chemical or toxicity testing methods to simple public perception surveys. Watershed managers can choose one or more of these indicators to better focus their monitoring efforts. Regardless of the parameters or technique, to be effective, an indicator must accomplish the following:

- Reflect a measurable attribute of a watershed goal or subwatershed management objective
- Be measured using scientifically valid protocols, quality controls, and assessment techniques to ensure that results are replicable, consistent, compatible with other data collection efforts, and statistically valid
- Be measured at one or more locations that will adequately characterize "typical" conditions in the management unit and establish reference conditions against which future data comparisons can be made

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- Be monitored over a long enough period to establish observable trends
- Be compatible with available finances, personnel, and other resources. The cost of implementing the watershed indicator is an important consideration.

The Center for Watershed Protection and EPA published a reference to help municipalities select a suite of indicators that will most effectively measure conditions in their watershed (Claytor and Brown, 1996). This publication, *Environmental Indicators to Assess Stormwater Control Programs and Practices*, presents profiles with information such as advantages, disadvantages, cost, and applicability for 26 indicators, which include water quality, physical/hydrological, biological, social, programmatic, and site indicators. The document is available online at http://www.cwp.org.

2.3.5 Establish Water Quality Indicators

Conduct water quality monitoring. This type of monitoring involves measuring pollutants in both runoff and baseflow conditions. The most commonly measured constituents are oxygen demand, nutrients, metals, pH, temperature, flow or discharge, solids (e.g., total suspended solids or turbidity), fecal coliform, and a measure of oil and hydrocarbons (e.g., total petroleum hydrocarbons [TPH] or polycyclic aromatic hydrocarbons [PAHs]). Measurements can be taken at management facilities or in receiving waters. This method allows for the identification of trends in water quality over time and can identify areas that are degraded relative to low-impact reference sites. Changes in water quality that result from changes in land use or from the implementation of management practices can be detected to prioritize future conservation or restoration efforts. The specific constituents found in receiving waters can aid in identifying the source of the pollution problem and help target management practices effectively. The methodology for water quality monitoring is well-outlined in specific protocols, and results are quantitative and easy to present and compare to other monitoring databases. However, the monitoring effort must be long-term because of the high variability in constituent concentrations, and it might be expensive because of labor requirements or equipment costs for automation. Volunteer monitoring programs can reduce some of the expense of monitoring while providing the additional benefit of educating the public. EPA's Volunteer Monitoring Web site has more information about volunteer monitoring (http://www.epa.gov/owow/monitoring/volunteer).

(1) *Conduct toxicity testing*. These methods, often called whole effluent toxicity (WET) tests, involve exposing standardized freshwater, marine, and estuarine vertebrates, invertebrates, and plants to water samples to directly measure the adverse effects of effluents. Both acute and short-term chronic effects can be assessed. The test organisms can be either resident species or species that will be restocked or reintroduced. Toxicity reduction evaluation (TRE) can be used to identify the agent of toxicity, which helps to identify the pollutant source and indicates which management practices would be appropriate to treat the problem. Although this method allows managers to distinguish among a range of conditions and chemicals, species' responses vary substantially with respect to the choice of species, location (laboratory or in situ), and duration of the test. Also, chronic toxic effects, which may take a long time to manifest, are not measured with this type of testing. The TRE process can be expensive and is often used to specifically identify pollutants when receiving waters have previously been identified as impaired through other, less-expensive methods.

More information on WET methods is available at http://www.epa.gov/OST/WET. Descriptions and guidance on other analytical methods are provided at http://www.epa.gov/ost/methods (USEPA, 2000d).

(2) *Measure the frequency at which water quality standards are exceeded*. This method is usually based on chemical standards and can be derived from existing data or as part of the biennial 305(b) reporting process. It can identify long-term trends in water quality, storm water impacts, and the effectiveness of management practices. However, because the ability to detect exceedances is highly dependent on the frequency and timing of sample collection, brief periods of exceedance might be missed (during storm flow) and long-term conditions inaccurately represented. Also, exceedance frequencies provide little information about causes and sources of pollution. Costs associated with this method are minimal because data are usually collected through other programs. Guidance and information on EPA and state water quality standards and criteria can be found at http://www.epa.gov/ost/standards (USEPA, 2001c).

(3) *Determine sediment pollutant levels*. This type of monitoring involves the determination of pollutant load carried by sediments and deposited in slow-moving receiving waters. Analysis is usually conducted using spectrophotometry and chromatographic tests of samples from natural or artificial water bodies. The extent of toxicity in sediments can be determined by comparing sample results to reference samples that are known to be relatively unimpacted. Measured pollutant levels can also be compared to existing standards for typical contaminants in sediment (USEPA, 2000d). Using sediment contamination as an indicator of water quality is often confounded by uncertainty related to levels of concern and long-term impacts, the inability to identify pollutant sources, and lag time between discharge and settling. However, long-term trends in sediment pollutant loading can be detected if monitoring is conducted over a long period.

(4) *Measure microbial contamination*. This type of monitoring involves measuring concentrations of microbes such as fecal coliform or *Escherichia coli* to ascertain the probable presence of pathogens in the water column. These pathogens result in the closure of beaches, fishing areas, and shellfish beds. Tracking the frequency of such closures may indicate contamination in effluent from industrial or municipal facilities or septic systems, or runoff from agricultural areas. In areas where no treatment facilities or septic systems are present, runoff can be identified as the main source of pathogens. Measuring microbe concentrations can help determine the effectiveness of management practices in removing this type of contamination from receiving waters.

Trends in beach or shellfish closures over time may indicate a developing problem if high concentrations or counts become more frequent, or they may demonstrate the effectiveness of management efforts if decreasing trends occur. However, many of the bacteria measured have a variety of nonhuman sources, making it difficult to identify the source of the pollution. In addition, they are short-lived in the water column, so depending on when samples are collected, the occurrence of high bacterial concentrations may not be detected even though they are present at certain times (e.g., during storm flows).

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Bacterial source tracking refers to a family of methods that can be used to distinguish among sources of fecal contamination and can aid in tracking illicit discharges to storm sewer systems. Bacterial source tracking requires development of a database of known sources against which samples can be compared (Zhang et al., 2003). The methods can be molecular (e.g. DNA fingerprinting, or more specifically, ribotyping, pulsed-field gel electrophoresis [PFGE], polymerase chain reaction, terminal restriction fragment length polymorphism) or non-molecular. Non-molecular procedures can be biochemical (e.g., antibiotic resistance analysis, carbon utilization, F-specific coliphage typing, cell wall fatty acid methyl ester) or chemical (e.g., caffeine detection, optical brightener detection). In general, molecular methods can offer the most precise identification of specific types of sources, but they also have the highest unit costs and the most time-consuming procedures. Biochemical procedures are simpler, less expensive, and faster, and allow a larger number of samples to be analyzed in a shorter period of time (USEPA, 2002). The technology in this subject area is constantly evolving and new procedures and more refined methods may be available as research progresses.

Zhang et al. (2003) described the use of the PFGE method of bacterial source tracking analysis on *E. coli* samples from Four Mile Run in Northern Virginia, which is a highly urbanized watershed with approximately 40 percent impervious surface. Four Mile Run is impaired due to bacterial contamination and has a TMDL in place to control bacterial sources. The PFGE analysis identified that waterfowl contribute 38 percent of the bacteria, humans and pets (combined) accounted for 26 percent, and raccoons contributed 25 percent. Deer (9 percent) and rats (11 percent) also contributed bacteria to Four Mile Run.

DNA testing is an expensive but effective molecular method for identifying the primary animal or animals (human, duck, dog, etc.) that contribute microbes to the water column. More information about bacterial source tracking can be found in a two-part article in *Stormwater* available at http://www.forester.net/sw_0105_detecting.html (Hager, 2001).

Antibiotic resistance analysis (ARA) is the most commonly used non-molecular method for tracking sources of bacteria. ARA is used to distinguish among sources by looking at patterns of antibiotic resistance found in bacteria from human and animal sources. Fecal bacteria from humans can exhibit greater resistance to certain antibiotics than bacteria from wildlife feces (Hager, 2001; USEPA, 2002). However, this method may be confounded by the presence of bacteria from agricultural operations such as feedlots or poultry operations where antibiotics are used.

EPA's Office of Research and Development's National Risk Management Research Laboratory (NRMRL) is working to develop an integrated system for screening fecal bacteria contamination from various animal sources. NRMRL is working to match the best molecular method to its target bacteria for rapid screening and identification of sources of fecal contamination in watersheds (Simpson, 2003).

(5) *Measure nonpoint source loadings.* It is possible to estimate the amount of pollutants transported in storm water runoff from various land uses by using empirical monitoring data, land use imperviousness and cover, area, and rainfall volume. Modeling of pollutant loads can establish baselines that can be used to determine whether changes have occurred as a

Maryland's Environmental Indicators

The state of Maryland has compiled several indicators to characterize environmental quality (MDE, 1999). These indicators embody a range of environmental attributes, from air quality to drinking water quality to public understanding and community support. The Non-Tidal Aquatic Systems category, which encompasses the range of plants and animals found in free-flowing rivers, streams, lakes, and most wetlands, includes several indicators that appropriately address Maryland's habitat and land uses and include physical, chemical, and biological measures:

- Miles of Streams Degraded by Abandoned Mine Drainage.
- Stream Miles Open to Migratory Fish.
- Physical Habitat Index (Non-Tidal).
- Benthic Macroinvertebrate Index of Biotic Integrity (Non-Tidal).
- Fish Index of Biotic Integrity (Non-Tidal).
- Riparian Forest Buffers.

The biological indicators consider communities of living organisms as found throughout the water column rather than any individual species, and their values reflect the physical and chemical water quality conditions described by other indicators. The Riparian Forest Buffers indicator was chosen because of its importance to physical and chemical habitat and its contribution in cycling nutrients to aquatic species and because a statewide benchmark had already been established through the Chesapeake Bay Program. More information on Maryland's environmental indicators is available at http://www.mde.state.md.us/enpa/ 2000_enpa/envi_indicators.

result of land use changes or implementation of management practices. Loadings can be calculated for small-scale studies using the Simple Method as described in *Controlling Urban Runoff: A Practical Manual for Planning and Designing Urban BMPs* (Schueler, 1987), which is available for purchase at http://www.mwcog.org. Alternatively, several computer simulation models are available to model changes in nonpoint source loads under different scenarios.

Another source of information for estimating pollutant releases is the Healthy Community Environmental Mapping program, called HUD E-MAPS (HUD and USEPA, 2000). HUD E-MAPS, which was developed by the Department of Housing and Urban Development (HUD) and EPA, combines EPA environmental data with information on HUD's community development and housing programs. The program provides location, type, and performance information on HUD-funded activities throughout the country, and select EPA pollution release information. The maps help communities to plan by allowing them to identify areas of pollutant releases when planning economic development and housing projects. The HUD E-MAPS program can be accessed at http://www.hud.gov/emaps.

2.3.6 Establish Physical and Hydrological Indicators

EPA's *Rapid Bioassessment Protocols for Use in Wadeable Streams and Rivers* (USEPA, 1999) and *Volunteer Stream Monitoring: A Methods Manual* (USEPA, 1997c) provide guidance on how to conduct assessments of a water body's physical, habitat, and hydrological characteristics. Both documents are available on the Internet: the former can be found at http://www.epa.gov/owow/monitoring/rbp, and the latter is located at http://www.epa.gov/owow/monitoring/volunteer/stream.

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EPA also provides guidance for lake and reservoir monitoring in *Lake and Reservoir Bioassessment and Biocriteria* (USEPA, 1998b), which is available at http://www.epa.gov/owow/monitoring/tech/lakes.html. Monitoring guidance for estuarine and coastal marine waters can be found in *Estuarine and Coastal Marine Waters: Bioassessment and Biocriteria Guidance* (USEPA, 2000a), located at http://www.epa.gov/ost/biocriteria/States/estuaries/estuaries1.html.

Additional monitoring guidance can also be obtained from EPA's Environmental Monitoring and Assessment Program (EMAP), a research program designed to develop the necessary tools for monitoring and assessing the nation's ecological resources. The objective of the program is to guide national monitoring initiatives and activities with improved scientific understanding of ecosystem integrity and dynamics. Information about the EMAP program is available at http://www.epa.gov/emap.

Methods for characterizing streams are contained in *Applied River Morphology* (Rosgen, 1996). Rosgen discusses geomorphic characterization of streams, which helps to differentiate between degraded and stable stream systems. This book also contains methods used to assess the current conditions of a stream and the departure from its potential. The Bank Erodibility Hazard (BHI) Rating Guide can be used to quickly determine bank erosion potential.

(1) *Measure stream widening/downcutting*. Measurements of stream width, depth, and bank characteristics taken over time can be used to indicate changes in the magnitude and frequency of storm flows caused by land use changes that affect stream geometry. Such measurements are also useful in identifying stream segments that are especially susceptible to erosion and areas where habitat is degraded to target areas for implementation of management practices. Many stream channels are already modified, so baseline conditions need to be established. This method cannot be used to predict changes, but it can help to diagnose a problem after it has occurred. Booth (1994) presents excellent guidance for conducting measurements of stream cross-sectional area.

(2) *Conduct physical habitat monitoring*. Monitoring of physical habitat is used to assess the potential of the stream to support different kinds of biota. Parameters such as weather, stream type and origin, land use, erosion, reach width and depth, canopy, proportion of stream morphological type (pool, riffle, and run), and presence or absence of large woody debris and aquatic vegetation can be measured easily and inexpensively and can provide information about which taxa would likely be found in the stream without water quality impacts (reference condition). If conducted over time, monitoring can provide information about past, present, and future changes in channel morphology. Although this method detects impacts from relatively low levels of development, it is not useful in pinpointing sources of degradation, nor does it offer insight into other water quality impacts.

(3) *Assess dry weather flows*. This method is used to assess the impact of urbanization on base flows, either as compared to a non-urbanized stream in the same ecoregion, or as a change over time. Impacted streams in humid areas show decreased flow, whereas perennial streams in arid regions show increased flow, as a result of urbanization. Evaluating pipe installations and impervious surfaces in humid regions and water use in arid regions allows this method to be used to identify causes of baseflow alteration. This method works well in conjunction

with stream widening/downcutting studies. It cannot be used to distinguish between urbanization and other causes of stream flow alteration such as irrigation, long-term drought, and the like, unless these factors are taken into account explicitly. Also, it is difficult to establish trends without extensive long-term data and knowledge about certain geologic conditions.

(4) *Measure flooding*. It is important to quantify changes in stream morphology over time because alterations in stream size or shape or in floodplain boundaries indicate that hydrologic changes have resulted from development in the watershed. These changes can be identified by comparing historical floodplain records to current floodplain maps, called Flood Hazard Boundary Maps (FHBMs). They are official maps issued by a community administrator that detail the boundaries of the flood, mudslide, and related erosion areas having special hazards that have been designated (FEMA, 2000). The maps can be obtained from local community map repository sites, from the Federal Emergency Management Agency (FEMA) online at http://msc.fema.gov, or through FEMA by phone, fax, or mail from the Map Service Center, P.O. Box 1038, Jessup, Maryland 20794-1038; telephone 800-358-9616; fax 800-358-9620.

(5) *Monitor stream temperature*. This method identifies areas where stream temperature has increased as a result of urbanization and loss of shading and buffers. Stream temperature can be measured over time or compared to other, low-impact watersheds. This monitoring method can be used to identify areas that would potentially benefit from riparian buffer enhancement and to measure the effectiveness of management practices used to regulate stream temperature. Changes in stream temperature can be an early warning sign that sensitive species will be lost without intervention. Climatic conditions can cause variability in stream temperature that is extraneous to trends caused by urbanization and can confound analyses. In addition, in should be noted that some management practices, such as ponds and wetlands, can result in increased temperature.

2.3.7 Establish Biological Indicators

Bioassessments are useful for detecting aquatic life impairments and identifying the causative agents and possible mitigation strategies. Additional bioassessments can indicate whether mitigation was successful and can direct further management activities. Monitoring of biological communities offers the following advantages:

- Biological communities reflect overall ecological integrity and directly relate to the primary goal of the Clean Water Act.

- Biological communities integrate the effects of different stressors and provide a broad measure of their aggregate impact.

- Biological communities provide an ecological measure of changes in environmental conditions.

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Development and Evaluation of Ecosystem Indicators for Urbanizing Midwestern Watersheds

Researchers at Purdue University are undertaking a study to develop predictive indicators of urbanization that are applicable to midwestern watersheds (Spacie et al., 2000). The objectives of this study are as follows:

- Quantify impacts on hydrologic regimes, water quality, and habitat structure of stream ecosystems using paired experimental watersheds.
- Develop linked models to accurately predict these impacts.
- Use the models to generate and test indicators of urbanization and hydrologic change with respect to biological responses to these changes.
- Use these indicators with the models to assess biological responses to alternative urbanization scenarios on larger scales.

Data from satellite imagery, intensive water quality and biological sampling, stream cross-section measurements, and physical habitat assessments will be used to develop and test the models. A dynamic hydrology model that can simulate cross-sectional averaged velocities, shear stress velocities, and water depth variability during storm peaks has been developed. Functional biological metrics and habitat quality indices will be correlated not only to land use but also to channel morphometry and flow variability.

For more information contact Anne Spacie, Department of Forestry and Natural Resources, Purdue University, 1159 Forestry Building, West Lafayette, Indiana 47907-1159; telephone 765-494-3621; e-mail aspacie@purdue.edu.

- Routine biological monitoring is inexpensive compared to chemical monitoring and toxicity tests.
- Biological monitoring is useful for evaluating impairment when criteria for specific ambient impacts do not exist.

Bioassessments can include evaluation of fish populations, benthic macroinvertebrate communities, periphyton, and single species monitoring. EPA's *Rapid Bioassessment Protocols for Use in Wadeable Streams and Rivers* (USEPA, 1999) contains descriptions of various methods for each community type. EPA (2000b) also published the *Stressor Identification Guidance Document*, which outlines a process to identify causes of biological impairment. The stressor identification process is outlined in Figure 2.2 and includes three major steps: (1) listing candidate causes of impairment; (2) analyzing new and existing data to generate evidence for each candidate cause; and (3) producing a causal characterization with the evidence generated in step 2 to draw conclusions about the stressors most likely to have caused the impairment. The *Stressor Identification Guidance Document* is available for download in PDF format at http://www.epa.gov/waterscience/biocriteria/stressors/stressorid.html or can be ordered through EPA's National Service Center for Environmental Publications at http://www.epa.gov/ncepihom/index.htm.

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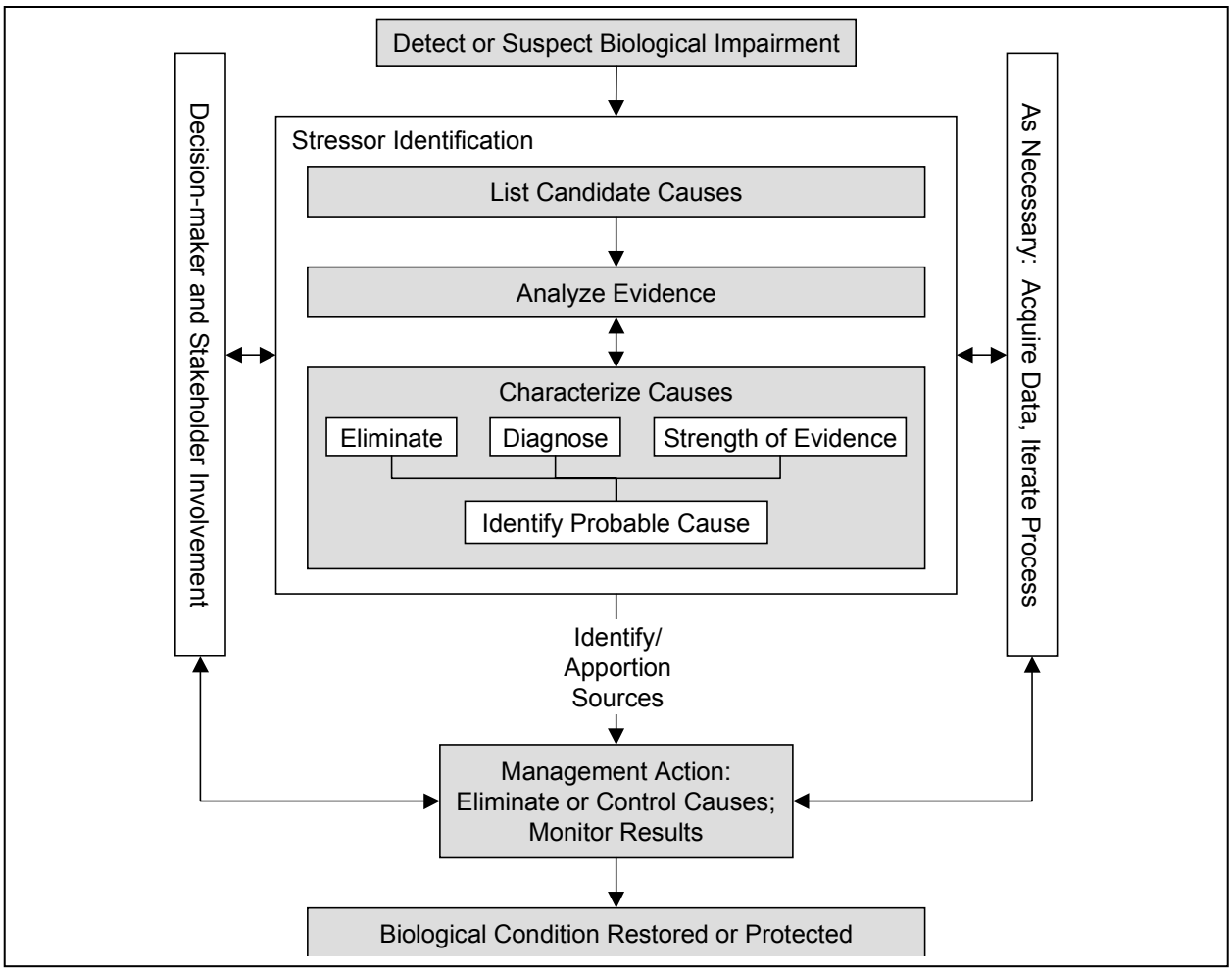

Figure 2.2: Conceptual diagram of the stressor identification process (USEPA, 2000b).

The Biological Assessment of Wetlands Workgroup (BAWWG) (USEPA, 2001b) provides information for establishing monitoring protocols for wetlands through its series of "state of the science" reports. These reports include introductory modules on wetland bioassessments and modules on specific methods, such as bioassessments for macroinvertebrates. Although the reports do not provide specific prescriptive guidance, they summarize current knowledge and provide options and recommendations to states for developing wetland bioassessment methods and programs. The modules also point out limitations of current methods and identify research needs. Information from BAWWG is available at http://www.epa.gov/owow/wetlands/bawwg/index.html.

(1) *Assess periphyton populations*. Changes in periphyton or plankton community structure and distribution patterns can indicate a water quality problem stemming from thermal pollution, toxic chemicals, nutrients, and sedimentation. Because periphyton have a short life cycle, they are especially good indicators of short-term impacts. Measurements of chlorophyll, a chemical common to all periphyton, can also be used as an indicator of eutrophication. Although there are several levels of sampling and analysis of periphyton populations, rapid sampling can be relatively easy and inexpensive and has little impact on the ecosystem.

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Also, standardized methods (biomass, chlorophyll) can be used to analyze and interpret algal communities without doing an extensive taxonomic evaluation, which requires specialized training. One problem with these indicators is that plankton populations vary seasonally and are highly transient, making them a poor indicator of site-specific conditions.

(2) *Assess macroinvertebrate assemblages*. Macroinvertebrates are relatively immobile and are good indicators of site-specific effects. They have a short life cycle and therefore are good indicators of short-term stress. Measurements of invertebrate populations are usually compared to populations from a reference condition to determine the severity of pollutant impacts. The presence or absence of particular species can be used to infer poor aquatic integrity because macroinvertebrate assemblages typically cover a broad range of trophic levels and pollution tolerances that allow interpretation of multiple effects. Macroinvertebrate sampling has some drawbacks, including the fact that populations are highly habitat-dependent and vary with season, stream flow, and region, which can confound results. In addition, taxa identification requires training and can be complex and time-consuming. Despite these drawbacks, volunteer monitoring programs can be used to collect macroinvertebrate data. Both *Rapid Bioassessment Protocols for Use in Wadeable Streams and Rivers* (USEPA, 1999) and *Volunteer Stream Monitoring: A Methods Manual* (USEPA, 1997c) provide guidance on how to conduct benthic macroinvertebrate assessments.

(3) *Assess fish assemblages*. Measurements of fish diversity, species richness, species pollutant tolerance, disease prevalence, and a variety of other metrics can be used to identify the nature and extent of a pollution or habitat problem. Measurements are taken in several different habitats within the stream or other water body and are usually compared to a regional reference condition to determine the extent of impairment. The methods can also be used to evaluate the success of management practices. Because fish have a relatively long lifespan, they often react to chronic levels of pollutants and long-term impacts. Fish are also easy to collect and identify. However, fish populations are influenced by many other variables, such as stream size, region, season, temperature, and flow conditions, that need to be taken into account when analyzing the data. Also, fish that migrate may be affected by conditions in another area that is not the area of interest. It is sometimes difficult to identify the source of problems in fish populations because of the prevalence of confounding factors that make interpretation of results difficult.

Biodiversity information on the Web via NatureServe

NatureServe, a nonprofit organization, partners with a network of natural heritage programs and conservation data centers to conduct expert local biodiversity inventories and analyze the results both nationally and internationally. Their Web site offers such data products as the NatureServe Explorer, which compiles conservation data on more than 50,000 plants, animals, and ecological communities in the United States and Canada. Users can search the database by any combination of name, location, and conservation status. The Web site also links to online data resources available from natural heritage programs and conservation data centers via the "Local Program Data" link. NatureServe provides links to ecology, animal, and plant data for download and provides links to other biodiversity resources on the Web. The NatureServe Web site can be accessed at http://www.natureserve.org.

(4) *Assess single species indicators*. Trout, salmon, and freshwater mussels are often used for this type of assessment. Some species are popular with the public, and their popularity can help in rallying support for better management. Measuring only one species is relatively easy and inexpensive and might provide early diagnosis of degradation, which can facilitate remediation efforts. However, natural population fluctuations in a single species can skew results, and without corroborating evidence there is no way to prove conclusively that degradation has occurred. It should be noted that focusing on protecting a single species may decrease protection of other threatened species.

(5) *Measure composite indicators*. This method typically involves developing an index that incorporates the results of several different bioindicators. Several metrics can be combined into a single integrity index, such as the number of native fish species or the number of intolerant macroinvertebrate taxa. Composite indicators provide a more comprehensive evaluation of storm water impacts than fish, macroinvertebrate, or single species indicators alone. Both long-term and short-term effects can be evaluated by using this type of metric. As with the other biological methods, populations are dependent on region, season, and flow. Reference site measurements are essential for valid comparisons when determining the extent of storm water impacts. Note: other measurements may be needed to identify sources of degradation.

2.3.8 Establish Programmatic Indicators

It is important to assess the effectiveness of a runoff management program. Claytor and Brown (1996) present several programmatic indicators that can be used to estimate the success of a management program and help to direct future efforts. These include:

- Number of illicit connections identified or corrected
- Number of management practices installed, inspected, and maintained
- Permitting and compliance
- Growth and development

Management Measure 12 discusses other ways to determine the effectiveness of runoff management programs.

2.3.9 Develop a Suite of Social Indicators

Watershed managers can use several methods to gauge public perception of water quality issues and nonpoint source programs. These "social indicators" include:

- Public attitude surveys
- Industrial/commercial pollution prevention
- Public involvement and monitoring
- User perception

More information about these indicators can be found in *Environmental Indicators to Assess Stormwater Control Programs and Practices* (Claytor and Brown, 1996).

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2.4 Information Resources

USGS's NAWQA Data Warehouse provides online access for invertebrate community data from 1,700 stream sites in more than 50 major river basins across the nation. Data from more than 5,000 invertebrate community samples that were collected from 1993 through 2002 can be found here. The data warehouse also provides data on fish communities from more than 1,000 stream locations, as well as data from thousands of water quality samples from approximately 6,400 stream sites, 7,000 wells, and streambed sediment and aquatic animal tissue. Samples have been analyzed for a number of constituents. The NAWQA Data Warehouse can be accessed at http://water.usgs.gov/nawqa/data.

The Caltrans *Guidance Manual: Storm Water Monitoring Protocols* (Caltrans, 2000a) provides step-by-step descriptions of the processes used to plan and implement a successful water quality monitoring program specific to runoff from transportation-related facilities. Although the guidance manual emphasizes uniform policies and procedures for monitoring, the *Statewide Storm Water Management Plan* (Caltrans, 2000b) describes minimum procedures and practices Caltrans uses to reduce pollutants discharged from storm water drainage systems. These documents, along with other storm water-related documents, can be downloaded in PDF format http://www.dot.ca.gov/hq/env/stormwater/special/index.htm.

Donigan and Huber (1991), in *Modeling of Nonpoint Source Water Quality in Urban and Non-Urban Areas*, reviewed nonpoint source assessment procedures and modeling techniques for both urban and non-urban land areas. Detailed reviews of specific methodologies and models are presented, along with overview discussions focusing on both urban and non-urban methods and models. Brief case studies of ongoing and recently completed modeling efforts are described and recommendations for nonpoint runoff quality modeling are presented. This document can be ordered from the National Technical Information Service at *www.ntis.gov* or by calling 800-553-6847.

EPA has assembled a Web site with information about and links to water quality models. This site includes basic information, EPA-supported models, other federal government-supported models, technical guidance for models, and model training and meetings. The Web site can be accessed at http://www.epa.gov/waterscience/wqm/.

Patten et al. (2000) have undertaken a study to develop improved indicators and innovative techniques for assessing and monitoring ecological integrity at the watershed level in the western United States. Their objectives are to develop practical, scientifically valid indicators that span multiple resource categories, are relatively scale-independent, address different levels of biological organization, can be rapidly and cost-effectively monitored by remote sensing, and are sensitive to a broad range of anthropogenic and natural environmental stressors. More information about this project can be found at http://es.epa.gov/ncer_abstracts/grants/99/ecological/patten.html (NCER, 2001).

Compendium of Tools for Watershed Assessment and TMDL Development (USEPA, 1997a) supports the watershed approach by summarizing available techniques and models that assess and predict physical, chemical, and biological conditions in water bodies. The publication contains descriptions of three major categories of models: watershed loading, receiving water,

and ecological. Watershed loading models can be used to simulate the generation and movement of pollutants from the source to discharge into receiving waters. Receiving water models can be used to simulate the movement and transformation of pollutants through lakes, streams, and rivers. Ecological models can be used to simulate plant and animal communities and their response to pollutants and habitat modification. This document is available through EPA's National Service Center for Environmental Publications at http://www.epa.gov/ncepihom/index.htm.

EPA's *Monitoring Guidance for Determining the Effectiveness of Nonpoint Source Controls* (USEPA, 1997b) contains an overview of nonpoint source pollution and covers the development of a monitoring plan, data analysis, quality assurance/quality control, and biological monitoring. The manual was written to assist users in the design of water quality monitoring programs to assess both impacts from nonpoint source pollution and the effectiveness of control practices and management measures. It is available through EPA's National Service Center for Environmental Publications at http://www.epa.gov/ncepihom/index.htm.

Volunteer Stream Monitoring (USEPA, 1997c) serves as a tool for program managers who want to launch a new stream monitoring program or enhance an existing program. It contains methods that have been adapted from those used successfully by existing volunteer programs. The guidance is available in HTML and PDF formats at http://www.epa.gov/owow/monitoring/volunteer/stream.

The *Lake and Reservoir Bioassessment and Biocriteria* (USEPA, 1998b) guidance was developed through the experience of existing state, regional, and national lake monitoring programs and is oriented toward practical decision-making rather than research. Its primary target audiences are state and tribal natural resource agencies. It is intended to provide managers and field biologists with functional methods and approaches that will facilitate the implementation of viable lake bioassessment and biocriteria programs that meet their needs and resources. The document can be obtained in HTML format at http://www.epa.gov/owow/monitoring/tech/lakes.html.

Rapid Bioassessment Protocols for Use in Wadeable Streams and Rivers: Periphyton, Benthic Macroinvertebrates, and Fish (USEPA, 1999) is a practical technical reference for conducting cost-effective biological assessments of lotic systems. This guidance is intended to provide basic, cost-effective biological methods for states, tribes, and local agencies that: (1) have no established bioassessment procedures; (2) are looking for alternative methodologies; or (3) may need to supplement their existing programs (not supersede other bioassessment approaches that have already been successfully implemented). The scope of this guidance is considered applicable to a range of planning and management purposes, i.e., the methods may be appropriate for priority-setting, point and nonpoint source evaluations, use-attainability analyses, and trend monitoring, as well as initial screening. The guidance is available in HTML and PDF formats at http://www.epa.gov/owow/monitoring/rbp.

The *Estuarine and Coastal Marine Waters: Bioassessment and Biocriteria Guidance* (USEPA, 2000a) provides an extensive collection of methods and protocols for conducting bioassessments in estuarine and coastal marine waters, as well as the procedures for deriving biocriteria from the results. Several case studies illustrate the bioassessment process and

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biocriteria derivation procedures. This document can be downloaded in PDF format at http://www.epa.gov/ost/biocriteria/States/estuaries/estuaries1.html.

The *Stressor Identification Guidance Document* (USEPA, 2000b) leads water resource managers through the process of stressor identification and evidence assembly. The guidance can be used whenever biological impairment is present in an aquatic ecosystem and the cause is unknown. The stressor identification process combines multiple methods to determine the causes of impairment, and the methods are presented in order of the kinds of evidence used, from site-specific to more general information. The *Stressor Identification Guidance Document* is available in PDF format at http://www.epa.gov/waterscience/biocriteria/stressors/stressorid.html.

Techniques for Tracking, Evaluating, and Reporting the Implementation of Nonpoint Source Control Measures: Urban (USEPA, 2000c) was written to assist local officials in focusing limited resources by using statistical sampling methods to assess, inspect, or evaluate a representative set of management practices, erosion and sediment controls, and onsite wastewater treatment systems. The document can be downloaded in PDF format at http://www.epa.gov/owow/nps/urban.pdf, or it can be ordered through EPA's National Service Center for Environmental Publications at http://www.epa.gov/ncepihom/index.htm.

EPA's Web site titled "An Introduction to Water Quality Monitoring" contains a wide variety of resources for those interested in learning more about water quality monitoring, automated data management, and geographic information systems (USEPA, 2001). Many EPA guidance documents, fact sheets, and final reports are available from this site, which can be accessed at http://www.epa.gov/owow/monitoring/monitor.html.

EPA's Web site, "Water Quality Criteria and Standards Plan" (USEPA, 1998d), describes six new criteria and standards program initiatives that EPA and the states and tribes will take over during the next decade. The plan presents a "vision" and strategy for meeting these important new initiatives and improvements and will guide EPA, states, and tribes in developing and implementing criteria and standards that provide a basis for enhancements to the TMDL program, NPDES permitting, nonpoint source control, wetlands protection, and other water resource management efforts. The Web site is located at http://www.epa.gov/ost/standards/quality.html.

EPA's Volunteer Monitoring Program provides technical assistance, serves as a regional contact for volunteer programs, manages grants to state agencies that undergo volunteer water monitoring and conduct public participation programs, and provides information exchange services for volunteers. The program's Web site (http://www.epa.gov/owow/monitoring/volunteer) provides a link to a listserver is available for volunteer monitoring program coordinators, as well as a national newsletter for volunteer monitors, a directory of volunteer monitoring programs, and manuals on volunteer monitoring methods and on planning and implementing volunteer programs.

EPA's Watershed and Water Quality Modeling Technical Support Center provides information and services to federal agencies, state and local governments, businesses, and individuals to help support implementation of the Clean Water Act. Support includes reviewing proposed TMDLs, providing oversight to TMDL development nationwide, serving as technical advisors, applying

models for TMDL development, assisting in data acquisition and analysis, assisting in TMDL implementation, analyzing BMP design and performance, and researching models for regulatory applications. The center's Web site can be accessed at http://www.epa.gov/athens/wwqtsc/index.html.

The P8—Urban Catchment Model by Walker (2000) is designed to predict the generation and transport of runoff pollutants in urban watersheds. The model was developed to design and evaluate runoff treatment control combinations in developments for pollutant removal efficiency. The most recent version of this DOS-based program (Version 2.4, published in February 2000), as well as data files and program documentation, is available for download from http://wwwalker.net/p8.

A useful water resource impact model is the Long-Term Hydrologic Impact Assessment (L-THIA), which was developed by Purdue University (2000) for land use planners to provide site-specific estimates of changes in runoff, recharge, and nonpoint source pollution resulting from past or proposed land use changes. The model uses regional climate data and user-provided location, land use, and soil group data for up to three different scenarios (past, present, and future). The results are in the form of tables, bar charts, and pie charts. The model is available at http://danpatch.ecn.purdue.edu/~sprawl/LTHIA7.

Vermont's Water Resources Board developed "A Scientifically Based Assessment and Adaptive Management Approach to Stormwater Management" as an appendix to the *Investigation into Developing Cleanup Plans for Stormwater Impaired Waters* (Docket No. INV-03-01). The assessment paper describes a framework for identifying storm water runoff problems and providing adaptive management to address controls for and treatment of runoff in problem areas. The framework represents a balance of the interests of many diverse constituents, focusing on surface water impairments and improvements to identify problems due to runoff and improvements due to runoff controls. The report, part of the Vermont Water Resources Board's Stormwater Docket, can be accessed at http://www.state.vt.us/wtrboard/docs/inv-03-01report.pdf.

NatureServe, a nonprofit organization, partners with a network of natural heritage programs and conservation data centers to conduct expert local biodiversity inventories and analyze the results both nationally and internationally. Its Web site offers such data resources as the NatureServe Explorer, which compiles conservation data on more than 50,000 plants, animals, and ecological communities in the United States and Canada. Users can search the database by any combination of name, location, and conservation status. The Web site also connects to online data resources available from natural heritage programs and conservation data centers via the "Local Program Data" link. NatureServe provides links to ecology, animal, and plant data for download and to other biodiversity resources on the Web. The NatureServe Web site can be accessed at http://www.natureserve.org.

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MANAGEMENT MEASURE 3
WATERSHED PROTECTION

3.1 Management Measure

Develop a watershed protection program to:

- Avoid development of areas that are particularly susceptible to erosion and sediment loss.
- Preserve areas that provide important water quality benefits and/or are necessary to maintain riparian vegetation and aquatic biota.
- Site development projects, including roads, highways, and bridges, to protect the natural integrity of water bodies and natural drainage systems.

3.2 Management Measure Description and Selection

3.2.1 Description

The purpose of this management measure is to reduce the generation of nonpoint source pollutants and to mitigate the impacts of urban runoff and associated pollutants from new development and redevelopment, including the construction of new and relocated roads, highways, and bridges. It is intended to provide general goals for local agencies and urban communities in developing comprehensive programs for guiding future development and land use activities in a manner that will prevent and mitigate the effects of nonpoint source pollution.

Although the goals of this management measure and Management Measure 4 (Site Development) are similar, this measure is intended to apply to larger watersheds or regional drainage basins rather than individual sites. The watershed protection and site development management measures are intended to be complementary. They can be used together with the other management measures in a comprehensive framework to control runoff and reduce nonpoint source pollution. (See Chapter 1 for a description of the runoff management program framework.)

Comprehensive planning is an effective nonstructural tool to control nonpoint source pollution. Where possible, growth should be directed toward areas where it can be sustained with minimal impact on the natural environment (Meeks, 1990). Poorly planned growth and development have the potential to degrade and destroy natural drainage systems and surface waters (Mantel et al., 1990). By making proper planning and zoning decisions, water quality managers can direct development and land disturbance away from areas that drain to sensitive waters. Land use designations and zoning laws can also be used to protect environmentally sensitive areas such as riparian corridors and wetlands.

Riparian buffers and wetlands can have the benefit of providing long-term pollutant removal capabilities without the comparatively high costs usually associated with constructing and maintaining structural controls. Conservation or preservation of these areas is important to protect the water quality of streams, wetlands, lakes, and reservoirs. Land acquisition programs help to preserve areas considered critical to maintaining surface water quality. Adequate buffer strips along streambanks provide protection for stream ecosystems, help stabilize the stream, and can prevent streambank erosion (Holler, 1989). Buffer strips can also protect and maintain near-stream vegetation that attenuates the release of sediment into stream channels. Levels of suspended solids have been shown to increase at a slower rate in stream channel sections with well-developed riparian vegetation (Holler, 1989).

3.2.2 Management Measure Selection

This measure was selected for several reasons. First, watershed protection is a technique that provides long-term water quality benefits, and many states and local communities have adopted this practice. Numerous state and local governments have already legislated and implemented detailed watershed planning programs that are consistent with this management measure. For example, Oregon, New Jersey, Delaware, and Florida have passed legislation that requires county and municipal governments to adopt comprehensive plans, including requirements to direct future development away from sensitive areas. Many municipalities and regions have adopted land use and growth controls, including the towns of Amherst and Norwood and the Cape Cod region of Massachusetts; Narragansett, Rhode Island; King County, Washington; and many others.

Second, there is general recognition that the protection of sensitive areas and areas that provide water quality benefits is integral to maintaining or minimizing the impacts of development on receiving waters and associated habitat. Without a comprehensive planning approach that includes the use of riparian buffers, open space, bioretention, and structural controls to maintain the predevelopment hydrologic characteristics of the site, significant water quality and habitat impacts are likely. The experience of communities across the country has shown that the use of structural controls without adequate local land use planning and zoning often does not adequately protect water quality and might even cause detrimental effects such as increased temperature.

Third, this measure is effective in producing long-term water quality benefits without the high operation and maintenance costs associated with structural controls. The Michigan Department of Environmental Quality (no date) compared the costs of two nonpoint source projects. One involved preserving an urbanizing watershed, and the other entailed restoring an urban watershed. Table 3.1 is a side-by-side cost comparison demonstrating that it is generally less costly to protect high-quality streams than to restore them.

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Table 3.1: Cost comparison of stream preservation vs. stream restoration (Michigan Department of Environmental Quality, no date).

	Bear Creek	York Creek
Type of nonpoint source project	Preservation	Restoration
Setting	Grand Rapids, MI, area stream	Grand Rapids, MI, area stream
Size	20,096 acres	2,110 acres
Level of urbanization	9.5% (1991)	19% (1993)
Stream category	High-quality trout stream	Former trout stream
Storm water ordinance	$10,000	$10,000
Decision-making GIS	$10,000	$10,000
Information/education program	$100,000	$80,000
Streambank stabilization	$15,000	$130,000
Storm water basin retrofits	–	$180,000
Additional storm water basins	–	$75,000
Other practices (habitat improvement, repairing road crossings, etc.)	$75,000	$190,000
Total cost	$210,000[a]	$675,000

[a] Total cost does not take into account the purchase cost or opportunity cost for not developing the land

3.3 Management Practices

A comprehensive watershed approach requires constant adjustments based on development patterns, population increases, changing land uses, the state of the resources, and the institutional capacity of the community to manage its resources. The practices listed below provide an overview of the approaches communities around the country are adopting or experimenting with to protect their water resources in a cost-effective way.

3.3.1 Resource Inventory and Information Analysis

Before a comprehensive program can be developed, communities should define the watershed boundaries, target areas, and pollutants of concern, and conduct resource inventory and information analysis. These activities can be done by using the best available information or collecting primary data, depending on funding availability and the quality of available data. Activities pursued under this process include assessment of ground water and surface water hydrology; evaluation of soil type and ground cover; identification of areas with water quality impairments; and identification of environmentally sensitive areas, such as steep or erodible uplands, wetlands, riparian areas, floodplains, aquifer recharge areas, drainageways, and unique geologic formations. Once environmentally sensitive areas are identified, those that are integral to the protection of surface waters and the prevention of nonpoint source pollution can be protected.

The City of Virginia Beach, Virginia, conducted a three-phase inventory of natural areas to help planners and public officials develop practices for resource protection. The data collection phase cost $13,867 (1991 dollars); the field inventory (Phase II), cost $54,624; and Phase III, preparation of a final report, cost $15,255 (Jenkins, 1991).

Richmond County, Virginia, developed the Richmond County Resource Information System (RIS) to provide a basis for responsible planning and development of shoreline areas. The

Watershed Approach to Storm Water and Flood Management

The Planning Department of Delaware County, New York, is leading the effort to develop long-term solutions to water quality impairment from urban runoff. The county's Stormwater and Flood Management program uses a two-phase approach: (1) inventorying and assessing sources of urban runoff and storm water infrastructure, and (2) local implementation and municipal plan development.

The inventory and assessment component involves a detailed evaluation of point and nonpoint sources of pollution in the Cannonsville Basin. Locations of potential sources were documented using a Global Positioning System and site characteristics such as soil type and land use were recorded. A GIS database was used to store this information along with existing infrastructure, topographic maps ,and planimetric maps.

The local implementation and municipal plan development component involves working with local municipalities as part of its Town Planning Advisory Service (TPAS) to develop local initiatives for water quality protection and to demonstrate the role of water quality in community economic development. The municipal plans help local officials integrate wellhead protection into water quality planning, prioritize management needs, establish maintenance programs, and incorporate runoff management into capital planning (Delaware County Departments of Planning and Public Works, 2003).

compilation and mapping of resource information are part of the county's planning and zoning program. In 1990, the program was supported by a $39,000 Federal Coastal Zone Management Grant, $45,000 from the Chesapeake Bay Foundation through a Virginia Environmental Endowment Grant, and $96,000 from the county's comprehensive plan budget (Jenkins, 1991).

3.3.1.1 Identify environmentally sensitive, critical conservation areas

The identification of environmentally sensitive areas, also referred to as critical conservation areas, is an essential component of a watershed protection program. These areas need to be identified to: (1) avoid developing areas susceptible to erosion and sediment loss; and (2) preserve areas that provide important water quality benefits, such as wetlands, permeable soils, forested buffers, and riparian areas. These types of lands are described in Table 3.2. Inventories of these areas can be developed using wetland inventories, soil maps, maps of critical habitat for endangered species, GIS tools, remote sensing, vegetative cover inventories/maps, and forest inventories, among other sources.

GIS Mapping for Open Space and Water Resource Protection

The towns of Westford, Littleton, Chelmsford, and Boxborough, located in the Merrimack River Watershed north of Boston, Massachusetts, are using GIS as a tool to guide efforts to protect critical open space lands and aquifers. The effort is part of Massachusetts' Community Preservation Initiative, which helps local officials address the tradeoff between environmental planning issues, such as habitat and watershed protection, and the growing needs of the community in terms of economic development, housing, and transportation. GIS provides local officials with the capability of identifying open space lands that are critical to protecting water resources and exploring the implications of various build-out scenarios, land preservation strategies, land uses, and densities (NALGEP, 2003).

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Table 3.2: Types of lands that should be preserved for watershed protection (adapted from Caraco et al., 1998).

Conservation Area	Description	Examples
Critical habitat	Essential spaces for plant and animal communities or populations	Tidal wetlands, freshwater wetlands, large forest clumps, springs, spawning areas in streams, habitat for rare or endangered species, potential restoration areas, native vegetation areas, coves
Aquatic corridor	Areas where land and water interact	Floodplains, stream channels, springs and seeps, steep slopes, small estuarine coves, littoral areas, stream crossings, shorelines, riparian forest, caves, and sinkholes
Hydrologic reserve	Undeveloped areas responsible for maintaining the predevelopment hydrologic response of a subwatershed	Forest, meadow, prairie, wetland, cropland, pasture, or managed forest
Water pollution hazard Source: Stapleton, 1999.	Any land use or activity that is expected to create a relatively high risk of water pollution	Septic systems, landfills, hazardous water generators, aboveground or underground tanks, impervious cover, surface or subsurface discharge of wastewater effluent, land application sites, storm water "hot spots," pesticide application, industrial discharges, and road salt storage areas
Cultural and historic sites Source: NPS, 2001.	Areas that provide a sense of place in the landscape and are important habitats for people	Historic or archaeological sites, trails, parkland, scenic views, water access, bridges, and recreational areas

3.3.1.2 Identify and protect drinking water sources

All drinking water sources, including surface and ground waters, should be considered for protection, and unfiltered sources will require the most stringent protection. More than 200 cities, towns, and tribes protect ground water public drinking water systems from contamination using a variety of local government tools such as zoning, subdivision controls, and transfer of development rights. The ordinances implementing these tools are varied and include measures

such as regulating onsite wastewater treatment systems and limiting nitrogen loading within wellhead protection areas (see section 1.3.1.2 in Management Measure 1, which describes different types of ordinances, including source water protection ordinances). This section introduces several tools to protect surface and ground water sources. Also, more information about identifying and protecting drinking water sources can be found at EPA's Office of Ground Water and Drinking Water Web site at http://www.epa.gov/ogwdw.

(1) *Delineate a Source Water Protection Area.* Delineation of a Source Water Protection Area requires identifying the boundaries of the area from which drinking water supplies are drawn. This information can be obtained from states, which are required to conduct an assessment of all public water systems. These assessments include a delineation, contaminant inventory, and susceptibility determination (see http://www.epa.gov/safewater/protect/swap.html for more information about state Source Water Assessment Programs). Local governments may choose to elaborate on the state's assessment before planning management activities.

(2) *Protect Sole Source Aquifers.* Sole Source Aquifer (SSA) designations are one tool to protect drinking water supplies in areas with few or no alternative sources. These areas are of special significance because if contamination occurred, using an alternative source would be prohibitively expensive. The designation protects an area's ground water resource by requiring EPA review of any proposed projects within the designated area that are receiving federal financial assistance. All proposed projects receiving federal funds are subject to a review to ensure they do not endanger the water source. Between January 1997 and January 1999, EPA reviewed 439 projects, 60 of which required modifications that were deemed necessary to protect the Sole Source Aquifers. Examples of federally funded projects that have been reviewed by EPA under the SSA protection program include highway improvements and new road construction, public water supply wells and transmission lines, wastewater treatment facilities, construction projects that involve disposal of storm water, agricultural projects that involve management of animal waste, and projects funded through Community Development Block Grants.

    EPA has developed Memoranda of Understanding (MOU) with other agencies to help establish review responsibilities under the Sole Source Aquifer Protection Program and to clarify what types of projects should or should not be referred to EPA. If you have questions about whether EPA needs to review a project in a particular Sole Source Aquifer, please contact the Sole Source Aquifer Coordinator for your state or territory (see http://www.epa.gov/safewater/swp/sumssa.html for lists and maps of Sole Source Aquifers in each of the EPA regions along with contact information for Sole Source Aquifer Coordinators).

(3) *Develop a local wellhead protection ordinance.* Wellhead protection refers to implementing pollution prevention and source controls to protect underground sources of drinking water. The Safe Drinking Water Act requires that State Wellhead Protection Programs be approved by EPA and incorporate delineation, contaminant source inventory, and source management. Local governments can also develop local wellhead protection ordinances to further protect drinking water supplies from contamination.

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(4) *Purchase property or development rights*. This practice is meant to guarantee community control over the activities conducted on lands that contribute to aquifers or surface waters. This may involve outright purchase of the land or just surface-use rights (see section 3.3.5 for a discussion of land acquisition options). New funds from the Safe Drinking Water Act allow land trusts and other local organizations to work with state agencies and water suppliers to identify and acquire critical lands and conservation easements.

3.3.2 Development of Watershed Management Plan

The resource inventory and information analysis component provides the basis for a watershed management plan, which is a comprehensive approach to addressing the needs of a watershed, including land use, urban runoff control practices, pollutant reduction strategies, and pollution prevention techniques.

For a watershed management plan to be effective, it should have measurable goals describing desired outcomes and methods for achieving the goals. Goals, such as reducing pollutant loads to surface water by 25 percent, can be articulated in a watershed management plan. Development and implementation of urban runoff practices, both structural and nonstructural, can be incorporated as methods for achieving the goal. The following describes the general steps for developing a watershed management plan (Livingston and McCarron, 1992):

1. Delineate and map watershed boundaries and subbasins within the watershed.
2. Inventory and map natural runoff conveyance and storage systems.
3. Inventory and map the manmade storm water conveyance and storage system.
4. Inventory and map land use by subbasin.
5. Inventory and map detailed soils by subbasin.
6. Establish a clear understanding of water resources in the watershed. Analyze water quality, sediment, and biological data. Analyze subjective information on problems such as citizen complaints. Evaluate water body use impairment, including the frequency, timing, and seasonality of the problem. Conduct a water quantity assessment (e.g., low flows, seasonality).
7. Inventory pollution sources in the watershed, including point sources (location, pollutants, loadings, flow capacity, etc.) and nonpoint sources (type, location, pollutants, loading, etc.). Include a land use/loading rate analysis for storm water, a sanitary survey for septic tanks, and dry weather flow monitoring to locate illicit discharges.
8. Identify and map future land use by subbasin. Conduct land use loading rate analyses to assess potential effects of various land use scenarios.
9. Identify planned short-term (five years) and long-term (20 years) infrastructure improvements. Runoff management deficiencies should be coordinated and scheduled with other infrastructure or development projects.
10. Determine infrastructure and natural resource management needs within each watershed.

11. Set resource management goals and objectives. Before corrective actions can be taken, a resource management target must be set. The target can be defined in terms of water quality standards, attainment of beneficial uses, or other local resource management objectives.
12. Determine pollutant reduction for existing and future land uses needed to achieve water quality goals.
13. Select appropriate management practices for both point and nonpoint sources that can be used to achieve the goal. Evaluate pollutant removal effectiveness, landowner acceptance, financial incentives and costs, availability of land operation and maintenance needs, feasibility, and availability of technical assistance.
14. Develop a watershed management plan. Since the problems in each watershed will be unique, each watershed management plan will be specific. However, all watershed plans will include elements such as an existing and future land use plan; a master storm water management plan that addresses existing and future needs; a wastewater management plan, including septic tank maintenance programs; and an infrastructure and capital improvements plan.

Development of a watershed management plan may involve establishing general land use designations that define allowable activities on a parcel of land. For example, land designated for low-density residential use would be limited to a density of two houses per acre, provided that all other regulations and requirements are met. All development activities allowed in a use category should be defined. By guiding uses within the planning areas, impacts to surface waters from urban runoff can be controlled. Those areas identified in the resource inventory and information analysis phase as environmentally sensitive and important to maintaining water quality can be preserved through various measures supported by state or local goals, objectives, and policies.

In Florida, local governments (counties and incorporated municipalities) were required to develop comprehensive plans based on existing information to guide short-term (five years) and long-term (20 to 25 years) growth and development. Local plans were required to be consistent with the state plan and the state growth management law and needed to identify environmentally sensitive areas and areas with water quality problems.

The Environmental Quality Corridor (EQC) System was established in Fairfax County, Virginia, to preserve floodplains, wetlands, shoreline areas, and steep valley slopes. EQCs were defined in the county's comprehensive plan and identified on the county land use map. If a parcel of land subject to a zoning or land use designation change contained an EQC, it was required to be set aside by the developer as part of development approval. Since its initiation, tens of thousands of acres have been set aside through the EQC program. The cost of implementing the program is part of the operating budget of the county planning department.

Howard County, Maryland, developed a Land Preservation and Recreation Plan as part of the county comprehensive plan. Under this plan, open space resources are purchased for preservation and recreation. The annual cost to update the plan, $25,000 (in 1991 dollars), is funded by the state. In FY 1990, the county received $1.14 million in state funds to update the plan and acquire land (Jenkins, 1991).

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3.3.3 Implement the Plan

Once critical areas have been identified, land use designations have been defined, and goals have been established to guide activities in the watershed, implementation strategies can be developed. At this point, the requirements of future development are defined. These requirements include, but are not limited to, permitted uses, construction techniques, and protective maintenance measures. Land development regulations may also prescribe natural performance standards, such as "rates of runoff or soil loss should be no greater than predevelopment conditions."

A useful planning tool is the Long-Term Hydrologic Impact Assessment (L-THIA), which was developed by Purdue University (2000) for land use planners to provide site-specific estimates of changes in runoff, recharge, and nonpoint source pollution resulting from past or proposed land use changes. The model uses regional climate data and user-provided location, land use, and soil group data for up to three different scenarios (past, present, and future). The results are in the form of tables, bar charts, and pie charts. The model is available at http://danpatch.ecn.purdue.edu/~sprawl/LTHIA7.

Listed below are examples of the types of development regulations and other implementation tools that have been successful at controlling nonpoint source pollution.

3.3.3.1 Develop ordinances or regulations requiring nonpoint source pollution controls for new development and redevelopment

These ordinances or regulations should address, at a minimum:

- Control of off-site urban runoff discharges (to control potential impacts of flooding);
- The use of source control BMPs and treatment BMPs;
- The performance expectations of BMPs, specifying design storm size, frequency, and minimum removal effectiveness, as specified by the state or local government;
- The protection of stream channels, natural drainageways, and wetlands;
- Erosion and sediment control requirements for new construction and redevelopment; and
- Treatment BMP operation and maintenance requirements and designation of responsible parties.

3.3.3.2 Plan infrastructure

Infrastructure planning is the multiyear scheduling and implementation of infrastructure improvements, such as roads, sewers, potable water delivery, landfills, public transportation, and urban runoff management facilities. Infrastructure planning can be an effective practice to help guide development patterns away from areas that provide water quality benefits, are susceptible to erosion, or are sensitive to disturbance or pollutant loadings. Where possible, long-term comprehensive plans to prevent the conversion of these areas to more intensive land uses should be drafted and adopted. Infrastructure should be planned for and sited in areas that have the capacity to sustain environmentally sound development. Development tends to occur in response to infrastructure availability, both existing and planned. New development should be targeted for areas that have adequate infrastructure to support growth in order to promote infill development,

prevent urban sprawl, and discourage the use of septic tanks where they are inappropriate (International City/County Management Association, 1979). Infill development may have the added advantage of municipal cost savings.

To discourage development in the environmentally sensitive East Everglades area, Dade County, Florida, has developed an urban services boundary (USB). In areas outside the USB, the county will not provide infrastructure and has kept land use densities very low. This strategy was selected to prevent urban sprawl, protect the Everglades wetlands (outside of Everglades National Park), and minimize the costs of providing services countywide. The area is defined in the county comprehensive plan, and restrictions have been implemented through the land development regulations (Metro-Dade Planning Department, 1988).

Congress has enacted similar legislation for the protection of coastal barrier islands. In 1981, the availability of federal flood insurance for new construction on barrier islands was discontinued. In 1982, Congress passed the Coastal Barriers Resources Act, establishing the Coastal Barrier Resource System (CBRS), and terminated a variety of federal assistance programs for designated coastal barriers, including grants for new water, sewage, and transportation systems. In 1988, similar legislation was passed for the Great Lakes area, adding 112 Great Lakes barrier islands. Additions to the CBRS in 1990 included parts of the Florida Keys, the U.S. Virgin Islands, Puerto Rico, and the Great Lakes (Simmons, 1991).

The result of the legislation and subsequent additions to the CBRS has been the establishment of approximately 1,326,000 acres of barriers that are ineligible for federal assistance for infrastructure and flood insurance (U.S. Fish and Wildlife Service (USFWS), 2002). This act has helped to guide development away from these sensitive coastal areas to more suitable locations. USFWS (2002) estimates that more than a billion dollars may be saved between 1983 and 2010 due to reduction of disaster relief and infrastructure construction costs.

3.3.3.3 Revise local zoning ordinances

Zoning is the division of a municipality or county into districts for the purpose of regulating land use. Usually defined on a map, the allowable uses within each zone are described in an official document, such as a zoning ordinance. Zoning is enacted for a variety of reasons, including preservation of areas that are environmentally sensitive or necessary to maintain environmental integrity (International City/County Management Association, 1979).

Within zoning ordinances, subdivision regulations govern the process by which individual lots are created out of larger tracts of land. Subdivision regulations are intended to ensure that subdivisions are appropriately related to their surroundings. General site design standards, such as preservation of environmentally sensitive areas, are one example of subdivision regulations (International City/County Management Association, 1979).

There are specific types of zoning ordinances that can be particularly useful in protecting water resources, including performance-based zoning, overlay zones, bonus or incentive zoning, large-lot zoning, agricultural protection zoning, watershed-based zoning, and urban growth boundaries. The following provides an overview of each of these types of zoning:

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3.3.3.3.1 Performance-based zoning

In performance-based zoning, developers are allowed flexibility in planning and designing the development as long as they meet minimum requirements set by the local government. These minimum requirements vary based on the particular resource protection objectives of the community but might include limiting the amount of impervious surfaces or preserving sensitive features such as wetlands or steep slopes with high erosion potential. Developers can choose lot sizes, building types, site layouts, and other development characteristics as long as they meet the minimum criteria. Performance-based zoning offers protection of natural resources for the community and increased flexibility for the developer. It requires greater effort on the part of the local government, however, to carefully tailor the language of the ordinance to ensure that resources are adequately protected, and to carefully review development proposals to ensure that performance criteria are met.

Officials in Columbia, Missouri, were interested in developing a uniform policy to deal with storm water pollution (Tritto, 2000). This effort was initiated in response to a recent back-and-forth battle between a developer and the Columbia City Council. Officials are reviewing a report developed by Missouri University researchers that evaluated the environmental sensitivity of 13 watersheds in the Columbia area using 12 criteria focused on human health and environmental protection. The report recommended limits on the percentage of impervious surfaces for developments based on categories of watershed sensitivity. Developers would be allowed to exceed these limits only by taking additional steps to control storm water pollution through the use of management practices. The approach recommended in the report would provide a financial incentive for developers to direct high-density developments to less-sensitive watersheds because tougher standards on impervious areas and the costs of storm water controls would make it more expensive to develop in environmentally sensitive watersheds. City officials are also reviewing storm water management policies in other cities to develop uniform guidelines so that developers are better-informed about what is expected of them.

3.3.3.3.2 Overlay zones

Overlay zones superimpose additional restrictions on existing zoning categories to provide extra protection for a particular natural resource. For example, if a wetland or endangered species habitat crosses the boundaries of several development zones, an overlay zone can be established to limit development in areas that affect the wetland. Overlay zones can also be used to limit development in areas with highly permeable soils to protect an underground drinking water source from contamination. The overlay zones would maintain the general land use category, such as residential or commercial, but would require additional protection, such as greater limits on impervious area or special vegetation protection requirements.

3.3.3.3.3 Bonus or incentive zoning

Bonus or incentive zoning is another method to allow developers greater flexibility in return for preservation of open space and sensitive or environmentally significant features. With incentive zoning, a developer might be allowed to develop at a higher density than normally allowed if in return he or she preserves additional open space, creates a wetland, or reduces the site's overall impervious area with underground parking, transportation modifications, or innovative site layouts. The success of bonus or incentive zoning is highly dependent on an individual developer's perception of the economic benefits of additional density credits; therefore, this type

of zoning cannot be relied upon to protect natural resources. However, bonus or incentive zoning can encourage voluntary and economically beneficial protection for open space and sensitive features.

3.3.3.3.4 Large-lot zoning

Large-lot zoning establishes a very low density of development; individual dwellings are built on lots of 5 acres or more. Large-lot zoning is most effective when lots are very large (5 to 20 acres) (Caraco et al., 1998). The purpose of large-lot zoning is to spread development thinly, thereby conserving a large proportion of open space on each lot and reducing impacts on water resources. This method can produce undesirable results, however, including

- Promoting sprawl;
- Fragmenting habitats with more extensive infrastructure and lawns;
- Increasing reliance on automobile transportation; and
- Excluding lower-income residents who cannot afford to purchase large parcels of land.

One approach to minimizing the negative impacts of large-lot zoning is to combine it with cluster zoning. In this way, a large area of open space can be protected, while accommodating new development in a more concentrated manner. Although used in many areas, large-lot zoning is not considered to be any more protective than other zoning tools.

3.3.3.3.5 Farmland preservation zoning

Farmland preservation ordinances are another type of measure to provide open space retention, habitat protection, and watershed protection. Farmland protection may be a less-costly means of controlling pollutant loadings than the implementation of urban runoff structural control practices. Much of the farmland currently being converted has soils that are stable and not highly erodible. Conversion of these farmlands often displaces farming activities to less-productive, more-erodible areas that may require increased nutrient and pesticide applications.

Many communities consider both agriculture and forestry to be an integral part of rural heritage and strive to preserve these industries and the open space associated with them. According to the 1997 National Resources Inventory, nearly 16 million acres of forest, cropland, and open space were converted to urban and other uses from 1992 to 1997. The average rate for those five years—3.2 million acres per year—is more than twice the conversion rate of 1.4 million acres per year recorded from 1982 to 1992 (USDA-NRCS, 2000).

Agricultural lands can be protected by implementing a modified large-lot zoning ordinance that makes residential development less economically attractive. Alternatively, a cluster development ordinance can be established that specifies a density for an agricultural development and also requires that dwellings be built on small lots, leaving the remainder of the site as agricultural open space. The ordinance can also specify that development must occur on the least-productive part of the lot so the richest soils can be reserved for cultivation.

Agricultural zoning ordinances can be combined with other initiatives to promote farming and forestry and to protect rural areas from being overtaken by urban sprawl (Sims, 2000b). The King County, Washington, executive official has undertaken several initiatives to promote diversity in lifestyle choices, encourage the continuation of farming and forestry, protect

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environmental quality and wildlife habitat, and maintain a link to the county's heritage by preserving rural areas. So far the county has reduced its development rate in rural areas from 15 percent in 1980 to 6 percent at present. The target is to further reduce the development rate to 4 percent. The county issued orders to close loopholes in subdivision and land segregation regulations, and it tightened subdivision requirements for rural lands. These efforts will ensure that new development is consistent with current environmental and development standards.

The county's initiatives include maintaining an agricultural district as an "unincorporated urban area" to permanently protect this area from development pressures, establishing the Puget Sound Fresh program to promote locally grown and produced products, establishing a Farm Link program to connect farmers with land to sell or lease with those wishing to farm, and providing improved services for rural community centers. The county also established a Rural Forest Commission to encourage forestry and maintain the forest land base in the county's rural areas. The county implemented a Farmlands Preservation Program, which has preserved 12,793 acres of agricultural lands through purchase or donation of development rights. Additionally, the county is able to preserve hundreds more acres of rural land each year through incentive-based taxation programs. Finally, King County's 2000 Comprehensive Plan includes the following goals and initiatives:

- Ensure that zoning complies with goals to reduce the rate of growth and protect the environment;
- Ensure that the types and scale of development in the rural area blend with traditional rural development;
- Implement recommendations from the forest commission to bolster King County's forest and farming economies; and
- Consider alternative uses of agricultural land, such as for wetland mitigation or recreation, such that these uses will not harm the integrity of agriculture in the county.

More information about King County's growth management initiatives can be found on the SmartGrowth Rural Legacy Web site at http://www.metrokc.gov/smartgrowth/rural.htm.

3.3.3.3.6 Watershed-based zoning

Historically, zoning has been used to establish limits on building density and to separate uses believed to be inherently incompatible (Arendt, 1997). Watershed-based zoning, in contrast, uses watershed and subwatershed boundaries as the basis for making land use decisions. Typically, zoning objectives focus on maintaining or reducing impervious cover in sensitive subwatersheds and redirecting development to subwatersheds that are better able to absorb their influence (Caraco et al., 1998).

Local, state, and federal officials recently approved the Riverside County (California) Plan, which involved multi-agency cooperation in identifying where development may occur and where land should be preserved (Verden, 2000). Over the next 50 years, the Riverside County Plan will serve as a blueprint for building new roads, shopping centers, and homes, while also preserving rapidly disappearing habitat. The plan is designed to avoid costly delays and confrontations between regulators and developers. With the population of Riverside County

expected to double in 20 years, the plan will help developers accommodate growth while it also protects rare plants and animals. State and federal land, transportation, and wildlife managers hope the Riverside County Plan will be a model for other communities struggling to balance development and preservation.

In 1992 Maryland enacted the Economic Growth, Resource Protection, and Planning Act to organize and direct comprehensive planning, regulating, and funding by state, county, and municipal governments in furtherance of a specific economic growth and resource protection policy (Maryland Department of Planning, no date). The policy is organized around seven statutory vision statements that must be pursued in county and municipal comprehensive plans where priorities for land use, economic growth, and resource protection are established. The seven statutory vision statements are:

- Development is concentrated in suitable areas.
- Sensitive areas are protected.
- In rural areas, growth is directed to existing population centers and resource areas are protected.
- Stewardship of the Chesapeake Bay and the land is a universal ethic.
- Conservation of resources, including a reduction in resource consumption, is practiced.
- To assure the achievement of the above, economic growth is encouraged and regulatory mechanisms are streamlined.
- Funding mechanisms are addressed to achieve these visions.

The visions must also be followed by the state in undertaking its various programs. Both state and local funding decisions on public construction projects must adhere to the visions. The Act also established an Economic Growth, Resource Protection, and Planning Commission to oversee, study, and report on progress towards implementation of the visions. More information about the act can be found at http://www.mdp.state.md.us/planningact.htm.

3.3.3.3.7 Urban growth boundaries

Urban growth boundaries are lines drawn around metropolitan areas to delineate where urban development can take place (inside the boundary) and where it may not (outside the boundary). Outside of urban growth boundaries, land use is restricted to agriculture, forestry, and open space (Nelson and Moore, 1993). The boundaries encourage more compact (i.e., infill) development, control urban sprawl, and help protect rural heritage. The approval process for new development can be streamlined within the growth boundary to further encourage development in these areas.

The duration or lifespan of growth boundaries is normally related to planning periods or cycles, typically 10 to 20 years. Boundaries should be examined at regular planning intervals, however, to assess whether conditions have changed since they were established.

Establishing the location of urban growth boundaries sometimes requires complex decision-making. Officials should be reasonably sure that there is sufficient land within the boundary to meet projected growth over the planning period and that public facilities and services can be

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provided at reasonable cost in a timely fashion. The potential impact of growth within the boundary on existing natural resources also needs to be determined. In the context of watershed planning, it is advantageous to use watershed boundaries or other natural features as urban growth boundaries. In this manner, key or sensitive watersheds can be protected from the impacts of development.

In Arizona, the 1998 Growing Smarter Act and its 2000 addendum, Growing Smarter Plus, were signed into law by Governor Jane Hull (Morrison, 2000). This legislation addresses the issue of development by strengthening the ability of communities in Arizona to plan for growth and to acquire and preserve open space. The Growing Smarter legislation requires communities to address growth and growth-related pressures by mandating general plans that identify growth areas, establish policies and strategies for new growth, identify open space needs, regionally plan for interconnected open space, and analyze the environmental impacts of the development anticipated by the general plan (City of Tucson, no date).

3.3.3.4 Establish limits on impervious surfaces, encourage open space, and promote cluster development

As described earlier, urban runoff contains high concentrations of pollutants washed off impervious surfaces (roadways, parking lots, loading docks, etc.). By retaining the greatest area of pervious surface and maximizing open space, nonpoint source pollution due to runoff from impervious surfaces can be kept to a minimum. Refer to section 4.3.2 for a detailed discussion of site design practices to reduce impervious surfaces in new developments.

The following are examples of successful implementation of open space requirements and cluster development:

- Brunswick, Maine, recently adopted an allowable impervious area threshold of 5 percent of any site to be developed in the defined coastal protection zone. The remaining 95 percent is required to be left natural or landscaped. The threshold was developed and adopted using a $28,000 grant.

- Virginia provides general guidance with regard to minimum open space and maximum impervious areas to local governments within the Chesapeake Bay watershed. While specific requirements are not associated with the guidance, local plans are required to contain criteria and must be approved by the Chesapeake Bay Local Assistance Board.

- Carroll County, Maryland, is a community with substantial farmland and open space. Because it is located close to both Baltimore and Washington, DC, the county amended its zoning ordinance to encourage cluster development and preserve open space. This and land protection efforts by Carroll County have resulted in protection of 33,000 acres by agricultural easements (Maryland Environmental Trust Land Conservation Center, 2002).

- Maryland adopted the Forest Conservation Act of 1991, which requires all public agencies and private landowners submitting a subdivision plan or application for a sediment control permit for an area greater than 40,000 square feet to develop a plan for retention of existing forest cover on-site. The act allows clearing that is essential to site

development, and it established a forest conservation fund for reforestation projects. In the first five years of implementation, the Forest Conservation Act has produced 22,508 acres of retained forest and 4,313 planted acres, while 12,210 acres of existing forest have been cleared (Honeczy, 2000).

- Broward County, Florida, has an open space program and encourages cluster development to reduce impervious surface area, protect water quality, and enhance aquifer recharge (Broward County, Florida, 1990).

- New Hampshire has a model shoreland protection ordinance that encourages grouping of residential units, provided a minimum of 50 percent of the total parcel remains as open space.

One way to increase open space while allowing reasonable development of land is to encourage cluster development. Clustering entails decreasing the allowable lot size while maintaining the number of allowable units on a site. Such policies provide planners the flexibility to site buildings on more suitable areas of the property and leave environmentally sensitive areas, such as wetlands or steep slopes, undeveloped. Criteria can vary. Advantages of cluster development include:

- Reducing the costs of infrastructure;
- Preserving sensitive areas;
- Increasing property values with proximity to open space; and
- Preserving ecological, aesthetic, and recreational values.

Planned unit development is a type of zoning that encourages the use of cluster development but does not require it. For example, a set number of units could be spread across the site under typical residential zoning, but under cluster zoning, the same number of units could be concentrated on smaller lots on only a portion of the site, preserving the other portion for common open space to protect sensitive features or for use as a recreation area.

3.3.3.5 Revitalize existing developed areas

Redeveloping existing areas can alleviate water quality impacts by reducing the strain of development on open space land and minimizing the amount of impervious surface added to the watershed. Existing impervious surfaces, such as declining shopping malls and retail centers, can provide large tracts of developable land and are a prime opportunity for mixed-use infill development. For additional discussion of options for revitalizing urban areas, see Management Measure 10—Existing Development.

3.3.3.6 Establish setback (buffer zone) standards

In coastal areas, setbacks or buffer zones adjacent to surface water bodies, such as rivers, estuaries, or wetlands, provide a transition between upland development and these water bodies. The use of setbacks or buffer zones may prevent direct flow of urban runoff from impervious areas into adjoining surface waters and provide pollutant removal, sediment attenuation, and infiltration. Riparian forest buffers function as filters to remove sediment and attached pollutants,

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as transformers that alter the chemical composition of compounds, as sinks that store nutrients for an extended period of time, and as a source of energy for aquatic life (USEPA, 1992). Setbacks or buffer zones are commonly used to protect coastal vegetation and wildlife corridors, reduce exposure to flood hazards, and protect surface waters by reducing and cleansing urban runoff (Mantel et al., 1990). The types of development allowed in these areas are usually limited to non-habitable structures and those necessary to allow reasonable use of the property, such as docks and unenclosed gazebos.

Factors for delineating setbacks and buffer zones vary with location and environment and include:

- Seasonal water levels;
- Nature and extent of wetlands and floodplains;
- Steepness of adjacent topography;
- Type of riparian vegetation;
- Quantity and velocity of runoff entering the buffer;
- Soil types and infiltration capacity;
- Density of development adjacent to the riparian corridor; and
- Wildlife values.

It is important that sheet flow, not concentrated flow, be directed to the buffer. High-velocity runoff from steeply sloped or highly impervious areas can promote excessive erosion and decreased pollutant removal. A flat, grassy area or a level spreader can be installed at the upland part of the buffer to slow the velocity of runoff and promote sheet flow. It is also important to consider that the pollutant removal capacity of a buffer is finite and can be exceeded in areas with high concentrations of pollutants in runoff.

Buffer width is an important measure of pollutant removal effectiveness. Buffers typically range from 20 to 200 feet wide and should include the 100-year floodplain, riparian areas including adjacent wetlands, steep slopes, or critical habitat areas (Schueler, 1995). A buffer at least 100 feet wide is recommended for water quality protection, and a 300-foot buffer is recommended to maintain a wildlife habitat corridor. Wider buffers offer increased detention times, infiltration rates, and diversity of soil, vegetation, and wildlife.

According to Herson-Jones et al. (1995), forested buffers achieve 50 percent TSS removal; 23 to 96 percent phosphorus removal depending on the extent of TSS removal; greater than 40 percent lead removal; more than 60 percent copper, zinc, aluminum, and iron removal; and more than 70 percent oil and grease removal.

Overall, aquatic buffers are highly effective at removing particulate pollutants, but less effective in removing soluble pollutants (such as nitrogen, for which documented removal rates range from -15 to 99 percent). Proper siting and design and regular maintenance enhance removal efficiency.

In general, EPA recommends that no habitat-disturbing activities should occur within tidal or non-tidal wetlands. In addition, a buffer area should be adequate to protect the identified wetland values. Minimum widths for buffers should be 50 feet for low-order headwater streams, with

expansion to as much as 200 feet or more for larger streams. In coastal areas, a 100-foot minimum buffer of natural vegetation landward from the mean high tide line helps to remove or reduce sediment, nutrients, and toxic substances entering surface waters.

3.3.3.6.1 Buffer ordinance

Buffer ordinances provide guidelines for buffer creation and maintenance. They should include the following provisions:

- Buffer boundaries to be clearly marked on local planning maps;
- Maintenance language that restricts vegetation and soil disturbance;
- Tables that illustrate buffer width adjustment by percent slope and type of stream; and
- Direction on allowable uses and public education.

A model ordinance and examples of buffer ordinances from across the country can be found at http://www.epa.gov/owow/nps/ordinance. Buffer ordinances and other water resource-related ordinances are also described in section 1.3.1.2.

The following are examples of setback or buffer requirements:

- Town commissioners in Apex and Cary, North Carolina, have agreed to set wider buffers between development and streams (Price, 2000). Under the new ordinance, buffers must be at least 50 feet wide along intermittent streams and must average 100 feet wide along perennial streams. The towns chose to use an average rather than a strict 100-foot minimum to allow landowners flexibility. In addition to the buffer ordinance, Apex and Cary halved the limit of impervious surfaces on a given tract of land over which retention ponds are required to control runoff (from 24 percent to 12 percent). Town officials will hold a public hearing to vote on the new regulations.

- Monroe County, Florida, requires a setback of 20 feet from high water on man-made or lawfully altered shorelines for all enclosed structures and 50 feet from the landward extent of mangroves or mean high tide line for natural water bodies with unaltered shorelines (Monroe County, Florida, Code, Section 9.5-286).

- Brunswick, Maine requires a buffer of 125 to 300 feet from mean high water within the Coastal Protection Zone (Section 315 of the Brunswick Zoning Ordinance), depending on the slope of the buffer, as designated on the town's land use map.

- Queen Anne's County, Maryland, established a standard shore buffer of 300 feet from the edge of tidal water or wetland, 50 percent of which must be forested.

- Maryland’s Critical Area Act requires the establishment of a minimum buffer of 100 feet of natural vegetation landward from the mean high-water line of tidal waters or the edge of tidal wetlands and tributary streams. Unless a property owner can demonstrate unwarranted hardship and prove no negative impact to water quality, plant, fish or wildlife habitat, the local jurisdiction will not permit disturbance or new development within the buffer except for access or water-dependent facilities. Any clearing that occurs for access or water-dependent facilities must be mitigated through a buffer management

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plan approved by the local jurisdiction (Critical Area Commission for the Chesapeake and Atlantic Coastal Bays, no date).

3.3.3.6.2 Vegetative and use strategies within management zones

Buffers can be divided into three zones—the streamside, middle, and upland zones (Herson-Jones et al., 1995). Dense vegetation in the streamside zone (recommended to be approximately 25 feet wide) prevents excessive activity in this sensitive area, maintains the physical integrity of the stream, and provides shade, litter, debris, and erosion protection. The width of a grassed or mostly forested middle zone (minimum of 50 feet) depends on the size of the stream and its floodplain and the location of protected areas such as wetlands or steep slopes. The upland zone, typically 25 feet wide, is an additional setback from the buffer and usually consists of lawn or turf. Zones in the buffer should be delineated to determine the types of vegetation that should be maintained or established.

Allowable land uses in the three zones vary. The streamside zone is limited to footpaths, runoff channels, and utility or roadway crossings. The middle zone may be used for recreation and runoff control practices. The upland zone may be used for many purposes, with the exception of septic systems, permanent structures, or impervious covers. A depression incorporated into the design of the upland zone can detain runoff during storms. This runoff is released slowly to the middle zone as sheet flow, which is then transferred to the dense streamside zone, designed to have minimal to no discharge of surface water to the stream.

3.3.3.6.3 Provisions for buffer crossings

Stream crossings should minimize impacts on buffer integrity while providing crossing points for linear forms of development such as roads, bridges, golf course fairways, underground utilities, enclosed storm drains, and outfall channels (Schueler, 1995). They should also be designed to provide fish passage and to withstand overbank flows from the 100-year storm event. Design considerations for buffer crossings include: minimizing the width of the crossing; orienting the crossing at a right angle to the stream; limiting the total number of crossings; ensuring that outfalls discharge at the invert elevation of the stream channel; and burying utility crossings at least 3 feet below the channel's invert elevation. An outfall should not be placed directly in the main channel. Energy-dissipating devices can be installed in outfalls to protect the streambed and adjacent banks.

3.3.3.6.4 Integration of structural runoff management practices where appropriate

Depressions can be incorporated into the upland part of a stream buffer to provide runoff detention during storms and to promote sheet flow over the middle zone of the buffer. A flat, grassed area or level spreader can also be used in the upland part of the buffer to create sheet flow and to promote infiltration over the rest of the buffer.

Storm water ponds and wetlands can be located inside or outside the buffer. According to Schueler (1995), ponds inside the buffer should be used only for runoff quantity control. Although ponds in the buffer treat the greatest possible drainage area, are more likely to maintain their water level during dry periods, provide a diversity of aquatic habitats, and can increase the total width of the buffer, they displace vegetation and might cause barriers to fish migration, modification of existing wetlands, and stream warming.

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3.3.3.6.5 Development of buffer education and awareness programs

Buffer education efforts should foster community awareness and encourage stewardship. These objectives can be met by posting signs along the buffer boundaries that describe allowable activities in different parts of the buffer. Buffer owners can be educated by distributing pamphlets, hosting stream walks, and holding meetings. New owners should be made aware of buffer limits and allowable uses when the property is transferred. Buffer stewardship can be encouraged through reforestation and "bufferscaping" programs. Annual inspections can be done with "buffer walks" to determine the extent of encroachment, devegetation, erosion, or excessive sediment deposition.

3.3.3.7 Establish slope restrictions

Slope restrictions can be effective tools to control erosion and sediment transport. Erosion rates depend on several site-specific factors including soil type, vegetative cover, and rainfall intensity. In general, as slope increases, there is a corresponding increase in runoff water velocity, which may result in increased erosion and sediment transport to surface waters (Dunn and Leopold, 1978).

3.3.3.8 Promote urban forestry

Urban forestry is an effective tool for protecting watersheds because it can provide some of the storm water management required in urban areas. Trees decrease runoff by intercepting rain and promoting infiltration. This reduces the peak runoff flow and the total runoff volume that communities must manage, which can be financially beneficial to communities that have to build and maintain sewer and drainage systems (ENN, 2001). Also, trees provide shade, which lowers the temperature of urban heat islands and runoff. Erosion and leaf litter in forested areas can contribute sediment and nutrients to receiving waters; therefore, an effort should be made to establish and maintain stable vegetation and to keep leaf litter on-site.

Several organizations dedicated to promoting urban forestry can provide information and other resources to interested groups or individuals. For example, American Forests (http://www.americanforests.org) is a conservation organization that is working to improve the environment with trees and forests. The organization's Urban Forest Center offers tools to measure the environmental benefits of trees, such as pollution reduction and storm water management. These tools include the Regional Ecosystem Analysis (REA) and CITYgreen software packages. REA uses a combination of satellite data, field surveys, CITYgreen software, and other GIS technology to measure a region's or city's tree canopy and calculate its dollar value. CITYgreen allows users to compare the economic benefits of various planning scenarios by testing landscape ordinances, evaluating site plans, and modeling development scenarios that capture the benefits of trees. An application of this tool in Fayetteville, Arkansas, found that increasing the city's tree cover from 27 to 40 percent could result in cost savings from runoff reduction of up to $135 million (NALGEP, 2003). Information about the software is available at http://www.americanforests.org/productsandpubs/citygreen/.

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TreePeople is another forestry organization. It works with the U.S. Forest Service and has enlisted the help of thousands of students and volunteers to plant seedlings in the mountains around Southern California. Its mission is to inspire people to take responsibility for improving their immediate environment. Information about TreePeople is available at http://www.treepeople.org/.

Houston's Urban Forests

American Forests conducted a study of a 3.2 million-acre area in Houston to document urban forest cover (ENN, 2001). They also analyzed 25 individual sites with aerial photography using CITYgreen to map and measure tree cover and to calculate the benefits of Houston's trees. Study results show that trees provide significant benefits in storm water runoff reduction, energy savings, and pollutant removal. The study found that Houston's tree cover reduces the need for storm water management by 2.4 billion cubic feet per peak storm event, saving $1.33 billion in one-time construction costs. As a result, American Forests made the following recommendations to the city of Houston:

- Improve green infrastructure by using tree cover data in land-use planning; growth management; and all transportation, public works, and development decision-making.
- Encourage the use of increased tree cover to met storm water needs.
- Work to increase tree cover in the metropolitan area.

3.3.3.9 Use site plan reviews and approval

A site plan review involves review of specific development proposals for consistency with the laws and regulations of the local government of jurisdiction. Potential development sites should be inspected to ensure that natural resources necessary for protecting surface water quality are preserved. Inspection ensures that the information presented in any application for development is accurate and that sensitive areas are noted for preservation. Inspections should also be conducted during and after development to ensure compliance with development conditions. Depending on the size of the local government and the amount of new development, this inspection could be incorporated into the duties of existing staff at minimal additional cost to the local government, or the inspection could require the addition of staff to conduct onsite inspections and monitoring. The effectiveness of such a program depends on the ability of the inspectors to evaluate property for its natural resource value and the practices used to protect areas necessary for the preservation of water quality.

Development approvals should contain conditions requiring maintenance of the area's environmental integrity and prevention of degradation from nonpoint source pollution, consistent with the goals, objectives, and policies of the comprehensive program and the requirements of the land development regulations. The criteria for new development are outlined as part of a development permit. Examples include the following:

– Areas for preservation or mitigation may be identified, similar to the Fairfax County Environmental Quality Corridor System (see section 3.3.2).

- The use of nonstructural and structural management practices described in this chapter for controlling nonpoint source pollution may be a condition of development approval.

- Setbacks and limits on impervious areas may be clearly defined in a condition for development approval, as is being done in the programs discussed above.

- Reduction in the use of pesticides and fertilizers on landscaped areas by encouraging the use of vegetation that is adaptable to the environment and requires minimal maintenance. (Xeriscaping techniques are described in Management Measure 4 and lawn and garden activities are described in Management Measure 9.)

3.3.3.10 Designate an entity or individual responsible for maintaining the infrastructure, including urban runoff management systems

The responsible party should be trained in the maintenance and management of urban runoff management systems. If desired, the local government could be designated to maintain urban runoff systems, with financial compensation from the developer. Because they are not usually trained in infrastructure maintenance, homeowners groups are not the best entity for monitoring infrastructure for adequacy, especially urban runoff management systems. This responsibility should belong to a responsible party that understands the complexity of urban runoff management systems, can determine when such systems are not functioning properly, and has the resources to correct the problem. Again, this is a duty that the local government can assume, with either existing staff or additional staff, depending on the size of the local government and the amount of new development occurring. The amount of funding needed depends on the size of the local government.

3.3.3.11 Use official mapping

Official maps can be used to designate and/or protect environmentally sensitive areas, zoning districts, identified land uses, or other areas that provide water quality benefits. When approved by the local governing body, these maps can be used as legal instruments to make land use decisions related to nonpoint source pollution.

3.3.3.12 Require environmental impact assessment statements

To evaluate the impact that proposed development may have on the natural resources of an area, some counties and municipalities require an environmental assessment as part of the development approval processes. These assessments can be incorporated into the land development regulation process. Areas to be covered include geology, slopes, vegetation, historical features, wildlife, and infrastructure needs (International City/County Management Association, 1979).

3.3.4 Cost of Planning Programs

The cost of planning programs depends on a variety of factors, including the level of effort needed to complete and implement a program. Many of the practices described in this section can be incorporated into ongoing activities of a state or local government.

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The Florida legislature funded the development of comprehensive programs and land development regulations required by the Local Government Comprehensive Planning and Land Development Regulation Act (1985). Distribution of funds was based on population according to formulas used for determining funding for the plan and land development regulations. A base amount was given to all counties that requested it. The balance of the monies was allocated to each county in an amount proportionate to its share of the total unincorporated population of all the counties. A similar distribution process was used for local governments. A total of $2.1 million was allocated for plan development; however, not all components of the plans address nonpoint source issues.

The effect of planning programs depends on many variables, including implementation of programs and monitoring of conformance with conditions of development approval.

3.3.5 Land or Development Rights Acquisition Practices

An effective way to preserve land necessary for protecting the environmental integrity of an area is to acquire it outright or to limit development rights. Land conservation includes more than simply preserving land in its current state. It also means taking responsibility for restoration of areas of the property that might already have been affected by urban runoff. Stewardship activities for land conservation might include:

- Resource monitoring
- General maintenance
- Control of exotic species
- Installation of structural runoff management practices

A government agency or a nonprofit organization, such as a land trust, often has a greater capacity to take on the responsibility of stewardship than do private owners. Consequently, many of the practices discussed below focus on how conservation lands, or at least property rights to those lands, can be transferred to such entities. In many instances, however, private owners successfully accomplish stewardship without any formal or binding relationship with a public or private conservation agency or organization.

Several organizations provide educational materials and training to help landowners learn to manage conservation areas for the benefit of water quality, wildlife, and other purposes. For example, the Land Trust Alliance, an organization that "promotes voluntary land conservation and strengthens the land trust movement by providing the leadership, information, skills, and resources land trusts need to conserve land for the benefit of communities and natural systems," has compiled a list of links to local land trust organizations. This list can be accessed at http://www.lta.org/resources/links (Land Trust Alliance, 2001). Other information on land conservation policy, news, success stories, training opportunities, and technical guidance is provided on the Land Trust Alliance's Web site at http://www.lta.org.

Additionally, The Conservation Fund Web site, at http://www.conservationfund.org, provides information on land acquisition, community initiatives, leadership training, and sustainable conservation solutions emphasizing the integration of economic and environmental goals.

Another resource is the Natural Lands Trust whose Web site, at http://www.natlands.org, provides information and resources pertaining to land preservation and land use planning.

The practices described below can be used to protect beneficial uses.

3.3.5.1 Fee simple acquisition/conservation easements

The most direct way to protect land for preservation purposes and associated nonpoint source control functions is fee simple acquisition, through either purchase or donation. Once a suitable area is identified for preservation, the area may be acquired along with the development rights. The more development rights that are associated with a piece of property, the more expensive it will be. Many state and local governments and private organizations have programs for purchasing land.

Conservation easements are legal restrictions on the present and future use of land. For preservation purposes, the easement holder, who is usually not the owner of the property, is able to control the rights of the property when the landowner might adversely impact resources on the property. In effect, the property owner gives up development rights within the easement while retaining fee ownership of the property (Mantel et al., 1990; Barrett and Livermore, 1983). The agreement between the easement holder and property owner is permanent, legally enforceable, and not subject to alteration unless permission is received in writing by the easement holder and all other cosigners (Arendt, 1997).

A conservation easement is a flexible tool that can be customized to set different levels of restrictions among different types of conservation areas in a parcel. In addition to protecting and maintaining environmental benefits in perpetuity, landowners who donate conservation easements to a government agency or nonprofit group typically realize substantial income, property, and estate tax benefits resulting from the charitable donations. Their property value might be lowered, however, because the development rights were removed. Consequently, tax and estate planning professionals need to be consulted when a conservation easement is being contemplated.

As an alternative, agricultural and forestry easements are specific types of conservation easements that allow continued use of land as farms or forests and prevent the land from being sold for commercial or residential development. The USDA Natural Resource Conservation Service currently manages the Farm and Ranch Lands Protection Program (FRPP), a voluntary program that provides matching funds to state, tribal, or local governments and non-governmental organizations with existing farm and ranch land protection programs to purchase conservation easements. FRPP is reauthorized in the Farm Security and Rural Investment Act of 2002, also known as the Farm Bill (NRCS, 2003).

3.3.5.2 Leases, deed restrictions, and covenants

Even though government agencies, land trusts, and other nonprofit organizations would prefer that conservation lands be acquired by donation or that conservation easements be placed on the property, some lands hold so much value as conservation areas that leasing is worth the expense and effort. Leasing a property allows the agency, trust, or organization to actively manage the land for conservation.

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Deed restrictions are included in deeds for the purpose of constraining use of the land. In theory, deed restrictions are designed to perform functions similar to those of conservation easements. In practice, however, deed restrictions have proven to be much weaker substitutes because unlike conservation easements, they do not necessarily designate or convey oversight responsibilities to a particular agency or organization to enforce protection and maintenance provisions. Also, deed restrictions can be relatively easy to modify or vacate through litigation. Modifying or nullifying an easement is difficult, especially if tax benefits have already been realized. For these reasons, conservation easements are generally preferred over deed restrictions.

A covenant is similar to a deed restriction in that it restricts activities on a property, but it is in the form of a contract between the landowner and another party. The term *mutual covenants* is used to describe a situation where one or more nearby or adjacent landowners are contracted and covered by the same restrictions.

3.3.5.3 Transfer of development rights

The principle of transfer of development rights (TDR) is based on the concept that ownership of real property includes the ownership of a bundle of rights that goes with it. These rights may include densities granted by a certain use designation, environmental permits, zoning approvals, and others. Certain properties have a bigger bundle of rights than others, depending on what approvals have been received by the owner. The TDR system takes all or some of the rights on one piece of property and moves them to another parcel. The purpose of TDRs is to shift future development potential from an area that is determined to be unsuitable for development (sending site) to an area deemed more suitable (receiving site). The development potential can be measured in a variety of ways, including number of dwelling units, square footage, acres, or number of parking spaces. Most TDR systems require a legal restriction for future development on the sending site. TDR programs can be either fixed so that there are only a certain number of sending and receiving sites in an area, or flexible so that a sender and receiver can be matched as the situation allows (Mantel et al., 1990; Barrett and Livermore, 1983).

This system is useful for the preservation of those areas considered necessary for maintaining the quality of surface waters, in that development rights associated with the environmentally sensitive areas can be transferred to less-sensitive areas. There are several examples of TDR use in the United States. The more successful projects include preservation of the New Jersey Pine Barrens and the Santa Monica Mountains in California. For the TDR concept to work, receiving and sending sites should be identified and evaluated, a simple, flexible program should be developed, and the use of the program should be promoted and facilitated (Mantel et al., 1990).

In contrast to a conventional down-zoning approach, which withholds from landowners the value associated with the right to develop, TDR systems allow a landowner to be compensated for that value by developing at another site.

Most TDR systems require a legal restriction to ensure that future development will not occur on the “sending” site. Also, TDR programs can be fixed so that there are only a certain number of sending and receiving sites in an area, or they can be flexible so that a sender and receiver can be matched as the situation allows. The following are general steps for setting up a TDR program (Redman/Johnston Associates, 1997):

- *Provide education and outreach*. The public should be familiar with the overall objectives of the program. Landowners and developers also need to be educated on how they will be affected.

- *Conduct an analysis of market conditions*. A successful program requires a market for TDR transfers.

- *Identify and designate TDR "receiving areas."* Receiving areas should be capable of supporting growth. Factors include adequate land area, infrastructure, public services, and consideration of environmental constraints.

- *Identify and designate TDR "sending areas."* Sending areas should support preservation and protection goals. Specific areas should be delineated to the parcel level.

- *Determine the nature of program*. Programs can be voluntary or mandatory. If mandatory, sending areas should be down-zoned to control growth.

- *Determine development potential and allocate TDRs*. Compute current allowable densities in both receiving and sending areas, and then allocate TDRs from sending areas based on desired densities. For example, down-zoning from a yield of 1 lot per 5 acres to 1 lot per 25 acres equates to 4 TDRs.

- *Consider a TDR Bank*. A TDR bank buys, holds, and sells TDRs. The bank can be either a government organization or a quasi-governmental entity.

Transfer of Development Credits Pilot Program, King County, Washington

King County, Washington's Transfer of Development Credits (TDC) Pilot Program is a voluntary initiative that allows residential densities to be transferred from rural areas to urban areas better suited to absorb additional density (King County Office of Regional Policy and Planning, 2001). The following provisions were made:

- A $1.5 million TDC bank was established to purchase and sell density credits.

- $500,000 was appropriated for urban amenities to improve neighborhoods that will receive increased density.

- An extensive outreach effort has been launched to inform stakeholders about the program and identify potential receiving sites.

- The Rural Forest Commission has reviewed and approved sending site criteria to be used by the TDC bank.

The first successful TDC was finalized in 2000 (Sims, 2000a). Forest land totaling 313 acres was protected from development. The density credits were transferred to a developer to add 500,000 square feet of commercial space in the nearby city of Issaquah.

More information about this TDC is presented at ww.metrokc.gov/exec/news/2000/032800.htm. More information about the King County TDC Pilot Program can be obtained from the program's Web site at http://www.metrokc.gov/exec/orpp/tdc or by contacting Mark Sollitto at 206-205-0705.

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– *Provide adequate resources*. A TDR program does not run itself. It needs staff and resources to administer and manage the program.

3.3.5.4 Purchase of development rights

In this process, the rights of development are purchased while the remaining rights remain with the fee title holder. Restrictions in the deed make it clear that the land cannot be developed based on the rights that have been purchased (Mantel et al., 1990).

Howard County, Maryland, has the goal of preserving 20,000 acres of farmland. Development rights are acquired in perpetuity with ¼th of 1 percent of the local land transfer tax used as funding. There is no cap on the percentage of assessed value that may be considered development value, and payment for development rights may be spread over 30 years to ease the capital gains tax burden on the landowner (Jenkins, 1991).

3.3.5.5 Land trusts

Land trusts may be established as publicly or privately sponsored nonprofit organizations with the goal of holding lands or conservation easements for the protection of habitat, water quality, recreation, or scenic value, or for agricultural preservation. A land trust may also pre-acquire properties that are conservation priorities if it enters the development market when government funds are not immediately available by securing bank funding with the government as guarantor (Jenkins, 1991).

3.3.5.6 Agricultural and forest districts

Agricultural or forest districting is an alternative to acquisition of land or development rights. Jurisdictions may choose to allow landowners to apply for designation of land as an agricultural or forest district. Tax benefits are received in exchange for a commitment to maintain the land in agriculture, forest, or open space.

Fairfax County, Virginia, taxes land designated as an agricultural or forest district based on the present use valuation rather than the usual potential use valuation. A commitment to agricultural or forestry activities must be shown, and sound land management practices must be used. The districts are established and renewed for eight-year periods (Jenkins, 1991).

3.3.5.7 Cost and effectiveness of land acquisition programs

The costs associated with land acquisition programs vary depending on the desired outcome. If land is to be purchased, the cost depend on the value of the land. An additional cost to be considered is the maintenance of the property once it is in public ownership. Easements and development rights are less expensive, and maintenance responsibility is retained by the owner. Depending on the size of the local government, implementation of these programs is usually part of the operating budget of the appropriate agency (planning department or parks and recreation department, for example).

The effectiveness of a land acquisition program is determined by the size of the parcel and the difference between predevelopment and potential postdevelopment pollutant loading rates. In

addition, wetlands and riparian areas have been shown to reduce pollutant loadings. The acquisition and preservation of these areas can be extremely important to water quality protection and decrease the cost of implementing structural BMPs. However, the use of wetlands for urban runoff treatment, in general, should be discouraged. Where no other alternative exists, states and local governments can target upland areas for acquisition to minimize the impacts to and preserve the function of wetlands. One option for acquiring land is a public/private partnership. For example, Harford County, Maryland, has targeted areas for purchase of conservation easements. The county staff is working jointly with a local land trust to acquire conservation easements and to educate people in environmentally sound land-use practices. The estimated cost for the program is $60,000 per year (Jenkins, 1991). To aid in the establishment of two local land trusts, Anne Arundel County, Maryland, provided $350,000 in seed money for capital expenditures such as land and easement procurement. The county also gives staff assistance to volunteers; additional support comes from contributions of money or land, grants, and fundraisers (Jenkins 1991).

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3.4 Information Resources

The Center for Watershed Protection's *Rapid Watershed Planning Handbook*, published in 1998, describes techniques communities can use to more effectively protect and restore water resources. This document is available for purchase from the Center for Watershed Protection's Web site (http://www.cwp.org).

The Chesapeake Bay Program's (1997) *Protecting Wetlands: Tools for Local Governments in the Chesapeake Bay Region* is available from the Chesapeake Bay Program's Web site at http://www.chesapeakebay.net.

The Conservation Fund's Web site, located at http://www.conservationfund.org, provides information on land acquisition, community initiatives, leadership training, and sustainable conservation solutions emphasizing the integration of economic and environmental goals.

Correll's (2000) Web site, entitled *Vegetated Stream Riparian Zones: Their Effects on Stream Nutrients, Sediments, and Toxic Substances*, presents an annotated and indexed bibliography of buffer strip literature. See http://www.unl.edu/nac/ripzone03.htm.

Eco-Compass (Island Press, 2000) is an information resource for urban sprawl issues. Developed by Island Press, Eco-Compass is an Internet guide to a wide range of environmental information, including ecosystems, communities, global change, and economics. The urban sprawl feature of Eco-Compass provides a summary of the major issues relating to sprawl as well as an examination of the lessons that can be learned from Atlanta, a city that has experienced tremendous growth in the past decade. The site also includes links to more than 50 of the best sprawl-related Web sites and publications. More information about Eco-Compass is available at http://www.islandpress.org/.

The Natural Lands Trust's 1997 publication, *Growing Greener: Putting Conservation into Local Codes,* is available from Natural Land Trust, 1031 Palmers Mill Road, Media, PA 19063; telephone 610-353-5587; e-mail planning@natlands.org. Other information and resources pertaining to land preservation and land use planning can be found at the Natural Lands Trust's Web site at http://www.natlands.org.

Schueler's (1995) manual, *Site Planning for Urban Stream Protection*, is available for download from the Center for Watershed Protection's Web site at http://www.cwp.org/SPSP/TOC.htm.

Based on the Local Government Commission's research of more than 150 "smart growth" zoning codes from across the nation, *Smart Growth Zoning Codes: A Resource Guide* will help planners design a zoning code that encourages the construction of walkable, mixed use neighborhoods and the revitalization of existing places. Each chapter analyzes a critical issue, such as design, streets, and parking, and highlights exemplary codes from across the country. The guidebook comes with a CD-ROM that contains copies of some of the best zoning codes in the United States and other resources. The guide is available for purchase ($25) from the LGC bookstore at http://www2.lgc.org/bookstore/detail.cfm?itemId=34.

The Smart Growth Network is a nationwide effort coordinated by EPA's Urban and Economic Development Division (International City/County Management Association, 2000). Through cooperative partnerships with a diverse network of organizations, EPA is working to encourage development that better serves the economic, environmental, and social needs of communities. The network provides a forum for information sharing, education, tool development and application, and collaboration on smart growth issues. Smart growth approaches focus on flexible zoning, preventive planning, intelligent management of natural resources and water quality, and implementation of treatment and control technologies at multiple scales from development sites to watershed planning. For more information about the Smart Growth Network, visit http://www.smartgrowth.org or contact ICMA—Smart Growth Network, 777 North Capitol St., NE, Suite 500, Washington, DC 20002-4201; telephone 202-962-3591; e-mail nsimon@icma.org.

The Mid-America Regional Council (MARC) initiated a project to raise awareness of the relationship between land development and transportation systems. In *Principles of Transit Supportive Development*, MARC (no date) presents alternative approaches to land development that encourage a more sustainable and balanced transportation system. The organization promotes community designs that enable citizens to walk, bike, ride transit, and drive from home to shops, schools, and services. For more information about the potential of transit supportive development, contact MARC at 816-474-4240 or visit their Web site at http://www.marc.org/transportation.

The Local Government Commission (http://www.lgc.org) is a nonprofit organization that provides peer networking opportunities, acts as an interface between city and county officials, and provides practical policy ideas for addressing serious environmental and social problems. The commission provides guidelines and resources for communities to improve their design, transportation, economic development, environment, energy, and waste prevention. A list of publications can be found at http://www2.lgc.org/bookstore/list.cfm?categoryId=1.

The Northeastern Illinois Planning Commission published *Model Stream and Wetland Protection Ordinance for the Creation of a Lowland Conservancy Overlay District: A Guide for Local Officials*, which can be ordered from its Web site at http://www.nipc.org/pubs-services/.

The National Association of Conservation Districts' Web site (http://www.nacdnet.org) contains a list of conservation districts across the country as well as conservation resources for districts, educators, and the public.

In July 2001 the National Governors' Association Center for Best Practices published *New Community Design to the Rescue: Fulfilling Another American Dream* (Hirschhorn and Souza, 2001), which provides alternatives to sprawl through "new community design." The book includes a checklist for local governments to evaluate communities and development projects for consistency with smart growth principles and provides examples of infill, suburban redevelopment, and greenfields projects that have successfully incorporated new community design principles. Innovative policies and actions taken by states to encourage new community design are also included. This publication can be purchased at the National Governors' Association Web site at http://www.nga.org or downloaded in PDF format at http://www.nga.org/cda/files/072001NCDFull.pdf.

"Protecting Water Resources with Smart Growth" is intended for audiences such as communities, local governments, state and regional planners already familiar with smart growth who are now seeking additional ideas on how to protect their water resources. The document is a compilation of 75 policies designed to protect water resources and implement smart growth. The majority of these policies (46) are oriented to the watershed, or regional level; the other 29 are targeted for specific development sites. The document is available for download in PDF format at http://www.epa.gov/smartgrowth/water_resource.htm.

Getting to Smart Growth: 100 Policies for Implementation was produced by the Smart Growth Network. The document highlights and describes techniques to help policymakers put smart growth principles into practice. The policies and guidelines, which have proven successful in communities across the U.S., range from formal legislative or regulatory efforts to informal approaches, plans, and programs. The primer describes 10 smart growth principles, specific policies for each principle, illustrations of their application in a community, and additional resources to aid communities in implementation. The document is available online in PDF format at http://www.smartgrowth.org/pdf/gettosg.pdf.

The concept of creating and maintaining an interconnected network of protected land and water, called "Green Infrastructure," is presented at http://www.greeninfrastructure.net. Green Infrastructure supports native species, maintains natural ecological processes, sustains air and water resources, and contributes to health and quality of life. This Web site, developed by The Conservation Fund with support from USDA Cooperative Forestry, contains information to aid in implementing a comprehensive conservation program and includes resources such as searchable profiles, training information, events, and references databases.

The Southeast Michigan Council of Governments (SEMCOG) published *Opportunities for Water Resource Protection in Local Plans, Ordinances and Programs: A Workbook for Local Governments*, which is a guide for local communities to protect water resources. The workbook provides checklists that guide users through the process of establishing a water resource protection program. It covers a wide range of topics, including land conservation, erosion and sediment control, public education, and pollution prevention. For each of these topics, case studies and checklists guide users through basic tools available for master planning, regulatory controls, and design standards. The document can be downloaded from http://www.semcog.org or ordered by calling 313-961-4266.

EPA's Green Communities Program encourages successful community-based environmental protection and sustainable community development. The Green Communities Assistance Kit provides technical assistance and training for planning green communities. Information about the Green Communities Program can be found at http://www.epa.gov/greenkit.

Other useful EPA publications:

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MANAGEMENT MEASURE 4
SITE DEVELOPMENT

4.1 Management Measure

Plan, design, and develop sites to:

- Maintain predevelopment site hydrology by using site design techniques that store, infiltrate, evaporate, or detain runoff;
- Protect areas that provide important water quality benefits or are particularly susceptible to erosion and sediment loss;
- Limit effective impervious area[a] by design and the use of management practices;
- Limit land disturbance activities, such as clearing and grading and cut-and-fill, to reduce erosion, sediment loss, and soil compaction; and
- Preserve natural drainage features and vegetation to the extent possible.

4.2 Management Measure Description and Selection

4.2.1 Description

The goals of this management measure are to reduce the generation of nonpoint source pollution, maintain predevelopment hydrology, and mitigate the impacts of urban runoff and associated pollutants from all site development, including activities associated with roads, highways, and bridges. Included in this section are management practices that can be applied during the site planning and review process to ensure that nonpoint source pollution and increases in the volume and rate of runoff are appropriately managed before, during, and after construction.

Although the goals of Management Measure 3 (watershed protection) are similar, this measure is intended to apply to individual sites at the catchment level (see Figure 1.3) rather than larger watersheds or regional drainage basins. The site development and watershed protection management measures are intended to complement each other and be used together within a comprehensive framework to control runoff and reduce nonpoint source pollution.

[a] Effective impervious area is the portion of total impervious cover that is directly connected to the storm drain network (Sutherland, 1995). These surfaces usually include street surfaces and paved driveways and sidewalks connected to or immediately adjacent to them, parking lots, and rooftops that are hydraulically connected to the drainage network (e.g., downspouts run directly to gutters or driveways).

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Programs designed to control increased runoff and nonpoint source pollution resulting from site development should include:

- Predevelopment planning and review processes to ensure watershed/subwatershed and site-level natural resource and performance goals are achieved;
- Guidance on assessing and designing sites to maintain predevelopment site hydrology;
- Appropriate pollution prevention practices to be incorporated into site development and use.
- Site plan review and conditional approval processes to ensure the preservation of environmentally sensitive areas and areas necessary for maintaining natural hydrology and water quality; and
- Requirements for erosion and sediment control plan review and approval prior to issuance of appropriate development permits.

In addition to the preceding provisions, the following objectives should be incorporated into the site development process:

- During site development, disturb only the smallest area necessary to perform current activities to reduce erosion and off-site transport of sediment.
- Avoid disturbance of unstable soils or soils particularly susceptible to erosion and sediment loss.
- Favor sites where development will conserve natural drainage areas and sensitive environmental features, and minimize erosion, sediment loss, and soil compaction.
- Revegetate the site as soon as possible after disturbance, preferably with native vegetation.
- Protect and retain existing vegetation to decrease concentrated flows, maintain site hydrology, and control erosion.
- Minimize imperviousness to the extent practicable.
- Develop and implement inspection and maintenance procedures to ensure that landscapes are maintained to avoid water quality impacts.
- Use natural hydrology as a design element, and avoid alteration, modification, or destruction of natural drainage features.
- Design sites to preserve vegetated or natural buffers adjacent to receiving waters.

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- Reforest areas within the same watershed in proportion to the acreage cleared of trees.
- Use porous pavements for areas of infrequent use (see section 5.3.2.3 in Management Measure 5).

The use of site planning and evaluation can significantly reduce the size of controls required to retain runoff and sediment on-site. Long-term maintenance burdens can also be reduced. Good site planning can attenuate runoff from development and can improve the effectiveness of the conveyance and treatment components of an urban runoff management system (Anacostia Restoration Team, 1992).

4.2.2 Management Measure Selection

This management measure was selected because the practices associated with it have been shown to be effective in protecting natural drainage features, reducing runoff quantity, and improving runoff quality. Site evaluation and protection of features that promote infiltration, filtration, and on-site detention will protect receiving water quality, maintain baseflow in receiving waters, and prevent or reduce further degradation of stream channels. Development in and around urban areas is inevitable as population growth puts pressure on suburbs and rural areas. This management measure recommends standards for new development that reduce environmental damage caused by development.

4.3 Management Practices

Many of the management practices in this section are considered "better site design techniques," planning techniques that are intended to be used to guide the layout of new developments to reduce the total effective impervious area, conserve natural habitats, and better distribute and infiltrate runoff. All aspects of an individual site, including soil types, slopes, and the location of environmentally sensitive features such as wetlands, forests, and meadows, should be examined to identify areas that should be preserved or restored. Better site design techniques can be used to identify the most efficient building and infrastructure layouts. It can also be used to develop a comprehensive strategy to reduce the quantity of runoff leaving the site and minimize the amount of pollutants generated on-site.

There are many advantages to better site design. Environmentally friendly site designs are more likely to be accepted by local governments and the community, thereby speeding plan approval. Site designs that preserve community open space also reduce the burden on the local government to provide recreational areas. In addition, better site design techniques reduce the amount and cost of infrastructure, which also in turn reduce engineering and maintenance costs. For example, runoff storage requirements for a low-impact development neighborhood in Pierce County, Washington, were reduced by more than 75 percent and the cost was 20 percent less than for conventional designs. These cost savings resulted primarily from the reduced size of runoff detention structures and the elimination of catch basins and pipes (Zickler, 2002).

Low-impact development practices can provide substantial benefits in terms of reducing the occurrence of combined sewer overflows (CSOs). Temporarily storing runoff in urban areas can greatly reduce the peak flow into storm water systems and provide a cost-effective way to

mitigate basement flooding and CSOs (USEPA, 1999). Two communities in Indiana successfully implemented street surface storage of runoff to reduce the occurrence of CSOs in a cost effective manner while also reducing peak flows to wastewater treatment plants. The distributed storage controls also offered some water quality benefits by temporarily detaining runoff during storms (USEPA, 1999).

From a marketing perspective, studies have shown that lots abutting forested or other open space are initially valued higher than lots with no adjacent open space, and over time they appreciate more than lots in conventional subdivisions (Arendt, 1996). For example, lots in an open space subdivision in Amherst, Massachusetts, experienced a 13 percent greater appreciation in value compared to a conventional development after 20 years, even though the lots in the conventional development were twice as large (Arendt, 1996).

From a quality-of-life standpoint, site designs that incorporate pedestrian paths and common open space foster a greater sense of community among residents. House lots are closer together, encouraging communication among neighbors. Additionally, common open space provides recreational opportunities that further encourage community interaction.

Finally, better site design offers environmental benefits, including protection of ecologically significant natural resources, reduction of runoff, and preservation of open space and wildlife habitat. Maintaining open space also increases the opportunity for alternative sewage and wastewater disposal and treatment practices such as land treatment, spray irrigation, and reclamation and reuse. In addition, the flexibility of better site design allows designers to site these wastewater treatment systems in the areas of the development best suited for them.

Overall, the practices presented in this management measure provide many advantages over conventional developments and can be implemented in most communities. In some cases, however, outdated development rules can discourage or prohibit some of these practices. Watershed managers should review the local building codes and regulations that govern new developments to determine whether better site design techniques are allowed or encouraged and work with the appropriate authorities to remove these impediments.

The second edition of the Bay Area Stormwater Management Agencies Association's *Start at the Source*, which was originally published in 1997, is an excellent resource on site design issues for watershed managers. This publication emphasizes the importance of considering runoff quality in the early stages of land planning and design. The new edition has been updated and expanded to include commercial, industrial, and institutional development, as well as a technical section that provides more detailed information on the characteristics, applications, design criteria, maintenance, and economics of the practices discussed in the document. More information about ordering this publication when it becomes available is provided on the Bay Area Stormwater Management Agencies Association's Web site at http://www.basmaa.org/ (BASMAA, no date).

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Pembroke Woods Subdivision, Emmittsburg, Maryland

Pembroke Woods is a 43-acre low impact development residential subdivision that the designers hail as the first subdivision designed and under construction using the *Low-Impact Development Design Strategies: An Integrated Design Approach* manual developed by Prince George's County, Maryland (2000a). The designers have identified significant cost savings for this development compared to the traditional development plan created in the 1990s. These include

- Eliminating the need for 2 storm water management ponds that had been envisioned in a prior concept plan for the site, yielding construction cost savings of $200,000.
- In place of those 2 storm water management ponds, 2.5 acres of undisturbed open space and wetlands were conserved, with cost savings realized in eliminating wetland mitigation costs.
- An additional 2 lots were created by revising the site plan, increasing the site yield from 68 to 70 lots and adding $90,000 to the project value.
- Approximately 3,000 linear feet of roads were converted from urban road to rural road, replacing curb & gutter with grass bioswales, yielding a savings of $60,000 in construction costs. Also, reducing the road with from 36 feet to 30 feet in the rural road section of the development reduced paving costs by 17 percent.

A brief project overview and contact information can be found at http://www.buckeyedevelopment.net/lowimpactdevelopment.htm.

4.3.1 Site Planning Practices

4.3.1.1 Select site designs that preserve or minimize impacts to predevelopment site hydrology and topography

Retaining the existing topography of a development site assists in maintaining natural drainage features and depressional storage areas that help infiltrate and attenuate flows and filter pollutants. Depressional storage areas, commonly found as ponded areas after storms or during the wet season, aid in reducing runoff volumes and trapping pollutants. To help preserve natural drainage, a developer can (Goldman et al., 1986):

- Construct buildings and parking areas on existing flat terrain;
- Locate buildings and roads along existing contours;
- Orient long buildings with the major portion parallel to contours;
- Stagger floor levels to adjust to gradient changes; and
- Fit the development to the topography.

4.3.1.2 Protect environmentally sensitive areas

Sites should be developed to avoid destroying wetlands, seeps, bogs, fens, springs, surface water bodies, and catchment areas that are important for sustaining the hydrology of the land. In addition, riparian buffers, both forested and covered with grasses, should be preserved to protect

surface water bodies. Steep slopes and highly erodible areas need to be protected to avoid landslides and soil movement into water bodies.

The increase in storm water runoff that results from urban development can dramatically impact the ecology of wetlands and other areas by altering characteristics of hydrology, water quality, and soil (USEPA, 1996). Urban development can also result in ecological changes due to fragmentation and habitat destruction. If the development of a site changes runoff characteristics, measures should be taken to prevent negative impacts to wetlands and other features. For example, Pohlig Builders of Malvern, Pennsylvania, incorporated measures to protect wetlands into its building plan after homeowners opposed the construction of seven high-end homes adjacent to a wetland area. Pohlig designed a vegetative filter strip to buffer runoff from the homes and provide treatment before runoff reached the wetlands. The filter strip was designed to eventually grow into a wooded area to enhance aesthetics and benefit water quality. A level spreader was added to convert concentrated runoff to sheet flow that can be more effectively treated, and extra erosion and sediment control measures were used during construction. The total additional cost of these measures was $30,000 (NAHB, 2003).

4.3.1.3 Practice site fingerprinting

The total amount of disturbed area in a site can be reduced by "fingerprinting" development, i.e., placing development in the most environmentally sound locations on the site and minimizing the size of the disturbed area and ultimate development footprint. Fingerprinting places development away from environmentally sensitive areas (wetlands, steep slopes, etc.), future open spaces and restoration areas, areas with trees to be saved, and temporary and permanent vegetative forest buffer zones. At a subdivision or lot level, ground disturbance is confined to areas where structures, roads, and rights-of-way will exist after construction is complete. Other site-level fingerprinting practices include reducing paving and compaction of highly permeable soils, minimizing the size of construction easements and material storage areas, minimizing impervious areas in the site design, clearly demarcating the disturbance area, maintaining existing topography and drainage divide, and disconnecting impervious areas (Prince George's County, Maryland, Department of Environmental Resources, 2000a).

4.3.1.4 Use cluster development

Cluster development is used to concentrate development and construction activity on a limited portion of a site, leaving the remainder undisturbed. Figures 4.1 and 4.2 show schematics of a residential cluster development and a rural cluster development. Clustering allows the design of more effective urban runoff management systems and reduces overall site-level erosion and sediment impacts. It also provides a mechanism to preserve environmentally sensitive areas and reduce infrastructure such as wastewater treatment systems, roads, sidewalks, and parking areas.

In addition to its environmental benefits, clustering can result in cost savings for municipalities because clustering and infill development typically require less new infrastructure, such as urban runoff treatment systems. The imposition of density controls may preclude clustering. Although minimum lot size requirements are useful in some instances, such as farmland preservation (see

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Management Measure 3), zoning ordinances should not preclude the implementation of clustered development as an alternative to conventional suburban development.

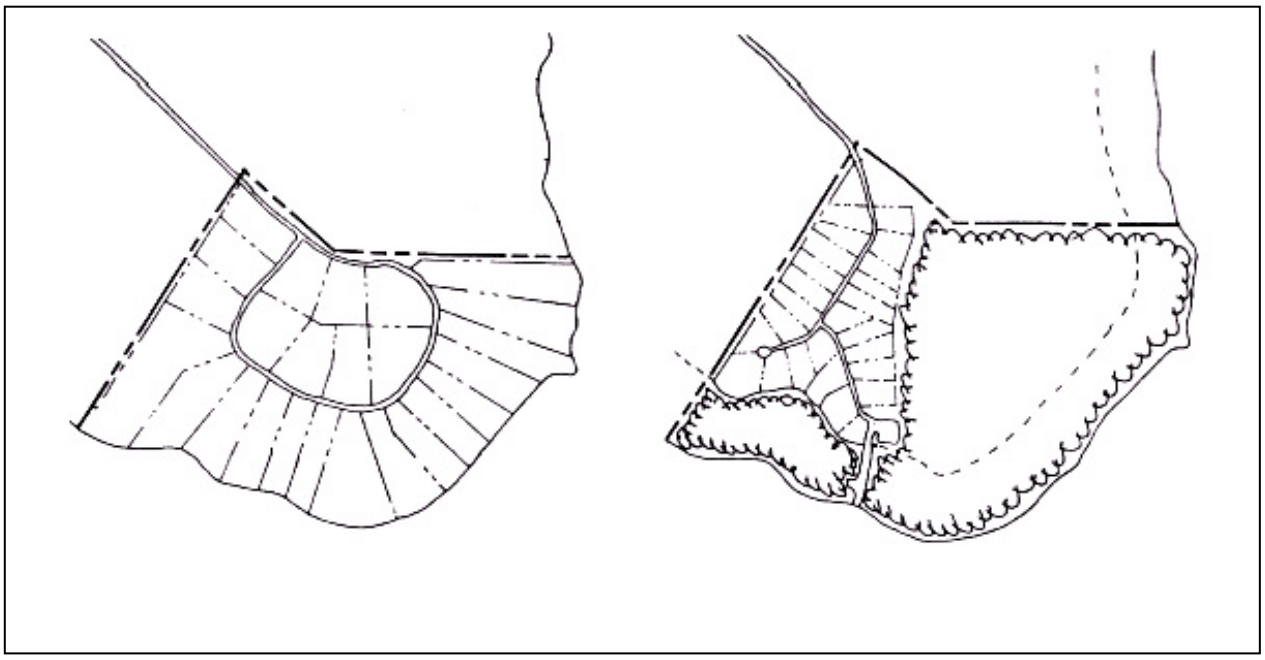

Figure 4.1: Schematic of a residential cluster development (Schueler, 1995).

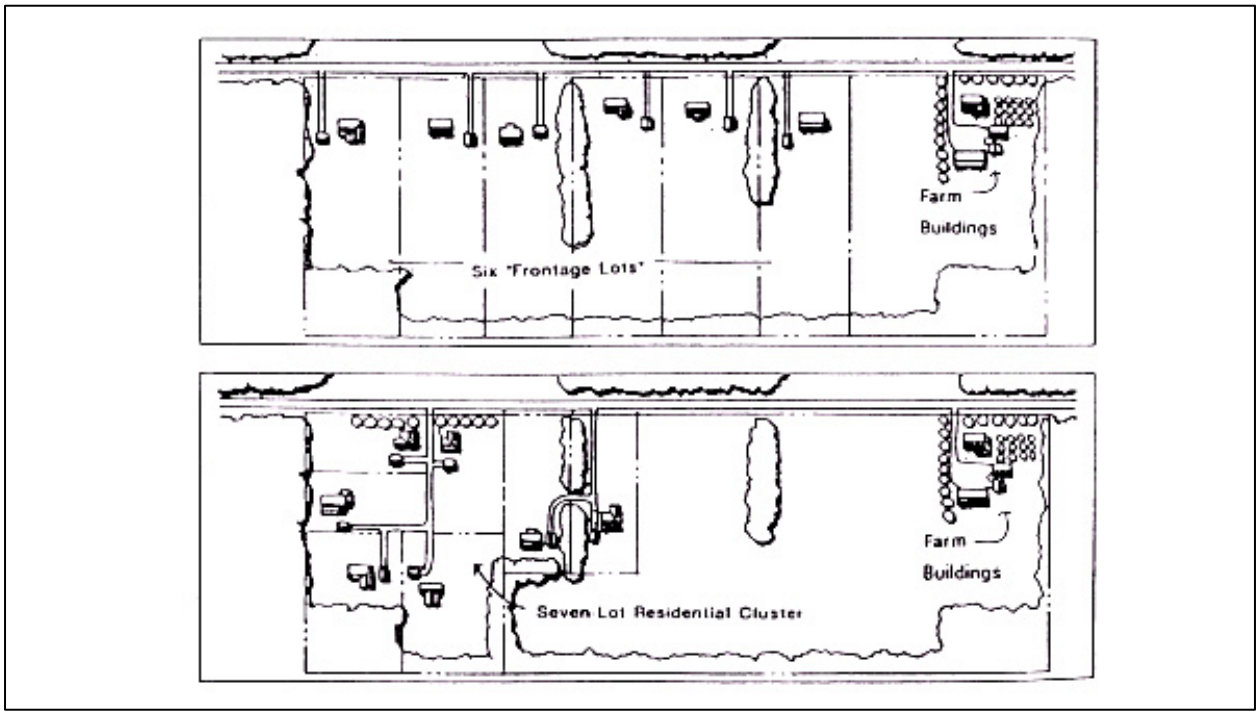

Figure 4.2: Schematic of a rural cluster development (Schueler, 1995).

4.3.1.5 Create open space

Open space development is a technique that concentrates development on one area of a site in exchange for open space in another area. Benefits associated with open space design include:

- A 40- to 60-percent reduction in impervious cover compared to conventional development designs;
- Increased property values;
- Reduced construction and development costs;
- Common recreational facilities (i.e., pedestrian paths, picnic areas, and athletic fields);
- Reduced infrastructure;
- Improved quality of life; and
- The use of community onsite/decentralized systems (see Nutrient Export case study below).

The following are some techniques for conserving open space:

- *By-right open space development*. This technique allows increased density on one portion of a site in exchange for open space on another portion. A large percentage of this open space can be dedicated as conservation land. To encourage open space development, municipalities can draft ordinances so that this is a "by-right" option, as opposed to a special exception or variance.
- *Density compensation*. This technique allows developers to increase housing density to offset potential housing lots lost to on-site buffers or other conservation lands.
- *Storm water credits*. Credit is given for implementation of source controls that reduce runoff volumes and pollutant concentrations before the remaining runoff reaches structural controls. Because performance is typically measured by comparing influent runoff to effluent runoff, storm water credits benefit operators of structural controls because credit for pollutant removal occurs before treatment.
- *Property tax credit*. The property tax credit is a technique for reducing, deferring, or exempting property taxes on conservation land. Typically, conservation easements are exchanged for the property tax credit.
- *Density bonus*. This bonus allows developers to increase density above base zoning density in exchange for conserving natural areas.
- *Off-site mitigation*. This term refers to the restoration or creation of wetlands in a designated off-site area if on-site wetlands are adversely affected and on-site mitigation is not feasible.

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Randall Arendt (1996), in his book, *Conservation Design for Subdivisions: A Practical Guide for Creating Open Space Networks*, presents a plain-language, illustrated guide for designing open space subdivisions. This publication is available from Natural Lands Trust, Inc., 1031 Palmers Mill Road, Media, PA 19063; phone 610-353-5587. The following topics are covered:

- Open space vs. conventional developments;
- Economic, social, and environmental benefits of open space designs;
- Roles and responsibilities of stakeholders in site development;
- A stepwise approach to designing an open space subdivision (discussed below);
- Ideas for creating an interconnected open space network;
- Seven case studies;
- Methods to modify existing regulations to encourage open space design;
- Management techniques for conservation lands;
- Sample house plans for open space subdivisions;
- Sample advertisements for developers to capitalize on open space design benefits; and
- Model ordinance provisions.

Arendt's multi-step process for creating conservation subdivisions involves two stages. The first, called the background stage, involves identifying the characteristics of the surrounding landscape and existing development and analyzing and delineating significant features of the site. The second stage involves integrating the site's feature information into a map and prioritizing conservation lands based on the features deemed most important, while maintaining the quantity of land necessary to develop the site to the desired density.

The background stage involves examining the surrounding landscape and existing development to identify conservation areas. It includes the following practices:

(1) *Understanding the locational context*. The layout of new development should consider proximity to traditional small towns or villages; if existing development is nearby, the design of the new community should reflect and extend the historical streetscape and pattern. In rural areas located away from existing development, informal, irregular, "organic" layouts can be used successfully without detracting from the surrounding landscape.

(2) *Mapping natural, cultural, and historic features.* A thorough analysis of a site's special features that may enhance or constrain development is an important step in planning a new development. Special features might already have been identified in a natural resources inventory conducted by local government or land trust organizations. The site analysis should include site visits and identify the conservation areas described in this section.

The following conservation areas are legally or logistically unbuildable and therefore must be avoided:

- *Wetlands*. Tidal and non-tidal saltwater and freshwater wetlands and the dry upland buffers surrounding them should be identified as areas to be conserved because they filter runoff, provide critical habitat at the land-water interface, and offer opportunities for recreation and environmental education. Soil survey maps, National

Wetlands Inventory maps, state or environmental agency wetland maps, or on-site delineations can be used to determine the extent of wetland habitat on the site.

- *Floodplains*. The 100-year floodplain, which can be determined from floodplain maps published by the Federal Emergency Management Agency (FEMA) (see Management Measure 2), should be left undeveloped to preserve a continuous riparian greenway and to prevent damage to property from flooding. To preserve views of the water on wooded sites, lower tree limbs can be removed. (This may be a reasonable alternative to developing closer to the water's edge.) Zoning requirements might dictate an additional 50- to 100-foot setback from the 100-year floodplain.

- *Slopes*. Slopes of more than 25 percent should not be developed because of their high potential for erosion. Slopes between 15 and 20 percent can be developed using special site planning but should be avoided when possible. Slope maps can be prepared from USGS topographic maps by an engineer, planner, or landscape architect, but site visits should confirm these conditions.

The following conservation areas typically are legally buildable but are historically or ecologically significant or desirable, and therefore they should be avoided when other land is available for development.

- *Soils*. Soil surveys, whether they are based on existing maps produced by NRCS or data gleaned from on-site testing, identify well-drained soils suitable for treating wastewater, poorly drained soils that might result in leaky basements or wetland conditions, and steep or stony soils that would be difficult to build on. Existing soil survey data might not be detailed enough to characterize site conditions, depending on the spatial variability of soil types in the region. High-intensity soil surveys and site surveys that are accurate to 0.1 acre should be used in highly variable circumstances.

- *Significant wildlife habitats*. Habitat for threatened or endangered wildlife, including travel corridors to food sources, homes, and breeding grounds, should be conserved. An additional buffer of open space is recommended. These habitat locations might have been officially documented already by state or local agencies. Habitat for wildlife species that are not threatened or endangered should also be considered for conservation areas where possible. Continuity in habitat areas is important; land that connects two isolated habitat areas provides a valuable corridor that extends the usable habitat for the species of concern.

- *Woodlands*. Woodlands often provide valuable wildlife habitat and contribute to the aesthetic value of a property. Where areas are mostly forested and clearing is required for site development, however, areas of mature forest or areas with unique species composition should be of higher conservation priority. In areas where woodland is not the predominant land use, as much of the existing tree cover as possible should be conserved on the property. An effort should be made to maintain corridors that connect forested areas to provide as much continuous forested habitat as possible.

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- *Farmland*. Agricultural lands can be conserved as open space if desired, although relatively small fields might not be lucrative and could pose a more significant water quality risk compared to residential development due to specific land management practices (tilling, fertilizer application) associated with agriculture. Another option for agricultural fields is to let them succeed to a more natural meadow state with grasses, wildflowers, and shrubs that could provide habitat for many birds and small mammals.

- *Historic, archaeological, and cultural features*. Areas with historic significance can be identified from official lists such as the National Register of Historic Places and state and local inventories of historic and cultural resources. Landowners and local historians should also be consulted for detailed information about a site's history. Although historic areas are not always protected from demolition, if other areas of the property are equally suitable for development, historic resources should be preserved.

- *Views into and out from the site*. Development should be designed to blend well with the surrounding landscape. Because developers typically want to site buildings to take advantage of attractive views, they often build in areas where structures are highly visible. Siting buildings away from the pinnacles of ridges and hills, designing buildings with lower profiles, and preserving or planting trees to shield buildings from view are all techniques that can be used to reduce the visual impact of development on the landscape. Views can be created by cutting a limited number of trees to create "view tunnels," or trimming lower limbs to create "view holes" through the foliage.

- *Aquifers and their recharge areas.* An aquifer recharge area is where water moves downward to the water table. In other words, recharge areas replenish groundwater. Unconfined aquifers are not covered by a layer of impermeable rock and are open to receive water from the land surface. Unconfined aquifers are typically recharged in topographically high areas or through sandy or gravelly soils. These areas should be conserved as open space to maintain ground water recharge. They should also be buffered with vegetation to filter solids and associated pollutants from runoff.

After background information has been obtained, the next step is to integrate the information and prioritize conservation areas. Typically, all of the features mentioned above are drawn onto overlay sheets or entered into a geographic information system (GIS). Once the significant features are shown together, areas most suitable for development become obvious. Where some conservation areas need to be sacrificed to achieve the development objectives, decisions must be made regarding ranking the conservation areas based on how special, unique, irreplaceable, environmentally valuable, historic, or scenic they are. Figure 4.3 shows an example site before development, developed with a conventional strategy, and developed with consideration of locational context and conservation areas (Arendt, 1996).

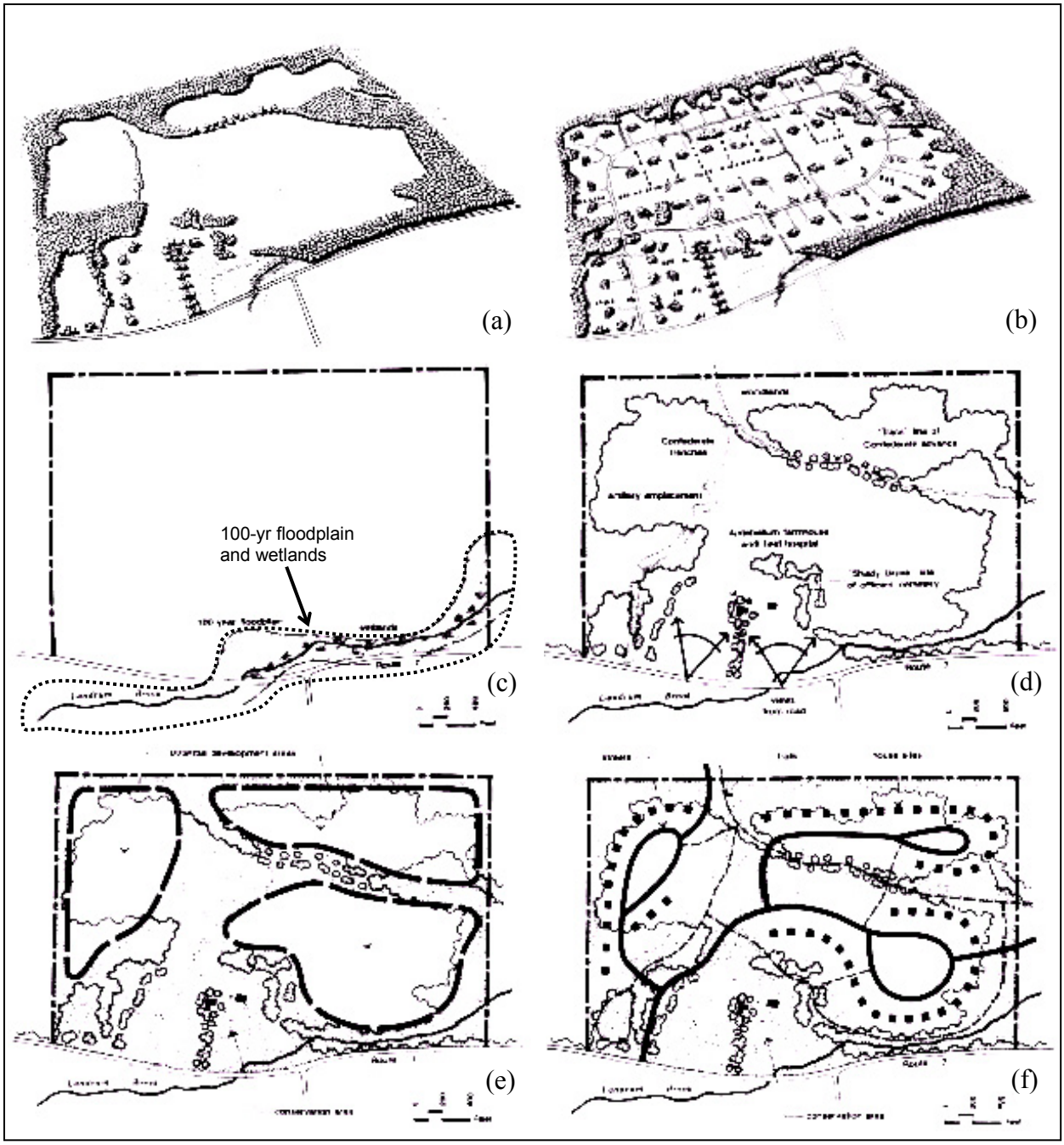

Figure 4.3: Development of a conservation subdivision. The site before development (a) and as designed with conventional development (b); identification of legally unbuildable (c) and legally buildable (d) conservation areas with features to be protected; and delineation of potential development areas (e and f) (adapted from Arendt, 1996).

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Comparison of Traditional and Low Impact Development Scenarios in Delaware

The Brandywine Conservancy and the Delaware Department of Natural Resources and Environmental Control presented a case study in *Conservation Design for Stormwater Management* (Delaware DNREC and the Brandywine Conservancy, 1997). The case study compares conventional site development to several alternative, low impact development scenarios at Chapel Run, a 96-acre site in Sussex County, Delaware. The Chapel Run site is located in a rural area and is categorized by Sussex County as a primarily agricultural area where low-density residential development is permitted. Conservation areas that were identified through a site investigation include a large area of woodland, much of which is on well-drained soils that generate little or no runoff, and a small area with steep slopes.

The proposed conventional design dictates dividing the site into 142 lots ½ acre in size. The conventional design does not take into consideration the sensitive areas identified in the site assessment and results in a site with 100 percent of the area disturbed after clearing and grading. Overall site imperviousness under conventional development would be 29 percent, assuming conventional road widths. On-site runoff management would be accomplished by a curb and gutter system that conveys runoff to two detention basins.

Two alternative designs were developed for the Chapel Run site: the parkway design and the village cluster design. Figure 4.4 shows lot layouts for the conventional and conservation designs. Table 4.1 shows a theoretical side-by-side comparison of the three types of developments with respect to lot size and layout, amount of disturbed and impervious area, hydrology, and costs. Table 4.2 shows differences in itemized costs for infrastructure and management practices between conventional and low impact alternative designs.

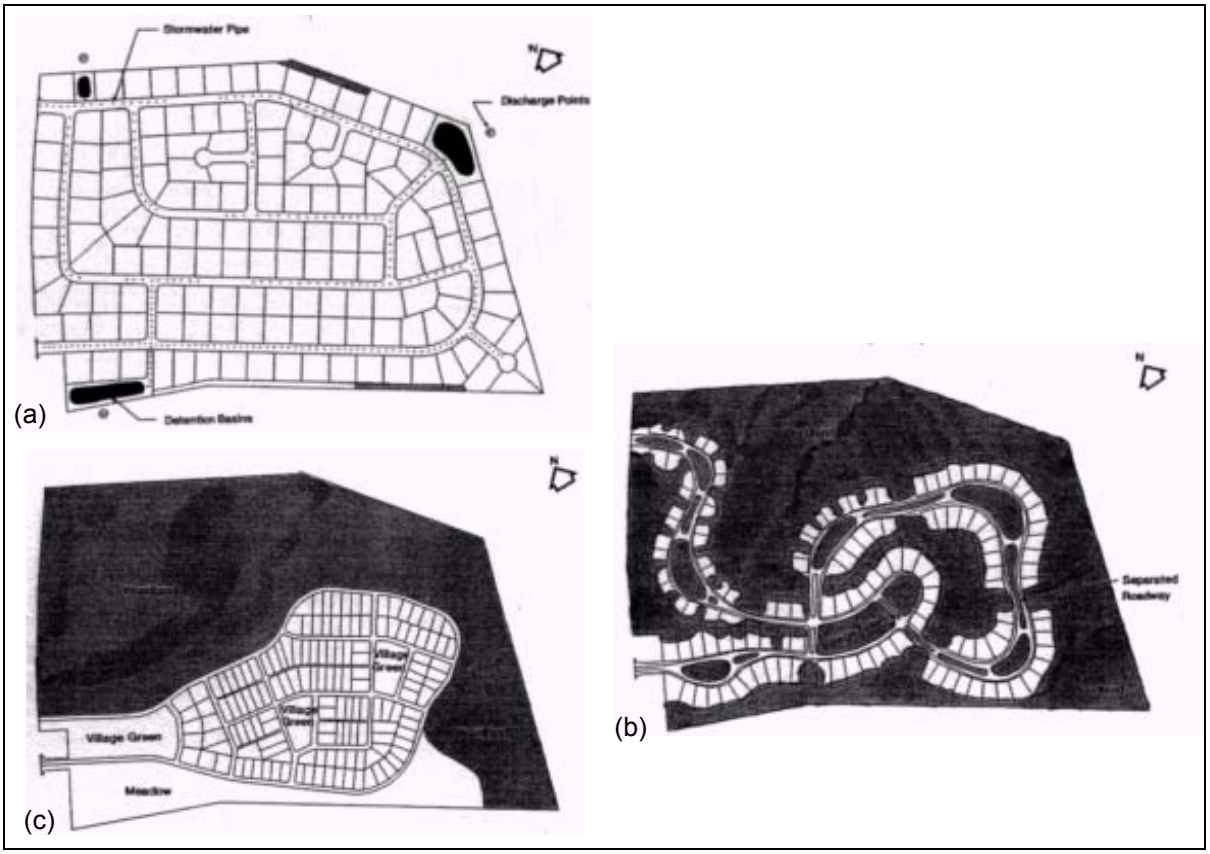

Figure 4.4: Schematic drawings of conventional (a), parkway (b), and clustered (c) development scenarios for the Chapel Run subdivision (Delaware DNREC and the Brandywine Conservancy, 1997).

Comparison of Traditional and Low-Impact Development Scenarios in Delaware (continued)

Table 4.1: Theoretical comparison of conventional and low-impact alternative designs for the Chapel Run site (DE DNREC and the Brandywine Conservancy, 1997). (Reductions are compared to the conventional design.)

Name	Conventional	Village	Parkway
Layout type	Conventional	Condensed cluster	Lots configured along curving road
Number of lots	142	142	142
Lot size	1/2-acre	1/8-acre	1/4-acre
Areas conserved	None	Woodland and high recharge areas	Woodland and high recharge areas
Percent of site in open space	0%	72.7%	49.7%
Impervious cover	29%	17.7%	14.9%
Impervious cover reduction	—	38%	48%
Street width	28 feet	20 feet	Two one-way lanes 12 feet wide with a pervious median
Undisturbed areas	0%	67.5%	59.6%
Runoff management system	Curb and gutter system that conveys runoff underground to two detention basins.	Swale conveyance system along roads that directs runoff to retention/ infiltration areas with level-spreading devices and low berms. These retention/infiltration areas are located throughout the site. Several village greens established on well-drained soils function as both recreation and infiltration areas.	Infiltration of runoff into depressed median (swales) along streets. Wide oval parkway centers used for retention/infiltration. These areas are designed with overflow piping to prevent flooding.
Average curve number[a]	78	66	65
Peak runoff rate for a 10-yr storm[a]	—	53 cfs	51 cfs
Water budget (gal)			
Precipitation	114,082,682	114,082,682	114,082,682
Runoff	31,584,217	21,812,868	17,782,776
Recharge	31,280,103	34,001,079	35,502,938
Evapotranspiration	51,223,261	58,208,796	60,802,278
Costs[b]			
Total	$2,460,200	$1,174,716	$887,705
Per lot	$17,325	$8,273	$6,259

[a] From USDA-NRCS's TR-55 model.

[b] Total cost for the Parkway design shown here differs from total cost published in DE DNREC and the Brandywine Conservancy (1997). Total cost shown here is based on itemized costs, provided in Table 4.2. These are conservative estimates, as in most cases additional costs such as grading have not been taken into account.

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Comparison of Traditional and Low-Impact Development Scenarios in Delaware (continued)

Table 4.2: Theoretical comparison of itemized costs for conventional and low-impact alternative designs for the Chapel Run site (DE DNREC and the Brandywine Conservancy, 1997).

Name	Conventional	Village	Parkway
Street			
Length installed	13,388 ft	11,828 ft	7,800 ft
Unit cost	$150/linear ft	$85/linear ft	$85/linear ft
Total cost	**$2,008,200**	**$1,005,380**	**$663,000**
Storm water detention ponds			
Number installed	3	0	0
Unit cost	$16,000 per pond		
Total Cost	**$48,000**	**$0**	**$0**
Storm water pipe			
Length installed	16,000 ft	2,000 ft	3,000 ft
Unit cost	$22/linear ft	$22/linear ft	$22/linear ft
Total cost	**$352,000**	**$44,000**	**$66,000**
Endwalls/inlets			
Number installed	40	5	10
Unit cost	$1,300 each	$1,300 each	$1,300 each
Total cost	**$52,000**	**$6500**	**$13,000**
Berms			
Length installed	0	1050 ft	1000 ft
Unit cost		$10/linear ft	$10/linear ft
Total cost	**$0**	**$10,500**	**$10,000**
Swales			
Length installed	0	22,570 ft	20,600 ft
Unit cost		$4.50/linear ft	$4.50/linear ft
Total cost	**$0**	**$101,565**	**$92,700**
Check dams			
Number installed	0	90	82
Unit cost		$75 each	$75 each
Total cost	**$0**	**$6771**	**$6150**
Reforestation			
Acres reforested	0	0	12.8
Unit cost			$2,925/ac
Total cost	**$0**	**$0**	**$36,855**
Total [a]	**$2,460,200**	**$1,174,716**	**$887,705**

[a] Total cost for the Parkway design shown here differs from total cost published in DE DNREC and the Brandywine Conservancy (1997). Total cost shown here is based on itemized costs. These are conservative estimates, as in most cases additional costs such as grading have not been taken into account.

4.3.2 On-Lot Impervious Surfaces

4.3.2.1 Reduce the hydraulic connectivity of impervious surfaces

Pollutant loading from impervious surfaces can be reduced by preventing the direct connection of the impervious area to an impervious conveyance system. This can be done in a number of ways, including:

(1) Routing runoff over lawn areas to increase infiltration;

(2) Discouraging the direct connection of downspouts to storm sewers, or the discharge of rooftop downspouts to driveways, parking lots, and gutters;

(3) Substituting swale and pond systems for curbs and gutters to increase infiltration; or

(4) Reducing the use of storm sewers to drain streets, parking lots, and backyards by routing runoff overland using curbless systems, curb cuts, sloped sidewalks, and bioretention cells.

If runoff is directed over lawns, care should be taken to alleviate soil compaction. Urban lawns that are highly disturbed and compacted do not necessarily function as pervious surfaces (for more information on managing runoff from lawns and landscaping, see Management Measure 9).

Figure 4.5 shows schematic representations of impervious areas that are directly connected and not directly connected (BASMAA, 1997).

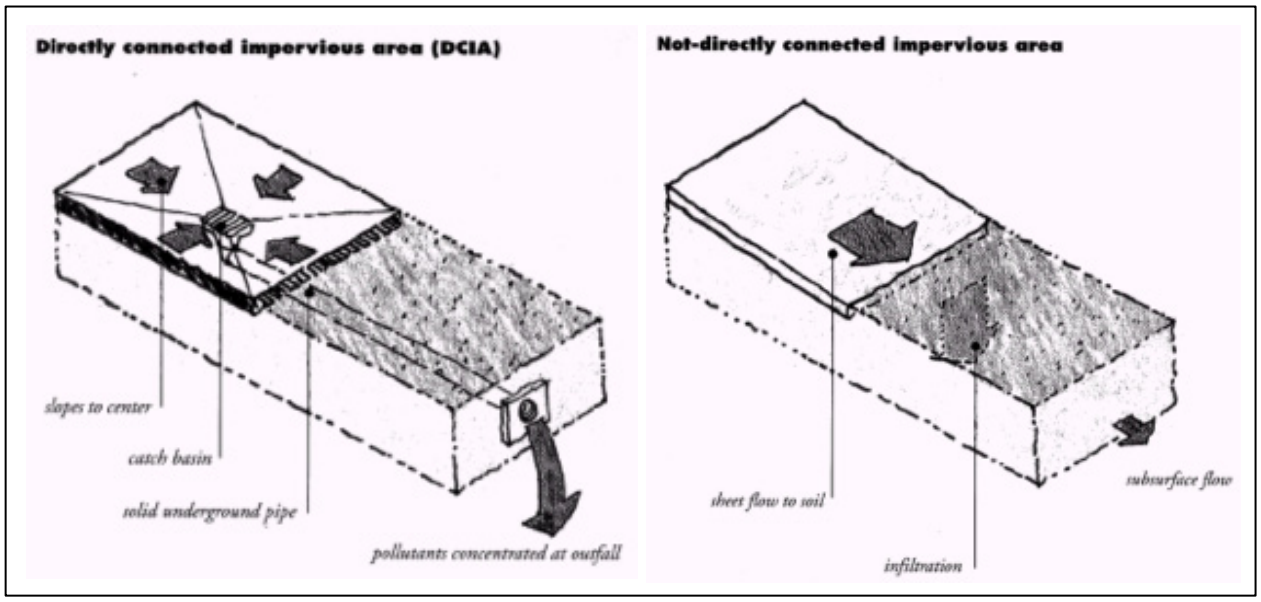

Figure 4.5: Schematic representation of directly connected and not-directly connected impervious areas (BASMAA, 1997).

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The Urban Runoff Pollution Mitigation ordinance passed by the City of Santa Monica, California, requires new developments to implement management practices to collect precipitation, increase infiltration, and manage urban runoff on-site rather than after it enters the storm drain system. Infiltration trenches are the most common on-site practices for single-family homes in the city, but biofilters, swales, and porous pavement are also used. Since 1995, when the ordinance came into effect, 600 new developments have implemented management practices, resulting in a 1.2 million-gallon decrease in storm water runoff for each storm of 0.1-inch rainfall or greater (Shapiro, 2003).

In Prince George's County, Maryland, Cheng et al. (no date) measured runoff from adjacent watersheds to compare the effects of conventional versus low-impact subdivision design. One watershed was developed using conventional subdivision design (curb, gutter, and pipe storm drainage), while the other watershed was developed using low-impact development (LID) techniques, including curbless roads, networks of grassy swales to convey runoff, and bioretention areas (with drop inlet structures where necessary to convey concentrated flows during larger storms). After two years of monitoring, the researchers found that the average peak flow rate of the LID site was 56 percent of that of the conventional site, and surface runoff volume for the LID site was 60 percent of that of the conventional site. Only 15 percent of rainfall was converted to runoff in the LID watershed compared to 19 percent in the conventional watershed, and the LID site had delayed runoff hydrographs and a higher frequency of small flow rates compared to the conventional site, which had a higher frequency of larger flow rates.

Gap Creek Low Impact Development Subdivision, Sherwood, Arkansas

The Gap Creek subdivision in Sherwood, Arkansas, was designed using a low impact development approach that involved implementing such practices as street designs that flow with the existing landscape, minimal site disturbance and preservation of native vegetation, preservation of natural drainage features, and a network of buffers and greenbelts that protect sensitive areas. The approach resulted in significant economic benefits arising from lower development costs, higher lot yield, and greater lot values (NRDC, 1999).

The developer took advantage of the open space that was preserved to maximize the number of lots that were adjacent to the uncleared areas, enhancing their marketability and increasing the value of those properties. The LID plan reduced the amount of site clearing and grading, yielding lower site preparation costs.

Additionally, enhancing natural drainage features resulted in less money spent on drainage infrastructure such as piping, curbs, gutters, and other runoff conveyance features. An additional cost savings was realized with shorter and narrower streets, which also reduced imperviousness. For example, the developer reduced street width from 36 to 27 feet and retained trees close to the curb line, resulting in savings of nearly $4,800 per lot.

The greater lot yield and high aesthetic curb appeal also resulted in larger profits. The developer was able to sell lots for $3,000 more than larger lots in competing areas and sold nearly 80 percent of the lots within the first year. Additional benefits can be found in 23.5 acres of green space and parks (Toolbase Services, no date).

The economic benefits are expected to exceed $2 million over original projected profits. Additional benefits of the LID design include lower landscaping and maintenance costs and more common open space and recreational areas.

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4.3.2.2 Practice rooftop greening

Rooftop greening has become an increasingly common practice in Europe and other parts of the world. This practice involves growing vegetation on the roofs of businesses and homes to intercept rainfall and promote evaporation rather than runoff (Natural Carpets, 1998). Rooftop mats are typically multilayered and include prevegetated coir fiber mats, a mineral-based substrate, and a synthetic matrix (see Figure 4.6). The coir fiber mat absorbs rainfall; the mineral substrate provides the plants with nutrients; and the synthetic matrix promotes drainage. Mats can be used on roofs with slopes of up to 30 degrees and are capable of reducing runoff by two-thirds (see Figure 4.7). These mats provide benefits other than runoff reduction, including:

- Visual aesthetics
- Protection of roofs from damaging solar radiation, wind, and precipitation
- Insulation
- Noise reduction
- Habitat for wildlife

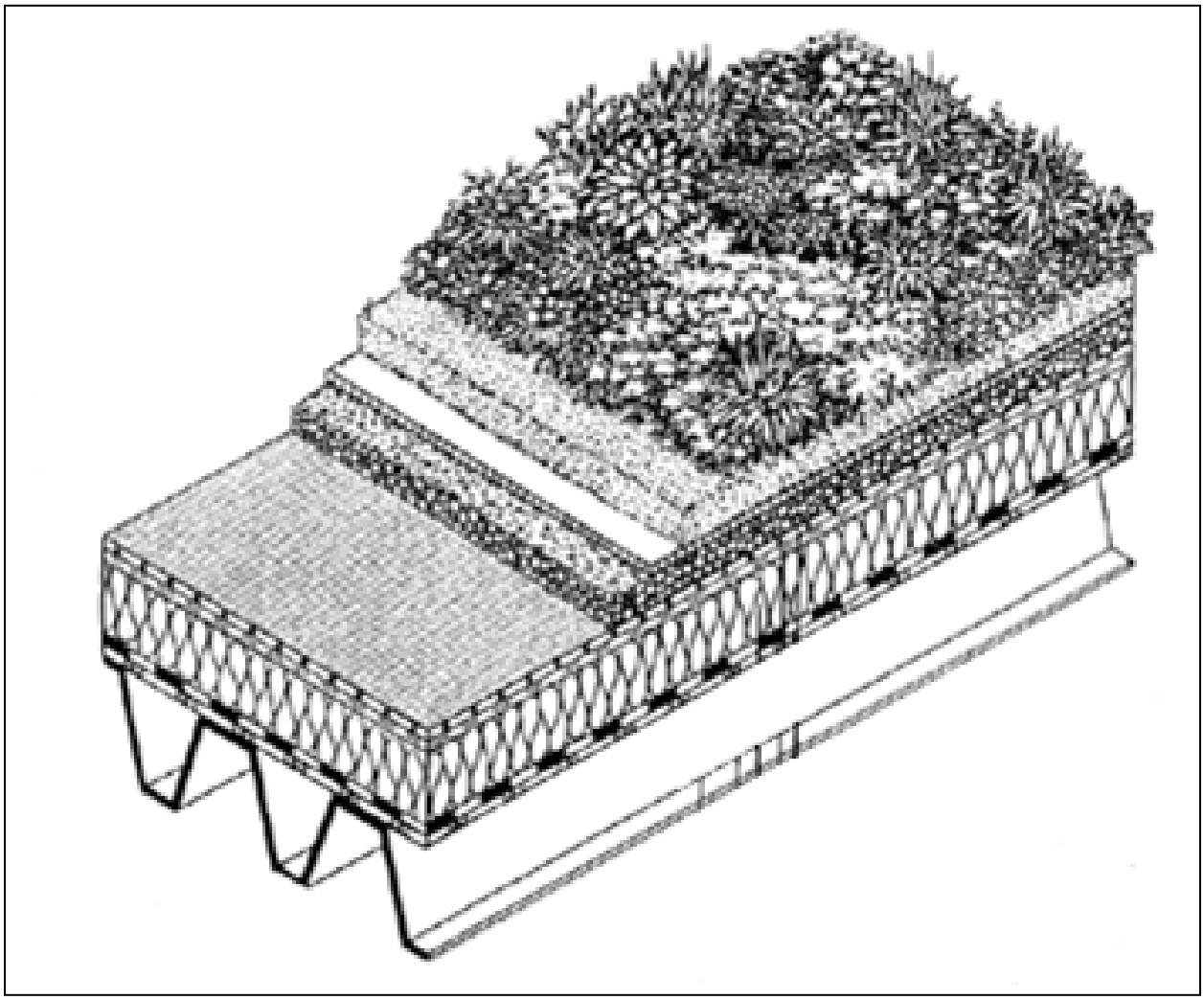

Figure 4.6: Components of the vegetated roof cover (USEPA, 2000).

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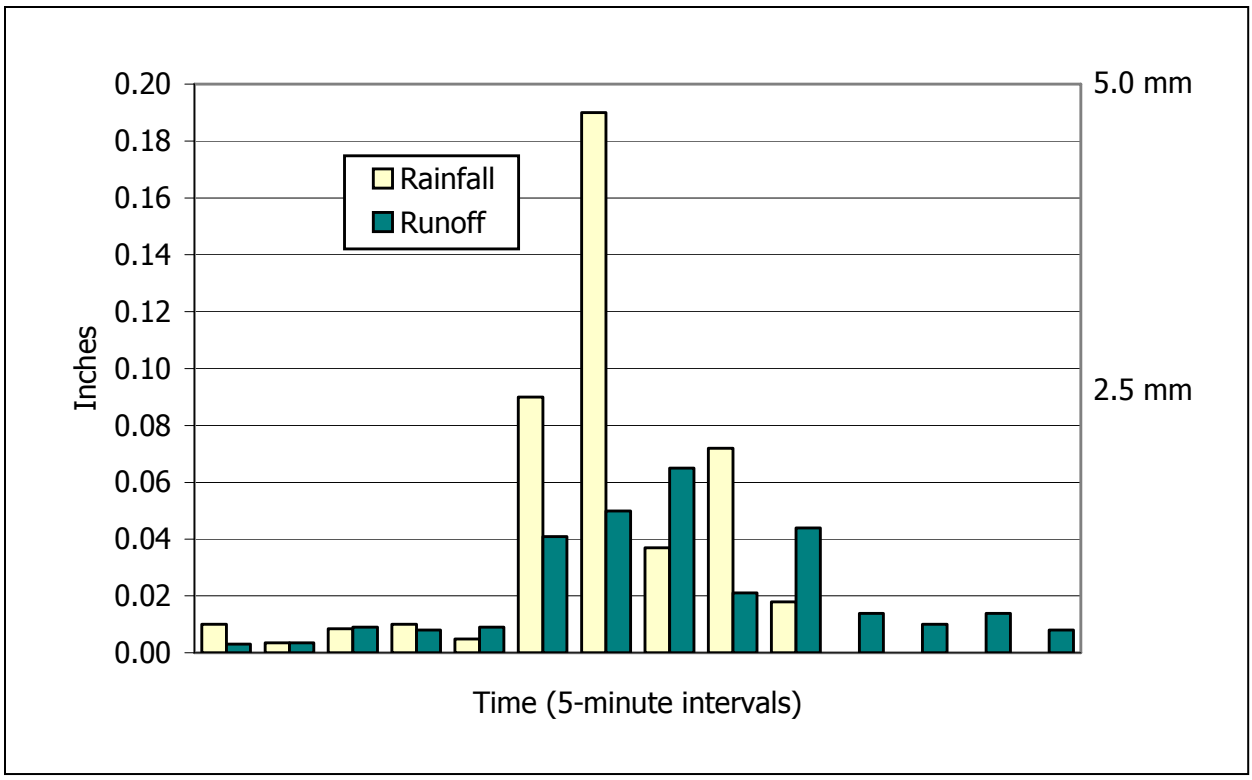

Figure 4.7: Runoff attenuation efficiency for a 0.4-inch rainfall event with saturated media (USEPA, 2000).

- Dust-trapping
- Evaporation and ambient cooling

Vegetation should be well-adapted to the growing conditions of the area where it is installed. Maintenance includes a limited amount of irrigation on steep slopes and periodic fertilization and weeding. Additional roof support might be necessary because the mats, when saturated with water, can add 5 to 17 pounds per square foot.

In response to a court order requiring $3 billion in storm water improvements, Atlanta is targeting commercial buildings for the installation of green roofs, with the anticipation that the resulting decrease in storm water runoff volume will provide water quality benefits. Commercial buildings are being targeted because commercial rooftops cover a huge amount of surface area in the city (Copeland, 2002).

Moran et al. (2004) studied runoff quality from two green roofs installed in North Carolina. They found that each green roof retained approximately 60 percent of the total recorded rainfall during a nine-month observation period. The green roofs reduced average peak flow by approximately 85 percent. Water quality data indicated higher concentrations of total nitrogen and total phosphorus were present in the green roof runoff than in the control roof runoff and in the rainfall at each green roof site. The researchers attribute this to nitrogen and phosphorus leaching from the soil media, which was composed of 15 percent compost. A soil column test of three different green roof soil media indicated that reducing organic matter in the soil media will

Rooftop Meadow Demonstration Project, Philadelphia, Pennsylvania

Rooftop meadows typically use foliage and a lightweight soil mixture to either absorb or filter and detain rainfall (Miller, 1998). Roof meadows are designed to control low-intensity storms by intercepting and retaining or storing water until the peak storm event has passed, while allowing the runoff from higher-intensity storm events to be safely conveyed away from the building. The plants help retain the hydrologic function of intercepting and delaying rainfall runoff by capturing and holding precipitation in the foliage, absorbing water in the root zone, and slowing the velocity of direct runoff by extending the flowpath through the vegetation.

A rooftop meadow demonstration project in Philadelphia, Pennsylvania, consists of a 3,000-ft^2 roof installed and monitored on top of an existing structure. The roof system was intended to mimic natural hydrologic processes of interception, storage, and detention to control the 2-year, 24-hour storm event. There are several distinguishing features of this rooftop meadow: (1) a synthetic underdrain layer that promotes rapid drainage of water from the surface of the roof deck; (2) a thin, lightweight growth medium that permits installation on existing conventional roofs without the need for structural reinforcement; and (3) a meadow-like setting of perennial *Sedum* varieties that have been selected to withstand the range of seasonal conditions typical of the Mid-Atlantic region without the need for regular maintenance.

The installed roof meadow is 3.4 inches thick, including the drainage layer, and weighs less than 5 lb/ft^2 when dry and less than 17 lb/ft^2 when saturated. The moisture content of the medium at field capacity is 45 percent of the volume. The saturated infiltration capacity is 3.5 inches per hour.

The runoff characteristics of the roof were simulated using rainfall records for 1994 from eastern Pennsylvania. The model predicted a 54 percent reduction in annual runoff volume and attenuation of 54 percent and 38 percent, respectively, for the 2- and 10-year, 24-hour Type II storm events. Monitoring of the pilot project for real and synthetic storm events was also conducted for a period of 9 months at 28- and 14-ft^2 trays. The most intense storm monitored was a 0.4-inch, 20-minute thunderstorm. The storm event occurred after an extended period of rainfall had fully saturated the medium. Although 44 inches of rainfall were recorded during this period, only 15.5 inches of runoff were generated from the trays. Runoff was negligible for storm events with less than 0.6 inch of rainfall. This demonstration project shows the advantages of reducing peak runoff rates on overloaded systems for a majority of the storm events and shows that some existing structures can be retrofitted to reduce runoff.

reduce the amount of nutrient leaching. Based on the results of this study, caution should be used when implementing green roofs in nutrient-sensitive watersheds; green roof components such as soil media composition should be selected with consideration of receiving water limitations.

Dunnett and Kingsbury (2004) describe examples of both large-scale and residential applications of green roofs and living walls, and they include technical information about constructing these structures in *Planting Green Roofs and Living Walls.* The authors cover structural engineering concerns as well as factors such as plant selection and environmental considerations that are important for the success of green roofs and living walls. The book is available for purchase at the Timber Press Web site at http://www.timberpress.com.

Another resource for information about green roofs is the proceedings of a conference entitled Green Roofs for Healthy Cities. A CD-ROM of the proceedings can be purchased from http://www.greenroofs.org/portland/proceedings.php and includes information on green roof design and implementation, technical research, and policy developments.

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A Better Site Design Approach to Runoff Management: Low Impact Development

The goal of low impact development (LID) is to maintain and enhance the predevelopment hydrologic regime of urban and developing watersheds. LID focuses on managing runoff in small, cost-effective landscape features on each lot rather than conveying runoff to large, costly storm water ponds located at the bottom of large drainage areas. Hydrologic functions such as infiltration, ground water recharge, and depressional storage are maintained using simple, small-scale practices such as bioretention facilities. A key objective of LID is to reduce the hydraulic connectivity of impervious surfaces. For example, instead of allowing storm water to run from a downspout down a driveway and into a storm sewer, direct the runoff onto a lawn or other pervious area. By disconnecting rooftop runoff from the storm drainage system, a community can decrease the volume of water conveyed to a storm drain by as much as 50 percent (Pitt, 1986) and avoid treatment and storage costs, decrease system maintenance costs, and reduce instream impacts. To avoid soggy areas in lawns, water can be directed to specially designed depression storage areas such as bioretention or infiltration areas.

The following is a list of fundamental practices of the LID approach that can be included in runoff management plans. These practices are presented in two publications by the Department of Environmental Resources of Prince George's County, Maryland: *Low-Impact Development Design Strategies: An Integrated Design Approach* (2000a) and *Low Impact Development Hydrologic Analysis* (2000b).

- *Use hydrology as the integrating framework.* Hydrology is used as the key feature when designing a development. Areas that play a critical role in the movement of water (e.g., streams, riparian and buffer areas, floodplains, wetlands, and ground water recharge sites) are identified first. Alternative layout schemes are then evaluated in terms of their impact on site hydrology. Key objectives are to minimize the amount of impervious cover created and to make created impervious areas function as "ineffective" impervious areas that are not directly connected to a storm drain network.
- *Think micromanagement.* Site hydrology is analyzed and dealt with at small scales. Using natural drainage as a design element, integrated management practices are scattered throughout the site, allowing for runoff distribution and the retention of natural hydrologic functions such as infiltration, depressional storage, and interception.
- *Control runoff at the source.* Management of runoff at or near the sources eliminates the need for large-scale runoff management practices such as concrete conveyance systems and storm water ponds.
- *Incorporate safety features into the design of management practices*. LID practices can require diversions or drainage to allow for overflow of runoff from large storms and storm events that occur during saturated conditions. This emergency drainage will protect the longevity of the structural practice against damage from high runoff volumes and flow velocities and enhance the acceptance of LID in the community.
- *Use simple, nonstructural methods.* Natural hydrologic functions rely on simple processes that promote infiltration, depressional storage, and interception of storm water. These characteristics can be implemented throughout the site using simple methods that incorporate native plants, soil, and gravel.
- *Create a multifunctional landscape.* A goal of the LID approach is to create a landscape where runoff is micromanaged and controlled at the source. Runoff management practices and natural landscape features can be used in tandem to reduce postdevelopment runoff volume and maintain the predevelopment time of concentration.

The Prince George's County LID publications can be ordered through the Internet at EPA's National Service Center for Environmental Publications Web site at http://www.epa.gov/ncepihom. They can also be ordered by phone, fax, or mail from USEPA/NSCEP, P.O. Box 42419, Cincinnati, Ohio 45242-2419, toll-free 800-490-9198, fax 513-489-8695.

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4.3.2.3 Relax frontage and setback requirements

Developers interested in increasing open space or conservation areas typically increase housing density by creating smaller lots or clustered developments and pool the space "savings" in a large open area accessible to all. This can be accomplished by reducing front, side, and rear yard setbacks and decreasing frontage distances. In addition to increasing housing density for open space development designs, relaxing frontage and setback requirements also decreases impervious cover. This occurs because narrower side yards mean narrower lots, which can in turn lead to shorter subdivision streets; shorter front yard setbacks lead to shorter driveways and sidewalks.

Frontage distance can be reduced by providing garage access through rear alleys. This approach eliminates driveways and allows homes to be sited on narrower lots. This helps reduce road frontage requirements and accommodate more homes on a given amount of road. Because of their limited traffic, the alleys can be paved with alternative treatments to retain more pervious area.

Areas with high potential for significant storm damage, earthquakes, or other catastrophes should take into consideration the appropriate setback distance to ensure emergency access in case of building collapse.

4.3.2.4 Modify sidewalk standards

Many conventional subdivision codes require paved sidewalks on both sides of the street in widths that range from 4 to 6 feet. Communities that want to reduce impervious cover and increase the use of pervious areas for runoff treatment should consider the following (always considering public safety first):

- Allowing sidewalks on only one side of the street or building them only where there is pedestrian demand;
- Increasing the distance between sidewalks and the street so sidewalk runoff has a better chance of infiltrating into the grass border area and not becoming street runoff. This will provide water quality as well as safety benefits;
- Grading sidewalks so that runoff drains into the yard rather than toward the street;
- Reducing the width of very wide sidewalks. Communities should consider the implications of reducing sidewalk widths, including pedestrian demand and wheelchair access, on a case-by-case basis. Three feet will typically allow passage for one wheelchair. Sidewalks in highly commercial areas and government centers should accommodate two wheelchairs abreast, but it may be appropriate for some residential areas to reduce sidewalk width to three feet.
- Maintain sidewalk widths but use porous pavement (see Management Measure 5).

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4.3.2.5 Modify driveway standards

In a sense, driveways are small-scale parking lots that are designed to accommodate two to four cars. Typical residential driveways and parking pads often total 400 to 800 square feet. Communities that want to reduce driveway impervious cover should consider:

- Shortening driveway length by shortening front yard setback requirements;
- Narrowing driveway widths;
- Encouraging the use of driveways that are shared by two or more homes; and
- Providing incentives for use of alternative driveway surfaces that allow for infiltration, such as porous pavers, gravel, or a two-track surface with grass in between.

4.3.3 Residential Street and Right-of-Way Impervious Surfaces

The largest percentage of impervious cover in residential neighborhoods is typically associated with the streets, driveways, and sidewalks that together aid in the transport of people to and from their various destinations. Management practices associated with residential streets and their rights-of-way typically are focused on minimizing impervious cover or treating runoff. In general, these objectives can be achieved by developing, updating, or revising codes, ordinances, and standards that determine the size, shape, and construction of residential streets and their rights-of-way.

4.3.3.1 Decrease street pavement width and length

Streets typically make up the largest percentage of transport system impervious cover in residential neighborhoods. Communities can significantly reduce this type of cover in new developments by revising street standards so that street pavement widths are based on traffic volume, on-street parking needs, and other variables rather than requiring all streets to have one universal width. Additionally, communities can encourage developers to design street networks that minimize the total length of pavement. The length of residential streets can be reduced by altering the design and placement of new development. Techniques include:

- Reducing frontage distances and side yard setbacks;
- Allowing narrower lots;
- Clustering smaller lots;
- Reducing the number of non-frontage roads; and
- Eliminating long streets that serve only a small number of homes.

4.3.3.2 Decrease street right-of-way width

A street right-of-way is a public easement corridor through which people, vehicles, runoff, utility services, and other items and materials move in, out, and around the development. A right-of-way usually includes the street itself, its gutters and curbs, and some amount of land on either

side of the street, which might contain sidewalks, utility easements, or other components. Options for minimizing right-of-way widths include:

- Eliminating some right-of-way components;
- Placing sidewalks on only one side of the street;
- Running utility pipes, cables, and other infrastructure underneath street pavement (this can result in traffic congestion from road construction if the infrastructure needs to be repaired or replaced); or
- Reducing street and sidewalk widths where appropriate.

On-street parking is a variable that should be closely examined in communities where reducing impervious cover is a goal. Some communities have implemented a concept known as "queuing streets." Queuing streets generally have one travel lane and one or two parking lanes. Cars wait between parked cars until approaching traffic passes before proceeding to the travel lane. This approach also helps slow traffic, which can improve safety.

Street width must provide for utility work (common utilities include water, sewer, gas, cable, phone, power, and fiber optics). If the street width is reduced, utilities can be installed together in a concrete trench with a removable top for maintenance access (Matsuno, 2003).

When considering these options, it is important to remember that public safety should not be compromised and traffic engineering principles must still be a significant design factor. In addition, areas with high potential for significant storm damage, earthquakes, or other catastrophes should take into consideration the appropriate right-of-way width to enable passage of emergency vehicles.

The Headwaters Project: A Sustainable Community

In 1998 the Department of Planning and Development in Surrey, British Columbia, initiated the Headwaters Project to develop a real example of a sustainable community. Part of this project is the *East Clayton Neighbourhood Concept Plan* (The Headwaters Project, 2000), a green infrastructure plan that is an integrated system of "green" streets and affordable housing sites. It has narrow streets that use one-third less blacktop than typical roadways. Storm water management is achieved through natural infiltration, which minimizes runoff and avoids downstream flooding events. Information about East Clayton and a copy of the concept plan are available at http://www.sustainable-communities.agsci.ubc.ca/projects/Headwaters/PDF/toc.pdf

4.3.3.3 Use alternative cul-de-sac designs

Cul-de-sacs (roads with one open and one closed end) are a popular design element in community road networks. The intent of cul-de-sacs is to provide more homebuyers with premium, "end-of-the-road" lots. The typical "bulb" found at the closed end of a cul-de-sac, however, represents a particularly large concentration of impervious cover. Communities can reduce the amount of impervious cover created by bulb-ending cul-de-sacs by

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- Eliminating cul-de-sac streets altogether;
- Using alternative designs for turnarounds, such as a T-shaped turnaround or a looped road;
- Reducing the radius of the turnaround bulb; or
- Incorporating a pervious cover island in the center of the turnaround bulb that accepts runoff.

As with modifications of street right-of-way width, public safety should not be compromised and traffic engineering principles must still be a significant design factor for this practice. Existing fire codes may dictate cul-de-sac width. Figures 4.8 and 4.9 show five turnaround options at the end of a residential street and the amount of impervious cover created by each option (Schueler, 1995).

4.3.4 Parking Lot Impervious Surfaces

Parking lots are considered by some to be one of the most damaging land uses in the urban landscape (CWP, 2000). Not only are parking lots very efficient at concentrating and delivering a large amount of runoff to receiving waters, thus exacerbating erosion problems, but they also act as a repository for pollutants associated with automobiles, which include nutrients, trace metals, and hydrocarbons.

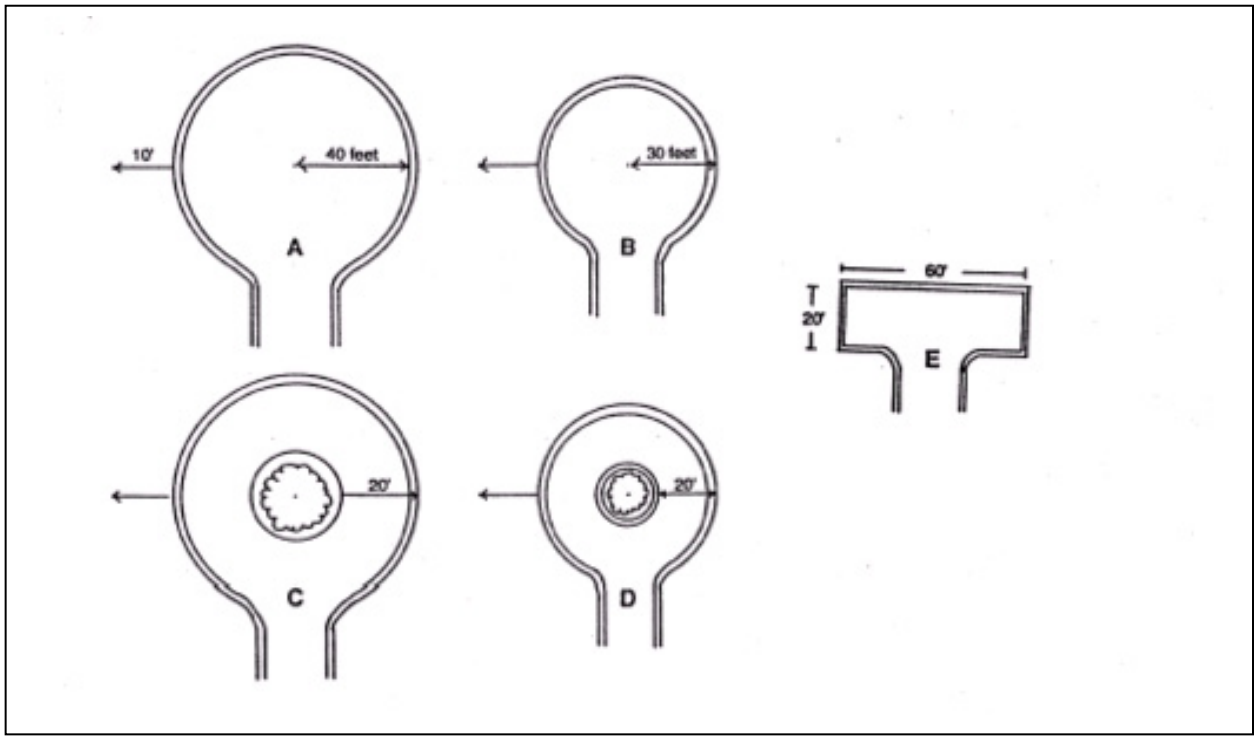

Figure 4.8: Five turnaround options at the end of a residential street (Schueler, 1995).

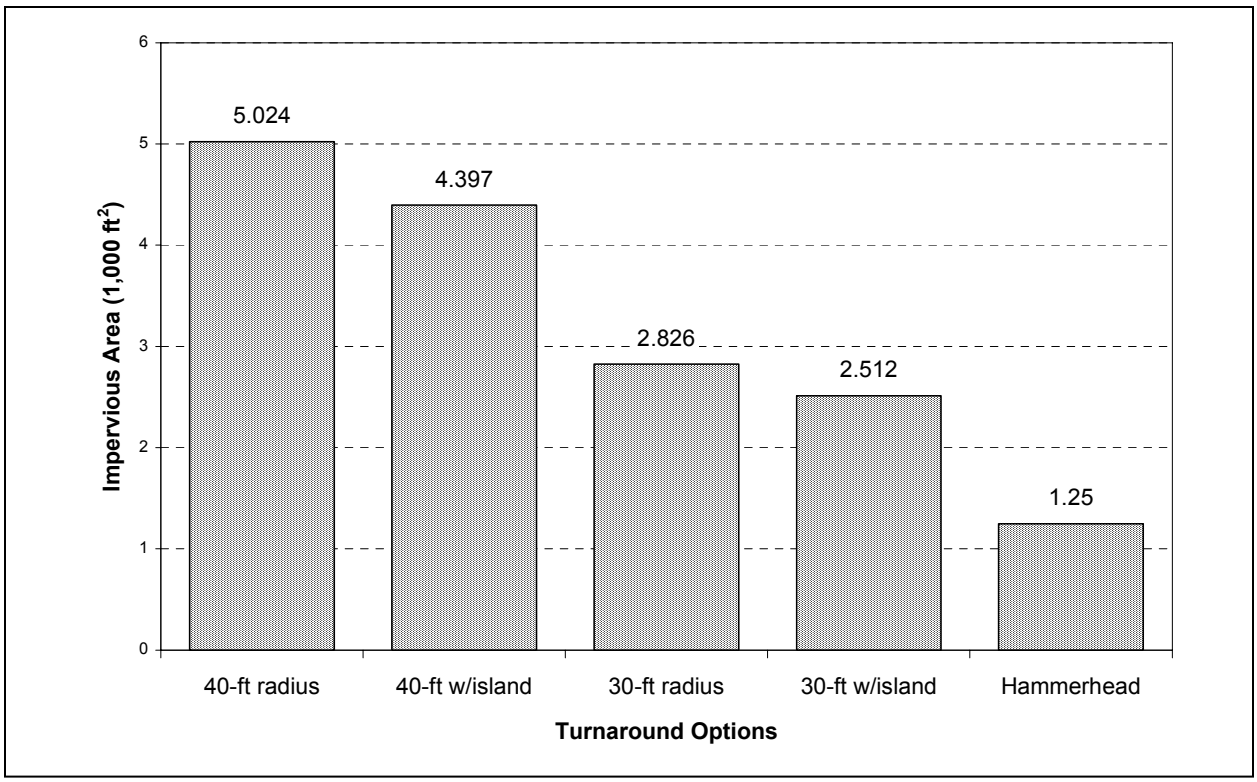

Figure 4.9: Impervious cover created by each turnaround option shown in Figure 4.8 (Schueler, 1995).

Innovative Turf Parking Lot Installation at a Connecticut Shopping Mall

The owners of Westfarms Mall, in the suburbs of Hartford, Connecticut, planned a 310,000-ft^2 expansion that required an additional 4 acres of overflow parking (Wilson et al., 1998). Local zoning boards and members of the community balked at this proposal because of the high ratio of impervious-to-pervious surfaces and concern for the quality and quantity of runoff generated by the new additions.

The traditional solution for handling the increased runoff was to install a large runoff detention pond, which would have cost $1million and was looked upon unfavorably by both the community and the mall owner. A 4-acre turf parking lot was implemented as an alternative and allows rainfall to infiltrate and recharge the ground water supply. To better support automobile traffic, the lot consists of a plastic honeycomb grid filled with sand and soil and laid atop a bed of crushed stone. Additionally, rooftop runoff is diverted to a tank located under the lot and the collected runoff is used to irrigate the turf. The turf would not hold up to everyday traffic, but overflow parking is needed only during the Christmas shopping season when the grass is dormant.

The cost of installing the turf lot was $500,000, which is half the cost of installing a pond. Even though the turf installation was more expensive than traditional pavement installation, the mall owner estimated that the installation would break even within 5 years because of lower maintenance requirements. An additional benefit of this innovative design was for the mall owner to gain the support of community members and local planning commissions.

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Traditionally, developers have provided an overabundance of parking as a convenience for shoppers, workers, and landowners. A goal of watershed managers should be to reduce the surface area of parking lots and integrate runoff treatment practices to reduce adverse impacts, while still providing enough spaces to meet the expected parking demand. This reduction can be accomplished by implementing better site design practices, such as:

- Redesigning building and parking area layouts to reduce walking distances and provide more efficient layouts.

- Ensuring that the number of spaces built reflects actual demand. Site planners should design the lot size to correspond to minimum local parking requirements and consider ways in which this requirement can be reduced. For example, less parking is needed if access to public transportation is provided. Also, a parking area can be shared if localities in close proximity have different peak parking times. For instance, a retail establishment with peak demand during weekdays can share parking with a church whose peak demand is on the weekend.

- Sizing parking lot dimensions to meet everyday demand and designating additional "spillover" parking areas to handle peak demand. Because these spillover areas will receive less traffic, alternative paving techniques (see Management Measure 5) can be used to increase infiltration.

- Reducing the dimensions of the normal parking spaces if allowable. Also, developers can designate a percentage of the available parking spaces for use by compact cars and reduce their dimensions correspondingly.

- Building multilevel parking structures when feasible. (Parking structures can sometimes be impractical from a cost standpoint.) Green roofs can be used on these parking garages to reduce imperviousness.

- Converting parking lot islands to bioretention areas (see Management Measure 5).

- Building below-grade parking where it does not affect groundwater or other subsurface resources.

- Working with municipalities to regulate the maximum number of parking spaces allowed in development, rather than a minimum.

When parking area is reduced, functional landscaping can be used to improve the aesthetics of the site and to allow room for the installation of runoff treatment practices such as infiltration basins, filter strips, and dry swales or detention practices like those described in Management Measure 5.

4.3.5 Xeriscaping Techniques

Xeriscaping is a landscaping concept that maximizes water conservation by using site-appropriate plants and an efficient watering system. It involves the use of landscaping plants that need minimal watering, fertilization, and pesticide application, and practices that reduce water

demand. For instance, mulching can help retain water and humidity and reduce the need for irrigation. Shading and windbreaks can reduce evaporation, particularly from young plants. In contrast to overhead sprinklers, drip irrigation waters plants directly on the roots without wetting plant leaves, helping to reduce evaporation and control disease. Timers are available that allow automatic watering with drip irrigation systems. Watering early in the morning can also reduce evaporation, and prevent the propagation of disease that often results from leaving foliage wet overnight (Relf, 1996). Xeriscaping can reduce the contribution of landscaped areas to nonpoint source pollution, and it can reduce landscape maintenance by as much as 50 percent, primarily as a result of the following (Clemson University Cooperative Extension Service, 1991):

- Reduction of water loss and soil erosion through careful planning, design, and implementation;
- Reduction of mowing by limiting lawn areas and using proper fertilization techniques; and
- Reduction of fertilization through soil preparation.

The specific benefits resulting from xeriscaping will vary based on the local climate and site conditions.

In 1991 the Florida legislature adopted a xeriscape law that requires state agencies to adopt and implement xeriscaping programs. The law requires that rules and guidelines be adopted for the implementation of xeriscaping along highway rights-of-way and on public property associated with publicly owned buildings constructed after July 1, 1992. Local governments are tasked with determining whether xeriscaping is a cost-effective measure for conserving water. If so, local governments are to work with the state water management districts in developing their xeriscape guidelines. Water management districts will provide financial incentives to local governments for developing xeriscape plans and ordinances. These plans must include:

- Landscape design, installation, and maintenance standards;
- Identification of prohibited plant species (invasive exotic plants);
- Identification of controlled plant species and conditions for their use;
- Specifications for maximum percentage of turf and impervious surfaces allowed in a xeriscaped area;
- Specifications for land clearing and requirements for the conservation of existing native vegetation; and
- Monitoring programs for ordinance implementation and compliance.

The law also includes a provision requiring local governments and water management districts to promote the use of xeriscape practices in existing developed areas through public education programs. California has passed a law requiring all municipalities to consider enacting water-efficient landscape requirements.

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Water Conservation and Xeriscaping in Albuquerque, New Mexico

The City of Albuquerque, New Mexico, recently adopted a new strategy to encourage water conservation and to ensure a lasting water supply for years to come (Bennett, 1999). The strategy includes

- Reducing per capita water consumption by 30 percent.
- Developing facilities to treat and distribute city-owned surface water in combination with more limited use of the aquifer.
- Developing systems to use reclaimed wastewater and low-quality shallow ground water to irrigate landscaped areas in specific corridors of the community.
- Aggressive preservation of ground water quality.

The city also developed a new ordinance, the Water Conservation Landscaping and Water Waste Ordinance, that includes the following provisions:

- Prohibits irrigation water from flowing or spraying into streets, storm drains, or adjoining property.
- Limits high-water-use turf to 20 percent of the total landscape for all new developments.
- Establishes design requirements to discourage turf on steep slopes or adjacent to streets.
- Establishes water budget goals for parks and golf courses.
- Requires that new sprinkler systems on large turf areas meet minimum uniformity standards.
- Requires spray irrigation to occur between 6:00 p.m. and 10:00 a.m. from April to September.

The full text of the ordinance can be found at *www.cabq.gov/resources*.

As a result of these changes in Albuquerque's water conservation policy, the city's water consumption has decreased by 24 percent and its irrigation professionals have experienced a substantial increase in business as landowners seek smarter solutions to irrigation problems. Improvements in irrigation technology and increased public awareness are likely to further decrease water consumption.

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4.4 Information Resources

In 1991 the Center for Watershed Protection published the *Consensus Agreement on Model Development Principles to Protect Our Streams, Lakes, and Wetlands*, which outlines the series of 22 nationally endorsed principles developed by the Site Planning Roundtable, a national cross-section of diverse planning, environmental, homebuilder, fire, safety, public works, and local government personnel, and details the basic rationale for their implementation. The *Consensus Agreement* can be purchased at http://www.cwp.org/.

The Center for Watershed Protection also published *Better Site Design: A Handbook for Changing Development Rules in Your Community* in 1998. This document outlines 22 guidelines for better developments and provides a detailed rationale for each principle. *Better Site Design* also examines current practices in local communities, details the economic and environmental benefits of better site designs, and presents case studies from across the country. It can be purchased at http://www.cwp.org/.

Wildlife Reserves and Corridors in the Urban Environment: A Guide to Ecological Landscape Planning and Resource Conservation, by Lowell Adams and Louise Dove (1989) reviews the knowledge base regarding wildlife habitat reserves and corridors in urban and urbanizing areas, and it provides guidelines and approaches to ecological landscape planning and wildlife conservation in such areas. It can be purchased from the Urban Wildlife Resources Bookstore at http://users.erols.com/urbanwildlife/bookstor.htm.

In 1997 Randall Arendt of the Natural Lands Trust, Inc., published *Growing Greener: Putting Conservation into Local Codes*. *Growing Greener* is a statewide community planning initiative designed to help communities use the development regulation process to their advantage to protect interconnected networks of greenways and permanent open space. The booklet can be downloaded in PDF format at http://www.dcnr.state.pa.us/growinggreener/growing.pdf.

The Low Impact Development Center was established to develop and provide information to individuals and organizations dedicated to protecting the environment and our water resources through proper site design techniques that replicate preexisting hydrologic site conditions. More information about this organization can be found on the Low Impact Development Center Web site at http://www.lowimpactdevelopment.org/ or by contacting the Center at 301-345-0440.

The Prince George's County, Maryland, Department of Environmental Resources produced two documents, *Low-Impact Development Design Strategies: An Integrated Design Approach* (EPA-841-B-00-003) and *Low-Impact Development Hydrologic Analysis* (EPA-841-B-00-002), that discuss site planning, hydrology, distributed integrated management practice technologies, erosion and sediment control, and public outreach techniques that can reduce storm water runoff from new and existing developments. Both publications can be ordered free of charge through EPA's National Service Center for Environmental Publications at http://www.epa.gov/ncepihom/index.htm.

Residential Streets, prepared by the American Society of Civil Engineers, the National Association of Home Builders, and the Urban Land Institute (1990), discusses design considerations for residential streets based on their function and their place in the neighborhood.

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The publication presents guidance on street widths, speeds, pavement types, streetscapes, rights-of-way, intersections, and drainage systems.

The Institute of Transportation Engineers (ITE) published *Traditional Neighborhood Development—Street Design Guidelines* (1997), in which traditional neighborhood designs that support pedestrian movement over automobile traffic are discussed, and design concepts such as on-street parking, street width, and sight distances are presented. The publication also includes a practical discussion of the time needed for community acceptance and travel behavior changes. ITE also published *Guidelines for Residential Subdivision Street Design* (1993), which presents a discussion of the overall design of a residential subdivision with respect to the adequacy of vehicular and pedestrian access, minimizing excessive vehicular travel, and reducing reliance on extensive traffic regulations. It also provides design considerations for local and collector streets and intersections, including such topics as terrain classifications, rights-of-way, pavements, curb types, and cul-de-sacs. These publications are available through the Institute of Transportation Engineers, 525 School Street, SW, Suite 410, Washington, DC 20024-2797, (202) 863-5486.

Street Design Guidelines for Healthy Neighborhoods is a guidebook intended to help communities implement designs for streets that are safe, efficient, and aesthetically pleasing. This publication can be purchased from the Local Government Commission's Center for Liveable Communities Web site at http://www2.lgc.org/bookstore/topic.cfm?topicId=11.

The Congress for the New Urbanism has compiled a database of jurisdictions across the country that have adopted reduced-width street standards (Cohen, 2000). The database also includes resources related to neighborhood design and transportation. The database can be viewed at http://www.sonic.net/abcaia/narrow.htm.

EPA has compiled a number of resources on its *Low Impact Development (LID)* Web page, with links to Web sites, a literature review, fact sheets, and technical guidance. The Web site is accessible at http://www.epa.gov/owow/nps/lid/.

The Local Government Commission has published a guidebook to assist local communities in overcoming regulatory obstacles to smart growth. *Smart Growth Zoning Codes: A Resource Guide* helps planners design zoning codes that encourage the construction of walkable, mixed-use neighborhoods. The guidebook comes with a CD-ROM containing examples of the best U.S. zoning codes and other resources. The book can be purchased for $25 from http://www2.lgc.org/bookstore/topic.cfm?topicId=1.

Dunnett and Kingsbury (2004) describe examples of both large-scale and residential applications of green roofs and living walls and include technical information about constructing these structures in *Planting Green Roofs and Living Walls.* The authors cover structural engineering concerns as well as factors such as plant selection and environmental considerations that are important for the success of green roofs and living walls. The book is available for purchase at the Timber Press Web site at http://www.timberpress.com.

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MANAGEMENT MEASURE 5
NEW DEVELOPMENT RUNOFF TREATMENT

5.1 Management Measure

By design or performance (a) reduce the postdevelopment loadings of total suspended solids (TSS) so that the average annual TSS loadings[a] are no greater than the predevelopment loadings, or (b) reduce the average annual TSS loadings by a minimum of 80 percent of the influent concentration of TSS[b].

Maintain the postdevelopment average volume and peak runoff rates at levels that are similar to predevelopment[c] levels or, through planning and/or design, control offsite discharges of runoff to prevent erosive impacts to downstream channels or shorelines.

Maintain discharge temperatures in runoff at levels similar to predevelopment levels or at levels that will protect aquatic communities from the thermal impacts of runoff.

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[a] In general, calculations of average annual TSS loadings will be based on TSS loadings from all storms below or equal to a predetermined maximum storm size. The most commonly used upper threshold that states use to calculate annual average TSS loadings is the 2-year, 24-hour storm. However, some states have recently reevaluated the benefits of controlling the 2-year versus the 1-year, 24-hour storm and, as a result, have adopted standards that require the control of all storms less than or equal to the 1-year, 24-hour storm.

EPA interprets predevelopment conditions to mean those conditions that exist prior to the current land use. In situations where the previous land use has resulted in unacceptable erosion and significant sediment movement offsite, a baseline reference condition can be used (e.g., the typical TSS loading rates from forested sites or meadows in the area). Average annual TSS loading calculations also should be based on the TSS discharge concentrations that occur after the site has been permanently stabilized.

[b] It is anticipated that the total TSS reductions will be calculated based on all reductions achieved through a system of structural and nonstructural management practices. The intent of this guidance is to promote the implementation of runoff management programs that protect receiving waters from increases of suspended solids that may, on an individual or cumulative basis, threaten or impair surface waters. Management practices and systems of practices should be selected based on achievement of water quality standards throughout the receiving watershed. TSS loading reduction goals therefore should be determined by assessing the capacity of the receiving water body to assimilate TSS from all contributing sources. EPA acknowledges that, in some jurisdictions, reducing 80 percent of the influent TSS concentration is not reasonable due to the presence of significant concentrations of colloidal particles. EPA also understands that treatment of these particles in many cases is not necessary to protect receiving waters and meet state or local water quality standards. In such cases, design or performance requirements should protect receiving waters from impairment from TSS loadings above the ambient TSS in receiving waters that are not due to anthropogenic sources.

[c] As with the TSS element of the measure, term *predevelopment* refers to runoff rates and volumes that exist on-site immediately before the planned land disturbance and development activities occur. Predevelopment is not intended to be interpreted as that period before any human-induced land disturbance activity has occurred. Watershed managers need to determine an appropriate reference or management condition as an objective to achieve. Also, for the purposes of this element of the management measure, the term *similar* is defined as "resembling though not completely identical."

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5.2 Management Measure Description and Selection

5.2.1 Description

During the development process, both the existing landscape and hydrology are altered. As development occurs, the following changes are likely to occur:

- Soil porosity decreases due to removal of vegetation and compaction of topsoil by construction equipment;
- Impermeable surfaces (paving and rooftops) increase (see Introduction);
- Artificial conveyances such as pipes and concrete channels are constructed;
- Slope angles become less acute;
- Vegetative cover decreases; and
- Surface roughness decreases.

These changes result in increased runoff volume and velocity, which may lead to accelerated erosion of streambanks, steep slopes, and unvegetated areas (Novotny, 1991). The grading of urbanized areas can increase the downward slope to a water body and destroy riparian buffer zones, or developers may level a site to facilitate construction activities. Destruction of in-stream and riparian habitat, increases in water temperature, streambed scouring, and downstream sedimentation of streambed substrates, riparian areas, and estuarine habitats may occur.

Everyday activities that occur after development may cause the discharge of pollutants in runoff that can have harmful effects on waters and habitat. Pollutants related to vehicle petroleum and coolant leaks and overflows, tire and brake wear, pet waste, pesticides, and fertilizers can be carried into estuaries, streams, rivers, and lakes through runoff. Soils and sediment can constitute a significant fraction of the solids on urban surfaces. Weather related erosion and transport of eroded soil (e.g., by wind and rain) increases solids in urban areas. Other sources of solids on urban surfaces are wear of automotive parts (brake pads, tires), combustion products from diesel- and gasoline-fueled engines, fireplaces, construction sites, and industrial facilities. An extensive discussion of these pollutants is presented in Chapter 1.

The goals of the new development runoff treatment management measure are to:

- Retain the predevelopment or pre-disturbance hydrological conditions of both surface and ground water;
- Remove suspended solids and associated pollutants entrained in runoff that result from activities occurring during and after development;
- Decrease the erosive potential of increased runoff volumes and velocities associated with development-induced changes in hydrology;

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- Preserve natural systems, including in-stream habitat, riparian areas, and wetlands; and

- Reduce the thermal impacts that result from impervious surfaces and treatment devices with large amounts of surface exposed to sunlight such as wet ponds.

Several issues require clarification to fully understand the scope and intent of this management measure. The watershed protection (3), site development (4), and new development runoff treatment (5) management measures are intended to be used together within a comprehensive framework to reduce nonpoint source pollution. Applied on-site and throughout watersheds, these three management measures can be used together to provide increased watershed protection and help prevent erosion, flooding, and increased pollutant loads generally associated with poorly planned development. Implementation of the watershed protection and site development management measures can help achieve the goals of the new development runoff treatment management measure.

5.2.1.1 Pollutants and total suspended solids

Many pollutants bind to and are entrained in sediment or particulate loadings. Particulates include suspended, settleable, and bedload solids. Metals, phosphorus, nitrogen, hydrocarbons, and pesticides are commonly found in urban sediments. The correlation between total suspended solids (TSS) and specific pollutants may vary (URS Greiner Woodward Clyde, 1999).

TSS is a measure of the concentrations of sediment and other solid particles suspended in the water column of a stream, lake, or other water resource. TSS is an important parameter because it quantifies the amount of sediment entrained in runoff. This information can be used to link sources of sediments to the resulting sedimentation in a stream, lake, wetland, or other water resources. As shown previously, TSS is also an indirect measure of other pollutants carried by runoff, because nutrients (phosphorus), metals, and organic compounds are typically attached to sediment particles. For these reasons TSS was selected as the prime or sole parameter associated with the first element of this management measure.

Sansalone and Buchberger (1997) found that the relative proportional mass of heavy metals (Zn, Cu, Pb) in highway runoff and snowbank samples increased with decreasing particle size. This effect was attributed to the increase in surface area binding sites that were present with smaller particles. In another study, Sansalone et al. (1998) observed that the greatest mass of contaminants in highway runoff is found on particles in the 425 to 850 micron (μm) range. Because average particle size varies across the U.S., it makes sense to address the particle size that most effectively captures the highest percentage of associated pollutants.

The quantity and size range of the suspended particles measured and reported as TSS at any given time depends on many factors including:

- The composition and extent of the sources of suspended solids in the watershed;

- The magnitude and duration of storms or dry weather periods preceding the sampling;

- Flow velocity, turbulence, and other conditions that promote the suspension of solids in the water column; and

- The sampling techniques employed.

Generally, individual particles found in a TSS sample are 62 μm (0.062 μm) or less in diameter and classified as either silts or clays (Table 5.1). Solids greater than 62 μm can also be found in the water column if conditions are turbulent enough to keep them in suspension.

Table 5.1: Sediment particle size distribution (shaded classes are found in a typical urban TSS sample).

General Class	Class Name	Diameter (μm)
Sand	Very coarse sand	2000–1000
	Coarse sand	1000–500
	Medium sand	500–250
	Fine sand	250–125
	Very fine sand	125–62
Silt	Coarse silt	62–31
	Medium silt	31–16
	Fine silt	16–8
	Very fine silt	8–4
Clay	Coarse clay	4–2
	Medium clay	2–1
	Fine clay	1–0.5
	Very fine clay	0.5–0.24
	Colloids	< 0.24

Erosion and entrainment of solids in runoff occur primarily during rainfall. Rainfall varies in magnitude through time, with large rainstorms occurring less frequently than small showers. Collectively, all the rainfall occurring during the year contributes to the annual sediment yield from a site. In order to focus on typical annual yields, however, the management measure states that yield calculations are to be based on the average annual TSS loadings from all storms less than or equal to the two-year, 24-hour storm. Setting this threshold eliminates the need to calculate or integrate the impacts of larger infrequent storms into the average annual sediment yield calculation.

The annual TSS loadings can be calculated by adding the TSS loadings that can be expected during an average one-year period from precipitation events less than or equal to the two-year, 24-hour storm. Removal of 80 percent of TSS can be achieved by reducing, over the course of the year, 80 percent of these loadings.

Critics of the TSS standard suggest that the sampling and analysis protocols employed for this measure do not fully capture the entire range of particle sizes found in some kind of samples. More specifically, TSS protocols tend to under-sample larger solids and therefore yield lower-than-actual values for management practice pollutant removal efficiency. However, under-sampling the larger particles that would easily settle out in a runoff treatment control results in higher overall removal rates of solids and fewer solids discharged to surface waters.

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There are alternatives to the TSS method, including turbidity and suspended sediment concentration (SSC). Monitoring turbidity in urban runoff is advantageous because the measurements can be conducted in situ using continuous methods (e.g., Secchi disk). It should be noted, however, that using turbidity as a surrogate for TSS may be appropriate only in instances where a strong statistical correlation has been established, such as in low-energy environments like lakes and estuaries. This correlation should be established on a case-by-case basis if turbidity is to be used as a surrogate.

The SSC method is used by the U.S. Geological Survey (USGS) as the standard for determining concentrations of suspended material in surface water samples (USGS, 2000). Gray et al. (2000) examined the comparability of SSC and TSS measurements. SSC and TSS are the predominant analytical methods used to quantify concentrations of solid-phase material in surface waters. SSC values are obtained by measuring the dry weight of all the sediment from a known volume of a water-sediment mixture. TSS data are produced by several methods, most of which involve measuring the dry weight of sediment from a known volume of a subsample of the original. Analysis of paired SSC and TSS data showed bias in the relationship between SSC and TSS. In samples where sand-size material was greater than nearly a quarter of the dry sediment mass, SSC values tended to be higher than corresponding paired TSS values.

According to Gray, the SSC method produces relatively reliable results for natural water samples, regardless of the amount or percentage of sand-size material in the samples. SSC and TSS are not comparable and should not be used interchangeably. Rather, the authors suggest using the SSC analytical method to enhance the accuracy and comparability of suspended solid-phase concentrations of natural waters (Gray et al., 2000). More information about the SSC analytical method can be found at http://www.astm.org/ by searching for standard number ASTM D 3977-97, *Standard Test Method for Determining Sediment Concentration in Water Samples* (ASTM International, 2002).

5.2.1.2 Runoff

Runoff management programs have traditionally focused on reducing or preventing induced flooding from new development. Performance standards were typically developed to control large storms, e.g., 50- or 100-year storms. Although the control of these large storms is still essential, it has become apparent in the last 20 years that a broad range of storms must be managed to prevent streambed and streambank erosion. Recent research points to the need to control total discharge volumes and rates so that they do not result in stream channel degradation. As a result, some states and local governments have developed performance requirements that are intended to prevent stream channel erosion as well as flooding of downstream properties.

This management measure was written to address the control of both peak runoff rates and average runoff volumes with the intent to maintain postdevelopment runoff characteristics at predevelopment levels. Even though EPA recommends that structural runoff controls be designed to control all storms less than or equal to the two-year, 24 hour storm, state and local governments should determine the locally appropriate storm size threshold to control based on local hydraulics, hydrology, meteorology and other regional and local factors. Watershed managers also should consider the development and implementation of volume and peak

discharge performance standards to address problems associated with the frequency and duration of erosive flows (MacRae and Rowney, no date). The use of low-impact development (LID) techniques may be one way to achieve these goals (Prince Georges' County, Maryland, Department of Environmental Resources, 2000a, 2000b).

5.2.2 Management Measure Selection

This management measure was selected because of the following factors:

- Removal of 80 percent of TSS is assumed to control heavy metals, phosphorus, and other pollutants.

- Several states and local governments have implemented a TSS removal treatment standard of at least 80 percent. Table 5.2 presents TSS reduction standards and design criteria for select state and local runoff management programs.

- Analysis has shown that constructed wetlands, wet ponds, and infiltration basins can remove 80 percent of TSS, provided they are designed and maintained properly. Other practices or combinations of practices can also be used to achieve the goal.

- A number of flood control practices can control postdevelopment volume and peak runoff rates and maintain predevelopment hydrological conditions, which will reduce or prevent streambank erosion and stream scouring. Table 5.3 presents peak discharge and volume standards and design criteria for select local runoff management programs.

- Urban streams often experience elevated temperatures due to an increase in impervious areas and a decrease in vegetative cover that would normally provide shading for wetlands and stream channels. Many of the practices presented in this management measure and throughout this guidance, such as infiltration practices, riparian buffers, and urban forestry, help to lower stream temperatures. Practices such as retention ponds may contribute to temperature elevation and should not be used in areas with temperature-sensitive fish or macroinvertebrates unless the other measures are taken to counteract this effect (i.e., plant vegetation to shade ponds, wetlands, or channels).

Table 5.2: Select local and state programs with TSS performance standards (adapted from Watershed Management Institute [WMI], 1997a).

Community/State	Standard	Criteria
Olympia, WA	80 percent removal of suspended solids.	Treat runoff volume of six-month, 24 hr storm
Orlando, FL	Reduce average annual TSS loading by 80 percent.	Treat first half-inch of runoff or the runoff from the first inch of rainfall, whichever is greater.
Winter Park, FL	Reduce average annual TSS loading by 80 percent.	Treat the first inch of runoff by retention.
Baltimore Co., MD	Remove at least 80 percent of the average annual TSS loading.	Treat the first half-inch of runoff from the site's impervious area.
South Florida Water Management District	Remove at least 80 percent of the average annual TSS loading.	Treatment volume varies from 1.0 to 2.5 inches times percent impervious area.

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Table 5.2 (continued).

Community/State	Standard	Criteria
Delaware	Remove at least 80 percent of the annual TSS loading.	Treat the first inch of runoff by approved management practices.
Florida	Remove at least 80 percent of the average annual TSS loading.	Treatment volume varies from 0.5 to 1.5 inches depending on the practice.
New Jersey	80 percent reduction in TSS.	Treat runoff volume of a storm of >1.25inches in two hours or the one-yr, 24-hr storm.
South Carolina	Remove at least 80 percent of the average annual TSS loading.	Treatment volume varies from 0.5 to 1.0 inch depending on the practice.

Table 5.3: Select local programs with peak discharge and/or runoff volume performance standards (adapted from WMI, 1997a).

Community/State	Peak discharge	Volume
Alexandria, VA	Postdevelopment rate cannot exceed predevelopment rate for two-yr and 10-yr, two-hr storm.	None
Austin, TX	Postdevelopment rate cannot exceed predevelopment rate for two-, 10-, 25-, and 100-yr, 24-hr storm.	None
Bellevue, WA	Postdevelopment rate cannot exceed predevelopment rate for two- and 10-yr, two-hr storm.	Multiple release rates for detention systems.
Olympia, WA	Postdevelopment rate cannot exceed predevelopment rate for two-yr and 100-yr, 24-hr storm.	Must infiltrate all of the 100-yr vol. on-site if percolation rate greater than 6 inches per hr.
Orlando, FL	Postdevelopment rate cannot exceed predevelopment rate for 25-yr, 24-hr storm.	In closed basins, retain runoff from 100-yr, 24-hr storm.
Washington, DC	Postdevelopment rate cannot exceed predevelopment rate for two-, 10-, and 100-yr, 24-hr storm.	None
Clark Co., WA	Postdevelopment rate cannot exceed predevelopment rate for two-, 10- and 100-yr, 24-hr storm.	Post-development vol. cannot exceed predevelopment vol. for two-yr, 24-hr storm.
SW Florida Water Management District	Postdevelopment rate cannot exceed predevelopment rate for 25-yr, 24-hr storm.	Post-development vol. cannot exceed predevelopment vol. for 25-yr, 24-hr storm.

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General Performance Standards for Storm Water Management in Maryland

To prevent adverse impacts from runoff, the Maryland Department of the Environment (MDE, 2000) developed 14 performance standards for development sites. These standards apply to any construction activity disturbing 5,000 or more square feet of land. The following standards are required at all sites where runoff management is necessary:

- Site designs shall minimize runoff generation and maximize pervious areas for runoff treatment.
- Runoff generated from development and discharged directly into a jurisdictional wetland or waters of the State of Maryland shall be adequately treated.
- Annual ground water recharge rates shall be maintained by promoting infiltration through the use of structural and nonstructural methods. At a minimum, the annual recharge from postdevelopment site conditions shall mimic the annual recharge from predevelopment site conditions.
- Water quality management shall be provided through the use of structural and nonstructural controls.
- Structural management practices for new development shall be designed to remove 80 percent and 40 percent of the average annual postdevelopment TSS and total phosphorus loads, respectively. It is presumed that a management practice complies with this performance standard if it is sized to capture the prescribed water quality volume, designed according to the specific performance criteria outlined in the Maryland Stormwater Design Manual (MDE, 2000), constructed properly, and maintained regularly.
- On the Eastern Shore, the postdevelopment peak discharge rate shall not exceed the predevelopment peak discharge rate for the 2-year frequency storm event. On the Western Shore, local authorities may require that the postdevelopment 10-year peak discharge not exceed the predevelopment peak discharge if the channel protection storage volume (Cp_v) is provided. In addition, safe conveyance of the 100-year storm event runoff control practices shall be provided.
- To protect stream channels from degradation, Cp_v shall be provided by 12 to 24 hours of extended detention storage for the 1-year storm event. Cp_v shall not be provided on the Eastern Shore unless the appropriate approval authority deems it necessary on a case-by-case basis.
- Runoff to critical areas with sensitive resources may be subject to additional performance criteria or may need to use or restrict certain management practices.
- All management practices shall have an enforceable operation and maintenance agreement to ensure the system functions as designed.
- Every management practice shall have an acceptable form of water quality pretreatment.
- Redevelopment, defined as any construction, alteration, or improvement exceeding 5,000 square feet of land disturbance on sites where existing land use is commercial, industrial, institutional, or multi-family residential, is governed by special sizing criteria depending on the increase or decrease in impervious area created by the redevelopment.
- Certain industrial sites are required to prepare and implement a storm water pollution prevention plan (SWPPP) and file a notice of intent (NOI) under the provisions of Maryland's Storm Water NPDES general permit. The SWPPP requirement applies to both existing and new industrial sites.
- Runoff from land uses or activities with higher potential for pollutant loadings, sometimes referred to as hotspots, may require the use of specific structural runoff control and pollution prevention practices. In addition, runoff from a hotspot land use may not be infiltrated without proper pretreatment.
- In Maryland, local governments are usually responsible for storm water management review authority. Prior to design, applicants should always consult with their local reviewing agency to determine if they are subject to additional storm water design requirements. In addition, certain earth disturbances may require NPDES construction general permit coverage from MDE.

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Delaware Urban Runoff Management Model

The Delaware Department of Natural Resources and Environmental Conservation (2005) developed the Delaware Urban Runoff Management Model (DURMM) to quantitatively estimate how "green technology" management practice designs achieve pollutant removal and flow reductions. Green technology includes the following management practices:

- Conservation site design
- Source area disconnection
- Biofiltration swales/grassed swales
- Terraces
- Bioretention structures
- Infiltration practices

These green technologies address some of the drawbacks of traditional runoff controls, including the following:

- Ponds and wetlands do not necessarily protect against streambank erosion
- Ponds and wetlands do not recharge groundwater.
- Ponds and wetlands require substantial land area
- Ponds and wetlands require significant maintenance.
- Discharges from multiple structural practices can overlap, resulting in downstream flooding.
- Discharges can elevate stream temperatures and sometimes contain high levels of algae.

DURMM provides a quantitative approach to define the benefits of conservation design and quantifies runoff reductions and pollutant reductions from filter strips, biofiltration and grassed swales, terraces, bioretention structures, and infiltration trenches. It also quantifies runoff reductions from source area disconnection. The Delaware Department of Natural Resources and Environmental Conservation is also developing a companion document specifically focused on riparian buffer system design.

Additional information on green technology BMPs or DURMM can be obtained by contacting Delaware's Division of Soil & Water Conservation at 302-739-4411.

5.2.3 General Categories of Urban Runoff Control

Structural practices to control urban runoff rely on several basic mechanisms:

- Infiltration;
- Filtration;
- Detention/retention; and
- Evaporation.

5.2.3.1 Infiltration practices

Infiltration facilities are designed to capture a treatment volume of runoff and percolate it through surface soils into the ground water system. This process:

- Reduces the total volume of runoff discharged from the site, which, in turn, decreases peak flows in storm sewers and downstream waters;

- Filters out sediment and other pollutants by various chemical, physical, and biological processes as runoff water moves through the bottom of the infiltration structure and into the underlying soil; and

- Augments ground water reserves by facilitating aquifer recharge. Groundwater recharge is vital to maintain stream and wetland hydrology. During dry weather, ground water recharge helps to assure baseflow necessary for survival of biota in wetlands and streams.

Treatment effectiveness depends on whether the facility is sited on-line or off-line, and on the sizing criteria used to design the facilities. Online systems receive all of the runoff from an area. Off-line practices receive diverted runoff for treatment and isolate it from the remaining fraction of runoff, which must still be controlled to prevent flooding. Off-line infiltration practices prevent all of the TSS and other pollutants contained in the volume of runoff infiltrated from exiting the site. Thus, the total annual load reduction depends on how much of the annual volume of runoff is diverted to the infiltration structure. On-line infiltration practices, on the other hand, have lower treatment effectiveness, averaging approximately 75 percent removal of TSS (WMI, 1997b).

The overall hydrologic benefits of infiltration practices may also vary depending on site characteristics and the frequency and intensity of storms. Holman-Dodds et al. (2003) modeled the potential for infiltration techniques to reduce the adverse hydrologic effects of urbanization. The study indicated that the greatest reductions in flow are achievable when rainfall is limited and relatively frequent, and when soils are relatively porous.

Infiltration facilities require porous soils (i.e., sands and gravels) to function properly. Generally, they are not suitable in soils with 30 percent or greater clay content or 40 percent or greater silt/clay content (WMI, 1997b). They are also not suitable:

- In areas with high water tables;
- In areas with shallow depth to impermeable soil layers;
- On fill sites, which have low permeability, or on steep slopes;
- In areas where infiltration of runoff would likely contaminate ground water;
- In areas where there is a high risk of hazardous material spills; or

- Where additional groundwater could form sinkholes.

Special protection for ground water is needed when runoff is used as a drinking water source in urban areas (see Management Measure 3—Watershed Protection). Certain types of infiltration facilities, called Class V injection wells, may be regulated as part of the federal Underground Injection Control (UIC) Program, authorized by the Safe Drinking Water Act. Class V wells discharge fluids underground. Class V wells include French drains, tile drains, infiltration sumps, and percolation areas with vertical drainage. Dry wells, bored wells, and infiltration galleries are all Class V wells. Class V wells do not include infiltration trenches filled with stone (with no piping), or excavated ponds, lagoons, and ditches (lined or unlined, without piping or drain tile) with an open surface. Compliance with federal regulations may include submitting basic inventory information about the drainage wells to the state or EPA and complying with specific construction, operation, permitting, and closure requirements (USEPA, 2003). Any questions

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regarding the applicability of the UIC regulations to a storm water facility should be directed to federal or state UIC contacts. This information is available at http://www.epa.gov/safewater/uic.html.

The effect of infiltration practices on ground water quality is unclear, but a few studies exist that indicate potential ground water quality concerns from infiltrating urban runoff (Pitt, et al., 1994; Fischer, no date; Ging et al., 1997, Morrow, 1999). For example, Fischer (no date) studied the effects of infiltration of urban runoff on ground water quality in the New Jersey Coastal Plain. He found that although many pollutants were removed from runoff before reaching the water table, elevated concentrations and occurrences of certain compounds and ions indicated contributions from urban runoff, implying that infiltration practices could have a detrimental effect on ground water quality. Conversely, Fischer hypothesized that infiltrating runoff would have the beneficial effect of diluting other compounds frequently present in ground water.

Pitt et al. (1994) summarized the potential for 25 pollutants to contaminate ground water, categorizing each as low, low/moderate, moderate, or high. Of these 25 pollutants, only one, chloride, has a high potential, and only fluoranthene and pyrene have a moderate potential. Nitrate, a highly soluble and mobile contaminant, was categorized as having a low/moderate potential for contamination, and the other 21 pollutants had low potential.

Heavy metals and hydrocarbons may pose a low risk of contamination, but several studies have indicated that concentrations of these pollutants decrease rapidly with depth (Barraud et al., 1999; Legret et al. 1999). Similarly, Dierkes and Geiger (1999) found that polycyclic aromatic hydrocarbons (PAHs) in highway runoff were removed in the top four inches of soil.

The presence of volatile organic compounds (VOCs) in ground water is another concern. A USGS study (Ging et al., 1997) analyzed the occurrence and distribution of VOCs in ground water in south-central Texas. Although less than 50 percent of the samples taken had VOC detections, 28 VOCs were detected in samples from 89 wells. Based on the results of this study, VOC contamination in ground water appears to be associated with urban development (Ging et al., 1997).

VOC contamination has also been detected in the ground water of the Lower Illinois River Basin. In 1996, water samples collected from 60 wells in the basin were sampled and analyzed for VOCs. There were only six VOC detections in more than 4,300 analyses of the ground water samples (although at least three of these detections may have been caused by well disinfection practices). Additionally, a VOC was detected in one sample from deep glacial drift, indicating that shallow aquifers may be more susceptible to VOC contamination than deep aquifers. Based on these results, the authors concluded that VOC contamination does not appear to be a major concern for ground water quality in rural areas of the Lower Illinois River Basin (Morrow, 1999).

Several studies have found that the potential for ground water contamination, particularly from heavy metals and hydrocarbons, is low when porous pavement and stone-filled subsurface infiltration beds are used. These systems provide treatment through adsorption, filtration, sedimentation, and biodegradation before runoff reaches the underlying soil (Balades et al., 1995; Legret and Colandini, 1999; Newman et al., 2002; Pratt et al., 1999; Swisher, 2002).

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5.2.3.2 Filtration practices

Filtration practices are so named because they filter particulate matter from runoff. The most common filtering medium is sand, but other materials, including peat/sand combinations and leaf compost material, have been used. Filtration systems provide only limited flood storage; therefore, they are most often implemented in conjunction with other types of quantity control management practices. Most filtration techniques require a forebay or clarifier to remove larger particles in runoff from clogging the filter media.

Biofiltration refers to practices that use vegetation and amended soils to retain and treat runoff from impervious areas. Treatment is through filtration, infiltration, adsorption, ion exchange, and biological uptake of pollutants.

5.2.3.3 Detention/retention practices

Runoff *detention* facilities provide pollutant removal by temporarily capturing runoff and allowing particulate matter to settle prior to release to surface waters. Dry detention runoff management ponds are one type of detention facility. Peak flows are reduced in drainage systems/receiving waters downstream of detention facilities.

Runoff *retention* facilities are used to capture runoff, which is subsequently withdrawn or evaporated. Therefore, peak flows and total flow volume can be reduced in downstream drainage systems/receiving waters. Wet runoff management ponds are one type of retention facility. These retention facilities can be designed to accept flow from receiving streams/drainage systems offline.

Both detention and retention facilities can use biological uptake as a mechanism for pollutant removal. Runoff management ponds can be designed to control the peak discharge rates, thereby reducing excessive flooding and downstream erosion in reaches of the drainage system/receiving stream immediately downstream. At some point downstream, however, runoff flow that is not retained will increase the volume of total flow, thereby increasing the risk of flooding and erosion if the receiving stream at that point does not have a stable channel and riparian area or floodplain.

Constructed wetlands are engineered systems designed to employ the water quality improvement functions of natural wetlands to treat and contain surface water runoff pollution and decrease pollutant loadings to surface waters. They can be designed with extended detention to control runoff peak flow and volume. Where site-specific conditions allow, constructed wetlands and retention basins should be located to minimize the impact on the surrounding areas (e.g., in upland areas of the watershed). Ponds, constructed wetlands, and other structural management practices degrade the functions of natural buffer areas and natural wetlands, and they may also interrupt surface water and ground water flow when soils are disturbed for installation. Therefore, the placement of structural management practices in natural buffers and natural wetlands should be avoided where possible.

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5.2.3.4 Evaporation practices

Runoff detention and retention facilities and other practices that temporarily store runoff can also evaporate it. Evaporation from runoff detention and retention areas such as rooftops, streets, basins, and ponds can be an important mechanism for runoff management in warm, dry climates.

5.3 Management Practices

Management practices to control urban runoff can be classified in seven categories. The following practices are described for illustrative purposes only. EPA has found these practices to be representative of the types of practices that can be applied successfully to achieve the new development runoff treatment management measure. As a practical matter, EPA anticipates that the management measure can be achieved by applying one or more management practices appropriate to the source(s), location, and climate. Thus, practices that by themselves do not achieve 80 percent TSS removal can be combined with other practices to achieve 80 percent removal (such that x + y + z = 80 percent). This is the "treatment train" approach, in which several types of practices are used together and integrated into a comprehensive runoff management system (WMI, 1997b). The seven categories include:

- Infiltration practices;
- Vegetated open channel practices;
- Filtering practices;
- Detention ponds or vaults;
- Retention ponds;
- Wetlands; and
- Other practices such as water quality inlets.

5.3.1 Infiltration Practices

These practices capture and temporarily store runoff before allowing it to infiltrate into the soil over several days. Design variants include:

- Infiltration basins;
- Infiltration trenches; and
- Pervious or porous pavements.

To prevent premature clogging, these practices must not receive drainage from a construction activity or site. Infiltration practices can be placed in service after the construction activity is complete or the site is stabilized.

5.3.1.1 Infiltration basins

Infiltration basins (Figure 5.1) are impoundments created by excavation or creation of berms or small dams. They are typically flat-bottomed with no outlet and are designed to temporarily store runoff generated from adjacent drainage areas (from 2 to 50 acres, depending on local conditions). Runoff gradually infiltrates through the bed and sides of the basin, ideally within 72 hours, to maintain aerobic conditions and ensure that the basin is ready to receive runoff from the

next storm. Infiltration basins are often used as an off-line system for treating the first flush of runoff flows or the peak discharges of the two-year storm.

The key to successful operation is keeping the soils on the floor and side slopes of the basin unclogged to maintain the rate of percolation. This is usually much easier said than done. For example, Schueler (1992) reported infiltration basin failure rates ranging from 60 to 100 percent

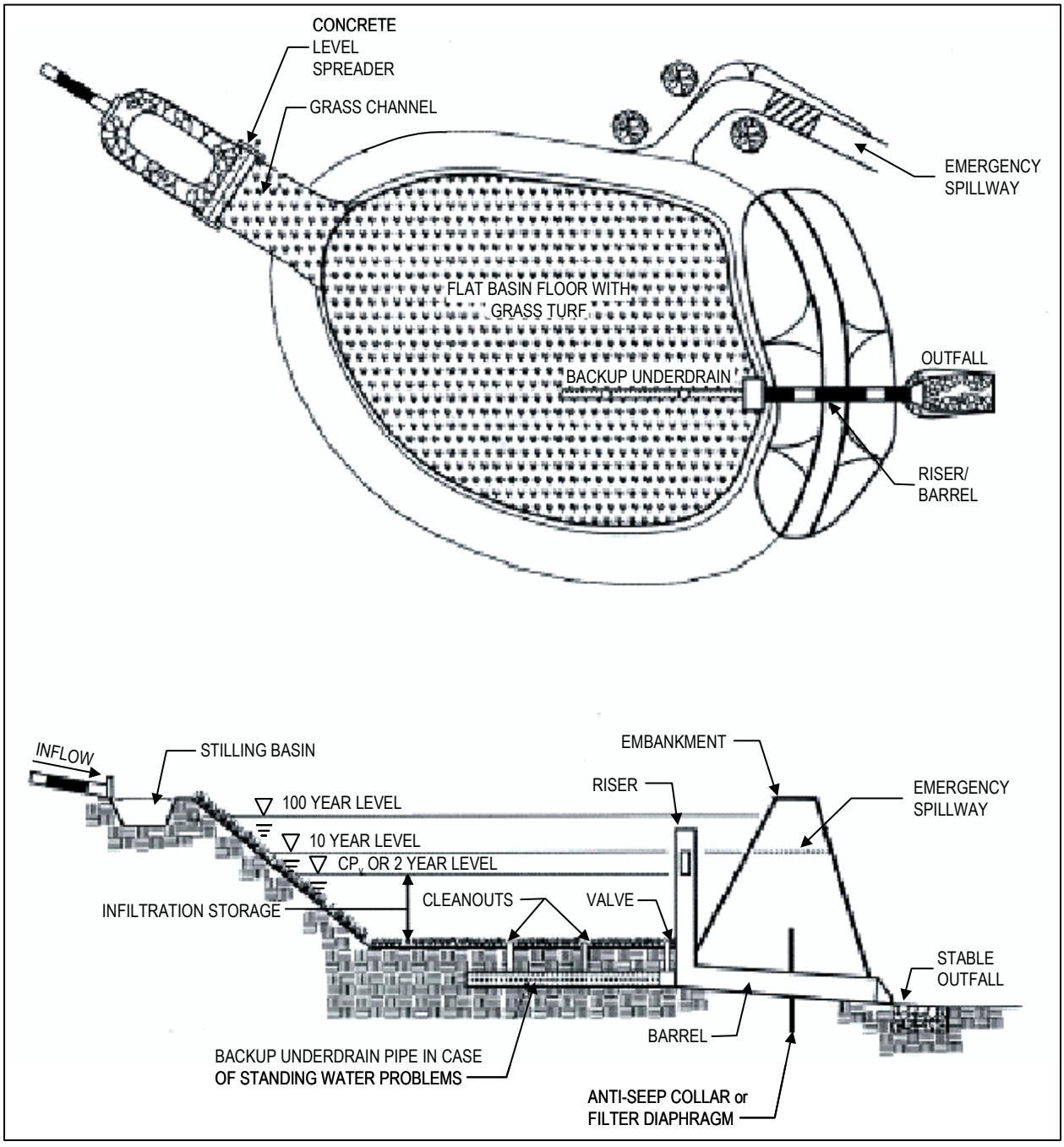

Figure 5.1: Schematic of an infiltration basin (MDE, 2000).

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in the mid-Atlantic region. To help keep sediment out of the basin, incoming runoff should be pretreated using vegetated filter strips, a settling forebay, or other techniques. Grasses or other vegetation should also be planted and maintained in the basin. If soil pores become clogged, the basin bottom should be roughened or replaced to restore percolation rates.

5.3.1.2 Infiltration trenches

Infiltration trenches (Figure 5.2) are shallow (2- to 10-feet deep) excavated ditches with relatively permeable soils that have been backfilled with stone to form an underground reservoir. The trench surface can be covered with a grating or can consist of stone, gabion, sand, or a grass-covered area with a surface inlet. Runoff diverted into the trench gradually infiltrates into the subsoil and, eventually, into the ground water. Trenches can be used on small, individual sites or for multi-site runoff treatment. Pretreatment controls such as vegetated filter strips should be incorporated into the design to remove sediment and reduce clogging of soil pores. More expensive than pond systems in terms of cost per volume of runoff treated, infiltration trenches are best-suited for drainage areas of less than 5 to 10 acres, or where ponds cannot be used.

Variations in the design of infiltration trenches include dry wells, which are pits designed to control small volumes of runoff (such as rooftop runoff) and exfiltration trenches. A typical dry well design includes a perforated pipe 3 to 4 feet in diameter that is installed vertically in deposits of gravely/sandy soil. Rock is then backfilled around the base of the well. An exfiltration trench is an infiltration trench that stores runoff water in a perforated or slotted pipe and percolates it out into a surrounding gravel envelope and filter fabric. Dry wells and other infiltration practices that involve subsurface drainage may be regulated by EPA's Underground Injection Control Program. See the EPA's Underground Injection Control Program Web site at http://www.epa.gov/safewater/uic.html for more information.

5.3.1.3 Pervious or porous pavements

Pervious pavement has the approximate strength characteristics of traditional pavement but allows rainfall and runoff to percolate through it. The key to the design of these pavements is the elimination of most of the fine aggregate found in conventional paving materials. There are two types of pervious pavement, porous asphalt and pervious concrete (WMI, 1997b). Porous asphalt has coarse aggregate held together in the asphalt with sufficient interconnected voids to yield high permeability. Pervious concrete, in contrast, is a discontinuous mixture of Portland cement, coarse aggregate, admixtures, and water that also yields interconnected voids for the passage of air and water. Underlying the pervious pavement are a filter layer, a stone reservoir, and a filter fabric. Stored runoff gradually drains out of the stone reservoir into the subsoil. Figure 5.3 shows several types of porous pavement. More information about pervious pavement can be found at http://www.gcpa.org/pervious_concrete_pavement.htm (Georgia Concrete & Products Association, 2003).

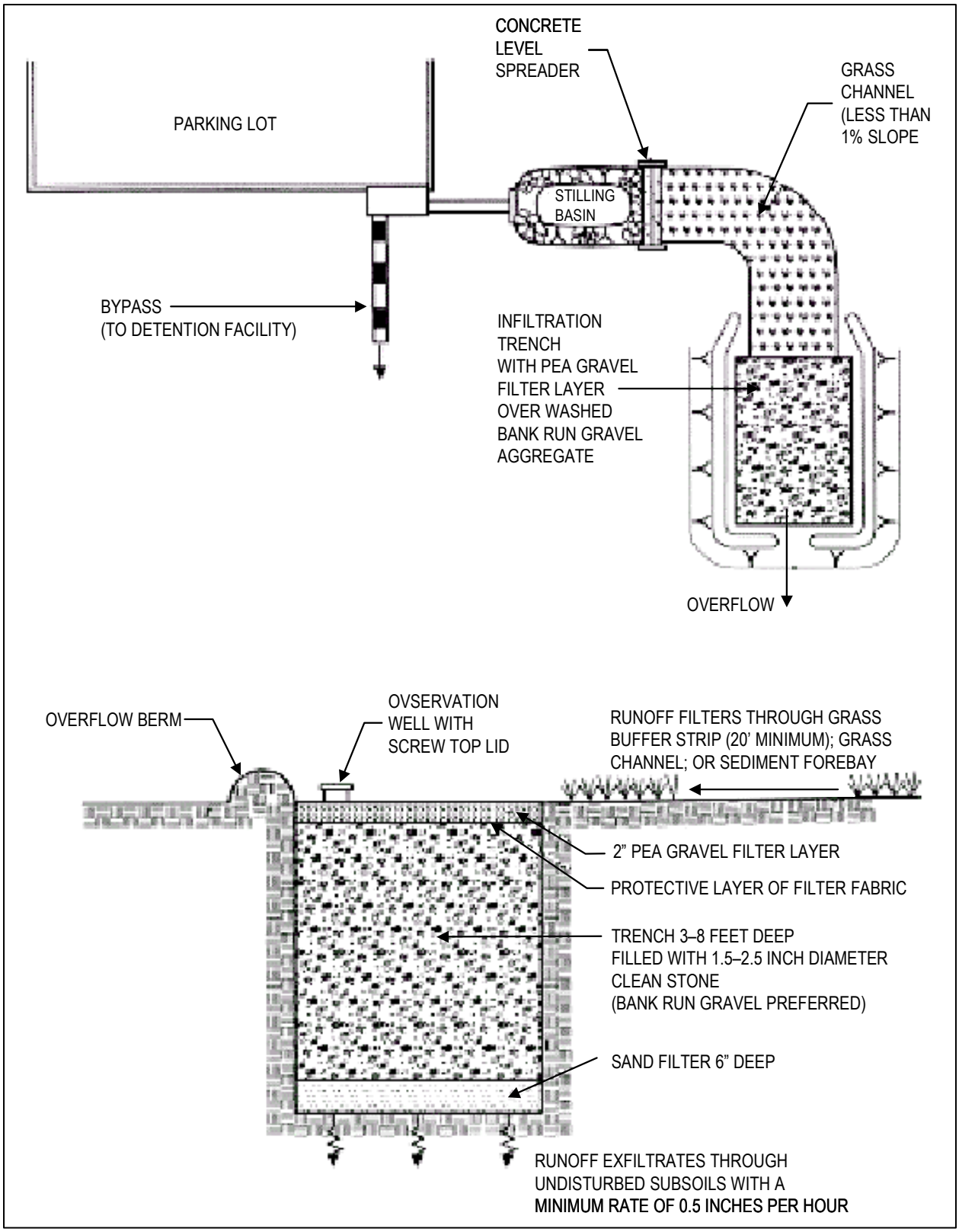

Figure 5.2: Schematic of an infiltration trench (MDE, 2000).

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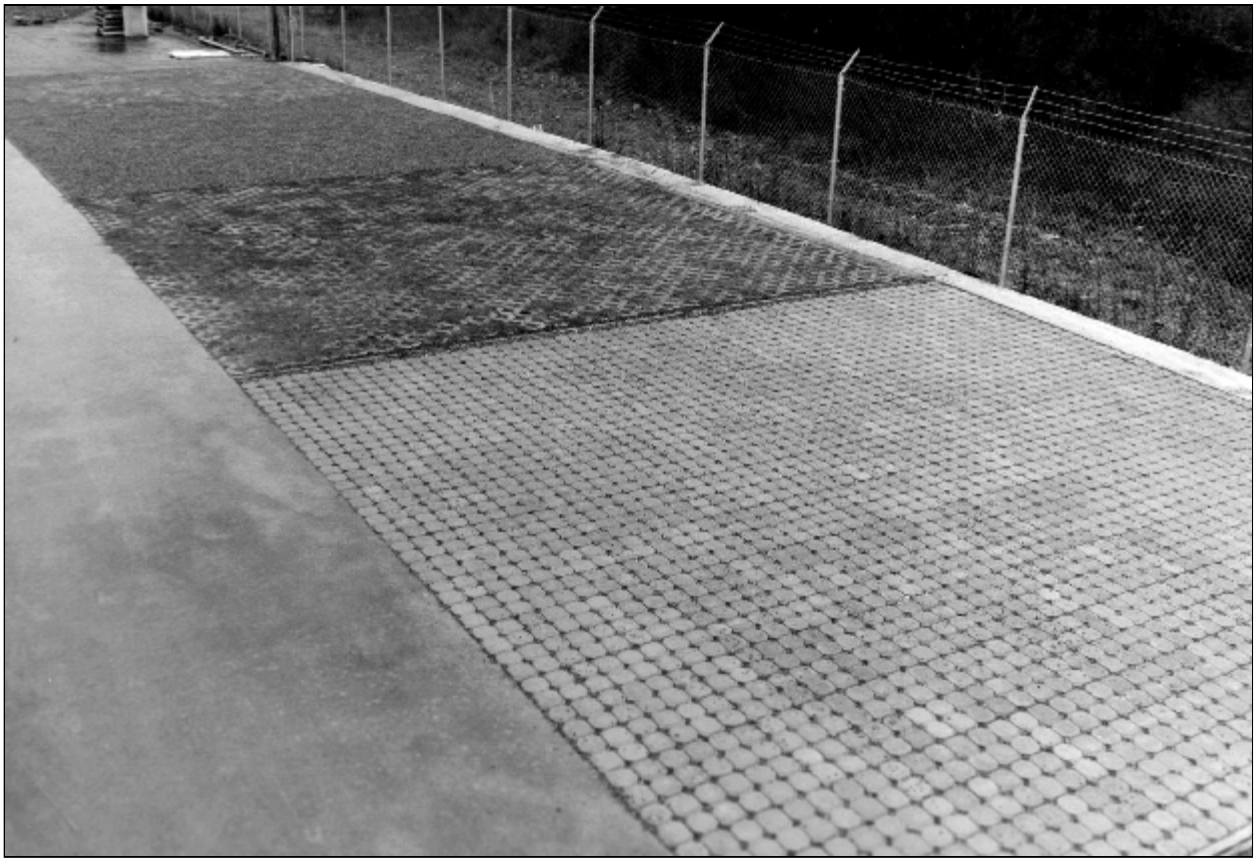

Figure 5.3: Photo showing several types of pervious modular pavement installations.

Modular pavement consists of individual blocks made of pervious material such as sand, gravel, or sod interspersed with strong structural material such as concrete. The blocks are typically placed on a sand or gravel base and designed to provide a load-bearing surface that is adequate to support personal vehicles, while allowing infiltration of surface water into the underlying soils. They usually are used in low-volume traffic areas such as overflow parking lots and lightly used access roads. An alternative to pervious and modular pavement for parking areas is a geotextile material installed as a framework to provide structural strength. Filled with sand and sodded, it provides a completely grassed parking area. More information about concrete pavers can be found at http://www.concretenetwork.com/concrete/porous_concrete_pavers/ (Concretenetwork.com, 2003).

Some states no longer promote the use of porous pavement because it tends to easily clog with fine sediments (Washington Department of Ecology, 1991). If this type of pavement is installed, a vacuum-type street sweeper should be used regularly to maintain porosity. Frequent washing with a high-pressure jet of water can also keep pores clear of clogging sediments. Sites where pervious pavement is to be installed must have deep, permeable soils, slopes of less than 5 percent, and no heavy vehicle traffic.

The City of Kinston, North Carolina, installed a permeable pavement parking lot as a demonstration and research project and to meet the daily parking needs of city employees (Hunt and Stevens, 2001). The final parking lot design included 26 stalls; 20 of the stalls were

The Bath Club Concourse Storm Water Rehabilitation Project, Florida

The Bath Club Concourse is located on a small barrier island community in North Redington Beach, Florida. A combination roadway and parking area, which connects Bath Club Circle and Gulf Boulevard, was previously an impervious slab of concrete pavement. The concourse could not absorb falling rain, which caused runoff to flow directly into a single storm sewer. The sewer would then carry pollutants directly to Boca Ciega Bay. In August 1990, the Water Management District and the town agreed to construct a stormwater rehabilitation project using pervious concrete pavement at the Bath Club Concourse (USEPA, 1999).

The main objective of the rehabilitation project was to reduce nonpoint source pollutant loading by reducing the volume of runoff discharging directly into Boca Ciega Bay. A second objective was to demonstrate an innovative way to treat or improve the quality of runoff in highly urbanized areas, where it can sometimes be difficult or expensive to manage runoff because of land constraints.

To maximize infiltration of runoff and reduce the amount of untreated runoff discharged directly into storm sewers, drainage was directed toward two pervious concrete parking areas. These areas were separated by an unpaved island in the center of the concourse, which also provides infiltration. Engineers installed two 150-foot under-drains to maximize infiltration by allowing subsurface soils to drain beneath the parking areas.

The rehabilitation project resulted in a significant reduction of direct discharge of runoff from the site. Estimates indicate that these improvements resulted in a 33 percent reduction in total on-site runoff volume. Additionally, the volume of surface runoff discharging directly to Boca Ciega Bay was reduced by nearly 75 percent. Overall removal efficiencies for the project, which are based on the pollutant removal efficiency of the under-drain/filter system, indicate that the project can remove 73 percent of lead (Bateman et al., no date). Other removal efficiencies and additional information about the project are available at http://www.stormwaterauthority.org/assets/103BFloridaRetrofits.pdf.

constructed using a concrete block paver filled with and overlaying sand, while the other six were constructed using a plastic grid paver with sandy soil and Bermuda grass. Monitoring results from a two-year study showed a 3- to 5-time reduction in peak runoff for storms greater than 0.5 inches based on calculated runoff coefficients (using the rational method). Of 48 rainstorms, only 11 (less than 25 percent) resulted in runoff generated from the parking lot The researchers found that annual maintenance to scarify the surface of the lot with a street sweeper helps to maximize permeability of the pavement. More information about the study, including several design recommendations, can be found at http://www5.bae.ncsu.edu/programs/extension/wqg/issues/101.pdf.

Brattebo and Booth (2003) examined the long-term effectiveness of permeable pavement by testing four commercially available permeable pavement systems for six years of regular parking use. The systems included the following:

- A flexible plastic grid system with virtually no impervious area, filled with sand and planted with grass;
- An equivalent plastic grid, filled with gravel;
- A concrete block lattice with approximately 60 percent impervious coverage, filled with soil and planted with grass; and

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- Small concrete blocks with approximately 90 percent impervious coverage, with the spaces between blocks filled with gravel.

At the end of the study, none of the systems showed major signs of wear. The pavements infiltrated nearly all rainwater, generating almost no surface runoff. The researchers compared the quality of infiltrated water to surface runoff from an asphalt area and found significantly lower levels of copper and zinc in the infiltrated water. Motor oil was not detected in infiltrated water but was detected in 89 percent of samples of surface runoff from asphalt. Measurements of infiltrated rainwater from five years earlier showed significantly higher concentrations of zinc and lower concentrations of copper and lead.

5.3.2 Vegetated Open Channel Practices

Vegetated open channels are explicitly designed to capture and treat runoff through infiltration, filtration, or temporary storage.

A vegetated swale is an infiltration practice that usually functions as a runoff conveyance channel and a filtration practice. It is lined with grass or another erosion-resistant plant species that serves to reduce flow velocity and allow runoff to infiltrate into ground water. The vegetation or turf also prevents erosion, filters sediment, and provides some nutrient uptake benefits. These practices are also known as biofiltration swales. Check dams are often used to reduce flow velocity. When used, sediment that collects behind check dams should be removed regularly.

Two types of channels are typically used in residential landscapes:

- *Grass channels*. These have dense vegetation, a wide bottom, and gentle slopes (Figure 5.4). Usually they are intended to detain flows for 10 to 20 minutes, allowing sediments to filter out.

- *Dry swales*. As with grass channels, runoff flows into the channel and is subsequently filtered by surface vegetation (Figure 5.5). From there, runoff moves downward through a bed of sandy loam soil and is collected by an underdrain pipe system. The treated water is delivered to a receiving water or another structural control. Dry swales are used in large-lot, single-family developments and on campus-type office or industrial sites. They are applicable in all areas where dense vegetative cover can be maintained. Because of a limited ability to control runoff from large storms, they are often combined with other structural practices. They should not be used in areas where flow rates exceed 1.5 feet per second unless additional erosion control measures, such as turf reinforcement mats, are used.

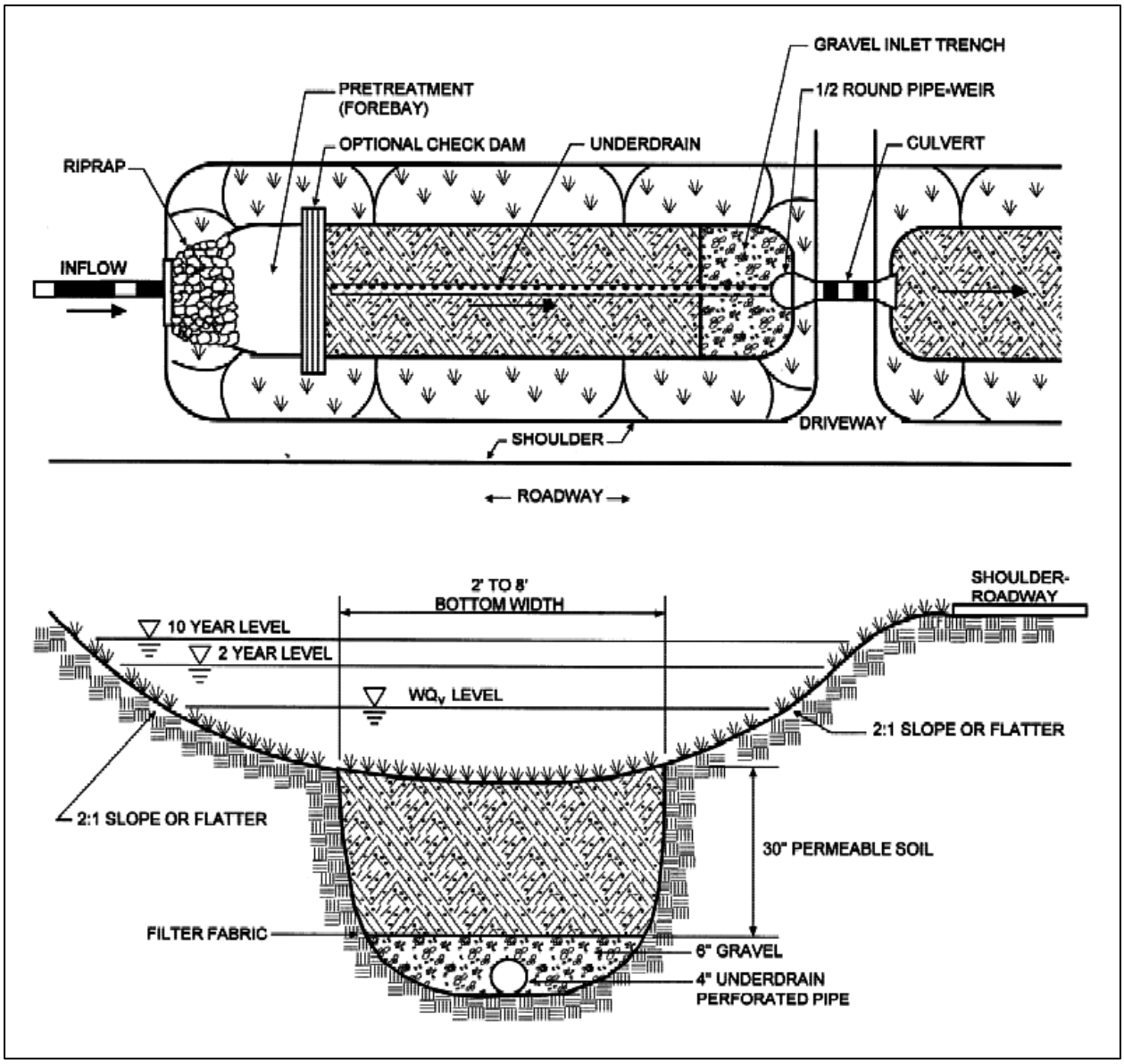

Figure 5.4: Schematic of a grass channel (Claytor and Schueler, 1996).

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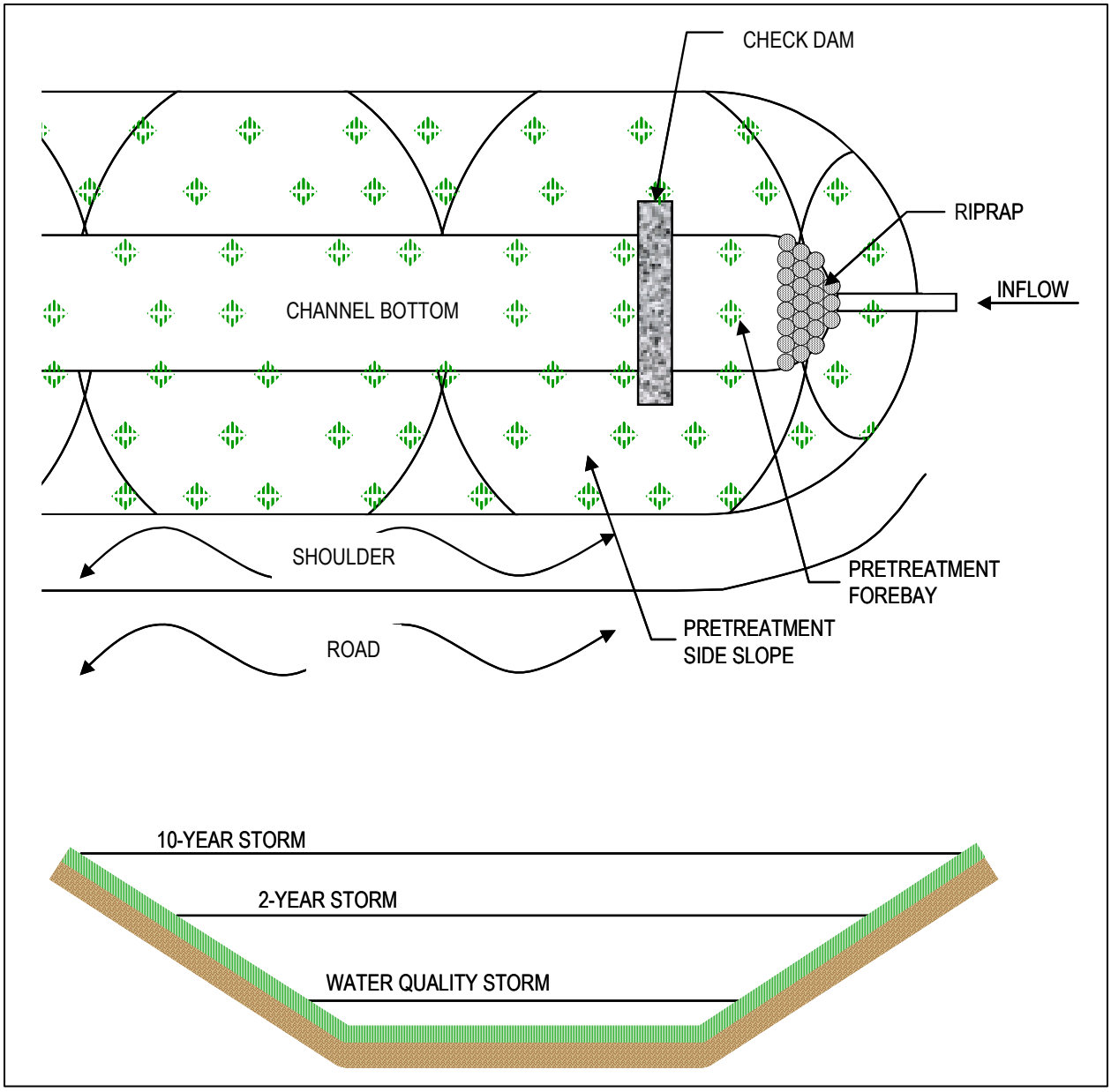

Figure 5.5: Schematic of a dry swale (adapted from MDE, 2000).

In a research study conducted by J.F. Sabourin and Associates (1999), two grass swale/perforated pipe systems and one conventional curb-and-gutter system were compared. Flow monitoring results indicate that much less water reached the outlet of the perforated pipe systems than the conventional system. Peak flows and total runoff volumes from the outlet of the perforated pipe/grass swale system were 2 to 6 percent of those of the conventional system, and total runoff volumes were 6 to 30 percent of conventional system volumes. Water quality monitoring results indicate that for most elements, concentrations measured in the perforated pipes were the same or lower than in the conventional system. Chloride concentrations were found to be higher in the perforated pipe system, most likely from the use of road salt. However, a loading analysis indicated that the perforated pipes released significantly fewer pollutants than the conventional system.

The authors also performed video inspections of the swale/perforated pipe sewershed. These inspections revealed a few interesting issues that can affect the performance of perforated pipe systems. Several unauthorized sanitary sewer connections had been made by some residents, and several raccoons were found living inside the pipes. Both can contribute to nutrient and pathogen problems in receiving waters.

J.F. Sabourin and Associates concluded that infiltration capacities of grass swales are optimum when they allow for proper drainage and hold enough moisture for sustaining grass and plant life. Exfiltration tests indicated that runoff volumes can be reduced by 40 to 60 percent by grass swales and perforated pipe drainage systems. With a direct connection, peak outflows can be 45 percent of the inflow.

5.3.3 Filtering Practices

Filtering practices capture and temporarily store runoff and pass it through a filter bed of sand, organic matter, soil, or other media. Filtered runoff may be collected and returned to the conveyance system, or allowed to exfiltrate into the soil. Design variants include:

- Surface sand filter;
- Underground sand filter;
- Organic filter;
- Pocket sand filter; and
- Bioretention areas.

5.3.3.1 Filtration basins and sand filters

Filtration basins are impoundments lined with a filter medium such as sand or gravel. Runoff drains through the filter medium and through perforated pipes into the subsoil. Detention time is typically four to six hours. Sediment-trapping structures are often used to prevent premature clogging of the filter medium (NVPDC, 1980; Schueler et al., 1992).

Sand filters are usually two-chambered practices: the first is a settling chamber and the second is a filter bed filled with sand or another filtering medium. As runoff flows into the first chamber, large particles settle out and finer particles and other pollutants are removed as runoff flows through the filtering medium. There are several modifications of the basic sand filter design, including the surface sand filter, underground sand filter, perimeter sand filter, organic media filter, and multi-chambered treatment train (Robertson et al., 1995). All of these filtering practices operate on the same basic principle. Modifications to the traditional surface sand filter were made primarily to fit sand filters into more challenging site designs (e.g., underground and perimeter filters) or to improve pollutant removal (e.g., organic media filter). The following are design variations for sand filtration devices:

(1) *Surface sand filter*. The surface sand filter (Figure 5.6) is an aboveground filter design. Both the filter bed and the sediment chamber are aboveground. The surface sand filter is designed as an off-line practice; only the water quality volume is directed to the filter. The surface sand filter is the least-expensive filter option and has been the most widely used.

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(2) *Underground sand filter*. The underground sand filter (Figure 5.7) is a modification of the surface sand filter, where all of the filter components are underground. Like the surface sand filter, this practice is an off-line system that receives only flows from small rainstorms. Underground sand filters are expensive to construct but consume very little space. They are well-suited to highly urbanized areas, and often included in groups of practices known as "ultra-urban BMPs."

(3) *Perimeter sand filter*. The perimeter sand filter (Figure 5.8) also includes the basic design elements of a sediment chamber and a filter bed. In this design, however, flow enters the system through grates, usually at the edge of a parking lot. The perimeter sand filter is the only filtering option that is on-line; all flow enters the system, but a bypass to an overflow chamber prevents system flooding. One major advantage of the perimeter sand filter design is that it requires little hydraulic head and thus is a good option in areas of low relief.

(4) Organic media filter. Organic media filters (Figure 5.9) are essentially the same as surface filters, with the sand replaced with or supplemented by another medium. Two examples are the peat/sand filter (Galli, 1990) and the compost filter system. It is assumed that these systems will provide enhanced pollutant removal for many compounds because of the increased cation exchange capacity achieved by increasing organic matter content.

(5) *Multi-chambered treatment train*. The multi-chambered treatment train (Figure 5.10) is essentially a "deluxe sand filter" (Robertson et al., 1995). This underground system consists of three chambers. Runoff enters into the first chamber where screening occurs, trapping large sediments and releasing highly volatile materials. The second chamber provides settling of fine sediments and further removal of volatile compounds and floatable hydrocarbons through the use of fine bubble diffusers and sorbent pads. The final chamber provides filtration by using a sand and peat mixed medium for reduction of the remaining pollutants. The top of the filter is covered by a filter fabric that evenly distributes the water volume and prevents channelization. Although this practice can achieve very high pollutant removal rates, it might be prohibitively expensive in many areas. It has been implemented only on an experimental basis.

(6) *Exfiltration/partial exfiltration.* In exfiltration designs, all or part of the underdrain system is replaced with an open bottom that allows infiltration to the ground water. When the underdrain is present, it is used as an overflow device in case the filter becomes clogged. These designs are best applied in the same soils where infiltration practices are used.

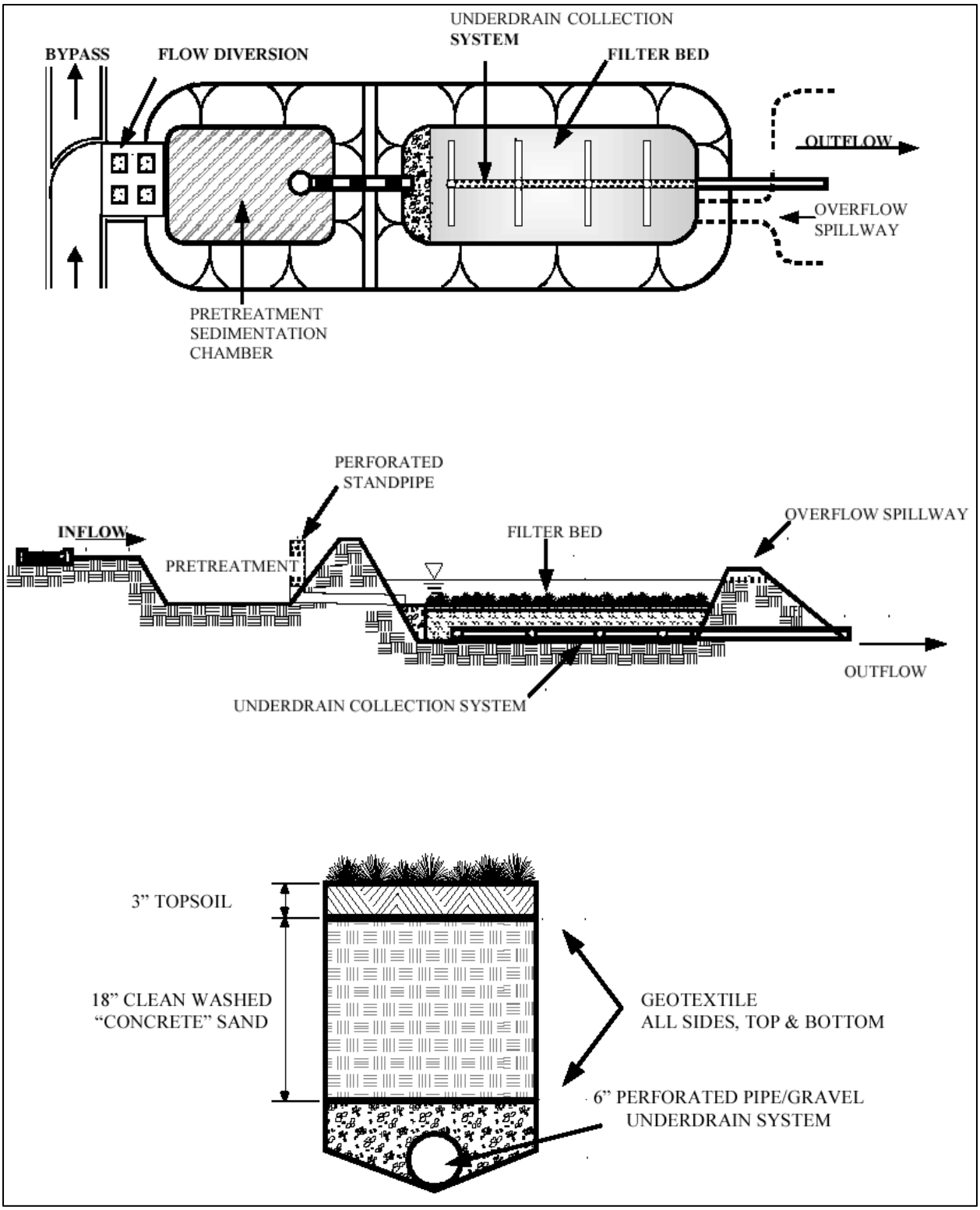

Figure 5.6: Schematic of a surface sand filter (MDE, 2000).

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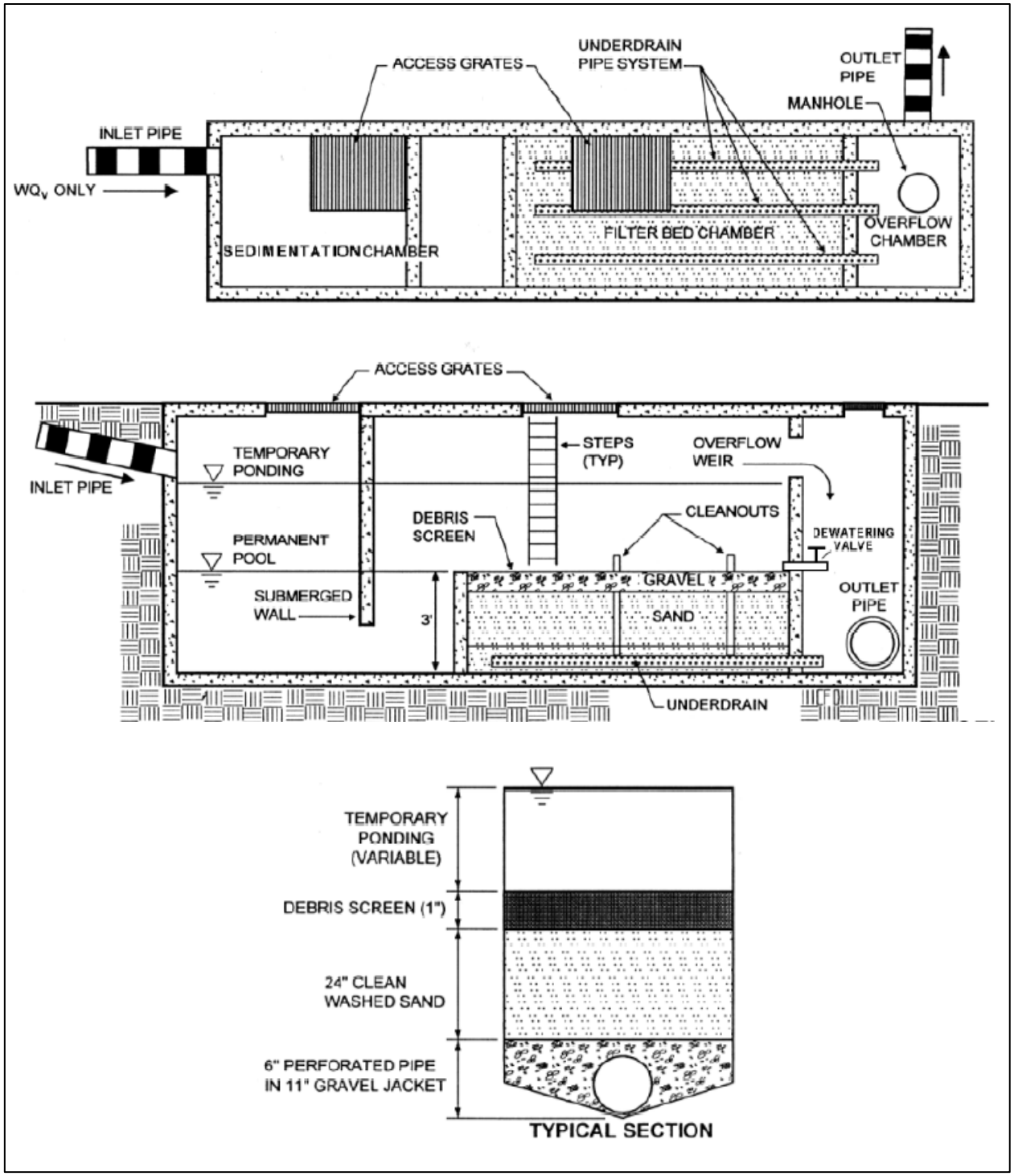

Figure 5.7: Schematic of an underground sand filter (MDE, 2000).

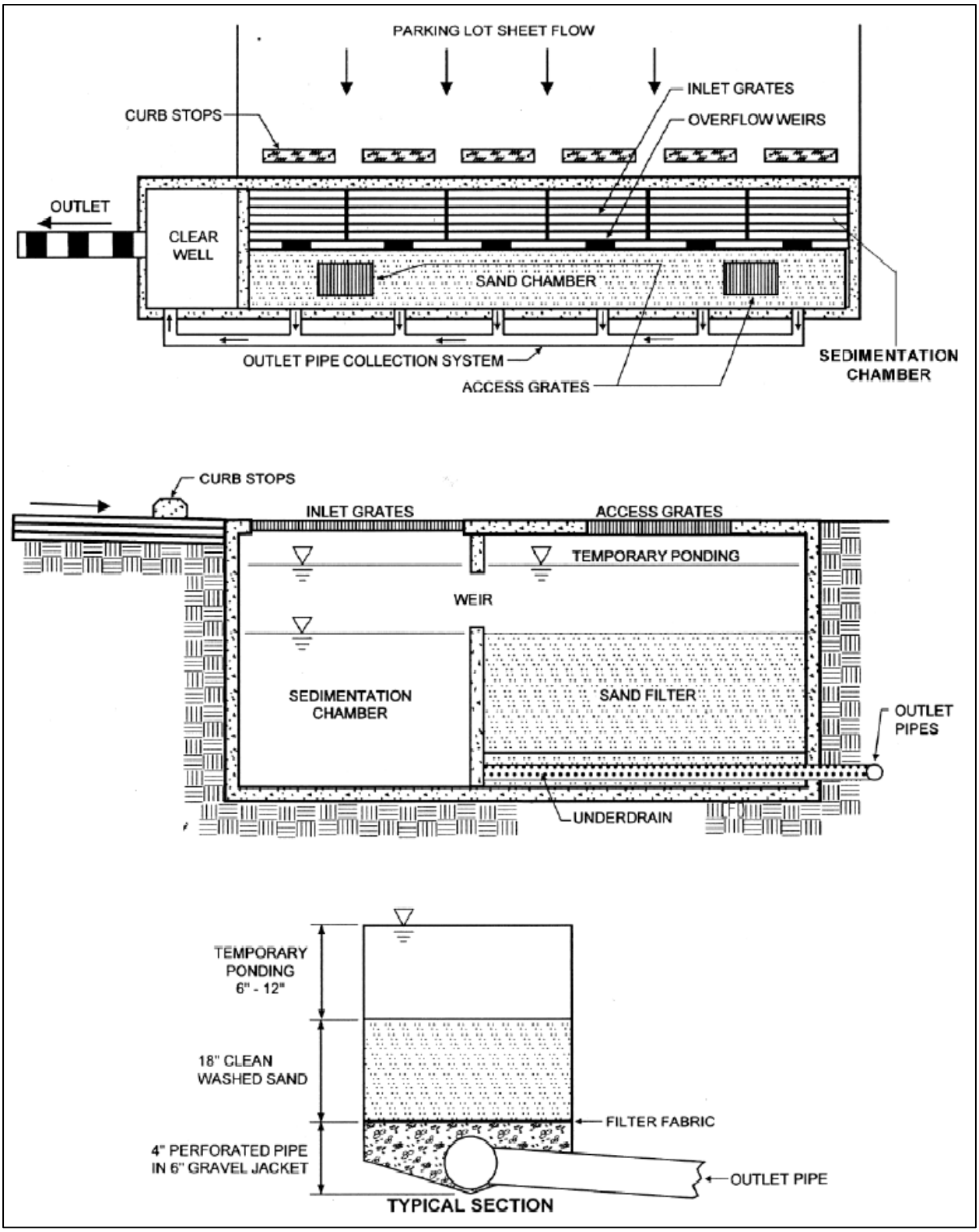

Figure 5.8: Schematic of a perimeter sand filter (MDE, 2000).

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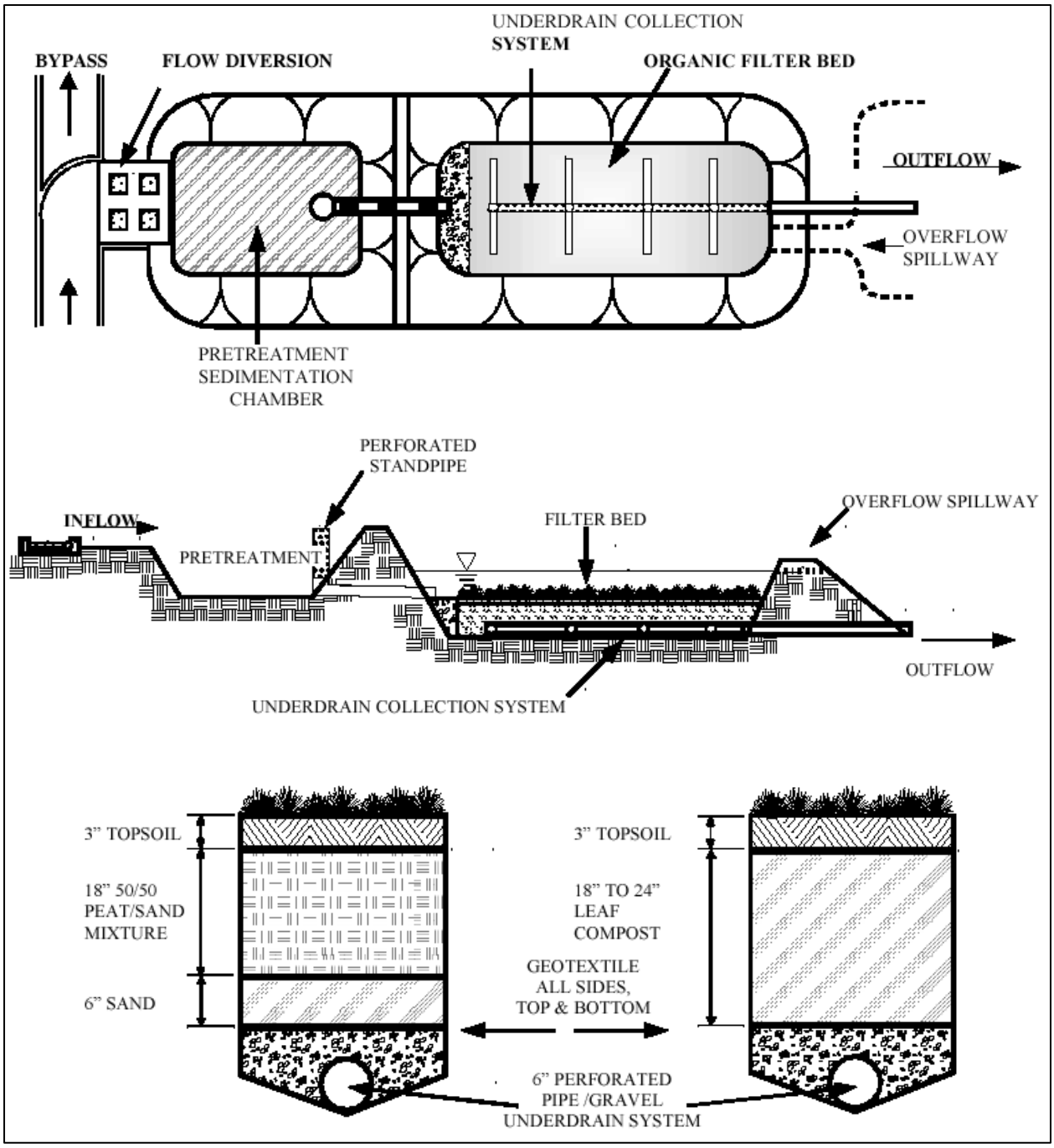

Figure 5.9: Schematic of an organic media filter (MDE, 2000).

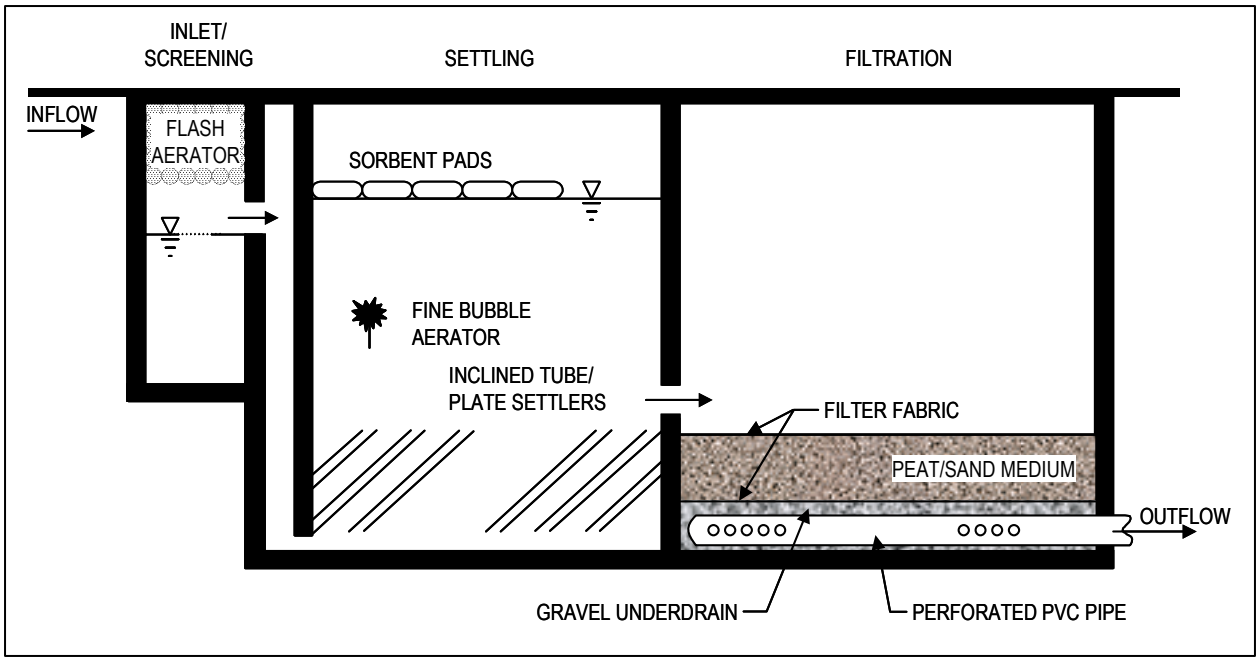

Figure 5.10: Schematic of a multi-chambered treatment train (Pitt, 1996).

5.3.3.2 Media filtration units

Similar to wastewater treatment technology, passive filtration units can be used to capture pollutants from runoff. Media filtration practices commonly use trenches filled with sand or peat. Other media, including types of crushed rock and composted leaves, can also be used. A basin collects the runoff and gradually routes discharge through cartridges filled with filter media. An emergency bypass prevents system flooding during large rainstorms. According to the Unified Sewerage Agency of Washington County in Oregon (WEF, 1998), composted leaf media trap particulates, adsorb organic chemicals, and remove 90 percent of solids, 85 percent of oil and grease, and 82 to 98 percent of heavy metals through cation exchange from leaf decomposition. Similar types of systems with various filter media are available commercially.

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Performance of a Compost Storm Water Treatment System in Hillsboro, Oregon

A compost storm water treatment facility was constructed to treat runoff from 3.9 acres of 5-lane arterial road and 70.1 acres of mixed residential land use in Hillsboro, Oregon (FHWA, no date). The system consists of a discharge pipe that conveys runoff from the drainage area into a forebay. Runoff then flows over a wooden baffle into two consecutive cells filled with Portland leaf compost material. After runoff filters through the compost medium, it is discharged to a rock drainbed separated from the compost by a layer of filter fabric.

Monitoring of the effluent between 1991 and 1994 showed average mass balance pollutant removals of 81 percent for oils and grease, 84 percent for petroleum hydrocarbons, 58 percent to 94 percent for nutrients, and 68 percent to 93 percent for metals. See Table 5.4 for additional pollutant removal results. More details on the design and performance of this study are available at http://www.fhwa.dot.gov/environment/ultraurb/5mcs5.htm.

Table 5.4: Pollutant removal efficiencies for the compost storm water treatment facility from 1991 to 1994.

Parameter		1991-1992	1992-1993	1993-1994
Turbidity	Combined	84.2 %	78.4 %	78.4 %
	First Flush	93.4 %	85.3 %	81.4 %
Total Suspended Solids	Combined	94.8 %	88.5 %	86.0 %
	First Flush	98.3 %	91.4 %	89.0 %
Chemical Oxygen Demand	Combined	66.9 %	76.3 %	74.0 %
	First Flush	89.5 %	82.1 %	79.8 %
Total Phosphorus	Combined	40.5 %	53.2 %	65.5 %
	First Flush	67.3 %	68.9 %	72.9 %
Total Kjeldhal Nitrogen	Combined	55.9 %	50.5 %	66.7 %
	First Flush	84 %	60.8 %	69.0 %
Iron	Combined	89 %	95.5 %	79.6 %
	First Flush	94 %	97.5 %	82.9 %
Chromium	Combined	61.2 %	74.5 %	64.3 %
	First Flush	92.4 %	80.8 %	72.8 %
Copper	Combined	66.7 %	63.5 %	64.1 %
	First Flush	83.7 %	73.9 %	70.7 %
Lead	Combined	N/A	85.1 %	81.4 %
	First Flush	N/A	89.0 %	84.0 %
Zinc	Combined	88.3 %	75.8 %	79.9 %
	First Flush	92.8 %	83.1 %	83.1 %

5.3.3.3 Bioretention systems

Bioretention systems (Figure 5.11 and Figure 5.12) are suitable to treat runoff on sites where there is adequate soil infiltration capacity and where the runoff volumes that are not infiltrated do not present a safety or flooding hazard. Typical applications for bioretention include parking areas with or without curbs, traffic islands, and swales or depressed areas that receive runoff from impervious areas.

Bioretention system designs are very flexible, can be adapted to a wide range of commercial, industrial, and residential settings, and can be linked in series or combined with structural devices to provide the necessary level of treatment depending on expected runoff volumes and pollutant loading. A common technique is to use bioretention areas to pre-treat sheet flow before it is channelized or collected in an inlet structure.

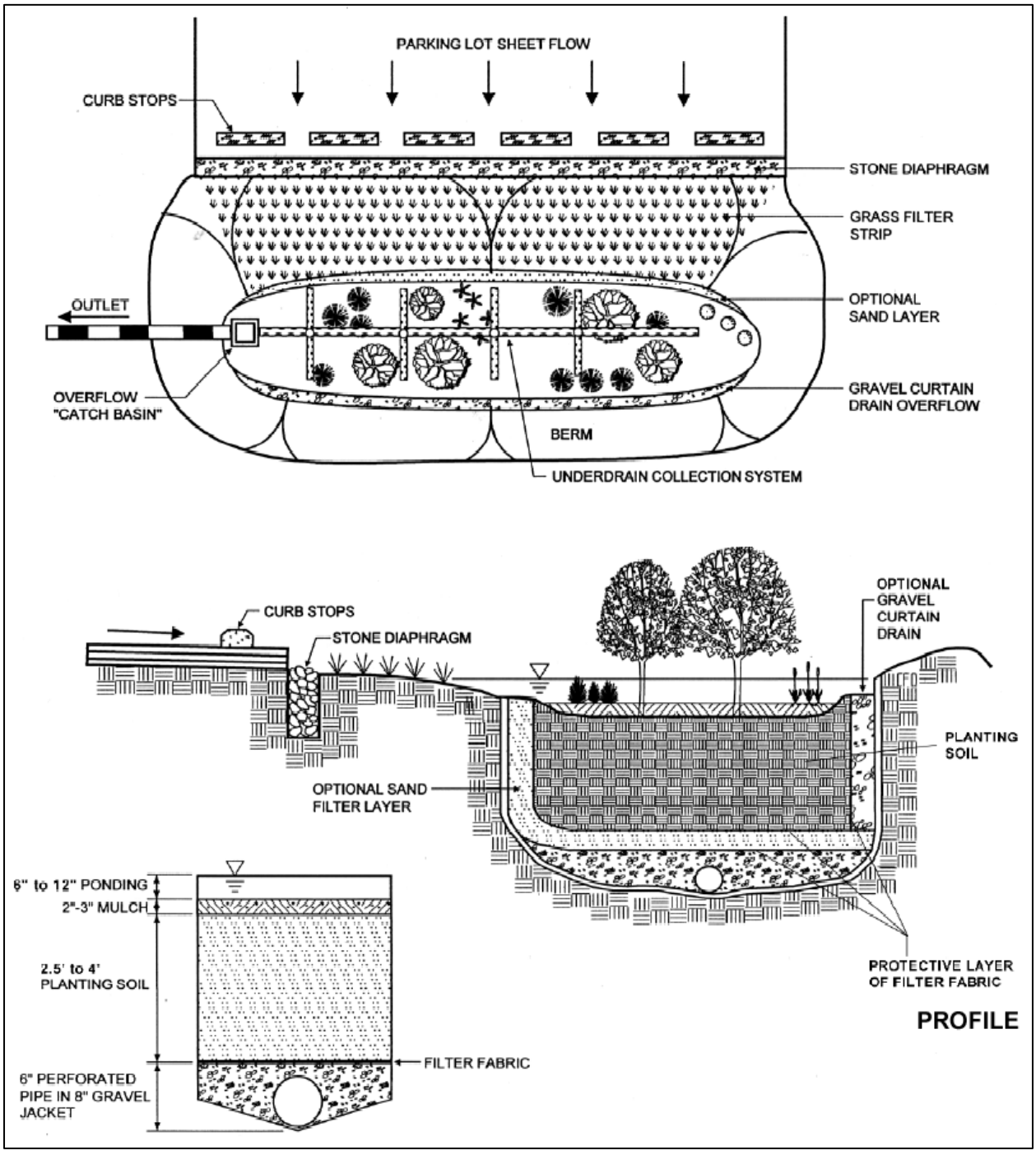

Figure 5.11: Schematic of a bioretention system (MDE, 2000).

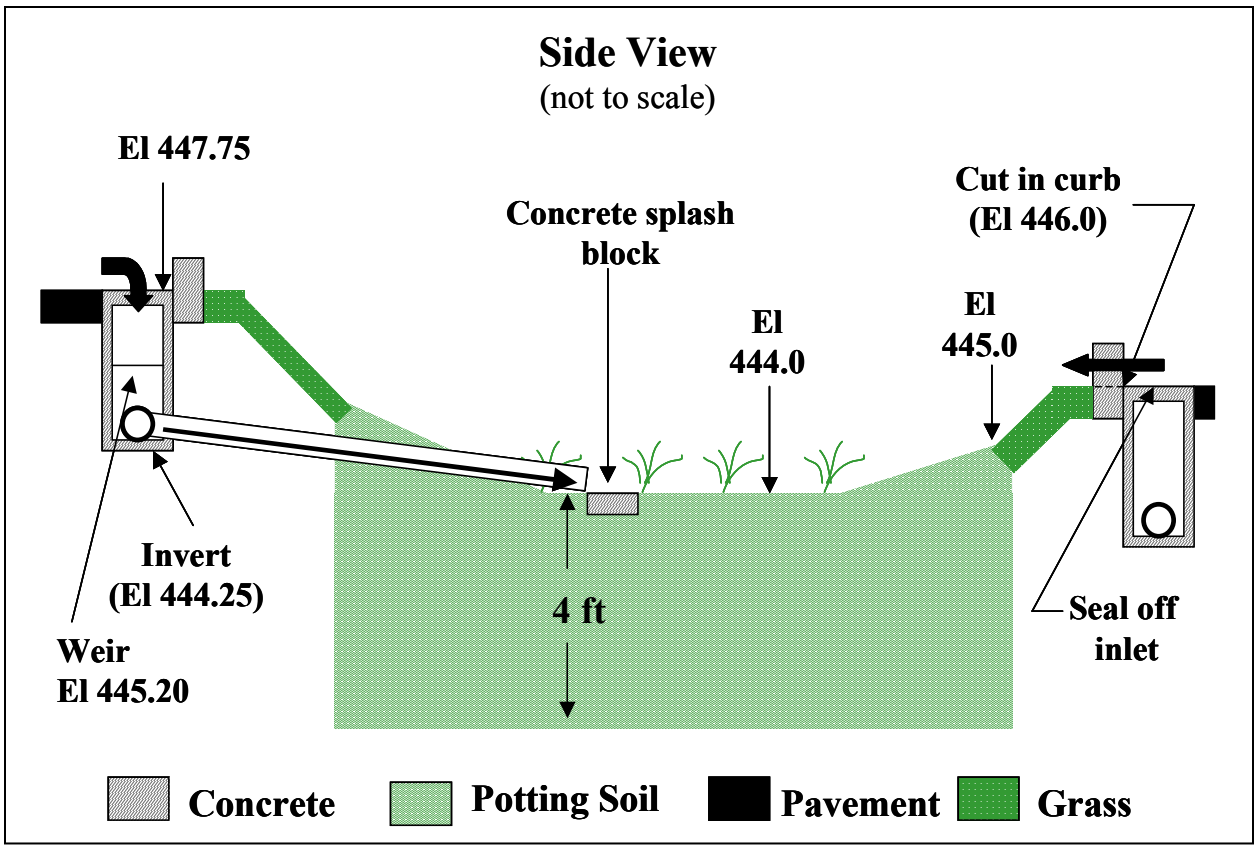

Figure 5.12: Schematic of a bioretention parking lot island (Traver, 2003).

Bioretention should not be used in areas:

- With mature trees;
- With slopes greater than 20 percent;
- With a water table within 6 feet of the land surface;
- With easily erodible soils;
- Below outfalls;
- Where concentrated flows are discharged; or
- Where excavation or cutting will occur.

To determine the appropriate design of the bioretention area with respect to the amount of runoff it receives, Prince George's County, Maryland, Department of Environmental Resources (1993), suggests a design based on a four-day maximum ponding period (appropriate for the Mid-Atlantic region). This four-day period is based on hydrologic, horticultural, and maintenance constraints such as plant tolerance of flooded conditions and mosquito-breeding concerns. Other considerations include infiltration rates for the root zone, sand layer, and in-situ material.

There is some flexibility with respect to size, shape, and placement of vegetation within the bioretention area. Other elements that should be incorporated into the design of the bioretention system include curb openings, a ponding area suitable to handle runoff from larger storms,

amended planting soil that provides the desired infiltration rate, and an under-layer sand or gravel bed or underground perforated pipe that facilitates infiltration.

Regular maintenance, including soil pH testing, mulching and repairing eroded areas, inspecting vegetation, ensuring that runoff is infiltrating as designed, and checking for damage caused by large storms, will help to ensure the longevity of bioretention areas. More information about the design, operation, and maintenance of bioretention systems can be found in Coffman and Winogradoff (1999) or Prince George's County, Maryland, Department of Environmental Resources (1993).

As for the performance of bioretention areas, in one research study, simulated runoff was pumped continuously into an area of 5.3 m^2 in six bioretention cells, and effluent samples were collected from the perforated drainpipes underlying the bioretention media. All six bioretention facilities showed greater than 99 percent removal efficiency for oil and grease. Total lead removal efficiency decreased when the TSS level in the effluent increased because lead was adsorbed onto the surface of the solids. TSS removal ranged from 72 to 99 percent, and lead removal rates ranged from 80 to 100 percent. For total phosphorus, the removal efficiency was found to be highly variable, ranging from 37 to 99 percent. Nitrate-nitrogen and ammonium-nitrogen removal efficiencies ranged from 2 to 7 percent and 5 to 49 percent, respectively. Overall, the bioretention cells contributed significantly to water quality improvement (Hsieh and Davis, 2003).

The developer of Somerset Community, a typical suburban development in Prince George's County, Maryland, incorporated bioretention areas into each lot to control runoff quantity and quality. The bioretention areas eliminated the need for a wet pond, allowed the development of six extra lots, and resulted in a cost savings of more than $4,000 per lot. Somerset residents have enthusiastically accepted their bioretention areas, are actively maintaining them, and have lodged few complaints. Safety issues and mosquitoes have not been a problem (Daniels, 1995, and Curry and Wynkoop, 1995).

The Inglewood Demonstration Project in Largo, Maryland, involved retrofitting an existing parking facility with bioretention areas and comparing the pollutant removal efficiency of a bioretention cell in a laboratory setting to that of a comparable facility constructed in a parking lot. This study showed the feasibility of retrofitting an existing parking facility and demonstrated the consistency of laboratory and field pollutant removal performance. Results showed that the runoff temperature was lowered 12 degrees Celsius, lead levels were lowered 79 percent, zinc levels were lowered 78 percent, and numerous other pollutant levels were also considerably reduced. The retrofit cost $4,500 to construct, while usual methods would have cost $15,000 to $20,000 and involved fewer environmental benefits and higher maintenance costs. Also, bioretention areas offer the ancillary benefit of aesthetic enhancement. It is interesting to note that a drought occurred after the installation of the plants, and although many of the other plants in the parking lot died or experienced severe drought stress, those in the bioretention facility survived because of the retained water supply (USEPA, 2000a).

SARB_002106

Using Landscaped Rain Gardens to Control Runoff

The city of Maplewood, Minnesota is seeking to improve drainage in its older neighborhoods through the use of rain gardens. A successful pilot project, which was implemented in 1995, was the starting point for the current citywide rain garden initiative. Rain gardens from the pilot project have prevented runoff from flowing out of the area, containing 100 percent of the flow. City officials decided to expand the project when they recognized the aesthetic and environmental benefits resulting from the pilot project rain gardens.

The city is focusing on demonstration, education, and outreach to convey the benefits of using rain gardens for runoff management, rather than requiring homeowners to participate. Although rain gardens can be a solution for people who are opposed to adding curbs and gutters to their streets, some are concerned that rain gardens may attract and breed mosquitoes. Before beginning a street improvement project for a specific neighborhood, the city holds neighborhood meetings and distributes a comprehensive educational mailing and questionnaire to homeowners. These materials contain a fact sheet that explains the purpose of rain gardens, how they are designed, how they work, their benefits, and the plants best suited for a variety of hydrologic conditions. A questionnaire is also included to ascertain existing drainage problems and to determine whether the homeowner would be willing to agree to use a rain garden.

Once a homeowner has decided that they want a rain garden, they choose the location and size. The city works with homeowners to make these types of decisions and to help them comply with restrictions on garden placement caused by existing trees, natural drainage, or the presence of gas and water mains and other utilities. Homeowners may choose from three standard rain garden sizes (12-foot by 24-foot, 10-foot by 20-foot, and 8-foot by 16-foot) and from one of six different garden themes, including an easy shrub garden, easy daylily garden, sunny garden, sunny border garden, butterflies and friends garden, Minnesota prairie garden, and shady garden.

To begin construction, the city's contractor excavates a gently sloping depression to collect the water. Rain garden depths vary depending on garden size and topography. The contractor digs a sump 42 inches wide and 3 feet deep at the deepest part of the garden to accommodate a geotextile filter fabric bag, which is filled with clean crushed rock. The sump promotes rapid infiltration to reduce the standing time of water in the rain garden. After the infiltration sump is in place, the contractor adds at least 8 inches of bedding material (typically a mixture of salvaged topsoil and clean organic compost) and covers the area with 3 to 4 inches of shredded wood mulch. Residents are provided with all necessary plants and a landscape plan at no additional cost. However, many Minnesota municipalities charge residents a street assessment to cover a percentage of the project cost.

The city's rain garden street improvement project typically costs 75 to 85 percent of a traditional curb and gutter project. Costs are kept low because most of the existing street material is recycled to use as the base aggregate. Additionally, plants are obtained at a reasonable cost and residents are responsible for the planting. Other long-term savings, which are difficult to quantify, result from the reduced demand on the city's downstream sewer infrastructure, which is not characteristic of conventional storm systems. The city may also be able to reduce the need for downstream storm sewer system upgrades and construction, including detention and treatment facilities designed to prevent pollution, erosion, and flooding problems.

More information about Maplewood's rain garden project is available from Chris Cavett, Assistant City Engineer, at 651-770-4554 or chris.cavett@ci.maplewood.mn.us (Terrene Institute, 2001).

5.3.4 Detention and Retention Practices

5.3.4.1 Detention ponds and vaults

These practices temporarily detain runoff to ensure that the postdevelopment peak discharge rate is equal to the predevelopment rate for the desired design storm (e.g. two-, 10-, or 25-year). These practices may also be used to provide temporary extended detention to protect downstream channels from erosion (e.g., 24-hour extended detention for a one-year storm).

Extended detention (ED) ponds (Figure 5.13) are an example of this type of facility. ED ponds temporarily detain a portion of urban runoff for up to 24 hours after a storm, using a fixed orifice to regulate outflow at a specified rate and allowing solids and associated pollutants time to settle out. ED ponds are normally dry between storm events and do not have any permanent standing water. These basins are typically composed of two stages: an upper stage, which remains dry except after larger storms, and a lower stage, which is designed for typical storms. Enhanced ED ponds are equipped with plunge pools or forebays near the inlet, a micropool at the outlet, and an adjustable reverse-sloped pipe as the ED control device (NVPDC, 1980; Schueler et al., 1992). Most ED ponds use a riser with an anti-vortex trash rack on top to control large floating solids.

Detention tanks and vaults are underground structures used to control peak runoff flows. They are usually constructed out of concrete (vaults) or corrugated metal pipe (tanks). Underground detention can also be achieved by retrofitting the over-capacity storm drain pipes with baffles. The baffles allow water to be stored in the pipes so it can be released at a slower rate. Pretreatment structures such as water quality inlets and sand filters can be used to treat runoff and remove trash and debris.

These systems are primarily applicable where space is limited and there are no other practical alternatives. Concrete vaults are relatively expensive and are often used to control small flows where system replacement costs are high. Corrugated metal pipe systems are less expensive and are often used to control larger volumes of runoff in parking lots, adjacent to rights-of-way, and in medians. These systems should be located where maintenance can be conducted with minimal disturbance.

Underground detention structures provide runoff quantity control but do not provide significant water quality control without modifications. Corrugated metal pipe systems can work in conjunction with infiltration to provide additional runoff treatment. This is accomplished by adding perforations to the pipe to allow it to store the water until it can be released into the soil (FHWA, no date).

5.3.4.2 Retention ponds

These practices use a permanent pool, extended detention basin, or shallow marsh to remove pollutants and can include:

- Micropool extended detention ponds;
- Wet ponds;
- Wet extended detention ponds; and
- Multiple pond systems.

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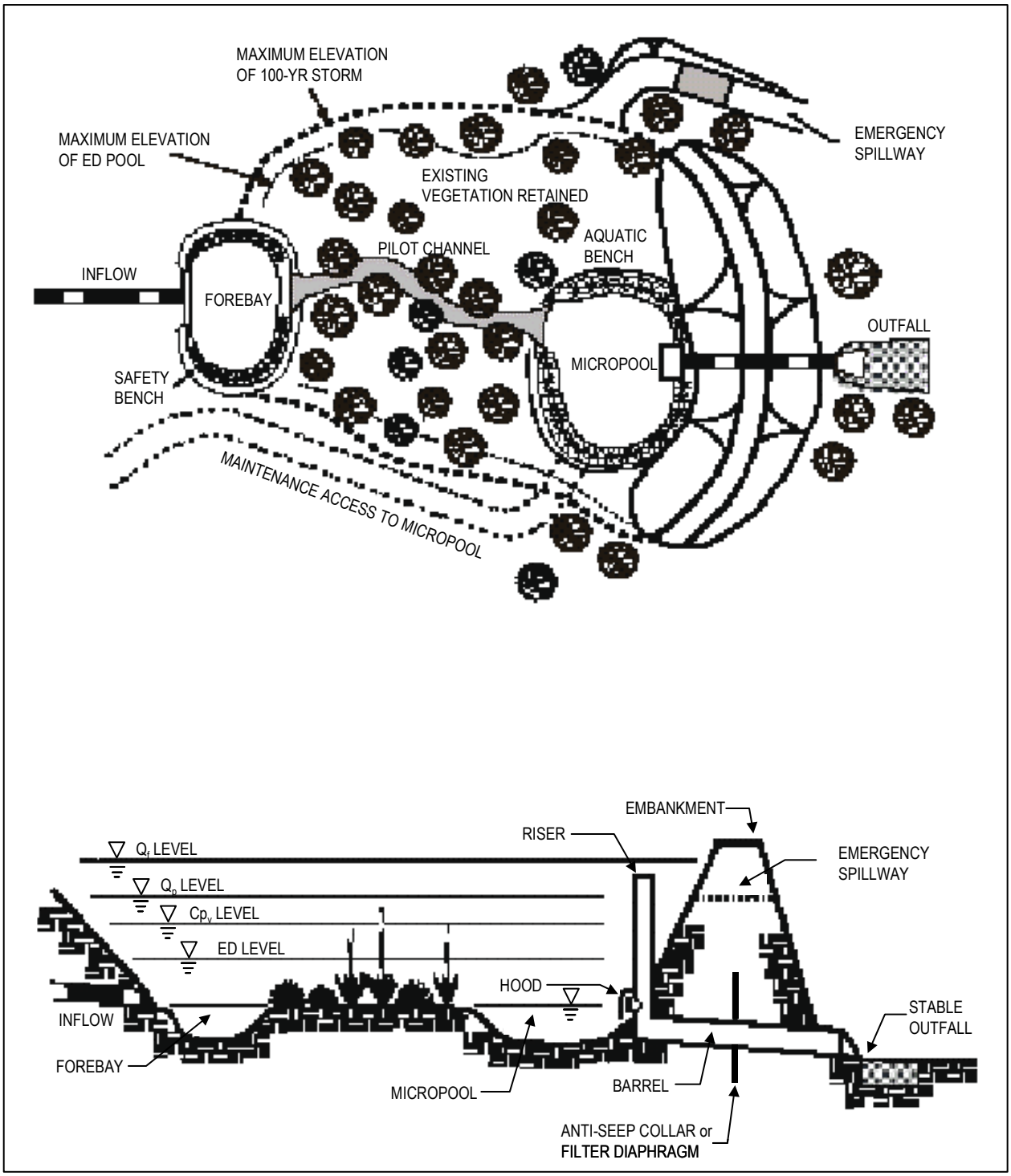

Figure 5.13: Schematic of a dry extended detention pond (MDE, 2000).

Ponds (Figure 5.14) are basins designed to maintain a permanent pool of water and temporarily store runoff (ED wet pond), which is released at a controlled rate. Ponds allow particulates to settle and can provide biological uptake of pollutants such as nitrogen or phosphorus. Enhanced designs include a forebay to trap incoming sediment where it can easily be removed. Often, a

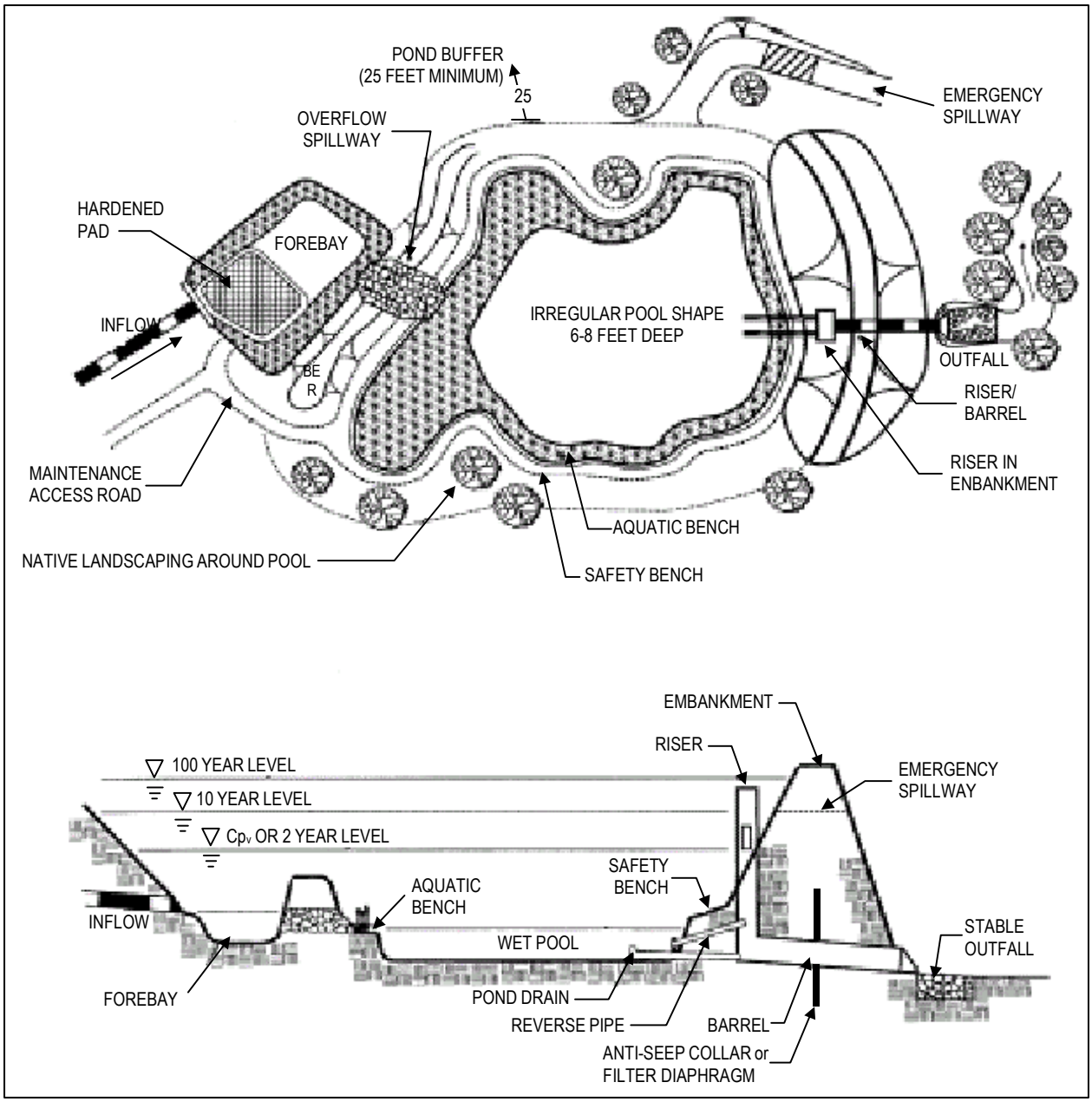

Figure 5.14: Schematic of a wet pond (MDE, 2000).

fringe wetland is installed around the perimeter of the pond to increase the habitat, aesthetic, and pollutant removal values of the facility. An outlet riser, sometimes combined with an anti-vortex trash device, is a common design modification. The design of wet ponds should account for the infiltration of ground water when the wet pond intercepts the water table. Table 5.5 presents several design considerations for ponds.

Table 5.5: Design considerations for ponds and wetlands (MDE, 2000).

Design Consideration	Ponds	Wetlands
Watershed Design Requirements		
Streams in intensely developed areas	Drainage area may limit the applicability of ponds except for pocket ponds.	Drainage area may limit the applicability of ponds except for pocket wetlands.
Cold-water streams	An offline design is recommended. Maximize shading of open pool areas.	An off-line design is recommended. Maximize shading of open pool areas.
Streams in sparsely developed areas	Require additional storage to ensure adequate downstream channel protection.	Require additional storage to ensure adequate downstream channel protection.
Aquifer protection	May require a liner depending on soil type.	May require a liner depending on soil type.
Reservoir protection	Require additional storage to ensure adequate downstream channel protection.	Require additional storage to ensure adequate downstream channel protection.
Shellfish beach located downstream	Provide moderate bacteria removal. Should be designed to prevent geese problems. Should provide permanent pools.	Provide 48-hr extended detention for maximum bacterial die-off.
Terrain Factors		
Low relief	The maximum normal pool depth should be 4 feet (dugout).	Wetlands are suitable for low-relief areas.
Karst	Require a poly or clay liner and geotechnical tests.	Require a poly or clay liner and geotechnical tests.
Mountainous	Embankment heights are restricted.	Embankment heights are restricted.
Physical Feasibility		
Soils	Depending on pond type, they may or may not require a liner or testing.	Certain soils may require a liner.
Water table	Must be at least 2 feet above water table if near a potentially contaminated "hotspot" or if underlain by an aquifer. Pocket ponds by definition are below the water table.	Must be at least 2 feet above water table if near a potentially contaminated "hotspot" or if underlain by an aquifer.
Drainage area	Minimum drainage area is 10 to 25 acres depending on type of pond. Pocket pond has a 5-acre maximum.	Minimum of 25 acres except pocket wetlands, which have a 5-acre maximum.
Site slope	Slopes should always be less than 15%	Slopes should be less than 8%.
Head	A 6- to 8-foot head is needed for all ponds except pocket ponds, which require a 4-foot head.	A 3- to 5-foot head is needed for most wetlands except pocket wetlands, which require a 2- to 3-foot head.
Ultra urban	Only pocket ponds are practical.	Pocket wetlands are sometimes practical; all others impractical.
Runoff Treatment Suitability		
Ground water recharge	No	No
Channel protection	Yes	Yes
Runoff Treatment Suitability (continued)		
Ground water recharge	No	No
Channel protection	Yes	Yes
Water quantity control	Yes	Yes
Large space requirements	Less space	More space
Community and Environmental Factors		
Maintenance	Easier	More difficult
Community acceptance	More acceptable	Less acceptable
Affordability	More affordable	Less affordable
Wildlife habitat	Yes	Yes

Used in combination with on-site and nonstructural practices, regional ponds are an important component of a runoff management program. The costs and benefits of regional, or off-site, practices compared to on-site practices should be considered as part of a comprehensive management program. For example, regional ponds can be located to treat runoff from existing development, and will result in overall net reductions on pollutant loads for the watershed (Fairfax County Environmental Coordinating Committee, 2002). Regional facilities can incorporate more advanced treatment technologies than on-site facilities (Maupin and Wagner, 2003). They can also provide community recreation and wildlife benefits, reduce peak and total flow, and be easier to maintain than dispersed controls. The City of Fairfax, Virginia, found that maintenance costs for a regional pond were about one-sixth those of on-site ponds (Fairfax County Environmental Coordinating Committee, 2002). Maintenance responsibilities and liability for regional runoff facilities belong to the municipality (Maupin and Wagner, 2003).

A study of 43 wadeable streams in Austin, Texas, showed that several indicators of stream health (ephemeroptera-plecoptera-trichoptera (EPT) richness and percent EPT abundance) were higher in streams with storm water ponds protecting 60 to 95 percent of their catchments than in streams with no storm water controls (Maxted and Scoggins, 2004). This trend was only significant in fully developed watersheds (having greater than 40 percent impervious cover). In watersheds with less than 40 percent impervious cover, storm water ponds had no significant impact on EPT richness or percent EPT abundance. The researchers attributed the lack of effects of storm water ponds to urban development in the reference watersheds and to the nature of the biological index used to gauge stream health, which was not tailored to the specific environmental conditions of the Austin area.

Research has shown that storm water ponds can increase property values. A survey in Columbia, Maryland, found that 75 percent of homeowners felt that permanent bodies of water such as storm water ponds added to real estate values. Seventy-three percent were willing to pay more for property located in a neighborhood with storm water control basins designed to enhance fish or wildlife uses (Adams et al., 1984; Tourbier and Westmacott, 1992; USEPA, 1995). Residents of a Champaign-Urbana, Illinois, neighborhood with storm water ponds stated that lots adjacent to a wet pond were worth an average of 21.9 percent more than comparable non-adjacent lots in the same subdivision. The same survey revealed that 82 percent would in the future be willing to pay a premium for a lot adjacent to a wet pond (Emmerling-DiNovo, 1995). In Alexandria, Virginia, condominiums alongside a 14-acre runoff detention pond sold for $7,500 more than comparable units not adjacent to the pond (USEPA, 1995).

Regional ponds do not, however, provide protection in contributing drainage systems, including upstream tributaries. These can experience damage from increased peak flow and flow volume. In addition, placement of regional ponds in low-lying areas may harm natural wetlands, and the ponds may create safety and liability issues. Siting ponds or other structural management practices within natural buffer areas and wetlands degrades their functions and may interrupt surface water and ground water flow when soils are disturbed for installation.

5.3.4.3 Constructed wetlands

Constructed wetlands (Figure 5.15) are engineered systems designed to treat runoff. They are typically designed to provide some of the functions of natural wetlands, e.g., wildlife habitat, in

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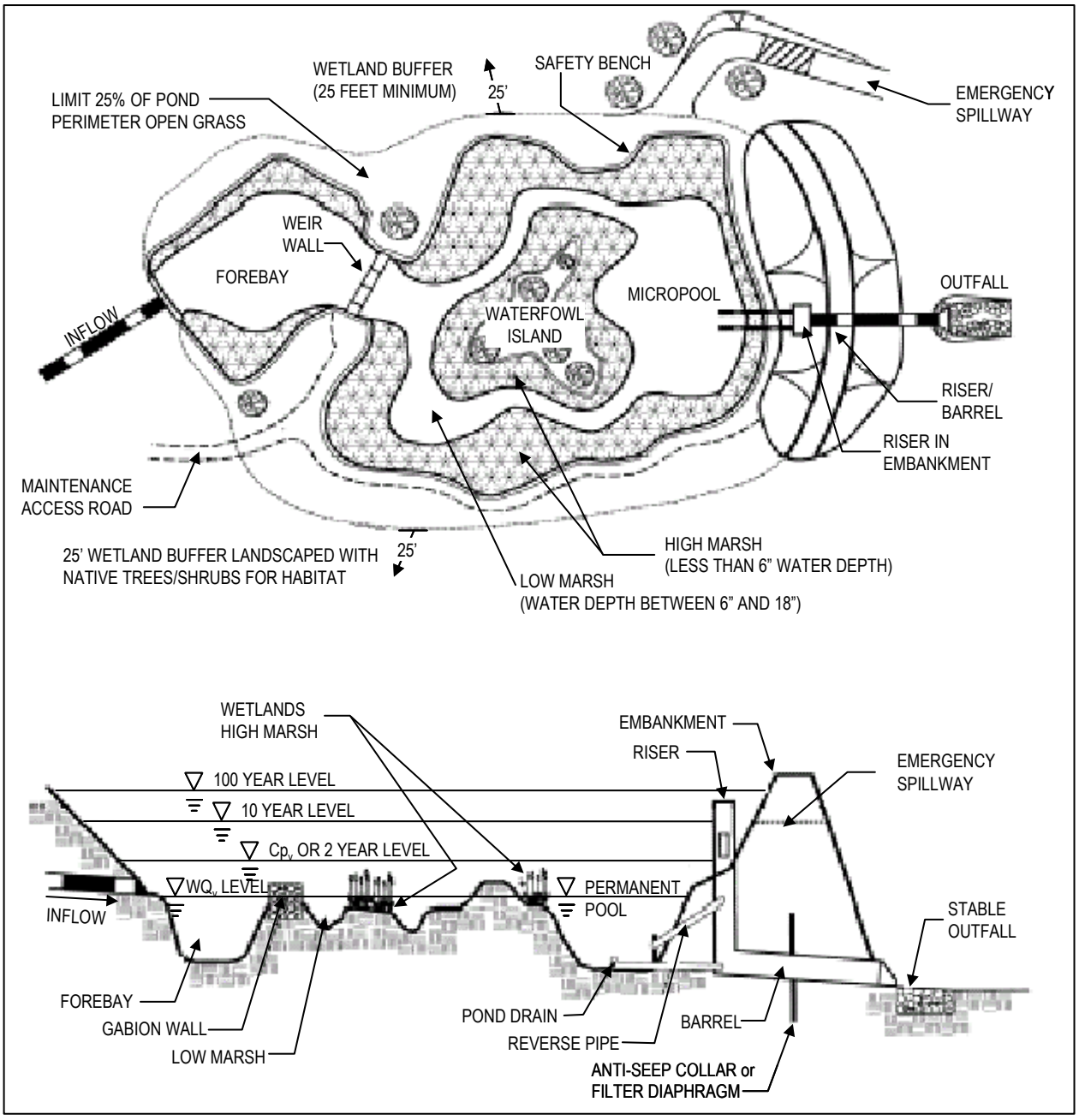

Figure 5.15: Schematic of a shallow wetland (MDE, 2000).

addition to controlling runoff volumes and pollutant loadings. There are many variations of constructed wetlands, such as shallow wetlands, extended detention wetlands, pond/wetland systems, and small isolated "pocket" wetlands. Constructed wetlands may contain some or all of the following elements: shallow vegetated areas, permanent pools, sediment forebays, transition areas, and weirs. Designs are intended to slow flow through the wetlands and provide maximum contact with wetland vegetation.

It should be noted, however, that constructed wetlands rarely replicate the functions of natural wetlands and should not be used for compensatory mitigation of natural wetlands and buffers.

Furthermore, constructed wetlands should be designed to receive periodic maintenance to ensure the wetland continues to function as designed.

Constructed wetlands are feasible at most sites and drainage areas where there is enough rainfall and/or snowmelt to maintain a permanent pool. In areas with highly permeable soils, other impermeable barriers, such as synthetic liners or clay, sometimes can be used to maintain enough water or moisture to support the wetland. Constructed wetlands should be located contiguous to existing wetlands wherever possible, unless there is concern about contaminants that may pose a threat to wildlife. Although it is technically feasible to construct a wetland on a small site (less than 1 acre), alternative control strategies should be considered when land constraints are present.

Constructed wetland systems can take several forms, including wet ponds with a wetland fringe, swale/ditch wetland depressions, and large-scale constructed wetlands used as mitigation wetlands or treatment wetlands. The choice of wetland designs depends on watershed characteristics, spatial and geomorphic constraints, runoff treatment requirements, and community and environmental factors. These considerations are outlined in Table 5.5.

In the San Diego Creek Watershed in southern California, constructed wetlands are being used as a regional runoff control technique. This approach, called the Natural Treatment System (NTS) Plan, is part of a watershed-wide management effort to meet total maximum daily load (TMDL) requirements for the San Diego Creek, which is impaired by sediment, nutrients, pathogens, heavy metals, and pesticides. The results of water quality modeling that accounted for the combined effects of the 44 planned facilities indicated that the TMDL for total nitrogen in base flows would be achieved, total phosphorus targets would be met in all but the wettest years and the fecal coliform target would be met in the dry season. While the NTS Plan is not meant to meet the TMDL for sediment, it will capture 1,900 tons annually, and the wetlands are estimated to remove 18 percent of the total zinc and 11 percent of the total copper and lead in runoff (Strecker et al., 2003).

New York City Bluebelt

The New York City Department of Environmental Protection (NYCDEP) has taken an innovative approach to solving drainage problems that have long plagued southern Staten Island. Instead of installing a conventional piped storm sewer system that would destroy the existing wetlands through drainage or filling, NYCDEP proposed to use a natural drainage system to convey, store, and filter runoff. The plan involves both preserving and restoring wetlands. In 1991, the agency began purchasing land along wetland corridors, and soon this network of property was termed the Bluebelt, because it mirrors the role a Greenbelt plays for open space areas by protecting water resources. The Bluebelt area is a total of 10,000 acres and includes 16 watersheds.

The constructed wetlands in the Bluebelt range from 0.5 to 2 acres in area and have a permanent pool that ranges from 12 to 24 inches deep. The wetlands are intended to provide water quality, flood control, and flow attenuation benefits for the region. More than 100 management practices were screened for their applicability, and in addition to constructed wetlands, meandering streams and outlet stilling basins were installed. Meandering streams convey runoff in open channels, providing a basis for the establishment and preservation of riparian areas. Outlet stilling basins mitigate the high velocities of runoff exiting conventional pipes. In the past 12 years, approximately half of the 89 planned management practices have been designed (Vokral et al, 2003).

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Desert Wetlands

A constructed wetland demonstration project is being tested in the Sonoran Desert to improve the New River, which consists primarily of wastewater from Mexico and agricultural drain water from California's Imperial Valley (Fortner, 2000). Without these two sources of water, the New River would run dry. Near Imperial, California, about halfway along the New River, 68 acres of wetlands were constructed as a demonstration project. These wetlands use a series of six cells to remove sediments and other pollutants from irrigation drain water. A few miles downstream, in Brawley, California, a similar project will treat water that is diverted directly from the New River. The site for this project consists of 7 acres and three cells. The two sites are collectively referred to as the Brawley Constructed Wetlands Demonstration Project.

The project is described as one of the most challenging constructed wetlands projects in the United States and will help researchers determine the best design for treating river and agricultural drain water. Scientists are aware that it will be challenging to construct a wetland to treat a severely impaired waterbody in a desert area. They will monitor the performance of the test sites before additional wetlands are built. Once the data is obtained, the Citizens' Congressional Task Force for the New River (comprised of citizens and representatives from environmental groups, local community organizations, and state and federal agencies) will decide whether to expand the project.

Wetlands and other runoff control systems should not be sited in areas where they disrupt or significantly alter the predevelopment hydrology unless restoration objectives apply. When designing the wetland, a variety of physical characteristics should be used to promote multiple wildlife and habitat functions. For example, an irregular shape increases the perimeter of the system and provides a greater variety of microhabitats along the shoreline. Also, an irregular shoreline can extend the perimeter of a constructed wetland by 10 to 20 percent with no increase in land requirements.

Shallow-water wetlands do not contain a large volume of water per surface area as would a typical wet pond. In general, the wetland should have a shallow slope with a permanent pool in the middle. To enable growth of emergent vegetation, static water depths should not exceed 2 to 3 feet. Depths greater than 2 to 3 feet are conducive to the growth of submerged aquatic vegetation. The use of deeper water (>3 feet) in an area that is easily accessible for small children should be discouraged. No area of the pond should have a depth greater than four feet. In general, 50 percent of the pond should have depths less than one foot, 30 percent should be 1 foot to 2 feet deep, and 20 percent should be 2 to 4 feet deep. Greater depths are allowable for the inflow forebay and around the outlet structure.

The Maryland Department of the Environment (2000) requires that the first inch of runoff from the site must be controlled and released over a 24-hour period to provide water quality treatment, while peak discharge control of the two- and 10-year storms must be provided for water quantity control. Local requirements should be used when designing the treatment capacity of a constructed wetland. Other factors such as steep slopes may necessitate deeper ponds to obtain adequate runoff control.

Individual soil analyses should be done during the site design phase to determine if a clay or plastic liner is needed to maintain a wetland environment. Wetland vegetation cannot usually survive unless a base flow is available to provide a permanent pool to keep plants wet. Rapid infiltration will remove this needed pool. If a liner is needed, it should have at least 1 foot of

The Use of Wetlands to Reduce Fecal Coliform

Unusually high levels of fecal coliform have been found in an area of Laguna Niguel, California. Runoff from a neighborhood is washing into Aliso Creek and then to the Pacific Ocean. In response to a cleanup order issued by state water regulators, city officials built a series of wetlands to filter fecal coliform out of runoff. The natural water treatment system will work in combination with an existing wetland, which has already been proven successful in cleaning waters to a level acceptable for swimming.

Upon completion, water will flow through a series of four stepped ponds, spread out, and remain in the wetlands for hours or days of treatment. It is estimated that it will take a year for all vegetation to grow in and nearly two years to attain maximum removal of bacteria. When the wetlands system is complete, the existing wetland will treat 35 to 40 percent of the runoff and the new wetlands will treat 35 percent of the runoff. The city hopes that the new wetlands will work as well as the existing wetlands in reducing fecal coliform from urban runoff (Vardon, 2000).

clean fill material placed on top of it for wetland plant growth (the fill material will also reduce the potential for puncture).

An island placed in the wetland can extend the length of the flow path that runoff must travel to traverse the pond. This increased flow path enhances the pollution removal function of the constructed wetland. The highest elevation of the island should be above that reachable by storage of the first inch of runoff. Islands in wetlands may attract geese, which can be undesirable in some urban settings, but there are ways to minimize habitat for geese in a constructed wetland. Because most runoff management ponds are fairly small compared with a natural marsh system, they do not provide the long glide path preferred by geese for landing and takeoff. Planting woody vegetation or allowing areas around the pond to grow without mowing also tends to discourage goose residency.

The following are typical elements of a constructed wetland:

(1) *Sediment forebays*. It is important that sediment forebays be placed at all locations where runoff enters the wetland. A forebay is designed for vehicle access to facilitate sediment removal while preventing disturbance of substrate that could disrupt wetland functions. The forebay should constitute approximately 10 percent of the total basin volume and should have a maximum depth of 4 feet. Where there are multiple inlets to the constructed wetland, the total volume of all the forebays should be 10 percent of the basin volume, with individual inlet forebays sized with respect to the percentage of contributing flow they receive. The use of stone riprap in the forebay will reduce the velocity of flow into the wetland portion of the basin and minimize resuspension of deposited sediments. An access to the forebay should be provided for cleanout equipment. An area adjacent to the constructed wetland should be set aside for disposal of the sediments that become trapped and are removed during periodic maintenance.

    The cleanout frequency of sediment forebays depends on the sediment load entering the constructed wetland. Each forebay should be inspected annually to ensure cleanout is being conducted as needed. Once the forebay has been filled to approximately 50 percent of its total volume (every 10 to 15 years), sediment should be removed, placed in an appropriate upland location, and stabilized. Costs for sediment forebay maintenance, including periodic

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inspection and cleaning, should be budgeted as a long-term operating expense if this practice is selected.

(2) *Diversion weir*. Diversion weirs may be needed for designs where the entire runoff volume is not directed to the constructed wetland. This diverted fraction of the runoff is often routed to collection systems or inlets. The amount of rainfall that may be diverted will vary according to local requirements and design objectives.

(3) *Outlet*. As is the case with all ponds having a normal pool of water, algae can clog outlets with small orifices that are needed for extended detention. A below-surface withdrawal structure may reduce or eliminate this problem.

(4) *Transition zone*. The maximum slope of the transition zone on wetland side slopes should be no greater than 10:1 (horizontal:vertical) and should extend at least 20 feet from the design pool of the constructed wetland. This area will be temporarily flooded whenever runoff is temporarily detained. Planting trees in the transition zone enhances nutrient uptake; the shading reduces temperature increases common in open water areas; and the trees provide habitat for wildlife. The transition zone should be mowed no more than once a year in late fall. Optimally, to promote the growth of woody vegetation, the transition area should not be mowed at all unless the pond is an embankment pond, in which case it should be mowed annually to prevent woody vegetation on the embankment.

(5) *Vegetation*. Placement of organic soils on the bottom of the pond will provide faster growth of planted or volunteer vegetation. Constructed wetlands should initially be planted with emergent plants and woody shrubs, and the wetlands should be allowed to succeed to a system dominated by woody shrubs and trees. The emergent wetland plants that are chosen should have tops that rise above the normal pool level.

It is important to consult local ecologists/plant specialists to choose suitable wetland species and to design a landscaping plan with appropriate vegetation density and spacing. Local specialists can also provide information regarding the optimal time to plant vegetation and help to design a maintenance schedule based on vegetation requirements. Native species should be used where feasible because they are well-adapted to local conditions. The USDA has a database (see http://www.plants.usda.gov/) of invasive and noxious species, which should be avoided.

The following specifications are provided as an example and apply to the Mid-Atlantic region (MDE, 2000):

- At least two aggressive species should be planted in the constructed wetland; their purpose is to rapidly spread to other unplanted areas of the wetland. In addition, at least three secondary species should be planted to increase the diversity, wildlife values, and appearance of the wetland. Ideally, plantings should include a mix of perennial and annual species.

- Plants should cover approximately 30 percent of shallow areas, with particular attention paid to areas adjacent to the shoreline. Plants should be spaced 2 to 3 feet

apart, and the same species of plants should be planted in a single area to avoid interspecies competition.

- Species that are not recommended for any use in a constructed wetland are *Phragmites australis* (common reed), *Lythrum salicaria* (purple loosestrife), and *Phalaris arundinacea* (reed canary grass). Periodic inspections are important to ensure that exotic or other pest species do not dominate the plant community. In certain situations where there is an initial invasion of an aggressive, undesirable species, selective removal of the plants might be warranted, especially if the plant community that was introduced has not had time to adequately establish itself.

- Depending on site conditions, planting *Typha latifolia* (cattail) may or may not be recommended. Despite the fact that it is considered an exotic species, cattail will eventually dominate the wetland community. Additionally, cattail is an excellent plant for water treatment from a filtration and sedimentation standpoint.

- Planting will be more successful if the water level can be drawn down immediately prior to planting. This drawdown will leave the soils saturated, a condition necessary for the plants, and will improve visibility, especially when a number of people are involved in planting. The potential for damaging previously planted vegetation is reduced if the plants are clearly visible. Upon completion of planting, the outlet structure drain valve should be closed so either storm or base flow can reestablish the normal pool elevation.

- Harvesting wetland plants is only appropriate in areas such as the southern United States where plant growth is the most important mechanism for nutrient uptake. Harvesting is not needed where microbial activity is the dominant pollutant removal mechanism.

Like wet ponds, wetlands can increase adjacent property values. One study in Boulder, Colorado, found that lots located alongside a constructed wetland sold for up to a 30 percent premium over lots with no water view (USEPA, 1995). In Wichita, Kansas, a developer enhanced existing wetlands rather than filling them, and the waterfront lots sell for a premium of up to 150 percent of comparable lots (USEPA, 1995).

5.3.5 Other Practices

Other practices used to control urban runoff have not been studied as extensively as those above but have been used with varying degrees of success. They include:

- Water quality inlets;
- Hydrodynamic devices;
- "Baffle boxes;"
- Catch basin inserts;
- Vegetated filter strips;
- Street surface storage;

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- On-lot storage; and
- Microbial disinfection.

In some cases, these practices are used for pretreatment or are part of an overall runoff management system, which is sometimes referred to as a "treatment train." For example, water quality inlets, catch basin inserts, and vegetated filter strips installed upslope of a wet pond or filtration practice will help remove a portion of the pollutants present in runoff before it enters the pond or filtration practice. These other practices in the treatment train improve runoff quality and can help extend the longevity of the filtration practice and wet pond.

5.3.5.1 Water quality inlets

Water quality inlets are underground retention systems designed to remove settleable solids. There are several water quality inlet designs. In their simplest form, catch basins are single-chambered urban runoff inlets in which the bottom has been lowered to provide 2 to 4 feet of additional space between the outlet pipe and the structure bottom for collection of sediment. Some water quality inlets include a second chamber with a sand filter to provide additional removal of finer suspended solids by filtration. The first chamber provides effective removal of coarse particles and helps prevent premature clogging of the filter medium.

Other water quality inlets include an oil/grit separator. Typical oil/grit separators consist of three chambers. The first chamber removes coarse material and debris; the second chamber provides separation of oil, grease, and gasoline; and the third chamber provides safety relief if blockage occurs (NVPDC, 1980). Although water quality inlets have the potential to perform effectively, they are not recommended because they are usually designed to bypass high flows, which can resuspend captured pollutants and flush them through the water quality inlet. Frequent maintenance and disposal of trapped residuals and hydrocarbons are necessary for these devices to continuously and effectively remove pollutants.

5.3.5.2 Hydrodynamic devices

A variety of engineered hydrodynamic devices, also called swirl separators or swirl concentrators, are available for removing pollutants from runoff. Swirl separators are modifications of the traditional oil-grit separator and include an internal component that creates a swirling motion as runoff flows through a cylindrical chamber. The concept behind these designs is that sediments settle out as runoff moves in this swirling path. Additional compartments or chambers, with or without pads, are sometimes present to trap oil and other floatables. Typically these devices are prefabricated and come in a range of sizes targeted at specific flow rates. At least two technologies are available. One is designed to remove suspended particles, oil, and grease during low flow conditions. The device removes particulate and floatable pollutants from runoff through settling of solids and floating of oils, greases, and litter. Higher runoff flows are diverted around the treatment unit so that scour and increased velocity do not carry the collected pollutants out of the treatment chamber. Maintenance requirements include the periodic removal of oil, greases, and sediments, typically by using a vacuum truck.

A second type of hydrodynamic device uses centrifugal motion to remove litter and debris and, potentially, larger sediment particles from runoff. This technology is designed to capture trash

rather than pollutants, and therefore it is most applicable in coastal areas and areas that receive heavy trash loads such as leaf litter, plastics, and cans. Prefabricated units are currently available with capacities up to 300 cubic feet per second (cfs). The devices are constructed so that a vacuum truck can regularly remove the floatable and settleable debris collected in the treatment chamber.

Limited data are available on the performance of these devices, and independently conducted studies suggest marginal fine particle and soluble pollutant removal. Therefore, swirl separators should not be used as a stand-alone practice for new development. Also, these devices require regular maintenance. Communities may reduce maintenance costs by sharing a vactor truck. Swirl separators are best installed on highly impervious sites. These products have application as pretreatment to another runoff treatment practice and in a retrofit situation where space is limited.

5.3.5.3 Baffle boxes

Sediment control devices called "baffle boxes" have been used in Brevard County, Florida, as an "end of pipe" treatment method (England, 1996). They are concrete or fiberglass boxes, typically 10 to 15 feet long and 6 to 8 feet high, which are placed at the end of existing storm drain pipes. The box is divided into multiple chambers by weirs set at the same level as the pipe invert to minimize hydraulic losses. Trash screens are incorporated in the design to remove floating debris. Baffle boxes have been shown to have a removal efficiency of up to 90 percent for sand or sandy clay at entrance velocities of up to 6 feet per second, and 28 percent removal efficiency for fly ash at the same velocity. Baffle box designs can be modified to serve as a retrofit installation at curb or manhole inlets or beneath grates. Regular maintenance, especially removal of sediment and debris, is essential to maintain the effectiveness of this practice.

5.3.5.4 Catch basin inserts

Catch basin inserts consist of a frame that fits below the inlet grate of a catch basin and can be fitted with various trays that target specific pollutants. Typically the frame and trays are made of stainless steel, cast iron, or aluminum to resist corrosion. The trays may contain a variety of media. Often more than one tray is included in the design with the first tray filtering out sediment. Subsequent trays typically address a specific targeted pollutant, (e.g., wood fiber or other absorbent materials for oils and grease, or activated carbon for organics, fertilizers, and pesticides). The device is typically designed to accept the design flow rate of the inlet grate with bypasses as the trays become clogged with debris. The media require routine maintenance for replacement, cleaning, or regeneration. Catch basin inserts are typically used for smaller drainage areas. Usually the media need replacement on a quarterly basis.

The City of Santa Monica installs catch basin inserts that catch trash and debris in areas of high pedestrian traffic. Catch basin screens attach to the face of the curb and block trash from the storm drain, allowing debris to be easily removed by maintenance personnel or a street sweeper. Inserts that also filter hydrocarbons are installed on streets with automotive businesses. The city has found these practices to be effective when they are chosen carefully to suit site characteristics and are carefully installed and maintained (Shapiro, 2003).

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5.3.5.5 Alum

Alum, which is an aluminum sulfate salt, can be added to storm water to cause fine particles to flocculate and settle out (USEPA, 2001a). It can help meet downstream pollutant concentration loads by reducing the concentrations of fine particles and soluble phosphorus. Alum can be added directly to or just before a pond or lake inlet, and booms can be used to ensure quiescent settling. When alum is injected into runoff it forms the harmless precipitates aluminum phosphate and aluminum hydroxide. These precipitates combine with heavy metals and phosphorus, causing them to be deposited into the sediments in a stable, inactive state. The collected mass of alum pollutants, precipitates, and sediments is commonly referred to as "floc." Frequent maintenance and disposal of the floc is required for continuous and effective operation.

5.3.5.6 Vegetated filter strips

Vegetated filter strips (VFSs) (Figure 5.16) are areas of land with vegetative cover that are designed to accept runoff as overland sheet flow from upstream development. Dense vegetative cover facilitates sediment attenuation and pollutant removal. Unlike grassed swales, vegetated filter strips are effective only for overland sheet flow and provide little treatment for concentrated flows. Grading and level spreaders can be used to create a uniformly sloping area that distributes the runoff evenly across the filter strip (Dillaha et al., 1989). Vegetated filter strips are often used as pretreatment for other structural practices, such as infiltration basins and infiltration trenches.

Typically, VFSs are used to treat very small drainage areas. The limiting design factor, however, is not the drainage area the practice treats but the length of flow leading to it. As runoff flows over the ground surface, it changes from sheet flow to concentrated flow. Rather than moving uniformly over the surface, the concentrated flow forms rivulets that are slightly deeper and cover less area than the sheet flow. When flow concentrates, it moves too rapidly to be effectively treated by a grassed filter strip.

VFSs should be designed on slopes between 2 and 6 percent. Steeper slopes encourage the formation of concentrated flow. Except in the case of very sandy or gravelly soil, runoff ponds on the surface on slopes flatter than 2 percent, creating potential mosquito-breeding habitat. Filter strips should not be used on soils with high clay content because they require infiltration for proper treatment. Very poor soils that cannot sustain a grass cover crop are also a limiting factor. Filter strips should be separated from the ground water by 2 to 4 feet to prevent contamination and to ensure that they do not remain wet between storms.

The design of VFSs is straightforward because they are not much more than a grassed slope. However, the following design features are critical to ensure that the filter strip provides some minimum amount of water quality treatment:

- A pea gravel diaphragm or stone drop should be used at the top of the slope. The pea gravel diaphragm (a small trench running along the top of the filter strip) serves two purposes. First, it acts as a pretreatment device, settling out sediment particles before they reach the practice. Second, it acts as a level spreader, maintaining sheet flow as runoff flows over the filter strip.

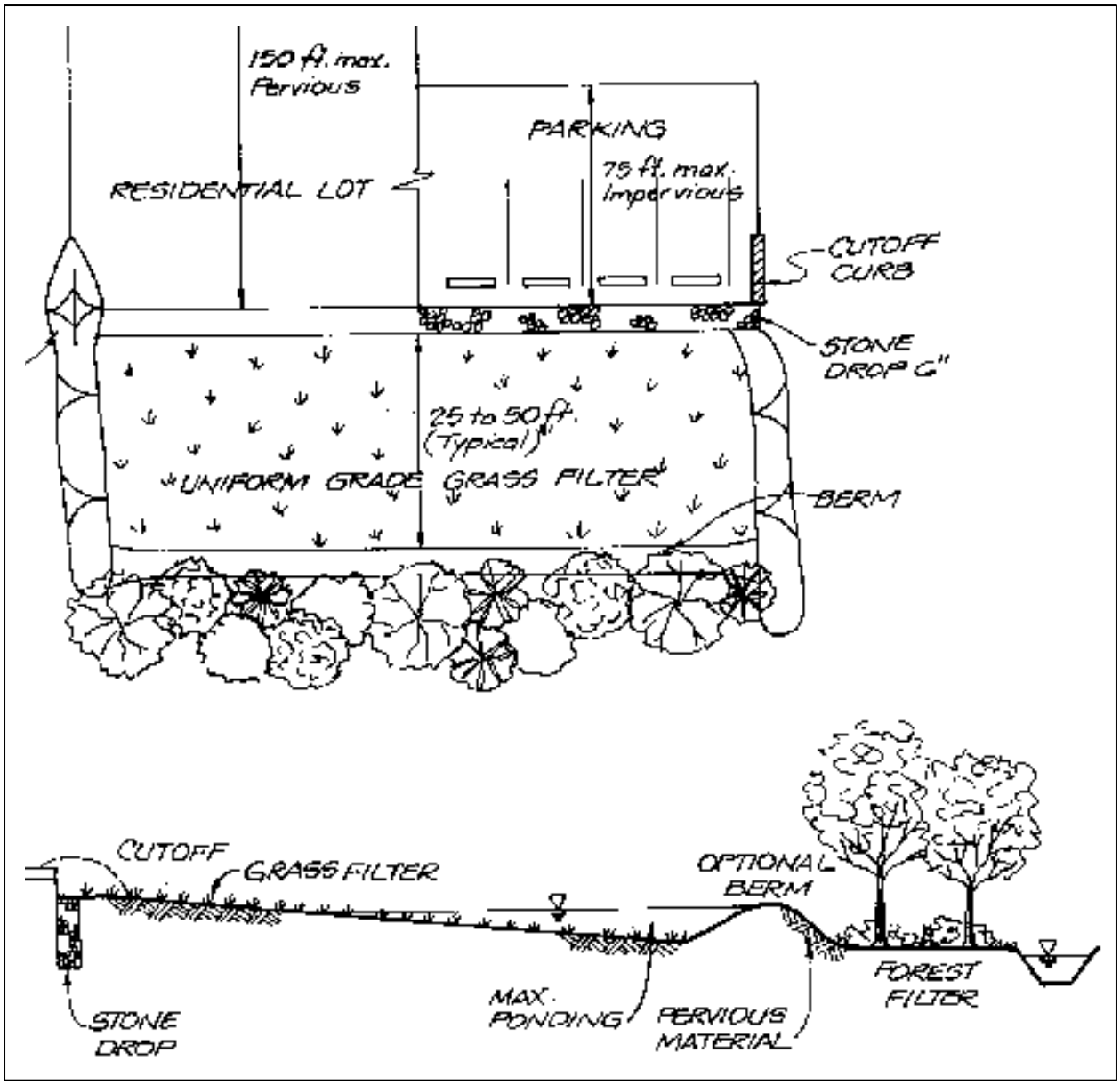

Figure 5.16: Schematic of a vegetated filter strip (Claytor and Schueler, 1996).

- The filter strip should be designed with a pervious berm of sand and gravel at the toe of the slope. This feature provides an area for shallow ponding at the bottom of the filter strip. Runoff ponds behind the berm and gradually flows through outlet pipes in the berm. The volume ponded behind the berm should be equal to the water quality volume. The water quality volume is the amount of runoff that will be treated for pollutant removal in the practice. Typical water quality volumes are the runoff from a 1-inch storm or ½-inch of runoff over the entire drainage area to the practice.

- The filter strip should have a length of at least 25 feet to provide water quality treatment.

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- Vegetation must be able to withstand relatively high velocity flows and both wet and dry periods.

- The slope should have a flat top and toe to encourage sheet flow and prevent erosion.

5.3.5.7 Street surface and subsurface storage

Runoff can be temporarily stored on and below the surface of streets in urban areas, as shown in Figure 5.17, to reduce peak flows to the storm sewer system (Carr et al., 1999). Runoff can be retained on and below the street using a combination of berms, flow regulators, and below-surface storage. Berms resemble speed bumps or speed humps but are broader and gentler; they retain water in a shallow pool on the street surface upstream of the berm. In some cases, this type of surface storage is inappropriate because it can result in damage to roadways. An alternative is subsurface storage in tanks or large sewer pipes. Both above- and below-ground storage systems, when combined with flow regulators that allow only a limited amount of runoff to enter the sewer system, mitigate basement flooding, combined sewer overflows, sanitary sewer overflows, and surface flooding. These systems should be designed with public safety in mind to minimize hydroplaning and icing in cold climates.

Figure 5.17: Runoff pooling on a street surface designed for temporary storage.

Two suburban Chicago, Illinois, towns—Skokie and Wilmette—implemented street-surface storage of runoff. The Skokie system has 2,900 flow regulators, 871 berms, 10 off-street storage facilities, 83 subsurface facilities, and several new storm and combined sewers (USEPA, 2000b). Wilmette's runoff storage system is composed of essentially all street storage. These systems have been effective in preventing flooding and overflows and are less expensive than other alternatives such as sewer separation and relief sewers. More information about these studies can be found at http://www.epa.gov/ednnrmrl/publications/reports/epa600r00065/epa600r00065.htm.

5.3.5.8 On-lot storage practices

The term "on-lot storage" refers to a series of practices that are designed to contain runoff from individual lots. The purpose of most on-lot practices is to manage rooftop or parking area runoff. The primary advantage of managing runoff from rooftops and parking lots is to disconnect these impervious surfaces, reducing the effective impervious cover in a watershed.

Johnston et al. (2003) modeled the downstream hydrologic and economic impacts of on-site runoff storage based on flood risk reduction on property values and costs of storm drainage

infrastructure. They found that use of reduced runoff practices provided property value benefits due to decreased flood risk of $21,600 to $36,300 per acre using countywide assessed values, or $17,540 to $29,240 per acre using U.S. Census Bureau census block median housing values. Benefits in avoided costs for storm drainage infrastructure (road culverts) totaled $247 to $836 per developed acre.

Although there are many on-lot treatment options, they can all be classified into one of three categories: (1) practices that infiltrate runoff; (2) practices that divert runoff to a pervious area; and (3) practices that store runoff for later use. The best option depends on the goals of a community, the feasibility at a specific site, and the preferences of the property owner.

Rooftop Runoff

Rooftop runoff, particularly in residential areas, generally has low pollutant concentrations compared with other urban sources (Schueler, 1994). Information on green rooftops can be found in Section 4.3.2.2. The practice most often used to infiltrate rooftop runoff is the dry well. In this design, the storm drain is directed to an underground rock-filled trench that is similar in design to an infiltration trench. French drains or Dutch drains can also be used for this purpose. In these designs, the relatively deep dry well is replaced with a long trench with a perforated pipe within the gravel bed to distribute flow throughout the length of the trench. Chamber systems, a widely marketed proprietary product, can be used in a similar manner.

Runoff can be diverted to a pervious area or to a treatment area using site grading or channels and berms. Treatment options can include grassed swales, bioretention cells, or filter strips. The bioretention design can be simplified for an on-lot application by limiting the pretreatment filter and in some cases eliminating the underdrain. Alternatively, rooftop runoff can simply be diverted to pervious lawn areas instead of discharging it directly to the street or a pipe drainage system.

Practices that store rooftop runoff, such as cisterns, chambers, and rain barrels (Figure 5.18), are the simplest designs for on-lot treatment systems. Some of these practices are available commercially and can be applied in a variety of site conditions. Cisterns and rain barrels are particularly valuable in the arid Southwest, where water is at a premium, rainfall is infrequent, and reuse for irrigation can save homeowners money.

Rain barrels typically range in cost from $60 to $135. These prices do not always include the cost of additional parts needed to link the rain barrel to a downspout. These parts generally range in cost from $5 to $18, depending on the manufacturer and the design of the rain barrel (Gardener's, 2001; Jade Mountain, 2000; Midwest, 2001; Spruce Creek, 2001). If

Figure 5.18: A rain barrel that collects runoff from a roof gutter downspout.

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homeowners want to save money, they can build their own rain barrel, which costs approximately $15 if recycled drums are available.

Information about building a simple rain barrel is available from the Maryland Green Building Program at http://www.dnr.state.md.us/ed/rainbarrel.html (MDNR, no date). Information is also available in *How to Make a Rain Barrel*, which was published by the city of Ottawa, Ontario (no date). The manual is available by contacting the city of Ottawa toll-free at 866-261-9799, or by e-mailing info@city.ottawa.on.ca.

It is important for municipalities planning to start a rain barrel program to consider water quality issues, climate, algae and mosquito control, homeowner attitudes and willingness, and the protection of home foundations. Rain barrels can be a reliable source of water for garden and lawn watering, but if the water is intended for consumption it is crucial that the roof materials and gutter system be examined for asbestos, lead paint, and bird droppings (Sands and Chapman, 2003).

The Milwaukee Metropolitan Sewerage District (MMSD) undertook a rain barrel project in response to problems with combined sewer overflows. The project involved 40,000 single-family homes with roof areas of approximately 1,200 square feet. Two 90-gallon rain barrels were installed at each home. The MMSD found the reduction in runoff volume attributed to rain barrels to be approximately 243 million gallons. While the effort did not reduce combined sewer overflow volumes for the MMSD, it did result in savings on treatment plant costs and increased environmental awareness. The MMSD plans to continue to incorporate rain barrels into an integrated management plan that might include additional on-lot treatment practices (Sands and Chapman, 2003).

On-lot treatment practices can be applied to almost all sites with very few exceptions (e.g., very small lots or lots with no landscaping). There are currently at least two jurisdictions that offer "credits" in exchange for the application of on-site runoff management practices. In Denver, Colorado, sites designed with methods to reduce "directly connected impervious cover," including disconnection of downspout runoff from the storm drain system, are permitted to use a lower impervious area when computing the required storage of runoff management facilities (DUDFC, 1992). Similarly, new regulations for Maryland allow designers to subtract each rooftop that is disconnected from the total site impervious cover when calculating required storage in runoff management practices (MDE, 2000).

Although most residential lots can incorporate on-lot treatment, the best option for a site depends on design constraints and the preferences of the homeowner. On-lot infiltration practices have the same restrictions regarding soils as other infiltration practices. If other design practices are used, such as bioretention or grassed swales, they need to meet the siting requirements of those sites. Of all of the practices, cisterns and rain barrels have the fewest site constraints. In order for the practice to be effective, however, homeowners need to have a use for the water stored in the practice, and the design must accommodate overflow and winter freezing conditions.

Although these runoff management practices are simple compared with many others, their design needs to incorporate the same basic elements. Pretreatment is important for all of these practices to ensure that they do not become clogged with leaves or other debris. Infiltration practices may

Santa Monica Urban Runoff Program

Santa Monica's comprehensive urban runoff program combines pollution prevention and on-site practices with a runoff recycling program designed to improve water quality and harvest dry weather runoff as a resource. By protecting existing water resources, increasing infiltration on-site, and harvesting runoff for reuse, the city is maximizing the use of storm water as a resource and decreasing the demand for imported water. The city's pollution prevention program protects water quality with education, municipal housekeeping, lawn care and landscaping practices, and an ordinance that requires good housekeeping practices on construction sites. On-site practices are required by the Urban Runoff Pollution Mitigation Ordinance and include infiltration practices, porous pavement, and other low impact development techniques. The city has also installed catch basin inserts and screens to capture trash, debris, and some soluble pollutants. Finally, the Santa Monica Urban Runoff Recycling Facility (SMURRF) harvests and treats dry weather runoff and makes it available for reuse as irrigation water or for indoor toilet flushing (Shapiro, 2003).

be preceded with a settling tank or, at a minimum, a grate or filter in the downspout to trap leaves and other debris. Rain barrels and cisterns also often incorporate some sort of pretreatment, such as a mesh filter at the top of the barrel or cistern.

Both infiltration practices and storage practices should incorporate some type of bypass so runoff from larger storms flows away from the house. With rain barrels or cisterns, this bypass may be a hose set at a high level within the device that directs runoff away from both the device and the building foundation. These practices also include a hose bib set at the bottom of the device so the homeowner can use the stored water for irrigation or other uses by attaching a standard garden hose to the hose bib.

One important design requirement for on-lot infiltration practices is locating the infiltration area sufficiently far from the house (at least 10 feet) to prevent undermining of the foundation or seepage into the basement.

Infiltration practices require regular removal of sediment and debris settled in the pretreatment area, and the infiltration medium needs to be replaced when it becomes clogged. Rain barrels and cisterns require minimal maintenance, but the homeowner must ensure that the hose remains elevated during the winter to prevent freezing and cracking. In addition, the tank requires cleaning approximately once a year.

On the basis of cost per unit area treated, on-lot practices are relatively expensive compared with other runoff storage and treatment options. It is difficult to make this comparison, however, because the cost burden of on-lot practices is borne directly by homeowners. Typical costs are $100 for a rain barrel and $200 for a dry well or French drain. Often, homeowners can reduce costs by creating their own on-lot practice rather than purchasing a commercial product.

Parking Lot Runoff

Standard parking lots typically drain rapidly through curb and gutter systems to prevent flooding. This practice, however, does little to improve water quality or protect receiving waters from high flows during and after storms. Innovative designs for parking lots incorporate pervious areas for drainage, whether at the perimeter or in various islands within the lot. These pervious areas

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should be designed to infiltrate runoff at rates that prevent excessive ponding, which could appear unsightly or create safety issues and nuisance mosquito habitat. In cases where existing soils have poor infiltration capacity, better-drained soils should be imported or perforated under-drains installed to store infiltrated runoff underground.

The use of large-diameter underground pipes constructed of concrete, corrugated steel, or high-density polyethylene (HDPE) is becoming a more common practice for large parking areas such as shopping malls and mixed-use developments. These underground pipes and vaults as well as chamber systems can store large quantities of runoff that can be reused as needed or released at rates that will not damage natural conveyance systems.

5.3.5.9 Microbial disinfection

Other practices can be used to treat runoff for specific pollutants other than sediment. For instance, in areas where microbial pollution is an issue, runoff can be treated using ozone or ultraviolet light to prevent disease and reduce exceedances of water quality due to pathogen contamination. The City of Encinitas, California, was concerned about the number of public health warnings at its primary seaside attraction, Moonlight Beach, due to high enterococcus and coliform bacteria counts. The main source of the microbial pollution was dry weather runoff from Cottonwood Creek, which discharges at Moonlight Beach. Despite extensive evaluation of the Cottonwood Creek drainage area to identify and reduce bacterial loading, public health warnings continued to be posted. In anticipation of a total maximum daily load for bacteria under development for the region, and to reduce or eliminate the number of beach postings, the City chose to install an ultraviolet (UV) disinfection facility with partial funding from California's Clean Beach Initiative. The UV treatment facility was designed to treat 150 gallons per minute of Cottonwood Creek's dry weather flow, with 15% of the creek's flow diverted around the facility to maintain biological connectivity between upstream and downstream waters. During times of high flow (i.e., during and after storms) and high turbidity, when the system's treatment effectiveness would be reduced, the system is shut down and flow is passed through without treatment. Early monitoring results showed a significant decrease in bacterial counts downstream of the treatment facility, with a removal efficiency of more than 99.9 percent that yielded an effluent quality of 2 bacteria per 100 mL. Filters built into the system were also effective at removing suspended sediment, reducing turbidity from an average of 14.0 mg/L in the influent to 5.0 mg/L in the effluent.

5.4 Performance and Cost Information for Management Practices

Some advantages, disadvantages, and costs of specific runoff control practices described above are listed in Table 5.6. Site-specific information, regional limitations, operation and maintenance burdens, and longevity for these practices are listed in Table 5.7.

Table 5.6: Advantages and disadvantages of management practices (MDE, 2000).

Practice	Advantages	Disadvantages	Comparative Cost[a]
Runoff control ponds			
Wet pond	– Can provide peak flow control – Can serve large developments; most cost-effective for larger, more intensively developed sites – Enhances aesthetics and provides recreational benefits – Little ground water discharge – Permanent pool in wet ponds helps to prevent scour and re-suspension of sediments – Provides moderate to high removal of both particulate and soluble urban runoff pollutants	– Not economical for drainage area less than 10 acres – Potential safety hazards if not properly maintained – If not adequately maintained, can be an eyesore, breed mosquitoes, and create undesirable odors – Requires considerable space, which limits use in densely urbanized areas with expensive land and high property values – Not suitable for hydrologic soil groups "A" and "B" (USDA-NRCS classification) unless a liner is used – With possible thermal discharge and oxygen depletion, may severely impact downstream aquatic life – Hydrologic damage to stream channels and aquatic habitat is possible due to flow volume.	Moderate to high compared to conventional runoff detention
Infiltration practices			
Infiltration basin	– Provides ground water recharge – Can serve large developments – High removal capability for particulate pollutants and moderate removal for soluble pollutants – When basin works, it can replicate predevelopment hydrology more closely than other BMP options – Basins provide more habitat value than other infiltration systems	– Possible risk of contaminating ground water – Only feasible where soil is permeable and there is sufficient depth to bedrock and water table – Fairly high failure rate – If not adequately maintained, can be an eyesore, breed mosquitoes, and create undesirable odors – Regular maintenance activities cannot prevent rapid clogging of infiltration basin	Construction cost moderate but rehabilitation cost high

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Table 5.6 (continued).

Practice	Advantages	Disadvantages	Comparative Cost[a]
Infiltration trench	– Provides ground water recharge – Can serve small drainage areas – Can fit into medians, perimeters, and other unused areas of a development site – Helps replicate predevelopment hydrology, increases dry weather baseflow, and reduces bankfull flooding frequency	– Possible risk of contaminating ground water – Only feasible where soil is permeable and there is sufficient depth to bedrock and water table – Since not as visible as other BMPs, less likely to be maintained by residents – Requires significant maintenance	– Cost-effective on smaller sites – Rehabilitation costs can be considerable
Concrete grid pavement	– Can provide peak flow control – Provides ground water recharge – Provides water quality control without additional consumption of land	– Requires regular maintenance – Not suitable for areas with high traffic volume – Possible risk of contaminating ground water – Only feasible where soil is permeable, there is sufficient depth to bedrock and water table, and there are gentle slopes	Information not available
Filtering practices			
Filtration basin	– Ability to accommodate medium-size development (3–80 acres) – Flexibility to provide or not provide ground water recharge – Can provide peak volume control	– Requires pretreatment of runoff through sedimentation to prevent filter media from premature clogging	Information not available
Bioretention	– Provides ground water recharge	–	
Open channel practices			
Grassed swale	– Requires minimal land area – Can be used as part of the runoff conveyance system to provide pretreatment – Can provide sufficient runoff control to replace curb and gutter in single-family residential subdivisions and on highway medians – Economical	– Low pollutant removal rates – Leaching from culverts and fertilized lawns may actually increase the presence of trace metals and nutrients	Low compared to curb and gutter
Structural management practices that do not consistently remove 80% TSS			
Vegetated filter strip	– Low maintenance requirements – Can be used as part of the runoff conveyance system to provide pretreatment – Can effectively reduce particulate pollutant levels in areas where runoff velocity is low to moderate – Provides excellent urban wildlife habitat – Economical	– Often concentrates water, which significantly reduces effectiveness – Ability to remove soluble pollutants highly variable – Limited feasibility in highly urbanized areas where runoff velocities are high and flow is concentrated – Requires periodic repair, regrading, and sediment removal to prevent channelization	Low

Table 5.6 (continued).

Practice	Advantages	Disadvantages	Comparative Cost[a]
Water quality inlet Catch basins with sand filter	– Provide high removal efficiencies of particulates – Require minimal land area – Flexibility to retrofit existing small drainage areas – Higher removal of nutrient as compared to catch basins and oil/grit separator	– Not feasible for drainage areas greater than 5 acres – Only feasible for areas that are stabilized and highly impervious – Not effective as water quality control for intense storms	Information not available
Water quality inlet Oil/grit separator	– Captures coarse-grained sediments and some hydrocarbons – Requires minimal land area – Flexibility to retrofit existing small drainage areas and applicable to most urban areas – Shows some capacity to trap trash, debris, and other floatables – Can be adapted to all regions of the country	– Not feasible for drainage area greater than 1 acre – Minimal nutrient and organic matter removal – Not effective as water quality control for intense storms – Concern exists for the pollutant toxicity of trapped residuals – Require high maintenance	High, compared to trenches and sand filters
Extended detention dry pond with micropool	– Can provide peak flow control – Possible to provide good particulate removal – Can serve large development – Requires less capital cost and land area when compared to wet pond – Does not generally release water or anoxic water downstream – Provides excellent protection for downstream channel erosion – Can create valuable wetland and meadow habitat when properly landscaped	– Removal rates for soluble pollutants are quite low – Not economical for drainage area less than 10 acres – If not adequately maintained, can be an eyesore, breed mosquitoes, and create undesirable odors	Lowest cost alternative in size range

[a]Comparative cost information from Schueler, 1992

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Table 5.7: Regional, site-specific, and maintenance considerations for management practices (USEPA, 1993; Caraco and Claytor, 1997; Schueler, in press).

Management Practice and Specifications	Cold Climate Restrictions (Caraco and Claytor, 1997)	Arid and Semi-Arid Regional Restrictions (Schueler, in press)
Infiltration basins *Size of drainage area*: Moderate to large *Site requirements:* Deep, permeable soils *Maintenance burdens*: High *Longevity:* Low	– Avoid areas with permafrost – Monitor ground water for chlorides – Do not infiltrate road/parking lot snowmelt if chlorides are a concern – Increase percolation requirements – Use 20 foot minimum setback between road subgrade and practice	– No recharge in hot-spot areas – Do not treat pervious areas – Use multiple pretreatment – Soil limitations exist in arid areas
Infiltration trenches *Size of drainage area*: Moderate *Site requirements:* Deep, permeable soils *Maintenance burdens*: High *Longevity:* Low	– Avoid areas with permafrost – Monitor ground water for chlorides – Do not infiltrate road/parking lot snowmelt if chlorides are a concern – Increase percolation requirements – Use 20-foot minimum setback between road subgrade and practice	– No recharge in hot-spot areas – Do not treat pervious areas – Use multiple pretreatment – Soil limitations exist in arid areas
Vegetated filter strips *Size of drainage area*: Small *Site requirements:* Low-density areas with low slopes *Maintenance burdens*: Low *Longevity:* Low if poorly maintained	– Small setback may be required between filter strips and roads when frost heave is a concern – Avoid areas with permafrost – Use cold- and salt-tolerant vegetation – Plowed snow can be stored in-practice	– Use drought-tolerant vegetation
Grassed swales *Size of drainage area*: Small *Site requirements*: Low-density areas with <15% slope *Maintenance burdens*: Low *Longevity:* High if maintained	– Avoid areas with permafrost – Use cold- and salt-tolerant vegetation – Plowed snow can be stored in the practice – Increase underdrain pipe diameter and size of gravel bed – Provide ice-free culverts – Ensure soil bed is highly permeable	– Not recommended for pollutant removal in arid areas – Of limited use in semi-arid areas – Ensure adequate erosion protection of channels
Porous pavement *Size of drainage area*: Small *Site requirements*: Deep permeable soils, low slopes, and restricted traffic *Maintenance burdens*: Moderate to high *Longevity:* Low	– Only use on non-sanded surfaces – Pavement may be damaged by snow plows – Maintenance is essential	
Filtration basins and sand filters *Size of drainage area*: Widely applicable *Site requirements*: Widely applicable *Maintenance burdens*: Moderate *Longevity:* Low to moderate	– Reduced treatment effectiveness during cold season – Underground filters only effective if placed below the frost line – Peat/compost media ineffective during winter and may become impervious if frozen	– Preferred in both arid and semi-arid areas. Arid area filters require greater pretreatment
Bioretention	– Reduced treatment effectiveness during cold season – Pretreatment should be used to prevent "choking" of vegetation	

Table 5.7 (continued).

Management Practice and Specifications	Cold Climate Restrictions (Caraco and Claytor, 1997)	Arid and Semi-Arid Regional Restrictions (Schueler, in press)
Water quality inlets *Size of drainage area*: Small *Site requirements:* Impervious catchments *Maintenance burdens*: Cleaned twice a year *Longevity:* High	– Few restrictions	
Extended detention dry ponds *Size of drainage area*: Moderate to large *Site requirements:* Deep soils *Maintenance burdens*: Dry ponds have relatively high burdens *Longevity:* High	– Protect inlet/outlet pipes – Use large-diameter (> 8 in) gravel in underdrain of outfall protection – Consider seasonal operation – Provide ice storage volume – Cold-tolerant vegetation	– Preferred in arid climates and acceptable in semi-arid climates
Wet ponds *Size of drainage area*: Moderate to large *Site requirements*: Deep soils *Maintenance burdens*: Low *Longevity:* High	– Protect inlet/outlet pipes – Use large-diameter (> 8 in) gravel in underdrain of outfall protection – Consider seasonal operation – Provide ice storage volume – Cold-tolerant vegetation	– Not recommended in arid areas and of limited use in semi-arid areas
Wetlands *Size of drainage area*: Moderate to large *Site requirements:* Poorly drained soils, space may be limiting *Maintenance burdens*: Annual harvesting of vegetation *Longevity:* High	– Protect inlet/outlet pipes – Use large-diameter (> 8 in) gravel in underdrain of outfall protection – Consider seasonal operation – Provide ice storage volume – Cold-tolerant vegetation	– Not recommended in arid areas and of limited use in semi-arid areas

Table 5.8 presents pollutant removal efficiency statistics for the management practices discussed in this section. These values originate from the *National Pollutant Removal Performance Database for Stormwater BMPs* (Caraco and Winer, 2000). The database was compiled through a comprehensive literature search focusing on runoff treatment practice monitoring sites from 1990 to present. In addition, approximately 60 previously collected monitoring studies from 1977 and 1989 were included in the database. All 139 studies meet the two following criteria: (1) the researchers used automated equipment that enabled flow or time-based composite samples; and (2) they documented the method used to compute removal efficiency. With respect to the number of storms sampled, more than three-quarters of the studies were based on five or more storm samples. The sample size was not reported in the remaining studies.

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Table 5.8: Effectiveness of management practices for runoff control (adapted from Caraco and Winer, 2000).

Runoff Treatment or Control Practice Category or Type	Median Pollutant Removal (Percent)							
	No. of studies	TSS	TP	OP	TN	NOx	Cu	Zn
Quality Control Pond	3	3	19	N/A	5	9	10	5
Dry Extended Detention Pond	6	61	20	N/A	31	-2	29	29
Dry Ponds	9	47	19	N/A	25	3.5	26	26
Wet Extended Detention Pond	14	80	55	69	35	63	44	69
Multiple-Pond System	1	91	76	N/A	N/A	87	N/A	N/A
Wet Pond	28	79	49	39	32	36	58	65
Wet Ponds	43	80	51	65	33	43	57	66
Shallow Marsh	20	83	43	66	26	73	33	42
Extended Detention Wetland	4	69	39	59	56	35	N/A	-74
Pond/Wetland System	10	71	56	37	19	40	58	56
Submerged Gravel Wetland	2	83	64	14	19	81	21	55
Wetlands	36	76	49	48	30	67	40	44
Organic Filter	7	88	61	30	41	-15	66	89
Perimeter Sand Filter	3	79	41	68	47	-53	25	69
Surface Sand Filter	7	87	59	N/A	31.5	-13	49	80
Vertical Sand Filter	2	58	45	21	15	-87	32	56
Bioretention	1	N/A	65	N/A	49	16	97	95
Filtering Practices[a]	18	86	59	*57*	38	-14	49	88
Infiltration Trench	3	100	42	100	42	82	N/A	N/A
Porous Pavement	3	95	65	10	83	N/A	N/A	99
Ditches[b]	9	31	-16	N/A	-9	24	14	0
Grass Channel	3	68	29	32	N/A	-25	42	45
Dry Swale	4	93	83	70	92	90	70	86
Wet Swale	2	74	28	-31	40	31	11	33
Open Channel Practices	9	81	34	*1.0*	*84*	31	51	71
Oil-Grit Separator	1	-8	-41	40	N/A	47	-11	17

Shaded rows show data for groups of practices (i.e., dry ponds include quality control ponds and dry extended detention ponds).
Numbers in italics are based on fewer than five data points.
[a] Excludes vertical sand filters
[b] Refers to open channel practices not designed for water quality.
TSS=total suspended solids, TP=total phosphorus, OP=ortho-phosphorus, TN=total nitrogen, NOx=nitrate and nitrite nitrogen, Cu=copper, Zn=zinc.

Strecker et al. (2000) identified problems with comparing different management practice effectiveness studies. They suggested that inconsistent study methods, lack of associated design information, and multiple reporting protocols make wide-scale assessments of management practices difficult. Also, differences in monitoring strategies and data evaluation methods contribute significantly to the wide range of reported management practice effectiveness.

EPA recognizes that 80 percent TSS removal efficiency cannot be achieved for each storm event and understands that TSS removal efficiency will fluctuate above and below 80 percent for individual storms. Researchers have noted that efficiency estimation is often based on pollutant loads into and out of the management practice on a storm-by-storm basis. Therefore, a multiple-study analysis or summary is based on the assumption that all storms are equal when computing average pollutant removal. Storm-by-storm comparisons are probably not effective because many storms are not large enough to displace the permanent pool volume. They recommend that effectiveness be evaluated using statistical characterizations of the inflow and outflow

concentrations because if enough samples are collected, total loads into and out of the management practice can be used reliably.

Strecker et al. (2000) also analyzed the use of effluent data to measure the influence of certain design criteria on management practice efficiency. Some studies suggest that management practices can only treat runoff to a specified pollutant concentration. However, if relatively clean water enters a practice, performance data based on removal efficiency might not fully characterize whether the practice is well designed and effective. Therefore, pollutant removal efficiency, when it is expressed as percent removal, might not be an accurate representation of

Verifying the Performance of Environmental Technologies

EPA's Environmental Technology Verification (ETV) Program, which began in October 1995, was instituted to verify the performance of innovative technical solutions to problems that threaten human health and the environment. ETV was created to significantly accelerate the entrance of new environmental technologies into the domestic and international marketplaces. The program operates through public and private testing partnerships to evaluate the performance of environmental technology in all media, including air, water, soil, ecosystems, waste, pollution prevention, and monitoring. More information about the ETV Program is available at http://www.epa.gov/etv (USEPA, 2001b).

Another method for evaluating technology is the Environmental Technology Evaluation Center (EvTEC), which was established by the Civil Engineering Research Foundation (CERF) through EPA's ETV Program. EvTEC is an independent, market-based approach to technology verification and was established to accelerate the adoption of environmental technologies into practice. More information about EvTEC is available at http://www.cerf.org/evtec (CERF, 2001).

EPA and NSF International, an independent, nonprofit testing organization, have developed a testing protocol to determine the viability of runoff treatment technologies and other wet weather flow controls, including runoff, combined sewer overflow (CSO), and sanitary sewer overflow (SSO). NSF International will also test and verify high-rate separation/clarification and high-rate disinfection technologies, flow monitoring equipment, and wet weather models.

Participants in the study include vendors who want to demonstrate the effectiveness of their technologies. Results of the pilot will be useful to a variety of stakeholders including municipalities, businesses, vendors, consulting engineers, and regulatory agencies. Once verification reports have been completed, vendors may use the results in their marketing efforts. Results will be made publicly available through EPA's and NSF's Web sites at http://www.epa.gov/etv and http://www.nsf.org/business/ETV_EPA_NSF/index.asp?program=ETVEPANSF, respectively. More information about the program is available at http://www.wateronline.com/content/news/article.asp?docid={17DDF263-29B8-11D5-A770-00D0B7694F32} (Water-Online, 2001).

International Stormwater Best Management Practices Database

The American Society of Civil Engineers, in cooperation with EPA, has compiled the *International Stormwater Best Management Practices Database*, which contains performance data from more than 200 management practice studies. Information provided for the management practices includes test site location, researcher contact data, watershed characteristics, regional climate statistics, management practice design parameters, monitoring equipment types, and monitoring data such as precipitation, flow, and water quality. More information on the database's purpose, design, and documentation can be found at http://www.bmpdatabase.org/.

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how well a management practice is performing. Although more research is necessary to accurately determine the effectiveness of management practices, Strecker et al. recommend that standard methods and detailed guidance on data collection be used to improve data transferability.

Table 5.9 presents information concerning the costs associated with selected structural practices. The sources of these data are publicly available articles (some are a compilation of numerous studies).

Table 5.9: Costs of selected management practices (Claytor and Schueler, 1996; Brown and Schueler, 1997).

Management Practice	Construction Costs[a]	Useful Life (years)	Total Annual Costs
Infiltration basin[b]			
Average	$0.55/ft^3 storage	25[c]	–
Report range	$0.22–$1.31/ft^3	–	$0.03–$0.05/ft^3
Probable range	$0.44–$0.76/ft^3	–	–
Infiltration trench[b]			
Average	$4.36/ft^3 storage	10[c]	–
Report range	$0.98–$10.04/ft^3	–	$0.03–$0.10/ft^3
Probable range	$2.73–$8.18/ft^3	–	–
Infiltration practices[d]			
Average	$2.99/ft^3 storage	–	–
Report range	$2.13-4.27/ft^3 storage	–	–
Vegetated swales[b]			
Established from seed			
Average	$7.09/linear ft	50[e]	$1.09/linear ft
Report range	$4.91–$9.27/linear ft	–	–
Established from sod			
Average	$21.82/linear ft	50[e]	$2.18/linear ft
Report range	$8.73–$54.56/linear ft	–	–
Porous pavement[b]			
Average	$1.64/ft^2	10[f]	$0.16/ft^2
Report range	$1.09-$2.18/ft^2	–	–
Concrete grid pavement[b]			
Average	$1.09/ft^2	20	$0.05/ft^2
Report range	$1.09–$2.18/ft^2	–	–
Filtration basins[b]			
Average (probable)	$5.46/ft^3 storage	25[g]	–
Report range	$1.09–12.00/ft^3	–	$0.11–$0.87/ft^3
Probable range	$2.18–9.82/ft^3	–	–
Bioretention practices[d]			
Average	$6.83/ft^3 storage	–	–
Filtration practices[d]			
Average	$2.63/ft^3 storage	–	–
Range	$2.13-6.40/ft^3 storage	–	–
Water quality inlet[b,h]			
Average	$2,182 each	50	$164 each
Report range	$1,200–3,273 each	–	–
Probable range	–	–	–
Water quality inlet with sand filter[b,h] Average (probable)	$10,900/drainage acre	50	$764/drainage acre

Table 5.9 (continued).

Management Practice	Construction Costs[a]	Useful Life (years)	Total Annual Costs
Oil/grit separator[b,h]			
Average	$19,640/drainage acre	50	$1,091/drainage acre
Report range	$16,370–$21,820/drainage acre	–	–
Stabilization with ground cover[b,h]			
From existing vegetation			
Average	$0	50	Natural: $109/acre
Report range	–	–	Managed: $873/acre
From seed			
Average	$436/acre	50	Natural: $131/acre
Report range	$218–$1,091/acre	–	Managed: $900/acre
From seed and mulch			
Average	$1,637/acre	50	Natural: $218/acre
Report range	$872–$3,819/acre	–	Managed: $982/acre
From sod			
Average	$12,330/acre	50	Natural: $764/acre
Report range	$4,910–$52,375/acre	–	Managed: $1,528/acre
Ext. Detention Dry Pond[b,h]			
Average	$0.55/ft^3 storage	50	–
Report range	$0.05–$3.49/ft^3	–	$0.008–$0.33/ft^3
Probable range	$0.10–$5.46/ft^3	–	–
Wet Pond and Extended Detention Wet Pond[b]	$0.55/ft^3 storage	50	$0.009–$0.08/ft^3
Storage vol. < 1 million ft^3	$0.05–$1.09/ft^3	–	–
Average	$0.55–$1.09/ft^3	–	–
Report range	$0.27/ft^3 storage	50	–
Probable range	$0.05–$0.55/ft^3	–	$0.009–$0.08/ft^3
Storage vol. > 1 million ft^3	$0.11–$0.55/ft^3	–	–
Average (probable)			
Report range (probable)			
Probable range			

[a]Costs updated using the Bureau of Labor Statistics Inflation Calculator.
[b]Claytor and Schueler, 1996.
[c]References indicate the useful life for infiltration basins and infiltration trenches at 25-50 and 10-15 years, respectively. Because of the high failure rate, infiltration basins are assumed to have a useful life span of 25 years and infiltration trenches are assumed to have a useful life span of 10 years.
[d]Brown and Schueler, 1997.
[e]Useful life is assumed to equal the life of the project, assumed to be 50 years.
[f]No information was available for porous pavement. It is assumed to be similar to infiltration trenches.
[g]No information was available for filtration basins. It was assumed to be similar to infiltration basins.
[h] These practices do not meet the 80 percent TSS removal, thus it is recommended that they be used with other management practices in a treatment train.

5.5 Managing Structural Controls to Reduce Mosquito-Breeding Habitat

In recent years, concern has been raised that storm water management facilities have been breeding grounds for mosquitoes (Conlon, 2002). This is a public health concern because mosquitoes are known vectors for disease-causing arboviruses such as malaria, yellow fever, dengue fever, St. Louis encephalitis, and West Nile virus, to name a few. The relationship

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between storm water management and mosquito breeding exists because the presence of standing and sometimes stagnant water facilitates the two aquatic stages of a mosquito's life cycle—the egg and larval stages.

Not all mosquito species are vectors for disease, but control is still warranted because, even if not a health risk, mosquitoes are considered a nuisance. Mosquito species have different habitat preferences, and two basic groups can breed in the urban environment: permanent water species and floodwater species (Metzger et al., 2002). Permanent water species would be likely to propagate in storm water management facilities that always contain water, such as wet detention ponds and constructed wetlands. Floodwater species would likely inhabit "dry" systems such as extended detention dry ponds that have fluctuating water levels.

This issue has caused a fair amount of controversy because mosquito-breeding habitats are prevalent in urban and suburban environments. Metzger et al. (2002) identified a few of the numerous manmade mosquito-breeding habitats in urban and suburban environments:

> Urban environments provide mosquitoes with a vast array of new habitats: humid and arid, above and below ground, small water-holding containers and large ponds, polluted and clean water. Aquatic habitats are found around people's homes (birdbaths, jars, flower pots, neglected pools and Jacuzzis and clogged rain gutters), in unregulated waste dumps (used tires, barrels, bottles, and cans), in parks (ponds, lakes, and streams), and in the city's own infrastructure (storm drains, sewer systems, catch basins, and culverts). Many of these sources are replenished frequently by stormwater and urban runoff (e.g., irrigation, washing cars). Adding to this, increasingly stringent urban stormwater runoff regulations have recently mandated the construction of structural practices for both volume reduction and pollution management, many of which have created additional sources of standing water. This abundance of habitats has favored mosquitoes and allowed many species to greatly expand their range and increase in number.

Although storm water management facilities are not the sole source of standing water, public concern has raised the question of how these facilities can be managed, redesigned, or otherwise modified to reduce the creation of disease vectors close to urban population centers.

The California Department of Health Services' Vector-Borne Disease Section (2002), in cooperation with the California Department of Transportation (Caltrans), undertook a study to evaluate retrofit opportunities for storm water management. Part of this study investigated the mosquito production of 37 structural management practices in southern California. Eight categories of practices were constructed and examined as part of the study: (1) biofiltration strips and swales; (2) filtration devices (Austin-type and Delaware-type sand media filters, multi-chambered treatment train sand media filters, and a proprietary canister filter); (3) extended detention basins; (4) infiltration devices (basins and trenches); (5) continuous deflective separators (CDSs); (6) an oil/water separator; (7) drain-inlet inserts; and (8) a constructed wetland (retention pond). The study consisted of comprehensive surveillance and monitoring of each practice for mosquito production, as well as follow-up monitoring after modifications had been made to reduce the potential to produce mosquitoes. Of the eight different technologies implemented by Caltrans, those that maintained permanent sources of standing water in sumps or

basins (MCTT, CDS, and the retention pond) provided excellent habitat for immature mosquitoes and frequently supported large populations relative to other structural designs. In contrast, practices designed to drain rapidly (i.e., biofiltration swales and strips, Austin-type sand media filters, infiltration basins and trenches, and extended detention basins) provided less-suitable habitats and rarely harbored mosquitoes.

The project was expanded to a nationwide investigation using phone and mail surveys and site visits to 150 agencies in 28 states. Of the 72 agencies that completed a questionnaire, 86 percent reported mosquito production associated with storm water management facilities. The survey found that inadequate maintenance resulted in accumulation of trash and other constituents (e.g., sediment, vegetation, organic debris).

The Southwest Florida Water Management District conducted a study to determine the extent to which storm water management facilities were breeding mosquitoes and offer recommendations for minimizing mosquito production (Livingston, no date). After examining more than 200 management practices with both permanent pools and intermittent pools, they found that 76 percent of all practices were mosquito productive, and that 66 percent of the permanently flooded practices and 69 percent of the intermittently flooded practices bred mosquitoes. Larval density was smaller and more dispersed in wet detention systems than in intermittently flooded systems. The wet detention systems that did not breed mosquitoes shared a paucity of vegetation, abundant fish, and good aeration. The intermittently flooded dry detention pond systems that did not produce mosquitoes were those that drained or dried within 72 hours.

The Florida researchers also investigated several pesticides and found them to be between 91 and 100 percent effective at controlling existing larval infestations in intermittently flooded systems within 24 hours of treatment, although one treatment in a system with high organic content was found to be ineffective against dense larval populations. The researchers also found that sustained-release materials such as pellets were effective for up to five weeks after application, whereas short-term controls required regular application.

Regular monitoring for mosquito adults and larvae, retrofitting and maintenance of practices to reduce the likelihood for breeding, and pesticide application where needed are the three key actions for eliminating mosquito breeding in storm water facilities. The Centers for Disease Control and Prevention discussed the role of pesticides that kill adult mosquitoes (adulticides) in mosquito management and recommended that their use be incorporated into an integrated pest management program that includes surveillance, source reduction, chemical control (larvicide and adulticide), biological control, and public relations and education (Rose, 2001).

Surveillance programs track diseases in bird populations, vector-borne pathogens in mosquitoes, mosquito populations, larval habitats, mosquito traps, biting counts, and reports by the public (Rose, 2001). Control activities are initiated when threshold populations are exceeded, and predictions are made from seasonal records and weather data.

Source reduction entails eliminating or altering larval habitats. This can be achieved through public education campaigns, with outreach to both children and adults. Additionally, state and local mosquito control agencies can alter the hydrology of open water and marshy areas to reduce or prevent the proliferation of mosquito larvae. Rose (2001) suggests techniques in which

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mosquito-producing areas in marshes are connected by shallow ditches to deep-water habitats to allow drainage or fish access, and minimally flooding the marsh during the summer but flap-gating impounded areas to reintegrate them to the estuary for the rest of the year.

Biological control can be achieved using various predators such as dragonfly nymphs and predacious mosquitoes (Rose, 2001). Mosquito fish are the most commonly used agents for biological control because they are easily reared, although they also feed on non-target species. Other types of organisms that might be used for mosquito control include several fish types other than *Gambusia*, as well as fungi, protozoans, nematodes, and predacious copepods.

It is essential that storm water managers and public works crews who maintain storm water management facilities be educated in integrated pest management. They should be trained to identify design flaws or maintenance needs that might create mosquito-breeding habitat, and they should know the procedures for reporting and remedying the problem. Pesticide handlers should have the required training under the Federal Insecticide, Fungicide, and Rodenticide Act and all chemicals should be applied at rates recommended on the packaging. Treated areas should be monitored after application to determine the efficacy of the applications and identify where pesticide resistance might be occurring.

There are steps that a storm water manager can take to reduce the likelihood that mosquitoes will breed in storm water management facilities. From a design standpoint, most management practices other than wet retention ponds are intended to drain within 72 hours. This is a safe drainage time because mosquitoes need at least that long for their aquatic life stages. Additionally, Metzger et al. (2002) found that several design features of storm water management practices contributed to vector production, including the use of sumps, catch basins, or spreader troughs that did not drain completely; the use of loose riprap that could hold small amounts of water; pumps or motors designed to "automatically" drain water from structures; and effluent pipes with discharge orifices prone to clogging because of their small diameter.

Livingston (no date) recommends the following design considerations to minimize mosquitoes:

- Designs must be based on site characteristics to ensure that the most appropriate type of storm water management facility is selected. Vegetated dry retention systems should be designed as off-line systems. They should be used only where the soil and water table conditions will assure that the system drains or dries within 24 to 36 hours, and where the seasonal high water table is at least two feet below the bottom of the system. If on-line retention areas are used, they should be designed to be dry within three days of a 25-year, 24-hour storm.

- Dry retention systems need to be carefully constructed to avoid compacting the soil and reducing its infiltration rate. They also should have flat bottoms to avoid having areas of standing water.

- To minimize decaying organic matter, the grass or other vegetation in dry retention areas should be regularly mowed and the clippings removed and composted.

- The littoral zone of wet detention areas should be planted with aquatic macrophytes such as *Sagittaria latifolia* (duck potato), *Sagittaria lancifolia* (lance-leaf arrowhead), *Juncus effusus* (soft rush), *Pontedaria lancifolia* (pickerelweed), *Juncus roemerianus* (needle rush), *Scirpus californicus* (giant bulrush), and *Scirpus validus* (soft stem bulrush). Cattails (*Typha* spp.) should never be planted in or allowed to remain in storm water systems as they grow very profusely, creating a large quantity of decaying matter.

- Wet detention systems should be stocked with native *Gambusia* spp. minnows (mosquito fish) to foster biological predation of mosquito larvae. If needed because of site conditions, a "minnow sump" should be excavated in the deepest part of the pond to assure permanent habitat and survival during droughts.

- Sustained-release larvicides should be used whenever necessary with systems known to be mosquito productive treated before the onset of the mosquito life cycle.

- Regular inspection and maintenance of storm water systems is essential to ensure that the facility drains as designed. Such maintenance involves removing submerged vegetation and clearing sediments away from inlets, outlets, and the bottom of the pool or holding area.

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5.6 Information Resources

The *Technology Review: Ultra-Urban Stormwater Treatment Technologies* (Brueske, 2000) was compiled to provide a review of "ultra-urban" storm water treatment technologies. These types of technologies are designed to remove pollutants from runoff in highly developed areas where land values are high and available space is limited. Ultra-urban technologies differ from traditional runoff treatment controls in that they are very compact and can be retrofitted into existing runoff collection systems. The document specifically analyzes four types of treatment technologies: gravity separation, swirl concentration, screening, and filtration. Technology review findings were then used to develop a design protocol for selecting and installing ultra-urban treatment technologies. This document can be downloaded in PDF format from http://depts.washington.edu/cuwrm/research/ultraurbn.pdf.

The California Department of Transportation (Caltrans) prepared two handbooks on storm water quality as an updated version of the *Construction Contractor's Guide and Specifications*. These new manuals are the *Construction Site Best Management Practices (BMPs) Manual* and the *Storm Water Pollution Prevention Plan (SWPPP) and Water Pollution Control Program (WPCP) Preparation Manual*. The two manuals provide background information on Caltrans' program to control water pollution, offer instructions for selecting and implementing construction site best management practices, and help to standardize the process for preparing and implementing the SWPPP and the WPCP. Caltrans requires contractors to prepare and implement a program to control water pollution during the construction of all projects. The manuals are available for download at http://www.dot.ca.gov/hq/construc/stormwater/manuals.htm.

The Milwaukee Metropolitan Sewerage District developed a manual entitled "Surface Water and Storm Water Rules Guidance Manual" in 2002 that is available on their Web site at http://www.mmsd.com/stormwaterweb/Startpg.htm. The document includes an extensive discussion of the principles of storm water management, descriptions of both structural and nonstructural measures to control storm water, and sizing procedures for detention basins, among other topics.

In August 1998 the Center for Watershed Protection published *Better Site Design: A Handbook for Changing Development Rules in Your Community*. The publication covers everything from basic engineering principles to "actual versus perceived" barriers to implementing better site designs. The handbook outlines 22 guidelines for better developments and provides a detailed rationale for each principle. *Better Site Design* also examines current practices in local communities, details the economic and environmental benefits of better site designs, and presents case studies from across the country. The document is available for purchase from the Center for Watershed Protection at http://www.cwp.org/.

In 2000 the Maryland Department of the Environment published the *Maryland Stormwater Design Manual*. The manual was designed to protect Maryland waters from the adverse impacts of urban runoff, to provide design guidance on the most effective structural and nonstructural management practices for development sites, and to improve the quality of management practices that are recommended by the state of Maryland. The first volume of the manual contains information on management practice siting and design on new development sites to

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comply with Maryland's 14 storm water performance standards. A unique feature is the use of storm water credits for rewarding innovative storm water management designs. The second volume contains detailed technical information on runoff control practices, including step-by-step design examples. Both volumes are available for download at http://www.mde.state.md.us/environment/wma/stormwatermanual.

In 1995 the Metropolitan Washington Council of Governments (MWCOG) published *Site Planning for Urban Stream Protection*, which presents a watershed approach to site planning and examines new ways to reduce pollutant loads and protect aquatic resources through nonstructural practices and improved construction site planning. The book also provides insight into the importance of imperviousness, watershed-based zoning, concentration of development, headwater streets, stream buffers, green parking lots, and other land planning topics. The document is available for purchase from MWCOG at http://www.mwcog.org/ic/95708.html.

The *Texas Nonpoint SourceBOOK* is an interactive Web tool that was designed to provide runoff management information to public works professionals and other interested parties in Texas and elsewhere. This site, which can be accessed at http://www.txnpsbook.org/, includes a beginner's guide to urban nonpoint source management issues, a discussion of water quality issues in Texas, elements of a storm water management program, information on storm water utilities, tips for assessing and selecting management practices, a comprehensive listing of links to other sites, frequently asked questions, and nonpoint source news.

In 1999 the Denver Urban Drainage and Flood Control District published the *Urban Storm Drainage Criteria Manual*. The manual was designed to provide guidance for local jurisdictions, developers, contractors, and industrial and commercial operators in selecting, designing, implementing, and maintaining management practices to improve runoff quality. The third volume of this manual is primarily targeted at developing and redeveloping residential and commercial areas. The manual is available for purchase at http://www.udfcd.org/.

In 1995 EPA published *Economic Benefits of Runoff Controls* (EPA-841-S-95-002), which contains a description of studies that document increases in property values and rental prices when properly designed runoff controls are used as visual amenities. The document is available for download from EPA's National Environmental Publications Internet Site (NEPIS) at http://www.epa.gov/ncepihom/nepishom.

EPA published the *Preliminary Data Summary of Urban Storm Water Best Management Practices* in 1999. The document summarizes existing information and data on the effectiveness of management practices to control and reduce pollutants in storm water. The report also provides a synopsis of what is currently known about the expected costs and environmental benefits of management practices, and identifies information gaps. The document is available for download in PDF format at http://www.epa.gov/ost/stormwater/usw_a.pdf.

In 1992 the Washington State Department of Ecology published its *Stormwater Management Manual for the Puget Sound Basin*. The manual is divided into five documents: Volume I: Minimum Technical Requirements; Volume II: Construction Stormwater Pollution Prevention; Volume III: Hydrologic Analysis and Flow Control Design; Volume IV: Source Control BMPs;

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and Volume V: Runoff Treatment BMPs. All five volumes are available for download at http://www.ecy.wa.gov/biblio/9911.html.

The Washington State Department of Ecology's Water Quality Program has developed a Nonpoint Source Pollution home page. This Web site, accessible at http://www.ecy.wa.gov/programs/wq/nonpoint, contains nonpoint source program information, posters, resources, and references. The Department of Ecology has also made available a copy of the draft of *Instream Flows in Washington State: Past, Present, and Future*. The document is available at http://www.olympus.net/community/dungenesswc/InstreamFlowversion12.PDF.

The Metropolitan Council of St. Paul/Minneapolis developed the *Urban Small Sites Best Management Practices (BMP) Manual* to provide assistance to communities in planning for storm water management for sites of less than 5 acres located in cold climates. The document focuses on low-impact development practices that promote the restoration and preservation of natural hydrology. The manual includes information on the selection of BMPs and model storm water ordinances and contains a regulatory analysis for watershed programs. The document is available at http://www.metrocouncil.org/environment/Watershed/bmp/manual.htm.

An excellent discussion of the design of infiltration techniques in limestone/carbonate bedrock areas can be found in a new design manual developed for the Lehigh Valley Planning Commission (LVPC) by Cahill Associates. The manual, *Technical Best Management Practice Manual and Infiltration Feasibility Report: Infiltration of Stormwater in Areas Underlain by Bedrock in the Little Lehigh Creek Watershed,* is available from the LVPC at 961 Marcon Boulevard, Suite 310, Allentown, Pennsylvania, 18109, 1-888-627-2626 (toll free), lvpc@lvpc.org.

The Virginia Municipal League published an article titled "Stafford County helps pioneer low impact design movement" describing the process by which Stafford County, Virginia, incorporated low-impact design into its development codes. The article includes links to Builders for the Bay, an organization that provides assistance to local communities wishing to update their codes, as well as several other helpful resources for communities. The article can be downloaded at http://www.vml.org/VTC/VTC3908-2.html.

The American Mosquito Control Association's Web site, located at http://www.mosquito.org/, offers information about mosquitoes and their control along with links, frequently asked questions, and West Nile virus information.

American Rivers developed a report on low impact development techniques for the Great Lakes region called *Catching the Rain: A Great Lakes Resource Guide for Natural Stormwater Management.* The report includes an overview of many runoff control techniques, including pros and cons of each practice. The report can be downloaded in PDF format from the American Rivers Web site at www.americanrivers.org (visit the "Resources" link and choose to view a complete list of publications).

The Villanova University Stormwater Partnership conducts research on management practices to control urban runoff. The organization has established a "Stormwater BMP Park" with a

constructed wetland, a biofiltration traffic island, and a porous concrete site. Research results and outreach materials can be found at http://www3.villanova.edu/VUSP/.

The EPA "Final Action for Effluent Guidelines and Standards for the Construction and Development Category" can be found at http://www.epa.gov/fedrgstr/. The Technical Development Document (EPA-821-B-04-001), which contains information on costs and technologies, is available from US EPA/NSCEP. P.O. Box 42419, Cincinnati, Ohio 45242-2419, (800) 490-9198 or http://www.epa.gov/waterscience/guide/construction.

EPA's *The Use of Best Managment Practices (BMPs) in Urban Watersheds* evaluates design, effectiveness, and cost considerations for storm water management practices. The document canbe downloaded in PDF format from http://www.epa.gov/ORD/NRMRL/pubs/600r04184/600r04184.pdf (cover and table of contents) and http://www.epa.gov/ORD/NRMRL/pubs/600r04184/600r04184chap1.pdf (Chapters 1–6).

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MANAGEMENT MEASURE 6
NEW AND EXISTING ON-SITE WASTEWATER TREATMENT SYSTEMS

6.1 Management Measure

Develop or maintain on-site wastewater treatment system (OWTS) permitting and installation programs that adequately protect surface water and ground water quality. Programs should include:

- A process to identify and protect sensitive areas (e.g., wellhead protection zones, nitrogen/phosphorus limited waters, shellfish habitat) and ensure that cumulative hydraulic discharges and mass pollutant loads from on-site systems do not impair surface or ground water;
- System selection, siting, design, and installation based on performance requirements, prescriptive technologies, protective setbacks, and separation distances that protect surface water and ground water resources;
- Education, training, licensing, and/or certification programs for system designers, site evaluators, permit writers, installers, inspectors, and other service providers; and
- Inspections of new on-site systems during and immediately following construction/installation to ensure that design and siting criteria are applied appropriately in the field.

Establish and implement management programs to ensure that newly permitted and existing on-site wastewater treatment systems are operated and maintained properly to prevent the impairment or degradation of surface and/or ground waters. On-site system operation and maintenance programs should include:

- System inventories and assessments of maintenance needs that provide management information regarding the types of systems in use and their location, capacity, installation date, owner, date of last inspection/service, and other data needed to support operation and maintenance oversight activities.
- Policies to ensure that on-site systems are managed, operated, and maintained to prevent degradation and impairment of surface and ground waters. These policies should include adequate authority to conduct inspections, revoke operating permits, and require pumping, repair, replacement, upgrade, or modification technologies when conditions indicate that surface and/or ground water resources might be adversely affected (e.g., eutrophication of surface waters, microbial or nitrate contamination of ground water).
- Periodic inspection and/or monitoring requirements to ensure that on-site systems are functioning properly. Inspection and monitoring programs should consider hydraulic, hydrologic, and mass pollutant loading impacts at both the site and watershed scales.
- Requirements to ensure that residuals pumped from the tank (i.e., septage) are reused or disposed of in a manner that does not present significant risks to surface waters or ground water resources.

6.2 Management Measure Description and Selection

6.2.1 Description

When properly planned, designed, installed, operated, and maintained, OWTSs (also referred to as septic systems) can effectively remove or treat contaminants such as pathogens, biochemical oxygen demand (BOD), and nutrients in human sewage. However, many on-site systems are failing because of age, inappropriate design, hydraulic/pollutant overloading, or poor maintenance (see Table 6.1). Detrimental impacts from on-site systems can occur when they are sited in sensitive ecological areas (such as wellhead protection zones, near nitrogen/phosphorus limited waters, or near beaches or shellfish habitat) or when they are installed at densities that exceed the hydraulic and hydrologic assimilative capacities of regional soils and aquifers. Pollutants of concern from on-site systems include pathogens, nitrogen compounds (e.g., nitrates), phosphorus, BOD, and other chemicals described in Table 6.2.

Table 6.1: Common causes of OWTS failure.

Type of failure	Contributing causes
Hydraulic	Excessive hydraulic loadings to undersized systems, low soil permeability, excessive ponding at the infiltrative surface, poor maintenance. Increases in water usage over a period of years can exceed the design capacity of the wastewater treatment system.
Organic	Excessive organic loading from unpumped or sludge-filled tanks results in biomat loss of permeability (biomats are discussed further in Section 6.3.1.5.2, which describes subsurface wastewater infiltration systems).
Soil depth to ground water table or bedrock	Insufficient soil depths (i.e., soil thickness between the subsurface wastewater infiltration system [SWIS] and ground water tables, impermeable strata, or bedrock is less than the recommended depth for soil texture and structure). High ground water is deleterious to pathogen removal and hydraulic performance.
System age	Systems more than 25 to 30 years old. Systems less than 25 to 30 years old experience considerably fewer hydraulic failures. Failure rates can more than triple for older systems. Regular tank pumping and use of alternating SWISs can prolong system life indefinitely.
Design failure	Inappropriate system design for the site; failure to adequately consider or characterize wastewater strength and flow (average daily and/or peak flows); failure to identify and consider restrictive soil/rock layers (e.g., fragipan) or regional geology (e.g., karst features, creviced bedrock); failure to assess landscape position.
System density	Cumulative effluent load from all systems in watershed or ground water recharge area exceeds the hydrologic capacity of the area to accept and/or properly treat effluent.

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Table 6.2: Pollutants of concern for OWTSs (adapted from Tchobanoglous and Burton, 1991).

Pollutant	Reason for concern
Pathogens	Microorganisms such as parasites, bacteria, and viruses can cause communicable diseases through direct/indirect body contact or ingestion of contaminated water or shellfish. Pathogens pose a particular threat when partially treated sewage pools on ground surfaces or migrates to recreational waters. Transport distances for some pathogens in surface or ground waters can be significant.
Nitrogen	Nitrogen is a plant nutrient that can contribute to eutrophication and depletion of dissolved oxygen in surface waters, especially in estuaries and coastal embayments. Excessive nitrate-nitrogen in drinking water can cause methemoglobinemia in infants and complications for pregnant women. Livestock also can suffer health impacts from drinking water high in nitrate.
Phosphorus	Phosphorus is a plant nutrient that can contribute to eutrophication of inland fresh waters and some marine waters and eventually deplete dissolved oxygen.
Household chemicals	Chlorine, ammonia, and other cleaning compounds in high volumes may disrupt or disable biological activity in the septic tank. Wastes from hobby or craft activities (paints, solvents, etc.) and disposal of non-organic liquid wastes (old furniture polish, pesticides/herbicides, etc.) in onsite/cluster systems can have similar impacts.
Pharmaceuticals and endocrine disruptors	Disposal of large quantities of outdated antibiotics and other medicinal products in septic tank-based systems can impair or halt biological treatment processes. Disposal of products containing chemicals that disrupt endocrine system functions (e.g., regulation of metabolism, blood sugar, reproduction, embryonic development) in on-site systems might result in leaching of these chemicals into groundwater and surface waters and impair water quality and/or aquatic organisms, in some cases. Research on this issue, including toxicology, transport, and fate of potential endocrine disruptors, is ongoing (USEPA, 1998a; North Carolina Department Environment and Natural Resources, no date).

Estimates of on-site system failure rates range from 5 to 25 percent and higher in some states (USEPA, 2001b), resulting in contamination of drinking water, beaches, shellfish beds, and surface water resources. In 1996 septic systems were a contributing source of pollution for more than one-third (36 percent) of the impaired miles of ocean shoreline surveyed. The National Oceanic and Atmospheric Administration (NOAA) reported in 1995 that the discharge of partially treated sewage from malfunctioning septic systems was identified as a principal or contributing factor in 32 percent of all harvest-limited growing areas (NOAA, 1995).

In addition, ponds, lakes, and coastal embayments have been impaired by algal blooms caused in part by nutrient over-enrichment from failing OWTSs. For example, in Sarasota County, Florida, 45,000 septic systems contribute four times as much nitrogen to Sarasota Bay as the city of Sarasota's wastewater treatment plant. Septic systems are adding an estimated 1.5 million pounds of nitrogen per year to Florida's Indian River Lagoon, causing a decrease in freshwater wetlands and commercial shellfish harvests (USEPA, 2003).

States have identified OWTSs as the third most common contributor to ground water pollution and a significant threat to drinking water sources (Parsons Engineering Science, 2000). A 1999 outbreak of gastroenteritis at the Washington County (New York) Fair was linked to a failing septic system at a nearby dormitory. A failed septic system was blamed for 46 cases of hepatitis A in Racine, Missouri, in 1992, and other states have reported both health and water resource impacts from poorly functioning OWTSs (Fobbs and Skala, 1992).

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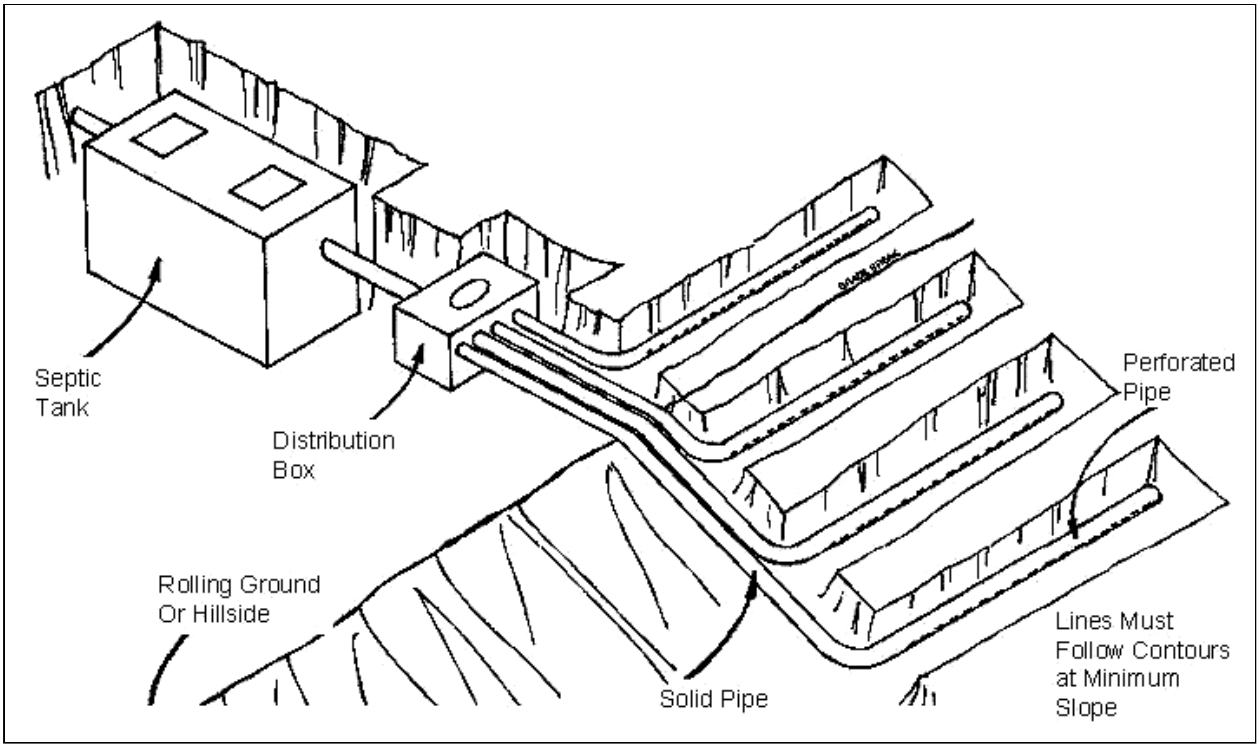

Figure 6.1: Conventional on-site wastewater treatment system.

OWTSs can generally be divided into two categories: conventional systems and alternative or innovative systems.

Conventional systems (see Figure 6.1) consist of a septic tank and a subsurface soil absorption field, commonly called a subsurface wastewater infiltration system (SWIS). Buried in the ground, septic tanks are essentially watertight, single- or multiple-chamber sedimentation and anaerobic digestion tanks. They are designed to receive and pretreat domestic wastewater, mediate peak flows, and keep settleable solids, oils, scum, and other floatable material out of the SWIS. Wastewater effluent is discharged from the tank and passes through pipes to a series of underground perforated pipes that can be wrapped in a permeable synthetic material. From there, the partially treated effluent flows onto and through the soil infiltrative surface, and finally into the SWIS infiltration medium (i.e., soil). Treatment occurs in the septic tank, on and within the biomat that forms at the soil infiltrative surface, and in the soil (or other medium); it then continues as the effluent moves through the underlying soil (biomats are discussed further in Section 6.3.1.5.2, which describes subsurface wastewater infiltration systems). Treated effluent that is not drawn into plant roots, incorporated into microbial biomass, or evaporated ultimately reaches ground waters and possibly nearby surface waters.

Alternative or innovative systems such as mound systems, fixed-film contact units, wetlands, aerobic treatment units ("package plants"), low-pressure drip applications, and cluster systems, are used in areas where conventional soil-based systems cannot provide adequate treatment of wastewater effluent. Areas that might not be suitable for conventional systems are those with nearby nutrient-sensitive waters, high densities of existing conventional systems, highly

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permeable or shallow soils, shallow water tables, large rocks or confining layers, and poorly drained soils. Alternative or innovative systems feature components and processes designed to promote degradation and/or treatment of wastes through biological processes, oxidation/ reduction reactions, filtration, evapotranspiration, and other processes. Cluster systems can be used to collect and treat wastewater from multiple facilities at a common site (e.g., lagoon, wetland, infiltration field). Alternative, innovative, and cluster systems often require individual septic tanks for each facility served to provide primary treatment and minimize fat, oil, grease, and solids loadings to secondary treatment units. (Note: Cluster systems that serve 20 or more people may be regulated by a federal, state, and/or local Underground Injection Control Program for Class V facilities. For more information, visit EPA's Underground Injection Control Program Web site at http://www.epa.gov/safewater/uic.html.)

Many states, tribes, and municipalities use a prescriptive approach to on-site system management. Such an approach assumes that a prescribed system design will adequately protect public health and water resources when installed at sites meeting established minimum requirements. Site evaluations are usually based on empirical approaches such as percolation tests and setback/separation distance requirements.

These evaluations do not typically consider regional hydrology or the density and cumulative discharge of existing and planned treatment systems. They do not consider the overall assimilative capacity of regional soils and hydrology and do not assess complex relationships among soil characteristics, site conditions, wastewater composition, biological mechanisms, and regional climate (Otis and Anderson, 1994). A prescriptive approach is often restrictive and arbitrary and can be underprotective or overprotective of public health and water quality.

A performance-based on-site system management approach does not require specifications for treatment methods or processes, but rather establishes treatment performance requirements for protecting human health and water resources. For example, this approach requires additional nitrogen removal in designated nutrient-sensitive areas without specifying the type of technology to be used (Code of Massachusetts Regulations, 1995). A report issued by the Maryland Department of the Environment and Maryland Office of Planning (2000) recommends installation of systems with enhanced nitrogen removal capabilities in designated "areas of special concern" to reduce nutrient loadings to the Chesapeake Bay and other sensitive waters.

Under a performance-based approach, officials are free to consider the application of alternative and innovative on-site systems in addition to conventional systems. Systems are planned, designed, sited, and installed to achieve specified performance requirements within the context of regional and individual site conditions, rather than requiring site conditions to conform to the soils, slopes, and other needs of a restricted set of prescribed technologies. Performance-based on-site programs also include rigorous and ongoing system management, such as periodic inspections and required maintenance. Such a management approach can result in fewer system failures and greater protection of public health, surface waters, and ground water.

EPA issued *EPA Voluntary National Guidelines for Management of Onsite and Clustered (Decentralized) Wastewater Treatment Systems* (USEPA, 2003), which recommends management measures for on-site systems based on the administrative and managerial capacity of management entities, the complexity of technologies used, and the value and proximity of

resources to be protected. The guidance contains tools and directions to assist states and communities in developing management programs based on local needs and resources, as well as risks to human health and water resources. Activities include planning, design, site evaluation, inspections, monitoring, funding, and other functions. The guidelines note the shortcomings of on-site programs that: (1) do not have a planning element that considers regional hydrology and system densities and discharges; and (2) do not have operation and maintenance requirements that ensure monitoring, periodic septic tank pumping, system repair, and upgrades when necessary. Many existing OWTS regulatory programs fail to consider the ability of regional soils to assimilate pollutants from dozens or hundreds of treatment systems in an area and often leave operation and maintenance of these systems to uninformed and untrained homeowners.

In *EPA Voluntary National Guidelines for Management of Onsite and Clustered(Decentralized) Wastewater Treatment Systems*, EPA recognizes the benefits of both conventional and alternative systems and emphasizes the importance of proper planning, site evaluation, system design, installation, inspection, operation, monitoring, and maintenance. On-site systems, like sewage treatment plants that serve urban areas, require periodic attention and regular servicing to ensure that treatment levels meet established performance requirements. Management programs must comply with performance requirements by ensuring sludge is pumped from tanks periodically, failed or failing systems are detected promptly and repaired or replaced, and undersized or underperforming systems are upgraded.

6.2.2 Management Measure Selection

This management measure was selected to ensure that new and existing on-site wastewater treatment systems function properly. If these systems fail, wastewater can pool on ground surfaces or migrate to aquifers or surface waters and cause significant public health or environmental problems (e.g., disease outbreaks, eutrophication, loss of dissolved oxygen). This management measure supports a performance-based approach to system management and is consistent with the *EPA Voluntary National Guidelines for Management of Onsite and Clustered (Decentralized) Wastewater Treatment Systems* (USEPA, 2003) and the *Onsite Wastewater Treatment System Manual* (USEPA, 2002a).

6.3 Management Practices

6.3.1 Permitting and Installation Programs

EPA believes that on-site system permitting and installation programs that protect surface and ground waters are necessary to decrease or eliminate risks to human health and sensitive ecological resources. Approaches that match the treatment capabilities of various on-site technologies to the conditions and sensitivity of the receiving environment (ground water or surface water) are preferred. EPA recognizes that, due to a lack of staff expertise, funding, assessment data, regulatory infrastructure, public support, and other resources, not all on-site regulatory agencies or management programs will have the ability to implement performance-based approaches.

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Therefore, alternative approaches, which include prescriptive standards that provide appropriate levels of protection for human health and water resources, are included among the acceptable management practices summarized in this section. These standards include prescribed treatment technologies, minimum requirements (e.g., soils, slopes) for proposed installation sites, mandatory setback and separation distances, and specific system component requirements (e.g., septic tank screens, grease traps). They will be considered acceptable management practices if they provide reasonable assurances of protecting public health and water resources when applied under the specific site conditions.

Elements supporting this Management Practice are listed below and correspond with the management measures listed in Section 6.1.

6.3.1.1 Planning activities

Comprehensive planning can provide valuable information and support for on-site system placement and management. Integrating planning with regulatory programs can provide a basis for ensuring the performance of existing systems and permitting future installations. Planning involves the examination of many variables:

- A wide range of environmental characteristics (e.g., ground water, topography, soils, climate, sensitive ecological resources);
- The locations and types of facilities that could be part of an overall wastewater management plan;
- The organizational and institutional structures that exist or may need to be created; and
- Financial support for their development and implementation.

At a minimum, planning should identify areas where:

- Installation of conventional systems can be allowed at specified densities;
- Alternative systems could be required; and
- On-site systems could be permitted only under strict design and performance requirements and assurances for long-term monitoring and maintenance.

6.3.1.1.1 *Comprehensive planning*

Comprehensive planning provides one of the best vehicles for ensuring that on-site management issues are considered under future growth and development scenarios. Comprehensive planning and zoning are closely related and are usually integrated. Comprehensive planning sets overall guidance and policies; zoning provides the detailed regulatory framework for implementation. Comprehensive planning that addresses environmental protection while providing adequate public services such as wastewater treatment can be administered through zoning regulations that:

- Specify prescriptive or performance requirements for individual or clustered systems installed in unsewered areas, preferably by watershed, subwatershed, or ground water recharge area;

- Limit, manage, or prevent development on sensitive natural resource lands or in designated critical areas (e.g., in wellhead protection zones or shellfish habitat runoff catchments, or near nutrient-sensitive waters and wetlands);

- Encourage development within urban growth areas serviced by sewer systems, if adequate capacity exists; and

- Consider factors such as system densities, hydraulic and pollutant output, proximity to water bodies, soil and hydrogeological conditions, water quality, and cumulative loadings from all systems, including future systems, in planning and zoning decisions. Large numbers of soil-based on-site systems discharging to a confined area (e.g., high-density subdivisions) can overwhelm the capacity of soils to assimilate and treat wastewater pollutants of concern, such as nutrients and pathogens.

It should be noted, however, that it is not necessary for the on-site regulatory agency or management entity to oversee or administer the planning program. In many areas, local or regional planning offices collect and store the types of information needed for on-site system management. Some of these offices have the ability to generate geographic information system (GIS) maps that can incorporate water resource, soil, topographic, and other information that provides screening-level site criteria for proposed installation of on-site systems. Coordination with planning offices to designate ecologically sensitive areas and those approved for future on-site system installations can significantly improve the management capabilities of the on-site regulatory agency or management program and improve watershed protection.

6.3.1.1.2 *Wastewater treatment continuum concept*

Decision-makers responsible for approving wastewater collection and treatment services for existing or new facilities often require information and guidance on the various options available. Protection of public health and valued water resources and cost are the primary decision-making criteria in most cases. Both centralized sewer service and decentralized/on-site systems protect public health and water resources, though treatment levels and cost may vary depending on technology, operational factors, system maintenance, and site-specific conditions (e.g., combined sewer overflows, bypasses, and nutrient removal requirements for centralized systems; and geology, soils, climate, and other factors for decentralized/on-site systems).

A number of wastewater treatment and collection options exist along the continuum between individual on-site systems and centralized sewer service. The following options are suggested for decision-makers seeking to improve collection and treatment in existing areas or to provide these services to new development (Venhuizen, 2000):

- Current practice, employing conventional septic tank/soil absorption field systems within the confines of each residential or facility lot;

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- Alternative on-site systems for each lot. Examples include sand filters, aerobic treatment units, vegetated submerged wetlands, and dispersal in shallow, pressure-dosed subsurface wastewater infiltration systems;

- Small-diameter collection/treatment facilities using septic tank effluent drains (STEDs) or other shallow, low-cost collection systems to pump or route the flow from each lot to a common site for final treatment and dispersal or discharge; or

- Centralized sewage collection and treatment with the option of either conventional or alternative treatment facilities at one centralized plant.

Each of these strategies should include oversight and management programs to ensure that collection and treatment equipment and processes continually meet performance requirements. The responsible management entity (RME) should be charged with keeping collection and treatment systems working. The RME should have sufficient authority to enforce programmatic and other requirements, pay for operational and other costs, and take necessary actions in the event of performance failure or emergencies.

Developing operation, maintenance, and management strategies for decentralized/on-site systems in a manner similar to those in existence for centralized systems—or incorporating on-site treatment options into the centralized system strategy—can help to ensure that public health and water resources are protected effectively and efficiently.

6.3.1.1.3 *Centralized sewage treatment*

As development activity increases the density of OWTS-served housing, commercial establishments, and other facilities in a region, it is sometimes cost-effective to extend service lines from centralized sewage treatment facilities (i.e., publicly owned treatment works or POTW) for wastewater collection and treatment at a central plant. Small towns in the past have typically only considered connections to a regional POTW or the construction of a treatment facility. Factors to consider other than costs when deciding whether it is beneficial to use decentralized/onsite systems, construct a new treatment plant, or extend service lines of a nearby system include the following:

- Age and operational history of existing OWTSs;

- The RME's capacity and authority to properly manage OWTSs;

- Future housing and other development trends based on land use planning information;

- Proximity and capacity of existing POTW service lines and treatment facilities;

- Potential for revision to an existing NPDES discharge permit;

- Suitable financing, land area, and site conditions for construction of POTWs or collection lines; and

- Hydrological impacts and catastrophic risk assessment due to failure of collection systems and POTWs.

6.3.1.2 System selection, site evaluation, design, and installation

On-site systems often fail because of improper design and inadequate site evaluation and/or installation. Some states require higher levels of treatment near wellhead recharge zones, nutrient-sensitive waters, shellfish habitat, or other areas of special concern. On-site wastewater treatment systems discharging pathogens that can reach wells or shellfish habitat areas, and those that discharge significant inputs of nitrogen or phosphorus to nutrient-sensitive waters, should be high-priority candidates for upgrade or replacement (Commonwealth Biomonitoring, 2001). A committee advising the Maryland Department of the Environment recommended in 2000 that legislation be adopted requiring county water and sewer agencies to designate areas of special concern to address elevated nitrogen inputs from existing and new on-site systems (Maryland Department of the Environment, 2000). State income tax credits of up to $1,100 per year for three years were suggested to assist homeowners with increased system costs. Existing systems would only require nitrate removal in these areas when system replacement was required.

6.3.1.2.1 *Performance-based programs*

Performance requirements for individual or clustered on-site treatment systems are most often based on assurances that system discharges will not cause violations of surface water quality standards or drinking water standards. A performance-based program includes the following components:

- Performance goals;
- Performance criteria;
- Performance requirements; and
- Performance monitoring.

(a) *Performance goals*. Performance goals define the larger issues that are important to consider in on-site system siting, selection, design, and management. A properly functioning on-site system should be able to meet two basic performance goals: protect public health and protect water resources.

An example of a performance goal might be to protect the surface water from nutrient enrichment in environmentally sensitive areas such as lakes or estuaries. Detailed planning, design, installation, and management programs can help prevent placement of inappropriate systems in areas with unsuitable soils, on sites adjacent to valued and sensitive surface water bodies, and at densities that exceed regional hydrologic and pollutant assimilative capacities. Such an approach can help control or minimize pollutant loadings and associated impacts on surface and ground waters.

Promoting System Upgrades Through Innovative Financing

The Code of Massachusetts Regulations allows a state tax credit of up to 40 percent of the cost of a new on-site system or system repairs. The credit is capped at $1,500 per year and $6,000 total and is limited to homeowners living in the residence served by the repaired or replaced on-site system (Code of Massachusetts Regulations, 2001).

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(b) *Performance criteria*. Performance criteria are measurable indicators that identify the pollutants of concern for a particular area so that benchmarks or performance requirements can be established to reduce further inputs of those pollutants. Performance criteria are used to quantify progress in achieving performance requirements for specific pollutants. Some examples of site-scale performance criteria include effluent concentration limits for nitrate, biochemical oxygen demand (BOD), fecal coliform bacteria, and overall flow. Watershed-scale criteria might include total hydraulic input to a ground water recharge zone from on-site systems, and total nitrogen load or total phosphorus load to ground water or surface waters.

(c) *Performance requirements*. Performance requirements are criteria-based limits that define acceptable environmental impacts and public health risks associated with on-site systems. Performance requirements are based on the type of water body that ultimately receives treated wastewater effluent (ground water or surface water) and the present or projected uses of that water body (e.g., drinking water source, shellfish habitat, contact recreation). Examples of a performance requirement might be that on-site systems in nitrogen-sensitive areas must not discharge more than 5 pounds of nitrogen per year, or that nitrate concentrations in OWTS effluent cannot be greater than 15–20 milligrams per liter (mg/L).

Resource protection performance requirements are based on the assumption that any given resource has a threshold (carrying or assimilative capacity) beyond which it cannot function and may deteriorate. Nitrogen requirements are more likely to be appropriate near marine waters because this nutrient is usually the limiting factor for algal growth in coastal areas. In ground waters, nitrogen can degrade drinking water resources as well. The Commonwealth of Massachusetts has designated certain areas, such as wellhead protection areas, areas in public water supply watersheds, and nitrogen-sensitive coastal embayments or other nitrogen-sensitive water bodies, as "Nitrogen-Sensitive Areas" (Code of Massachusetts Regulations, 1995) and has issued requirements to ensure their protection. Environmentally sensitive areas might include nitrogen-limited coastal waters, phosphorus-limited inland waters, shellfish habitat, and ground water used as drinking water. Typical performance criteria and examples of corresponding performance requirements are listed below:

- Fecal coliform bacteria as an indicator of the possible presence of pathogens (e.g., less than 200 colony-forming units per 100 milliliters [cfu/100 ml]) for support of primary contact recreation or 14 cfu/100 ml in shellfish waters

- Nitrogen in the form of nitrate in potable ground water (e.g., less than 10 mg/L) and as total nitrogen in nitrogen-limited coastal waters to prevent or reduce enrichment

- Phosphorus concentration in surface waters where phosphorus is the limiting element for algal growth (e.g., less than 0.025 mg/L to support warm water aquatic habitat)

- BOD for surface waters requiring high levels of dissolved oxygen for propagation of fish and shellfish (e.g., 5–10 parts per million of 5-day BOD after tertiary treatment to support warm water aquatic habitat)

- Nuisance factors (e.g., no objectionable odors emanating from the septic tank or infiltration field area, no sewage surfacing to minimize risk of human contact)

(d) *Performance monitoring*. Performance monitoring tracks progress in achieving performance requirements. Typical approaches involve measuring or assessing performance criteria at some specified point of compliance (e.g., a designated performance boundary). For example, if waters of a commercial shellfish habitat in a coastal bay are experiencing elevated bacterial contamination, a fecal coliform bacteria performance requirement for on-site systems in the area might be established at the property line or shoreline of the lot. A variety of monitoring programs have been developed to assess the performance of on-site systems. Approaches include measurement of chemical parameters (e.g., nitrogen, phosphorus, BOD, nitrate) in effluent or receiving waters; analysis of fecal coliform/fecal streptococcus ratios; and a variety of new, experimental, analytical approaches using molecular, chemical, or biochemical methods (e.g., ribotyping, antibiotic resistance analysis, randomly amplified polymorphic DNA, pulse field gel electrophoresis, caffeine tracking) (Hagedorn, 2000). Validation and cost issues prevent widespread use of the newer methodologies at the present time, but research in the field shows significant promise.

The Critical Point Monitoring (CPM) approach being developed in Washington State provides a systematic approach to choosing critical locations to monitor specific water quality parameters (Eliasson et al., 2001). The program is most suitable for responsible management entities operating comprehensive management programs. CPM provides an appropriate framework for monitoring treatment train components (i.e., septic tank, infiltration field, sand/media filters, aerobic treatment units), though it should be recognized that evaluations of overall system effectiveness—and compliance with performance requirements—should be based on monitoring at designated performance boundaries.

Tracer dye tests, analysis of *E. coli* concentrations in receiving waters, and system inspections are the most widely used methods for monitoring on-site system performance at present. The first only provides indirect hydrologic information, while the latter two offer direct utility to assess whether performance goals are being achieved. For the purpose of watershed-scale monitoring and modeling, the use of output criteria derived from typical performance ranges of on-site system types used in the area is a common practice. Models can be useful tools to predict potential ground water impacts if they are based on site- or regional-specific characteristics and are calibrated to achieve the best estimates of actual field results. They are rarely accurate under all conditions, however, and must be supplemented with actual field monitoring results when available.

6.3.1.2.2 *Modeling system performance and impacts*

There have been relatively few attempts at developing modeling tools to predict and simulate nutrient fate and transport mechanisms from on-site system effluent (Tetra Tech, 2000; Bicki and Brown, 1991; Harmesen et al., 1991). Most of the work has focused on identifying nitrate loading to ground water for the purpose of planning for drinking water protection. Computer models require a considerable amount of site-specific information regarding wastewater characteristics, discharge volumes, soils, topography, underlying geology, ground water, and climate, but they can be useful tools for assessing the long-term impacts of OWTSs in an area and developing strategies to mitigate potential problems.

The State of Florida developed a computerized model to assess ground water contamination potential in selected hydrogeologic regions as a tool to guide development of subdivision

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regulations (Florida HRS, 1993). The model incorporated features of the state's varied surficial hydrology and soil regimes and provided estimations of the transport and fate of nitrogen compounds. The Florida model uses a steady-state, one-dimensional flow field with three-dimensional dispersion and assumes retardation and first-order decay rates to be zero. Nitrate contaminant plumes generated by the model show a variety of dispersion and transport scenarios and confirm that increasing lot size from four homes per acre to two homes per acre (and even fewer in areas of high porosity) reduce nitrate concentration and migration in ground water by approximately 50 percent (from 10 mg/L to 5 mg/L 700 feet downgradient of the subdivision under study). The results suggest that concerns over nitrate contamination of ground waters from large, densely developed subdivisions with OWTSs are not unfounded. They support recommendations to monitor ground water nitrate concentrations below and downgradient of large subdivisions with home densities greater than four units per acre.

Another model developed for the Indian River Lagoon National Estuary Program found that nitrogen inputs linked to on-site systems constituted 12 percent of the total nitrogen load into the lagoon, an amount nearly equal to the load from cattle. The loading model provides a mechanism for calculating total nitrogen inputs into the aquatic system, and it attempts to predict the nitrogen concentrations in ground water based on hydrological parameters (University of Massachusetts, 2000). Efforts to calibrate the ground water prediction capabilities of the model are ongoing.

6.3.1.2.3 *Applying system siting criteria*

Conventional and many alternative on-site systems include a SWIS, which requires a certain minimum area of soil, sand, or other treatment media to effectively remove pathogens and other pollutants. Under a prescriptive approach, setbacks from wells, surface waters, building foundations, and property boundaries are minimum requirements necessary to eliminate or reduce threats to public health and the environment. Setbacks are used only rarely but can be established based on soil type, slope, characteristics of the water table (as defined by the implementing agency), sensitivity of aquatic resources, and type of on-site system. Under a prescriptive program, setback guidelines also should be established for both conventional and alternative on-site systems. Recommendations for horizontal separation distances are based on the degree of pre-soil application treatment achieved, as well as site-specific factors such as climate, topography, soil permeability, ground water gradient, ground water flow, and geology. The management entity should adopt measures that restrict the placement of wastewater treatment systems in inappropriate soils, in proximity to valuable surface waters, and at densities too high for soils to treat pollutants sufficiently. One example is the lack of available concentrations of certain metals that retard phosphorus movement to nearby surface waters.

Separation and setbacks can also be used under the performance-based approach. Under this approach, setback or separation distances should be based upon research or field data that demonstrate pollutant removals needed to meet performance requirements given the specific site conditions and treatment technology applied. Pretreatment systems that discharge effluent containing concentrations of bacteria, nitrogen, and phosphorus below requirements established to protect water quality can be sited closer to water resources if impact analyses determine that contamination risk is unlikely.

6.3.1.2.4 *Site evaluations that assess suitability for specific technologies*

States vary greatly in their approach to evaluating site suitability; such approaches range from no specific requirements to very detailed evaluations that require qualified soil scientists and hydrogeologists (NSFC, 1995). A performance-based approach to site evaluation may involve one or more of three evaluation approaches:

1. *Soil-based.* Sites are characterized by conducting a soil profile analysis, usually through the use of soil maps, field data, and inspection of the soil profile in a backhoe pit. Many states now require a soil profile analysis to determine site suitability for conventional systems.

   The soil-based approach focuses on site-specific observation of soil properties that significantly affect the performance of soil-based on-site systems. The soil-based approach has two major advantages: (1) direct observation of soil properties provides a considerable amount of quantitative and qualitative information that can be used to select or modify on-site system design; and (2) site evaluations for individual systems can sometimes be completed in a single visit. The major disadvantage of this approach is that it provides little quantitative information on hydrologic properties and characteristics of the region and sub-watershed. The risk of inadequate hydrogeologic characterization increases when on-site system densities increase.

   Soil assessments are best conducted by observing the soil profile on the wall of a backhoe pit that is 48 to 72 inches deep. Soil layers should be characterized to a depth of at least 3 to 5 feet below the proposed excavation of the effluent absorption field, especially in highly porous soils. Characterizing the soil profile in a backhoe pit is best accomplished using natural lighting because soil texture, structure, color, mottling, and iron or manganese concretions can be observed, assessed, and described more accurately. Hand augers tend to disturb and compress the soil and disguise soil layers, making it difficult to observe structure and other features. Pits should be excavated at the perimeter of the soil absorption field rather than in the middle of it because settling might cause problems with distribution piping and absorption trench stability, and the disturbance could modify subsequent soil system performance.

2. *Hydrogeologic-based*. Surface water and ground water hydrology and the geology of the management area are characterized to determine treatment technology selection and maximum system densities. Zones can be created to establish minimum lot sizes, maximum discharge rates per acre, or minimum treatment efficiencies (e.g., effluent nitrogen concentrations). Percolation rate tests, which have been used extensively in the past to characterize wastewater dispersion in the soil, do not predict treatment effectiveness or ensure future hydraulic performance.

   Hydrogeologic-based evaluations originated with the development of the percolation test in the 1920s. Although the percolation test is simple to conduct and can provide some information on relative infiltration rates, it does not necessarily provide design information because of its inability to discern what controls the rate of water loss from the hole. Also, the test cannot accurately predict infiltration rates at equilibrium operation or in downgradient zones through which the effluent will migrate.

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Hydrogeologic characterization can also include testing for hydraulic conductivity, porosity, and permeability, usually requiring multiple extended site visits. Cluster and small community on-site systems (> 2000 gpd) require more extensive hydrogeologic characterization. Multifactor approaches for site evaluation use information regarding soils, hydrogeology, mineralogy, cation exchange, and possibly other information such as regional effluent loading models.

3. *Multifactor-based*. A variety of factors (e.g., soils, climate, ground water conditions, slopes, OWTS densities, proximity to and status of water resources) in the management area are characterized to establish zones reflecting likely treatment effectiveness and the potential for public health and environmental impacts. Conventional systems are permitted in nonsensitive zones that meet minimum soil, separation/setback, and other prescriptive requirements. Alternative systems should be required for sensitive sites that cannot support conventional SWIS-based applications. Sites within sensitive zones can be required to meet performance standards and to be closely managed for continued compliance.

Regardless of approach, the objective of the site investigation is to evaluate the wastewater treatment and dispersal capabilities of the site and surrounding area. The site evaluation systematically gathers information that is used to narrow the range of OWTS design options to the one that best accomplishes the overall performance goals of protecting human health and the environment. The evaluation should begin with a consideration of both regional hydrology and the density and discharge of existing OWTSs in the area. Regional planning programs, where they exist, can provide a significant amount of information during this stage of the process. Other reconnaissance activities prior to the actual site visit should include researching the following: soil surveys; geology, topography, and surface water and ground water resources; OWTS installations in the vicinity and their operating record; well locations and hydrogeological records in the area; and maps showing utility lines and other features that might have an impact on design and placement of the system.

Landscape position, location of treatment unit components, slopes, trees, and other features (e.g., drainages, fences, pipelines, electric lines) should be noted on a site plan that is filed with permit documents. The soil analysis should include identification of the major horizons and their structure, texture, color, mottles and concretions, as well as other notable features (e.g., rocks, organic matter, wetness). If percolation tests are used, they should be conducted in strict accordance with established procedures and should always be accompanied by a detailed investigation of the soil profile and regional conditions. Permitting of OWTSs on the basis of percolation tests alone is not recommended.

Table 6.3 presents a list of site features that might require evaluation prior to selecting the system design and installation site. The site evaluation process typically differs for individual OWTSs and larger-scale cluster or small community systems; i.e., data on every feature on the checklist does not have to be collected for every individual home site. Site assessments should be performed to determine the soil infiltration rate, expected soil pollutant removal capacity, acceptable hydraulic loading rate, and required depth to the water table, at a minimum, prior to design and application for a construction permit for on-site systems. A simple individual home site evaluation can be accomplished in a single site visit when a soil-based approach is used.

Three American Society for Testing and Materials (ASTM) practices covering surface characterization (ASTM, 1995), subsurface soil characterization (ASTM, 1996b), and preliminary sizing and delineation of subsurface soil absorption or constructed filter field areas (ASTM, 1996a) give specific guidance on how this can be accomplished (http://www.astm.org/). Surface and some subsurface characterization practices are shown in Table 6.4. The ASTM standard practice for characterizing subsurface conditions through test pit inspection is summarized in Table 6.5. These practices can be specified when hiring contractors and consultants.

Table 6.3: Site features that should be evaluated before OWTS design and installation.

Type	Site Feature
Surface Features	Location of property boundaries, location of existing and/or proposed structures, location of surface water features (landscape position and land form, including intermittent and perennial drainage ways, irrigation ditches, streams, swales, depressions, water bodies, and wetlands), topography (use local regulatory suitability criteria or Natural Resources Conservation Service [NRCS] soil survey classes), location of water supply sources (well, public water supply reservoir), location of buried anthropogenic features (water lines, utility lines, etc.), location of disturbed soil (cut and fill), other significant features (large trees, bedrock at the surface, etc.)
Soil Features	Major soil horizons, texture and structure of each horizon, color, mottles, other relevant features of each horizon (rupture resistance, penetration resistance, wetness, pore characteristics, presence of roots), depth to bedrock, depth to low permeability (i.e., restrictive) soil horizons (fragipan, caliche, duripan, etc.), depth and thickness of strong textural contrasts. Phosphorus (P) Index when P retention is needed.
Hydrogeologic Features	Depth to seasonal high water table and shallow ground water tables, potentiometric surface, ground water flow direction and gradient, percolation test results, saturated hydraulic conductivity (estimated, field, and laboratory), ground water time of travel to points of interest, unsaturated hydraulic conductivity relationships, other water budget parameters (precipitation, potential evapotranspiration, etc.)

Table 6.4: Practices to characterize surface and subsurface features of proposed OWTS sites (ASTM, 1995, 1996b).

Description of activity	Information from research
Preliminary Documentation	– Site survey map – Soil survey, U.S. Geological Survey (USGS) topographic map – Aerial photos, wetland maps – Natural resource inventories – Applicable regulations and/or setbacks – Hydraulic loading rates – Criteria for alternative OWTSs – Size of house or facility – Loading rates, discharge types – Planned location of water well
Scheduling	– Planned construction schedule – Date and time for meeting
Description of Activity	– Information from field study
Identification of Unsuitable Areas	– Water supply separation distances – Regulatory buffer zones and setbacks – Limiting physiographic features

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Table 6.4 (continued).

Description of activity	Information from research
Subsurface Investigations	– Ground water depth from pit or auger – Soil profile from backhoe pit – Percolation tests
Identification of Recommended OWTS Site	– Integration of all collected data – Identification of preferred areas – Assessment of gravity-based flow – Final selection of OWTS site

Table 6.5: Practices to characterize subsurface conditions through test pit inspection (ASTM, 1996a).

Description of activity	Process steps	Information to be collected
Select backhoe pit site(s) near but not in proposed drainfield	Orient pit so that sunlight illuminates vertical face of pit	Proposed location of soil absorption field
Excavate pit to depth required by regulations	Pit excavation	Required ground water separation distance, soil profile depth
Enter test pit	– Take safety precautions – Beware of cave-ins – Select area of pit wall to examine	Safe depths for unbraced pit walls
Expose natural soil structure	Use soil knife, blade, screwdriver, or other tool to pick at area 0.5 m wide along full height of pit wall	Soil structural type (e.g., prismatic, columnar, angular blocky, subangular blocky, platy, granular)
Describe soil horizons	– Note master soil horizon layers – Describe features of each horizon	List soil horizon features: – Depth of horizon and thickness – Moisture content – Color (i.e., hue, value, chroma) – Volumetric percentage of rock – Size, shape, type of rock found – Texture of <2mm fraction of horizon – Presence or absence of mottles and other redoximorphic features – Soil structure by grade – Level of cementation – Presence or absence of carbonates – Soil penetration resistance – Abundance, size, and distribution of roots
Determine lateral changes in soil profile	Use hand auger and/or compare to profile of second pit	Determine changes, if any, in soil profile across proposed site
Interpret results	Identify limiting depths	– Check vertical separation distances – Identify mottled layers and concretions – Determine depth to saturation – Measure depth to confining layer
Issue site report	Log all data onto survey form	Develop system type, site location, and installation recommendations

Several systems have been developed to perform source water vulnerability assessments and to map locations where site conditions might preclude the use of conventional on-site systems. A system such as the DRASTIC methodology (Aller et al., 1987) can be used to map areas where aquifers might be vulnerable to pollution from on-site systems. DRASTIC considers soil permeability, depth to ground water, and aquifer characteristics. Florida adapted the DRASTIC approach to produce digital maps showing potential areas where ground water threats might increase (http://www.dep.state.fl.us/gis/datadir.asp). The U.S. Department of Agriculture (USDA) developed soil maps that contain detailed information on regional soils, including suitability for conventional on-site systems, and is updating these maps in some areas. The USDA National Soils Survey Center (http://ssldata.nrcs.usda.gov/) provides county-level soil information nationwide.

States are implementing GIS-based programs for identifying and mapping critical water supplies and aquifer protection areas. Some states have established zones that define effluent quantity and quality and system options available to meet those requirements. Computer simulation models have also been developed that assess the impact from locating on-site systems at various densities within a watershed. For example, the Buzzards Bay Project of the National Estuary Program provides an online nitrogen input modeling spreadsheet that can be adapted for local use by entering appropriate information for land use, nitrogen loading rates, watershed size, projected build-out, and other parameters (http://www.buzzardsbay.org/nitrmang/bbploadcalc.xls).

6.3.1.3 Education, training, licensing, and/or certification programs

In the past, a few states established training programs for site evaluators and adopted more-stringent codes for system design, setback distances, and general site requirements (Kreissl, 1982). If a site were declared unsuitable by these evaluators under the code prescriptions, some of these states would allow professional engineers to propose system designs that could overcome site limitations. Many jurisdictions (regulatory agencies) have begun to favor employing trained, experienced, professional staff who can make judgments and decisions on system design and siting in an efficient, effective manner. This practice must be differentiated from programs that use compliance enforcement staff to design systems. Such approaches are not recommended due to potential conflicts of interest resulting from design and compliance determinations by the same entity.

Most states have minimum requirements (e.g., college coursework, state-sponsored training) for oversight agency staff (e.g., health department permitting personnel), but some states have more stringent competency requirements.

In many states, system installers must be certified (see Table 6.6). Florida requires installers to meet certain minimum requirements, demonstrate experience, provide references, pass an examination, and complete six hours of approved classroom instruction annually to retain their certification. Minnesota has had a certification program for installers, designers, pumpers, and inspectors since the early 1970s; the program became mandatory for all service providers in 1994. Maine instituted a licensing program for site evaluators in 1974 and saw system failure rates drop to insignificant levels (Kreissl, 1982). Site evaluators in Maine must now be licensed professional geologists, soil scientists, or engineers with at least one year of relevant field

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experience. They must also pass a written examination and a field practices test (Maine Department of Health Services, 1996).

Requirements for site evaluators, system designers, installers, inspectors, and maintenance service providers vary widely among the states. Some states have few, if any, requirements for service personnel, whereas other states require professional certification and ongoing training for most service providers (see Table 6.6). In addition, some states issue permits or grant exemptions that allow homeowners to design and install on-site treatment systems at their primary residence.

Table 6.6: Survey of state certification and licensing programs for onsite wastewater service providers (Noah, 2000).

State	Contractors	Installers	Inspectors	Pumpers	Designers	Engineers	Geologists	Operators
AL	Y	Y	Y	Y	N	Y	Y	Y
AK	Y	Y	NA	NA	NA	Y	NA	NA
AZ	Y	Y	NA	Y	NA	Y	Y	NA
AR	N	Y	N	Y	Y	N	N	N
CA	N	N	N	N	N	N	N	N
CO	N	N	N	N	N	Y	N	Y
CT	NA	Y	Y	Y	NA	Y	NA	NA
DE	Y	Y	N	Y	Y	Y	N	Y
FL	Y	Y	Y	Y	Y	Y	Y	Y
GA	Y	Y	Y	Y	N	N	N	N
HI	N	N	N	N	N	Y	N	Y
ID	N	Y	Y	Y	N	N	N	N
IL	Y	Y	NA	Y	NA	NA	NA	NA
IN	N	N	N	N	N	N	N	N
IA	N	N	N	Y	N	N	N	N
KS	NA	NA	NA	NA	NA	Y	Y	Y
KY	Y	Y	Y	Y	N	N	N	N
LA	NA	Y	NA	NA	NA	NA	NA	NA
ME	N	Y	Y	N	Y	Y	Y	N
MD	N	Y	Y	N	N	N	N	N
MA	Y	Y	Y	Y	Y	Y	N	Y
MI	N	N	N	N	N	N	N	N
MN	NA	Y	Y	Y	Y	NA	NA	Y
MS	NA	Y	Y	Y	NA	NA	NA	NA
MO	Y	N	N	Y	N	Y	N	N
MT	N	N	N	N	N	N	N	N
NE	N	N	N	N	N	N	N	N
NV	NA	NA	NA	NA	NA	NA	NA	NA
NH	N	Y	N	N	Y	Y	N	Y
NJ	N	N	N	N	N	N	N	N
NM	Y	Y	N	N	N	N	N	N
NY	N	N	N	Y	N	N	N	N
NC	N	N	Y	N	N	N	N	Y
ND	Y	Y	Y	N	N	N	N	N
OH	N	N	N	N	N	N	N	N
OK	Y	Y	N	Y	Y	N	N	Y
OR	Y	Y	Y	Y	Y	Y	Y	Y
PA	N	N	Y	N	N	Y	Y	N
RI	Y	Y	Y	N	Y	Y	N	Y

Table 6.6 (continued).

State	Contractors	Installers	Inspectors	Pumpers	Designers	Engineers	Geologists	Operators
SC	Y	Y	NA	Y	NA	NA	NA	NA
SD	N	Y	N	N	N	N	N	N
TN	N	Y	N	Y	N	Y	Y	Y
TY	N	Y	Y	Y	N	N	N	Y
UT	N	N	N	N	N	N	N	N
VT	N	N	N	N	Y	N	N	Y
VA	N	N	N	N	N	Y	Y	Y
WA	N	N	Y	N	Y	N	N	N
WV	N	N	N	Y	N	N	N	N
WI	N	Y	Y	Y	Y	Y	Y	N
WY	N	N	N	N	Y	Y	Y	N

Y = yes; N = no; NA = not available.

NSF Onsite Wastewater Inspector Accreditation Program

NSF International has developed an accreditation program to verify the proficiency of persons performing inspections on existing on-site wastewater treatment systems (NSF International, 2000). The accreditation program includes written and field tests and provides credit for continuing education. Inspectors who pass the tests and receive accreditation are listed on the NSF International Web site and in the NSF Listing Book, which is circulated among industry, government, and other groups.

The accreditation process includes four components. A written examination, conducted at designated locations around the country, covers a broad range of topics relating to system inspections, including equipment, evaluation procedures, trouble-shooting, and the NSF International Certification Policies. The field examination includes an evaluation of an existing on-site wastewater treatment system. An ethics statement, required as part of the accreditation, includes a pledge by the applicant to maintain a high level of honesty and integrity in the performance of evaluation activities. Finally, the continuing education component requires requalification every 5 years through retesting or earning requalification credits through training or other activities.

To pass the written examination, applicants must answer correctly at least 75 of the 100 multiple choice questions and score at least 70 percent on the field evaluation. A 30-day wait is required for retesting if the applicant fails either the written or field examination.

These code provisions, which are linked to outdated farmstead or homestead exemptions, should require some demonstration of competency on the part of the prospective homeowner designer or installer. For example, Alaska allows homeowners to design and install systems at their residence if they complete an approved training course and comply with state design, construction, and siting requirements. Approval is granted after the homeowner submits an infiltration field size estimate based on a professional analysis (i.e., by an engineer or a laboratory) of soils at the proposed site (Alaska Administrative Code, 1999). Another approach could include providing technical assistance for system design and close oversight of installation to ensure that homeowner-installed systems meet performance requirements.

On-site programs should establish minimum criteria for all service providers to ensure protection of public health and water resources. The Maine program requires that site evaluators be licensed and that designers of systems treating more than 2,000 gallons per day or systems with unusual wastewater characteristics be registered professional engineers. Prerequisites for applying for a

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license and taking the certification examination are either a degree in engineering, soils, geology, or a similar field plus one year of experience, or a high school diploma or equivalent and four years of experience (Maine Department of Human Services, 1996).

Some jurisdictions opt to secure planning, operation, maintenance, and inspection services by partnering with other agencies or contracting with private entities to perform these functions. For example, the Massachusetts communities of Yarmouth and Dennis contract with an engineering firm to conduct system inspections (Shephard, 1996). Many management agencies in highly developed areas depend on regional planning or environmental agencies for guidance on the hydraulic and pollutant assimilation capacity of water resources in areas proposed for development. When on-site management functions are performed by outside entities, it is important to establish clear, consistent, and reasonable program requirements, administrative processes, and communication procedures.

6.3.1.4 Inspection of new on-site wastewater treatment systems

Verifying that systems are constructed and installed as designed helps to ensure that they will perform as intended. A construction management program that includes multiple field inspections will ensure that system design and specifications are followed during the construction process. If a system is not constructed and installed properly, the chances of failure increase. For example, if the natural soil structure is not preserved during the installation process (i.e., if equipment compacts or smears infiltration field soils) the infiltration field can be significantly impaired. Most failures of conventional on-site system soil absorption fields have been attributed to hydraulic overloading (USEPA, 1993a). These failures can be exacerbated by poor design and installation practices. Effective on-site system management programs ensure proper system construction and installation through construction permitting, inspections during construction, and designer/installer certification programs.

Design and plan reviews before construction begins help to acquaint the installer with site conditions as characterized by the site evaluator and the proposed system design. During this review, details of the construction schedule, inspections, and final permit issuance can be discussed and agreed upon. In general, construction should conform to the approved plan and use appropriate methods, materials, and equipment. Typical regulatory mechanisms to ensure proper installation are reviews of site evaluation procedures and findings, and inspections of systems during and after installation. The review and inspection process should include:

- Preconstruction meeting of the owner, designer, regulator, and contractor;
- Inspection after delivery of components;
- Inspections during and after construction (e.g., during excavation and installation of components, and after backfilling); and
- Issuance of a permit to operate the system as designed and built.

During the construction process, inspections should verify compliance with approved construction documents and procedures. If there are not enough management program personnel to conduct these inspections, a trained/certified inspector should be assigned to oversee

installation and certify that it has been conducted and recorded properly. The construction process for soil-based systems must be flexible, as construction during wet weather may compact, smear, or otherwise alter soil structure.

6.3.1.5 Installation of conventional or alternative systems

As noted previously, selection of an on-site system should consider climate, regional hydrology, site slopes, soil, ground water characteristics, and the quality requirements of the water(s) receiving on-site system effluent. Design, operation, and maintenance information for on-site systems can be found in the *Design Manual: Onsite Wastewater Treatment and Disposal Systems* (USEPA, 1980), the *Onsite Wastewater Treatment System Manual* (USEPA, 2002a) and the *Draft Onsite Wastewater System Management Handbook* (USEPA, 2002b). Table 6.7 summarizes the different treatment technologies used to remove various pollutants of concern.

A conventional on-site system consists of a septic tank, as shown in Figure 6.2, and a SWIS. Septic tanks perform the following four important functions:

1. Removal of settleable and floatable solids, oils, and grease from raw wastewater;
2. Storage of the removed solids;

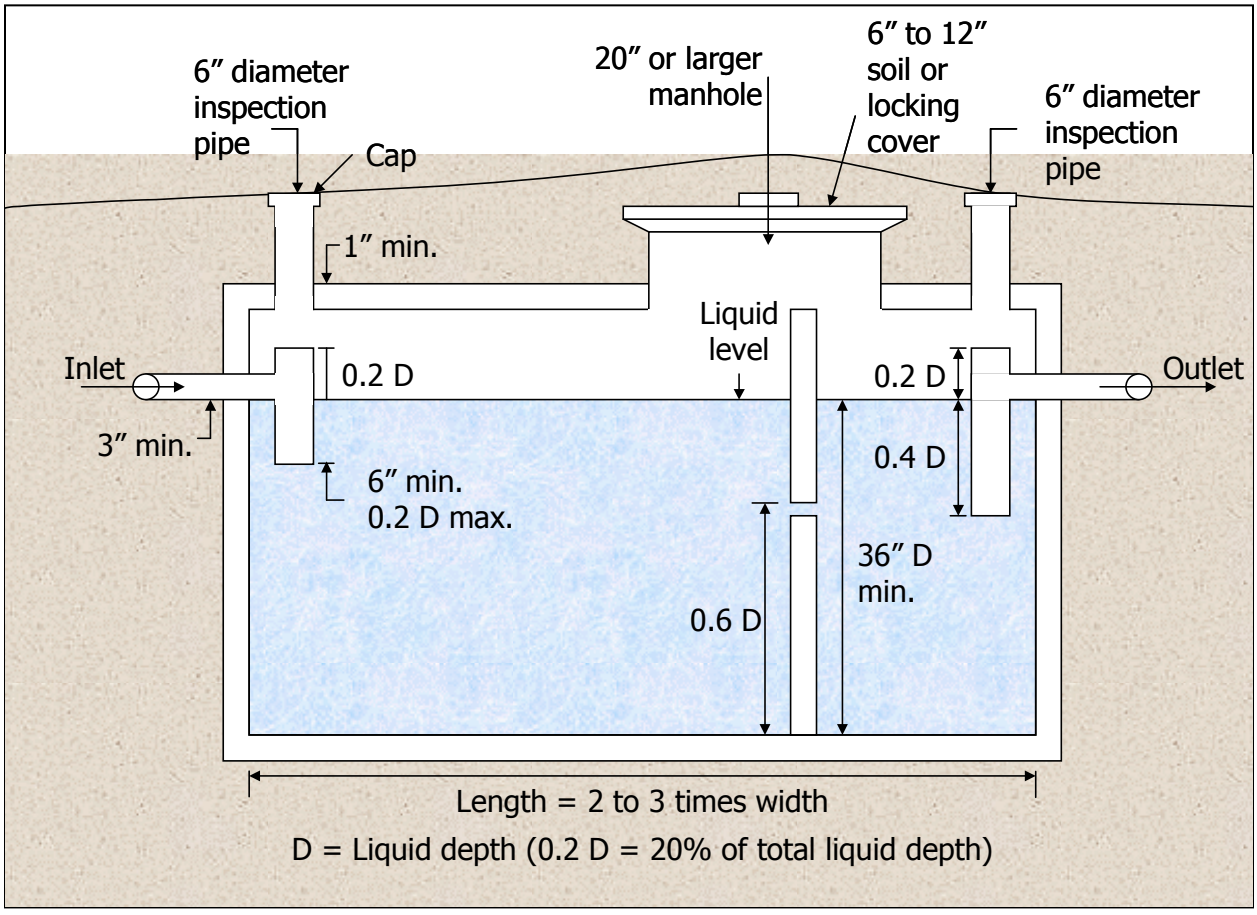

Figure 6.2: Septic tank detail (University of Missouri Extension Service, 1997).

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3. Partial anaerobic digestion (liquefaction) of settled organic matter; and
4. Flow attenuation.

Table 6.7: Treatment technologies for OWTSs.

Treatment objective	Treatment process	Treatment methods
Suspended solids removal	Sedimentation	Septic tank Free water surface constructed wetland Vegetated submerged bed Lagoons Septic tank effluent screens
	Filtration	Packed bed media filters[a] Mechanical disc filters Soil infiltration
Soluble carbonaceous BOD and ammonia removal	Activated sludge	Extended aeration Fixed film activated sludge Sequencing batch reactors
	Fixed film aerobic bio-reactor	Soil infiltration Packed bed media filters[a] Trickling filter Fixed film activated sludge Rotating biological contactors
	Lagoons/wetlands	Free water surface constructed wetland
Nitrogen removal	Biological nitrification/ denitrification	Activated sludge (nitrification only) Sequencing batch reactor (only if designed with certain operating modes) Fixed film bio-reactor (nitrification only) Recirculating media filter Fixed film activated sludge (nitrification only) Anaerobic upflow filter (denitrification only) Anaerobic submerged media reactor (denitrification) Submerged vegetated bed (denitrification) Free water surface constructed wetland
	Ion exchange	Cation exchange (ammonium) Anion exchange (nitrate)
Phosphorus removal	Adsorption	Soil infiltration Iron-rich packed bed media filter Sequencing batch reactor (only if designed with certain operating modes)
Pathogen removal (bacteria, viruses, and parasites)	Filtration/predation/inactivation	Soil infiltration Packed bed media filters[a]
	Disinfection	Hypochlorite feed Ultraviolet light
Grease removal	Flotation/adsorption	Grease trap Septic tank Mechanical skimmer
	Aerobic biological treatment[b]	All types

[a] Including dosed systems; granular [sand, gravel, glass], peat, textile, foam.
[b] Incidental removal will occur, although overloading is possible.

Removal of total suspended solids (TSS) is usually 70 to 85 percent for well-designed septic tanks. Other pollutant removal rates are affected by the characteristics of the wastewater. Typically, reduction of BOD is 40 to 60 percent. Nitrogen and phosphorus removals are approximately 10 to 20 percent, while fecal coliforms are reduced by approximately 1 log (USEPA 2002a). The conventional system accepts both graywater (wastewater from showers,

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sinks, and laundry) and blackwater (wastewater from toilets). Depending on climate, diet, and other factors, the tank will need to be pumped every 3 to 5 years, since the pumping interval depends on the rate of accumulation of sludge, oils, and grease. Periodic visual inspection or remote sensing of the depth of those accumulations is possibly the most efficient way to determine pumping intervals.

A gravity-flow SWIS is the most commonly used treatment and discharge method for OWTS septic tank effluent. Soil absorption systems usually consist of covered excavations filled with porous media and perforated pipes or plastic leaching chambers with a distribution system for introducing and dispersing wastewater throughout. SWISs work well at sites with moderately permeable soils and sufficient vertical depth to ground water (i.e., the seasonally high water table), bedrock, or other limiting layer. The most common types of hydraulic failure of these systems are clogging of the infiltrative surface, insufficient separation distance to the water table, insufficient percolation capacity of the soil, and hydraulic overloading. Trenches and leaching chambers are the most widely used designs for both individual residences and commercial establishments. Uniform distribution and dosing via siphons or pressurized distribution are the best methods of pollutant removal because they distribute the wastewater load widely and uniformly across a large surface and sidewall area.

6.3.1.5.1 *Pollutant removal processes for conventional systems*

Nitrogen in domestic wastewater can be removed through effective linking of aerobic and anaerobic biochemical transformation processes, but in general, most conventional septic systems are not considered effective in removing nitrogen without additional treatment in the soil. Septic tanks remove approximately 30 percent of the nitrogen in raw domestic wastewater (University of Wisconsin, 1978). Percolation through 3 to 5 feet of soil can remove 0 to 20 percent of the total nitrogen in septic tank effluent (Siegrist, 2001). Additional nitrogen removal is possible under optimum soil and denitrification (e.g., anaerobic and carbon-rich) conditions. Factors that favor denitrification in soil absorption fields include fine-grained soils such as silts and clays, layered soils that feature alternating fine-grained and coarse-grained layers, and organic matter or sulfur compounds in the infiltrative medium. Placing the soil absorption field high in the soil profile where organic matter is more likely to exist, and dosing effluent to achieve alternating wet/dry (anaerobic/aerobic) cycles, can aid denitrification and reduce nitrate leaching. Maine's Coastal Nonpoint Source Control Program and Division of Health Engineering favor shallow leach field installations to take advantage of the treatment potential in the upper soil horizon. Monitoring of shallow SWISs in Maine found total nitrogen reductions of 41 to 91 percent (Leyden, 1999).

In those areas where nitrogen is a problem pollutant, existing systems may be retrofitted to improve nitrogen removal, and new systems should include treatment components that are capable of removing nitrogen. Retrofitting upon failure of systems in these areas is recommended. Also, it is important to consider the density and overall discharge of on-site treatment systems. As the density of residences increases, lot sizes decrease and nitrogen impacts on surface and ground waters intensify. Lots of 1/2 acre to 5 acres are generally the minimal requirement of prescriptive codes for siting conventional on-site systems. The Code of Massachusetts Regulations identifies certain wellhead protection areas, public water supply recharge zones, and coastal embayments as nitrogen-sensitive areas and requires treatment systems in those areas to meet nitrogen loading limitations. For example, recirculating sand

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filters or equivalent technologies must be employed to limit total nitrogen (nitrogen as nitrate, nitrite, or ammonia) concentrations in effluent to no more than 25 mg/L and to remove a minimum of 40 percent of the influent nitrogen load. All systems in nitrogen-sensitive areas must discharge no more than 440 gallons of design flow per day per acre unless system effluent meets a nitrate standard of 10 mg/L or other nitrogen removal technologies or attenuation strategies are used (Code of Massachusetts Regulations, 1995). Any zone requiring such systems should have a management entity to assure sustained performance by these systems.

One of the most effective nitrogen removal methods is the recirculating sand filter (Table 6.8), which has been shown to remove approximately 50 percent of the total nitrogen from residual wastewater (USEPA, 1993b and 2002a). Other innovative and alternative systems have been developed to address site constraints and to provide improved on-site treatment and dispersal of wastewater. Many of these systems use advanced nutrient removal processes to enhance the ability of on-site systems to protect surface and ground water quality. Such systems include recirculating sand (nitrogen removal) and anaerobic upflow filters (denitrification), intermittent sand filters (nitrification), and subsurface-flow constructed wetlands (denitrification). The subsurface flow constructed wetland (i.e., vegetated submerged beds) and anaerobic upflow filters require nitrification of septic tank effluent before it enters the treatment process. Nitrification technologies include trickling filters with highly permeable plastic media, single-pass media filters, aerated sequencing batch reactors, activated sludge treatment systems, and filtration systems that use peat or other materials in place of sand. Table 6.8 presents an estimated performance summary for a variety of treatment technologies.

Another primary nutrient, phosphorus, is often the limiting factor for algal growth and eutrophication in freshwater systems. Because other nutrients necessary for the growth of algae and other aquatic plants are usually present in inland waters, low concentrations of phosphorus can lead to a direct increase in growth. Studies have shown that lakes with phosphorus concentrations as low as 20 to 30 parts per billion can become highly productive or eutrophic. Conventional OWTSs (septic tanks/SWISs) remove only 15 to 30 percent of the phosphorus in raw wastewater. Favorable phosphorus removal conditions exist for SWISs in most soils of the United States, but some phosphorus loading problems might be encountered in areas with older systems, highly permeable soils (e.g., sands), mineral-poor soils, nearby surface waters, and high system densities. Some technologies can enhance phosphorus removal (e.g., sand filters with high iron-content sand, sequencing batch reactors operated in certain modes).

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Table 6.8: Wastewater constituents of concern and representative estimates of concentrations in the effluent of various treatment units (adapted from Siegrist et al., 2000).

Constituents of concern	Direct or indirect measures	Tank-based treatment unit effluent concentrations					SWIS percolate into ground water at 3- to 5-ft depth (% removal)
		Domestic STE[a]	Domestic STE with N-removal recycle[b]	Aerobic unit effluent	Recirculating sand filter effluent[c]	Recirculating foam or textile filter effluent[c]	
Oxygen demand	BOD_5 (mg/L)	140-200	80-120	5-50	2-15	5-15	>90
Particulate solids	TSS (mg/L)	50-100	50-80	5-100	5-20	5-10	>90
Nitrogen	Total N (mg N/L)	40-100	10-30	25-60	10-50	30-60	10-20
Phosphorus[d]	Total P (mg P/L)	5-15	5-15	4-10	3-9	4-10	0-100
Bacteria (e.g., *Clostridium perfringens, Salmonella, Shigella*)	Fecal coliform (organisms per 100 mL)	10^6-10^8	10^6-10^8	10^3-10^6	10^1-10^3	10^1-10^3	>99.99
Virus[e] (e.g., hepatitis, polio, echo, coxsackie, coliphage)	Specific virus (pfu/mL)	0-10^5	0-10^4	0-10^4	0-10^3	0-10^3	>99.9
Organic chemicals (e.g., solvents, petro-chemicals, pesticides)	Specific organics or totals (µg/L)	0 to trace	0 to trace	0 to trace	0 to trace	0 to trace	>99
Heavy metals (e.g., Pb, Cu, Ag, Hg)	Individual metals (µg/L)	0 to trace	0 to trace	0 to trace	0 to trace	0 to trace	>99

[a] Septic tank effluent (STE) concentrations given are for domestic wastewater. However, restaurant STE is markedly higher, particularly in BOD_5, COD, and suspended solids, while concentrations in graywater STE are noticeably lower in total nitrogen.
[b] N-removal accomplished by recycling STE through a packed bed for nitrification with discharge into the influent end of the septic tank for denitrification.
[c] Operated in recirculating mode.
[d] P-removal by adsorption or precipitation is highly dependent on media capacity, P loading, and system operation.
[e] Episodically present at high levels.

6.3.1.5.2 *Septic tanks*

Septic tanks are designed to retain a minimum 24- to 48-hour wastewater flow and are usually the first component in OWTSs. Additional treatment components (e.g., soil absorption field, sand/media filter) are necessary because the quality of septic tank effluent is not adequate for direct discharge. The septic tank should be watertight for two reasons: (1) infiltration into the tank can cause hydraulic overloading of treatment and/or dispersal components; and (2) leaks can cause discharge of scum and sludge to subsequent processes and increase potential for surface and ground water contamination. Many states and counties require tanks to be watertight. For example, Suffolk County, New York, regulations state that "all joints shall be sealed so that the tank is watertight and certified as to watertightness after installation. Tanks that are cast in place must be certified by a licensed professional engineer and, as a minimum, have the floor and walls monolithically poured." Oregon septic tank standards stipulate that tanks are to be tested by filling them with water to a level 2 inches above the point of riser connection to the top of the tank. Leakage of no more than 1 gallon during a 24-hour period must be demonstrated. Because of leakage concerns, cast concrete and polyethylene tanks are preferred over those constructed of metal, redwood, concrete block, brick, or other materials, unless equipped with a watertight liner.

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Septic tanks should be fitted with a regularly serviced effluent screen, commonly called a filter, at the outlet pipe. Several states and localities (e.g., Connecticut, Georgia, Florida, Alabama, North Carolina, Contra Costa County, California) now require septic tank screens to help protect the integrity of the SWIS for long-term performance (Schaub, 2000; Stuart, 2000). Screens not only prevent the discharge of neutrally buoyant solids and reduce TSS during tank upsets, but also provide an early warning sign that an inspection is needed, since they will clog and cause plumbing fixtures to drain poorly as they screen solids attempting to exit the tank through the outlet pipe.

Because septic tanks need to be serviced, the top of a septic tank riser should extend above the ground surface. Older installations can be difficult to locate when these features are not provided. Both septic tanks and SWISs are usually required to be at least 50 to 100 feet from any surface water body, but this setback might not be adequate in some cases (e.g., high-porosity soils, high water tables). Septic tanks should be inspected and pumped every 3-5 years.

6.3.1.5.3 *Subsurface wastewater infiltration systems*

Infiltration trenches containing perforated pipe and stone are the most widely used method for treating and dispersing septic tank effluent, though other septic tank effluent infiltration approaches (plastic open-bottomed leaching chambers, perforated pipes encased in net-wrapped foam pellets, and alternate media such as tire chips) have been used successfully. SWIS trenches are typically about 2 to 4 feet deep and about 2 to 3 feet wide. Soils, surface water drainage, and the slope of the land influence the location of the tank and field (Dickey et al., 1996). For example, septic systems are usually required to be located downslope from all wells, although ground water might not always follow this gradient. Trenches typically range in length from 45 to 100 feet.

Infiltration occurs through the bottom and sides of the trench. Gravelly soils promote rapid movement of wastewater contaminants, and poor-permeability soils (clays, etc.) require very large SWISs to accept the entire wastewater volume. Shallow trenches are generally preferred to deeper trenches because the upper soil horizons are usually more permeable and greater aeration and evapotranspiration can occur. A reserve area for future repairs or additions to the drainage field is often required by state code.

Septic tank effluent can be distributed to soil absorption system components by gravity, dosing, or uniform application. Dosing refers to periodically (e.g., 4 to 24 times per day) releasing effluent to the SWIS using a pump or siphon after a predetermined quantity has accumulated. Similarly, uniform application stores the effluent for a short time, after which it is pumped through smaller-diameter perforated pipes throughout the entire trench length to achieve uniform distribution. Distribution boxes have long been a source of poor performance in gravity-dosed systems, and they must be inspected frequently after initial installation because uneven settling causes uneven distribution of effluent. Ports with cam-type levelers can be adjusted to compensate for settling where regular inspection is required. Distribution boxes that do not have access ports or are not inspected or maintained are not recommended.

Uniform application can result in the least amount of infiltrative surface clogging and greatest treatment efficiency. Maintenance of trenches and beds is minimal, particularly if the tank is pumped regularly. Alternating SWIS systems are especially effective because they allow the use

of one or more leaching systems while others rest for six months to a year to restore their effectiveness.

Most SWISs are designed to oxidize carbonaceous organics and convert the ammonium in septic tank effluent to nitrate by providing an aerobic environment. Nitrogen removal capabilities of SWISs are minimal and depend in part on temperature. Nitrate is water-soluble and travels freely to ground water. Elevated nitrate concentrations in ground water used as drinking water can cause the childhood illness methemoglobinemia (blue baby syndrome), can cause problems during pregnancy, and can present a risk to poultry livestock. In soils with no denitrifying capability, nitrate can travel with the ground water to nearby surface waters. Nitrogen loadings in coastal areas can cause eutrophication and related problems (e.g., low dissolved oxygen) that impair the life functions of desirable aquatic biota.

Some clogging of infiltrative surface pores from biomass and slimes produced by natural wastewater decomposition processes occurs under normal conditions. In coarser soils, this "biomat" improves treatment performance. Research conducted in Marion County, Florida, found that the predominant cause of hydraulic failure in systems less than five years old was hydraulic overload. After 15 years of service, root clogging was the cause of hydraulic failure in most cases. In general, SWISs located high in the soil profile provide access to both carbon (from organic matter) and oxygen (diffusion from ground surface), two elements needed for biochemical wastewater decomposition processes. Shallow placement also maximizes vertical separation between the infiltrative surface and ground water.

The vertical distance between the soil infiltration system and ground water is an important consideration. If seepage from the SWIS reaches the ground water in an area where unsaturated soil depth is inadequate, it could contaminate drinking water supplies. Furthermore, during wet seasons, ground water might rise into the SWIS, causing sewage to move upward toward the ground surface. This is especially important to consider in areas with a high water table (Lockwood, 1997) or in areas with poor permeability. Dickey et al. (1996) recommend that SWISs be placed at least 4 feet above the ground water table during the wettest season. The type of soil also influences the potential for ground water contamination. If sewage is applied to coarse soils, for example, the potential for contamination may be higher (Dickey et al., 1996). Clays that crack when dry or contain other types of macropores can also have a high contamination potential.

Installation of a conventional septic tank with a SWIS typically costs between $3,000 and $5,000 per home**,** but costs vary widely based on site-specific physical and regulatory limitations.

6.3.1.5.4 *Leaching chambers*

Molded plastic leaching chambers (see Figure 6.3) have been used in lieu of trench-based perforated pipe and aggregate infiltration systems to distribute septic tank effluent to the soil for final treatment. A typical leaching chamber infiltration system consists of interconnected arch-shaped bottomless chamber segments, installed below grade in level beds that comprise the drain field network. Aggregate is not needed, although porous media (e.g., gravel) is often used to fill in around the exterior of the vented chamber sidewalls to accommodate delivery of effluent through the sidewalls when ponding in the chambers occurs. Sizing of the network is based on wastewater characteristics, flows, and site conditions (soils, depth to groundwater/bedrock, etc.).

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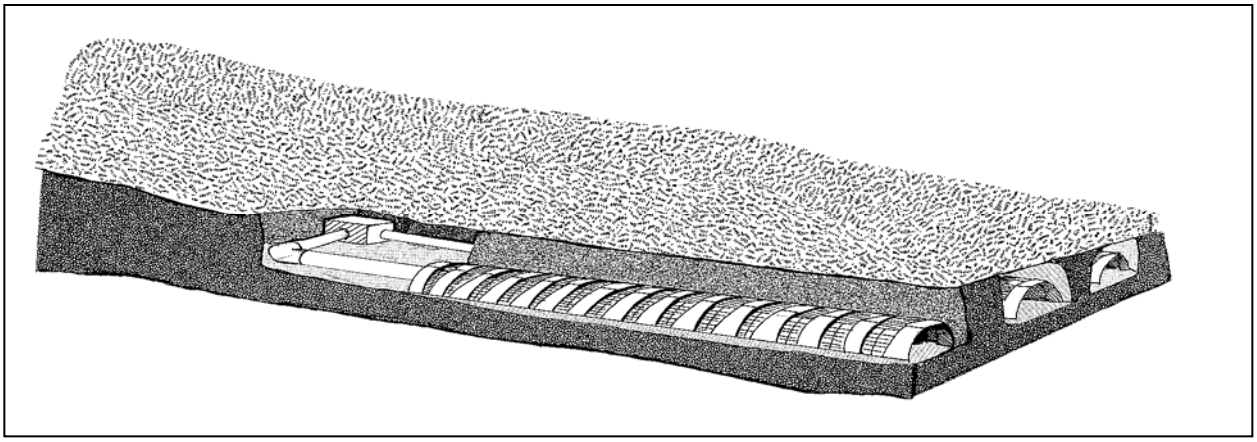

Figure 6.3: Leaching chamber subsurface wastewater infiltration system (Hoover et al., 1996).

Chamber systems have increased in use due to their performance, cost, light weight, and ease of installation.

6.3.1.5.5 *Alternative systems*

Several states have adopted provisions for the use of alternative and innovative technologies. Massachusetts has adopted a provision of its state environmental code that allows "approval of innovative (dispersal) systems if it can be demonstrated that their impact on the environment and hazard to public health is not greater than that of other approved systems" (Code of Massachusetts Regulations, 1995). Commonly referred to as Title 5, this legislation requires evaluation of pollutant loadings as well as management requirements prior to approval of alternative systems (Venhuizen, 1992).

The State of Maryland's regulations assert that the Maryland Department of the Environment (MDE) and the approving authority "shall consider all possible methods for correcting existing system failures and providing facilities for homes that lack indoor plumbing and, based on a case-by-case evaluation, provide the best technical guidance in attempting to resolve existing pollution or public health problems" (Code of Maryland Regulations, 2001). Alternative technology (with appropriate management) can be used for new construction on existing lots of record where site limitations prevent the use of conventional on-site systems. State regulations require that the local health unit and MDE monitor these systems for not less than two years.

More information on the alternative technologies described below is available from the National Small Flows Clearinghouse Environmental Technology Initiative (http://www.nesc.wvu.edu/nsfc/nsfc_ETI.htm) and EPA (http://www.epa.gov/owm/decent/treat.htm). An extensive list of links to public and private sector OWTS resources can be found at http://centreforwaterresourcesstudies.dal.ca/cwrs/onsite/info.htm. For information on loading rates, design, and performance capabilities for conventional and alternative treatment systems, refer to the *Onsite Wastewater Treatment System Manaual* (USEPA, 2002a). Table 6.9 provides a summary of capital and maintenance cost data for selected OWTS technologies.

Table 6.9: Summary of estimated capital and operation and maintenance costs for OWTSs (adapted from Hoover, 1997).

System Type	Costs (dollars)					
	Total materials & installation	Present value of total O&M[1]	Total over life of system	Amortized monthly materials & installation	Average monthly present value of O&M[1]	Average monthly over the life of the system
Septic Tank and Gravity Distribution						
Alone	2,504	6,845	9,349	20	19	39
With chambers	3,336	7,032	10,368	27	20	46
With styrene foam	2,846	6,920	9,767	23	19	42
With large diameter pipes	3,816	7,156	10,971	31	20	51
With pressure manifold	4,774	7,707	12,482	38	21	60
With pressure manifold and chambers	5,593	7,889	13,482	45	22	67
With pressure manifold and styrene foam	5,103	7,777	12,881	41	22	63
With pressure manifold large-diameter pipes	6,073	8,013	14,085	49	22	71
With sand filter pretreatment	7,296	12,069	19,364	59	34	92
With peat filter pretreatment	11,808	12,604	24,412	95	35	150
With recirculating sand filter pretreatment	6,226	12,059	18,285	50	33	84
With wetland cell	5,574	23,231	28,805	45	65	109
With 18" fill mound	4,507	6,850	11,357	36	19	55
With 18" fill mound and chambers	5,326	7,032	12,357	43	20	62
Septic Tank and LPP Distribution						
Alone	4,523	12,319	16,843	36	34	71
With sand filter pretreatment	10,223	13,338	23,561	82	37	119
With recirc. Sand filter pretreatment	8,232	13,007	21,239	66	36	102
In at-grade system	4,590	12,345	16,935	37	34	71
Septic Tank and Drip Distribution						
Alone	11,163	13,082	24,245	90	36	126
With sand filter pretreatment	15,994	14,101	30,095	129	39	168
With recirculating sand filter pretreatment	14,872	14,094	28,966	120	39	159
With sand filter pretreatment and chlorine disinfection	16,408	21,244	37,652	132	59	191
With recirculating sand filter pretreatment and chlorine disinfection	15,285	21,237	36,522	123	59	182
with sand filter pretreatment and UV disinfection	17,867	21,655	39,522	144	60	204
With recirculating sand filter pretreatment and UV disinfection	16,744	21,757	38,501	135	60	195
Septic Tank and Gravity Distribution						
Alone	2,504	6,845	9,349	20	19	39
With chambers	3,336	7,032	10,368	27	20	46
Septic Tank and Spray Irrigation						
With sand filter pretreatment and chlorine disinfection	11,890	20,670	32,580	96	57	153
With recirculating sand filter pretreatment and chlorination	10,768	20,663	31,431	87	57	144
With sand filter pretreatment and UV	13,349	21,190	34,539	107	59	166
With recirculating sand filter pretreatment and UV	12,227	21,183	33,410	98	59	157
Denitrification System Black Water and Gray Water Separation						
With gravity distribution	9,963	13,508	23,471	80	38	118
With LPP distribution	12,565	15,070	27,635	101	42	143

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Table 6.9 (continued).

System Type	Costs (dollars)					
	Total materials & installation	**Present value of total O&M[1]**	**Total over life of system**	**Amortized monthly materials & installation**	**Average monthly present value of O&M[1]**	**Average monthly over the life of the system**
Other Types						
Aerobic treatment unit and gravity distribution	8,037	36,406	44,443	65	101	166
Septic tank and pressure-dosed sand mound system	4,863	12,407	17,269	39	34	74
Septic tank filter or screen (installation or retrofit into existing tank only)	200-400	938	1,250	1	<1	<1

Note: These numbers could be considered in the low to moderate range and may vary in other regions because of differences in material and labor costs.
[1] O&M = Operation and Maintenance

Regardless of the type of soil, sand, or other medium used for the absorption field, some sort of minimal maintenance is often required. It is important to restrict the operation of heavy equipment within the area proposed for soil absorption fields to prevent compaction of the soil structure and system clogging. Vehicles or other heavy equipment should not be operated over previously installed absorption fields or filters for the same reason. Concrete tanks are often capable of withstanding heavy loads, but operation of vehicles or other heavy equipment directly above them can cause settling or structural failure that can affect tank performance. Finally, because of the clogging effect of roots, vegetation above absorption fields and filter media should be restricted to types with short root structures. Trees or shrubbery should be immediately removed from absorption fields or filter medium installations.

6.3.1.5.6 *Elevated systems*

Mound systems are alternative soil absorption systems typically used at sites where insufficient ground water separation distances or slow-permeability soil conditions exist (see Figure 6.4). Mound systems are usually designed so that the effluent from the septic tank flows to a dosing tank and is then pumped to the top of the mound, which is constructed above the natural soil surface. The mound consists of a layer of suitable sand fill, an absorption bed filled with aggregate within the sand fill, and a covering layer of topsoil. The topsoil layer should be at least 6 inches deep and serves as a growth medium for vegetation. Converse and Tyler (2000) advise that mounds not be built on grades steeper than 25 percent.

At-grade systems are similar to mound systems, but the absorption bed is built directly on the ground surface, with aggregate placed on tilled soil instead of on top of raised sand. At-grade systems are typically designed for sites unsuitable for subsurface systems, but with less-restrictive conditions than sites where mounds would be needed (Converse and Tyler, 2000).

Pollutant removal effectiveness and operation and maintenance are similar to those of conventional systems with pressurized distribution. A mound system is more expensive to install than a typical soil absorption trench system. The cost of a complete mound system, including a septic tank, is typically $7,000 to $12,000 installed. Operation and maintenance include septic tank pumping every 3 to 5 years; annual or semiannual inspection of the pump, float switches, tank, and dosing chamber; and maintenance of vegetative cover (i.e., grass) to prevent erosion.

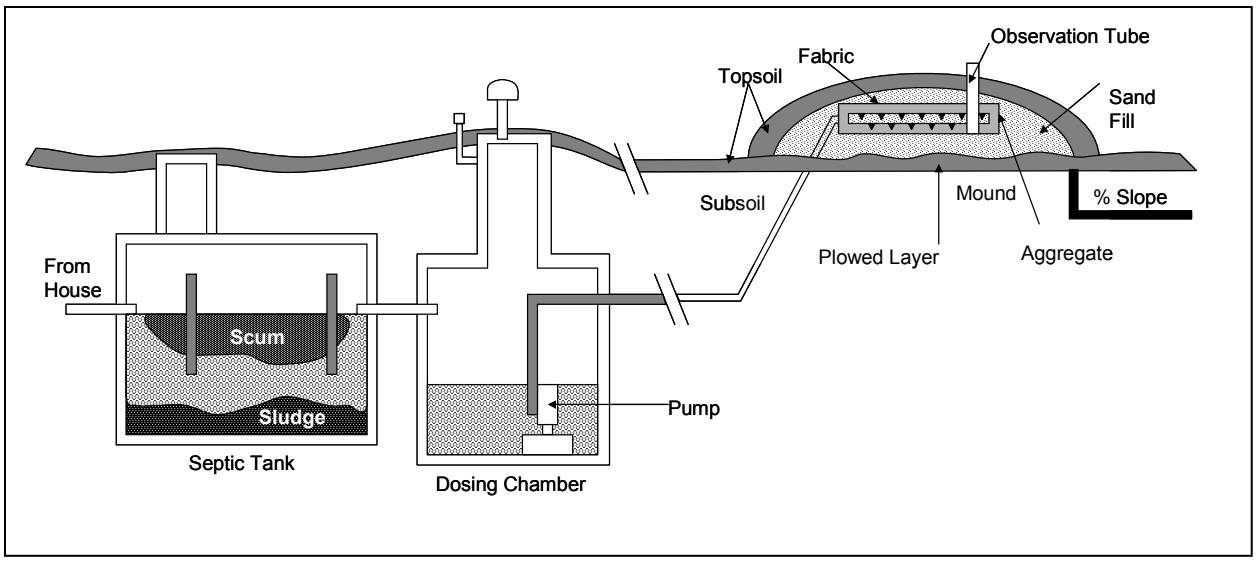

Figure 6.4: Schematic of a typical mound system (Ohio State University, no date).

6.3.1.5.7 *Intermittent sand/media filters*

An intermittent filter system receives and treats effluent from the septic tank via sand or other media (e.g., peat or composite materials) before it is discharged to the soil absorption field. Periodic, uniform dosing of septic tank effluent is distributed to the surface of the sand/media filter. The filter consists of a bed (either open or buried) of granular, synthetic, or organic material from 24 to 36 inches deep. Microorganisms living and growing on the filter medium consume nutrients and other wastes and facilitate aerobic decomposition of organic matter in the wastewater. The treatment medium is underlain by leveled rock or gravel and collector drains. Siphon or pressure distribution of septic tank effluent is used to dose wastewater to the surface of the media. Free access filters (media exposed to the atmosphere) should be covered with removable covers to prevent operation and maintenance problems (such as those caused by dust and rain), and should include insulation in cold and wet regions.

Intermittent media filters might become clogged as the pore space between the grains of the medium begins to fill with excessive amounts of inert biological materials. Resting the filter for several months in warm weather will restore hydraulic conductivity (Tyler et al., 1985). Free access filters should be checked every three to four months to prevent surface problems. Periodic raking is recommended to remove leaves and other debris where the system is not covered.

Intermittent sand filters typically produce high-quality effluents with BOD_5 and suspended solids concentrations below 10 mg/L (Tchobanoglous and Burton, 1991). Nitrogen compounds are almost completely nitrified if the filter remains aerobic, although nitrification rates might fall during cold weather. Total nitrogen removal rates average 15 to 35 percent (USEPA, 2002a). Installation cost ranges from $5,000 to $10,000. Systems that use peat or other organic media in place of the soil/sand filter media have been installed in several areas of the country to serve single- and multiple-family residences. This technology has shown excellent results in many applications but is still under study and considered a provisional application subject to monitoring in most jurisdictions.

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Sand Filter System, Washington Island, Wisconsin

Washington Island, Wisconsin, covers a 36-square-mile area. Its geology consists of shallow soils and fissured, cavernous carbonate bedrock. Sinkholes are not uncommon and the threat of ground water contamination is real. Conventional systems serve older developments on the island, but the potential for ground water contamination from pathogens and nitrate spurred interest in alternative technologies. As part of a demonstration project, recirculating sand filters were installed and evaluated for 2 years. The demonstration project showed that total nitrogen could be reduced by 60 to 90 percent. Water quality was also improved by inserting an anaerobic upflow filter between the septic tank and the sand filter dosing tank.

Operation and maintenance include monitoring influent and effluent, inspecting the dosing equipment, maintaining the filtration medium surface (i.e., raking and replacing as needed), checking the discharge orifices for buildup or blockage, and flushing the distribution manifold annually. Costs for operation and maintenance of these systems include three or four visits per year ($100 to $150/year), in addition to septic tank maintenance.

6.3.1.5.8 *Recirculating sand/media filters*

A recirculating sand/media filter is a modified intermittent filter that recirculates the effluent from the filter through the septic tank and/or the recirculation tank before it is discharged to the wastewater infiltration system. The addition of the recirculation loop in the system enhances pollutant removal effectiveness by providing a denitrification step (i.e., in the septic or recirculating tank) in the treatment process. Nitrogen is both nitrified (in the media filter) and denitrified in these systems, resulting in 40 to50 percent or more (if enhanced) nitrogen removal. Recirculation rates of 3:1 or higher are generally recommended. Recirculating media filters can be used in new, on-site systems or applied to retrofits of failing conventional systems (Bruen and Piluk, 1994), particularly at sites with nitrogen concerns. Recirculating media filter effluent might also be appropriate for soil absorption systems with low-permeability soils.

BOD and suspended solid concentrations in the effluent are typically less than 10 mg/L (Roy and Dube, 1994; Bruen and Piluk, 1994; Loudon, 1996). Recirculating sand filters typically cost $8,000 to $11,000.

Operation and maintenance include monitoring effluent; inspecting the dosing equipment; maintaining the filtration surface (i.e., raking as needed); checking the discharge orifices for buildup and blockage; and flushing the distribution manifold annually in addition to septic tank maintenance.

6.3.1.5.9 *Anaerobic upflow filters*

An anaerobic upflow filter (AUF), which may resemble a septic tank filled with gravel, is designed so that the effluent flows up through the bottom of the AUF filter media (e.g., ⅜-inch gravel). Anaerobic bacteria that convert nitrate in the influent to nitrogen gas grow on the surfaces of the filter medium. Septic tank effluent is gravity-dosed or pumped (depending on site conditions) to the bottom of the AUF and up through the filter to the top, where a collection pipe transports it to a dosing chamber and/or SWIS for final discharge. A nitrogen-removal system may include a septic tank, a sand filter, an AUF, and a soil absorption field. AUFs are relatively small (e.g., 4 feet deep and 6 feet in diameter) (Boyle, 1995) and sized to allow retention times of 24 to 48 hours.

Nutrient Export from Conventional vs. Open Space Development in Maryland

Zielinski et al. (2000) undertook a study to compare nutrient export from several conventional development projects and the same projects designed using alternative open space strategies (see Management Measure 4 for a discussion of conventional and alternative development scenarios). One site was a low-density residential subdivision in Maryland. In the conventional design, each lot had an on-site private septic system and the neighborhood had a septic reserve field of approximately 10,000 square feet. When the site was redesigned to preserve open space, the individual septic systems were replaced with shared septic systems that used more advanced recirculating sand filter technology with better nutrient removal capacity and lower construction and installation costs. When the two development scenarios were modeled to determine relative rates of nutrient export, the redesigned septic system showed a substantial decrease in nutrient output. However, despite the use of more advanced technology, septic systems remained the predominant source of exported nutrients.

Total nitrogen concentrations from AUFs treating fully nitrified influent can range from less than 3 to 23 mg/L or higher, with removal efficiencies of approximately 60 to 70 percent. Boyle (1995) reported average total nitrogen concentrations below 15 mg/L in a recirculating sand filter-anaerobic upflow filter system. The cost of the filter varies by manufacturer and is approximately $1,000 to $1,500. Operation and maintenance tasks are minimal, especially if the filter medium consists of large gravel (i.e., > 1 inch). Sand-sized media will clog and should not be considered. Inspection of wastewater levels in the septic tank and AUF filter tank, as well as periodic inspection of pumps, float switches, discharge orifices, and other components, should be conducted to ensure continuous performance.

6.3.1.5.10 *Cluster systems*

For the purposes of this guidance, a cluster system is defined as a collection of individual on-site systems that provide primary treatment in septic tanks at each site. Septic tank effluent is collected and routed to another site for further treatment. Other designs in which primary treatment occurs at the treatment site instead of the septic tank are also possible. Collection and movement of effluent to the final treatment site can be accomplished by gravity flow or pumps.

Additional treatment for cluster systems may involve the use of conventional SWISs, sand filters, AUFs, constructed wetlands, aerobic lagoons, or aerobic treatment. The use of cluster systems can be advantageous in the case of inadequate soil, groundwater, or space at individual homes, or when better soil at is available at another location in the development.

6.3.1.5.11 *Constructed wetlands*

Constructed wetlands have traditionally been used for polishing effluent that has already had some degree of treatment. Vegetated submerged beds (VSBs), also known as submerged constructed wetlands, subsurface flow constructed wetlands, or plant rock filters (see Figure 6.5), are designed primarily to reduce concentrations of BOD and suspended solids in wastewater effluent from the septic tank. VSBs consist of horizontal flow gravel filters with wetland-type vegetation (e.g., cattails, canna lilies) and are usually underlain with an impermeable liner (e.g., plastic sheeting). The vegetation has a minimal role in treatment in this application. Residential vegetated submerged beds are normally followed by subsurface infiltration trenches or chambers.

The performance of constructed wetlands is not significantly degraded in colder climates during winter months because removal is by physical and chemical processes. Recent tests that

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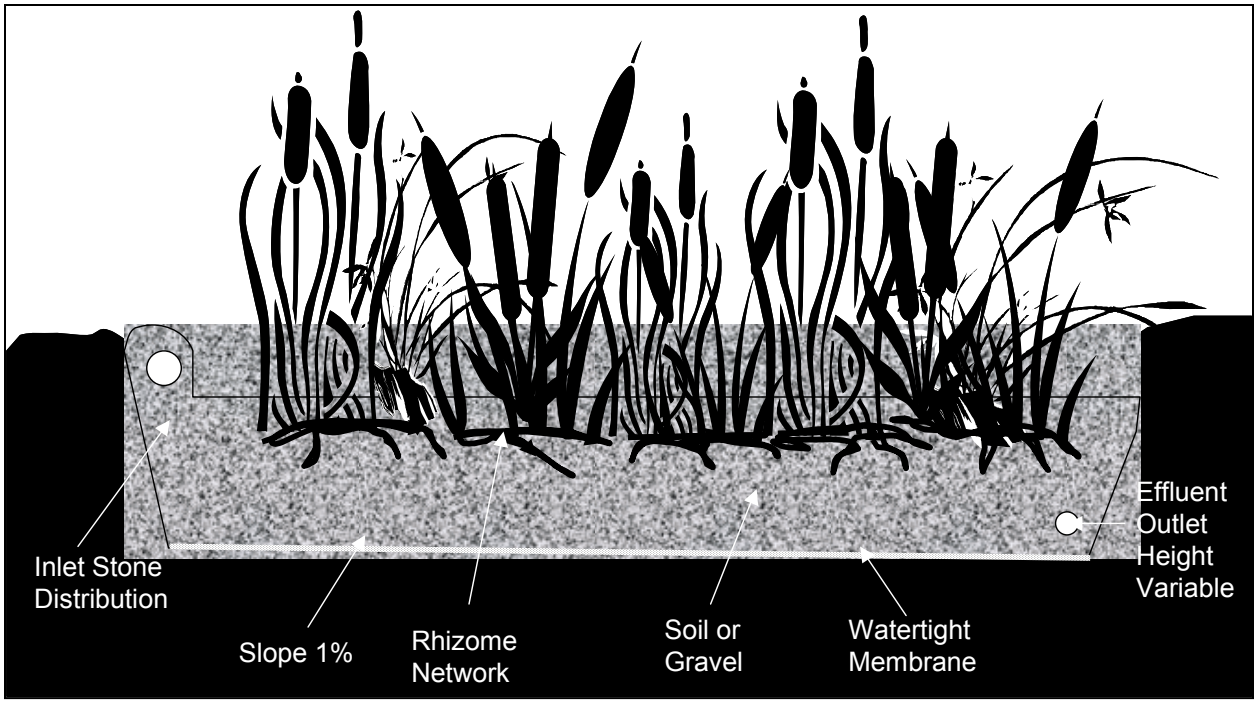

Figure 6.5: Components of a vegetated submerged bed.

incorporated a submerged aeration line in the wetland cell have shown promise in facilitating nitrification/denitrification (Wallace, 2000).

Constructed wetlands are configured as free-water surface wetlands, which can facilitate aerobic treatment processes, or subsurface flow wetlands, which are generally anaerobic. Removal rates for fecal coliform, BOD, and suspended solids can be as high as 90 percent for a gravel-based VSB (White and Shirk, 1998). However, removal of nitrogen and phosphorus compounds (e.g., ammonium, nitrate, SRP) is typically much less. Nitrogen removal can be enhanced through designs that accommodate nitrification-denitrification processes—i.e., aerobic treatment followed by anaerobic treatment zones—but significant phosphorus removal is much more difficult to achieve (USEPA, 2001a). Estimated costs for VSBs range from approximately $10,000 to $20,000 for a system serving a typical residence. Maintenance tasks include removing dead vegetation; inspecting and cleaning the inlet and outlets; inspecting wastewater levels in the tank and filter bed; and ensuring wastewater levels do not rise above the filter medium.

6.3.1.5.12 *Sequencing batch reactors*

A sequencing batch reactor (SBR) is a modified cyclically aerated and decanted activated sludge treatment system. The SBR carries out aeration, sedimentation, and clarification via timed cycles in the same tank. Continuously fed SBRs are compartmented to reduce short-circuiting. SBRs remove BOD and TSS from wastewater. Modification to the operational mode can enhance removal of phosphorus and nitrogen. Development of reliable and versatile control systems has been a major factor in the increased use of SBRs during recent years. However, repair and replacement costs and operator knowledge requirements should be considered in decisions regarding this technology.

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SBRs can be used for new developments or connected to existing septic systems and can be designed to collect effluent from multiple septic tanks for treatment at a common site. SBRs can be sited in relatively small areas of only a few hundred square feet. SBR costs, operation, and maintenance requirements are greater than those of conventional on-site systems. SBRs can be suitable alternatives for sites where high-density development and/or unsuitable soils preclude adequate treatment of effluent by conventional systems.

With appropriate design and operation, SBR plants have been reported to produce high-quality effluents with very good removal rates for BOD and TSS. Typical ranges of $CBOD_5$ (carbonaceous 5-day BOD) are from 5 to 15 mg/L, while TSS levels can range from 10 to 30 mg/L in well-operated systems. Fecal coliform removal of 1 to 2 logs can be expected (USEPA, 2002b). By using an anaerobic-aerobic operating mode, significant nitrogen and phosphorus removals are also possible.

6.3.1.5.13 *Aerobic treatment units*

Packaged aerobic treatment units have been used for residential on-site use for nearly 40 years. Treatment unit storage volumes can provide a hydraulic retention time of several days based on typical household flows. These systems require regular supervision, operation, and maintenance to be effective. Since maintenance has been a particular problem with these units, requiring a perpetual maintenance contract at the time of permitting is strongly recommended. Packaged aerobic treatment units generally include pretreatment by settling (usually in a septic tank) to remove fats, oils, grease, and solids. Effluent is usually discharged to a SWIS. When additional treatment (e.g., filtration, disinfection, etc.) is provided, discharge to surface waters may be possible if a Clean Water Act Section 402 (National Pollutant Discharge Elimination System) permit is obtained. Power requirements can be significant for certain types of package plants. Mixed liquor solids must be disposed of regularly, so the system should be inspected at least every three months.

Extended aeration units can achieve BOD concentrations ranging from 30 to 50 mg/L and suspended solids concentrations ranging from 40 to 60 mg/L in well-operating systems, often reflecting 75 to 95 percent removal efficiency (Kellam et al., 1993; Ayres and Associates, 1991; Tchobanoglous and Burton, 1991). Installing a sand filter or other polishing unit to treat wastewater after an extended aeration unit can improve BOD and suspended solids removal performance, although nitrate levels might increase as a result (Kellam et al., 1993). Costs typically range from $3,000 to $6,000 for an installed unit, with maintenance costs of $200 to $300 per year.

6.3.1.5.14 *Fixed film systems*

Fixed film systems feature media (e.g. plastic disks, pellets, gravel, tire chips, fabric media, foam pellets) with large amounts of surface area where microorganisms that digest wastes become attached and grow. Colonies of bacteria and other organisms develop into a biologically active slime layer that is sustained by nutrients and other constituents in the effluent. As wastewater flows over the media, colonies of microorganisms extract soluble organic matter and nutrients as a source of carbon and energy. Oxygen, which is required by these microorganisms, can be supplied by natural ventilation or by mechanical or diffused aeration within the wastewater.

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Fixed film systems include trickling filters (where the wastewater flows down through a bed of gravel, carbon-based, or composite media such as tire pellets, fabric strips, foam pellets, etc.) and rotating biological contactors (rotating plastic discs colonized by wastewater flora/fauna partially submerged in the wastewater). These systems require pretreatment of sewage in a septic tank. Final effluent can be discharged to a SWIS or reused. Disinfection is necessary if effluent may come into contact with humans or disease vectors. Both systems can achieve TSS concentrations of 60 to 80 mg/L and BOD levels of 80 to 90 mg/L. Maintenance includes periodic inspection of wastewater levels in the septic tank; inspection of pump switches and discharge orifices; and cleaning or replacement of the growth medium at regular intervals, or more frequently if clogging develops.

6.3.1.5.15 *Pressure distribution systems*

Low-pressure effluent distribution into the soil using technologies developed by the drip irrigation industry offers significant treatment performance improvements. Pumping effluent to the dispersal field typically creates a large flow surge that distributes effluent uniformly throughout the dispersal field. This minimizes localized overloading and the consequent potential for eventual failure (Venhuizen, 1995). Pressure systems are placed very high in the soil profile and use periodic dosing to distribute effluent to the soil matrix. Pressure distribution trenches are typically shallow and narrow, providing ease of installation and maximum carbon availability for treatment processes. Reaeration of the infiltrative surface and drying of the biomat between doses reduce potential clogging threats and help to ensure nitrification of ammonia in the septic tank effluent. Drip irrigation distribution lines are typically installed with a vibratory plow at shallower depths (i.e., 8-12 inches below surface grade) and should be preceded with pretreatment by a septic tank and fixed film filter to prevent clogging of emitters (USEPA, 2002a).

6.3.1.5.16 *Evapotranspiration*

Evapotranspiration (ET) systems are designed to remove wastewater through evaporation and transpiration; they are used mostly in dry climates (e.g., Arizona, New Mexico). They have been used in wetter climates where ET potential is sufficiently high in certain months. Seepage from an ET system can be reduced or eliminated by using a plastic, PVC, or clay liner, but leaving the system unlined allows both percolation and evapotranspiration to occur. Wastewater is applied below the surface to the sand medium of the ET system. Water moves to the soil surface by capillary action for use by plants or is evaporated to the atmosphere. Performance strongly depends on climate, available surface area, and physical properties of the sand. Properly operating ET systems must evaporate or transpire more water than is applied as waste or collected during precipitation. More than 5,000 ET systems are in use in the United States. The cost of installation ranges from $10,000 to $15,000, but operation and maintenance costs are generally quite low.

6.3.1.5.17 *Spray irrigation*

Spray irrigation is commonly used to discharge septic tank effluent as irrigation water to hayfields or other vegetated areas not used to produce food crops. Spray irrigation can effectively dispose of effluent from OWTSs. However, strict controls on human contact with discharges that might contain pathogens are required. Design of spray irrigation systems must consider soil permeability, slopes, climate, and the water and nutrient needs of vegetation growing on the spray field. Additional treatment and disinfection of spray irrigation water is

necessary if human contact with the spray field or wet vegetation is likely. Successful applications have been installed in shallow soils in the Northeast. It is recommended that effluent be treated prior to spraying to remove most BOD for odor-prevention. Spray devices should not be activated during wet weather, freezing temperatures, or saturated soil conditions. Because large buffer areas around the spray sites are usually required, extensive land is required, limiting this option to very large lots.

6.3.1.5.18 *Disinfection devices*

In some areas (e.g., source water protection areas and sites near recreational lakes, and coastal beaches), pathogen contamination from on-site systems is a major concern. Disinfection devices can be used in conjunction with the technologies summarized above to treat effluent for pathogens before it is discharged. The three most common methods of disinfection in the United States are chlorination, ozonation, and ultraviolet (UV) disinfection (NSFC, 1998).

Installation of these devices in an on-site system increases its cost and adds to operation and maintenance requirements. Single-home chlorinators in non-dosed conventional OWTSs have a poor track record when applied without management oversight. These units can greatly overdose or not dose at all if proper operation and maintenance are not performed. Chlorine is a powerful biocide and can have significant impacts on aquatic biota at concentrations well below 1 mg/L. Some states (e.g., Maryland) have additional requirements for maximum chlorine concentrations in effluent or prohibit the use of halogen (i.e., chlorine and iodine) processes. UV units generally require controlled dosing of a high-quality influent (BOD of 30 mg/L and TSS of 30 mg/L or better) for consistent performance. Maintenance includes periodically cleaning UV tube surfaces to maintain integrity and inspecting the contact chamber to ensure that solids have not accumulated. Annual replacement of UV bulbs is suggested. UV units cost $1,000 to $2,000 (installed) or about the same as tablet chlorinator units. Operation and maintenance costs for UV are about $150 to $200, similar to the chlorinator.

6.3.1.5.19 *Water separation systems*

A water separation system separates graywater from sinks, tubs, and appliances from toilet blackwater. The graywater is treated by using a somewhat smaller conventional OWTS or a SWIS. The blackwater can be treated in another OWTS or stored in a holding tank and periodically hauled off site for treatment or disposal. For extreme situations or for seasonal residents, some form of separation of toilet wastes from bath and kitchen wastes can be helpful. Most nitrogen discharges in residential wastewater come from human wastes, and they also provide almost half of phosphorus, TSS, and BOD. Use of holding tanks can be very expensive owing to the cost of $0.10 to $0.20 per gallon for pumping and hauling.

6.3.1.5.20 *Vaults or holding tanks*

Vaults or holding tanks are used to contain wastewater in emergencies or other temporary situations and to hold wastewater from a blackwater system. These systems require frequent pumping, which can be expensive if the total wastewater flow is contained.

6.3.2 Operation and Maintenance Programs

This chapter discusses two broad functions that have an impact upon on-site wastewater treatment systems: regulatory oversight and management. In the following discussion, oversight

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refers to the regulatory and enforcement functions (e.g., issuing permits, compelling compliance with local or state codes) typically performed by the regulatory authority (i.e., state health departments and their agents, which are usually local health departments). The term management includes other functions and services that may or may not fall under the direction of the regulatory authority, such as long-term planning, ensuring that septic tanks are pumped regularly, conducting periodic system inspections, arranging for financial assistance for installations/repairs, and other activities.

Management services may be provided by a management entity separate from the regulatory authority, such as a sanitation district, contracted firm, or homeowners' association. It is important to recognize that while the enforcement of codes and regulations (i.e., by the regulatory authority) provides a very basic level of protection for public health and environmental resources, the execution of management tasks (e.g., planning, monitoring, operation, maintenance, inspection) by a designated management entity helps to ensure that long-term system use meets established performance requirements.

Implementation of the various management program elements will undoubtedly be subject to the authority of the regulatory agency or agencies, but may be accomplished by another management entity, such as a public or private utility, regional planning agency, or water monitoring council. Some management program elements may require special arrangements or agreements if they are to be performed by a separate management entity. For example, where state codes require the regulatory authority to oversee system design and permitting, a formal agreement would likely be required if an outside management entity assumed those duties. The exact nature of the relationship between the regulatory authority and any management entities servicing a particular jurisdiction will vary considerably and depend upon the capacity of the regulatory authority, state and local codes, and the ability of management entities to provide designated services in an acceptable manner.

According to the U.S. Census Bureau (1997b), approximately 25 percent of the estimated 112 million occupied homes in the United States are served by on-site systems, a proportion that has changed little since 1970. Distribution and density of homes with OWTSs varies widely by state, with a high of about 55 percent in Vermont and a low of around 9.8 percent in California. New England states have the highest proportion of OWTS-served homes: New Hampshire and Maine both report that about half of all homes are served by on-site systems. More than a third of homes in the southeastern states depend on OWTSs, including approximately 48.5 percent in North Carolina and about 40 percent in both Kentucky and South Carolina.

More than half of the nearly 26 million homes with on-site treatment systems are more than 30 years old (U.S. Census Bureau, 1997a, 1999) and a significant number report problems. A survey conducted by the U.S. Census Bureau (1997a) estimated that 403,000 homes experienced septic system breakdowns within a three-month period during 1997, with 31,000 reports of four or more breakdowns at the same home. Typical reported malfunction rates average between 1 and 5 percent annually, with reported failure rates in a study conducted in the State of Washington ranging between 2.6 percent and 6.1 percent (USEPA, 1993b). It has been estimated that in some areas of Connecticut, 4 percent of on-site systems fail each year. The failure rate might be high because many on-site systems are approved in areas with unsuitable soil conditions.

Reported failure rates may underestimate true failure rates because they typically consider only plumbing backup and sewage surfacing, and not ground water or surface water contamination. Parsons Engineering Science (2000) reported that dye testing conducted for the Rouge River National Wet Weather Demonstration Project found failure rates (defined as short-duration appearance of dye in receiving waters) of 39 to 72 percent. Nelson et al. (1999) reported that estimates of partial and total system failure rates in some states range as high as 50 percent and more in some cases, but definitions of failure were highly variable and included all systems that were not designed according to the states revised codes.

Besides design, installation, and maintenance problems, regional hydraulic overloading (i.e., hundreds or thousands of densely sited systems discharging into a single ground water aquifer or subwatershed) can cause OWTSs to fail to meet requirements for protection of public health and water quality. Other factors include lack of maintenance and system age. In some areas, on-site systems are installed at a density that exceeds the capacity of the local soil to assimilate hydraulic and pollutant discharge loads. In addition, the design life of many OWTSs built between 1960 and 1980 has been exceeded. System owners are not likely to repair or replace aging OWTSs unless sewage backup, septage pooling on lawns, or targeted monitoring and failure documentation occurs. Approaches for reducing operation and maintenance failures through development of management activities and systems are outlined below.

The following sections describe recommended management measures that promote the protection of public health and water resources from risks linked to on-site systems. More information on OWTS management measures and system technologies, as well as case studies from across the nation, are available from EPA at http://cfpub.epa.gov/owm/septic/home.cfm and from the National Small Flows Clearinghouse at http://www.nesc.wvu.edu/nsfc/nsfc_index.htm. A model framework for management programs and other information on OWTS issues is posted by the National On-Site Wastewater Recycling Association at http://www.nowra.org/.

6.3.2.1 Development of system inventories and assessment of maintenance needs

System inventories are critical elements of an effective on-site/decentralized system management program. An inventory is essential to both long- and short-term planning. Knowledge of factors such as system location, type, age, maintenance schedule, and potentially affected water resources is necessary to predict watershed and site-specific pollutant loadings. This knowledge is also needed to achieve a community's public health, environmental, and fiscal goals.

Inventories can also give owners information regarding the proper operation and maintenance of their systems. A typical inventory will contain information such as: owner name, contact information, system type, location, installation date, design capacity, and last date of service.

Clermont County, Ohio, developed an OWTS owner database by cross-referencing water line and sewer service customers (Caudill, 1998). Because most people in the county were public water line customers, subtracting those who were also connected to the public sewer system yielded a database of nearly all the OWTS users. Contact information from the database was used to mass-mail information on system operation and maintenance and the county's new inspection program to 70 percent of the target audience. Other approaches used in the Clermont County outreach program were advisory groups, homeowner education meetings, news releases

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and interview programs, meetings with real estate agents, presentations at Farm Bureau meetings, displays at public events, and targeted publications.

System inventories are essential elements for management programs, and most jurisdictions maintain databases of new systems through their permitting programs. However, older systems (e.g., those installed prior to 1970) are often not included in those data files. Some on-site management programs or other entities conduct inventories of older systems when they are included in a special study area. For example, Cass County and Crow Wing County, Minnesota, have developed projects to inventory and inspect systems at more than 2,000 properties near lakes in the north-central part of the state (J. Sumption, Deputy Director of Cass County, Minnesota, Environmental Services, 2000). The project inventoried but did not inspect systems that were less than five years old unless a complaint or other report indicated possible problems. Costs for inventorying and inspecting 234 systems in one lake watershed totaled $9,000, or nearly $40 per site (J. Sumption, Deputy Director of Cass County, Minnesota, Environmental Services, 2000).

In some cases, data necessary for on-site system management may be held and administered by other agencies. For example, land and water resource characterization data are often collected, stored, and analyzed by environmental or planning agencies. Developing data-sharing policies with other entities through cooperative agreements can help all organizations involved with health and environmental issues improve their efficiency and overall program performance. The RME should ensure that data on existing systems are available to health and water resource organizations (usually regulatory authorities) so that their activities and analyses reflect this important aspect of public health and environmental protection.

Education for system owners is an important component of the outreach for management programs that rely on homeowners for system operation and maintenance. Educational initiatives are most effective when they result in understanding of the relationship between ground water and surface water, and how septic system siting, design, installation, operation, and maintenance can affect those resources and public health. Surveys show that many people have their septic tank pumped only after the system fails. Property owners who are educated in proper system operation and maintenance practices, and who understand the consequences of system failure, are more likely to take actions to ensure that their systems function properly. Typical public outreach and education program topics for homeowners in the present system of prescriptive and conventional on-site systems include:

- How an on-site wastewater treatment system works;
- System siting and design considerations;
- How on-site systems can affect health, ground water, and surface water;
- The importance of water conservation in minimizing hydraulic failures;
- Practices to reduce mass pollutant loadings and toxic inputs to the system;
- Typical operation and maintenance practices, procedures, and timetables;
- How delaying septic tank pumpout can cause solids to clog infiltration systems; and
- Costs of repairs, upgrades, or replacement of system components.

Inventories of existing systems can be developed by consulting wastewater treatment plant service area maps, identifying areas not served by POTWs, and working with public and private

utilities (drinking water, electricity, and septage pumpers and haulers) to develop a database of system owners and contact information.

A variety of commercially available software exists for managing system inventory and other information. Electronic databases can make collecting, retrieving, using, and integrating data fairly easy after the initial implementation (data entry) and learning curve have been overcome. For example, if system locations are described in terms of specific latitude and longitude coordinates, a data layer for existing on-site systems can be created and overlaid on geographic information system (GIS) topographical maps. Adding information on on-site wastewater hydraulic output, estimated mass pollutant loads, and transport times expected for specified hydrogeomorphological conditions can help managers understand how water resources become contaminated. This can also help target remediation and prioritization actions to sources primarily responsible. Models can also be constructed to predict impacts from proposed development and suggest guidance on performance requirements for on-site systems in proposed development areas.

6.3.2.2 Management, operation, and maintenance policies

There are three basic approaches for developing and implementing a management program (see below). In addition, EPA has issued the *EPA Voluntary National Guidelines for Management of Onsite and Clustered (Decentralized) Wastewater Treatment Systems* (USEPA 2003). See http://cfpub.epa.gov/owm/septic/home.cfm for management guidelines, technology fact sheets, links, and other information). The guidelines describe five progressive tiers of management in the form of model programs that can be tailored by local communities to meet their public health and water resource protection needs (Table 6.10). Appropriate adoption of these guidelines based on level of risk and value of resources affected by on-site systems is strongly recommended. Table 6.11 shows an example matrix of different on-site system management program elements and functional responsibilities.

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Table 6.10: Guidelines for OWTS management programs under a tiered approach (adapted from USEPA, 2002a).

Program type	Program objectives	Basic management program elements
System inventory and awareness of operation and maintenance needs	– Owner awareness of permitting program, installation, and operation and maintenance needs – Compliance with codes and regulations	– Only conventional systems allowed – Prescriptive design and site requirements – Owner education to promote operation and maintenance – Complaint inspections and investigations – Point-of-sale inspections
Management through maintenance contracts	– Maintain prescriptive program for sites that meet siting criteria – Permit proven alternative systems on sites not meeting criteria	– Prescriptive design/site requirements – Measurable operation and maintenance requirements – Allowances for approved alternatives – Operation and maintenance contracts for alternative systems – Inspections, owner education
Operating permits	– System design based on site conditions and performance requirements – System performance verified through permit renewal inspections	– Wide variety of designs allowed – Performance governs acceptability – Compliance monitoring essential – Property sale or change of use triggers compliance assurance inspection
Management entity operation and maintenance	Public or private entity assumes operation and maintenance responsibilities for all systems in management area	– Performance governs acceptability – Operating permits ensure compliance – All systems are inspected regularly – Monthly/yearly fees support program – Owner relieved of operation and maintenance responsibility
Management entity ownership	– Public or private entity owns and operates all systems in management area – Similar to centralized sewage treatment service approach	– Performance governs acceptability – Operating permits ensure compliance – All systems are inspected regularly – Monthly/yearly fees support program – Management entity responsible for operation and maintenance – Management entity finances installation, repairs

Table 6.11: Program elements and functional responsibilities example matrix.

Program Element	Responsible Party							Comments
Planning								
Stakeholder involvement process								
Watershed assessments								
Sensitive area and critical area designations								
Performance Requirements								
Health and environmental goals								
General requirements								
Requirements for sensitive and critical areas								
Site Evaluation								
Wastewater characterization procedures								
Site suitability analysis								
Design								
Prescriptive or performance criteria								
Design review and approval process								
Construction								
Permitting requirements and process								
Construction and/or installation oversight								
Operation and Maintenance								
Owner/operator requirements								
Performance certification approaches								
Residuals Management								
Residuals removal/disposal requirements								
Tracking and reporting system								
Certification and Licensing								
Staff and service providers covered								
Certification/licensing requirements								
Education and Training								
System owner/operator education								
Requirements for staff and service providers								
Provision of training programs								
Inspections and Monitoring								
Routine (point-of-sale) and emergency inspections								
Targeted surface water and ground water monitoring								
Corrective Actions								
Compliance schedules and enforcement program								
Repair, upgrade, or replacement oversight								
Record Keeping and Reporting								
Existing and new systems inventory								
Tracking system for permits/inspection/maintenance								
Financial/administrative/program management								
Financial Assistance								
Funding source development								
Administration/management funding								
Installation and operation and maintenance assistance								

● State Health Department
■ State Water Agency
▲ District/County/Local Health Department
✪ County or Local Government Office
▼ Local/Regional Planning Office
◆ Utility District
✷ System Owner
✦ Private Contractor

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6.3.2.2.1 *Voluntary Management*

An effective voluntary program develops recommended guidelines and educational materials and distributes this information to the homeowner or system operator. Voluntary management programs are highly dependent on comprehensive, easy-to-understand educational materials and an aggressive outreach program that includes distribution of the materials, training workshops, and site visits to provide individual assistance.

In 1997 the University of Minnesota Cooperative Extension Service published a guide for homeowners that incorporates important elements of an on-site training program. The guide is available online at http://www.extension.umn.edu/distribution/naturalresources/DD6583.html. Another equally useful guide can be found on the North Carolina Cooperative Extension Web site at http://ces.soil.ncsu.edu/soilscience/publications/Soilfacts/AG-439-22.

6.3.2.2.2 *Regulatory Management*

Under this approach, the regulatory authority—typically a district or local health department—oversees and enforces an on-site program of system design, permitting, installation, operation, and maintenance authorized under state and local codes. The codes may require routine inspections by the health officer either on an annual basis or at the time of property transfer, as is

On-site System Operating Permits in St. Louis County, Minnesota

St. Louis County, located in the northeastern region of Minnesota, extends from the southwestern tip of Lake Superior north to the Canadian border. The physical characteristics of the region are poorly suited for application of traditional on-site treatment systems. Many of the soils are very slowly permeable lacustrine clays, shallow to bedrock, and often near saturation. The existing state code restricts on-site systems to sites with permeable soils of sufficient unsaturated depths to maintain a 3-foot separation distance to the saturated zone. The county has adopted performance requirements that can be followed in lieu of the prescriptive requirements where less than 3 feet of unsaturated, permeable soils exist. In such cases the county requires the owner to continuously demonstrate and certify that the system is meeting performance requirements. This is achieved through the issuance of renewable operating permits for all alternative treatment systems. The operating permit is based on evaluation of system performance rather than design prescription and includes the following:

- System (technology) description.
- Description of environmental conditions.
- Site evaluation documentation.
- Performance requirements.
- System design, construction plan, specifications, and construction drawings.
- Maintenance requirements.
- Monitoring requirements (frequency, protocol, and reporting).
- Contingency plan to be implemented if the system fails to perform to requirements.
- Enforcement and penalty provisions.

The permit is issued for a limited term, typically 5 years. Renewal requires that the owner document that the permit requirements have been met. If documentation is not provided, a temporary permit is issued with a compliance schedule. If the compliance schedule is not met, the county has the option of reissuing the temporary permit and/or assessing penalties. The permit program is self-supporting through permit fees.

the case in Washtenaw County, Michigan (Washtenaw County, 1999), the Code of Massachusetts Regulations, and other state and local statutes. Financial incentives and disincentives usually aid compliance; these can vary from small fines for poor system maintenance to mandatory repairs if the wastewater treatment system is not functioning properly. Inspection fees can cover program costs. Some jurisdictions (e.g., Florida) issue renewable operating permits and/or ground water discharge permits to manage system operation and maintenance. These permits may require homeowners either to have a contract with an authorized inspection and maintenance contractor or to demonstrate that periodic inspection and maintenance procedures have been performed (Florida Statutes, 2001). Permits or inspection requirements for alternative systems, especially those with mechanical components, are recommended.

6.3.2.2.3 *Direct management*

Another option for managing and maintaining on-site systems is a management entity, typically a wastewater utility or district. From a regulatory standpoint, an OWTS management program can save both time and money by allowing a management entity to execute various management program tasks. Incorporating on-site systems into a local or regional wastewater management district, with the district responsible for system operation and maintenance, is a means to ensure that small wastewater systems in a designated area function properly and do not threaten ground water or surface water. State legislation to create wastewater management districts is sometimes required. Enabling legislation for special districts allows district personnel to enter private properties within the district for the purpose of inspecting, repairing, upgrading, or replacing on-site systems. Taxpayers in the proposed district often must vote to create the special district.

The regulatory authority also may decide to perform these tasks and assume overall responsibility for managing the on-site systems in its jurisdiction. Health departments can serve as the management entity under some of the approaches outlined above because they often have considerable permitting, installation, and inspection authority. Regardless of the approach, system users usually pay an annual fee that is applied to operation, maintenance, and management costs. Texas law authorizes local governments to petition the Texas Natural Resource Conservation Commission to assume management authority for on-site systems (Texas

On-Site Sewage Management Ordinance, Chippewa County, Michigan

Chippewa County is located on Michigan's Upper Peninsula, along the shores of Lake Superior. Over the past 10 years, the number of requests for OWTS permits has tripled. The high demand for property in the county, as well as its increased value as a tourist destination, has dramatically increased the county's population. Many of the properties to be developed are located in environmentally sensitive areas, including fractured bedrock and limestone, which puts the county's ground water at high risk of contamination from faulty septic systems.

The county's Environmental Health Department amended the existing sanitary codes to allow the installation of alternative on-site systems for lakeshore areas. County officials worked with a Michigan State University professor to educate the citizens and local officials of Chippewa County about the values of these alternative systems. Some of these alternative systems include recirculating systems, single-pass filter systems, sewage waste lagoons, and mound systems. In the end, both the public and the local government supported the new codes, and no new bacterial contamination has been found since the codes were passed.

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Administrative Code, 1997). Procedures that can be used to apply the wastewater management district concept to a specific problem area include:

- Researching relevant legal and regulatory issues;
- Conducting a thorough site investigation;
- Identifying the specific geographic area to be included within the wastewater management district;
- Selecting the performance standards to be met and the means of attaining them;
- Preparing accurate cost estimates;
- Receiving approval from ratepayers within the proposed district for the creation of the management district;
- Preparing and adopting regulations, as needed, to establish the wastewater management district; and
- Adopting a management strategy (including operational, administrative, and financial processes).

Resources are available to help management entities explore the concept of an onsite wastewater management district. For example, the City of Austin, Texas, provides online resources related to its study of management district establishment (see http://www.ci.austin.tx.us/wri/altern.htm)

6.3.2.3 Inspection and monitoring programs

Inspection and monitoring programs are recommended to assess current and likely (future) on-site wastewater impacts. A means of inventorying existing and new systems, conducting inspections, providing monitoring data, or responding to treatment failures should be developed. As noted above, information on new systems (system owner, contact information, system type, location, design life and capacity, recommended service schedule) should be collected by the OWTS regulatory agency at the time of permitting and installation. Telephone, door-to-door, or mail surveys can be helpful to gather information on system type, tank capacity, installation date, last date of service (e.g., pumping, repair), problem incidents, and other relevant information. A number of private firms marketing new treatment technology packages (e.g., fixed film reactors, sand/media filters, aeration units) include remote monitoring services as part of the system package. For example, some companies install controls that continuously upload key system data (e.g., flow rates, pump cycles) to dedicated Web sites. Management staff can monitor the performance of multiple systems by accessing these Web sites, allowing detection of problems before massive failures occur. The per-unit cost of remote monitoring, which is required under the system installation contract, can range from $25 to $50 or more, depending on the type of unit and maintenance needs. The extra expense for necessary equipment is typically less than 10 percent of the cost of the packaged system.

6.3.2.3.1 *System inspections*

On-site system operation and performance inspections should check for the following (USEPA, 2002a):

- Evidence of vehicles being driven over the septic tank or reserve field;
- Installation of pavement, driveways, or structures over the septic tank or reserve field;
- Wet areas or poor drainage in or around the infiltration field;
- Slow flushing or gurgling of water in plumbing fixtures;
- Leaking toilets or addition of significant wastewater-generating fixtures such as water softeners;
- Additions to the house or building after system installation;
- Surface drainage patterns in the area of the tank and infiltration field;
- Broken or open tank access covers or doors; and
- Sludge or scum buildup in the septic tank; clogging of tank filters (if present).

More-detailed inspections of the system are recommended if there is evidence of a problem and should include the following:

- Pump and inspect the tank for structural deficiencies.
- Inspect the pumping components of the system.
- Test the system by filling the tank and observing the water level rise and fall.
- Inspect the baffles, valves, or other key appurtenances.
- Check all piping from the fixtures to the tank.
- Inspect runoff pathways of water from roofs, driveways, and other sources.
- Uncover distribution boxes (if used), and check flow distribution.
- Check for plumbing fixture leaks.

Inspections can be conducted in several ways (USEPA, 1993b). Homeowners can serve as monitors if they are educated and trained on how to inspect their own systems; however, this approach has not been effective in most cases. Brochures are often made available to instruct individuals on how to monitor their systems and the steps to take if they determine that their on-site system is not functioning properly. It should be noted, however, that homeowners rarely inspect their own systems, even with training. Trained inspectors are the best means for identifying failing systems.

Inspections can be conducted at the time of property transfer (point-of-sale inspections). Massachusetts has a rule that has required regular inspections since 1995. Colorado mandates inspections at the time of transfer, although its inspection requirements are less stringent than those of other states. Inspections are discussed further in *EPA Voluntary National Guidelines for*

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Comprehensive Monitoring and Inspection Program in Nags Head

The town of Nags Head has implemented a program to identify and address on-site system impacts in that North Carolina Outer Banks community. The town's Septic Health Initiative Program secured competitive bids for tank pumping and inspection and will reimburse full inspection costs (about $65) and provide a $30 rebate on the next water bill if the system owner has the tank pumped. Monitoring consists of a series of ground water well and surface sites that are tested for fecal coliform, ammonia, dissolved oxygen, nitrate, pH, salinity, phosphorus, specific conductance, and turbidity. An education program complements the effort by circulating information on treatment processes, operation, and maintenance (Krafft, 2001).

Management of Onsite/Decentralized Wastewater Treatment Systems (http://cfpub.epa.gov/owm/septic/home.cfm).

Inspection programs operated by OWTS management agencies, special districts, and utilities can be the most effective in terms of cost and results. The State of Arizona requires routine operation and maintenance inspections for alternative on-site systems and pre-sale inspections (NSFC, 1995). Massachusetts requires inspections by a certified individual at the time of property transfer. Minnesota requires property transfers to be accompanied by certification that the on-site system is performing in a satisfactory manner. More than half of all Minnesota counties and most lending entities require inspections because of market-driven desires to ensure that on-site systems are operating properly at the time of property sale (Prager, 2000). Massachusetts also requires that systems with a design flow of 10,000 gal/day or more be inspected every three years, and shared facilities must be inspected annually (Massachusetts Department of Environmental Protection, 1996). Some counties (e.g., Washtenaw County, Michigan) with mandatory property transfer inspection programs require inspectors to be certified. New Hampshire requires an assessment and an on-site system inspection by a permitted designer prior to the sale of any developed waterfront property (New Hampshire Code of Administrative Rules, 2001).

States and localities can also indirectly assess whether on-site systems are failing through surface water and ground water monitoring. If indicator pollutants (e.g., fecal coliform as an indicator of potential pathogen contamination) are found, nearby on-site systems should be inspected to determine if they are a contributing or primary source of the contaminants. For example, residents living along the shore of Ten Mile Lake in Minnesota support a lake association that conducts regular fecal coliform monitoring below lakefront homes. High coliform concentrations prompt system inspections and involvement of property owners in remediation discussions. Owners who repair their system or install a new one are added to the OWTS "honor roll," which is published in the association's monthly newsletter.

Health department personnel and/or system inspectors often use tracer dye to observe effluent movement (USEPA, 1991). Many local agencies use non-toxic tracer dye to determine wastewater migration into nearby wells or surface waters. Tracer dye, which is typically flushed down the toilet, is often used to demonstrate to system owners that effluent is migrating rapidly into nearby surface waters or ground water. Rapid movement of effluent, that is, 20 to 30 feet in less than 30 minutes, may indicate that subsurface infiltration and treatment of wastewater have been short-circuited. Other confirmatory tests should be employed to verify this fact.

Galveston Bay Project Targets "Hot Spots"

In support of the Galveston Bay Estuary Program, the Galveston county health department conducted an intensive survey of on-site systems in the Dickinson Bayou watershed to identify failed systems and improve homeowner operation of existing systems. During the first part of the project, 36 of 90 (40 percent) systems inspected exhibited some degree of failure and were likely contributing to significant fecal coliform water quality violations in the bayou (Galveston County Health District, 1998).

A variety of online resources are available for agencies seeking information on the operation, maintenance, or inspection of on-site systems. The Rhode Island Department of Environmental Management published the *Septic System Checkup* inspection guide in 2000 and posted an online version at http://www.dem.ri.gov/pubs/regs/regs/water/isdsbook.pdf. A general operation and maintenance manual entitled *The Septic System Owner's Guide* is available online from the University of Minnesota Extension Service at http://www.extension.umn.edu/distribution/naturalresources/DD6583.html. For links to other online resources, visit the links page maintained by the Consortium of Institutes for Decentralized Wastewater Treatment at http://www.onsiteconsortium.org/links.cfm. The Wayne County, Ohio, Health District also has an extensive list of links on its Web site (http://wchd.neobright.net/wc_wastewater_tx2.html).

6.3.2.3.2 *Improving system effectiveness through water conservation and pollutant reduction*

In addition to structural methods to remove nitrogen and other pollutants from wastewater, management practices that reduce wastewater flow and/or pollutants are effective. Reducing the overall hydraulic load by installing water-saving devices and adopting water conservation practices can increase the residence times for wastewater pretreatment and, most importantly, reduce the amount of wastewater that must be infiltrated into the soil. Jarrett et al. (1985) stated that 75 percent of soil absorption field failures could be attributed to hydraulic overloading. Several practices are available to retrofit these failing systems so that they operate properly. Eliminating the use of garbage disposals (pollutant reduction), installing low-volume plumbing fixtures (flow reduction), and adopting water conservation practices (flow reduction) are usually the most cost-effective approaches for reducing pollutant and hydraulic loads to the field.

Reduced loading of organics and chemicals can extend the useful life of the on-site system and improve treatment effectiveness. Mass pollutant loads in the OWTS can be significantly decreased by avoiding detergents that contain phosphates, cleaning food debris and grease from dishes before washing, removing or not using in-sink garbage disposal units, and eliminating the disposal of sanitary napkins and disposable diapers in toilets. Inputs of discarded antibiotics, dialysis unit discharges, and toxic cleaners and other chemicals can cause treatment process upsets and may impact public health if they reach the ground water. These problems can be addressed through homeowner education and better disposal practices. See Management Measure 9 (Pollution Prevention) for more information about proper disposal practices.

Reducing hydraulic loads can achieve significant reductions in OWTS failure rates. In 1992 Congress adopted the Energy Policy Act, which established national standards governing water use and energy conservation for showers, kitchen sinks, basins, and toilets (see Table 6.12). Several states have implemented specific water conservation practices (USEPA, 1998b). If low-flow plumbing fixtures are used, it is important that on-site system design not be modified to

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decrease the required septic tank size. The use of smaller septic tanks could negate the advantages of using low-flow plumbing fixtures by increasing organic loading rates to the soil infiltrative surface.

Table 6.12: Comparison of current and federally mandated flow rates and flush volumes (USEPA, 1998b).

Fixture	Current Practice	Energy Policy Act of October 1992	Potential reduction in water used (%)
Kitchen Sink	3.0 gpm	2.5 gpm	17
Lavatory	3.0 gpm	2.5 gpm	17
Shower	3.5 gpm	2.5 gpm	29
Tub	6.0 gpm	4.0 gpm	33
Water closet (tank)	3.5 gal	1.6 gal	54
Water closet (valve)	3.5 gal	1.6 gal	54
Urinal	3.0 gal	1.5 gal	50

Eliminating the use of garbage disposals can significantly reduce the loading of suspended solids and BOD to OWTSs (Table 6.13) unless OWTSs are designed for their use. Eliminating garbage disposals can decrease the buildup of solids in the septic tank and reduce the frequency of pumping required. A number of states have regulations prohibiting the installation of garbage disposals where on-site systems are used. New OWTSs can be designed to accommodate garbage disposals and the associated increase in organic and solids loadings to wastewater by increasing tank volume or pumping frequency (USEPA, 2001c).

Table 6.13: Residential wastewater pollutant contributions by source (adapted from USEPA, 1992b).

Parameter		Garbage disposal (gpcd)	Toilet (gpcd)	Bathing, sinks, appliances (gpcd)	Approximate total (gpcd)
BOD_5	Mean	18.0	16.7	28.5	63.2
	Range	10.9–30.9	6.9–23.6	24.5–38.8	–
	% of total	(28%)	(26%)	(45%)	(100%)
TSS	Mean	26.5	27.0	17.2	70.7
	Range	15.8–43.6	12.5–36.5	10.8–22.6	–
	% of total	(37%)	(38%)	(24%)	(100%)
Nitrogen	Mean	0.6	8.7	1.9	11.2
	Range	0.2–0.9	4.1–16.8	1.1–2.0	–
	% of total	(5%)	(78%)	(17%)	(100%)
Phosphorus	Mean	0.1	1.6	1.0	2.7
	Range	–	–	–	–
	% of total	(4%)	(59%)	(37%)	(100%)

6.3.2.4 Management of residuals to ensure that they do not present significant risks to human health or water resources

On-site systems are not maintenance-free systems. Huang (1983) stated that half of on-site system failures are due to poor operation and maintenance. Most residential septic tanks are designed for approximately 72- to 96-hour retention of wastewater to allow for the removal of solids, greases, and fats. Some of the solids retained in the tank decompose naturally by bacterial and chemical action. As sludge accumulates on the bottom of the tank, however, the decrease in

tank volume available for storing settleable solids and raw wastewater results in less contact time. When sludge or scum levels get too near the outlet entrance level, solids can move directly to the soil absorption system and cause clogging (Mancl and Magette, 1991). Septic tank effluent screens can provide some protection from neutrally buoyant solids and during tank upsets, but periodic removal of solids from the tank is necessary to protect the soil absorption system. Most tanks should be pumped out every three to five years in lieu of a regular inspection program. If a septic system is not pumped out regularly, failure will not occur immediately; however, continued neglect will cause the SWIS to fail because it is no longer protected from greases, oils, and solids. Failure may require replacement, often at considerable expense.

Responsibility for ensuring proper operation and maintenance is most often left to homeowners. Homeowners generally are not properly trained or informed on how to take care of their systems, and many do not care to do so. On-site system regulatory authorities and management entities have recognized the need for more comprehensive management programs and have developed educational and other programs to help owners understand their responsibility for system management. Some regulatory authorities have opted for a more proactive approach and have developed inspection programs, renewable permits, and financial incentives (e.g., low-interest loans, grants) for installing, upgrading, or repairing underperforming systems. More than 100 OWTS management programs that provide operational oversight beyond initial permitting are now operating across the country (Knowles, G., Coordinator, National Onsite Demonstration Program (NODP) Phase IV, personal communication, 2000; see also http://www.nodp.wvu.edu/).

The primary objective of a residuals management program is to establish procedures and rules for handling and disposing of accumulated sludge and wastewater removed from tanks (i.e., septage, also called biosolids) in an affordable manner that protects public health and ecological resources. When planning a program, it is important to have a thorough knowledge of legal and regulatory requirements regarding handling and disposal. In general, state and local septage management programs that incorporate land application or disposal to landfills must comply with Subpart C of 40 CFR (U.S. Code of Federal Regulations) Part 503. Detailed guidance for identifying, selecting, developing, and operating reuse or disposal sites for septage can be found in the two process design manuals*: Land Application of Sewage Sludge and Domestic Septage* and *Surface Disposal of Sewage Sludge and Domestic Septage* (USEPA, 1995 a and b), which are posted on the Internet at http://www.epa.gov/ORD/WebPubs/sludge.pdf. Additional information can be found in *Domestic Septage Regulatory Guidance* (USEPA, 1993a).

States and municipalities typically establish additional public health and environmental protection regulations for residuals handling, transport, treatment, and reuse or disposal. In addition to regulations, practical limitations such as land availability, site conditions, buffer zone requirements, hauling distances, fuel costs, and labor costs play a major role in evaluating septage reuse or disposal options. These options generally fall into three basic categories: land application; treatment at a wastewater treatment plant; or treatment at a special septage treatment facility. Initial steps in the residuals reuse or disposal decision-making process include characterizing the quality and quantity of the septage to be produced annually and determining potential adverse impacts associated with various reuse or disposal scenarios. In general, program officials strive to minimize the exposure of humans, animals, ground water, and surface water to potentially toxic or hazardous chemicals and pathogenic organisms found in septage.

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Other key aspects of residuals management programs are tracking or manifest systems that identify septage sources, pumpers, transport equipment, final destination, and treatment, along with procedures such as vector control, wet weather runoff, and access to disposal sites for controlling human exposure to residuals.

6.4 Information Resources

The *Onsite Wastewater Treatment System Manual* (EPA, 2002a) is an update to EPA's 1980 manual entitled *Design Manual: Onsite Wastewater Treatment and Disposal Systems*. This comprehensive reference manual is designed to provide state and local governments with guidance on the planning, design, and oversight of onsite systems. This manual will also be useful for onsite wastewater professionals, developers, land planners, and academics. It is available in PDF format from http://www.epa.gov/ORD/NRMRL/Pubs/625R00008/625R00008.htm.

EPA Voluntary National Guidelines for Management of Onsite/Decentralized Wastewater Treatment Systems is a set of recommended practices needed to raise the level of performance of on-site/decentralized wastewater systems through improved management programs. Five model programs are presented as a progressive series: (1) system inventory and awareness of maintenance needs; (2) management through maintenance contracts; (3) management through operating permits; (4) operation and maintenance by a public or private management entity; and (5) ownership and management by a public or private management entity. Each of these model programs includes a set of recommended approaches for planning, siting, design, performance, installation, operation, maintenance, and monitoring of wastewater systems. The guidelines can be obtained at EPA's Office of Wastewater Management Web site at http://cfpub.epa.gov/owm/septic/home.cfm.

Funded by the U.S. Environmental Protection Agency, the National Small Flows Clearinghouse (NSFC) helps small communities and individuals find affordable wastewater treatment options to protect public health and the environment. The NSFC Web site, which can be accessed at http://www.nesc.wvu.edu/nsfc/nsfc_index.htm, offers news, publications, databases, discussion groups, information about innovative and alternative wastewater technology projects (through EPA's Environmental Technology Initiative project), and links related to small wastewater systems.

The ASTM International Web site (http://www.astm.com/) offers guides to standard practices and technical publications on environmental assessment and waste management practices that can be useful for siting, designing, and installing OWTSs.

The American Society of Agricultural Engineers (ASAE) offers several proceedings from conferences focusing on on-site wastewater treatment at its publications page (http://www.asabe.org/pubs/PubCat02/waste.html). ASAE also has a searchable library of technical articles (http://asae.frymulti.com/), many of which pertain to OWTSs.

The National Onsite Wastewater Recycling Association (NOWRA) Web site, which can be accessed at http://www.nowra.org/, offers a calendar of events related to OWTSs, contact information for state and local OWTS organizations, links to OWTS-related businesses and organizations, the *Onsite Insight* newsletter, technical guidance for owners and operators of OWTSs, a bookstore with conference proceedings available for purchase, and the *Model Framework for Unsewered Wastewater Infrastructure*, which is a guide for establishing future national policy for onsite systems.

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MANAGEMENT MEASURE 7
BRIDGES AND HIGHWAYS

7.1 Management Measure

Plan, design, operate, and maintain highways and bridges to:

- Protect sensitive ecosystems, including wetlands and estuaries, by minimizing road- and bridge-related impacts and water crossings, and by establishing protective measures including setbacks during construction;

- Reduce the runoff of pollutants through the use and proper maintenance of structural controls;

- Reduce the generation of pollutants from maintenance operations by minimizing the use of pesticides, herbicides, fertilizers, and deicing salts and chemicals; and

- Reduce the generation and runoff of pollutants during highway and bridge repair operations by decreasing the use of hazardous materials and incorporating practices to prevent spillage into sensitive areas.

7.2 Management Measure Description and Selection

7.2.1 Description

Motor vehicles generate runoff pollutants through emission and deposition of automobile exhaust and through discharges of both fluids and solid particles while traveling and braking. In a study of traffic-generated particulates in Cincinnati (where the average daily traffic load is 150,000 vehicles), Sansalone and Buchberger (1997) found that of the 13,500 mg of particulates per square meter of road surface generated per day, 44 to 49 percent originated from pavement wear, 28 to 31 percent from tire wear, and 15 percent from engine and brake pad wear. The study also found that 6 percent of particulates were deposited from settleable exhaust and 3 percent from atmospheric deposition.

A study by Shepp (1996) examined generation of petroleum hydrocarbons in urban runoff from four land uses: all-day parking lots, streets, gas stations, and convenience stores. Shepp found that convenience stores had the highest hydrocarbon concentration (see Figure 7.1). Evaluation of the land uses and their respective catchment areas suggested that the degree of automotive exposure (a combination of duration of exposure to vehicles with engines running and volume of traffic) is the primary factor in the generation of petroleum hydrocarbons in runoff from automotive-intensive land uses.

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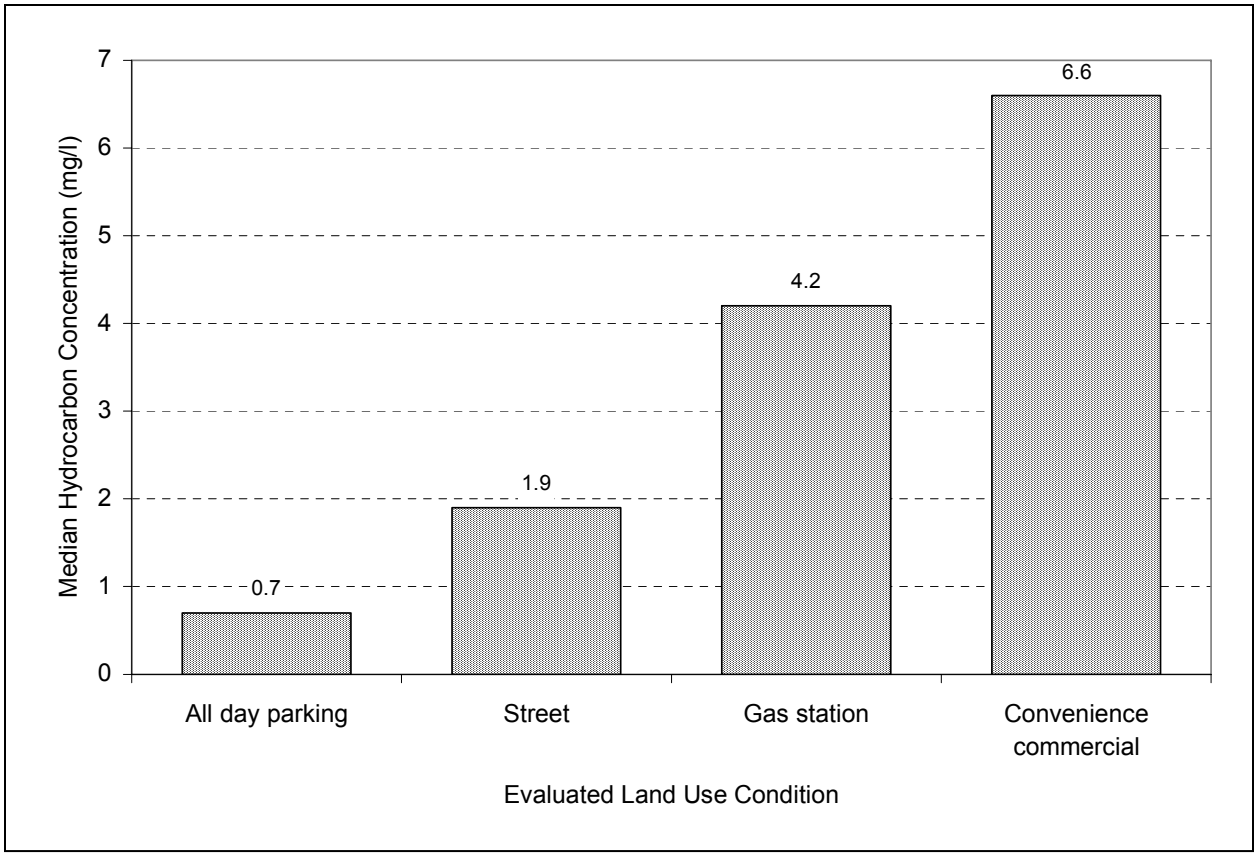

Figure 7.1: Median hydrocarbon concentrations by land use (Shepp, 1996).

The National Water Quality Assessment Program (NAWQA) of the U.S. Geological Survey (USGS) recently conducted studies on water pollution related to sprawl-induced traffic. These studies show a consistently positive correlation between increases in vehicular traffic associated with urban sprawl and the buildup of polycyclic aromatic hydrocarbons (PAHs) in 10 lakes and reservoirs in six metropolitan areas across the country. PAH sources related to motor vehicle use include tire wear, roadway wear, exhaust and soot, and crankcase oil releases (Van Metre et al., 2000). A study in Austin, Texas, demonstrated that elevated levels of PAHs found in Barton Springs sediments, although not toxic on their own, yielded 100 percent mortality in test invertebrates (amphipods, *Hyalella azteca*), when the organisms were exposed to UV radiation (Hayward et al., 2002). Mahler and Van Metre (2004) identified abrasion of coal tar emulsion sealants on parking lots as contributing significant amounts of PAHs to local water bodies and speculated that they could be the dominant source of PAHs in some urban watersheds. The U.S. Fish and Wildlife Service (USFWS) found that 50 to 68 percent of brown bullhead catfish collected from the Anacostia River in Washington, DC, had liver tumors and 13 to 23 percent had skin tumors (Reel, 2004). The USFWS attributed these tumors to DNA changes linked to PAHs from vehicle emissions and runoff.

Roads tend to accumulate particulate matter from roadsides, salting and sanding, dirty cars, brake pad dust, aerial deposition, and surface deterioration. Sansalone and Tribouillard (1999) and Sansalone et al. (1998) measured the deposition and size distribution of particles deposited on highways. They found that accumulation of particulate matter was significantly greater along the

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downslope of the highway than along the upslope and that particle size distributions (PSDs) along the downslope were consistently coarser across the entire size gradation than the upslope and pavement PSDs (Sansalone and Tribouillard, 1999). Solids in the 2 to 8 μm range generated the largest counts and were rapidly washed from the pavement in a "first flush" effect (Sansalone et al., 1998). Lateral pavement sheet flow rate and duration controlled the yield and size of transported solids; particle transport was mass-limited during extended, high-intensity events, but was flow-limited during intermittent, low-intensity events with high traffic (Sansalone et al., 1998).

These particles, when transported in runoff to receiving waters, contribute to high levels of total suspended solids and turbidity and act as carriers for pollutants that adhere to their surfaces. Because of this adsorption phenomenon, surface area can be an important determinant in pollutant loading from highways. A relationship exists between particle size and surface area. Sansalone et al. (1998) found that particles 425 μm to 850 μm in size contributed the greatest total surface area. Sansalone and Tribouillard (1999) found that total surface area decreased with decreasing particle size. Particle-specific surface area, however, increased with decreasing particle size (Sansalone and Tribouillard, 1999; Sansalone et al., 1998), but measured values deviated from the monotonic pattern expected for spherical particles (Sansalone et al., 1998).

Because total surface area is predominantly associated with the coarser fraction, heavy metal mass (adhered to particle surfaces) is also strongly associated with this fraction (Cristina et al., 2000). Cumulative analyses for lead, copper, cadmium, and zinc in snow residuals indicated that more than 50 percent of these heavy metals (by mass) was associated with particles greater than 250 μm, and more than 80 percent was associated with particles greater than 50 μm (Sansalone and Glenn, unpublished).

Heavy metals such as lead, iron, and aluminum are typically particulate-bound in urban runoff (Sansalone and Buchberger, 1997). Sansalone and Glenn (2000), however, found that lead was predominantly dissolved in highway runoff, a phenomenon they attributed to low urban rainfall pH and alkalinity and relatively short pavement residence times. Other metals predominantly found in the dissolved phase in highway runoff were zinc, cadmium, and copper (Sansalone and Buchberger, 1997; Sansalone and Glenn, 2000).

The California Department of Transportation (Caltrans) conducted a study of highway runoff quality from 1999 to 2000 at 100 locations throughout the state. Caltrans found a positive correlation between the concentration of most pollutants and traffic volume. In addition, more than 30 percent of the total arsenic, cadmium, chromium, copper, nickel, silver, and zinc were found in the dissolved state (Kayhanian et al., 2001).

The partitioning of heavy metals between the particulate-bound and dissolved fractions raises important questions for watershed managers regarding storm water treatment. It was previously thought that metals were associated with particulates and that removing sediment and reducing turbidity would address these pollutants. However, new research indicates that event mean concentrations of dissolved zinc, cadmium, and copper can exceed surface water quality discharge standards and can exhibit a "first flush" effect that cannot be mitigated by settling. In addition, the dissolved nature of these metals makes them highly mobile and bioavailable.

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Other pollutants found in highway runoff, along with their likely sources, are shown in Table 7.1. Although runoff characteristics tend to be site-specific, a number of studies have been performed to compile typical concentrations of highway pollutants from a range of different locations from Northhampton, England, to Durham, North Carolina. Table 7.2 shows the range of values for highway contaminants presented by Newberry and Yonge (1996). These concentration levels vary significantly among the different locations. Suspended solids, for example, had concentration levels ranging from 45 mg/L to 798 mg/L; ranges for other parameters were even greater. For some pollutants, such as solids, heavy metals, and organics, concentration levels have been found to correlate with traffic volume.

Table 7.1: Primary sources of highway runoff pollutants (Adapted from NCHRP, 1999).

Pollutants	Primary Source
Particulates	Pavement wear and vehicle maintenance
Lead, cadmium, copper	Tire wear, lubricating oil and grease, bearing wear
Nitrogen, phosphorus	Roadside fertilizer application
Chromium, copper, nickel, cadmium	Metal plating, moving engine parts, brake lining wear
Chloride, sulfates	Deicing salts
PCBs, pesticides	PCB catalyst in synthetic tires, spraying highway rights-of-way
Cyanide	Anti-cake compound used to keep deicing salt granular
Petroleum, ethylene glycol	Spills and leaks of motor lubricants, antifreeze, hydraulic fluids

Table 7.2: Range of average values for runoff contaminant concentration for selected highway contaminants (Newberry and Yonge, 1996).

Contaminant	Concentration (mg/L)	Load (kg/ha/yr)	Load (kg/ha/event)
Suspended solids	45–798	314–11,862	84–107.6
Lead	0.073–1.78	0.08–21.2	0.008–0.22
Phosphorus	0.073–1.78	0.6–8.23	—
Biological oxygen demand	0.113–0.998	30.6–164	0.98
Polycyclic aromatic hydrocarbons	12.7–37	0.005–0.018	—

Runoff from the construction, operation, and maintenance of highways and bridges can adversely affect vegetation, surface waters, and wetlands with a variety of pollutants, including sediments, heavy metals, hydrocarbons, and toxic substances. Runoff issues associated with construction of highways and bridges are addressed in Management Measure 8—Construction Site Erosion, Sediment, and Chemical Control. Although the runoff constituents and concentration levels vary with highway type and location, the sources of highway runoff pollutants fall into three basic categories: vehicle traffic, snowmelt and ice-melt containing deicing chemicals, and chemicals used to manage roadside vegetation.

The specific impacts of highway and bridge runoff on aquatic ecosystems are both site-specific and runoff event-specific. In general, highway pollutants can affect water quality through either acute toxicity or gradual accumulation. Potential adverse environmental effects associated with specific constituents include the following:

- *Suspended solids* increase turbidity, transport other pollutants adhered to particle surfaces, and reduce runoff storage capacity in ponds and lakes.

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- *Heavy metals* are toxic to many aquatic organisms and can bioaccumulate in fish tissues, thus posing potential health risks to humans.

- *Nutrients* degrade water quality by stimulating the growth of algae and aquatic weeds. Rapid increases in these populations can then deplete oxygen levels to the extent that fish and other aerobic organisms die off.

- *Biochemical oxygen demand (BOD)* reduces dissolved oxygen levels as a result of the biological processes that break down organic constituents in runoff.

- *PAHs* include compounds such as benzo(a)pyrene that are found in petroleum products and are carcinogenic. These compounds can pose risks to human health if drinking water or fish become contaminated with them. PAHs in streams and lakes usually do not pose a health risk for people because they tend to adhere to sediment particles rather than dissolve in water. As a result, the risk of drinking water degradation is low (Van Metre et al., 2000). Aquatic invertebrates were impacted in the previously identified study from Austin, Texas (Hayward et al., 2002).

Paved roadways often generate higher loads of metals and toxicants than other nonpoint source pollutants[1]. Nutrient loadings from highways tend to be of concern when they are located upstream of a reservoir or estuary.

Winter maintenance activities to prevent ice and snow buildup on highways can also be significant contributors to loadings of particulates, salts, and various other chemicals. Salts in particular can harm both vegetation and aquatic ecosystems. Other highway maintenance activities, including roadside vegetation management, can also contribute herbicides, pesticides, and nutrients to runoff pollutant loads.

In several studies, Sansalone and Glenn (2002a, 2002b, and unpublished) examined the characteristics of snowbanks and snowmelt. Table 7.3 summarizes their findings for several pollutants and physical characteristics. From their research, they concluded the following:

- Traffic and winter maintenance practices generate significant levels of inorganic and organic constituents, many of which become predominantly particulate-bound in the snowbank with increasing residence time.

- The accretion of traffic-generated constituents in urban highway snow is relatively rapid within the first 12 hours of the snowbank's exposure to traffic.

A research team at Oregon State University, under the National Cooperative Highway Research Program (NCHRP, 2000) identified potentially mobile constituents from highway construction and repair materials and measured their potential impact on surface and ground waters. The

[1] Several recent studies cited by the Federal Highway Administration (FHWA) indicate that few significant environmental impacts have been associated with roads with an average daily traffic volume of less than 30,000 vehicles (USDOT, 1996).

materials tested were conventional, recycled, and waste materials; and excluded constituents originating from construction processes, vehicle operation, maintenance operations, and atmospheric deposition. The research team established laboratory methods to realistically simulate the leaching of constituents from construction and repair materials in typical highway environments. They also established methods to evaluate the removal, reduction, and retardation of leached constituents by environmental processes in the highway right-of-way. The team produced extensive data sets of laboratory test results for highway construction and repair materials, and they expressed the results as aquatic toxicity and chemical concentrations. They then developed a software program called IMPACT, which estimates the fate and transport of leachates surrounding the highway right-of-way. IMPACT contains an extensive, readily accessible database of laboratory test results for materials ranging from common construction and repair products to waste and recycled materials proposed for use in highway construction.

Table 7.3: Results of three studies that analyzed chemical and physical parameters of snowmelt (Sansalone and Glenn, 2002a, 2002b, and unpublished).

Parameter	Result
Bulk density	Bulk densities increased as TSS accumulation continued and the snow matrix began to melt or evaporate.
Particle size distribution and bulk density	For all sites, particle sizes ranged from 10,000 μm to less than 25 μm, with a mean bulk density of 1,225 μm.
Specific gravity	Specific gravity of residual solids ranged from 2.5 to 3.2 g/cm^3 across the gradations; the lower specific gravity was associated with particles less than 100 μm.
Chloride and conductivity	Conductivity and chloride concentrations increased rapidly at first because of initial deicing salt applications at each site. Strong correlations indicated that conductivity trends were mainly a function of chloride trends.
Hardness	Hardness increased rapidly to nearly 100 mg/L during initial snow accumulation and remained relatively constant (100–300 mg/L) for most of the study. This increase is likely a result of liquid $CaCl_2$ mixed with rock salt and $CaCO_3$ as part of the TSS captured by the snow matrix.
COD	Temporal trends toward increasing total chemical oxygen demand (COD) exerted by roadway snow are similar to trends in TSS, with COD values of 100,000 mg/L.
TDS and TSS	Although accretion of total dissolved solids (TDS) was initially rapid with a decrease late in the event, total suspended solids (TSS) accretion demonstrated a more gradual increasing trend for the duration of roadway snow, approaching 100,000 mg/L.
Cyanide	Applications of 216,000 kg of rock salt containing cyanide as an anti-caking agent resulted in a discharge of approximately 6 kg of cyanide along the interstate.
Metals	Concentrations for lead, copper, cadmium, zinc, and cyanide were orders of magnitude higher than those of the control site and exceeded storm water runoff concentrations by 1 to 2 orders of magnitude.

Note: TSS = total suspended solids, TDS = total dissolved solids, COD = chemical oxygen demand, $CaCl_2$ = calcium chloride, $CaCO_3$ = calcium carbonate.

7.2.2 Management Measure Selection

This management measure was selected to provide general guidance on practices that can be integrated into highway and bridge maintenance and repair operations. The management measure also includes guidance for siting and constructing highways and bridges. The management measures for watershed protection; site development; new development runoff treatment; and construction site erosion, sediment, and chemical control (Management Measures 3, 4, 5, and 8) are also applicable to the planning and constructing of highways and bridges.

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7.3 Management Practices

The use of structural and nonstructural runoff control practices during the planning, design, operation, and maintenance of highways and bridges can significantly mitigate the adverse effects of runoff. Specifically, by using environmentally sensitive highway and bridge designs and implementing proper operation and maintenance practices, highway authorities can reduce both the volume and concentration of contaminants generated by motor vehicle traffic and maintenance and repair operations. In addition, controls can be used to store and treat contaminants so that pollutant loadings can be further reduced or prevented from entering sensitive ecosystems.

7.3.1 Site Planning and Design Practices

A wide range of environmental planning and design management practices, especially those presented in Management Measures 3 and 4, can be used to reduce the environmental impacts of highways and bridges and can be initiated long before a road is completed. In general, highways and bridges should be planned so that mileage through sensitive environments, such as wetlands and estuaries, is minimized. River crossings should be avoided if possible, and sufficient setbacks should be established during construction to minimize disturbance of the surrounding environment. During the siting process, consideration should also be given to maintaining sufficient setbacks for the protection of drinking water sources. Efforts should be taken to avoid channelization and floodplain alteration to allow natural processes to continue after roads are in place.

Highway development is most disruptive adjacent to water bodies, riparian areas, and wetland areas because it increases sediment loss, alters surface drainage patterns, changes the subsurface water table, and results in loss of wetland and riparian habitat. Highway structures should not restrict tidal flows into salt marshes and other coastal wetland areas because such restrictions might facilitate the intrusion of freshwater plants and reduce the growth of salt-tolerant species. To safeguard these fragile areas, highways should be sited with sufficient setback distances between the highway right-of-way and any wetlands or riparian areas.

Bridge construction can also adversely affect water circulation and quality in wetland areas, necessitating special techniques to accommodate construction. By locating highways and bridges away from sensitive areas and establishing buffer zones where possible, environmental degradation from erosion and runoff can be mitigated during construction, operation, and maintenance of roadways.

As discussed previously, roads and highways have been shown to accumulate pollutants that are carried in runoff. Decreasing impervious cover by reducing the area of pavement or number of road miles could lower this pollution potential. However, each individual community should weigh the benefits of alternative road designs against the use of low-impact development techniques or treatment controls (see Management Measures 4 and 5, respectively). Where road surfaces are constructed, disconnecting and infiltrating runoff using structural runoff controls can mitigate impacts of roads and provide sufficient water quality protection.

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7.3.2 Soil Bioengineering and Other Runoff Controls for Highways

Soil bioengineering techniques can be used to augment or replace structural slope stabilization practices such as retaining walls. They are appropriate for relatively moderate slopes where vegetation can be established easily. Soil bioengineering techniques can create wildlife habitats and promote infiltration of rainfall and runoff in addition to stabilizing slopes. Installation of bioengineering practices can be labor-intensive, and periodic inspection and maintenance, especially after large storms, is necessary to repair slumps and replace dead vegetation. Soil engineers or scientists should confirm that the stability and structural integrity of the site are appropriate for soil bioengineering practices. Several kinds of soil bioengineering practices are described by the U.S. Department of Agriculture (USDA, 1992):

7.3.2.1 Live stakes

The use of live stakes involves inserting and tamping live, rootable vegetative cuttings into the ground to create a living root mat that stabilizes the soil by reinforcing and binding soil particles together and extracting excess soil moisture. Live stakes are appropriate for repairing small earth slips and slumps caused by excessively wet soil and should be used only at sites with relatively uncomplicated conditions. They are especially useful when construction time is limited and an inexpensive method is desired. They can be used to secure erosion control measures and can be used in combination with other bioengineering techniques. Finally, they facilitate plant colonization by providing a favorable microclimate for plant growth. Native species that are appropriate for the soil conditions onsite should be used wherever possible.

7.3.2.2 Fascines

Fascines are long bundles of branch cuttings bound together into sausage-like structures. They are installed in contoured or angled trenches and are secured to the slope with both live and dead stakes. They reduce surface erosion and rilling, protect slopes from shallow slides, and reduce long slopes into a series of shorter slopes that trap and hold soil. They also enhance vegetative growth by creating a microclimate conducive to plant growth.

7.3.2.3 Brushlayers

Brushlayering is much like the fascine technique except branches are placed perpendicular to the slope contour. This method is more effective than fascines with respect to earth reinforcement and mass stability. Brushlayers break up the slope length, preventing surface erosion, and reinforce the soil with branch stems and roots, providing resistance to sliding or shear displacement. Brushlayers also trap debris, aid infiltration on dry slopes, dry excessively wet sites, and mitigate slope seepage by acting as horizontal drains. Brushlayers facilitate vegetation establishment by providing a stable slope and a favorable microclimate for growth.

7.3.2.4 Branchpacking

Branchpacking involves reinforcing a slope with alternating layers of live branch cuttings and compacted backfill. This technique is useful to repair small, localized slumps and holes in earthen embankments other than dams. Branchpacking produces a filter barrier that reduces

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erosion and scouring and provides immediate soil reinforcement. Branchpacking is not effective in slump areas more than 4 feet deep or 5 feet wide.

7.3.2.5 Live gully repair

Live gully repair is a technique that is similar to branchpacking but is used to repair rills and gullies. Live gully repairs offer immediate reinforcement and reduce the velocity of concentrated flows. They also provide a filter barrier that reduces further rill and gully erosion. This technique is appropriate only to repair rills or gullies less than 2 feet wide, 1 foot deep, and 15 feet long.

7.3.2.6 Live cribwalls

A live cribwall is a hollow, boxlike structure of interlocking untreated logs or timber members installed with backfill material and layers of live branch cuttings. The live cuttings eventually take over the structural functions of the wall once the roots have become established. Live cribwalls are appropriate for stabilizing the toe of a slope and reducing its steepness. They should not be used in areas that are subject to large lateral stresses. Cribwalls provide both immediate and long-term stabilization and are useful where space is limited. They should be tilted if the system is built on a smoothly sloped surface, or they can be constructed in a stair-step fashion.

7.3.2.7 Vegetated rock gabions

Vegetated rock gabions consist of wire mesh or chain-link baskets layered with live branch cuttings that take root inside the gabions and bind the structure to the slope. These structures are appropriate for stabilizing the toe of a slope and reducing its steepness, especially in areas where space is limited. They should not be used in areas that are subject to large lateral stresses and should not be more than 5 feet tall.

7.3.2.8 Vegetated rock walls

Vegetated rock walls consist of a combination of rocks and live branch cuttings used to stabilize the toe of steep slopes. These structures are appropriate for stabilizing areas where space is limited and natural rock is available. The wall should not exceed 5 feet in height.

7.3.2.9 Joint planting

Joint planting stabilizes slope faces by planting live cuttings in spaces between the stones of riprap. The plantings improve drainage, bind rock materials to the slope, and help prevent washout of fine materials. Joint planting can be used where riprap has already been installed, or it can be part of a new riprap installation.

7.3.2.10 Other runoff and sediment controls for highways

Other runoff controls, such as grassed swales and filter strips, wet ponds, extended detention dry ponds, and storm water wetlands, can be used to control highway runoff. These measures are described in detail in Management Measure 5. Additionally, sediment traps and basins and inlet protection (described in Management Measure 8) can be used to collect runoff from highways, especially during construction and repair operations when pollutant loadings are great.

Highway Management Plans for Storm Water Control

In Delaware County, New York, the Department of Public Works (DPW) is extending its highway runoff management program to include town roads. This involves inventorying and assessing town roads, identifying priority storm water management needs, training highway superintendents, and evaluating and monitoring management practices. The DPW plans to dedicate a storm water/highway engineer to assist towns in prioritizing their highway storm water projects. Funding will be provided through the Catskill Watershed Corporation's Stormwater Retrofit Program and matched with capital planning funds in town highway budgets. The intent of the program is to maximize efficiency by targeting the areas critically in need of redesign, repair, and rebuilding (Delaware County Departments of Planning and Public Works, 2003). For more information, contact the Delaware County Department of Watershed Affairs, (607) 746-8914.

7.3.3 Structural Runoff Controls for Bridges

Highway runoff controls have been extensively documented and implemented. A mitigation strategy specific to bridges is crucial, however, because of the unique limitations associated with bridge building and repair. These limitations include (Transportation Research Board, 2002a):

- A lack of lateral right-of-way on which to build mitigation measures, causing runoff to be drained back onto land;
- Topographic and slope constraints at some bridges that prohibit gravity drainage back to land;
- The need to factor additional weight of storm water piping into the design of a new or retrofitted bridge; and
- The need to address maintenance constraints and safety concerns.

The Transportation Research Board (TRB) (2002b) developed a report that addresses these and other issues specific to bridge runoff. The TRB described a process for assessing sites for the potential for bridge deck runoff to cause water quality problems and for developing mitigation procedures. The process is particularly applicable in the case of large bridge construction or reconstruction projects over sensitive or highly valued receiving waters. It is also applicable in cases where regulations and policies are ambiguous or require reconsideration. This report, *Assessing the Impacts of Bridge Deck Runoff Contaminants in Receiving Waters,* is available from the TRB at http://www.trb.org/.

7.3.3.1 Scupper drains with runoff conveyance systems

Bridges have traditionally been designed to direct runoff away from the roadway as efficiently as possible without regard to impacts on the environment below the deck. While there is a significant body of research on the environmental impacts of highway runoff, there are few studies that directly address the chemical characteristics of runoff from bridge decks, and even fewer that also address the effects of that runoff on biota or other receiving water uses. Several studies have shown that direct scupper drainage into some types of water bodies, such as small lakes, can result in localized increases of metal concentrations in sediments and in aquatic biota. (TRB, 2002a).

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More recently, bridge designs have been enhanced to address the potential effects of runoff pollutant loadings, especially on water bodies. The most prevalent mitigation practice is to direct the drainage from the bridge to an on-shore treatment system. For example, the runoff can be conveyed from scupper drains through a pipe onto the shore, from which it is sent to a retention pond or other runoff treatment practice. A scupper drain is an opening in the floor of a bridge that provides a means for rain or other water accumulated on the roadway surface to drain into the space beneath the structure (ODOT, 2001). Rather than draining directly to the water below, the runoff can be routed to the shore for treatment. The FHWA and EPA have developed recommendations on the design and use of scupper drains to address bridge deck runoff. Among the practices they recommend are:

- The spacing between scuppers should be maximized in accordance with established maximum hydrologic and hydraulic design. As scupper spacing increases, the volume of water that passes through each scupper increases, thus creating velocities high enough to flush outlets clogged by deposits from low-volume rainfalls.

- Careful detailing is critical when connecting scuppers to drain pipes. Because of poorly designed routing, drain pipes often create more problems than they prevent. For example, piping that is routed with too many elbows can easily clog, resulting in a buildup of contaminated runoff.

- Gravity flow collection systems should be used wherever possible.

Collection systems for scupper drains may be used to minimize the impacts of bridge runoff, although they may be expensive. Depending on the length of the bridge and traffic volume, as well as river size and climate, bridge runoff might constitute only a small fraction of the overall pollutant load to a receiving water body. Furthermore, the topography and approach slope at some bridge locations might preclude design or retrofit for gravity drainage back to land, therefore requiring the use of a pump to discharge the runoff into a suitable water quality treatment practice (TRB, 2002a). The addition of pumps could significantly increase the cost of the collection system and operation and maintenance requirements. In some cases, controlling runoff from other pollutant sources may be more cost-effective when a watershed approach is used.

7.3.3.2 Other runoff treatment practices

Runoff treatment practices like ponds, wetlands, infiltration basins and trenches, media filters, bioretention areas, vegetated swales, filter strips, and hydrodynamic devices (see Management Measure 5) can be installed on the shore to treat runoff collected and routed by scupper drains and pipes. If a bridge does not have scupper drains, runoff can be routed to the shore via gutters. Depending on site conditions, such as the space available for the practice, the suitability of the soils for filtration or infiltration, and the quantity and quality of the bridge runoff, some practices may be more cost-effective than others.

7.3.4 Bridge Operation and Maintenance Controls

Bridge repairs are those activities necessary to maintain the structural integrity and designated use of the bridge. Bridge repairs encompass a wide array of activities, ranging from minor

operation practices, such as line painting, to major structural repairs. Bridge scraping and painting, which are required to prevent corrosion, can be significant sources of pollutant loads if proper management practices are not used.

Of the most common bridge maintenance activities, bridge painting has the greatest potential for environmental impact. A 1996 study found that up to 80 percent of steel bridges repainted each year had been painted with lead paint, and this material along with cleaners and abrasives, can directly enter the surrounding environment (Young et al., 1996). Paint overspray and solvents can be toxic to aquatic life (Dalton et al., 1985), and metal bridge cleaning has been found to pose a serious water quality problem (TRB, 2002b). The cost of implementing measures to mitigate the impacts of bridge painting are estimated to be an additional 10 to 20 percent for containment and 10 to 15 percent for waste disposal (Young et al, 1996).

Although most construction activities take place away from water bodies, bridge operation and maintenance activities occur within close proximity to a water body. Therefore, management practices to minimize potential adverse effects on the surrounding environment are recommended. It should be noted that, in some cases, federal regulations, including Section 404 of the Clean Water Act and Section 9 of the Rivers and Harbors Act (33 USC 401) might apply to these construction activities. Section 404 regulates the discharge of dredged or fill material to the aquatic environment or the nation's waters. Section 9 of the Rivers and Harbors Act prohibits the construction of any bridge, dam, dike, or causeway over or in navigable waterways without Congressional approval.

7.3.4.1 Enclosures

The following types of enclosures can be used to collect pollutants during bridge maintenance:

(1) *Free-hanging enclosures*. Free-hanging enclosures include tarps, drapes, plastic sheeting, screens, and rigid panels of which only two corners (or one side) are supported. Free-hanging tarps generally provide relatively low containment efficiency (estimated at no more than 50 percent). Considerations for material selection include visibility inside the enclosure, material strength, and air permeability. Free-hanging enclosures are not practical for large, high bridges where high winds can rip the materials or create a “sail effect.”

(2) *Total structural enclosures*. Total structural enclosures are drapes, tarps, screens, plastic sheeting, or rigid panels attached to a rigid steel or wood framework, scaffolding, or existing walls. Design considerations include interior air quality, visibility, structural adequacy of the enclosure, portability, and reusability. Enclosures can be used to encapsulate only part of a large structure at a time. Therefore, portability and reusability should be considered.

(3) *Negative pressure systems*. Negative pressure containment systems are used to prevent dust from escaping from an enclosure when pressurized air blasting is used for paint removal. Such systems draw outside air into the enclosure to the surface being treated; the air then exits through a filter system. The resulting continuous air exchange eliminates leaks of paint dust and abrasives to the outside, improves worker visibility, and reduces health hazards and dust accumulation on structural surfaces and equipment. These systems can be cumbersome

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and expensive, however, and it is sometimes difficult to maintain a constant negative pressure in the enclosure.

7.3.4.2 Containment and collection

Fully enclosed containment structures have been found to recover 80 to 95 percent of abrasives, paint particles, and dust (Appleman, 1992). The following practices can be used to contain and/or collect pollutants during bridge maintenance activities:

(1) *Cofferdams*. Cofferdams are temporary structures used to displace water and provide dry access to submerged support structures for bridges. Cofferdams can be used during bridge construction and maintenance operations involving painting or repairing of steel structures that are in contact with the water body.

(2) *Barges*. Barges situated below the bridge with tarps or shields attached from the barge to the bridge or work platform can be used for debris capture, although winds often make this practice infeasible.

(3) *Containment booms*. Containment booms can be placed in underlying waters to capture floating debris (e.g., paint chips, fines). Lead particles and abrasives usually sink, but use of booms keeps these materials from spreading downstream while they are suspended in the water column.

(4) *Vacuum sanders*. Vacuum sanders can be used to remove paint from bridges and collect dust and chips. Sanders have been shown to immediately capture 98 percent of the dust generated, which reduces cleanup of containment areas and offers increased safety to maintenance workers (USEPA, 2001).

7.3.5 Nonstructural Runoff Control Practices

The structural management practices for highways and bridge decks described previously are designed to reduce pollutant loadings to the environment by holding and treating the highway runoff generated by precipitation. Nonstructural management practices are designed to achieve source control and can be used to augment on-site structural or other runoff management facilities. Most of the nonstructural practices for managing highway runoff pollution are applicable to virtually all highway situations, even if a specific runoff problem has not been identified.

The following management practices for highway runoff are intended to reduce the volume of particulates available for transport by runoff or to filter and settle out suspended solids. Although the practices described do not represent the complete universe of highway management practices, they are among those commonly implemented across the United States.

7.3.5.1 Implement street sweeping

Curb systems act as traps for particulates and other pollutants. The advantage of well-maintained, traditional curbs is that they trap pollutants on the paved surface, and when combined with regular vacuum street sweeping, they can be effective at removing pollutants

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prior to mobilization in runoff. However, if they are not properly maintained, pollutants build up and are washed out by storm water.

Street sweeping is a common practice in many communities. Street sweeping programs can be optimized to significantly reduce trash and other pollutants on urban streets. Study results suggest that reductions of up to 80 percent in annual TSS and associated pollutants could be achieved by using bimonthly to weekly sweepings. Sweeping frequency would vary with patterns of precipitation, sediment accumulation, and resuspension. The effectiveness of any street sweeping operation will vary with land use, precipitation, and the accumulation dynamics of contaminated sediments (Sutherland and Jelen, 1997). Table 7.4 shows concentrations of constituents often found in street dirt.

Table 7.4: Street dirt chemical quality (Bannerman et al., 1983; Pitt, 1979; Pitt, 1985; Pitt, 2001).

Constituent	Mass of Constituent in Street Dirt (mg constituent / kg total solids)
Phosphorus	400–1,500
Total Kjeldahl Nitrogen	290–4,300
Chemical Oxygen Demand	65,000–340,000
Copper	110–420
Lead	530–7,500
Zinc	260–1,200
Cadmium	<3–5
Chromium	31–180

Sweeping technology can have a profound effect on sweeping results. Previously, sweepers were unable to pickup very fine sediments that can be highly contaminated. One study found that the effectiveness of conventional street sweeping equipment ranged from a 35 percent removal of large particles to an increase in the loading of small particles by 10 percent. The equipment performed more efficiently on a smooth asphalt street, showing a 12 percent reduction in small particles (Pitt, 2001). Today, new street sweeping technology has proven to be an effective management practice for reducing pollutant loads to waterways. High-efficiency pavement sweepers are thought to be very effective at picking up a large portion of the very fine particulate material that accumulates on street surfaces. A high-efficiency sweeper uses strong vacuums and the mechanical action of brooms, combined with an air filtration system that returns only clean air to the atmosphere. Minton et al. (1998) found that simulated results for high-efficiency sweepers in residential areas reduced annual TSS wash-off by 51 to 87 percent. Other sweepers reduced annual TSS in these same areas by up to 71 percent. When sweeping in major arterials with high pollutant loads, simulated results indicated that annual TSS wash-off was reduced by 49 to 85 percent. Other tested sweepers reduced annual TSS wash-off in major arterials by up to 24 percent (Minton et al., 1998). When a high-efficiency sweeper was tested in a tandem sweep behind a mechanical broom sweeper, it was able to pick up 141 percent more material than the mechanical broom sweeper (Schwarze Industries, 2004). When the high-efficiency sweeper swept directly after a regenerative air sweeper, it was able to pick up 44 percent additional material.

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High-efficiency sweepers were also compared to wet detention vaults (see Section 5.3.1.1; Sutherland et al., 1998). Simulated results indicate that high-efficiency sweepers removed 40 to 75 percent of annual TSS, while wet detention vaults removed 75 to 91 percent. All removal efficiency ranges depended on sweeping frequency. These projected water quality benefits of high-efficiency street sweeping are based on modeling.

7.3.5.2 Consider alternatives to curbs

As a design alternative, eliminating curbs from roads and highways allows runoff to be filtered through vegetated shoulders or medians and infiltrate to the ground water. Where curbs are necessary for traffic control or other reasons, curb breaks can be incorporated to disconnect the impervious surface and direct runoff to pervious areas. This may not be feasible for streets with high traffic volume and/or on-street parking demand. The structural integrity of the pavement can be maintained by "hardening" the interface between the swale and the pavement with grass pavers, geo-synthetics, or a low-rising concrete strip along the pavement edge. Maintenance requirements for grass channels are generally comparable to those of curb and gutter systems and involve turf mowing, debris removal, and periodic inspections.

7.3.5.3 Install catch basin inserts

Catch basin inserts can be used to treat pollutants in runoff from curbs and road surfaces before entering the storm drain system. These devices are discussed in detail in Management Measure 5 (section 5.3.5.4).

7.3.5.4 Control litter and debris on roadsides

Roadside litter control practices that have traditionally been implemented to address health and aesthetic concerns can also improve runoff quality by limiting trash in runoff conveyance and treatment systems and receiving water bodies. An effective litter and debris control program should include the following source controls:

- Conducting regular trash and debris removal and disposal;
- Educating the public with signs along roads and at rest areas;
- Enforcing littering and illegal dumping laws;
- Sealing cracks and applying pothole surface treatments that minimize the loosening of aggregate and road base debris by tires; and
- Sponsoring Adopt-A-Highway or Adopt-A-Road programs. Many state highway administrations or departments of transportation sponsor Adopt-A-Highway programs that allow businesses and community groups to conduct litter removal and beautification activities on state-owned roads. The city and county equivalent is called Adopt-A-Road.

7.3.5.5 Manage pesticide and herbicide use

Over-application of pesticides and herbicides may cause excess chemicals to leach to ground waters or flow into surface waters. Herbicides and pesticides have the same toxic effect on aquatic plants and organisms as they do on the terrestrial plants and organisms to which they were applied. Practices such as applying according to label instructions, applying at the proper time, applying only the types and amounts necessary, and considering the environmental conditions and hazards at the site are important ways to prevent pesticides and herbicides from entering water bodies. Pesticides, herbicides, and integrated pest management are discussed at length in Management Measure 9 (section 9.3.2).

7.3.5.6 Reduce fertilizer use

Improper application of fertilizers along roadsides can result in excess nutrients being transported to surface waters or leaching to ground water. Methods to reduce fertilizer use are presented in detail in Management Measure 9 (section 9.3.2).

7.3.5.7 Reduce direct discharges

Direct discharges of highway runoff to receiving waters should be avoided wherever possible. This involves the use of collection/conveyance through closed conduits. Highway runoff should be routed through one or a combination of runoff treatment practices, as described in Management Measure 5, before it is discharged to receiving waters.

7.3.5.8 Practice dewatering

Dewatering is a temporary method used to filter sediment-laden water from excavated areas on construction sites prior to discharge to a storm drain or surface waters. Dewatering pumps are applicable wherever sediment-laden water must be removed from a construction site. Dewatering practices should be considered a last-resort control measure. Adequate erosion and sediment control measures must be considered first.

7.3.5.9 Practice spill prevention and control

Prevention and control of spills eliminates or minimizes the discharge of pollutants to water bodies. Water bodies adjacent to construction sites are at highest risk of contamination from an uncontained spill. Several steps can be taken to reduce the risks: handle hazardous and nonhazardous materials, such as concrete, solvents, asphalt, sealants, and fuels, as infrequently as possible and observe all federal, state, and local regulations when using, handling, or disposing of these materials. Spill control devices such as absorbent snakes and mats should be placed around chemical storage areas, and they can be used in an emergency to contain a spill.

7.3.5.10 Properly handle and dispose of concrete and cement

Concrete and cement-related mortars can be toxic to aquatic life. Proper handling and disposal should minimize or eliminate discharges into watercourses. Fresh concrete and cement mortar should not be mixed on-site, and both dry and wet materials should be stored away from water bodies and storm drains. These materials should be covered and contained to prevent contact

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with rainfall or runoff. Washout should not be discharged into streets, storm drains, drainage ditches, or watercourses. A washout area should be designated, and wash water should be treated on-site or discharged to the sanitary sewer.

7.3.5.11 Manage contaminated soil and water

Soil, ponded runoff, and ground water can become contaminated if exposed to hazardous materials and should be properly managed to prevent health hazards and minimize or eliminate discharge of pollutants to storm drains and watercourses. Excavation, transport, and disposal of contaminated soil and water, as well as hazardous waste, must be in accordance with the rules and regulations of EPA, the U.S. Department of Transportation, the Department of Toxic Substances Control, and state and local regulatory agencies.

7.3.5.12 Practice environmentally friendly winter road maintenance

Some of the most damaging runoff can be generated from the melting of snow or ice that has been treated with salts or other chemicals. For example, the buildup of salts along roadsides over the course of a winter can damage and reduce the effectiveness of structural controls such as vegetative filter strips and grass-lined channels. Salts in surface or ground waters can adversely affect water quality and damage wetlands. The corrosive effects of salts also damage road infrastructure, especially bridge decks. According to TRB (1991), road salt has caused more premature bridge deck deterioration than any other factor.

Deicing chemicals deposited on road surfaces can contaminate runoff, as can chemicals that are stored in a manner that puts them in contact with precipitation or runoff. Plowed snow piled in parking lots and along roadsides often contains pollutants such as chlorides, sand, and grit, as well as hydrocarbons and heavy metals. These piles should not be deposited into water bodies or stored near water bodies. Treated snow should never be stored on a frozen pond surface because it can cause density stratification, which can prevent reoxygenation in addition to chloride problems.

Three general types of management practices can be employed to reduce the impact of salt damage on the environment. The first is to implement anti-icing operations that help reduce the amount of chemicals required to maintain safe road conditions; the second is to use alternative deicing materials, which are less corrosive and are presumably less damaging to the environment. The third is to properly store salts or other deicing chemicals to prevent runoff contamination.

(1) *Anti-icing operations*. Anti-icing operations are performed before a storm starts. The purpose of these operations is to prevent snow or ice from accumulating on road surfaces. One of the main advantages of successful anti-icing strategies is reducing the amount of chemicals and abrasives used to keep roads clear. Since 1994, 15 states have participated in the FHWA's project to test and evaluate the effectiveness of anti-icing operations. Anti-icing operations typically use the same chemicals used for deicing, but in different forms. For example, test results found that pre-wetting deicing salt and using brine solutions are effective approaches and result in fewer handling problems.

The ultimate success of anti-icing operations depends on the timing of application. Central to this approach is the use of Roadway Weather Information Systems (RWIS), which report road conditions through pavement sensors that monitor pavement temperatures and the amount of anti-icing materials present on the pavement. When this information is combined with meteorological data and fed into a central database, various modeling techniques can be applied to accurately predict the start of ice formation on pavements and the appropriate times to start anti-icing operations. The cost of implementing and maintaining an RWIS must be compared to the cost of labor and materials for deicing and snow removal. For example, the West Virginia Parkway Authority installed four RWIS units along a 95-mile stretch of highway and calculated that the agency was able to save sufficient outlays for materials and labor to pay for the system within a year. In a state with fewer snowstorms, however, the economics of installing an RWIS may be less advantageous.

Another technology option is the installation of infrared sensors on the bottoms of snowplows. These sensors measure the actual temperature of the roadway as the truck passes over it, allowing a more accurate calculation of the amount of salt needed. As part of its "smart salting" program, the Vermont Department of Transportation installed trial sensors on the bottoms of four snowplows. The agency estimates that it was using 20 to 30 percent more salt than needed because of inaccurate temperature readings. The program has currently been expanded statewide, where the average reduction in salt usage is 28 percent, resulting in an approximate savings of $2.2 million (Lehner et al., 1999).

(2) *Alternative deicers*. Over the years, the FHWA and numerous states have experimented with alternative deicing chemicals, including liquid calcium magnesium acetate (CMA), liquid calcium chloride, liquid magnesium chloride, and liquid potassium acetate. Research has found that these chemicals have both advantages and disadvantages compared to salt (see Table 7.5). Calcium chloride works better at lower temperatures but is also corrosive. CMA appears to be much less harmful to the environment. Its disadvantage is that it is significantly more expensive than salt; the NRC estimated that CMA can cost 20 times more than salt and would increase the total cost of chemical application five-fold (Chollar, 1996). CMA is also less successful than other salts at lower temperatures and is slower to act than salt.

Table 7.5: Advantages and disadvantages of road salt and alternative deicing chemicals.

Type	Advantages	Disadvantages
Road salt	– Low cost ($30-40/ton) – Readily available	– Impact on the environment – Corrosiveness
Alternative deicing chemicals	– Reduced corrosivity – Reduced impact on the environment – $CaCl_2$ can be used in very low temperatures (-20ºF)	– Higher cost (from several hundred dollars per ton to several thousand per ton) – CMA starts to act at a slower rate than salt

In general, alternatives to road salt are still being researched and tested throughout the Midwest and Northeast, but overall costs tend to be higher for these products. Less environmentally damaging products such as CMA, however, can be used selectively to protect sensitive areas like wetlands without dramatically increasing overall cost to the highway authority.

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(3) *Proper storage of deicing chemicals.* Placing deicing chemicals in storage buildings minimizes the likelihood of polluting surface and ground waters with contaminated runoff and eliminates the economic loss from chemicals that are dissolved and washed away by precipitation. A permanent under-roof storage facility is the best way to protect chemicals from precipitation and runoff, but where this is not possible, salt piles and chemical containers should be stored on impermeable bituminous pads and covered with a tarp or other waterproof cover.

7.4 Information Resources

The U.S. Geological Survey (USGS) and the Federal Highway Administration (FHWA) developed an online searchable bibliography of more than 2,600 pertinent references to be published in the catalog of available information that is being collected to characterize pollutant loadings and impacts attributable to highway storm water runoff. The catalog includes reports on highway-runoff water quality, urban/storm water issues, atmospheric deposition, and highway/urban runoff management practices from the USGS, FHWA, EPA, and state transportation agencies. The database can be accessed at http://ma.water.usgs.gov/fhwa/biblio/default.htm.

The Local Technical Assistance Program Web site hosts a "Rural Roads Resources" page that includes a compendium of Web sites, manuals, videos, and other media pertaining to road design and maintenance. The site also hosts an email listserver pertaining to rural roads issues. The Local Technical Assistance Program Resources can be accessed at http://www.ltapt2.org/ by clicking "Resources."

The California Regional Water Quality Control Board produced *the Erosion and Sediment Control Field Manual* for the San Francisco Region in 1998. The document is available for a fee using an order form found at http://www.swrcb.ca.gov/stormwtr/orderform.html.

The FHWA published a study by Dorman et al. (1996) called *Detention and Overland Flow for Pollutant Removal from Highway Stormwater Runoff*, which provides guidelines for the design of management measures for the removal of pollutants from highway storm water runoff. The guidelines are based on the results of field and laboratory studies to verify design procedures and assumptions and the review of other studies. For a copy of this document, contact FHWA's Office of the Natural Environment by sending an email to environment@fhwa.dot.gov.

Fisheries and Oceans Canada published *Protecting Fish and Fish Habitat: Bridge Construction and Demolition*, a fact sheet that details the hazards to aquatic life of bridge construction and demolition and recommends practices to reduce environmental damage. This document is available at http://www.dfo-mpo.gc.ca/canwaters-eauxcan/infocentre/guidelines-conseils/factsheets-feuillets/nfld/fact18_e.asp.

In 1992, Northern Virginia Planning District Commission and Engineers Surveyors Institute produced the *Northern Virginia BMP Handbook: A Guide to Planning and Designing Best Management Practices in Northern Virginia*. This handbook is available for download at http://www.novaregion.org/pdf/NVBMP-Handbook.pdf.

The Staff Transportation Board of the National Research Council produced a primer for a study entitled *Environmental Impact of Construction and Repair Materials on Surface and Ground Waters*. It is written in nontechnical language and explains how the test methods and supporting computer software can provide answers to questions about the environmental impact of new construction or the repair or rehabilitation of existing highways (NCHRP, 2000). Published reports from NCHRP are available from http://www.trb.org.

The Transportation Research Board (TRB) published several studies that investigate the environmental impacts of activities related to transportation infrastructure. These publications

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are available at http://www4.trb.org/trb/onlinepubs.nsf. For example, the National Cooperative Highway Research Program developed a synthesis of information on environmental management practices for highway and street maintenance. This report, entitled *Best Management Practices for Environmental Issues Related to Highway and Street Maintenance*, is available in hard copy from the Transportation Research Board's bookstore (http://trb.org/bookstore/) for $30. Other titles include *Highway Deicing: Comparing Salt and Calcium Magnesium Acetate* (available electronically at http://trb.org/publications/sr/sr235.html or for $22 from the online bookstore); *Assessing the Impacts of Bridge Deck Runoff Contaminants in Receiving Waters—Volume 1:Final Report*, available electronically at http://gulliver.trb.org/publications/nchrp/nchrp_rpt_474v1.pdf, and *Assessing the Impacts of Bridge Deck Runoff Contaminants in Receiving Waters—Volume 2: Practitioner's Handbook*, available at http://gulliver.trb.org/publications/nchrp/nchrp_rpt_474v2.pdf. Publications pending as of spring 2005 include *Guidelines for the Selection of Snow and Ice Control Materials To Mitigate Environmental Impacts* (NCHRP Project 6-16) and *Winter Highway Operations* (NCHRP topic 34-10), which reports on advances and new practices since TRB's last guide for snow and ice control. Both publications will be available at http://www.trb.org.

The TRB's *Environmental Stewardship Practices, Procedures, and Policies for Highway Construction and Maintenance* (NCHRP 25-25(04)) includes numerous management practices in highway construction and maintenance. The guidance was developed from the literature, state transportation agency manuals and procedures, and the contributions of state departments of transportation and practitioners. The document serves as a guide to the development of environmental management systems and environmental strategic plans, both at the organizational level and in specific functional areas such as road construction, vegetation management, materials recycling, winter road maintenance, and many other topics. The document can be downloaded in PDF format from http://www4.trb.org/trb/crp.nsf/reference/boilerplate/Attachments/$file/25-25(4)_FR.pdf.

TRB's *Evaluation of Best Management Practices and Low Impact Development for Highway Runoff Control*, expected to be published in late 2004, includes a users' guide for management practice selection, a design manual, and monitoring guidelines to evaluate and optimize the control of runoff from highways. Visit http://www.trb.org, and enter "NCHRP 25-20" into the search field to access the report.

The Natural Resources Conservation Service (1992) published *Soil Bioengineering for Upland Slope Protection and Erosion Reduction,* which provides specifications for installing bioengineering practices to reinforce slopes and prevent erosion. This document is available for download at http://www.info.usda.gov/CED/ftp/CED/EFH-Ch18.pdf.

The U.S. Department of Transportation's (1995) *Best Management Practices for Erosion and Sediment Control* can be downloaded from the DOT's online publications site at http://isddc.dot.gov/.

The FHWA (1996) published the *Manual of Practice for an Effective Anti-Icing Program: A Guide For Highway Winter Maintenance Personnel*, which can guide maintenance personnel in developing a systematic and efficient practice for maintaining roads in the best condition possible during a winter storm. It describes the factors that should be understood and addressed

in an anti-icing program, with the recognition that development of a program must be based on the specific needs of the site or region. It focuses on weather information and materials and methods that will best address site conditions such as level of service, highway agency resources, climatological conditions, and traffic. The manual can be downloaded in HTML format from http://www.fhwa.dot.gov/reports/mopeap/mop0296a.htm.

The Michigan Department of Transportation (1993) conducted a detailed study on the environmental effects and costs of using several deicing products, including salt, calcium magnesium acetate, an agricultural byproduct, a magnesium chloride product, calcium chloride, a type of concrete pavement, and sand. The study can be accessed at http://www.michigan.gov/documents/toc-deice_51451_7.pdf. More information on alternative deicers can be found at http://www.betterroads.com/articles/prod801.htm, http://www.forester.net/sw_0106_deicing.html, and http://www.wsdot.wa.gov/partners/pns/htm/resources.htm.

The Pacific Northwest Snowfighters Association Web site (http://www.wsdot.wa.gov/partners/pns/) provides resources pertaining to deicing and anti-icing products and practices, such as a list of approved products, deicing specifications, a fact sheet on magnesium chloride, and testing methods and protocols for deicing products (Washington State Department of Transportation, 2002).

Funded by EPA, the Composting Council Research and Education Foundation (CCREF), in conjunction with the United States Composting Council (USCC), developed *Compost Use on State Highway Applications* to promote compost use on state and local roadside applications. Its goal is to provide individuals and organizations—namely, roads and highways staff, policy makers, product specifiers, project designers and engineers, environmental officers, landscapers, and other interested parties—involved in the maintenance and management of roadsides and highways, with the tools necessary to use composted products to meet their specific project requirements. The document is available for download in PDF format at http://www.epa.gov/epaoswer/non-hw/compost/highway/.

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MANAGEMENT MEASURE 8 CONSTRUCTION SITE EROSION, SEDIMENT, AND CHEMICAL CONTROL

8.1 Management Measure

Plan, design, and operate construction site land disturbance activities such that:

- An approved erosion and sediment control plan or similar administrative document that contains erosion and sediment control provisions is prepared and implemented prior to land disturbance.
- Erosion is reduced and, to the extent practicable, sediment is retained on-site during and after construction.
- Good housekeeping practices are used to prevent off-site transport of waste material and chemicals.
- The application and generation of pollutants, including chemicals are minimized.

8.2 Management Measure Description and Selection

8.2.1 Description

This management measure is intended to reduce the amount of sediment generated from construction sites (erosion control) and reduce the off-site transport of sediment and construction-related chemicals (sediment and chemical control). This measure is intended to work in concert with the Watershed Protection, New Development Runoff Treatment, and Site Development Management Measures in a comprehensive watershed management program framework.

Several pollutants of concern are associated with construction activities, including the following: sediment; pesticides; fertilizers used for vegetative stabilization; petrochemicals (oils, gasoline, and asphalt degreasers); construction chemicals such as concrete products, sealers, and paints; wash water associated with these products; paper; wood; garbage; and sanitary waste (Washington State Department of Ecology, 1991).

The variety of pollutants present at a site and the severity of their effects are dependent on a number of factors:

- *The nature of the construction activity*. During the clearing and grading stage, sediment is likely to be the primary pollutant of concern since few other materials are present, whereas during the building phase, concrete wash, paints, varnishes, stucco, and other materials are being used on a daily basis, increasing the likelihood of spills.

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- *The physical characteristics of the construction site*. Most pollutants generated at construction sites are carried to surface waters by runoff. Therefore, the factors that affect runoff volume, such as the amount, intensity, and frequency of rainfall; soil infiltration rates; surface roughness; slope length and steepness; and size of the denuded area, also affect pollutant loadings.

- *The proximity of surface waters to the nonpoint pollutant source*. As the distance separating pollutant-generating activities from surface waters decreases, the likelihood of water quality impacts increases.

The following section is an expanded discussion of the pollutants of concern that can be generated by and released from construction activities.

8.2.1.1 Sediment

Runoff from construction sites is by far the largest source of sediment in urban areas under development. Soil erosion removes more than 90 percent of sediment by weight in urbanizing areas where most construction activities occur (Canning, 1988). Table 8.1 illustrates some of the sediment loading rates associated with construction activities across the United States. As shown in Table 8.1, erosion rates from natural areas such as undisturbed forested lands are typically less than 1 ton/acre/year, whereas erosion from construction sites ranges from 7.2 to 500 tons/acre/year.

Loss of sediment can cause impacts both on and off the construction site. On-site loss of soil reduces or eliminates the remaining soil's ability to provide nutrients, regulate water flow, and protect plants. Losses of nutrients and nutrient-holding capacity result in a less-fertile environment for lawns and plants. Lost organic matter also results in increased soil density and compaction, which can reduce the available water-holding capacity on-site. These reductions result in poorer plant growth and reduced infiltration of fertilizers and pesticides, which can contribute to the transport of these chemicals by runoff into nearby lakes and streams. Finally, organic matter is a food source and habitat for beneficial microorganisms and invertebrates. If organic matter is lost due to erosion, the soil's natural ability to combat outbreaks of pests and diseases is reduced (SQI, 2000).

Eroded sediment from construction sites causes many problems in coastal areas, including adverse impacts on water quality, critical habitats, submerged aquatic vegetation beds, recreational activities, and navigation (APWA, 1991). Water quality impacts include unwanted biological growth caused by excess nitrogen and phosphorus, and increased turbidity. Eroded sediment can also build up in stream channels and lower flow capacity, resulting in more frequent flooding in areas that never flooded or rarely flooded in the past. Reducing the incidence of flooding can also be beneficial in alleviating the financial burden of cleaning up sediment-damaged areas (SQI, 2000). Excessive erosion and sedimentation also can reduce the capacity of reservoirs.

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Table 8.1: Erosion and sediment associated with construction (USEPA, 1993).

Location	Problem	Reference
Franklin County, Florida	Sediment yield (ton/ac/yr): Forest < 0.5 Rangeland < 0.5 Tilled 1.4 Construction site 30 Established urban < 0.5	Franklin County, Florida, 1987
Wisconsin	Erosion rates range from 30 to 200 ton/ac/yr (10 to 20 times those of cropland).	Wisconsin Legislative Council, 1991
Washington, DC	Erosion rates range from 35 to 45 ton/ac/yr (10 to 100 times greater than agriculture and stabilized urban land uses).	MWCOG, 1987
Anacostia River Basin, Maryland and Washington, DC	Sediment yields from portions of the Anacostia Basin have been estimated at 75,000 to 132,000 ton/yr. Total basin acreage = 112,640 acres.	U.S. Army Corps of Engineers, 1990
Anacostia River Basin, Maryland and Washington, DC	Erosion rates range from 7.2 to 100.8 ton/ac/yr. Total basin acreage = 112,640 acres.	USGS, 1978
Washington	Erosion rates range from 50 to 500 ton/ac/yr. Natural erosion rates from forests or well-sodded prairies are 0.01 to 1.0 ton/ac/yr.	Washington State Department of Ecology, 1989
Alabama North Carolina Louisiana Oklahoma Georgia Texas Tennessee Pennsylvania Ohio Kentucky	1.4 million tons eroded per year. 6.7 million tons eroded per year. 5.1 million tons eroded per year. 4.2 million tons eroded per year. 3.8 million tons eroded per year. 3.5 million tons eroded per year. 3.3 million tons eroded per year. 3.1 million tons eroded per year. 3.0 million tons eroded per year. 3.0 million tons eroded per year.	Woodward Clyde, 1991

8.2.1.2 Pesticides

Insecticides, rodenticides, and herbicides are used on construction sites to improve human health conditions, reduce maintenance and fire hazards, and curb the growth of weeds and woody plants. Common pesticides employed include synthetic, relatively water-insoluble chlorinated hydrocarbons, organophosphates, carbamates, and pyrethrins. Over-application of pesticides on

Soil Erosion from Two Small Construction Sites in Dane County, Wisconsin

Most construction regulations require sites with more than 5 acres disturbed to have some type of erosion control plan. Sites that are less than 5 acres typically require minimal erosion control measures. To evaluate the significance of erosion on sites less than 5 acres as a source of sediment to surface waters, two small construction sites (less than 5 acres each) in Dane County, Wisconsin, were studied (USGS, 2000).

Results indicate that small construction sites are potential sources of high amounts of erosion and that sediment loads from the active construction phase are significantly higher than those during the preconstruction and postconstruction periods. These sediment loads were dramatically reduced when mulching and seeding were used to control erosion. The results of this study support the need for erosion control plans for small construction sites.

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revegetated areas can lead to contamination of soils and subsequent contamination of surface water and ground water. The use of pesticides is controlled by federal or state regulations, such as the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) of 1996.

8.2.1.3 Petroleum products

Petroleum products used during construction include fuels and lubricants for vehicles, power tools, and general equipment maintenance. Specific petroleum pollutants include gasoline, diesel oil, kerosene, lubricating oils, and grease. Asphalt paving can be particularly harmful because it releases various oils after application until fully cured (NCHRP, 2000).

8.2.1.4 Fertilizers

Fertilizers are used on construction sites when revegetating graded or disturbed areas. Fertilizers contain nitrogen and phosphorus, which in large doses can adversely affect surface water quality, causing eutrophication.

8.2.1.5 Solid wastes

Trees and shrubs removed during land clearing contribute to the load of solid wastes generated during construction activities. Other common wastes are wood and paper from packaging and building materials, scrap metals, sanitary wastes, rubber, plastic and glass, and masonry and asphalt products. Improper disposal of food containers, paint canisters, cigarette packages, leftover food, and aluminum foil also contributes solid wastes to the construction site.

8.2.1.6 Construction chemicals

There are many sources of chemicals at construction sites. For example, chemicals such as paints, acids for cleaning masonry surfaces, cleaning solvents, asphalt products, soil additives used for stabilization, and concrete-curing compounds are used on construction sites and can be carried off in runoff. Other pollutants, such as wash water from concrete mixers, acid and alkaline solutions from exposed soil or rock, and alkaline-forming natural elements, can also be present and contribute to nonpoint source pollution. Improperly stored construction materials, such as creosote- or pressure-treated lumber or solvents, can lead to leaching of pollutants to surface water and ground water. People disposing of construction chemicals should follow all applicable state and local laws. Some chemicals may need to be disposed of by a licensed waste management firm.

Improper fueling and servicing of vehicles can lead to dumping of significant quantities of petroleum products onto the ground. These pollutants can then be washed off the site in urban runoff, even when proper erosion and sediment controls are in place. Pollutants carried in solution in runoff or attached to sediments may not be adequately controlled by erosion and sediment control practices (Washington Department of Ecology, 1991). Oils, waxes, and water-insoluble pesticides can form surface films on water and solid particles. Oil films can also concentrate water-soluble insecticides. Once present in runoff, these pollutants can be nearly impossible to control other than by the use of very costly water treatment facilities (Washington Department of Ecology, 1991).

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In addition to spill prevention, one of the best methods to control petroleum pollutants is to retain the sediments that have come into contact with these chemicals through use of erosion and sediment control practices. Improved maintenance and storage facilities reduce the chance of contaminating a construction site. One of the greatest concerns related to the use of petroleum products is the method for waste disposal. Dumping petroleum product wastes into sewers and other drainage channels is illegal and could result in fines or site closure.

8.2.1.7 Contaminated soils

Contaminated soils can be encountered during excavation activities that uncover previously known or unknown site contamination. New contamination also can result from a spill or leak of a hazardous material used at the construction site (e.g., a release from a material or waste storage area). If previously unknown contamination is encountered, its nature should be determined. Sampling and analysis will be required to determine what types of contaminants are present and, therefore, how the contaminated soil needs to be handled.

8.2.2 Management Measure Selection

This management measure was selected to reduce sediment mobilization and transport off of the construction site area. This management measure was selected because construction activities have the potential to increased loadings of toxic substances and nutrients in water bodies. Various states and local governments regulate the control of sediment and chemicals on construction sites through spill prevention plans, erosion and sediment control plans, or other administrative devices. The practices provided herein are commonly used and well-described in handbooks and guidance manuals, and they have been shown to be both economical and effective.

The measures were selected for the following reasons:

- Setting numeric load reduction goals for construction site pollutant loadings is generally not practical; sediment and other pollutant loadings from exposed areas vary greatly, and some sediment loss is usually inevitable.

- Erosion and sediment control plans (ESCs) and specifications are required by many state and local governments to accomplish the performance goals for this measure. These ESC plans contain specifications and designs for the proper selection and placement of ESC practices. These practices have been proven to be effective when implemented at construction sites.

- Current procedure typically relies on a set of practices selected based on site-specific conditions.

- The combined effectiveness of erosion and sediment controls in systems is not easily quantified.

- An ESC plan is necessary to provide details regarding the selection, use, inspection, and maintenance of management practices to ensure they are effective in controlling erosion and preventing off-site discharges of sediment.

Eugene, Oregon's goals for erosion and sediment control on construction sites

The City of Eugene, Oregon, requires that, to the maximum extent feasible, management practices that meet a specified set of outcomes be employed at construction sites, including the following (NRDC, 1999):

- No deposit or discharge of sediment onto adjacent properties or into waterbodies.
- No degradation of waterbodies due to the removal of vegetation.
- No discharge or runoff containing construction-related contaminants into the city's runoff conveyance system or related natural resources.
- No deposit of construction-related material exceeding 0.5 cubic foot for every 1,000 square feet of lot size onto public rights-of-way and private streets and into the city's runoff conveyance system and related natural resources.

8.3 Management Practices

8.3.1 Erosion and Sediment Control Programs

8.3.1.1 Prepare erosion and sediment control plans

In many municipalities, erosion and sediment control plans are required under ordinances enacted to protect water resources (Table 8.2). These plans describe how a contractor or developer will reduce soil erosion and contain and treat runoff that is carrying eroded sediments. Plans typically include descriptions and locations of soil stabilization practices, perimeter controls, and runoff treatment facilities that will be installed and maintained before and during construction activities. In addition to special area considerations, the full ESC plan review inventory should include:

- Topographic and vicinity maps
- Site development plan
- Construction schedule
- Erosion and sedimentation control plan drawings
- Detailed drawings and specifications for practices
- Design calculations
- Vegetation plan

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Table 8.2: ESC plan requirement for selected states (Adapted from USEPA, 1993; Environmental Law Institute, 1998).

State	General Requirements for ESC Plan
Delaware	ESC plans required for sites over 5,000 ft^2. Temporary or permanent stabilization must occur with 14 days of disturbance.
Florida	ESC plans required on all sites that need a runoff management permit.
Georgia	ESC plan required for all land-disturbing activities.
Indiana	ESC plan required for sites over 5 acres.
Maine	ESC plans required for sites adjacent to a wetland or water body. Stabilization must occur at completion or if no construction activity is to occur for seven days. If temporary stabilization is used, permanent stabilization must be implemented within 30 days.
Maryland	ESC plans required for sites over 5,000 ft^2 or 100 yd^3.
Michigan	ESC plans required for sites over 1 acre or within 500 ft of a water body. Permanent stabilization must occur within 15 days of final grading. Temporary stabilization is required within 30 days if construction ceases.
Minnesota	ESC plans required for land development over 1 acre.
New Jersey	ESC plans required for sites over 5,000 ft^2.
North Carolina	ESC plans required for sites over 1 acre. Controls must retain sediment on-site. Stabilization must occur within 30 days of completion of any phase of development.
Ohio	ESC plans required for sites over 5 acres. Permanent stabilization must occur within seven days of final grading or when there is no construction activity for 45 days.
Oklahoma	ESC plans required for sites over 5 acres.
Pennsylvania	All earth disturbance activities require implementation and maintenance of ESC practices to minimize the potential for accelerated erosion and sedimentation. Written ESC plans are required for all earth disturbance activities 5,000 square feet or greater. Upon completion of an earth disturbance activity or any stage or phase of an activity, the site shall be immediately seeded, mulched, or otherwise protected from accelerated erosion and sedimentation.
South Carolina	ESC plans required for all sites unless specifically exempted. Perimeter controls must be installed. Temporary or permanent stabilization is required for topsoil stockpiles and all other areas within seven days of disturbance.
Virginia	For areas within the jurisdiction of the Chesapeake Bay Preservation Act, no more land is to be disturbed than necessary for the project. Indigenous vegetation must be preserved to the greatest extent possible.
Washington	ESC provisions are incorporated into the state runoff management plan.
Wisconsin	ESC plans required for all sites over 4,000 ft^3. Temporary or permanent stabilization is required within seven days.

Brown and Caraco (1997) identified several general objectives that should be addressed in an effective ESC plan:

- *Minimize clearing and grading*. Clearing and grading should occur only where absolutely necessary to build and provide access to structures and infrastructure. This approach reduces earth-working and ESC control costs by as much as $5,000 per acre (Schueler, 1995). Clearing should be done immediately before construction, rather than leaving soils exposed for months or years (SQI, 2000).

- *Protect waterways and stabilize drainageways*. All natural waterways within a development site should be clearly identified before construction activities begin. Clearing should generally be prohibited in or adjacent to waterways. Sediment control practices such as check dams may be needed to stabilize drainageways and retain sediment on-site.

- *Phase construction to limit soil exposure*. Construction phasing is a process by which only a portion of the site is disturbed at any one time to complete the needed building in that phase. Other portions of the site are not cleared and graded until exposed soils from the earlier phase have been stabilized and the construction is nearly completed.

- *Stabilize exposed soils immediately*. Seeding or other stabilization practices should occur as soon as possible after grading. In colder climates, a mulch cover is needed to stabilize the soil during the winter months when grass does not grow or grows poorly.

- *Protect steep slopes and cuts*. Wherever possible, clearing and grading of existing steep slopes should be completely avoided. If clearing cannot be avoided, practices should be implemented to prevent runoff from flowing down slopes.

- *Install perimeter controls to filter sediments*. Perimeter controls are used to retain sediment-laden runoff or filter it before it exits the site. The two most common perimeter control options are silt fences and earthen dikes or diversions.

- *Employ advanced sediment-settling controls*. Traditional sediment basins are limited in their ability to trap sediments because fine-grained particles tend to remain suspended and the design of the basins themselves is often simplistic. Sediment basins can be designed to improve trapping efficiency through the use of perforated risers; better internal geometry; the installation of baffles, skimmers, and other outlet devices; gentler side slopes; and multiple-cell construction (see section 3.3: Sediment Control Practices).

ESC plans ensure that provisions for control measures are incorporated into the site planning stage of development. They also help to reduce the incidence of erosion and sediment problems, and improve accountability if a problem occurs. An effective plan for runoff management on construction sites controls erosion, retains sediments on-site to the extent practicable, and reduces the adverse effects of runoff. Climate, topography, soils, drainage patterns, and vegetation affect how erosion and sediment should be controlled on a site (Washington State Department of Ecology, 1989).

An effective ESC plan includes both structural and nonstructural controls. Nonstructural controls address erosion control by decreasing erosion potential, whereas structural controls are both preventive and mitigative because they control erosion and sediment movement. Typical nonstructural erosion controls include:

- Plans and designs to minimize disruption of the natural features (drainage, topography, vegetative cover);
- Phased grading to minimize the area of bare soil exposed at any given time;
- Scheduling of activities during the time of year with the least erosion potential; and
- Stabilization, e.g., mulching and seeding of exposed areas.

Structural controls include:

- Perimeter controls;
- Sediment basins and traps;
- Silt fences or filter fabrics;

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- Stream crossing areas for natural and man-made areas; and
- Stabilization of cut-and-fill slopes caused by construction activities.

Some erosion and soil loss is unavoidable during land-disturbing activities. Although proper siting and design help prevent development of areas prone to erosion, construction activities invariably result in conditions where erosion can occur. To reduce the adverse impacts associated with construction, the construction management measure was written to promote the use of a system of nonstructural and structural erosion and sediment controls for incorporation into an ESC plan. Erosion controls reduce the amount of sediment transported off-site, thereby reducing the need for sediment controls and lowering overall costs. When erosion controls are used in conjunction with sediment controls, the size of the sediment control structures and associated maintenance may be reduced, decreasing overall treatment costs (SWRPC, 1991).

8.3.1.2 Provide education and training opportunities for construction personnel

One of the most important factors determining whether erosion and sediment controls will be properly installed and maintained on a construction site is the knowledge and experience of the contractor. Many communities require certification for key on-site employees who are responsible for implementing the ESC plan. Certification can be accomplished through municipally sponsored training courses. Municipalities also can hold mandatory preconstruction or pre-wintering meetings and conduct regular and final inspection visits to transfer information to contractors (Brown and Caraco, 1997). Information that should be covered in training courses and meetings includes the importance of ESC practices for water quality protection; developing

Contractor/Developer Certification Programs in Delaware and Maine

Delaware requires that at least one person on any construction project be formally certified. The Delaware program requires certification for any foreman or superintendent who is in charge of on-site clearing and land-disturbing activities for sediment and runoff control associated with a construction project. Responsible personnel are required to obtain certification by completing a Department of Natural Resources and Environmental Control-sponsored or approved training program. All applicants seeking approval of a sediment and runoff plan must certify that all personnel involved in the construction project will have a certificate of attendance at a Department-sponsored or approved training course before initiation of any land-disturbing activity (Delaware DNREC, no date). A description of this certification requirement is provided at the DNREC Web site at *www.dnrec.state.de.us/newpages/ssregs14.htm*.

The Maine Department of Environmental Protection offers the Voluntary Contractor Certification Program (VCCP), which is a nonregulatory, incentive-driven program to broaden the use of effective erosion control techniques. The VCCP is open to any contractor who is involved with soil disturbance activities, including filling, excavating, landscaping, and other types of earthworks. For initial certification, the program requires attendance at two 6-hour training courses and the successful completion of a construction site evaluation. To maintain certification, a minimum of one 4-hour continuing education course within every 2-year period thereafter is required. Local soil and water conservation district personnel will complete construction site evaluations during the construction season. Certifications are valid until December 31 of the second year after issuance. Certification entitles the holder to advertise services as a "DEP Certified Contractor" (MDEP, 1999). More information about this program is provided on the MDEP Web site at *janus.state.me.us/dep/blwq/training/is-vccp.htm.*

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The California Department of Transportation's Storm Water Management Plan

The California Department of Transportation (Caltrans) operates one of the most comprehensive storm water drainage systems in the United States. It has recently undertaken a multifaceted program to investigate and address pollutant load reduction in California's storm water runoff. To improve storm water management, Caltrans created the Storm Water Task Force (SWTF) to monitor, train, and educate its employees and hired contractors about pollution prevention measures. The SWTF's goals are to raise awareness and to change work habits so that Caltrans employees can more effectively address storm water issues. The SWTF uses the following techniques to accomplish their goals (Borroum et al., 2000):

- Inspecting projects and facilities for compliance with erosion, sediment control, and waste management requirements.
- Providing classroom and on-the job training and consulting.
- Publishing a monthly storm water bulletin for employees and state and local regulatory agencies.
- Reviewing storm water pollution prevention plans for construction sites.
- Providing feedback on how well methods work and what improvements could be made to improve performance.
- Preparing specialized training materials, such as videos and model pollution prevention plans.
- Providing input for storm water guidance manuals and water pollution control specifications for highway design and construction.

and implementing ESC plans; the importance of proper installation, regular inspection, and diligent maintenance of ESC practices; and recordkeeping for inspections and maintenance activities. Training and education should logically extend to all on-site personnel responsible for implementing a construction runoff control plan.

8.3.1.3 Establish plan review and modification procedures

ESC plans should be flexible to account for unexpected events that occur after the plans have been approved, including:

- Discrepancies between planned and as-built grades;
- Weather conditions;
- Altered drainage; and
- Unforeseen construction requirements.

Changes to an ESC plan should be made based on regular inspections that identify whether the ESC practices were appropriate or properly installed or maintained.

8.3.1.4 Assess ESC practices after storm events

Inspecting an ESC practice after storm events shows whether the practice was installed or maintained properly. Such inspections also help determine whether a practice requires cleanout,

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repair, reinforcement, or replacement with a more appropriate practice. Inspecting after storms is the best way to ensure that ESC practices remain in place and effective at all times during construction activities.

8.3.1.5 Ensure ESC plan implementation

Because funding for ESC programs is not always dedicated, budgetary and staffing constraints may thwart effective program implementation. Brown and Caraco (1997) recommend several management techniques to ensure that ESC programs are properly administered:

- Local leadership committed to the ESC program;
- Redeployment of existing staff from the office to the field or training room;
- Cross-training of local review and inspection staff;
- Submission of erosion prevention elements for early planning review;
- Prioritization of inspections based on erosion risk;
- Requirement of designers to certify the initial installation of ESC practices;
- Investment in contractor certification and private inspector programs;
- Use of public-sector construction projects to demonstrate effective ESC controls;
- Enlistment of the talents of developers and engineering consultants in the ESC program; and
- Revision and update of the local ESC manual.

To facilitate public participation, a hotline can be established to allow for citizen "monitoring" and reporting of any illicit discharges. Materials should be distributed or public service announcements made to advertise the hotline.

An allowance item that acts as an additional "insurance policy" for complying with the erosion and sediment control plan also can be added to bid or contract documents (Deering, 2000a). This allowance covers costs to repair storm damage to erosion and sediment control measures as specified in the erosion and sediment control plan. This allowance does not cover storm damage to property that is not related to the erosion and sediment control plan, because this would be covered under traditional liability insurance. Damage caused by severe and continuous rain, windblown objects, fallen trees or limbs, or high-velocity, short-term rain on steep slopes and existing grades would be covered by the allowance, as would deterioration from exposure to the elements or excessive maintenance for silt removal. The contractor is responsible for complying with the erosion and sediment control plan by properly implementing and maintaining all specified measures and structures. The allowance does not cover damage to practices caused by improper installation or maintenance.

A study by University of North Carolina researchers measured the effects of erosion and sediment control regulations, inspections, and enforcement on stream biological condition at 17 construction sites in central North Carolina (Reice and Andrews, 2000). At each site, upstream, downstream, and at-site samples were taken before construction began, during the peak land disturbance, and after the project was completed and released by the regulatory agency. Benthic and fish communities, in addition to several water chemistry variables and leaf litter decomposition rates, were sampled. The researchers found a number of results:

- Virtually all at-site samples showed some degradation relative to upstream controls.
- Impacts at sites downstream from construction sites were highly variable.
- Degree of degradation was significantly affected by enforcement activities; stronger enforcement resulted in less environmental impact on the streams.
- The stringency of the erosion and sediment control regulations proved unimportant compared to enforcement.

They concluded that staffing, workload, attitudes, and enforcement activities strongly influenced downstream conditions.

8.3.2 Erosion Control Practices

Erosion controls are used to reduce the amount of sediment removed during construction and to prevent sediment from entering runoff. Erosion control is based on two main concepts: (1) disturb the smallest area of land possible for the shortest period of time, and (2) stabilize disturbed soils to prevent erosion from occurring. Table 8.3 shows cost and effectiveness information for several erosion control practices.

8.3.2.1 Schedule projects so clearing and grading are done during the time of minimum erosion potential

Often a project can be scheduled when the erosion potential of the site is relatively low. In many parts of the country, there is a certain period of the year when erosion potential is relatively low and construction scheduling could be very effective. For example, in the Pacific region, if construction can be completed during the six-month dry season (May 1 to October 31), temporary erosion and sediment controls may not be needed. In addition, in other areas of the country, erosion potential in northern and high-elevation areas is very high during the spring thaw. During that time, snowmelt generates a constant runoff that can erode soil. In addition, construction vehicles can easily turn the soft, wet ground into mud, which is more easily washed off the site. Therefore, in the north, limitations should be placed on clearing and grading during the spring thaw (Goldman et al., 1986).

8.3.2.2 Phase construction

Construction site phasing involves disturbing only small portions of a site at a time to prevent erosion in areas where no activity is occurring (CWP, 1997c). Grading and construction are completed and soils are effectively stabilized on one part of the site before they commence at another. This is different from the more traditional practice of construction site sequencing, in which construction occurs at only one part of the site at a time but site grading and other site-disturbing activities typically occur all at once, leaving portions of the disturbed site vulnerable to erosion. Construction site phasing must be incorporated into the overall site plan early on. Elements to consider when phasing construction activities include (CWP, 1997c):

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- Managing runoff separately in each phase;
- Determining whether water and sewer connections and extensions can be included in the disturbed area and installed during the initial phases of disturbance; and
- Providing separate construction and residential accesses to prevent conflicts between residents living in completed stages of the site and construction equipment working on later stages.

Table 8.3: Cost and effectiveness of selected erosion control practices.

Practice	Percent TSS Removal	Effectiveness References	Cost (2001 Dollars[a])	Cost References
Earth dike	NA	NA	Small dikes: $2.50–$6.50/linear ft Large dikes: $2.50/yd^3	NAHB, 1995; SWRPC, 1991
Pipe slope drain	NA	NA	$5/linear ft for flexible PVC pipe; inlet and outlet structures additional	NAHB, 1995
Terraces	1%–12% slope: 70% less erosion 12%–18% slope: 60% less erosion 18%–24% slope: 55% less erosion	USEPA, 1993	Average: $6/linear ft Range: $1.20–$14.50/linear ft	USEPA, 1993
Check dams	NA	NA	$100/dam (constructed of rock)	NAHB, 1995
Seeding	Average: 90% Range: 50%–100%	USEPA, 1993	Average: $0.10/yd^2 Range: $0.05–$0.25/yd^2 Maintenance costs: 15%–25% of installation costs	USEPA, 1993
Mulching	53%–99.8% reduction of soil loss 24%–78% reduction in water velocity	Harding, 1990	Average: $0.38/yd^2 Range: $0.21–$0.87/yd^2	USEPA, 1993
Sodding	98–99%	USEPA, 1993	Average: $2.20/yd^2 Range: $1.10–$12/yd^2 Maintenance costs: 5% of installation costs	USEPA, 1993
Erosion control blankets	70% wheat straw/30% coconut fiber: 98.7% Straw: 89.2%–98.6% Curled wood fiber: 28.8%–93.6% Jute mats: 60.6% Synthetic fiber: 71.2% Nylon monofilament: 53.0%	CWP, 1997a	Biodegradable materials: $0.50–$0.57/yd^2 Permanent materials: $3.00–$4.50/yd^2 Staples: $0.04–$0.05/staple	Erosion Control Systems, Inc., personal communication, March 14, 2001
Chemical stabili-zation	PAM: 77–93%	Rosa-Espinosa et al., No date	PAM: $1.30–$38.50/lb	Entry and Sojka, 1999; Sojka and Lentz, 1996

[a]Costs adjusted for inflation using the Consumer Pricing Index (BLS, 2001).

A comparison of sediment loss from a typical development and from a comparable phased project showed a 42 percent reduction in sediment export in the phased project (CWP, 1997c).

Phasing can also provide protection from complete enforcement and shutdown of the entire project. If a contractor is in noncompliance in one phase or zone of a site only, that will be the area affected by enforcement activities. This approach can help to minimize liability exposure and protect the contractor financially (Deering, 2000b).

8.3.2.3 Practice site fingerprinting

Areas of a construction site are often unnecessarily cleared. Site fingerprinting involves clearing only those areas essential for conducting construction activities, leaving other areas undisturbed. The proposed limits of land disturbance should be physically marked off to ensure that only the land area required for buildings, roads, and other infrastructure is cleared. Existing vegetation, especially vegetation on steep slopes, should be avoided and preserved through fencing, signage, and site plan notations.

8.3.2.4 Locate potential pollutant sources away from steep slopes, water bodies, and critical areas

Material stockpiles, borrow areas, access roads, and other land-disturbing activities should be located away from critical areas such as steep slopes, highly erodible soils, and areas that drain directly into sensitive water bodies to reduce the potential for pollutant loadings.

8.3.2.5 Route construction traffic to avoid existing or newly planted vegetation

Where possible, construction traffic should be directed over areas that must be disturbed for other construction activity. This practice reduces the net total area that is cleared and susceptible to erosion. It also may help to decrease the area of compacted soils.

8.3.2.6 Protect natural vegetation with fencing, tree armoring, and retaining walls or tree wells

Tree armoring protects tree trunks from being damaged by construction equipment. Fencing can also protect tree trunks, but it should be placed at the tree's drip line or critical root zone. A tree's drip line is the minimum area around the tree in which the tree's root system should be undisturbed by cut, fill, or soil compaction caused by heavy equipment. When cutting or filling must be done near a tree, a retaining wall or tree well should be used to minimize the cutting of the tree's roots, the quantity of fill placed over the tree's roots, or soil compaction.

8.3.2.7 Protect environmentally sensitive areas

When construction is taking place in an aquifer recharge area, wetland, floodplain, or other sensitive area, special consideration should be given to minimizing the environmental impacts of construction activities. Disturbance to these areas should be limited and measures taken to reduce impacts if work is conducted near or in these features. For example, the North Carolina Department of Transportation (NCDOT) used an innovative technique to reduce the impact of cleanup activities on sensitive wetlands surrounding the newly constructed Croatan Sound Bridge. NCDOT used industrial vacuums traditionally used by the shipbuilding and roofing industries to move materials off-site rather than running potentially damaging vehicles over the

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wetlands. Even with the purchase cost of the new equipment, NCDOT estimates a savings of more than $3 million.

8.3.2.8 Stockpile topsoil and reapply as a soil amendment to reestablish vegetation

Topsoil is essential to establish new vegetation, and it should be stockpiled and then reapplied to the site for revegetation. Reestablishment of vegetation is one of the most common and least expensive means to stabilize disturbed soils.

The Importance of Soil Amendments

Soil with adequate soil structure, pore space, organic content, and biological activity not only promotes the establishment of new vegetation, but it also provides water quality benefits. When soils are compacted during construction activities and organic matter is not replaced, the following consequences may occur (Low Impact Development Center, 2003):

- Reduced infiltration capacity, resulting in increased runoff, erosion, scouring, and sediment and other pollutant loads to receiving waters.
- Decreased ground water recharge rates.
- Reduced availability of subsurface water to plants, requiring homeowners to water more frequently.

Soil amendments minimize development impacts on native soils by restoring infiltration capacity and the chemical characteristics of healthy soils. Amended soils provide greater infiltration and subsurface storage, which helps to maintain predevelopment conditions. Soil amendments provide the following water quality benefits (Low Impact Development Center, 2003):

- Increased infiltration capacity of soil.
- Filtering and breakdown of potential pollutants.
- Decomposition of potential pollutants by soil microbes.
- Reduced need for fertilizers, pesticides, and irrigation due to increased nutrients and moisture-holding capacity in soil.
- Increasing soil stability, reducing erosion potential.
- Added protection to ground water resources, especially from heavy metal contamination.

Soil can be amended using compost, mulch, topsoil, lime and gypsum. A thorough analysis of the native soil should be conducted to maximize the benefits of soil amendments.

Soil should be amended at the completion of construction to avoid compaction from heavy equipment. Care should be taken to ensure that amendments are implemented during the right season and under the right conditions in relation to other landscaping activities.

8.3.2.9 Cover or stabilize soil stockpiles

Unprotected stockpiles are very prone to erosion and therefore must be protected. Small stockpiles can be covered with a tarp to prevent erosion. Large stockpiles should be stabilized by erosion blankets, seeding, and/or mulching.

8.3.2.10 Use wind erosion controls

Wind erosion controls limit the movement of dust from disturbed soil surfaces and encompass many different practices. Wind barriers block air currents and are effective in controlling soil movement due to wind. Many different materials can be used as wind barriers, including solid board fences, snow fences, and bales of hay. Sprinkling moistens the soil surface with water and must be repeated as needed to be effective for preventing wind erosion (Delaware DNREC, 1989); however, applications must be monitored to prevent excessive runoff and erosion.

8.3.2.11 Intercept runoff above disturbed slopes and convey it to a permanent channel or storm drain

Earth dikes, perimeter dikes/swales, or diversions can be used to intercept and convey runoff from above disturbed areas to undisturbed areas or drainage systems. An earth dike is a temporary berm or ridge of compacted soil that channels water to a desired location. A perimeter dike/swale or diversion is a swale with a supporting ridge on the lower side that is constructed from the soil excavated from the adjoining swale (Delaware DNREC, 1989). These practices should be used to intercept flow from denuded areas or newly seeded areas and to keep clean runoff away from disturbed areas. The structures should be stabilized within 14 days of installation. A pipe slope drain, also known as a pipe drop structure, is a temporary pipe placed from the top to the bottom of a slope to convey concentrated runoff down the slope without causing erosion (Delaware DNREC, 1989).

8.3.2.12 On long or steep, disturbed, or man-made slopes, construct benches, terraces, or ditches at regular intervals to intercept runoff

Benches, terraces, or ditches break up a slope by providing areas of low slope in the reverse direction. These structures keep water from proceeding down the slope at increased volume and velocity. Instead, the flow is directed to a suitable outlet or protected drainage system. The frequency of benches, terraces, or ditches will depend on the erodibility of the soils, steepness and length of the slope, and rock outcrops. This practice should be used if there is a potential for erosion along the slope.

8.3.2.13 Use retaining walls

Retaining walls can be used to decrease the steepness of a slope. If the steepness of a slope can be reduced, the runoff velocity and erosion potential can be decreased.

8.3.2.14 Provide linings for urban runoff conveyance channels

Construction activities often increase the velocity and volume of runoff. Increases in runoff velocity and volume often cause erosion in newly constructed or existing urban runoff

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conveyance channels. If the runoff during or after construction will cause erosion in a channel, the channel should be lined or flow control practices should be installed. The first choice of lining is grass or sod because they reduce runoff velocities and provide water quality benefits through filtration and infiltration. If the velocity in the channel would erode the grass or sod, turf reinforcement mats, riprap, concrete, or gabions can be used.

8.3.2.15 Use check dams

Check dams are small, temporary dams constructed across a swale or channel. They can be constructed using gravel, rock, gabions, or straw bales. They are used to reduce the velocity of concentrated flow and, therefore, to reduce erosion in a swale or channel. Proper design and maintenance of check dams is crucial to their ability to function as an erosion control measure. Design considerations include dams to control runoff velocity; hydraulic capacity to store and release runoff in a non-erosive manner; stability of dam construction materials; foundation preparation; construction moisture; and density control. Maintenance requirements include the periodic removal of sediment collected above the dam; immediate repair of damage; and removal of temporary dams when they are no longer needed (Loser, 2003).

8.3.2.16 Seed disturbed areas

Seeding establishes a vegetative cover on disturbed areas and is very effective in controlling soil erosion once a dense vegetative cover has been established. Seeding establishes permanent erosion control in a relatively short amount of time and has been shown to decrease solids load by 99 percent (CWP, 1997a). The three most common seeding methods are: (1) broadcast seeding, in which seeds are scattered on the soil surface; (2) hydroseeding, in which seeds are sprayed on the surface of the soil with a slurry of water; and (3) drill seeding, in which a tractor-drawn implement injects seeds into the soil surface. Broadcast seeding is most appropriate for small areas and for augmenting sparse and patchy grass covers. Hydroseeding is often used for large areas (in excess of 5,000 square feet) and is typically combined with tackifiers, fertilizers, and fiber mulch. Drill seeding is expensive and is cost-effective only on sites greater than 2 acres. Bare soils should be seeded or otherwise stabilized within 15 calendar days after final grading. Denuded areas that are inactive and will be exposed to rain for 15 days or more should also be temporarily stabilized, usually by planting seeds and establishing vegetation during favorable seasons. In very flat, non-sensitive areas with favorable soils, stabilization may involve simply seeding and fertilizing. The Soil Quality Institute (SQI, 2000) recommends that soils compacted by grading should be broken up or tilled before vegetating.

To establish a vegetative cover, it is important to use seeds from adapted plant species and varieties that have a high germination capacity. Supplying essential plant nutrients, testing the soil for toxic materials, and applying an adequate amount of lime and fertilizer can overcome many unfavorable soil conditions and establish adequate vegetative cover. Soils should be tested prior to application to determine the amount of lime or fertilizer needed. Specific information about seeds, various species, establishment techniques, and maintenance can be obtained from *Erosion Control & Conservation Plantings on Noncropland* (Landschoot, 1997) or a local Cooperative State Research, Education, and Extension Service (http://www.csrees.usda.gov/) or Natural Resources Conservation Service (http://www.nrcs.usda.gov) office.

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8.3.2.17 Use mulches

Newly established vegetation does not have as extensive a root system as existing vegetation, and therefore it is more prone to erosion, especially on steep slopes. Additional stabilization should be considered during the early stages of seeding. This extra stabilization can be accomplished using mulches or mulch mats, which can protect the disturbed area while vegetation becomes established.

Mulching involves applying plant residues, compost material, or other suitable materials on disturbed soil surfaces. Mulch and mulch mat materials include tacked straw, wood chips, jute netting, coir/coconut fiber, and compost mix, and are sometimes covered by blankets or netting. Mulching alone should be used only for temporary protection of the soil surface or when permanent seeding is not feasible. The useful life of mulch varies with the material used and the amount of precipitation, but is approximately two to six months. Mulching and/or sodding may be necessary as slopes become moderate to steep, as soils become more erodible, and as areas become more sensitive.

During the times of the year when vegetation cannot be established, mulch should be applied to moderate slopes and soils that are not highly erodible. On steep slopes or highly erodible soils, multiple mulching treatments should be used.

The Texas Transportation Institute (2004) undertook a study to measure the performance of the use of compost and shredded wood mulches on highway rights-of-way. The institute found that compost applied to sand produced 92 percent vegetation cover, compost on clay produced 99 percent vegetation cover, and wood chips treated with a tackifier on clay produced 95 percent vegetation cover. Other treatments, including wood chips/tackifier on sand and wood chips with tackifier and germination stimulant on sand and clay did not produce adequate vegetation cover for erosion control (only 48 to 57 percent cover). They concluded that mulch could be advantageous as an erosion control method because it did not need to be removed after construction and it acted as a soil amendment to encourage vegetation establishment. Additionally, use of natural mulches such as compost and wood chips promotes recycling of waste materials and reduces the amount of wastes disposed of in landfills.

Hydromulches containing biosolids or other fertilizers are often useful on soils with poor nutrient organic content and in situations where there are steep slopes or other erosive forces that affect revegetation (e.g., wind).

8.3.2.18 Use sodding for permanent stabilization

Sodding permanently stabilizes an area with a thick vegetative cover. Sodding provides immediate stabilization and should be used in critical areas or where establishing permanent vegetation by seeding and mulching would be difficult. Sodding is also a preferred option when there is high erosion potential during the period of vegetative establishment from seeding. According to the Soil Quality Institute (SQI, 2000), soils that have been compacted by grading should be broken up or tilled before placing sod.

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8.3.2.19 Install erosion control blankets

Turf reinforcement mats (TRMs) combine vegetative growth and synthetic materials to form a high-strength mat that helps prevent soil erosion in drainage areas and on steep slopes (USEPA, 1999). TRMs enhance the natural ability of vegetation to permanently protect soil from erosion. They are composed of interwoven layers of non-degradable geosynthetic materials, such as polypropylene, nylon, and polyvinyl chloride netting, stitched together to form a three-dimensional matrix. They are thick and porous enough to allow filling and retention of soil.

In addition to providing scour protection, the mesh netting of TRMs is designed to enhance vegetative root and stem development. By protecting the soil from scouring forces and enhancing vegetative growth, TRMs can raise the threshold of natural vegetation to withstand higher hydraulic forces on stabilization slopes, streambanks, and channels. In addition to reducing flow velocities, the use of natural vegetation provides removal of particulates through sedimentation and soil infiltration and improves the aesthetics of a site.

In general, TRMs should not be used:

- To prevent deep-seated slope failure due to causes other than surficial erosion;
- When anticipated hydraulic conditions are beyond the limits of TRMs and natural vegetation;
- Directly beneath drop outlets to dissipate impact force (although they can be used beyond the impact zone); or
- Where wave height might exceed 1 foot (although they may be used to protect areas up-slope of the wave impact zone).

The performance of a TRM-lined conveyance system depends on the duration of the runoff event to which it is subjected. For short-term events, TRMs are typically effective at flow velocities of up to 15 ft/sec and shear stresses of up to 8 lb/ft^2 (USEPA, 1999), however, specific high-performance TRMs may be effective under more severe hydraulic conditions. Practitioners should check with manufacturers for the specifications and performance limits of different products.

In general, the installed cost of TRMs ranges from $\$5/yd^2$ to $\$15/yd^2$ (USEPA, 1999). Factors influencing the cost of TRMs include: (1) the type of TRM material required; (2) site conditions, such as the underlying soils, the steepness of the slope, and other grading requirements; and (3) installation-specific factors such as local construction costs.

In most cases, TRMs cost considerably less than concrete and riprap solutions. For example, a project in Aspen, Colorado, used more than 23,000 yd^2 of TRMs to line channels for a horse ranch development project (Theisen, 1996). The TRMs were installed at a cost of $\$8.25/yd^2$. This cost was substantially less than the $\$20/yd^2$ estimate for the rock riprap alternative.

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8.3.2.20 Use chemicals such as PAM to stabilize soils

Polymers can be used to reduce erosion and also to control sediment contained in runoff. Polyacrylamide (PAM) is a polymer produced mainly for agricultural use to control erosion and promote infiltration on irrigated lands (Sojka and Lentz, 1996). It is also being tested for use at construction sites to reduce erosion from disturbed areas (Aicardo, 1996; Roa-Espinosa et al., no date). When applied to soils, PAM binds to soil particles and forms a gel that decreases soil bulk density, absorbs water, and binds fine-grained soil particles.

PAM is available in powder form or as aqueous concentrate, in blocks and cubes, and as an emulsified concentrate; each type has benefits and drawbacks that alter its applicability in different settings and by different application methods. PAM costs $1.30 to $38.50 per pound (Entry and Sojka, 1999; Sojka and Lentz, 1996) and has been shown to achieve a 77 to 93 percent reduction in sediment loss from disturbed sites (Roa-Espinosa et al., no date).

Application of PAM improves surface water quality by decreasing suspended solids and the phosphorus, nitrogen, pesticides, pathogens, salts, metals, and BOD usually associated with sediment loading. However, PAM may detrimentally affect ground water quality by increasing leaching of nutrients, pesticides, and pathogens as a result of improved infiltration. Although careful application of PAM at prescribed rates can partially mitigate its negative effects on ground-water quality, its effects on water quality and wildlife are still unknown.

Questions have arisen as to PAM's environmental toxicity. Anionic PAM, the form found most often in erosion control products, has not been proven to be toxic to aquatic, soil, or plant species. The molecule is too large to cross membranes, so it is not absorbed by the gastrointestinal tract, is not metabolized, and does not bioaccumulate in living tissue. Cationic PAM, although not of major concern for erosion control applications, has been shown to be toxic to fish because of its affinity to anionic hemoglobin in the gills.

Most of the concern for PAM toxicity has arisen because of acrylamide (AMD), the monomer associated with PAM and a contaminant of the PAM manufacturing process. In laboratory experiments, AMD has been shown to be both a neurotoxin and a carcinogen. Current regulations require that AMD not exceed 0.05 percent in PAM products. Although there seems to be little risk from AMD as a result of prescribed application of PAM, it is uncertain what effects might result from spills, over-application, or other accidents.

Flocculation and filtration of colloidal solids in construction site runoff

Runoff discharged from an unstabilized sediment basin at a commercial construction site was not meeting water quality standards due to high suspended solids content, despite a filtering device installed at the basin's outflow. The filter was designed to filter larger particles and gross solids, but did not treat silt-sized and colloidal particles. To address the smaller particle sizes, the contractor installed a sump consisting of 2 parts: a pit into which a 1,000-foot pipe discharged runoff for settling and a grid of jute baffles that would filter finer floc. A polyacrylamide blend was used to stabilize the pit and baffle grid. Solid blocks of flocculant were placed in the upstream end of the discharge pipe to introduce the material gradually into the runoff stream. Mixing occurred in the pipe, settling of floc occurred in the quiescent pit, and the baffles filtered remaining solids and floc. Samples taken at inflow and outflow points show dramatic clarification of runoff (Price and Company, Inc., 2004).

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Polymers for Sediment Control

Polymers also can be used to control sediments that have been mobilized and entrained in runoff. Minton and Benedict (1999) examined the use of polymers to clarify construction site runoff that had been detained on-site.

The researchers used a multi-phase system to remove sediments and associated pollutants from construction site runoff. The first phase involved collection of storm water at interception points using the permanent drainage system installed early in the construction period and/or building excavations (see Figure 8.1). The collected runoff was then diverted, usually by pumping, to one or more storage ponds. (The permanent postdevelopment detention and treatment system, as required by local regulations, could be used for this storage during the construction phase given that it has sufficient capacity to handle site runoff, with supplemental storage provided as necessary.) The water was then pH-adjusted to optimize flocculation based on the particular polymer used. Finally, the water was pumped to one of two treatment cells, during which time the polymer was added (upstream of the transfer pump to maximize mixing and flocculation).

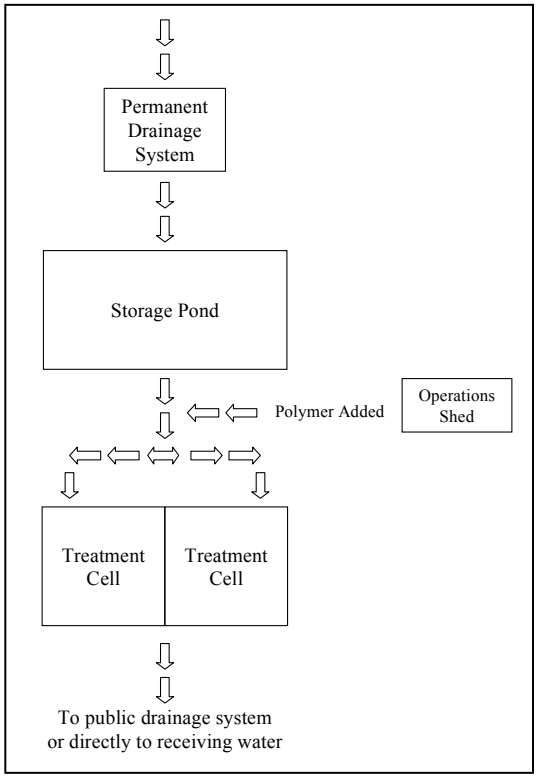

Figure 8.1: Schematic of the basic polymer treatment system (Minton and Benedict, 1999).

Two treatment cells were used so that settling could take place in one cell while runoff was pumped into the second cell. The floc was allowed to settle for a few hours to several days, with the most common practice being an overnight settling period. Water was discharged to the public discharge system using a float device with a 4-inch discharge system and a 12-inch clearance to keep the float from picking up settled sediment. Alternatively, the clarified water could be discharged to the sanitary sewer if problems arose in the treatment system.

Table 8.4 presents performance data for the six sites studied. Median turbidities of the untreated storm water varied between sites. These differences might have been caused by differences in the percentage of soil fines, the slopes, and the application of standard management practices. Developers at the test sites reported costs to be between 0.8 and 1.5 percent of the total construction cost, while another developer reported an approximate cost of $\$1/ft^2$ for the treatment system. Temporary storage and treatment ponds, as well as piping, pumps, and other equipment, accounted for the majority of the costs associated with polymer treatment.

Table 8.4: Summary of operating performance data for six test sites (Minton and Benedict, 1999)[a].

	Polymer Dosage		Influent Turbidity		Effluent Turbidity		pH Control	
Site	Range	Median	Range	Median	Range	Median	Frequency[b]	Type[c]
1	25–250	75	12–2,960	200	1–45	6	45%	acid
2	10–200	100	31–4,700	2,000	1.9–39	11	16%	both
3	50–>100	100	12.9–900	150	0.5–45	7	18%	soda ash
4	50–200	100	8–4,000	400	<1–32.5	6	0%	–
5	300–400	350	2,780–17,000	14,000	0.8–23	8	97%	soda ash
6	85–140	110	17–6,650	117	1.7–18	4	85%	both

[a] Excludes the start-up period when effluent turbidities were not yet at desired levels (usually a week or two for most sites). [b] Approximate percentage of the number of operating days on which pH adjustment occurred. [c] Most frequent form of pH adjustment: soda ash or sulfuric acid.

8.3.2.21 Use wildflower cover

Because of the hardy drought-resistant nature of wildflowers, in some cases they may be more beneficial as an erosion control practice than turf grass. Though not as dense as turf grass, wildflower thatches and associated grasses are expected to be as effective in erosion control and contaminant absorption. An additional benefit of wildflower thatches is providing habitat for wildlife, including insects and small mammals. Because thatches of wildflowers do not need fertilizers, pesticides, or herbicides, and watering is minimal, implementation of this practice may result in cost savings. A wildflower thatch requires several years to become established, but maintenance requirements are minimal once established. Native seeds should be used because they will be better adapted to local conditions. If possible, the seed source should be within 250 miles of the proposed project for promotion of native species.

8.3.3 Sediment Control Practices

Sediment controls capture sediment that is transported in runoff. Filtration and gravitational settling during detention are the main processes used to remove sediment from urban runoff. Table 8.5 shows cost and effectiveness information for several sediment control practices.

8.3.3.1 Install sediment basins

Sediment basins, also known as silt basins, are engineered impoundment structures that allow sediment to settle out of the urban runoff. They are installed prior to full-scale grading and remain in place until the disturbed portions of the drainage area are fully stabilized. They are generally located at the low point of sites, away from construction traffic, where they can be used to trap sediment-laden runoff. Basin dewatering is achieved either through a single riser and drainage hole leading to a suitable outlet on the downstream side of the embankment or through the gravel of the rock dam. In both cases, water is released at a substantially slower rate than would be possible without the control structure.

The following are general specifications for sediment basin design criteria as presented in Schueler (1997):

- Provide 1,800 to 3,600 cubic feet of storage per contributing acre (a number of states, including Maryland, Pennsylvania, Georgia, and Delaware, recently increased the storage requirement to 3,600 ft^3 or more [CWP, 1997b]).
- Surface area equivalent to 1 percent of drainage area (optional, seldom required).
- Riser with spillway capacity of 0.2 $ft^3/s/ac$ of drainage area (peak discharge for 2-year storm with 1-foot freeboard).
- Length-to-width ratio of 2 or greater.
- Basin side slopes no steeper than 2:1 (horizontal to vertical).
- Safety fencing, perforated riser, dewatering (optional, seldom required).

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Table 8.5: Cost and effectiveness for selected sediment control practices.

Practice	Percent TSS Removal	Effectiveness References	Cost (2001 dollars[a])	Cost References
Sediment basin	Average: 70% Range: 42%-100%	CWP, 1997d; Millen et al., No date; USEPA, 1993	For 50,000 ft^3 of storage space: Average: \$0.80/ft^3 Range: \$0.25–\$1.70/ft^3 storage For more than 50,000 ft^3 of storage space: Average: \$0.40/ft^3 Range: \$0.13–\$0.52/ft^3 storage	USEPA, 1993
Modified risers and skimmers	Single orifice: 83% Perforated risers: 68%–94% Perforated risers w/filter fabric: 79% Skimmer: 83%–97%	Jarrett, 1999, Schueler, 1997	NA	NA
Sediment trap	50%–70%	Stahre and Urbonas, 1990	Average: \$0.80/ft^3 storage Range: \$0.25–\$2.65/ft^3 storage Maintenance costs: 20% of installation costs	Brown and Schueler, 1997; USEPA, 1993
Silt fence	40%–100%	Barrett et al., 1995; Wishowski et al., 1998; CWP, 1997e	\$3.80–\$9.90/linear ft	SWRPC, 1991; USEPA, 1992
Inlet protection	NA	NA	\$65–\$131/inlet	USEPA, 1993
Stabilized construction entrance	NA	NA	Without wash rack: Average: \$2,620/entrance Range: \$1,310–\$5,240/entrance With wash rack: Average: \$3,930/entrance Range: \$1,310–\$6,550/entrance	USEPA, 1993
Vegetated filter strips	75-ft width: 54% 15-ft width: 84%	Yu et al., 1993	Established from existing vegetation: \$0 Established from seed: Average: \$530/acre Range: \$270–\$1,310/acre Established from sod: Average: \$14,190/acre Range: \$6,000–\$63,300/acre Note: Values do not include land costs or costs associated with installing a level spreader	USEPA, 1993

[a]Costs adjusted for inflation using the Bureau of Labor Statistics Inflation Calculator. NA: Not available

Sediment basins can be classified as either temporary or permanent structures, depending on the length of their service. If they are designed to function for less than 36 months, they are classified as temporary; otherwise, they are considered permanent. Temporary sediment basins can also be converted into permanent urban runoff management ponds. Conversion minimizes additional disturbance and can be used where it will be difficult to restore an area previously used as a temporary sediment basin. When sediment basins are designed as permanent structures, they must meet all standards for wet ponds. It is important to note that even the best-designed sediment basin seldom exceeds 60 to 75 percent TSS removal. This number should be taken into consideration when selecting a sediment control practice. As described above, trapping

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efficiency in sediment basins can be improved through the use of advanced sediment-settling controls.

8.3.3.2 Use modified risers and skimmers

Because traditional riser designs provide little treatment to remove sediments, efforts have been made to improve the design of sediment basins to facilitate greater pollutant removal. Modifications to traditional designs that improve sediment removal efficiency include using perforated risers or perforated risers wrapped in a gravel jacket or filter fabric. An alternative to the riser is a skimmer device that floats on the surface of water in the basin (Faircloth, 1999). The skimmer is made of a straight section of PVC pipe equipped with a float and attached with a flexible coupling to a flow-controlled outlet at the base of the riser. Because the skimmer floats, it rises and falls with the level of water in the basin and drains only the cleanest top layer of runoff. Since the skimmer falls to the bottom of the basin as the basin drains, it is capable of more thorough dewatering than a traditional riser, thereby restoring the maximum runoff storage capacity. The sediment-removal performance of basins equipped with skimmer dewatering devices has been shown to be nearly 97 percent for a simulated 2-year, 24-hour storm (Schueler, 1997).

Jarrett (1999) tested the sediment-removal effectiveness of several types of basins (outlet placement, deeper/shallower, barrier/no barrier) and outlet designs, including perforated risers (with and without filter fabric), single-orifice risers, and several sizes of skimmers. Table 8.6 shows the sediment retention efficiency results of Jarrett's different treatments.

Jarrett drew the following conclusions from his study:

- Perforated risers and single-orifice risers had similar sediment losses.
- Deeper permanent pools resulted in greater sediment removal.
- Sediment loss was attributed partly to resuspension and partly to basin erosion.
- Perforated risers resulted in 1.8 times greater sediment loss than skimmers when the outlet devices were placed in the principal spillway.
- Barriers that trisect basin volume reduced sediment loss when perforated risers were used but did not reduce sediment loss when skimmers were used.
- Silt-sized particles were most likely to be lost from sediment basins.
- Longer dewatering time resulted in less overall sediment loss.

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Table 8.6: Sediment retention efficiency[a] of sediment basins (Jarrett, 1999).

Treatment[b]	Outlet Control	Basin Size (m^3)	Hydrograph Volume Injected (m^3)	Emergency Spillway Used	Barrier Used	Dewatering Time (hr)	Permanent Pool Depth (m)	Sediment Loss (kg)	Sediment Retention Efficiency (%)
1	Perforated riser	140	100	No	No	24	0.15	32	79
2	Single orifice	140	100	No	No	24	0.15	26	83
5	Perforated Riser	140	100	No	No	24	0.46	1	92
6	Perforated riser with filter fabric	140	100	No	No	?	0.15	32	79
7	Skimmer	140	100	No	No	24	0.15	17	89
8	Perforated riser	140	100	No	Yes	24	0.15	24	84
9	Skimmer	140	100	No	No	24	0.15	20	87
10	Perforated riser	140	100	No	No	6	0.15	49	68
10	Perforated riser	140	100	No	No	168	0.15	9	94
10	Skimmer	140	100	No	No	6	0.15	22	86
10	Skimmer	140	100	No	No	168	0.15	5	97
11	Perforated riser	140	100	Yes	No	24	0.15	44	71
11	Skimmer	140	100	Yes	No	24	0.15	26	83
11a	Perforated riser	50	50	No	No	24	0.15	22	86
11a	Skimmer	50	50	No	No	24	0.15	7	95
3,4	Resuspension equaled 24% of sediment lost from basin								
3,4	Erosion from basin sides and bottom equaled 24% of sediment lost from basin								
1	Basin suspension was completely mixed during hydrograph inflow								
1	Basin suspension quickly stratified when inflow energy was reduced to zero								

[a]The 90 percent and greater TSS removal rates might be difficult to achieve in the field because (1) sizing criteria are much higher in Pennsylvania; (2) these were laboratory, not field, tests; and (3) maintenance was above average.
[b]In all treatments, effective soil injected was 154 kg.

8.3.3.3 Install sediment traps

Sediment traps are small impoundments that allow sediment to settle out of runoff water. They are typically installed in a drainageway or other point of discharge from a disturbed area. Temporary diversions can be used to direct runoff to the sediment trap. Sediment traps are ideal for sites 1 acre and smaller and should not be used for areas greater than 5 acres. They typically have a useful life of approximately 18 to 24 months. A sediment trap should be designed to maximize surface area for infiltration and sediment settling. This design increases the effectiveness of the trap and decreases the likeliness of backup during and after periods of high runoff intensity. The approximate storage capacity of each trap should be at least 1800 ft^3/acre of disturbed area draining into the trap (Smolen et al., 1988). (A number of states, including Maryland, Pennsylvania, Georgia, and Delaware, recently increased the storage requirement to 3,600 ft^3 or more [CWP, 1997b].)

8.3.3.4 Use silt fence

Silt fence, also known as filter fabric fence, is available in several mesh sizes from many manufacturers. Sediment is filtered out as runoff flows through the fabric. Such fences should be used only where there is sheet flow (no concentrated flow), and the maximum drainage area to the fence should be 0.5 acre or less per 100 feet of fence. To ensure sheet flow, a gravel collar or

level spreader can be used upslope of the fence. Many types of fabrics are available commercially. The characteristics that determine a fence's effectiveness include filtration efficiency, permeability, tensile strength, tear strength, ultraviolet resistance, pH effects, and creep resistance.

The longevity of silt fences depends heavily on proper installation and maintenance. CWP (1997d) identified several conditions that limit the effectiveness of silt fences:

- The length of the slope exceeds 50 feet for slopes of 5 to 10 percent, 25 feet for slopes of 10 to 20 percent, or 15 feet for slopes greater than 20 percent.
- The silt fence is not aligned parallel to the slope contours.
- The edges of the silt fence are not curved uphill, allowing flow to bypass the fence.
- The length of disturbed area draining to the fence is greater than 100 feet.
- The fence receives concentrated flow without reinforcement.
- The fence was installed below an outlet pipe or weir.
- The silt fence is upslope of the exposed area.
- The silt fence alignment does not consider construction traffic.
- Sediment deposits behind the silt fence reduce capacity and increase breach potential.
- The alignment of the silt fence mirrors the property line or limits of disturbance but does not reflect ESC needs.

EvTEC tests a static slicing silt fence installer

A static slicing silt fence installer was recently tested by EPA's Environmental Technology Evaluation Center (EvTEC, 2001). The goal of the testing was to determine if slicing was as better method than trenching with respect to performance, cost, and ease of use. The static slicing method, an alternative to traditional trenching methods, involves inserting a narrow custom-shaped blade at least 10 inches into the ground and simultaneously pulling silt fence fabric into the opening created as the blade is pulled through the ground. The tip of the blade is designed to slightly disrupt soil upward, preventing horizontal compaction of the soil and simultaneously creating an optimum soil condition for future mechanical compaction. Compaction follows using a tire on the tractor that pulls the slicing machine. Post-setting and driving, followed with attaching the fabric to the post, finalizes the installation.

EvTEC found that the slicer performed as well as or better than the best trenching method and was superior to less stringent methods of trenching. Slicing took less time (1.75 to 4 times faster) and was therefore cost-effective because of man-hour savings. The slicing method prevented runoff seepage and blowout better than most trenching methods and performed as well as the best trenching method. Overall, the static slicing method offers several advantages over traditional trenching methods, including maneuverability, minimal soil-handling and manual labor, consistent depth and compaction, and ease of installation in windy conditions, on steep side slopes, through rocky soils, and in saturated conditions.

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These conditions can be avoided with proper siting, installation, and maintenance. Silt fences typically have a useful life of approximately 6 to 12 months.

8.3.3.5 Install compost filter berms

Compost berms can be installed by spraying compost mixture along the perimeter of a denuded area to form a mound. The berms are designed to filter runoff by absorbing flows into the compost mixture's void space and gradually releasing them into the ground or offsite. They are usually installed at the bottom of a slope, but they also can be installed at the top of the denuded area to prevent clean runoff from entering exposed areas. Berms are typically installed in lieu of silt fence and are sized at 1 foot high and 2 feet wide (Tyler, 2001).

Compost berms can be used in conjunction with compost blankets (a sprayed layer of compost mix that functions as a mulch, see section 8.3.2.17); a berm at the top of the slope protects the compost blankets from erosion by preventing water from flowing underneath the protective layer, and a berm at the bottom of the slope provides filtration (Tyler, 2001).

Caine (2001) installed a triangular cross-section compost berm that was 16 to 18 inches high and 36 inches wide at its base. Installation cost was approximately $3.68 per linear foot. Runoff detention time was 17 to 26 minutes. Water was distributed throughout the berm and was released at multiple points. The berm filtered the runoff such that turbidity was reduced by 67 percent. Caine noted that the runoff mobilized humic and tannic acids from the organic material, causing the water passing through the berm to become discolored. One benefit of compost berms is that they do not require removal after construction is completed; they can be spread over the ground surface as topsoil or a soil amendment.

Mesh socks filled with composted material can be used in lieu of filter berms where the use of loose material is not practical, such as where flows might be concentrated near stream banks or shorelines (Goldstein, 2002). These filter socks function in the same manner as compost filter berms, but they are more contained.

8.3.3.6 Establish inlet protection

Inlet protection consists of a barrier placed around a storm drain inlet, which traps sediment before it enters the storm sewer system. There are five basic types of inlet protection structures: silt fence barriers, straw bale inlet barriers, block and gravel drop inlet filters, block and gravel curb inlet filters, and various excavated drop inlet protection measures (NAHB, 1995). The structures should be placed at the perimeter of the inlet structure. Inlet protection is appropriate for small drainage areas (1 acre or less) and can be used during rainy seasons (California Regional Water Quality Control Board, 1999). The structures can handle sheet flow with velocities less than 0.014 m^3/s; block and gravel barriers should be used in cases where concentrated flows exceed 0.014 m^3/s.

8.3.3.7 Designate and reinforce construction entrances

A construction entrance is a pad of gravel or rock over filter cloth located where traffic enters and leaves a construction site. As construction vehicles drive over the gravel, mud and sediment are collected from the vehicles' wheels. To maximize the effectiveness of this practice, the rock

pad should be at least 50 feet long and 10 to 12 feet wide. The gravel should be 1- to 2-inch aggregate 6 inches deep laid over a layer of filter fabric. Maintenance might include pressure-washing the gravel to remove accumulated sediments and adding more rock to maintain adequate thickness. Runoff from this entrance should be treated before exiting the site. This practice can be combined with a designated truck wash-down station to ensure sediment is not transported off-site.

8.3.3.8 Install vegetated filter strips

Vegetated filter strips are low-gradient vegetated areas that are planted and used to filter overland sheet flow. Runoff must be evenly distributed across the filter strip. Channelized flows decrease the effectiveness of filter strips. Level spreading devices are often used to distribute the runoff evenly across the strip (Dillaha et al., 1989).

Vegetated filter strips should have relatively low slopes and adequate length and should be planted with erosion-resistant plant species. The main factors that influence the removal efficiency are the vegetation type, soil infiltration rate, and flow depth and travel time. These factors are dependent on the contributing drainage area, slope of strip, degree and type of vegetative cover, and strip length. Maintenance requirements for vegetated filter strips include sediment removal and inspections to ensure that dense, vigorous vegetation is established and concentrated flows do not occur.

8.3.3.9 Use vegetated buffers

Like filter strips, vegetated buffers provide a physical separation between a construction site and a water body. The difference between a filter strip and a vegetated buffer area is that a filter strip is an engineered system (soils, plants, slope, width, depth), whereas a buffer is a naturally occurring filter system. Vegetated buffers remove nutrients and other pollutants from runoff, trap sediments, and shade the water body to optimize light and temperature conditions for aquatic plants and animals (Welsch, no date). Preservation of vegetation for a buffer should be planned before any site-disturbing activities begin to minimize the impact of construction activities on existing vegetation. Trees should be clearly marked at the drip-line to preserve them and to protect them from ground disturbances around the base of the tree.

Proper maintenance of buffer vegetation is important. Maintenance requirements depend on the plant species chosen, soil types, and climatic conditions. Maintenance activities typically include fertilizing, liming, irrigating, pruning, controlling weeds and pests, and repairing protective markers (e.g., fluorescent fences and flags).

8.3.4 Develop and Implement Programs to Control Chemicals and Other Construction Materials

8.3.4.1 Develop and implement a materials management program

Areas where materials are stored at a construction site can be sources of runoff contamination due to poor housekeeping and accidental spills. Improving storage and materials management

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practices will help minimize exposure and risk. Erodible or potentially hazardous materials should be stored in such a manner as to prevent contact with rainfall or runoff. In general, materials should be stored in a secure, dry, covered area that is equipped with an impermeable floor and berms to prevent spills from reaching surrounding soils, ground water, and surface water. Conducting an inventory of all materials used on-site and assessing the potential they pose for contact with runoff will help in implementing effective controls.

Properly store, handle, and apply pesticides. In general, pesticides should be used only when absolutely necessary. Instructions listed on the packaging should be followed when using, handling, or disposing of these chemicals. Consideration should be given to local regulations that may govern the use or disposal of pesticide chemicals or their containers. To reduce the risk of contaminating runoff, the following practices should be implemented:

- Store pesticides in a secure, dry, covered area that has an impermeable floor.
- Provide curbs or dikes around the storage area to prevent spills and leaks from reaching unprotected areas.
- Provide site personnel with the proper pesticide spill response training and have adequate measures on-site to contain and clean up pesticide spills.
- Strictly follow recommended application rates and application methods.
- Handle pesticide wastes appropriately. Many pesticides are considered hazardous wastes when they are disposed of. Pesticide wastes should be managed as required by all applicable waste regulations.

Properly store, handle, and apply petroleum products. The following practices can help to reduce the risk of runoff contamination from petroleum products:

- Store petroleum products in designated areas that are covered, have impermeable floors, and are surrounded with dikes, berms, or absorbent pads to contain any spills.
- Provide site personnel with the proper spill response training and have adequate measures on-site to contain and clean up petroleum spills. Store spill cleanup equipment in fuel storage areas or on board maintenance and fueling vehicles.
- Conduct periodic preventive maintenance of on-site equipment and vehicles to prevent leaks.

Properly store, handle, and apply fertilizers and detergents. A number of steps can be taken to reduce the risks of nutrient pollution:

- Minimize the use of fertilizers and detergents. Determine the smallest amounts needed for the tasks at hand and avoid using unnecessary amounts. Apply fertilizers and use detergents only in the recommended manner and never in amounts greater than those recommended.

- When applying fertilizers to soil, apply them at a depth of 2 to 6 inches and not on the surface. This approach will limit the contact between runoff and nutrients.

- Apply fertilizers more frequently but at lower application rates.

- Implement appropriate erosion and sediment control practices that will control and limit the amount of nutrients leaving the site due to attachment to soil particles.

- Conduct washing/cleaning operations in designated areas that are equipped to contain wash water and prevent it from being discharged to the site runoff collection and conveyance system.

- Do not mix surplus products together unless following specific instructions from the manufacturer.

Properly store, handle, and apply hazardous products. Most problems associated with the disposal of hazardous materials are the result of carelessness, not following recommended procedures, or not using common sense. The following suggestions are meant to provide general guidance for disposal of hazardous materials:

- Determine what hazardous materials are being used on-site and which hazardous waste streams, if any, are generated as a result of construction activities. Once all of the hazardous materials used and hazardous wastes generated are identified, it is possible to implement an appropriate waste management and disposal strategy.

- Know the applicable hazardous waste regulations and the associated requirements for storing, marking, and disposing of wastes. Someone on-site should be trained to properly manage hazardous wastes. If waste disposal obligations are not clearly understood, contact the correct regulatory agency to find out what specific requirements must be followed.

- Use as much of a product as possible before disposing of containers. Containers that are not empty but have been stored for disposal can be sources of drips, leaks, or spills, and they can contaminate landfills or other disposal areas.

- Do not remove the original product label from the container. It contains important use, safety, and disposal information about the product.

8.3.4.2 Develop and implement a spill control plan

Construction sites should be equipped with suitable equipment to contain and clean up spills of hazardous materials in the areas where the materials are stored or used. Accidental spills of materials used at construction sites can be sources of runoff pollution if not addressed appropriately. All spills should be cleaned up immediately after they occur. Creation of a site-specific spill control and response plan in combination with spill response training for designated on-site personnel can be effective in dealing with accidental spills and preventing the contamination of soil, water, and runoff. Preparation of a spill containment, control, and countermeasures (SPCC) plan might be required to meet regulatory requirements (e.g.,

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requirements regarding storage of specified chemicals above certain volume thresholds). Site managers should be aware of all applicable requirements and should contact regulatory authorities if requirements are not known.

Even if a formal plan is not required, preparing one is a good idea. In general, an SPCC plan should include guidance to site personnel on the following:

- Proper notification when a spill occurs;
- Site responsibility with respect to addressing the cleanup of a spill;
- Stopping the source of a spill;
- Cleaning up a spill;
- Proper disposal of materials contaminated by the spill;
- Location of spill response equipment programs; and
- Training for designated on-site personnel.

A periodic spill "fire drill" should be conducted to help train personnel on proper responses to spills and to keep response actions fresh in their minds.

8.3.4.3 Develop and implement a waste disposal program

Implementation of good waste disposal practices at construction sites can help to significantly reduce the potential for runoff contamination. Wastes generated at construction sites can include surplus maintenance chemicals, refuse building materials, hazardous wastes, or contaminated soil and spill cleanup materials. General practices to manage such wastes include solid waste disposal, recycling, hazardous waste management, and spill prevention and cleanup measures.

(1) *Develop procedures for disposal of construction wastes*. Construction projects can generate a significant amount of what is commonly referred to as "construction wastes." Such wastes are unique to the activity and might include the following:

- Trees and shrubs removed during clearing and grubbing;
- Packaging materials such as wood, paper, plastic, and polystyrene;
- Scrap or surplus building materials such as scrap metal, rubber, plastic, glass, and masonry;
- Paints and paint thinners; and
- Demolition debris such as concrete rubble, asphalt, and brick.

To ensure proper disposal of construction wastes, the following steps should be followed:

- Select a designated on-site waste collection area.
- Provide an adequate number of containers with lids or covers that can be placed over the containers prior to rainfall.

- Locate containers in a covered area when possible.
- Arrange for waste collection before containers overflow.
- Explore recycling options for specific wastes generated at the site. Wastes such as used oil, used solvents, and construction debris can often be reclaimed or recycled, thereby reducing the amount of waste actually requiring permanent disposal. Numerous companies can provide recycling services, including the provision and maintenance of on-site recycling containers.
- Implement appropriate response procedures immediately when a spill does occur.
- Plan for additional containers and more frequent pickups during the demolition phase of construction activities.
- Ensure that all construction wastes are disposed of at facilities authorized to receive such wastes.

(2) *Develop procedures for disposal of hazardous products*. The correct method of disposal of hazardous products varies with the product used. Follow the manufacturer's recommended method as printed on the product label.

(3) *Develop procedures for disposal of contaminated soils*. Options for disposal of contaminated soil depend on the nature of the soil contamination. Under no circumstances should contaminated soils be disposed of in adjoining properties or in swamps or other wetlands because they will still pose a threat to surface and ground water. The appropriate solid and/or hazardous waste regulatory agency should be contacted concerning the proper procedures for characterizing, removing, and disposing of contaminated soil. Typically, contaminated soils can either be excavated and removed or cleaned on-site. In situ techniques include applying chemicals that break down or neutralize the contaminant, venting or sparging the soil to oxidize the contaminant, and using biological treatment to metabolize and destroy the contaminant.

(4) *Develop procedures for disposal of concrete truck waste*. Many construction projects include the use of concrete. Usually the concrete is mixed off-site and delivered to the project by truck. The concrete is poured and a residual amount of concrete remains in the truck, or the concrete is found to be unacceptable and is rejected by the construction inspector or foreman. The truck may be cleaned of residual concrete on-site. Excess concrete and wash water should be disposed of in a manner that prevents contact between these materials and runoff. For example, dikes could be constructed around the area to contain these materials until they harden, at which time they can be properly disposed of.

(5) *Develop procedures for disposal of sandblasting grits*. Sandblasting is frequently used to remove paint and dirt from surfaces. The grit generated contains both the spent blasting grit (commonly sand or steel granules) and the particles of paint or dirt removed from the surface. Sandblasting residue can be a hazardous waste if the material removed contains hazardous metals such as cadmium, lead, and chromium, which are sometimes found in paints. For this reason, sandblasting residue should not be allowed to be released to the ground or discharged

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to a storm sewer or sanitary sewer, where it can cause soil or water contamination. Instead, it should be evaluated to determine whether it constitutes a hazardous waste. If determined to be a hazardous waste, it should be properly handled and disposed of; if not a hazardous waste, it should be properly managed and disposed of as a solid waste. Dumping wastes into sewers and other drainage channels is illegal and can result in fines or job shutdown (USEPA, 1993).

(6) *Develop procedures for disposal of sanitary wastes.* Construction sites usually are equipped with temporary sanitary facilities such as portable toilets for on-site personnel. Sanitary wastes can also be disposed of through septic systems or sanitary sewers. The type of facilities used on-site will dictate the appropriate management practices used to deal with the wastes. Domestic waste haulers should be contracted to regularly remove the sanitary and septic wastes and to maintain the facilities in good working condition. This maintenance will help to prevent overloading of the system, which could result in discharges in runoff. All septic systems should be installed, operated, and maintained in accordance with appropriate regulations. Any discharges to the sanitary sewer systems should be done in accordance with local sewer authority regulations.

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8.4 Information Resources

EPA's National Menu of Best Management Practices for Stormwater Phase II developed numerous fact sheets describing management practices for construction site operators. The fact sheets cover both erosion control and sediment control topics, and they include sections for applicability, design considerations, costs, and effectiveness. They are available on EPA's Web site at http://www.epa.gov/npdes/menuofbmps (select "Construction Site Stormwater Runoff Control").

California's *Storm Water Best Management Practice Handbook: Construction* outlines waste management practices in a set of fact sheets that include erosion controls (scheduling, velocity dissipation devices, slope drains, stream bank stabilization, polyacrylamide, preservation of existing vegetation, hydraulic mulch, hydroseeding, soil binders, straw mulch, geotextiles and mats, wood mulching, earth dikes, and drainage swales), sediment controls (silt fence, storm drain inlet protection, chemical treatment, sediment basins, sediment traps, check dams, fiber rolls, gravel bag berms, street sweeping and vacuuming, sandbag barriers, straw bale barriers, stabilized construction entrances and exits, stabilized construction roadways, entrance/outlet tire washing), and wind erosion control. It can be downloaded in PDF format from http://www.cabmphandbooks.org/Construction.asp.

The *Erosion and Sediment Control Field Manual* from the San Francisco Regional Water Quality Control Board describes management practices for construction site planning and management, erosion and sediment control, pollution prevention, and sampling guidelines. Descriptions of practices are concise and include full-color graphics and installation information including guidelines, timing, and limitations. The manual also includes the new Phase II regulations, sampling and monitoring guidelines, and long-term maintenance information. Also available are several erosion and sediment control videos (in English and Spanish); guidelines for construction projects; a CD training kit for construction site planning and management for compliance with NPDES requirements; and the1999 version of the *Erosion and Sediment Control Field Manual.* It can be purchased for $30 at http://store.abag.ca.gov/construction.asp.

The *Kentucky Erosion Prevention and Sediment Control Field Guide* from the Kentucky Division of Water covers the entire erosion and sediment control process. The guide begins with sections on pre-project planning and operational activities and continues with erosion prevention and sediment control by starting at the top of the hill, above the project site, and proceeding down the slope through the bare soil area, ditches and channels, traps and basins, and to the waterways below. The guide can be downloaded in PDF format from http://www.water.ky.gov/sw/nps/Publications.htm.

The Minnesota Local Technical Assistance Program offers courses, videos, and guidebooks pertaining to erosion control and drainage. More information about these products can be found at http://www.mnltap.umn.edu/.

There are several research laboratories that conduct independent testing of erosion control products. The Texas Transportation Institute's Hydraulics, Sedimentation, and Erosion Control Laboratory conducts side-by-side, full-scale, performance comparisons of roll-type erosion control materials and flexible channel liners. Product testing information can be found at

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http://tti.tamu.edu/enviro_mgmt/facilities/hec/. The St. Anthony Falls Laboratory has an "applied research" Web page (http://www.safl.umn.edu/research/applied/index.html) with links to studies gauging the effectiveness of erosion control products.

Storm Water Management for Construction Activities: Developing Pollution Prevention Plans and Best Management Practices (USEPA, 1992), published by EPA's Office of Wastewater Management, provides summary guidance on the development of storm water pollution prevention plans and helps users select appropriate management practices to control erosion and sediment loss resulting from construction activities. It was designed to provide technical support for construction activities that are subject to pollution prevention requirements under NPDES permits for storm water point source discharges. This document can be viewed in PDF format at http://www.epa.gov/npdes/pubs/owm0307.pdf or it can be ordered from the National Service Center for Environmental Publications (NSCEP) at http://www.epa.gov/ncepihom/index.htm or by calling 513-489-8190 (Publication # EPA 833-R-92-001).

CPESC, Inc. offers certification for erosion and sediment control professionals. This program is sponsored by the Soil and Water Conservation Society and the International Erosion Control Association to educate field professionals on the best methods for controlling erosion and sediment and to provide evidence of professional qualifications. More information about the certification program can be found at http://www.cpesc.net.

The City of Knoxville, Tennessee, developed a manual that describes storm water management practices that the city recommends. The manual includes an introduction to storm water management practices, a discussion of the theory of erosion control, steps for selecting practices, and detailed fact sheets for each practice that include design, inspection, and maintenance information. The fact sheets cover four subject areas: activities and methods, erosion and sediment, industrial and commercial, and storm water treatment. The manual can be downloaded in PDF format at http://www.ci.knoxville.tn.us/engineering/bmp_manual.

The Delaware Department of Natural Resources and Environmental Control has assembled course materials and associated standards and specifications that contain descriptions of Delaware's BMPs for erosion, sediment, and runoff control, as well as their certification requirements for contractors. These materials, entitled *Sediment and Stormwater Management Certified Construction Reviewer Course and Associated Delaware State and DOT Standards/Specifications*, can be obtained by calling 302-739-4411.

The North Carolina Department of Environment, Health, and Natural Resources (NCDEHNR, no date) developed a suite of references pertaining to erosion and sediment control, including the *Erosion and Sediment Control Planning and Design Manual*, which provides extensive details and procedures for developing site-specific erosion and sedimentation control plans. The *North Carolina Erosion and Sediment Control Field Manual* is a conveniently sized field reference for construction and installation of erosion and sedimentation control measures and devices (does not include design charts). The *North Carolina Sediment Control Inspector's Guide* explains how to conduct inspections and evaluate projects, what to look for, and how to interact with customers. The *North Carolina Erosion and Sediment Control Practices: Video Modules* demonstrate the actual construction of 12 of the most commonly installed erosion and sediment

control measures. Information for purchasing these materials can be found at the NCDEHNR Web site at http://www.dlr.enr.state.nc.us/pages/sedimentation.html.

The Texas Department of Transportation developed specifications for the use of compost for erosion control in the form of temporary erosion control devices and biodegradable erosion control logs. These specifications include a description of the practice, materials required, and construction, installation, and maintenance of the control. The specifications and other information about the use of compost for erosion control can be found at the Texas Department of Transportation Web site at http://www.dot.state.tx.us/des/landscape/compost/specifications.htm.

The Composting Council Research and Education Foundation and the U.S. Composting Council (no date) developed a manual describing ways in which compost can be used for state highway projects. The manual includes case study examples of compost use for slope stabilization, vegetation establishment, and erosion and sediment control; compost specifications and analytical testing methods; and statistics describing compost usage. *Compost Use on State Highway Applications* can be downloaded in PDF format from http://www.epa.gov/epaoswer/non-hw/compost/highway/.

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MANAGEMENT MEASURE 9
POLLUTION PREVENTION

9.1 Management Measure

Implement pollution prevention and education programs to reduce nonpoint source pollutants generated from the following activities:

- The improper storage, use, and disposal of household chemicals, including automobile fluids, pesticides, paints, solvents, etc.;
- Lawn and garden activities, including the improper application and disposal of lawn and garden care products, and the disposal of leaves and yard trimmings;
- Turf management on golf courses, parks, and recreational areas;
- Commercial activities, including parking lots and gas stations;
- Improper disposal of pet wastes; and
- Activities that generate trash.

9.2 Management Measure Description and Selection

9.2.1 Description

This management measure is intended to prevent or reduce nonpoint source pollutant loadings generated from a variety of activities within urban areas. Everyday activities of citizens, municipal employees, and businesses have the potential to contribute to nonpoint source pollutant loadings. These activities include improper use and disposal of household chemicals, lawn and garden maintenance, turf grass management, operation and maintenance of diesel and gasoline vehicles, illicit discharges to urban runoff conveyances, commercial activities, and improper pet waste disposal. Reducing pollutant generation can decrease adverse water quality impacts from these sources.

The practices presented in this management measure are often referred to as source reduction practices. They are nonstructural in nature (i.e., they do not require infrastructure) and can be used to reduce pollutant generation and maintenance costs. Source control practice costs are typically associated with programmatic expenses such as signage, outreach materials, workshops, and development and enforcement of ordinances. Although agricultural sources are not specifically addressed in this chapter, agricultural sources in an urban or suburban watershed should also be considered when developing a pollution prevention plan (see Management Measure 1 – Program Framework and Objectives). Source controls for agriculture can be found

Getting in Step: A Guide to Effective Outreach in Your Watershed

Getting in Step is a guide published by EPA to provide a summary of useful tools for developing and implementing an effective watershed outreach plan. The manual uses a step-by-step approach to help watershed practitioners address public perceptions, promote management activities, and inform or motivate stakeholders. Getting in Step is divided into three parts, as follows:

- Part I presents the overall framework for developing and implementing an outreach plan. It provides specific information about defining goals and objectives; identifying the target audience; creating, packaging, and distributing the message; and evaluating the outreach plan.
- Part II provides tips and examples for developing and enhancing outreach materials, with emphasis on elements of composition and layout, using artwork and photos, establishing a watershed identity, packaging the watershed message, and estimating costs.
- Part III provides specific tips on working with the news media to gain improved media coverage of water quality issues.

Getting in Step also includes worksheets, graphics for use without permission, and information on additional outreach and education resources. The manual is available for download from http://www.epa.gov/owow/watershed/outreach/documents/getnstep.pdf or by calling Books on Demand at 1-800-521-3042.

in *National Management Measures to Control Nonpoint Source Pollution from Agriculture*, which can be accessed at http://www.epa.gov/owow/nps/agmm/index.html.

9.2.1.1 Household chemicals

Many everyday household chemicals are flammable, combustible, toxic, explosive/reactive, or corrosive. If these chemicals are released into the environment, they can pose long-term threats to human health, wildlife, vegetation, and other environmental resources. Unlike industrial hazardous wastes, not all household chemicals are regulated by federal, state, and local laws. In fact, the Federal Resource Conservation and Recovery Act, which regulates hazardous waste, has a special exemption for "household hazardous wastes" as defined in the act (Kopel, 1998). It is important to note that state and local regulations may be more stringent than federal regulations. The Federal Insecticide, Fungicide, and Rodenticide Act regulates the use and disposal of pesticides, herbicides, and fungicides through labeling. It is important that users of these chemicals follow label instructions carefully, because they provide specific information that help prevent harm to human and environmental health.

The four main avenues for household chemicals to become problem pollutants are through leaks and spills, improper use, improper storage, and improper disposal.

(1) *Leaks and spills*. Chemicals leaking from improperly maintained automobiles and lawn equipment or faulty containers can accumulate on roads, driveways, and lawns and be carried by runoff to receiving water bodies.

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(2) *Improper use*. Failure to follow label instructions properly may result in over-application of fertilizers or pesticides and can lead to chemical accumulation in the soil and grass. These chemicals can leach to ground water or be carried by runoff to surface waters.

(3) *Improper storage*. Improper storage of chemicals can lead to spills that can contaminate runoff and ground water or result in dangerous chemical reactions.

(4) *Improper disposal*. It is a common practice for citizens to pour unwanted chemicals, such as detergents, cleansers, or automotive fluids, onto their lawns or driveways or directly down storm drains. Contrary to popular belief, most storm sewers do not connect to wastewater treatment plants—chemicals disposed of this way could be discharged directly to receiving water bodies. Additionally, when chemicals are poured down drains connected to a wastewater treatment plant or septic system, they could interfere with treatment systems by killing the bacteria that metabolize pollutants, causing water discharged from the plants to be contaminated. Ground water is also at risk because runoff can carry these chemicals through the soil to the water table. Product labels describe requirements for proper disposal and should be followed carefully.

(5) *Outdoor car washing*. This activity can result in high loads of nutrients, metals, and hydrocarbons being carried to receiving waters during dry weather conditions when the wash water flows into the storm drain system. According to surveys, 50 to 75 percent of households wash their own cars and 60 percent of those households wash their cars at least once a month (Schueler and Swann, 2000b).

9.2.1.2 Failing septic systems

Approximately one in four American households relies on a septic system to dispose of their wastewater. Septic systems have a failure rate of 5 to 35 percent, depending on soil conditions and other factors. When septic systems fail, the untreated or partially treated wastewater discharges to surface and ground waters. A survey conducted in the Chesapeake Bay watershed found that the average age of septic systems in the area was about 27 years, which is seven years beyond the design life of an unmaintained system. About half the owners indicated that they had not inspected or cleaned out their system in the previous three years. (Schueler and Swann, 2000b).

9.2.1.3 Lawn and garden activities

Lawn care practices are often targeted by watershed managers as contributors of pesticides and nutrients to runoff. A nationwide study by the U.S. Geological Survey (USGS) in 1999 found a high incidence of insecticides and herbicides in urban streams. Insecticides commonly used in homes, gardens, and commercial areas were found more frequently and in higher concentrations in urban streams than in agricultural streams. These concentrations often exceeded guidelines for the protection of aquatic life. Herbicides, such as those used for weed control, were found in 99 percent of sampled streams, but rarely at levels that exceeded guidelines.

A recent summary of the water quality monitoring efforts by USGS's National Water Quality Assessment Program (2004) revealed high concentrations of pesticides, most commonly diazinon, malathion, chlorpyrifos, and carbaryl, in urban waterways; these chemicals were

typically found in higher concentrations in urban streams than in agricultural streams. Although several of these pesticides are used commonly in household applications, findings in Thornton Creek near Seattle suggested that many of the pesticides were from commercial or municipal activities because the chemicals are not readily available on the retail market.

Surveys showed that roughly half of the total diazinon applications in the San Francisco Bay Region were to lawns and landscaped areas. In 1995, 27 percent of urban creeks sampled in the San Francisco Bay Region demonstrated potentially toxic levels of diazinon (Katznelson and Mumley, 1997). Research on diazinon indicates that even proper use, characterized by following label instructions, can result in harmful levels of diazinon in urban streams (Schueler and Swann, 2000d).

While these results alone do not specify the relative contribution of lawn care activities to urban pollution, they do indicate that there is a need for watershed-specific management actions. Many aspects of the risks associated with commonly occurring pesticides in the environment are not yet clearly understood. Drinking water standards have only been established for 10 of the 75 pesticides detected by the USGS National Water Quality Analysis**,** and aquatic life criteria have been developed for only six (Graffy, 1998; USGS, 1999).

Maintaining a healthy lawn might require fertilizers, pesticides, and heavy watering in some areas. Overuse of fertilizers, pesticides, and water can lead to excessive growth, increased pest problems, and environmental damage. In terms of fertilizer inputs, nutrients typically are applied to lawns at about the same rates as for row crops. One study in Marquette, Michigan, indicated that nitrogen and phosphorus concentrations in runoff from lawns were five to 10 times higher than runoff from other land uses (Schueler and Swann, 2000e). Contrary to popular belief, it is possible to achieve a beautifully landscaped yard with judicious use of fertilizers, pesticides, and irrigation. A large body of literature by turf researchers shows that healthy and well-managed turf grass can actually slow runoff and trap pollutants (Beard and Green, 1994; Schueler and Swann, 2000c; USEPA, 1992). The products applied to lawns—fertilizers, pesticides, and herbicides—can pollute runoff if label instructions are not properly followed. Studies on the characteristics of urban lawns have shown that the soils are often compacted, increasing runoff to the point that it is comparable to runoff on some pavements (NCSCS, 2000). Fertilizers contain nitrogen and phosphorus, which become pollutants when runoff carries excess fertilizers into lakes and streams. Excessive nutrients stimulate algae growth that can lead to death and decay of aquatic vegetation due to light and oxygen deprivation.

Lawns also require physical maintenance in the form of mowing, raking, and removing weeds, clippings, and branches. Yard trimmings comprised 12 percent of the total tonnage of municipal solid waste generated in 2000, second only to paper products (USEPA, 2002). Alternative practices can reduce the quantity of yard wastes generated by lawns and enable reuse of yard wastes to extend the capacity of landfills.

9.2.1.4 Commercial activities

Runoff from commercial land uses, such as shopping centers, office parks, and parking lots or garages may contain high hydrocarbon loadings and metal concentrations that are twice those found in the average urban area. These loadings can be attributed to heavy traffic volumes and

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large areas of impervious surface on which automotive-related pollutants concentrate (refer to Management Measure 7, Bridges and Highways, for a discussion of automobile-related pollutants). Other commercial uses, such as vehicle maintenance, liquids storage, and equipment storage and maintenance, can also introduce pollutants to runoff.

In most communities, gas stations are designated as a commercial land use and are subject to the same controls as shopping centers and office parks. However, gas stations may generate high concentrations of heavy metals, hydrocarbons, and other automobile-related pollutants. Since gas stations have high potential loadings and pollutant profiles similar to those of industrial sites, good housekeeping controls, such as those used on industrial sites, are recommended.

Restaurants are sometimes considered hot spots for nonpoint source pollution because they generate oils and grease that can contaminate runoff when disposed of improperly. Grease can also clog sanitary sewer laterals if sinks are not equipped with grease traps or interceptors, resulting in sanitary sewer overflows and increased maintenance of sewer lines. Poor housekeeping practices in the outdoor areas of restaurants, such as storing food waste in uncovered or leaky garbage bins and dumpsters or hosing off floor mats in the parking lot, can cause bacteria, detergents, organic matter, and other pollutants to come into contact with runoff.

Municipalities can target pollution prevention campaigns to specific commercial activities that are suspected of contributing to nonpoint source pollution. Typically, these campaigns involve an assessment of commercial facilities to identify the types of waste produced. The campaigns also outline methods to reduce the total amount of pollutants generated on-site and to properly dispose of pollutants. A set of rules and use limitations that a commercial tenant must agree to as a condition of occupying a site can be implemented in commercial covenants, conditions, and restrictions.

9.2.1.5 Pet wastes

When pet waste is not properly disposed of, it can wash into nearby water bodies or be carried by runoff into storm drains. Since most urban storm drains do not connect to treatment facilities, but rather drain directly into lakes and streams, untreated animal waste can become a significant source of runoff pollution. As pet waste decays in a water body, the degradation process uses oxygen and sometimes releases ammonia. Low oxygen levels and the presence of ammonia, combined with warm temperatures, can be toxic to fish and aquatic life. Pet waste also contains nutrients that promote weed and algae growth. Perhaps most importantly, pet waste carries microbes, such as bacteria, viruses, and parasites, that can pose a health risk to humans and wildlife. For example, fatalities in sea otters off the coast of California have been traced to a protozoan, *Toxoplasma gondii*, found in cat feces. *T. gondii* can cause fatal brain infections in otters and muscle cysts in humans (Glausiusz, 2002). Pet waste can be controlled through enforcement of ordinances (e.g., warnings and citations, public education, signage, and disposal containers).

9.2.1.6 Trash

Trash and floating debris in waterways have become significant pollutants, especially near urban areas where a large volume of trash can be generated in a concentrated area. Trash contributes to

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visual pollution and detracts from the aesthetic qualities of the landscape. Boaters have complained that trash and debris clog engine intake valves and propellers, resulting in expensive repairs. Finally, municipalities must incur the cost of clean-up efforts to restore water quality.

9.2.2 Management Measure Selection

This management measure was selected to identify ways in which communities can implement practices that bring about behavioral changes to reduce nonpoint source pollutant loading from the sources listed in the management measure. Such activities include public education, proper management of maintained landscapes, source reduction, training and runoff control plans for commercial sources, pet waste management activities, and trash control. Communities can select practices that best fit local priorities and funding. It is important for the watershed manager to note that community acceptance is often the major determinant of whether education and outreach activities and administrative mechanisms such as certification and training requirements are practical and effective solutions.

9.3 Management Practices

9.3.1 Household Chemicals

A host of biodegradable cleaners and other less-toxic chemicals are commercially available. Such alternative products typically contain chemicals that rapidly break down in soil and water into fewer toxic constituents, or they are reusable or recyclable. These include low-phosphate or phosphate-free detergents and water-based products. These alternative products can be used in combination with traditional chemicals as part of an integrated pest management program or for everyday household cleaning. Although there may be instances when it is necessary to use stronger chemicals (for example, to target bacteria), often a simple, milder cleanser will do the job.

Although alternative products are generally less harmful than commercial cleaners, it is still just as important to follow their instructions for proper storage and handling. Alternative products and homemade mixtures should be stored in clean, store-bought containers and properly labeled to avoid confusion with food or drink (USEPA, no date; USEPA and Perdue University, 1997). While some alternative products may claim to be disinfectants, cleaners that are registered as disinfectants must meet EPA testing requirements. The EPA's *Source Reduction Alternatives Around the Home*, which is part of the *Consumer Handbook for Reducing Solid Waste*, provides a brief discussion of alternative cleaning methods as well as proper storage and handling procedures (USEPA, no date).

A 1994 study compared commercial cleaners with various alternative products, including lemon juice, vinegar, ammonia, baking soda, and borax. The study found that commercial cleaners were more effective than the alternatives at both soil removal and microbial reduction. Alternative cleaners were found to achieve soil removal with some additional work. Among the alternative cleaners, borax and ammonia were most effective at soil removal. Vinegar was most effective in reducing microbial contamination. The study recommended sequential use to maximize cleaning effectiveness (USEPA and Purdue University, no date).

The key to preventing household chemicals from entering receiving waters is to educate the public about the importance of taking care when storing and disposing of everyday materials.

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The practices discussed below are intended to inform the public on proper procedures for handling and disposing of household chemicals to prevent pollution and to instill a sense of responsibility for their actions and choices as consumers.

9.3.1.1 Educate the public on proper storage and disposal of household chemicals

Watershed managers can produce outreach materials describing methods that citizens should follow to store household chemicals in appropriate containers and storage areas to prevent leaks, spills, accidental ingestion, and fire or explosion hazards. Tips can include covering piles of chemicals that can come into contact with rainfall or runoff; ensuring that containers for volatile, corrosive, or otherwise harmful chemicals are intact; and clearly labeling all containers with the name of the material and proper storage and disposal procedures. Pesticides, herbicides, and fungicides are addressed below in the Pest Management section.

Citizens should also be encouraged to follow the manufacturer's recommendations for disposal of household chemicals. Many communities across the country have implemented programs to collect and safely dispose of these chemicals, such as providing year-round collection facilities or sponsoring what many communities call “household hazardous waste” collection days. Effective outreach programs keep citizens informed about the location and hours of operation of disposal facilities and provide a list of waste products that are accepted.

Recycling of certain household chemicals, especially used oil and batteries, can reduce the amount of potentially harmful materials that enter a landfill. Many municipalities and automotive service stations provide used oil and antifreeze recycling facilities for “do-it-yourselfers” to encourage environmentally sound chemical management. Outreach materials, such as pamphlets and utility bill inserts, can be developed to inform the public of locations and hours of operation of local recycling facilities.

9.3.1.2 Conduct storm drain marking

Storm drain marking involves labeling storm drain inlets with painted or prefabricated messages that warn citizens of the environmental hazards of dumping materials into storm drains. Marking projects are typically conducted by volunteer groups in cooperation with local authorities. The messages can be a simple phrase to remind passersby that the storm drains connect to local water bodies and that dumping pollutes those waters. Some specify which water body the inlet drains to or name the particular river, lake, or bay. Common messages include “No Dumping—Drains to Water Source,” “Drains to River,” and “You Dump it, You Drink it. No Waste Here.” Communities with a large Spanish-speaking population might wish to develop markers in both English and Spanish or use a graphic without text (Davenport, 2003).

9.3.1.3 Encourage responsible car washing practices

Schueler and Swann (2000b) summarized results of several surveys of automobile owners and their car washing behavior. The researchers found that 55 to 70 percent of households wash their own cars, with the remainder taking their cars to commercial car washes. Sixty percent of residents washed their cars at least once a month, and between 70 and 90 percent of residents reported that their car wash water drained directly to the street and presumably into the runoff conveyance system. These results indicate that an appreciable amount of wash water laden with

detergents, dirt, and automotive fluids can wash into the storm drain system or directly into receiving waters in urban areas.

It is preferable for citizens to patronize commercial car washing facilities because they are mandated under the regulatory authority of the NPDES program (see the Introduction for a description of the NPDES program) to treat and/or reuse wash water, whereas residential car washing activities are exempt from requirements under Phase I MS4 permits and Phase II general permits (USEPA, 2003b). If commercial facilities are not available or if residents prefer to wash their cars themselves, they should be encouraged to wash their cars less often, especially in areas with water bodies sensitive to nutrient enrichment. Another practice to reduce the impact of car washing on receiving waters is to wash cars on grass or another permeable surface to filter dirt and detergents (this practice should be avoided in areas that recharge drinking water supplies). Additionally, citizens should use a sponge and bucket to reduce the amount of wash water used and to allow it to be disposed of down a household drain that is connected to the sanitary sewer or septic system. Finally, low-phosphate detergents should be used to minimize the eutrophic effects of wash water in receiving waters.

Community car washes, such as those conducted for fundraisers, are not specifically addressed in Phase II MS4 requirements, but may be a particularly large source of contaminated runoff. Some communities are experimenting with fundraiser registration, practices that block storm drains during community car washes, and the designation of pervious areas for the diversion of runoff. Kitsap County, Washington, uses a patented device called a Bubble Buster to divert water away from storm drains during community car washes (USEPA, 2003b).

9.3.2 Lawn, Garden, and Landscape Activities

Lawns are a significant feature of urban landscapes. This large area of managed landscape has the potential to contribute to urban runoff pollution due to over-fertilization, overwatering, over-application of pesticides, and direct disposal of lawn clippings, leaves, and trimmings. Also, erosion from bare patches of poorly managed lawns contributes sediment to watercourses, and disposal of lawn clippings in landfills can reduce the capacity of these facilities to handle other types of waste. Public education for citizens and municipal crews with respect to pest tolerance and proper handling of fertilizers, pesticides, water, and yard waste can greatly reduce the potential for adverse impacts to waters receiving runoff from lawns. Municipalities and watershed managers should develop an outreach campaign that targets citizens, lawn care businesses, landscapers, and municipal crews. Materials should highlight the following steps to help citizens and lawn care professionals maintain healthy, attractive lawns with less maintenance and fewer chemical inputs:

- Lawn conversion
- Soil building
- Grass selection
- Mowing and thatch management
- Minimal fertilization
- Weed control and tolerance
- Pest management
- Sensible irrigation

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While all of the above practices are applicable to both citizens and lawn care professionals, they will differ when implemented due to differences in scale. For example, lawn care services may have multiple employees, carry large quantities of fertilizers and pesticides, and manage vast expanses of turf. Therefore, in addition to the above practices, good housekeeping is particularly important for lawn care professionals, landscapers, and municipal crews. Housekeeping includes implementing materials management and spill prevention plans and conducting employee training (see the Commercial Activities section). In addition, site development considerations for landscaped areas and golf courses should aim to protect local water bodies by avoiding sensitive areas, providing sufficient buffers, and ensuring erosion and sediment control during construction and maintenance activities (Center for Resource Management, 1996). See Management Measure 3—Watershed Protection and Management Measure 8—Construction Site Erosion and Sediment Control for more information about buffers and erosion and sediment control, respectively. Information resources specific to citizens and landscape professionals are provided at the end of this chapter.

Local cooperative extension services can provide assistance with the practices described in this section. State-specific cooperative extension service information is available from the Cooperative State Research, Education, and Extension Service (CSREES) at http://www.csrees.usda.gov/qlinks/partners/state_partners.html. Cooperative extensions are part of a nationwide organization authorized by Congress, and each state has designated a land grant university to administer its cooperative extension. Cooperative extensions conduct applied research and educational outreach such as workshops, conferences, fact sheets, and newsletters. These organizations are an excellent resource for information and assistance with lawn care practices. For example, the Virginia Tech Cooperative Extension Web site, http://www.ext.vt.edu/, maintains the *Database of Fact Sheets on Home Gardening and Insecticides/Pesticides*. The Rutgers University Cooperative Extension publishes fact sheets such as *How to Calculate the Amount of Fertilizer Needed for your Lawn* and *Best Management Practices for Home Lawns* (http://www.rce.rutgers.edu/).

NRCS's Backyard Conservation

USDA's Natural Resources Conservation Service (2000) Web site sponsors a Backyard Conservation Web site (http://www.nrcs.usda.gov/feature/backyard/) that presents technical information and management practices to "increase food and shelter for birds and other wildlife, control soil erosion, reduce sediment in waterways, conserve water and improve water quality, inspire a stewardship ethic, and beautify the landscape." The Web site includes 10 conservation practice standards, such as composting, mulching, nutrient management, pest management, and terracing, which have been modified for use in suburban landscapes.

9.3.2.1 Lawn conversion

Grasses are very water-hungry and labor-intensive landscaping plants when compared to ground cover, flowers, shrubs, and trees. Therefore, to reduce the maintenance requirements of a lawn and address problem areas where turf is difficult to grow, property owners could identify areas where turf grass can be replaced with other types of plantings. These areas include lawn edges, frost pockets, exposed areas, dense shade, steep slopes, and wet, boggy areas. Replacement

vegetation that is best suited to local conditions should be chosen to replace turf. Recommendations for drought-tolerant plants are available from a local extension office. State-specific cooperative extension service information is available from the Cooperative State Research, Education, and Extension Service (CSREES) at http://www.csrees.usda.gov.

9.3.2.2 Soil building

Lawn owners should analyze their soil every one to three years to determine its suitability for supporting a lawn and to identify whether additives are needed or adjustments should be made to optimize growing conditions. Soil characteristics that should be measured include pH, fertility, compaction, texture, and earthworm content. Soil test kits (for pH and fertility) can be purchased inexpensively at a garden center, or samples can be analyzed for free by a local cooperative extension service. Soil tests reveal whether fertilizer or lime is needed, helping to avoid over-fertilization and loss of nutrients. Surveys have indicated that only 10 to 20 percent of citizens test their soil to determine fertilization needs (Schueler and Swann, 2000c).

Prior to planting, sandy and heavy clay soils may be amended by adding organic compost to improve aeration and nutrient-holding capacity. Compacted soil under an established lawn should be aerated to improve the flow of water, fresh air, and nutrients to the system. Aeration is a non-chemical technique that relieves compaction, increases rooting, helps prevent thatch accumulation, incorporates organic matter into the soil surface, and helps prevent damage by insects and disease (Troutman, 2003). Core cultivators, which aerate by pulling small plugs of soil from the lawn, can be found at many local rental agencies (Mugaas, 1999). Soil texture can be determined with a settling test or by squeezing a handful of moistened soil through the fist. If soils prove to be very sandy or very clayey, organic matter such as compost, manure, or grass clippings should be added (USEPA, 1992). While the presence of earthworms is an indicator of healthy soil, the presence of white, healthy roots is the ultimate goal. Rooting can be checked by cutting a four-inch deep slice or plug of turf and soil. Roots should be at least four inches deep, and the tips should be white. Poor root condition may be a result of compacted soils, ineffective watering practices, or poor fertilization (Troutman, 2003). If a lawn does need soil amendments (e.g., an adjustment to pH or aeration to address compaction) a local cooperative extension service can provide the technical guidance necessary to care for the lawn properly (USEPA, 1992). State-specific cooperative extension service information is available from the Cooperative State Research, Education, and Extension Service (CSREES) at http://www.csrees.usda.gov. For more information on soil amendments, see the discussion of Erosion Control Practices in Management Measure 8—Construction Site Erosion, Sediment and Chemical Control.

9.3.2.3 Grass selection

Grass seed is available in a wide range of cultivated varieties, so citizens are able to choose the grass type that grows well in their particular climate, matches site conditions, and is consistent with the property owner's desired level of maintenance. Consideration should be given to seasonal variations in rainfall and temperature. Several grass varieties have been developed with increased resistance to disease and insect damage, which reduces pesticide use. Some turf varieties have high levels of endophytes, a fungus that does not threaten the grass but eradicates common lawn pests such as billbugs, sod webworms, and aphids. Tall fescue, zoysia grass, and Bermuda grass tend to be highly resistant to insects (Audubon Society, 2000). Other varieties

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have been selected to be slow growing, which requires less mowing, fertilizer, and water. Care should be taken to select the species and cultivated variety that are best adapted to the site conditions. Selecting the correct variety will result in a healthier lawn that is better able to compete with weeds and resist insects and disease (Bruneau, 2001; USEPA, 1992).

9.3.2.4 Mowing and thatch management

Each turf grass variety has an ideal mowing height range. Turf grasses use water more efficiently and out-compete weeds better when kept at the higher end of the ideal mowing height range. Mowing grass too short decreases rooting and increases the need for frequent watering. Tall turf competes more vigorously against weeds and can usually tolerate more insect and disease pressure (Troutman, 2003). Property owners might need to mow grass more frequently to maintain a minimum healthy height, depending on the type of grass planted and the local climate. Property owners should understand that grass grows at different rates throughout the seasons. As a result, some lawns may need to be mowed every four or five days when they are growing rapidly (Troutman, 2003). Therefore, grass should be mowed only as needed. If excessive thatch (which can prevent nutrients and water from reaching grass roots) has developed, the lawn should be dethatched by raking or using an automated dethatcher, or it could be sprinkled with compost and then aerated. Some grasses are more prone to developing thick layers of thatch than others. A thatch layer less than ½ inch can be beneficial by providing insulation and increasing the turf's resiliency (Mugaas, 1999; Murphy, 1994; USEPA 1992).

To prevent insects and weeds, property owners should mow high and frequently, and keep mower blades sharp to avoid tearing or injuring the grass. Longer grass is exposed to more sunlight, which allows it to develop a deep root system and increases tolerance to drought, insect damage, and disease. Lawns should not be cut shorter than 2½ to 3½ inches because weeds can grow more easily in short grasses. Grass can be cut lower in the spring and fall to stimulate root growth, but not shorter than 1½ inches (Audubon Society, 2000; USEPA, 1992). Table 9.1 lists recommended mowing heights for various types of grasses.

Table 9.1: Mowing heights for various grass types (PCLAA, No Date).

Grass Type	Mowing Height
Kentucky Bluegrass	3.0 in.
Fescues & Ryegrass	3.0 in.
Bent grass	1.0 in.
Bermuda grass	1.0 to 1.5 in.
Zoysia grass	1.0 to 1.5 in.
St. Augustine grass	3.0 in.
Bahia grass	3.0 in.
Centipede grass	1.5 in.

9.3.2.5 Yard waste management

Recent concerns about landfill capacity have prompted a number of states to ban the disposal of yard waste in landfills (Fickes, 2002). Approximately 3,800 yard waste composting programs were operating in the United States during 2000 (USEPA, 2002). Most of these were located in the Northeast, Midwest, and South where landfill capacity is of concern and many states have

Yard Waste Ban

In Syracuse, New York, a 1992 ban on yard waste disposal resulted in 45 percent of households composting yard waste and 55 percent leaving clippings on the lawn. The ban, instituted by the Onondaga County Resource Recovery Agency (OCRRA) in North Syracuse, prohibited grass, leaves, and brush from being disposed of with the trash. OCRRA has run an eight-year, $300,000 public education campaign. OCRAA's outreach program involves home composting workshops; the distribution of flyers, and TV, radio, and newspaper ads with the themes "A Recipe for Compost," "Time for a Trim," and "Keep Your Clippings on the Lawn" (Lalonde, 2000).

instituted yard waste bans. In the West, where landfill capacity is relatively high and no statewide yard waste bans exist, there are only approximately 400 composting programs.

Yard trimmings accounted for nearly half the municipal waste eliminated or diverted through source reduction programs in 2000 (USEPA, 2002). Source reduction has been a successful component of municipal waste management, and is a major reason why landfill capacity at a national level remains relatively constant. In fact, source reduction is estimated to have prevented a 25 percent increase in solid waste in 2000. As of 2000, 34 states had more than 10 years of landfill capacity remaining, 12 had five to 10 years, and two had less than five years of capacity remaining. (USEPA, 2002).

Yard clippings can be managed by reapplying them to lawns, or by composting at home or at community composting facilities. Reapplying clippings to yards, known as grass-cycling, reduces solid waste and can decrease the need for fertilizer and water by adding nutrients and limiting evaporation. Yard clippings do not contribute to thatch buildup, because thatch is comprised of the stems and roots of grass, not the blades (Mugaas, 1999; Relf, 1997). Removing a mower's collection bag is an easy way to automatically incorporate grass-cycling into regular mowing activities (PLCAA, no date (a)). Yard waste can also be composted and reapplied to improve water retention, add nutrients, and reduce erosion (Relf, 2001). Full bans on disposal are not the only option for yard waste management; partial bans and voluntary programs can also help to encourage citizens to employ yard waste management practices such as composting and leaving clippings on the lawn. Communities can integrate yard waste into their solid waste management program by offering curbside collection services or providing public drop-off sites (USEPA, 1994).

9.3.2.6 Minimal fertilization

Based on the results of the soil test described above, a lawn might require additional nutrients to promote or maintain healthy growth. Nutrients can be partly supplied by leaving a moderate amount of fine grass clippings on the lawn after mowing—these clippings can provide nearly half of the required nutrients to the lawn and they hold in moisture, speed decomposition, and relieve the burden of landfills to handle excess yard waste. Additional nutrients can be supplied with compost or commercial fertilizers that are of an organic or encapsulated nitrogen type, but they should be applied at or below the rates prescribed on the packaging. Compost or organic and encapsulated nitrogen fertilizers reduce the risk of nutrient leaching and have been shown to release nutrients more gradually. Slow-release fertilizers are also beneficial for reducing nitrogen

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losses from soils that are prone to leaching (Bureau, 2001). Organic products offer the additional benefits of increasing soil condition and promoting the growth of desirable soil organisms.

Timing of fertilization is very important. Cool-season grasses respond best to fall fertilization followed by light applications of fertilizer in the spring. Warm-season grasses generally benefit more from spring and summer fertilization. Fertilizers require water for activation; a light watering is usually enough (note that fertilizer should not be applied if rainfall is expected).

Excessive fertilization causes unwanted growth and the need to mow more often. Fertilizing at the wrong time of year may favor the growth of weeds rather than healthy turf. Excessive fertilization along with excessive watering can lead to the buildup of thatch that can increase insect and disease problems (Troutman, 2003).

The City of Austin recently commissioned Texas A&M University to conduct a study of the potential effects of residential lawn care practices on water quality in Stillhouse Spring, located in the environmentally sensitive recharge zone of the Northern Edwards Aquifer. Water quality tests have shown that nitrate levels in the aquifer are among the highest in the city. Nine different fertility treatments on test plots were studied. The plots were tested for appearance and the amount of nitrogen, phosphorous, and potassium that leached through the soil to ground water. The study resulted in a reevaluation of recommended fertilization practices for citizens. Recommendations still include soil testing, careful calculation of fertilizer amounts, and grass-cycling. However, researchers found that organically fertilized plots had less nitrogen leaching, were denser and more attractive, and were successful in retaining soil moisture and decreasing runoff in storm events. Because soils in Austin are particularly high in phosphorus, citizens in the area are now advised to use low-phosphorus fertilizers (Provin, 2002). Additional studies of residential lawn care practices and regionally specific runoff from urban lawns would be a beneficial addition to the large body of research on turf grass.

A local cooperative extension service should be consulted about the proper use of fertilizers. State-specific cooperative extension service information is available from the Cooperative State Research, Education, and Extension Service (CSREES) at http://www.csrees.usda.gov.

9.3.2.7 Weed control and tolerance

A property owner must decide how many weeds can be tolerated before action is taken to eradicate them. A few weeds will not substantially interrupt the continuity of the turf. The best way to keep weeds at bay is to maintain a healthy, dense lawn that shades the ground surface, preventing weed seedlings from taking root. However, if weeds do take hold, they should be dug or pulled out. Chemical herbicides should be used to spot-treat weeds, not applied universally. A local cooperative extension service should be consulted about the proper use of herbicides. State-specific information regarding cooperative extension services is available from CSREES at http://www.csrees.usda.gov.

9.3.2.8 Pest management

Integrated Pest Management (IPM) is an effective and environmentally sensitive approach that relies on a combination of common-sense practices. IPM programs use current, comprehensive information on the life cycles of pests and their interaction with the environment. This

Targeted Herbicide Application

Targeted herbicide application, which uses infrared and other technologies, can help locate and control roadside weeds at lower costs than conventional weed control methods (Stidger, 2001). Patchen, Inc., which is located in Ukiah, California, manufactures small sensors that can be used on trucks or other equipment to pinpoint the location of undesirable plants and then target and spray the weed with herbicide. Each sensor views a 12-inch wide area and upon finding weeds, it signals a spray nozzle to deliver a precise amount of herbicide. The unit will spray only on weeds and not on bare ground. Several California Department of Transportation districts have already mounted the sensors onto equipment. According to company reports, a side-mounted strip of sensors at the rear of the vehicle lets the unit target and spray roadside weeds at 10 miles an hour. Sensors can be also used at night when there is less traffic because the sensors have their own light source. Compared to broadcast or manual spot spraying, sensors reduce the quantity of herbicide used and cut overall costs by 50 to 80 percent. Sensors also cut costs by reducing required work hours, because only the driver is needed to apply the herbicide.

Research at North Carolina State University (Burton and Skroch, 1997) developed an herbicide applicator to attach to weed mowers to control roadside vegetation. The unit applies a film of chemical to the weed stem as the mower cuts the plant. Between 70 and 90 percent of the herbicide is absorbed into the plant to prevent future growth. With other methods, as much as 80 to 90 percent of the sprayed chemical misses its target and is wasted.

The Minnesota Department of Transportation tested four innovative herbicide sprayer designs in an effort to reduce costs. According to a research report, all four sprayers saved money when compared to traditional sprayer use. Net annual savings from each of the four sprayers ranged between $23,255 and $65,812.

information, in combination with available pest control methods, is used to manage pest damage by the most economical means and with the least possible hazard to people, property, and the environment.

IPM is not a single pest control method but a series of pest management evaluations, decisions, and controls. IPM is a sustainable approach to managing pests by combining biological, cultural, physical, and chemical tools. Biological controls involve the use of natural enemies to manage pests. Cultural practices include mowing, fertilization, irrigation, aeration, dethatching, and rolling. Physical controls include removal of insects and affected plant material by hand or removal of pests with store-bought traps. Chemical controls involve the use of pesticides. Municipalities can encourage citizens and lawn care professionals to practice IPM and train municipal maintenance crews to use these techniques for public open space.

Effective pest management begins with maintenance of a healthy, vigorous lawn that is naturally disease-resistant. Mulching can be used to prevent weeds where turf is absent; fencing can be installed to keep rodents out; and netting can be used to keep birds and insects away from leaves and fruit. Planting disease-resistant species and alternating different types of plants can help prevent infestation. In addition, simple pest prevention techniques can reduce the likelihood that pesticides will be needed. These include destroying hiding places such as diseased plants and fallen fruit, cleaning up pet waste, and removing puddles (USEPA, 1995). Citizens should monitor plants for obvious damage and should check for the presence of pest organisms. It is important to be able to distinguish beneficial insects and arachnids, such as green lacewings, ladybugs, and most spiders, from ones that will damage plants. When damage is detected or

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when harmful organisms are present, citizens should determine the level of damage the plant is able to tolerate. No action should be taken if the plant can maintain growth and fertility in the presence of these pest organisms. If controls are needed, there is an arsenal of low-impact pest management controls and practices to choose from that include preventative measures such as planting disease-resistant species and promoting beneficial organisms. See the USDA Regional Pest Management Centers Information System Web site at http://www.ipmcenters.org/ for more low impact strategies.

Integrated Pest Management (IPM) combines the use of these lower-impact practices with targeted chemical controls. Chemical controls are highly effective but may result in damage to or death of desirable species, such as bees. If strong chemical pesticides are applied improperly, they can contaminate receiving waters. Several less-toxic pesticide alternatives are available to prevent infestations or halt current infestations. Biopesticides, for example, are used to control pests without the use of poison. Biopesticides can be "biochemical," such as garlic and pheromones, or "microbial," such as bacteria, fungi and viruses (USEPA, 2003). Garlic and baking soda have been shown to be effective when applied as an aqueous solution to plants. Other pest control alternatives include insecticidal soap, which destroys pest membranes, *Bacillus thuringiensis* (a beneficial bacteria found in compost and other organic soil additives), milky spore (a natural bacteria that kills the grub phases of Japanese beetles), and dormant oil sprays applied when the plants are not growing. When used as a component of IPM programs, biopesticides can greatly decrease the need for conventional pesticides. The Biopesticides and Pollution Prevention Division in EPA's Office of Pesticide Programs promotes the use of biopesticides as components of IPM programs. The Biopesticides Web site, http://www.epa.gov/pesticides/biopesticides, provides information on biopesticide registration, active ingredients, product lists, and contact information.

Municipalities should try to select the least-toxic, least-water-soluble, and least-volatile pesticides possible. Pesticides should be evaluated based on their toxicity and their potential to run off to surface water or leach into ground water (Peacock et al., no date). Organophosphate pesticides, such as diazinon and chlorpyrifos, were popular because they target a broad range of pests and they are less expensive than newer, less-toxic pesticides. A risk assessment by EPA has determined that chlorpyrifos posed an unacceptable risk to public health, particularly children's health (USEPA, 2000). It was found that diazinon posed unacceptable risks to agricultural workers, birds, and other wildlife species. Chlorpyrifos was removed from retail sale and residential uses in 2001, and diazinon was phased out in 2004. Synthetic pyrethroids are more selective and typically much less toxic than organophosphates, yet they still can harm beneficial insects. When applying pesticides such as these, careful and judicious use is recommended to avoid harming non-target species.

Pesticide applicators should always read and follow instructions on the label. Pesticides should be applied to minimize drift or runoff, and they should not be sprayed near water sources. Application should be avoided during windy conditions or when rain is forecast. Granular applications should be avoided or minimized near impervious surfaces and bodies of water. Equipment should be checked for proper calibration before pesticide application. After pesticides are applied, label directions should be followed to safely dispose of containers. A local cooperative extension service can be consulted about the proper use of pesticides. State-specific

information regarding cooperative extension services is available from CSREES at http://www.csrees.usda.gov.

Pest management methods can also be controlled legislatively. In response to the negative effects of many pesticides, some localities are planning to restrict or prohibit the use of certain hazardous pesticides (Johnson, 1999). For example, the city of Seattle and King County, Washington, intend to stop using pesticides that are deemed most hazardous to control bugs and weeds along roads, in parks, and on other public land. The plan will phase out the use of dozens of harmful pesticides as the city and county explore less toxic alternatives. Pesticides that will be phased out contain known cancer-causing ingredients, seep quickly into ground water or surface water, or are labeled highly toxic to birds, fish, or other animals. There will be exceptions to the ban on some chemicals, but generally only if there are major health or safety considerations.

Restrictions on the use of certain pest control products were also implemented in California. In 1994 a bill was passed that would restrict the sale and use of copper-containing root killers and copper and tri-butyl tin-containing cooling tower additives (City of Palo Alto, California, Environmental Compliance Division, 1997). These pest control products contribute to the Regional Water Quality Control Plant's exceedances of San Francisco Bay discharge standards. When used, these products are discharged to sanitary sewer systems or to storm drains that flow untreated to creeks and bays. Because cost-effective alternatives for these products are available, the Regional Water Quality Control Plant and other local wastewater treatment plants have urged restrictions on the three types of chemicals. In December 1995 the California Department of Pesticide Regulation adopted regulations that made it illegal to sell or use copper-based root control products and tri-butyl tin-containing cooling water additives within the nine San Francisco Bay area counties. These regulations became permanent in November 1996.

9.3.2.9 Point-of-sale education

Municipalities and local cooperative extensions can encourage IPM by promoting education at the point of purchase. Two studies found that most citizens who apply pesticides used home and garden centers as their source of information on pest management (Lajeunesse et al., 1997; Sclar et al., 1997). Educating store employees on less-toxic alternatives, keeping less-toxic materials in stock, and providing information on the proper use of pesticides will help facilitate the IPM process. Czapar et al. (1998) surveyed 656 retail stores in Illinois that sell pesticides. Approximately 83 percent of the survey respondents were willing to send employees to a training program on pesticides, safe handling practices, and how to recommend appropriate pesticides to customers.

The Bay Area Stormwater Management Agencies Association in the San Francisco Bay Area established the "Our Water, Our World" program to educate citizens on less-toxic alternatives to pesticides without using negative messages about conventional products. The program consists of partnerships with local retail stores that display alternative products and educational materials. The program also involves media and advertising campaigns, efforts to institute regulatory change, and monitoring of the effects of the program. Initial results from 20 participating stores indicated an increase in the sale of less-toxic products and employee satisfaction with the associated training programs (http://www.epa.gov/oppbppd1/PESP/strategies/2000/basmaa00.htm).

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Bio Integral Resource Center IPM Partnership Program

The Bio Integral Resource Center (BIRC) in the San Francisco Bay Area has developed a partnership between water pollution prevention agencies, nurseries, hardware stores, and the local cooperative extension to educate the public on less-toxic pest management. The program focuses on educating consumers about pest control products at the point of purchase from nurseries and hardware stores. BIRC encourages stores to carry less-toxic products and trains employees on the use of these products.

BIRC also conducts a Healthy Garden Workshop, which is a four-hour public seminar to introduce home gardeners to various aspects of IPM such as monitoring, physical controls, horticultural controls, and biological controls. Additional topics include water conservation and the use of native plants. An illustrated Healthy Garden Handbook accompanies the workshop, and an instructor's guide is available to assist others who are interested in giving the class (http://www.pesp.org/2000/birc00-final.htm).

Alliance for Chesapeake Bay IPM Partnership Program

The Alliance for Chesapeake Bay IPM Partnership Program promotes IPM by citizens through a partnership with retailers in which less-toxic pest control options are labeled with the slogan, "From your home to our streams…Choose less toxic products." The program includes employee training workshops, IPM informational displays and fact sheets available at participating retail stores. Partnerships with garden clubs and Master Gardeners provide training on minimizing environmental impacts and less-toxic pest management techniques.

IPM information displays began appearing in retail locations in central Pennsylvania in March 2003. The IPM project is funded by the National Foundation for IPM Education and the Environmental Protection Agency. For more information contact: Susan Richards, 717-737-8622, http://www.acb-online.org/project.cfm?vid=89.

9.3.2.10 Sensible irrigation

The natural reaction of grasses to drought stress is to become dormant, halting growth, conserving resources, and turning dry and brown. In spite of this natural drought tolerance mechanism, many property owners strive to maintain lush, green lawns, even in times of dry weather. Watering practices vary from a light sprinkling to regular, sometimes excessive, automated watering. Underwatering fails to provide water below a few inches of soil, causing grasses to be fragile and shallow-rooted. Overwatering promotes excessive growth and humid, disease-prone conditions that can damage the lawn. Overwatering can also result in runoff and leaching of nutrients (PLCAA, no date (b)). One study found that overwatering increased by five to 11 times the amount of nitrogen leached (Morton et al., 1998).

It is best to water deeply, but not too often. Deep watering encourages the grass to grow deep roots, whereas shallow watering maintains shallow roots and reduces the lawn's ability to retain moisture during dry periods (USEPA, 1992). The lawn should be watered only when needed and sprinklers should be carefully calibrated to wet the soil to a depth of 6 inches without causing runoff. Additionally, watering should be done early in the morning to prevent excessive evaporation (USEPA, 1992). Determining and controlling the rate, amount, and timing of

watering will reduce soil erosion, runoff, and fertilizer and pesticide movement. An irrigation system should be designed to have an average application rate that is less than the infiltration capacity of the soil to avoid surface ponding and to maximize water percolation. Trickle and drip irrigation systems can save water by more directly irrigating the roots, resulting in less evaporation than overhead sprinklers (Relf, 1996).

Moisture in a home lawn can be retained more efficiently with organic matter, mulch, shade, and windbreaks. Organic matter increases the capacity of sandy soils to hold moisture and the availability of moisture in clay soils. Mulching helps reduce evaporation and retain moisture and humidity. Providing partial shade, particularly in the summer, and blocking wind, can also decrease moisture demand (Relf, 1996).

9.3.3 Commercial Activities

9.3.3.1 Detect and eliminate illicit connections

Illicit connections are defined as "illegal and/or improper connections to storm drainage systems and receiving waters" (Caraco et al., 1998). A discharge of industrial wastewater to a storm sewer is "illicit" because discharges of that type would ordinarily require a permit under NPDES. Many building owners and operators are unaware that improper connections exist in their facilities. In extreme cases of illicit dumping, legal action is necessary.

Illicit discharge detection and elimination programs are designed to prevent contamination of surface and ground water supplies by monitoring, inspection, and removal of these non-storm water discharges, which are illegal if an ordinance has been enacted. These ordinances grant a municipality the authority to inspect properties suspected of releasing contaminated discharges into storm drain systems. Another important factor is the establishment of enforcement actions for those properties found to be in noncompliance or that refuse to allow access to their facilities. EPA (1999), in conjunction with the Center for Watershed Protection, published a model ordinance for illicit discharges on their model ordinances Web site (http://www.epa.gov/nps/ordinance/discharges.htm). The model ordinance includes language to address illicit discharges in general as well as illicit connections specifically from industrial sites. Municipalities should modify the language to take into consideration enforcement methods that are appropriate for the local area. The Center for Watershed Protection (Brown et al., 2004) also published *Illicit Discharge Detection and Elimination: A Guidance Manual for Program Development and Technical Assessments*. This publication provides information on cost-effective methods to detect and eliminate illicit discharges from municipal storm drains. The document is available for download at http://www.cwp.org/PublicationStore/TechResearch.htm.

Identification of illicit and improper connections is necessary for all sanitary and storm sewer systems, especially in areas where pollutants with unknown sources have been detected in receiving waters. The level and type of industrial activities and the surrounding land uses will affect the methods used to identify illicit connections.

The following are some practices used to prevent, discover, and eliminate illicit connections:

- Conducting water quality monitoring and field screening at outfalls and in receiving waters to identify areas where pollutant levels are elevated. Consider bacterial source

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tracking analysis to determine the origins of elevated bacteria levels (see Section 2.3.5 for more information about water quality indicators and bacterial source tracking).

- Instituting building and plumbing codes to prevent connections of potentially hazardous pollutant sources to storm drains.

- Organizing structures to be inspected for illicit connections by building age, with older buildings identified as priorities. Businesses whose activities have the greatest potential to create sources that could adversely affect water quality and pose human health problems also should be given priority.

- Mapping each area to be surveyed and indicating the route of the sewer system and the locations of storm drains on the map. This enables watershed managers to estimate the likely locations of illicit connections.

- Surveying individual buildings to discover where connections to the storm drain exist.

- Inspecting sewer lines with television equipment to visually identify all physical connections.

- Comparing the results of field tests and video inspections with the known connections on the map. Areas with suspected connections should be further investigated.

- Instituting mandatory inspections for new development, redevelopment, and remodeling projects.

- Removing and testing sediment from catch basins or equivalent structures.

- Inspecting questionable connections to determine whether they should be connected to the storm drain system or to the sanitary sewer. Methods of illicit connection identification, such as dye testing, visual inspection, smoke testing, and flow monitoring, are described below.

  - *Dye testing*. Flushing fluorometric dye into suspected connections can be useful to identify illicit connections. Once the dye has been introduced into the suspected connection, the water in the collection system is monitored to determine whether a connection is present.

  - *Visual inspection*. Remotely guiding television cameras through sewer lines is another way to identify physical connections.

  - *Smoke testing*. Smoke testing is another method used to discover illicit connections. Zinc chloride smoke is injected into the sewer line and emerges via vents on connected buildings or through cracks or leaks in the sewer line. By monitoring and recording where the smoke emerges, crews can identify all connections, legal and illegal, to the sewer system. (Mechanisms on drains should prevent the smoke from entering buildings; however, in some instances, this will occur. It is important to

notify the public that the smoke is nontoxic, though it should be avoided as it can cause irritation of the nose and throat in some people.)

- *Flow monitoring*. Monitoring increases in storm sewer flows during dry weather can lead investigators to sources of infiltration or flow due to illicit connections.

Rain can hamper efforts to monitor flows and conduct visual inspections. Smoke and dye testing are more accurate than visual inspection and are the preferred methods for identifying illicit connections.

The cost of smoke testing, dye testing, visual inspection, and flow monitoring can be significant and time-consuming. Site-specific factors, such as the level of impervious area, the density and ages of buildings, and land use will determine the level of investigation necessary. Case studies in Michigan have estimated the cost of two full-time field staff and other required support to be between $182,000 and $187,000 annually (Ferguson et al., 1997).

An illicit discharge detection program can be an effective method to reduce the quantity of pollutants related to industrial and commercial activities that enter the storm drain system. For example, the Montgomery County, Maryland, Department of Environmental Protection (MCDEP) has an illicit discharge detection and elimination program called "Pipe Detectives" that uses volunteer monitoring and community hotlines to identify suspicious discharges (MCDEP, 1997). When discharges are reported, DEP consults maps of surrounding areas and targets these areas for additional monitoring to narrow the search for the illicit connection. In one instance, a "milky white" discharge was reported in an area with many small businesses and large apartment buildings. Businesses were sent informational letters advising them of the discharge and requesting their assistance in identifying it by allowing MCDEP to survey the properties. Through this cooperative effort, three illicit connections were detected and removed, including a sink that was used to wash paintbrushes (the source of the milky white discharge).

The City of Portland, Oregon, addressed illicit discharges from industrial sites by developing a memorandum of agreement with the Oregon Department of Environmental Quality, the state agency charged with administering municipal storm water permits. The purpose of the agreement was to streamline the enforcement process by delegating authority to administer the permits to the city. The agreement specified the city's role in inspections, compliance, and enforcement. The first component of the city's Illicit Discharge Elimination Program involves the prioritization of storm water outfalls based on pipe size, land use, historical pollution problems, complaints, and monitoring data. These outfalls are subject to dry weather monitoring, and once pollutants are detected, upstream investigations are conducted. Second, the Connection Verification Program inventoried all connections to the MS4 from individual properties and reviewed them for questionable connections. A citizen complaint program and partnership agreements facilitate public input and participation and provide a low-cost way to improve enforcement efforts (Pronold, 2003).

The Santa Clara Valley (California) Nonpoint Source Control Program published a guide with pollution prevention practices for industrial facilities entitled *Best Management Practices for Industrial Storm Water Pollution Control* (Duke and Shannon, 1992). The guide presents 21 practices intended to reduce nonpoint source loadings from industrial and commercial

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activities, including employee and customer training; illicit discharge elimination; waste storage, handling, and disposal; equipment inspection and maintenance; facility design features; and storm water management. The guide presents detailed technical guidance for common pollutants generated by commercial and industrial activities. The Santa Clara Valley Nonpoint Source Control Program has other pollution prevention publications that target specific businesses, such as automotive repair, construction trades and roadwork, landscape/gardening and pool maintenance, mobile cleaners and detailers, and restaurants. Additional information can be obtained by contacting the Nonpoint Source Control Program Information Line at 800-794-2482.

9.3.3.2 Encourage good housekeeping practices at commercial facilities

One of the best and least-expensive ways to reduce or eliminate pollutants in runoff is to limit the exposure of materials that can be eroded or dissolved by rainfall and runoff. An inventory of the items on commercial sites that are exposed to rain and runoff provides useful information and a starting point for exposure-reduction activities. To help keep rain from contacting pollutants, businesses should be advised to keep dumpsters and other containers securely closed, store containers under cover, and cover stockpiled materials, such as gravel, wood chips, and building materials, with plastic sheeting. Businesses should be asked to clean up their sites, but not by washing grit and grime into the storm drain system. Instead they should pick up litter, sweep, dispose of sweepings in the garbage (unless they are hazardous and require special disposal), and use absorbent materials such as manufactured absorbent snakes, kitty litter, or sawdust to absorb oils.

9.3.3.3 Provide training and education for employees and customers

Education of employees and customers at commercial sites is key to establishing good pollution prevention practices. Training programs provide information on material handling and spill prevention and response to better prepare employees in case of an emergency. Employees should also be trained on the purpose, operation, and maintenance of pollution prevention management practices. Employees can be continually educated with periodic training courses and with signs reminding workers of good housekeeping practices. Customers should be informed of efforts to

Illicit Discharge Elimination Training

The Wayne County, Michigan, Department of Environment's Illicit Connection/Discharge Elimination Training Program provides training for county and local staff responsible for illicit discharge detection and elimination. The training program involves technical presentations, "hands on" instruction in investigative techniques, and provision of software to aid in program management. Each participant receives a notebook containing recommended standard operating procedures and field forms. State-of-the-art technology is employed, including Global Positioning System (GPS) for locating outfalls and a GIS/database software package developed by the County for site investigation. The goal of the software package is to promote coordination in reporting/tracking of illicit connections/discharges. The training program also instructs participants in the use of chemical analysis field kits for measuring water quality parameters. As of September 2002, the program had trained nearly 800 state, local and community personnel (Tuomari, 2003; Wayne County Department of Environment, 2001).

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reduce waste and pollution using signage or pamphlets so they will be less likely to contribute to pollution problems that are ultimately the responsibility of the business.

9.3.3.4 Devise spill prevention, control, and clean-up plans

The best way to avoid runoff contamination from spilled materials is to prevent the spill from occurring. Careful storage of materials in sound, clearly labeled containers, and regular inspection and maintenance of equipment, are key practices to prevent spills. Materials stored outdoors should be covered and kept on a paved area to protect them from being mobilized by wind and runoff. If not roofed, the storage area should be designed to drain with a slight slope (approximately 1.5 percent) to an area that will provide treatment prior to disposal. Runoff from other areas should be excluded to reduce the volume of runoff requiring treatment by installing berms, curbs, or diversions on the perimeter of the storage area. Secondary containment should be used when liquids are stored, and runoff or spills from the containment area should be directed to the sanitary sewer where permissible or to an appropriate storage or treatment facility for reuse or disposal.

Business managers should develop and post a set of well-defined procedures for handling spills of any materials that might be exposed to rainfall or runoff. Procedures should cover small, easy-to-handle spills as well as large spills that require employees to contact emergency personnel. The procedures should emphasize that spills must be cleaned up promptly and should specify how each type of material should be handled. The use of water for clean-up should be strongly discouraged. Shop rags should be used for small spills of non-volatile chemicals, and used rags should be sent to a professional cleaning service to prevent them from causing a pollution problem in a landfill or other disposal area. Larger spills should be absorbed with vermiculite, sawdust, kitty litter, or absorbent "snakes." Disposal methods depend on the hazard level of the spilled material. Nonvolatile liquids can be cleaned up with a wet/dry shop vacuum and disposed of with the rest of the facility's waste. Drains or inlets to storm sewers should be plugged during spill remediation to prevent off-site export of pollutants.

9.3.3.5 Conduct an environmental audit

Another approach to pollution prevention at commercial sites is to focus on source reduction, which reduces the amount of waste materials that have the potential to contaminate runoff. A reduction assessment can be performed to evaluate the type and amount of materials currently used, processes conducted, and wastes generated. Such an assessment can provide recommendations for modifying the commercial process to generate less waste, using alternative raw materials to generate non-hazardous wastes, and identifying recycling options to reduce the amount of wastes that require disposal. EPA's Office of Pollution Prevention and Toxics Web site (http://www.epa.gov/oppt/pollutionprevention/) offers technical information and assistance about environmental audits for both businesses and state regulatory agencies (USEPA, 2001a).

9.3.3.6 Practice safe equipment washing and maintenance

It is important when washing and maintaining equipment to adhere to certain pollution prevention measures. The flow of water resulting from cleaning industrial equipment, must be discharged as process wastewater to the sanitary sewer and is not allowed in storm drains, in

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most cases. When cleaning greasy equipment or trucks, a special cleaning area should be designated and equipment installed to capture, pre-treat, and discharge the wash water to the sanitary sewer. In addition, instructional signs that prohibit changing vehicle oil, washing with solvents, and other activities should be posted in non-wash areas. Finally, sumps or drain lines should be installed to collect wash water for treatment and discharge to the sanitary sewer.

Waste materials from vehicle maintenance activities also deserve special attention. Proper storage of materials and proper disposal of waste products are imperative. For example, waste oil, antifreeze, spent solvents, and some other liquids can be recycled. Spent batteries, however, should not be discarded with trash, but must either be disposed of as a hazardous waste or returned to the dealer from whom they were purchased. In addition vehicle maintenance should be performed in an indoor garage, not in an outdoor parking area. If performing work outdoors, all oil and grease should be captured unless precautions are taken to prevent them from being carried in runoff, such as with the use of absorbent pads in inlets or grates.

9.3.3.7 Use care when performing construction, repairs, or remodeling

When repairing, remodeling, or constructing buildings there are several key techniques that can prevent adverse effects on natural systems. Paints should be mixed where spills can be recovered or cleaned easily, and an impermeable ground cloth should be used while painting. Paint chips and scrapings might contain lead and should be managed properly to prevent contamination of water or soil. Paint buckets and barrels of materials should be stored away from contact with runoff. During painting clean-up, if a water-based paint was used, brushes and equipment should be cleaned in a sink connected to the sanitary sewer; if oil-based paints were used, they should be stored or recycled and not be disposed of in the sink or storm drain. Spray painting requires a few extra precautions. Temporary scaffolding should be used to hang drop cloths or draperies to shield the user from the wind, to collect overspray, and to minimize the spreading of windblown materials. Users should be aware of air quality restrictions on spray paints that use volatile chemicals and should consider water-based spray paints instead to minimize adverse effects on air quality.

Sand blasting can be controlled to keep particles off of paved surfaces and out of storm drains by placing a tarp or ground cloth beneath the work to capture the blasting medium, protect the work area from wind, and capture airborne particles.

9.3.3.8 Proper disposal of pet waste

Pet owners have several options for properly managing pet waste. Collecting the waste and flushing it down the toilet, where it can be treated by a sewage treatment facility or septic tank, is the preferred method. Small quantities can also be buried in the yard (when ground water is not used in the home), where the waste can decompose slowly. When buried, the waste should be at least 5 inches below the ground surface and away from water bodies and vegetable gardens. In public areas, the waste can be sealed in a plastic bag and thrown in the trash, which is legal in most areas (Water Quality Consortium, 1999).

Many communities implement pet waste management programs by posting signs in parks or other areas frequented by pet owners, sending mailings, and making public service

Los Angeles County Pet Waste Program

The Los Angeles County Department of Public Works Environmental Programs Division developed a program to control pet waste (Lehner et al., 1999). By profiling various groups of pet owners, the division identified the best targets for reducing coastal pollution. The program included a multimedia campaign to educate new and existing pet owners about the water quality impacts of pet waste. The program also distributed clean-up kits to owners and installed plastic bag dispensers in parks. The division established partnerships with local pet stores and pet supply companies to promote the program.

announcements. Many communities have "pooper scooper" ordinances that govern pet waste clean-up. Some of these laws specifically require anyone who takes an animal off his or her property to carry a bag, shovel, or scoop. Any waste left by the animal must be cleaned up immediately (Hill and Johnson, 1994). In addition to postings, many communities have installed "pet waste stations" in popular dog parks. These stations contain waste receptacles as well as a supply of waste collection bags, scoops, and shovels.

9.3.4 Trash

When developing control strategies for trash, one should keep in mind the source of the trash and the most prevalent types of trash to target ways to control it. Second, the costs for each control strategy should be evaluated, and a budget should be developed that takes into consideration the services and facilities that are already available. Third, regular cleaning and maintenance of storm water control infrastructure is necessary to prevent the accumulation of trash at control structures from becoming a hazard. Finally, it is important to understand that control strategies should not just transport trash to another water body but should also reduce the quantity of trash entering water bodies.

There are two methods of trash control: source controls and structural controls. There are four source control types: community education, improved infrastructure, waste reduction, and clean-up campaigns. Community education, such as informing citizens about options for recycling and waste disposal and educating them about the consequences of littering, is one of the best ways to reduce the amount of trash that enters runoff control structures and receiving waters. Another topic that should be emphasized is proper trash storage and disposal. Improved infrastructure can include optimizing the location, number, and size of trash receptacles, recycling bins, and cigarette butt receptacles based on expected need. Waste reduction includes encouraging consumers to purchase products with less disposable packaging and manufacturers to reduce the amount of packaging they use. Finally, clean-up campaigns are an effective way to reduce trash. Municipal projects such as street sweeping (see section 7.3.5.1), receptacle servicing, and clean-up crews along roadsides can also be effective in preventing trash from accumulating and entering waterways. Municipalities should review their litter control program to determine if the number and placement of receptacles is adequate and if regular maintenance activities (e.g., sweeping, receptacle servicing) are preventing litter from entering receiving waters.

Structural controls include physical filtering structures and continuous deflection separation. Physical filtering structures concentrate diffuse, floating debris and trash and prevent it from traveling downstream. Some examples are trash racks, mesh nets, bar screens, and trash booms. Continuous deflection separation targets trash from storm flows during and after heavy

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precipitation and involves physical separation of solids and floatables from water in runoff detention structures.

The costs for trash controls vary depending on the method employed. For example, the cost of a community education program or a plan to increase the number of trash receptacles can be minimal, depending on the quality of existing programs and extent of existing infrastructure. On the other hand, a structural control strategy can be quite costly. Physical filtering structures, including trash racks, bar screens, and silt traps, can range from $250,000 to $1 million or more, not including maintenance. A large-scale, continuous deflection separation device for urban runoff can cost as much as $3 million (capital cost only).

9.3.5 Nonpoint Source Pollution Education for Citizens

Many citizens know very little about nonpoint source pollution. Schueler and Swann (2000a) reported that an estimated 41 percent of the population had an idea of what the term "watershed" means, and only 22 percent understood that runoff is the most common source of pollution to streams, rivers, and oceans. Therefore, watershed and nonpoint source education for citizens is important to increase awareness about the environmental consequences of everyday actions. A survey of the effectiveness of outreach programs showed that media campaigns and intensive training of target audiences are the most effective ways to effect change in citizen behavior (up to 10 percent change in behavior in target populations). Specifically, TV ads and programs, newspaper ads, radio ads, and direct mail campaigns were shown to be the most influential and memorable messages to the public. Table 9.2 provides a summary of cost information and target audiences for various outreach methods.

Table 9.2: Select cost and audience information for various outreach techniques (Worlton, 2003).

Element	Cost	Unit	Audience
Flyers	$0.40–$1.20	Each	Limited by requests
Fact Sheets	$0.40–$1.20	Each	Limited by requests
Radio	$2,000 or more	Per station	500,000–2,000,000
Television	$2,400 or more	Per month	250,000–500,000 per day
Billboards	$700	Per board	6,800 per day
Markers	$2.94	Each	0–5,000 per day
Trailers	$165	Per theater	5,000 or more per day

Schueler and Swann (2000a) recommend the following techniques to effectively market a watershed message:

- Present a simple, direct watershed message, repeat it frequently, use multiple types of media, and emphasize the connection between the message and a local water body.
- Develop awareness of the connection between yards, streets, storms, and streams.
- Pool resources with other local or regional organizations to expand the campaign's budget.

- Use cable network and public television channels for commercials and targeted TV programs to more effectively reach target audiences.

- Focus the campaign on one or more target audiences. Many communities are ethnically and culturally diverse, and a portion of the population speaks languages other than English, which requires a campaign specifically tailored to the local demographics. Communities can also direct messages to children or focus efforts towards reaching the disadvantaged, who otherwise might not have the opportunity to learn about or participate in programs and activities. A survey of watershed demographics and problem pollutants should be conducted to better identify target populations.

- Keep the message simple and humorous and develop durable, attractive, non-technical outreach materials.

- Educate and partner with private-sector companies such as septic tank cleaners, commercial car washes, and oil change franchises.

9.3.5.1 Use multilingual nonpoint source messages

Many communities are ethnically and culturally diverse, and a portion of the population speaks languages other than English. The messages contained in signs, brochures, advertisements, newsletters, and other outreach materials that are printed only in English are mostly lost on these groups. For example, in areas such as southern Florida and southern California, where a large proportion of the population consists of Spanish-speaking immigrants, it is important to reach out to non-English-speaking residents and inform them about storm water pollution issues and the importance of clean water, because their activities can generate a substantial amount of pollution. This type of expanded outreach program is not limited to these areas. Census 2000 figures show increasing minority populations in urban centers and suburbs such as Washington, DC (Fernandez, 2001; Cohn and Witt, 2001), and New York (Cohn, 2001), among others.

Outreach materials can be printed in multiple languages based on the demographics of a community. The North Central Texas Council of Governments (NCTCOG), as part of its pollution prevention and public awareness campaign, printed articles, press releases, brochures, flyers, and bill stuffers in both English and Spanish (NCTCOG, 2000). The University of Texas at Austin designed and installed storm drain markers in both English and Spanish (University of Texas at Austin, 1997).

9.3.5.2 Use classroom education to deliver nonpoint source messages

Providing nonpoint source education to children through schools delivers the educational message not only to students but to their parents as well, because children often take home what they learn. Watershed managers have partnered with educators and experts to develop storm water-related curricula for the classroom. Fortunately, these lessons need not be elaborate or expensive to be effective.

An example of this type of education is the Children's Water Festival in Albuquerque, New Mexico. Several hundred fourth-grade students from schools in the area engaged in hands-on

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earning activities about water science, history, geography, and drama. The Albuquerque-based Ciudad Soil and Water Conservation District used its "Rolling River" educational model to show how all the components of a watershed are connected and how changes in one part affect others. Students created a mini-river, purified water from the Rio Grande, and built aquifers from edible ingredients. They also used a computer model to make projections of water use in the future and a ground water model to see how water moves underground. Students analyzed water samples and played the roles of algae, fish, and raptors to understand how toxins can travel through the food chain. They created wetlands, simulated flood and drought situations, changed the infrastructure, and then observed the effects of their manipulations.

9.4 Information Resources

9.4.1 General

The Center for Watershed Protection published *Illicit Discharge Detection and Elimination: A Guidance Manual for Program Development and Technical Assessments*. This publication provides information on cost-effective methods to detect and eliminate illicit discharges from municipal storm drains. The document is available for download at http://www.cwp.org/PublicationStore/TechResearch.htm.

EPA's GreenScapes program provides cost-efficient and environmentally friendly solutions for large-scale landscaping. GreenScapes encourages companies, government agencies, and other entities to make more holistic decisions regarding waste generation and disposal. The GreenScapes program emphasizes four elements: reduce, reuse, recycle, and re-buy**.** More information about the GreenScapes program can be found at the program's Web site at http://www.epa.gov/greenscapes.

EPA's Office of Solid Waste has released "A Collection of Solid Waste Resources" on CD-ROM. This resource contains more than 300 publications on hazardous and non-hazardous waste; documents are listed by topic and are searchable, and some documents are in both English and Spanish. More information about this CD-ROM is available at EPA's Office of Solid Waste Web site at http://www.epa.gov/epaoswer/osw/cdoswpub.htm.

EPA's Used Oil Management Program developed the "You Dump It, You Drink It" campaign aimed to educate the Hispanic automotive repair and service industry and consumers about the impacts of improper disposal of used oil. The campaign includes posers, brochures, and bumper stickers in both English and Spanish. These materials, a description of the Used Oil Management Program, and relevant publications, rules, notices, regulations, and links can be found at http://www.epa.gov/epaoswer/hazwaste/usedoil/index.htm.

Appropriate Technology Transfer in Rural Areas (ATTRA) published the guidance *Integrated Pest Management: Fundamentals of Sustainable Agriculture*, which provides a basic understanding of IPM for individuals interested in agriculture. It incorporates the steps that need to be taken prior to IPM implementation, the tools used, and some ideas about future trends for IPM. The ATTRA publication is available at http://www.attra.org/attra-pub/ipm.html (Dufour and Bachmann, 1998).

The City of Seattle's ProIPM (Seattle Public Utilities, 2000) is the Green Gardening Program's series of IPM fact sheets for landscaping professionals. The fact sheets were designed to assist landscapers in the field and when explaining the IPM approach to clients. Each provides essential facts about various northwestern United States pest or disease problems, including information regarding pest identification, life cycle information, monitoring, damage threshold, and treatments. The fact sheets are available for download at http://www.seattle.gov/util/Services/Yard/For_Landscape_Professionals/Integrated_Pest_Management/index.asp or by calling the Green Gardening Program at 206-547-7561. The ProIPM Web site also provides information about proper disposal methods for pesticide products.

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The U.S. Air Force's PRO-ACT program is an environmental research service and information exchange clearinghouse (PRO-ACT, 2000). PRO-ACT's *Integrated Pest Management Fact Sheet* provides information regarding IPM policy and guidance, typical components of an IPM program, control techniques available to pest managers, and management practices that can be implemented in an IPM program. The fact sheet is available at http://www.afcee.brooks.af.mil/pro-act/fact/intpst.asp. PRO-ACT may be contacted by phone at 800-233-4356 or by e-mail at pro-act@hqafcee.brooks.af.mil.

The USDA Regional Pest Management Centers Information System Web site (http://www.ipmcenters.org/) provides information about agricultural commodities, pests, and pest management practices, as well as links to each of the four Regional Pest Management Centers. Users can access the complete Crop Profiles and Pest Management Strategic Plans databases, an IPM Expertise database, information on pesticide use, current pest management research, funding opportunities, and links to related sites. Additional region-specific information, news, and announcements can be found at the regional Web sites.

NRCS (no date) has prepared a backyard conservation tip sheet that provides the public with information on pest management. The tip sheet helps readers to identify the problem, to know what to look for, and to control various types of pests with mechanical, physical, biological, and chemical control strategies. The NRCS tip sheet is available at http://www.nrcs.usda.gov/feature/backyard/pdf/PestMgt.pdf.

The International Turf Producers Foundation (ITPF, no date) recently published *Water Right: Conserving Our Water, Preserving Our Environment*. The publication provides information about a variety of water topics, including water use and conservation, environmental and economic benefits of responsible landscape management, and landscape water conservation techniques. The document is available for download at http://www.turfgrasssod.org/waterright.html or can be obtained by contacting ITPF at 1855 Hicks Road, Suite C, Rolling Meadows, Illinois, 60008; 847-705-9898 or 800-405-8873.

Audubon Magazine published *The Audubon Guide to Home Pesticides* in 2000. This guide provides citizens with a list of popular pesticides, along with their typical uses, their toxicity to humans and wildlife, EPA's toxicity rating, and alternatives for each of the chemicals. The guide is available for download at http://www.magazine.audubon.org/pdf/pesti_chart.pdf.

The Pest Management Branch of the California Department of Pesticide Regulation published *Suppliers of Beneficial Organisms in North America*. The publication lists 143 commercial suppliers of 130 beneficial organisms that are used for biological control. Suppliers are located in Canada, Mexico, and the United States. The booklet is available for download at http://www.cdpr.ca.gov/docs/ipminov/bensuppl.htm.

The EXtension TOXicology NETwork (EXTOXNET) is a joint effort of the University of California at Davis, Oregon State University, Michigan State University, Cornell University, and the University of Idaho. EXTOXNET provides a variety of information about pesticides, including discussions of toxicological issues of concern; toxicology newsletters, fact sheets, and information briefs; pesticide information profiles; and other resources for toxicology information. The network can be accessed at http://ace.orst.edu/info/extoxnet.

The National Pesticide Telecommunication Network is a cooperative effort of Oregon State University and the U.S. Environmental Protection Agency. The network is a source of chemical, health, and environmental information about more than 600 pesticide active ingredients incorporated into at least 50,000 different products registered for use in the U.S. since 1947. The toll-free telephone service (800-858-7378) provides information about pesticide products, recognition and management of pesticide poisoning, toxicology, and environmental chemistry to any caller in the United States, Puerto Rico, or the Virgin Islands.

Nonpoint Education for Municipal Officials (NEMO) is an educational program created by the University of Connecticut for local land use decision-makers that addresses the relationship between land use and protection of natural resources, particularly water resources. NEMO is an award-winning program that uses remote sensing, geographic information systems, and Internet technologies. The NEMO model is being adapted around the country, and NEMO projects are being planned and implemented by various agencies and organizations. This nationwide group, under the leadership and coordination of the University of Connecticut NEMO Project, is called the National NEMO Network. Additional information about NEMO is available at http://www.nemo.uconn.edu/.

Organic Gardening magazine and Web site (http://www.organicgardening.com/) provide information about organic pest control and help users find soil-testing labs in their area.

Riversides is a Canadian nonprofit organization that promotes source control and nonpoint source pollution prevention strategies. An important component of the Riversides Web site is H_2infO: The Water Information Network, which provides information about current campaigns, resources, and services offered by the network. Also offered are listservers and links to agencies, associations, and non-governmental organizations. The H_2infO Web site can be accessed at http://www.h2info.org/. Also, H_2infO can be contacted at 590 Jarvis Street, Suite 200, Toronto, Ontario, Canada, M4Y 2J4; phone 416-392-1757; fax 416-960-9944; e-mail input@H2infO.org.

EPA's Biopesticide Web site provides users with specific information about biopesticides, including fact sheets, decision documents, product lists, labels, company lists, study reviews, bibliographies, regulatory information, and federal register notices. The Web site can be accessed at http://www.epa.gov/pesticides/biopesticides.

EPA (1995) published the *Citizen's Guide to Pest Control and Pesticide Safety*, which provides users with important information about pesticides, including steps to control pests in and around the home; alternatives to chemical pesticides; methods for choosing, using, storing, and disposing of pesticides; how to reduce exposure when others use pesticides; how to choose a pest control company; and what to do if someone is poisoned by a pesticide. The guide is available at http://www.epa.gov/oppfead1/Publications/Cit_Guide/citguide.pdf.

EPA (1999) published *Education Projects in the Office of Water: A How-to Guide for Developing Environmental Education Projects*. The document provides a road map for creating quality environmental education projects and outlines EPA's procedural guidelines for producing a product or supporting related projects already in existence. It also lists publications, contacts, and references, including Web sites, training opportunities, and available materials, that provide the reader with further detail and insight into the process of developing effective environmental

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education pieces. A list of agencies and organizations that have water-related environmental education programs and projects is provided in an appendix. The publication is available from EPA's National Service Center for Environmental Publications Web site at http://www.epa.gov/ncepihom. It can also be ordered by phone, fax, or mail from USEPA/NSCEP, P.O. Box 42419, Cincinnati, Ohio 45242-2419; toll-free 800-490-9198; fax 513-489-8695.

The Commonwealth of Kentucky published *Turfgrass: Best Management Practices for Protection of Water Resources* (USEPA, 2001b). The manual provides information and guidance on turf grass management practices that decrease adverse effects on water resources. Information about the manual, along with a list of commonly used best management practices for turf management, is available at http://www.epa.gov/Region4/water/nps/projects/ky94-2.htm.

The Council of State Governments (1999) published *Getting in Step: A Guide to Effective Outreach in Your Watershed*. The guide presents a step-by-step approach for developing and implementing an effective watershed outreach plan. *Getting in Step* is available for download in PDF format at http://www.epa.gov/owow/watershed/outreach/documents/getnstep.pdf or by calling Books on Demand (800-521-3042).

State-specific cooperative extension service information is available from the Cooperative State Research, Education, and Extension Service (CSREES) at http://www.csrees.usda.gov/.

The California Peer Review Project, funded by the California Integrated Waste Management Board, compiles and reviews scientific research on the health effects, environmental effects, and efficacy of alternative household products. The project allows interested parties to participate during the review process, and findings from these literature reviews are available for download on the Web site (http://www.peerreview.com/).

The Stormwater Quality Management Committee, sponsored by the Clark County Regional Flood Control District in Las Vegas, Nevada, has developed a Web site devoted to its campaign to prevent pollution from urban runoff. The site has a number of resources for developing education and outreach materials, including examples of a bus stop shelter ad campaign, public service announcements, brochures, and community presentations at http://www.lvstormwater.com/.

The EPA's Web site, *Yard Trimmings/Food Scraps,* provides basic information on the environmental and economic benefits of recycling yard waste and food scraps. It also includes descriptions of practices for citizens, links to case studies, and technical fact sheets. The site can be accessed at http://www.epa.gov/epaoswer/non-hw/muncpl/yard.htm.

In 1994 the EPA published *Composting Yard Trimmings and Municipal Solid Waste,* a 151-page manual on the inclusion of composting as part of an integrated solid waste management program. It provides guidance on program development, facility siting and design, and costs and benefits, and includes information on many helpful resources. This manual can be downloaded in PDF format at http://www.epa.gov/epaoswer/non-hw/compost/cytmsw.pdf.

The Region 4 DoD Pollution Prevention Partnership published *Best Management Practices Resource Guide—Household Hazardous Waste* to guide pollution prevention activities on

military bases, but the information is applicable to any pollution prevention initiative. It includes guidance on proper management of household chemicals, as well as descriptions of applicable state and federal laws, regulations and reporting requirements, and state resources. It describes various types of collection programs, lists resources for disposal and recycling by material type, and includes examples of outreach and education materials. The resource guide is available in PDF format at http://www.p2pays.org/ref/13/12935.pdf.

9.4.2 Yards: General Resources

The Bay Area Water Pollution Prevention Agency's "Our Water, Our World" program published *Less-Toxic Pest Management: Problem Pesticides,* a fact sheet describing the current state of chlorpyrifos and diazinon regulation, as well as some additional pesticides of concern. It provides information on alternative pest management techniques and sources of additional information. The site can be accessed at http://www.ci.livermore.ca.us/wrd/pdf_files/pesticides.pdf.

The *National Foundation for IPM Education* (NFIPME) is a non-profit organization that promotes education, provides information, and encourages research on integrated pest management. The Web site, http://www.ipm-education.org/, contains links to sponsored programs and information on grants for pesticide environmental stewardship.

Robert Mugaas at The University of Minnesota Cooperative Extension published *Responsible Fertilizer Practices for Lawns.* The paper provides soil-specific information on fertilizer application practices to protect water quality. It can be accessed at http://www.extension.umn.edu/distribution/horticulture/DG6551.html.

9.4.3 Yard Resources for Homeowners

Water Quality and Home Lawn Care, by the North Carolina State University Cooperative Extension, takes citizens through the process of establishing a healthy lawn and maintaining it using practices that protect water quality. It provides specific instructions on watering, mowing, and fertilization. This fact sheet can be downloaded in PDF format from http://www.turffiles.ncsu.edu/PUBS/MANAGEMENT/HOMELAWN.PDF.

The U.S. EPA publication *Healthy Lawn, Healthy Environment* is a user-friendly brochure that describes lawn care practices for citizens. It covers the basic principles of soil building, mowing techniques, appropriate thatch buildup, and IPM. The brochure also discusses important considerations for citizens in selecting a professional lawn care service. The brochure can be downloaded in PDF format from http://www.epa.gov/oppfead1/Publications/lawncare.pdf.

9.4.4 Yard Resources for Lawn Care Professionals

The University of Florida Cooperative Extension maintains a database of fact sheets for lawn care professionals, *Professional Lawn and Landscape Fact Sheets*. The fact sheets cover athletic fields, golf courses, roadsides, interiorscapes and non-residential lawns. The fact sheets can be downloaded from http://edis.ifas.ufl.edu/TOPIC_Professional_Lawn_and_Landscape.

The North Carolina State University Cooperative Extension's fact sheet, *Water Quality & Commercial Lawn Care*, is a resource for lawn care professionals on fertilizer, mowing, and irrigation practices. It includes information on the leaching potential of specific chemicals, turf

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grass selection, and fertilizer use. The fact sheet is available in PDF format at http://www.turffiles.ncsu.edu/pubs/new/commcare.pdf.

The North Carolina State University Cooperative Extension has published *Pest Control for Professional Turfgrass Managers*. This document includes information on proper use and leaching potential for commonly used insecticides and herbicides. It provides information on tolerance and disease resistance for turf grass species. It is available for free download in PDF format from http://ipm.ncsu.edu/AG408/turfgrass.pdf.

Water Quality for Golf Course Superintendents and Professional Turf Managers, produced by the North Carolina State University Cooperative Extension, describes lawn care practices that help to protect water quality. The discussion covers turf grass selection, IPM, mowing, and fertilizer practices that are specific to commercial lawn care. The fact sheet is available as a PDF at http://www.turffiles.ncsu.edu/PUBS/MANAGEMENT/PROTURF.PDF.

North Carolina State University Cooperative Extension's fact sheet, *Water Quality and Pesticide Selection for Professional Turf Managers,* provides guidance on the chemical selection process and information on leaching potential and toxicity for herbicides, insecticides, and fungicides. The fact sheet is available as a PDF at www.turffiles.ncsu.edu/PUBS/MANAGEMENT/PESTFORMAT1.PDF.

The Cooperative Extension at Rutgers State University maintains an online *Database of Commercial Turfgrass and Landscape Maintenance Fact Sheets*, a resource for lawn care professionals. It is accessible at http://www.rce.rutgers.edu/pubs/subcategory.asp?cat=5&sub=35.

The Golf Course Superintendents Association of America (GCSAA) has developed a set of principles for the protection of water quality in golf course planning and siting, design, construction, and maintenance. These principles and practices are summarized in the online publication, *Golf and the Environment.* It can be accessed at http://www.gcsaa.org/resources/facts/principles.asp.

The Professional Lawn Care Association of America's *Grasscycling Guide* describes recommended mowing heights for various grass types, the benefits of recycling grass clippings, and simple techniques for returning grass clippings to lawns. The guide is available in PDF format at http://turf.ufl.edu/BMPmanual.pdf.

The Florida Department of Environmental Protection produced *Best Management Practices for Protection of Water Resources in Florida* to provide guidance on specific lawn care industry practices to protect water quality. The manual covers practices such as employee training, irrigation system design, the design and installation of landscapes, and irrigation system maintenance. It explains techniques for mulching, mowing and pruning, material disposal, fertilizer application, IPM, and spill prevention. It is available for download in PDF format at http://miami-dade.ifas.ufl.edu/programs/fyn/publications/PDF/GI-BMP6-20-02.pdf.

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MANAGEMENT MEASURE 10
EXISTING DEVELOPMENT

10.1 Management Measure

Develop and implement watershed management programs to reduce runoff pollutant concentrations and volumes from existing development and redevelopment:

- Identify opportunities to reduce pollutants in priority local and/or regional watersheds (e.g., improvements to existing urban runoff control structures, including the addition of infiltration, filtration, retention, and detention practices).
- Devise a schedule for implementing appropriate runoff controls.
- Limit destruction of natural conveyance systems.
- Where appropriate, preserve, enhance, or establish buffers along surface water bodies and their tributaries.
- Promote redevelopment that reduces runoff volumes and pollutants.

10.2 Management Measure Description and Selection

10.2.1 Description

The purpose of this management measure is to protect or improve surface water quality by developing and implementing watershed management programs that pursue the following objectives:

- Reduce surface water runoff pollution loadings from areas where development has already occurred.
- Reduce the volume and peak runoff rates of surface water runoff to reduce runoff flow, increase infiltration, and minimize habitat degradation and sediment loadings from erosion of streambanks and other natural conveyance systems.
- Preserve, enhance, or establish buffers that provide water quality benefits along water bodies and their tributaries.

Maintaining water quality becomes increasingly difficult as urbanization occurs and areas of impervious surface increase. Increased peak runoff volumes from impervious surfaces result in alteration of stream channels, natural drainageways, and riparian habitat. This alteration, in turn, results in elimination or reduction of predevelopment aquatic flora and fauna and degradation of predevelopment water quality. Other effects include increased bank cutting, streambed scouring, embedded cobbles, siltation, increases in instream water temperature, decreases in dissolved oxygen, and changes to the natural structure and flow of the stream or river.

Protecting water quality in urbanized areas is difficult because of many factors, including diverse pollutant loadings, large runoff volumes, limited areas suitable for surface water runoff treatment systems, the high implementation costs associated with structural controls, and the destruction or absence of buffer zones that can filter pollutants and prevent the destabilization of streambanks and shorelines.

An important nonstructural component of many watershed management plans is the establishment and preservation of buffers and natural systems (e.g., by policy, code, or ordinance). These areas help to maintain and improve surface water quality by filtering and infiltrating urban runoff. In areas of existing development, natural buffers and conveyance systems may have been altered as urbanization occurred. Where possible and appropriate, additional impacts on these areas should be minimized, and if the areas are degraded, their functions should be restored. Establishing and protecting buffers is most appropriate along surface water bodies and their tributaries where water quality and the biological integrity of the water body are dependent on the presence of an adequate buffer or riparian area. Buffers may be necessary where the buffer or riparian area:

- Reduces significant nonpoint source pollutant loadings;
- Provides habitat necessary to maintain the biological integrity of the receiving water;
- Reduces undesirable thermal impacts on the water body; or
- Reduces erosion.

Structural practices may be a suitable option to decrease the nonpoint source pollution loads generated from developed areas in addition to nonstructural controls (see Management Measure 9: Pollution Prevention). In such situations, a watershed plan can be used to integrate the construction of new surface water runoff treatment structures and to retrofit existing surface water runoff management systems.

Retrofitting is a process that involves the modification of existing surface water runoff control structures or surface water runoff conveyance systems that were initially designed to control flooding, not to serve a water quality improvement function. By enlarging existing surface water runoff structures, changing the inflow and outflow characteristics of such devices, and increasing runoff detention and retention time, sediment and associated pollutants can be removed from the runoff. Retrofit of structural controls is often the only feasible alternative for improving water quality in developed areas. Where existing development or financial constraints limit treatment options, targeting or identifying priority pollutants and selecting the most appropriate retrofits that will result in the greatest improvement to water quality may be necessary.

Once key pollutants have been identified, an achievable water quality target for the receiving water should be set to improve current levels based on an identified objective or to prevent degradation of current water quality. Extensive site evaluations should then be performed to assess the performance of existing surface water runoff management systems and to pinpoint low-cost structural changes or maintenance programs for improving pollutant removal efficiency. Where flooding problems exist, source controls, low-impact development (LID), and infiltrative controls should be incorporated into the design of surface water runoff controls. Available land is often limited in urban areas, and the lack of suitable areas frequently restricts the use of conventional pond systems. In heavily urbanized areas, sand filters, biofilters, or water

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quality inlets with oil/grit separators might be appropriate for retrofits because they do not limit use of the land.

10.2.2 Management Measure Selection

The first and second components of this management measure were selected to encourage communities to develop and implement watershed management programs. Local conditions, availability of funding, and problem pollutants vary widely among communities. Watershed management programs allow communities to select and implement the practices that best address local needs. Prioritizing local and/or regional pollutant reduction opportunities and setting schedules for implementing appropriate controls were selected as logical starting points for establishing an institutional framework to address nonpoint source pollutant reduction. The first two parts of Section 10.3: Management Practices, "Identify, Prioritize and Schedule Retrofit Opportunities" and "Implement Retrofits as Scheduled" address these two components.

The third and fourth components of this management measure were selected to preserve, enhance, and establish areas within existing development, such as natural streams, ponds, and wetlands and aquatic buffers, that provide positive water quality benefits. These natural systems provide efficient runoff conveyance as well as aesthetic benefits. These components are addressed by the third, fourth, and fifth parts of Section 10.3: Management Practices: "Restore and Limit the Destruction of Natural Runoff Conveyance Systems," "Restore Natural Streams," and "Preserve, Enhance, or Establish Buffers."

The fifth component is addressed by part 5 of Section 10.3: Management Practices, "Revitalize Urban Areas." This component was selected to encourage redevelopment of urban areas that may be contributing to water quality problems via impervious surfaces, contaminated soils, or land uses that result in poor runoff quality or increased runoff volumes. Multiple goals such as surface water and ground water quality improvement, soil remediation, and quality-of-life enhancements may be simultaneously achieved using such an approach.

The Brownfields program, managed by EPA under the authority of the Small Business Liability Relief and Brownfields Revitalization Act of 2002 (USEPA, 2002b), promotes redevelopment of these areas and also can be an effective source of funding and expertise to achieve the above goals. The Act

- Provides legislative authority for the Brownfields program including grants for assessment and clean-up;
- Expands the current Brownfields program by increasing its funding authority up to $200 million per year including up to $50 million per year to assess and clean up brownfields with petroleum contamination;
- Expands eligibility for assessment and clean-up grants;
- Includes a new provision for direct clean-up grants of up to $200,000 per site;
- Streamlines current requirements for the brownfields clean-up revolving loan fund and makes funding available to nonprofit organizations;

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- Applies the Davis Bacon Act, which maintains local wage and labor standards for federal construction work, on the same terms as the authority for the current program; and

- Makes funds available for technical assistance, training, and research.

More information about the Small Business Liability Relief and Brownfields Revitalization Act can be found at http://www.epa.gov/brownfields/sblrbra.htm.

Cost was a major factor in the selection of this management measure. EPA acknowledges the following constraints to implementing nonpoint source controls for existing development:

- High costs and other limitations inherent in treating existing sources to levels consistent with the standards set for developing areas;

- Frequent lack of suitable areas for structural treatment systems that can adequately protect receiving waters;

- Lack of universal cost-effective treatment options;

- Frequent lack of funding for mandatory retrofitting; and

- Extraordinarily high costs associated with implementing retention ponds and exfiltration systems in developed areas.

10.3 Management Practices

10.3.1 Identify, Prioritize, and Schedule Retrofit Opportunities

In the watershed assessment phase of the urban runoff management cycle, watershed managers should identify water bodies that have been degraded by urban runoff and prioritize them for restoration based on the costs and benefits for watershed stakeholders. One method to halt further degradation and initiate water body recovery is to retrofit existing runoff management practices or conveyance structures. It is important for watershed managers to have clear goals and realistic expectations for retrofitting existing structures. Each retrofit project should be planned in the context of a comprehensive watershed plan, and managers should have a clear set of objectives to ensure that the project results in measurable improvements in hydrologic, habitat, and/or water quality indicators.

10.3.1.1 Evaluate existing data

The first step in identifying candidate sites for storm water retrofitting is to examine existing data. These data can include results from a watershed assessment, topographic maps, land use or zoning maps, property ownership maps, aerial photos, and maps of the existing drainage network. For example, results from a watershed assessment can be used to identify areas with good habitat and water quality that should be protected, as well as areas with poor habitat and water quality that need to be improved. Topographical maps can be used to delineate drainage units within the watershed at the subwatershed and catchment levels. Land use or zoning maps can be used to estimate areas of high impervious cover to target areas that contribute a large amount of runoff to receiving waters, while property maps provide land ownership data. Finally,

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aerial photographs can be used to identify open spaces that can be more easily developed into runoff management facilities. According to the Center for Watershed Protection (CWP, 1995a), the best retrofit sites:

- Are located adjacent to existing channels or at the outfall of storm drainage pipes;
- Are located within an existing open area;
- Have sufficient runoff storage capacity;
- Are feasible for diverting runoff to a potential treatment area (forested or vegetated area) or structural management practice; and
- Have a sufficient drainage area to contribute meaningfully to catchment water quality.

Specific areas well-suited for new runoff controls include undeveloped parkland and open space, golf courses, wide floodplains, highway rights-of-way, and edges of parking lots.

Information for potential retrofit sites, such as location, ownership, approximate drainage area, utility locations, and other pertinent details, can be compiled in a retrofit inventory sheet (CWP, 1995a). A site visit can provide information on site constraints, topography, adjacent sensitive land uses, receiving water conditions, utility crossings, and other considerations that would affect the feasibility of implementing the management practice. At this point, a conceptual sketch for rerouting drainage and siting management practices should be drawn and preliminary cost estimates made for each site.

10.3.1.2 Choose appropriate management practices based on site conditions

The choice of one potential retrofit site over another for management practice implementation can be based on several different factors in addition to site limitations and cost. For instance, the preliminary goals of a retrofit program may be to preserve streams or reaches known to have high-quality habitat or exceptional water quality. The goal of another program may be to restore poor habitat and degraded water quality. The program may elect to target particular land uses thought to contribute the majority of pollutants to receiving waters. Retrofit facilities also can be installed to treat runoff from large parts of a watershed or subwatershed (regional controls), thereby requiring fewer overall projects. Once retrofit sites are identified and prioritized, a schedule for installing new facilities or updating old facilities should be devised.

10.3.1.3 Incorporate low-impact development practices into existing development

In many cases, sites that are already developed can be retrofitted with low-impact development practices such as biofilters, rain barrels, rooftop greening, and cisterns (see Management Measure 5 for a more detailed discussion of these practices). Soil rehabilitation and tree planting can also contribute to the reduction of runoff. All of these practices can be designed on a small scale to accommodate space constraints that may be present on developed sites. The use of these practices will aid in retaining runoff on-site and help to reduce the total volume of runoff reaching receiving waters. For example, in Washington, DC, trees have saved $4.74 billion in gray infrastructure costs per 30-year construction cycle, and reduced the need for storm water retention structures by 949,000 ft^3 (NALGEP, 2003).

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The City of Chicago has incorporated low-impact development practices such as rooftop greening and downspout disconnection into its urban runoff management strategy. The City Hall Rooftop Garden is a $1.5 million retrofit project to demonstrate the benefits of green roofs. The city has published *A Guide to Rooftop Gardening* (http://www.cityofchicago.org/Environment/GreenTech/pdf/GuidetoRooftopGardening.pdf) to communicate the lessons learned from this project and provide information to the public on green roof development. The city is also targeting flood-prone areas for its downspout disconnection campaign, distributing door hangers and brochures to residents, and encouraging the use of rain barrels (Murante, 2003).

The *Low-Impact Development Design Strategies: An Integrated Design Approach* (Prince George's County, Maryland, Department of Environmental Resources, 2000) and the Low Impact Development Center Web site (http://www.lowimpactdevelopment.org/) can provide more information about these and other practices appropriate for existing developments. Additionally, a search for "urban forestry" on the USDA Forest Service's Web site (http://www.fs.fed.us/) produces many good references about how trees can be used to reduce runoff volume and improve runoff quality.

10.3.1.4 Identify undeveloped and privately owned land for acquisition

In addition to the installation of conventional storm water management practices, the acquisition and preservation of open space in developed watersheds can protect against the threat of further development, reduce runoff volume, and provide storm water treatment. This practice involves the identification of parcels in a developed watershed that are undeveloped or privately owned and can be protected or restored to provide storm water benefits by attenuating additional runoff volume and peak flow. This watershed-wide planning effort involves mapping open space, cadastral data (e.g., property boundaries, subdivision lines, buildings), drainage systems, urban forests, floodplains, and other land use data. The planning effort also involves selecting sites based on their proximity to receiving waters, the condition of the soil and vegetation, and ease of purchase. Selected parcels are purchased, restored if necessary, and modified to receive and retain more runoff using berms or diversions (O'Leary, 2003). For more information on land acquisition, see Management Measure 3: Watershed Protection.

10.3.1.5 Use routine maintenance as an opportunity for retrofitting existing infrastructure

One of the major challenges in controlling runoff from existing development is the potentially high cost of retrofitting infrastructure to reduce runoff quantity and improve quality. One way to reduce costs is to modify runoff controls during routine maintenance procedures. Retrofits can be constructed as part of the routine maintenance and repair of urban infrastructure. This approach requires less capital outlay for retrofit compared to large-scale, capital-intensive approaches. For example, pervious surfaces can be installed when resurfacing parking areas, and newly disturbed areas can be restored to the desired vegetative condition (e.g., forest or meadow). When storm water ponds are dredged every few years, sediment forebays can be redesigned to improve performance.

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Retrofitting Catch Basins for On-Street Runoff Storage

An example of a retrofit to reduce downstream impacts of urbanization can be found in the towns of Skokie and Wilmette, Illinois. These towns are urban areas that are served by a combined sewer system (CSS). Both communities wanted to control CSS surcharge but did not want to build expensive relief sewers. As a result, they were willing to try alternative approaches. The towns decided to modify street cross sections and storm drain inlets to allow runoff to be stored temporarily on the street surface during storm events to reduce hydraulic loading to CSSs. The street surface storage projects combined the following elements (USEPA, 2000b):

- Street storage.
- Downspout disconnection.
- Flow regulators.
- Subsurface storage.
- New storm and combined sewer systems.
- Improvements to existing storm and combined sewer systems.

The projects involved installing a system of street berms, 7 to 9 inches high, at the curb line to detain water on the street. Flow regulation devices were installed at catch basin outlets to reduce the rate of storm water flow to the CSS. Both the street surface and the inlet structure were used for storage. Subsurface storage facilities were also installed in the street right-of-way and in other public areas at critical points in the system and in pedestrian walkways, parking areas, and high-traffic areas, where ponding was unacceptable.

The project resulted in a number of benefits. Researchers estimated a cost savings from using street storage rather than conventional sewer separation systems. Estimated costs for the Skokie system are approximately 38 percent of conventional sewer separation system costs. Berm costs are a small fraction of the overall cost of the CSS surcharge relief project. Another benefit of the storage system is traffic control. Berms can function as speed humps and help control traffic. The street storage system also reduces the volume and frequency of combined sewer overflows, resulting in less runoff-related pollution entering receiving waters. Icing of ponded areas during the winter was not a problem because retention times were relatively short (less than 30 minutes), but consideration should be given to safety hazards associated with ponded water during periods of high rainfall.

10.3.2 Implement Retrofit Projects as Scheduled

CWP (1995b) describes six common types of retrofitting projects:

- Modifying existing runoff management facilities;
- Constructing new management practices at the upstream end of road culverts;
- Constructing new management practices at storm drainage pipe outfalls;.
- Constructing small instream practices in channels;
- Constructing management practices at the edge of large parking areas and
- Constructing new management practices in highway rights-of-way.

10.3.2.1 Retrofit existing runoff management facilities

Many older dry detention basins were designed for the singular purpose of flood control. In some cases, a facility of this type can be converted into an extended detention pond/wetland or a conventional wet pond. If this retrofit is designed well, it will increase pollutant removal capabilities and aquatic habitat functions without losing any of its flood control benefits. This modification also typically results in only minimal impacts on the surrounding environment. Dry

detention ponds can be modified to accommodate a greater variety of species by transforming them into constructed wetlands or installing aquatic platforms, which are shallow benches on which aquatic vegetation can be planted (see Section 5.3.1.3 for more information about constructed wetlands; Fairfax County Environmental Coordinating Committee, 2002).

The retrofit process often includes:

- Analyzing existing hydraulic characteristics and the flood control design specifications of the facility;
- Determining whether there is available storage for water quality treatment;
- Excavating the pond bottom to create permanent pool storage (for pond and wetland systems) if water quality storage is available;
- Raising the embankment or modifying the outlet structure to obtain additional storage if extended detention is needed;
- Increasing the flow path from inflow point to discharge point by using baffles or earthen berms or by regrading the pond's contours to increase particulate settlement; and
- Addressing safety considerations, such as fencing and adding underwater benches or shallow fringe areas along shorelines, to reduce the risk of drowning.

Bioengineering to enhance water quality benefits

The City of Griffin, Georgia, constructed a bioengineering system within the North Griffin Regional Detention Pond and within a forested wetland area downstream of the pond to improve water quality in the receiving waterbody, Flint River. The bioengineering system is comprised of specific species of vegetation that provide natural filtration and breakdown of pollutants in runoff. The wetland plants selected include cattail, bulrush, pickerel weed, soft rush, wool grass, southern cutgrass, and shallow sedge. Experts chose these species based on their anticipated ability to break down and filter various pollutants commonly found in runoff. The system has low maintenance requirements and relatively low construction and operating costs in comparison to conventional treatment facilities. In addition to water quality benefits, the system will enhance wildlife habitat (City of Griffin, no date). The Consulting Engineers Council of Georgia recognized the project design and performance success with an Engineering Excellence Award in February 2000. The Georgia Environmental Protection Division and USEPA Clean Water Act (CWA) Section 319(h) Program also acknowledged the project's achievement (Greuel and Feldner, 2001). A detailed summary of this project is available in EPA's Section 319 Success Stories, Vol. III at http://www.epa.gov/owow/nps/Section319III/GA.htm.

10.3.2.2 Modify the upstream end of road culverts

A good retrofit opportunity can sometimes be found at the upstream end of a road culvert. A gabion, concrete weir structure, or riser/barrel control structure can be installed to create a small, permanent micropool excavated to provide water storage, water quality, and habitat benefits. This method can be used to provide a dry extended detention basin with a maximum depth of 6 feet above the culvert invert. If the upstream area is open floodplain, it might be possible to construct a wet pond or extended detention pond/wetland retrofit.

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Cost-Effectiveness Study of Retrofitting Runoff Treatment Facilities

EPA's Office of Research and Development investigated retrofitting wet-weather flow treatment facilities to determine their feasibility and cost-effectiveness (Moffa et al., 2000). The following retrofit scenarios were analyzed:

- Converting or retrofitting primary settling tanks with dissolved air flotation and lamellae (thin, flat membranes or layers) and/or microsand-enhanced plate or tube settling units.
- Retrofitting existing wet-weather flow storage tanks to provide enhanced settling/treatment and post-storm solids removal.
- Converting dry ponds to wet ponds for enhanced treatment.
- Retrofitting wet-weather flow storage tanks for dry-weather flow augmentation.
- Using storage for sanitary sewer overflow control.
- Retrofitting for industrial wastewater control in a combined sewer system.
- Bringing outdated/abandoned treatment plants back on-line as wet-weather flow treatment facilities.

The cost-benefit analysis examined site-specific, operational, cost, and design parameters. Each retrofit scenario was analyzed over a range of flow and/or volume conditions. The study revealed that in certain circumstances, retrofitting existing wet-weather flow treatment facilities is technically feasible and can be more cost-effective than construction of new conventional control and treatment facilities. The authors concluded that these results were highly site-specific and recommended that retrofitting existing control facilities be identified as one of several alternatives to reduce impacts from storm events. The full report is available at the Office of Research and Development's Web site at http://www.epa.gov/ednnrmrl/news/main.htm.

Because roadways are not constructed as runoff management embankments, special measures might be necessary to ensure that these facilities meet dam safety specifications for seepage control and passage of the 100-year storm. Consideration and evaluation of secondary impacts, such as modification of the 100-year floodplain, creation of fish migration barriers, and changes to the wetland hydrologic regime is also warranted with this type of retrofit.

10.3.2.3 Modify storm drainage pipe outfalls

A volume of runoff can be diverted at or near a storm drainage pipe outfall to a sand filter, peat-sand (or other medium) filter, bioretention system, centrifugal deflection system, off-line wetland or pond system, or other water quality treatment facility for treatment before it reenters a receiving water.

10.3.2.4 Add retention structures to channelized streams

Small weir walls or check dams can sometimes be placed in small, previously channelized streams to retain sediments and create a ponding area for wetland vegetation. This type of retrofit is usually easy to install and can provide moderate pollutant removal benefits. Because it can

potentially affect channel design flows and the floodplain, however, careful analysis must be conducted before the instream practice is implemented. In addition, cleanout frequency should be considered before selecting this practice, as regular maintenance will be needed to remove trapped sediments.

10.3.2.5 Install runoff management practices in or adjacent to large parking areas

Retrofit practices can be installed near large parking lots to capture, detain, and/or treat runoff. Infiltration practices such as bioretention areas, porous pavement, sand filters, and underground vaults are good candidates. Two examples of successful use of bioretention areas can be found at http://www.epa.gov/owow/nps/bioretention.pdf (USEPA, 2000a). In addition, a case study illustrating the effectiveness of porous pavement in reducing runoff is provided at http://www.epa.gov/owow/nps/pavements.pdf (USEPA, 2000b).

10.3.2.6 Construct new practices in highway rights-of-way

Existing highway systems can have significant open spaces for the installation of various practices. For example, cloverleaf open space can be an ideal location for storm water wetlands and pond systems if drainage areas and patterns allow. Care must be taken to avoid creating a safety hazard for traffic, and maintenance access should be an integral part of the design.

10.3.2.7 Install trash-capturing devices

Trash racks are inclined metal grates that trap floatables as water passes through. The racks can be installed at storm sewer inlets or outfalls or in the stream itself. These structures effectively remove trash from the water, but they require a high level of maintenance (inspection for damage or clogging after storms and regular trash removal). If these racks are poorly maintained, their effectiveness decreases and they can clog, which can cause a flood hazard. A less-expensive alternative to metal trash racks is plastic mesh trash collectors with floating piers that stretch across the width of the stream. They are easier to maintain because they are simply removed and replaced with a new collector.

The applicability of these trash collection methods is limited to small streams with relatively low flow and low-level trash inputs. More substantial trash collection methods, such as vortex devices that use centrifugal force to separate floatables from water, can be installed to handle larger flows or high trash loads.

10.3.2.8 Install inlet and grate inserts

A wide variety of inserts that trap oil and grease from parking lots, maintenance yards, and streets are also commercially available. These can be used with or without trash capture in storm drain inlets and grates. Inspection and maintenance one to four times per year (depending on pollutant concentrations in runoff) is usually recommended. Catch basin inserts are discussed in more detail in Management Measure 5 (section 5.3.5.4).

10.3.3 Restore and Limit the Destruction of Natural Runoff Conveyance Systems

Existing development has likely resulted in a modification of natural drainage patterns as compared to predevelopment conditions. As a result, increases typically occur in imperviousness,

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runoff, peak flows during storm events, erosion, and pollutant transport. The use of traditional runoff management technology, such as piping, channeling, and curbing, has aggravated these impacts.

Efforts should be made to restore previously developed or redeveloping sites so they more closely mimic predevelopment hydrologic conditions. The predevelopment condition should be estimated based on historical records and existing slopes, soils, and natural drainage features. Consideration should be given to the time of concentration—the time it takes water to travel from the farthest point in a subwatershed to the outlet. (Sites might contain multiple subwatersheds and multiple outlets.) Paving and curbing substantially reduce time of concentration, resulting in high peak flows during storms. Time of concentration can be increased substantially by modifying drainage patterns and installing infiltration and detention practices. The practices presented in this section can be used to increase time of concentration on a particular site. Additional technical guidance for restoration practices can be found at EPA's River Corridor and Wetland Restoration Web site at http://www.epa.gov/owow/wetlands/restore (USEPA, 2002a). Another resource is *Stream Corridor Restoration: Principles, Processes, and Practices* (FISRWG, 1998), which can be downloaded at http://www.nrcs.usda.gov/technical/stream_restoration/newgra.html or ordered by contacting the National Technical Information Service, 5285 Port Royal Road, Springfield, VA 22161; telephone 703-605-6000 or 800-553-NTIS; e-mail orders@ntis.fedworld.gov.

10.3.3.1 Disconnect impervious areas

Roof downspouts can be disconnected from streets and culverts and runoff diverted over vegetated areas or infiltration systems (for treatment) or into cisterns or rain barrels (for reuse; see Management Measure 5 for more information on these practices). Also, roadway runoff can be converted to sheet flow and directed to vegetated buffers, infiltration devices, or other pervious areas.

Rooftop runoff also can be controlled with a vegetated roof cover. These systems consist of a high-quality waterproof membrane covered by drainage material, a planting medium, and vegetation. Vegetated roof covers use foliage and a lightweight soil mixture to absorb, filter, and detain rainfall. The systems are designed to control high-intensity storms by intercepting and retaining water until the rainfall peak passes (USEPA, 2000d). Additionally, vegetated roof covers improve insulation and reduce the amount of reflected solar radiation, resulting in lower temperatures in urban areas. More information about vegetated roof covers can be found at http://www.epa.gov/owow/nps/roofcover.pdf.

The City of Portland, Oregon, encourages residents to reduce the connectivity of impervious surfaces through its Downspout Disconnection Program, originally established in 1996 to address problems with combined sewer overflows. Through an interagency agreement, the local plumbing code was revised to allow downspout disconnection without a permit. The program has developed safety standards that establish criteria for the feasibility of a disconnection, as well as an inspection and maintenance program to ensure safety. Homeowners can choose to have the city disconnect a downspout free of charge, or they can disconnect it themselves and receive a cash incentive. Since the start of the program, nearly 17,000 homes have been disconnected and data have been collected on an additional 20,000 potential disconnections (Hottenroth, 2003).

More information about the Downspout Disconnection Program can be found at http://www.portlandonline.com/oni/index.cfm?c=28992.

10.3.3.2 Encourage overland sheet flow

Concentrated flow of runoff during storms results in decreased time of concentration, decreased infiltration, and increased erosion due to high runoff velocity. Careful regrading to reduce steep slopes slows runoff, promotes infiltration, and reduces erosion. (Note that regrading efforts should not result in increased compaction; if compaction has occurred, soil amendments and rehabilitation may be necessary.) A level spreader, which typically consists of a shallow, gravel-filled trench that receives concentrated flows and converts them to sheet flow, can be installed to convey runoff to vegetated areas. A flat, grassy area can also be used to promote overland flow.

10.3.3.3 Increase flow path

Increasing the path of runoff results in increased storm water detention and increased travel time. Directing concentrated flows from impervious areas to infiltration areas, swales, dry wells, cisterns, or bioretention facilities increases the time it takes for runoff to leave the site and mitigates peak runoff flows.

10.3.3.4 Use open swales in place of traditional storm drain systems

Grassed swales are an effective and natural means of conveying runoff. Because the water comes into contact with vegetation, the runoff velocity decreases, which promotes infiltration, reduces erosion, and lengthens time of concentration. Because grassed swales are wider and shallower than conventional channels, runoff is less concentrated. They are especially appropriate alongside roadways or on the border of a site. Swales can be combined with terraces and infiltration devices to enhance runoff retention. Swale installation requires a minimum amount of excavating and regrading. Vegetation should be established immediately to prevent excessive erosion; while vegetation is being established, geotextiles or turf reinforcement mats can be used to stabilize exposed soils in the swale.

One neighborhood in Seattle, Washington, underwent a transformation from conventional to natural drainage systems as part of a pilot project, called "SEA Street" (for Street Edge Alternatives), conducted by Seattle Public Utilities. Monitoring before and after the installation of swales indicated a decline from approximately 5,000 cubic feet of runoff from 8 inches of rain to only 132 cubic feet of runoff from 9 inches of rain. The project, which cost approximately $800,000, was equivalent to the cost of a conventional curb-and-gutter system and provides additional water quality benefits and an anticipated boost to property values (Taus, 2002). More information about this project can be found at http://www.ci.seattle.wa.us/util/About_SPU/Drainage_&_Sewer_System/Natural_Drainage_Systems/Street_Edge_Alternatives/index.asp.

10.3.3.5 Establish vegetation throughout the site

Vegetation intercepts rainfall, decreases runoff velocity by increasing surface roughness, and promotes infiltration. Establishing vegetated areas in strategic locations that currently receive runoff from impervious areas requires minimal effort, especially when native plant species are

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used. Excess compaction of these areas by heavy equipment should be avoided. To enhance the benefits of vegetated areas, part of a site can be regraded during redevelopment activities to direct runoff to these areas. See Management Measure 3: Watershed Protection (section 3.3.3.8) for a discussion of urban forestry practices that can help in achieving these goals.

10.3.3.6 Reestablish ground water recharge

Traditional development techniques that focus on quickly conveying runoff off-site have resulted in decreased infiltration of rainfall to ground water. This ground water deficit results in a lowered water table and decreased seepage and baseflow in streams during dry periods. Infiltration practices can be installed to promote ground water recharge. Such practices include infiltration trenches, infiltration basins, sand filters, biofiltration systems, and vegetated areas underlain by permeable soils (see Management Measure 5: New Development Runoff Treatment).

A Watershed Restoration Plan for the Norwalk River Watershed

Habitat quality and water quality in the Norwalk River watershed of southeastern Connecticut have been degraded by erosion, sediment, pesticides, excessive algae growth, driftwood and other impoundments, and other types of pollution associated with increased watershed urbanization (NWRI, 1998). In 1997 federal, state, and local government agencies, environmental groups, and concerned citizens formed the Norwalk River Watershed Initiative (NRWI) to halt further degradation and promote water quality recovery. Subcommittees were tasked with developing goals for four key issues: (1) habitat restoration; (2) land use, flood protection, and open space; (3) water quality; and (4) stewardship and education.

The NWRI assessed existing water quality and riparian conditions based on data collected by the Connecticut Department of Environmental Protection, U.S. Geologic Survey, and U.S. Department of Agriculture. They also identified land uses that contribute to water quality problems, areas where stream channels had been modified by dams or flood control projects, and point sources such as municipal wastewater treatment facilities.

Based on the results of the assessment, the NWRI developed the Norwalk River Watershed Action Plan, which describes specific objectives and action items to accomplish those objectives for each of the four key areas listed above. Each objective contains a list of specific tasks with the implementing group clearly identified, the proposed time line for each task, and a measure of the tasks' success. The NWRI also developed an outreach program to foster stewardship and to educate watershed residents about the impacts of daily activities that contribute to the degradation of the Norwalk River watershed.

For more information on the Watershed Action Plan or to obtain a copy of the plan, contact the Norwalk River Watershed Coordinator, Connecticut Department of Environmental Protection, Bureau of Water Management, 79 Elm Street, Hartford, CT 06106; telephone 860-424-3096; e-mail tessa.gutowski@po.state.ct.us.

Restoration in the Anacostia River Watershed

The Anacostia River has been cited nationally as exemplifying urban watershed problems (AWRC, 1998). These problems are typified by

- Conversion of natural drainage networks into man-made channels.
- Increased runoff and urban pollutants from impervious surfaces.
- Channel erosion and associated loss of aquatic habitat from changes in land use.
- Sediments laden with toxic substances and other pollutants from motor vehicles.
- Electrical transformers, past applications of persistent pesticides, poorly timed applications of fertilizers, combined sewer overflows, atmospheric deposition, and pet waste.
- Thousands of tons of trash and debris.

As a result of this degradation, in 1987 a concerted effort to restore and protect the Anacostia watershed was initiated in the form of the Anacostia Watershed Restoration Agreement and the establishment of the Anacostia Watershed Restoration Committee (AWRC), which involved the District of Columbia, Montgomery and Prince George's counties in Maryland, the State of Maryland, the U.S. Army Corps of Engineers, the Metropolitan Washington Council of Governments, and the Interstate Commission on the Potomac River Basin. The cooperative effort was expanded in 1996 with the creation of the AWRC's Anacostia Watershed Citizens Advisory Committee (AWCAC). The AWCAC has brought formal recognition of the importance and need for citizen input and involvement in the restoration.

The AWRC established a framework to guide long-term restoration efforts and identified 580 restoration projects to correct existing environmental problems and enhance overall ecosystem quality. As of 1997 approximately $20 million had been spent on implementing roughly 29 percent of the 580 identified projects, with additional millions of dollars spent on planning, design, land acquisition, and maintenance. An additional $54 million had been spent on engineering controls designed to reduce the impacts of combined sewer overflows on the tidal river and of leaking, aging sewer lines on tributary streams. As a result of the restoration efforts, the submerged aquatic vegetation once absent from the river is beginning to reappear, signaling some improvement in water clarity, as the volume and concentrations of pollutants from urban runoff have been reduced. The successes have required the identification of problems and associated solutions, coordination of programs, and the mobilization of critical government, political, and financial resources. Key features in the success of the Anacostia program have been the development of common watershed restoration goals and the identification and establishment of partnerships.

More information about the Anacostia Watershed Restoration Project can be found at http://www.anacostia.net/awrc.htm.

10.3.3.7 Protect sensitive areas

Areas that should be considered for preservation and restoration at sites with existing development include riparian areas, 100-year floodplains, wetlands, woodlands and valuable trees, and areas with permeable soils. Steep slopes and erosive soils should be protected and stabilized to the extent possible.

10.3.4 Restore Natural Streams

Streams degraded by prior urbanization should be restored, if possible, using preexisting conditions as a goal or guideline. Eight restoration tools can be applied to help restore urban streams. These tools are intended to compensate for stream functions and processes that have been diminished or degraded by prior watershed urbanization. Best results are usually obtained

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when the tools are applied together; otherwise, the same sources that degraded the stream remain unchanged, causing similar effects.

A resource for information about restoring natural streams is *Stream Corridor Restoration: Principles, Processes, and Practices* (FISRWG, 2000), which is available for purchase or download at http://www.usda.gov/stream_restoration/newgra.html. Another resource is *Urban Stream Restoration: A Video Tour of Ecological Restoration Techniques* (Riley, 1998b), which is available for purchase at http://www.noltemedia.com/nm/urbanstream/index2.html. Finally, the Center for Watershed Protection developed 11 manuals, collectively called the Urban Subwatershed Restoration Manual Series, that present the information needed to restore small urban watersheds in a format that can easily be accessed by watershed groups, municipal staff, environmental consultants, and other users. The manuals are available for a fee in hard copy or as a download at http://www.cwp.org/USRM_verify.htm.

10.3.4.1 Partially restore the predevelopment hydrologic regime

The primary objective of storm water management is to reduce the frequency of bankfull flows and other erosive events in the contributing watershed. This is often done by constructing upstream storm water retrofit ponds that capture and detain increased storm water runoff for up to 24 hours before release (i.e., extended detention). Extended detention systems are often designed to control the one-year, 24-hour storm. Storm water retrofit ponds are often critical in the restoration of small and mid-sized streams, but they might be less cost-effective in larger streams and rivers unless implemented on a watershed basis.

10.3.4.2 Stabilize channel morphology

Over time, urban stream channels can become enlarged and are subject to severe bank and bed erosion. Therefore, it is important to stabilize the channel and, if possible, restore equilibrium to the channel geometry. In addition, it is useful to provide undercuts or overhead tree canopy to improve fish habitat. Depending on the stream order, the impervious cover in the watershed, and

Restoring Channel Morphology in a North Carolina Stream

Long Leaf Creek is located in an urbanized watershed along coastal North Carolina (Sotir, 2000). The stream had deepened and widened as a result of increased runoff and severe storms, including hurricanes. The changes resulted in reduced aesthetic value, damaged riparian vegetation and aquatic and terrestrial habitats, and degraded water quality. Managers selected a soil bioengineering approach over other alternatives after considering such issues as erosion control, streambank stabilization, safer and healthier environment, flood control, timely project completion, environmental and aesthetic improvement, property loss minimization, hydraulic efficiency, and cost feasibility. They installed live fascines, brush layer/live fascine combinations, joint planting, and vegetated geogrids.

The survival rates of the live vegetation ranged from 60 to 80 percent depending on the species used; maintenance proved to be a key factor in survival rates. Several important needs were identified, including studying bed conditions in areas that have had high deposits of mobile materials, employing sophisticated grade control structures, following installation procedures and maintenance schedules, and encouraging communication and cooperation between engineers and wetland scientists.

the height and angle of eroded banks, a series of different tools can be applied to stabilize the channel and prevent further erosion. Bank stabilization measures include revegetated riprap and soil bioengineering methods (see Management Measure 7) such as willow stakes, brush bundles, bio-logs, lunker structures, and rootwads.

10.3.4.3 Restore instream habitat structure

Most urban streams have poor instream habitat structure, often typified by indistinct and shallow low-flow channels within a much larger and unstable storm channel. The goal is to restore instream habitat structure that has been blown out by erosive floods. Key restoration elements include creating pools and riffles, confining and deepening the low-flow channels, and providing greater structural complexity across the streambed. Typical tools include installation of log check dams, stone wing deflectors, and boulder clusters along the stream channel.

Urban Stream Restoration in the Waukegan River, Illinois

An urban stream restoration project is underway in the Waukegan River in Illinois to repair channel instabilty caused by runoff from impervious surfaces and lack of storm water controls. The project uses biotechnical bank restoration to stabilize streambanks and low stone weirs to restore pool and riffle sequences. A habitat monitoring design was also used to document water quality changes. The project has improved biological diversity through pool and riffle restoration, yet it did not significantly improve stream fisheries. For more information about the project, refer to *Section 319 Nonpoint Source National Monitoring Program: Successes and Recommendations* (NCSU, 2000).

10.3.4.4 Reestablish riparian cover

Riparian cover is an essential component of the urban stream ecosystem. Riparian cover is necessary to stabilize banks, provide large woody debris and detritus, and provide shade to maintain water temperatures. Reestablishment of the riparian cover plant community along the stream network is often essential to achieve the goals and objectives of the program. This can entail active reforestation of native species, removal of exotic species, or changes in mowing operations to allow gradual succession. Establishment of an urban stream buffer can achieve many of these objectives (see section 3.3.3.6 of Management Measure 3 for a discussion of setbacks/stream buffer zones).

Citizen Involvement in Planting Riparian Forests

In Lexington, Kentucky, a unique program is underway to restore riparian areas to local streams. Because the city's limited budget does not allow for an expensive riparian planting effort, Reforest the Bluegrass was established as a cooperative effort by local private and nonprofit organizations, citizen groups, and government agencies. Reforest the Bluegrass provides training for citizen volunteers to participate in replanting efforts. The program provides public education for participants and for local residents through outreach, while significantly reducing program costs. Participants are taught the value of riparian systems in protecting water quality, combating the "urban heat island" effect, and providing habitat for wildlife. As of April 2002, nearly 4,000 volunteers had planted 108,000 seedlings. The program was financed with $85,000 from local government and $50,000 from private donations, compared with an estimated cost $675,000 if the project had been completed by contractors (Gabbard and Poe, 2003).

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Restoring Atlanta's Watersheds

The International Life Sciences Institute's Risk Science Institute (RSI) was tasked with assessing the condition of streams in Atlanta, Georgia; developing a watershed management implementation plan; and identifying specific watershed restoration activities that would improve riparian habitat and water quality in four example subwatersheds (RSI, 1998). They identified several habitat and water quality impacts that can be attributed to urbanization, including

- Increased magnitude and frequency of bankfull and subbankfull events.
- Stream channel dimensions out of equilibrium with hydrologic regime.
- Enlarged, highly modified channels.
- Increased sediment load due to upstream channel erosion.
- Decreased baseflow.
- Decreased wetted perimeter.
- Degraded in-stream habitat structure.
- Reduced large woody debris.
- Increased number of stream crossings, which are potential barriers to fish migration.
- Fragmentation and narrowing of riparian forests.
- Degraded water quality.
- Increased summer stream temperatures.
- Reduced aquatic diversity.
- Combined sewer overflows.

To address these issues, RSI developed a watershed management program for the Atlanta region that includes the following elements:

- Creation of an institutional framework for watershed management (Management Measure 1).
- Development of a comprehensive storm and surface water control program.
- Establishment of erosion and sediment control programs.
- Establishment of detention pond requirements.
- Expansion of the tree canopy.
- Management of buffers, sensitive areas, and floodplains.
- Establishment of land development provisions.
- Daylighting of streams.
- Relocation of utilities.
- Eradication of invasive and exotic species.
- Development of a public education and outreach campaign.

RSI also developed several objectives for the watershed management program and identified environmental indicators that can be used to gauge the effectiveness of management activities (see Management Measure 2). Finally, RSI examined four subwatersheds to identify specific management practices that can be used to fulfill the objectives of the watershed management program. In each case study, they identified the activities in the subwatershed that were contributing to resource degradation and suggested methods, such as separating storm and sanitary sewers and improving storm water infiltration, that would reduce runoff to prevent further waterbody degradation. These methods would also increase the effectiveness of in-stream and riparian restoration activities. RSI then identified site-specific restoration activities such as streambank stabilization, riparian buffer management, and creation or restoration of in-stream habitat.

For more information about the Watershed Management Program for Atlanta or to receive a copy of RSI's report, contact the Risk Science Institute, International Life Sciences Institute, 1126 16th Street, NW, Washington, DC 20036-4810; e-mail rsi@ilsi.org.

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10.3.4.5 Protect critical stream substrates

A stable, heterogeneous streambed is often a critical requirement for fish spawning and secondary production by aquatic insects. The bed of an urban stream, however, is often highly unstable and clogged by deposits of fine sediment. It is often necessary to mechanically restore the quality of stream substrates at points along the stream channel. Often, the energy of urban storm water can be used to create cleaner substrates through the use of flow concentrators and other manufactured devices. (See Management Measure 5 for more information about these practices.) If thick deposits of sediment have accumulated on the bed, mechanical sediment removal might be needed.

10.3.4.6 Promote recolonization of the aquatic community

It may be difficult to reestablish the fish community in an urban stream if downstream fish barriers prevent natural recolonization. In these instances it is important to seek the judgment of a fishery biologist to determine whether downstream fish barriers exist, whether they can be removed, or whether selective stocking of native fish is needed to recolonize the stream reach.

10.3.4.7 Daylight streams

Daylighting involves returning a stream that has been buried in a pipe or culvert to the surface. In many cases the stream can be restored to its original channel, but sometimes a new channel must

Daylighting Jolly Giant Creek, Arcata, California

A classic example of daylighting is Arcata, California's Jolly Giant Creek (Pinkham, 1998). The daylighting and stream restoration project was initiated in 1991 by a high school biology teacher, Lewis Armin-Hoiland, and Humboldt State University students Melissa Bukosky and Tom Hagberg. They initially started the project to provide environmental education to high school and college students on stream ecology and restoration, but Bukosky continued to gather data and designed a new channel and restoration plan for the creek.

The Redwood Community Action Agency, a nonprofit regional development organization, obtained a grant from the California Department of Water Resources Urban Streams Restoration Program. Other funding sources included U.S. Fish and Wildlife Service Challenge Cost-Share, the city of Arcata, and donations from a local heavy equipment contractor and the National Tree Trust. A substantial amount of volunteer labor was used for revegetation and to conduct assessment and monitoring. Funding for the project totaled $120,000.

The first phase of the stream restoration project included removing nearly 100 feet of culvert; installing a sedimentation basin, a ⅓-acre pond, and 75 feet of new stream channel; providing bank stabilization and flow control measures; and rerouting the stream through an older dry channel with existing riparian vegetation. The second phase involved creating a new channel within the old, wider channel at an abandoned mill site; creating berms around part of the property; restoring more than 400 feet of the Jolly Giant Creek; and providing a seasonal wetland and wet weather detention pond with substantial runoff storage capacity.

For more information contact Richard Pinkham, Senior Research Associate, Rocky Mountain Institute, 1739 Snowmass Creek Road, Snowmass, CO 81654; telephone 970-927-3807; e-mail rpinkham@rmi.org.

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be engineered. Flow control structures and flood control measures can be incorporated into the design of the new or restored channel. Planting, restoring, and maintaining streambank vegetation and providing a diversity of instream habitat for submerged aquatic vegetation, fish, and aquatic insects are important aspects of the stream restoration project.

Daylighting typically requires a large capital investment for acquiring permits, engineering designs and expertise, equipment and labor for excavation, and plantings and labor to establish desirable stream morphology. Because communities are typically in favor of daylighting projects, many of these costs can be offset by recruiting sponsors such as property owners, community groups, housing associations, municipalities, environmental groups, and contractors. The benefits of a daylighting project for a particular stream reach should be carefully considered and weighed against the cost to determine whether the project is worthwhile.

A source of information is *Daylighting: New Life for Buried Streams*. In addition to summary findings, recommendations, and conclusions, the report provides information about completed and proposed daylighting projects (Pinkham, 2000).

10.3.5 Preserve, Enhance, or Establish Buffers

Stream buffers may be present as part of previous development, but it is unlikely that existing buffers were established or maintained to maximize pollutant removal. As the intensity of surrounding development increases, runoff and pollutant loads increase and can result in damage to the buffer. If the buffer is not protected from disturbance or excessive traffic, it can deteriorate over time. Buffers serve several important functions: they help improve soil and water quality, stabilize streambanks, decrease flood severity, replenish ground water supply, and provide wildlife habitat (Schultz et al., 1996). Some steps that can be taken to preserve or enhance existing buffers include:

- Delineating buffer boundaries and establishing management zones within the buffer (streamside, middle, and upland zones);
- Developing vegetative and use strategies within these zones;
- Establishing provisions for buffer crossings;
- Integrating structural runoff management practices where appropriate to protect the buffers and to augment their performance; and
- Developing buffer education and awareness programs.

A buffer can be established in the area between the stream and existing development when buildings are set back from the stream to prevent damage from flooding. These areas can be mapped and buffer boundaries established based on runoff and pollutant loadings. In some cases, impervious surfaces in the buffer need to be removed or parts of the buffer regraded to ensure maximum pollutant removal efficiency. The buffers are then divided into three zones—the streamside, middle, and upland zones—that contain different types of vegetation and accomplish pollutant removal in different ways (Herson-Jones et al., 1995). Design considerations for stream buffers are discussed in more detail in Management Measure 3.

10.3.6 Redevelop Urban Areas to Decrease Runoff-Related Impacts

10.3.6.1 Encourage infill development

Infill development is a tool planners use to encourage siting of new development on unused lands in existing urban areas. Infill development usually works in tandem with community redevelopment initiatives to foster revitalization of existing neighborhoods by replacing dilapidated buildings and underused properties with new housing or businesses. However, from a water quality perspective, if infill development is promoted on unused lands in existing developed areas, sites should be selected that result in decreased pollutant loadings and runoff volumes. Open space that provides valuable flood control and pollutant removal functions should be preserved or enhanced if possible. Trees within existing developments should be protected or replanted as necessary.

Infill and redevelopment can be employed in either large or small projects. One impediment to more widespread implementation of infill projects is the existing condition of a potential redevelopment site in terms of environmental constraints. The restrictive nature of many land use regulations and pressing social and economic issues may also impede implementation. Faced with these constraints, local governments often need to modify local zoning or building codes to make infill development and redevelopment more inviting to developers. Experience has shown that citizen involvement has often been a catalyst for leveraging funding or revising codes for this type of renewal.

10.3.6.2 Assess vacant, abandoned lots and areas of potentially contaminated soils to promote redevelopment

In many urbanized areas, changes in development patterns and economic decline have resulted in deterioration or abandonment of industrial and commercial sites. Many of these sites have contaminated and compacted soils that discharge polluted runoff during and after storms. These underused areas can be identified and assessed to determine if redevelopment or remediation can result in significant reductions in pollutant loadings or flow to improve surface water or ground water quality. Social and economic benefits may also accrue. Redevelopment plans can include the use of practices such as disconnection of impervious areas to reduce the total effective impervious area (see section 4.3.2) or infiltration practices including bioretention and onsite runoff storage.

EPA's Office of Solid Waste and Emergency Response has a brownfields initiative that encourages the redevelopment of abandoned, lightly contaminated industrial sites in economically stressed communities (USEPA, 1999). The program provides funding and guidance to help communities locate potential brownfields redevelopment sites, to perform soil and ground water assessments to determine the nature and extent of contamination, and to promote environmental clean-up and redevelopment of these sites. The program includes tax incentives for potential redevelopers and waivers of liability for past contamination. It encourages federal, state, and local coordination of enforcement activities and stakeholder and community involvement to identify and plan new uses for brownfields to promote environmental health and safety, environmental justice, and economic growth for economically depressed communities.

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The brownfields initiative has several advantages for communities with underused, potentially contaminated sites. It provides a catalyst for assessment of urban areas for sites in need of clean-up and redevelopment to improve the community's surface water and ground water quality, quality of life, and property values. Redeveloping properties that have already been disturbed helps to prevent development of greenfields—undeveloped suburban areas—and slows the growth of imperviousness in the outskirts of urban areas. It also provides an incentive for communities to alleviate soil and ground water contamination and to convert abandoned, eyesore lands to viable businesses, recreational facilities, or other uses.

In 2002, the brownfields program was expanded and strengthened through ratification of the Small Business Liability Relief and Brownfields Revitalization Act (see http://www.epa.gov/brownfields/sblrbra.htm for more information). More information about EPA's Brownfields Initiative is available at http://www.epa.gov/brownfields.

Chicago Calumet Initiative

Calumet is located on the southeast side of Chicago along the Calumet River, adjacent to Lake Michigan, that has been subject to more than 120 years of heavy industrial activity. Calumet currently has thousands of acres of contaminated brownfields located amongst open space that serves as habitat for many types of wildlife, including birds listed by the state as endangered or threatened.

In 2000 Chicago mayor Richard Daley and former Governor George Ryan launched the "Calumet Initiative," a revitalization project that involves brownfields clean-up, the preservation of land and wetlands, urban forestry, renewable energy, and low impact development. The City is working in partnership with the Illinois Department of Natural Resources, the U.S. Forest Service, EPA, the Fish and Wildlife Service, the Illinois Environmental Protection Agency, and 15 other governmental partners.

The Initiative includes plans to redevelop 3,000 acres of brownfields into a region with sustainable industries such as a new Ford Motor Company supplier park that uses low impact development techniques and minimizes runoff to adjacent waterbodies. The Calumet Tax Increment Financing District was established to encourage industries to relocate to the revitalized area.

The Calumet Open Space Reserve will provide 4,800 acres of rehabilitated and preserved wetlands and crucial habitat for the 700 plant and 200 bird species that occupy the land currently. The property will be managed through a watershed-based ecological management strategy combined with land acquisition and preservation (NALGEP, 2003).

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10.4 Information Resources

The *Anacostia Watershed Restoration Progress and Conditions Report 1990–1997* summarizes accomplishments and ongoing projects of the Anacostia Watershed Resoration Committee as they relate to their six restoration goals. In addition, the report provides recommendations to the committee for future actions to sustain and further promote the restoration effort.

The Federal Interagency Stream Restoration Working Group (2000), which is a collaboration among of 15 federal agencies including EPA and USDA, published *Stream Corridor Restoration: Principles, Processes, and Practices*. This document covers background information about stream corridors, including processes, characteristics, and disturbances; development of a stream corridor restoration plan; and application of restoration principles to stream corridor projects. *Stream Corridor Restoration: Principles, Processes, and Practices* can be purchased or downloaded in PDF format at http://www.nrcs.usda.gov/technical/stream_restoration/newgra.html.

Riparian Buffer Strategies for Urban Watersheds (Herson-Jones et al., 1995) provides guidance on riparian buffer programs used to mitigate the impact of urban areas on nearby streams. The document uses the results of a national survey of riparian buffer programs as well as a comprehensive review of riparian buffer literature to make recommendations on buffer design. It also analyzes buffer pollutant removal potential and pollution prevention techniques via chemical, biological, and physical processes. It is available for purchase at http://www.mwcog.org/ic/95703.html.

The Save Our Streams Program is a national watershed education and outreach program by the Izaak Walton League (no date). The league offers many stream-related resources, including information on stream projects and publications such as *A Citizen's Streambank Restoration Handbook*. The Save Our Streams Program can be reached by e-mail at sos@iwla.org, by calling 1-800-BUG-IWLA, or by visiting the Web site at http://www.iwla.org/sos.

The Natural Resources Conservation Service's National Conservation Buffer Initiative Web site (http://www.nrcs.usda.gov/feature/buffers/) contains information about buffers, links to technology information, and buffer initiative contacts (NRCS, no date).

Urban Restoration: A Video Tour of Ecological Restoration Techniques (Riley, 1998b) is a video tour of six urban stream restoration sites. It includes background information on how the projects were funded and organized with community involvement and the history and principles of restoration. Additionally, examples are presented of stream restoration in very urbanized areas, recreating stream shapes and meanders, creek daylighting, soil bioengineering, and ecological flood control projects. A companion to the video is *Restoring Streams in Cities: A Guide for Planners, Policymakers, and Citizens* (Riley, 1998a). This book includes detailed information on all relevant components of stream restoration projects, from historical background to hands-on techniques. The book and video can be purchased at http://www.noltemedia.com/nm/urbanstream/index2.html.

EPA and the LID Center conducted a literature review of LID studies to assess the state of knowledge about LID practices (USEPA, 2000c). The final report contains a brief overview of LID principles and programmatic issues such as use, ownership, and cost. The heart of the

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document is a summary of the information available regarding the pollutant removal effectiveness of the most common LID practices. The report is available for download in PDF format at http://www.epa.gov/owow/nps/lidlit.html. This page also contains links to low-impact development fact sheets on bioretention, vegetated roof covers, permeable pavements, and street surface storage of runoff.

EPA's River Corridor and Wetland Restoration Web site contains general information about restoration and its benefits, a list of restoration guiding principles that cover the entire life of a restoration project from early planning to postimplementation monitoring, restoration project descriptions, and links to other restoration resources. The site is located at http://www.epa.gov/owow/wetlands/restore.

The Center for Watershed Protection developed 11 manuals, called the Urban Subwatershed Restoration Manual Series, that present the information needed to restore small urban watersheds in a format that can easily be accessed by watershed groups, municipal staff, environmental consultants, and other users. The manuals are available for a fee in hard copy or as a download at http://www.cwp.org/USRM_verify.htm.

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MANAGEMENT MEASURE 11
OPERATION AND MAINTENANCE

11.1 Management Measure

Develop a program for regular inspection and maintenance of urban runoff management practices.

- Develop and implement an operation and maintenance plan for urban runoff management practices. The plan should include scheduled inspections, scheduled maintenance activities, and scheduled evaluations of operation and maintenance practices.
- Inspect, maintain, and repair runoff treatment controls to maintain design treatment capacity.
- Inspect, maintain, and restore riparian buffers.

11.2 Management Measure Description and Selection

11.2.1 Description

The maintenance of storm water controls is essential to ensure that overall program goals are met and that each management practice or set of practices continues to function as designed. Storm water controls need to be periodically inspected and maintained as necessary to fine-tune performance, prevent malfunction, and address any problems that may arise. Although maintenance issues should be a major consideration during the management practice selection process, they are often overlooked and inadequately planned for and budgeted. As a result, many management practices fail to perform as intended.

An operation and maintenance (O&M) plan is one way to systematically ensure that scheduled inspections, maintenance, and practice evaluations occur. Formalizing an operation and maintenance plan also can be helpful in determining and securing the funding necessary to properly operate and maintain runoff management practices.

Program managers should consider incorporating the following elements in their operation and maintenance programs:

- Scheduled inspections (based on climate, precipitation, and runoff management practice);
- Scheduled maintenance activities, such as removal of forebay sediment;
- Use of maintenance checklists to systematize and document the inspection process; and
- Initial and follow-up monitoring of management practices to establish performance baselines and trends to guide maintenance activities.

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Maintenance activities may vary by management practice. For example, vegetation management is necessary for some extended detention wet ponds and constructed wetlands to maintain optimal removal efficiency, to avoid the net export of nutrients during winter, and to maintain design flow patterns. Removal of sediment build-up is essential to maintain properly functioning practices. Infiltration devices must be protected and maintained to prevent pore clogging and loss of infiltration capacity.

Preventative maintenance may also be necessary to protect the performance of management practices. Run-on sedimentation from off-site areas may need to be addressed through stabilization measures to prevent unnecessary maintenance expenditures.

The incorporation of maintenance considerations into management practice designs will often reduce subsequent maintenance costs and repairs and help to avoid failures. For example, the removal of material from sediment traps can be facilitated by designs that allow easy access to accumulated sediments without specialized equipment. Safe and convenient access to inlet and outlet structures can reduce maintenance costs and prevent nuisance flooding. Finally, the use of proper construction techniques and phasing can reduce the potential for initial clogging of infiltration devices during the construction process.

Enforcement of inspection and maintenance programs is crucial to their success. A 1992 study in Maryland evaluated 250 storm water practices to determine whether they were being maintained in compliance with the state's Stormwater Management Act. The researchers found that after a few years, approximately one-third of the practices were not functioning as designed, and most required maintenance. Approximately one-half of the facilities were undergoing sedimentation and many had problems with clogging (Lindsey et al., 1992). Implementing the practices described under this management measure can help develop an effective O&M program for continued effectiveness and longevity of runoff management practices.

11.2.2 Management Measure Selection

This management measure was selected because improper operation and maintenance of runoff control practices can result in poor performance and increased discharge of pollutants to downstream waters. Flooding may occur and downstream channel stability could be jeopardized. Poorly maintained runoff systems also may increase risks to public safety and the potential for property damage.

To prevent these potential impacts, effective maintenance programs should include standards for the inspection and maintenance of runoff controls. The entities responsible for maintaining runoff controls must be clearly identified and adequate resources must be provided to conduct the necessary maintenance activities. Because maintenance issues are critical to successful program implementation, they should be planned for at the outset of the runoff management program and conducted continuously for the lifespan of the practice(s).

The following section contains descriptions of specific O&M requirements for various types of management practices.

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11.3 Management Practices

11.3.1 Establishing an Operation and Maintenance Program

The following section outlines several practices that will facilitate development of a runoff control O&M program.

11.3.1.1 Establish a runoff control operation and maintenance ordinance

One way for local governments to ensure that maintenance of runoff control facilities is performed is to establish an ordinance that mandates these activities. The O&M language in a runoff control ordinance can specify that runoff management practices must be designed to facilitate easy maintenance and require that regular maintenance activities be performed.

EPA (2000) has provided model ordinance language (at http://www.epa.gov/nps/ordinance) that includes consideration of maintaining runoff control management practices. Ordinance language examples from across the country are provided, including a sample maintenance agreement, a sample easement and right-of-way agreement, an inspection checklist, and a performance bond.

It is important for O&M ordinances to contain language that requires the identification of the specific entity or entities responsible for long-term maintenance and requires regular inspection visits. The ordinance also should provide design guidelines that can help ease the maintenance burden, such as the inclusion of maintenance easements. Note that runoff control ordinance language regarding the maintenance of erosion and sediment control practices differs from that regarding maintenance of postconstruction controls because of the short-term nature of the former.

The City of Alexandria, Virginia has incorporated inspection and maintenance requirements into the Alexandria Zoning Ordinance. The ordinance requires the submission of a long-term inspection and maintenance plan that identifies all maintenance requirements and responsible parties. A standard maintenance and monitoring agreement approved by the city council is required for urban runoff practices in Alexandria and cannot be modified without council approval (Bell, 1997).

11.3.1.2 Make provisions for maintenance in the design and construction of management practices

Because maintenance programs play such an important role in ensuring the proper operation of most structural practices and some source controls, emphasis should be given to maintenance issues when identifying management practices under any runoff management program. Making provisions for maintenance at the design and construction phase involves identifying the urban runoff practices to be used when designing a new facility. Practices should be designed so that maintenance equipment (mowers and vacuum trucks) can easily access the site. Many practices have been designed with inadequate pre-treatment (i.e., without a sediment basin at the inlet), and they have not performed as anticipated. Inlet and outlet structures also tend to clog easily without proper design and maintenance. Adequate size and storage volume based on expected sediment loads from the contributing drainage area should be factored into the design of inlets and pre-treatment structures.

11.3.1.3 Identify mechanisms for program funding

It is important to identify the entity responsible for operating and maintaining structural runoff control practices. The responsible party can be a property owner, homeowners' association, certified contractor, or local government agency. Local governments may assume the responsibility of maintaining privately owned facilities. When private entities do not fulfill their maintenance responsibilities and the facilities fail, the burden of maintaining runoff control and performing downstream restoration may ultimately fall under the local government's responsibility. Public financing for maintenance of both public and private facilities can be generated from general tax revenues, storm water utility fees, inspection or permit fees, or dedicated contributions. Sources of funding should be dedicated to runoff program budgets and or maintenance programs whenever possible. A discussion of these and other financing options for maintenance of runoff control facilities is provided in Chapter 8 of the Watershed Management Institute's *Operation, Maintenance, and Management of Stormwater Management Systems* (1997).

It is important that the funding source for maintenance of runoff control facilities be supported by the public. The Watershed Management Institute (1997) stresses the importance of public education to inform citizens about the locations and functions of runoff control facilities and the importance of regular maintenance. The institute believes that citizens and government officials will be more willing to allocate funds to projects that they know will provide tangible benefits to the community. The institute also recommends that funding programs for maintenance activities have the following attributes:

- Be based on a stable source of consistent funds that will ensure a long-term commitment of personnel, equipment, and materials;
- Be compatible with the local organizational structure to allow use of existing billing, collection, and bookkeeping operations;
- Include provisions for four essential operations: (1) program administration; (2) accounting and budgeting; (3) revenue management; and (4) information management;
- Be based on an equitable, understandable, and defensible fee or rate structure;
- Be continually reviewed and updated to meet the changing maintenance needs of the runoff control program; and
- Be consistent with applicable state laws and regulations.

11.3.1.4 Plan regular inspections

Inspections are essential to maintain the successful operation of the facility. Inspectors should have on hand equipment necessary for taking measurements and making minor repairs, be trained in identifying and remedying problems, and have a set of standard inspection procedures from which to work. An inspection schedule and checklist for each type of management practice should be developed and followed. Inspections and maintenance should be conducted both on a regular schedule and following storms to identify and repair any damage.

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11.3.1.5 Schedule maintenance, cleaning, and debris removal to avoid sediment accumulation

Sediment and debris can contain hazardous contaminants and can clog filtration and infiltration practices, reducing their effectiveness over time. In addition to major structural controls, maintenance programs should include measures for cleaning catch basins and drainage channels. Establishment of an effective O&M program should include the creation of maintenance logs and identification of specific maintenance triggers for each class of control (e.g., removing sediment from forebays every year and retention ponds every five years, cleaning catch basins at least annually prior to the rainy season, removing litter from channels twice a year). If maintenance activities are scheduled infrequently, regular inspections should be made to ensure that the control is operating adequately. Additionally, maintenance should be performed following significant storms.

11.3.1.6 Make provisions for monitoring treatment criteria

Regularly monitoring the influent to and effluent from structural management practices will support program goals by facilitating development of a database to track the effectiveness of these practices, which can help guide future decisions about management practice implementation. These data will make it easier to quantify the performance of the practice and determine the behavior of the system as a result of regular maintenance.

11.3.1.7 Implement training and certification programs to provide educational opportunities for management practice operators

Training and certification programs are gaining popularity around the country at both the state and local levels. Municipalities sometimes use contractors to conduct inspections and maintenance because resources are not available to purchase equipment and hire dedicated staff. Good training programs can ensure that inspections and maintenance activities are carried out in a thorough and consistent manner. Also, training programs can be customized to address local concerns and conditions such as high flows, highly erodible soils, or invasive species.

11.3.1.8 Disposal of residuals

Runoff can carry both natural and anthropogenic pollutants and materials to receiving waters. Natural materials, such as leaves and soils, can accumulate in the system and cause localized flooding. Anthropogenic sources, which include oil and grease, heavy metals, deicing materials, and litter, can become adsorbed to leaf litter and sediments (Lenhart and Harbaugh, 2000). The mixed composition of solids that are removed from the storm drain system (termed residuals) can require special handling and treatment, which increases disposal costs (Field and O'Shea, 1994). The characteristics of residuals tend to vary with season and land use. Table 11.1 summarizes the results of a number of studies analyzing residuals in runoff (Field and O'Shea, 1992; Marquette University, 1982; Schueler and Yousef, 1994).

Table 11.1: Properties of urban storm water solids/residuals (adapted from USEPA, 1999).

Properties of Residuals	Wet Ponds[1]	Sediment Basin[2]	Swirl and Helical Bend Solids Separators[3]	In-Line Upsized Storm Conduit[4]	Urban Storm Water Runoff Residuals[5]
Solids					
Volatile Suspended Solids	6%	104–155 mg/l	107,310 mg/l	25,800 mg/l	90 mg/l
Total Suspended Solids	43%	233–793 mg/l	344–1,140 mg/l	161,000 mg/l	415 mg/l
Nutrients					
Phosphorus	583 mg/kg	< 5 mg/l	<5 mg/l	0.3–2,250 mg/l	502–1,270 mg/kg
Total Kjeldahl Nitrogen	2,931 mg/kg	<5 mg/l	<5 mg/l	0.3–2,250 mg/l	1,140–3,370 mg/kg
Heavy Metals					
Zinc	6–3,171 mg/kg				302–352 mg/kg
Lead	11–748 mg/kg				251–294 mg/kg
Chromium	4.8–120 mg/kg				168–458 mg/kg
Nickel	3–52 mg/kg				69–143 mg/kg
Copper	2–173 mg/kg				251–294 mg/kg
Cadmium	No detect–15 mg/kg				
Iron		6.1–2,970 mg/l	6.1–2,970 mg/l	6.1–2,970 mg/l	
Hydrocarbons	2,087-12,892 mg/kg				

[1] Scheuler and Yousef, 1994
[2] Marquette University, 1982 (Racine, Wisconsin)
[3] Marquette University, 1982 (Boston, Massachusetts)
[4] Marquette University, 1982 (Lansing, Michigan)
[5] Field and O'Shea, 1992

A system for managing residuals in runoff should address the proper handling and disposal of both liquid and solid residuals. Ponds, infiltration practices, vegetative controls, and catch basin inserts have different removal mechanisms, and the type of residuals generated from these practices will vary. All residuals should be tested for contamination (unless the management entity has determined that residuals from an individual practice or category of practices pose no hazard), and maintenance employees should be trained in properly identifying and handling contaminated waste according to the requirements of the Resource Conservation and Recovery Act (RCRA) and state and local regulations (USEPA, 1999). Removal mechanisms and requirements for specific practices are described below.

Non-hazardous solids in residuals can be recycled, sent to a landfill, or applied to land. Land application involves spreading the material on designated land at approved application rates. The material should not be applied to cropland, but application to a nonagricultural vegetated area may be appropriate (USEPA, 1999). Disposal of the waste in a landfill may be the most expensive option because of travel costs, testing requirements, and disposal fees (Lenhart and Harbaugh, 2000).

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There are a number of low-cost options for recycling. Coarse sand and gravel can be used for road base, and road sand can be recycled for winter maintenance activities. The City of Olympia, Washington uses dried solids from treatment systems by mixing them with cement. The organic portion of residuals can be composted after removing the coarse inorganic materials. These organic residuals can then be combined with yard debris, leaves, straw, or soil. The Washington Department of Transportation mixes solids with mulch and bark for use as topsoil along roadsides (Lenhart and Harbaugh, 2000). In general, urban runoff residuals have very low nutrient content and thus require mixing with high nutrient content organic matter to provide fertilization benefits (Field and O'Shea, 1994).

Additional considerations for the disposal of residuals include air and noise pollution from machinery operation at the disposal site, unpleasant odors, possible ground water or surface water contamination, and public health. To address these issues, local and state agencies should address the following when developing guidelines for disposal of residuals: application rates, treatment requirements, site suitability, and proximity to schools, parks, and residential areas (Field and O'Shea, 1994).

The City of Everett, Washington uses a source separation system that requires operators of vacuum trucks to determine whether contamination of residuals is suspected based on sheen, odor, and color. Residuals suspected of contamination are handled in accordance with state and local regulations. Otherwise, materials are collected and recycled as aggregate material on medians and selected roadsides after being tested for contamination (Lenhart and Harbaugh, 2000).

11.3.2 Source Control Operation and Maintenance

11.3.2.1 Infrastructure

(1) *Street sweeping.* Street cleaning reduces pollutants carried in runoff from street surfaces. The frequency of cleanings should reflect the rate of pollutant buildup and should increase just before the rainy season. An effective program requires that street sweeping be conducted on a regular basis. Sweeper operators require training, and equipment needs to be maintained regularly to ensure that it is functioning as designed. Finally, parking restrictions can be implemented to guarantee adequate cleaning despite on-street parking. Table 11.2 shows O&M costs associated with street sweeping. See Management Measure 7 for more information about types of street sweepers (brush vs. vacuum sweepers and their relative effectiveness, section 7.3.5.1) and roadside trash removal (section 7.3.5.4).

Table 11.2: Street sweeper O&M costs (adapted from CWP, 1998).

Maintenance Considerations		Sweeper Type	
		Mechanical Sweeper	Vacuum-Assisted Sweeper
O&M costs (1998 dollars)	Cost ($/curb mile)	30	15
	Weekly sweeping ($)	1,680	946
	Biweekly sweeping ($)	840	473
	Monthly sweeping ($)	388	218
	4 times per year sweeping ($)	129	73
	Twice per year sweeping ($)	65	36
	Annual sweeping ($)	32	18
Expected life (years)		5	8

(2) *Storm drain flushing*. This practice is used to remove deposited materials from storm drain pipes to maintain their flow capacity. The flushing schedule should be designed to prevent excessive buildup based on estimated inputs from the contributing drainage areas, cleaning history, and visual inspections. Flushing is performed either at or upstream from problem areas. There are costs to consider for collecting and disposing of sediments, debris, and flush water, in addition to supplying flush water and treating sediment-laden water if the storm drains are being flushed to a receiving water body.

(3) *Catch basin cleaning*. Cleaning catch basins removes excess pollutants, thereby reducing high pollutant concentrations in a storm's first flush, preventing clogging, and restoring sediment-trapping capacity. Maintenance should target areas with the greatest pollutant loading and those near sensitive water bodies. A maintenance log should be kept to track progress. If there are many catch basins in a community, mechanical cleaners (vacuums or bucket loaders) may be required; otherwise, hand cleaning will suffice. Proper record-keeping, waste disposal, and safety procedures are essential for a successful program.

(4) *Highway, bridge, and road maintenance*. Maintenance of roads and bridges can be a significant source of pollutants. Some methods to prevent materials from contaminating runoff are limiting the use of salts; using suspended tarps, vacuums, or booms to reduce pollutant drift onto waters from scraping and painting; and training road crews in proper waste control and disposal methods. Treatment controls also can be used on-site to reduce the amount of polluted runoff that enters receiving waters. Runoff reduction, conveyance, and treatment practices (e.g., infiltration swales in median strips) can be incorporated into the design of new roadways and bridges to help contain pollutants from traffic as well as from

Sediment Removal from Catch Basins

The Delaware County, New York, Department of Public Works, with the assistance of the Catskill Watershed Corporation, purchased a vacuum truck capable of removing sediment from culverts and catch basins. The truck, which has a 30-foot pipe reach and a 12 cubic yard storage capacity, is available for use by neighboring counties based on need and availability. In the first month of operations, approximately 700 cubic feet of sediment was removed. The sediment s disposed of without posing a threat of contamination to the Cannonsville and Pepacton reservoirs. The County will be sampling sediment in an attempt to quantify the amount of contaminants removed (Delaware County Departments of Planning and Public Works, 2003).

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maintenance activities. For more information about runoff management practices for roads, highways, and bridges, see Management Measure 7: Bridges and Highways.

11.3.2.2 Trash in channels and creeks

Clean-up of trash from streams and storm water conveyance infrastructure can reduce pollutant levels in downstream waters. Areas where dumping occurs frequently can be identified and inspected regularly, and "no littering" or "no dumping" signs can be posted to deter future dumping. Steep fines for dumping may also discourage potential transgressors. Associated costs for these practices are the purchase of signs and equipment, paying personnel to conduct inspections and clean-up, and providing landfill space to dispose of recovered items. Cost savings can be achieved through community or volunteer clean-up programs.

11.3.3 Treatment Control Operation and Maintenance

Runoff treatment controls require periodic inspection and maintenance to ensure that sediment, trash, and overgrown vegetation are not impeding their performance. Regular inspections should be performed along with routine maintenance. Nonroutine maintenance may be required to repair structures, control erosion, and remove unwanted vegetation. Table 11.3 and the following practices describe maintenance costs, activities, and schedules for several categories of urban runoff treatment practices.

Table 11.3: Maintenance costs, activities, and schedules for runoff control practices in 1998 dollars (Adapted from CWP, 1998).

Category	Management Practice	Annual Maintenance Cost (% of Construction Cost)	Maintenance Cost for a "Typical" Application	Maintenance Activity	Schedule
Detention ponds or vaults	Dry ponds	~1%	$1,200	– Cleaning and removal of debris after major storms (>2" rainfall) – Harvesting of vegetation when a 50% reduction in the original open water surface area occurs – Repair of embankment and side slopes – Repair of control structure	Annual or as needed
				– Removal of accumulated sediment from forebays or sediment storage areas when 60% of the original volume has been lost	5-year cycle
				– Removal of accumulated sediment from main cells of pond once 50% of the original volume has been lost	20-year cycle

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Table 11.3 (continued).

Category	Management Practice	Annual Maintenance Cost (% of Construction Cost)	Maintenance Cost for a "Typical" Application	Maintenance Activity	Schedule
Ponds	Extended detention ponds, wet ponds, multiple pond systems, "pocket" ponds	3%–6%	$3,000–$6,000	– Cleaning and removal of debris after major storm events (>2" rainfall) – Harvesting of vegetation when a 50% reduction in the original open water surface area occurs – Repair of embankment and side slopes – Repair of control structure	Annual or as needed
				– Removal of accumulated sediment from forebays or sediment storage areas when 60% of the original volume has been lost	5-year cycle
				– Removal of accumulated sediment from main cells of pond once 50% of the original volume has been lost	20-year cycle
Wetlands	Shallow wetlands, pond wetlands, "pocket" wetlands	~2%	$3,800	– Cleaning and removal of debris after major storm events (>2" rainfall) – Harvesting of vegetation when a 50% reduction in the original open water surface area occurs – Repair of embankment and side slopes – Repair of control structure	Annual or as needed
				– Removal of accumulated sediment from forebays or sediment storage areas when 60% of the original volume has been lost	5-year cycle
				– Removal of accumulated sediment from main cells of pond once 50% of the original volume has been lost	20-year cycle

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Table 11.3 (continued).

Category	Management Practice	Annual Maintenance Cost (% of Construction Cost)	Maintenance Cost for a "Typical" Application	Maintenance Activity	Schedule
Infiltration practices	Infiltration trench	5%–20%	$2,300–$9,000	– Removal of accumulated sediment from forebays or sediment storage areas when 60% of the original volume has been lost	5-year cycle
				– Removal of accumulated sediment from main cells of pond once 50% of the original volume has been lost	20-year cycle
	Infiltration basin	1%–3%	$150–$450	– Cleaning and removal of debris after major storm events; (>2" rainfall) – Mowing and maintenance of upland vegetated areas – Sediment cleanout	Annual or as needed
		5%–10%	$750–$1,500	– Removal of accumulated sediment from forebays or sediment storage areas when 50% of the original volume has been reduced	3- to 5-year cycle
Open channel practices	Dry swales, grassed channels, biofilters	5%–7%	$200–$2,000	– Mowing and litter/debris removal – Stabilization of eroded side slopes and bottom – Nutrient and pesticide use management – Dethatching of swale bottom and removal of thatching – Discing or aeration of swale bottom	Annual or as needed
				– Scraping of swale bottom, and removal of sediment to restore original cross-section and infiltration rate – Seeding or sodding to restore ground cover (use proper erosion and sediment control)	5-year cycle

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Table 11.3 (continued).

Category	Management Practice	Annual Maintenance Cost (% of Construction Cost)	Maintenance Cost for a "Typical" Application	Maintenance Activity	Schedule
Filtration practices	Sand filters	11%–13%	$2,200	– Removal of trash and debris from control openings – Repair of leaks from the sedimentation chamber or deterioration of structural components – Removal of the top few inches of sand, and cultivation of the surface, when filter bed is clogged	Annual or as needed
				– Clean-out of accumulated sediment from filter bed chamber once depth exceeds approximately ½ inch, or when the filter layer will no longer draw down within 24 hours – Clean-out of accumulated sediment from sedimentation chamber once depth exceeds 12 inches	3- to 5-year cycle
	Bioretention	5%–7%	$3,000–$4,000	– Repair of erosion areas – Mulching of void areas – Removal and replacement of all dead and diseased vegetation – Watering of plant material	Biannual or as needed
				– Removal of mulch and application of a new layer	Annual
	Filter strips	$320/acre (maintained)	$1,000	– Mowing and litter/debris removal – Nutrient and pesticide use management – Aeration of soil on the filter strip – Repair of eroded or sparse grass areas	Annual or as needed.

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11.3.3.3 Ponds and wetlands

Extended dry detention ponds are submerged only during storms and are dry between storms. Depending on the type of vegetative cover used, they may require mowing at least once a month to maintain turf grass cover, or once a year to prevent the establishment of woody vegetation. Sediments should be removed when they are dry and cracked to separate them from vegetation more easily. Pilot or low-flow channels require inspection to prevent undermining of concrete channels and overgrowth of stone channels. Inlets and outlets should be cleared of sediment and debris to prevent clogging.

Wet ponds are susceptible to algae blooms as a result of high nitrogen levels and may need to be cleaned periodically. Sediments that accumulate in the pond inlet or forebay should be removed more frequently than fine sediment, which collects near the pond outlet. Sediment removal requires draining the pond (some water to maintain fish populations should be left), collection of solids, and drying and testing of the residuals before disposal. Pond water should be disposed of in a locally approved manner; it should be tested for pollutants and released to the receiving water, if allowed, or pumped and hauled to a disposal facility. During the period in which the stockpiled materials are drying, erosion controls should be implemented to prevent sediment loss. All structures and surrounding areas should be inspected for leakage, seepage, corrosion, and wear and tear. Inspectors and crews should pay special attention to structural integrity to ensure that ponds operate safely.

Constructed wetlands should be inspected approximately four times per year to determine if they are retaining and discharging storm water at an appropriate rate and whether maintenance is needed. Constructed wetlands require periodic cropping; removal of trash, weeds, invasive species, or woody vegetation; repair of animal burrows in embankments; and clearing of inlets and outlets. Side slopes should be stabilized with vegetative cover to prevent erosion. Wetland plants should be thinned and transplanted as necessary to maintain adequate cover throughout the wetland. In general, semiannual sediment removal is recommended to ensure that treatment capacity is maintained. Mosquitoes may be a problem in some areas, and introducing natural predators such as mosquito fish (*Gambusia*) can be one method of control. Consultation with a wetland scientist is recommended to ensure that the constructed wetland functions as intended.

11.3.3.4 Infiltration practices

Infiltration practices, such as basins, trenches, vegetated swales, and porous pavement, are subject to clogging from sediment, oil, grease, and microbes. Clogging impairs their effectiveness in reducing runoff volume and pollutant loading to downstream waters. When clogging occurs, standing water tends to collect. Seasonal water table fluctuations or ground water mounding can also cause standing water. Facility inspection during dry periods will identify whether standing water is present and provide clues to the possible causes. Inspections should include a site assessment of the contributing drainage area because sediment accumulation in a facility stems from erosion in surrounding areas that can be prevented if the areas are adequately stabilized. The frequency of required maintenance depends on loads from the contributing drainage areas.

If clogging results in pooling, sediment can be removed to restore the facility to its original capacity. If the standing water results from high water table conditions, the facility owner should consider converting the site to a permanent pool facility such as a constructed wetland or detention pond. For systems designed with filter fabric to collect sediments, periodic inspections can identify when and where the mesh should be replaced. In cold climates where street sanding occurs in the winter, the filter fabric in infiltration devices adjacent to roads and parking lots should be replaced prior to spring.

Promotion of a vegetative cover will help to maintain percolation rates, slow runoff velocity, and minimize ground water pollution. To maintain aeration and permeability, nonvegetated basins require tilling or disking and leveling after sediment is removed. Vegetated filters adjacent to infiltration trenches should be cleared of sediments periodically to prevent sediment loading to the trench.

Regular monitoring of infiltration rates after storms will indicate when maintenance is required to maintain the system's treatment design capacity.

11.3.3.5 Filtration practices

Filtration practices include media filters (typically sand) and biofilters. Sand filters contain two phases: a sedimentation chamber and a filtration chamber. The sedimentation chamber can be inspected by measuring to determine if the deposited sediments are becoming deep enough to interfere with the filtration chamber. Different types of sand filters require different levels of maintenance. The Austin sand filter system usually requires maintenance every five to 10 years, depending on the stability of soils in the contributing areas, and can be treated like a dry detention facility. The filter component can be raked of fine sediments or skimmed with a shovel to restore permeability. The Washington and Delaware sand filter sedimentation chambers, which maintain a pool of water, should be vacuumed to remove sediment when inspections identify accumulation greater than 75 percent of capacity. Filtration chambers for these systems may need to be cleaned of fine particles as frequently as twice per year to maintain their efficiency and prevent overflows. A flat-bottomed shovel can be used to remove the sediment-laden filter media and roughen surfaces to improve permeability.

Each system should be inspected for vandalism, leaks, cracks, or damage to concrete at least once per year. These problems should be remedied immediately. Forebays should be pumped or cleaned as necessary. All materials removed from the systems should be tested for contamination and to identify how the material should be disposed of (e.g., as clean fill, in a landfill, or as a hazardous waste).

Biofiltration system vegetation should be mowed periodically to maintain an optimum height (2 to 6 inches) that maximizes infiltration and minimizes runoff velocity. Special effort should be made to promote native species and exclude invasive species, which can grow too vigorously and reduce treatment capacity. Some natural vegetation replacement is desirable, such as wetland plants that colonize a low-lying biofilter. Inspection and maintenance records should reflect these changes.

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Biofiltration facilities should be inspected and maintained regularly. Sediment removal is an important and sometimes expensive part of biofilter maintenance. Sediment should be removed when it fills 20 percent of the design depth in any spot or starts to cover vegetation. Efforts should be made to return the system to its original topographic and vegetative condition once the sediment has been removed. Inlets and outlets should be cleared of particles and debris to prevent backups and overflows. Biofiltration systems may also need periodic replacement or amendment of system soils if clogging has occurred.

Maintenance equipment for the tasks described previously, along with purchase and rental costs, is presented in Table 11.4.

Table 11.4: Typical O&M equipment and material costs (WMI, 1997).

Equipment	Purchase	Rent (per day)
Grass Maintenance		
Hand mower	$300–$500	$25–$50
Riding mower	$3,000–$7,000	$75–$150
Tractor mower	$20,000–$30,000	$150–$450
Trimmer/edger	$200–$500	$25–$35
Spreader	$100–$200	$20–$30
Chemical sprayer	$200–$500	$25–$40
Vegetative Cover Maintenance		
Hand saw	$15–$20	$5
Chain saw	$300–$800	$15–$35
Pruning shears	$25–$40	$5
Shrub trimmer	$200–$300	$25–$35
Brush chipper	$2,000–$10,000	$100–$300
Sediment, Debris, and Trash Removal		
Vactor truck	$100,000–$250,000	$700–$1,200
Front-end loader	$60,000–$120,000	$250–$500
Backhoe	$50,000–$100,000	$250–$500
Excavator	>$100,000	$400–$1,000
Grader	>$100,000	$400–$1,000
Transportation		
Van	$18,000–$30,000	$50–$100
Pickup truck	$15,000–$25,000	$50–$100
Dump truck	$40,000–$80,000	$100–$200
Light-duty trailer	$3,000–$6,000	$50–$100
Heavy-duty trailer	$10,000–$20,000	$100–$250
Miscellaneous		
Shovel	$15	$5
Rake	$15	$5
Pick	$20	$5
Wheelbarrow	$100–$250	$15–$25
Portable compressor	$800–$2,000	$50–$150
Portable generator	$750–$2,000	$50–$150
Concrete mixer	$750–$1,500	$50–$100
Welding equipment	$750–$2,000	$50–$100
Materials		
Topsoil	$35–$50/cubic yard	
Fill Soil	$15–$30/cubic yard	
Grass seed	$5–$10/pound	
Soil amenities	$0.10–$0.25/square foot	

Table 11.4 (continued).

Equipment	Purchase	Rent (per day)
Materials (continued)		
Chemicals	$10–$30/gallon	
Mulch	$25–$40/cubic yard	
Dry mortar mix	$5/50-pound bag	
Concrete delivered	$60–$100/cubic yard	
Machine/motor lubricants	$5–$10/gallon	
Paint	$20–$40/gallon	
Paint Remover	$10–$20/gallon	

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11.4 Information Resources

The South Carolina Department of Health and Environmental Control (2000) published *A Citizen's Guide to Stormwater Pond Maintenance in South Carolina*, which is available for download in PDF format at http://www.scdhec.net/eqc/admin/html/eqcpubs.html. The booklet is intended as a guide for homeowners' associations and others responsible for the proper maintenance of storm water ponds. Photos and descriptions of nuisance aquatic plant species are presented in the guide to aid in identifying these species and removing them from ponds. Copies of the guide are available from Ward Reynolds at 843-747-4323.

The Stormwater Manager's Resource Center (CWP, no date) has sample O&M checklists available for download from its Web site (http://www.stormwatercenter.net/). When at the site's homepage, click on "Manual Builder" and choose "Construction and Maintenance Checklists" from the pull-down list. There are checklists for the following practices: ponds, infiltration trenches, infiltration basins, bioretention facilities, sand filters, and open channel practices.

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MANAGEMENT MEASURE 12
EVALUATE PROGRAM EFFECTIVENESS

12.1 Management Measure

Develop and implement a program to evaluate and improve the effectiveness of the urban runoff management program.

12.2 Management Measure Description and Selection

12.2.1 Description

The purposes of this management measure are to:

- Determine whether implementation of the runoff management program framework is protecting and/or improving water quality by evaluating management practices that are being used to meet Management Measure 1. If these practices aren't effective, improvements to the runoff management program framework should be implemented.

- Periodically reassess the watershed (see Management Measure 2) to determine whether water quality has improved or declined. Based on this assessment, each management measure should be reevaluated to determine whether additional practices should be implemented, if improvements should be made to existing practices, or if specific practices should be discontinued.

12.2.2 Management Measure Selection

This management measure was selected because runoff management programs need to be dynamic (i.e., they need to be periodically adjusted to respond to changing conditions and optimize program effectiveness and expenditures). Areas where program improvement is possible should be identified. Programs that are periodically reviewed and evaluated also are perceived as being more effective, and they will be more likely to receive the public and political support necessary to achieve success. The basic elements of a successful program evaluation are described in this management measure.

12.3 Management Practices

12.3.1 Assess the Runoff Management Program Framework

It is important for watershed managers to objectively assess the runoff management program framework to determine whether the goals of the Program Framework and Objectives Management Measure (Management Measure 1) are being met. This effort should be undertaken periodically to identify aspects of the program that need to be strengthened or revised. Each

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aspect of the program framework will require a different type of measurement. Watershed managers can choose from both qualitative and quantitative measures as indicators of program effectiveness, using the watershed baseline conditions as a point of reference (see Management Measure 2: Watershed Assessment). Quality assurance and quality control procedures should be followed regardless of whether qualitative or quantitative measures are used.

There are several factors that should be considered when designing an evaluation program. First, some urban management practices, or aspects of their implementation that can be analyzed, vary with time of year, phase of construction, or length of time after installation. Another consideration is that variables generally will not directly relate to management measure implementation, as most urban management measures are combinations of several management practices. Evaluation of management measure implementation, therefore, usually will be based on separate assessments of two or more management practices, and the implementation of each management practice will be based on a unique set of variables. Finally, it is very important to consider the purpose of the program when selecting the variables for which the information is collected.

EPA has developed the Web-based *Measurable Goals Guidance for Phase II MS4s* to assist small municipal separate storm sewer system (MS4) owners and operators in complying with the requirement to select measurable goals to evaluate the effectiveness of individual control measures and the storm water management program as a whole. Even though this document is intended for use by NPDES-permitted MS4 operators, it contains guidance valuable to any institution developing a storm water management program that includes management practices and methods for program evaluation. It includes examples of management practices with corresponding measurable goals and environmental indicators that can be used to document the effectiveness of both management practices and storm water programs. The guidance is available online at http://cfpub.epa.gov/npdes/stormwater/measurablegoals/index.cfm.

12.3.1.1 Qualitative measures

Urban runoff management programs can be evaluated using any number of qualitative measures, such as those presented by WMI (1997a):

- Project permit review times
- Frequency of inspections
- Evaluation by targeted groups
- Appearance of control practices on sites
- Response time for complaints
- Number of permits issued
- Number of individuals trained
- Recognition by others
- Enforcement actions taken
- Maintenance activities
- Reduced number of complaints

For example, Delaware uses the number of individuals attending training courses and receiving state certification as one measure of program success. In addition to monitoring water chemistry,

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sediments, and the biological community, Florida measures program success by the number of local government storm water utilities implemented, as well as the number of educational and public involvement activities.

Watershed managers can use a combination of measures to assess their program framework based on goals and priorities that were identified at the outset of program implementation. In addition to the qualitative measures listed above, watershed managers can track the implementation, operation, and maintenance of management practices as indicators of the success of a program framework. See Section 12.3.2 for a discussion of management practice tracking.

12.3.1.2 Quantitative measures

Another way for watershed managers to gauge the effectiveness of their runoff management program framework is to quantitatively determine if water quality or habitat has improved. Quantitative measures include:

- Chemical monitoring of practices
- Chemical monitoring of receiving waters
- Biological monitoring of receiving waters (bioassessments)
- Habitat assessments
- Stream flow monitoring
- Stream shoreline condition assessments
- Sediment monitoring (deposition, chemistry)
- Measuring the volume of material removed by street sweeping and catch basin cleaning
- Temperature monitoring

See the section 12.3.3, "Gauge Improvements in Water Quality Resulting from Management Practice Implementation" for a more thorough discussion of the different types of monitoring that can be used to gauge changes in water quality after practice implementation.

12.3.1.3 Quality assurance/quality control

An integral part of the design phase of any monitoring project is quality assurance/quality control (QA/QC). Development of a quality assurance project plan (QAPP) is the first step for incorporating QA/QC into a monitoring project. The QAPP is a critical document for the data collection effort inasmuch as it is used to integrate the technical and quality aspects of the planning, implementation, and assessment phases of the project. The QAPP documents how QA/QC elements will be implemented throughout a project's life. It states expectations and requirements and provides procedures for data collection and data management that are specific to the project. Development and implementation of a QA/QC program, including preparation of a QAPP, can require up to 10 to 20 percent of project resources (Cross-Smiecinski and Stetzenback, 1994). A thorough discussion of QA/QC is provided in Chapter 5 of EPA's *Monitoring Guidance for Determining the Effectiveness of Nonpoint Source Controls* (USEPA, 1997).

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12.3.2 Track Management Practice Implementation

Implementation monitoring can be used to determine the extent to which management measures and practices are implemented in accordance with relevant standards and specifications. This involves establishing a program that tracks either whether the practices have been implemented or whether management practices have been operating and maintained as designed. For example, some states and municipalities have developed programs that track and record septic tank maintenance or erosion and sediment control practices, or that inventory all runoff control structures.

It is not always possible to track the implementation of every management practice of interest. Sampling a subpopulation and extrapolating the findings to the entire population may be preferred due to time, funding, or personnel constraints. Lack of adequate legal authority may also hinder the collection of data sufficient to track management practice implementation. If an inventory of all management practices of interest is not possible, care should be taken to prepare a statistically valid sampling plan. The primary basis for selecting a design approach should be based on a careful review of study objectives and the pros and cons of each sampling method. An extensive discussion of the different sampling designs and methods for analysis can be found in *Techniques for Tracking, Evaluating, and Reporting the Implementation of Nonpoint Source Control Measures: Urban* (USEPA, 2000), which is available on EPA's Nonpoint Source Web site at http://www.epa.gov/owow/nps/urban2.html. Below are several tools that can be used to track management practice implementation.

12.3.2.1 Track permits

States and local agencies employ a variety of legal mechanisms, including nuisance prohibitions, general water pollution discharge prohibitions, land use planning and regulation laws, building codes, health regulations, and criminal laws to regulate urban nonpoint source water pollution (Environmental Law Institute, 1997). Although not all pollutant-generating activities are covered by these mechanisms, they present opportunities for inventorying management practice implementation. Activities that are typically regulated in some manner include erosion and sediment control, onsite sewage disposal systems, runoff from development sites, construction activities, and industrial activities. A permitting system places on the applicant the burden of obtaining and supplying all necessary data and information to obtain the permit. Issuance of these permits encourages compliance with local laws and regulations in the construction and operation of management practices.

12.3.2.2 Use operation and maintenance records

In many instances, proper operation and maintenance of a management practice are as important as proper design and installation. Regular inspection of management practices can identify the need for repairs or retrofits in addition to identifying areas in the watershed that require additional management resources. If the right types of information are collected when a management practice is installed, it becomes much easier to track operation and maintenance activities and ascertain the cost and effectiveness of the practice.

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12.3.2.3 Use geographic information systems

Geographic information systems (GISs) are useful tools for inventorying management practice implementation. A GIS can detect and track trends in management practice implementation, land treatment, changes in land use, and virtually any data related to management practices and water quality. Another advantage is the ability of a GIS to update information and integrate it with existing data in a timely manner. GISs allow watershed managers to do more than just manage information in a database—they are powerful analysis tools that can be used to design sampling protocols for tracking studies and help watershed managers analyze program effectiveness by integrating land treatment and water quality information.

12.3.2.4 Develop surveys

Surveys of property managers and developers can be used to collect background information about management practice implementation, such as:

- Type, number, and size of management practices installed
- Management practice location/watershed
- Land use (i.e., residential, commercial, industrial)
- Percent impervious area
- Inspection results
- Operation and maintenance practices

Maryland's GIS-Based Restoration Project Tracking Database

The Maryland Department of Natural Resources has developed a Restoration Project Tracking Database that provides a list of riparian forest buffer and stream restoration projects by watershed and county with details such as waterway; length, width, area, and other quantifiers as appropriate; and details about the project such as owner type, planting reason, year established or completed, and project components. These data can be displayed in tabular format and are linked on the Web site to an interactive GIS for the public and interested parties to browse (MDNR, 2004). The database can be accessed at http://dnrweb.dnr.state.md.us/watersheds/surf/tracking/track_map.htm.

Maryland also has a "BMP Tracking Reports" Web site (http://dnrweb.dnr.state.md.us/watersheds/surf/bmp/) that provides tributary-specific information regarding implementation of management practices. This information is used to help measure Maryland's progress in reducing nonpoint source pollution and meeting the goals of the Chesapeake Bay 2000 agreement. Users can choose a statewide management practice summary report or they can generate a report by tributary. They list 3 categories of practices: urban practices, resource protection and improvement practices, and agricultural practices. The data for each management practice type is summarized by year in units appropriate for the practice. For example, the urban practice "Erosion and Sediment Control" was implemented on 2,213 acres in 2000, 11,133 acres in 2001, and 10,442 acres in 2002. More information is provided for each practice, including a photo, a brief description, and general pollutant removal information for different land use applications (if the practice is applicable in multiple settings). The pollutant removal information is limited to nitrogen, phosphorus, and sediment.

To complete these efforts, Maryland DNR developed estimates from the Departments of Agriculture, Environment, and Natural Resources. This information was compiled from data received from volunteer groups and county, state, and federal reports provided to each department.

- Dates of management practice installation
- Design specifications
- Type of water body or area protected
- Previous management practices used
- Erosion and sediment control plans (for construction)
- Dates of plan preparation and revisions
- Date of initial plan implementation
- Total acreage under management
- Certification requirements

Watershed managers can use the information obtained from these surveys to identify locations for new management practices and to more closely examine practices used upstream of waters known to be degraded to determine if they are operating as designed or if they require redesign or maintenance.

12.3.2.5 Consider expert evaluations

Expert evaluations may be needed to augment or verify information provided in surveys. Experts are especially useful in determining the following:

- Proper design
- Proper installation
- Adequacy of operation and maintenance plans and activities
- Verification of conclusions derived from self-evaluations (i.e., an objective third party's review of data and reports)

Each of these tools can be used to help watershed managers locate management practices and identify those that are not performing as expected (i.e., not meeting the goals of the management measures). These tools can be used separately or in combination to obtain and organize management practice data and use it to better meet the goals of the management measures.

12.3.3 Gauge Improvements in Water Quality Resulting from Management Practice Implementation

Watershed managers can determine the effectiveness of the runoff program by monitoring changes in water quality after the management measures and practices are implemented. The most fundamental step in the development of a monitoring plan is to define the goals of the monitoring program. Monitoring goals are broad statements such as "to measure improvements in Elephant Butte Reservoir" or "to verify nutrient load reductions into the Chesapeake Bay." Designing a monitoring plan also includes selecting sampling variables, a sampling strategy, station locations, data analysis techniques, the length of the monitoring program, and the overall level of effort to be invested.

Once the monitoring goals have been established, existing data and constraints should be considered. A thorough review of literature pertaining to water quality studies previously conducted in the geographic region of interest should be completed before starting a new study.

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The review should help determine whether existing data provide sufficient information to address the monitoring goals and what data gaps exist.

The next step should be to identify project constraints such as finances, staffing, and time. Clear and detailed information should be obtained on the time frame for management decisions, the amounts and types of data that must be collected, the level of effort required to collect them, and the equipment and personnel needed to conduct the monitoring. This will determine whether available personnel and budget are sufficient to implement or expand the monitoring program.

As with its design, the program's level of monitoring is largely determined when goals and objectives are set, although there is some flexibility for achieving most monitoring objectives. Watershed managers should determine the appropriate timeframe and geographic scope of the monitoring program based on program goals and objectives. For example, if the objective is to determine the effectiveness of a nutrient management program for reducing nutrient inputs to a downstream lake, monitoring a subwatershed for five years or longer might be necessary.

Watershed managers also need to determine the size of the watershed, because many have an influence on stream characteristics and water quality, and therefore on the complexity of the monitoring program design. These factors include drainage patterns, stream order, stream type, climate, number of landowners in the area, homogeneity of land uses, watershed geology, and geomorphology. An analysis of these considerations in combination with budgetary and time constraints will determine the exact nature of the monitoring program.

It is important to ensure that expectations for the monitoring program are realistic. Ward et al. (1990) identify the following key steps to ensure that policymakers and other stakeholders know the types of information that a monitoring program can produce:

- Perform a thorough review of the legal basis for the management effort and define the resulting implications for monitoring.
- Review the administrative structure and procedures developed from the law in order to define the information expectations of the management staff.
- Review the ability of the monitoring program to supply information.
- Formulate an information expectations report for the monitoring system.
- Present the information expectations report to all users of the information.
- Develop consensus as to an agreeable formulation of information expectations and related monitoring system design criteria.

The next task when developing a monitoring program plan is to set monitoring objectives, which are more specific statements than goals and can be used to complete the monitoring design process. The objectives must be detailed enough to allow the designer to define precisely what data will be gathered and how the resulting information will be used.

Another important aspect of setting up a monitoring and evaluation program is variable selection. Variables should be selected based on the monitoring objectives. For example, if a dissolved oxygen problem is suspected, then dissolved oxygen should be monitored in addition to biochemical oxygen demand, sediment oxygen demand, temperature, and nutrients. Surrogate measures can also be used to satisfy monitoring objectives. For example, if the objective is to monitor the condition of salmon spawning areas, surrogate measures are necessary because the condition of salmon spawning areas is a composite of many factors. Good surrogate variables would be stream bank undercut, embeddedness, and vegetative overhang (Platts et al., 1983). The corresponding surrogate goals could be to reduce cobble embeddedness and to increase vegetative overhang to appropriate levels for salmon spawning. Subsequent monitoring goals could be to document changes in cobble embeddedness and vegetative overhang.

Because there are numerous variables to choose from and monitoring budgets are limited, some method to prioritize variable selection is often necessary. Table 12.1 shows groups of variables and examples of each. When available, existing data should be used to guide variable selection. Further discussion on variable selection, prioritization, and optimization are provided by USDA (1996), MacDonald et al. (1991), and Sherwani and Moreau (1975). In some cases, optimal variable selection is not possible, which may be due to lack of local data. In such cases, the researcher might need to rely on professional judgement and the review of monitoring programs of similar nature and scope.

Table 12.1: Examples of variables that can be measured to assess changes in management practice implementation and water quality.

Variable Type	Examples
Physical and chemical water quality data	Flow (streams), temperature, transparency, suspended sediment, sedimentation transparency, suspended sediment, sedimentation rate, dissolved oxygen, pH, conductivity, alkalinity/acid neutralizing capacity (lakes), and nutrients.
Biological data	Bacteria, algal biomass, macrophyte biomass and location, macroinvertebrate and fish populations.
Precipitation data	Total rainfall, rainfall intensity, storm interval, and storm duration.
Land use data	Treatments applied to land, current and historical use of the land, spatial and temporal information on land use activities, and changes in land use made before and during a project.
Topographic data	Slope length, slope steepness, slope shape, channel slope, channel side slope.
Soil characteristics data	Hydrologic soil group, soil organic carbon content, depth to water, net recharge, aquifer media, and vadose zone characteristics.

Designing and implementing a monitoring program often requires an interdisciplinary approach that may require interagency coordination and input. In many cases, technical staff will need to integrate "new" monitoring with what is already being done to demonstrate to program managers that duplicate work is not proposed. The most effective way to achieve this goal is to bring all the involved agencies and other stakeholders in the monitoring effort together. One or more agencies should coordinate to clarify project roles and responsibilities. Agreements to participate can be formalized as commitments and specified in the quality assurance project plan.

Such coordinated cooperation permits each involved party to offer the results of its ongoing activities to the monitoring effort, lessens the burden on each participating agency, and may

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decrease overall project costs. For example, USGS might already have a tracking system for management practices, while other agencies, including the U.S. Fish and Wildlife Service and EPA, might have other ongoing monitoring programs. When multiple agencies are involved in the monitoring program, each can benefit from the others' efforts.

Two types of objectives will be discussed in this section: analyzing trends in water quality and measuring the effectiveness of management practices.

12.3.3.1 Conduct trend monitoring

Trend monitoring can be useful for determining whether there has been a change in the extent to which management measures and management practices are being implemented. Trend monitoring involves long-term tracking of changes in one or more parameters. Public attitudes, land use, and the use of various urban management practices are examples of parameters that could be measured with trend monitoring.

Isolating the impacts of either individual or sets of management measures and management practices on water quality also requires trend monitoring. Because trend monitoring involves measuring a change (or lack thereof) in some parameter over time, it is necessarily of longer duration and requires establishment of a baseline. Any changes in the measured parameter are then detected in reference to the baseline. Baseline monitoring requires ascertaining the existing conditions before some management action or change in land use occurs. Factors such as weather conditions should be considered if baseline monitoring is to be used as a reference point for trend analysis and management decisions. The ability to relate water quality changes to changes in land management depends on the quality and quantity of data collected on land management practices.

Public attitudes, land use, and the use of various urban management practices are examples of parameters that could be measured with trend monitoring. Isolating the impacts of management measures and management practices on water quality also requires trend monitoring. For example, an objective of trend analysis can be to answer the question, "Is water quality changing over time?"

12.3.3.2 Conduct effectiveness monitoring

Effectiveness monitoring involves evaluating individual management practices or groups of management practices to determine the extent of pollution control they provide. Monitoring for individual management practices can typically be conducted on a plot or field scale, whereas monitoring for management practice systems is usually conduced on a watershed scale. Studies of some individual practices can be conducted in a relatively short time (less than five years), while others might take longer. Evaluation of management practice systems is typically conducted over a long term (more than five years) because management practice implementation can take years to affect water quality. In fact, there may be a lag in response time that may be 10 to 20 years or longer. This type of monitoring is difficult due to the presence of pollutant reserves in soil and sediments, the effect of many land uses within a study area, the variety of approaches that landowners use to implement similar management practice systems, and the need to track land management as well as water quality and climatic variables.

A guidance manual describing protocols for monitoring the effectiveness of storm water management practices, *Urban Stormwater BMP Performance Monitoring*, is available for download in PDF format from the International Stormwater Best Management Practices Database Web site (http://www.bmpdatabase.org/docs/Urban Stormwater BMP Performance Monitoring.pdf). Along the same lines, EPA's Environmental Technology Verification Center offers the *Protocol for the Verification of Stormwater Source Area Treatment Technologies* (http://www.epa.gov/etv/pdfs/vp/04_vp_stormwater.pdf).

12.3.4 Develop and Implement a Schedule to Improve the Management Program Framework

Data on management practice effectiveness and water quality should be carefully reviewed to determine where deficiencies in the runoff management exist. Effectiveness monitoring results should be compared with expected values published in the literature or with values provided with proprietary products. If the system is underperforming, possible causes should be considered:

- Is the practice properly designed and sized?
- Are site conditions (geology, land use, etc.) inappropriate for this practice?
- Were maintenance activities not performed as scheduled or needed?
- Were influent pollutant concentrations different than expected?

The next step is to determine whether the management practice needs to be retrofitted, replaced, or removed. Is pretreatment needed? Should a treatment train approach be used? Should additional capacity be added? Should maintenance be scheduled more frequently? A plan should be developed to implement proposed changes on a practice-by-practice basis.

A review of monitoring data on ambient water quality should be conducted to determine if water quality is improving. Consideration should be given to activities or events that might have skewed results (i.e., flooding, drought, landslides, significant changes in surrounding land use). If water quality has not improved, the following questions should be asked:

- Are management practices not performing as well as they should be?
- Were the wrong practices selected?
- Are additional practices needed?

Monitoring data should be examined to determine which pollutants and sources (if known) are a problem, and additional activities to address these sources should be proposed.

Once a list of planned changes to the program has been compiled, each project should be prioritized. Projects that should receive a higher priority are those that are most likely to improve water quality, those that the community has shown support for or is likely to support, and those that are relatively straightforward or inexpensive to implement. Implementation of proposed projects should be completed before the next program evaluation (usually within five years).

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12.4 Information Resources

Restoring Life in Running Waters: Better Biological Monitoring (Karr, 1998) describes how and why biological monitoring and multi-metric indices can be used to assess environmental degradation and how this information can be integrated into regulatory and policy decisions. This book can be purchased at bookstores or ordered from Island Press at http://www.islandpress.com/.

Monitoring Guidance for Determining the Effectiveness of Nonpoint Source Controls, published by EPA's Office of Water in 1997, gives an overview of nonpoint source pollution and covers the development of a monitoring plan, data analysis, quality assurance/quality control, and biological monitoring. It can be ordered through EPA's National Service Center for Environmental Publications at http://www.epa.gov/ncepihom/index.htm.

Techniques for Tracking, Evaluating, and Reporting the Implementation of Nonpoint Source Control Measures: Urban (USEPA, 1998) helps local officials to focus limited resources by establishing statistical sampling to assess, inspect, or evaluate a representative set of management practices, erosion and sediment controls, and onsite wastewater treatment systems. The document can be downloaded in PDF format at http://www.epa.gov/owow/nps/urban.pdf, or it can be ordered through EPA's National Service Center for Environmental Publications at http://www.epa.gov/ncepihom/index.htm.

EPA's Volunteer Monitoring Program provides technical assistance, serves as a regional contact for volunteer programs, manages grants to state agencies that organize volunteer monitoring programs, and provides information exchange services for volunteers. A listserver is available for volunteer monitoring program coordinators on the EPA Web site, http://www.epa.gov/owow/monitoring/volunteer. Also available are a national newsletter for volunteer monitors, a directory of volunteer monitoring programs, and manuals on volunteer monitoring methods and planning and implementing volunteer programs.

Urban Stormwater BMP Performance Monitoring: A Guidance Manual for Meeting the National Stormwater BMP Database Requirements presents monitoring protocols for studies measuring the effectiveness of storm water management practices and is available for download in PDF format from the International Stormwater Best Management Practices Database Web site (http://www.bmpdatabase.org/docs/Urban Stormwater BMP Performance Monitoring.pdf).

EPA's Environmental Technology Verification Center developed the *Protocol for the Verification of Stormwater Source Area Treatment Technologies* (http://www.epa.gov/etv/pdfs/vp/04_vp_stormwater.pdf), which establishes guidelines for measuring the effectiveness of storm water treatment technologies. The protocol was developed to ensure that technology verification studies are carried out in a consistent and objective manner that assesses the appropriate performance characteristics.

12.5 References

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SECTION C-11
ATTACHMENTS

WATER QUALITY MONITORING

PROGRAM EFFECTIVENESS ASSESSMENT
2005-06

ATTACHMENT C-11.1

Dry Weather Monitoring Data

Attachment C-11.1
County of Orange Dry Weather Monitoring Site Data
San Diego Region
2005-06 PEA

3	Site Name	Date	Time	Watershed	GIS Coordinates		Physicals								Chemical								Bacteria		
							Discharge Rate	Dissolved Oxygen	Electrical Conductivity	pH	Water Temperature	Turbidity	Air Temperature	Hardness as $CaCO_3$	Phenols	Ammonia as N	Nitrate as N	Surfactsnats (MBAS)	Reactive Phosphorous	Total Chlorine	Total Suspended Solids (TSS)	Oil & Grease	Total Coliform	Fecal Coliform	Enterococcus
					Lat	Long	cfs	mg/L	µS/cm		^{0}C	NTU	^{0}C	mg/L	mg/L								CFU/100mL		
Criterion 1	**Outside Tolerance Interval**							**6.11**		**7.03-8.27**	**23.44**	**16.7**	**18.14**		**0.01-0.02**	**1.16**	**5.3**	**0.45**	**2.92**	**0.13**	**78.08**		**330,000**	**106,000**	**55,000**
Criterion 2	Basin Plan Objective							5		6.5-9		20						0.5	0.1		75				
Criterion 3	Warning Level based on Experience								6000		40				>0.02	0.65	10			1					
Criterion 4	CTR Acute Criterion																								
Criterion 5	CTR Chronic Criterion																								
Criterion 6	LC_{50} for Toxicity Test Organism																								
	Targeted Site	Random Site																							
Random	COL02P50	7/15/03	12:47	San Juan Cre	N 33.59(	W 117.(	0.086	8.86		7.91	19.42	2.66	32	520	<0.02	0.06	0.9	<0.05	2.24	0.02	<5	<5	4,350	3,100	2,400
Random	COL02P50	8/20/03	11:00	San Juan Cre	N 33.59(	W 117.(	0.137	6.92		7.5	20.2	2.24	30	568	<0.02	0.08	1.1	<0.05	2.22	0.03	<5	<5	620	130	280
Random	COL02P50	9/9/03	09:30	San Juan Cre	N 33.59(	W 117.(	0.84	6.93		7.07	18.17	7.38	27	988	<0.02	0.02	1.2	0.05	2.54	0.01	<5	<5	1,490	130	870
Random	COL02P50	6/21/04	09:30	San Juan Cre	N 33.59(	W 117.(	0.189	8.84	2075	7.55	17.3	1.02	21	762			1.1	0.13	1.48	0.01	<5		530	380	590
Random	COL02P50	7/29/04	12:30	San Juan Cre	N 33.59(	W 117.(	0.018	8.5	3423	7.82	21.8	10.6		1364		0.09	4	0.1	1.24	0.02	20		16,400	6,300	11,100
Random	COL02P50	9/9/04		San Juan Cre	N 33.59(	W 117.(	DRY																		
Random	COL02P50	9/13/04	12:54	San Juan Cre	N 33.59(	W 117.(	0.288	8.91	1734	7.31	19.67	0.89		796			1.1		2.76	0.05	<5		6,300	4,200	3,100
Random	COL02P50	6/10/05	11:25	San Juan Cre	N 33.59(	W 117.(	0.4	9.1	2224	7.16	16.29	0.45	25	748	0	0.01	1.5	0.03	0.89	0.03	<5	<5	6,000	40	50
Random	COL02P50	8/3/05	10:15	San Juan Cre	N 33.59(	W 117.(	0.684	8.39	2070	7.31	19.5	0.63	29	610	0	0.01	1.9	0.02	1.76	0.04	<5	<5	4,500	20	90
Random	COL02P50	9/7/05	09:00	San Juan Cre	N 33.59(	W 117.(	0.49	8.87	2138	7.27	15.6	0.4	23	690	0	0.01	1.2	0.02	1.27	0.06	<5	<5	30	20	<10
Random	COL02P50	5/25/06	13:10	San Juan Cre	N 33.59(	W 117.(	0.352	8.8	1917	7.48	16.24	0.67	25	670	0	0.03	2.3	0.08	1.6	0.02	<5	<5	3,000	210	80
Random	COL02P50	6/29/06	09:25	San Juan Cre	N 33.59(	W 117.(	0.198	10.14	2150	7.19	18.44	1.51	28	745	0.01	0.03	1.4	0.1	2.55	0.02	<5	<5	190	60	140
Random	COL02P50	8/29/06	09:35	San Juan Cre	N 33.59(	W 117.(	0.35	8.52	2115	7.7	17.42	0.78	23	720	0.02	0.03	1	0.13	1.48	0.01	<5	<5	8,000	600	400
Random	COL02P55	7/15/03	14:00	San Juan Cre	N 33.56(	W 117.(	0.18	7.38		8.09	**28.62**	3.98	32	540	<0.02	0.07	1.7	<0.05	0.86	0.08	7	<5	27,000	18,000	13,000
Random	COL02P55	8/20/03	12:30	San Juan Cre	N 33.56(	W 117.(	0.018	6.86		8.2	21.4	8.05	36	690	<0.02	0.06	5.2	<0.05	1.15	0.04	14	<5	18,700	3,600	5,800
Random	COL02P55	9/9/03	11:00	San Juan Cre	N 33.56(	W 117.(	0.01	7.52		7.42	20.29	4.92	29	1452	<0.02	0.14	**6**	<0.05	0.4	0.05	25	<5	6,800	4,100	5,400
Random	COL02P55	6/21/04	10:30	San Juan Cre	N 33.56(	W 117.(	0.054	9.59	2305	7.95	18.74	15.9	21	1160		0.08	3.9	0.03	2.13		12		16,800	3,900	10,400
Random	COL02P55	7/29/04	11:45	San Juan Cre	N 33.56(	W 117.(	0.126	8.36	2180	7.6	20.03	0.91		776			0.5	0.08	1.43	0.11	<5		1,140	630	620
Random	COL02P55	9/9/04		San Juan Cre	N 33.56(	W 117.(	DRY																		
Random	COL02P55	6/10/05	09:50	San Juan Cre	N 33.56(	W 117.(	0.017	6.83	2799	7.65	18.44	15.6	25	915	0	0.44	3.8	0.12	1.84	0.03	29	<5	**470,000**	43,000	**113,000**
Random	COL02P55	8/3/05	09:20	San Juan Cre	N 33.56(	W 117.(	0.104	8.19	1792	7.63	21.13	13.6	32	575	0	0.19	4	0.03	2.01	0.04	36	<5	**440,000**	**200,000**	28,000
Random	COL02P55	9/7/05	07:25	San Juan Cre	N 33.56(	W 117.(	0.108	8.4	1352	7.27	19.1	**18.8**	21	484	0	0.07	4.1	0.06	2.62	0.02	37	<5	180,000	80,000	37,000
Random	COL02P55	5/25/06	10:05	San Juan Cre	N 33.56(	W 117.(	0.028	8.55	2739	7.85	17.51	8.43	25	962	0	**2.6**	**6.5**	0.1	1.99	0.04	20	<5	**550,000**	**110,000**	9,000
Random	COL02P55	6/29/06	08:01	San Juan Cre	N 33.56(	W 117.(	0.278	**6**	1887	7.5	19.73	8.57	27	625	0.01	**3.16**	4.6	0.18	2.74	0.02	14	<5	**640,000**	26,000	47,000
Random	COL02P55	8/29/06	07:30	San Juan Cre	N 33.56(	W 117.(	0.081	7	2171	7.8	19.83	5.46	19	690	0.02	0.62	4.5	0.18	2.43	0.04	12	<5	67,000	27,000	16,000

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Attachment C-11.1
County of Orange Dry Weather Monitoring Site Data
San Diego Region
2005-06 PEA

3			Pesticides					Dissolved Metals						
	Site Name	Date	Diazinon	Chlorpyrifos	Malathion	Dimethoate	Disulfoton	Chromium	Nickel	Copper	Zinc	Silver	Cadmium	Lead
			ng/L					µg/L						
Criterion 1	**Outside Tolerance Interval**		**271**	**10**	**57.4**	**10**			**88**	**15**	**75**		**9**	**2**
Criterion 2	Basin Plan Objective													
Criterion 3	Warning Level based on Exp													
Criterion 4	CTR Acute Criterion							1707.86	1512.89	49.62	379.3	37.44	19.1	280.01
Criterion 5	CTR Chronic Criterion							554.01	168.04	29.28	382.4		6.25	10.91
Criterion 6	LC_{50} for Toxicity Test Organi		450	570	5000	43000								
	Targeted Site	Random S												
Random	COL02P50	7/15/03	<5	<5	<5	<5		<8.00	<4.00	2.8	55	<2.00	<1.00	<2.00
Random	COL02P50	8/20/03	<5	<5	<5	<5		<8.00	<4.00	<2.00	18	<2.00	<1.00	<2.00
Random	COL02P50	9/9/03	<5	<5	<5	<5		<8.00	<4.00	4.8	27	<2.00	<1.00	<2.00
Random	COL02P50	6/21/04	64	<5	<5	<5	<10	<8.00	5	<2.00	71	<2.00	<1.00	<2.00
Random	COL02P50	7/29/04	<5	<5	<5	<5	<10	<8.00	**280**	8.9	**120**	<2.00	**88**	<2.00
Random	COL02P50	9/9/04												
Random	COL02P50	9/13/04	13	<5	<5	<5	<10	<8.00	8.4	<2.00	38	<2.00	<1.00	<2.00
Random	COL02P50	6/10/05	<1	<1	<1	<1	<1	<0.50	12	0.97	6.6	<0.50	<0.50	<0.50
Random	COL02P50	8/3/05	<10	<10	<10	<10	<10	<0.50	7.9	0.54	4.8	<0.50	<0.50	<0.50
Random	COL02P50	9/7/05	<10	<10	<10	<10	<10	<0.50	7.5	0.59	4.7	<0.50	<0.50	<0.50
Random	COL02P50	5/25/06	<2	<1	<3	<3	<1	<0.50	12	0.8	7.4	<0.50	<0.50	<0.50
Random	COL02P50	6/29/06	19	<1	<3	<3	<1	<0.50	11	<0.50	5.6	<0.50	<0.50	<0.50
Random	COL02P50	8/29/06	<2	<1	<3	<3	<1	<0.50	7.1	1.1	5.8	<0.50	<0.50	<0.50
Random	COL02P55	7/15/03	<5	<5	<5	<5		<8.00	61	4.1	33	<2.00	**16**	<2.00
Random	COL02P55	8/20/03	94	<5	<5	<5		<8.00	**230**	5.9	75	<2.00	**75**	<2.00
Random	COL02P55	9/9/03	<5	<5	<5	<5		<8.00	**290**	4.3	**87**	<2.00	**110**	<2.00
Random	COL02P55	6/21/04	<5	<5	<5	<5	<10	<8.00	**210**	5.2	**120**	<2.00	**68**	<2.00
Random	COL02P55	7/29/04	43	<5	<5	<5	<10	<8.00	6.6	3.2	35	<2.00	<1.00	<2.00
Random	COL02P55	9/9/04												
Random	COL02P55	6/10/05	<1	<1	<1	<1	<1	0.61	**210**	4.8	73	<0.50	**49**	<0.50
Random	COL02P55	8/3/05	<10	<10	<10	<10	<10	<0.50	75	3.9	18	<0.50	**18**	<0.50
Random	COL02P55	9/7/05	<10	<10	<10	<10	<10	<0.50	61	3.7	22	<0.50	**12**	<0.50
Random	COL02P55	5/25/06	<2	<1	<3	<3	<1	0.96	**220**	8.9	66	<0.50	**61**	<0.50
Random	COL02P55	6/29/06	<2	<1	<3	<3	<1	<0.50	88	6.5	39	<0.50	**11**	<0.50
Random	COL02P55	8/29/06	30	<1	26	<3	<1	0.63	71	5.1	30	<0.50	5.2	<0.50

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Attachment C-11.1
County of Orange Dry Weather Monitoring Site Data
Santa Ana Region
2005-06 PEA

	Site Name	Date	Time	Watershed	GIS Coordinates		Physicals								Chemical										Bacteria		
					Lat	Long	Discharge Rate	Dissolved Oxygen	Electrical Conductivity	pH	Water Temperature	Turbidity	Air Temperature	Hardness as $CaCO_3$	Phenols	Ammonia as N	Nitrate as N	Surfactsnats (MBAS)	Reactive Phosphorous	Total Chlorine	Total Suspended Solids (TSS)	Oil & Grease	Dissolved Copper	Dissolved Hexa Chrom.	Total Coliform	Fecal Coliform	Enterococcus
							cfs	mg/L	µS/cm		^{0}C	NTU	^{0}C	mg/L	mg/L										CFU/100mL		
Criterion 1	**Outside Tolerance Interval**							**6.11**		**7.03-8.2**	**23.44**	**16.7**	**18.14**		**0.01-0.0**	**1.16**	**5.3**	**0.45**	**2.92**	**0.13**	**78.08**				**330,000**	**106,000**	**55,000**
Criterion 2	Basin Plan Objective							5		6.5-9		20						0.5			75						
Criterion 3	Warning Level based on Experience								6000		40				>0.02	0.65	10			1							
Criterion 4	CTR Acute Criterion																										
Criterion 5	CTR Chronic Criterion																										
Criterion 6	LC_{50} for Toxicity Test Organism																										
	Targeted Site	Random Site																									

Random	COF13@FH	5/30/06	11:45	Newport Bay	N 33.76˚	W 117.	0.36	15.58	2093	7.93	19.68	3.26	22	730	0	0.06	3.5	**0.57**	0.72	0.03	<5	<5		0.02	26,000	7,000	1,500
Random	COF13@FH	7/21/06	08:45	Newport Bay	N 33.76˚	W 117.	0.63	12.21	1754	8.03	22.02	4.67	24	608	0	0.04	2.7	0.07	0.83	0.05	14	<5		0	70,000	30,000	29,000
Random	COF13@FH	9/15/06	08:55	Newport Bay	N 33.76˚	W 117.	0.78	8.74	1121	8.2	20.6	4.25	**16**	625	0	0.03	3.5	0.02	0.62	0.03	9	<5		0.01	130,000	51,000	19,000

Attachment C-11.1
County of Orange Dry Weather Monitoring Site Data
Santa Ana Region
2005-06 PEA

	Site Name	Date	Pesticides					Dissolved Metals						
			Diazinon	Chlorpyrifos	Malathion	Dimethoate	Disulfoton	Chromium	Nickel	Copper	Zinc	Silver	Cadmium	Lead
			ng/L					µg/L						
Criterion 1	**Outside Tolerance Interval**		**271**	**10**	**57.4**	**10**			**88**	**15**	**75**		**9**	**2**
Criterion 2	Basin Plan Objective													
Criterion 3	Warning Level based on Exper													
Criterion 4	CTR Acute Criterion							1708	1513	49.6	379	37.4	19.1	280
Criterion 5	CTR Chronic Criterion							554	168	29.3	382		6.25	10.9
Criterion 6	LC_{50} for Toxicity Test Organisr		450	570	5,000	43,000								
	Targeted Site	Random Sit												
Random	COF13@FH	5/30/06	<2	<1	<3	<3	<1	<0.50	12	3.8	10	<0.50	0.77	<0.50
Random	COF13@FH	7/21/06	<2	<1	<3	<3	<1	<0.50	1.9	2.5	6.9	<0.50	<0.50	<0.50
Random	COF13@FH	9/15/06	<2	<1	<3	<3	<1	<0.50	4.2	2.2	4.7	<0.50	<0.50	<0.50

C-11.0 WATER QUALITY MONITORING SUMMARY AND ANALYSES

C-11.1 Introduction

In response to the First Term Permits from the Santa Ana and San Diego Regional Boards, the Permittees developed and implemented a water quality monitoring program (1993 DAMP Appendix K) to aid in the detection and control of illicit connections and illegal discharges to the municipal storm drain systems and to meet other program performance objectives. The monitoring program focused on estimating pollutant loads in urban stormwater runoff, tracked compliance with water quality objectives, searched for sources of pollutants and addressed impacts on areas of special concern.

In response to the Second Term Permits, the Permittees conducted a two-year re-evaluation and revision of the water quality monitoring program in order to re-focus the efforts to determine the role, if any, of urban stormwater discharges to the impairment of beneficial uses and to provide technical information to support an effective urban stormwater management program to reduce the beneficial use impairments determined to be associated with urban stormwater (2000 DAMP Appendix K).

The Permittees also initiated several water quality planning efforts, conducted additional water quality evaluations in response to technical requests from the Regional Board and participated in various regional research and/or monitoring programs. The combination of these efforts will aid the Permittees in determining the extent and degree of the relationship between urban stormwater runoff and impairment of beneficial uses within the aquatic resources of Orange County.

This report presents the results of water quality monitoring, conducted between July 1, 2005 and June 30, 2006, in the portion of Orange County under the jurisdiction of the Santa Ana Regional Board.

C-11.2 Program Development

C-11.2.1 Pre-NPDES Water Quality Monitoring

From 1973 to 1990, the Principal Permittee conducted routine water quality monitoring on drainage facilities which are tributary to water bodies identified as waters of the state by the Regional Boards. The receiving waters were also monitored routinely to assess the chronic effects on established beneficial uses.

When the monitoring program was initiated in 1973, monthly nutrient and trace element sampling was performed at several locations. Sediment samples were collected semiannually to assess the impact of contaminant deposition and adsorption. Additional constituents such as mercury, selenium, DDT, PCBs and radioactivity were also evaluated on a semiannual basis to address public concerns regarding the pollution threat from these constituents.

C-11.2.2 First Term Permit Water Quality Monitoring

In order to bring the pre-NPDES water quality monitoring program into conformance with the 1990 federal NPDES regulations and the First Term Permit objectives (**Section 11.2**), field screening to detect gross contamination was added to the program and the number of sampling sites in the channels and receiving waters were increased in order to better assess the amount and type of contamination in the storm drain system.

The First Term Permit water quality monitoring program consisted of field screening for illegal discharges and illicit connections (channels only); dry-weather and stormwater runoff monitoring and a receiving water program.

C-11.2.3 Second Term Permit Water Quality Monitoring

While the First Term Permit monitoring program produced useful information, the Permittees recognized (as has the rest of the nation) the high degree of uncertainty regarding the link between urban stormwater runoff and actual impairment of beneficial uses within the aquatic resources of Orange County.

Therefore, in response to the Second Term Permit objectives, the Permittees conducted a systematic re-evaluation of the water quality monitoring program which led to a re-statement of the monitoring program's primary goals. The primary and parallel goals of the monitoring program were re-stated as:

- To determine the role, if any, of urban stormwater discharges in the impairment of beneficial uses; and
- To provide technical information to support effective urban stormwater management program actions to reduce the beneficial use impairment determined to be associated with urban stormwater.

In order to organize the vast array of monitoring activities needed to carry out the objectives and goals, the Permittees identified three separate key elements within the Final Monitoring Program (May 1999).

These three key elements are:

- A focus on known sites (or Warm Spots) where constituents are substantially above system-wide averages;
- A parallel (and somewhat overlapping) focus on areas of critical aquatic concern (herein referred to as critical aquatic resources or CARs); and
- A countywide reconnaissance program to identify specific sources of contamination from sub-watershed areas as well as specific land use investigations in order to evaluate the effectiveness of a variety of BMPs.

The Final Monitoring Program includes an underlying rationale for each monitoring element, a discussion of how monitoring data will be used in decision-making, identification of potential links to other relevant monitoring programs being carried out

by other agencies, a description of the basic monitoring design, identification of additional study design steps, and a description of anticipated monitoring activities.

These monitoring elements include many locations from the pre-NPDES and First Term Permit water quality monitoring programs that were of value because of the length of their historical record. Each key element of the Final Monitoring Program contains a description of the monitoring activities proposed to accomplish the objectives described above, as well as a description of the process for making decisions about how the monitoring program will respond to incoming data over time. This process can be used at any time throughout the life of the monitoring program to re-evaluate the direction of the program, or to reassess the appropriate allocation of resources within the program.

The Final Monitoring Program and subsequent elements utilize a five-year timeline (1998/99 - 2002/03) for addressing the goals/objectives associated with each task. This timeline is reflective of the dynamic nature of the monitoring program and the fact that many of the objectives will require a substantial investment of resources before they are finalized.

C-11.2.4 Third Term Permit Water Quality Monitoring Under Order R8-2002-0010

In 2002 and 03, the Program completed development of the Third Term Permit monitoring programs for wet and dry weather, respectively. This program extends stormwater monitoring to a broader range of locations and to a wider array of methods for measuring impacts. For example, the Third Term monitoring plan will more completely examine storm drains that discharge directly to the coast and pose a potential health risk to swimmers and bathers. In addition, the new plan for the first time investigates the effects of stormwater plumes on the near shore marine environment. Inland, the new monitoring plan has expanded to include bioassessment studies of creeks, along with the more consistent use of toxicity testing. Combined with the existing measurement of chemical parameters, this "triad" approach is intended to describe impacts more fully; more accurately identify their sources, and target follow-up studies and BMPs more effectively. Thus, the Third Term Permit monitoring program includes five key elements:

- Mass emissions monitoring
- Estuary / wetlands monitoring
- Bacteriological / pathogen monitoring
- Bioassessment
- Dry weather reconnaissance
- Land use correlations
- TMDL/303(d) listed water body monitoring (nutrient TMDL)

- TMDL/303(d) listed water body monitoring (toxics TMDL).

The overall monitoring approach and methods are summarized in the following sections.

C-11.2.5 Additional Local Water Quality Monitoring

Any additional water quality monitoring conducted by the Permittees is described and summarized within the Performance Evaluation Assessment (PEA) of the respective Permittee.

C-11.3 Monitoring Approach

The objectives of the Receiving Waters Monitoring Program, as stated in the Third Term Permit, are to:

1. Develop and support an effective municipal urban runoff and non-point source control program
2. Define water quality status, trends, and pollutants of concern associated with urban storm water and non-storm water discharges and their impact on the beneficial uses of the receiving waters
3. Characterize pollutants associated with urban storm water and non-storm water discharges and to assess the influence of urban land uses on water quality and the beneficial uses of receiving waters
4. Identify significant water quality problems related to urban storm water and nonstorm water discharges
5. Identify other sources of pollutants in storm water and non-storm water runoff to the maximum extent possible (e.g., atmospheric deposition, contaminated sediments, other non-point sources, etc.)
6. Identify and prohibit illicit discharges
7. Identify those waters, which without additional action to control pollution from urban stormwater discharges, cannot reasonably be expected to attain or maintain applicable water quality standards required to sustain the beneficial uses in the Basin Plan (TMDL monitoring)
8. Evaluate the effectiveness of existing municipal storm water quality management programs, including an estimate of pollutant reductions achieved by the structural and nonstructural BMPs implemented by the permittees
9. Evaluate costs and benefits of proposed municipal storm water quality control programs to the stakeholders, including the public.

The monitoring program described in the following section meets these objectives (with the proviso that evaluating the overall effectiveness and cost-benefit relationships of municipal stormwater programs, including specific BMPs, requires further effort beyond the scope of the water quality monitoring program outlined in the Permit and detailed in the following section). Each of the eight monitoring program elements directly addresses specific permit objectives.

The Monitoring Program continues and expands the previous monitoring program's emphasis on assessing impacts on aquatic resources, documenting long-term trends in water quality, targeting problematic discharge sites for more focused investigations, and adding additional monitoring elements. The following objectives for each program element include descriptions of management goals, monitoring strategies, reference conditions, and temporal and spatial extent, as appropriate:

Mass emissions monitoring:	Using measurements of a range of urban contaminants, loads, as well as exceedances of relevant standards, evaluate trends over time.
Estuary / wetlands monitoring:	Using measurements of key pollutants, loads, and biological community parameters, describe impacts on estuarine and wetlands ecosystems and the relationship of any impacts to runoff, based on theoretical and empirical expectations about the structure and function of healthy communities.
Bacteriological / pathogen monitoring:	Using measurements of a suite of bacterial indicators, identify spatial and temporal patterns of elevated level in order to prioritize problem areas.
Bioassessment:	Using a "triad" of indicators (bioassessment, chemistry, toxicity), describe impacts on stream communities and the relationship of any impacts to runoff, based on comparisons with reference locations and a regional IBI on a year-to-year timeframe.
Reconnaissance:	Using measurements of key pollutants, identify potential illegal discharges and illicit connections, based on comparison with historical data and available estimates of background levels.
Land use correlations:	Using an experimental, "before-after," design, identify changes in runoff associated with the urbanization of previously agricultural land.
TMDL/303(d) listed water body monitoring – nutrient TMDL:	Using measurements of nutrients, track progress of nutrient control measures over time, based on comparison with TMDL targets.
TMDL/303(d) listed water body monitoring - toxics TMDL	Using measurements of key pollutants, identify potential sources and pathways of toxic compounds and track progress of control measures over time, based on comparison with TMDL targets.

The Monitoring Program will reflect the Management Program's continued evolution toward watershed management and toward addressing a more complex set of questions that integrate multiple Program elements. For example, the inclusion of an adaptive toxicity testing component in the mass emissions program element provides the ability to more fully characterize toxicity and then track its upstream source(s) on a watershed scale. As another example, the reconnaissance program (focused on identifying illegal discharges and illicit connections) will make use of the growing databases of commercial and industrial facilities resulting from the cities' ongoing inventories of such facilities. Further, the inclusion of bioassessment and estuary/wetlands program elements enables the Monitoring Program to investigate the relationship of important biological endpoints to chemical contamination and physical changes in habitat. Overall, the monitoring program described in the following sections has expanded its focus on identifying the sources of problems, while continuing important historical data collection on trends at key sites.

Finally, the receiving water quality monitoring program responds explicitly to Section 3.3.1, Item 2, of the DAMP, which states that water quality problems will be identified through a Countywide monitoring program and other assessments.

C-11.4 Description of Monitoring Procedures

C-11.4.1 Mass Emissions Monitoring

The Permittees use time-composite sampling and continuous discharge measurement as the primary method of monitoring the concentration and load of constituents at their Mass Emissions sites. This type of sampling is conducted with automatic samplers that consist of programmable pumps (peristaltic) that transport water from the channel to a collection reservoir in the auto-sampler base. The collection reservoir can be a single large composite bottle or a series of up to 24 bottles. The auto-sampler program can be modified to vary sample volumes and frequency of collection. Two automatic samplers were used at each Mass Emissions site. One auto-sampler was used for monitoring water chemistry and the other was used for monitoring aqueous toxicity.

To collect samples for the analysis of water chemistry, 8, 1.8-liter glass bottles were used in the auto-sampler base. The water chemistry an auto-sampler was programmed to collect three discrete samples per 1.8-liter bottle. To collect samples for toxicity testing, a single 5-gallon glass bottle was used in the auto-sampler base. The two samplers were programmed to collect at the same frequency to maintain the consistency between the composite samples produced by each.

Three storms were monitored at each Mass Emissions site. For each storm the water chemistry was monitored with a series of 3 to 5 composite samples collectively spanning approximately 96-hours. The sampling for toxicity testing was coincident with just one of these composite samples. The Permittees chose the following temporal segments of storms that would be monitored for toxicity.

- Storm 1 – first flush (first hour of storm);

- Storms 2 and 3 – 24-hour period beginning three hours after the initiation of the first flush sampling by the water chemistry auto-sampler.

For dry weather discharge evaluations, the automatic samplers are programmed to collect a discrete sample once an hour for a 24-hour period. During each storm the automatic sampling programs were initiated when the water level in the channel rose above a triggering device (level actuator or flow meter) hardwired to the respective auto-sampler. When possible, a single triggering device was used to trigger both samplers simultaneously. For the water chemistry sampler (and the toxicity sampler during the first storm) the frequency of collection during the first hour of a storm was set at 1 sample/12 minutes. After the sixth sample is collected at the one-hour mark, the collection frequency is decreased to once every 2 hours. Sampling of water chemistry spans approximately 96 hours to allow comparison of the data to 96-hour guidance criteria for chronic aquatic toxicity from the California Toxics Rule (CTR). The concentrations of dissolved heavy metals in the composite samples can be compared to acute toxicity criteria from the CTR. The concentrations of organophosphate pesticides can be compared to literature values of LC_{50}s for toxicity testing organisms.

Autosampler maintenance is performed periodically to change bottles, icepacks, and power supplies.

The first six samples collected during each storm were composited and represented the "first flush". The remaining bi-hourly storm samples were used to prepare composite samples that were representative of the subsequent parts of the storm. Unless a 24-hour composite sample was prepared for comparison to toxicity testing results, the samples beyond the first flush were composited using the stage hydrograph for the channel, or by evaluating the electrical conductivities of the samples in each bottle. Using hydrographs from the Principal Permittee's Automated Local Evaluation in Real Time (ALERT) system, samples collected beyond the first flush and representing the storm peak and recession were composited into a single sample. Storms spanning multiple days were broken up into two or more composite samples.

In the absence of a streamgauge hydrograph for the sampled channel, the conductivity of each discrete sample (in order of collection) is measured. Changes in conductivity usually denote the beginning or end of storm runoff. After the "first flush" of a storm, conductivities tend to immediately decrease during the rise of the storm hydrograph and slowly rise after the recession. Sample appearance (turbidity or fluvial sediment) can also be used in the compositing process. Storm samples tend to be more turbid and contain more fluvial sediment. Using these electroanalytical measurements and visual observations as a guide, composite samples can be prepared to evaluate various parts of a storm.

Water chemistry samples are analyzed for pH, electrical conductivity, turbidity, nitrate, ammonia, total Kjehldahl Nitrogen (TKN), total phosphate, orthophosphate, dissolved and total organic carbon, total suspended and settleable solids, volatile suspended solids, chloride, sulfate, , and total recoverable and dissolved cadmium, copper,

chromium, lead, nickel, selenium, silver, and zinc. Priority pollutant scans performed on the first flush of the first monitored storm of the year at each site. Grab samples collected at the time of auto-sampler servicing and submitted for bacteriological analyses.

An aliquot of each samples collected for total recoverable metals analyses was filtered with a 0.45 micron groundwater filtering capsule. The filtered and the unfiltered samples were then acidified with analytical grade nitric acid and submitted to the contract laboratory for analysis.

Toxicity of stormwater runoff samples was evaluated using three toxicity tests with marine organisms. The toxicity due to pesticides was measured using the mysid (*Mysidopsis bahia* a.k.a. *Americamysis bahia*) survival/growth test. The toxicity due to dissolved metals was measured using the sea urchin (Stronglyocentrotus *purpuratus*) fertilization and embryo development tests. In the Newport Bay watershed stormwater toxicity tests also included fathead minnow (*Pimephales promelas*) survival /growth and *Ceriodaphnia dubia* survival / reproduction. During dry-weather monitoring the toxicity tests were conducted only with freshwater organisms. The tests include *Ceriodaphnia* survival / reproduction, *Selenastrum* growth, and *Hyallela azteca* survival. In the Newport Watershed fathead minnow survival /growth was also evaluated.
Time composite monitoring is supported by the Principal Permittee's precipitation and streamgaging network which consists of recording and/or transmitting ALERT gages. Mechanical recording raingages are weighing bucket type. Accumulated rainfall is recorded in analog format on drum charts. The ALERT precipitation gages are tipping bucket type with data loggers. Data are recorded and transmitted in digital format; sensitivity is 1 mm (0.04 inches) of accumulated rainfall.

The Principal Permittee uses several types of streamgauges to monitor changes in water level. The oldest design is the stilling well with water level float; the newer types are manometer gages or pressure transducers. Data (water level versus time) are recorded on strip charts. The ALERT interface to these gages consists of a connection from the recorder chart drive to an ALERT shaft encoder. ALERT information is recorded on a data logger and transmitted to the Principal Permittee Katella yard base station in digital format. Sensitivity of the transmitted and recorded ALERT record is user-variable with the greatest sensitivity being a change in water level of 0.01 feet.

C-11.4.2 Estuary / Wetlands Monitoring

Estuary / Wetlands monitoring focuses on three receiving waters and their major tributaries. These receiving waters are the Newport Bay, Huntington Harbor / Bolsa Bay, and the Talbert Marsh. Monitoring was conducted at 12 locations in these receiving waters during dry-weather and storm runoff conditions. Because there are significant equipment and manpower demands for monitoring of a receiving water and its tributaries for the same dry-weather or stormwater event each receiving water system is monitored separately. Dry-weather monitoring consisted of 24-hour composite sampling of the tributaries and monitoring the respective receiving waters on the subsequent day. Stormwater monitoring of the tributaries is conducted according to the Mass Emissions monitoring protocol. Sampling of the receiving waters during a storm is conducted over

a 4-day period with three samplings, with each sampling separated from the prior sampling by two days.

All the tributary channel sites, with the exception of Talbert Channel, are also mass emissions sites. The availability of mass emissions data for these channels will assist in identifying potential relationships between patterns and trends in the estuaries/wetlands and the inputs of key pollutants.

Some sites in receiving waters are situated near the mouths of channels that represent major inputs of runoff, and there is a minimum of one site in each estuary that is free of direct runoff influences from the channels, including UNBCHB, LNBHIR, LNBTUB, and BBOLR. Comparisons between these two types of sites will help identify runoff impacts. An attempt is made to sample the estuary / wetland sites in Huntington Harbour, Bolsa Bay, and Talbert Marsh during two storm events per year and twice during the dry season. The dry-weather monitoring was conducted once prior to the beginning of the storm season (October) and once after the end (May). Dry-weather monitoring was conducted quarterly at the sites that are part of the Toxics TMDL. Sites in Upper Newport Bay have a somewhat different sampling regime because they are also part of the nutrient TMDL Regional Monitoring Program (RMP) which has a separate set of monitoring requirements. These four sites were monitored monthly throughout the year, in addition to the two storms.

The constituents measured in the input channels were the same as those sampled in the mass emissions element. The constituents measured in the estuaries / wetlands themselves depend on the season, on whether the sample is an aqueous or a sediment sample, and on the location of the monitoring site.

During stormwater events, the monitoring in the receiving waters included chemical analyses for nutrients, total and dissolved metals, dissolved organic carbon, and organophosphorus pesticides. In-situ measurements were made in the water column from the surface to the bottom at 1-meter increments. These measurements included electrical conductivity, pH, temperature, and dissolved oxygen. Samples were evaluated for aqueous toxicity using the sea urchin fertilization test, sea urchin embyro development test and the mysid survival / growth test. The nutrients samples were collected at the surface to evaluate impacts on plant growth in the photic zone. The other samples are collected using a depth-integrating, composite technique to determine the average condition in the water column.

Quarterly dry-weather monitoring in the receiving waters included the aqueous analyses described above and a benthic sediment component to evaluate sediment chemistry and sediment toxicity. The sediment chemistry analytes included total organic carbon, particle size distribution, metals, organochlorine pesticides, PCBs, organophosphate pesticides, and pyrethroid pesticides. Sediment toxicity was evaluated using the 10-day amphipod survival test with *Eohaustorius estuarius*.

Once a year, usually during the summer, the benthic sediment sampling also includes monitoring of the benthic invertebrate community for taxonomy

Monthly sampling in the Upper Newport Bay is also conducted to evaluate nutrient loading from the San Diego Creek. Monthly monitoring of nitrogen and phosphorus in the sediments of the Upper Newport Bay was added in 1999/2000 reporting period to assist with the CARs evaluation.

C-11.4.3 Bacteriological / Pathogen Monitoring

The Permittees selected nine coastal stormdrains to monitor the effects of urban runoff on the coastal zone. The following selection criteria were used:

- The stormdrain has an equivalent circular diameter greater than 39-inches and/or a daily dry-weather discharge volume exceeding 100,000 gallons;
- Outlet of the stormdrain is posted with a warning sign by the Orange County Health Care Agency;
- The flow from the stormdrain reaches the surfzone at least seasonally; and
- The stormdrain and the surfzone are accessible by monitoring staff.

Monitoring was conducted on both the discharge from the stormdrain and the surfzone 25 yards up-coast and 25 yards down-coast of the stormdrain-ocean interface. Grab samples were collected weekly for the analysis of total coliform, fecal coliform, and *Enterococcus* bacteria. An estimate of the flow rate from the stormdrain was made and the temperatures of the stormdrain discharge and the surfzone down-coast were measured.

In addition to these nine coastal stormdrains, seven inland channels and/or creeks that are currently impaired for pathogens were also monitored.

The following criteria were established for monitoring:

- Samples were not collected on the day of rainfall;

- Samples were not collected from a stormdrain during the period when its discharge was diverted to a sanitation district; and

- During stormdrain diversion only a sample from the surfzone (down-coast of the stormdrain-ocean interface) was collected.

The following is a description of the methods used for grab-sample collection and flow estimation.

- Collecting the sample

    - The sample containers (120-ml plastic bottles) were provided by the County of Orange Health Care Agency's Public Health Laboratory. Each bottle contained a small amount of sodium thiosulfate as a preservative.

- At each site, bacteriological sample bottles were filled using aseptic technique to avoid contaminating the sample. Samples were collected directly into the sample container to avoid cross-contamination from a transfer device. A fresh pair of powder-free disposable gloves was used at each site.

- The bottles were labeled with a sample ID number prior to collecting the sample. The date, time, and sampler initials were recorded on a logsheet. Sampling staff also recorded any observations that may have an influence on the quality of the sample including the presence of animal or human activity in the area, animal feces, stormwater runoff, etc.

- Samples from the stormdrain were collected a closely as possible to the center of the flow line. For wider channels a telescoping pole was used to collect the sample from the center. To avoid contamination by sediment at the bottom of the storm drain, samples were allowed to flow into the bottles rather than scooping the sample into the bottles. Surfzone samples were collected in ankle deep water. Sample bottles were filled to the bottle shoulder to allow space for mixing. After filling the bottles were carefully capped and placed in an ice-chest for transport to the laboratory.

- The time from sample collection to delivery to the laboratory was kept below six hours.

- Temperature measurement was conducted with a calibrated thermometer

- The discharge from each stormdrain was classified as either flowing to the surfzone or not flowing to the surfzone

- Estimating the flow rate was conducted using one of the following methods:

  - Measuring the time required for a container of known volume to be filled by the discharge from the pipe or,

  - Measuring the cross-sectional area of water in the pipe or drain. If the diameter of the pipe is known the cross-sectional area in ft^2 is

$$Area = R^2 \arccos\frac{R-h}{R} - (R-h)\sqrt{2Rh-h^2}$$

    Where R is the radius of the pipe, h is the depth of water (all in feet). This cross-sectional area was multiplied by the measured or estimated velocity (ft/sec) to determine the flow rate in ft^3/sec. The velocity was determined using one of the following methods.

    - Using a Global Water Flow Probe, Marsh McBirney Flowmate, etc.

    - Using the static stick method where the velocity of the water is calculated by $v = \sqrt{2gh}$ where v is the velocity in feet per second, h is the velocity head,

and g is the acceleration due to gravity (32 ft/sec^2). Velocity head is the difference in the folding scale reading when measuring the depth with the wide edge perpendicular to the flow to that with the edge parallel to the flow. It is also known as the pile-up.

- Using the floating leaf method where the time required for a floating object to travel a known distance (e.g. 6 feet) is measured.

C-11.4.4 Bioassessment

The Permittees with assistance of Regional Board staff have selected nine channels and three reference sites to conduct urban stream bioassessments using California Stream Bioassessment Procedure (CSBP) established by the California Department of Fish and Game (DF&G). A contract laboratory conducts the bioassessment sampling and taxonomic analyses on behalf of the Permittees. A description of the CSBP can be found at http://www.dfg.ca.gov/cabw/Field/csbpwforms.html.

In order to conduct the triad analysis, at the time of bioassessment sampling the Permittees collected grab samples for chemical and toxicity analysis. The suite of chemical constituents is the same as analyzed in the Mass Emissions Program. The aqueous toxicity is evaluated using three freshwater organisms, *Ceriodaphnia dubia*, *Selanastrum capricornutum*, and *Hyallela azteca*. In the Newport Bay watershed toxicity testing organisms also include fathead minnow.

C-11.4.5 Dry Weather Reconnaissance

The Reconnaissance Program was developed to aid in source identification in areas of known water pollution problems. Stations were prioritized as part of the monitoring program design. Site-specific designs have been established and source identification conducted as each site is addressed. In prior years reconnaissance activities in the Santa Ana Region focused on the Construction Circle drain in Irvine and Collins Channel in Orange.

The monitoring program for the Third Term Permit includes a reconnaissance element that will focus on approximately 40 "targeted" stormdrains in the Santa Ana Region. These drains were identified by the Permittees as potential conduits for illegal discharges and illicit connections. Monitoring involved five separate visits to each site during the dry season (May 1 – September 30). Each site visit consisted of a visual reconnaissance, in-situ measurements of physical characteristics (flow rate, specific conductance, pH, temperature, turbidity and dissolved oxygen), and field analysis of nitrate, ammonia, reactive phosphorus, total chlorine, phenols, surfactants, dissolved copper and hexavalent chromium, and water hardness. Samples were collected and submitted for laboratory analysis of total suspended solids, dissolved metals, oil and grease, indicator bacteria and organophosphate pesticides.

Unusual observations or measurements in the field were reported immediately to the respective Permittee representative. The field and laboratory results were entered into a

statistical database, which determined if those results would require additional reconnaissance by the respective Permittee. The "average" condition was determined from analysis of results from randomly selected stormdrains throughout the County. There are two triggers for upstream watershed reconnaissance. The first is exceedance of the tolerance interval bound based on the average condition established by the random sites. The second is exceedance of the site-specific control chart bound, which has been tentatively established as 3.9 standard deviations above the average (mean) value for any monitored parameter. If two consecutive measurements exceed either trigger level, reconnaissance will be initiated by the Permittee.

C-11.4.6 Land Use Correlations

Seven sites have been established to monitor the effects of changes in land use on the quality of receiving waters, in particular, the impacts of increasing development and the conversion of agricultural land on the pollutant loading to the Upper Newport Bay. This Program element is based on an experimental design that uses a series of comparisons to help isolate the impacts of specific kinds of land use changes.

The monitoring design includes three experimental conditions and one reference site, all in the City of Irvine:

- Grassland to residential conversion (SJQF14d)
- Grassland to residential conversion (SJQF14u)
- Agriculture to residential conversion (HINF25d)
- Agriculture to residential conversion (HINF25u)
- Military Installation (Marine Corps Air Station – Tustin) to residential conversion (TABF09)
- Military Installation (Marine Corps Air Station – Tustin) to residential conversion (SASF10)
- Reference (BORF20).

Monitoring was conducted monthly for the same suite of water quality parameters as is monitored in the mass emissions element of the Program. In addition, two storms per year were sampled.

C-11.4.7 TMDL / 303(d) Listed Waterbody Monitoring (Nutrient TMDL)

Dry Weather Monitoring

At each site, discrete water samples are collected at one hour intervals for 24 hours using automatic samplers (ISCO 3700 or 6700 models) with tygon or Teflon-lined strainer tubing. The discrete samples are mixed together to form a composite sample and three aliquots are submitted to the contract laboratory for analysis. An aliquot which is acidified with sulphuric acid (H_2SO_4) as a preservative is analyzed for nitrate/nitrite as nitrate, total ammonia as nitrogen, total Kjeldahl nitrogen, and total phosphate as phosphate. A filtered, un-acidified aliquot is analyzed for ortho-phosphate. An un-filtered, un-acidified aliquot is analyzed for pH, electrical conductivity, turbidity, total

suspended solids, and volatile suspended solids. Field measurements of dissolved oxygen, temperature, pH, and conductivity are recorded using a multi-parameter probe each time the automatic samplers are serviced (i.e. when the samples are collected for processing by County staff).

Storm Event Monitoring

Composite surface water samples are collected at two (2) hour intervals for a 96-hour period using automatic samplers with tygon or Teflon-lined strainer tubing. A level actuator is attached to the sampler that triggers the first sample collection when the water level rises to point representative of stormwater flow. Depending on the magnitude of the storm three to five composite samples are prepared from the 96-hr sampling period. As described above three aliquots of each composite sample are submitted to the contract laboratory for analysis.

Flow Data

The flow data used to calculate nutrient loadings are collected year round from nine stations in the Newport Bay watershed. Of these nine stations, seven stations are operated by the County of Orange and two are operated by the United States Geological Survey (USGS). The stations are:

- San Diego Creek at Campus Drive (OC)
- Santa Ana-Delhi at Irvine Avenue (OC)
- Peters Canyon Wash at Barranca Parkway (OC)
- San Diego Creek at Culver Drive (OC)
- El Modena-Irvine at Michelle Drive (OC)
- Lane Channel at McCabe Way (OC)*
- Costa Mesa Channel at Westcliff Drive(OC)*
- Bonita Canyon Creek at MacArthur Boulevard (USGS)
- Agua Chinon Channel at Irvine Boulevard (USGS).

**station not equipped with real-time reporting capabilities*
OC – County of Orange

Five of the seven of the County of Orange stations are equipped with a continuous water-stage recorder and ALERT transmitter/data logger which provide the ability for the County to monitor rainfall and channel water level in real-time. The USGS stations are equipped with continuous water-stage recorders and a satellite telemetry system that can be viewed (with minimal time delay) on the USGS internet home page.

Discharge records for the BARSED, MIRF07, SADF01, SDMF05, and WYLSED stations are computed from water-stage recorder charts, WaterLog digital data, ALERT data using the XStream Measures Data Reduction System, and the Hydstra Time-Series Data Management System. Through these systems, automatic computations of surface water records are performed by electronically converting gage heights to discharges from channel ratings. Regular streamgaging measurements and field visits conducted at each station help to ensure the accuracy of the surface water records. The County of Orange is

currently developing rating curves for Lane Channel (LANF08) and Costa Mesa Channel (CMCG02). Presently, the County of Orange operates ultrasonic water level sensors at these two monitoring stations. For this report, dry weather flow rates from Lane Channel were based on monthly instantaneous discharge measurements since November of 2003. Any flow data from these two stations are considered preliminary and provide estimations only. The County of Orange records water discharge data on a July 1 through June 30 water year. Final water discharge data are published by Environmental Resources in the Annual Hydrological Data Report.

Discharge records for USGS stations are computed by the USGS. Data from these stations are collected by automatic recorders or by field personnel and relayed through satellites to USGS offices where they are stored and processed. The USGS records water discharge data on an October 1 through September 30 water year. The USGS finalizes and publishes the daily data on an annual basis in a series of water-data reports.

Until the County of Orange and the USGS publish final flow data, all flow data are considered provisional and should be used to provide estimations only.

C-11.5 Methods of Data Analysis

C-11.5.1 Comparison to Water Quality Guidance

Acute (CMC-Criteria Maximum Concentration) and chronic (CCC-Criteria Continuous Concentration) aquatic toxicity criteria from the CTR were used as guidance to evaluate dissolved metals data collected from storm channels and harbors. Water quality criteria from the CTR and other sources are presented in **Table C- 11.1** and for sediment from other sources in **Table C- 11.2**.

California Water Code Section 13170 authorizes the State Water Resources Control Board (SWRCB) to adopt water quality control plans for waters where standards are required by the Federal Clean Water Act (CWA) and its 1987 amendments, the Water Quality Act (WQA). According to Section 303(c)(2)(B) of the CWA, these plans must contain water quality objectives for priority pollutants that could be reasonably expected to affect the beneficial uses of the waters of the State.

On March 2, 2000, the State adopted the United States Environmental Protection Agency's (USEPA) Rules establishing numeric water quality criteria for priority toxic pollutants (commonly referred to as the CTR) for the State of California. The CTR sets criteria for dissolved heavy metals in freshwater that are based on water hardness and separate criteria for saltwater. The dissolved metals data were compared to the acute (instantaneous maximum concentration) and chronic (4-day average concentration) criteria for guidance purposes.

According to the CTR, for waters with a hardness of 400 mg/l or less as calcium carbonate, the actual ambient hardness of the surface water shall be used in those equations. For waters with a hardness of over 400 mg/l as calcium carbonate, a hardness of 400 mg/l as calcium carbonate shall be used with a default Water-Effect Ratio (WER)

of 1, or the actual hardness of the ambient surface water shall be used with a WER. For this reporting period the former method was used.

In applying the CTR criteria to freshwater, if the time period to which the guidance applies is less than the length of the sampled period, a measured concentration greater than that guidance value will constitute an exceedance. For example, if the acute guidance for lead (at a hardness of 100 mg/L as $CaCO_3$) is 65 µg/L, a concentration of 68 µg/L during a 24-hour period will be considered an exceedance of the guidance criterion.

In computing the mean concentration during a sampled period with multiple composite samples, values below the detection limit were assumed to be zero. This assumption allows for a more consistent evaluation from year to year as detection limits are lowered with alternative methods of analysis or new technology. The assumption also gives greater confidence to a designation of an exceedance of a guidance criterion as it reduces the likelihood that the exceedance was caused by an erroneous estimation of a non-detected value. During the latter part of the 2004-05 monitoring year, a new analytical services contract was established which required the laboratories to report lower detection limits for metals in freshwater and saltwater.

With respect to the saltwater guidance from the CTR, the average concentrations of dissolved metals in depth-integrated samplings from each 4-day storm monitoring of the Harbors and Bays were compared to the 4-day guidance criteria. The dissolved metals concentrations in each grab sample were compared to the acute toxicity guidance criteria. There is no chronic guidance criterion for silver so only the acute criterion was used. Since total chromium was analyzed only the criteria for trivalent chromium (Chromium III) were used.

C-11.5.2 Toxicity testing

Toxicity tests span varying time periods depending on the type of organism function (survival, growth, reproduction, etc.) being evaluated. Endpoint data are used to compute statistics that can be compared against regulatory criteria. These statistics include Acute Toxicity Units (TUa) and Chronic Toxicity Units (TUc).

The concentration that causes 50% mortality of the organisms (the median lethal concentration, or LC_{50}) is calculated from the data for 96 hours (96-hour acute LC_{50}) and for day seven (seven-day chronic LC_{50}) using USEPA methods. The LC_{50} values are point-estimates expressed as "percent sample;" the lower the LC_{50} percentage the more toxic the sample. For acute regulatory standards, the LC_{50} acute value is used. For chronic regulatory standards, the seven-day chronic effects are estimated using the NOEC, or No Observed Effect Concentration, for both survival and reproduction. This is the highest concentration tested in which there was no statistically significant effect on the survival or reproduction compared to the control response. The lower the NOEC, the more toxic the sample.

For purposes of assessment between sites or between samplings, the endpoints described above are transformed into toxic units (TU). Toxic units are further divided into toxic units acute (TUa) and toxic units chronic (TUc) for acute and chronic endpoints, respectively. As toxicity increases, the toxic units increase.

TUa and TUc values are calculated very differently and are not interchangeable or related. The TUa equals 100/96-hr acute LC_{50}. If the LC_{50} is greater than 100%, then the TUa is calculated by the following formula:

TUa = log(100-S)/1.7 where S = percentage of survival in 100% sample. If S > 99%, the TUa is reported as zero, which is the lowest TUa value possible. The percent survival in the 100% concentration used in this formula is expressed as a percentage of the control survival. The TUc equals 100/NOEC. The lowest TUc possible, which indicates no toxicity, is 1. TUc values were calculated separately for survival and reproduction endpoints.

For some tests, if the test data meet acceptability criteria, inhibition concentrations, an IC_{25} and an IC_{50}, are calculated. These are the concentrations that cause a 25 percent or 50 percent inhibition of an organism's function such as growth, or cell density, in the *Selanastrum* test.

A reference toxicant test is also run to establish whether the test organisms used fall within the normal range of sensitivity. The reference toxicant test is conducted with known concentrations of a given toxicant (e.g., copper sulfate is used for *Ceriodaphnia*). The effect on the survival and reproduction of the animals is compared to historical laboratory data for the test species and reference toxicant. If the values are within two standard deviations of the historical average, the test organisms are considered to fall within the normal range of sensitivity.

Standard operating procedures for each of the specific tests conducted for both marine and freshwater organisms are detailed in **Attachment C-11-I**.

For toxicity tests conducted as part of the mass loads and ambient coastal program elements, available LC_{50} and EC_{50} data on key contaminants were used to compare the observed toxicity (measured as toxic units) to the expected toxicity. This analysis focused on the mass loads and ambient coastal program elements because toxicity was rarely observed in the bioassessment monitoring. The toxicity testing organisms used in this Program tend to be more sensitive to some categories of toxicants than others. For example, the Mysidopsis survival/growth (MSG) test tends to be very sensitive to OP pesticides and ammonia but less sensitive to metals. The Sea Urchin Fertilization (SUF) test is sensitive to dissolved metals and ammonia but not very sensitive to OP pesticides. The calculation of the predicted toxicity for each test reflects these sensitivities in that only the impact due to metals and ammonia is evaluated in the SUF test and only the impact due to OP pesticides and ammonia is evaluated in the MSG test.

LC_{50} data for the Mysidopsis bahia 96-hour survival test for ammonia, Chlorpyrifos, Diazinon, Dimethoate and Malathion were obtained from the PAN Exotoxicity database

http://www.pesticideinfo.org/Search_Ecotoxicity.jsp which contains the results of over 220,000 toxicity tests. Results can be sorted by species, chemical or effect. Additional data were obtained from SCCWRP research studies. EC_{50} data for the sea urchin 40 minute fertilization test for ammonia, copper, and zinc were obtained from the same sources. The observed concentration of each chemical constituent (from the aquatic chemistry samples collected at the same time) was divided by the appropriate LC_{50} or EC_{50} value to produce an estimated TU_a from each constituent. These estimated TU_as were then summed and compared to the observed TU_a from the toxicity test, as in the following equations:

$$\frac{\text{Concentration of toxicant}}{\text{Average literature value of } LC_{50} \text{ or } IC_{50} \text{ of toxicant}}$$

The total predicted toxicity from n toxicants is $\sum_{i}^{n} \frac{[toxicant_i]}{[LC_{50} or IC_{50}]_i}$

The calculated TUa from the toxicity test can be compared to this predicted toxicity.

This approach to comparing observed and predicted toxicity has potential shortcomings, including:

- The lack of availability of relevant LC_{50} and EC_{50} data for the full range of chemical constituents of concern
- The implicit assumption of simple additivity of toxic effects. While probably not true, there is no clear guidance on how to accurately represent synergistic effects, which could very well vary from site to site and over time
- The fact that the predicted toxicity in several instances is larger than the observed toxicity, which serves to weaken confidence in the reliability of the LC_{50} and EC_{50} data.

Despite these shortcomings, this approach is useful for:

- Assessing the overall accuracy or reliability of the toxicity results
- Identifying specific chemicals that appear to contribute most to toxicity and that are therefore targets for further study and/or source identification and reduction efforts
- Identifying monitoring locations that may have consistently high levels of unexplained toxicity. In these cases, more sophisticated studies may be called for.

C-11.5.3 Mass Load Calculations

Mass loads were calculated using chemical and hydrographic data. Water level records from permanent streamgaging stations at or near the sampling site were processed using Hydstra and XstreamMeasures software. Water levels from the station's continuous strip chart recorder were digitized and converted to discharge rates using stage-discharge relationships (channel ratings). At sites which had ISCO water level recorders, the data loggers were downloaded periodically and the information was stored in Hydstra.

Using the respective rating tables for each site, the water level data were converted to flow rates. The total discharge in acre-feet during each sampled period was computed. By multiplying the total water discharge per sampled period by the pollutant concentration of the composite sample from the period and applying the proper conversion factors (acre-feet to lbs. of water), a mass load in pounds or tons of contaminant was calculated. For data reported as ND (non-detected), one-half of reported laboratory detection limits were used in the calculations.

Event mean pollutant concentrations were calculated to produce a site mean EMC that could be used in the estimation of the mass loads from unsampled storms. To calculate the EMC of a monitored storm the sum of the mass load from each composite sampling during a storm was divided by the total sampled volume of water during the same period. After applying the appropriate conversion factors, an event mean concentration in mg/L or μg/L was calculated. The annual EMC was calculated as the flow weighted average of all storms monitored during the year at that site.

Mean EMCs were used to estimate mass loads from un-sampled storms during the monitoring year in two distinct ways. The first estimates total annual loads on a site-by-site basis and the second on a watershed basis. In the first approach, an average site EMC for each stormwater contaminant was calculated by simply calculating the flow weighted average of the measured EMCs throughout the year. These site mean EMCs were then used to estimate mass loads from un-sampled storms. To estimate these mass loads, the site mean EMC for a stormwater contaminant from a particular station was multiplied by the total annual volume of water discharged during un-sampled storms, and the appropriate unit conversion factors [2.718 liter • lbs/mg • ac-ft. In the second approach, the watershed load was calculated by simply summing the total estimated annual loads from each monitoring site in the watershed. Only EMCs in which the 75-120% of the total storm runoff volume was sampled were used in these calculations.

C-11.5.4 Evaluation of Bacteriological / Pathogen Data

Coastal stormdrain data consist of temperature measurements and concentrations of bacterial indicators in the discharge and upstream and downstream of larger flowing stormdrains. Data analysis consisted of:

1. Comparing indicator levels at each drain to the state's AB411 standards
2. Ranking drains in terms of the proportion of total possible exceedances of the AB411 standards
3. Plotting indicator levels in the receiving water vs. those in the drain
4. Ranking drains in terms of the slope of the linear regression of receiving water indicator levels vs. those in the drain.

These analyses were performed for the entire year and for the AB411 season alone. The following paragraphs describe methods for analyses #'s 2 – 4.

For analysis #2, the actual number of receiving water samples collected at each drain throughout the year was summed. This did not always equal 312 (i.e., 52 weeks x 3

indicators x 2 locations) because it was not possible to collect the full suite of samples at each site throughout the entire year. The total number of AB411 exceedances was then divided by the total number of samples, resulting in a proportion for each drain between 0 and 1.0. The exceedance proportion for each site was then indicated on a map of the sampling sites, according to the following color scheme:

- Green: 0 - < 0.14
- Blue: 0.14 - < 0.40
- Yellow: 0.40 - < 0.75
- Red: 0.75 – 1.0

For analysis #3, the receiving water values for each indicator were plotted vs. the indicator values in the drain during the same sampling event, with receiving water values on the y-axis and drain values on the x-axis. Separate plots are presented for each indicator at each drain, with upstream and downstream data displayed with distinct symbols. The plots are divided into sectors suggesting the conclusions and possible management actions that would be appropriate when a preponderance of the data points fall into one sector or another.

For analysis #4, data were log transformed and then a standard least squares linear regression calculated for relationship between receiving water indicator values and drain values. A separate regression was calculated for each indicator / drain combination. Sites were then ranked in terms of the "p" value for the regression for each indicator. The "p" value reflects the strength of the drain – receiving water relationship. In combination with the other analyses, this can be used to help assess each drain's likely effect on receiving water conditions.

Analysis results were then evaluated to identify consistent spatial and temporal patterns. Drains with exceedance and/or regression ranks were evaluated more carefully to identify potential explanatory factors in their drainage areas.

Data analysis for the inland channels proceeded somewhat differently because sampling consisted simply of grab samples in the channel, rather than samples from a drain discharge and from surfzone stations up- and downcoast. Indicator levels for each sample were compared to AB411 standards and the proportion of exceedances calculated, for both the entire year and the AB411 season. The sites were then ranked in terms of their exceedance proportions. Exceedance proportions were mapped as described above.

C-11.5.5 Bioassessment and Index of Biotic Integrity (IBI)

A complete description of methods for calculating the Index of Biotic Integrity for each site is contained in the annual report of the bioassessment monitoring, posted on the Program's website at http://www.ocwatersheds.com/StormWater/swp_documents_intro.asp. In brief, each site is evaluated in terms of a series of metrics (**Table C-11.3**), which are then scored (**Table C-11.4**) to provide a basis for determining the IBI scores themselves for each site.

These scoring ranges are based on data from the southern California region, from southern Monterey County to the Mexican border. This southern California IBI is more representative of reference conditions throughout the whole of the southern California area than was the original IBI, which was based only on data from streams in the San Diego region. The use of the more broadly applicable IBI follows the California Department of Fish and Game protocol. In addition, the Stormwater Monitoring Coalition is planning a number of efforts to improve the IBI's ability to monitor conditions in the urbanized coastal zone. These include developing an IBI for low-gradient urban streams, a perennial stream succession survey, and developing a regional bioassessment monitoring program for southern California.

C-11.5.6 Evaluation of triad data

Evaluation of triad data (i.e., bioassessment, water chemistry, toxicity) was based on the framework developed by the Stormwater Monitoring Coalition's Model Stormwater Monitoring committee. This approach, which is described in detail in the SMC's report to the State Water Resources Control Board (ftp://ftp.sccwrp.org/pub/download/PDFs/419_smc_mm.pdf), is based on a weight of evidence approach that compares each of the three legs of the triad against each other. **Table C-11.5**, drawn from the SMC's report, summarizes the types of conclusions that can be drawn from various combinations of triad results. Thus, there is no routine or standard method for evaluating triad data. However, the triad data from the bioassessment stations for the most part led to relatively clear interpretations of causal factors for observed conditions.

Three additional analyses are included in this year's report to more thoroughly examine the relationships among the three legs of the triad. (In actuality, there are four legs if the physical habitat data collected as part of the bioassessment protocol are considered separately from the biological community data.)

For the first analysis, thresholds were established for each of the four data types (IBI, physical habitat, aquatic chemistry, and toxicity) in order to divide the range of values for each data type into four categories representing conditions from excellent to poor. IBI and physical habitat categories were based on the Fish and Game interpretation framework for these data types. Aquatic chemistry thresholds focused on dissolved metals. At each station, the total number of CTR exceedances at each sampling time was divided by the total number of constituents with relevant CTR criteria, resulting in a proportion for each station between 0 and 1.0. The exceedance proportion for each station was then indicated on a map of the sampling sites, according to the following color scheme:

- Green: 0 - < 0.14
- Blue: 0.14 - < 0.40
- Yellow: 0.40 - < 0.75
- Red: 0.75 – 1.0

Toxicity categories were based on the number of toxicity tests that showed toxicity above 25% mortality in the undiluted sample (100% concentration) or, for *Selenastrum*, if the cell count in the 100% concentration sample was 2.5 times greater than the control. For each site, icons on a map of the monitoring sites representing the four data types were then colored green, blue, yellow, or red to summarize the overall range of conditions at each site.

For the second analysis, all data from the first three years of bioassessment sampling were analyzed for spatial and temporal patters in the benthic invertebrate community. These patterns were then compared to potential explanatory variables (physical habitat, aquatic chemistry, toxicity) to identify potentially causative relationships among the different data types. Two methods were used to describe spatial and temporal patterns in the benthic invertebrate community: cluster analysis and two-way coincidence tables.

Cluster analysis defines groups of stations with similar community composition. The results are displayed in a hierarchical tree-like structure called a dendrogram. On the dendrogram, two groups are first defined, and within these groups subgroups are defined. Subsequently, subgroups within the subgroups are defined. This process is continued until all stations are a separate subgroup. The hierarchical nature of the dendrogram allows the analyst to choose groups of stations that represent a scale of community differences relevant to the present project. Cluster analysis is also used to define groups of species that tend to have similar distributional patterns among the stations.

A two-way coincidence table is the station-species abundance data matrix displayed as a table of symbols indicating the relative abundances of the species at the stations. The rows and columns of the table are arranged to correspond to the order of stations and species along the respective station and species dendrograms. Since similar entities (stations or species) will tend to be closer together along a dendrogram, the row and column orders will efficiently show the pattern of species over the stations and station groups.

Since the rows and columns of the two-way coincidence table are ordered according to the dendrograms, the two-way coincidence table is also used to help delimit the station and species groups defined by the cluster analyses. At each potential separation of subgroups defined by the dendrogram, the two way coincidence table is examined to see the corresponding group differences in terms of species presences and abundances. This allows the analyst to choose groups with a level of community differences consistent with the goals of the project.

The methods discussed above are described only in very general terms. The specific steps included:

- Preliminary biotic data transformation, using a square root transformation and standardization by species mean of values >0 (Smith, 1976; Smith et al., 1988) [1]
- Calculation of a Dissimilarity Index for cluster analysis of stations, using the Bray-Curtis Index, step-across procedure for dissimilarity >.8 (Bradfield and Kenkel, 1987; Clifford and Stephenson, 1975; Smith, 1984; Williamson, 1978)[2]
- Calculation of similarities for cluster analysis of species, using flexible clustering (β=-.25) (Clifford and Stephenson, 1975; Lance and Williams, 1967; Smith, 1982)[3]
- Creation of the two-way coincidence table (Kiddawa, 1968; Smith, 1976)[4].

The distribution of the external parameters measured at each station/survey is described with box and whisker Plots (Tukey, 1977)[5], as illustrated in the example below:

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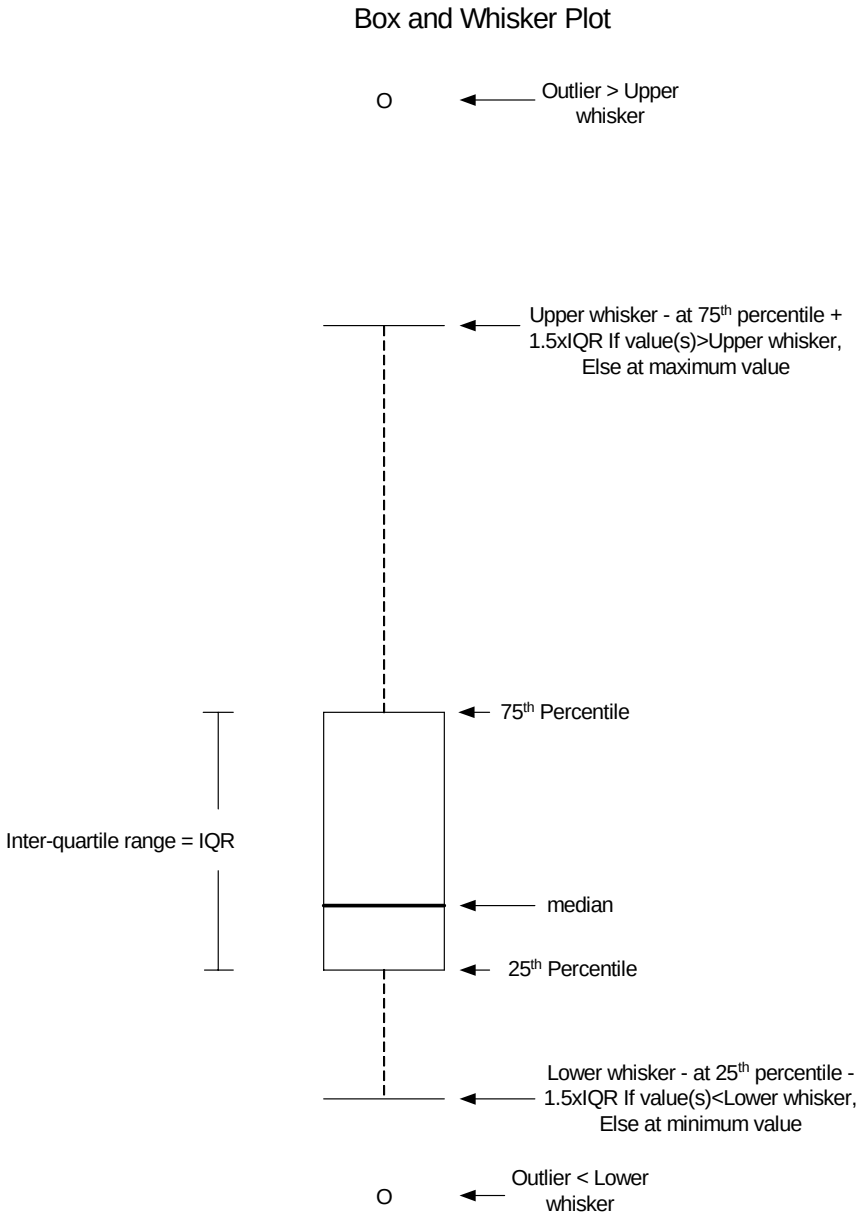
[1] Smith, R.W. 1976. Numerical Analysis of Ecological Survey Data. PhD thesis, Univ. of S. Calif., Los Angeles. 401 pp.
Smith, R.W., B.B. Bernstein, and R.L. Cimberg. 1988. Community-Environmental Relationships in the Benthos: Applications of Multivariate Analytical Techniques. Chapter 11 In: Marine Organisms as Indicators. Springer-Verlag. New York: 247-326.

[2] Bradfield, G.E. and N.C. Kenkel. 1987. Nonlinear ordination using shortest path adjustment of ecological distances. Ecology 68(3): 750-753.
Clifford, H.T. and W. Stephenson. 1975. An Introduction to Numerical Classification. Academic Press, New York: 229 pp.
Smith, R.W. 1984. The re-estimation of ecological distance values using the step-across procedure. EAP Technical Report No. 2. Email: rs@robertsmith.net.
Williamson, M.H. 1978. The ordination of incidence data. J. Ecol. 66: 911-920.

[3] Clifford, H.T. and W. Stephenson. 1975. An Introduction to Numerical Classification. Academic Press, New York: 229 pp.
Lance, G.N., and W.T. Williams. 1967. A general theory of classificatory sorting strategies. I. Hierarchical systems. Computer J. 9: 373-380.
Smith, R.W. 1982. Analysis of ecological survey data with SAS and EAP. Proc. 7th Annual SAS Users' Group International (SUGI). SAS Institute Inc. P.O. Box 8000, Cary NC 27511: 610-615.

[4] Kikkawa J. 1968. Ecological association of bird species and habitats in Eastern Australia; similarity analysis. J. Anim. Ecol. 37: 143-165.
Smith, R.W. 1976. Numerical Analysis of Ecological Survey Data. PhD thesis, Univ. of S. Calif., Los Angeles. 401 pp.

[5] Tukey, J.W. 1977. Exploratory Data Analysis. Addison-Wesley, Menlo Park, CA. 506 pp.



C-11.5.6 Prioritization of Reconnaissance Sites for Source Identification

Values of monitored constituents at dry weather reconnaissance sites were compared to tolerance intervals calculated from the set of random urban background sites as well s to the control charts generated from the past monitoring data at each individual site. Instances in which data values for specific contaminants exceeded either one of these criteria for two consecutive monitoring events were flagged for further source identification efforts to identify upstream sources of pollution.

C-11.5.6 Identification of Parameter Trends Associated With Land Use Change

Evaluation of monitoring data from the land use transition sites was based on an examination of trends described by linear regression analysis. The data for each parameter at each site was $\log_{10}$ transformed and then analyzed with least squares linear regression. The trend lines for the upstream and downstream sites at each location were plotted on the same graph, along with data from the single control site.

Parameters for which the trend lines for the upstream and downstream sites diverged substantially were flagged for further consideration. A substantial divergence in the slope of the regression line between the upstream and downstream sites would indicate the possibility that the development (located between the upstream and downstream sites) was affecting water quality. Site-specific information on channel and watershed characteristics, as well as on the nature of the development, were used to evaluate the strength of the conclusion that development had affected water quality.

C-11.6 Analysis of Data

The following sections present data summaries and interpretations for each of the major monitoring program components.

C-11.6.1 Mass Emissions Monitoring

Mass loading monitoring is conducted for a wide range of constituents at the stations shown in **Figure C-11.1**. The intent is to monitor each station during periods of stormwater runoff as well as during dry weather. Water chemistry data from mass emissions stations were used to calculate loads and to assess water quality with respect to applicable acute and chronic toxicity criteria from the CTR.

Table C-11.6 contains the measured stormwater mass loads of nutrients and dissolved metals and **Table C-11.7** the corresponding flow-weighted event mean concentrations (EMC) of these constituents. The concentrations of dissolved metals in each composite sample collected in the Mass Emissions program element were compared to both the chronic and acute toxicity criteria from the CTR. Both freshwater and saltwater criteria were used, depending on whether the monitoring station discharged directly to the ocean or an estuarine environment, and on whether there was another station further downstream. **Attachment C-11.II** presents all of these data highlighting those which exceeded the criteria and **Table C-11.8** summarizes the comparisons to the CTR criteria. Exceedances of the saltwater criteria were relatively frequent, with 49 of 132 samples exceeding the CTR, mostly due to copper, and the majority of the stations exhibiting exceedances. The proportion of exceedances is lower this year than last.

The toxicity results (**Table C-11.9**) show substantial toxicity for the sea urchin fertilization (0% fertilization in the undiluted sample) and for the mysid survival and growth tests (0% survival and 0% growth in the undiluted sample) in the first flush of the storm collected at Costa Mesa Channel (CMCG02) on October 16, 2005. The water chemistry results from this sample (**Attachment C-11.II**) showed high levels of dissolved

zinc (270 µg/L), dissolved copper (61 µg/L) and Malathion (199 ng/L). The dissolved zinc and copper levels most likely caused the effects in the sea urchin test. The Malathion level, although significant, was not high enough to account for the effects in the mysid test. The mortality to the mysids must have been caused by an unmeasured toxicant, possibly a pyrethroid or carbamate pesticide.

The sea urchin fertilization test showed significant inhibition in the undiluted samples from several other channels during that same storm. These channels included Central Irvine (CICF25), Peters Canyon (BARSED), San Diego Creek at Harvard (WYLSED), San Diego Creek at Campus (SDMF05), Bolsa Chica (BCC02), East Garden Grove Wintersburg (EGWC05), and Carbon Creek (CARB01). All of these sites except WYLSED and SDMF05 showed significant levels (>20 µg/L) of dissolved zinc.

There was substantial toxicity observed in the sea urchin fertilization test from stormwater samples collected on January 14, 2006 at Fullerton Creek (FULA03), Bolsa Chica Channel, Coyote Creek (CCBA01), and Carbon Creek. The aquatic chemistry data for these samples showed significant amounts of dissolved zinc.

The undiluted sample from CARB01 on March 28, 2006 showed only 5% survival in the the mysid survival test. The sample from FULA03 on the same date showed 65% survival for the mysid test. The water chemistry from each of these sites did not show any results that would be indicative of the toxicity results. The toxicity most likely was caused by unmeasured toxicants.

C-11.6.2 Estuary / Wetlands Monitoring

The estuary / wetlands monitoring included three distinct portions that will be reported on separately. The first was a benthic sediment triad monitoring effort that took place in the fall of 2005. This analysis will look for related patterns among the three data types (sediment chemistry, sediment toxicity, benthic infauna) sampled at the same time. The second was a set of additional paired sediment chemistry and sediment toxicity samples collected at several addition times during the year. These two types of data will be compared to search for potential relationships between sediment toxicity and specific chemical constituents in the sediment. The third monitoring element consists of paired aquatic chemistry and aquatic toxicity samples taken at several points during the year. As for sediment chemistry and toxicity, these two types of data will be evaluated for potential causal patterns that could help explain instances of elevated toxicity.

Benthic triad analysis, August 2005

Sediment monitoring at the estuary and wetlands stations (**Figures C-11.3a-b**) was based on the Triad approach, and included benthic infaunal, toxicity, and sediment chemistry analyses. **Attachment C-11.III** shows the sediment chemistry results and **Table C-11.10** the sediment toxicity testing results and **Table C-11.11** the benthic infauna community analysis. **Table C-11.12** describes the BRI scoring ranges in terms of amount of deviation from reference condition.

Attachment C-11.III shows that, in August 2005, exceedances of the NOAA Effects Range Median (ERM) concentration occurred at only one station, LNBRIN, for copper and mercury. In contrast, anthropogenic enrichment occurred for copper and cadmium at nearly all Upper Newport Bay stations, for copper, cadmium, and zinc at all Lower Newport Bay stations, and for copper, cadmium, and lead at virtually all Huntington Harbour stations.

During the August survey, sediment toxicity was consistently highest in Upper Newport Bay, with all these stations showing amphipod survival percentages of 20% or less. Both Huntington Harbour stations also exhibited high levels of toxicity, with survival of around 50% at two of the three stations. A comparison of these results with the chemistry data in **Attachment C-11.III** does not reveal any noticeable relationship between the level of toxicity and the level either of individual constituents or of contaminants overall. The State Water Quality Control Board's current effort to develop sediment quality objectives (SQO) for bays and estuaries has shown, using a large dataset from across the state, that the relationship between sediment chemistry and toxicity is very noisy at best. This is due to the fact that the bioavailability of contaminants in the sediment is highly variable and is affected by a number of poorly understood factors, making it extremely difficult to draw firm conclusions about the relationship between sediment chemistry and toxicity on a site-specific basis. The pending SQOs will provide a rigorous assessment framework for combining sediment chemistry, sediment toxicity, and benthic infauna data for site and water body assessment.

Figure C-11.4 and **Table C-11.13** provide a larger regional context for assessing toxicity results from the estuary / wetlands stations. They show that toxicity in Newport Bay and Huntington Harbour / Talbert Marsh is, on the average, in the very upper range of toxicity in the Southern California Bight, a finding that has been consistent across the past two Bight surveys (1998 and 2003). The broader pattern of sediment toxicity, along with its potential sources, are discussed in the following section which addresses the entire set of sediment chemistry and toxicity results for the monitoring year.

The benthic infaunal analysis (**Table C-11.11**, **Figure C-11.5a-b** shows that five of the 13 stations fall within the reference or Response Level 1 conditions, while three fall in Response Level 3, with more than 50% of reference species lost. The other five stations fell between these two extremes. **Figure C-11.6** shows that there was no consistent relationship between BRI scores and sediment toxicity. The upper plot in **Figure C-11.6** shows that the regression line for all the August 2005 data from both locations is not statistically significant. Regression lines calculated for each location separately (lower plot) are also non-significant. This suggests that effects on the benthic infaunal community may not be driven by sediment toxicity, but by other factors such as physical disturbance. It also suggests that simple sediment chemistry values do not reliably predict potential toxicity, except perhaps at the extremes. These relationships are currently under investigation as part of the State Water Resources Control Board's Sediment Quality Objectives project. The findings and guidance from that effort will be applied by the Program as they become available.

Sediment chemistry and toxicity analysis

Attachment C-11.III shows that only a few samples exceeded the NOAA Effects Range Median (ERM) concentration, with all those exceedances occurring at the Lower Newport Bay station LNBRIN, in the Rhine Channel, which exceeded the ERM for copper and mercury on every monitoring date. Because of its historical contamination, the Rhine Channel has been a focus of assessment and cleanup efforts. In contrast, anthropogenic enrichment occurred for copper and cadmium at nearly all Upper Newport Bay stations, for copper, cadmium, and zinc at all Lower Newport Bay stations, and for copper, cadmium, and lead at virtually all Huntington Harbour stations. Sediment concentrations at these stations, however, did not exceed the ERM for these constituents. Sediment concentrations displayed no apparent seasonal patterns. Sediment characteristics changed markedly across sampling events at times, with several stations showing large increases or decreases in the percent clay and percent silt/clay. These changes were not correlated with changes in chemistry concentrations or in toxicity.

Sediment toxicity varies somewhat over time (**Table C-11.10**), with occasional large changes in toxicity at the same station. For example, toxicity increased dramatically at HUNBCC between August 2005 and June 2006, but decreased over the same time period at HUNWAR, both in Huntington Harbour. Similarly, sediment toxicity decreased substantially at UNBNSB between August 2005 and June 2006, yet increased at UNBCHB, both in Upper Newport Bay, over the same time period. The Bight Program also documented some increases and decreases in sediment toxicity over the five year period between the 1998 and 2003 studies. However, despite such occasional changes, the broad spatial pattern of sediment toxicity remained fairly stable, as shown in **Figure C-11.7a-b**.

The patterns of sediment toxicity were compared to those for sediment chemistry over the course of the year to assess whether potential sources of elevated toxicity could be identified. Stations UNBJAM and UNBCHB exhibited the highest levels of toxicity, but sediment chemistry values on these dates were not elevated compared to other stations at times. At the other extreme, Station LNBRIN consistently had the highest survival, but also exhibited the highest levels of copper, zinc, and mercury in the sediments.

As noted above, this overall lack of consistency between sediment chemistry and toxicity is not surprising. The Bight Program, in both its 1998 and 2003 surveys, demonstrated that Newport Bay has the highest sediment toxicity of any embayment along the southern California coast. The Bight Program concluded that this toxicity was not due to usual sources such as metals, DDT/DDE, or PCBs, but to some unknown toxicant. There is general agreement among stormwater scientists that older pesticides, such as Diazinon and Chlorpyrifos, are being replaced by a newer class of pyrethroid pesticides. Studies to establish LC_{50}'s for these pesticides are only now being conducted and the Program has only very recently begun to monitor them; thus, it is not possible to directly evaluate their potential role in sediment toxicity. However, the four samples from UNBJAM submitted for sediment toxicity analyses showed extreme toxicity in the 10-day amphipod survival test with *Eohaustorius*. These results are consistent with the Bight

'03 results from the same area. Two samples from this station submitted for Pyrethroid pesticide analyses showed significant amounts of Bifenthrin. Future monitoring efforts should increase their focus on this new class of pesticides.

Aquatic chemistry and toxicity analysis

The estuary / wetlands program component also included both aquatic toxicity testing (with marine test organisms) and aquatic chemical sampling. **Attachment C-11.IV** presents the overall chemistry results, with exceedances of the acute saltwater CTR highlighted, and **Table C-11.14** a summary of the numbers of acute CTR exceedances at each sampling station. **Table C-11.10** presents the aqueous toxicity testing results using marine test organisms.

Table C-11.14 shows that there were only two CTR exceedances, both for copper. In addition, organophosphate pesticides, with the exception of Malathion, were consistently below detection limit. These detected levels of Malathion however, were more than an order of magnitude lower than literature values of 96-hr LC_{50}s for the mysid survival test. Detected amounts of Malathion were sometimes, but not always associated with elevated toxicity. There were many instances of elevated toxicity (**Table C-11.10**) that were not associated with elevated levels of any measured constituent. There is no overall consistency between measured aquatic chemistry results and the toxicity pattern. Perhaps pyrethroid pesticides may be the cause. Literature values of LC_{50}s for Bifenthrin and Permethrin in the 96-hr mysid survival test are 4 and 90 ng/L respectively.

C-11.6.3 Bacteriological / Pathogen Monitoring

Coastal and channel stormdrain monitoring took place at the sites shown on **Figure C-11.8**. The results of the bacteriological / pathogen monitoring are presented in **Attachment C-11-V** with exceedances of the AB411 standards in the surfzone highlighted in bold. The data do display substantial differences between stations in their relative frequency of exceedances of the AB411 single-sample standards, which are:

- Total coliforms: 10,000 cfu / 100 ml
- Fecal coliforms: 400 cfu / 100 ml
- *Enterococcus*: 104 cfu / 100 ml.

Table C-11.15 shows the proportion of all samples exceeding AB411 standards in the receiving water upstream and downstream of coastal drains, and in inland channels, both for the entire year and for the AB411 season (April 1 through October 30). It should be noted that comparison of the water quality in the inland channels to the AB411 standards was only done for comparison purposes as the AB411 standards are for ocean water contact.

The results show that the proportion of exceedances is relatively low for the entire year along the coast but higher during the AB411 season. Thus, winter storm flows do not appear to be increasing the level of contamination at these shoreline sites. Sites HB1,

HB2, HB4, and HB5, along Huntington Beach, had the highest number of exceedances along the coast. Exceedance rates within channels, however, were much higher and occurred at about the same rate for the entire year and in the AB411 season. This information is presented visually in **Figures C-11.9** and **C-11.10**, which show that spatial distribution of exceedance proportions. Coastal sites are consistently rated much cleaner than the inland channels. **Table C-11.16** shows that exceedances of AB411 standards were spread relatively equally across all three indicators, at both coastal and channel sites and in both seasons.

Table C-11.17 provides the average discharge rate, over the entire year, for each coastal stormdrain. There is no apparent relationship between the proportion of exceedances (**Table C-11.15)** and the discharge rates, all of which are low. In addition, the coastal stormdrains at Huntington Beach (HB1 – HB5) discharge at the inland edge of the beach and these discharge points are separated by the width of the beach (about 100 yards) from the surfzone. Thus, except during large storms, the discharge sinks into the sand and does not reach the surfzone. The remaining discharges are coastal creeks that drain into Crystal Cove State Park. These creeks all have a receiving pond at the bottom of the creek, which then drains directly into the ocean.

Exceedances along the coast were sometimes, but not always, associated with elevated levels in the stormdrain itself. **Figures C-11.11** and **C-11.12** illustrate analysis approaches used to systematically investigate the relationship between indicator concentrations in the stormdrain itself and in the receiving water, for both the entire year and for the AB411 season. **Figure C-11.11** is divided into segments that represent different likely conclusions about the extent to which the stormdrain discharge is causing elevated indicator levels in the receiving water. **Figure C-11.12** illustrates how linear regressions of the receiving water indicator values against those from the drains provide additional insight into the relationship between the drains and the nearby receiving water. (A complete set of these figures for all sites, indicators, and conditions can be found in **Attachment C-11.VI**.) **Table C-11.18a-b** ranks the drains in terms of the strength of this relationship, as measured by the significance, or "p" value, of the regression slope for the entire year and for the AB411 season. It is important to remember that a statistically significant regression is not, by itself, indicative of a potentially problem drain. A statistically significant regression must be combined with a relatively high proportion of exceedances, particularly in the AB411 season and a relatively high rate of discharge that reaches the surfzone.

Taken together, these analyses identified several overall patterns, including:

- Relatively low exceedance rates along the coast and high exceedance rates in inland channels
- Similar exceedance rates for the entire year and for the AB411 season, for both the coastal drains and the inland channels
- Similar exceedance rates for all three indicators
- Tighter relationships between indicator values in discharges and in the surfzone (as shown by regression) for the drains in Crystal Cove than for the drains along Huntington Beach.

Data from **Tables C-11.15 - C.11.18a-b** show clearly that there is little cause for concern about contamination rates at coastal sites. Discharge rates are very low, as are exceedance rates. On the other hand, channel sites were uniformly contaminated, with very high exceedance rates. However, these inland channels are not heavily used for body contact recreation.

C-11.6.4 Bioassessment

IBI ratings

Figure C-11.13 displays the bioassessment monitoring sites, which are sampled twice each year, in fall and spring. **Figures C-11.14** and **C-11.15** present the IBI scores for each bioassessment monitoring site (**Table C-11.19**). The urban affected sites in the study region had IBI ratings of Poor to Very Poor in both the fall 2005 and spring 2006 surveys. The reference sites had ratings that ranged from Fair to Good.

The IBI rating of most sites remained relatively consistent across the two surveys. The five sites that did change rating did so by only one category, with two urbanized sites decreasing from the boundary of Very Poor / Poor to Very Poor. Two reference sites decreased from Fair to Poor and the third reference site increased from Fair to Good. In all cases except the one reference site that increased from Fair to Good, all shifts between the fall and spring surveys were to a lower category. In general, there was less spread among the IBI scores in the spring survey. All sites in the spring survey were rated as Very Poor, while three sites in the fall survey (UBPF19, BGH01, and LCRF05) were near or at the borderline of the Poor rating. The IBI scores for the latter two of these sites dropped substantially between fall and spring. These changes were due to the loss of tolerant and non-insect taxa in BGH01 and tolerant, non-insect, and predator taxa in LCRF05.

Spatial pattern analysis

In addition to describing patterns and trends in benthic invertebrate, a further purpose of the bioassessment program element is to determine whether physical habitat, aquatic chemistry, and/or toxicity are correlated with IBI scores. If strong correlations exist, then this would suggest a causal relationship. The most recent ROWD for the San Diego Region, which analyzed data from 2002 through spring of 2005, showed that there were no apparent correlations between IBI scores and either toxicity or aquatic chemistry. In contrast, there was a broad relationship between higher physical habitat scores and higher IBI scores. In addition, the pattern of several components of the physical habitat score mimicked patterns in the biological community across the region. While there is only one year of data yet available for the Santa Ana Region, analogous approaches were used to search for such correlations among biological patterns on the one hand and aquatic chemistry, toxicity, and physical habitat on the other.

First, broad patterns for each of the four types of indicator (i.e., IBI, physical habitat, aquatic chemistry, toxicity) were mapped. **Figures C-11.16a** and **C-11.16b** show that

stations in the San Diego Creek watershed have the worst IBI scores in the fall sampling, with poor IBI scores more widespread in the spring sampling. In neither survey were there any clear relationships at this broad scale between IBI scores and any other type of variable. Thus, sites with poor overall IBI condition did not also have poor scores on either physical habitat, toxicity, or aquatic chemistry.

Relationship to aquatic toxicity and chemistry

Second, and at a greater level of specificity, the detailed monitoring data for bioassessment, aquatic chemistry, and toxicity were examined to determine whether there are any clear relationships among these at a finer level of detail. Toxicity data (**Table C-11.20**), from both the fall 2005 and spring 2006 sampling periods, show that there were no instances of elevated toxicity, though there were some instances of reduced *Cerioidaphnia* survival and reproduction at stations BCWG04 and BGH01. These results may have been due to the high dissolved solids in the samples from both coastal sites. Both these stations had IBI scores in the mid- to upper-range of the urbanized sites.

The aquatic chemistry results (**Table C-11.21**)provide no clear insight into other potential causes of the relatively minor toxicity observed at these two stations. Other than elevated levels of cadmium, the levels of potential toxicants at these sites did not differ from those at the other bioassessment sites. Taken together, the toxicity and aquatic chemistry results suggest that neither toxicity nor contamination is a cause of lower IBI scores.

Biological cluster analysis

The third analysis used a more powerful set of analyses to search for relationships between the biological patterns in the benthic community on the one hand and patterns in potential explanatory variables in the toxicity, aquatic chemistry, and physical habitat data.

As a first step, the species data from all surveys was clustered to identify groupings of sites that were similar in terms of their community composition. **Figure C-11.17** shows the cluster analysis of all sites over the two surveys and **Figure C-11.18** the two-way coincidence table of the relative distribution of species in each site at each sampling time. Horizontal and vertical lines on the two-way coincidence table identify major groupings of species and sites, respectively. (Sites are identified by their site number, year of sampling, and month of sampling. Relative species abundances are shown as symbols. The abundance of each species was standardized in terms of its maximum at each site over all surveys. Smaller symbols represent a lower proportion of maximum abundance and larger symbols a larger proportion.)

These two figures clearly show three dominant patterns. First, reference sites are concentrated at the upper end of the dendrogram, which is equivalent to the left side of the two-way coincidence table. Second, fall and spring samples tend to group together within small subdivisions of the larger site pattern. This reflects a consistent difference in benthic communities between these two sampling times. Third, species with broader

distributions across sites and times are concentrated in the lower half of the two-way coincidence table. Species with such broad distributions tend to be more pollution and/or disturbance tolerant. In contrast, species in the upper half of the two-way coincidence table have much more restricted distributions and in fact are found primarily at the reference sites. A closer examination of the species groups shown in the two-way table shows that the first and second species group (concentrated in reference sites and upper watershed sites with relatively high IBI scores) is a diverse assemblage of several very sensitive types of organisms. The third species group is transitional between sensitive and pollution tolerant species, while the fourth and fifth species groups (at the bottom of the two-way table) include moderately tolerant (fourth species group) to very tolerant (fifth species group) species characteristic of very disturbed sites.

Correlation with physical habitat parameters

Variables were then grouped into biological parameters (e.g., numbers of taxa, magnitude of toxicity), physical habitat parameters (e.g., elevation, bank stability), water quality parameters (e.g., pH, dissolved oxygen), and potential pollutant parameters (e.g., copper, Diazinon). The values of each parameter were then plotted for each site group in the fall and spring surveys (**Figures C-11.19** and **C-11.20**, respectively), using box and whisker plots. "Group" on the x-axis of the box and whisker plots refers to the site groups from the dendrograms and two-way tables.

The box and whisker plots (**Figures C-11.19** and **C-11.20**) document that a subset of variables show consistent differences among the site groups and are therefore possible causes, or at least strong correlates, of the differences in community composition and IBI scores. In both spring (**Figures C-11.19a**) and fall (**Figure C-11.20a**), IBI score is strongly correlated with number of taxa. The two-way table (**Figures C-11.18**) shows that the reference sites near the left side of the tables have larger numbers of species. This is because they generally contain populations of both tolerant (widely distributed) and intolerant (narrowly distributed) species. However, toxicity did not differ in any consistent way across the site groups, in either spring or fall.

The pattern of physical parameters across site groups (**Figures C-11.19b** and **C-11.20b**) varies depending on the parameter. This is why the overall physical habitat score was not strongly related to IBI score in **Figure C-11.16a-b**. A subset of physical habitat parameters differs markedly across the site groups. In general, in both spring and fall, channel alteration, embeddedness, and riparian vegetation zone differed markedly across the site groups, with instream cover, riffle frequency, vegetation protection, and velocity depth regimes also showing a lesser degree of difference across the site groups. In addition, sediment deposition and copper appeared strongly related to the biological pattern in spring, while sediment deposition was only weakly related in the fall. Other chemical parameters were either strongly (volatile suspended solids, total Kjeldahl nitrogen in the spring) or weakly (turbidity, nitrate-nitrite, ortho-phosphate, chromium, cadmium, diazinon) related to the biological pattern.

Given that this is the first year of bioassessment monitoring, it would not be wise to draw firm conclusions from these results. However, the apparent relationship of

biological pattern with physical habitat parameters (e.g., channel alteration, riparian vegetation zone) has been observed in a number of other bioassessment programs, including the County's bioassessment monitoring in the San Diego Region. On the other hand, strong relationships between the biological pattern and water chemistry have not been typically observed in other programs. The relationships observed here may be causal, or it may simple be due to the fact that chemical contamination and physical habitat alteration are highly correlated in urbanized environments. This issue will be investigated more thoroughly as more data become available.

C-11.6.5 Reconnaissance

The dry weather reconnaissance stations are shown in **Figure C-11.21**. The dry weather period (May 1 – September 30) does not precisely match the Program's reporting period (July 1 – June 30). For purposes of meeting the Program's annual reporting requirements, future reports will include from July 1 through June 30 of each monitoring year.

Approval of the Santa Ana Region monitoring programs by the Santa Ana Regional Water Quality Control Board in July of 2005 meant that during the reporting period, dry weather monitoring commenced in this portion of Orange County for the first time under the Third Term Permits in May of 2006. Since only two months of data are available for this monitoring year, it was not possible to calculate tolerance intervals or control charts to determine if particular stations are of interest.

Up to date monitoring results can be viewed on the Program's website at the following link:
ftp://watershed-mgr:2alau54n@pfrdftp.ocgov.com/NPDESstormwater/DAMP/11.0%20Water%20Quality%20Monitoring/
For reference, the dry weather program monitoring results from both regions for the reporting period are presented in **Attachment C-11-VII**.

In the Santa Ana Region, there are 41 targeted sites and 10 random sites. Since the Santa Ana Region DWMP did not commence until May 2006, and this report only includes data through June of 2006, there were not enough sampling events for a site to experience consecutive exceedances of a tolerance interval for a consecutive instance. Tolerance Intervals from the San Diego Region DWMP are being applied in the Santa Ana Region DWMP until there is enough data to compare the two regions to determine if there is a need to calculate separate tolerance intervals. With almost four years of random site data in the San Diego Region, it could take a couple more years before a meaningful determination can be made.

C-11.6.6 Land Use Correlations

Figure C-11.22 shows the locations of the monitoring sites, which are sampled monthly in dry weather conditions and twice a year during storms. **Attachment C-11.VIII** presents the monitoring data.

The primary purpose of this program element is to determine whether several different types of land use conversions are correlated with detectable changes in water quality downstream of the conversion. This question was assessed by examining linear regression plots of log-transformed data at each site. A substantial divergence in the slope of the regression line between the upstream and downstream sites would suggest that the development (located between the upstream and downstream sites) was potentially affecting water quality.

This analysis identified several instances that met this criterion (**Table C-11.22**), in the data from the grassland to residential landuse conversion in both dry weather and storms. There were no instances of diverging trend lines in the other conditions (Tustin Air Base to residential in dry weather and storms; agriculture to residential in either dry weather or storms). The lack of significant trend at the Tustin Air Base monitoring sites are most likely due to the fact that the development had barely begun at the end of the monitoring period, whereas development had been ongoing for nearly two years at the grassland location. The results from the grassland storm conditions are suggestive of development effects, because all trends are toward higher constituent levels in the downstream stations. However, these trends are all based on a single sampling event in April of 2006 in which the values for the upstream and downstream stations diverged sharply (**Figure C-11.23a-b**). Despite the large differences between the upstream and downstream stations at this single point in time, it is risky to draw any firm conclusions from a single data point. Further, the April 2006 storm was smaller (1.08 inches) than two of the earlier storms during which upstream and downstream values were similar (October and December 2004, 5.3 and 2.01 inches, respectively). It is thus difficult to imagine these nearly identical patterns could both be due to development effects. Data from these sites will be followed closely in future monitoring events to assess whether the trend lines continue to diverge.

Figure C-11.23a-b shows the trend line plots for the instances identified in **Table C-11.22**. Only trace elements and nitrate/nitrite showed strongly diverging trend lines. The pattern for nickel (higher at the upstream station) was different from that for copper, chromium, and selenium (higher at the downstream station). Data from the control site was sampled during storms but was not considered useful in assessing comparisons of the upstream and downstream stations for three reasons. First, the control station is in a different watershed and was dry except during storm flows, suggesting that conditions did not reflect those at the other stations. Second, sediments at the control station had a much higher percentage of sand than sediments at the other stations, further suggesting that conditions at the control station differed substantially from those at the other stations. Third, there are only three storms in the dataset to date, not enough to reliably determine whether upstream stations were tracking the control station.

These results potentially identify constituents that have been affected by development activities in the three target areas. These results, however, are not definitive for a number of reasons and require further site-specific investigation. First, the length of the time series is relatively short and it is well known that stormwater characteristics vary

widely both over time and between even closely spaced locations. Thus, apparent differences in trends between upstream and downstream sites could be a coincidence due to spatial and temporal variability. Second, monitoring began nearly coincident with the beginning of development activities in two of the three study areas. As a result, there is little or no data to demonstrate how the upstream and downstream sites behaved relative to each other in the absence of development. It is possible, for example, that trends were diverging prior to the development for some unknown reason. Third, there are no validated models, either conceptual or numerical, that provide a basis for creating and/or testing hypotheses about how specific development activities could affect water quality. In the absence of such models, the analysis must depend on an examination of trends and ad hoc attempts to construct reasonable explanations for these. Finally, the design lacks the replication (i.e., multiple monitoring sites in each condition) needed to quantitatively evaluate whether any observed divergence in trend is greater than what would be expected between any two sites randomly selected from the same condition.

Because of the difficulties in statistically evaluating the robustness of the potential associations with land use changes, further site-specific investigations will be conducted focused on the particular candidates identified in **Figure C-11.23a-b**.

C-11.6.7 Additional toxicity analyses

Past interpretations of toxicity testing results have depended in part on subjective comparisons of the observed toxicity to chemistry results. In some cases, more rigorous TIE (toxicity identification evaluation) studies can provide more detailed insight into the specific chemical compounds contributing to observed toxicity. TIE's can be problematic, however, because their cost and the logistics involved in performing them preclude carrying them out in all instances. For this reason, TIEs were targeted at those monitoring sites where substantial toxicity was observed during the past monitoring year. If toxicity was observed during the current monitoring year, then TIEs were immediately performed using the same sample water.

TIE's were performed in two instances, on samples from the Upper Newport Bay stations UNBJAM and UNBSDC. Both were in response to a finding of toxicity in the *Eohaustorius* test during sediment sampling. The TIE treatments failed to reduce the toxicity, suggesting that the toxicity was due to an unknown compound. This finding corresponds to the conclusions from the Bight Program's investigations of sediment toxicity in Newport Bay, i.e., that it is not due to typically sampled contaminants such as DDT/DDE, PCB, or metals.

In addition to TIE's, aquatic toxicity test results from several components of the water quality monitoring program (mass emissions, estuary / wetlands, and bioassessment) were combined to present a picture of how toxicity is distributed throughout the region. The average mortality rate of test organisms at each station was used to place each station into one of four categories representing relative intensity of toxicity. **Figures C-11.24** and **11.25** show the distribution of relative toxicity across the region. Toxicity is much more widespread in wet than in dry weather. During wet weather, aquatic

toxicity is more prevalent inland, along the center of the Newport Bay watershed and at the three stations in the San Gabriel / Coyote Creek watershed. In contrast, toxicity is much less prevalent at monitoring stations along the coastline. During dry weather, there is little toxicity apparent throughout the region.

In last year's report, the potential relationship between toxicity and the levels of specific constituents in the water were further investigated by comparing the observed toxicity with that predicted from the observed concentration of key constituents and the LC_{50} or EC_{50} for each toxicity test. These preliminary results showed promise by, for example, identifying instances in which there were large amounts of unexplained toxicity and by suggesting that elevated levels of zinc were largely unavailable biologically. While there were several candidate sites for which this analysis would have useful, it was not possible to extend it to these instances. The available databases of LC_{50}'s do not include data for many of the specific test organisms and test durations the Program currently uses, nor for new classes of toxicants of interest, such as pyrethroid pesticides. As a result, the Program will work with the SMC and toxicity researchers to promote the development of these LC_{50}s.

C-11.6.8 Additional Comparisons to CTR

Aquatic chemistry samples from several components of the water quality monitoring program (mass emissions, estuary / wetlands, bioassessment) are evaluated in comparison to thresholds established in the CTR. While such CTR thresholds are available for only a portion of the constituents measured in the program's samples, the combination of CTR exceedances from all available program components provides an overview of contamination patterns across the region. In addition to tabulating the number of exceedances at each station, the overall percentage of exceedances at each station (out of all samples collected at each station) was used to place stations into one of four categories representing relative frequency of exceedances.

Table C-11..26 summarizes exceedances of acute CTR criteria for all water quality monitoring stations in the Santa Ana region. For purposes of this assessment, all program components (mass emissions, estuary / wetlands, bioassessment) were combined into one dataset, in order to better represent the spatial pattern of exceedances across the region.

Exceedances overall are predominantly due to copper, with a much smaller percentage due to zinc. Exceedances of the CTR for cadmium, lead, and silver were extremely rare and thus not included in **Table C-11.23**. Most exceedances occur at a subset of the stations in the Newport Bay and Anaheim Bay – Huntington Harbour watersheds, with exceedances much more prevalent during wet weather. **Figures C-11.26** and **C-11.27** visually summarize these regional patterns, using the data presented in **Table C-11.23**.

Within these larger patterns, the CTR exceedance data help identify locations where targeted special studies to identify upstream sources should be implemented. These are stations with more than a handful of samples where the exceedance rate was among the highest:

- BCC02
- EGWC05
- ABCC03
- CMCG02
- SADF01

However, there was no apparent relationship between the CTR exceedance patterns and the toxicity patterns described in the preceding section. The five stations with elevated CTR exceedance rates were rated relatively highly in terms of their overall toxicity.

C-11.6.9 Priority Pollutant Scan

The results of the priority pollutant scan are presented in **Attachment C-11.IX** and these data did not suggest the presence of new constituents of concern. Because several years of data were available for organo-phosphate pesticides, these data were selected for further examination of their trends over time. **Figure C-11.28** illustrates the overall pattern in aquatic concentrations of these pesticides:

- Trends over time are more apparent in dry weather than in stormwater samples
- Chlorpyrifos and Dimethoate are typically below detection limit
- Diazinon has declined over the past few years
- Malathion has not declined and may in fact be increasing, except in Costa Mesa Channel.

In addition, there is broad concern among stormwater managers that Diazinon and Chlorpyrifos are being replaced by pyrethroid pesticides, which are not monitored for in water because they are tightly bound to particles. The Program has only recently begun to monitor for pyrethroid pesticides in sediment samples and it is too early to draw conclusions about spatial and temporal patterns of this class of pesticides. However, sediment samples in Costa Mesa Channel, San Diego Creek at Campus Drive and at the UNBJAM station in Upper Newport Bay did show the presence of Bifenthrin, although this pesticide was not present in sediment samples from other channels. The priority pollutant scan also documented the presence of phthalates and PAHs, two other constituents of concern.

C-11.6.10 TMDL/303(d) Listed Waterbody Monitoring – Nutrient TMDL

The Nutrient TMDL's reporting process is in transition between a single annual report and a new requirement for submission of quarterly reports. The most recent annual report, covering the past four quarters, is presented in **Attachment C-11.X**.

C-11.6.11 Special Studies

Special studies are called for in the NPDES permit under a variety of situations in which data from the core monitoring program questions that can only be answered by focused

site-specific studies. One such study was conducted in the Santa Ana Region during the past monitoring year.

Expanded Sampling of Hicks Canyon Wash

Hick's Canyon Wash has been sampled throughout the term of the NPDES monitoring program for nutrients, originating in part from permitted discharges from commercial nurseries. Once the monitoring plan for third term permit was approved by the Santa Ana Board, an expanded evaluation of Hicks Canyon Wash was initiated to investigate the possible contributions of pesticides, herbicides, and any associated toxicity effects.

This evaluation consisted of bimonthly dry-weather sampling of water chemistry to establish baseline conditions. Monitoring was conducted using the protocols (sans flow monitoring) established in the Mass Emissions program element. One storm and one 24-hr dry-weather discharge was evaluated for both water chemistry and aquatic toxicity. In parallel with these efforts, a one-time reconnaissance of all upstream tributaries and underground drains was conducted to identify that the main sources of dry-weather runoff from the watershed.

The results of the reconnaissance indicate that the primary source of dry-weather runoff is residential development and not agricultural landuses. The dry-weather concentrations of OP pesticides were generally undetectable during the summer and fall months with a few detectable amount of Diazinon. Chlorpyrifos was detected in some samples beginning in February 2006 and by the end of the year Dimethoate and/or Malathion had also been found in at least one sampling. The dry-weather sample submitted for toxicity testing in mid-December 2005 showed significant amounts of toxicity in the mysid survival test (TUa=3.08 with 0% survival in the undiluted sample). The mysid growth test yielded a TUa of 2.61 with 0% growth in the undiluted sample. No results from the chemistry analyses could explain these toxicity results. The Ceriodaphnia survival / reproduction and fathead minnow survival / growth tests showed minor or no toxic effects.

The stormwater toxicity sample from a storm in late February 2006 showed significant toxicity (5% survival in the undiluted sample) in the mysid survival test. The corresponding chemistry sample showed detectable levels of Diazinon and Malathion.

C-11.6.12 Summary

The first year of monitoring under the Third Term Permit has begun the process of collected a more expanded suite of information for regional and watershed assessment of receiving water conditions and potential impacts on these from urban runoff. The expanded scope of the monitoring program encompasses not only inland creeks and streams but coastal bays and estuaries as well.

The mass emissions results continue building a long-term record of loads. A recent trend analysis conducted for the Report of Waste Discharge (ROWD) showed that there were no long-term trends in metals and nutrients, once the influence of rainfall and total

suspended solids (TSS) was accounted for. However, more recent data showed that certain pesticides that have been the target of management actions (e.g., Diazinon) have clearly declined over the past few years, while Malathion may have increased in some locations. In addition, while toxicity was present at several stations during two storm events, there was no apparent relationship between the occurrence and severity of toxicity and the levels of potential toxicants in the aquatic chemistry samples.

The estuary / wetlands program component included both sediment and water quality analyses. The benthic infaunal data, which were collected coincident with sediment toxicity and sediment chemistry data, documented a range of benthic community conditions. However, there was no consistent relationship between the benthic community and either sediment toxicity or sediment chemistry, despite the presence at some stations of elevated toxicity and/or chemistry values. This suggests that effects on the benthic infaunal community may not be driven only by sediment toxicity, but by other factors such as physical disturbance. It also suggests that simple sediment chemistry values do not reliably predict potential toxicity, except perhaps at the extremes. These relationships are currently under investigation as part of the State Water Resources Control Board's Sediment Quality Objectives project. The findings and guidance from that effort will be applied by the Program as they become available.

The Program's current results confirmed previous findings that Newport Bay has a high level of sediment toxicity. The Program's previous studies, as well as those conducted by the Bight Program, have concluded that this toxicity is not due to usual sources such as metals, DDT/DDE, or PCBs, but to some unknown toxicant. One possible exception to this generalization is the Rhine Channel, where mercury and copper were both consistently above the NOAA ERM value. Recent research suggests that pyrethroids, which are strongly sediment bound, may be a source of toxicity. However, tools for evaluating pyrethroid toxicity in estuarine sediments, such as LC_{50}'s, are not yet available. In contrast, LC_{50}'s for freshwater are available for some pyrethroids, and there were some instances in which pyrethroids in sediments from channels were above the LC_{50}.. The Program should therefore promote the studies needed to develop these tools, perhaps through the Stormwater Monitoring Coalition. While methods for TIE's for examining the source of aquatic toxicity are well developed, sediment TIE methods are complex, problematic, and unreliable. Thus, attempts to better identify the source(s) of sediment toxicity in the region must depend on monitoring an expanded list of constituents, more in-depth correlative analyses, and taking advantage of spatial and temporal comparisons available within the region.

The estuary / wetlands monitoring also include aquatic chemistry and toxicity. Elevated toxicity was frequently observed, but this was not apparently related to the levels of potential toxicants in the water column. There were only two exceedances of the CTR criteria. As for sediment toxicity, further studies of the source(s) of observed toxicity will be needed in order to identify the constituents causing toxicity.

The bacteriological / pathogen monitoring effort included stations both along the coastline and in inland channels. In general, exceedances of the AB411 standard were much higher in channels than along the coast, with similar exceedance rates for the

entire year and for the AB411 season. Exceedance rates were similar for all three indicators. Along the coast, where the sampling design made it possible to assess the strength of the relationship between drain discharges and the receiving water, drains in Crystal Cove had a much tighter relationship with conditions in the receiving water than did the drains along Huntington Beach. However, discharge rates of these drains are very low, as are the exceedance rates, suggesting that there is little cause for concern about potential health impacts from these discharges. While exceedance rates for the inland channels are very high, these sites are not commonly used for body contact recreation.

The bioassessment monitoring effort, in its first year, documented the fact that biological communities are clearly impacted in the urbanized portions of the watershed. A simple graphical correlation analysis provided preliminary suggestions about potential causal mechanisms for these impacts. Several physical habitat parameters displayed the same pattern as the biological community, as did a few aquatic chemistry constituents such as copper. However, degradation of physical habitat and chemical contamination are highly correlated in this region and further analyses will be needed to tease apart the relative influence of chemical contamination and physical habitat. It is useful to note, however, that findings in several other bioassessment programs have identified the key role played by modifications to physical habitat in determining the pattern of IBI scores.

The dry weather reconnaissance program has just begun and has not yet collected enough data to identify sites of concern.

The data from the land use correlation monitoring is suggestive of development impacts, as indicated by diverging trend lines between the upstream and downstream stations. On the other hand, many of these trend lines are based on one or few data points. It will be important to continue this monitoring in order to lengthen the time series of data and to more closely investigate the relationship of water quality to development. This will require building a conceptual model of potential mechanisms of impact and then evaluting these with the monitoring data. The control station should be discontinued. It is not useful in assessing impacts because it is a single station (thus providing no estimate of natural background variability) and is in a different watershed / habitat than the comparison sites. Given the inherent differences among the comparison conditions, the appropriate control is the upstream stations.

Regional summaries of toxicity and CTR exceedance data provide an overview of patterns across the region. Toxicity is much more widespread in wet weather and is concentrated along the center of the Newport Bay watershed and in the northwest portion of the region. There is very little toxicity during dry weather. CTR exceedances are also more prevalent at inland stations, although this pattern is somewhat influenced by the types of sampling conducted in different portions of the watershed. Virtually all the CTR exceedances are for copper.

Priority pollutant scans were combined with past data on water column levels of pesticides to document trends in key organophosphate pesticides. This analysis showed that Chlorpyrifos and Dimethoate are typically below their respective detection limits,

Diazinon has declined markedly over the past few years, and Malathion has not declined and may in fact be increasing, except in Costa Mesa Channel. The priority pollutant scans also revealed the presence of phthalates and PAHs, two other constituents of concern. The priority pollutant scans did not reveal the presence of any unexpected compounds.

C-11.7 Quality Assurance / Quality Control

The quality of data produced by each of the three contractor laboratories and the Public Health Laboratory was evaluated by submitting quality assurance (QA) samples to the labs with each batch of environmental samples. Many of the (QA) samples were synthetic, comprised of aliquots of prepared standard solutions in Nanopure water matrices. The level of total dissolved solids (TDS) in each of the synthetic samples was adjusted with Ultrex grade sodium chloride to simulate comparable levels of TDS in environmental samples. These samples were used to assess the accuracy of each laboratory. Splits of the environmental samples were also submitted to evaluate the precision of the laboratories.

The contractor laboratories also conduct internal quality control programs utilizing certified reference materials (CRMs), spiked and replicate samples.

The quality of analyses performed by Dry-weather Reconnaissance monitoring staff was maintained by routinely requiring these staff to analyze synthetically prepared standards.

The results of the quality assurance program are summarized in tabular and graphic form in **Attachment C-11-XI**. Control charts were created to show the performance of the laboratories over the course of the monitoring year. The upper (UCL) and lower (UCL) control limits are shown on each of the control charts.

The results of the QA program show that:

- The accuracy of analyses for pathogen indicator bacteria met the acceptance criteria provided by the QA sample vendors. It appears from the graphic that the greatest accuracy was seen in the analyses for *Enterococcus* bacteria.
- The analyses for nutrients and trace metals in freshwater were generally good.
- The analyses of silver and selenium in seawater showed a low recovery bias. The program is working with the contract laboratory to resolve this issue.
- From July through September 2005 the recoveries in the analyses of organophosphate pesticides were unacceptable. A new contract laboratory was selected to provide these analyses. Subsequent analyses were much improved.
- The accuracy of field chemical analyses in the Dry-weather reconnaissance programs was generally acceptable with one notable exception. An MBAS determination on 6/8/06 yielded a result of 3.6 mg/L when the standard contained only 0.2 mg/L.

Table C-11.1 Applicable Water Quality Guidance for the Protection of Aquatic Life

Water Quality Measurement	California Toxics Rule (CTR) Freshwater dissolved metals H=ln(water hardness in mg/L as $CaCO_3$)	CTR Saltwater Dissolved metals	Ocean Plan Toxic Mat. Limits Total metals	Region 8/9 Basin Plans
Lead ug/L H=ln Hardness	4 day =[1.462-0.146H][exp(1.273H-4.705)] 1 hour =[1.462-0.146H][exp(1.273H-1.460)]	4day = 8.1 1hr = 210	Daily max = 8 Inst. max = 20	
Cadmium ug/L	4 day = [1.107-0.042H][exp(0.7852H-2.715)] 1 hour = [1.137-0.042H][exp(1.128H-3.6867)]	4day = 9.3 1hr =42	Daily max = 4 Inst. max = 10	
Hexavalent Chromium ug/L		4day = 50 1hr = 1100	Daily max = 8 Inst. max = 20	
Nickel ug/L	4 day = 0.997[exp(0.846H+0.0584)] 1 hour = 0.998[exp(0.846H + 2.255)]	4day = 8.2 1hr = 74	Daily max = 60 Inst. max = 150	
Copper ug/L	4 day = 0.96[exp(0.8545H-1.702)] 1 hour = 0.96[exp(0.9422H-1.70)]	4day = 3.1 1hr = 4.8	Daily max = 12 Inst. max = 30	
Silver ug/L	1 hour = 0.85[exp(1.72H-6.52)]	1hr = 1.9	Daily max = 2.8 Inst. max = 7	
Zinc ug/L	4 day = 0.986[exp(0.8473H+0.884)] 1 hour = 0.978[exp(0.8473H+0.884)]	4 day = 81 1 hr = 90	Daily max = 80 Inst. max = 200	
Turbidity				Natural Max. increase 0-50 NTU 20% over natural 50-100 NTU 10 NTU >100 NTU 10% over natural
pH				6.5 - 8.5 freshwater 7.0 - 9.0 saltwater (SDR) 7.0 - 8.5 saltwater (SAR)
Dissolved Oxygen				>5.0 mg/L MAR & WARM >6.0 mg/L COLD
Unionized Ammonia*				SDR = 0.025 in receiving waters SAR (See below)

* [Unionized Ammonia] = $\frac{[NH_4\text{-}N]+[NH_3\text{-}N]}{1+10^{(pKa-pH)}}$ where $pka = 0.09018 + \frac{2729.92}{T}$

T= degrees Kelvin = C+273.16

SAR Unionized Ammonia (UIA) Criteria for waterbodies designated as WARM

Acute Objective = 0.822[0.87/FT/FPH/2] where

$FT = 10^{0.03(20-T)}$ $0 \le T \le 25^oC$

$FT = 0.7079$ $25 \le T \le 30^oC$

$FHP = [1+10^{(7.4-pH)}]/1.25$ $6.5 \le pH \le 9$

$FHP = 1$ $8 \le pH \le 9$

Chronic Objective = 0.822[0.87/FT/FHP/RATIO] where

$FT = 10^{0.03(20-T)}$ $0 \le T \le 20^oC$

$FT = 1$ $20 \le T \le 30^oC$

$FHP = [1+10^{(7.4-pH)}]/1.25$ $6.5 \le pH \le 8$

$FHP = 1$ $8 \le pH \le 9$

$RATIO = \frac{24[10^{(7.7-pH)}]}{1+10^{(7.4-pH)}}$ $6.5 \le pH \le 7.7$

$RATIO = 13.5$ $7.7 \le pH \le 9$

Table C-11.2 Applicable Sediment Quality Guidelines for the Protection of Marine Aquatic Life

NOAA's Screening Concentrations

Metals (ppm)	ER-L	ER-M
Cadmium	1.2	9.6
Chromium	81	370
Copper	34	270
Lead	46.7	218
Nickel	20.9	51.6
Silver	1.0	3.7
Zinc	150	410
Organics (ppb)		
Acenaphthene	16	500
Acenaphthylene	44	640
Anthracene	85.3	1100
Fluorene	19	540
2-Methyl naphthalene	70	670
Naphthalene	160	2100
Phenanthrene	240	1500
Low molecular weight PAH	552	3160
Benzo(a)anthracene	261	1600
Benzo(a)pyrene	430	1600
Chrysene	384	2800
Dibenzo(a,h)anthracene	63.4	260
Fluoranthene	600	5100
Pyrene	665	2600
High molecular weight PAH	1700	9600
Total PAH	4022	44792
Chlordane	0.05	6
p,p' –DDD	2	20
p,p' –DDE	2.2	27
p,p' –DDT	1	7
Total DDT	1.58	46.1
Dieldrin	0.02	8.0
Total PCBs	22.7	180

ER-L - Effects Range Low

The ERL represents the concentration corresponding to the 10th percentile in toxicity testing. No effects are likely below the ER-L.

ER-M - Effects Range Median

The ERM represents the concentration corresponding to the 50th percentile or median value. Effects are likely above the ER-M.

SCCWRP Iron Normalization Regression Coefficients

Iron (% dry) Versus	Sample Size	r^2	Slope (m)	Intercept (b)	± 99% Prediction Interval
Cadmium (mg/dry g)	83	0.734	0.0978	0.0055	0.1274
Chromium (mg/dry g)	88	0.882	16.50	-0.021	11.56
Copper (mg/dry g)	96	0.833	7.40	-2.01	6.50
Lead (mg/dry g)	103	0.738	4.350	0.0836	5.199
Nickel (mg/dry g)	110	0.533	9.850	-0.407	19.596
Silver (mg/dry g)	99	0.581	0.0795	-0.0183	0.1426
Zinc (mg/dry g)	88	0.967	31.50	-1.95	15.45

Table C-11.3. IBI Metrics Used to Characterize Communities

Metric	Description	Response to Impairment
Richness Measures		
Taxa Richness	Total number of individual taxa	Decrease
EPT Taxa	Number of taxa in the Ephemeroptera (mayfly), Plecoptera (stonefly) and Trichoptera (caddisfly) insect orders	Decrease
Coleoptera Taxa	Number of taxa in the insect order (Coleoptera, beetles)	Decrease
Dipteran Taxa	Number of taxa in the insect order (Diptera, "true flies")	Increase
Non-Insect Taxa	Number of non-insect taxa	Increase
Composition Measures		
EPT Index	Percent composition of mayfly, stonefly, and caddisfly larvae	Decrease
Sensitive EPT Index	Percent composition of mayfly, stonefly, and caddisfly larvae with tolerance values between 0 and 3	Decrease
Shannon Diversity Index	General measure of sample diversity that incorporates richness and evenness (Shannon and Weaver 1963)	Decrease
Tolerance/Intolerance Measures		
Tolerance Value	Value between 0 and 10 weighted for abundance of individuals designated as pollution tolerant (higher values) or intolerant (lower values)	Increase
Percent Dominant Taxa	Percent composition of the single most abundant taxon	Increase
Percent Chironomidae	Percent composition of the tolerant dipteran family Chironomidae	Increase
Percent Intolerant Organisms	Percent of organisms in sample that are highly intolerant to impairment as indicated by a tolerance value of 0, 1 or 2	Decrease
Percent Tolerant Organisms	Percent of organisms in sample that are highly tolerant to impairment as indicated by a tolerance value of 8, 9 or 10	Increase
Functional Feeding Groups (FFG)		
Percent Collector-Gatherers	Percent of macrobenthos that collect or gather fine particulate matter	Increase
Percent Collector-Filterers	Percent of macrobenthos that filter fine particulate matter	Increase
Percent Scrapers	Percent of macrobenthos that graze upon periphyton	Increase
Percent Predators	Percent of macrobenthos that feed on other organisms	Variable
Percent Shredders	Percent of macrobenthos that shreds coarse particulate matter	Decrease
Percent Other	Percent of macrobenthos that are parasites, macrophyte herbivores, piercer herbivores, omnivores, and xylophages	Variable
Abundance		
Estimated Abundance	Estimated number of BMIs in sample calculated by extrapolating from the proportion of organisms counted in the subsample	Variable

Table C-11.4. IBI Scoring Ranges for the Seven Metrics Included in the IBI Values

Metric Scoring Ranges for the Southern California IBI										
Metric Score	Coleoptera Taxa	EPT Taxa		Predator Taxa	% Collector Individuals		% Intolerant Individuals		% Non-Insect Taxa	% Tolerant Taxa
	All Sites	6	8	All Sites	6	8	6	8	All Sites	All Sites
10	>5	>17	>18	>12	0-59	0-39	25-100	42-100	0-8	0-4
9		16-17	17-18	12	60-63	40-46	23-24	37-41	9-12	5-8
8	5	15	16	11	64-67	47-52	21-22	32-36	13-17	9-12
7	4	13-14	14-15	10	68-71	53-58	19-20	27-31	18-21	13-16
6		11-12	13	9	72-75	59-64	16-18	23-26	22-25	17-19
5	3	9-10	11-12	8	76-80	65-70	13-15	19-22	26-29	20-22
4	2	7-8	10	7	81-84	71-76	10-12	14-18	30-34	23-25
3		5-6	8-9	6	85-88	77-82	7-9	10-13	35-38	26-29
2	1	4	7	5	89-92	83-88	4-6	6-9	39-42	30-33
1		2-3	5-6	4	93-96	89-94	1-3	2-5	43-46	34-37
0	0	0-1	0-4	0-3	97-100	95-100	0	0-1	47-100	38-100

Cumulative IBI Scores				
Very Poor	Poor	Fair	Good	Very Good
0-19	20-39	40-59	60-79	80-100

Table C-11.5. Decision Framework for Interpreting Triad Results

	Chemistry	Toxicity	Benthic Alteration	Example Conclusions	Possible Actions or Decisions
1.	Exceedance of water quality objectives	Evidence of toxicity	Indications of alteration	Strong evidence of pollution-induced degradation	Use TIE to identify contaminants of concern, based on TIE metric Initiate upstream source identification as a high priority
2.	No persistent exceedances of water quality objectives	No evidence of toxicity	No indications of alteration	No evidence of current pollution-induced degradation Potentially harmful pollutants not yet concentrated enough to cause visible impact	No immediate action necessary Conduct periodic broad scans for new and/or potentially harmful pollutants
3.	Exceedance of water quality objectives	No evidence of toxicity	No indications of alteration	Contaminants are not bioavailable Test organisms not sensitive to problem pollutants	TIE would not provide useful information with no evidence of toxicity Continue monitoring for toxic and benthic impacts Initiate upstream source identification as a low priority Consider whether different or additional test organisms should be evaluated
4.	No persistent exceedances of water quality objectives	Evidence of toxicity	No indications of alteration	Unmeasured contaminant(s) or conditions have the potential to cause degradation Pollutant causing toxicity at very low levels	Recheck chemical analyses; verify toxicity test results Consider additional advanced chemical analyses Use TIE to identify contaminants of concern, based on TIE metric Initiate upstream source identification as a medium priority
5.	No persistent exceedances of water quality objectives	No evidence of toxicity	Indications of alteration	Alteration may not be due to toxic contamination Test organisms not sensitive to problem pollutants	No action necessary due to toxic chemicals Initiate upstream source identification (for physical sources) as a high priority Consider whether different or additional test organisms should be evaluated

	Chemistry	Toxicity	Benthic Alteration	Example Conclusions	Possible Actions or Decisions
6.	Exceedance of water quality objectives	Evidence of toxicity	No indications of alteration	Toxic contaminants are bioavailable, but in situ effects are not demonstrable Benthic analysis not sensitive enough to detect impact Potentially harmful pollutants not yet concentrated enough to change community	Determine if chemical and toxicity tests indicate persistent degradation Recheck benthic analyses; consider additional data analyses If recheck indicates benthic alteration, perform TIE to identify contaminants of concern, based on TIE metric Initiate upstream source identification as a high priority If recheck shows no effect, use TIE to identify contaminants of concern, based on TIE metric Initiate upstream source identification as a medium priority
7.	No persistent exceedances of water quality objectives	Evidence of toxicity	Indications of alteration	Unmeasured toxic contaminants are causing degradation Pollutant causing toxicity at very low levels Benthic impact due to habitat disturbance, not toxicity	Recheck chemical analyses and consider additional advanced analyses Use TIE to identify contaminants of concern, based on TIE metric Initiate upstream source identification as a high priority Consider potential role of physical habitat disturbance
8.	Exceedance of water quality objectives	No evidence of toxicity	Indications of alteration	Test organisms not sensitive to problem pollutants Benthic impact due to habitat disturbance, not toxicity	TIE would not provide useful information with no evidence of toxicity Initiate upstream source identification as a high priority Consider whether different or additional test organisms should be evaluated Consider potential role of physical habitat disturbance

Table C-11.6
Mass Loads from Sampled Storms: 2005-06 SAR

Station	Period	Volume Sampled	Type	Nitrate As NO_3	NH_3 as N	TKN	Total Phos. as PO_4	Ortho Phos. as P	TSS	VSS	Cd	Cr	Cu	Pb	Ni	Ag	Zn	As	Se
		ac-ft		lbs					tons		lbs								
BCC02	Jan 14-18, 2006	74	Total	2938	10	423	145	15	2.2	0.91	0.05	0.33	3.44	0.63	1.46	0.05	15.67	0.89	0.24
			Dissolved								0.05	0.15	1.81	0.12	1.19	0.05	9.03	0.84	0.19
	Mar 27-Apr 1, 2006	718	Total	9782	154	1352	2017	191	87.4	13.5	0.49	7.31	34.8	13.24	11.84	0.49	205.26	3.96	0.64
			Dissolved								0.49	1.55	12.71	0.49	6.11	0.49	70.48	2.93	0.6
	May 22-26, 2006	282	Total	4023	263	1168	600	44	24.3	5.8	0.22	1.8	10.79	4.23	5.9	0.21	54.14	2.3	0.67
			Dissolved								0.19	0.51	6.4	0.19	5.21	0.19	21.11	1.78	0.56
CARB01	Jan 14-18, 2006	28	Total	790	4	131	75	4	2.5	1.0	0.02	0.17	1.87	0.5	0.52	0.02	7.78	0.41	0.09
			Dissolved								0.02	0.05	0.88	0.04	0.36	0.02	2.49	0.38	0.07
	Mar 27-Apr 1, 2006	656	Total	4085	89	1115	3150	145	278.6	57.3	2.86	11.39	91.47	54.8	18.03	0.45	675.34	5.64	2.98
			Dissolved								0.45	1.14	12.19	0.45	5.83	0.45	31.13	2.37	0.67
	May 22-26, 2006	216	Total	3721	145	843	511	51	3.6	2.2	0.15	0.51	8.64	1.3	2.86	0.15	29.99	1.44	0.42
			Dissolved								0.15	0.33	6.9	0.28	2.79	0.15	19.07	1.36	0.42
CCBA01	Jan 14-18, 2006	168	Total	5657	23	700	255	16	14.8	4.8	0.12	1.04	6.72	1.77	3.61	0.12	31.94	2.07	0.72
			Dissolved								0.11	0.41	3.09	0.11	2.43	0.11	10.84	1.57	0.72
	Mar 28-Apr 1, 2006	1531	Total	15025	208	1965	4905	356	253.8	39.9	1.04	13.45	63.09	22.9	29.78	1.05	273.52	7.59	1.69
			Dissolved								1.04	2.59	27.34	1.04	14.6	1.04	38.65	5.79	2.09
	May 22-26, 2006	583	Total	10209	319	1651	1002	77	17.9	5.9	0.43	1.68	18.26	3.24	9.41	0.41	69.52	2.74	1.37
			Dissolved								0.42	0.86	12.68	0.4	8.32	0.4	37.04	2.48	1.39
FULA03	Jan 14-18, 2006	41	Total	955	7	138	92	9	3.1	1.2	0.03	0.26	2.25	0.74	0.99	0.03	10.27	0.32	0.07
			Dissolved								0.03	0.06	0.87	0.03	0.64	0.03	3.39	0.3	0.04
	Mar 27-Apr 1, 2006	493	Total	5956	94	936	1732	149	97.8	16.6	0.6	6.94	27.24	10.61	12.19	0.34	133.38	2.34	0.55
			Dissolved								0.34	2.25	12.22	0.34	6.19	0.34	33.84	1.63	0.65
	May 22-26, 2006	194	Total	2989	156	1013	611	58	40.8	8.6	0.69	1.84	12.92	3.92	5.89	0.13	68.13	1.15	0.37
			Dissolved								1.13	0.21	5.14	0.21	3.96	0.13	17.06	0.98	0.17

Table C-11.6
Mass Loads from Sampled Storms: 2005-06 SAR

Station	Period	Volume Sampled	Type	Nitrate As NO_3	NH_3 as N	TKN	Total Phos. as PO_4	Ortho Phos. as P	TSS	VSS	Cd	Cr	Cu	Pb	Ni	Ag	Zn	As	Se
		ac-ft		lbs					tons		lbs								
BARSED	Oct 16-21, 2005	121	Total	5681	180	743	499	74	13.2	2.8	0.08	1.37	6.36	1.48	2.62	0.08	20.73	1.61	3.98
			Dissolved								0.08	0.38	2.79	0.08	1.97	0.08	5.95	1.34	4.25
	Feb 27-Mar 4, 2006	699	Total	32660	128	1847	3178	545	152.4	24.5	0.54	6.36	36.15	9.8	11.35	0.47	132.42	6.9	11.59
			Dissolved								0.47	1.32	11.65	0.47	7	0.47	25.24	4.85	11.65
CICF25	Feb 27-Mar 4, 2006	53	Total	11697	53	275	418	95	20.7	2.8	0.11	0.67	3.07	0.81	1.24	0.04	10.72	0.64	0.08
			Dissolved								0.04	0.14	1.35	0.04	0.79	0.04	1.85	0.49	0.04
CMCG02	Feb 27-Mar 2, 2006	17	Total	152	16	63	54	14	0.92	0.45	0.01	0.11	1.23	0.21	0.19	0.01	4.27	0.07	0.01
			Dissolved								0.01	0.07	0.85	0.04	0.15	0.01	2.2	0.06	0.01
SADF01	Oct 16-20, 2005	97	Total	2493	174	763	389	45	8.3	2.9	0.13	1.09	10.84	2.23	3.07	0.07	37.45	0.81	0.98
			Dissolved								0.07	0.45	5.5	0.38	2.51	0.07	20.62	0.73	0.92
	Feb 27-Mar 4, 2006	354	Total	5422	227	744	649	88	37.1	9.0	0.24	2.34	23.45	8.57	5.65	0.24	83.22	1.82	2.97
			Dissolved								0.24	0.38	6.95	0.24	3.84	0.24	13.94	1.29	2.55
SDMF05	Oct 16-20, 2005	471	Total	35186	886	3696	1771	273	25.0	9.8	0.02	0.11	0.57	0.08	0.62	0.02	1.33	0.41	0.69
			Dissolved								0.02	0.02	0.32	0.02	0.55	0.02	0.62	0.44	0.78
	Feb 27-Mar 4, 2006	2175	Total	73044	1010	5046	9537	1604	500.1	75.1	5.42	19.63	102.04	26.44	36.93	1.48	327.7	21.16	14.88
			Dissolved								1.46	3.01	37.85	1.46	19.75	1.46	58.84	15.25	11.85
WYLSED	Oct 17-21, 2005	128	Total	8556	207	1004	643	113	21.0	5.7	0.27	1.52	6.27	1.08	3.85	0.09	18.02	1.85	0.63
			Dissolved								0.09	0.22	2.99	0.09	2.76	0.09	4.17	1.64	0.55
	Feb 27-Mar 4, 2006	564	Total	23990	394	1320	3697	510	312.3	63.9	1.79	9.3	34.77	9.4	16.11	0.38	122.76	6.85	1.28
			Dissolved								0.38	0.74	17.36	0.38	6.64	0.38	17.65	4.09	0.64

Table C-11.7
Flow-weighted Event Mean Concentrations for Sampled Storms: 2005-06 SAR

Station	Period	Volume Sampled	Type	Nitrate As NO_3	NH_3 as N	TKN	Total Phos. as PO_4	Ortho Phos. as P	TSS	VSS	Cd	Cr	Cu	Pb	Ni	Ag	Zn	As	Se	Hardness as $CaCO_3$
		ac-ft		mg/L							µg/L									mg/L
BARSED	Oct 16-21, 2005	121	Total	17.27	0.55	2.26	1.52	0.22	80.2	17.2	0.24	4.17	19.34	4.50	7.97	0.24	63.03	4.90	12.10	343.3
			Dissolved								0.24	1.16	8.48	0.24	5.99	0.24	18.09	4.07	12.92	
	Feb 27-Mar 4, 2006	699	Total	17.19	0.07	0.97	1.67	0.29	160.4	25.8	0.28	3.35	19.03	5.16	5.97	0.25	69.70	3.63	6.10	198.1
			Dissolved								0.25	0.69	6.13	0.25	3.68	0.25	13.28	2.55	6.13	
CICF25	Feb 27-Mar 4, 2006	53	Total	81.20	0.37	1.91	2.90	0.66	287.9	39.2	0.76	4.65	21.31	5.62	8.61	0.28	74.41	4.44	0.56	234.4
			Dissolved								0.28	0.97	9.37	0.28	5.48	0.28	12.84	3.40	0.28	
CMCG02	Feb 27-Mar 2, 2006	17	Total	3.29	0.35	1.36	1.17	0.30	40.0	19.4	0.22	2.38	26.62	4.54	4.11	0.22	92.41	1.51	0.22	72.5
			Dissolved								0.22	1.51	18.40	0.87	3.25	0.22	47.61	1.30	0.22	
SADF01	Oct 16-20, 2005	97	Total	9.46	0.66	2.89	1.48	0.17	63.3	22.3	0.49	4.13	41.11	8.46	11.64	0.27	142.04	3.07	3.72	296.1
			Dissolved								0.27	1.71	20.86	1.44	9.52	0.27	78.21	2.77	3.49	
	Feb 27-Mar 4, 2006	354	Total	5.63	0.24	0.77	0.67	0.09	77.1	18.6	0.25	2.43	24.37	8.91	5.87	0.25	86.49	1.89	3.09	246.6
			Dissolved								0.25	0.39	7.22	0.25	3.99	0.25	14.49	1.34	2.65	
SDMF05	Oct 16-20, 2005	471	Total	27.48	0.69	2.89	1.38	0.21	39.1	15.4	0.02	0.09	0.45	0.06	0.48	0.02	1.04	0.32	0.54	29.2
			Dissolved								0.02	0.02	0.25	0.02	0.43	0.02	0.48	0.34	0.61	
	Feb 27-Mar 4, 2006	2175	Total	12.36	0.17	0.85	1.61	0.27	169.2	25.4	0.92	3.32	17.26	4.47	6.25	0.25	55.43	3.58	2.52	158.2
			Dissolved								0.25	0.51	6.40	0.25	3.34	0.25	9.95	2.58	2.00	
WYLSED	Oct 17-21, 2005	128	Total	24.59	0.59	2.89	1.85	0.32	120.5	32.9	0.78	4.37	18.02	3.10	11.07	0.26	51.79	5.32	1.81	311.0
			Dissolved								0.26	0.63	8.59	0.26	7.93	0.26	11.99	4.71	1.58	
	Feb 27-Mar 4, 2006	564	Total	15.65	0.26	0.86	2.41	0.33	407.4	83.4	1.17	6.07	22.68	6.13	10.51	0.25	80.08	4.47	0.83	148.0
			Dissolved								0.25	0.48	11.32	0.25	4.33	0.25	11.51	2.67	0.42	

Table C-11.7
Flow-weighted Event Mean Concentrations for Sampled Storms: 2005-06 SAR

Station	Period	Volume Sampled	Type	Nitrate As NO_3	NH_3 as N	TKN	Total Phos. as PO_4	Ortho Phos. as P	TSS	VSS	Cd	Cr	Cu	Pb	Ni	Ag	Zn	As	Se	Hardness as $CaCO_3$
		ac-ft		mg/L							µg/L									mg/L
BCC02	Jan 14-18, 2006	74	Total	14.61	0.05	2.1	0.72	0.07	21.6	9.0	0.25	1.64	17.10	3.13	7.26	0.25	77.91	4.42	1.19	218.5
			Dissolved								0.25	0.75	9.00	0.60	5.92	0.25	44.89	4.18	0.94	
	Mar 27-Apr 1, 2006	718	Total	5.01	0.08	0.69	1.03	0.10	89.6	13.8	0.25	3.75	17.83	6.78	6.07	0.25	105.18	2.03	0.33	94.8
			Dissolved								0.25	0.79	6.51	0.25	3.13	0.25	36.11	1.50	0.31	
	May 22-26, 2006	282	Total	5.25	0.34	1.52	0.78	0.06	63.5	15.1	0.29	2.35	14.08	5.52	7.70	0.27	70.63	3.00	0.87	193.9
			Dissolved								0.25	0.67	8.35	0.25	6.80	0.25	27.54	2.32	0.73	
CARB01	Jan 14-18, 2006	28	Total	10.38	0.05	1.72	0.99	0.05	65.8	27.4	0.26	2.23	24.57	6.57	6.83	0.26	102.22	5.39	1.18	160.0
			Dissolved								0.26	0.66	11.56	0.53	4.73	0.26	32.72	4.99	0.92	
	Mar 27-Apr 1, 2006	656	Total	2.29	0.05	0.63	1.77	0.08	312.5	64.3	1.60	6.39	51.30	30.73	10.11	0.25	378.75	3.16	1.67	72.2
			Dissolved								0.25	0.64	6.84	0.25	3.27	0.25	17.46	1.33	0.38	
	May 22-26, 2006	216	Total	6.34	0.25	1.44	0.87	0.09	12.2	7.4	0.26	0.87	14.72	2.21	4.87	0.26	51.08	2.45	0.72	110.2
			Dissolved								0.26	0.56	11.75	0.48	4.75	0.26	32.48	2.32	0.72	
CCBA01	Jan 14-18, 2006	168	Total	12.39	0.05	1.53	0.56	0.04	64.9	21.0	0.26	2.28	14.72	3.88	7.91	0.26	69.95	4.53	1.58	585.9
			Dissolved								0.24	0.90	6.77	0.24	5.32	0.24	23.74	3.44	1.58	
	Mar 28-Apr 1, 2006	1531	Total	3.61	0.05	0.47	1.18	0.09	122.0	19.2	0.25	3.23	15.16	5.50	7.16	0.25	65.73	1.82	0.41	105.7
			Dissolved								0.25	0.62	6.57	0.25	3.51	0.25	9.29	1.39	0.50	
	May 22-26, 2006	583	Total	6.44	0.2	1.04	0.63	0.05	22.7	7.5	0.27	1.06	11.52	2.04	5.94	0.26	43.87	1.73	0.86	150.8
			Dissolved								0.27	0.54	8.00	0.25	5.25	0.25	23.37	1.57	0.88	
FULA03	Jan 14-18, 2006	41	Total	8.57	0.06	1.24	0.83	0.08	55.3	21.0	0.27	2.33	20.19	6.64	8.88	0.27	92.16	2.87	0.63	213.4
			Dissolved								0.27	0.54	7.81	0.27	5.74	0.27	30.42	2.69	0.36	
	Mar 27-Apr 1, 2006	493	Total	4.44	0.07	0.7	1.29	0.11	146.0	24.7	0.45	5.18	20.33	7.92	9.10	0.25	99.54	1.75	0.41	111.3
			Dissolved								0.25	1.68	9.12	0.25	4.62	0.25	25.25	1.22	0.49	
	May 22-26, 2006	194	Total	5.67	0.3	1.92	1.16	0.11	154.8	32.8	1.31	3.49	24.50	7.43	11.17	0.25	129.20	2.18	0.70	228.0
			Dissolved								2.14	0.40	9.75	0.40	7.51	0.25	32.35	1.86	0.32	

Table C-11.8. Summary of Exceedances of CTR Criteria at Mass Loading Stations for Sampled Storms 2004-2005

				Freshwater		Saltwater			
		Sample Size		Acute		Acute		Chronic	
Station	Channel	Acute	Chronic	Cu	Zn	Cu	Zn	Cu	Ni
BARSED	Peters Canyon Wash at Barranca Parkway	8	2						
BCC02	Bolsa Chica Channel at Westminster	13	3			7		3	1
CARB01	Carbon Creek at Bloomfield	13	3						
CCBA01	Coyote Creek d/s Artesia Blvd.	13	3						
CICF25	Central Irvine Channel at I-5	8	1	1					
CMCG02	Costa Mesa Channel at Highland	6	1			6	2	1	
EGWC05	East Garden Grove Wintersburg Channel at Gothard	9	2			9		2	
FULA03	Fullerton Creek at Highland Ave	12	3	2	1				
HCWF27	Hicks Canyon Wash u/s confluence of F06	4	1	1					
SADF01	Santa Ana Delhi Channel u/s Irvine Avenue	7	2			6		2	1
SDMF05	San Diego Creek at Campus Drive	7	2			2		2	
WYLSED	San Diego Creek at Harvard Avenue	7	2						
	Totals	107	25	4	1	30	2	10	2

Table C-11.9
Toxicity Testing at Mass Emission Monitoring Sites: 2005-06 SAR

Station	Date Start	Type	Sed Tox H. Azteca % Surv	Acute Hyallela Azteca Survival Surv in 100%	TUa	Chronic Sea Urchin Fertilization Fert in 100%	NOEC	TUc	96 hr IC_{50}	Chronic Sea Urchin Development NOEC	TUc	96 hr IC_{50}	Chronic Mysidopsis Bahia Survival and Growth: Survival Surv in 100%	NOEC	TUc	96 hr IC_{50}	TUa	Growth Grwth in 100%	NOEC	TUc	96 hr IC_{50}
HCWF27	2/27/06	SF				80.75	100.00	1.00	>100	100.00	1.00	>100	5.00	<50.00	>2.00	62.50	1.60	33.33	50	2.00	86.27
CICF25	8/21/05	DW	0.00	100.00	0.00																
	10/16/05	FF				16.75	<50.00	>2.00	74.51				52.50	50	2.00	>100	0.99	52.98	50	2.00	95.10
	11/1/05	DW	17.50	100.00	0.00																
	2/27/06	SF				100.00	100.00	1.00	>100	50.00	2.00	82.62	27.50	50	2.00	78.91	1.27	100.00	100	1.00	>100
BARSED	8/21/05	DW	95.00	100.00	0.00																
	10/17/05	SF				1.00	<50.00	>2.00	28.01				62.50	50	2.00	>100	0.93	64.29	100	1.00	>100
	11/1/05	DW	5.00	90.00	0.59																
	3/1/06	SF				100.00	100.00	1.00	>100	100.00	1.00	>100	75.00	50	2.00	78.91	1.27	100.00	100	1.00	>100
	6/26/06	DW	17.50	100.00	0.00																
WYLSED	8/21/05	DW	0.00	100.00	0.00																
	10/17/05	FF				9.00	<50.00	>2.00	70.29				85.00	100	1.00	>100	0.69	100.00	100	1.00	>100
	11/1/05	DW	55.00	75.00	0.82																
	2/27/06	SF				98.50	100.00	1.00	>100	100.00	1.00	>100	70.00	100	1.00	>100	0.87	100.00	100	1.00	>100
	6/26/06	DW		90.00	0.59																
SDMF05	8/21/05	DW	92.50	100.00	0.00																
	10/16/05	FF				21.00	<50.00	>2.00	73.10				90.00	100	1.00	>100	0.59	100.00	100	1.00	>100
	11/1/05	DW	57.00	100.00	0.00																
	2/27/06	SF				92.50	100.00	1.00	>100	100.00	1.00	>100	87.50	100	1.00	>100	0.65	45.49	<6.25	>16.00	5.16
	6/26/06	DW	78.00	95.00	0.41																
SADF01	8/21/05	DW	95.00	95.00	0.41																
	10/16/05	FF				1.00	<50.00	>2.00	30.44				90.00	100	1.00	>100	0.59	100.00	100.00	1.00	>100
	11/1/05	DW	50.00	95.00	0.41																
	2/27/06	SF				91.75	100.00	1.00	>100.0	100.00	1.00	>100	97.50	100	1.00	>100	0.23	94.45	100.00	1.00	>100
	6/26/06	DW	95.00	65.00	0.91																
CMCG02	8/21/05	DW	0.00	85.00	0.69																
	10/16/05	FF				0.00	<50.00	>2.00	25.00				0.00	<50	>2.00	58.70	1.70	0.00	50.00	2.00	54.04
	11/1/05	DW	20.00	64.29	1.56																
	2/27/06	SF				94.25	100.00	1.00	>100	100.00	1.00	>100	67.50	100	1.00	>100.00	0.89	46.71	<6.25	>16.00	4.97

Table C-11.9
Toxicity Testing at Mass Emission Monitoring Sites: 2005-06 SAR

Station	Date Start	Type	Sed Tox	Acute Hyallela Azteca Survival		Chronic Sea Urchin Fertilization				Chronic Sea Urchin Development			Chronic Mysidopsis Bahia Survival and Growth								
													Survival					Growth			
			H. Azteca	Surv in		Fert in			96 hr			96 hr	Surv in					Grwth in			
			% Surv	100%	TUa	100%	NOEC	TUc	IC_{50}	NOEC	TUc	IC_{50}	100%	NOEC	TUc	96 hr IC_{50}	TUa	100%	NOEC	TUc	96 hr IC_{50}
TBTD02	11/15/05	DW				100.00	100.00	1.00	>100	100.00	1.00	>100	92.50	100	1.00	>100.00	0.51	79.31	100.00	1.00	>100.00
EGWC05	8/23/05	DW		100.00	0.00																
	10/18/05	SF				0.00	50.00	2.00	74.23				92.50	100	1.00	>100.00	0.51	100.00	100.00	1.00	>100.00
	11/14/05	DW		90.00	0.59																
	3/29/06	SF																			
BCC02	8/23/05	DW		100.00	0.00																
	10/18/05	SF				0.00	50.00	2.00	74.22				80.00	100	1.00	>100.00	0.77	100.00	100.00	1.00	>100.00
	11/14/05	DW		85.00	0.69																
	1/14/06	SF				4.50	<6.25	>16.00	69.97	25.00	4.00	69.83	90.00	100	1.00	>100.00	0.59	48.87	100.00	1.00	86.21
	3/28/06	SF				100.00	100.00	1.00	>100	100.00	1.00	>100	97.50	100	1.00	>100.00	0.23	100.00	100.00	1.00	>100.00
CARB01	8/23/05	DW		100.00	0.00																
	10/18/05	SF				0.00	50.00	2.00	74.43				90.00	100	1.00	>100.00	0.59	100.00	100.00	1.00	>100.00
	11/14/05	DW		100.00	0.00																
	1/14/06	SF				0.00	25.00	4.00	71.47	12.50	8.00	67.18	70.00	100	1.00	>100.00	0.87	68.81	100.00	1.00	>100.00
	3/27/06	SF				92.00	50.00	2.00	>100	100.00	1.00	>100	90.00	100	1.00	>100.00	0.59	100.00	100.00	1.00	>100.00
	3/28/06	SF				100.00	100.00	1.00	>100	25.00	4.00	>100	5.00	<6.25	>16.00	4.03	24.81	100.00	100.00	1.00	>100.00
CCBA01	8/23/05	DW		100.00	0.00																
	10/18/05	SF				89.00	50.00	2.00	>100				97.50	100	1.00	>100.00	0.23	100.00	100.00	1.00	>100.00
	11/14/05	DW		100.00	0.00																
	1/14/06	SF				20.00	25.00	4.00	76.57	25.00	4.00	73.47	70.00	50	2.00	>100.00	0.87	100.00	100.00	1.00	>100.00
	3/28/06	SF				98.50	100.00	1.00	>100	100.00	1.00	>100	85.00	100	1.00	>100.00	0.69	100.00	100.00	1.00	>100.00
FULA03	8/23/05	DW		100.00	0.00																
	10/18/05	SF				81.50	50.00	2.00	>100				95.00	100	1.00	>100.00	0.41	100.00	100.00	1.00	>100.00
	11/14/05	DW		90.00	0.59																
	1/14/06	SF				25.50	<6.25	>16.00	77.10	12.50	8.00	74.16	60.00	50	2.00	>100.00	0.94	100.00	100.00	1.00	>100.00
	3/27/06	SF				93.75	50.00	2.00	>100	100.00	1.00	>100	65.00	50	2.00	>100.00	0.91	100.00	100.00	1.00	>100.00

Table C-11.9
Toxicity Testing at Mass Emission Monitoring Sites: 2005-06 SAR

Station	Date Start	Type	Chronic Selenastrum Algae Growth			Chronic Fathead Larvae Survival and Growth										Chronic Ceriodaphnia Survival and Reproduction									
						Survival					Growth					Survival					Reproduction				
			NOEC	TUc	96 hr IC_{50}	Surv in 100%	NOEC	TUc	96 hr IC_{50}	TUa	Grth in 100%	NOEC	TUc	96 hr IC_{50}		Surv in 100%	NOEC	TUc	10day IC_{50}	TUa	Repro in 100%	NOEC	TUc	10day IC_{50}	
HCWF27	2/27/06	SF																							
CICF25	8/21/05	DW	<6.25	>10.00	79.91	90.00	100.00	1.00	>100.00	0.59	100.00	100.00	1.00	>100		100.00	100.00	1.00	>100.00	0.00	100.00	100.00	1.00	>100.00	
	10/16/05	FF				100.00	100.00	1.00	>100.00	0.00	100.00	100.00	1.00	>100		100.00	100.00	1.00	>100.00	0.00	100.00	100.00	1.00	>100.00	
	11/1/05	DW	100.00	1.00	>100.00	85.00	100.00	1.00	>100.00	0.69	100.00	100.00	1.00	>100		100.00	100.00	1.00	>100.00	0.00	100.00	100.00	1.00	>100.00	
	2/27/06	SF																							
BARSED	8/21/05	DW	100.00	1.00	>100.00	100.00	100.00	1.00	>100.00	0.00	100.00	100.00	1.00	>100		100.00	100.00	1.00	>100.00	0.00	100.00	100.00	1.00	>100.00	
	10/17/05	SF				92.50	100.00	1.00	>100.00	0.51	78.28	50.00	2.00	>100		100.00	100.00	1.00	>100.00	0.00	100.00	100.00	1.00	>100.00	
	11/1/05	DW	100.00	1.00	>100.00	97.50	100.00	1.00	>100.00	0.23	100.00	100.00	1.00	>100		100.00	100.00	1.00	>100.00	0.00	100.00	100.00	1.00	>100.00	
	3/1/06	SF																							
	6/26/06	DW	50.00	2.00	>100.00	45.00	100.00	1.00	40.43	2.47	83.73	100.00	1.00	>100		100.00	100.00	1.00	>100.00	0.00	98.30	100.00	1.00	>100.00	
WYLSED	8/21/05	DW	100.00	1.00	>100.00	95.00	100.00	1.00	>100.00	0.41	100.00	100.00	1.00	>100		80.00	100.00	1.00	>100.00	0.00	100.00	100.00	1.00	>100.00	
	10/17/05	FF				95.00	100.00	1.00	>100.00	0.41	96.23	100.00	1.00	>100		90.00	100.00	1.00	>100.00	0.59	100.00	100.00	1.00	>100.00	
	11/1/05	DW	100.00	1.00	>100.00	100.00	100.00	1.00	>100.00	0.00	100.00	100.00	1.00	>100		90.00	100.00	1.00	>100.00	0.59	100.00	100.00	1.00	>100.00	
	2/27/06	SF																							
	6/26/06	DW	100.00	1.00	>100.00	75.00	100.00	1.00	>100.00	0.82	59.09	50.00	2.00	>100		100.00	100.00	1.00	>100.00	0.00	100.00	100.00	1.00	>100.00	
SDMF05	8/21/05	DW	12.50	8.00	80.52	97.50	100.00	1.00	>100.00	0.23	100.00	100.00	1.00	>100		100.00	100.00	1.00	>100.00	0.00	100.00	100.00	1.00	>100.00	
	10/16/05	FF				100.00	100.00	1.00	>100.00	0.00	93.36	100.00	1.00	>100		100.00	100.00	1.00	>100.00	0.00	100.00	100.00	1.00	>100.00	
	11/1/05	DW	100.00	1.00	>100.00	97.50	100.00	1.00	>100.00	0.23	100.00	100.00	1.00	>100		100.00	100.00	1.00	>100.00	0.00	83.25	100.00	1.00	>100.00	
	2/27/06	SF																							
	6/26/06	DW	100.00	1.00	>100.00	25.00	100.00	1.00	32.76	3.05	42.97	100.00	1.00	39.16		100.00	100.00	1.00	>100.00	0.00	100.00	100.00	1.00	>100.00	
SADF01	8/21/05	DW	100.00	1.00	>100.00	95.00	100.00	1.00	>100.00	0.41	100.00	100.00	1.00	>100		100.00	100.00	1.00	>100.00	0.00	100.00	100.00	1.00	>100.00	
	10/16/05	FF				97.50	100.00	1.00	>100.00	0.23	100.00	100.00	1.00	>100		100.00	100.00	1.00	>100.00	0.00	100.00	100.00	1.00	>100.00	
	11/1/05	DW	100.00	1.00	>100.00	92.50	100.00	1.00	>100.00	0.51	100.00	100.00	1.00	>100		100.00	100.00	1.00	>100.00	0.00	88.84	100.00	1.00	>100.00	
	2/27/06	SF																							
	6/26/06	DW	50.00	2.00	>100.00	35.00	<50.00	>2.00	47.50	2.11	65.55	100	1.00	>100		90.00	100.00	1.00	>100.00	0.59	92.41	100.00	1.00	>100.00	
CMCG02	8/21/05	DW	100.00	1.00	>100.00	95.00	100.00	1.00	>100.00	0.41	100.00	100.00	1.00	>100		100.00	100.00	1.00	>100.00	0.00	100.00	100.00	1.00	>100.00	
	10/16/05	FF				80.00	50.00	2.00	>100.00	0.77	33.73	<50.00	>2.00	76.23		100.00	100.00	1.00	>100.00	0.00	100.00	100.00	1.00	>100.00	
	11/1/05	DW	100.00	1.00	>100.00	100.00	100.00	1.00	>100.00	0.00	100.00	100.00	1.00	>100		100.00	100.00	1.00	>100.00	0.00	100.00	100.00	1.00	>100.00	
	2/27/06	SF																							

Table C-11.9
Toxicity Testing at Mass Emission Monitoring Sites: 2005-06 SAR

Station	Date Start	Type	Chronic Selenastrum Algae Growth			Chronic Fathead Larvae Survival and Growth									Chronic Ceriodaphnia Survival and Reproduction								
						Survival					Growth				Survival					Reproduction			
			NOEC	TUc	96 hr IC_{50}	Surv in 100%	NOEC	TUc	96 hr IC_{50}	TUa	Grth in 100%	NOEC	TUc	96 hr IC_{50}	Surv in 100%	NOEC	TUc	10day IC_{50}	TUa	Repro in 100%	NOEC	TUc	10day IC_{50}
TBTD02	11/15/05	DW																					
EGWC05	8/23/05	DW	100.00	1.00	>100.00										100.00	100.00	1.00	>100.00	0.00	100.00	100.00	1.00	>100.00
	10/18/05	SF													90.00	100.00	1.00	>100.00	0.59	100.00	100.00	1.00	>100.00
	11/14/05	DW	12.50	8.00	>100.00										100.00	100.00	1.00	>100.00	0.00	100.00	100.00	1.00	>100.00
	3/29/06	SF																					
BCC02	8/23/05	DW	100.00	1.00	>100.00										100.00	100.00	1.00	>100.00	0.00	100.00	100.00	1.00	>100.00
	10/18/05	SF													80.00	100.00	1.00	>100.00	0.77	100.00	100.00	1.00	>100.00
	11/14/05	DW	100.00	1.00	>100.00										90.00	100.00	1.00	>100.00	0.59	85.76	100.00	1.00	>100.00
	1/14/06	SF																					
	3/28/06	SF																					
CARB01	8/23/05	DW	100.00	1.00	>100.00										100.00	100.00	1.00	>100.00	0.00	100.00	100.00	1.00	>100.00
	10/18/05	SF													90.00	100.00	1.00	>100.00	0.59	100.00	100.00	1.00	>100.00
	11/14/05	DW	100.00	1.00	>100.00										100.00	100.00	1.00	>100.00	0.00	100.00	100.00	1.00	>100.00
	1/14/06	SF																					
	3/27/06	SF																					
	3/28/06	SF																					
CCBA01	8/23/05	DW	50.00	2.00	>100.00										100.00	100.00	1.00	>100.00	0.00	100.00	100.00	1.00	>100.00
	10/18/05	SF													100.00	100.00	1.00	>100.00	0.00	100.00	100.00	1.00	>100.00
	11/14/05	DW	50.00	2.00	>100.00										100.00	100.00	1.00	>100.00	0.00	100.00	100.00	1.00	>100.00
	1/14/06	SF																					
	3/28/06	SF																					
FULA03	8/23/05	DW	100.00	1.00	>100.00										100.00	100.00	1.00	>100.00	0.00	100.00	100.00	1.00	>100.00
	10/18/05	SF													100.00	100.00	1.00	>100.00	0.00	100.00	100.00	1.00	>100.00
	11/14/05	DW	100.00	1.00	>100.00										100.00	100.00	1.00	>100.00	0.00	100.00	100.00	1.00	>100.00
	1/14/06	SF																					
	3/27/06	SF																					

Table C-11.10
Aquatic and Sediment Toxicity Testing at Estuaries / Wetlands Stations : 2005-06 SAR

Station	Site Name	Event	Type	10-day Amphipod Survival Test	Chronic Sea Urchin Fertilization					Chronic Sea Urchin Development				Chronic Mysidopsis Bahia Survival and Growth										Chronic Inland Silversides Larvae Survival and Growth									
														Survival					Growth					Survival					Growth				
					Fert in			96 hr				96 hr		Surv in			96 hr		Grwth in			96 hr		Surv in			96 hr		Grwth in			96 hr	
				% Surv	100%	NOEC	TUc	IC_{50}	TUa	NOEC	TUc	IC_{50}		100%	NOEC	TUc	IC_{50}	TUa	100%	NOEC	TUc	IC_{50}	TUa	100%	NOEC	TUc	IC_{50}	TUa	100%	NOEC	TUc	IC_{50}	TUa
HUNBCC	Huntington Harbour	8/19/05	DW	85.00	99.25	100.00	1.00	>100.00	0.00	100.00	1.00	>100.00		92.60	100.00	1.00	>100.00	0.51	99.24	100.00	1.00	>100.00	0.00										
	Bolsa Chica Channel	3/29/06	SW		100.00	100.00	1.00	>100.00	0.00	100.00	1.00	>100.00		85.00	100.00	1.00	>100.00	0.69	100.00	100.00	1.00	>100.00	0.00										
		3/31/06	SW		100.00	100.00	1.00	>100.00	0.00	100.00	1.00	>100.00		100.00	100.00	1.00	>100.00	0.00	100.00	100.00	1.00	>100.00	0.00										
		4/2/06	SW		100.00	100.00	1.00	>100.00	0.00	100.00	1.00	>100.00		67.50	100.00	1.00	>100.00	0.89	63.06	50.00	2.00	>100.00	0.92										
		5/22/06	SW		56.75	25.00	4.00	>100.00	0.96	50.00	2.00	>100.00		97.50	100.00	1.00	>100.00	0.23	75.57	100.00	1.00	>100.00	0.82										
		6/22/06	DW	3.00	97.50	100.00	1.00	>100.00	0.23	100.00	1.00	>100.00		82.50	100.00	1.00	>100.00	0.73	100.00	100.00	1.00	>100.00	0.00										
HUNCRB	Huntington Harbour	8/19/05	DW	54.00	98.00	100.00	1.00	>100.00	0.18	100.00	1.00	>100.00		92.50	100.00	1.00	>100.00	0.51	100.00	100.00	1.00	>100.00	0.00										
	Christiana Bay	3/29/06	SW		100.00	100.00	1.00	>100.00	0.00	100.00	1.00	>100.00		100.00	100.00	1.00	>100.00	0.00	100.00	100.00	1.00	>100.00	0.00										
		3/31/06	SW		100.00	100.00	1.00	>100.00	0.00	100.00	1.00	>100.00		100.00	100.00	1.00	>100.00	0.00	100.00	100.00	1.00	>100.00	0.00										
		4/2/06	SW		100.00	100.00	1.00	>100.00	0.00	100.00	1.00	>100.00		82.50	100.00	1.00	>100.00	0.73	91.77	100.00	1.00	>100.00	0.54										
		5/22/06	SW		69.25	25.00	4.00	>100.00	0.88	100.00	1.00	>100.00		65.00	25.00	4.00	>100.00	0.91	47.35	25.00	4.00	46.60	2.15										
		6/22/06	DW	52.00	100.00	100.00	1.00	>100.00	0.00	100.00	1.00	>100.00		87.50	100.00	1.00	>100.00	0.65	100.00	100.00	1.00	>100.00	0.00										
HUNWAR	Huntington Harbour	8/19/05	DW	45.00	97.75	100.00	1.00	>100.00	0.21	100.00	1.00	>100.00		90.00	100.00	1.00	>100.00	0.59	100.00	100.00	1.00	>100.00	0.00										
	Warner	3/29/06	SW		98.50	100.00	1.00	>100.00	0.10	100.00	1.00	>100.00		92.50	100.00	1.00	>100.00	0.51	75.10	100.00	1.00	>100.00	0.82										
		3/31/06	SW		100.00	100.00	1.00	>100.00	0.00	100.00	1.00	>100.00		100.00	100.00	1.00	>100.00	0.00	100.00	100.00	1.00	>100.00	0.00										
		4/2/06	SW		100.00	100.00	1.00	>100.00	0.00	100.00	1.00	>100.00		60.00	50.00	2.00	>100.00	0.94	92.10	100.00	1.00	>100.00	0.53										
		5/22/06	SW		68.00	25.00	4.00	>100.00	0.89	100.00	1.00	>100.00		92.50	100.00	1.00	>100.00	0.51	100.00	100.00	1.00	>100.00	0.00										
		6/22/06	DW	82.00	100.00	100.00	1.00	>100.00	0.00	100.00	1.00	>100.00		92.50	100.00	1.00	>100.00	0.51	100.00	100.00	1.00	>100.00	0.00										
TGDC05	Bolsa Bay	8/19/05	DW	68.00	95.75	100.00	1.00	>100.00	0.37	100.00	1.00	>100.00		92.50	100.00	1.00	>100.00	0.51	100.00	100.00	1.00	>100.00	0.00										
	d/s Tide Gate	3/29/06	SW		100.00	100.00	1.00	>100.00	0.00	95.75	1.00	>100.00		90.00	100.00	1.00	>100.00	0.59	100.00	100.00	1.00	>100.00	0.00										
		3/31/06	SW		100.00	100.00	1.00	>100.00	0.00	100.00	1.00	>100.00		97.50	100.00	1.00	>100.00	0.23	76.78	100.00	1.00	>100.00	0.80										
		4/2/06	SW		100.00	100.00	1.00	>100.00	0.00	100.00	1.00	>100.00		80.00	100.00	1.00	>100.00	0.77	100.00	100.00	1.00	>100.00	0.00										
		5/22/06	SW		73.75	50.00	2.00	>100.00	0.83	25.00	4.00	>100.00		70.00	50.00	2.00	>100.00	0.87	46.59	12.50	8.00	70.97	1.41										
		6/22/06	DW	68.00	98.00	100.00	1.00	>100.00	0.18	100.00	1.00	>100.00		87.50	100.00	1.00	>100.00	0.65	100.00	100.00	1.00	>100.00	0.00										
BBOLR	Bolsa Bay Pier	8/19/05	DW	90.00	96.50	100.00	1.00	>100.00	0.32	100.00	1.00	>100.00		90.00	100.00	1.00	>100.00	0.59	100.00	100.00	1.00	>100.00	0.00										
		3/29/06	SW		100.00	100.00	1.00	>100.00	0.00	100.00	1.00	>100.00		92.50	100.00	1.00	>100.00	0.51	100.00	100.00	1.00	>100.00	0.00										
		3/31/06	SW		100.00	100.00	1.00	>100.00	0.00	100.00	1.00	>100.00		100.00	100.00	1.00	>100.00	0.00	100.00	100.00	1.00	>100.00	0.00										
		4/2/06	SW		99.50	100.00	1.00	>100.00	0.00	100.00	1.00	>100.00		65.00	100.00	1.00	>100.00	0.91	98.39	100.00	1.00	>100.00	0.12										
		5/22/06	SW		70.50	100.00	1.00	>100.00	0.86	100.00	1.00	>100.00		65.00	25.00	4.00	>100.00	0.91	56.82	25.00	4.00	>100.00	0.96										
		6/22/06	DW	79.00	98.75	100.00	1.00	>100.00	0.06	50.00	2.00	>100.00		80.00	100.00	1.00	>100.00	0.77	100.00	100.00	1.00	>100.00	0.00										
TBTMAR	Talbert Marsh	8/19/05	DW	77.00	98.75	100.00	1.00	>100.00	0.06	100.00	1.00	>100.00		100.00	100.00	1.00	>100.00	0.00	100.00	100.00	1.00	>100.00	0.00										
		3/29/06	SW		100.00	100.00	1.00	>100.00	0.00	100.00	1.00	>100.00		85.00	50.00	2.00	>100.00	0.69	100.00	100.00	1.00	>100.00	0.00										
		3/31/06	SW		100.00	100.00	1.00	>100.00	0.00	100.00	1.00	>100.00		95.00	100.00	1.00	>100.00	0.41	100.00	100.00	1.00	>100.00	0.00										
		4/2/06	SW		100.00	100.00	1.00	>100.00	0.00	100.00	1.00	>100.00		0.00	25.00	4.00	36.82	2.72	0.00	25.00	4.00	57.65	1.73										
		5/22/06	SW		66.00	100.00	1.00	>100.00	0.90	100.00	1.00	>100.00		100.00	100.00	1.00	>100.00	0.00	91.48	100.00	1.00	>100.00	0.55										
		6/22/06	DW	88.00	100.00	100.00	1.00	>100.00	0.00		1.00	>100.00		87.50	100.00	1.00	>100.00	0.65	100.00	100.00	1.00	>100.00	0.00										

Table C-11.10
Aquatic and Sediment Toxicity Testing at Estuaries / Wetlands Stations : 2005-06 SAR

Station	Site Name	Event	Type	10-day Amphipod Survival Test	Chronic Sea Urchin Fertilization					Chronic Sea Urchin Development				Chronic Mysidopsis Bahia Survival and Growth										Chronic Inland Silversides Larvae Survival and Growth									
														Survival					Growth					Survival					Growth				
					Fert in 100%	NOEC	TUc	96 hr IC_{50}	TUa	NOEC	TUc	96 hr IC_{50}		Surv in 100%	NOEC	TUc	96 hr IC_{50}	TUa	Grwth in 100%	NOEC	TUc	96 hr IC_{50}	TUa	Surv in 100%	NOEC	TUc	96 hr IC_{50}	TUa	Grwth in 100%	NOEC	TUc	96 hr IC_{50}	TUa
				% Surv																												
UNBJAM	Upper Newport Bay	8/26/05	DW	0.00	80.05	<50.00	>1.00	>100.00	0.76	100.00	1.00	>100.00		87.50	100.00	1.00	>100.00	0.65	100.00	100.00	1.00	100.00	0.00										
	Unit I Basin	11/17/05	DW	0.00	100.00	100.00	1.00	>100.00	0.00	100.00	1.00	>100.00		97.50	100.00	1.00	>100.00	0.23	82.98	100.00	1.00	100.00	0.72										
		2/28/06	SW		60.50	100.00	1.00	>100.00	0.94	100.00	1.00	>100.00		97.50	100.00	1.00	>100.00	0.23	81.73	100.00	1.00	>100.00	0.74	92.50	100.00	1.00	>100.00	0.51	100.00	100.00	1.00	>100.00	0.00
		3/2/06	SW		87.75	50.00	2.00	>100.00	0.64	100.00	1.00	>100.00		95.00	100.00	1.00	>100.00	0.41	100.00	100.00	1.00	>100.00	0.00										
		3/4/06	SW		100.00	100.00	1.00	>100.00	0.00	100.00	1.00	>100.00		0.00	12.50	8.00	36.88	2.71	0.00	25.00	4.00	39.54	2.53										
		4/19/06	DW	0.00	99.25	100.00	1.00	>100.00	0.00	100.00	1.00	>100.00		75.00	100.00	1.00	>100.00	0.82	47.62	100.00	1.00	41.44	2.41										
		6/20/06	DW	3.00	100.00	100.00	1.00	>100.00	0.00	100.00	1.00	>100.00		42.50	50.00	2.00	>100.00	1.04	68.25	100.00	1.00	>100.00	0.88										
UNBSDC	Upper Newport Bay	8/26/05	DW	5.00	81.25	50.00	2.00	>100.00	0.75	50.00	2.00	>100.00		92.50	100.00	1.00	>100.00	0.51	100.00	100.00	1.00	100.00	0.00										
	Unit II Basin	11/17/05	DW	44.00	96.75	50.00	2.00	>100.00	0.30	98.50	1.00	>100.00		95.00	100.00	1.00	>100.00	0.41	96.62	100.00	1.00	100.00	0.31										
		2/28/06	SW		63.75	100.00	1.00	>100.00	0.92	100.00	1.00	>100.00		97.50	100.00	1.00	>100.00	0.23	100.00	100.00	1.00	>100.00	0.00	80.00	100.00	1.00	>100.00	0.77	100.00	100.00	1.00	>100.00	0.00
		3/2/06	SW		94.25	100.00	1.00	>100.00	0.45	25.00	4.00	>100.00		100.00	100.00	1.00	>100.00	0.00	76.99	<6.25	>16.00	>100.00	0.80										
		3/4/06	SW		100.00	100.00	1.00	>100.00	0.00	100.00	1.00	>100.00		0.00	25.00	4.00	41.49	2.41	0.00	25.00	4.00	32.74	3.05										
		4/19/06	DW	21.00	100.00	100.00	1.00	>100.00	0.00	100.00	1.00	>100.00		82.50	100.00	1.00	>100.00	0.73	100.00	100.00	1.00	>100.00	0.00										
		6/20/06	DW	6.00	100.00	100.00	1.00	>100.00	0.00	100.00	1.00	>100.00		57.50	<50.00	>2.00	>100.00	0.96	69.33	100.00	1.00	>100.00	0.87										
UNBNSB	Upper Newport Bay	8/26/05	DW	20.00	91.75	50.00	2.00	>100.00	0.54	<50.00	1.00	>100.00		90.00	100.00	1.00	>100.00	0.59	100.00	100.00	1.00	100.00	0.00										
	Northstar Beach	11/17/05	DW	13.00	96.75	50.00	2.00	>100.00	0.30	100.00	1.00	>100.00		97.50	100.00	1.00	>100.00	0.23	99.11	100.00	1.00	100.00	0.00										
		2/28/06	SW		66.25	12.50	8.00	>100.00	0.90	<6.25	>16.00	>100.00		100.00	100.00	1.00	>100.00	0.00	100.00	100.00	1.00	>100.00	0.00										
		3/2/06	SW		97.75	100.00	1.00	>100.00	0.21	100.00	1.00	>100.00		95.00	100.00	1.00	>100.00	0.41	100.00	100.00	1.00	>100.00	0.00										
		3/4/06	SW		100.00	100.00	1.00	>100.00	0.00	100.00	1.00	>100.00		90.00	100.00	1.00	>100.00	0.59	70.11	50.00	2.00	>100.00	0.87										
		4/19/06	DW	16.00	99.50	100.00	1.00	>100.00	0.00	100.00	1.00	>100.00		65.00	100.00	1.00	>100.00	0.91	100.00	100.00	1.00	>100.00	0.00										
		6/20/06	DW	84.00	100.00	100.00	1.00	>100.00	0.00	100.00	1.00	>100.00		72.50	100.00	1.00	>100.00	0.85	98.70	100.00	1.00	>100.00	0.07										
UNBCHB	Upper Newport Bay	8/26/05	DW	3.00	90.25	50.00	2.00	>100.00	0.58	100.00	1.00	>100.00		85.00	100.00	1.00	>100.00	0.69	100.00	100.00	1.00	100.00	0.00										
	Coast Highway Bridge	11/17/05	DW	3.00	97.25	100.00	1.00	>100.00	0.26	100.00	1.00	>100.00		100.00	100.00	1.00	>100.00	0.00	100.00	100.00	1.00	100.00	0.00										
		2/28/06	SW		69.25	100.00	1.00	>100.00	0.88	53.75	>16.00	>100.00		95.00	100.00	1.00	>100.00	0.41	100.00	100.00	1.00	>100.00	0.00										
		3/2/06	SW		89.25	50.00	2.00	>100.00	0.61	25.00	4.00	>100.00		97.50	100.00	1.00	>100.00	0.23	75.90	100.00	1.00	>100.00	0.81										
		3/4/06	SW		98.50	100.00	1.00	>100.00	0.10	100.00	1.00	>100.00		97.50	100.00	1.00	>100.00	0.23	77.72	100.00	1.00	>100.00	0.79										
		4/19/06	DW	28.00	90.00	100.00	1.00	>100.00	0.59	100.00	1.00	>100.00		77.50	100.00	1.00	>100.00	0.80	100.00	100.00	1.00	>100.00	0.00										
		6/20/06	DW	29.00	100.00	100.00	1.00	>100.00	0.00	100.00	1.00	>100.00		67.50	100.00	1.00	>100.00	0.89	93.30	100.00	1.00	>100.00	0.49										
LNBHIR	Lower Newport Bay	8/26/05	DW	3.00	94.25	100.00	1.00	>100.00	0.45	100.00	1.00	>100.00		92.50	100.00	1.00	>100.00	0.51	100.00	100.00	1.00	100.00	0.00										
	Harbor Island Reach	11/17/05	DW	3.00	100.00	100.00	1.00	>100.00	0.00	100.00	1.00	>100.00		95.00	100.00	1.00	>100.00	0.41	100.00	100.00	1.00	100.00	0.00										
		2/28/06	SW		56.75	100.00	1.00	>100.00	0.96	100.00	1.00	>100.00		97.50	100.00	1.00	>100.00	0.23	100.00	100.00	1.00	>100.00	0.00										
		3/2/06	SW		94.50	100.00	1.00	>100.00	0.44	100.00	1.00	>100.00		97.50	100.00	1.00	>100.00	0.23	100.00	100.00	1.00	>100.00	0.00										
		3/4/06	SW		100.00	100.00	1.00	>100.00	0.00	100.00	1.00	>100.00		90.00	100.00	1.00	>100.00	0.59	56.71	<6.25	>16.00	5.54	18.05										
		4/20/06	DW	12.00	92.00	100.00	1.00	>100.00	0.53	100.00	1.00	>100.00		82.50	100.00	1.00	>100.00	0.73	100.00	100.00	1.00	>100.00	0.00										
		6/21/06	DW	13.00	96.75	100.00	1.00	>100.00	0.30	100.00	1.00	>100.00		80.00	100.00	1.00	>100.00	0.77	76.75	100.00	1.00	>100.00	0.80										
LNBTUB	Lower Newport Bay	8/26/05	DW	77.00	92.00	100.00	1.00	>100.00	0.53	100.00	1.00	>100.00		92.50	100.00	1.00	>100.00	0.51	100.00	100.00	1.00	100.00	0.00										
	Turning Basin	11/17/05	DW	78.00	99.50	100.00	1.00	>100.00	0.00	100.00	1.00	>100.00		95.00	100.00	1.00	>100.00	0.41	94.93	100.00	1.00	100.00	0.41										
		2/28/06	SW		57.25	50.00	2.00	>100.00	0.96	100.00	1.00	>100.00		95.00	100.00	1.00	>100.00	0.41	68.36	25.00	4.00	>100.00	0.88										
		3/2/06	SW		74.25	50.00	2.00	>100.00	0.83	100.00	1.00	>100.00		100.00	100.00	1.00	>100.00	0.00	100.00	100.00	1.00	>100.00	0.00										
		3/4/06	SW		97.50	100.00	1.00	>100.00	0.23	100.00	1.00	>100.00		95.00	100.00	1.00	>100.00	0.41	84.13	100.00	1.00	>100.00	0.71										
		4/20/06	DW	90.00	73.50	<50.00	>2.00	>100.00	0.84	50.00	2.00	>100.00		77.50	100.00	1.00	>100.00	0.80	56.82	100.00	1.00	>100.00	0.96										
		6/21/06	DW	36.00	95.50	100.00	1.00	>100.00	0.38	100.00	1.00	>100.00		95.00	100.00	1.00	>100.00	0.41	100.00	100.00	1.00	>100.00	0.00										
LNBRIN	Lower Newport Bay	8/26/05	DW	66.00	95.00	100.00	1.00	>100.00	0.41	100.00	1.00	>100.00		90.00	100.00	1.00	>100.00	0.59	100.00	100.00	1.00	100.00	0.00										
	Rhine Channel	11/17/05	DW	88.00	98.50	100.00	1.00	>100.00	0.10	100.00	1.00	>100.00		95.00	100.00	1.00	>100.00	0.41	100.00	100.00	1.00	100.00	0.00										
		2/28/06	SW		65.25	50.00	2.00	>100.00	0.91	<6.25	>16.00	>100.00		95.00	100.00	1.00	>100.00	0.41	100.00	100.00	1.00	>100.00	0.00	80.00	100.00	1.00	>100.00	0.77	100.00	100.00	1.00	>100.00	0.00
		3/2/06	SW		81.75	50.00	2.00	>100.00	0.74	50.00	2.00	>100.00		100.00	100.00	1.00	>100.00	0.00	100.00	100.00	1.00	>100.00	0.00										
		3/4/06	SW		100.00	100.00	1.00	>100.00	0.00	100.00	2.00	>100.00		95.00	100.00	1.00	>100.00	0.41	33.44	100.00	1.00	>100.00	1.07										
		4/20/06	DW	97.00	83.00	50.00	2.00	>100.00	0.72	50.00	2.00	>100.00		92.50	100.00	1.00	>100.00	0.51	88.31	100.00	1.00	>100.00	0.63										
		6/21/06	DW	66.00	99.00	100.00	1.00	>100.00	0.00	100.00	1.00	>100.00		75.00	100.00	1.00	>100.00	0.82	100.00	100.00	1.00	>100.00	0.00										

Table C-11.11 Benthic Infaunal Community Analysis From Estuary / Wetlands Stations

Community Measure	Newport Bay Stations						
	LNBHIR	LNBRIN	LNBTUB	UNBCHB	UNBJAM	UNBNSB	UNBSDC
Number of species	45	24	9	67	15	25	31
Abundance	335	776	25	2992	246	180	3032
Shannon-Wiener diversity index	3.01	1.94	2.03	2.72	1.61	2.18	2.38
Margalef diversity index	7.57	3.46	2.49	8.25	2.54	4.62	3.74
Evenness	0.79	0.61	0.92	0.65	0.60	0.68	0.69
Dominance index	12	4	5	8	3	5	6
BRI	35	50	72	28	53	42	56

Community Measure	Huntington Harbour / Talbert Marsh Stations					
	BBOLR	HUNBCC	HUNCRB	HUNWAR	TBTMAR	TGDC05
Number of species	16	61	21	61	17	28
Abundance	339	1127	436	1320	169	1229
Shannon-Wiener diversity index	1.63	2.13	2.15	3.09	2.29	2.21
Margalef diversity index	2.57	8.54	3.29	8.35	3.12	3.80
Evenness	0.59	0.52	0.71	0.75	0.81	0.66
Dominance index	2	4	5	12	6	5
BRI	60	32	57	44	37	53

Table C-11.12. BRI Threshold Levels of Benthic Community Condition for Bays and Estuaries

BRI Threshold	Level	Definition
<31	Reference	
31 – 42	Response level 1	>5% of reference species lost
42 – 53	Response level 2	>25% of reference species lost
53 – 73	Response level 3	>50% of reference species lost
>73	Response level 4	>80% of reference species lost

Table C-11.13. Sediment Toxicity in Estuary / Wetlands in a Regional Context, Using Data from the Bight 03 Bays and Harbors Stratum

Area	% Highly toxic	% Moderately toxic	% Nontoxic
Wetlands / Estuaries	46 / 55 *	39 / 25	15 / 20
S. California Bight overall	10	37	53
Anaheim Bay	0	50	50
Dana Point	0	0	100
San Pedro Bay	5	37	58
Marina del Rey	0	25	75
Mission Bay	0	50	50
Newport Bay	63	25	13
Oxnard Harbor	0	0	100
Redondo Harbor	0	0	100
San Diego Bay	0	47	53

* percentage to the left of the slash is based only on the August 2005 survey; percentage to the right of the slash is based on data from the entire year

Highly toxic: < 50% survival
Moderately toxic: ≥ 50 - < 83% survival
Nontoxic: ≥ 83% survival

Table C-11.14. Summary of Exceedances of the Acute Saltwater CTR at Estuary / Wetlands Stations

			Saltwater				
		Sample Size	Acute				
Station	Channel	Acute	Cd	Cu	Pb	Ni	Zn
BBOLR	Bolsa Bay at observation pier	8					
HUNBCC	Huntington Harbour d/s of Bolsa Chica Ch.	8					
HUNCRB	Huntington Harbour in Christiana Bay	8					
HUNWAR	Huntington Harbour at Warner Avenue	8					
LNBHIR	Lower Newport Bay at Harbor Island Reach	5					
LNBRIN	Lower Newport Bay at Rhine Channel	4		1			
LNBTUB	Lower Newport Bay at TUB	5					
TBTMAR	Talbert Marsh	8					
TGDC05	Bolsa Bay d/s E. Garden Grove Wintersburg Ch.	8		1			
UNBCHB	Upper Newport Bay at Coast Highway	5					
UNBJAM	Upper Newport Bay - Unit I Basin	5					
UNBNSB	Upper Newport Bay at Northstar Beach	5					
UNBSDC	Upper Newport Bay - Unit II Basin	5					
	Totals	82		2			

Table C-11.15. Proportion of All Samples Exceeding AB411 Standards Near Coastal Stormdrains

Entire Year			AB411 Season		
Rank	Station[1]	Avg Hits	Rank	Station	Avg Hits
1	PPC	0.008	1	PPC	0.000
2	WFC	0.019	1	WFC	0.000
3	MDC	0.038	2	MDC	0.038
4	BGC	0.048	3	BGC	0.051
5	HB2	0.053	4	HB3	0.068
5	HB4	0.053	5	HB1	0.076
6	HB3	0.057	5	HB2	0.076
7	HB5	0.064	5	HB4	0.076
8	HB1	0.068	6	HB5	0.083
9	SDMF05	0.333	7	SDMF05	0.303
10	SUNC07	0.643	8	EGWC05	0.600
11	SADF01	0.730	9	BCC02	0.684
12	EGWC05	0.761	10	SUNC07	0.733
13	BCC02	0.833	11	SADF01	0.909
14	CMCG02	0.969	12	CMCG02	1.000

[1] Sites with three-letter site names are coastal sites; all other sites are within inland channels.

Table C-11.16. Number of AB411 Exceedances in Each Monitoring Condition

	Entire Year			AB411 Season		
	ENT	**FC**	**TC**	**ENT**	**FC**	**TC**
Coastal	46	34	26	17	21	22
Channel	220	186	202	97	91	92
Total	**266**	**220**	**228**	**114**	**112**	**114**

Table C-11.17. Volume of Flow in Cubic Feet per Second at Coastal Stormdrain Sites, on an Annual Basis

Station Code	Avg Discharge Rate	Relative Flow Rate
BGC	0.9845	Low
HB1	0.0305	Low
HB2	0.0561	Low
HB3	0.0112	Low
HB4	0.0147	Low
HB5	0.0174	Low
MDC	0.3183	Low
PPC	0.0436	Low
WFC	0.0928	Low

Flow	Category
< 1	Low
1 - 3.99	Medium
> 4	High

Table C-11.18a. Coastal Stormdrain Sites Ranked in Terms of Significance of Regression Slopes for All Bacterial Indicators, Based on Data From the Entire Year

Enterococcus			Fecal Coliform			Total Coliform		
Rank	Station	P-Value	Rank	Station	P-Value	Rank	Station	P-Value
1	MDC	< 0.0001	1	MDC	0.0421	1	MDC	< 0.0001
2	HB4	0.0168	2	HB2	0.0601	2	PPC	0.0001
3	HB2	0.0306	3	WFC	0.1068	3	HB4	0.0135
4	WFC	0.0322	4	HB4	0.1505	4	WFC	0.0181
5	PPC	0.088	5	HB3	0.2914	5	HB1	0.0953
6	BGC	0.3654	6	HB1	0.4279	6	HB2	0.1139
7	HB1	1	7	BGC	1	7	BGC	0.1238
7	HB3	1	7	HB5	1	8	HB3	1
7	HB5	1	7	PPC	1	8	HB5	1

Table C-11.18b. Coastal Stormdrain Sites Ranked in Terms of Significance of Regression Slopes for All Bacterial Indicators, Based on Data From the AB411 Season

Enterococcus			Fecal Coliform			Total Coliform		
Rank	Station	P-Value	Rank	Station	P-Value	Rank	Station	P-Value
1	MDC	0.0028	1	HB1	0.0014	1	HB1	0.0002
2	HB2	0.0145	2	WFC	0.0036	2	MDC	0.0016
3	HB4	0.0546	3	MDC	0.0065	3	WFC	0.0027
4	PPC	0.2613	4	HB4	0.0136	4	HB4	0.0057
5	BGC	1	5	PPC	0.0162	5	HB2	0.0062
5	HB1	1	6	HB2	0.0287	6	PPC	0.0417
5	HB3	1	7	HB5	0.0471	7	BGC	1
5	HB5	1	8	BGC	0.1161	7	HB3	1
5	WFC	1	9	HB3	0.1952	7	HB5	1

Table C-11.19. Stream Bioassessment Monitoring Sites in 2005-2006

Hydrologic Unit	Station Designation	Location	Station Coordinates	Elevation
Aliso Creek	UBPF19	Serrano Creek Park	33.64899 117.69747	404
Newport Coast	BGH01	Buck Gully Wash @ Little Corona Beach	33.59001 117.86836	23
Newport Bay	BCWG04	Big Canyon Wash @ Back Bay Drive	33.63139 117.88200	77
San Diego Creek	BCF04	Bonita Canyon Channel @ Bonita Creek Park	33.64808 117.86236	33
	TWF05	San Diego Creek @ Harvard Avenue	33.66908 117.83571	48
	UHAF05	San Diego Creek @ Harbor Street	33.68679 117.81702	47
	LCRF05	San Diego Creek near Hiway 133	33.65531 117.76131	201
	BPF06	Peter's Canyon Wash @ Barranca Pkwy	33.69262 117.82133	46
Santa Ana River	VICE08	Santiago Creek	33.77397 117.86025	182
	REF-MC	Modeska Creek @ Modeska Canyon	33.70874 117.61452	1426
	REF-SVC	Silverado Canyon Creek d/s of Belha Way	33.74578 117.60185	1634
	REF-SNC	Santiago Creek u/s of Irvine Lake	33.77323 117.68313	843

Table C-11.20
Aqueous Toxicity Testing Results from Bioassessment Monitoring Locations : 2005-06 SAR

Station Code	Site Name	Event	Acute Hyallela Azteca Survival		Chronic Selenastrum Algae Growth			Chronic Ceriodaphnia Survival and Reproduction									Chronic Fathead Larvae Survival and Growth								
								Survival					Reproduction				Survival					Growth			
			Surv in 100%	TUa	NOEC	TUc	96 hr IC_{50}	Surv in 100%	NOEC	TUc	10-day IC_{50}	TUa	Repro in 100%	NOEC	TUc	10-day IC_{50}	Surv in 100%	NOEC	TUc	96 hr IC_{50}	TUa	Grwth in 100%	NOEC	TUc	96 hr IC_{50}
SGLR-039	Coyote Creek d/s Western Ave (SGR special study)	9/1/05	95	0.41	100.00	1.00	>100.00	100.00	100.00	1.00	>100.00	0.00	100.00	100.00	1.00	>100.00									
SGLR-066	Fullerton Creek (SGR special study)	6/22/06						100.00	100.00	1.00	>100.00	0.00	100.00	100.00	1.00	>100.00									
		6/22/06						100.00	100.00	1.00	>100.00	0.00	100.00	100.00	1.00	>100.00									
UBPF19	Serrano Creek in Serrano Creek Park	10/12/05	100	0.00	100.00	1.00	>100.00	100.00	100.00	1.00	>100.00	0.00	100.00	100.00	1.00	>100.00	95.00	100.00	1.00	>100.00	0.41	94.93	100.00	1.00	>100.00
		7/13/06	100	0.00	100.00	1.00	>100.00	90.00	100.00	1.00	>100.00	0.59	96.04	100.00	1.00	>100.00	92.50	100.00	1.00	>100.00	0.51	90.59	100.00	1.00	>100.00
REF-MC	Santiago Creek in Modjeska Canyon	10/12/05	100	0.00	50.00	2.00	>100.00	100.00	100.00	1.00	>100.00	0.00	100.00	100.00	1.00	>100.00									
		7/13/06	100	0.00	100.00	1.00	>100.00	90.00	100.00	1.00	>100.00	0.59	61.88	<50.00	>2.00	>100.00									
REF-SNC	Santiago Creek u/s Irvine Lake	10/12/05	100	0.00	<50.00	>1.00	>100.00	100.00	100.00	1.00	>100.00	0.00	94.87	100.00	1.00	>100.00									
		7/13/06	100	0.00	100.00	1.00	>100.00	100.00	100.00	1.00	>100.00	0.00	97.03	100.00	1.00	>100.00									
BPF06	Peters Canyon Wash at Barranca Parkway	10/13/05	100	0.00	100.00	1.00	>100.00	100.00	100.00	1.00	>100.00	0.00	100.00	100.00	1.00	>100.00	85.00	100.00	1.00	>100.00	0.69	100.00	100.00	1.00	>100.00
		7/12/06	90	0.59	100.00	1.00	>100.00	70.00	100.00	1.00	>100.00	0.87	54.11	50.00	2.00	>100.00	97.50	100.00	1.00	>100.00	0.23	100.00	100.00	1.00	>100.00
UHAF05	San Diego Creek u/s Harvard Ave	10/13/05	100	0.00	100.00	1.00	>100.00	100.00	100.00	1.00	>100.00	0.00	100.00	100.00	1.00	>100.00	87.50	100.00	1.00	>100.00	0.65	37.48	100.00	1.00	>100.00
		7/12/06	95	0.41	100.00	1.00	>100.00	100.00	100.00	1.00	>100.00	0.00	100.00	100.00	1.00	>100.00	90.00	100.00	1.00	>100.00	0.59	100.00	100.00	1.00	>100.00
LCRF05	San Diego Creek at Laguna Canyon Rd	10/13/05	100	0.00	100.00	1.00	>100.00	100.00	100.00	1.00	>100.00	0.00	100.00	100.00	1.00	>100.00	65.00	50.00	2.00	>100.00	0.91	93.54	100.00	1.00	>100.00
		7/13/06	90	0.59	100.00	1.00	>100.0	90.00	100.00	1.00	>100.00	0.59	87.62	100.00	1.00	>100.00									
TWF05	San Diego Creek d/s Michaelson near IRWD	10/13/05	100	0.00	100.00	1.00	>100.00	100.00	100.00	1.00	>100.00	0.00	100.00	100.00	1.00	>100.00	95.00	100.00	1.00	>100.00	0.41	100.00	100.00	1.00	>100.00
		7/12/06	85	0.69	100.00	1.00	>100.00	90.00	100.00	1.00	>100.00	0.59	100.00	100.00	1.00	>100.00	90.00	100.00	1.00	>100.00	0.59	100.00	100.00	1.00	>100.00
BCF04	Bonita Canyon Channel at Bonita Creek Park	10/27/05	95	0.41	100.00	1.00	>100.00	100.00	100.00	1.00	>100.00	0.00	100.00	100.00	1.00	>100.00	97.50	100.00	1.00	>100.00	0.23	100.00	100.00	1.00	>100.00
		7/12/06	85	0.69	100.00	1.00	>100.00	100.00	100.00	1.00	100.00	0.00	100.00	100.00	1.00	>100.00	87.50	100.00	1.00	>100.00	0.65	100.00	100.00	1.00	>100.00
BCWG04	Big Canyon Wash u/s Back Bay Dr	10/27/05	85	0.69	100.00	1.00	>100.00	90.00	100.00	1.00	>100.00	0.59	44.02	<50.00	>2.00	63.24	92.50	100.00	1.00	>100.00	0.51	100.00	100.00	1.00	>100.00
		7/12/06	95	0.41	100.00	1.00	>100.00	50.00	100.00	1.00	>100.00	1.00	4.25	50.00	2.00	93.45	95.00	100.00	1.00	>100.00	0.41	100.00	100.00	1.00	>100.00
BGH01	Buck Gully at Little Corona Beach	10/27/05	95	0.41	100.00	1.00	>100.00	30.00	50.00	2.00	>85.71	1.17	2.41	50.00	2.00	69.49	95.00	100.00	1.00	>100.00	0.41	100.00	100.00	1.00	>100.00
		7/12/06	60	0.94	100.00	1.00	>100.00	20.00	50.00	2.00	80.00	1.25	21.23	<50.00	>2.00	61.11									

Table C-11.21
Aquatic Chemistry at Bioassessment Sampling Locations: 2005-06 SAR

Location	Date	Type	Field Measurements				Turbidity	Specific Conductance	pH	Nitrate as NO_3	Ammonia as N	TKN	Total Phosphate as PO_4	ortho phosphate as P	TSS	VSS	Diazinon	Chlorpyrifos	Dimethoate	Malathion	Cd	Cr	Cu	Pb	Ni	Ag	Zn	As	Se	Hardness as $CaCO_3$
			EC	pH	TEMP	DO																								
			µS		C	mg/L	NTU	µS		mg/L							ng/L				µg/L									mg/L
BCF04	10/27/05 8:15	DT	2933	7.35	16.77	8.08	5.25	3500	8.05	3.3	< 0.1	0.6	0.58	0.16	10	3	< 10	< 10	< 10	< 10	< 0.5	1.6	2.8	< 0.5	8.9	< 0.5	8.4	2.6	4.7	785
BCF04	10/27/05 8:15	DF																			< 0.5	0.69	1.4	< 0.5	8.3	< 0.5	7.1	2.4	5.1	
BCF04	7/12/06 11:30	DT	2668	7.73	19.96	8.64	3.04	2770	7.87	3.22	<0.1	0.43	0.75	0.22	8	2	17.4	< 1	< 3	13.3	<0.5	1.8	2.9	9.6	<0.5	<0.5	7.2	2.6	4.5	640
BCF04	7/12/06 11:30	DF																			<0.5	0.96	1.5	8.4	<0.5	<0.5	5.1	2.9	3.6	
BCWG04	10/27/05 9:13	DT	4580	7.45	17.78	9.00	5.28	5590	7.65	< 0.4	< 0.1	1.4	1.88	0.47	10	8	< 10	< 10	< 10	< 10	1.7	< 0.5	4.3	< 0.5	21	< 0.5	7.1	3.1	20	1645
BCWG04	10/27/05 9:13	DF																			< 0.5	< 0.5	1.9	< 0.5	20	< 0.5	4.6	2.4	25	
BCWG04	7/12/06 12:50	DT	2965	7.53	22.78	8.17	3.42	4190	7.57	2.29	<0.1	0.61	0.75	0.2	10	4	< 2	< 1	< 3	< 3	2.4	0.66	3.5	18	0.91	<0.5	7.5	2.2	26	1525
BCWG04	7/12/06 12:50	DF																			0.64	<0.5	1.3	18	<0.5	<0.5	4.9	2.2	25	
BGH01	10/27/05 10:55	DT	6728	7.41	16.99	9.68	0.95	8100	7.93	0.8	< 0.1	0.5	0.18	0.04	< 5	< 1	< 10	< 10	< 10	< 10	2.8	< 0.5	1.9	< 0.5	33	< 0.5	2.8	1.6	73	2550
BGH01	10/27/05 10:55	DF																			1.2	< 0.5	1.6	< 0.5	34	< 0.5	2.3	1.3	69	
BGH01	7/12/06 14:00	DT	6549	7.82	21.71	10.97	1.04	6720	7.85	<0.4	<0.1	0.35	0.17	0.03	5	3	< 2	< 1	< 3	< 3	3.2	<0.5	1.9	32	<0.5	<0.5	3.9	1.6	38	2445
BGH01	7/12/06 14:00	DF																			1.2	<0.5	1.6	35	<0.5	<0.5	4.1	1.2	39	
BPF06	10/13/05 10:15	DT	2440	9.18	20.1	19.67	3.71	2780	8.22	33.6	0.1	0.7	0.4	0.08	6	2	< 10	< 10	< 10	< 10	< 0.5	< 0.5	2.5	< 0.5	6.2	< 0.5	5.2	8.2	40	815
BPF06	10/13/05 10:15	DF																			< 0.5	< 0.5	2.1	< 0.5	6.8	< 0.5	4.1	8.7	40	
BPF06	7/12/06 7:45	DT	2149	7.94	22.28	7.62	2.34	2220	7.93	28.6	<0.1	0.69	0.24	0.04	7	3	19	< 1	< 3	< 3	<0.5	0.7	5.9	7.7	<0.5	<0.5	7.3	9.1	26	570
BPF06	7/12/06 7:45	DF																			<0.5	0.52	4.3	7.4	<0.5	<0.5	5.6	8.8	25	
LCRF05	10/13/05 8:15	DT	1785	8.8	16.44	10.6	5	2010	7.8	17.1	0.3	0.8	1.95	0.61	6	1	< 10	< 10	< 10	< 10	< 0.5	< 0.5	3.6	< 0.5	7.4	< 0.5	11	5.3	1.2	440
LCRF05	10/13/05 8:15	DF																			< 0.5	< 0.5	2.5	< 0.5	7.5	< 0.5	8.2	5.9	1.6	
LCRF05	7/13/06 13:45	DT	1978	8.54	31.96	10.99	3.23	1950	8.52	29.5	<0.1	0.87	1.45	0.37	6	3	< 2	< 1	< 3	< 3	<0.5	<0.5	5.5	11	<0.5	<0.5	16	6.2	1.5	580
LCRF05	7/13/06 13:45	DF																			<0.5	<0.5	4.2	11	<0.5	<0.5	13	6.3	1.3	
REF-MC	10/12/05 10:00	DT	696	8.22	14.46	11.08	0.32	896	7.9	< 0.4	< 0.1	< 0.2	< 0.06	< 0.02	< 5	< 1	< 10	< 10	< 10	< 10	< 0.5	< 0.5	< 0.5	< 0.5	2.5	< 0.5	< 2	< 0.5	< 0.5	
REF-MC	10/12/05 10:00	DF																			< 0.5	< 0.5	< 0.5	< 0.5	2.6	< 0.5	< 2	< 0.5	< 0.5	
REF-MC	7/13/06 11:15	DT	452	7.45	21.68	6.75	1.17	724	7.77	<0.4	<0.1	<0.2	<0.06	<0.02	< 5	1	< 2	< 1	< 3	< 3	<0.5	<0.5	<0.5	3.9	<0.5	<0.5	4.3	<0.5	<0.5	375
REF-MC	7/13/06 11:15	DF																			<0.5	<0.5	<0.5	2.9	<0.5	<0.5	4.3	0.51	<0.5	
REF-SNC	10/12/05 12:15	DT	890	8.09	20.6	11.91	0.37	1180	7.98	< 0.4	< 0.1	< 0.2	< 0.06	< 0.02	< 5	< 1	< 10	< 10	< 10	< 10	< 0.5	< 0.5	1.2	< 0.5	3.6	< 0.5	5.5	1.2	< 0.5	
REF-SNC	10/12/05 12:15	DF																			< 0.5	< 0.5	< 0.5	< 0.5	4.1	< 0.5	< 2	1.4	< 0.5	
REF-SNC	7/13/06 8:15	DT	1015	8.13	19.27	9.45	3.24	1050	8.04	<0.4	<0.1	<0.2	0.07	<0.02	< 5	2	< 2	< 1	< 3	< 3	<0.5	<0.5	0.5	5	<0.5	<0.5	< 2	1.4	0.61	475
REF-SNC	7/13/06 8:15	DT					2.11	1030	8.11	<0.4	<0.1	<0.2	<0.06	<0.02	< 5	3	< 2	< 1	< 3	< 3	<0.5	<0.5	0.59	6	<0.5	<0.5	2.7	1.4	0.51	
REF-SNC	7/13/06 8:15	DF																			<0.5	<0.5	<0.5	4.4	<0.5	<0.5	4	1.2	0.66	
REF-SNC	7/13/06 8:15	DF																			<0.5	<0.5	<0.5	6.3	<0.5	<0.5	3.1	1.2	<0.5	
REF-SVC	10/12/05 11:20	DT	1062	8.09	14.4	10.21	0.2	1400	7.93	< 0.4	< 0.1	< 0.2	< 0.06	< 0.02	< 5	< 1	< 10	< 10	< 10	< 10	< 0.5	< 0.5	0.8	< 0.5	5.4	< 0.5	7.9	1	4.1	
REF-SVC	10/12/05 11:20	DF																			< 0.5	< 0.5	0.69	< 0.5	5.1	< 0.5	7.4	0.92	3.2	
REF-SVC	7/13/06 10:15	DT	1175	7.93	18.78	9.18	0.57	1200	8.01	0.4	<0.1	<0.2	0.09	<0.02	< 5	1	< 2	< 1	< 3	< 3	<0.5	<0.5	0.86	6.4	<0.5	<0.5	10	0.91	3.2	665
REF-SVC	7/13/06 10:15	DF																			<0.5	<0.5	0.77	6.1	<0.5	<0.5	17	1.1	3.5	
SGLR-039	7/7/05 10:00	DT	1572	9.46	26.95	17.66															< 0.5	2.2	6.9	1.6	5.4	< 0.5	20	2	2.6	158
SGLR-039	7/7/05 10:00	DF																			< 0.5	1.3	3.6	< 0.5	4.6	< 0.5	9.1	1.7	2.9	

DT - Dry weather, total metals
DF - Dry weather, dissolved metals

Table C-11.21
Aquatic Chemistry at Bioassessment Sampling Locations: 2005-06 SAR

Location	Date	Type	Field Measurements				Turbidity	Specific Conductance	pH	Nitrate as NO_3	Ammonia as N	TKN	Total Phosphate as PO_4	ortho phosphate as P	TSS	VSS	Diazinon	Chlorpyrifos	Dimethoate	Malathion	Cd	Cr	Cu	Pb	Ni	Ag	Zn	As	Se	Hardness as $CaCO_3$
			EC	pH	TEMP	DO																								
			µS		C	mg/L	NTU	µS		mg/L							ng/L				µg/L									mg/L
TWF05	10/13/05 12:00	DT	2708	8.99	19.07	8.11	1.42	3080	7.72	36.6	0.2	0.9	0.53	0.15	< 5	< 1	< 10	< 10	< 10	< 10	< 0.5	< 0.5	2.4	< 0.5	7.7	< 0.5	6.5	7.1	18	744
TWF05	10/13/05 12:00	DF																			< 0.5	< 0.5	2.3	< 0.5	8.5	< 0.5	6.3	6.6	13	
TWF05	7/12/06 10:00	DT	2552	7.65	23.26	7.28	2.4	2660	7.76	35.5	0.17	1.03	0.35	0.07	6	2	5.7	< 1	< 3	< 3	<0.5	0.64	4.1	7.7	<0.5	<0.5	6.7	6.7	19	690
TWF05	7/12/06 10:00	DF																			<0.5	0.51	3.2	7.5	<0.5	<0.5	7.2	7.1	17	
UBPF19	10/12/05 8:30	DT	1370	7.93	15.81	9.85	0.5	1760	7.83	7.2	< 0.1	0.6	0.2	0.05	< 5	< 1	< 10	< 10	< 10	< 10	< 0.5	< 0.5	5	< 0.5	7.1	< 0.5	13	4.3	1.1	
UBPF19	10/12/05 8:30	DF																			< 0.5	< 0.5	2.2	< 0.5	6.9	< 0.5	5.7	5.3	1.5	
UBPF19	7/13/06 12:50	DT	1355	8.35	28.13	12.13	1.06	1420	8.35	8.03	<0.1	0.54	0.45	0.07	< 5	1	< 2	< 1	< 3	< 3	<0.5	<0.5	3.4	9.7	<0.5	<0.5	9.8	6.3	1.4	545
UBPF20	7/13/06 12:50	DF																			<0.5	<0.5	3.1	9.6	<0.5	<0.5	8.5	6.4	1.4	
UHAF05	10/13/05 9:15	DT	22.18	8.82	16.42	12.49	1.1	2530	7.98	41.3	0.2	0.7	0.99	0.3	< 5	< 1	< 10	< 10	< 10	< 10	< 0.5	< 0.5	2.2	< 0.5	9.2	< 0.5	5	6.8	3.3	595
UHAF05	10/13/05 9:15	DF																			< 0.5	< 0.5	2.1	< 0.5	8.5	< 0.5	4.4	6.7	3.5	
UHAF05	7/12/06 8:45	DT	2190	8.1	21.99	11.15	2.45	2280	8.03	75.8	<0.1	0.67	0.88	0.24	12	4	< 2	< 1	< 3	< 3	<0.5	1.2	3.7	13	<0.5	<0.5	10	6.1	4.1	720
UHAF05	7/12/06 8:45	DF																			<0.5	1	2.8	11	<0.5	<0.5	6.9	5.7	3.9	
	Special Study - San Gabriel River Watershed																													

DT - Dry weather, total metals
DF - Dry weather, dissolved metals

Table C-11.22. Summary of Instances of Divergent Trends at Upstream and Downstream Land Use Sites

	Grassland Dry	Grassland Storm
Copper dissolved	HIGHER in downstream	
Copper total	HIGHER in downstream	HIGHER in downstream *
Chromium dissolved	HIGHER in downstream	
Chromium total	HIGHER in downstream	
Nickel dissolved	HIGHER in upstream	HIGHER in upstream *
Nickel total	HIGHER in upstream	
Selenium dissolved	HIGHER in downstream	
Selenium total	HIGHER in downstream	
Nitrate/Nitrite	HIGHER in downstream	HIGHER in downstream *
Lead total		HIGHER in downstream *
Zinc total		HIGHER in downstream *
TSS		HIGHER in downstream *
VSS		HIGHER in downstream *

* Based on just one data point

Table C-11.23. Summary of CTR Exceedances Across All Program Elements

Watershed	Program	Weather	CTR Type	Station	Sampling Events	Cu	Ni	Zn
Anaheim Bay-Huntington Harbour	Mass Emissions	Dry	SW	BCC02	5	0	0	0
Anaheim Bay-Huntington Harbour	Mass Emissions	Dry	SW	EGWC05	5	2	0	0
Anaheim Bay-Huntington Harbour	Mass Emissions	Storm	FW	ABCC03	9	4	0	0
Anaheim Bay-Huntington Harbour	Mass Emissions	Storm	FW	WMCC04	3	2	0	0
Anaheim Bay-Huntington Harbour	Mass Emissions	Storm	SW	BCC02	14	8	0	0
Anaheim Bay-Huntington Harbour	Mass Emissions	Storm	SW	EGWC05	10	10	0	0
Coyote Creek	Bioassessment	Dry	FW	SGLR-039	1	0	0	0
Newport Bay	Bioassessment	Dry	FW	BCF04	1	0	0	0
Newport Bay	Mass Emissions	Dry	FW	ACWF18	3	0	0	0
Newport Bay	Mass Emissions	Dry	FW	BARSED	35	0	0	0
Newport Bay	Mass Emissions	Dry	FW	BCF04	16	0	0	0
Newport Bay	Mass Emissions	Dry	FW	CICF25	35	1	0	0
Newport Bay	Mass Emissions	Dry	FW	HCWF27	29	0	0	0
Newport Bay	Mass Emissions	Dry	FW	LANF08	6	0	0	0
Newport Bay	Mass Emissions	Dry	FW	MIRF07	5	0	0	0
Newport Bay	Mass Emissions	Dry	FW	SICG03	2	0	0	0
Newport Bay	Mass Emissions	Dry	FW	WYLSED	35	0	0	0
Newport Bay	Bioassessment	Dry	FW	BCWG04	1	0	0	0
Newport Bay	Mass Emissions	Dry	SW	CMCG02	45	44	0	2
Newport Bay	Mass Emissions	Dry	SW	SADF01	22	16	0	1
Newport Bay	Mass Emissions	Dry	SW	SDMF05	46	2	0	0
Newport Bay	Mass Emissions	Storm	FW	ACWF18	5	0	0	0
Newport Bay	Mass Emissions	Storm	FW	BARSED	31	5	0	0
Newport Bay	Mass Emissions	Storm	FW	BCF04	8	1	0	0
Newport Bay	Mass Emissions	Storm	FW	CICF25	16	3	0	0
Newport Bay	Mass Emissions	Storm	FW	HCWF27	12	1	0	0
Newport Bay	Mass Emissions	Storm	FW	LANF08	10	1	0	0
Newport Bay	Mass Emissions	Storm	FW	MIRF07	10	5	0	0

Watershed	Program	Weather	CTR Type	Station	Sampling Events	Cu	Ni	Zn
Newport Bay	Mass Emissions	Storm	FW	WYLSED	26	1	0	0
Newport Bay	Mass Emissions	Storm	SW	CMCG02	11	11	0	3
Newport Bay	Mass Emissions	Storm	SW	SADF01	8	7	0	1
Newport Bay	Mass Emissions	Storm	SW	SDMF05	11	3	0	0
Newport Bay/Costa Mesa (G)	Estuaries / Wetlands	Dry	SW	LNBHIR	5	0	0	0
Newport Bay/Costa Mesa (G)	Estuaries / Wetlands	Dry	SW	LNBRIN	4	1	0	0
Newport Bay/Costa Mesa (G)	Estuaries / Wetlands	Dry	SW	LNBTUB	4	0	0	0
Newport Bay/Costa Mesa (G)	Estuaries / Wetlands	Dry	SW	UNBCHB	5	0	0	0
Newport Bay/Costa Mesa (G)	Estuaries / Wetlands	Dry	SW	UNBJAM	5	0	0	0
Newport Bay/Costa Mesa (G)	Estuaries / Wetlands	Dry	SW	UNBNSB	5	0	0	0
Newport Bay/Costa Mesa (G)	Estuaries / Wetlands	Dry	SW	UNBSDC	5	0	0	0
Newport Bay/Costa Mesa (G)	Estuaries / Wetlands	Storm	SW	LNBHIR	3	0	0	0
Newport Bay/Costa Mesa (G)	Estuaries / Wetlands	Storm	SW	LNBRIN	2	0	0	0
Newport Bay/Costa Mesa (G)	Estuaries / Wetlands	Storm	SW	LNBTUB	3	0	0	0
Newport Bay/Costa Mesa (G)	Estuaries / Wetlands	Storm	SW	UNBCHB	3	0	0	0
Newport Bay/Costa Mesa (G)	Estuaries / Wetlands	Storm	SW	UNBJAM	3	0	0	0
Newport Bay/Costa Mesa (G)	Estuaries / Wetlands	Storm	SW	UNBNSB	3	0	0	0
Newport Bay/Costa Mesa (G)	Estuaries / Wetlands	Storm	SW	UNBSDC	3	0	0	0
Newport Coast	Bioassessment	Dry	FW	BGH01	1	0	0	0
San Diego Creek	Bioassessment	Dry	FW	BPF06	1	0	0	0
San Diego Creek	Bioassessment	Dry	FW	LCRF05	1	0	0	0
San Diego Creek	Bioassessment	Dry	FW	TWF05	1	0	0	0
San Diego Creek	Bioassessment	Dry	FW	UBPF19	1	0	0	0
San Diego Creek	Bioassessment	Dry	FW	UHAF05	1	0	0	0
San Gabriel River/Coyote Creek	Mass Emissions	Dry	FW	CARB01	6	0	0	0
San Gabriel River/Coyote Creek	Mass Emissions	Dry	FW	CCBA01	6	0	0	0
San Gabriel River/Coyote Creek	Mass Emissions	Dry	FW	FULA03	6	0	0	0
San Gabriel River/Coyote Creek	Mass Emissions	Storm	FW	CARB01	14	1	0	0
San Gabriel River/Coyote Creek	Mass Emissions	Storm	FW	CCBA01	14	0	0	0
San Gabriel River/Coyote Creek	Mass Emissions	Storm	FW	FULA03	13	2	0	1
Santa Ana River	Bioassessment	Dry	FW	REF-SVC	1	0	0	0

Watershed	Program	Weather	CTR Type	Station	Sampling Events	Cu	Ni	Zn
Santa Ana River	Mass Emissions	Dry	FW	TBTD02	4	0	0	0
Santa Ana River	Bioassessment	Dry	FW	REF-MC	1	0	0	0
Santa Ana River	Bioassessment	Dry	FW	REF-SNC	1	0	0	0
Talbert	Estuaries / Wetlands	Dry	SW	TBTMAR	2	0	0	0
Talbert	Estuaries / Wetlands	Storm	SW	TBTMAR	6	0	0	0
Westminster	Estuaries / Wetlands	Dry	SW	BBOLR	2	0	0	0
Westminster	Estuaries / Wetlands	Dry	SW	HUNBCC	2	0	0	0
Westminster	Estuaries / Wetlands	Dry	SW	HUNCRB	2	0	0	0
Westminster	Estuaries / Wetlands	Dry	SW	HUNWAR	2	0	0	0
Westminster	Estuaries / Wetlands	Dry	SW	TGDC05	2	0	0	0
Westminster	Estuaries / Wetlands	Storm	SW	BBOLR	6	0	0	0
Westminster	Estuaries / Wetlands	Storm	SW	HUNBCC	6	0	0	0
Westminster	Estuaries / Wetlands	Storm	SW	HUNCRB	6	0	0	0
Westminster	Estuaries / Wetlands	Storm	SW	HUNWAR	6	0	0	0
Westminster	Estuaries / Wetlands	Storm	SW	TGDC05	6	1	0	0

Date: November 13, 2006

s:\GIS\mxds\SAR_Mass_Emissions_Stations_Overview.mxd

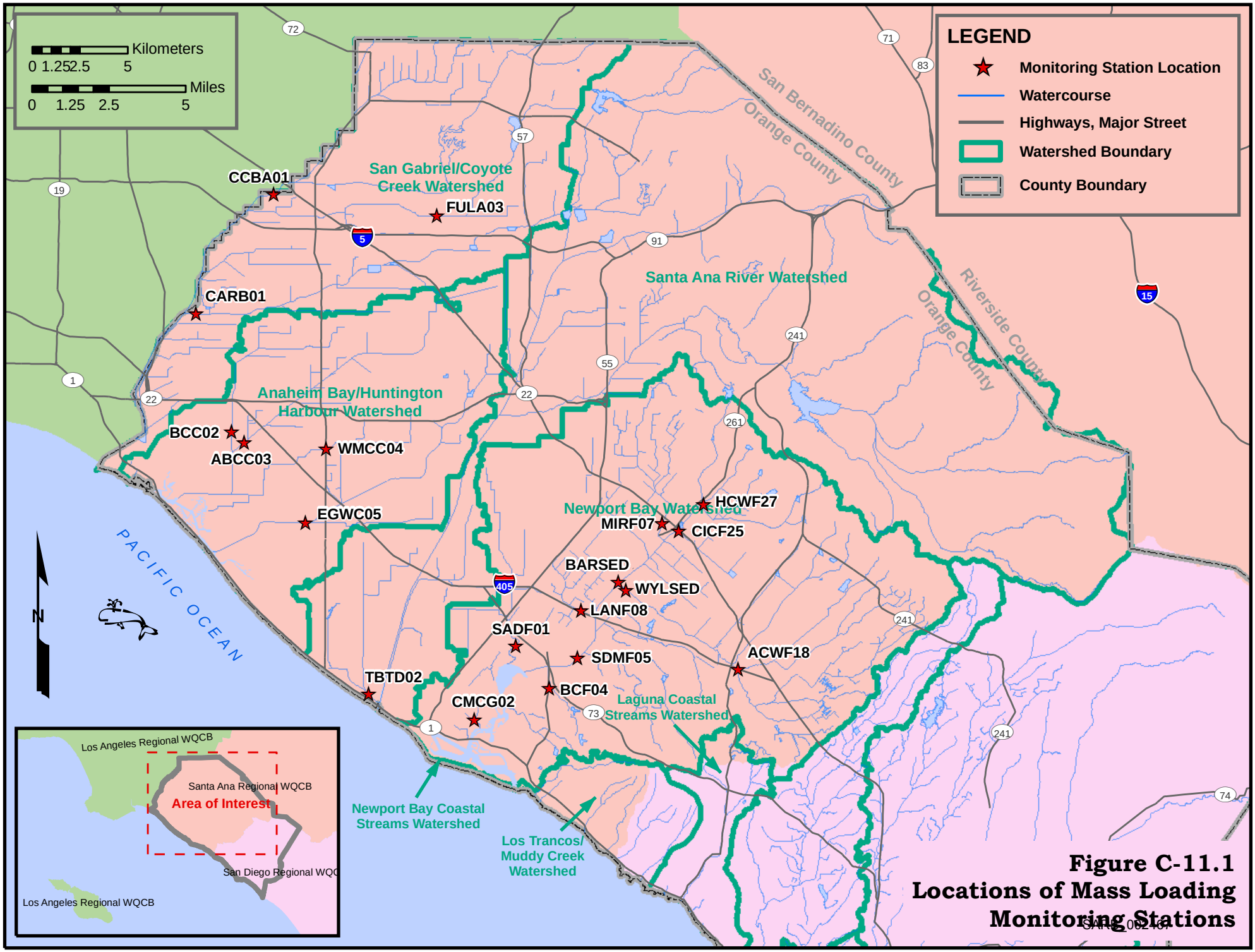
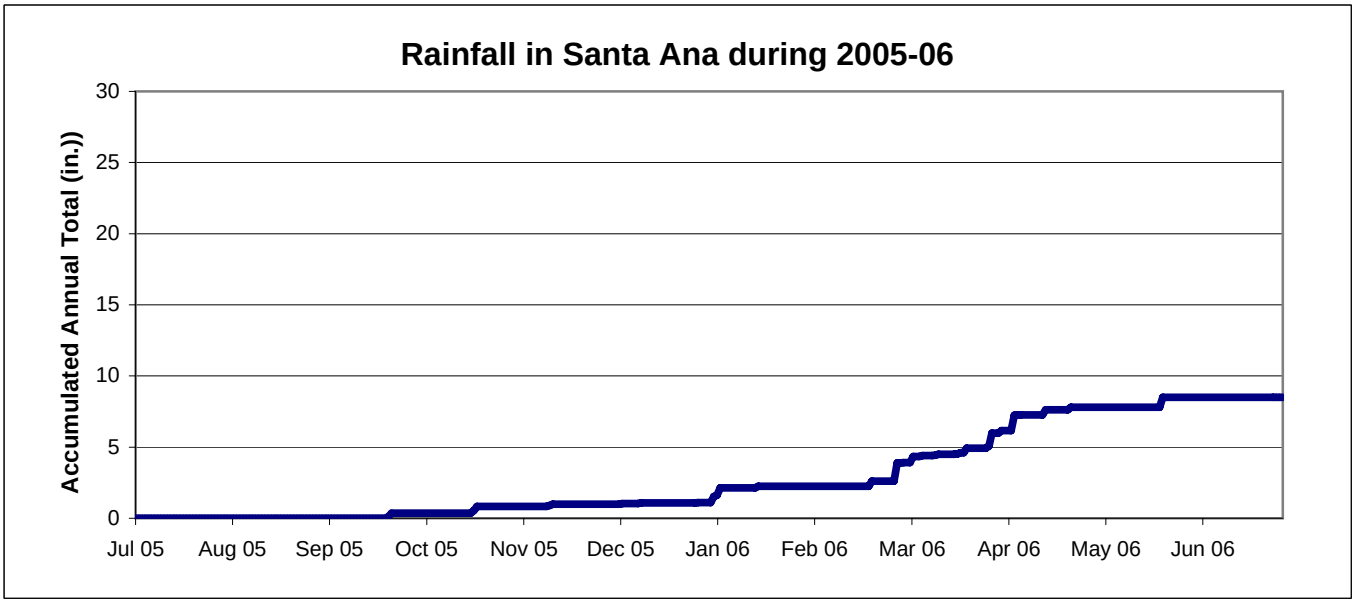


Figure C-11.1
Locations of Mass Loading Monitoring Stations

Figure C-11.2


Rainfall in Santa Ana during 2005-06
Accumulated Annual Total (in.))
30
25
20
15
10
5
0
Jul 05
Aug 05
Sep 05
Oct 05
Nov 05
Dec 05
Jan 06
Feb 06
Mar 06
Apr 06
May 06
Jun 06

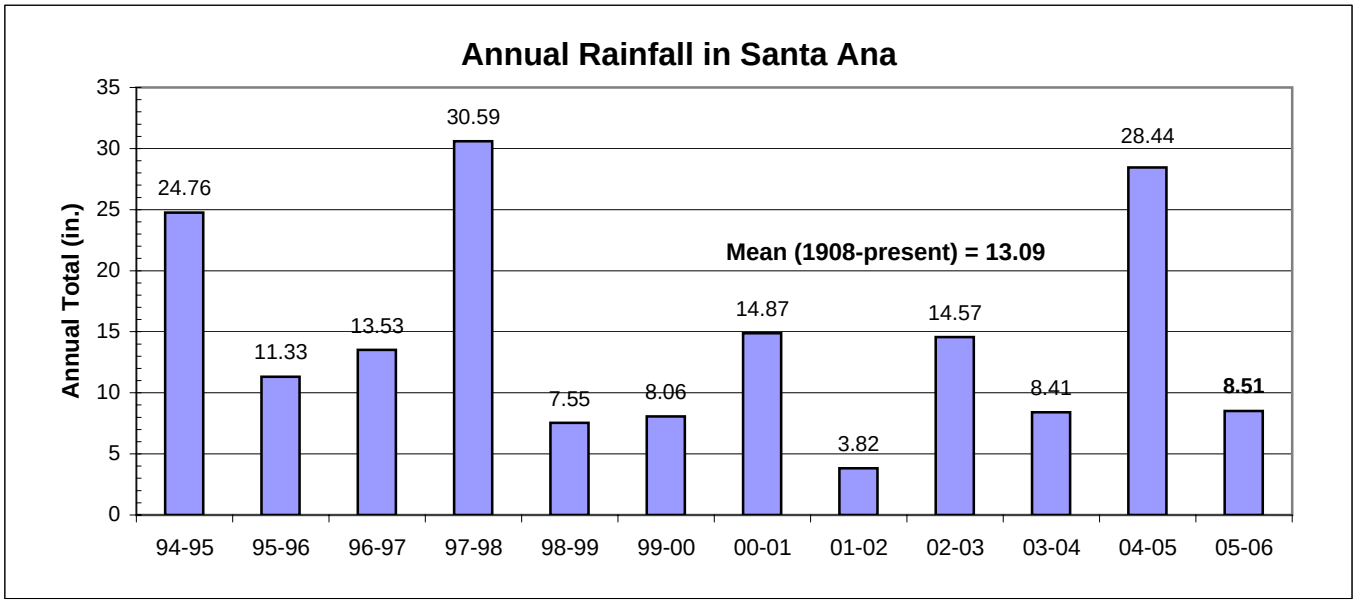

Annual Rainfall in Santa Ana
Annual Total (in.)
35
30
25
20
15
10
5
0
24.76
11.33
13.53
30.59
7.55
8.06
14.87
3.82
14.57
8.41
28.44
8.51
Mean (1908-present) = 13.09
94-95
95-96
96-97
97-98
98-99
99-00
00-01
01-02
02-03
03-04
04-05
05-06

Figure C-11.3a
Locations of Estuary/Wetland Monitoring Stations in Newport Bay

LEGEND

★ Monitoring Site Location

N

0 1,000 2,000 4,000 6,000 Feet

0 0.25 0.5 1 Mile

Aerial Source: USGS Jan-Mar 2203 0.65m Color Los Angeles 02

Date: November 10, 2006

s:\GIS\mxds\Huntington_Harbour_Stations_Overview.mxd

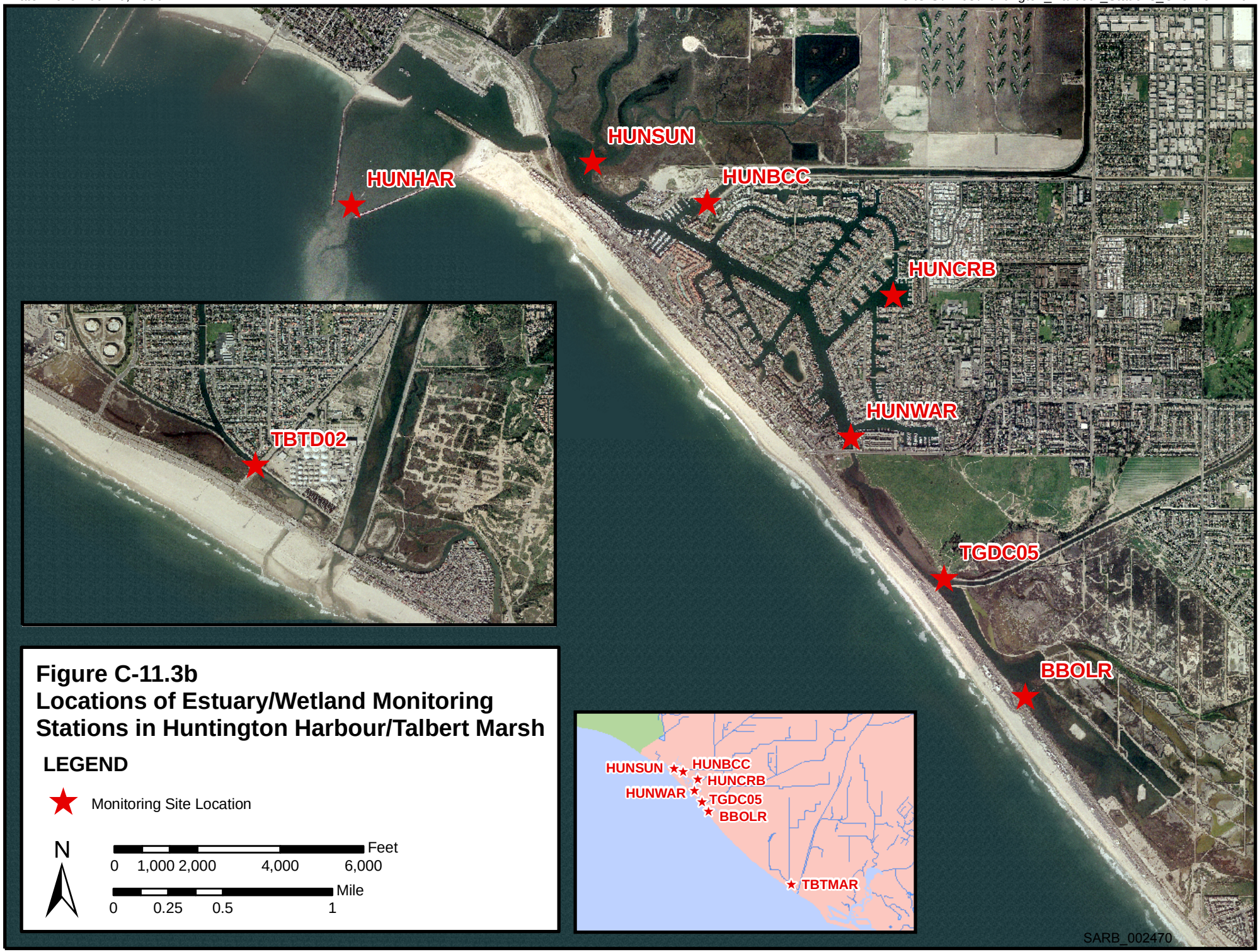


Figure C-11.3b
Locations of Estuary/Wetland Monitoring Stations in Huntington Harbour/Talbert Marsh

LEGEND

★ Monitoring Site Location

N

0 1,000 2,000 4,000 6,000 Feet

0 0.25 0.5 1 Mile

Aerial Source: USGS Jan-Mar 2203 0.65m Color Los Angeles 02

Figure C-11.4
Cumulative Frequency Curve of Benthic Toxicity from Bight 03

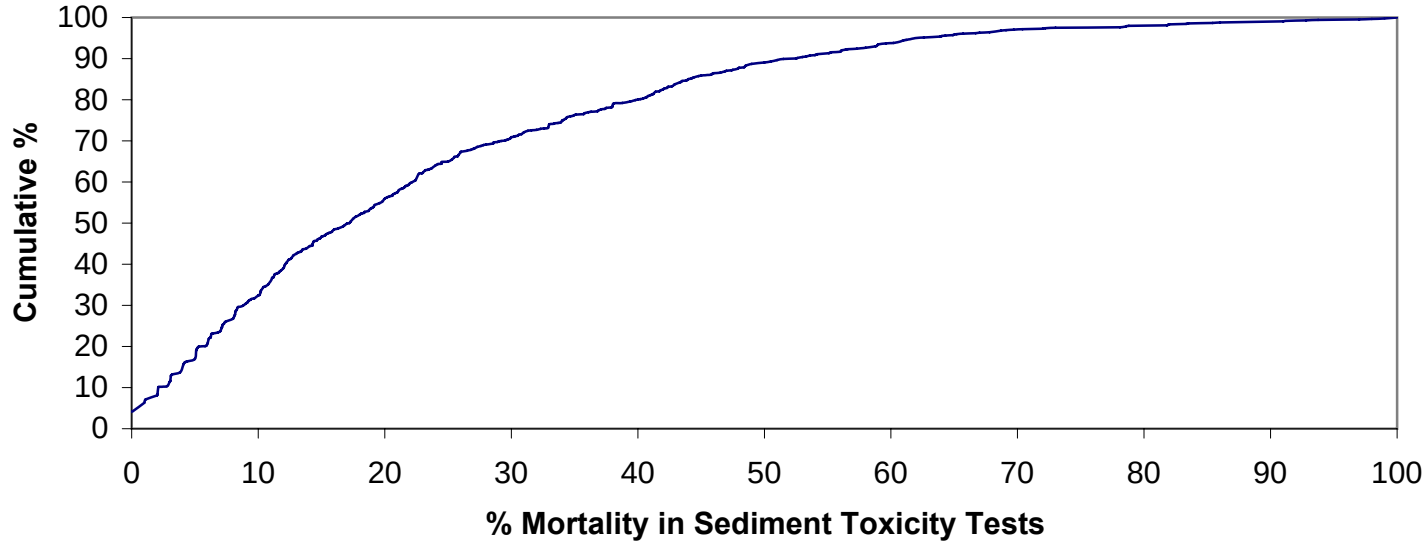


Figure C-11.5a. BRI Scores for the Estuary / Wetlands Monitoring Stations in Newport Bay

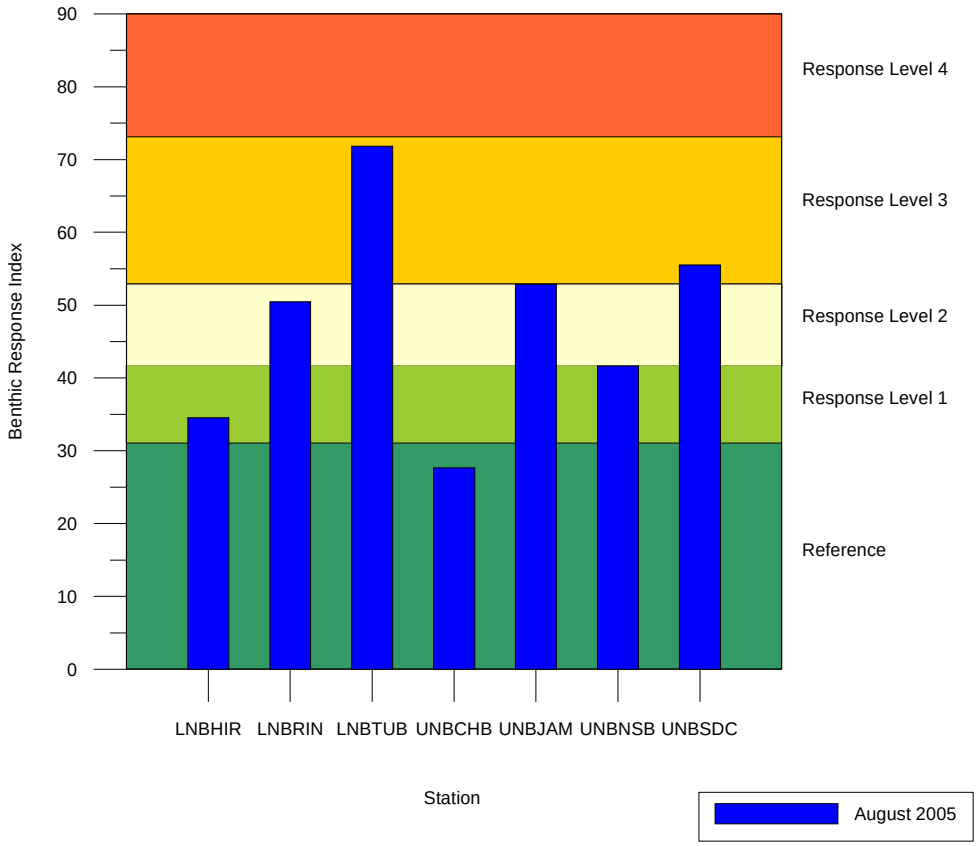


Figure C-11.5b. BRI Scores for the Estuary / Wetlands Monitoring Stations in Huntington Harbour / Talbert Marsh

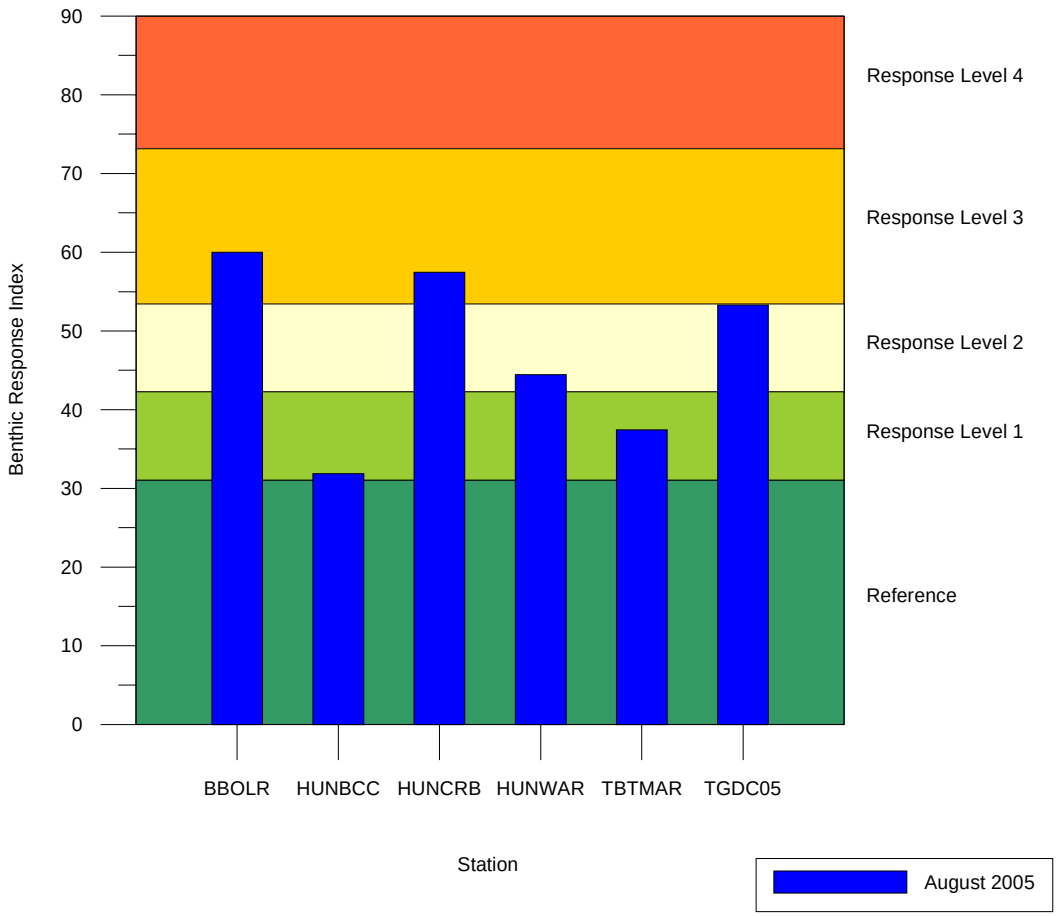
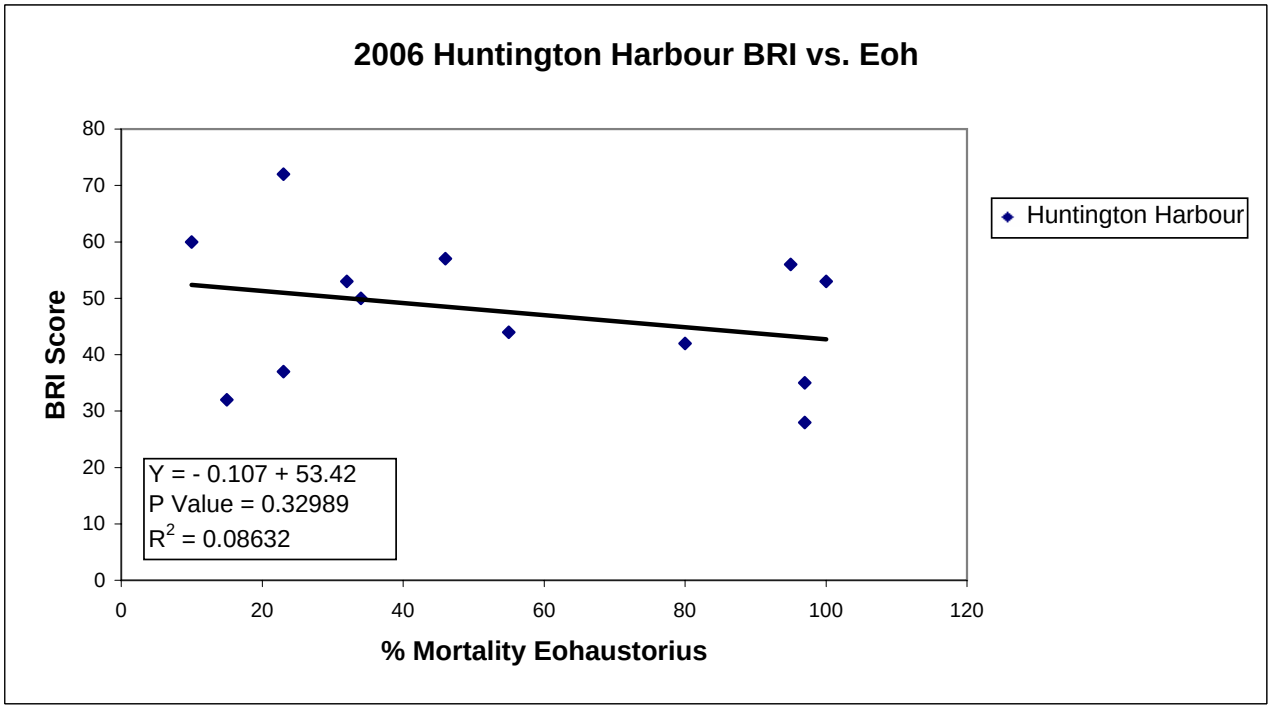
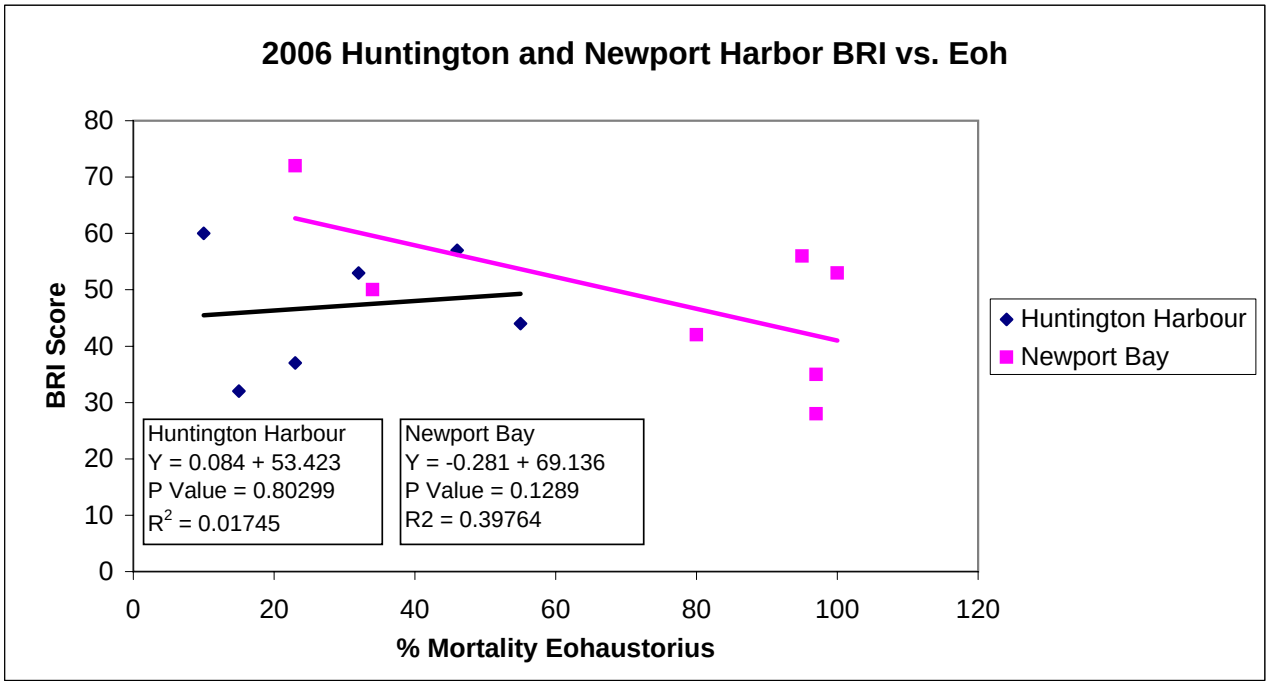


Figure C-11.6
BRI Scores vs. Sediment Toxicity





Station	Date	Amphipod Survival	Station	Date	Amphipod Survival
UNBJAM	8/26/2005	0%	LNBHIR	8/26/2005	3%
	11/17/2005	0%		11/17/2005	3%
	4/19/2006	0%		4/20/2006	12%
	6/20/2006	3%		6/21/2006	13%
UNBSDC	8/26/2005	5%	LNBTUB	8/26/2005	77%
	11/17/2005	44%		11/17/2005	78%
	4/19/2006	21%		4/20/2006	90%
	6/20/2006	6%		6/21/2006	36%
UNBNSB	8/26/2005	20%	LNBRIN	8/26/2005	66%
	11/17/2005	13%		11/17/2005	88%
	4/19/2006	16%		4/20/2006	97%
	6/20/2006	84%		6/21/2006	66%
UNBCHB	8/26/2005	3%			
	11/17/2005	3%			
	4/19/2006	28%			
	6/20/2006	29%			

Note: Percent amphipod survival is relative to control group

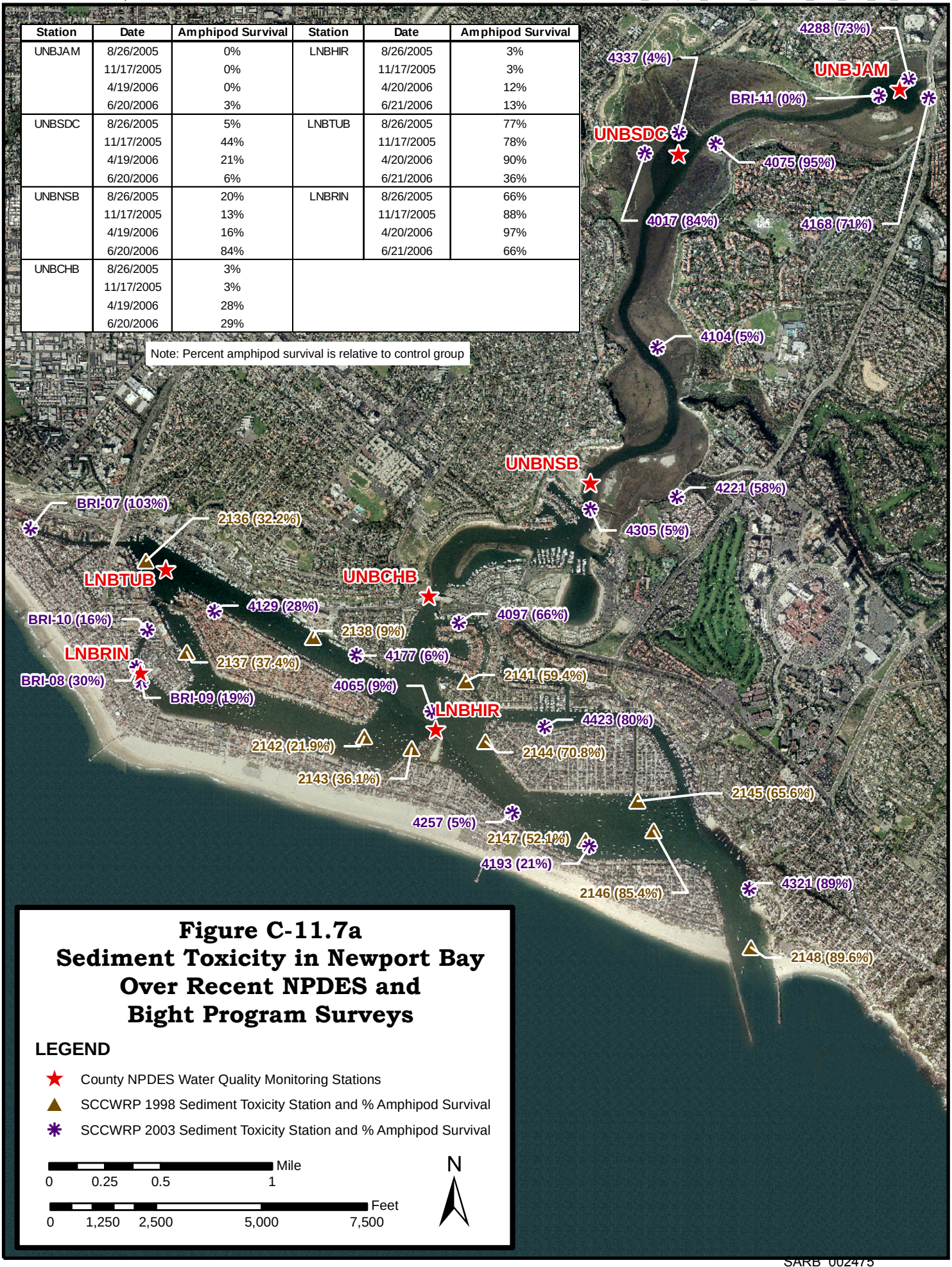


Figure C-11.7a
Sediment Toxicity in Newport Bay Over Recent NPDES and Bight Program Surveys

LEGEND

- ★ County NPDES Water Quality Monitoring Stations
- ▲ SCCWRP 1998 Sediment Toxicity Station and % Amphipod Survival
- ✱ SCCWRP 2003 Sediment Toxicity Station and % Amphipod Survival

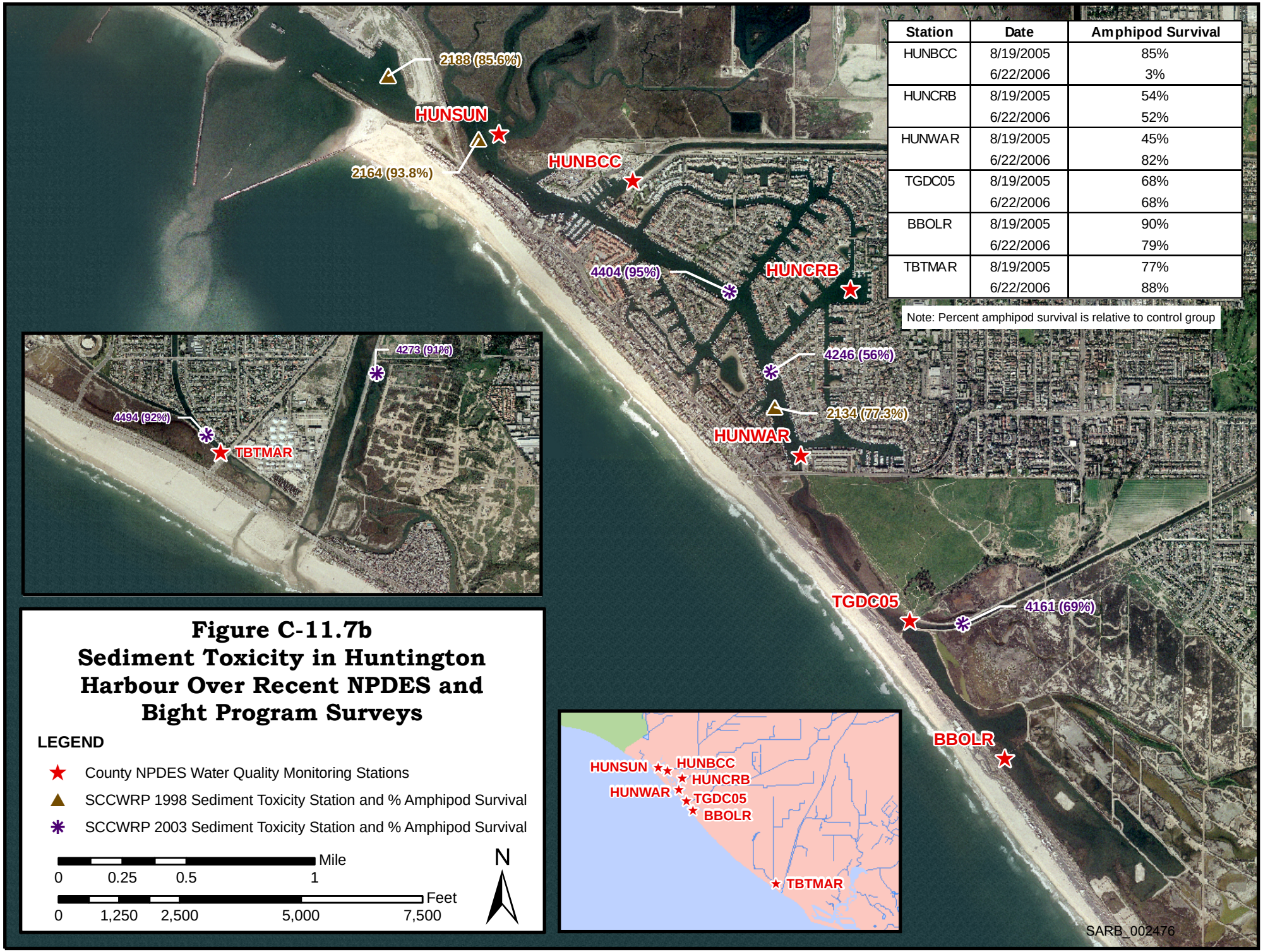
Mile
0 0.25 0.5 1

Feet
0 1,250 2,500 5,000 7,500

N

Aerial Source: USGS Jan-Mar 2003 0.65m Color Los Angeles

SARB_002475



Station	Date	Amphipod Survival
HUNBCC	8/19/2005	85%
	6/22/2006	3%
HUNCRB	8/19/2005	54%
	6/22/2006	52%
HUNWAR	8/19/2005	45%
	6/22/2006	82%
TGDC05	8/19/2005	68%
	6/22/2006	68%
BBOLR	8/19/2005	90%
	6/22/2006	79%
TBTMAR	8/19/2005	77%
	6/22/2006	88%

Note: Percent amphipod survival is relative to control group

Figure C-11.7b
Sediment Toxicity in Huntington Harbour Over Recent NPDES and Bight Program Surveys

LEGEND

- ★ County NPDES Water Quality Monitoring Stations
- ▲ SCCWRP 1998 Sediment Toxicity Station and % Amphipod Survival
- ✱ SCCWRP 2003 Sediment Toxicity Station and % Amphipod Survival

Mile
0 0.25 0.5 1

Feet
0 1,250 2,500 5,000 7,500

N

Date: November 10, 2006

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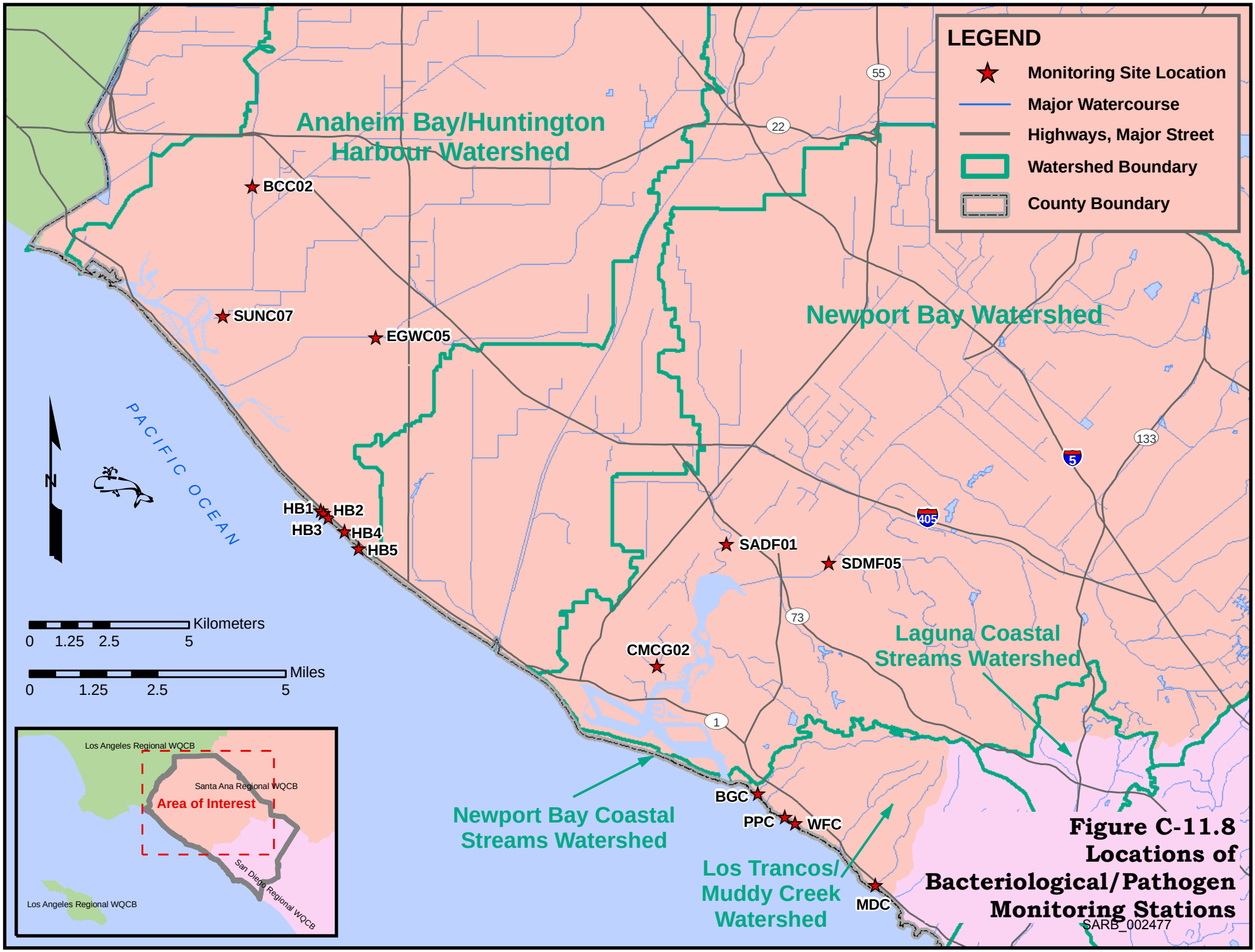

Figure C-11.8
Locations of Bacteriological/Pathogen Monitoring Stations

SARB_002477

Date: November 27, 2006

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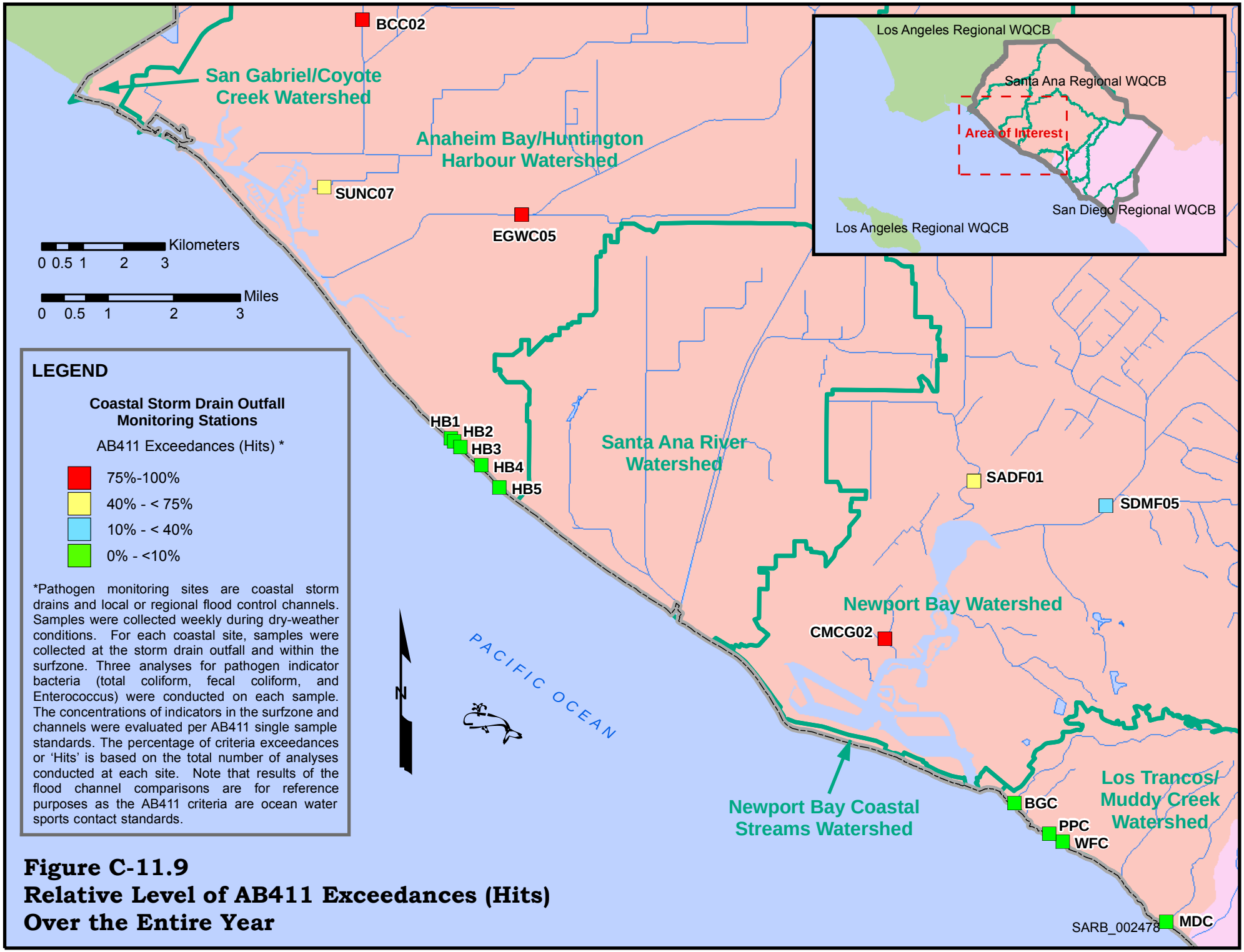

Figure C-11.9
Relative Level of AB411 Exceedances (Hits) Over the Entire Year

Date: November 27, 2006

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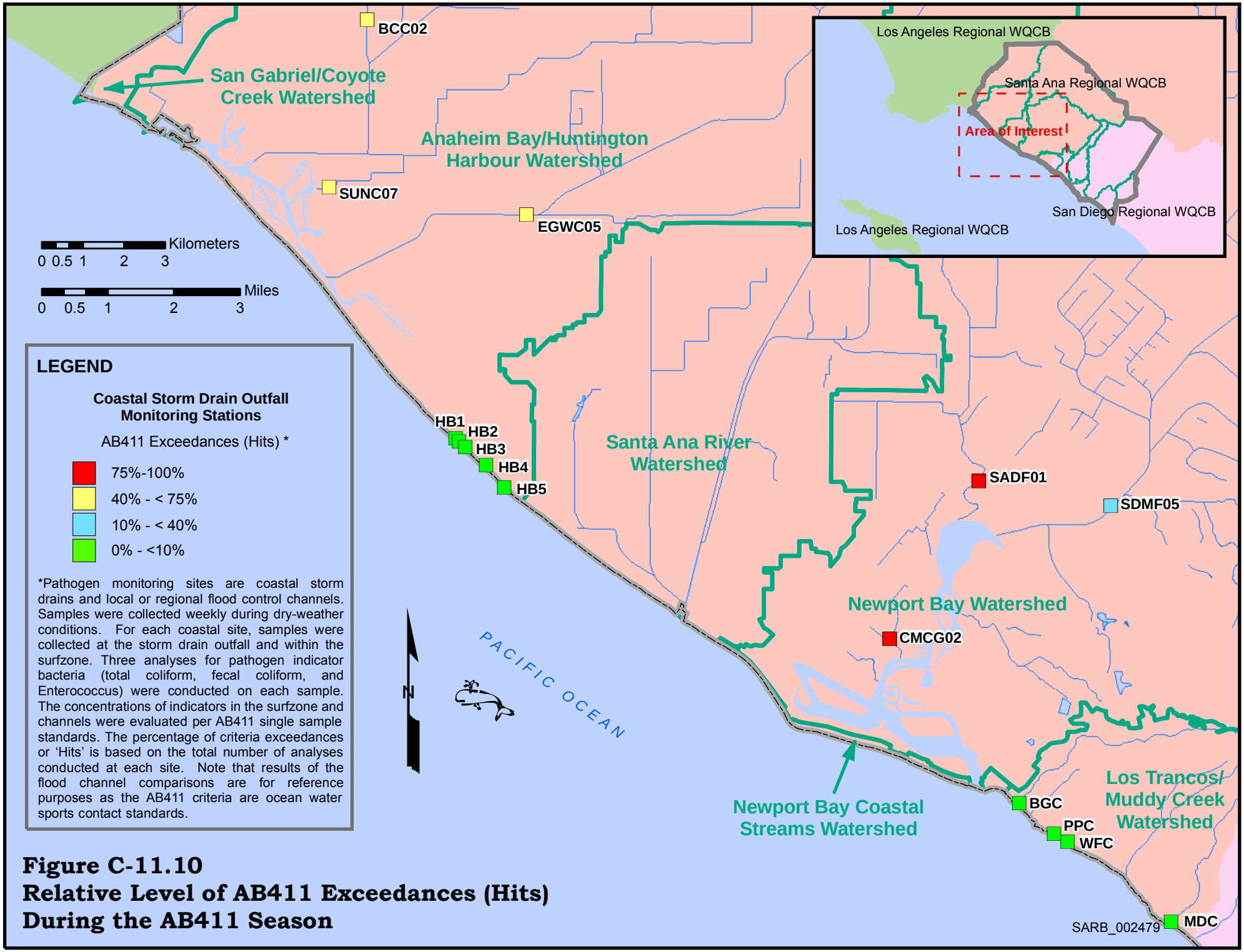
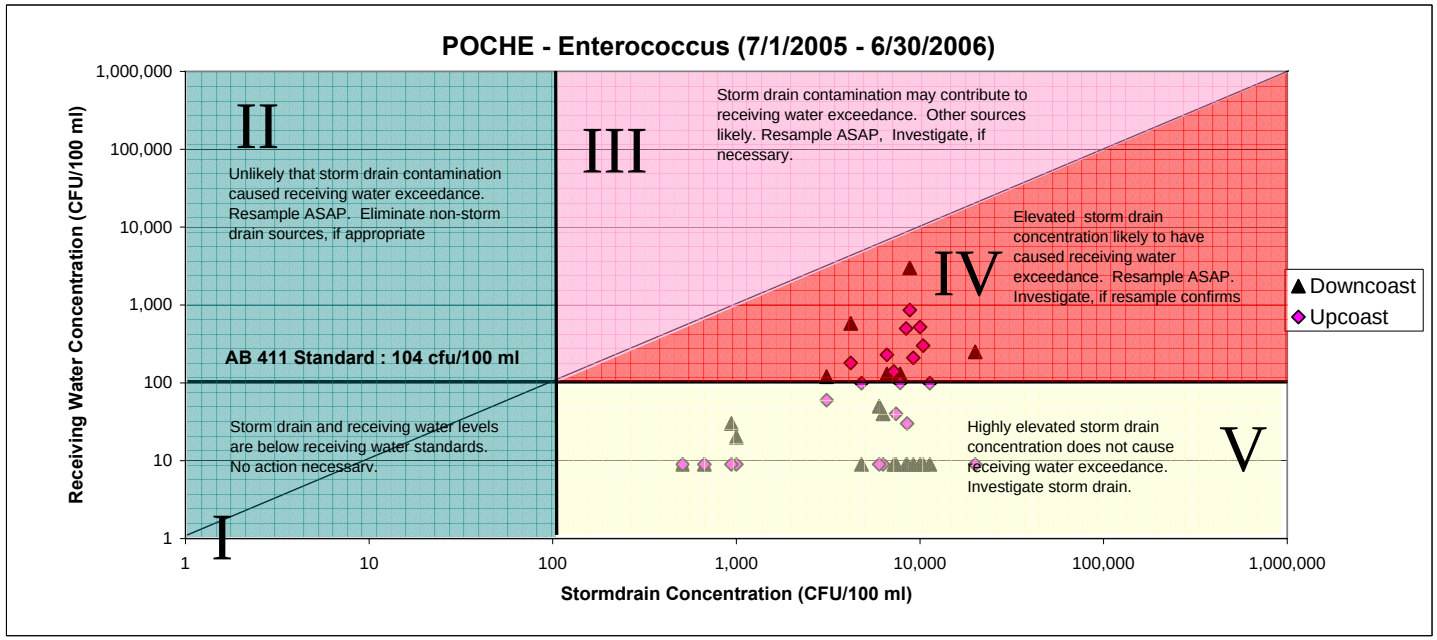


Figure C-11.10
Relative Level of AB411 Exceedances (Hits) During the AB411 Season

Figure C-11.11
Examples of Strong and Weak Relationships between Indicator Bacteria in the Stormdrain Discharge and Receiving Waters



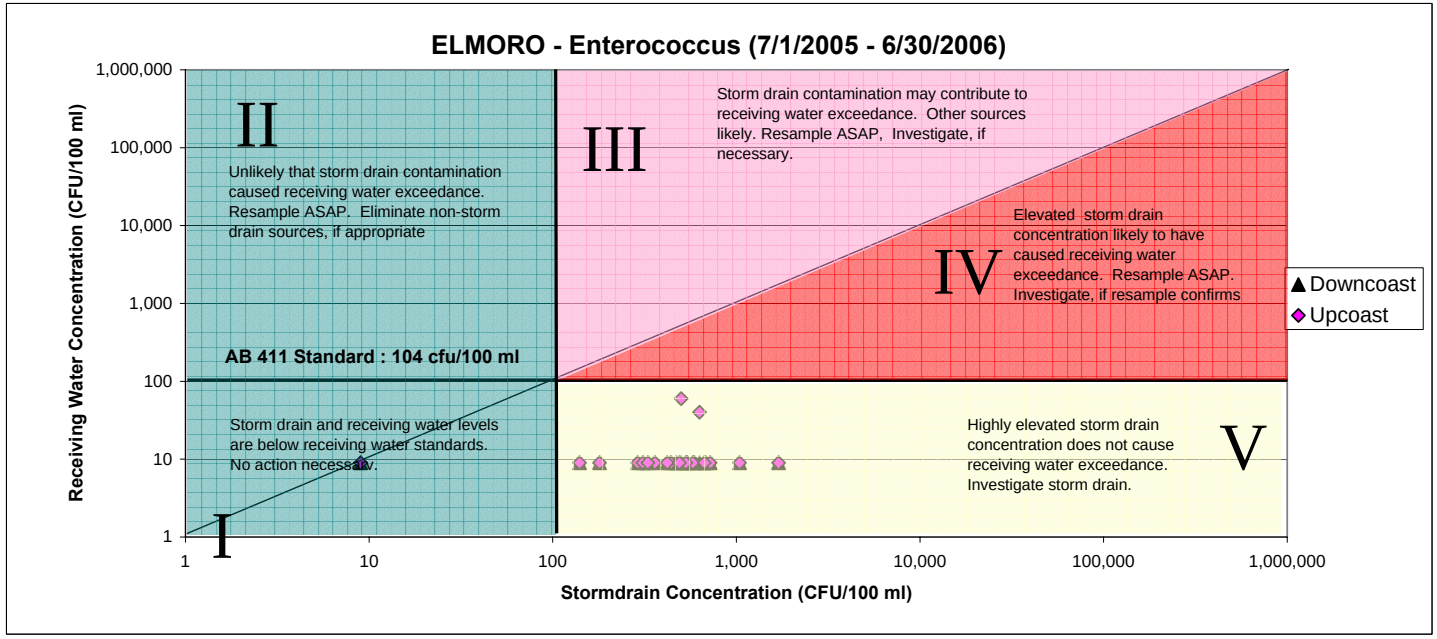
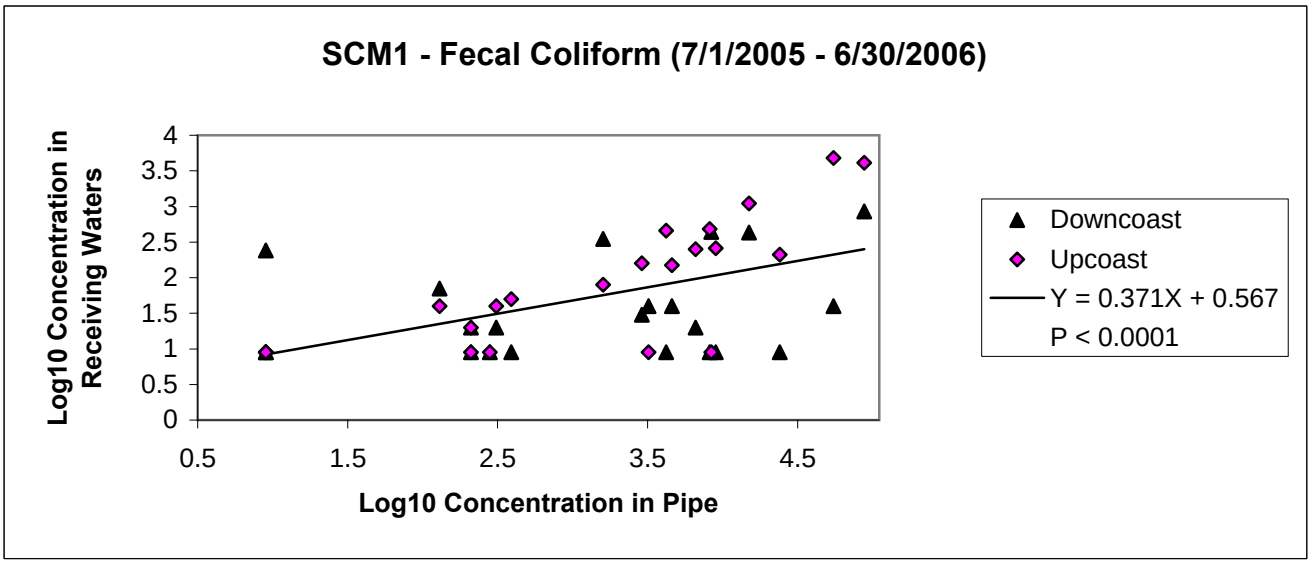
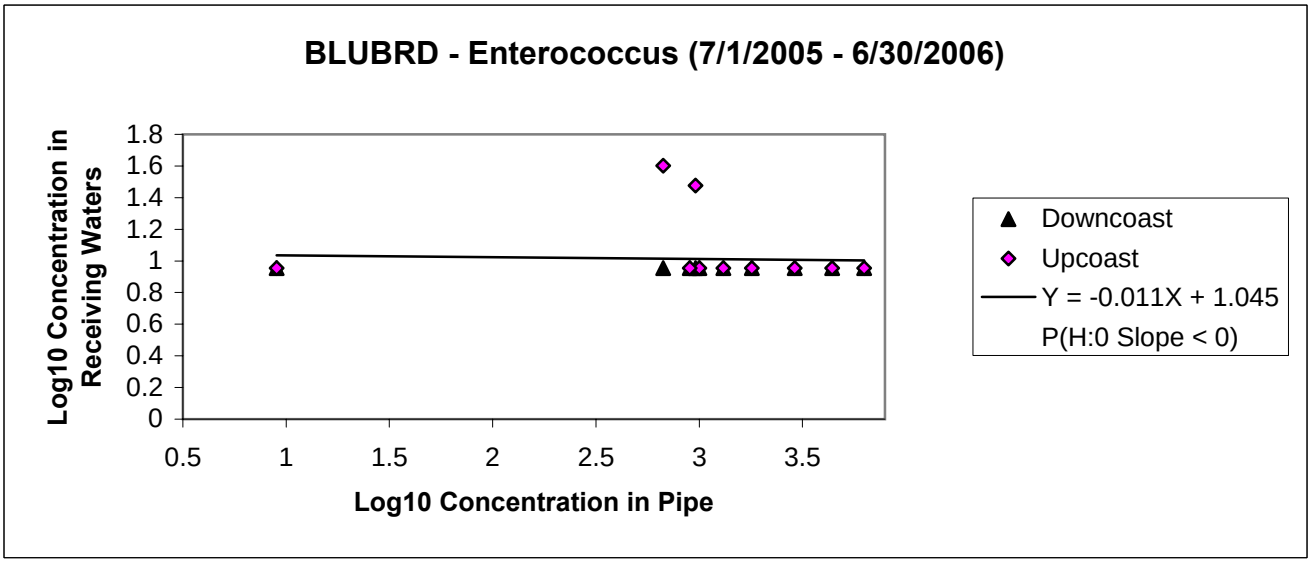


Figure C-11.12
Examples of Strong and Weak Correlations between
Receiving Waters and Stormdrain Discharges





Null Hypothesis : slope<or=0 (i.e. no relationship)
P values: Probability that null hypothesis is true given the data

Date: November 13, 2006

s:\GIS\mxds\SAR_Bioassessment_Stations_Overview.mxd

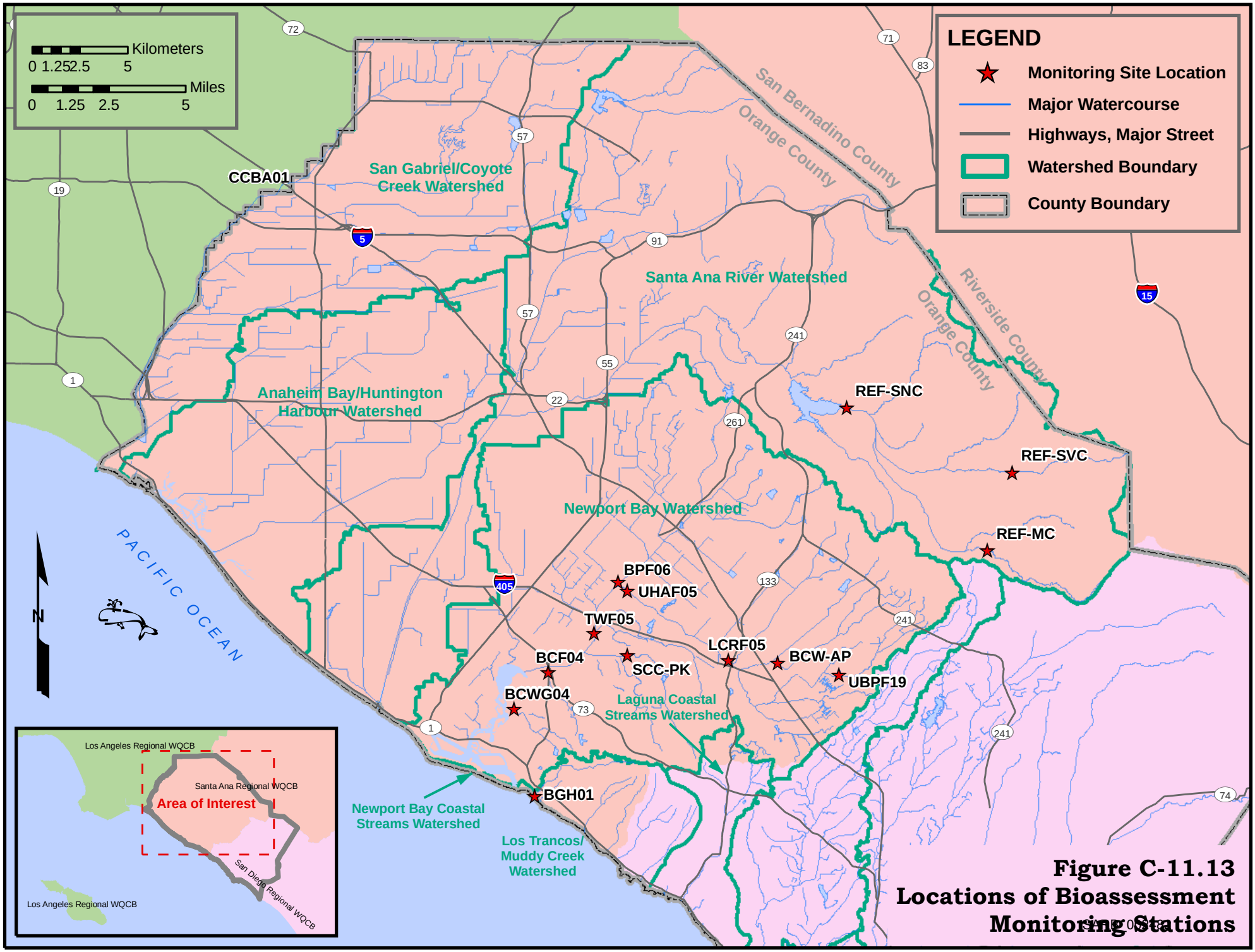
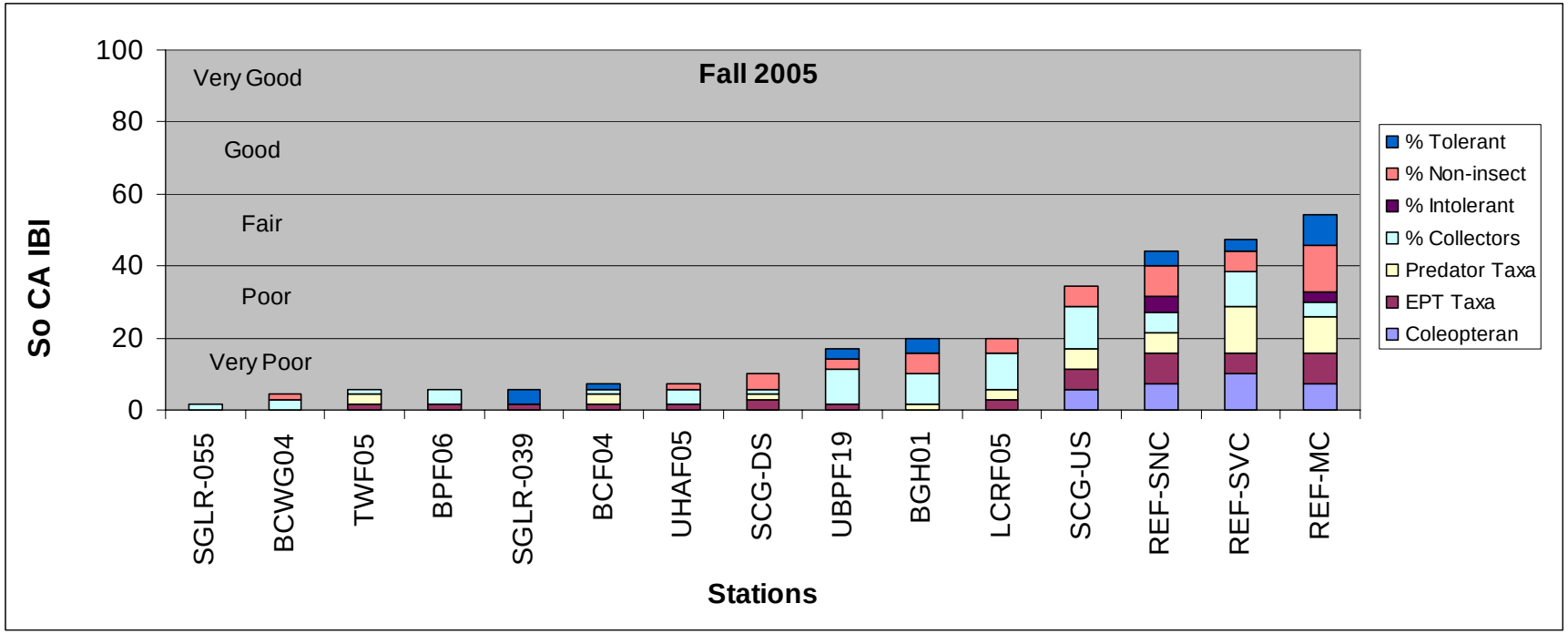


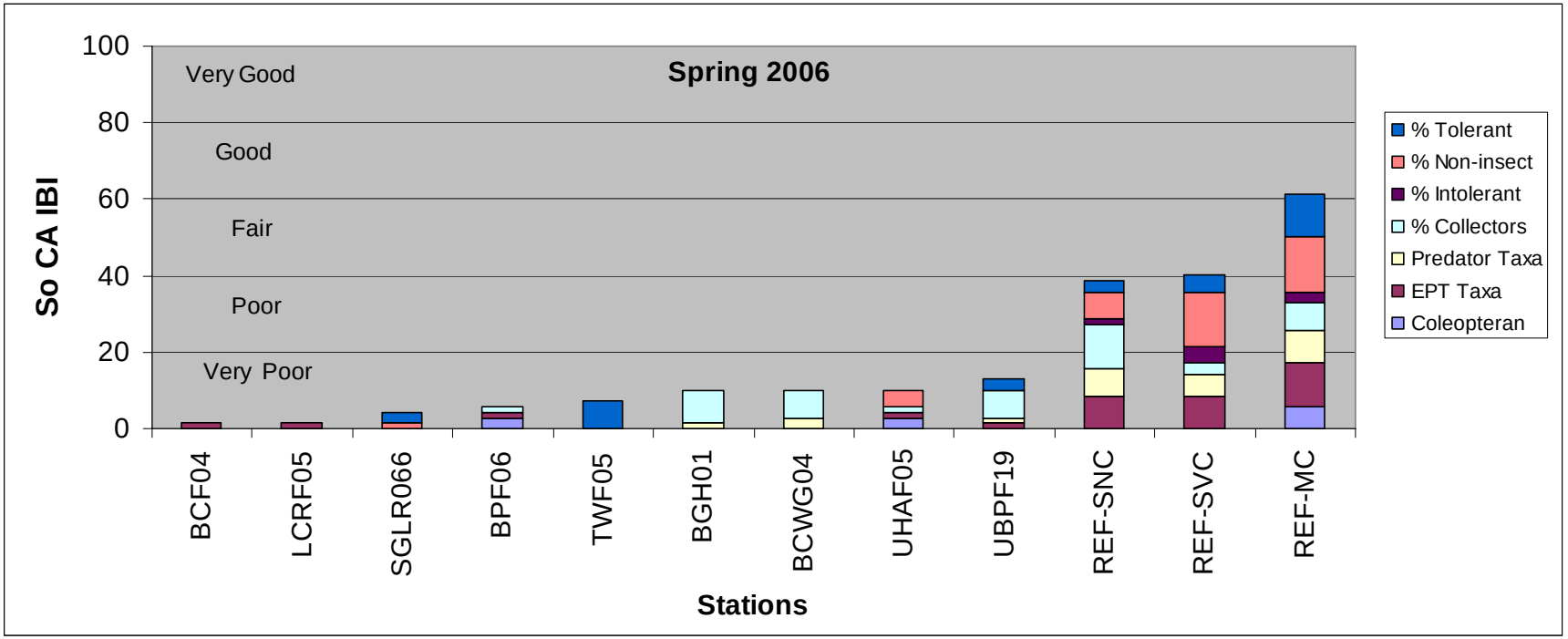
Figure C-11.13
Locations of Bioassessment Monitoring Stations

Figure C-11.14. IBI Results of the Fall 2005 Sampling



Note: sites SGLR-055, SGLR-039, and SCG-DS are special study sites that are not part of the core program.

Figure C-11.15. IBI Results of the Spring 2006 Sampling



Note: site SGLR-066 is a special study site that is not part of the core program.

Date: November 27, 2006

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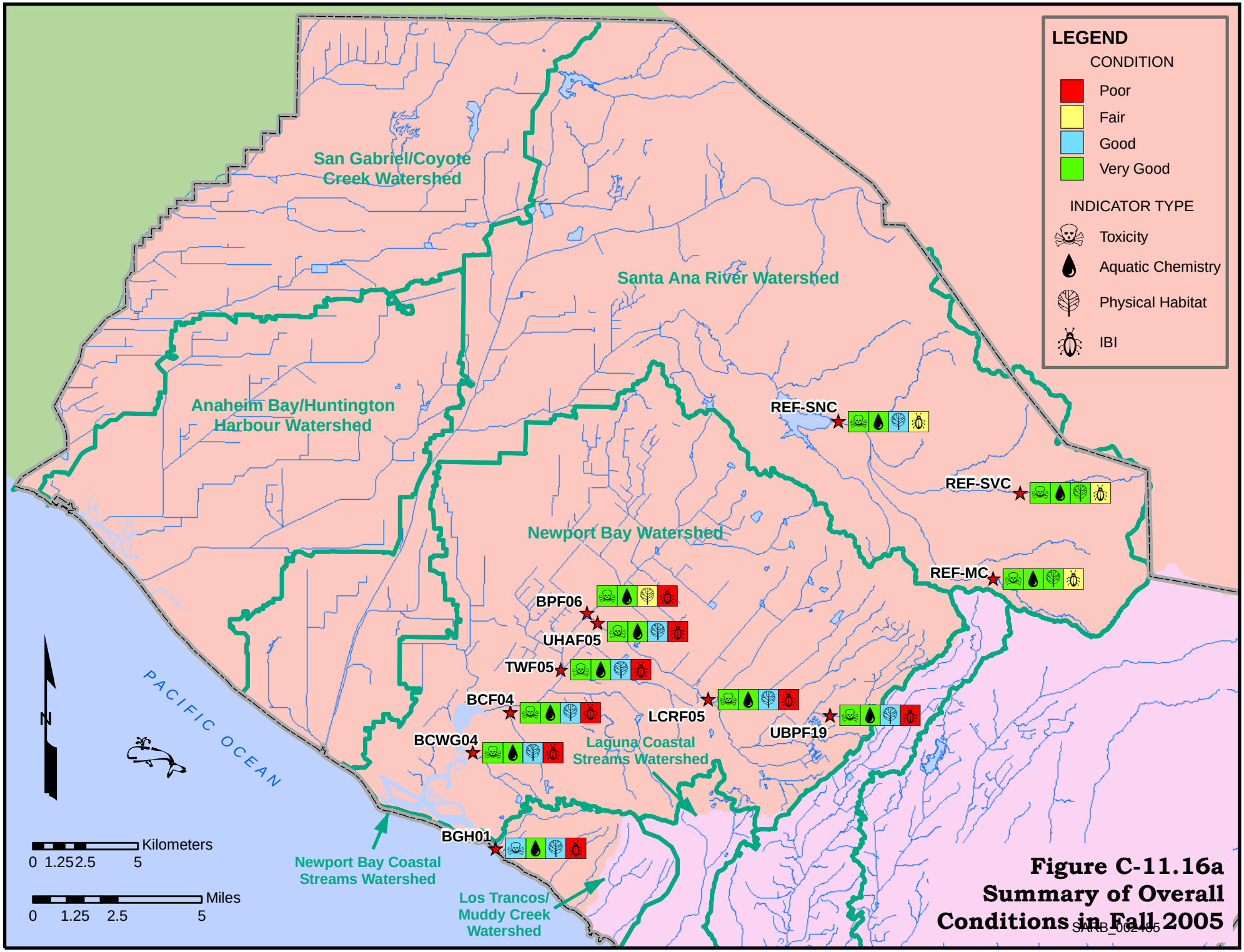

Figure C-11.16a
Summary of Overall Conditions in Fall 2005

SARB_002485

Date: November 27, 2006

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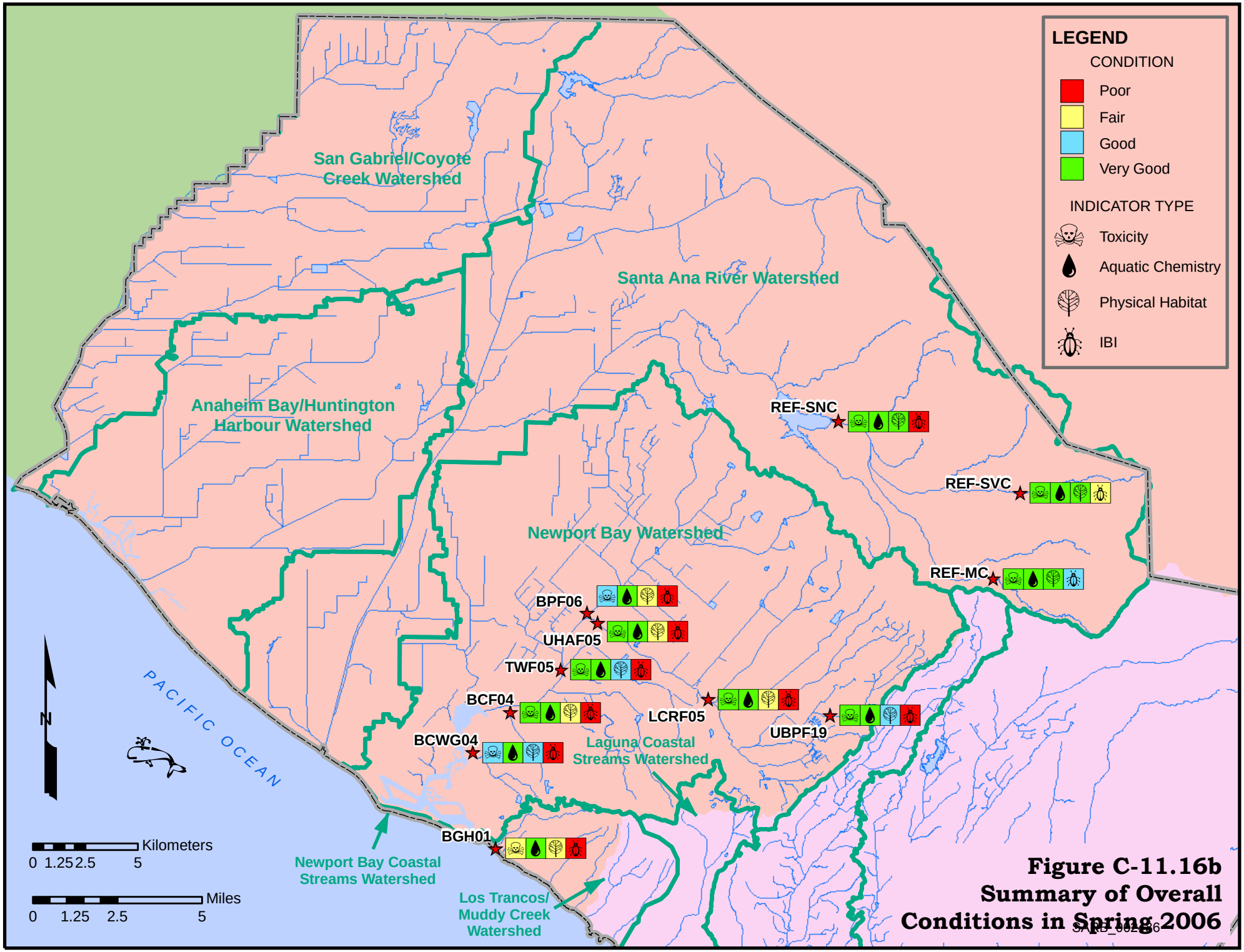
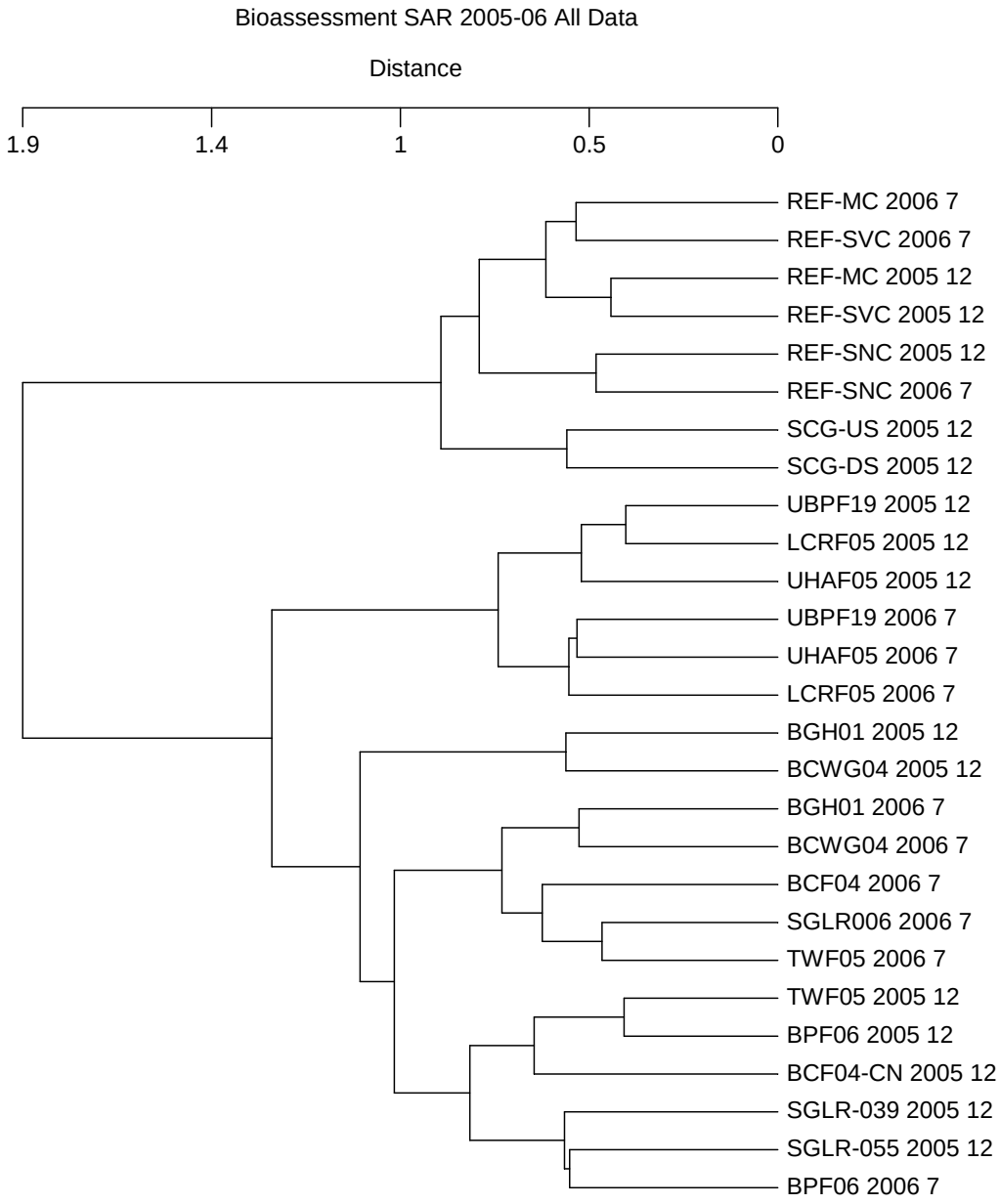


Figure C-11.16b
Summary of Overall Conditions in Spring 2006

SAR_00286

Figure C-11.17. Station Dendrogram for 2005-2006 Bioassessment Survey



10/25/2006

Figure C-11.18. Two-way Coincidence Table of Stations and Species for 2005-2006 Bioassessment Survey

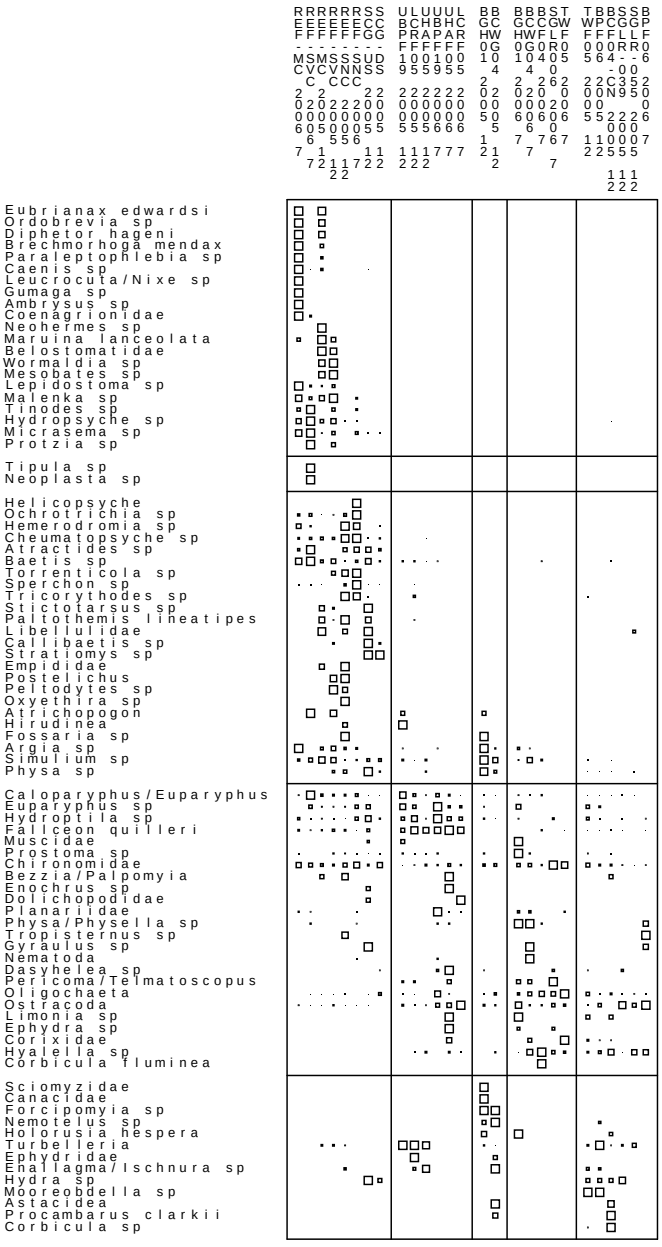


Figure C-11.19a
Box and Whisker Plots of Biological Related Parameters for the Fall 2005 Bioassessment Survey

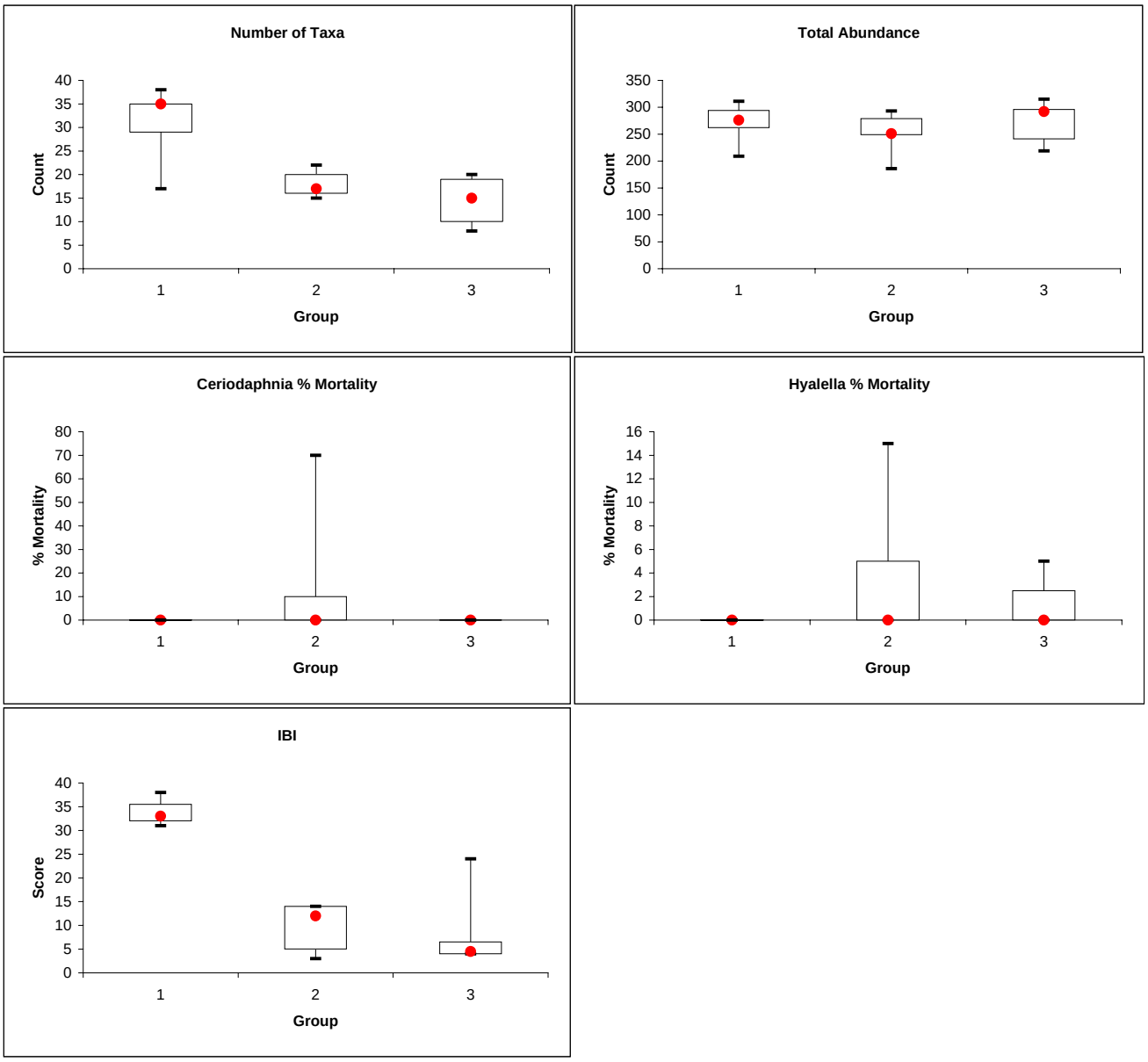


Figure C-11.19b
Box and Whisker Plots of Physical Habitat Parameters for the Fall 2005 Bioassessment Survey

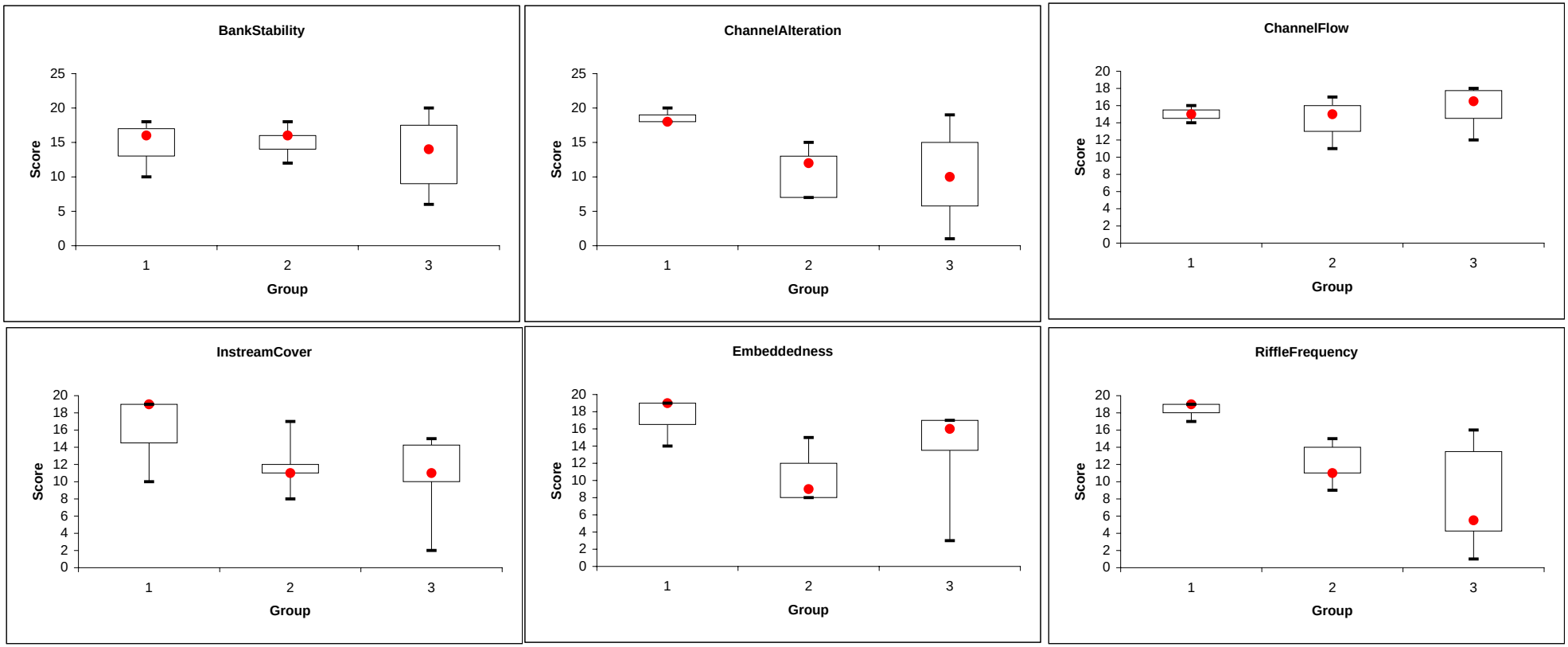


Figure C-11.19b
Box and Whisker Plots of Physical Habitat Parameters for the Fall 2005 Bioassessment Survey

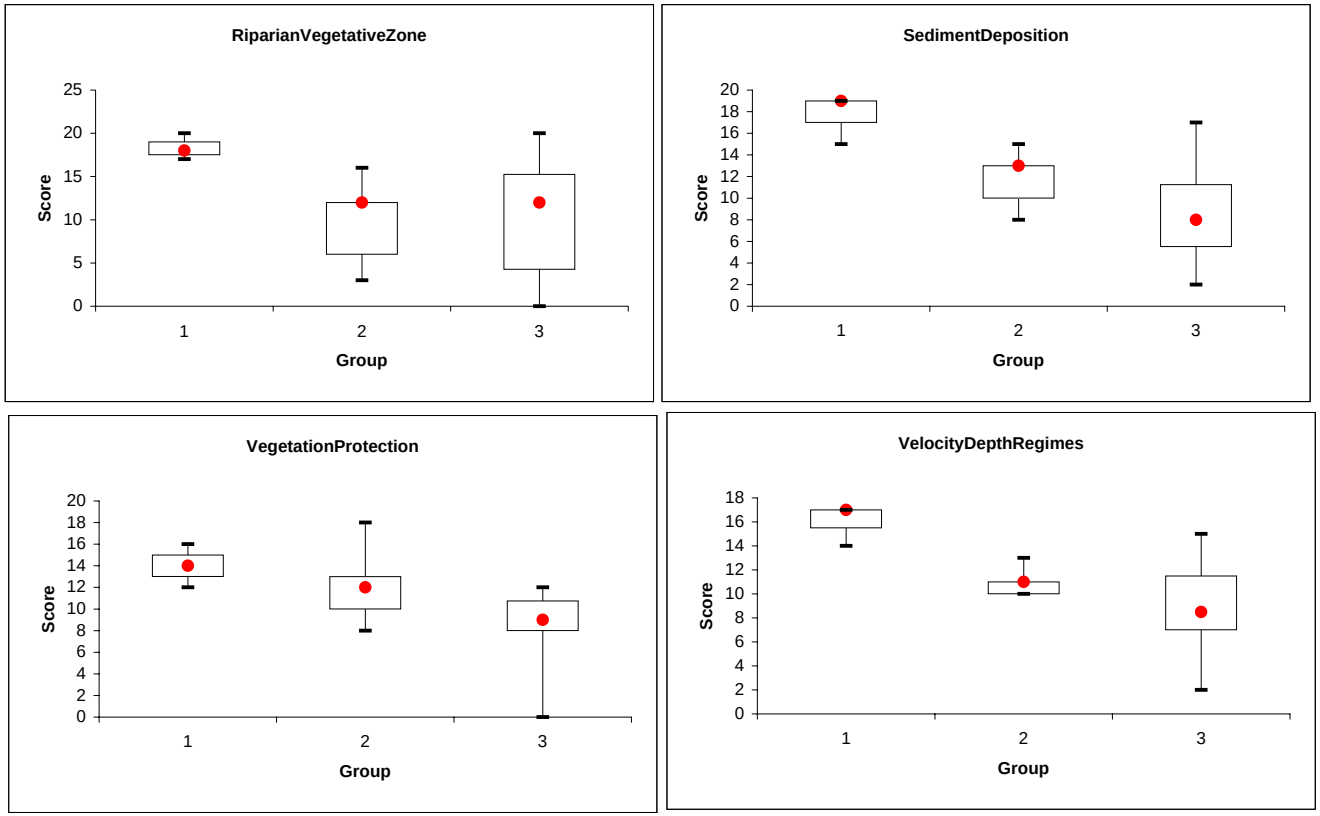


Figure C-11.19c
Boxplots of Related Water Quality Parameters for the Fall 2005 Bioassessment Survey

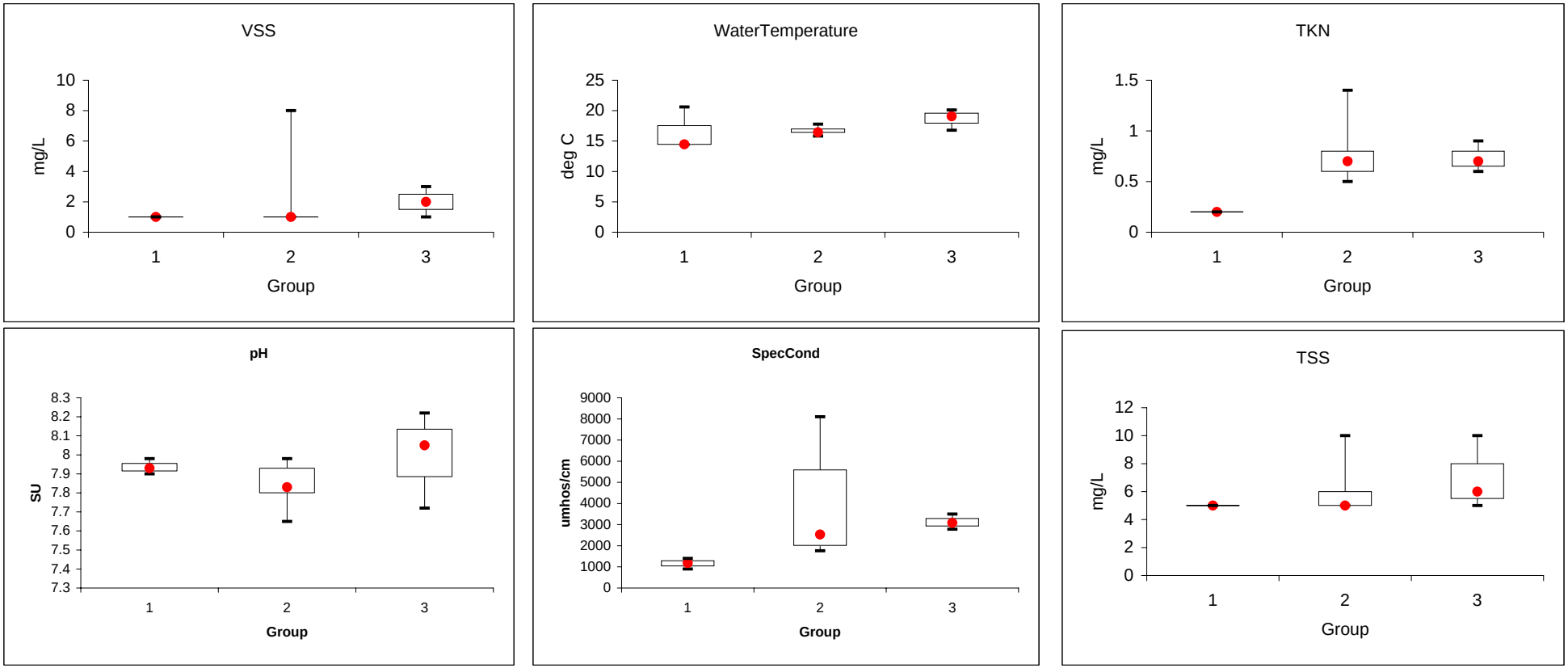
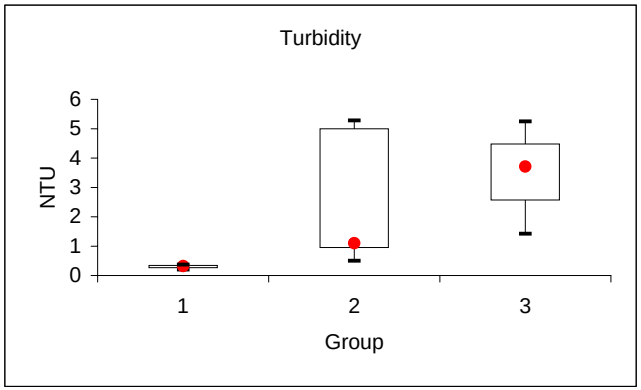
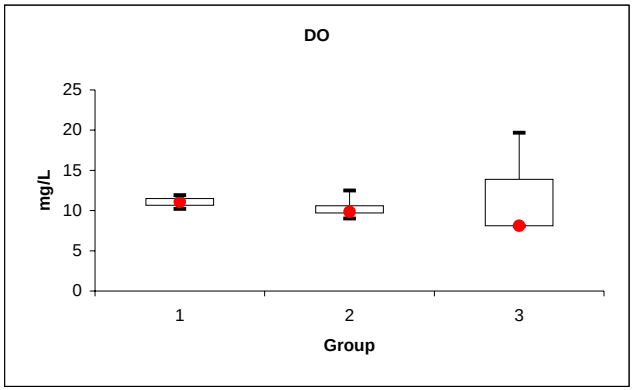
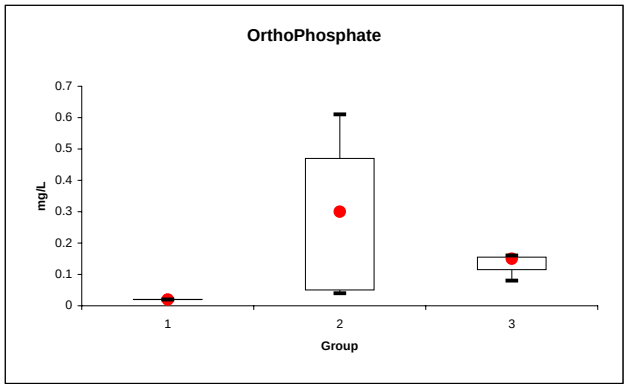


Figure C-11.19c
Boxplots of Related Water Quality Parameters for the Fall 2005 Bioassessment Survey







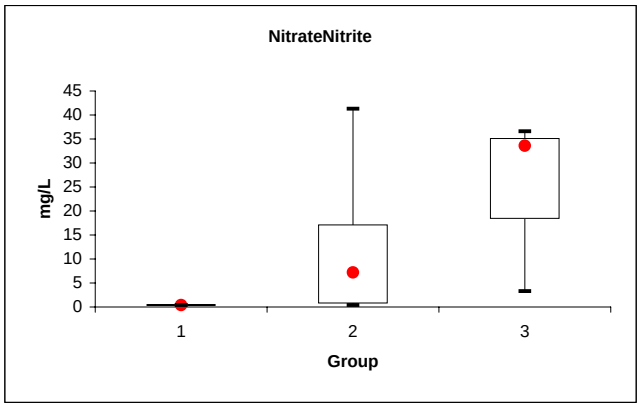


Figure C-11.19d
Boxplots of Related Pollutant Parameters for the Fall 2005 Bioassessment Survey

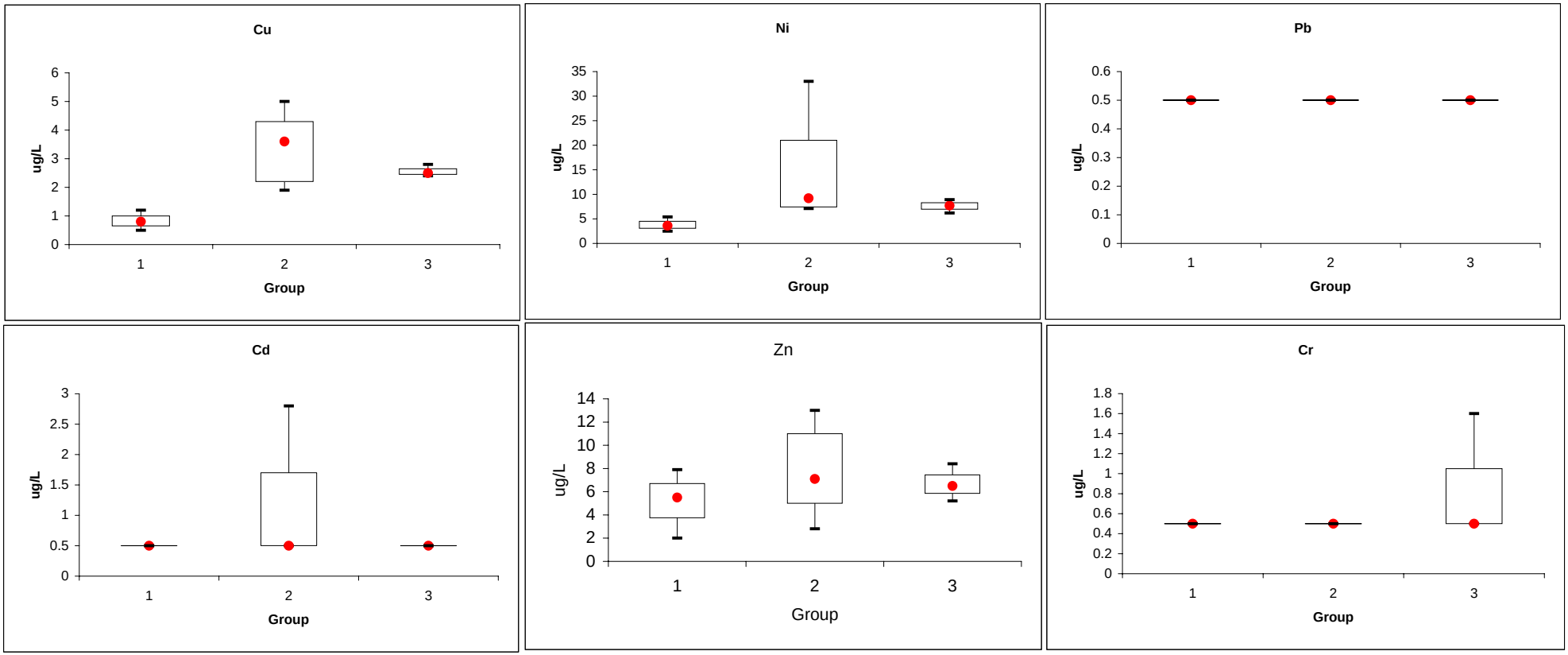
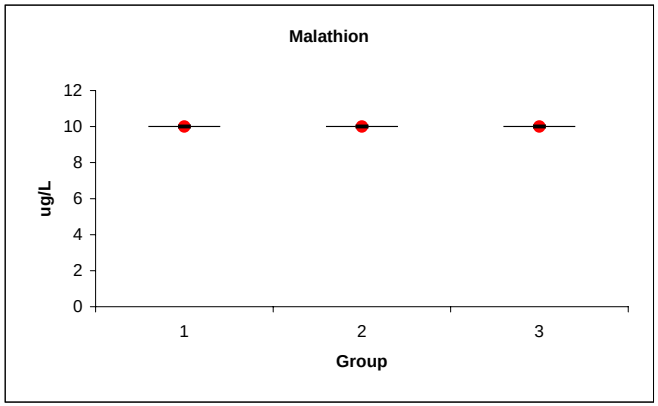


Figure C-11.19d
Boxplots of Related Pollutant Parameters for the Fall 2005 Bioassessment Survey



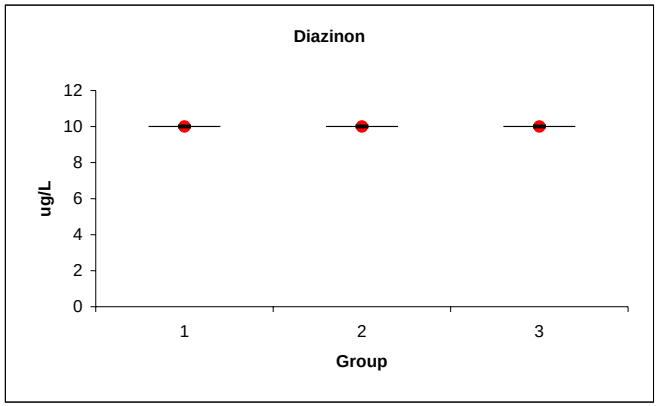


Figure C-11.20a
Box and Whisker Plots of Related Biological Parameters for the Spring 2006 Bioassessment Survey

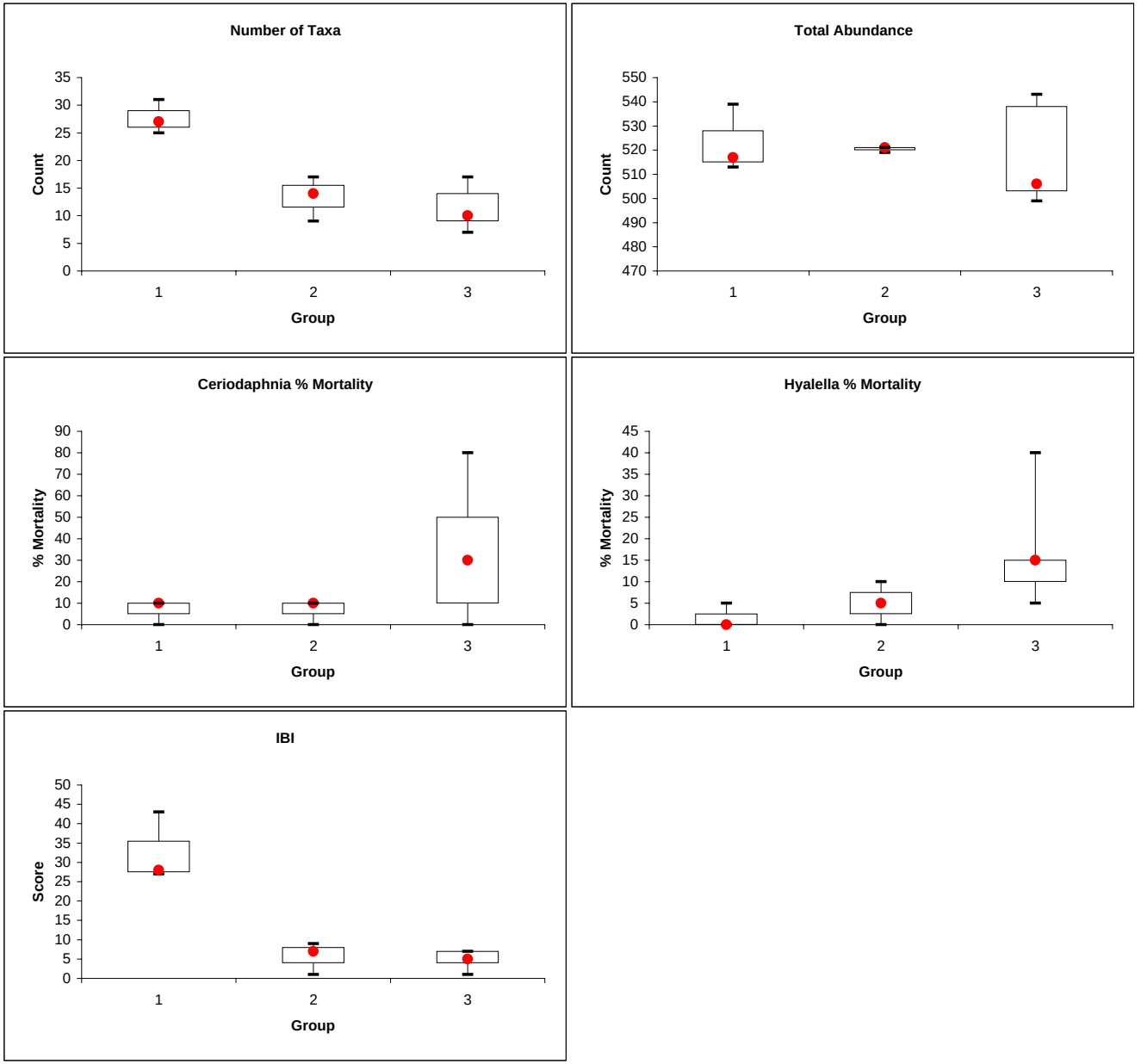


Figure C-11.20b
Box and Whisker Plots of Physical Habitat Parameters for the Spring 2006 Bioassessment Survey

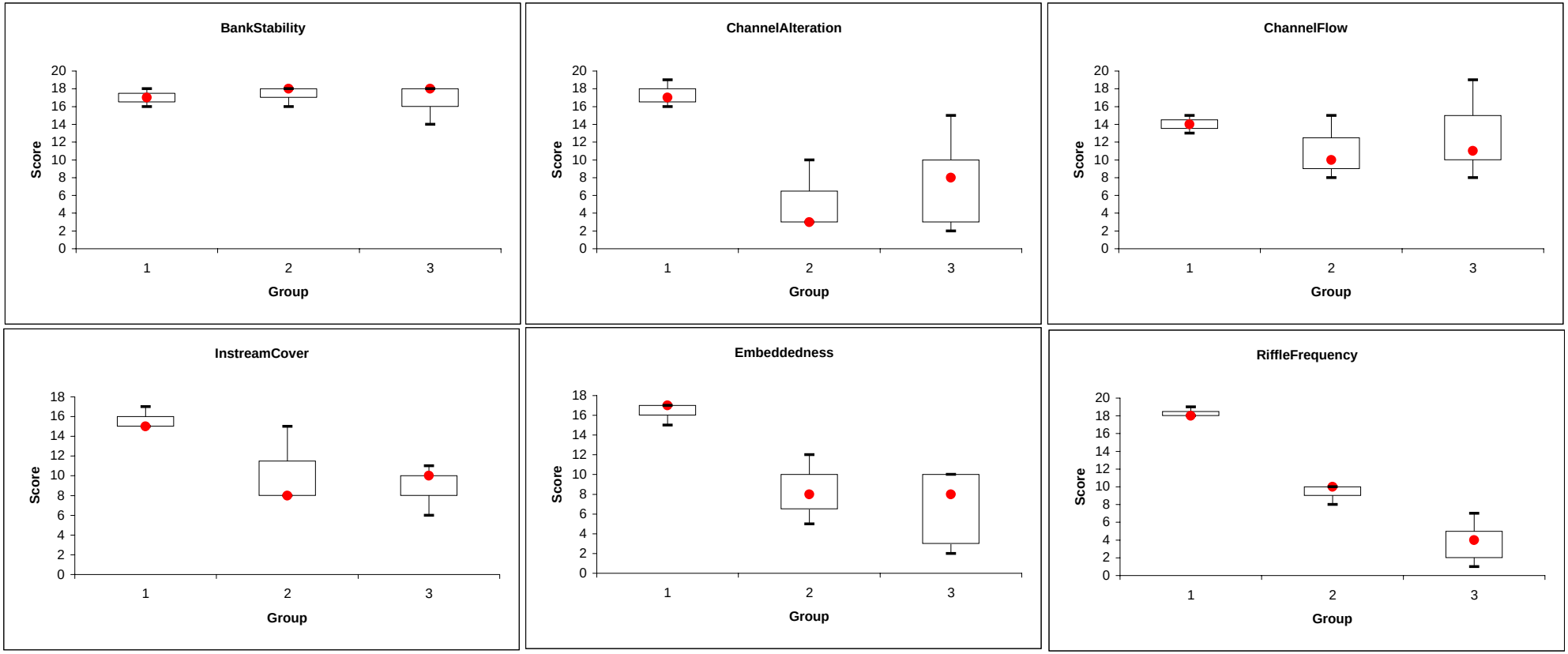


Figure C-11.20b
Box and Whisker Plots of Physical Habitat Parameters for the Spring 2006 Bioassessment Survey

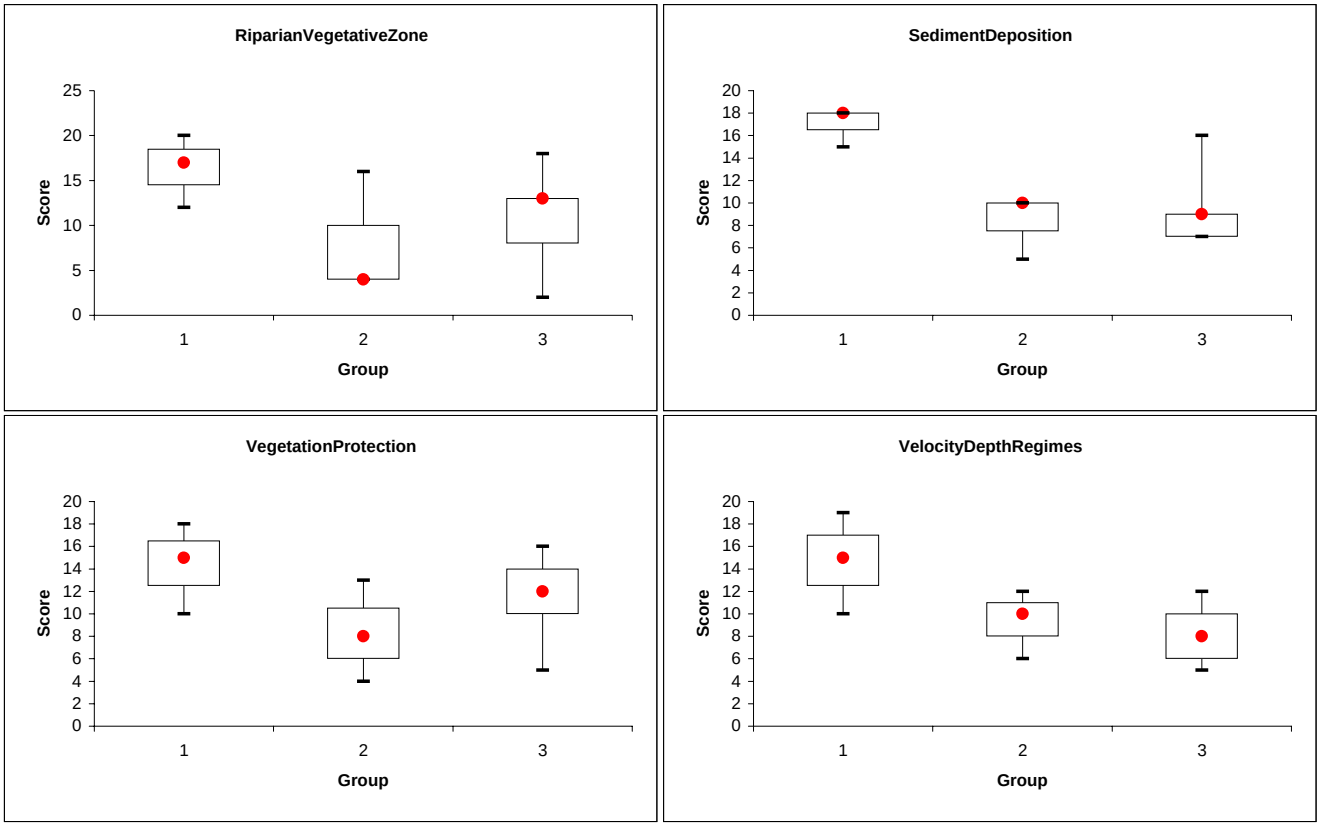


Figure C-11.20c
Box and Whisker Plots of Related Water Quality Parameters for the Spring 2006 Bioassessment Survey

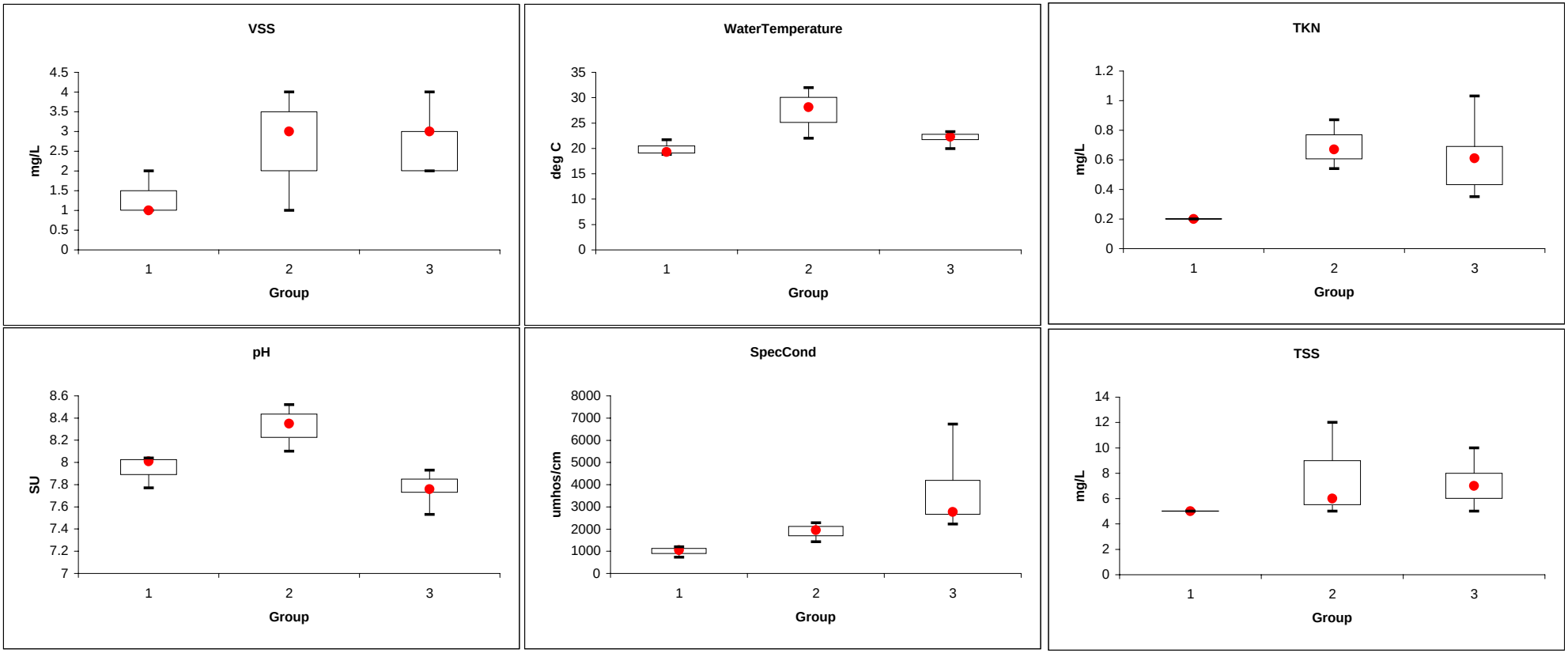
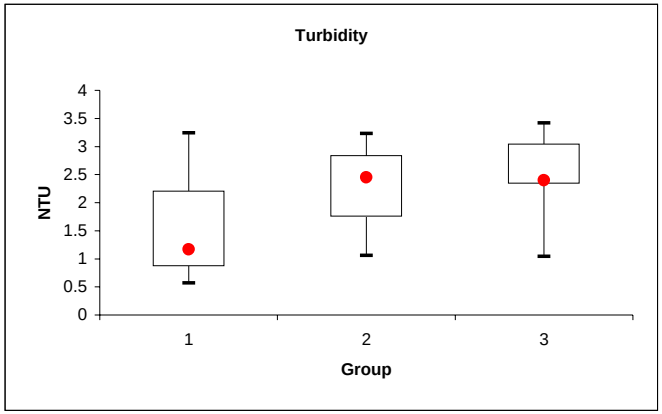
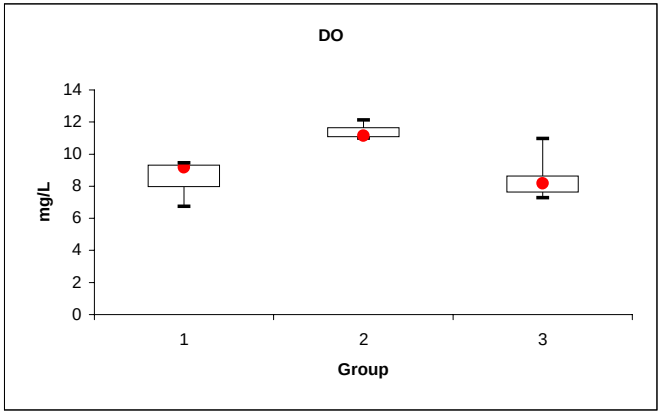
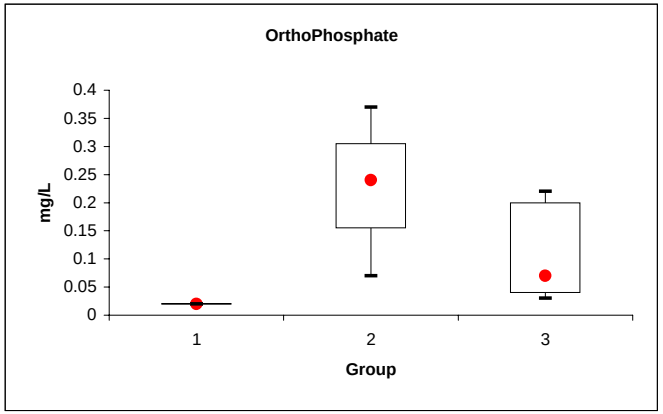


Figure C-11.20c
Box and Whisker Plots of Related Water Quality Parameters for the Spring 2006 Bioassessment Survey







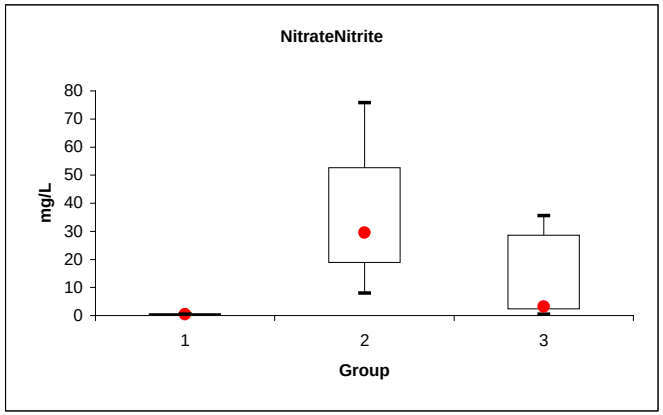
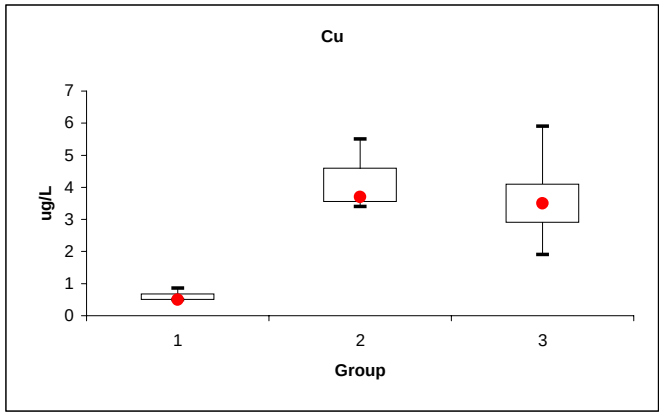
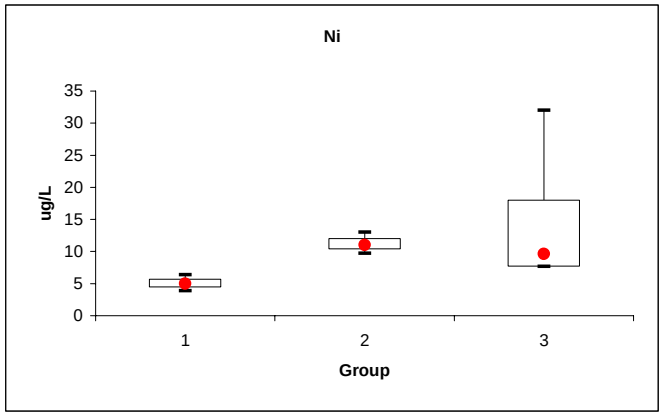
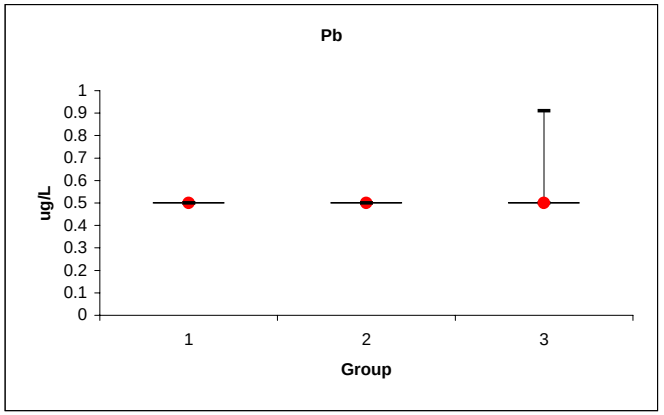
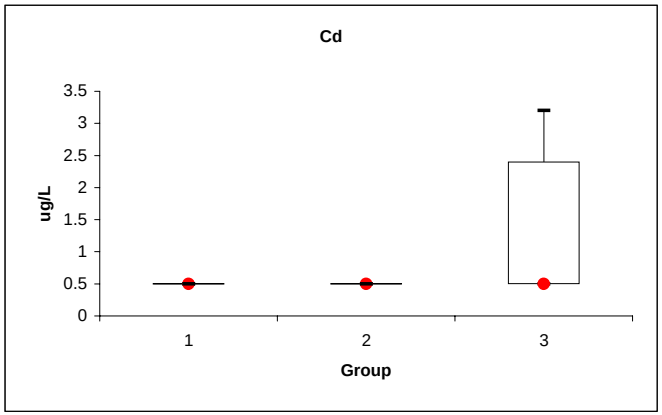


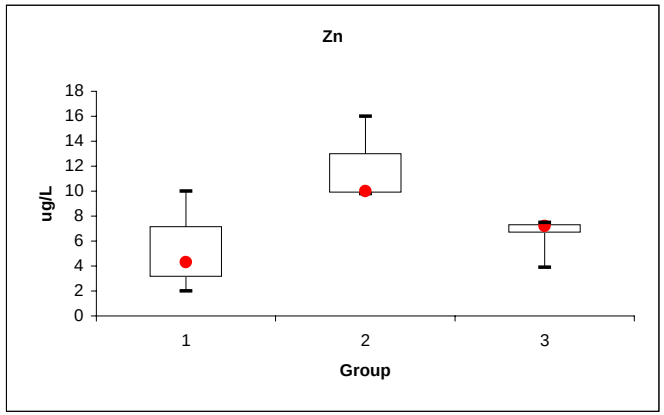
Figure C-11.20d
Box and Whisker Plots of Related Pollutant Parameters for the Spring 2006 Bioassessment Survey











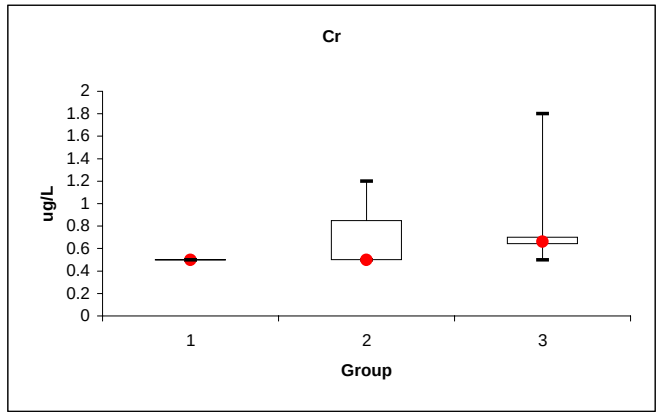
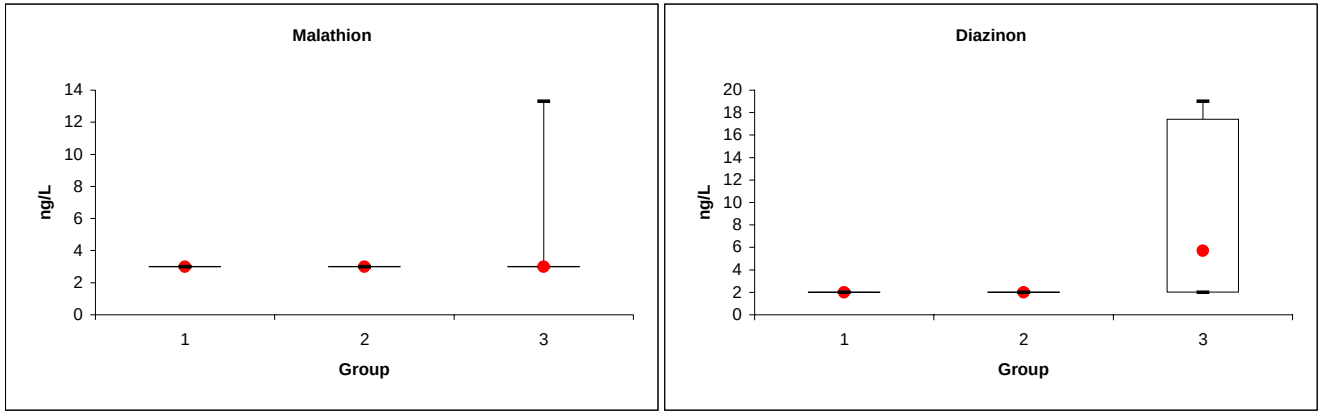


Figure C-11.20d
Box and Whisker Plots of Related Pollutant Parameters for the Spring 2006 Bioassessment Survey



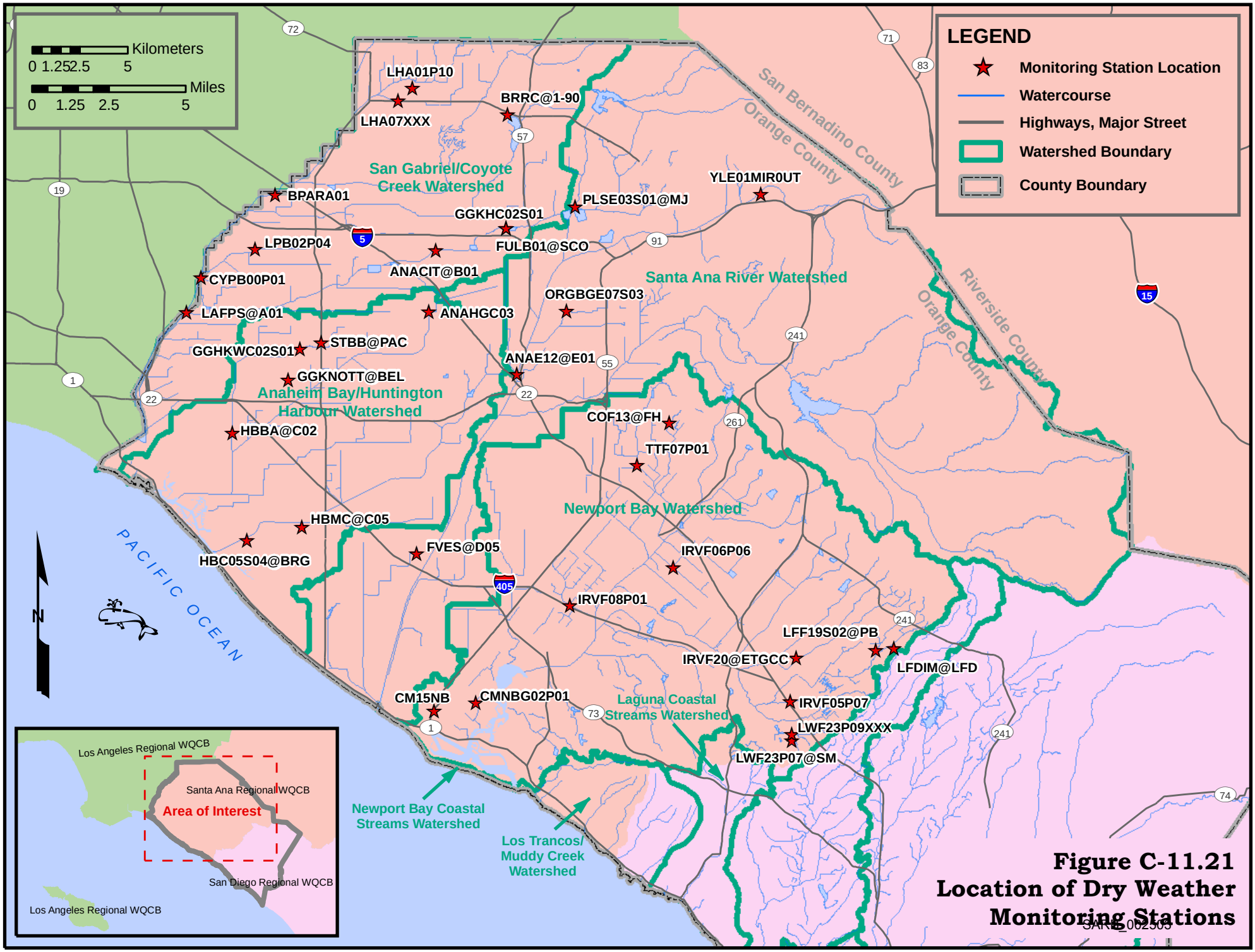


Figure C-11.21
Location of Dry Weather Monitoring Stations

Date: November 13, 2006

s:\GIS\mxds\SAR_Land_Use_Stations_Overview.mxd

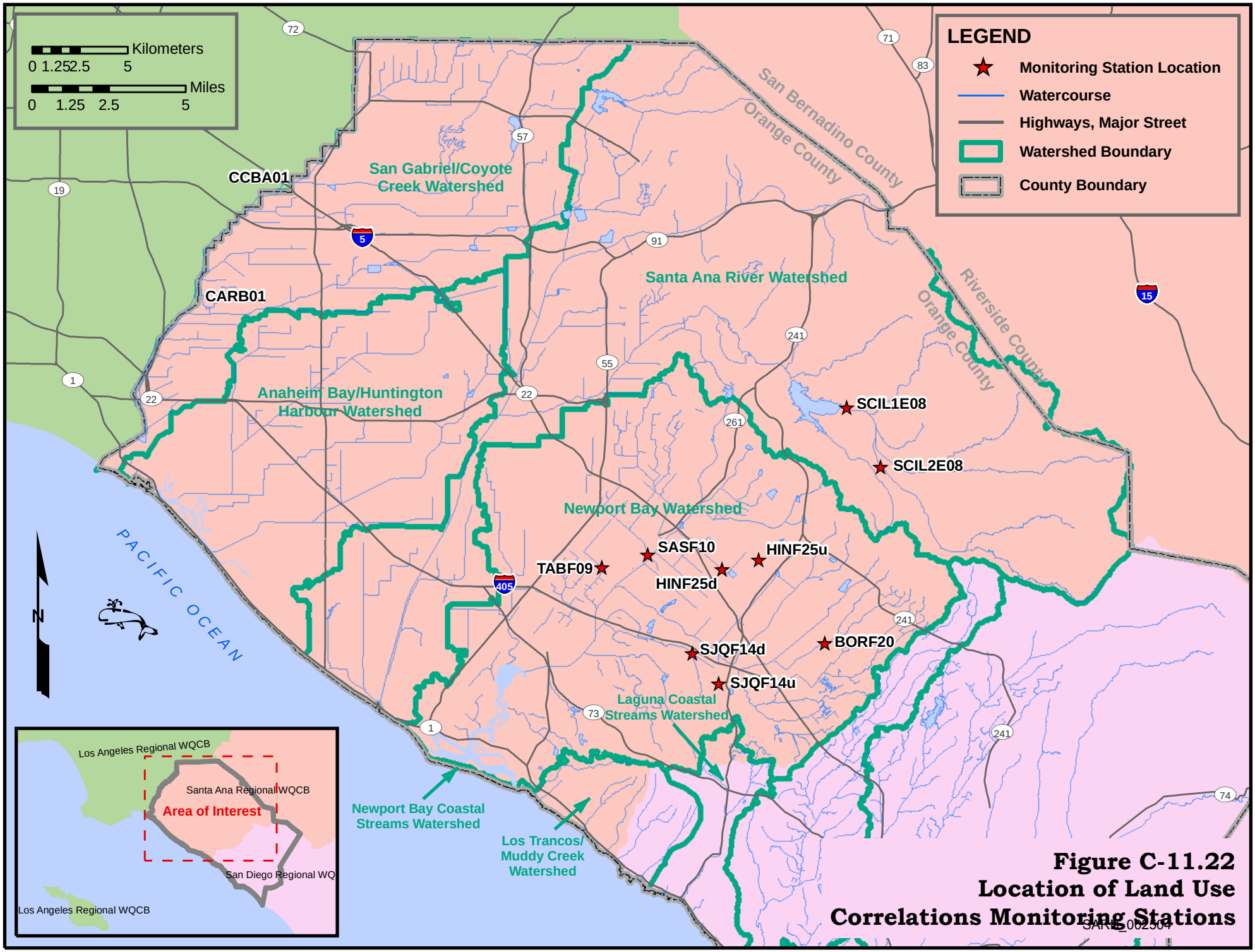
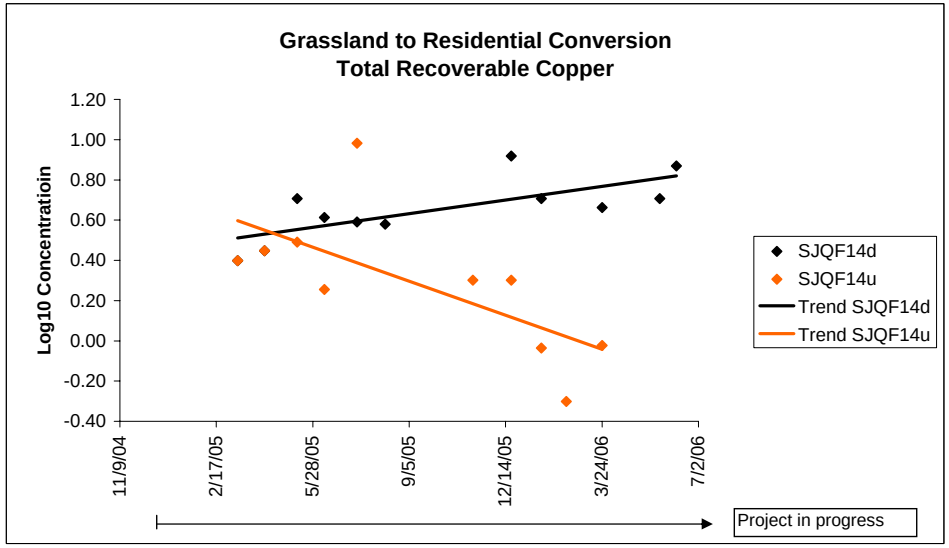
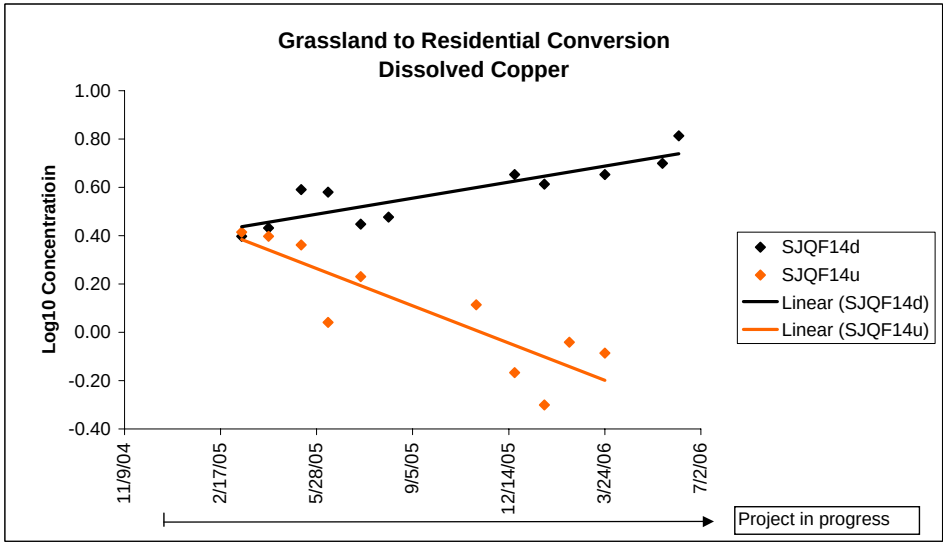


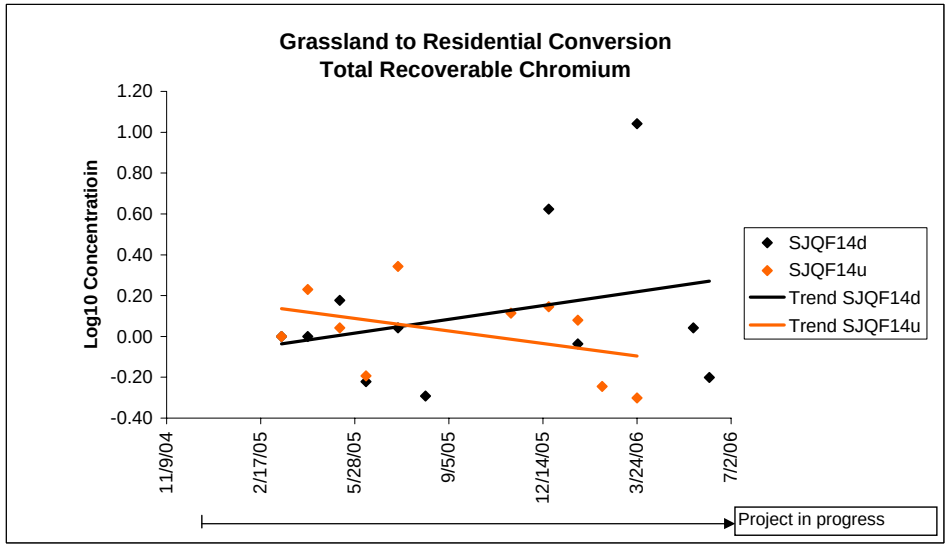
Figure C-11.22
Location of Land Use Correlations Monitoring Stations

SAR2_002504

Figure C-11.23a
Trends in Dry Weather Concentrations of Trace Elements and Nutrients
Upstream and Downstream of a Grassland to Residential Landuse Conversion







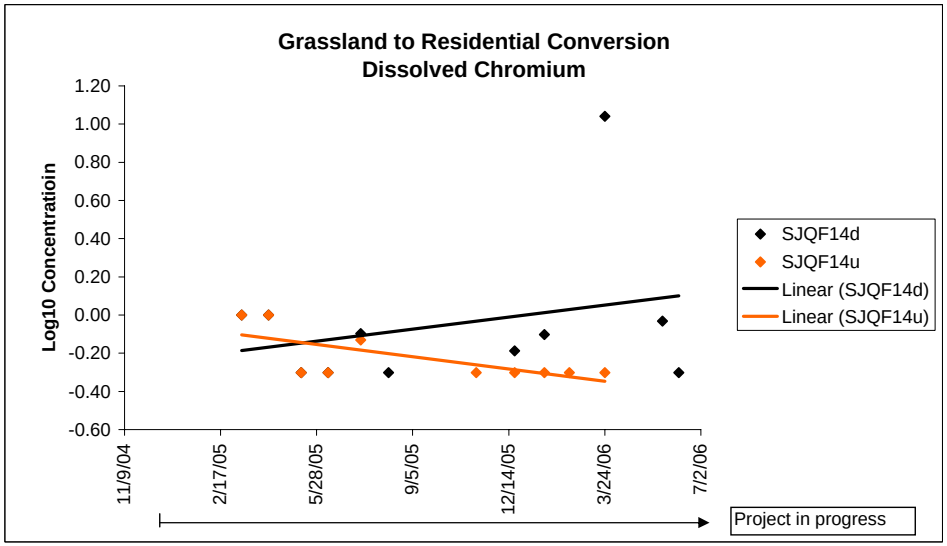
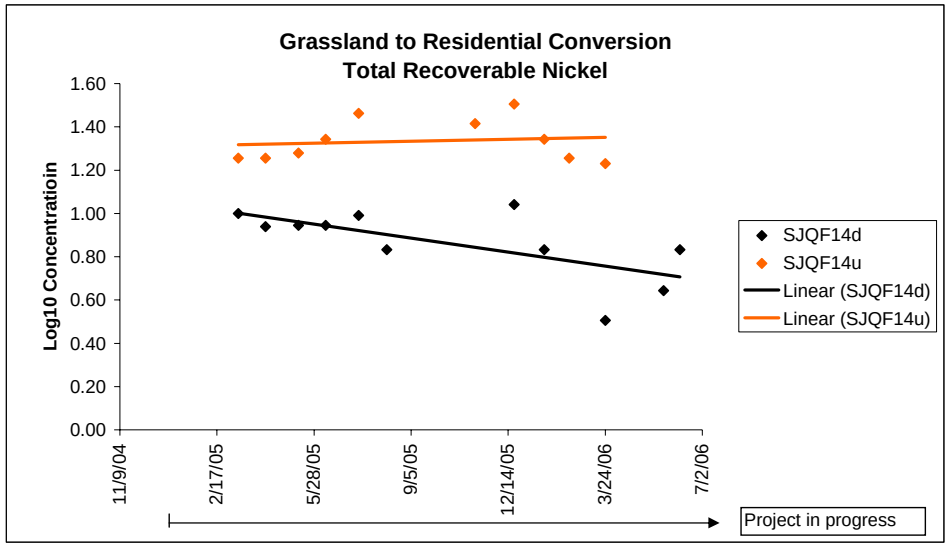
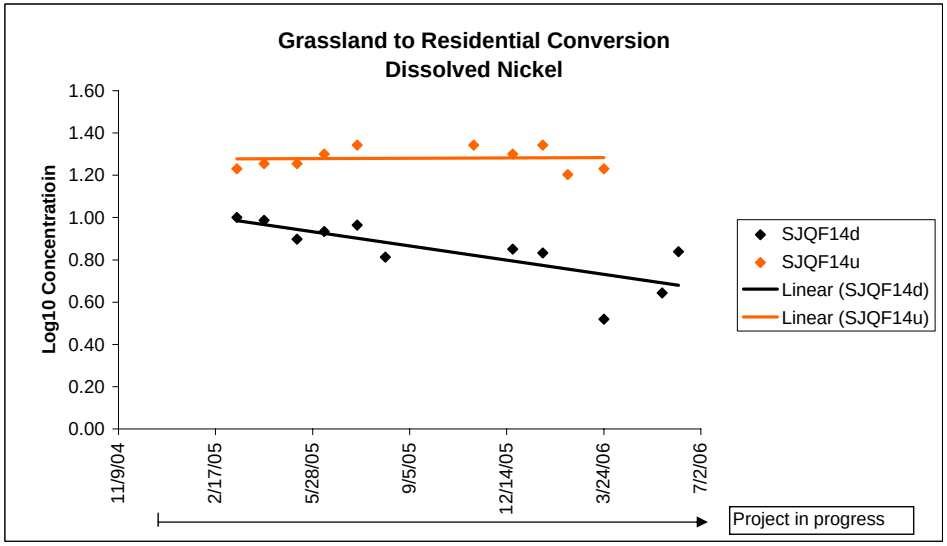
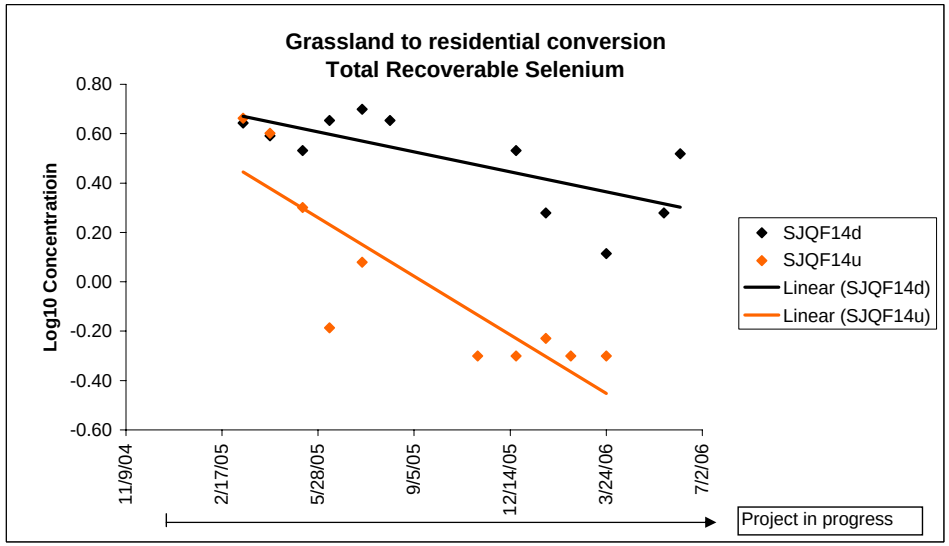


Figure C-11.23a
Trends in Dry Weather Concentrations of Trace Elements and Nutrients
Upstream and Downstream of a Grassland to Residential Landuse Conversion







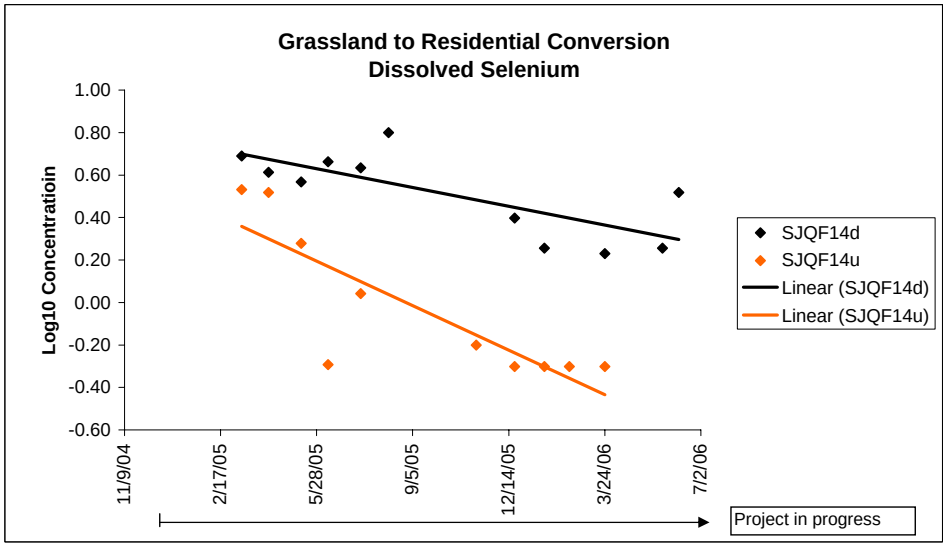
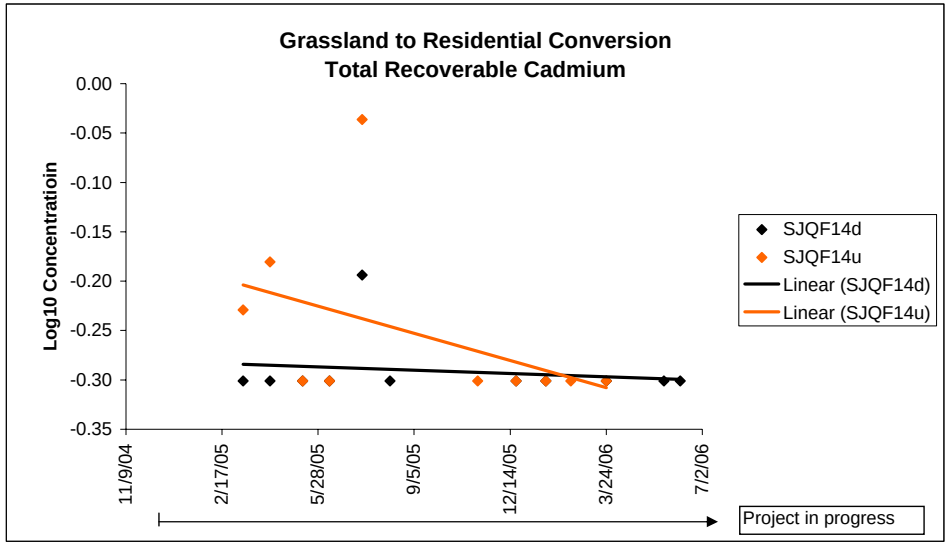
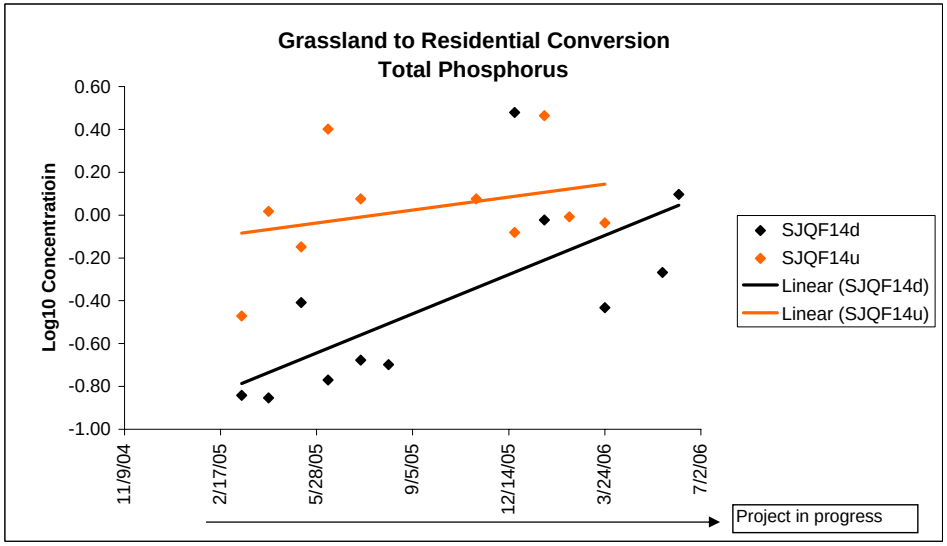


Figure C-11.23a
Trends in Dry Weather Concentrations of Trace Elements and Nutrients
Upstream and Downstream of a Grassland to Residential Landuse Conversion





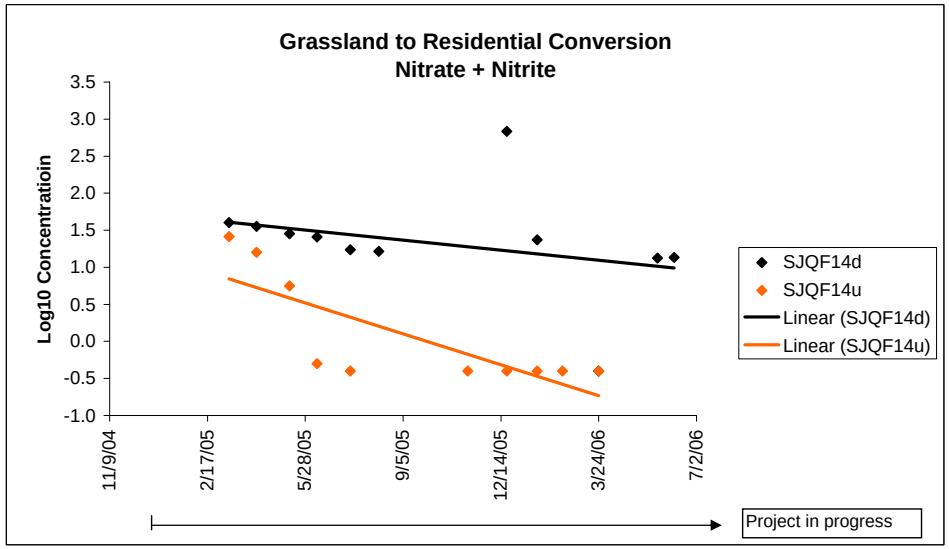
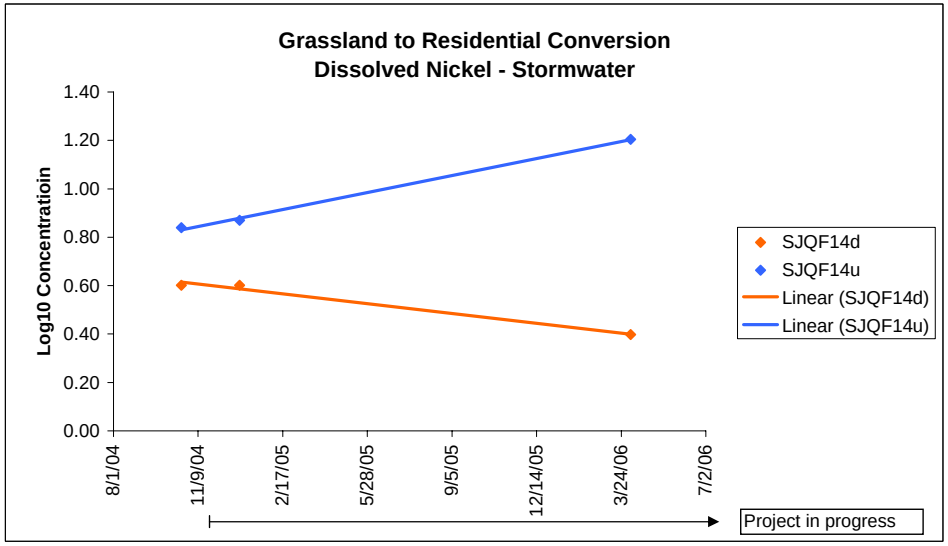
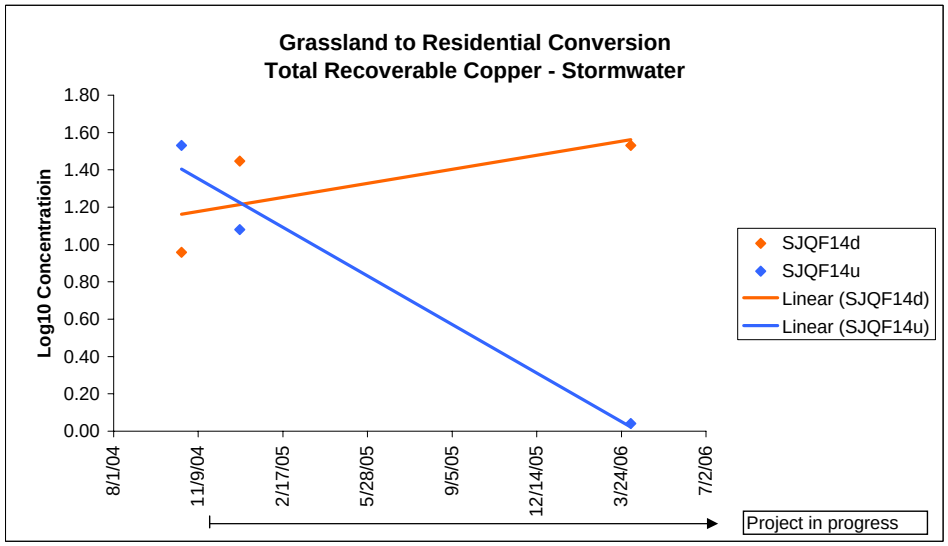
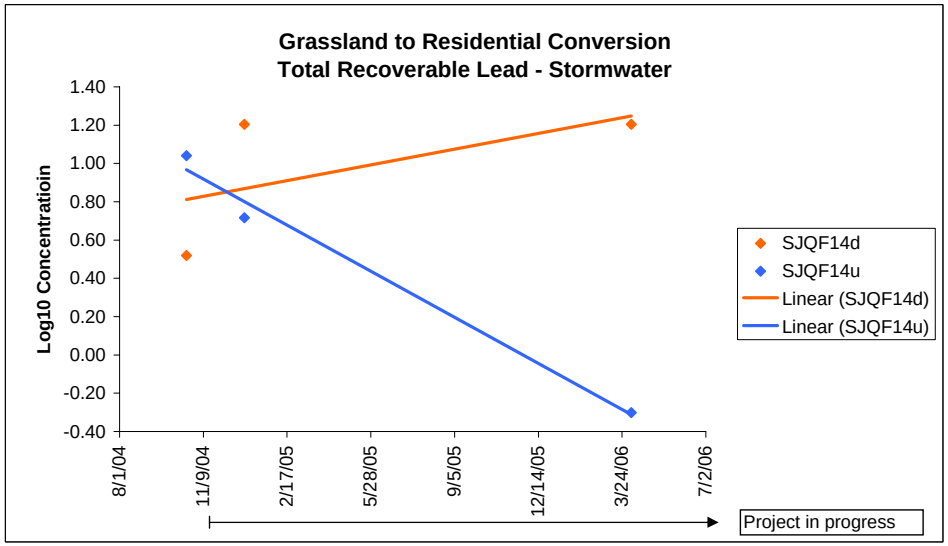


Figure C-11.23b
Trends in Stormwater Concentrations of Trace Elements and Nutrients Upstream and Downstream of a Grassland to Residential Landuse Conversion







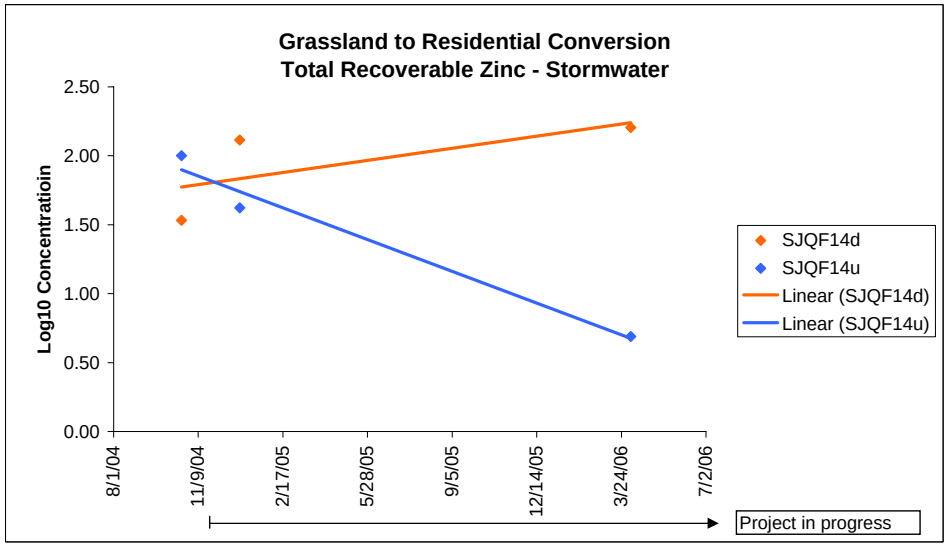
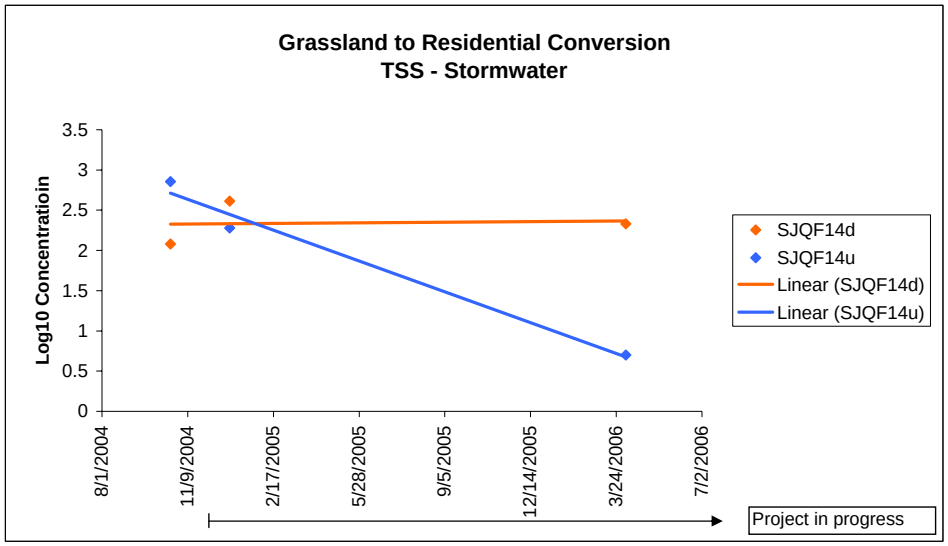
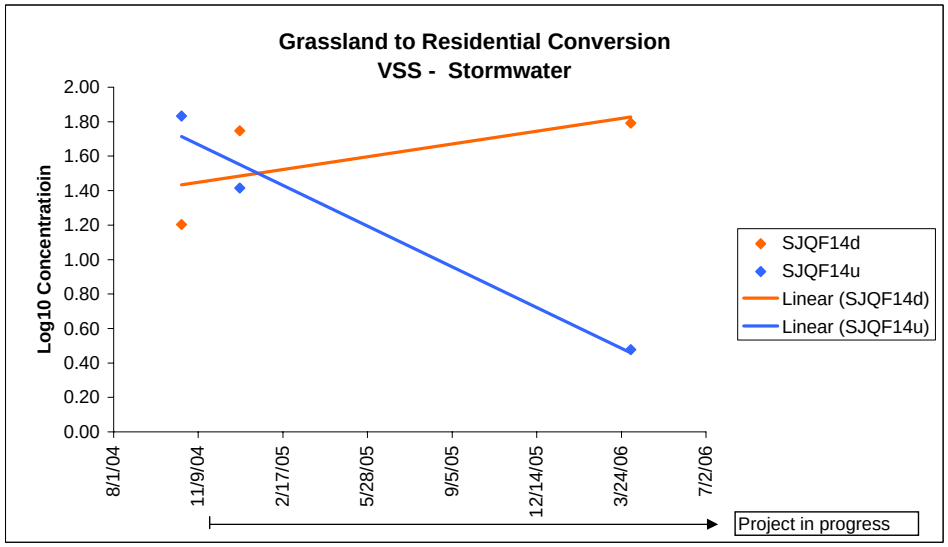
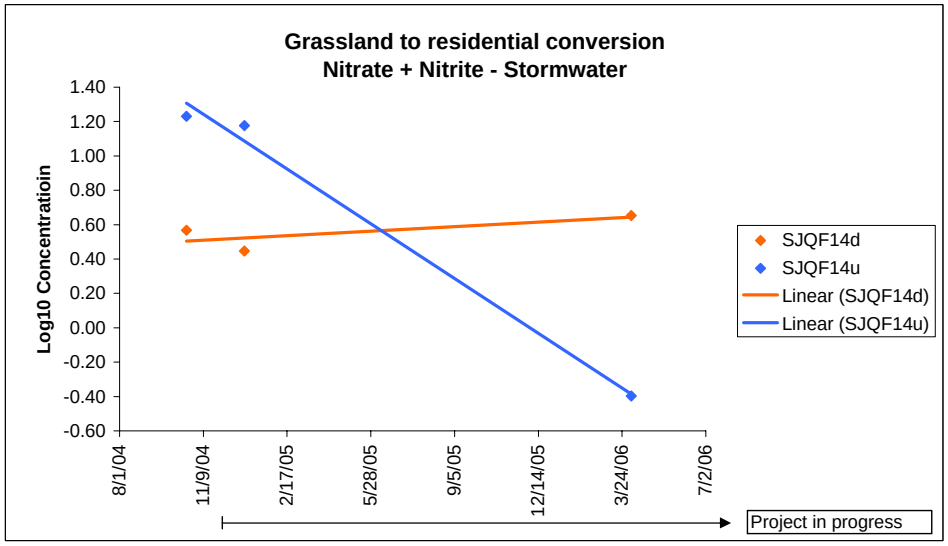


Figure C-11.23b
Trends in Stormwater Concentrations of Trace Elements and Nutrients Upstream and Downstream of a Grassland to Residential Landuse Conversion







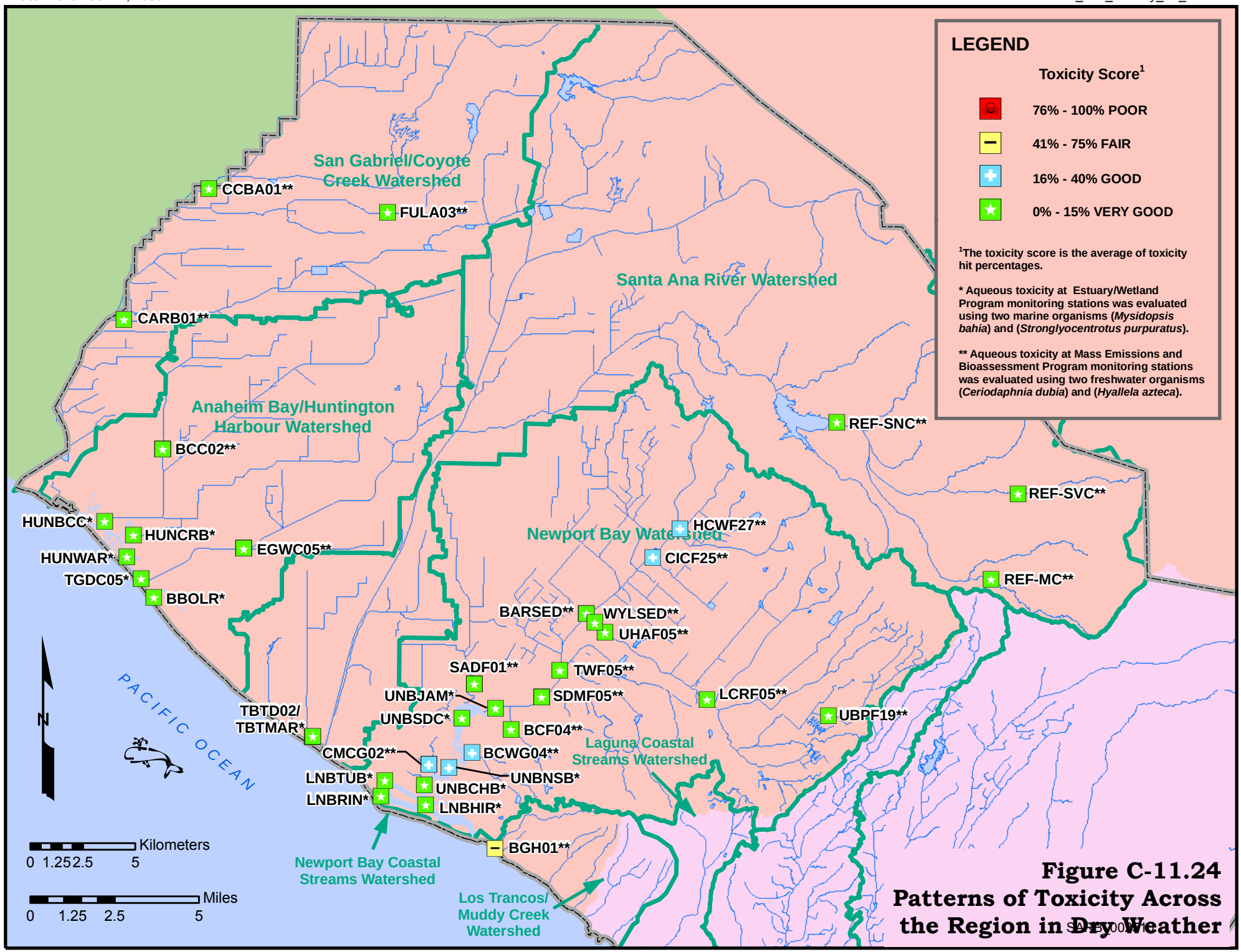


Figure C-11.24
Patterns of Toxicity Across the Region in Dry Weather

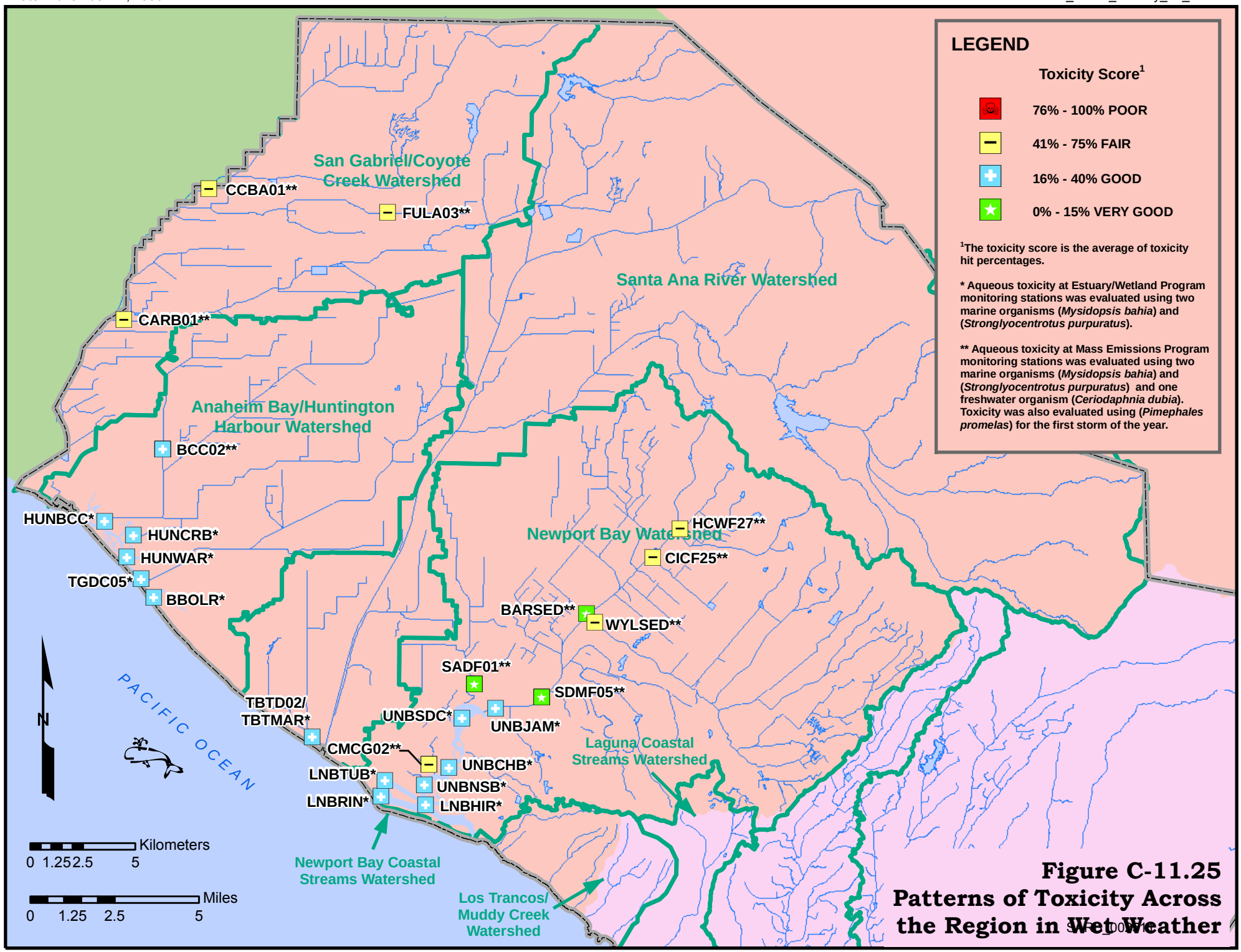


Figure C-11.25
Patterns of Toxicity Across the Region in Wet Weather

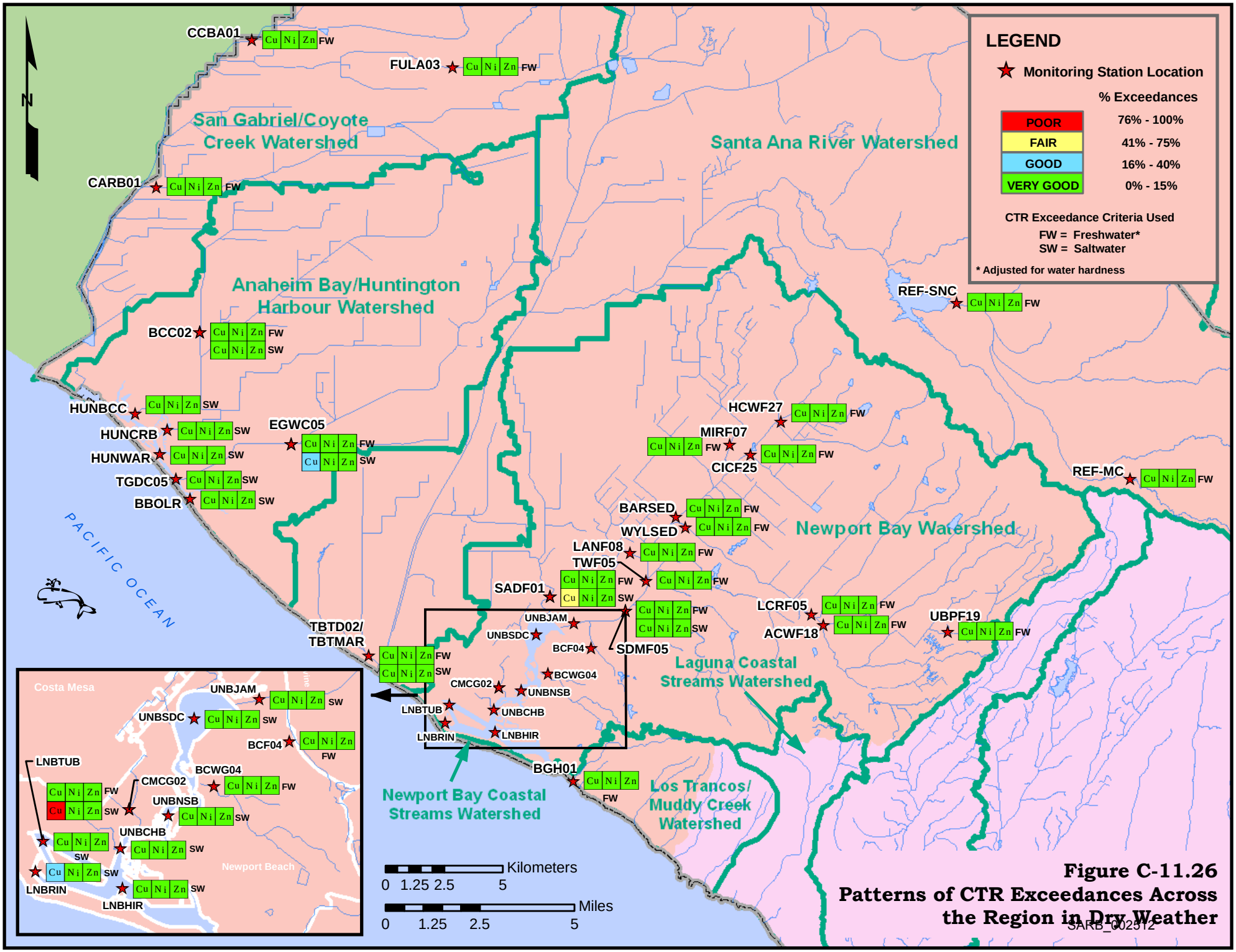


Figure C-11.26
Patterns of CTR Exceedances Across the Region in Dry Weather

SARB_092312

Date: November 14, 2006

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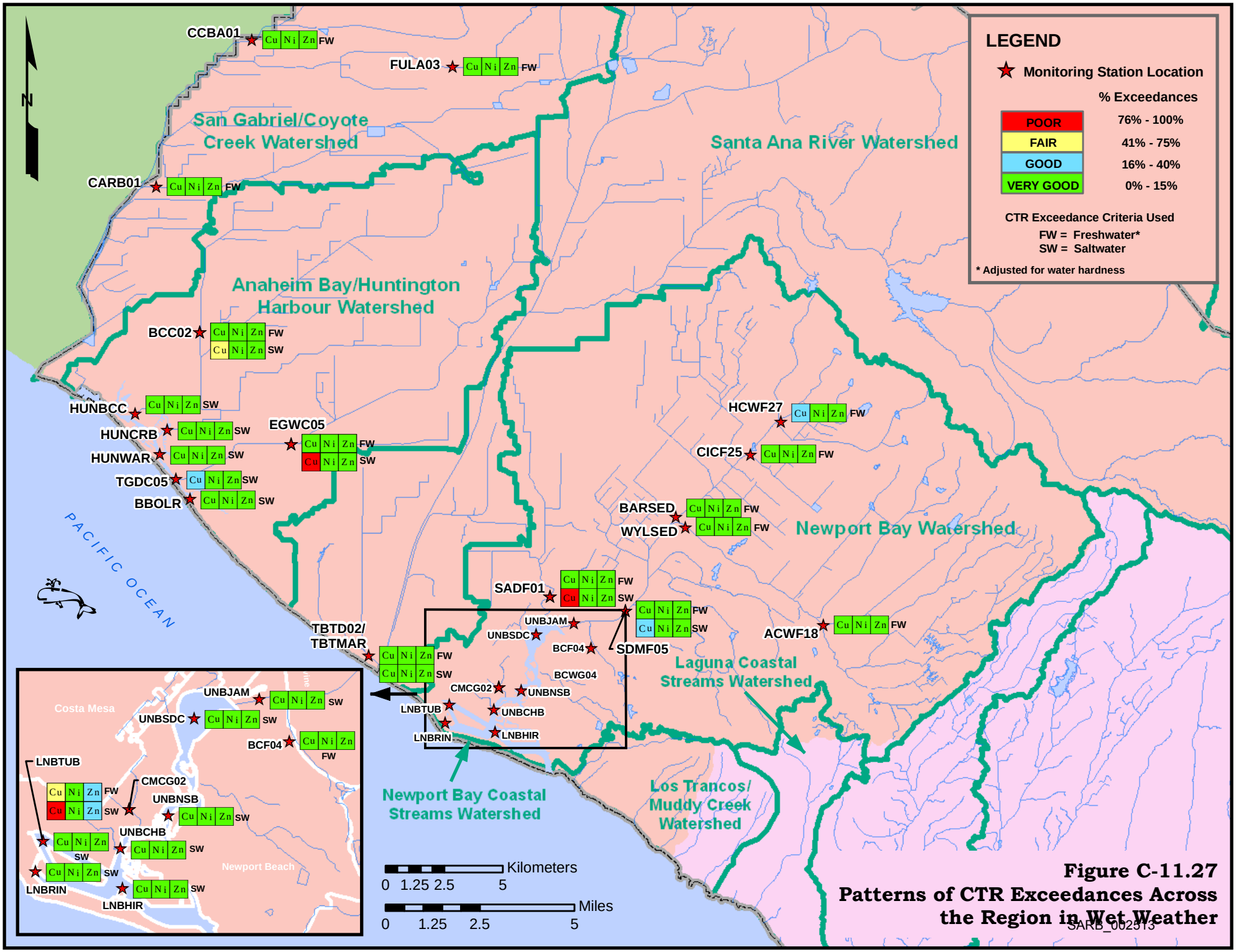
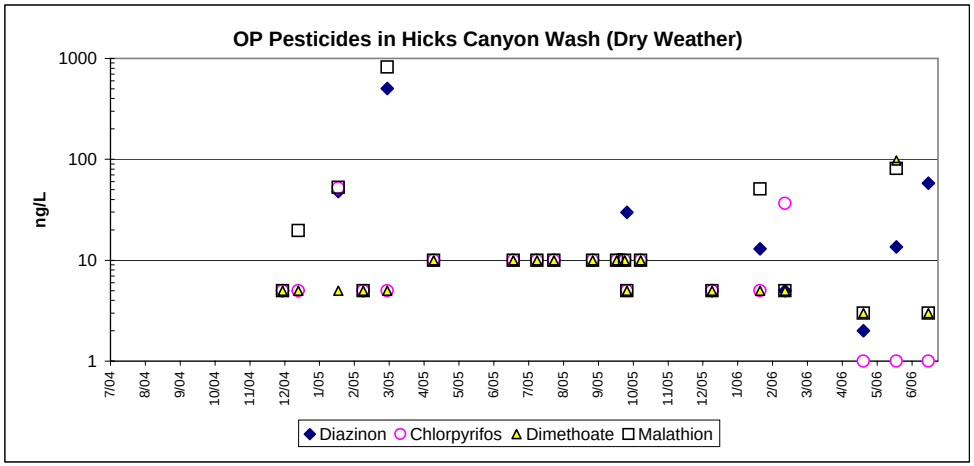
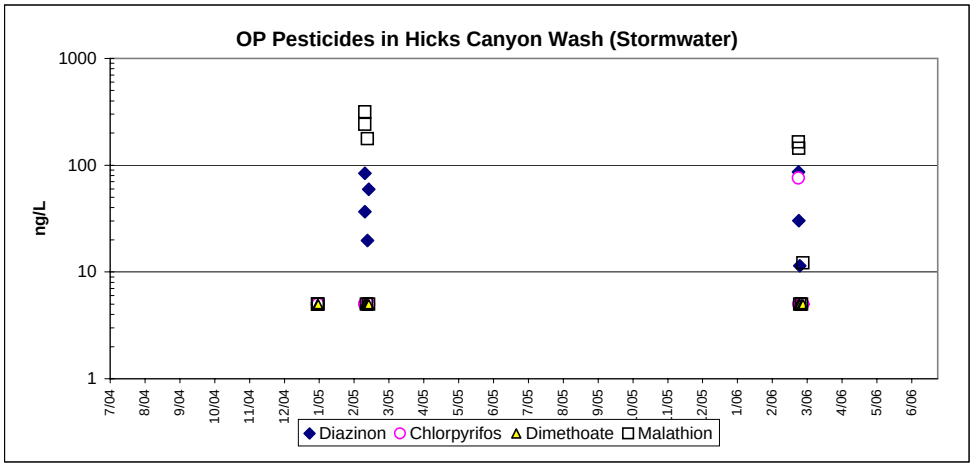
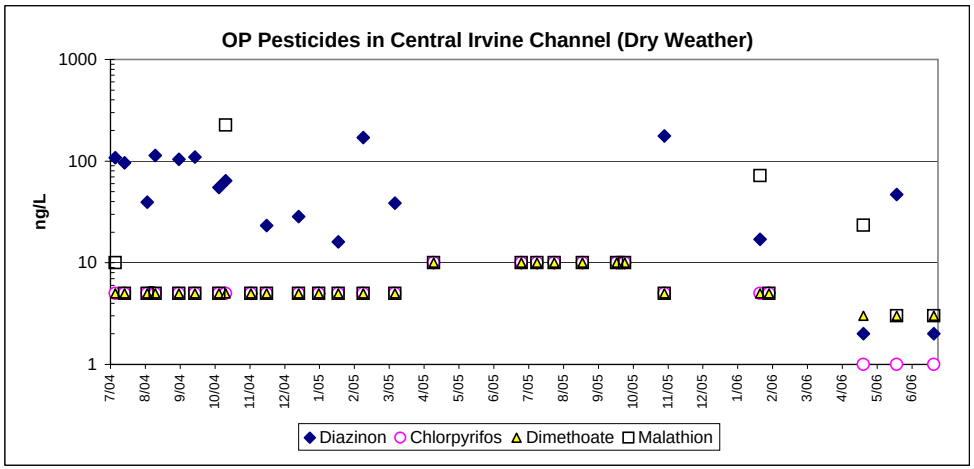


Figure C-11.28
Trends Over Time of Selected Organophosphate Pesticides







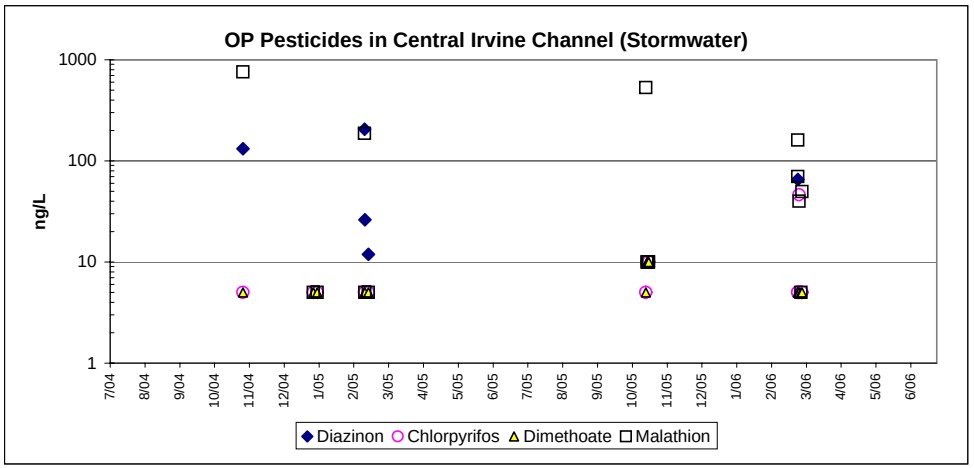
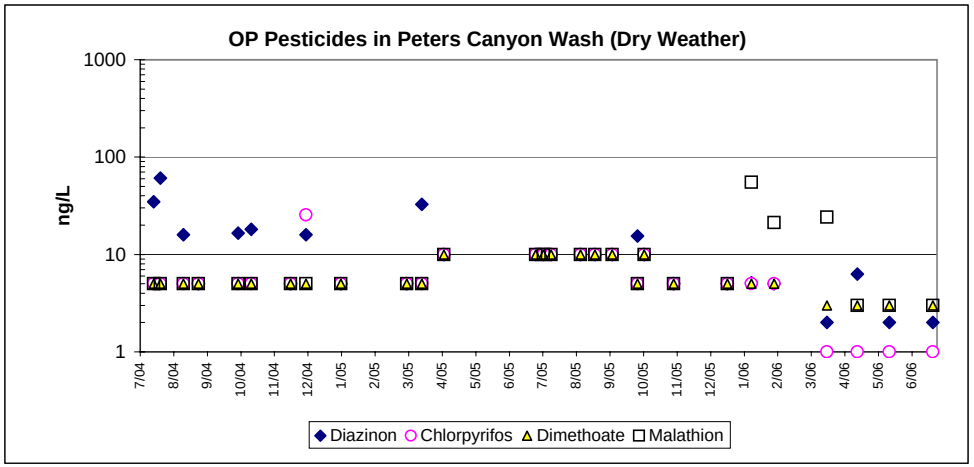
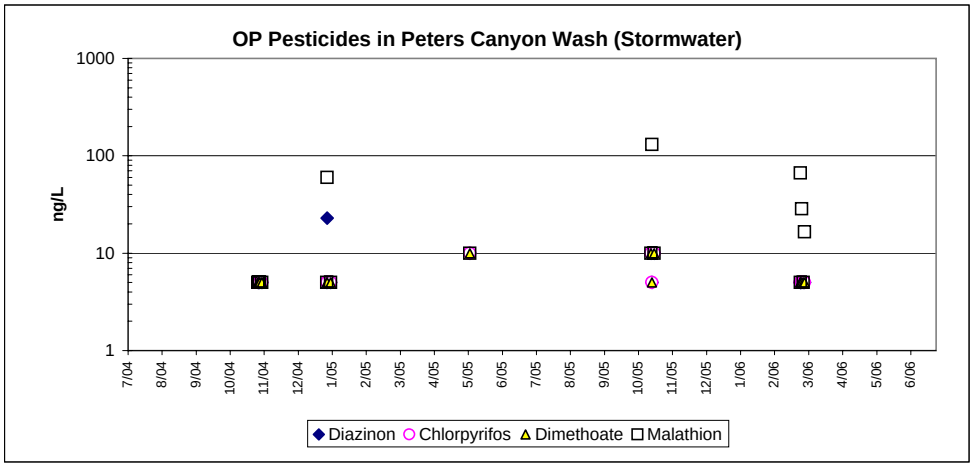
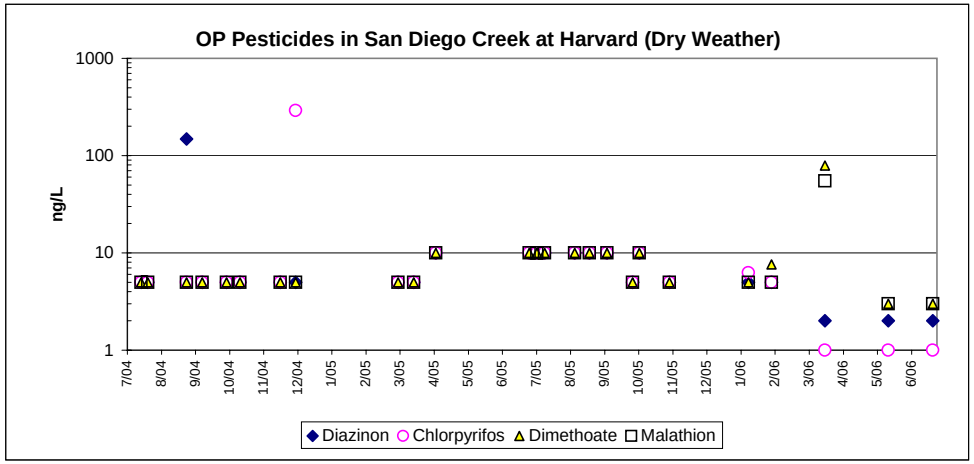


Figure C-11.28
Trends Over Time of Selected Organophosphate Pesticides







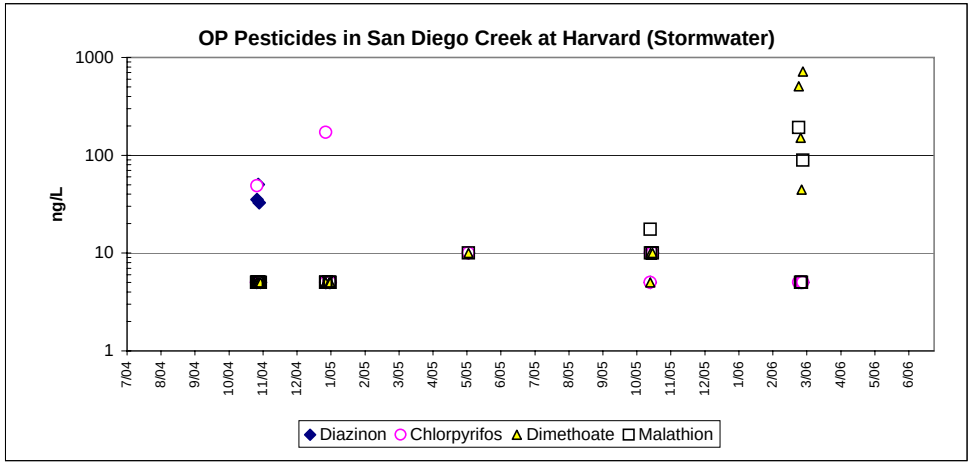
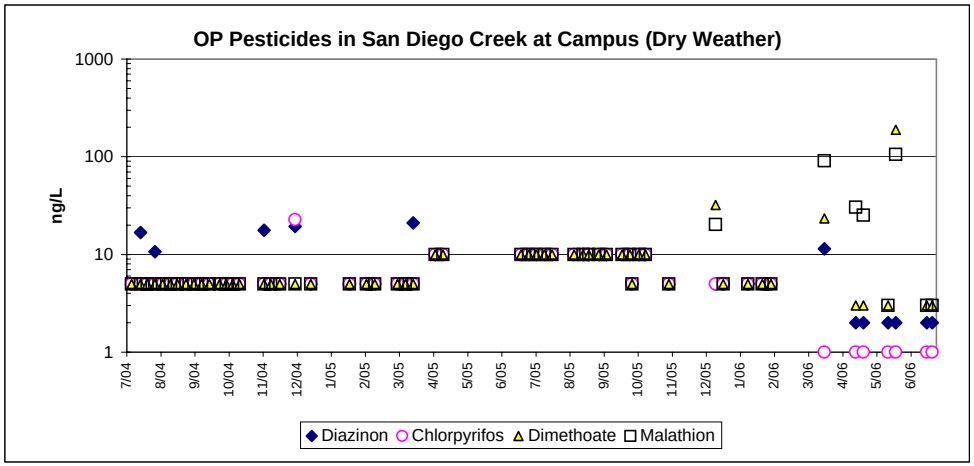


Figure C-11.28
Trends Over Time of Selected Organophosphate Pesticides



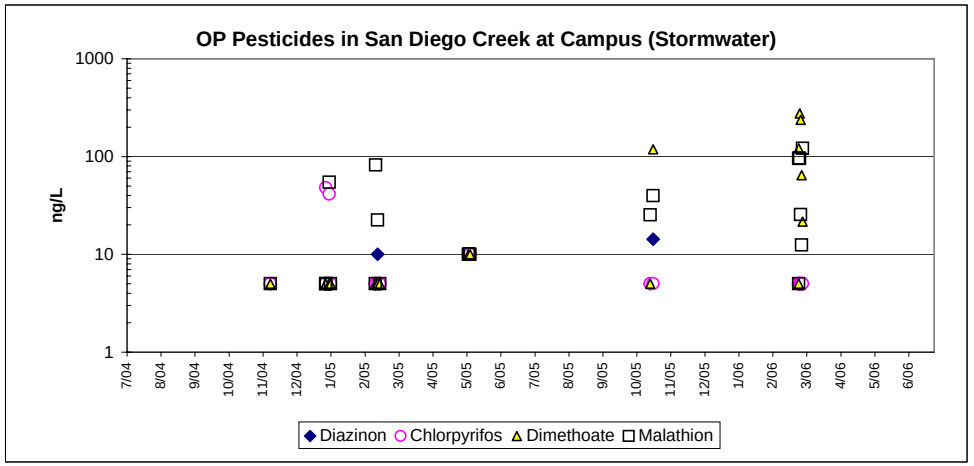
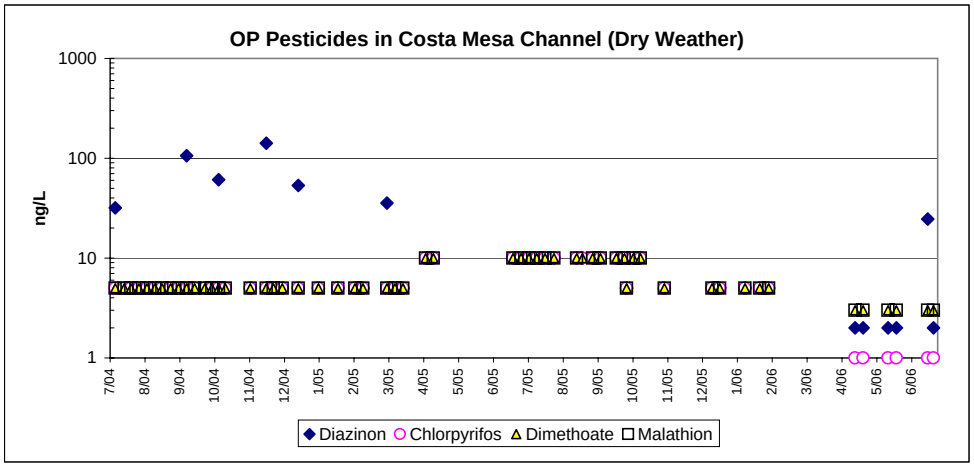
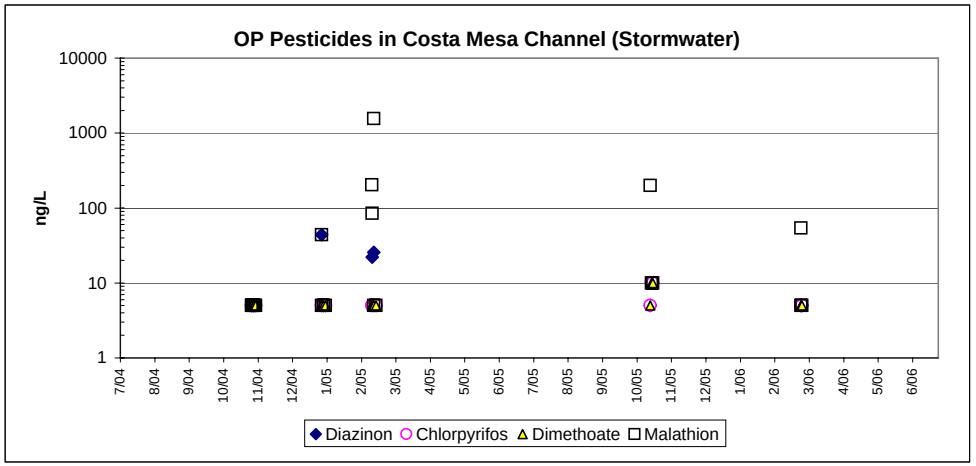
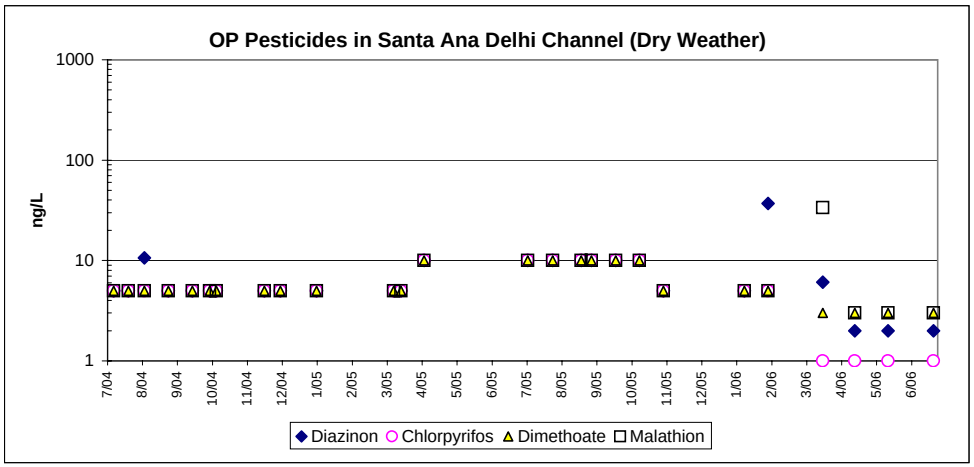


Figure C-11.28
Trends Over Time of Selected Organophosphate Pesticides







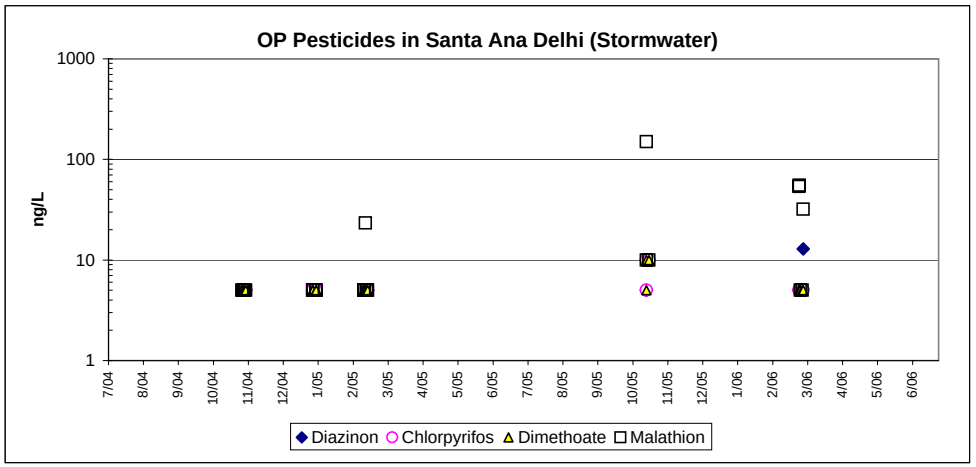
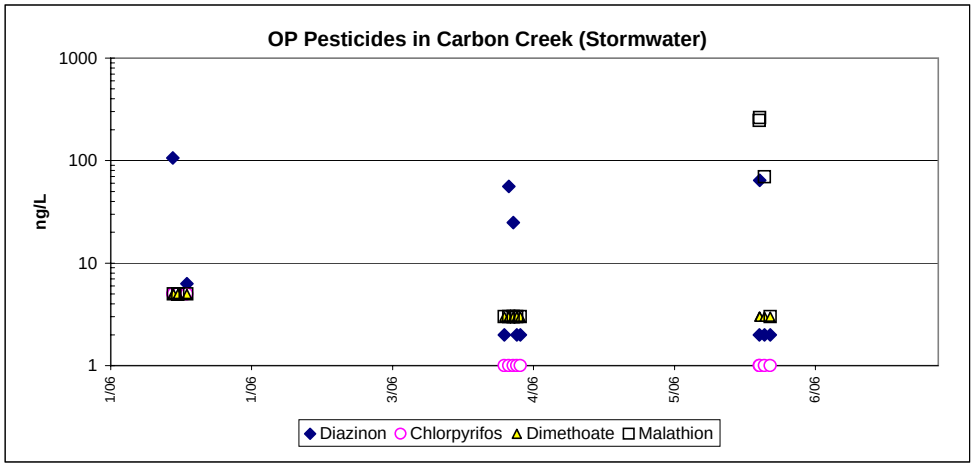


Figure C-11.28
Trends Over Time of Selected Organophosphate Pesticides



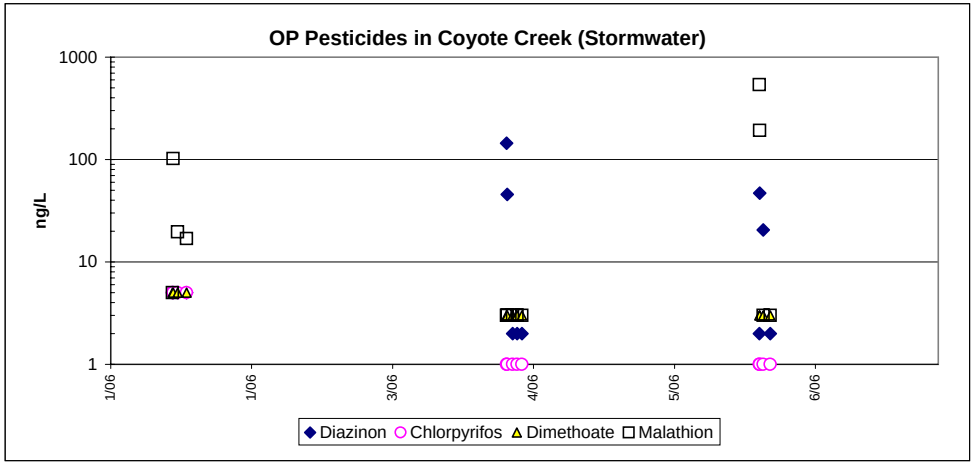
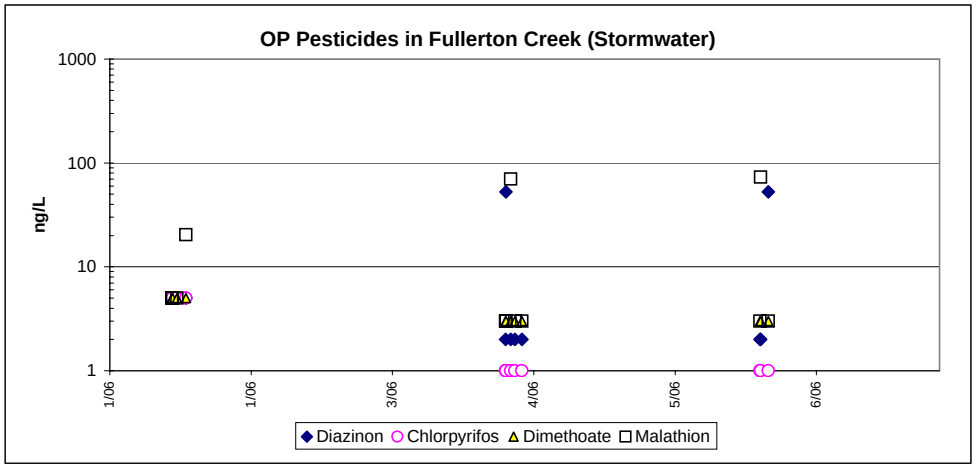


Figure C-11.28
Trends Over Time of Selected Organophosphate Pesticides



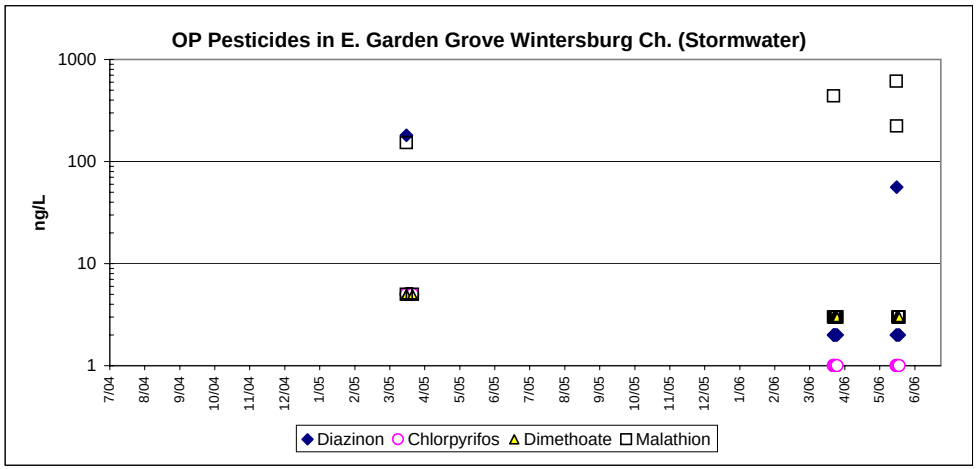
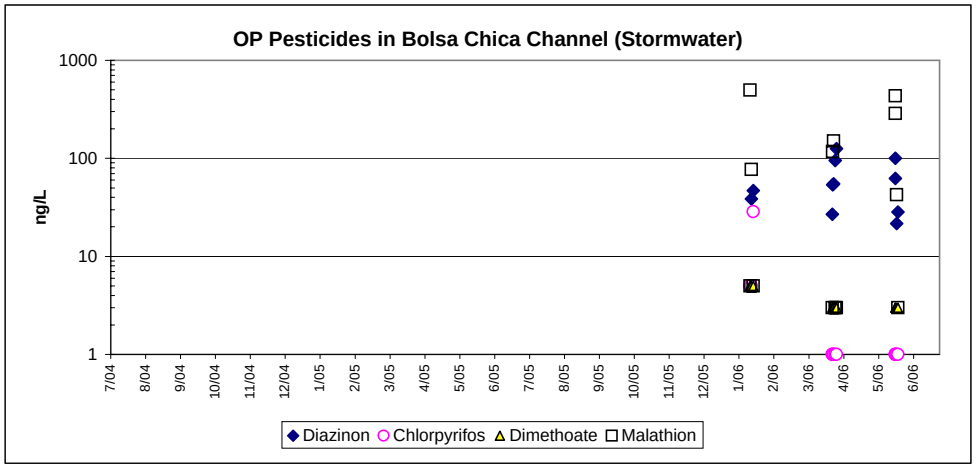


Figure C-11.28
Trends Over Time of Selected Organophosphate Pesticides



STANDARD OPERATING PROCEDURE FOR ACUTE EFFLUENT TOXICITY TESTS
(EPA 5th Ed. Methodology)

ENDPOINT DESCRIPTION
Juvenile fish or invertebrates are exposed to various concentrations of effluent for 24-96 hours. The endpoint is mortality.

DILUTION WATER
Water used for this test is reconstituted fresh or saltwater. Known amounts of reagent grade salts or standard sea salts are added to high quality D.I. water until the dilution hardness and alkalinity or salinity is equal to that of the effluent.

EFFLUENT CONCENTRATIONS
Test dilutions are typically prepared at 100%, 50%, 25%, 12.5%, and 6.25%. If needed, lower dilutions can be set at ranges where a dilution is at least 50% that of the next highest concentration. If the toxicity of the sample is unknown, a 24-hour preliminary range-finding test using a wider range of concentrations can be prepared. A control using the same dilution water is included with all tests.

Test chambers are new or pre-cleaned, glass beakers, ranging in size from 30-250 ml (depending upon the species chosen). For rainbow or brook trout, 5-liter disposable glass aquaria are used. Test solution volumes range from 25-200 ml (or 4 liters for trout). Each beaker or aquarium is labeled with a lab number and effluent concentration.

Test containers are placed on wire racks in a constant temperature room of either 19-21 or 24-26 deg C (11-13 deg C for trout). Beginning with the lowest concentration, graduated cylinders are used to pour the proper amount of the well-mixed effluent in each beaker. Dilution water is then poured in each container to the desired volume.

Solutions are not aerated unless oxygen values fall below 4.0 mg/l (6.0 mg/l for trout). Rate of aeration should not exceed 100 bubbles per minute.

TEST ORGANISMS
Juvenile animals are obtained from licensed breeders or collectors (Thomas Fish Company at Anderson, Ca., Brezina and Associates at Dillon Beach, Ca., or Aquatox in Hot Springs, Arkansas and are delivered by Greyhound bus, UPS, or Federal Express. Upon arrival, the condition of the animals and number of mortalities during shipment are recorded.

Ages of organisms used and test temperatures in bioassays are:

Ceriodaphnia dubia less than 24 hours@25ºC
Daphnia spp. less than 24 hours@25ºC
Pimephales promelas 1-14 days; less than or equal to 24-hrange in age @ 25ºC
Oncorhynchus mykiss 15-30 days (after yolk sac absorption to 30 days) @ 12ºC

Mysidopsis bahia 1-5 days; less than or equal to 24-h range in age, @20ºC + 1ºC or 25ºC + 1ºC, Salinity @5-30ppt + 10%
Menidia beryllina 9-14 days; less than or equal to 24-h range in age, @20ºC + 1ºC or 25ºC + 1ºC, Salinity @1-32ppt + 10%
Holmesimysis costata 3-4 days post-hatch juveniles; @15ºC + 1ºC, Salinity @34ppt + 2ppt
Atherinops affinis 7-15 days @21ºC, Salinity @10-30ppt

PERCENT SURVIVAL TESTS
Occasionally, only a percent survival test in undiluted effluent is required. The same procedures apply in this test as a standard bioassay, except that only undiluted waste and the control are used. Tests are reported as percent survival in undiluted sample instead of LC_{50}.

CHEMICAL AND PHYSICAL PARAMETERS
Dissolved oxygen, pH, and temperature are measured in all controls and concentrations before introducing fish, and at 24-hour intervals thereafter. The hardness and alkalinity are measured in the control and highest concentration at the beginning and end of each test. Residual chlorine and conductivity or salinity are measured in the control and highest treatment concentration at the beginning of the test. Calibrated thermographs continuously record temperatures throughout the test. A uniform photoperiod of 16 hours light and 8 hours dark at an intensity of 50-100 foot-candles is maintained.

DELIVERY OF ORGANISMS AND TEST DURATION
Within one hour after the preparation of test solutions, typically 10 randomly chosen animals are delivered to each duplicate test tank using a small-mesh dip-net or disposable pipette (total of 20 animals per concentration). The test begins when animals are introduced into the test chambers and continues for 24, 48, or 96 hours, depending upon requirements. Test solutions are renewed at 48 hours. Animals are fed at 48 hours, with the exception of *Oncorhynchus mykiss* which are not fed and *Mysidopsis bahia* are fed 0.2 mL concentrated suspension of *Artemia nauplii* < 24-h old daily, if the test lasts longer than this.

Mortalities and chemical measurements are recorded every 24 hours, and dead animals are removed as soon as they are observed. Excess food is removed after feeding.

DISPOSAL OF FISH AND TANKS
At the end of the test, animals are destroyed before being disposed of by placing them in a zip-lock bag with ethanol. Effluents are poured down the drain unless they are highly toxic, in which case the client is asked to pick up the sample and any dilutions. Test tanks and aeration pipets are broken down and disposed of at a local landfill.

ANALYSIS
A review of concentration-response relationships is conducted on all multi-concentration tests following guidelines in EPA821-B-00-004, July 2000, *Method Guidance and Recommendations for Whole Effluent Toxicity(Wet) Testing (40 CFR Part 136).*

The flowchart shown in Figure 6 of the method reference (USEPA 2002) is used for determining the LC_{50} statistical test. When an LC_{50} can be determined, the toxicity of the waste is also expressed as toxic units, where:

TC(tu) = 100/96-hr LC_{50}

When there is less than 50% mortality in 100% waste, the toxic units are expressed as:

TC(tu) = Log (% Mortality)/ 1.7

TEST VALIDITY
1) Mortality cannot exceed 10% in the controls.
2) Test must be set within 36 hours of collection.
3) D.O. above or equal to 4 mg/l (6 mg/l for trout).
4) Loading limits must not exceed 1.1 g/l at 25 deg C, 0.65 g/l at 20 deg C, and 0.4 g/l at 25 deg C.

REFERENCES
USEPA. 2002. *Methods for Measuring the Acute Toxicity of Effluents and Receiving Waters to Freshwater and Marine Organisms*. (5th ed). EPA-821-R-02-012.

EPA-821-B-00-004, July 2000, *Method Guidance and Recommendations for Whole Effluent Toxicity (Wet)*
Testing (40 CFR Part 136).

Revised 3/10/2006

STANDARD OPERATING PROCEDURES FOR CHRONIC MYSID SHRIMP (*Mysidopsis bahia*) TOXICITY TEST

ENDPOINT DESCRIPTION

Seven-day-old mysid shrimps (*Mysidopsis bahia*) are exposed in a static renewal systems to various test solutions for seven days. The endpoints are survival, growth, and egg development.

DILUTION WATER

Uncontaminated local (collected near Anacapa Island) natural seawater adjusted to 20-30 ± 2 ppt salinity is used for holding, control, and dilution waters. Water is collected in new five-gallon cubitainers prior to testing and stored at 15 degrees C for up to 24 hours. For longer holding times, water must be stored at 4 degrees C, and at no time should water be stored for any longer than 96 hours.

EFFLUENT CONCENTRATIONS

Test solutions are prepared on the day of initiation and every 24 hours for seven days. Five concentrations, a reference control, and a brine control (each with eight replicate test chambers) are used.

Test chambers are 8-oz plastic disposable cups containing 150 ml of test solution. Mysids are contained within 200-micron Nytex screens cemented around a petri dish with silicone sealant. Each cylinder fits inside the beaker, the liquid is poured in and the mysids are added. All beakers are labeled prior to preparation.

Glassware cleaning Procedure:

1. Wash in warm, soapy water.
2. Rinse with tap water.
3. Rinse with reagent grade acetone.
4. Rinse with D.I. water.
5. Soak in 3N HCL for 24 hours.
6. Rinse with D.I. water.
7. Rinse with 2N HNO3.
8. Rinse with D.I. water.
9. Soak in D.I. water for 24 hours.
10. Rinse with D.I. water.
11. Air dry.

All glassware is rinsed with reference seawater prior to mixing concentrations.

A 1-l glass volumetric flask, various sizes of volumetric pipettes, and a 250-ml graduated cylinder are used to prepare solutions. A total volume of 1600 ml is needed for each concentration; eight replicates and one 400-ml sample for measuring chemical parameters. Effluent concentrations are set according to client requirements.

Hypersaline brine is used to adjust salinity. Six to eight liters of reference seawater are frozen 48 hours before the test. After 24 hours, the water is allowed to partially thaw for about one hour and the liquid is combined into a 1-liter container. If the salinity is not between 60 and 80 ppt, the container is frozen again for 24 hours. After an hour of thawing, the water is separated from the ice. The salinity is then usually between 60 and 80 ppt.

The amount of brine to add to each effluent concentration to obtain a final salinity of 20 $\pm$ 2 ppt is calculated using the following formula:

$$V_B = V_E (20-S_E) / (S_B-20)$$

V_B=Volume of Brine to add
V_E=Volume of Effluent
S_E=Salinity of Effluent
S_B=Salinity of Brine

Brine controls are used in all tests when salinity adjustment is necessary. The brine controls contain the same amount of brine added to the highest effluent concentration plus deionized (D.I.) water equal to the amount of effluent added and filled to the 1-l mark with reference seawater. The pH of all brine mixtures are checked and adjusted to within 0.1 units of the dilution water by dropwise addition of dilute HCl or NaOH.

Effluents with salinity greater than 10 ppt, or tests with effluent concentrations greater than 10% use the following formula to calculate the amount of D.I. to add:

$$V_B = V_E (20) / (S_B-20)$$

The amount of D.I. to add is calculated by solving for V_E.

Effluent concentrations are prepared by combining effluent, hypersaline brine and dilution water using the appropriate dilution factors, volumetric pipets and flasks. Concentrations are mixed from the lowest to the highest to avoid any possible contamination.

STANDARD TOXICANT CONCENTRATIONS

Stock solutions of copper chloride are prepared by Environmental Resource Associates in Arvada, Colorado. The 10,000-ug/l stock is traceable to NBS standards and is guaranteed stable for up to one year. Stocks are replaced after one year or sooner if necessary. A

reference test is performed concurrently with each effluent test conducted. A sample of stock solution is analyzed for verification of the copper concentration by a local, certified laboratory at the time of the test to ensure there is no contamination. Solutions consist of one replicate each of 10, 18, 32, 56 and 100 μg/l copper. Solutions are renewed three times throughout the test.

SHIPPING OF TEST ORGANISMS

One to three-day-old mysids are shipped from Brezina and Associates in northern California and arrive the following day. Animals are held in cleaned 20-liter glass aquaria at a density of no more than 20 mysids per liter. Animals are slowly acclimated to test conditions during the holding period. Mysids are fed twice per day and the water is changed every other day.

CHEMICAL PARAMETERS

Dissolved oxygen is measured at the beginning and end of each 24-hour exposure in one test chamber at all test concentrations and in the control. Temperature, pH, and salinity are measured at the end of each 24-hour exposure period in one test chamber at all test concentrations and in the control. pH is measured in the effluent samples daily.

INITIATION OF THE TEST

After concentrations are prepared and chemical measurements are recorded, 5 animals are carefully transferred into each Nytex cylinder using a disposable transfer pipet. After transfer, mysids are fed <24 hour old Artemia nauplii.

INCUBATION

Mysids in test containers are placed under low light (50 to 100 footcandles) at 26-27 deg C with a photoperiod of 16 hours light and 8 hours dark. Test salinity is 20-30 $\pm$ 2 ppt. Thermographs continuously record temperatures through-out the testing period. Containers are covered with plastic wrap to prevent evaporation during the test. Aeration is only necessary when the D.O. falls below 60%.

TEST SOLUTION RENEWAL

Test solutions are renewed daily and prepared in clean 1000-ml beakers. Each Nytex cylinder is carefully lifted from the old solution and transferred into the new solution taking care not to disturb the mysids. The effluent which has been stored in the refrigerator is warmed to 26 deg C before mixing solutions.

Before transferring mysids, the bottom of each petri dish is cleaned of all debris by siphoning with a transfer pipet. Numbers of live animals are recorded and all dead animals are removed. The mysids are fed enough <24 hour old Artemia nauplii twice per

day to ensure that some Artemia remain alive overnight. The Artemia are rinsed with filtered seawater prior to being added to test chambers.

New food suitability is determined in a side-by-side test using four replicates. One treatment is fed the new food and the other is fed food known to be suitable.

TERMINATION OF TEST

After 7 days, the test is terminated. Most of the test solution is poured off and replaced with clean water. The number of surviving immatures, males, females with eggs, and females without eggs is recorded. The larvae are rinsed in D.I. water and placed in clean, tared aluminum weigh boats and dried at 105 deg C for 6 hours. Immediately after removal from the oven, boats are placed in a desiccator overnight to completely cool before weighing. All weights are measured to the nearest 0.01 mg. The average dry weight is determined for each replicate.

ANALYSIS

The *Toxcalc* program is used to interpret data. The pro-portion of surviving animals is determined in each container and the data is arcsine, square root transformed. ANOVA is used to compare concentrations and Dunnett's Test compares concentrations to the control which determines the NOEC. The average dry weight number of females with eggs are determined for each replicate and tested for homogeneity within replicates. Dunnett's Test is used to compare concentrations with the control which determines the NOEC.

TEST ACCEPTABILITY

1. Control survival must be greater than 80%.

2. Average dry weight must be greater than 0.20 mg/mysid in the controls.

3. Control fecundity should also be used if egg production by 50% of females is achieved.

REFERENCES

USEPA. 1991. *Short-Term Methods for Estimating the Chronic Toxicity of Effluents and Receiving Waters to Marine and Estuarine Organisms*. EPA-600/4-91/003.

USEPA. 1988. *Short-Term Methods for Estimating the Chronic Toxicity of Effluents and Receiving Waters to Marine and Estuarine Organisms*. EPA-600/4-87/028.

Revised 8/25/03

Sea Urchin Development Test

STANDARD OPERATING PROCEDURES FOR PURPLE SEA URCHIN AND SAND DOLLAR FERTILIZATION BIOASSAYS (EPA/600/R-95/136)

ENDPOINT DESCRIPTION

Sea urchin (*Strongylocentrotus purpuratus*) or sand dollar (*Dendraster excentricus*) sperm cells are exposed to test solutions for 20 minutes prior to addition of eggs in various effluent concentrations. Fertilized eggs are exposed for another 20 minutes. The endpoint is fertilization success determined by the presence or absence of a membrane.

DILUTION WATER

Sources include: 1) Receiving water: seawater collected from clean areas near the vicinity of the outfall, 2) 0.2 micron, filtered, UV sterilized seawater from Proteus Seafarms in Oxnard, California, or 3) reconstituted seawater using "Tropic Marin" brand sea salts and deionized (D.I.) water. The holding and testing temperature for this test is 12 $\pm$ 1 deg C.

EFFLUENT CONCENTRATIONS

Test solutions are prepared prior to spawning. Five concentrations, a control and a brine control (if salinity adjustment is needed) each with four replicate test chambers are used. Test chambers are 3-ml Falcon brand, well plates with covers. All flasks are rinsed with reference sea water and numbered before solutions are prepared.

Glassware cleaning procedure:

1. Wash in warm, soapy water, rinse with tap water,
2. Rinse with reagent grade acetone, rinse with D.I. water,
3. Soak in 3N HCL for 24 hours, rinse with D.I. water,
4. Rinse with 2N HNO3, rinse with D.I. water,
5. Soak in D.I. water for 24 hours,
6. Rinse with D.I. water,
7. Air dry.

All glassware is rinsed with reference seawater prior to mixing solutions. Beginning with the effluent control, a one-liter glass volumetric flask, various volumetric pipettes, and a 100-ml graduated cylinder are used to prepare solutions. A total volume of 60 ml is needed per dilution; four replicates and one 50-ml sample for measuring chemical parameters. Effluent dilutions are set according to client requirements.

For concentrations above 5.6%, a brine is used to adjust salinity. Six to eight liters of reference seawater are frozen 48 hours before the test. After 24 hours, the water is allowed to partially thaw for about one hour and the liquid is combined into a one-liter container. If the salinity is not between 60 and 80 ppt, the container is frozen again for 24 hours. After an hour of thawing, the water is separated from the ice. The salinity is then usually between 60 and 80 ppt. The amount of brine to add to each effluent concentration to obtain a final salinity of 34 $\pm$ 2 ppt is calculated using the following formula:

$$V_B = V_E (34 - S_E) / (S_B - 34)$$

V_B=Volume of Brine to add
V_E=Volume of Effluent
S_B=Salinity of Brine
S_E=Salinity of Effluent

Brine controls are used in all tests when salinity adjustment is necessary. The brine controls contain the same amount of brine added to the highest effluent concentration plus D.I. water equal to the amount of effluent added. The pH of all mixtures are adjusted to within 0.1 units of the dilution water by dropwise addition of dilute HCl or NaOH. For effluents with salinity greater than 10 ppt, or tests with effluent concentrations greater than 10%, the following formula is used to calculate the amount of D.I. to add:

$$V_B = V_E (34) / (S_B - 34)$$

The amount of D.I. to add is calculated by solving for V_E.

Effluent concentrations are prepared by combining effluent, hypersaline brine, and dilution water using the appropriate dilution factors. Concentrations are mixed from the lowest to the highest to avoid potential contamination.

REFERENCE TOXICANT CONCENTRATIONS

Stock solutions of copper chloride are prepared by Environmental Resource Associates in Arvada, Colorado. The 10,000 μg/l stock is traceable to NBS standards and is guaranteed stable for up to one year. The stock is discarded after this time. Five replicates and a sample for chemical and physical parameters are prepared by mixing 0.28, 0.5, 0.9, 1.6 and 2.8 ml with reference seawater in a 500 ml volumetric flask. Before each test, a sample of stock solution is sent to a local, certified laboratory for analysis to ensure the stock has not been contaminated.

SPAWNING OF ANIMALS

Urchins or sand dollars are rinsed off in clean seawater, injected with 1 ml of 0.5 M KCl through the peristomal membrane (0.5 ml through oral opening for sand dollars). Females are inverted over beakers to collect the eggs. Sperm is collected without dilution using a micropipette and placed in a small beaker on ice. The beaker should be covered with parafilm. Sperm should be checked for motility using a microscope. Sperm must be used within four hours. Eggs are rinsed into a large beaker and are washed two or three times with clean seawater (with settling allowed between washings).

DETERMINATION OF EGG DENSITY

A sample of eggs from each spawning female is inspected under a microscope, and batches containing immature, small, or misshapen eggs are discarded. The remaining batches of eggs are pooled and combined into a one-liter glass beaker. The eggs are suspended evenly into the solution, and a 1-ml sub-sample is removed and combined with 9 ml of seawater in a 10-ml graduated cylinder. This solution is also thoroughly mixed. A 1-ml sub-sample is again removed and added to a Sedgewick-Rafter slide, and eggs are counted microscopically. Counts should be between 200 and 245 eggs per ml. The stock solution is adjusted as needed to obtain the necessary concentration.

PREPARATION OF SPERM

A 0.025-ml sub-sample of sperm pooled preferably from four males is diluted with 100 ml of seawater and is thoroughly mixed. 9 ml of this solution is combined with 1 ml of acetic acid (to inactivate the sperm) and a 0.1 ml of solution is added to a hemacytometer. Hemacytometer counts should be between 51 and 408 using a five-square counting pattern, and, if not, the stock solution is adjusted.

TRIAL ESTIMATE OF FERTILIZATION

0.03 ml of sperm solution and 0.30 ml of egg suspension are combined with 3 ml of seawater. The embryos are inspected under a microscope, and if fertilization is greater than 80% the test is initiated. If lower, sperm and egg solutions are reprepared. An "egg blank" (with no sperm added) is also inspected in order to ensure that pre-fertilization has not occurred.

FERTILIZATION OF EGGS

The recommended initial sperm to egg ratio for fertilization of the eggs is 500:1. The following equations are used to determine the correct volume of the sperm dilution to add to the egg dilution.

volume of egg dilution X 1,000 eggs/ mL = total # of eggs in dilution

total # of eggs in dilution X 500 sperm/ egg = # sperm needed

# of sperm needed ÷ # sperm/mL in sperm dilution = mL sperm solution

This volume of the sperm dilution is added to the egg dilution and mixed gently with a plunger. After 10 minutes, fertilization is checked. If fertilization is not at least 90%, a second volume of the sperm dilution is added. After 10 minutes, fertilization is rechecked. If the fertilization is still not at least 90%, then the test is restarted with different gametes.

DELIVERY OF FERTILIZED EGGS TO THE TEST CHAMBERS

The fertilized egg mixture is gently mixed. 0.25 mL of the egg solution is delivered to each vial using an automatic pipette with the tip cut off to providing a 0.5mm opening. The embryos are delivered into the test chambers directly from the pipette, taking care not to touch the pipette to the test solution. The egg solution temperature is held within 1˚ C of the test solutions. The eggs are kept well mixed during the delivery procedure.

INCUBATION

The embryos are incubated for 72 hours in the test chambers at 15 $\pm$ 1˚ C at ambient light level.

TERMINATION OF THE TEST

Temperature, pH, dissolved oxygen, and salinity are measured at the end of the exposure period in at least one test chamber at each concentration and in controls.

0.5mL of 1% glutaraldehyde is added to each test chamber, gently mixed and stored for later examination.

COUNTING

Embryos are counted within one week of preservation. Vials are placed on an inverted microscope. The first 100 embryos encountered are counted, examined and recorded.

ENDPOINTS

Normal larvae should have a pyramid shape with a pair of skeletal rods that extend at least half the length of the long axis of the larvae. The gut should be differentiated into three parts. If the gut appears lobed and constricts distally in specimens with an obstructed view, then normal gut development may be inferred. Finally, if development of post-oral arms are observed, the development is determined to be normal. All other embryos are scored as abnormal.

TEST ACCEPTABILITY

1. 80% normal shell development must be observed in controls.
2. The minimum significant difference is <25% relative to the controls.
3. The sperm count for the final sperm stock must not exceed 33,600,000/ml.
4. 90% fertilization of the egg/sperm mixture must be achieved prior to initiation of the test.
5. Dilution water egg blanks and effluent egg blanks should contain essentially no eggs with fertilization membranes.

REFERENCES

US EPA. 1995. *Short-Term Methods for Estimating the Chronic Toxicity of Effluents and Receiving Waters to West Coast Marine and Estuarine Organisms.* EPA/600/R-95/136.

Chapman, G.A. 1994. *Sea urchin* (Strongylocentrotus purpuratus) *and sand dollar* (Dendraster excentricus) *fertilization test method*. USEPA. Newport, Oregon (draft).

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State Water Resources Control Board. 1996. *Procedures Manual for Conducting Toxicity Tests Developed by the Marine Bioassay Project.* 96-IWQ.

Revised 8/25/03

Sea Urchin Fertilization Test

STANDARD OPERATING PROCEDURES FOR PURPLE SEA URCHIN AND SAND DOLLAR FERTILIZATION BIOASSAYS (EPA/600/R-95/136)

ENDPOINT DESCRIPTION

Sea urchin (*Strongylocentrotus purpuratus*) or sand dollar (*Dendraster excentricus*) sperm cells are exposed to test solutions for 20 minutes prior to addition of eggs in various effluent concentrations. Fertilized eggs are exposed for another 20 minutes. The endpoint is fertilization success determined by the presence or absence of a membrane.

DILUTION WATER

Sources include: 1) Receiving water: seawater collected from clean areas near the vicinity of the outfall, 2) 0.2-micron, filtered, UV sterilized seawater from Proteus Seafarms in Oxnard, California, or 3) reconstituted seawater using "Tropic Marin" brand sea salts and deionized (D.I.) water. The holding and testing temperature for this test is 12 $\pm$ 1 deg C.

EFFLUENT CONCENTRATIONS

Test solutions are prepared prior to spawning. Five concentrations, a control and a brine control (if salinity adjustment is needed) each with four replicate test chambers are used. Test chambers are 3-ml Falcon brand, well plates with covers. All flasks are rinsed with reference sea water and numbered before solutions are prepared.

Glassware cleaning procedure:

1. Wash in warm, soapy water, rinse with tap water,
2. Rinse with reagent grade acetone, rinse with D.I. water,
3. Soak in 3N HCL for 24 hours, rinse with D.I. water,
4. Rinse with 2N HNO_3, rinse with D.I. water,
5. Soak in D.I. water for 24 hours,
6. Rinse with D.I. water,
7. Air dry.

All glassware is rinsed with reference seawater prior to mixing solutions. Beginning with the effluent control, a one-liter glass volumetric flask, various volumetric pipettes, and a 100-ml graduated cylinder are used to prepare solutions. A total volume of 60 ml is needed per dilution; four replicates and one 50-ml sample for measuring chemical parameters. Effluent dilutions are set according to client requirements.

For concentrations above 5.6%, a brine is used to adjust salinity. Six to eight liters of reference seawater are frozen 48 hours before the test. After 24 hours, the water is allowed to partially thaw for about one hour and the liquid is combined into a one-liter container. If the salinity is not between 60 and 80 ppt, the container is frozen again for 24 hours. After an hour of thawing, the water is separated from the ice. The salinity is then usually between 60 and 80 ppt. The amount of brine to add to each effluent concentration to obtain a final salinity of 34 $\pm$ 2 ppt is calculated using the following formula:

$$V_B = V_E (34 - S_E) / (S_B - 34)$$

V_B=Volume of Brine to add
V_E=Volume of Effluent to add
S_E=Salinity of Effluent
S_B=Salinity of Brine

Brine controls are used in all tests when salinity adjustment is necessary. The brine controls contain the same amount of brine added to the highest effluent concentration plus D.I. water equal to the amount of effluent added. The pH of all mixtures are adjusted to within 0.1 units of the dilution water by dropwise addition of dilute HCl or NaOH. For effluents with salinity greater than 10 ppt, or tests with effluent concentrations greater than 10%, the following formula is used to calculate the amount of D.I. to add:

$$V_B = V_E (34) / (S_B - 34)$$

The amount of D.I. to add is calculated by solving for V_E.

Effluent concentrations are prepared by combining effluent, hypersaline brine, and dilution water using the appropriate dilution factors. Concentrations are mixed from the lowest to the highest to avoid potential contamination.

REFERENCE TOXICANT CONCENTRATIONS

Stock solutions of copper chloride are prepared by Environmental Resource Associates in Arvada, Colorado. The 10,000-µg/l stock is traceable to NBS standards and is guaranteed stable for up to one year. The stock is discarded after this time. Five replicates and a sample for chemical and physical parameters are prepared by mixing 0.28, 0.5, 0.9, 1.6 and 2.8 ml with reference seawater in a 500-ml volumetric flask. Before each test, a sample of stock solution is sent to a local, certified laboratory for analysis to ensure the stock has not been contaminated.

SPAWNING OF ANIMALS

Urchins or sand dollars are rinsed off in clean seawater, injected with 1 ml of 0.5 M KCl through the peristomal membrane (0.5 ml through oral opening for sand dollars). Females are inverted over beakers to collect the eggs. Sperm is collected without dilution using a micropipette and placed in a small beaker on ice. The beaker should be covered with parafilm. Sperm should be checked for motility using a microscope. Sperm must be used within four hours. Eggs are rinsed into a large beaker and are washed two or three times with clean seawater (with settling allowed between washings).

DETERMINATION OF EGG DENSITY

Sea Urchin Fertilization Test

A sample of eggs from each spawning female is inspected under a microscope, and batches containing immature, small, or misshapen eggs are discarded. The remaining batches of eggs are pooled and combined into a one-liter glass beaker. The eggs are suspended evenly into the solution, and a 1-ml sub-sample is removed and combined with 9 ml of seawater in a 10-ml graduated cylinder. This solution is also thoroughly mixed. A 1-ml sub-sample is again removed and added to a Sedgewick-Rafter slide, and eggs are counted microscopically. Counts should be between 200 and 245 eggs per ml. The stock solution is adjusted as needed to obtain the necessary concentration.

PREPARATION OF SPERM

A 0.025-ml sub-sample of sperm pooled preferably from four males is diluted with 100 ml of seawater and is thoroughly mixed. 9 ml of this solution is combined with 1 ml of acetic acid (to inactivate the sperm) and a 0.1 ml of solution is added to a hemacytometer. Hemacytometer counts should be between 51 and 408 using a five-square counting pattern, and, if not, the stock solution is adjusted.

TRIAL ESTIMATE OF FERTILIZATION

0.03 ml of sperm solution and 0.30 ml of egg suspension are combined with 3 ml of seawater. The embryos are inspected under a microscope, and if fertilization is greater than 80% the test is initiated. If lower, sperm and egg solutions are reprepared. An "egg blank" (with no sperm added) is also inspected in order to ensure that prefertilization has not occurred.

INOCULATION OF TEST CHAMBERS

Each test chamber is inoculated with 0.03 ml of sperm. After exactly 20 minutes following sperm addition, 0.30 ml of the egg solution is added to each chamber (in the same sequence as the sperm addition). Exactly 20 minutes following egg inoculation, 0.10 ml of 25% glutaldehyde is added to preserve the embryos.

EXAMINATION OF EMBRYOS

100 embryos from each well plate chamber are examined and scored as either fertilized or unfertilized depending upon the presence or absence of a vitelline membrane. Percent fertilization is recorded for each replicate.

TEST ACCEPTABILITY

1. Egg fertilization at the NOEC must be greater than 80% that of the controls.
2. The minimum significant difference is <25% relative to the controls.
3. The sperm count for the final sperm stock must not exceed 33,600,000/ml.
4. If the sperm count for the final sperm stock is between 5,600,000 and 33,600,000/ml it must not exceed 2X of the target density from the trial, or if no target density was specified for the test, the high sperm density controls (0.2-ml sperm stock) must have at least 5% higher fertilization than the low sperm density controls (0.05-ml sperm stock).

5. Dilution water egg blanks and effluent egg blanks should contain essentially no eggs with fertilization membranes.

REFERENCES

US EPA. 1995. *Short-Term Methods for Estimating the Chronic Toxicity of Effluents and Receiving Waters to West Coast Marine and Estuarine Organisms.* EPA/600/R-95/136.

Chapman, G.A. 1994. *Sea urchin* (Strongylocentrotus purpuratus) *and sand dollar* (Dendraster excentricus) *fertilization test method*. USEPA. Newport, Oregon (draft).

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Revised 8/25/03

STANDARD OPERATING PROCEDURES FOR RED ABALONE TOXICITY TEST
ENDPOINT DESCRIPTION

Fertilized eggs of the red abalone, *Haliotis rufescens*, are exposed to various effluent concentrations and allowed to develop into veliger larvae. The endpoint is the proportion of normal verses abnormal larval development after 48 hours.

DILUTION WATER
Three types of water may be used as a dilution source: 1) receiving water: seawater collected from areas around the vicinity of outfall. 2) Natural, 1 um filtered, UV sterilized salt water from a mariculture facility in Oxnard, California. 3) Reconstituted sea salts using "Tropic Marin" brand sea salts and highly purified D.I. water.

All reference toxicant tests use the same water source each time a test is conducted. Water is obtained in the open ocean near Anacapa Island and is filtered through a 0.2 um filter. Water is collected in new five gallon cubitainers prior to testing and stored at 15 deg C.

EFFLUENT CONCENTRATIONS
Five concentrations, a control and a brine control (if salinity adjustment is needed) each with five replicate test chambers are used. One of the five chambers is analyzed for chemical/physical parameters at the beginning and end of the test. The chambers used are 70 ml sterile Corning plastic culture flasks with screw caps. All flasks are rinsed with reference sea water and numbered for randomization before solutions are prepared.

Glassware cleaning procedure:

1. Wash in warm, soapy water.
2. Rinse with tap water.
3. Rinse with reagent grade acetone.
4. Rinse with D.I. water.
5. Soak in 3N HCL for 24 hours.
6. Rinse with D.I. water.
7. Rinse with 2N HNO3.
8. Rinse with D.I. water.
9. Soak in D.I. water for 24 hours.
10. Rinse with D.I. water.
11. Air dry.

All glassware is rinsed with reference seawater prior to mixing concentrations. A 1000 ml glass volumetric flask, various sizes of volumetric pipettes, and a 250 ml graduated cylinder are used to prepare solutions. A total volume of 1000 ml is needed for each solution. Effluent concentrations are typically set according to client requirements. For concentrations above 2%, a brine is used to adjust salinity. Six to eight liters of reference seawater are frozen 48 hours before the test. After 24 hours, the water is allowed to partially thaw for about one hour and the liquid is combined into a 1-liter

container. If the salinity is not between 60 and 80 ppt, the container is frozen again for 24 hours. After an hour of thawing, the water is separated from the ice. The salinity is then usually between 60 and 80 ppt.

The amount of brine to add to each effluent concentration to obtain a final salinity of 34 + 2 ppt is calculated using the following formula:

$VB = VE\ (34\text{-}S_E) / (SB - 34)$

VB=Volume of Brine to add
VE=Volume of Effluent
SE=Salinity of Effluent
SB=Salinity of Brine

Brine controls are used in all tests when salinity adjustment is necessary. The brine controls contain the same amount of brine added to the highest effluent concentration plus D.I. water equal to the amount of effluent added and filled to the 1-liter mark with reference seawater. The pH of all brine mixtures are checked and adjusted to within 0.1 units of the dilution water by dropwise addition of dilute HCl or NaOH.

Effluents with a salinity greater than 10 ppt, or tests with effluent concentrations greater than 10% use the following formula to calculate the amount of D.I. to add:

$V_B = V_E\,(34) / (S_B - 34)$

The amount of D.I. to add is calculated by solving for V_E.

Effluent concentrations are prepared by combining effluent, hypersaline brine and dilution water using the appropriate dilution factors. Concentrations are mixed from the lowest to the highest to avoid any possible contamination.

REFERENCE TOXICANT CONCENTRATIONS
Stock solutions of zinc sulfate (ZnSO4) are prepared by Environmental Resource Associates in Arvada, Colorado. The 10,000 ug/l stock is traceable to NBS standards and is guaranteed stable for one year. After one year, it is discarded. A reference test is performed concurrently with each effluent test. A sample of stock is analyzed by a local, certified laboratory at the time of the test to ensure there is no contamination of the stock solution.

Reference toxicant solutions consist of five replicates of 0 (control), 18, 32, and 56 ug/l zinc sulfate. One replicate is used for measuring chemical/physical parameters. Concentrations are obtained by mixing 1.8, 3.2 and 5.6 ml of 10,000 ug/l Stock in a 1-liter volumetric flask.

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OBTAINING EMBRYOS

Test embryos are usually obtained from the abalone hatchery on the day of the test. Test concentrations are being mixed while the animals are spawning. The beginning test temperature depends on the spawning temperature (ambient ocean water). There is never more than a 1 deg C difference between the two temperatures.

Immediately after fertilization, the embryos are checked for sperm/egg ratio (<100), rinsed, condensed into a one gallon plastic bottle, wrapped in newspaper, placed in an ice chest, and transported to the laboratory (15-20 minutes). Embryos are poured in a 1-l cylinder and gently mixed with a perforated plunger. Five replicate counts of evenly suspended embryos are made with a 1-ml wide bore pipet.

Embryo density is adjusted by either diluting, or by settling and pouring off excess water to obtain a density between 200 and 300 embryos/ml. The tests conducted with embryos are initiated within one hour of fertilization.

SPAWNING ABALONE

Occasionally, the hatchery cannot spawn when a test needs to be conducted. When this occurs, abalone broodstock are obtained from a local aquaculture source and held in the laboratory for one week prior to spawning. The holding tanks are cleaned daily of any uneaten food and/or fecal material and the organisms are fed an ample supply of fresh kelp. Fresh, altered seawater is exchanged at a 50:50 ratio with tank water every other day. After the animals are spawned, they are returned for reproductive conditioning under flow-through conditions.

The day before the test, four male and four female abalone are rinsed off in 1-um filtered seawater and separately placed into two 30-liter buckets with aerated seawater.

Three hours prior to spawning, abalone are transferred to clean five gallon buckets filled with six liters of aerated, 1-um filtered seawater. 12.1 gm of Tris is dissolved into 50 ml D.I. water. After the Tris has dissolved, H2O2 is prepared by pouring 10 ml H_2O_2 (30%) into 40 ml D.I. water (1:5 dilution). 25 ml of Tris and 25 ml of H_2O_2 are then poured into each bucket and mixed well. Abalone are exposed for 2.5 hours at 15 deg C. Both buckets are emptied, rinsed and refilled to the top with fresh 1 um filtered seawater.

The abalone begin spawning about 3 hours after chemical introduction. If spawning occurs before chemicals have been removed, buckets are immediately drained, rinsed, and refilled.

FERTILIZATION

As females spawn, eggs settle to the bottom. The water is gently swirled to make an even layer without allowing eggs to come in contact with each other. Clumps of eggs are removed. When a sufficient number of eggs have been obtained, or one-half hour has passed since first male spawn, the eggs are siphoned into a third bucket with one liter of filtered seawater. As males spawn, sperm directly above the respiratory pore is collected

into a 500 ml flask. Sperm is collected every 15 minutes until spawning is complete. The freshest sperm is used to fertilize eggs.

When enough eggs have been collected, about 200 ml of sperm-laden water is poured into the bucket containing eggs. The mixture is then gently swirled with a low flow of seawater to allow fertilization. When the bucket is half full, water flow is stopped and eggs settle to the bottom of the bucket. Immediately after fertilization, the water is carefully siphoned off as much as possible without disturbing the eggs. The bucket is then filled again with seawater and embryos are allowed to settle. Eggs are then siphoned into a 1 liter beaker. Eggs are examined under the microscope to make certain they have not been over-fertilized. One to 100 sperm should be visible around a single egg. If there is a great number of sperm/egg (>1000), the eggs will not develop and must be discarded.

STANDARD OPERATING PROCEDURES FOR GIANT KELP TOXICITY TEST
ENDPOINT DESCRIPTION

Viable zoospores of the giant kelp, Macrocystis pyrifera, are exposed for 48 hours to various effluent concentrations and are allowed to settle and germinate. The two endpoints measured after the 48-hour exposure period are germination success and growth of germination tubes.

DILUTION WATER
Three types of water may be used as a dilution source: 1) receiving water: seawater collected from areas around the vicinity of outfall. 2) Natural, 1 um filtered, UV sterilized salt water from the University of California at Santa Barbara. 3) Reconstituted sea salts using "Tropic Marin" brand sea salts and highly purified D.I. water.

All reference toxicant tests use the same water source each time a test is conducted. The holding and testing temperature for this test is 15 + 1° C.

EFFLUENT CONCENTRATIONS
Test solutions are prepared concurrently during the release of zoospores. Five concentrations, a control, and a brine control (if salinity adjustment is needed) each with five replicate test chambers are used. A separate container is analyzed for chemical/physical parameters during the test. Test chambers are 5 ml coverglass slides. All slides are numbered for test randomization before the test is started.

Glassware cleaning procedure:
1. Wash in warm, soapy water.
2. Rinse with tap water.
3. Rinse with reagent grade acetone.
4. Rinse with D.I. water.
5. Soak in 3N HCL for 24 hours.
6. Rinse with D.I. water.
7. Rinse with 2N HNO3.
8. Rinse with D.I. water.
9. Soak in D.I. water for 24 hours.
10. Rinse with D.I. water.
11. Air dry.

All glassware is rinsed with reference seawater prior to preparation of concentrations. A 1-liter glass volumetric flask, various sizes of volumetric pipettes, and a 250 ml graduated cylinder are used to prepare solutions. A total volume of 100 ml is needed for each solution. Effluent concentrations are set according to client requirements.

For concentrations above 2%, a brine is used to adjust salinity. Six to eight liters of reference seawater are frozen 48 hours before the test. After 24 hours, the water is allowed to partially thaw for about one hour, and the liquid is combined into a 1-liter container. If the salinity is not between 60 and 80 ppt, the container is frozen again for 24

hours. After an hour of thawing, the water is separated from the ice. The salinity is then usually between 60 and 80 ppt.

The amount of brine to add to each effluent concentration to obtain a final salinity of 34 + 2 ppt is calculated using the following formula:

$V_B = V_E (34 - S_E) / (S_B - 34)$

V_B=Volume of Brine to add
S_E=Salinity of Effluent
V_E=Volume of Effluent to add
S_B=Salinity of Brine

Brine controls are used in all tests when salinity adjustment is necessary. The brine controls contain the same amount of brine added to the highest effluent concentration plus D.I. water equal to the amount of effluent added and filled to the 1-liter mark with reference seawater. The pH of all brine mixtures are checked and adjusted to within 0.1 units of the dilution water by dropwise addition of dilute HCl or NaOH.

Effluents with salinity greater than 10 ppt, or tests with effluent concentrations greater than 10% use the following formula to calculate the amount of D.I. to add:

$V_B = V_E (34) / (S_B - 34)$

The amount of D.I. to add is calculated by solving for V_E. Effluent concentrations are prepared by combining effluent, hypersaline brine and dilution water using the appropriate dilution factors. Concentrations are mixed from the lowest to the highest to avoid any possible contamination.

REFERENCE TOXICANT CONCENTRATIONS

Stock solutions of copper chloride are prepared by Environmental Resource Associates in Arvada, Colorado. The 10,000 ug/l stock is traceable to NBS standards and is guaranteed to be stable for one year. The stock discarded after this time. A reference test is performed concurrently with each effluent test. A sample of stock solution is analyzed by a local certified laboratory at the time of the test to ensure there has been no contamination.

Reference toxicant solutions consist of five replicates each of 0 (control), 5.6, 10, 18, 32, 56, 100, and 180 ug/l. Concentrations are obtained by mixing 0.56, 1.0, 1.8, 3.2, 5.6, and 10 ml stock solution (respectively) with 0.2 ul of filtered reference water in a 1-liter volumetric flask.

PARAMETERS AND TEST CONDITIONS

The test is performed at 15 deg C under low light conditions (50 microeinsteins) with a photoperiod of 16 hours light and 8 hours dark. Temperature is measured daily; and dissolved oxygen, salinity, and pH are measured at the beginning and end of the test. Thermographs continuously record incubator temperatures throughout the testing period.

ZOOSPORE RELEASE

Sporophyll blades are obtained from wild populations collected by either Kim Siewers in Santa Cruz, California or David Gutoff in San Diego California the day before the test. Zoospores are released within 24 hours of collection to ensure viability. As test concentrations are being prepared in another part of the laboratory, sporophylls are rinsed with filtered seawater and gently scrubbed with a soft bristle vegetable brush. Clean blades are then desiccated by placing them on paper towels and exposing them to air for one hour. The blades are then rinsed again and put into a one liter beaker of filtered seawater. Release of zoospores is indicated by a slight cloudiness in the water. The spores are checked for viability by observing a subsample under 100X magnification. The zoospore release process must not exceed 2 hours.

After release, the blades are removed and the zoospore mixture is allowed to settle for 30 minutes, and the top 250 ml are decanted into a clean beaker. Five replicate hemacytometer counts are taken from a 9 ml sub-sample containing 1 ml of alcohol. Spore density is corrected by multiplying the count by 1.11.

PREPARATION FOR RESIDUAL CHLORINE TESTS

When residual chlorine is the toxicant of concern, the required volume of dilution water is added to the test containers first, and the zoospores are then added to the dilution water. An effluent sample is dosed with the required concentration of chlorine, and after the appropriate decay time, the effluent is added to the testing containers.

DELIVERY OF ZOOSPORES

The volume of zoospore mixture needed to deliver 7500 spores/ml to each test chamber is calculated. The volume should not exceed 1% of the test solution volume. A micropipet is used to deliver the volume needed for 7,500 spores/ml in each container. Zoospores are taken from the top 5 centimeters of the solution to ensure that only swimming zoospores are collected. Before the spores are delivered, a subsample is examined to verify that the zoospores are still swimming.

INCUBATION

Gametophytes are incubated for 48 hours at 15 deg C and 50 microeinsteins light intensity of 16 hours light and 8 hours dark photoperiod. During this time, zoospores settle on the coverglass slide, germinate, and develop into the characteristic "dumbell" gametophyte stage.

ANALYSIS

After 48 + 2 hours, samples are preserved with 0.1% glutaraldehyde. The slides should be examined within two weeks of preservation. The first 100 spores encountered are examined under 400X magnification. Germination is successful when a germ tube is

present on the settled zoospore. Circular zoospores with little or no protuberances (less than 3 microns) are considered non-germinated. Care is taken not to count objects similar in appearance to non-germinated spores. Kelp spores are green-brown in color, spherical and lack motility. They exhibit a light green fluorescence when the fine adjustment is moved up and down slightly. An object is not counted if it cannot be identified. Germ tube growth is analyzed by randomly choosing ten, straight germ tubes and measuring and recording their lengths.

DATA ANALYSIS

The Toxcalc computer program is used to analyze data. Randomized test container numbers are assigned to their correct concentrations, proportions of germinated spores and germ tube lengths are entered into the program, and proportions are arcsine-square root transformed. ANOVAs compare concentrations and Dunnett's test compares concentrations to the control. The NOECs can be determined from the results of these tests.

TEST ACCEPTABILITY

1. No less than 70% mean control germination in the reference toxicant test. In effluent test, brine control cannot be lower than 70% germination.
2. Germ tube length in all controls must be at least 10 microns.
3. Germination NOEC must be below 110 ug/l and germ tube growth NOEC must be below 35 ug/l in reference toxicant tests.
4. Between replicate variability cannot exceed 70 in ANOVA mean square or 5.29 Standard Error in Dunnett's for germination.
5. Germ tube length Standard Error in Dunnett's must be lower than 2.19.
6. Brine controls cannot be significantly different from dilution water controls.

REFERENCES

US EPA. 1995. Short-Term Methods for Estimating the Chronic Toxicity of Effluents and Receiving Waters to West Coast Marine and Estuarine Organisms. EPA/600/R-95/136.

Hunt, J., Anderson, B. Abalone development: Short-term Toxicity Test Protocol. Procedures Manual for Conducting Toxicity Tests Developed by the Marine Bioassay Project. State Water Res. Control Board. Sacramento (Current Ed.).

State Water Resources Control Board. 1996. Procedures Manual for Conducting Toxicity Tests Developed by the Marine Bioassay Project. 96-IWQ.

Revised 3/10/2006

STANDARD OPERATING PROCEDURES FOR Ceriodaphnia SURVIVAL AND REPRODUCTION TOXICITY TEST

ENDPOINT DESCRIPTION

Less than 24-hour old Ceriodaphnia are exposed to different concentrations in a static renewal system until 60% of the surviving organisms have three broods of offspring. Control organisms usually produce three broods during a seven-day period. The endpoints are survival and reproduction.

DILUTION WATER AND CULTURE MEDIA

Control and dilution water used for this test is moderately hard reconstituted fresh water.

EFFLUENT CONCENTRATIONS

Test solutions are prepared at test initiation and every 24 hours for seven days. Five concentrations and a control, each with ten replicate test chambers, are used. 30-m1 disposable plastic cups are used as testing chambers. The cups are not washed prior to use but glassware used to make effluent dilutions are cleaned by the following method:

1. Wash in warm, soapy water, rinse with tap water.
2. Rinse with reagent grade acetone, rinse with D.I. water.
3. Soak in 3N HCL for 24 hours, rinse with D.I. water.
4. Rinse with 2N HNO3, rinse with D.I. water.
5. Soak in D.I. water for 24 hours.
6. Rinse with D.I. water.
7. Air dry.

Effluent samples typically arrive on ice and must be warmed on a hot plate until temperatures reach 25 deg C. Various sizes of graduated cylinders are used to prepare solutions. A total volume of 500 m1 is needed for each concentration: ten replicates and one 250-m1 sample for measuring chemical parameters. Effluent concentrations are typically set at 100%, 56%, 32%, 18%, and 10%, but if higher toxicity is suspected, concentrations are set at lower ranges provided there is a 56% difference between dilutions.

STANDARD TOXICANT CONCENTRATIONS

A reference toxicant test is run in conjunction with each effluent test conducted. Copper chloride is used as the standard. Ten replicates of six concentrations are prepared at 0, 1, 3, 5, 10, and 20 ppb. One gallon of each concentration is prepared at the beginning of the test and renewals are made daily.

7-day Ceriodaphnia Survival/Reproduction Test

TEST ORGANISMS

A culture brood stock of Ceriodaphnia is kept on an ongoing basis to ensure adequate supply of neonates. The brood board consists of sixty cups, each containing 15 m1 of culture media. One neonate is placed in each cup in the board initiation day and its survival and young are monitored for a period of two weeks. The organisms are fed daily and are transferred to a fresh medium three times weekly. On transfer days, the adult is transferred to fresh medium and the young are counted and discarded (or used in a test). After two weeks, a new board is started using neonates from adults which produce at least eight young in their third brood. Cultures usually produce at least 15 young per adult in three broods (7 days or less). A mass culture is also maintained in case a population crash occurs in the brood board. Neonates from this culture are used only to start a new brood board and are not directly used for the test. Mass cultures are fed daily and transferred to fresh media weekly. The population is culled periodically to about 50 individuals.

FOOD PREPARATION

Ceriodaphnia are fed a combination of yeast, cerophyll, "Tetramin" brand fish food, and green algae (Selenastrum). The yeast, cerophyll, and Tetramin mixture is prepared in the following manner. One week prior to making food, 5.0 grams of Tetramin is added to one liter of deionized water and mixed in a blender. The slurry is poured into an Imhoff cone, covered and aerated for seven days at ambient laboratory temperatures. Any water lost during this digestion procedure is replaced. At the end of the digestion period, the mixture is poured into a flask and allowed to settle for one hour. The supernatant is then filtered through a nytex 100 mesh screen into another 1-liter beaker. The filtered supernatant is combined with the cerophyll and yeast. Fresh; dry "Fleischmans" brand yeast (5.0 grams) is dissolved into one liter of deionized water on a stir plate. The suspension is not allowed to settle and is immediately combined with equal parts of cerophyll and Tetramin. Excess suspension is discarded. 5.0 grams of cerophyll is placed in a blender with one liter of deionized water and mixed for five minutes. This mixture is filtered through a 110 mesh nytex screen. Equal portions of the three types of prepared food are mixed, and aliquots are poured into 125-m1 plastic beakers and frozen until needed. Thawed food is kept in the refrigerator for up to two weeks and fed to the Ceriodaphnia daily. Following food preparation and before aliquots are poured, a suspended solids analysis is performed and the mixture is either concentrated of diluted to obtain a result of 1800 mg/l. The suspended solids are monitored in the following manner:

1. Two pans are oven dried and weighed.
2. The combined YCTF is shaken to get a uniform sample.
3. 5.0 ml are dispensed in each of the two pans.
4. Pans are dried for at least four hours then allowed to cool in the desiccator.
5. Pans are weighed again.
6. The weights are converted to mg/l by:

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Difference in wt. of pans X $\frac{1000}{0.005}$

7. The dilution factor is obtained by: $\frac{\text{mg/l TSS}}{1800 \text{ mg/l}}$

this result is multiplied by volume of YCTF to set the final volume after dilution.

8. If a large dilution factor was used, this is repeated after dilution to confirm TSS.
9. The acceptable solids level is between 1700 and 1900 mg/l.

Algae is prepared from an ongoing stock culture maintained in the laboratory. The algae used for the Selenastrum toxicity test is inoculated into fresh media weekly. The remainder of algae is placed in the refrigerator, allowed to settle, and then concentrated. When algae is needed for feeding, a portion of the concentrate is diluted to 3.0 to 3.5 x 10 (7) cells/mi. The density is obtained by hemacytometer counts. Once the final cell density is obtained, the bottle is labeled and recorded in a log book. This concentrate is used for one month. The suitability of each new food supply is determined in a side-by-side test using two treatments with four replicates per treatment. One treatment is fed the new food and the other is fed food already known to be suitable.

FEEDING

Cultures are fed daily. 0.1 m1 YCTF and 0.1 mi algae are delivered to each cup.

INITIATION OF THE TEST

After effluent concentrations are prepared, the chemical measurements are recorded: dissolved oxygen, pH and conductivity are measured at the beginning and end of each 24-hour exposure period in each test concentration and the control. Alkalinity and hardness are measured in the highest concentration and the control at the beginning of the test. Thermographs continuously record temperatures (25 $\pm$ 1 deg C), and a photoperiod of 16 hours light and 8 hours dark is maintained throughout the testing period. Neonates which are less than 24 hours old and within, 8 hours of the same age are selected from individual brood boards. Ten board animals with 8 or more young are selected for setting up the test. The ten brood cups are placed in a row. Each concentration of effluent has ten cups. One neonate from the same female is placed in each concentration of effluent. This blocking procedure allows the performance of each female to be tracked. If the female produces one weak offspring or male, the likelihood of producing all weak offspring or males is greater. By using this technique, poor performance of young from a given female can be omitted from all concentrations (See USEPA 1989.)

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TEST SOLUTION RENEWAL

Test solutions are renewed daily and prepared in clean 500-m1 beakers. A minimum of three effluent samples are received from the client for use on days 1, 3 and 5. Samples are stored at 4 deg C. The test organisms are transferred to fresh solutions using disposable transfer pipets. Care is taken to release the animals beneath the surface of the water so that no air is trapped under the carapace. The number of live young and the adult mortality is reported. The young are discarded after recording.

TERMINATION OF THE TEST

Tests are finished when at least 60% of surviving control females have produced a third brood (usually seven days).

ANALYSIS

Toxcalc, a computer program is used to analyze data. The flow charts for statistical analysis of survival and growth as described in the EPA manual are followed to obtain NOEC estimates.

TEST ACCEPTABILITY

1. Control survival must be greater than 80%.
2. Reproduction in controls must average 15 or more young per surviving female.

REFERENCE

USEPA. 1991. *Short-Term Methods for Estimating the Chronic Toxicity of Effluents and Receiving Waters to Fresh-water Organisms*. EP A-600/4-91/002.

USEPA. 1989. *Short-Term Methods for Estimating the Chronic Toxicity of Effluents and Receiving Waters to Fresh-water Organisms*. EP A-600/4-89/001.

Revised: 8/25/03

STANDARD OPERATING PROCEDURES FOR THE CHRONIC FATHEAD MINNOW LARVAE TOXICITY TEST

ENDPOINT DESCRIPTION

Twenty-four hour old fathead minnow larvae (*Pimephales promelas*) are exposed in a static renewal system to various test solutions for seven days. The endpoints are survival and growth (increase in weight) of the larvae compared to the controls.

DILUTION WATER

Dilution and control water used for this test is moderately hard, reconstituted fresh water.

EFFLUENT CONCENTRATIONS

Test solutions are prepared at test initiation and every 24 hours for seven days. Five concentrations and a control, each with four replicate test chambers, are used. The chambers are 250-ml borosilicate glass crystallizing dishes. The larvae are contained within 200-micron Nytex screens cemented around a petri dish with silicone sealant. Each cylinder fits inside the dish, the liquid is poured in and the fish are added. All dishes are labeled. Glassware cleaning procedure:

1. Wash in warm, soapy water, rinse with tap water.
2. Rinse with reagent grade acetone, rinse with D.I. water.
3. Soak in 3N HCL for 24 hours, rinse with D.I. water.
4. Rinse with 2N HNO3, rinse with D.I. water.
5. Soak in D.I. water for 24 hours.
6. Rinse with D.I. water.
7. Air dry.

Effluent samples arrive on ice and must be placed on a heat plate until temperatures reach 25 deg C before set-up. Various sizes of graduated cylinders are used to prepare solutions. A total volume of 1,250 ml is needed for each concentration: four replicates and one 250-ml sample for measuring chemical parameters. Effluent concentrations are typically set at 100%, 56%, 32%, 18% and 10% but if higher toxicity is suspected, concentrations may be at lower ranges as long as the 56% difference between dilutions is maintained.

STANDARD TOXICANT CONCENTRATIONS

A reference toxicant test is run in conjunction with each effluent test conducted. Copper chloride is used as the standard. Four replicates of six concentrations are prepared at 0, 38, 75, 100, 150, and 300 ppb. One gallon of each concentration is prepared at the beginning of the test and renewals are made daily.

SHIPPING OF TEST ORGANISMS

Newly hatched larvae are shipped from Aquatox in Hot Springs, Arkansas and arrive at Aquatic Bioassay the following day. The conditions of the organisms are checked, and the tests begin the day of arrival to ensure that 24-hour old larvae are used.

CHEMICAL PARAMETERS

Aeration is used only when dissolved oxygen (D.O.) concentrations fall below 40% saturation. If this becomes necessary, chambers are aerated at a rate not to exceed 100 bubbles per minute. At the beginning of the test and every 24 hours thereafter, the following measurements are recorded: temperature, pH, and conductivity. Dissolved oxygen is measured at the beginning and end of each 24 hour exposure period in one test chamber at all test concentrations and the control. Hardness and alkalinity measurements are made daily on the control and highest concentration as well.

INITIATION OF THE TEST

After concentrations are prepared and chemical measurements are recorded, 10 animals are carefully transferred into each Nytex cylinder using disposable transfer pipets. Containers are randomly placed on racks in a temperature controlled room at 25 $\pm$ 1 deg C with a photoperiod of 16 hours light and 8 hours dark. Thermographs continuously record temperatures during the testing period.

FEEDING

The fish in each chamber are fed approximately 700-1000 newly hatched (<24 hours old) brine shrimp twice daily, once in the morning and then after renewal of the test solutions. The larvae are not fed on the last day of the test. All brine shrimp nauplii are rinsed with D.I. water and concentrated before use. The amount of food provided is sufficient to ensure the presence of a small amount of uneaten food at the next feeding. The suitability of each new food supply is determined in a side-by-side test using two treatments with four replicates per treatment. One treatment is fed the new food and the other is fed food already known to be suitable.

TEST SOLUTION RENEWAL

Test solutions are renewed daily and prepared in clean 1000-ml beakers. Each Nytex cylinder is carefully lifted from the old solution and transferred into the new solution, taking care not to disturb the larvae. The effluent which has been stored in the refrigerator is warmed to 25 deg C before mixing solutions. Before transferring larvae, the bottom of each petri dish is cleaned of all debris by siphoning with a transfer pipet. Numbers of live larvae is recorded and all dead animals are removed.

TERMINATION OF TEST

After the 7-day exposure period, the test is terminated. The number of surviving larvae are recorded and then transferred into labeled vials containing 70% ethanol for subsequent weight determination. Immediately before drying, the larvae are rinsed in D.I. water. They are then individually placed in clean, tared aluminum weigh boats and dried at 100 deg C for a minimum of 6 hours. Immediately after removal from the oven, boats are placed in a desiccator overnight to completely cool before weighing. All individual weights are measured to the nearest 0.01 mg. For each test chamber, the final dry weight is divided by the original number of larvae to determine average individual dry weight. In addition, the control final dry weight is divided by the number of surviving fish to determine if the weight acceptability criteria has been met.

ANALYSIS

The Toxcalc computer program is used to analyze data. The flowcharts for statistical analysis of survival and growth as described in the EPA manual are followed to obtain NOEC estimates.

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TEST ACCEPTABILITY

1. Control survival must be greater than 80%.
2. Average dry weight must be greater than 0.25 mg.

REFERENCE

USEPA. 1991. *Short-Term Methods for Estimating the Chronic Toxicity of Effluents and Receiving Waters to Fresh-water Organisms*. EPA-600/4-91/002.

USEPA. 1989. *Short-Term Methods for Estimating the Chronic Toxicity of Effluents and Receiving Waters to Fresh-water Organisms*. EPA-600/4-89/001.

Revised: 8/25/03

STANDARD OPERATING PROCEDURE FOR ACUTE EFFLUENT TOXICITY TESTS
(EPA 5th Ed. Methodology)

ENDPOINT DESCRIPTION

Juvenile fish or invertebrates are exposed to various concentrations of effluent for 24-96 hours. The endpoint is mortality.

DILUTION WATER

Water used for this test is reconstituted fresh or saltwater. Known amounts of reagent grade salts or standard sea salts are added to high quality D.I. water until the dilution hardness and alkalinity or salinity is equal to that of the effluent.

EFFLUENT CONCENTRATIONS

Test dilutions are typically prepared at 100%, 50%, 25%, 12.5%, and 6.25%. If needed, lower dilutions can be set at ranges where a dilution is at least 50% that of the next highest concentration. If the toxicity of the sample is unknown, a 24-hour preliminary range-finding test using a wider range of concentrations can be prepared. A control using the same dilution water is included with all tests.

Test chambers are new or pre-cleaned, glass beakers, ranging in size from 30-250 ml (depending upon the species chosen). For rainbow or brook trout, 5-liter disposable glass aquaria are used. Test solution volumes range from 25-200 ml (or 4 liters for trout). Each beaker or aquarium is labeled with a lab number and effluent concentration. Test containers are placed on wire racks in a constant temperature room of either 19-23 or 24-26 deg C (11-13 deg C for trout). Beginning with the lowest concentration, graduated cylinders are used to pour the proper amount of the well-mixed effluent in each beaker. Dilution water is then poured in each container to the desired volume.

Solutions are not aerated unless oxygen values fall below 4.0 mg/l (6.0 mg/l for trout). Rate of aeration should not exceed 100 bubbles per minute.

TEST ORGANISMS

Juvenile animals are obtained from licensed breeders or collectors (Thomas Fish Company at Anderson, Ca., Brezina and Associates at Dillon Beach, Ca., or Aquatox in Hot Springs, Arkansas and are delivered by Greyhound bus, UPS, or Federal Express. Upon arrival, the condition of the animals and number of mortalities during shipment are recorded.

Ages of organisms used and test temperatures in bioassays are:

Ceriodaphnia dubia	less than 24 hours@25ºC
Daphnia spp.	less than 24 hours@25ºC
Pimephales promelas	1-14 days; less than or equal to 24-hrange in age @ 25ºC
Oncorhynchus mykiss	15-30 days (after yolk sac absorption to 30 days) @ 12ºC
Mysidopsis bahia	1-5 days; less than or equal to 24-h range in age, @20ºC $\pm$ 1ºC or 25ºC $\pm$ 1ºC, Salinity @5-30ppt $\pm$ 10%
Menidia beryllina	9-14 days; less than or equal to 24-h range in age, @20ºC $\pm$ 1ºC or 25ºC $\pm$ 1ºC, Salinity @1-32ppt $\pm$ 10%

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Holmesimysis costata	3-4 days post-hatch juveniles; @15ºC ± 1ºC, Salinity @34ppt ± 2ppt
Atherinops affinis	7-15 days @21ºC, Salinity @10-30ppt
Hyalella azteca	7-14days, 1-2 day range in age, @23 ± 1°C

PERCENT SURVIVAL TESTS

Occasionally, only a percent survival test in undiluted effluent is required. The same procedures apply in this test as a standard bioassay, except that only undiluted waste and the control are used. Tests are reported as percent survival in undiluted sample instead of LC50.

CHEMICAL AND PHYSICAL PARAMETERS

Dissolved oxygen, pH, and temperature are measured in all controls and concentrations before introducing fish, and at 24-hour intervals thereafter. The hardness and alkalinity are measured in the control and highest concentration at the beginning and end of each test. Residual chlorine and conductivity or salinity are measured in the control and highest treatment concentration at the beginning of the test. Calibrated thermographs continuously record temperatures throughout the test. A uniform photoperiod of 16 hours light and 8 hours dark at an intesity of 50-100 foot-candles is maintained.

DELIVERY OF ORGANISMS AND TEST DURATION

Within one hour after the preparation of test solutions, typically 10 randomly chosen animals are delivered to each duplicate test tank using a small-mesh dip-net or disposable pipette (total of 20 animals per concentration). The test begins when animals are introduced into the test chambers and continues for 24, 48, or 96 hours, depending upon requirements. Test solutions are renewed at 48 hours. Animals are fed at 48 hours, with the exception of *Oncorhynchus mykiss* which are not fed and *Mysidopsis bahia and Hyalella azteca* are fed 0.2 mL concentrated suspension of Artemia nauplii ≤ 24-h old daily, if the test lasts longer than this. Mortalities and chemical measurements are recorded every 24 hours, and dead animals are removed as soon as they are observed. Excess food is removed after feeding.

DISPOSAL OF FISH AND TANKS

At the end of the test, animals are destroyed before being disposed of by placing them in a zip-lock bag with ethanol. Effluents are poured down the drain unless they are highly toxic, in which case the client is asked to pick up the sample and any dilutions. Test tanks and aeration pipets are broken down and disposed of at a local landfill.

ANALYSIS

A review of concentration-response relationships is conducted on all multi-concentration tests following guidelines in EPA821-B-00-004, July 2000, *Method Guidance and Recommendations for Whole Effluent Toxicity (Wet) Testing (40 CFR Part 136)*.

The flowchart shown in Figure 6 of the method reference (USEPA 2002) is used for determining the LC_{50} statistical test. When an LC_{50} can be determined, the toxicity of the waste is also expressed as toxic units, where:

$$TC(tu) = \frac{100}{96\text{-hr } LC_{50}}$$

When there is less than 50% mortality in 100% waste, the toxic units are expressed as:

$$TC(tu) = \frac{\text{Log (\% Mortality)}}{1.7}$$

TEST VALIDITY

1) Mortality cannot exceed 10% in the controls.
2) Test must be set within 36 hours of collection.
3) D.O. above or equal to 4 mg/l (6 mg/l for trout).
4) Loading limits must not exceed 1.1 g/l at 25 deg C, 0.65 g/l at 20 deg C, and 0.4 g/l at 25 deg C.

REFERENCES

USEPA. 2002. *Methods for Measuring the Acute Toxicity of Effluents and Receiving Waters to Freshwater and Marine Organisms*. (5th ed). EPA-821-R-02-012.

EPA-821-B-00-004, July 2000, *Method Guidance and Recommendations for Whole Effluent Toxicity (Wet) Testing (40 CFR Part 136).*

EPA 600/R-99/064, March 2000, *Methods for Measuring the Toxicity and Bioaccumulation of Sediment-associated Contaminants with Freshwater Invertebrates Waters to Freshwater and Marine Organisms*. (2nd ed)

Revised 12/7/04

STANDARD TOXICANT CONCENTRATIONS

A reference toxicant test is run in conjunction with effluent test. Zinc chloride is used as the standard. Three replicates of five concentrations are prepared at 0, 100, 180,320, and 560 ppb.

CHEMICAL PARAMETERS

No aeration is required in the algae test. At the beginning of the test the following measurements are recorded in the high, medium, and low test concentrations and the control: dissolved oxygen, temperature, pH, hardness, alkalinity and residual chlorine. Calibrated thermographs record temperatures continuously throughout the test.

INITIATION OF THE TEST

The algal inoculum is prepared no more than 2-3 hours before test initiation. *Selenastrum* from a 4 to 7 day stock culture is used. 10,000 cells per ml (±10%) is required. Cell density is checked in the final inoculum and in three of the test solutions within two hours of inoculation. The volume of stock culture required is obtained by:

$$\text{vol.} = \frac{\text{no. flasks x test vol per flask x 10,000 cells/ml}}{\text{cell density (cells/ml) in stock culture}}$$

This concentrate is diluted to obtain a final density of 1,250,000 cells/ml. The test begins when algae is added to the flasks. The 1,250,000 cell/ml inoculum is mixed well and 1 ml is added to each test solution.

INCUBATION

Test flasks are incubated under continuous cool white fluorescent lighting (400 ± 40 ft-c) at 25 ± 1 deg C and shaken twice daily by hand. The flasks are randomly rotated daily to minimize possible spatial differences in illumination and temperature.

TERMINATION OF THE TEST

After 96 hours, the test is terminated. The algal growth is measured by Coulter Counter calibrated against the hemacytometer. Three replicate counts are made for each flask. The flask is shaken vigorously and 2 m1 are placed in a vial containing 10 m1 of 1 % saline, stirred and run through the Coulter Counter.

ANALYSIS

Toxcalc, a computer program, is used to analyze data. The flowchart for statistical analysis of growth as described in the EPA manual are followed to obtain NOEC estimates.

TEST ACCEPTABILITY

1. Algal density in the control must exceed 2 x 10 (5) cells/ ml at end of test.

2. Control variability cannot vary more than 20% among replicates.

REFERENCE

USEPA. 1991. *Short-Term Methods for Estimating the Chronic Toxicity of Effluents and Receiving Waters to Fresh-water Organisms*. EPA-600/4-91/002.

USEPA. 1989. *Short-Term Methods for Estimating the Chronic Toxicity of Effluents and Receiving Waters to Freshwater Organisms*. EPA-600/4-89/00 1.

Revised: 8/25/03

Aqueous Chemistry at Mass Loading Stations: 2005-06 SAR

Site	Composite or Grab Time		Samples		FieldMeasurements				Turbidity	Specific Conductance	pH	Nitrate as NO_3	Ammonia as N	TKN	Total Phosphate as PO_4	ortho phosphate as P	TSS	VSS	Diazinon	Chlorpyrifos	Dimethoate	Malathion	Cd	Cr	Cu	Pb	Ni	Ag	Zn	As	Se	Hardness as $CaCO_3$
	Start	End	Type	#	EC	pH	TEMP	DO	NTU	µS			mg/L						ng/L				ug/L									mg/L
ACWF18	7/20/05 9:10		DT		1231	7.14	21.47	11.05	2.28	1180	7.65	5.2	2.4	3.5	3.83	0.99	9	4	< 10	< 10	< 10	< 10	< 0.5	0.58	11	< 0.5	5.9	< 0.5	38		1.3	398
ACWF18	7/20/05 9:10		DF																				< 0.5	< 0.5	6.3	< 0.5	6.1	< 0.5	34		1.9	
ACWF18	8/17/05 10:45		DT		1510	9.26	23.97	10.35	4.8	1420	7.65	16.9	0.2	1.5	2.45	0.68	10	5	< 10	< 10	< 10	< 10	0.52	1.1	8.3	0.6	8.6	< 0.5	22		1.6	445
ACWF18	8/17/05 10:45		DF																				< 0.5	0.77	4.9	< 0.5	7.9	< 0.5	16		1.4	
ACWF18	9/14/05 8:55		DT		1089	8.54	20.46	8.56	4.03	1220	7.82	9.5	0.3	1.8	2.96	0.8	18	7					< 0.5	1.5	21	1.6	6.3	< 0.5	71		1.3	250
ACWF18	9/14/05 8:55		DF																				< 0.5	0.67	7.5	< 0.5	5.3	< 0.5	34		1.4	
ACWF18	10/12/05 7:25		DT		1229	8.89	18.23	8.42	1.83	1360	7.73	8	0.2	0.9	1.77	0.56	< 5	< 1	< 10	< 10	< 10	< 10	< 0.5	< 0.5	2	< 0.5	8.6	< 0.5	6.8		1	826
ACWF18	10/12/05 7:25		DF																				2	< 0.5	1.3	< 0.5	9.1	< 0.5	8.7		1.2	
ACWF18	12/6/05 10:15		DT		1025	8.23	13.08	10.94	596	1110	8.02	19.5	0.5	1.3	5.69	0.62	996	121					3	18	38	18	25	< 0.5	190		1.9	965
ACWF18	12/6/05 10:15		DF																				< 0.5	< 0.5	6.5	< 0.5	6.6	< 0.5	12		2.1	
ACWF18	1/4/06 10:45		DT		1311	7.93	14.05	11.69	50.2	1640	7.88	60.5	0.6	0.9	1.25	0.28	128	20					< 0.5	9.7	11	1.9	9.4	< 0.5	38		1.6	485
ACWF18	1/4/06 10:45		DF																				< 0.5	6.2	4.7	< 0.5	9.1	< 0.5	8.5		2.3	
ACWF18	2/16/06 9:45		DT		1621	7.76	11.59	10.66															< 0.5	1.7	8.4	< 0.5	7.4	< 0.5	8.7		1.4	740
ACWF18	2/16/06 9:45		DF						1.77	1640	8.06	55.2	0.2	0.9	2.66	0.04	< 5	< 1					< 0.5	1.3	7.7	< 0.5	7.6	< 0.5	8.7		1.3	
ACWF18	3/15/06 10:20		ST		954	7.94	12.61	10.06	11.2	2120	7.44	99	0.1	0.5	0.94	0.26	21	3					< 0.5	4.1	5.3	< 0.5	8.8	< 0.5	9.8		1.9	670
ACWF18	3/15/06 10:20		SF																				< 0.5	4.1	5	< 0.5	8.6	< 0.5	7.8		1.9	
ACWF18	4/4/06 14:45		ST		88	9.47	18.77	9.65	313	76	8.40	1	1.9	2.2	2.24	0.15	377	47					0.83	4.1	11	5.3	5.3	< 0.5	75		< 0.5	60
ACWF18	4/4/06 14:45		SF																				< 0.5	0.79	3.5	< 0.5	1.5	< 0.5	5.1		< 0.5	
ACWF18	4/26/06 9:50		DT		1407	7.72	19.86	8.26	1.17	1430	7.79	29.5	< 0.1	0.6	1.78	0.52	< 5	< 1					0.71	0.68	7.7	< 0.5	7.1	< 0.5	27		1.3	400
ACWF18	4/26/06 9:50		DF																				0.76	0.66	6.5	< 0.5	6.9	< 0.5	26		1.4	
ACWF18	6/8/06 8:59		DT		1318	8.02	19.48	6.25	2.1	1280	8.14	36.6	< 0.1	1.1	2.79	0.87	< 5	< 1					< 0.5	1.4	9.1	< 0.5	8.3	< 0.5	11		1.3	485
ACWF18	6/8/06 8:59		DF																				< 0.5	1.4	8.3	< 0.5	7.3	< 0.5	8.3		1.5	
BARSED	7/5/05 7:39	7/6/05 6:39	DT	24					3.8	2400	8.19	35.2	< 0.1	0.7	0.15	< 0.02	5	2	< 10	< 10	< 10	< 10	< 0.5	0.85	5.1	< 0.5	6.2	< 0.5	9.4		35	750
BARSED	7/5/05 7:39	7/6/05 6:39	DF	24																			< 0.5	0.81	4.5	< 0.5	6	< 0.5	10		36	
BARSED	7/6/05 7:40		SVC		2621	8.78	20.36	6.96																								
BARSED	7/12/05 8:27	7/13/05 7:27	DT	24					3.5	2500	8.16	32.2	< 0.1	e 0.4	0.18	< 0.02	8	3	< 10	< 10	< 10	< 10	0.63	1.4	15	1.2	8	< 0.5	6.1		35	740
BARSED	7/12/05 8:27	7/13/05 7:27	DF	24																			0.58	1.1	6.6	0.61	7.8	< 0.5	4		35	
BARSED	7/13/05 11:08		SVC		2403	8.3	28.07	6.83																								
BARSED	8/4/05 12:02		DT		2360	9.04	29.05	21.87	3.42	3080	8.55	29	0.1	0.9	0.27	0.06	9	3	< 10	< 10	< 10	< 10	< 0.5	0.51	2.9	< 0.5	5	< 0.5	5.2		26	660
BARSED	8/4/05 12:02		DF																				< 0.5	< 0.5	2.3	< 0.5	5.3	< 0.5	5.8		24	
BARSED	8/8/05 8:56	8/9/05 7:56	DT	24					3.89	3340	8.21	28.7	0.2	1.2	0.27	< 0.02	5	3	< 10	< 10	< 10	< 10	< 0.5	0.54	5.6	< 0.5	5	< 0.5	6.3		40	666
BARSED	8/8/05 8:56	8/9/05 7:56	DF	24																			< 0.5	0.53	4.7	< 0.5	5.3	< 0.5	5.6		40	
BARSED	8/9/05 8:48		SVC		2589	8.97	23.25	21.19																								
BARSED	8/21/05 9:11	8/22/05 8:11	DT	24					3.37	2550	8.10	31.9	< 0.1	1.1	0.29	< 0.02	23	9	< 10	< 10	< 10	< 10	< 0.5	0.59	3.2	< 0.5	6.2	< 0.5	5.4	7.7	36	815
BARSED	8/21/05 9:11	8/22/05 8:11	DF	24																			< 0.5	< 0.5	2.8	< 0.5	6.7	< 0.5	5.1	7.2	36	
BARSED	8/22/05 8:19		DT		2514	9.2	20.96	8.75																								
BARSED	9/6/05 8:02	9/7/05 7:02	DT	24					5.71	2200	8.20	30.7	0.2	0.98	0.53	0.07	37	9	< 10	< 10	< 10	< 10	< 0.5	1	5.8	0.57	7.1	< 0.5	9.3		33	640
BARSED	9/6/05 8:02	9/7/05 7:02	DF	24																			< 0.5	< 0.5	4	< 0.5	5.8	< 0.5	4.8		31	
BARSED	9/7/05 8:33		SVC		2503	8.95	20.64	7.65																								
BARSED	9/20/05 13:34		ST		1329	7.57	22.53	9.88	29.7	1420	7.26	19.5	1.5	8.5	3.18	0.19	2120	420	37.9	< 5	< 5	88.7	2.2	28	110	30	44	< 0.5	460		31	
BARSED	9/20/05 13:34		SF																				< 0.5	2.4	13	1.2	17	< 0.5	79		11	
BARSED	10/5/05 8:14	10/6/05 7:14	DT	24					3.49	2640	8.06	26.7	< 0.1	1.9	1.17	0.04	222	32	< 10	< 10	< 10	< 10	< 0.5	3.3	12	2.9	9.1	< 0.5	36		32	705
BARSED	10/5/05 8:14	10/6/05 7:14	DF	24																			< 0.5	< 0.5	4.1	< 0.5	5.2	< 0.5	2.6		33	
BARSED	10/6/05 8:44		SVC		2491	8.63	17.6	12.95																								
BARSED	10/16/05 22:30	10/16/05 23:30	ST	6					102	936	7.75	12.4	0.9	5.7	4.61	0.28	616	142	< 5	< 5	< 5	131	1.7	20	77	37	20	< 0.5	450	10	12	685
BARSED	10/16/05 22:30	10/16/05 23:30	SF	6																			< 0.5	1.1	5.6	< 0.5	5.6	< 0.5	19	4.7	11	
BARSED	10/17/05 1:30	10/18/05 19:30	ST	22					22.5	1010	7.52	16	0.6	2.6	1.69	0.24	90	20	< 10	< 10	< 10	< 10	< 0.5	4.8	22	5.2	8.4	< 0.5	73	5	10	300
BARSED	10/17/05 1:30	10/18/05 19:30	SF	22																			< 0.5	1.3	9.5	< 0.5	6.2	< 0.5	21	3.9	11	
BARSED	10/17/05 9:20		SVC		1323	7.07	19.01	6.87																								
BARSED	10/18/05 21:30	10/21/05 1:30	ST	27					7.68	2180	8.13	22.6	0.3	0.7	0.7	0.16	28	3	< 10	< 10	< 10	< 10	< 0.5	1.1	6.7	0.92	5.8	< 0.5	13	4.3	21	520
BARSED	10/18/05 21:30	10/21/05 1:30	SF	27																			< 0.5	0.56	4.1	< 0.5	5	< 0.5	5.3	4.8	21	

ST - Stormwater total metals; SF - Stormwater, dissolved metals
DT - Dry weather, total metals; DF - Dry weather, dissolved metals
SVC - Autosampler service time

e- estimated

Aqueous Chemistry at Mass Loading Stations: 2005-06 SAR

Site	Composite or Grab Time		Samples		FieldMeasurements				Turbidity	Specific Conductance	pH	Nitrate as NO_3	Ammonia as N	TKN	Total Phosphate as PO_4	ortho phosphate as P	TSS	VSS	Diazinon	Chlorpyrifos	Dimethoate	Malathion	Cd	Cr	Cu	Pb	Ni	Ag	Zn	As	Se	Hardness as $CaCO_3$
	Start	End	Type	#	EC	pH	TEMP	DO											ng/L								ug/L					
					µS		C	mg/L	NTU	µS			mg/L																			mg/L
BARSED	10/19/05 9:00		SVC		1809	8.72	17.04	10.66																								
BARSED	10/21/05 8:30		SVC		2371	8.863	19.17	5.94																								
BARSED	11/1/05 9:15	11/2/05 8:15	DT	24	2285	8.97	19.43	22.42	8.82	2000	8.23	27.7	< 0.1	0.7	0.41	0.06	30	7	< 5	< 5	< 5	< 5	< 0.5	1.1	5.3	0.92	5.7	< 0.5	13		27	590
BARSED	11/1/05 9:15	11/2/05 8:15	DF	24																			< 0.5	< 0.5	3.1	< 0.5	5.1	< 0.5	4.5		28	
BARSED	11/2/05 9:50		SVC		2285	8.97	19.43	22.42											< 5	< 5	< 5	< 5	0.88	12	42	15.6	21.8	1.06	174	12.6	13.8	590
BARSED	11/29/05 10:50	11/30/05 9:50	DT	24	2635	8.27	17.51	18.86	2.85	2630	8.15	51.2	< 0.1	0.7	0.45	0.08	10	4	15.5	< 5	< 5	< 5	< 0.5	1.2	4.3	< 0.5	9.7	< 0.5	7.8		37	800
BARSED	11/29/05 10:50	11/30/05 9:50	DF	24																			< 0.5	2.6	3.8	< 0.5	9.3	< 0.5	9.9		42	
BARSED	12/20/05 9:56	12/21/05 8:56	DT	24					9.42	2110	8.21	41.1	< 0.1	0.8	0.39	0.05	20	4	< 5	< 5	< 5	< 5	< 0.5	1.2	6.1	0.81	11	< 0.5	11		39	
BARSED	12/20/05 9:56	12/21/05 8:56	DF	24																			< 0.5	< 0.5	3.1	< 0.5	6.1	< 0.5	4.4		35	
BARSED	12/21/05 8:54		SVC		2703	7.08	14.23	4.79																								
BARSED	12/28/05 11:00		DT		2401	8.23	18.26	17.87	5.11	2500	8.54	41.1	< 0.1	1.2	0.6	0.07	22	7	< 5	< 5	< 5	< 5	< 0.5	1.4	5.1	0.52	7.6	< 0.5	9.1		27	800
BARSED	12/28/05 11:00		DF																				< 0.5	0.7	3.2	< 0.5	7.9	< 0.5	8.5		31	
BARSED	1/11/06 10:14	1/12/06 9:14	DT	24					1.88	2990	8.13	62.5	< 0.1	0.6	0.24	0.03	9	4	e 5.14	< 5	< 5	55.3	< 0.5	0.79	3.3	< 0.5	7.7	< 0.5	8.3		53	880
BARSED	1/11/06 10:14	1/12/06 9:14	DF	24																			< 0.5	0.69	2.4	< 0.5	7.3	< 0.5	5.5		49	
BARSED	1/12/06 9:15		SVC		2831	8.19	13.03	16.5																								
BARSED	2/1/06 7:50	2/2/06 6:50	DT	24					3.8	2620	8.36	36.1	< 0.1	0.5	0.35	0.04	17	8	< 5	< 5	< 5	21.2	< 0.5	0.8	3.6	< 0.5	6.5	< 0.5	7.9	7.7	32	1565
BARSED	2/1/06 7:50	2/2/06 6:50	DF	24																			< 0.5	0.86	3	< 0.5	7.1	< 0.5	3.5	8.1	29	
BARSED	2/2/06 8:05		SVC		2726	8.09	13.74	14.92																								
BARSED	2/27/06 16:10	2/27/06 17:10	ST	6					182	950	7.41	11.9	0.3	1.7	3.68	0.19	754	128	< 5	< 5	< 5	< 5	1.4	16	74	24	18	< 0.5	330	9	8.7	264
BARSED	2/27/06 16:10	2/27/06 17:10	SF	6																			< 0.5	2.4	13	< 0.5	5.9	< 0.5	18	6	7.8	
BARSED	2/27/06 19:10	2/28/06 17:10	ST	12					60	530	7.37	13.9	< 0.1	1	1.69	0.3	168	27	< 5	< 5	< 5	66.7	< 0.5	3.4	20	5.1	5.5	< 0.5	71	3.2	3.4	140
BARSED	2/27/06 19:10	2/28/06 17:10	SF	12																			< 0.5	0.67	6.2	< 0.5	3.2	< 0.5	14	2.2	3.6	
BARSED	2/28/06 11:35		SVC		464	7.87	16.81	10.39																								
BARSED	2/28/06 19:10	3/2/06 9:10	ST	20					11.6	1900	7.90	51.4	< 0.1	1	1.4	0.3	36	6	< 5	< 5	< 5	28.6	< 0.5	1.6	8	1.2	8.1	< 0.5	27	5.7	21	565
BARSED	2/28/06 19:10	3/2/06 9:10	SF	20																			< 0.5	0.77	5.7	< 0.5	6.4	< 0.5	9.6	5.5	17	
BARSED	3/2/06 10:06		SVC		2277	7.72	16.77	11.7																								
BARSED	3/2/06 11:10	3/3/06 9:10	ST	12					5.91	2750	8.18	41.7	< 0.1	0.6	0.6	0.14	11	3	< 5	< 5	< 5	< 5	< 0.5	1.4	4	< 0.5	8	< 0.5	9.4	10	40	776
BARSED	3/2/06 11:10	3/3/06 9:10	SF	12																			< 0.5	1.2	3.1	< 0.5	9.6	< 0.5	5.2	7.7	39	
BARSED	3/3/06 11:10	3/4/06 9:10	ST	12					115	1200	7.45	20.7	0.2	0.8	1.8	0.19	182	29	< 5	< 5	< 5	16.6	0.54	4	19	8	8	< 0.5	87	4.9	14	362
BARSED	3/3/06 11:10	3/4/06 9:10	SF	12																			< 0.5	0.76	6.2	< 0.5	5.1	< 0.5	11	3	15	
BARSED	3/4/06 10:14		SVC		1694	7.81	15.58	11.46																								
BARSED	3/21/06 7:12	3/22/06 6:12	DT	24					54	1700	7.82	38.4	0.4	1.1	1.54	0.21	86	14	< 2	< 1	< 3	24.1	< 0.5	2.1	8.3	2.4	6.8	< 0.5	26		20	505
BARSED	3/21/06 7:12	3/22/06 6:12	DF	24																			< 0.5	0.52	4.8	< 0.5	6.2	< 0.5	5.7		22	
BARSED	3/21/06 8:45		SVC		2168	7.67	14.4	6.55																								
BARSED	4/18/06 7:54	4/19/06 6:54	DT	24					9.24	2740	8.34	38.8	0.1	0.7	0.4	0.04	17	8	6.3	< 1	< 3	< 3	< 0.5	1.2	4.2	< 0.5	10	< 0.5	13		35	800
BARSED	4/18/06 7:54	4/19/06 6:54	DF	24																			< 0.5	0.91	3	< 0.5	11	< 0.5	6.5		36	
BARSED	4/19/06 9:02		SVC		2545	8.28	18.17	17.68																								
BARSED	5/17/06 9:03	5/18/06 8:03	DT	24					4.9	2690	8.24	38.1	< 0.1	0.77	0.19	< 0.02	13	2	< 2	< 1	< 3	< 3	< 0.5	1.1	5.5	< 0.5	8	< 0.5	8.1		31	675
BARSED	5/17/06 9:03	5/18/06 8:03	DF	24																			< 0.5	0.73	4.7	< 0.5	8.1	< 0.5	5.8		33	
BARSED	5/18/06 8:43		SVC		2372	8.03	20.69	9.47																								
BARSED	5/29/06 8:11	5/30/06 7:11	DT	24					4.51	2420	8.39	38.6	0.13	0.99	0.25	< 0.02	15	5					< 0.5	0.88	4.5	< 0.5	7	< 0.5	6.2		40	765
BARSED	5/29/06 8:11	5/30/06 7:11	DF	24																			< 0.5	0.68	3.8	< 0.5	7	< 0.5	4.8		40	
BARSED	5/30/06 9:00		SVC		2588	8.26	21.05	16.55																								
BARSED	6/26/06 7:41	6/27/06 6:41	DT	24					5.15	2700	8.11	32.7	0.13	0.77	0.25	< 0.02	10	3	< 2	< 1	< 3	< 3	< 0.5	0.77	6.2	< 0.5	10	< 0.5	7.6	8.3	37	725
BARSED	6/26/06 7:41	6/27/06 6:41	DF	24																			< 0.5	0.58	4.8	< 0.5	8.6	< 0.5	5.6	7.5	35	
BARSED	6/27/06 8:42		SVC		2916	7.83	22.61	10.69																								
BCC02	8/23/05 10:29	8/24/05 9:29	DT	24	2274	8.82	22.85	11.83	1.75	2330	7.98	7	0.2	1.7	0.1	< 0.02	< 5	< 1	< 10	< 10	< 10	< 10	< 0.5	< 0.5	3.3	< 0.5	3.4	< 0.5	2.8	nr	2	380
BCC02	8/23/05 10:29	8/24/05 9:29	DF	24																			< 0.5	< 0.5	3.2	< 0.5	3.8	< 0.5	4.6	nr	2.4	
BCC02	8/24/05 9:32		SVC		2274	8.82	22.85	11.83											< 5	< 5	< 5	< 5	0.47	19.6	22.7	23.2	12.6	< 0.025	149	3.17	0.71	380
BCC02	10/18/05 10:54		ST		225	8.97	17.28	8.94	19	212	7.42	4.3	0.7	1.4	1.05	0.21	28	8	122	< 5	< 5	465	< 0.5	2	13	5.2	5.1	< 0.5	75	2.1	< 0.5	50
BCC02	10/18/05 10:54		SF																				< 0.5	0.92	8	1.1	4.3	< 0.5	44	2.1	< 0.5	

ST - Stormwater total metals; SF - Stormwater, dissolved metals
DT - Dry weather, total metals; DF - Dry weather, dissolved metals
SVC - Autosampler service time

e- estimated

Aqueous Chemistry at Mass Loading Stations: 2005-06 SAR

Site	Composite or Grab Time		Samples		FieldMeasurements				Turbidity	Specific Conductance	pH	Nitrate as NO_3	Ammonia as N	TKN	Total Phosphate as PO_4	ortho phosphate as P	TSS	VSS	Diazinon	Chlorpyrifos	Dimethoate	Malathion	Cd	Cr	Cu	Pb	Ni	Ag	Zn	As	Se	Hardness as $CaCO_3$
	Start	End	Type	#	EC	pH	TEMP	DO																								
					µS		C	mg/L	NTU	µS			mg/L						ng/L				ug/L									mg/L
BCC02	11/14/05 10:35	11/15/05 9:35	DT	24					2.78	26400	8.08	16.8	0.5	1.2	0.35	0.06	4	2	13.2	< 5	< 5	< 5	< 0.5	< 0.5	3.1	0.53	6.2	< 0.5	11	2.1	1.3	502
BCC02	11/14/05 10:35	11/15/05 9:35	DF	24																			< 0.5	< 0.5	2.3	< 0.5	6.1	< 0.5	8.4	2.2	1.9	
BCC02	1/14/06 13:23	1/14/06 14:23	ST	6					7.89	2390	8.15	22.7	< 0.1	1.8	0.53	0.05	17	4	< 5	< 5	< 5	< 5	< 0.5	1.3	9.4	1.8	7.9	< 0.5	27	3	2.1	505
BCC02	1/14/06 13:23	1/14/06 14:23	SF	6																			< 0.5	0.56	4.5	< 0.5	6.2	< 0.5	11	3.2	1.9	
BCC02	1/14/06 16:23	1/15/06 14:23	ST	12					11.7	783	7.60	13.2	< 0.1	2.2	0.77	0.08	22	10	< 5	< 5	< 5	497	< 0.5	1.8	19	3.4	7.1	< 0.5	89	2.1	1	156
BCC02	1/14/06 16:23	1/15/06 14:23	SF	12																			< 0.5	0.82	10	0.67	5.7	< 0.5	52	1.9	0.72	
BCC02	1/15/06 13:15		SVC		886	8.04	15.35	10.53																							
BCC02	1/15/06 16:23	1/17/06 10:23	ST	22					4.15	1760	7.97	13.4	< 0.1	1.6	0.51	< 0.02	22	6	38.7	< 5	< 5	77	< 0.5	0.91	8.6	2	7.3	< 0.5	35	2.3	1.6	405
BCC02	1/15/06 16:23	1/17/06 10:23	SF	22																			< 0.5	< 0.5	4.6	< 0.5	6.8	< 0.5	16	2.2	1.6	
BCC02	1/17/06 11:51		SVC		2580	8.03	12.26	12.79																							
BCC02	1/17/06 12:23	1/18/06 14:23	ST	14	2815	7.61	14.71	13.22	9.2	2650	7.97	25.6	< 0.1	1.2	0.33	0.06	19	4	46.9	28.5	< 5	< 5	< 0.5	0.57	5.8	1.5	7.6	< 0.5	19	2.2	2.3	550
BCC02	1/17/06 12:23	1/18/06 14:23	SF	14																			< 0.5	< 0.5	3.7	< 0.5	7.1	< 0.5	13	2.8	2.6	
BCC02	1/18/06 14:25		SVC		2815	7.61	14.71	13.22																							
BCC02	2/8/06 10:49	2/9/06 9:49	DT	24					6.31	2750	8.01	19.7	0.4	1.5	0.32	0.05	12	4	24.6	< 5	< 5	12.4	< 0.5	0.6	5.5	1.2	6.8	< 0.5	14	2.4	2.2	700
BCC02	2/8/06 10:49	2/9/06 9:49	DF	24																			< 0.5	< 0.5	3.7	< 0.5	6.7	< 0.5	6.1	2.2	2	
BCC02	2/9/06 10:30		SVC		2617	7.22	14.61	10.73											< 5	< 5	< 5	< 5	0.34	20	20.3	20.5	11.3	0.07	124	2.16	0.63	700
BCC02	3/27/06 23:03	3/28/06 0:03	ST	6					10.2	2110	8.09	14.3	0.3	1.6	0.55	0.07	21	6	27	< 1	< 3	< 3	< 0.5	1	13	1.9	6.6	< 0.5	26	2.6	1.5	340
BCC02	3/27/06 23:03	3/28/06 0:03	SF	6																			< 0.5	< 0.5	7.4	< 0.5	6.1	< 0.5	13	2.5	1.2	
BCC02	3/28/06 2:03	3/29/06 0:03	ST	12					38	422	7.67	5	< 0.1	0.7	1.16	0.1	106	16	53.9	< 1	< 3	117	< 0.5	4.3	20	7.8	6.5	< 0.5	120	2	< 0.5	86
BCC02	3/28/06 2:03	3/29/06 0:03	SF	12																			< 0.5	0.86	6.9	< 0.5	3	< 0.5	39	1.4	< 0.5	
BCC02	3/28/06 12:50		SVC		304	8.33	16.25	10.55																							
BCC02	3/29/06 2:03	3/30/06 4:03	ST	14					12	575	7.63	4.4	0.2	0.6	0.47	0.09	16	4	54.9	< 1	< 3	151	< 0.5	1.3	8	2.3	3.9	< 0.5	40	2.1	0.6	116
BCC02	3/29/06 2:03	3/30/06 4:03	SF	14																			< 0.5	0.53	4.7	< 0.5	3.5	< 0.5	24	1.9	0.5	
BCC02	3/29/06 9:56		SVC		334	7.95	15.69	14.76																							
BCC02	3/30/06 6:03	3/31/06 8:03	ST	14					6.32	1900	8.02	10	0.3	1.2	0.3	0.05	13	10	95.2	< 1	< 3	< 3	< 0.5	0.94	7.3	1.7	7.2	< 0.5	29	3	1.2	352
BCC02	3/30/06 6:03	3/31/06 8:03	SF	14																			< 0.5	< 0.5	4.1	< 0.5	6.6	< 0.5	16	2.9	1.3	
BCC02	3/31/06 9:15		SVC		2211	7.96	15.16	9.4																							
BCC02	3/31/06 10:03	4/1/06 2:03	ST	9					1.75	2340	8.08	17.2	0.3	1	0.32	0.05	12	3	126	< 1	< 3	< 3	< 0.5	0.63	5.3	1.1	7.8	< 0.5	17	3.2	1.9	430
BCC02	3/31/06 10:03	4/1/06 2:03	SF	9																			< 0.5	< 0.5	4.1	< 0.5	7.6	< 0.5	11	2.9	1.8	
BCC02	4/2/06 10:30		SVC		1378	7.92	16.17	12.72																							
BCC02	5/22/06 2:11	5/22/06 3:11	ST	6					150	780	7.47	12.4	0.44	6.41	3.51	< 0.04	736	136	100	< 1	< 3	435	1	17	56	36	20	0.64	350	6.3	1.4	230
BCC02	5/22/06 2:11	5/22/06 3:11	SF	6																			< 0.5	1.1	8.2	< 0.5	7.4	< 0.5	25	2.2	1.3	
BCC02	5/22/06 5:11	5/23/06 9:11	ST	15					13.8	840	7.60	4.76	0.34	1.27	0.65	0.06	29	9	62.5	< 1	< 3	288	< 0.5	1.6	12	4	7	< 0.5	57	2.8	0.81	185
BCC02	5/22/06 5:11	5/23/06 9:11	SF	15																			< 0.5	0.65	8.4	< 0.5	6.7	< 0.5	28	2.3	0.68	
BCC02	5/22/06 10:38		SVC		341	8.05	18.65	8.7																							
BCC02	5/23/06 11:11	5/24/06 9:11	ST	12					3.17	2100	8.04	6.35	0.32	1.52	0.29	0.02	< 5	< 1	21.7	< 1	< 3	42.4	< 0.5	0.65	7.5	0.9	10	< 0.5	22	3.8	1.7	475
BCC02	5/23/06 11:11	5/24/06 9:11	SF	12																			< 0.5	< 0.5	6.6	< 0.5	9.9	< 0.5	19	3.9	1.5	
BCC02	5/24/06 10:45		SVC		2339	7.89	25.02	12.28																							
BCC02	5/24/06 11:11	5/26/06 3:11	ST	21					2.23	2650	8.45	11.4	0.25	1.08	0.25	0.03	11	2	28.4	< 1	< 3	< 3	0.53	0.76	7.2	0.93	8.6	< 0.5	15	3.8	2.3	480
BCC02	5/24/06 11:11	5/26/06 3:11	SF	21																			< 0.5	< 0.5	6.3	< 0.5	8.7	< 0.5	9.8	3.3	1.9	
BCC02	5/26/06 10:30		SVC		2718	8.04	21.44	10.54																							
BCF04	7/19/05 11:17	7/20/05 10:17	DT	24					6.42	2570	8.06	0.8	0.1	0.4	0.82	0.14	27	7	< 10	< 10	< 10	< 10	< 0.5	0.8	8.6	< 0.5	6.6	< 0.5	8.4		2.8	868
BCF04	7/19/05 11:17	7/20/05 10:17	DF	24																			< 0.5	< 0.5	5.9	< 0.5	6.1	< 0.5	5.2		3.1	
BCF04	8/16/05 10:25	8/17/05 9:25	DT	24					5.3	2690	8.08	1.2	< 0.1	0.6	0.74	0.2	6	1					< 0.5	0.79	11	< 0.5	7	< 0.5	7.8		2.6	684
BCF04	8/16/05 10:25	8/17/05 9:25	DF	24																			< 0.5	< 0.5	9	< 0.5	6.5	< 0.5	5.6		4.8	
BCF04	8/17/05 12:13		SVC		2868	9.2	19.08	14.32																							
BCF04	9/14/05 10:04		DT		2969	8.55	17.13	10.29	2.79	3170	7.97	1.7	0.2	0.6	0.59	0.15	12	1					< 0.5	0.92	1.8	< 0.5	8	< 0.5	3.9		3.4	925
BCF04	9/14/05 10:04		DF																				< 0.5	< 0.5	1.2	< 0.5	7.4	< 0.5	2.3		3.7	
BCF04	10/11/05 9:50	10/12/05 8:50	DT	24					4.25	3320	8.05	1.9	0.1	1.3	0.76	0.15	36	8	< 10	< 10	< 10	< 10	< 0.5	1.6	9.6	< 0.5	8.4	< 0.5	11		3	662
BCF04	10/11/05 9:50	10/12/05 8:50	DF	24																			< 0.5	< 0.5	7.1	< 0.5	7.3	< 0.5	6.3		4	
BCF04	10/12/05 8:50		SVC		2957	8.8	15.64	10.25																							

ST - Stormwater total metals; SF - Stormwater, dissolved metals
DT - Dry weather, total metals; DF - Dry weather, dissolved metals
SVC - Autosampler service time

e- estimated

Aqueous Chemistry at Mass Loading Stations: 2005-06 SAR

Site	Composite or Grab Time		Samples		FieldMeasurements				Turbidity	Specific Conductance	pH	Nitrate as NO_3	Ammonia as N	TKN	Total Phosphate as PO_4	ortho phosphate as P	TSS	VSS	Diazinon	Chlorpyrifos	Dimethoate	Malathion	Cd	Cr	Cu	Pb	Ni	Ag	Zn	As	Se	Hardness as $CaCO_3$
	Start	End	Type	#	EC	pH	TEMP	DO																								
					µS		C	mg/L	NTU	µS			mg/L						ng/L				ug/L									mg/L
BCF04	11/14/05 10:25		DT		2803	8.25	15.48	10.92	2.15	2710	8.13	2.4	< 0.1	0.5	0.54	0.08	6	3	< 5	< 5	< 5	< 5	< 0.5	0.78	2	< 0.5	6.9	< 0.5	4.8		1.9	705
BCF04	11/14/05 10:25		DF																				< 0.5	< 0.5	1.7	< 0.5	7	< 0.5	3.4		3.1	
BCF04	12/6/05 11:15		DT		2805	8.01	9.04	12.65	1.31	3020	8.05	3.7	< 0.1	0.4	0.45	0.12	< 5	< 1					< 0.5	0.66	2.2	< 0.5	7	< 0.5	5.3		3.8	1100
BCF04	12/6/05 11:15		DF																				< 0.5	< 0.5	1.3	< 0.5	8.1	< 0.5	3.4		5.4	
BCF04	1/4/06 11:25		ST		2023	7.71	12.18	12.37	2	1940	7.98	2.9	0.3	0.5	0.56	0.16	< 5	< 1					< 0.5	0.5	2.6	< 0.5	8.8	< 0.5	4.7		2.6	525
BCF04	1/4/06 11:25		SF																				< 0.5	< 0.5	2.1	< 0.5	8.3	< 0.5	4.1		2.6	
BCF04	2/15/06 10:19	2/16/06 9:19	DT	24					2.2	2560	7.88	2.6	0.2	0.6	0.87	0.22	8	3					< 0.5	< 0.5	5.4	< 0.5	7.2	< 0.5	8.6		2.6	870
BCF04	2/15/06 10:19	2/16/06 9:19	DF	24																			< 0.5	< 0.5	4.6	< 0.5	6.96	< 0.5	7.9		2.8	
BCF04	2/16/06 10:20		SVC		2660	7.85	11.38	12.16																								
BCF04	3/21/06 8:24	3/22/06 7:24	DT	24					4.6	1220	7.82	0.9	0.2	0.3	0.41	0.09	9	3					< 0.5	0.8	6.9	< 0.5	3.8	< 0.5	6.8		1.2	285
BCF04	3/21/06 8:24	3/22/06 7:24	DF	24																			< 0.5	< 0.5	5.4	< 0.5	3.5	< 0.5	4.2		1.1	
BCF04	3/21/06 9:17		SVC		1688	7.89	10.71	13.66																								
BCF04	4/17/06 12:00	4/18/06 11:00	DT	24					1.97	2350	8.07	3.1	0.1	0.5	0.92	0.25	4	1					< 0.5	0.5	12	< 0.5	8.5	< 0.5	12		2.4	610
BCF04	4/17/06 12:00	4/18/06 11:00	DF	24																			< 0.5	< 0.5	11	< 0.5	8.1	< 0.5	11		3	
BCF04	4/18/06 11:03		SVC		1940	7.48	13.71	8.21																								
BCF04	4/24/06 9:00	4/25/06 8:00	DT	24					8.54	1800	8.06	2	< 0.1	0.5	0.91	0.25	10	2													2.5	
BCF04	4/24/06 9:00	4/25/06 8:00	DF	24																											2.7	
BCF04	4/25/06 11:06		SVC		2244	7.88	14.54	13.86																								
BCF04	5/1/06 9:00	5/2/06 8:00	DT	24					3.82	2520	8.05	2.8	< 0.1	0.5	1.31	0.32	20	5													3.5	
BCF04	5/1/06 9:00	5/2/06 8:00	DF	24																											3.4	
BCF04	5/2/06 9:22		SVC		2505	7.89	16.46	7.14																								
BCF04	6/7/06 9:15	6/8/06 8:15	DT	24					4.53	2470	8.17	3.69	< 0.1	0.54	1	0.23	19	6					1.4	1.2	11	< 0.5	9	< 0.5	10		3.2	610
BCF04	6/7/06 9:15	6/8/06 8:15	DF	24																			1.3	< 0.5	8.5	< 0.5	8.1	< 0.5	6.7		3	
BCF04	6/8/06 10:09		SVC		2694	7.87	18.56	7.87																								
CARB01	8/23/05 9:55	8/24/05 8:55	DT	24					2.45	5310	2.45	8.5	0.2	1.7	0.19	0.03	5	5	< 10	< 10	< 10	< 10	0.53	3.1	21	1.1	5.8	< 0.5	32	nr	2.6	365
CARB01	8/23/05 9:55	8/24/05 8:55	DF	24																			< 0.5	< 0.5	6.8	< 0.5	3.4	< 0.5	8.1	nr	2.2	
CARB01	8/24/05 8:52		SVC		1511	8.82	20.93	15.32																								
CARB01	10/18/05 10:09		ST		150	9.22	17.07	12.93	13.9	129	7.21	3.7	0.6	1.3	1.03	0.19	28	12	25.4	< 5	< 5	318	< 0.5	1.9	14	5.8	4.1	< 0.5	77	1.4	< 0.5	36
CARB01	10/18/05 10:09		SF																				< 0.5	0.59	8	1.1	2.9	< 0.5	41	1.4	< 0.5	
CARB01	11/14/05 9:59	11/15/05 8:59	DT	24					1.14	1520	8.49	9.5	< 0.1	0.9	0.14	< 0.02	< 5	< 1	15.6	< 5	< 5	< 5	< 0.5	< 0.5	4.6	< 0.5	3.2	< 0.5	5.9	2.7	1.4	238
CARB01	11/14/05 9:59	11/15/05 8:59	DF	24																			< 0.5	< 0.5	4.1	< 0.5	3.4	< 0.5	5.4	2.7	1.4	
CARB01	11/15/05 10:26		SVC		1225	8.59	20.97	23.31																								
CARB01	1/14/06 12:13	1/14/06 13:13	ST	6					11.7	747	7.70	14.9	< 0.1	2.9	1.26	0.03	99	34	106	< 5	< 5	2350	< 0.5	2.4	33	8.8	9.1	< 0.5	130	2.9	1.2	158
CARB01	1/14/06 12:13	1/14/06 13:13	SF	6																			< 0.5	0.65	18	< 0.5	5.7	< 0.5	26	1.9	1.3	
CARB01	1/14/06 15:13	1/15/06 13:13	ST	12					11.5	647	7.68	8.6	< 0.1	2	1.24	0.07	86	36	< 5	< 5	< 5	< 5	< 0.5	2.8	30	8.6	7.6	< 0.5	130	2.7	0.97	118
CARB01	1/14/06 15:13	1/15/06 13:13	SF	12																			< 0.5	0.88	13	0.55	4.9	< 0.5	40	2.4	0.68	
CARB01	1/15/06 12:36		SVC		430	8.38	17.9	15.78																								
CARB01	1/15/06 15:13	1/17/06 11:13	ST	23					2.2	1230	8.39	14.7	< 0.1	0.8	0.28	< 0.02	6	3	< 5	< 5	< 5	< 5	< 0.5	0.54	8.7	0.74	4.8	< 0.5	24	2.4	1.7	275
CARB01	1/15/06 15:13	1/17/06 11:13	SF	23																			< 0.5	< 0.5	6.8	< 0.5	4.2	< 0.5	14	2.8	1.5	
CARB01	1/17/06 11:24		SVC		1669	8.43	16.58	23.48																								
CARB01	1/17/06 13:13	1/18/06 13:13	ST	13	1756	8.24	17.08	22.95	1.48	1560	8.35	16.5	< 0.1	0.9	0.13	< 0.02	< 5	< 1	e 6.3	< 5	< 5	< 5	< 0.5	< 0.5	8.1	< 0.5	4.2	< 0.5	11	3.1	2.4	310
CARB01	1/17/06 13:13	1/18/06 13:13	SF	13																			< 0.5	< 0.5	7.1	< 0.5	4.1	< 0.5	9.7	3	2.2	
CARB01	1/18/06 13:20		SVC		1756	8.24	17.08	22.95																								
CARB01	2/8/06 9:25	2/9/06 8:25	DT	24					0.9	1430	8.13	10.6	< 0.1	0.9	0.11	< 0.02	5	3	< 5	< 5	< 5	< 5	< 0.5	< 0.5	6.3	< 0.5	3.3	< 0.5	6.2	2.7	1.9	580
CARB01	2/8/06 9:25	2/9/06 8:25	DF	24																			< 0.5	< 0.5	6	< 0.5	3.6	< 0.5	4.8	2.7	1.8	
CARB01	2/9/06 10:29		SVC		1744	8.23	16.81	12.9																								
CARB01	3/27/06 13:59	3/28/06 11:59	ST	12					5.96	1180	8.74	5.5	< 0.1	1	0.45	0.03	24	8	< 2	< 1	< 3	< 3	< 0.5	1.2	16	2.3	4.2	< 0.5	36	2.3	1.5	152
CARB01	3/27/06 13:59	3/28/06 11:59	SF	12																			< 0.5	0.58	12	< 0.5	3.4	< 0.5	12	2.2	1.2	
CARB01	3/28/06 9:35		SVC		228	8	15.64	10.66																								
CARB01	3/28/06 13:59	3/29/06 11:59	ST	12					13.4	179	7.52	1.8	< 0.1	0.6	1.95	0.09	356	73	56.1	< 1	< 3	< 3	1.8	7.2	57	35	11	< 0.5	430	3.3	1.7	56
CARB01	3/28/06 13:59	3/29/06 11:59	SF	12																			< 0.5	0.67	6.4	< 0.5	3.2	< 0.5	18	1.2	< 0.5	

ST - Stormwater total metals; SF - Stormwater, dissolved metals
DT - Dry weather, total metals; DF - Dry weather, dissolved metals
SVC - Autosampler service time

e- estimated

Aqueous Chemistry at Mass Loading Stations: 2005-06 SAR

Site	Composite or Grab Time		Samples		FieldMeasurements				Turbidity	Specific Conductance	pH	Nitrate as NO_3	Ammonia as N	TKN	Total Phosphate as PO_4	ortho phosphate as P	TSS	VSS	Diazinon	Chlorpyrifos	Dimethoate	Malathion	Cd	Cr	Cu	Pb	Ni	Ag	Zn	As	Se	Hardness as $CaCO_3$
	Start	End	Type	#	EC	pH	TEMP	DO																								
					µS		C	mg/L	NTU	µS			mg/L						ng/L				ug/L									mg/L
CARB01	3/29/06 11:40		SVC		240	8.85	17.69	16.16																								
CARB01	3/29/06 13:59	3/30/06 5:59	ST	9					2.87	540	8.15	4.9	< 0.1	0.4	2.06	0.03	5	2	24.9	< 1	< 3	< 3	< 0.5	0.7	9.1	1.2	3.2	< 0.5	28	1.7	0.56	92
CARB01	3/29/06 13:59	3/30/06 5:59	SF	9																			< 0.5	0.51	8.7	< 0.5	3.3	< 0.5	18	1.6	0.67	
CARB01	3/30/06 7:59	3/30/06 23:59	ST	9					1.06	1060	8.91	6.3	< 0.1	0.5	0.08	< 0.02	< 5	< 1	< 2	< 1	< 3	< 3	< 0.5	0.53	7.6	< 0.5	3	< 0.5	9.9	2.5	1.3	122
CARB01	3/30/06 7:59	3/30/06 23:59	SF	9																			< 0.5	< 0.5	7.5	< 0.5	2.9	< 0.5	7.7	2.4	1.4	
CARB01	3/31/06 1:59	4/1/06 13:59	ST	7					0.66	1220	8.24	6.2	< 0.1	0.7	0.09	< 0.02	< 5	< 1	< 2	< 1	< 3	< 3	< 0.5	< 0.5	8	< 0.5	4.2	< 0.5	13	2.3	1.8	280
CARB01	3/31/06 1:59	4/1/06 13:59	SF	7																			< 0.5	< 0.5	7.4	< 0.5	4.7	< 0.5	16	2.5	1.5	
CARB01	3/31/06 8:50		SVC		1427	8.47	14.73	14.27																								
CARB01	4/2/06 9:51		SVC		1232	8.79	15.41	15.95																								
CARB01	5/22/06 1:29	5/22/06 1:53	ST	3								7.36	0.33	3.57	1.17				< 2	< 1	< 3	247	< 0.5	3.7	30	10	9.2	< 0.5	150	4.6	2.1	350
CARB01	5/22/06 1:29	5/22/06 1:53	SF	3																			< 0.5	< 0.5	7.8	< 0.5	5.7	< 0.5	19	2.5	1.5	
CARB01	5/22/06 4:17	5/23/06 2:17	ST	12					6.23	476	7.47	6.15	0.25	1.42	0.91	0.09	13	8	64.2	< 1	< 3	262	< 0.5	0.89	15	2.3	4.8	< 0.5	53	2.3	0.59	95
CARB01	5/22/06 4:17	5/23/06 2:17	SF	12																			< 0.5	0.58	12	0.5	4.7	< 0.5	34	2.2	0.61	
CARB01	5/22/06 9:58		SVC		190	7.82	18.21	9.09																								
CARB01	5/23/06 4:17	5/24/06 8:17	ST	15					2.2	1360	8.35	9.72	0.18	1.67	0.42	0.06	< 5	< 1	< 2	< 1	< 3	69.4	< 0.5	< 0.5	9.7	0.62	5.7	< 0.5	20	4	2.26	300
CARB01	5/23/06 4:17	5/24/06 8:17	SF	15																			< 0.5	< 0.5	9	< 0.5	5.9	< 0.5	17	3.8	2.2	
CARB01	5/24/06 9:47		SVC		1540	8.36	24.1	16.86																								
CARB01	5/24/06 10:17	5/26/06 2:17	ST	21					1.7	1600	8.84	8.19	0.23	1.31	0.26	0.05	< 5	< 1	< 2	< 1	< 3	< 3	< 0.5	< 0.5	9.5	< 0.5	5.2	< 0.5	14	4.4	2.1	290
CARB01	5/24/06 10:17	5/26/06 2:17	SF	21																			< 0.5	< 0.5	8.8	< 0.5	4.9	< 0.5	11	4	2	
CARB01	5/26/06 9:40		SVC		1761	8.35	20.57	13.02																								
CCBA01	8/23/05 9:22	8/24/05 8:22	DT	24					2.53	1430	8.51	9.7	0.2	1.5	0.12	< 0.02	16	10	< 10	< 10	< 10	< 10	< 0.5	0.55	3.6	< 0.5	4.2	< 0.5	35	nr	2.3	390
CCBA01	8/23/05 9:22	8/24/05 8:22	DF	24																			< 0.5	< 0.5	2.8	< 0.5	4.4	< 0.5	3.1	nr	2.7	
CCBA01	8/24/05 8:17		SVC		1385	8.98	20.22	15.17																								
CCBA01	10/18/05 9:26		ST		590	8.98	16.41	11.62	78	561	7.69	5	0.5	2.2	1.87	0.17	203	39	31.9	< 5	< 5	102	1	7.9	23	12	14	< 0.5	97	3.2	2.1	176
CCBA01	10/18/05 9:26		SF																				< 0.5	< 0.5	3.7	< 0.5	4.5	< 0.5	12	1.6	1.8	
CCBA01	11/14/05 9:13	11/15/05 8:13	DT	24					0.75	1570	8.61	20.1	< 0.1	0.7	0.08	< 0.02	< 5	< 1	20	< 5	< 5	< 5	< 0.5	0.9	9.3	< 0.5	4.4	< 0.5	6.2		2.8	440
CCBA01	11/14/05 9:13	11/15/05 8:13	DF	24																			< 0.5	0.83	2.8	< 0.5	4.5	< 0.5	4.7	1.4	2.5	
CCBA01	11/15/05 9:45		SVC		1551	8.65	18.32	23.36																								
CCBA01	1/14/06 10:46	1/14/06 11:46	ST	6					13	466	7.39	12.9	< 0.1	2.9	1.64	0.1	259	55	< 5	< 5	< 5	< 5	2.4	12	65	32	26	3.5	530	4	1.5	126
CCBA01	1/14/06 10:46	1/14/06 11:46	SF	6																			< 0.5	0.9	13	< 0.5	4.6	< 0.5	44	1.2	0.92	
CCBA01	1/14/06 13:46	1/15/06 11:46	ST	12					9.1	692	7.96	9.9	< 0.1	1.7	0.64	0.04	80	26	< 5	< 5	< 5	102	< 0.5	2.6	17	4.7	8.3	< 0.5	84	2.3	1.2	612
CCBA01	1/14/06 13:46	1/15/06 11:46	SF	12																			< 0.5	0.9	7.3	< 0.5	5.1	< 0.5	28	1.6	1.3	
CCBA01	1/15/06 11:50		SVC		1023	8.27	16.62	14.52																								
CCBA01	1/15/06 13:46	1/17/06 9:46	ST	23					1.43	1480	8.39	20.7	< 0.1	0.7	0.28	< 0.02	< 5	< 1	< 5	< 5	< 5	19.7	< 0.5	0.83	4.8	< 0.5	5.9	< 0.5	7.4	2.3	2.7	460
CCBA01	1/15/06 13:46	1/17/06 9:46	SF	23																			< 0.5	0.84	4.4	< 0.5	6.3	< 0.5	5.4	2.4	2.5	
CCBA01	1/17/06 10:53		SVC		1682	8.44	12.99	16.63																								
CCBA01	1/17/06 11:46	1/18/06 11:46	ST	13					1.4	1670	8.23	24.3	< 0.1	1.1	0.1	< 0.02	< 5	< 1	< 5	< 5	< 5	16.9	< 0.5	0.99	5.1	< 0.5	6.2	< 0.5	8.5	1.7	3.6	525
CCBA01	1/17/06 11:46	1/18/06 11:46	SF	13																			< 0.5	0.96	4.6	< 0.5	6	< 0.5	8.3	1.8	2.8	
CCBA01	1/18/06 11:46		SVC		1604	8.3	15.66	19.31																								
CCBA01	2/8/06 8:31	2/9/06 7:31	DT	24					0.82	1440	8.18	19.8	< 0.1	0.9	0.09	< 0.02	< 5	< 1	14.2	< 5	< 5	< 5	< 0.5	0.82	5.5	< 0.5	5	< 0.5	6.3	1.5	2.6	630
CCBA01	2/8/06 8:31	2/9/06 7:31	DF	24																			< 0.5	0.83	4.8	< 0.5	4.6	< 0.5	4.9	1.6	2.5	
CCBA01	2/9/06 9:52		SVC		1562	8.37	14.44	18.98											< 5	< 5	< 5	< 5	0.57	10.6	9.16	5.86	6.34	0.1	56.1	1.5	0.76	630
CCBA01	3/28/06 2:59	3/28/06 3:59	ST	6					17	485	7.84	9.3	0.2	1	0.62	0.04	64	14	144	< 1	< 3	< 3	< 0.5	2.7	14	3.5	5.3	4.8	71	1.2	0.92	104
CCBA01	3/28/06 2:59	3/28/06 3:59	SF	6																			< 0.5	1	6.8	< 0.5	3.8	1.7	23	1.1	0.85	
CCBA01	3/28/06 5:59	3/29/06 3:59	ST	12					50	212	7.82	3	< 0.1	0.5	1.34	0.09	138	21	45.8	< 1	< 3	< 3	< 0.5	3.6	18	6.6	6.9	< 0.5	82	1.7	< 0.5	64
CCBA01	3/28/06 5:59	3/29/06 3:59	SF	12																			< 0.5	0.64	7.5	< 0.5	2.8	< 0.5	11	1.2	< 0.5	
CCBA01	3/28/06 8:40		SVC		321	8.79	15.35	12.35																								
CCBA01	3/29/06 8:58		SVC		387	8.39	14.23	16.48																								
CCBA01	3/29/06 9:59	3/30/06 7:59	ST	14					50	621	8.15	4.6	< 0.1	0.4	0.87	0.08	92	16	< 2	< 1	< 3	< 3	< 0.5	2.5	9.3	3.3	7.7	< 0.5	32	2.1	0.65	184
CCBA01	3/29/06 9:59	3/30/06 7:59	SF	14																			< 0.5	0.58	4.6	< 0.5	4.9	< 0.5	5.5	1.8	0.95	
CCBA01	3/30/06 9:59	3/31/06 7:59	ST	12					21.6	1210	8.48	7.6	< 0.1	0.6	0.41	0.03	38	8	< 2	< 1	< 3	< 3	< 0.5	1.6	6.3	1.4	8.5	< 0.5	16	2.2	2	344

ST - Stormwater total metals; SF - Stormwater, dissolved metals
DT - Dry weather, total metals; DF - Dry weather, dissolved metals
SVC - Autosampler service time

e- estimated

Aqueous Chemistry at Mass Loading Stations: 2005-06 SAR

Site	Composite or Grab Time		Samples		FieldMeasurements				Turbidity	Specific Conductance	pH	Nitrate as NO_3	Ammonia as N	TKN	Total Phosphate as PO_4	ortho phosphate as P	TSS	VSS	Diazinon	Chlorpyrifos	Dimethoate	Malathion	Cd	Cr	Cu	Pb	Ni	Ag	Zn	As	Se	Hardness as $CaCO_3$
	Start	End	Type	#	EC	pH	TEMP	DO																								
					µS		C	mg/L	NTU	µS			mg/L						ng/L				ug/L									mg/L
CCBA01	3/30/06 9:59	3/31/06 7:59	SF	12																			< 0.5	0.64	4	< 0.5	7.2	< 0.5	6.9	2.1	2.5	
CCBA01	3/31/06 8:15		SVC		1478	8.53	13.67	14.47																								
CCBA01	3/31/06 9:59	4/1/06 7:59	ST	12					2.36	1290	8.21	13.1	< 0.1	0.6	0.11	< 0.02	< 5	< 1	< 2	< 1	< 3	< 3	< 0.5	1.8	5.1	< 0.5	7.4	< 0.5	9.4	1.8	2.4	405
CCBA01	3/31/06 9:59	4/1/06 7:59	SF	12																			< 0.5	0.84	4.7	< 0.5	7.1	< 0.5	7.5	1.7	2.4	
CCBA01	4/2/06 9:15		SVC		922	8.95	12.94	15.19																								
CCBA01	5/22/06 1:39	5/22/06 2:57	ST	6					70	183	7.16	3.99	0.48	4.78	1.68	< 0.02	372	100	< 2	< 1	< 3	538	0.64	6.1	30	13	9.9	3.9	200	2.3	0.59	235
CCBA01	5/22/06 1:39	5/22/06 2:57	SF	6																			< 0.5	< 0.5	6.3	< 0.5	2.8	< 0.5	15	0.86	< 0.5	
CCBA01	5/22/06 4:39	5/22/06 20:39	ST	9					6.68	414	7.47	6.37	0.21	1.05	0.67	0.05	24	8	46.9	< 1	< 3	193	< 0.5	1.1	12	2.2	5.8	< 0.5	47	1.7	0.72	125
CCBA01	5/22/06 4:39	5/22/06 20:39	SF	9																			< 0.5	0.56	8.2	< 0.5	5.1	< 0.5	25	1.5	0.75	
CCBA01	5/22/06 9:17		SVC		480	8.11	17.65	9.96																								
CCBA01	5/22/06 22:39	5/24/06 8:39	ST	18					2.23	1220	8.34	7.32	< 0.1	1	0.33	0.05	< 5	< 1	20.6	< 1	< 3	< 3	0.65	0.58	6.8	< 0.5	7.6	< 0.5	12	2	2.1	400
CCBA01	5/22/06 22:39	5/24/06 8:39	SF	18																			0.6	< 0.5	6.5	< 0.5	7	< 0.5	9	2.3	1.9	
CCBA01	5/24/06 8:55		SVC		1452	8.51	20.66	14.23																								
CCBA01	5/24/06 10:39	5/26/06 8:39	ST	24					0.72	1490	8.81	7.09	0.19	0.74	0.11	0.02	< 5	< 1	< 2	< 1	< 3	< 3	< 0.5	0.61	5.8	< 0.5	6.8	< 0.5	6.1	2.1	2.6	420
CCBA01	5/24/06 10:39	5/26/06 8:39	SF	24																			< 0.5	0.56	5.4	< 0.5	6.6	< 0.5	4.8	2.1	2.5	
CCBA01	5/26/06 9:10		SVC		1575	8.6	20.21	15.46																								
CICF25	7/12/05 8:05	7/13/05 7:05	DT	24					3.6	942	8.86	< 0.4	0.4	2.8	1.99	1.58	18	11	< 10	< 10	< 10	< 10	0.81	1.3	30	2.5	8.5	< 0.5	28		2.3	310
CICF25	7/12/05 8:05	7/13/05 7:05	DF	24																			0.78	0.91	27	1.1	7.7	< 0.5	7.8		2.3	
CICF25	7/13/05 11:25		SVC		935	9.87	34.35	4.18																								
CICF25	7/27/05 8:10	7/28/05 7:10	DT	24					7.88	1270	8.82	< 0.4	0.1	2.4	2.7	0.63	22	10	< 10	< 10	< 10	< 10	< 0.5	0.73	20	0.83	8.8	< 0.5	20		1	365
CICF25	7/27/05 8:10	7/28/05 7:10	DF	24																			< 0.5	0.5	14	< 0.5	7.5	< 0.5	8.4		1.3	
CICF25	7/28/05 8:00		SVC		1126	8.99	22.31	10.04																								
CICF25	8/9/05 8:07		DT		868	9.06	21.46	18.84	2620	1240	8.24	< 0.4	0.8	74.4	73.6	0.71	2890	800	< 10	< 10	< 10	< 10	4.7	27	320	39	39	< 0.5	880		2.3	236
CICF25	8/9/05 8:07		DF																				< 0.5	< 0.5	8.8	< 0.5	5.3	< 0.5	13		1.2	
CICF25	8/21/05 8:42	8/22/05 7:42	DT	24	1097	9.47	19.86	10.09	25.4	945	8.27	2.2	0.1	9.9	7.09	0.6	480	160	< 10	< 10	< 10	< 10	0.86	7.9	75	9.9	11	< 0.5	190	6.8	1.2	380
CICF25	8/21/05 8:42	8/22/05 7:42	DF	24																			< 0.5	< 0.5	9.1	< 0.5	5.3	< 0.5	8.8	4	0.7	
CICF25	8/22/05 7:20		SVC		1097	9.47	19.86	10.09											< 5	< 5	< 5	< 5	0.58	9.88	9.03	9.64	4.79	< 0.025	44.1	3.38	0.35	380
CICF25	8/31/05 9:55		DT		1568	8.72	22.59	10.92	0.73	1520	8.18	64	0.2	1.4	1.4	0.38	5	3	< 10	< 10	< 10	< 10	< 0.5	1.7	7.6	< 0.5	3.9	< 0.5	10		7.1	665
CICF25	8/31/05 9:55		DF																				< 0.5	3.4	5.3	< 0.5	4.3	< 0.5	6.6		10	
CICF25	9/20/05 9:15	9/21/05 8:15	DT	24	1069	8.89	20.54	24.11	11.2	857	7.58	24.1	0.5	3.4	1.42	0.25	21	9	< 10	< 10	< 10	< 10	< 0.5	2	27	1.7	13	< 0.5	93		9.4	612
CICF25	9/20/05 9:15	9/21/05 8:15	DF	24																			< 0.5	1.6	24	0.75	13	< 0.5	74		7.7	
CICF25	9/20/05 13:12		ST		501	8.47	22.93	14.3	53.8	551	7.37	18.4	1.3	7.8	3.41	0.35	190	62	54	< 5	< 5	259	< 0.5	4.7	55	5.7	19	< 0.5	170		1.7	
CICF25	9/20/05 13:12		SF																				< 0.5	2	39	1.3	17	< 0.5	100		1.6	
CICF25	9/21/05 8:44		SVC		1069	8.89	20.54	24.11																								
CICF25	9/27/05 9:17	9/28/05 8:17	DT	24					1.8	1250	9.19	< 0.4	0.2	1.7	1.04	0.24	< 5	< 1	< 10	< 10	< 10	< 10	< 0.5	0.69	28	< 0.5	6.2	< 0.5	16		4.2	317.5
CICF25	9/27/05 9:17	9/28/05 8:17	DF	24																			< 0.5	0.5	22	< 0.5	5.8	< 0.5	7.6		4.3	
CICF25	9/28/05 9:02		SVC		980	9.22	20.62	16.48																								
CICF25	10/16/05 20:13	10/16/05 21:13	ST	6					99	1130	7.71	39.3	0.7	5.2	3.39	0.25	437	58	< 5	< 5	< 5	530	1.4	11	30	7.2	18	< 0.5	180	7.6	2.7	870
CICF25	10/16/05 20:13	10/16/05 21:13	SF	6																			< 0.5	0.89	12	< 0.5	10	< 0.5	52	6.2	3.5	
CICF25	10/17/05 8:37		SVC		686	7.13	18.87	11.35																								
CICF25	10/17/05 23:13	10/18/05 7:13	ST	15					177	736	7.57	58.9	0.5	3.3	3.36	0.51	300	50	< 10	< 10	< 10	< 10	0.77	8.6	25	6.9	11	< 0.5	99	6	1.3	276
CICF25	10/17/05 23:13	10/18/05 7:13	SF	15																			< 0.5	1	9.9	< 0.5	5.8	< 0.5	13	4.9	0.89	
CICF25	10/18/05 9:13	10/19/05 7:13	ST	12					13.4	1180	7.84	84.5	0.4	2.1	2.96	0.81	20	6	< 10	< 10	< 10	< 10	< 0.5	2.1	13	0.92	7.8	< 0.5	24	7.8	1.7	564
CICF25	10/18/05 9:13	10/19/05 7:13	SF	12																			< 0.5	1.2	11	< 0.5	6.7	< 0.5	14	5.9	1.7	
CICF25	10/19/05 8:28		SVC		1295	8.96	15.78	14.58																								
CICF25	10/19/05 9:13		SVC		1295	8.96	15.78	14.58																								
CICF25	10/19/05 9:13	10/21/05 1:13	ST	21					64.4	1380	8.48	47.5	0.2	1.7	3.04	0.72	103	16	< 10	< 10	< 10	< 10	< 0.5	3.7	14	2.3	8.5	< 0.5	34	4.9	1.6	375
CICF25	10/19/05 9:13	10/21/05 1:13	SF	21																			< 0.5	0.63	9.7	< 0.5	6.2	< 0.5	9.1	5.3	2.1	
CICF25	10/21/05 8:00		SVC		1095	8.88	17.48	9.97																								
CICF25	10/25/05 10:13		DT		1397	7.22	18.95	13.15	2.86	1240	8.95	50.1	0.2	1.5	2.43	0.37	5	3	2.3	< 10	< 10	< 10	< 0.5	1.4	9.8	< 0.5	4.4	< 0.5	11		7.6	740
CICF25	10/25/05 10:13		DF																				< 0.5	1.3	8.2	< 0.5	4.4	< 0.5	6.4		7.8	

ST - Stormwater total metals; SF - Stormwater, dissolved metals
DT - Dry weather, total metals; DF - Dry weather, dissolved metals
SVC - Autosampler service time

e- estimated

Aqueous Chemistry at Mass Loading Stations: 2005-06 SAR

Site	Composite or Grab Time		Samples		FieldMeasurements				Turbidity	Specific Conductance	pH	Nitrate as NO_3	Ammonia as N	TKN	Total Phosphate as PO_4	ortho phosphate as P	TSS	VSS	Diazinon	Chlorpyrifos	Dimethoate	Malathion	Cd	Cr	Cu	Pb	Ni	Ag	Zn	As	Se	Hardness as $CaCO_3$
	Start	End	Type	#	EC	pH	TEMP	DO																								
					µS		C	mg/L	NTU	µS			mg/L						ng/L				ug/L									mg/L
CICF25	11/1/05 8:49	11/2/05 7:49	DT	24					11	1000	9.02	10.8	0.2	1.4	1.52	0.26	90	14	177	< 5	< 5	< 5	< 0.5	2.5	14	2.9	5.5	< 0.5	27	3.2	11	365
CICF25	11/1/05 8:49	11/2/05 7:49	DF	24																			< 0.5	0.64	9.4	< 0.5	4.6	< 0.5	5.3	2.9	14	
CICF25	11/2/05 9:00		SVC		1330	9.44	18.77	18.11																								
CICF25	11/8/05 10:00		DT		1040	9.16	17.64	12.76	1.64	1440	8.92	40.1	0.1	1.5	0.69	0.12	5	5	< 10	< 10	< 10	< 10	< 0.5	0.97	6.9	< 0.5	6.1	< 0.5	7.6		5	795
CICF25	11/8/05 10:00		DF																				< 0.5	1	5.9	< 0.5	5.7	< 0.5	4.3		6.3	
CICF25	12/6/05 9:10		DT		1429	7.88	12.22	11.32	1.98	1840	7.80	72.7	0.7	0.7	0.91	0.25	< 5	< 1	18.3	< 5	< 5	2400	< 0.5	1.9	7.9	< 0.5	6.8	< 0.5	11		14	820
CICF25	12/6/05 9:10		DF																				< 0.5	1.6	6.9	< 0.5	5.6	< 0.5	9.2		16	
CICF25	12/22/05 8:16		DT		656	9.02	12.76	21.85	2.1	915	9.20	< 0.4	< 0.1	1.3	0.81	0.19	< 5	< 1	34	< 5	< 5	< 5	< 0.5	1.7	9.5	< 0.5	4.7	< 0.5	17		1.4	385
CICF25	12/22/05 8:16		DF																				< 0.5	1.5	9.4	< 0.5	4.3	< 0.5	11		1.5	
CICF25	1/19/06 10:24		DT		208	8.4	14.13	13.62	1.25	1540	8.46	66.7	< 0.1	1.1	0.45	0.13	< 5	< 1	e 7.1	< 5	< 5	< 5	< 0.5	1.6	5.1	< 0.5	4.3	< 0.5	5.6		11	480
CICF25	1/19/06 10:24		DF																				< 0.5	1.8	4.7	< 0.5	4.4	< 0.5	3.5		11	
CICF25	1/24/06 8:41	1/25/06 7:41	DT	24					2.01	1390	8.61	61.5	0.1	1.9	1.05	0.19	5	3	17	< 5	< 5	72	< 0.5	0.86	17	< 0.5	6.5	< 0.5	26		1.4	390
CICF25	1/24/06 8:41	1/25/06 7:41	DF	24																			< 0.5	0.75	15	< 0.5	8.4	< 0.5	20		1.3	
CICF25	1/25/06 9:17		SVC		1156	8.86	11.82	10.7																								
CICF25	2/1/06 7:21	2/2/06 6:21	DT	24					1.32	986	8.84	2.3	0.3	1.1	0.39	0.09	< 5	< 1	< 5	< 5	< 5	< 5	< 0.5	0.51	12	< 0.5	3.4	< 0.5	7.9	1.7	2.1	525
CICF25	2/1/06 7:21	2/2/06 6:21	DF	24																			< 0.5	< 0.5	11	< 0.5	3.9	< 0.5	5.9	2.1	1.4	
CICF25	2/2/06 8:30		SVC		1136	8.67	12.39	10.89																								
CICF25	2/22/06 8:11	2/23/06 7:11	DT	24					1.17	917	8.92	15.8	< 0.1	1.5	0.58	0.11	< 5	< 1					< 0.5	0.57	14	< 0.5	5.1	< 0.5	8.9		1.1	200
CICF25	2/22/06 8:11	2/23/06 7:11	DF	24																			< 0.5	0.55	13	< 0.5	4.6	< 0.5	6.9		1	
CICF25	2/23/06 7:54		SVC		825	7.99	7.41	16.61																								
CICF25	2/27/06 15:59	2/27/06 16:59	ST	6					109	242	6.83	14.4	0.6	2.2	3.83	0.24	592	113	65.6	< 5	< 5	161	1.3	11	76	15	14	< 0.5	380	4.2	0.51	68
CICF25	2/27/06 15:59	2/27/06 16:59	SF	6																			< 0.5	0.9	12	< 0.5	3.8	< 0.5	24	2.1	< 0.5	
CICF25	2/27/06 18:59	2/28/06 16:59	ST	12					128	743	7.00	91.2	0.2	1.8	2.7	0.73	260	36	< 5	< 5	< 5	69.8	0.76	4.5	20	5.1	8.4	< 0.5	67	3.9	0.64	245
CICF25	2/27/06 18:59	2/28/06 16:59	SF	12																			< 0.5	0.92	9.5	< 0.5	5.6	< 0.5	16	3.3	< 0.5	
CICF25	2/28/06 10:52		SVC		961	8	16.47	10.74																								
CICF25	2/28/06 18:59	3/2/06 8:59	ST	20					10.7	817	7.54	86.3	< 0.1	1.6	2.55	0.64	41	8	< 5	46.3	< 5	39.8	< 0.5	1.7	12	0.96	6.8	< 0.5	16	4.4	< 0.5	280
CICF25	2/28/06 18:59	3/2/06 8:59	SF	20																			< 0.5	1.3	10	< 0.5	6.5	< 0.5	9.3	4	< 0.5	
CICF25	3/2/06 9:31		SVC		794	9.9	19.23	16.94																								
CICF25	3/2/06 10:59	3/3/06 8:59	ST	12					5.23	939	8.95	17.6	< 0.1	2	1.49	0.41	11	5	< 5	< 5	< 5	< 5	< 0.5	2.7	14	0.78	5.7	< 0.5	24	5	2	236
CICF25	3/3/06 10:59	3/4/06 8:59	ST	12					393	614	7.56	58.2	1.3	2.7	3.94	0.57	667	79	< 5	< 5	< 5	49.8	1.2	8	28	12	11	< 0.5	120	6.4	0.57	178
CICF25	3/3/06 10:59	3/4/06 8:59	SF	12																			< 0.5	0.81	7.9	< 0.5	4.2	< 0.5	5.9	3.2	< 0.5	
CICF25	3/4/06 9:41		SVC		652	8.39	15.92	13.25																								
CICF25	4/10/06 8:57	4/11/06 7:57	DT	24					5.11	716	9.19	3.6	0.1	1.3	0.75	0.16	< 5	1					< 0.5	1.6	12	< 0.5	5.2	< 0.5	9.9		1.1	205
CICF25	4/10/06 8:57	4/11/06 7:57	DF	24																			< 0.5	1.3	11	< 0.5	4.7	< 0.5	5		0.91	
CICF25	4/11/06 9:30		SVC		707	10.55	17.9	18.75																								
CICF25	4/25/06 9:13	4/26/06 8:13	DT	24					8.19	998	9.03	40.3	0.2	1.6	1.09	0.23	< 5	< 1	< 2	< 1	< 3	23.4	< 0.5	0.86	17	< 0.5	5.7	< 0.5	18		1.5	275
CICF25	4/25/06 9:13	4/26/06 8:13	DF	24																			< 0.5	0.85	15	< 0.5	5.1	< 0.5	11		1.5	
CICF25	4/26/06 9:16		SVC		876	10.61	18.01	19.45																								
CICF25	5/10/06 8:46	5/11/06 7:46	DT	24					3.31	821	9.09	< 0.4	0.2	1.54	2.32	0.55	10	7					< 0.5	0.87	19	< 0.5	4.4	< 0.5	16		0.96	195
CICF25	5/10/06 8:46	5/11/06 7:46	DF	24																			< 0.5	0.67	16	< 0.5	3.8	< 0.5	7.5		1	
CICF25	5/11/06 8:34		SVC		862	9.22	19.66	15.84																								
CICF25	5/24/06 13:19	5/25/06 12:19	DT	24					1.52	1060	9.47	50	0.53	3.06	2.34	0.58	< 5	< 1	46.8	< 1	< 3	< 3	0.58	1.4	14	< 0.5	6.6	< 0.5	17		1.6	330
CICF25	5/24/06 13:19	5/25/06 12:19	DF	24																			0.56	1.3	14	< 0.5	6.5	< 0.5	13		1.5	
CICF25	6/22/06 11:50		DT		891	10.66	35.63	15.93	5.05	953	10.21	0.57	< 0.1	2.79	2.1	0.12	74	41	< 2	< 1	< 3	< 3	< 0.5	1	19	0.8	6.2	< 0.5	30		1.3	208
CICF25	6/22/06 11:50		DF																				< 0.5	0.52	13	< 0.5	5.6	< 0.5	4.2		0.92	
CICF25	6/26/06 7:07	6/27/06 6:07	DT	24					13.5	1160	7.67	< 0.4	1.68	2.79	9.97	0.63	360	190	< 2	< 1	< 3	< 3	1.2	4.7	74	5.5	13	< 0.5	160	8.6	2	245
CICF25	6/26/06 7:07	6/27/06 6:07	DF	24																			0.51	0.55	16	< 0.5	6.1	< 0.5	8.8	4.9	1.4	
CICF25	6/27/06 8:11		SVC		1166	8.47	22.46	14.64																								
CMCG02	7/5/05 9:06	7/6/05 8:06	DT	24					3.9	1230	8.73	< 0.4	0.2	1.6	0.9	0.16	< 5	4	< 10	< 10	< 10	< 10	< 0.5	0.66	15	1.2	6.3	< 0.5	25		0.94	280
CMCG02	7/5/05 9:06	7/6/05 8:06	DF	24																			< 0.5	0.57	11	0.87	4.6	< 0.5	20		1.1	
CMCG02	7/6/05 8:39		SVC		866	8.95	20.06	11.57																								

ST - Stormwater total metals; SF - Stormwater, dissolved metals
DT - Dry weather, total metals; DF - Dry weather, dissolved metals
SVC - Autosampler service time

e- estimated

Aqueous Chemistry at Mass Loading Stations: 2005-06 SAR

Site	Composite or Grab Time		Samples		FieldMeasurements				Turbidity	Specific Conductance	pH	Nitrate as NO_3	Ammonia as N	TKN	Total Phosphate as PO_4	ortho phosphate as P	TSS	VSS	Diazinon	Chlorpyrifos	Dimethoate	Malathion	Cd	Cr	Cu	Pb	Ni	Ag	Zn	As	Se	Hardness as $CaCO_3$
	Start	End	Type	#	EC	pH	TEMP	DO																								
					µS		C	mg/L	NTU	µS			mg/L						ng/L				ug/L									mg/L
CMCG02	7/12/05 9:26	7/13/05 8:26	DT	24	1091	8.61	22.76	16.9	2	1250	8.51	< 0.4	0.1	1.5	0.89	0.32	33	6	< 10	< 10	< 10	< 10	0.57	0.96	21	1.8	6.7	< 0.5	29		1.6	320
CMCG02	7/12/05 9:26	7/13/05 8:26	DF	24																			0.59	0.97	11	1.1	6	< 0.5	13		1.5	
CMCG02	7/13/05 10:04		SVC		1091	8.61	22.76	16.9																								
CMCG02	7/19/05 11:43	7/20/05 10:43	DT	24					2.67	1440	8.38	0.7	0.8	3.7	0.91	0.09	5	3	< 10	< 10	< 10	< 10	< 0.5	< 0.5	11	1.5	4.7	< 0.5	28		0.81	290
CMCG02	7/19/05 11:43	7/20/05 10:43	DF	24																			< 0.5	< 0.5	7.7	0.7	4.9	< 0.5	19		0.81	
CMCG02	7/27/05 10:23	7/28/05 9:23	DT	24	1169	9.01	23.81	11.19	11.9	1440	7.98	< 0.4	0.3	2.4	1.14	0.12	35	19	< 10	< 10	< 10	< 10	< 0.5	1.4	19	4.7	6.6	< 0.5	72		1	290
CMCG02	7/27/05 10:23	7/28/05 9:23	DF	24																			< 0.5	< 0.5	8.4	0.89	5.4	< 0.5	21		0.92	
CMCG02	7/28/05 9:26		SVC		1169	9.01	23.81	11.19																								
CMCG02	8/4/05 13:35		DT		1055	9.69	31.59	11.27	5.49	1500	9.52	< 0.4	0.2	1.8	0.75	0.12	8	6	< 10	< 10	< 10	< 10	< 0.5	0.56	11	1.1	4.7	< 0.5	24		0.77	280
CMCG02	8/4/05 13:35		DF																				< 0.5	< 0.5	7.9	0.56	4.2	< 0.5	17		0.67	
CMCG02	8/9/05 9:32		DT		1413	9.39	22.4	25.43	3.79	1930	8.60	< 0.4	0.3	6.2	0.54	< 0.02	9	7	< 10	< 10	< 10	< 10	< 0.5	< 0.5	8.7	1.1	4.4	< 0.5	16		0.82	320
CMCG02	8/9/05 9:32		DF																				< 0.5	< 0.5	5.4	< 0.5	4.5	< 0.5	13		0.77	
CMCG02	8/16/05 10:49	8/17/05 9:49	DT	24					9	1520	8.01	< 0.4	0.7	3.5	1.28	0.22	22	13	< 10	< 10	< 10	< 10	< 0.5	0.66	12	2.1	5.3	< 0.5	53		0.62	320
CMCG02	8/16/05 10:49	8/17/05 9:49	DF	24																			< 0.5	< 0.5	6.6	0.67	5.2	< 0.5	26		0.59	
CMCG02	8/17/05 12:53		SVC		1212	9.93	29.24	15.59																								
CMCG02	8/21/05 11:34	8/22/05 10:34	DT	24					14.1	1230	8.47	< 0.4	0.2	2.3	0.97	0.05	19	6	< 10	< 10	< 10	140	< 0.5	1.1	11	1.8	4.8	< 0.5	27	2.1	0.71	265
CMCG02	8/21/05 11:34	8/22/05 10:34	DF	24																			< 0.5	< 0.5	4.9	< 0.5	4.6	< 0.5	17	2	0.95	
CMCG02	8/22/05 10:41		SVC		1172	9.82	23.74	14.95											< 5	< 5	< 5	< 5	1.53	17.4	81.2	130	17.5	< 0.025	260	3.73	1.69	265
CMCG02	8/30/05 10:02	8/31/05 9:02	DT	24					4.1	2310	8.90	< 0.4	0.5	2.2	1.3	0.25	18	9	< 10	< 10	< 10	< 10	< 0.5	0.61	14	1.8	5	< 0.5	38		0.52	255
CMCG02	8/30/05 10:02	8/31/05 9:02	DF	24																			< 0.5	< 0.5	8.8	0.69	5	< 0.5	21		0.88	
CMCG02	8/31/05 11:13		SVC		771	9.3	26.68	12.97																								
CMCG02	8/31/05 11:14		DT		771	9.3	26.68	12.97																								
CMCG02	9/6/05 9:27	9/7/05 8:27	DT	24					2.52	1150	8.27	< 0.4	0.2	1.6	0.71	0.13	9	9	< 10	< 10	< 10	< 10	< 0.5	< 0.5	11	1.2	4.7	< 0.5	18		0.85	275
CMCG02	9/6/05 9:27	9/7/05 8:27	DF	24																			< 0.5	< 0.5	7.3	0.57	4.6	< 0.5	12		0.59	
CMCG02	9/7/05 9:53		SVC		910	9.24	21.83	14.11																								
CMCG02	9/14/05 11:04		DT		849	9.29	23.84	15.75	2.94	1250	9.09	< 0.4	0.3	1.4	0.75	0.11	9	1	< 10	< 10	< 10	< 10	< 0.5	< 0.5	8.3	1.3	3.8	< 0.5	30		0.71	350
CMCG02	9/14/05 11:04		DF																				< 0.5	< 0.5	4.4	< 0.5	3.8	< 0.5	18		0.94	
CMCG02	9/20/05 3:15		ST		2301	7.82	22.22	19.24	31.5	207	7.03	9.1	0.9	3.8	2.37	0.54	60	30	< 5	< 5	< 5	345	0.51	4.6	66	14	13	< 0.5	360		< 0.5	
CMCG02	9/20/05 3:15		SF																				< 0.5	2.5	47	4.7	11	< 0.5	260		< 0.5	
CMCG02	9/20/05 10:50	9/21/05 9:50	DT	24					15	573	7.24	8.3	0.6	3.1	2.12	0.47	24	14	< 10	< 10	< 10	< 10	< 0.5	2.7	49	7.8	13	< 0.5	220		0.68	530
CMCG02	9/20/05 10:50	9/21/05 9:50	DF	24																			< 0.5	1.7	40	3.2	13	< 0.5	180		0.56	
CMCG02	9/21/05 10:15		SVC		780	8.5	19.68	12.49																								
CMCG02	9/27/05 10:37	9/28/05 9:37	DT	24					2.34	1880	8.56	< 0.4	< 0.1	2.9	1.53	0.41	8	5	< 10	< 10	< 10	< 10	< 0.5	0.81	18	1.7	7.6	< 0.5	45		1.9	270
CMCG02	9/27/05 10:37	9/28/05 9:37	DF	24																			< 0.5	< 0.5	14	0.59	5.8	< 0.5	24		1.1	
CMCG02	9/28/05 10:11		SVC		961	9.2	19.31	21.02																								
CMCG02	10/5/05 9:49	10/6/05 8:49	DT	24					2.41	1300	8.26	0.6	< 0.1	1.7	0.92	0.2	< 5	< 1	< 10	< 10	< 10	< 10	< 0.5	< 0.5	13	0.91	4.4	< 0.5	26		1.1	242
CMCG02	10/5/05 9:49	10/6/05 8:49	DF	24																			< 0.5	< 0.5	11	0.5	4.4	< 0.5	19		1.3	
CMCG02	10/6/05 10:17		SVC		1121	9.19	19.57	15.65																								
CMCG02	10/11/05 10:30	10/12/05 9:30	DT	24					2.46	1160	8.63	0.7	0.2	1.2	1.11	0.29	< 5	< 1	< 10	< 10	< 10	< 10	< 0.5	< 0.5	13	1.2	4.1	< 0.5	24		0.74	196
CMCG02	10/11/05 10:30	10/12/05 9:30	DF	24																			0.54	< 0.5	11	< 0.5	4.7	< 0.5	18		0.8	
CMCG02	10/12/05 9:30		SVC		1026	9.01	18.43	11.91																								
CMCG02	10/16/05 16:46	10/16/05 17:46	ST	6					68	310	6.70	8.9	1.1	4.3	2.03	0.38	56	28	< 5	< 5	< 5	199	< 0.5	4.3	78	11	16	< 0.5	350	2.8	< 0.5	620
CMCG02	10/16/05 16:46	10/16/05 17:46	SF	6																			< 0.5	2.5	61	3	15	< 0.5	270	2.4	0.68	
CMCG02	10/17/05 11:51		SVC		475	7.62	20.3	14.04																								
CMCG02	10/17/05 19:46	10/18/05 23:46	ST	26					13.8	296	7.38	3.9	0.5	1.7	1.41	0.38	25	10	< 10	< 10	< 10	< 10	0.57	2.8	37	6.6	7.1	< 0.5	130	2.1	0.5	76
CMCG02	10/17/05 19:46	10/18/05 23:46	SF	26																			< 0.5	1.7	27	1.8	5.6	< 0.5	89	2.5	0.52	
CMCG02	10/19/05 1:46	10/20/05 21:46	ST	23					4.45	1050	8.88	1.2	0.2	1.1	0.92	0.24	< 5	< 1	< 10	< 10	< 10	< 10	< 0.5	0.71	16	1.1	4.9	< 0.5	39	2.2	0.85	250
CMCG02	10/19/05 1:46	10/20/05 21:46	SF	23																			< 0.5	0.56	15	< 0.5	4.7	< 0.5	30	2.2	0.81	
CMCG02	10/19/05 10:31		SVC		768	9.13	18.96	13.59																								
CMCG02	10/21/05 10:53		SVC		1054	9.28	18.88	13.4																								
CMCG02	10/25/05 11:28		DT		1039	8.15	22.9	18.64	3.96	985	9.41	3.6	0.2	1.6	1.32	0.23	27	16	< 10	< 10	< 10	< 10	< 0.5	0.73	11	1.6	4.6	< 0.5	45		0.68	720

ST - Stormwater total metals; SF - Stormwater, dissolved metals
DT - Dry weather, total metals; DF - Dry weather, dissolved metals
SVC - Autosampler service time

e- estimated

Aqueous Chemistry at Mass Loading Stations: 2005-06 SAR

Site	Composite or Grab Time		Samples		FieldMeasurements				Turbidity	Specific Conductance	pH	Nitrate as NO_3	Ammonia as N	TKN	Total Phosphate as PO_4	ortho phosphate as P	TSS	VSS	Diazinon	Chlorpyrifos	Dimethoate	Malathion	Cd	Cr	Cu	Pb	Ni	Ag	Zn	As	Se	Hardness as $CaCO_3$
	Start	End	Type	#	EC	pH	TEMP	DO																								
					µS		C	mg/L	NTU	µS			mg/L						ng/L				ug/L									mg/L
CMCG02	10/25/05 11:28		DF																				< 0.5	< 0.5	7.7	< 0.5	4.1	< 0.5	29		0.99	
CMCG02	11/1/05 10:53	11/2/05 9:53	DT	24					2.1	1000	9.01	0.8	< 0.1	1.8	0.71	0.15	< 5	< 1	< 5	< 5	< 5	< 5	< 0.5	< 0.5	11	0.61	4.2	< 0.5	27		0.83	300
CMCG02	11/1/05 10:53	11/2/05 9:53	DF	24																			< 0.5	< 0.5	9.4	< 0.5	4.3	< 0.5	20		0.74	
CMCG02	11/2/05 12:45		SVC		1134	10.11	21.88	16.72																								
CMCG02	11/8/05 11:15		DT		1128	9.79	19.81	16.33	1.68	1270	9.85	2.2	0.1	6.8	0.61	0.09	7	4	< 10	< 10	< 10	< 10	< 0.5	< 0.5	9.7	0.74	3.9	< 0.5	15		0.86	630
CMCG02	11/8/05 11:15		DF																				< 0.5	< 0.5	8	< 0.5	3.3	< 0.5	9.1		1	
CMCG02	11/14/05 11:22		DT		1332	9.93	22.25	18.49	2.03	1320	9.74	2.6	0.1	2.2	0.8	0.1	15	12	< 5	< 5	< 5	< 5	< 0.5	0.65	15	0.96	3.9	< 0.5	20		1	258
CMCG02	11/14/05 11:22		DF																				< 0.5	0.54	12	< 0.5	4.1	< 0.5	9.3		0.88	
CMCG02	11/22/05 11:48		DT						1.89	945	9.53	1.6	0.1	1.5	1.64	0.46	< 5	< 1	< 10	< 10	< 10	< 10	< 0.5	0.5	12	0.91	3.7	< 0.5	24		0.9	
CMCG02	11/22/05 11:48		DF																				< 0.5	< 0.5	10	0.61	3.5	< 0.5	17		0.78	
CMCG02	11/29/05 12:09	11/30/05 11:09	DT	24	536	8.93	19.27	16.3	8.58	1350	7.99	1	0.5	2.4	1.98	0.49	< 5	< 1	< 5	< 5	< 5	< 5	< 0.5	< 0.5	13	1.1	4.7	< 0.5	41		0.83	260
CMCG02	11/29/05 12:09	11/30/05 11:09	DF	24																			< 0.5	< 0.5	11	0.67	4.4	< 0.5	32		0.86	
CMCG02	12/6/05 12:40		DT		520	9.5	19.09	9.93	2.02	941	9.26	2.1	< 0.1	1	3.25	0.85	12	7	< 5	< 5	< 5	< 5	< 0.5	0.6	12	2.1	4.7	< 0.5	53		1.2	580
CMCG02	12/6/05 12:40		DF																				< 0.5	< 0.5	8.5	0.6	4.2	< 0.5	38		1.1	
CMCG02	12/12/05 11:15		DT		973	9.3	16.45	18.66																								
CMCG02	12/13/05 9:31	12/14/05 8:31	DT	24					2.06	1030	8.69	2.7	0.2	1.5	0.91	0.22	< 5	< 1	< 5	< 5	< 5	< 5	< 0.5	0.87	13	0.66	4	< 0.5	18		0.76	590
CMCG02	12/13/05 9:31	12/14/05 8:31	DF	24																			< 0.5	0.81	11	< 0.5	3.8	< 0.5	13		0.8	
CMCG02	12/14/05 9:55		SVC		570	8.63	13.11	18.74																								
CMCG02	12/20/05 9:57	12/21/05 8:57	DT	24					1.81	932	8.70	4.7	0.3	1.5	0.92	0.22	< 5	< 1	< 5	< 5	< 5	< 5	< 0.5	0.55	12	0.65	5	< 0.5	20		1.2	
CMCG02	12/20/05 9:57	12/21/05 8:57	DF	24																			< 0.5	0.8	9.6	< 0.5	3.5	< 0.5	15		1.4	
CMCG02	12/28/05 9:35		DT		947	7.93	14.48	14.55	3.38	980	8.82	3.1	0.3	2.7	1.55	0.21	32	18	< 5	< 5	< 5	< 5	< 0.5	0.81	15	2.1	6	< 0.5	68		0.73	220
CMCG02	12/28/05 9:35		DF																				< 0.5	< 0.5	9.2	< 0.5	4.9	< 0.5	43		0.87	
CMCG02	1/4/06 12:08		ST		1066	8.9	18.42	16.99	3.32	1170	9.11	5.6	0.2	1	0.65	0.15	7	4					< 0.5	0.51	9.9	1.2	4.8	< 0.5	26		0.9	285
CMCG02	1/4/06 12:08		SF																				< 0.5	< 0.5	8.2	0.51	5.8	< 0.5	19		1.4	
CMCG02	1/11/06 11:15	1/12/06 10:15	DT	24					1.89	1330	8.68	3.8	< 0.1	1.3	0.6	0.1	< 5	< 1	< 5	< 5	< 5	< 5	< 0.5	< 0.5	11	0.72	4.6	< 0.5	36		0.93	315
CMCG02	1/11/06 11:15	1/12/06 10:15	DF	24																			< 0.5	< 0.5	7.9	< 0.5	4.4	< 0.5	26		0.77	
CMCG02	1/12/06 10:45		SVC		1159	9	14.62	18.45																								
CMCG02	1/19/06 12:07		DT		1133	8.53	17.42	19.68	5.6	1180	9.33	3.1	< 0.1	1.4	1.18	0.09	20	3	< 5	< 5	< 5	< 5	< 0.5	0.52	9.8	1.4	4.6	< 0.5	31		1.1	330
CMCG02	1/19/06 12:07		DF																				< 0.5	< 0.5	7.8	< 0.5	4.3	< 0.5	17		1	
CMCG02	1/24/06 9:34	1/25/06 8:34	DT	24					3.52	1130	8.12	3.5	0.3	1.3	1.28	0.24	6	5	< 5	< 5	< 5	< 5	< 0.5	1.7	12	1.6	4.4	< 0.5	30		0.77	285
CMCG02	1/24/06 9:34	1/25/06 8:34	DF	24																			< 0.5	3.2	10	0.74	4.4	< 0.5	24		0.77	
CMCG02	1/25/06 10:08		SVC		1157	8.16	13.45	14.52																								
CMCG02	2/1/06 9:42	2/2/06 8:42	DT	24					1.7	1200	8.78	2.1	0.3	1.1	0.78	0.13	6	5	< 5	< 5	< 5	< 5	< 0.5	0.58	12	0.86	5.6	< 0.5	30	1.4	0.71	970
CMCG02	2/1/06 9:42	2/2/06 8:42	DF	24																			< 0.5	< 0.5	9.1	< 0.5	5.1	< 0.5	22	1.3	0.62	
CMCG02	2/2/06 9:23		SVC		1011	8.33	13.71	15.45																								970
CMCG02	2/7/06 9:31	2/8/06 8:31	DT	24					3.12	1050	8.63	3.8	0.7	2.3	1.02	0.12	14	11					< 0.5	0.56	16	1.2	5.2	< 0.5	27		0.81	330
CMCG02	2/7/06 9:31	2/8/06 8:31	DF	24																			< 0.5	< 0.5	13	< 0.5	5.2	< 0.5	18		0.75	
CMCG02	2/8/06 9:16		SVC		931	8.67	12.74	18.14																								
CMCG02	2/15/06 11:00	2/16/06 10:00	DT	24					1.77	1220	7.86	2.6	0.3	2.9	0.75	0.09	6	4					< 0.5	< 0.5	11	1.2	4.9	< 0.5	33		0.81	565
CMCG02	2/15/06 11:00	2/16/06 10:00	DF	24																			< 0.5	< 0.5	9.2	0.65	4.2	< 0.5	27		0.79	
CMCG02	2/16/06 10:45		SVC		1203	9.04	13.58	18.76																								
CMCG02	2/22/06 9:16	2/23/06 8:16	DT	24					1.48	969	8.53	3.5	< 0.1	1.3	0.72	0.13	< 5	< 1					< 0.5	0.89	14	0.91	4.8	< 0.5	27		0.82	300
CMCG02	2/22/06 9:16	2/23/06 8:16	DF	24																			< 0.5	0.62	11	0.53	4.8	< 0.5	21		0.85	
CMCG02	2/27/06 16:19	2/27/06 17:19	ST	6					50.2	257	6.75	7.4	0.9	3.2	2.8	0.26	307	126	< 5	< 5	< 5	< 5	0.64	6.1	81	20	13	< 0.5	330	2.4	< 0.5	48
CMCG02	2/27/06 16:19	2/27/06 17:19	SF	6																			< 0.5	1.5	33	1.1	8.7	< 0.5	100	1.7	< 0.5	
CMCG02	2/27/06 19:19	2/28/06 17:19	ST	12					8.89	197	7.94	2.9	0.3	1.2	1.02	0.3	19	11	< 5	< 5	< 5	53.9	< 0.5	2	22	3.3	3.3	< 0.5	73	1.4	< 0.5	70
CMCG02	2/27/06 19:19	2/28/06 17:19	SF	12																			< 0.5	1.4	17	0.76	2.8	< 0.5	43	1.2	< 0.5	
CMCG02	2/28/06 14:15		SVC		280	9.95	21.59	12.64																								
CMCG02	2/28/06 19:19	3/2/06 11:19	ST	21					1.57	961	8.33	4.7	< 0.1	1	0.59	0.13	< 5	< 1	< 5	< 5	< 5	< 5	< 0.5	0.84	14	0.88	5.4	< 0.5	29.8	1.6	0.8	295
CMCG02	2/28/06 19:19	3/2/06 11:19	SF	21																			< 0.5	0.77	12	< 0.5	5.2	< 0.5	22	1.6	0.73	
CMCG02	3/2/06 12:01		SVC		1111	9.24	22.02	18.67																								

ST - Stormwater total metals; SF - Stormwater, dissolved metals
DT - Dry weather, total metals; DF - Dry weather, dissolved metals
SVC - Autosampler service time

e- estimated

Aqueous Chemistry at Mass Loading Stations: 2005-06 SAR

Site	Composite or Grab Time		Samples		FieldMeasurements				Turbidity	Specific Conductance	pH	Nitrate as NO_3	Ammonia as N	TKN	Total Phosphate as PO_4	ortho phosphate as P	TSS	VSS	Diazinon	Chlorpyrifos	Dimethoate	Malathion	Cd	Cr	Cu	Pb	Ni	Ag	Zn	As	Se	Hardness as $CaCO_3$
	Start	End	Type	#	EC	pH	TEMP	DO																								
					µS		C	mg/L	NTU	µS			mg/L						ng/L				ug/L									mg/L
CMCG02	3/15/06 11:41		ST		1131	9.29	21.93	19.36	2.56	1160	9.52	3.3	0.3	1.1	0.6	0.08	7	5					< 0.5	0.66	12	1.3	4.4	< 0.5	19		0.58	245
CMCG02	3/15/06 11:41		SF																				< 0.5	0.64	10	< 0.5	5.9	< 0.5	12		0.7	
CMCG02	3/21/06 8:24		ST		883	8.95	12.41	18.44	2.81	937	8.54	3.2	0.2	0.9	0.46	0.07	6	3	< 2	< 1	< 3	< 3	< 0.5	< 0.5	8.4	0.65	4.5	< 0.5	18		0.61	235
CMCG02	3/21/06 8:24		SF																				< 0.5	< 0.5	7.9	< 0.5	4.6	< 0.5	15		0.6	
CMCG02	3/27/06 9:46		ST		1209	9.78	18.25	19.4	4.43	1240	9.43	1.6	< 0.1	1.8	0.6	0.09	5	2					< 0.5	0.64	11	0.78	4.4	< 0.5	23		1	260
CMCG02	3/27/06 9:46		SF																				< 0.5	< 0.5	10	< 0.5	4.5	< 0.5	19		0.97	
CMCG02	4/10/06 10:26	4/11/06 9:26	DT	24					2.56	1350	8.94	2.1	< 0.1	0.5	0.43	0.04	< 5	1					< 0.5	1.4	10	1.8	5.7	< 0.5	18		0.87	300
CMCG02	4/10/06 10:26	4/11/06 9:26	DF	24																			< 0.5	1.5	8.5	< 0.5	6.1	< 0.5	13		0.69	
CMCG02	4/11/06 10:37		SVC		1250	9.22	17.68	17.7																								
CMCG02	4/18/06 9:37	4/19/06 8:37	DT	24					2.75	1320	8.96	1.3	0.1	0.8	0.43	0.05	< 5	< 1	< 2	< 1	< 3	< 3	< 0.5	< 0.5	12	0.72	6.2	< 0.5	23		0.71	315
CMCG02	4/18/06 9:37	4/19/06 8:37	DF	24																			< 0.5	< 0.5	11	< 0.5	6.1	< 0.5	15		0.75	
CMCG02	4/19/06 10:12		SVC		1257	9.1	20.18	18.45																								
CMCG02	4/25/06 9:19	4/26/06 8:19	DT	24					1.94	1250	8.94	0.7	0.1	1.4	0.74	0.14	< 5	< 1	< 2	< 1	< 3	< 3	< 0.5	0.57	11	1.5	5.1	< 0.5	32		0.88	265
CMCG02	4/25/06 9:19	4/26/06 8:19	DF	24																			< 0.5	< 0.5	11	0.8	4.7	< 0.5	28		0.82	
CMCG02	4/26/06 11:03		SVC		1248	9.27	21.36	15.79																								
CMCG02	5/2/06 8:45	5/3/06 7:45	DT	24					11.9	1240	8.62	1.2	0.2	1.6	1.45	0.03	8	7					< 0.5	0.67	15	1.2	6.3	< 0.5	200		0.92	236
CMCG02	5/2/06 8:45	5/3/06 7:45	DF	24																			< 0.5	0.6	13	0.7	6	< 0.5	140		0.77	
CMCG02	5/3/06 11:48		SVC		1230	9.34	20.72	8.02																								
CMCG02	5/10/06 9:38	5/11/06 8:38	DT	24					3.39	1470	8.63	1.5	0.17	2.83	0.83	0.08	12	9					< 0.5	0.84	15	1.5	6	< 0.5	41		1.1	225
CMCG02	5/10/06 9:38	5/11/06 8:38	DF	24																			< 0.5	0.51	12	< 0.5	5.4	< 0.5	23		0.51	
CMCG02	5/11/06 9:30		SVC		1277	8.56	18.37	11.84																								
CMCG02	5/17/06 11:26	5/18/06 10:26	DT	24					4.54	1390	8.85	< 0.4	0.47	2.33	0.96	0.19	8	4	< 2	< 1	< 3	< 3	< 0.5	< 0.5	13	1.2	5.9	< 0.5	39		< 0.5	425
CMCG02	5/17/06 11:26	5/18/06 10:26	DF	24																			< 0.5	< 0.5	11	0.65	6.2	< 0.5	36		0.77	
CMCG02	5/18/06 10:40		SVC		1211	8.95	19.39	12.52																								
CMCG02	5/24/06 14:11	5/25/06 8:11	DT	18					4.02	1310	8.83	2.11	0.13	6.52	0.96	0.19	< 5	3	< 2	< 1	< 3	< 3	< 0.5	0.8	24	1.9	7.3	0.64	73		0.96	275
CMCG02	5/24/06 14:11	5/25/06 8:11	DF	18																			< 0.5	0.58	18	0.77	7.1	< 0.5	53		0.99	
CMCG02	5/29/06 9:27	5/30/06 8:27	DT	24					3.12	1160	8.76	0.47	0.16	2.4	0.79	0.08	11	7					< 0.5	0.59	14	1.3	5.5	< 0.5	45		1.1	285
CMCG02	5/29/06 9:27	5/30/06 8:27	DF	24																			< 0.5	< 0.5	10	0.57	5	< 0.5	28		0.9	
CMCG02	5/30/06 10:23		SVC		435	9.11	22.37	14.39																								
CMCG02	6/7/06 9:40	6/8/06 8:40	DT	24					3.34	1110	8.89	0.82	0.19	4.27	0.82	0.12	10	6					< 0.5	0.63	16	1.9	5.4	< 0.5	29		0.67	410
CMCG02	6/7/06 9:40	6/8/06 8:40	DF	24																			< 0.5	< 0.5	8.7	< 0.5	4.8	< 0.5	16		0.65	
CMCG02	6/8/06 10:35		SVC		1484	9.06	20.66	13.12																								
CMCG02	6/13/06 10:41	6/14/06 9:41	DT	24					7.52	1120	8.68	< 0.4	0.21	2.34	1.34	0.22	9	6					< 0.5	0.54	42	1.4	7	< 0.5	46		0.64	310
CMCG02	6/13/06 10:41	6/14/06 9:41	DF	24																			< 0.5	< 0.5	32	0.81	6.6	< 0.5	34		0.68	
CMCG02	6/14/06 10:43		SVC		1272	9.03	24.12	14.17																								
CMCG02	6/21/06 9:28	6/22/06 8:29	DT	24					2.2	1120	7.87	< 0.4	< 0.1	2.35	1	0.14	10	< 1	24.6	< 1	< 3	< 3	< 0.5	< 0.5	14	1.3	6.4	< 0.5	30		0.57	228
CMCG02	6/21/06 9:28	6/22/06 8:29	DF	24																			< 0.5	< 0.5	11	0.85	6.7	< 0.5	24		0.63	
CMCG02	6/22/06 13:00		SVC		740	9.73	31.14	11.96																								
CMCG02	6/26/06 9:57	6/27/06 8:57	DT	24					1.94	1150	7.51	< 0.4	0.24	2.3	2.35	0.58	8	< 1	< 2	< 1	< 3	< 3	< 0.5	0.53	12	1.3	6.3	< 0.5	32	2.3	0.91	210
CMCG02	6/26/06 9:57	6/27/06 8:57	DF	24																			< 0.5	< 0.5	9.4	0.73	6.1	< 0.5	27	2.4	0.79	
CMCG02	6/27/06 11:35		SVC		946	8.28	22.74	9.76																								
EGWC05	8/23/05 10:57	8/24/05 9:57	DT	24					2.08	1740	8.10	1.6	0.1	1.2	0.11	< 0.02	< 5	< 1	< 10	< 10	< 10	< 10	< 0.5	< 0.5	4.2	< 0.5	4.9	< 0.5	3.5	3.5	2.3	385
EGWC05	8/23/05 10:57	8/24/05 9:57	DF	24																			< 0.5	< 0.5	4.4	< 0.5	5.4	< 0.5	4.4	3.9	2	
EGWC05	8/24/05 10:04		SVC		1699	8.92	24.14	12.39											< 5	< 5	< 5	< 5	0.25	2.47	4.97	11.9	3.83	< 0.025	36.8	1.43	0.41	385
EGWC05	10/18/05 11:38		ST		355	9.24	18.14	8.22	17.8	317	7.51	4.7	0.6	1.6	1.05	0.2	25	8	65.3	< 5	< 5	1080	< 0.5	1.8	14	4.4	5.7	< 0.5	54	2.2	0.56	84
EGWC05	10/18/05 11:38		SF																				< 0.5	0.83	8.5	0.85	4.3	< 0.5	27	1.9	< 0.5	
EGWC05	11/14/05 11:16	11/15/05 10:16	DT	24					2.77	1600	8.15	7.7	0.2	0.9	0.25	0.04	3	2	17.6	< 5	< 5	< 5	< 0.5	< 0.5	3.5	< 0.5	6	< 0.5	9		1	372
EGWC05	11/14/05 11:16	11/15/05 10:16	DF	24																			< 0.5	< 0.5	3	< 0.5	6.4	< 0.5	8.3	1.9	1.5	
EGWC05	11/15/05 11:32		SVC		1689	8.22	20.79	10.35											< 5	< 5	< 5	< 5	0.35	8.6	18.7	9.8	6.3	0.24	85.4	1.96	1	372
EGWC05	2/8/06 11:47	2/9/06 10:47	DT	24					4.53	1760	7.94	8.2	0.1	1.2	0.35	< 0.02	28	6	< 5	< 5	< 5	< 5	< 0.5	0.83	8.2	1.5	7.8	< 0.5	18	2.2	2.5	740
EGWC05	2/8/06 11:47	2/9/06 10:47	DF	24																			< 0.5	< 0.5	5.3	< 0.5	7	< 0.5	8.4	1.6	2.3	

ST - Stormwater total metals; SF - Stormwater, dissolved metals
DT - Dry weather, total metals; DF - Dry weather, dissolved metals
SVC - Autosampler service time

e- estimated

Aqueous Chemistry at Mass Loading Stations: 2005-06 SAR

Site	Composite or Grab Time		Samples		FieldMeasurements				Turbidity	Specific Conductance	pH	Nitrate as NO_3	Ammonia as N	TKN	Total Phosphate as PO_4	ortho phosphate as P	TSS	VSS	Diazinon	Chlorpyrifos	Dimethoate	Malathion	Cd	Cr	Cu	Pb	Ni	Ag	Zn	As	Se	Hardness as $CaCO_3$
	Start	End	Type	#	EC	pH	TEMP	DO																								
					µS		C	mg/L	NTU	µS			mg/L						ng/L				ug/L									mg/L
EGWC05	2/9/06 11:00		SVC		1742	7.73	16.92	17.07																								
EGWC05	3/27/06 23:18	3/28/06 0:18	ST	6					5.2	1660	7.94	5.1	< 0.1	0.9	0.37	< 0.02	15	8	< 2	< 1	< 3	< 3	< 0.5	0.52	9	0.74	7.1	< 0.5	20	1.9	2.1	450
EGWC05	3/27/06 23:18	3/28/06 0:18	SF	6																			< 0.5	< 0.5	7.3	< 0.5	7.2	< 0.5	11	1.8	2.5	
EGWC05	3/28/06 2:18	3/29/06 0:18	ST	12					26.9	482	7.66	3.4	< 0.1	0.8	1.53	< 0.02	186	38	< 2	< 1	< 3	438	< 0.5	4.2	29	13	7.9	< 0.5	130	2.5	0.65	128
EGWC05	3/28/06 2:18	3/29/06 0:18	SF	12																			< 0.5	0.65	9.6	< 0.5	4.3	< 0.5	17	1.4	0.53	
EGWC05	3/28/06 13:30		SVC		274	8.4	16.4	10.66																								
EGWC05	3/29/06 2:18	3/29/06 22:18	ST	11					14.5	295	7.52	1.8	< 0.1	0.5	0.7	0.07	47	13	< 2	< 1	< 3	< 3	< 0.5	1.8	12	6.2	4.2	< 0.5	48	1.6	< 0.5	92
EGWC05	3/29/06 2:18	3/29/06 22:18	SF	11																			< 0.5	< 0.5	5.4	< 0.5	2.6	< 0.5	12	1.4	< 0.5	
EGWC05	3/29/06 10:32		SVC		179	8.25	15.81	14.47																								
EGWC05	3/30/06 0:18	3/31/06 4:18	ST	14					7.24	1010	8.08	3.9	< 0.1	1	0.54	0.05	19	9	< 2	< 1	< 3	< 3	< 0.5	0.76	8.8	1.6	6	< 0.5	21	2	0.91	216
EGWC05	3/30/06 0:18	3/31/06 4:18	SF	14																			< 0.5	< 0.5	5.9	< 0.5	6.2	< 0.5	12	1.7	0.99	
EGWC05	3/31/06 6:18	4/1/06 2:18	ST	11					4.75	1440	8.15	5.4	< 0.1	1.1	0.46	0.04	11	10	< 2	< 1	< 3	< 3	< 0.5	< 0.5	7.1	0.64	8	< 0.5	14	2.5	1.6	355
EGWC05	3/31/06 6:18	4/1/06 2:18	SF	11																			< 0.5	< 0.5	6.1	< 0.5	8.1	< 0.5	9.9	2	1.6	
EGWC05	3/31/06 9:39		SVC		1463	8.34	16.1	12.83																								
EGWC05	4/2/06 11:10		SVC		728	8.75	19.38	15.41																								
EGWC05	5/22/06 1:37	5/22/06 2:37	ST	6					42.5	803	7.34	8.14	0.84	3.49	1.58	< 0.02	256	76	< 2	< 1	< 3	614	0.52	4.5	39	14	13	< 0.5	210	5.1	1.2	380
EGWC05	5/22/06 1:37	5/22/06 2:37	SF	6																			< 0.5	0.72	14	0.76	11	< 0.5	58	2.3	1.3	
EGWC05	5/22/06 4:37	5/23/06 10:37	ST	16					11.1	510	7.45	4.57	0.31	1.22	0.83	0.07	33	13	56.2	< 1	< 3	223	< 0.5	1.2	15	4.4	7.3	< 0.5	60	2.6	0.84	125
EGWC05	5/22/06 4:37	5/23/06 10:37	SF	16																			< 0.5	< 0.5	8.6	< 0.5	6.4	< 0.5	23	2.1	0.72	
EGWC05	5/22/06 11:20		SVC		253	7.96	20.45	10.09																								
EGWC05	5/23/06 12:37	5/24/06 10:37	ST	12					2.75	1290	8.07	4.4	0.24	1.03	0.39	0.05	< 5	< 1	< 2	< 1	< 3	< 3	< 0.5	< 0.5	6.2	0.81	8.6	< 0.5	18	3.5	1.9	350
EGWC05	5/23/06 12:37	5/24/06 10:37	SF	12																			< 0.5	< 0.5	5.2	< 0.5	8.2	< 0.5	12	3.3	1.4	
EGWC05	5/24/06 11:22		SVC		1194	8.09	26.38	17.55																								
EGWC05	5/24/06 12:37	5/26/06 2:37	ST	20					2.02	1660	8.52	4.5	0.17	1.05	0.33	0.05	7	5	< 2	< 1	< 3	< 3	< 0.5	< 0.5	5.7	0.68	6.3	< 0.5	12	3.5	2.2	430
EGWC05	5/24/06 12:37	5/26/06 2:37	SF	20																			< 0.5	< 0.5	5.2	< 0.5	5.8	< 0.5	8	2.9	2.3	
EGWC05	5/26/06 11:00		SVC		1767	8.23	23.43	13.01																								
FULA03	8/23/05 8:49	8/24/05 7:49	DT	24					4.09	1460	8.40	0.7	0.2	1.5	0.39	0.06	15	4	< 10	< 10	< 10	< 10	< 0.5	< 0.5	4.9	0.97	5.9	< 0.5	13	nr	0.53	390
FULA03	8/23/05 8:49	8/24/05 7:49	DF	24																			< 0.5	< 0.5	3.6	< 0.5	7.2	< 0.5	7.5	nr	0.97	
FULA03	8/24/05 7:50		SVC		1487	8.84	19.85	10.38											< 5	< 5	< 5	< 5	1.52	29.9	41.1	50.4	19.5	< 0.025	230	3.65	1.82	390
FULA03	10/18/05 8:51		ST		296	8.95	16.35	9.68	78	2750	7.45	5.6	0.5	1.9	2.24	0.22	237	37	19	< 5	< 5	150	0.95	7.8	24	12	14	< 0.5	130	2.8	0.83	80
FULA03	10/18/05 8:51		SF																				< 0.5	0.81	9.4	0.74	5.7	< 0.5	41	1.4	0.67	
FULA03	11/14/05 8:22	11/15/05 7:22	DT	24					8.43	1420	8.43	10.2	< 0.1	0.9	0.31	0.03	< 5	< 1	< 5	< 5	< 5	< 5	< 0.5	< 0.5	4.8	< 0.5	6.1	< 0.5	15		0.68	380
FULA03	11/14/05 8:22	11/15/05 7:22	DF	24																			< 0.5	< 0.5	4	< 0.5	6	< 0.5	12		< 0.5	
FULA03	11/15/05 9:06		SVC		1571	8.44	14.07	17.63											< 5	< 5	< 5	< 5	0.23	9.99	8.46	48.9	4.14	0.16	59.4	0.91	0.35	380
FULA03	1/14/06 11:23	1/14/06 12:23	ST	6					17	417	6.81	10.8	< 0.1	4.6	2.85	< 0.02	310	197	< 5	< 5	< 5	< 5	1.2	7	81	23	30	< 0.5	410	2.4	0.79	100
FULA03	1/14/06 11:23	1/14/06 12:23	SF	6																			< 0.5	1.7	33	1.6	21	< 0.5	170	1.3	0.78	
FULA03	1/14/06 14:23	1/15/06 12:23	ST	12					18.5	620	7.85	8.1	< 0.1	1.2	0.81	0.09	58	20	< 5	< 5	< 5	< 5	< 0.5	2.5	21	7.2	8.7	< 0.5	96	1.4	0.59	192
FULA03	1/14/06 14:23	1/15/06 12:23	SF	12																			< 0.5	0.52	7.7	< 0.5	5.2	< 0.5	30	1.3	< 0.5	
FULA03	1/15/06 11:15		SVC		603	7.63	12.11	12.95																								
FULA03	1/15/06 14:23	1/17/06 10:23	ST	23					5.78	1030	8.27	10.9	0.2	0.9	0.72	0.06	< 5	< 1	< 5	< 5	< 5	< 5	< 0.5	0.64	7.5	1.2	6.6	< 0.5	27	1.4	0.89	345
FULA03	1/15/06 14:23	1/17/06 10:23	SF	23																			< 0.5	< 0.5	4.8	< 0.5	6.2	< 0.5	13	1.6	0.86	
FULA03	1/17/06 10:22		SVC		982	8.39	10.81	14.22																								
FULA03	1/17/06 12:23	1/18/06 12:23	ST	13					5.25	1140	8.35	9.9	< 0.1	1	0.35	0.03	7	6	< 5	< 5	< 5	20.3	< 0.5	< 0.5	5.8	0.7	6.7	< 0.5	19	1.4	0.72	330
FULA03	1/17/06 12:23	1/18/06 12:23	SF	13																			< 0.5	< 0.5	4.9	< 0.5	6.5	< 0.5	13	1.4	1	
FULA03	1/18/06 12:35		ST		1061	8.49	14.4	16.87																								
FULA03	2/8/06 7:45	2/9/06 6:45	DT	24					0.96	1330	8.07	5.1	< 0.1	0.6	0.18	< 0.02	< 5	< 1	< 5	< 5	< 5	< 5	< 0.5	0.72	7.2	< 0.5	6.2	< 0.5	11	1.2	0.77	585
FULA03	2/8/06 7:45	2/9/06 6:45	DF	24																			< 0.5	0.78	6.6	< 0.5	6.3	< 0.5	11	1.2	0.79	
FULA03	2/9/06 9:13		SVC		1441	8.24	11.47	13.33											< 5	< 5	< 5	< 5	0.27	4.74	14.4	5.58	3.58	0.04	57.6	0.96	0.22	585
FULA03	3/27/06 20:07	3/27/06 21:07	ST	6					28.1	441	6.91	4.7	0.4	2.1	1.46	0.03	90	32	< 2	< 1	< 3	< 3	< 0.5	3.5	39	7.7	10	< 0.5	170	1.6	< 0.5	112
FULA03	3/27/06 20:07	3/27/06 21:07	SF	6																			< 0.5	1.5	25	0.84	7.8	< 0.5	87	1.2	< 0.5	
FULA03	3/27/06 23:07	3/28/06 21:07	ST	12					39.8	400	7.64	4.9	< 0.1	0.8	0.99	0.08	77	18	52.6	< 1	< 3	< 3	< 0.5	5	22	8.2	8.1	< 0.5	120	1.6	< 0.5	116

ST - Stormwater total metals; SF - Stormwater, dissolved metals
DT - Dry weather, total metals; DF - Dry weather, dissolved metals
SVC - Autosampler service time

e- estimated

Aqueous Chemistry at Mass Loading Stations: 2005-06 SAR

Site	Composite or Grab Time		Samples		FieldMeasurements				Turbidity	Specific Conductance	pH	Nitrate as NO_3	Ammonia as N	TKN	Total Phosphate as PO_4	ortho phosphate as P	TSS	VSS	Diazinon	Chlorpyrifos	Dimethoate	Malathion	Cd	Cr	Cu	Pb	Ni	Ag	Zn	As	Se	Hardness as $CaCO_3$
	Start	End	Type	#	EC	pH	TEMP	DO																								
					µS		C	mg/L	NTU	µS			mg/L						ng/L				ug/L									mg/L
FULA03	3/27/06 23:07	3/28/06 21:07	SF	12																			< 0.5	2.4	11	< 0.5	5	< 0.5	36	1.1	< 0.5	
FULA03	3/28/06 8:05		SVC		339	7.91	15.19	10.11																								
FULA03	3/28/06 23:07	3/29/06 19:07	ST	11					256	349	7.63	3.5	0.1	0.5	1.88	0.17	278	38	< 2	< 1	< 3	69.8	0.82	5.8	18	7.9	11	< 0.5	68	2	0.67	96
FULA03	3/28/06 23:07	3/29/06 19:07	SF	11																			< 0.5	0.5	5.8	< 0.5	3.8	< 0.5	6.7	1.4	0.87	
FULA03	3/29/06 8:30		SVC		326	7.96	13.58	11.99																								
FULA03	3/29/06 21:07	3/31/06 7:07	ST	18					84	607	8.38	5.9	0.1	0.7	0.96	0.1	95	15	< 2	< 1	< 3	< 3	< 0.5	2.5	11	2.8	8.2	< 0.5	31	2	0.88	172
FULA03	3/29/06 21:07	3/31/06 7:07	SF	18																			< 0.5	< 0.5	6.3	< 0.5	5.6	< 0.5	6.4	1.5	1.1	
FULA03	3/31/06 7:49		SVC		711	8.51	13.37	12.62																								
FULA03	3/31/06 9:07	4/1/06 1:07	ST	9					33.5	664	8.55	4.7	0.1	0.6	0.5	0.06	24	4	< 2	< 1	< 3	< 3	< 0.5	1.1	8	1.3	6.6	< 0.5	21	1.9	0.64	240
FULA03	3/31/06 9:07	4/1/06 1:07	SF	9																			< 0.5	< 0.5	6.5	< 0.5	6.2	< 0.5	12	1.9	0.89	
FULA03	4/2/06 8:45		SVC		420	8.83	12.36	12.74																								
FULA03	5/22/06 1:57	5/22/06 2:57	ST	6					200	532	6.68	11.2	1.06	6.9	2.32	0.02	816	176	< 2	< 1	< 3	< 3	1.6	16	90	34	34	< 0.5	580	4	0.81	770
FULA03	5/22/06 1:57	5/22/06 2:57	SF	6																			< 0.5	1.2	16	1.2	16	< 0.5	100	1.7	0.71	
FULA03	5/22/06 4:57	5/23/06 18:57	ST	20					17.1	446	7.66	4.86	0.15	0.92	0.98	0.13	27	5	< 2	< 1	< 3	73	1.3	1.1	12	2.4	6.7	< 0.5	43	1.8	0.69	115
FULA03	5/22/06 4:57	5/23/06 18:57	SF	20																			2.7	< 0.5	8.7	< 0.5	5.8	< 0.5	20	1.9	< 0.5	
FULA03	5/22/06 8:38		SVC		429	7.77	18.29	10.06																								
FULA03	5/23/06 20:57	5/26/06 6:57	ST	30					2.08	733	8.94	1.84	0.11	1.18	0.46	0.1	< 5	< 1	52.6	< 1	< 3	< 3	0.72	< 0.5	8.1	< 0.5	6.6	< 0.5	16	2.1	0.56	190
FULA03	5/23/06 20:57	5/26/06 6:57	SF	30																			0.58	< 0.5	6.8	< 0.5	6.5	< 0.5	9.9	1.9	< 0.5	
FULA03	5/24/06 8:20		SVC		730	8.47	19.41	11.7																								
FULA03	5/26/06 8:45		SVC		844	8.54	19.74	12.51																								
HCWF27	7/12/05 7:45	7/13/05 6:45	DT	24					9.6	1160	7.98	9.6	< 0.1	2.7	2.88	1.98	46	18	< 10	< 10	< 10	< 10	1.1	3.1	39	2.6	7.4	< 0.5	140		2.1	300
HCWF27	7/12/05 7:45	7/13/05 6:45	DF	24																			0.83	1.5	14	0.67	5.7	< 0.5	31		1.6	
HCWF27	7/13/05 11:42		SVC		1408	8.22	23.05	6.06																								
HCWF27	7/27/05 7:43	7/28/05 6:43	DT	24					12	1410	8.11	9.3	0.2	3.3	3.1	0.78	27	11	< 10	< 10	< 10	< 10	< 0.5	1.8	26	1.3	6.9	< 0.5	40		0.89	305
HCWF27	7/27/05 7:43	7/28/05 6:43	DF	24																			< 0.5	< 0.5	12	< 0.5	5.4	< 0.5	16		0.83	
HCWF27	7/28/05 7:47		SVC		904	8.89	21.81	9.13																								
HCWF27	8/4/05 11:29		DT		1138	8.95	22.42	10.02	6.24	1460	8.04	16.3	2	3.7	4.15	1.3	21	9	< 10	< 10	< 10	< 10	< 0.5	1.4	13	0.57	6.3	< 0.5	29		0.84	290
HCWF27	8/4/05 11:29		DF																				< 0.5	0.76	7.2	< 0.5	5.4	< 0.5	14		0.73	
HCWF27	8/30/05 8:08	8/31/05 7:08	DT	24					0.93	2780	8.17	6.5	0.2	2.2	2.18	0.63	18	6	< 10	< 10	< 10	< 10	< 0.5	0.91	16	0.67	4.4	< 0.5	20		1	535
HCWF27	8/30/05 8:08	8/31/05 7:08	DF	24																			< 0.5	< 0.5	11	< 0.5	4.2	< 0.5	11		0.89	
HCWF27	8/31/05 9:29		SVC		1121	8.77	21.7	9.47																								
HCWF27	9/20/05 10:50	9/21/05 9:53	DT	24					10.8	991	7.84	33.6	1.9	4.5	2.76	0.68	42	16	< 10	< 10	< 10	< 10	< 0.5	3.8	42	2.5	12	< 0.5	85		1.3	830
HCWF27	9/20/05 10:50	9/21/05 9:53	DF	24																			< 0.5	2.1	34	< 0.5	13	< 0.5	47		3.4	
HCWF27	9/21/05 10:15		SVC		1049	7.86	20.16	16.19																								830
HCWF27	9/27/05 9:02	9/28/05 8:02	DT	24					2.01	1370	8.05	11	< 0.1	2.1	1.97	0.62	12	6	< 10	< 10	< 10	< 10	< 0.5	0.99	19	0.73	5.3	< 0.5	25		0.85	322.5
HCWF27	9/27/05 9:02	9/28/05 8:02	DF	24																			< 0.5	0.54	13	< 0.5	5	< 0.5	14		1.7	
HCWF27	9/28/05 8:49		SVC		1116	8.92	19.13	11.35																								
HCWF27	10/11/05 8:50	10/12/05 7:50	DT	24					15.8	1340	7.77	5.9	0.5	16.3	6.52	0.59	595	225	< 10	< 10	< 10	< 10	2.8	13	140	17	17	< 0.5	430		2.8	342
HCWF27	10/11/05 8:50	10/12/05 7:50	DF	24																			< 0.5	< 0.5	7.7	< 0.5	5	< 0.5	9.1		1.1	
HCWF27	10/12/05 7:59		SVC		796	8.91	18.74	8.81																								
HCWF27	10/25/05 9:40		DT		1111	7.2	18.71	10.47	15.6	1010	8.42	14.9	0.2	1.1	1.74	0.53	< 5	< 1	< 10	< 10	< 10	< 10	< 0.5	0.7	8.8	< 0.5	4.9	< 0.5	14		0.86	985
HCWF27	10/25/05 9:40		DF																				< 0.5	0.61	7.4	< 0.5	4.9	< 0.5	10		0.62	
HCWF27	11/8/05 9:15		DT		1176	8.82	17.78	10.8	1.33	1220	8.24	6.7	0.1	1.3	1.58	0.45	< 5	2	< 10	< 10	< 10	< 10	< 0.5	0.54	7.1	< 0.5	4.1	< 0.5	8.4		0.84	740
HCWF27	11/8/05 9:15		DF																				< 0.5	< 0.5	6.1	< 0.5	4.4	< 0.5	5.7		1.2	
HCWF27	11/29/05 10:18	11/30/05 9:18	DT	24	645	8.13	16.12	9.92	5.64	1250	7.67	20.6	2.2	5.5	2.65	0.81	66	20	29.9	< 5	< 5	< 5	0.54	2.6	20	2.9	6.7	< 0.5	53		1.1	302
HCWF27	11/29/05 10:18	11/30/05 9:18	DF	24																			< 0.5	0.59	6.9	< 0.5	5.6	< 0.5	16		1.4	
HCWF27	12/13/05 8:08	12/14/05 7:08	DT	24					1.92	1160	8.07	18	1	1.8	1.52	0.48	< 5	< 1	< 5	< 5	< 5	< 5	< 0.5	0.5	7.7	< 0.5	4.7	< 0.5	7.9		0.98	790
HCWF27	12/13/05 8:08	12/14/05 7:08	DF	24																			< 0.5	< 0.5	7.8	< 0.5	4.6	< 0.5	7.9		1	
HCWF27	12/14/05 8:08		SVC		1199	7.99	14.14	12.52																								
HCWF27	12/28/05 11:30		DT		1275	8.24	15.18	10.77	3.19	1320	8.58	11.1	< 0.1	1.3	1.64	0.4	20	12	< 5	< 5	< 5	< 5	< 0.5	1.1	16	0.66	6.9	< 0.5	19		0.67	425
HCWF27	12/28/05 11:30		DF																				< 0.5	< 0.5	9.2	< 0.5	6.4	< 0.5	6.5		0.96	

ST - Stormwater total metals; SF - Stormwater, dissolved metals
DT - Dry weather, total metals; DF - Dry weather, dissolved metals
SVC - Autosampler service time

e- estimated

Aqueous Chemistry at Mass Loading Stations: 2005-06 SAR

Site	Composite or Grab Time		Samples		FieldMeasurements				Turbidity	Specific Conductance	pH	Nitrate as NO_3	Ammonia as N	TKN	Total Phosphate as PO_4	ortho phosphate as P	TSS	VSS	Diazinon	Chlorpyrifos	Dimethoate	Malathion	Cd	Cr	Cu	Pb	Ni	Ag	Zn	As	Se	Hardness as $CaCO_3$
	Start	End	Type	#	EC	pH	TEMP	DO																								
					µS		C	mg/L	NTU	µS			mg/L						ng/L				ug/L									mg/L
HCWF27	1/19/06 10:02		DT		1572	8.17	12.17	20.63	1.6	2370	8.47	8.7	< 0.1	0.7	0.4	0.09	5	4	< 5	< 5	< 5	10.1	< 0.5	< 0.5	3.2	< 0.5	7.7	< 0.5	3.5		3.1	835
HCWF27	1/19/06 10:02		DF																				< 0.5	< 0.5	2.7	< 0.5	7.1	< 0.5	2.3		3.7	
HCWF27	1/24/06 8:22	1/25/06 7:22	DT	24					2.65	1270	7.94	12.7	0.2	2.2	1.49	0.44	5	4	13	< 5	< 5	51	< 0.5	4.6	16	0.77	6.4	< 0.5	27		1.1	370
HCWF27	1/24/06 8:22	1/25/06 7:22	DF	24																			< 0.5	1.1	12	< 0.5	4.2	< 0.5	15		1.2	
HCWF27	1/25/06 9:04		SVC		1110	7.67	12.94	17.54																								
HCWF27	2/15/06 8:35	2/16/06 1:35	DT	18					1.6	1290	8.04	17.3	1.3	2.4	2.33	0.62	< 5	2	< 5	36.7	< 5	< 5	< 0.5	2.3	10	0.56	6.7	< 0.5	14		0.57	570
HCWF27	2/15/06 8:35	2/16/06 1:35	DF	18																			< 0.5	< 0.5	9.2	< 0.5	4.3	< 0.5	12		1	
HCWF27	2/16/06 8:35		SVC		1106	7.75	12.72	9.35																								
HCWF27	2/22/06 7:53	2/23/06 6:53	DT	24					2.07	1200	7.90	10.9	0.4	1.4	1.18	0.36	6	4					< 0.5	0.58	12	< 0.5	4.2	< 0.5	12		1.1	275
HCWF27	2/22/06 7:53	2/23/06 6:53	DF	24																			< 0.5	< 0.5	9.6	< 0.5	4.4	< 0.5	9		0.76	
HCWF27	2/23/06 7:41		SVC		1044	7.51	11.52	12.2																								
HCWF27	2/27/06 15:11	2/27/06 16:11	ST	6					38	263	6.91	7.9	0.9	2.4	2.7	0.15	287	85	86.4	75.6	< 5	165	0.82	8.3	75	11	12	< 0.5	270	4.1	< 0.5	86
HCWF27	2/27/06 15:11	2/27/06 16:11	SF	6																			< 0.5	1.7	18	< 0.5	4.8	< 0.5	29	3.1	< 0.5	
HCWF27	2/27/06 18:11	2/28/06 16:11	ST	12					176	788	7.88	18.8	0.3	1.3	1.78	0.4	397	39	30.3	< 5	< 5	144	0.63	5	17	4.4	7.5	< 0.5	68	4.2	< 0.5	215
HCWF27	2/27/06 18:11	2/28/06 16:11	SF	12																			< 0.5	0.99	8.4	< 0.5	3.7	< 0.5	8.9	3.2	0.51	
HCWF27	2/28/06 10:16		SVC		956	8.26	15.29	10.53																								
HCWF27	2/28/06 18:11	3/2/06 8:11	ST	20					1.12	1600	8.35	14	< 0.1	1.1	1.19	0.35	< 5	< 1	11.4	< 5	< 5	< 5	0.73	1.2	8.8	< 0.5	7.5	< 0.5	17	4.7	0.87	480
HCWF27	2/28/06 18:11	3/2/06 8:11	SF	20																			0.67	1.1	8.5	< 0.5	6.7	< 0.5	15	4.7	0.83	
HCWF27	3/2/06 9:03		SVC		1233	8.01	13.25	11.16																								
HCWF27	3/2/06 10:11	3/3/06 8:11	ST	12					1.93	1300	8.09	11.9	0.2	1.3	1.19	0.34	< 5	< 1	< 5	< 5	< 5	< 5	< 0.5	1	11	< 0.5	5.3	< 0.5	16	3.8	0.79	346
HCWF27	3/3/06 10:11	3/4/06 8:11	ST	12					193	966	7.94	12.5	< 0.1	1.1	2.51	0.33	416	54	< 5	< 5	< 5	12.2	0.77	5	19	7.6	8.9	< 0.5	60	5.4	0.66	252
HCWF27	3/3/06 10:11	3/4/06 8:11	SF	12																			< 0.5	0.83	8.6	< 0.5	4.7	< 0.5	6.7	3.7	0.68	
HCWF27	3/4/06 9:12		SVC		1130	8.36	12.54	11.08																								
HCWF27	4/10/06 8:27	4/11/06 7:27	DT	14					38.9	2340	8.08	8.8	0.3	1	2.35	0.44	57	12					< 0.5	1.5	13	1	6.3	< 0.5	30		0.75	390
HCWF27	4/10/06 8:27	4/11/06 7:27	DF	14																			< 0.5	0.93	11	< 0.5	6.3	< 0.5	17		0.7	
HCWF27	4/11/06 9:00		SVC		953	8.21	13.81	11.31																								
HCWF27	4/25/06 7:47	4/26/06 6:47	DT	24					1.95	1340	8.21	12.5	0.7	2.1	2.46	0.73	< 5	< 1	< 2	< 1	< 3	< 3	< 0.5	2	13	< 0.5	5.6	< 0.5	28		1	315
HCWF27	4/25/06 7:47	4/26/06 6:47	DF	24																			< 0.5	1.8	11	< 0.5	5.2	< 0.5	25		0.94	
HCWF27	4/26/06 9:00		SVC		879	8.33	15.04	11.56																								
HCWF27	5/10/06 8:23	5/11/06 7:23	DT	24					3.45	1110	8.07	8.1	0.57	2.34	2.99	0.81	9	5					< 0.5	1.2	16	< 0.5	4.9	< 0.5	28		1.3	220
HCWF27	5/10/06 8:23	5/11/06 7:23	DF	24																			< 0.5	0.81	12	< 0.5	5.6	< 0.5	21		0.87	
HCWF27	5/11/06 8:15		SVC		1007	8.28	17.3	10.14																								
HCWF27	5/24/06 12:59	5/25/06 12:00	DT	24					3.2	1060	8.56	8.43	0.16	1.33	2.61	0.77	< 5	3	13.6	< 1	97.6	81.1	0.52	1.3	14	< 0.5	4.8	< 0.5	23		1.3	255
HCWF27	5/24/06 12:59	5/25/06 12:00	DF	24																			0.5	1.1	13	< 0.5	4.3	< 0.5	19		1.4	
HCWF27	6/13/06 8:06	6/14/06 7:06	DT	15					2.8	1100	8.19	8.45	0.49	1.85	2.86	0.86	8	4					0.94	1	17	0.51	4.7	< 0.5	26		1.7	280
HCWF27	6/13/06 8:06	6/14/06 7:06	DF	15																			0.56	0.78	14	< 0.5	4.3	< 0.5	18		1.7	
HCWF27	6/14/06 8:36		SVC		835	8.35	18.89	9.68																								
HCWF27	6/21/06 10:51	6/22/06 9:51	DT	24					1.47	1100	8.11	7.34	< 0.1	1.71	2.59	0.85	14	4	58.1	< 1	< 3	< 3	< 0.5	1.1	16	0.59	6	< 0.5	20		1.3	224
HCWF27	6/21/06 10:51	6/22/06 9:51	DF	24																			< 0.5	0.78	12	< 0.5	6	< 0.5	13		0.82	
HCWF27	6/22/06 11:22		SVC		910	8.36	20.46	9.21																								
LANF08	7/19/05 10:35	7/20/05 9:35	DT	24					4.76	5730	7.97	26.5	0.3	0.9	0.41	0.03	12	5	< 10	< 10	< 10	< 10	< 0.5	2	14	0.64	8.5	< 0.5	14		19	1010
LANF08	7/19/05 10:35	7/20/05 9:35	DF	24																			< 0.5	1.8	11	< 0.5	8.7	< 0.5	14		19	
LANF08	7/20/05 9:45		DT																< 10	< 10	< 10	< 10										
LANF08	8/16/05 9:52	8/17/05 17:52	DT	9					8.1	5230	8.10	21.8	0.1	1.1	0.6	0.08	10	3					< 0.5	1.5	13	0.88	12	< 0.5	16		16	1300
LANF08	8/16/05 9:52	8/17/05 17:52	DF	9																			< 0.5	0.73	8.2	< 0.5	7.9	< 0.5	7.8		17	
LANF08	8/17/05 9:55		SVC		5881	9.07	21.81	8.87																								
LANF08	9/14/05 8:02		DT		5585	8.5	20.7	7.06	4.16	6220	7.56	26.1	0.2	1.2	0.55	0.1	24	7					< 0.5	0.98	5.9	0.7	12	< 0.5	14		16	1512
LANF08	9/14/05 8:02		DF																				< 0.5	0.51	4.5	< 0.5	11	< 0.5	12		19	
LANF08	10/6/05 9:20		DT		6277	8.64	19.94	10.74	4.69	6540	7.83	25.4	< 0.1	1.1	0.71	0.14	14	5					< 0.5	1.1	15	1	10	< 0.5	22		14	1450
LANF08	10/6/05 9:20		DF																				< 0.5	< 0.5	11	< 0.5	8.7	< 0.5	13		16	
LANF08	11/22/05 10:23		DT						4.67	6060	8.02	35.6	0.2	0.9	0.53	0.11	8	4	< 10	< 10	< 10	< 10	< 0.5	1.2	9.1	1.2	9.6	< 0.5	27		17	

ST - Stormwater total metals; SF - Stormwater, dissolved metals
DT - Dry weather, total metals; DF - Dry weather, dissolved metals
SVC - Autosampler service time

e- estimated

Aqueous Chemistry at Mass Loading Stations: 2005-06 SAR

Site	Composite or Grab Time		Samples		FieldMeasurements				Turbidity	Specific Conductance	pH	Nitrate as NO_3	Ammonia as N	TKN	Total Phosphate as PO_4	ortho phosphate as P	TSS	VSS	Diazinon	Chlorpyrifos	Dimethoate	Malathion	Cd	Cr	Cu	Pb	Ni	Ag	Zn	As	Se	Hardness as $CaCO_3$
	Start	End	Type	#	EC	pH	TEMP	DO																								
					µS		C	mg/L	NTU	µS			mg/L						ng/L				ug/L									mg/L
LANF08	11/22/05 10:23		DF																				< 0.5	0.83	3.9	< 0.5	9.9	< 0.5	18		19	
LANF08	12/14/05 8:32		DT		5938	7.62	13.08	11.61	4.89	6250	7.83	36.5	0.2	1.1	0.86	0.21	21	4					< 0.5	1.9	12	1.3	16	< 0.5	25		17	810
LANF08	12/14/05 8:32		DF																				< 0.5	0.9	6.4	< 0.5	12	< 0.5	17		17	
LANF08	1/4/06 10:03		DT		4635	7.53	15.11	7.34	7.68	2680	7.69	29.5	0.7	1	0.6	0.14	7	3					< 0.5	2.9	6.4	0.8	14	< 0.5	45		10	1085
LANF08	1/4/06 10:03		DF																				< 0.5	2.6	4	< 0.5	18	< 0.5	38		11	
LANF08	2/7/06 8:42	2/8/06 7:42	DT	24					9.31	4780	8.03	30.9	0.2	1.1	0.62	0.1	11	4					< 0.5	3.4	9.3	1	13	< 0.5	19		15	1260
LANF08	2/7/06 8:42	2/8/06 7:42	DF	24																			< 0.5	1.3	6	< 0.5	12	< 0.5	14		14	
LANF08	2/8/06 8:30		SVC		4905	7.31	14.63	10.87																								
LANF08	3/21/06 7:48	3/22/06 7:07	DT	24					32.4	2360	7.82	4.2	0.3	0.6	1.15	0.11	130	20					1.1	4.4	26	7.2	8.4	< 0.5	100		2.2	580
LANF08	3/21/06 7:48	3/22/06 7:07	DF	24																			< 0.5	0.62	5.8	< 0.5	4.4	< 0.5	17		2.2	
LANF08	3/21/06 9:43		SVC		3633	7.79	17.21	5.16																								
LANF08	5/2/06 8:07	5/3/06 7:07	DT	24					2.33	5160	8.16	20.3	< 0.1	0.5	0.39	0.04	< 5	2					< 0.5	2.2	12	< 0.5	12	< 0.5	19		14	1236
LANF08	5/2/06 8:07	5/3/06 7:07	DF	24																			< 0.5	1.9	10	< 0.5	12	< 0.5	16		12	
LANF08	5/3/06 10:19		SVC		5277	8.1	20.05	8.76																								
LANF08	6/7/06 8:37	6/8/06 7:37	DT	24					4.01	5930	8.14	15.5	0.13	0.91	0.61	0.09	12	4					< 0.5	0.97	9.6	0.78	13	< 0.5	21		11	1260
LANF08	6/7/06 8:37	6/8/06 7:37	DF	24																			< 0.5	0.65	7.5	< 0.5	13	< 0.5	15		11	
LANF08	6/8/06 9:30		SVC		5691	7.95	21.07	7.8																								
MIRF07	7/19/05 10:14	7/20/05 9:14	DT	24					2.86	1370	8.80	1.5	0.2	2	0.88	0.1	21	10	< 10	< 10	< 10	< 10	< 0.5	0.64	36	0.92	5.1	< 0.5	19		2.6	264
MIRF07	7/19/05 10:14	7/20/05 9:14	DF	24																			< 0.5	< 0.5	27	< 0.5	5.7	< 0.5	9.9		2.7	
MIRF07	8/16/05 9:13	8/17/05 8:13	DT	24					13.6	1290	8.35	7	0.1	1.8	1.11	0.25	25	10					< 0.5	0.86	19	1.2	4.8	< 0.5	23		1.9	396
MIRF07	8/16/05 9:13	8/17/05 8:13	DF	24																			< 0.5	< 0.5	12	< 0.5	4.5	< 0.5	9.4		2.8	
MIRF07	8/17/05 10:16		SVC		1212	9.35	24.52	19.12																								
MIRF07	9/14/05 7:31		DT		1320	8.56	18.8	8.31	2.75	1420	8.06	8.7	0.2	1.2	0.99	0.24	14	8					< 0.5	0.54	9.8	0.79	5.1	< 0.5	16		2.6	475
MIRF07	9/14/05 7:31		DF																				< 0.5	< 0.5	5	< 0.5	4.7	< 0.5	11		3	
MIRF07	10/5/05 7:53	10/6/05 6:53	DT	24					2.43	1710	8.31	4.8	< 0.1	3.2	0.86	0.17	5	4					< 0.5	< 0.5	24	0.52	5.9	< 0.5	16		2.2	420
MIRF07	10/5/05 7:53	10/6/05 6:53	DF	24																			< 0.5	< 0.5	19	< 0.5	5	< 0.5	10		2.2	
MIRF07	10/6/05 8:23		SVC		1517	8.69	16.43	12.2																								
MIRF07	11/22/05 9:50		DT						1.56	1820	8.98	9.2	0.1	0.7	0.86	0.22	< 5	< 1	< 10	< 10	< 10	< 10	< 0.5	< 0.5	9.7	< 0.5	4.5	< 0.5	7.2		2.6	
MIRF07	11/22/05 9:50		DF																				< 0.5	< 0.5	8.1	< 0.5	5.1	< 0.5	5.2		2.7	
MIRF07	12/20/05 9:39	12/21/05 8:39	DT	24					1.36	1330	8.71	8.2	< 0.1	0.9	0.45	0.1	< 5	< 1					< 0.5	< 0.5	26	< 0.5	6.4	< 0.5	18		3.1	
MIRF07	12/20/05 9:39	12/21/05 8:39	DF	24																			< 0.5	< 0.5	23	< 0.5	7	< 0.5	17		3	
MIRF07	1/4/06 10:20		DT		1468	8.48	15.55	15.32	13.1	1660	8.56	13.8	0.4	1.6	0.57	0.15	11	2					< 0.5	0.84	5.4	0.51	5.5	< 0.5	12		2.4	430
MIRF07	1/4/06 10:20		DF																				< 0.5	< 0.5	4.3	< 0.5	7	< 0.5	7.9		2.6	
MIRF07	2/8/06 8:12		DT		1533	7.71	10.31	15.08	1.75	1500	8.25	8.3	0.1	1.4	0.4	0.06	8	6					< 0.5	< 0.5	9.6	< 0.5	5.7	< 0.5	10		3.1	555
MIRF07	2/8/06 8:12		DF																				< 0.5	< 0.5	7.7	< 0.5	5.6	< 0.5	7.6		2.5	
MIRF07	3/21/06 6:56	3/22/06 5:56	DT	24					4.41	856	8.87	5.2	< 0.1	1.2	0.38	0.05	8	3					< 0.5	0.8	11	0.68	3.3	< 0.5	19		1.4	290
MIRF07	3/21/06 6:56	3/22/06 5:56	DF	24																			< 0.5	0.52	9.1	< 0.5	3.2	< 0.5	8		1.5	
MIRF07	3/21/06 8:20		SVC		1146	8.03	10.61	8.33																								
MIRF07	5/2/06 7:42	5/3/06 6:42	DT	24					16.7	1520	8.61	6.9	< 0.1	2.7	0.55	< 0.02	25	5					< 0.5	1.9	31	1.4	6.9	< 0.5	28		3.2	394
MIRF07	5/2/06 7:42	5/3/06 6:42	DF	24																			< 0.5	0.92	25	< 0.5	5.5	< 0.5	14		2.9	
MIRF07	5/3/06 9:53		SVC		2109	8.99	18.7	10.44																								
MIRF07	6/7/06 8:09	6/8/06 7:09	DT	24					2.26	1130	8.17	6.37	0.42	2.34	1.33	0.31	20	9					< 0.5	0.81	27	0.92	6.9	< 0.5	35		2	415
MIRF07	6/7/06 8:09	6/8/06 7:09	DF	24																			< 0.5	< 0.5	21	< 0.5	6.3	< 0.5	19		2	
MIRF07	6/8/06 8:27		SVC		1431	8.52	20.36	13.48																								
SADF01	7/5/05 8:47	7/6/05 7:47	DT	24					2	2610	8.01	12.4	< 0.1	0.6	0.12	< 0.02	< 5	2	< 10	< 10	< 10	< 10	< 0.5	0.66	18	0.51	8.5	< 0.5	12		11	850
SADF01	7/5/05 8:47	7/6/05 7:47	DF	24																			< 0.5	0.56	12	< 0.5	8.7	< 0.5	11		11	
SADF01	7/6/05 8:21		SVC		2820	8.77	20.32	8.61																								
SADF01	7/27/05 9:51	7/28/05 8:51	DT	24					3.24	2940	7.99	10.9	0.1	0.9	0.16	< 0.02	7	3	< 10	< 10	< 10	< 10	< 0.5	< 0.5	19	0.64	8.8	< 0.5	14		10	900
SADF01	7/27/05 9:51	7/28/05 8:51	DF	24																			< 0.5	< 0.5	13	< 0.5	8.8	< 0.5	10		11	
SADF01	7/28/05 8:45		SVC		2690	8.84	23.37	9.86																								
SADF01	8/17/05 12:50		DT		2420	9.32	26.34	17.57																								

ST - Stormwater total metals; SF - Stormwater, dissolved metals
DT - Dry weather, total metals; DF - Dry weather, dissolved metals
SVC - Autosampler service time

e- estimated

Aqueous Chemistry at Mass Loading Stations: 2005-06 SAR

Site	Composite or Grab Time		Samples		FieldMeasurements				Turbidity	Specific Conductance	pH	Nitrate as NO_3	Ammonia as N	TKN	Total Phosphate as PO_4	ortho phosphate as P	TSS	VSS	Diazinon	Chlorpyrifos	Dimethoate	Malathion	Cd	Cr	Cu	Pb	Ni	Ag	Zn	As	Se	Hardness as $CaCO_3$
	Start	End	Type	#	EC	pH	TEMP	DO																								
					µS		C	mg/L	NTU	µS			mg/L						ng/L				ug/L									mg/L
SADF01	8/21/05 11:04	8/22/05 10:04	DT	24					1.62	2670	8.08	11.9	< 0.1	0.9	0.2	< 0.02	< 5	< 1	< 10	< 10	< 10	< 10	< 0.5	< 0.5	6.9	< 0.5	9.1	< 0.5	10	1.8	9.8	1095
SADF01	8/21/05 11:04	8/22/05 10:04	DF	24					1.62	2670	8.08	11.9	< 0.1	0.9	0.2	< 0.02	< 5	< 1	< 10	< 10	< 10	< 10	< 0.5	< 0.5	6.9	< 0.5	7.9	< 0.5	6.4	1.8	9.8	
SADF01	8/22/05 10:07		SVC		2638	9.41	22.54	17.12																								
SADF01	8/30/05 9:45	8/31/05 8:45	DT	24					0.55	1030	8.02	11.6	0.1	1	0.12	< 0.02	< 5	< 1	< 10	< 10	< 10	< 10	< 0.5	< 0.5	13	< 0.5	5.8	< 0.5	7.2		9.8	850
SADF01	8/30/05 9:45	8/31/05 8:45	DF	24																			< 0.5	< 0.5	11	< 0.5	8	< 0.5	8.8		10	
SADF01	8/31/05 10:48		SVC		2480	8.79	24.79	18.98																								
SADF01	8/31/05 10:49		DT		2480	8.79	24.79	18.98																								
SADF01	9/20/05 2:45		ST		594	7.91	22.07	4.03	52.2	660	7.03	10.6	1	7	3.11	0.12	430	160	77.3	< 5	< 5	< 5	2.1	17	180	57	31	0.64	870		2.2	
SADF01	9/20/05 2:45		SF																				< 0.5	2.5	29	4.4	17	< 0.5	220		1.2	
SADF01	9/20/05 14:26	9/21/05 4:56	DT	14					21.4	1280	7.16	3.9	1.7	12.3	3.2	0.04	200	90	< 10	< 10	< 10	< 10	1.8	7	110	20	31	< 0.5	540		4.6	712
SADF01	9/20/05 14:26	9/21/05 4:56	DF	14																			0.59	3.2	44	3.7	30	< 0.5	370		2.8	
SADF01	9/21/05 9:55		SVC		1480	7.76	21.37	13.25																								
SADF01	9/28/05 10:00		DT		1435	8.96	20.49	16.04	2.44	2980	7.94	10.4	0.1	1	0.27	< 0.02	13	7	< 10	< 10	< 10	< 10	< 0.5	< 0.5	15	0.51	9	< 0.5	16		11	910
SADF01	9/28/05 10:00		DF																				< 0.5	< 0.5	7.8	< 0.5	10	< 0.5	10		12	
SADF01	10/11/05 10:10	10/12/05 9:10	DT	24					1.37	3060	7.87	12.5	0.2	0.9	0.31	0.04	< 5	< 1	< 10	< 10	< 10	< 10	< 0.5	< 0.5	32	< 0.5	8.3	< 0.5	12		10	436
SADF01	10/11/05 10:10	10/12/05 9:10	DF	24																			< 0.5	< 0.5	21	< 0.5	8.4	< 0.5	12		11	
SADF01	10/12/05 9:10		SVC		2620	8.83	18.97	8.59																								
SADF01	10/14/05 10:35		DT		2546	8.83	20.99	14.93																								
SADF01	10/16/05 16:56	10/16/05 17:56	ST	6					7.2	2070	7.73	15.6	1	2.6	0.87	0.09	14	11	< 5	< 5	< 5	150	0.62	1.6	39	4.1	11	< 0.5	120	2.9	8.3	1125
SADF01	10/16/05 16:56	10/16/05 17:56	SF	6																			< 0.5	0.95	21	1.5	11	< 0.5	74	2.7	7.4	
SADF01	10/16/05 19:56	10/18/05 21:56	ST	26					18.3	730	7.24	9.2	0.7	3.2	1.62	0.18	70	25	< 10	< 10	< 10	< 10	0.55	4.6	46	9.5	12	< 0.5	160	3.2	3.3	234
SADF01	10/16/05 19:56	10/18/05 21:56	SF	26																			< 0.5	1.9	23	1.5	9.7	< 0.5	87	2.8	3	
SADF01	10/17/05 11:08		SVC		919	7.14	19.51	6.73																								
SADF01	10/18/05 23:56	10/20/05 21:56	ST	24					15.3	2190	8.02	10.6	0.4	1	0.59	0.12	23	6	< 10	< 10	< 10	< 10	< 0.5	1.3	11	2	9.1	< 0.5	32	2.2	6.1	640
SADF01	10/18/05 23:56	10/20/05 21:56	SF	24																			< 0.5	0.65	7.5	0.93	8.1	< 0.5	24	2.4	6.1	
SADF01	10/19/05 10:07		SVC		1660	8.81	19.65	10.26																								
SADF01	10/21/05 10:26		SVC		2525	8.88	19.2	10.42																								
SADF01	10/25/05 11:07		DT		2278	7.16	21.17	14.02	2.11	2200	8.07	13.9	0.2	0.5	0.41	0.11	< 5	< 1	< 10	< 10	< 10	< 10	< 0.5	0.5	5.7	< 0.5	7.9	< 0.5	13		9.2	1180
SADF01	10/25/05 11:07		DF																				< 0.5	< 0.5	3.3	< 0.5	8.2	< 0.5	10		8.9	
SADF01	11/1/05 10:31	11/2/05 9:31	DT	24					1.34	3000	8.19	14.5	0.8	1.3	0.21	0.03	< 5	1	< 5	< 5	< 5	< 5	< 0.5	< 0.5	6.5	< 0.5	8.1	< 0.5	11	1.5	12	960
SADF01	11/1/05 10:31	11/2/05 9:31	DF	24																			< 0.5	< 0.5	5.1	< 0.5	8.1	< 0.5	9.7		10	
SADF01	11/2/05 12:05		SVC		2457	9.02	21.62	18.79											< 1	< 1	< 1	< 1	0.22	2.69	17.1	37.7	7.14	0.8	91.1	1.42	0.74	960
SADF01	11/14/05 10:55		DT		2580	8.03	19.62	16.27	1.01	2710	8.07	16.2	< 0.1	0.6	0.36	< 0.02	< 5	< 1	< 5	< 5	< 5	< 5	< 0.5	0.9	5	< 0.5	8.4	< 0.5	13		9.4	930
SADF01	11/14/05 10:55		DF																				< 0.5	0.79	3.6	< 0.5	8.4	< 0.5	11		9.1	
SADF01	12/6/05 11:55		DT		2661	8	16.25	21.46	1.12	2890	8.09	17.1	< 0.1	0.6	0.14	< 0.02	< 5	< 1	< 5	< 5	< 5	< 5	< 0.5	< 0.5	4.5	< 0.5	13	< 0.5	9.5		13	1585
SADF01	12/6/05 11:55		DF																				< 0.5	< 0.5	3.2	< 0.5	10	< 0.5	8.4		15	
SADF01	12/28/05 9:55		DT		2321	7.72	15.62	13.59	1.79	2400	7.96	14.3	< 0.1	0.8	0.21	< 0.02	< 5	< 1	< 5	< 5	< 5	< 5	< 0.5	0.5	7.6	< 0.5	11	< 0.5	14		6.1	875
SADF01	12/28/05 9:55		DF																				< 0.5	< 0.5	4.7	< 0.5	11	< 0.5	12		7.6	
SADF01	1/11/06 11:48	1/12/06 10:48	DT	25					11.04	2300	7.96	13.4	< 0.1	0.9	0.39	0.05	9	5	< 5	< 5	< 5	< 5	< 0.5	0.64	11	0.86	7.7	< 0.5	16		8.4	725
SADF01	1/11/06 11:48	1/12/06 10:48	DF	25																			< 0.5	< 0.5	7.1	< 0.5	7.8	< 0.5	10		8.7	
SADF01	1/12/06 10:12		SVC		2650	8.04	14.9	13.66																								
SADF01	2/1/06 9:16	2/2/06 8:16	DT	24					5.8	2350	8.07	11.9	0.1	0.7	0.45	< 0.02	49	20	37	< 5	< 5	< 5	< 0.5	0.63	7.9	0.96	9.8	< 0.5	16	1.8	8.1	1015
SADF01	2/1/06 9:16	2/2/06 8:16	DF	24																			< 0.5	< 0.5	4.8	< 0.5	9.8	< 0.5	11	1.5	7.6	
SADF01	2/2/06 9:03		SVC		2470	7.61	14.43	13.61																								
SADF01	2/27/06 16:02	2/27/06 17:02	ST	6					33.5	1340	7.25	14	0.8	2.6	1.45	< 0.02	195	56	< 5	< 5	< 5	53.7	1.3	4.9	82	19	14	< 0.5	240	2.4	5.2	398
SADF01	2/27/06 16:02	2/27/06 17:02	SF	6																			0.52	1.1	32	1.5	10	< 0.5	81	1.5	4.9	
SADF01	2/27/06 19:02	2/28/06 17:02	ST	12					15.7	488	7.58	2.5	0.3	0.8	0.61	0.09	82	20	< 5	< 5	< 5	55.3	< 0.5	2.3	26	8.6	5	< 0.5	86	1.9	1.7	135
SADF01	2/27/06 19:02	2/28/06 17:02	SF	12																			< 0.5	< 0.5	7.6	< 0.5	3.3	< 0.5	10	1.4	1.6	
SADF01	2/28/06 13:50		SVC		437	7.92	19.08	10.97																								
SADF01	2/28/06 19:02	3/2/06 7:02	ST	19					21.6	2700	7.88	23.9	< 0.1	0.6	0.36	0.06	10	3	< 5	< 5	< 5	< 5	< 0.5	0.63	7.9	0.98	12	< 0.5	26	1.8	13	905
SADF01	2/28/06 19:02	3/2/06 7:02	SF	19																			< 0.5	0.51	4.8	< 0.5	11	< 0.5	21	1.6	12	

ST - Stormwater total metals; SF - Stormwater, dissolved metals
DT - Dry weather, total metals; DF - Dry weather, dissolved metals
SVC - Autosampler service time

e- estimated

Aqueous Chemistry at Mass Loading Stations: 2005-06 SAR

Site	Composite or Grab Time		Samples		FieldMeasurements				Turbidity	Specific Conductance	pH	Nitrate as NO_3	Ammonia as N	TKN	Total Phosphate as PO_4	ortho phosphate as P	TSS	VSS	Diazinon	Chlorpyrifos	Dimethoate	Malathion	Cd	Cr	Cu	Pb	Ni	Ag	Zn	As	Se	Hardness as $CaCO_3$
	Start	End	Type	#	EC	pH	TEMP	DO																								
					µS		C	mg/L	NTU	µS			mg/L						ng/L				ug/L									mg/L
SADF01	3/2/06 9:02	3/3/06 7:02	ST	12					3.5	3130	8.03	29.8	< 0.1	0.6	0.34	0.05	15	6	< 5	< 5	< 5	< 5	< 0.5	0.83	9.9	1.4	13	< 0.5	29	1.9	17	1090
SADF01	3/2/06 11:30		SVC		1111	9.24	22.02	18.67																								
SADF01	3/3/06 9:02	3/4/06 7:02	ST	12					42	1270	7.49	13.1	< 0.1	0.7	0.93	0.1	70	16	12.9	< 5	< 5	32	< 0.5	3.1	21	11	7.8	< 0.5	96	1.9	6.1	514
SADF01	3/3/06 9:02	3/4/06 7:02	SF	12																			< 0.5	0.89	6.4	< 0.5	5.8	< 0.5	29	1.2	5.4	
SADF01	3/4/06 11:53		SVC		2219	7.91	17.05	14.71																								
SADF01	3/21/06 8:50	3/22/06 7:50	DT	24					3.04	1930	7.87	18.6	0.2	0.5	0.31	0.04	< 5	< 1	6.1	< 1	< 3	33.6	< 0.5	0.6	6.3	0.94	7.7	< 0.5	22		8.7	675
SADF01	3/21/06 8:50	3/22/06 7:50	DF	24																			< 0.5	0.5	5.6	< 0.5	7.2	< 0.5	20		8.3	
SADF01	3/21/06 8:54		SVC		2651	7.88	14.96	12.94																								
SADF01	4/18/06 9:18	4/19/06 8:18	DT	24					1.19	3150	8.08	31.1	0.9	1.4	0.31	0.04	< 5	< 1	< 2	< 1	< 3	< 3	< 0.5	0.67	6.6	< 0.5	18	< 0.5	17		16	1110
SADF01	4/18/06 9:18	4/19/06 8:18	DF	24																			< 0.5	< 0.5	5.6	< 0.5	18	< 0.5	16		16	
SADF01	4/19/06 9:55		SVC		3095	7.91	18.76	12.97																								
SADF01	5/17/06 10:51	5/17/06 14:51	DT	6					5.03	26100	8.30	16.9	0.27	1.35	0.34	< 0.02	42	14	< 2	< 1	< 3	< 3	< 0.5	0.76	12	1.4	12	< 0.5	18		10	870
SADF01	5/17/06 10:51	5/17/06 14:51	DF	6																			< 0.5	< 0.5	8	< 0.5	13	< 0.5	6.6		10	
SADF01	5/18/06 10:12		SVC		2755	7.94	19.75	10.32																								
SADF01	5/29/06 9:05	5/30/06 8:05	DT	24					1.26	2970	8.10	26.1	0.29	0.87	0.11	< 0.02	< 5	1					< 0.5	< 0.5	7.8	< 0.5	13	< 0.5	8.4		18	1225
SADF01	5/29/06 9:05	5/30/06 8:05	DF	24																			< 0.5	< 0.5	6.4	< 0.5	13	< 0.5	6.8		17	
SADF01	5/30/06 10:00		SVC		3210	8.05	21.49	18.07																								
SADF01	6/14/06 10:15		DT		3106	8.23	22.72	19.05	1.32	3020	8.24	25.9	0.19	0.69	0.17	< 0.02	< 5	1					< 0.5	< 0.5	8.2	< 0.5	13	< 0.5	7		16	1175
SADF01	6/14/06 10:15		DF																				< 0.5	< 0.5	5.9	< 0.5	13	< 0.5	5.3		14	
SADF01	6/26/06 9:33	6/27/06 11:03	DT	10					1.2	3130	8.06	25.9	< 0.1	0.62	0.15	< 0.02	7	3	< 2	< 1	< 3	< 3	< 0.5	< 0.5	6.3	< 0.5	15	< 0.5	7.2	1.6	16	1175
SADF01	6/26/06 9:33	6/27/06 11:03	DF	10																			< 0.5	< 0.5	4.9	< 0.5	13	< 0.5	7.5	1.4	13	
SADF01	6/27/06 10:48		SVC		3031	7.76	23.36	14.3																								
SDMF05	7/5/05 8:23	7/6/05 7:23	DT	24					35.1	2770	8.40	10.5	0.2	1.3	0.58	< 0.02	70	25	< 10	< 10	< 10	< 10	< 0.5	1.3	5.4	1	6.5	< 0.5	16	4.8	16	620
SDMF05	7/5/05 8:23	7/6/05 7:23	DF	24																			< 0.5	< 0.5	3.5	< 0.5	6.1	< 0.5	7.2	4.7	17	
SDMF05	7/6/05 8:05		SVC		2794	9.02	24.53	13.91																								
SDMF05	7/12/05 9:20	7/13/05 3:02	DT	19					29.4	2830	8.31	12.7	< 0.1	1.6	0.44	< 0.02	57	17	< 10	< 10	< 10	< 10	0.64	1.5	12	2.5	10	< 0.5	19	6.6	18	625
SDMF05	7/12/05 9:20	7/13/05 3:02	DF	19																			0.56	0.7	2.3	0.56	8	< 0.5	5.5	5.5	19	
SDMF05	7/13/05 10:38		SVC		2839	8.23	25.93	19.44																								
SDMF05	7/19/05 11:02	7/20/05 10:02	DT	24					16.4	2840	8.22	11.9	< 0.1	1.2	0.39	< 0.02	44	15	< 10	< 10	< 10	< 10	< 0.5	0.59	5.3	0.69	5.3	< 0.5	4.9	5.4	19	700
SDMF05	7/19/05 11:02	7/20/05 10:02	DF	24																			< 0.5	< 0.5	4.2	< 0.5	5.5	< 0.5	4.5	4.8	18	
SDMF05	7/28/05 8:31		DT		2970	8.9	26.81	10.39	28.3	2880	8.29	13.1	< 0.1	1.4	0.4	< 0.02	60	16	< 10	< 10	< 10	< 10	< 0.5	1.5	5	1	8.2	< 0.5	28	7.2	18	660
SDMF05	7/28/05 8:31		DF																				< 0.5	< 0.5	2.9	< 0.5	7.2	< 0.5	6.6	7.4	19	
SDMF05	8/4/05 13:01		DT		2846	9.18	26.89	11.34	18.4	3810	8.37	14.1	< 0.1	1.4	0.33	0.03	31	11	< 10	< 10	< 10	< 10	< 0.5	0.97	2.2	1	6.4	< 0.5	8.1	5.5	15	670
SDMF05	8/4/05 13:01		DF																				< 0.5	< 0.5	1.2	< 0.5	5.9	< 0.5	5.5	5	15	
SDMF05	8/8/05 9:33	8/9/05 8:33	DT	24					23.3	3980	8.32	8.7	0.1	1.7	0.41	< 0.02	50	36	< 10	< 10	< 10	< 10	< 0.5	0.87	6.4	1.2	6.4	< 0.5	12	5.9	15	650
SDMF05	8/8/05 9:33	8/9/05 8:33	DF	24																			< 0.5	< 0.5	4.2	< 0.5	6	< 0.5	4	6.3	17	
SDMF05	8/9/05 9:14		SVC		2886	9.16	26.22	16.92																								
SDMF05	8/16/05 10:13	8/17/05 9:13	DT	24					17.2	2790	8.13	18	< 0.1	0.8	0.41	0.02	26	8	< 10	< 10	< 10	< 10	< 0.5	0.87	4.7	0.82	6.4	< 0.5	7.9	5.2	16	710
SDMF05	8/16/05 10:13	8/17/05 9:13	DF	24																			< 0.5	< 0.5	3	< 0.5	6	< 0.5	2.6	5.2	18	
SDMF05	8/17/05 11:45		SVC		2955	9.15	23.65	13.02																								710
SDMF05	8/21/05 10:24	8/22/05 9:24	DT	24					12.4	2930	8.22	11.5	< 0.1	1.4	0.36	< 0.02	< 5	< 1	< 10	< 10	< 10	< 10	< 0.5	0.58	2.9	0.57	8.7	< 0.5	5.4	5.6	20	715
SDMF05	8/21/05 10:24	8/22/05 9:24	DF	24																			< 0.5	< 0.5	2.6	< 0.5	7.4	< 0.5	3.1	5.4	16	
SDMF05	8/22/05 9:26		SVC		2962	9.43	24.33	12.57																								
SDMF05	8/30/05 9:21	8/31/05 8:21	DT	24					3.76	1600	8.27	13.1	0.1	1.5	0.36	< 0.02	30	8	< 10	< 10	< 10	< 10	< 0.5	0.79	5.1	0.92	6.1	< 0.5	7.5	5	14	950
SDMF05	8/30/05 9:21	8/31/05 8:21	DF	24																			< 0.5	< 0.5	5.9	< 0.5	8.6	< 0.5	4.4	6.1	19	
SDMF05	8/31/05 10:24		SVC		3032	8.72	26.5	12.94																								
SDMF05	8/31/05 10:36		DT		3032	8.72	26.5	12.94																								
SDMF05	9/6/05 9:01	9/7/05 8:01	DT	24					9.21	2500	8.18	11.9	0.2	1	0.36	< 0.02	31	9	< 10	< 10	< 10	< 10	< 0.5	0.92	4.2	0.92	6.8	< 0.5	6.6	5.2	15	680
SDMF05	9/6/05 9:01	9/7/05 8:01	DF	24																			< 0.5	< 0.5	2.9	< 0.5	6.6	< 0.5	3.3	4.7	16	
SDMF05	9/7/05 9:17		SVC		2938	9.05	24.28	12.43																								
SDMF05	9/14/05 9:36		DT		2641	8.76	22.79	15.62	9.48	3140	8.22	16.9	0.2	1.5	0.44	< 0.02	28	7	< 10	< 10	< 10	< 10	< 0.5	0.58	2.4	0.64	6.6	< 0.5	4.6	5.3	18	770

ST - Stormwater total metals; SF - Stormwater, dissolved metals
DT - Dry weather, total metals; DF - Dry weather, dissolved metals
SVC - Autosampler service time

e- estimated

Aqueous Chemistry at Mass Loading Stations: 2005-06 SAR

Site	Composite or Grab Time		Samples		FieldMeasurements				Turbidity	Specific Conductance	pH	Nitrate as NO_3	Ammonia as N	TKN	Total Phosphate as PO_4	ortho phosphate as P	TSS	VSS	Diazinon	Chlorpyrifos	Dimethoate	Malathion	Cd	Cr	Cu	Pb	Ni	Ag	Zn	As	Se	Hardness as $CaCO_3$
	Start	End	Type	#	EC	pH	TEMP	DO																								
					µS		C	mg/L	NTU	µS			mg/L						ng/L				ug/L									mg/L
SDMF05	9/14/05 9:36		DF																				< 0.5	< 0.5	1.6	< 0.5	5.9	< 0.5	2.2	5.1	21	
SDMF05	9/20/05 10:03	9/21/05 9:03	DT	24					12.5	1810	7.25	22.4	0.8	6.3	1.4	0.06	28	16	< 10	< 10	< 10	< 10	0.5	2.9	23	2.6	18	< 0.5	94	5.9	12	609
SDMF05	9/20/05 10:03	9/21/05 9:03	DF	24																			< 0.5	2.1	14	0.88	17	< 0.5	76	5.6	7.9	
SDMF05	9/20/05 14:16		ST		2295	7.79	22.24	2.26	13.7	2540	7.30	33.1	< 0.1	6.2	1.41	0.05	33	17	< 5	< 5	< 5	125	0.64	2.8	15	1.7	15	< 0.5	65	6.7	15	
SDMF05	9/20/05 14:16		SF																				< 0.5	2	8.4	0.6	15	< 0.5	50	7.5	16	
SDMF05	9/21/05 9:30		SVC		1080	7.58	21.54	12.75																								
SDMF05	9/27/05 9:57	9/28/05 8:57	DT	24					2.69	3380	8.30	31.3	< 0.1	1.2	0.36	0.03	25	10	< 10	< 10	< 10	< 10	< 0.5	0.64	5.2	< 0.5	10	< 0.5	7.7	5.9	21	700
SDMF05	9/27/05 9:57	9/28/05 8:57	DF	24																			< 0.5	< 0.5	3.8	< 0.5	8.6	< 0.5	4.4	6.5	25	
SDMF05	9/28/05 9:26		SVC		2916	9.03	22.72	14.57																								
SDMF05	9/28/05 9:27		DT		2916	9.03	22.72	14.57																								700
SDMF05	10/5/05 9:28	10/6/05 8:28	DT	24					3.6	3010	8.19	29.2	< 0.1	1.3	0.32	< 0.02	22	5	< 10	< 10	< 10	< 10	< 0.5	0.87	6	0.56	7.1	< 0.5	7.5	5.4	18	715
SDMF05	10/5/05 9:28	10/6/05 8:28	DF	24																			< 0.5	< 0.5	3.8	< 0.5	5.7	< 0.5	2.5	5.5	20	
SDMF05	10/6/05 9:41		SVC		2864	8.83	21.22	14.68																								
SDMF05	10/11/05 9:28	10/12/05 8:28	DT	24					4.29	3070	8.27	30.5	0.2	1.1	0.39	0.03	31	7	< 10	< 10	< 10	< 10	< 0.5	1.1	6	0.78	7.6	< 0.5	11	6.5	17	402
SDMF05	10/11/05 9:28	10/12/05 8:28	DF	24																			< 0.5	< 0.5	3.7	< 0.5	7.5	< 0.5	5	6.5	19	
SDMF05	10/12/05 8:28		SVC		2658	8.88	20.79	13.31																								
SDMF05	10/14/05 10:05		DT		2975	8.89	20.41	17.32																								
SDMF05	10/16/05 22:41	10/16/05 23:41	ST	6					5.85	2410	8.13	28.9	0.4	1.2	0.62	0.11	22	6	< 5	< 5	< 5	25.3	< 0.5	1.2	6.3	0.95	6.4	< 0.5	17	5.8	15	1105
SDMF05	10/16/05 22:41	10/16/05 23:41	SF	6																			< 0.5	< 0.5	3.2	< 0.5	5.7	< 0.5	5.5	5.3	18	
SDMF05	10/17/05 1:41	10/19/05 9:41	ST	5					23.5	1440	7.73	27.6	0.7	3	1.4	0.21	40	16														
SDMF05	10/17/05 10:28		SVC		920	7.14	18.27	6.76																								
SDMF05	10/19/05 9:49		SVC		1001	8.86	18.41	8.34																								
SDMF05	10/19/05 11:41	10/20/05 3:41	ST	21					14.8	1960	8.00	25.9	0.6	1.2	1.2	0.28	26	6	14.3	< 5	119	39.7	< 0.5	1.4	7.4	1	8.1	< 0.5	17	5.2	8.3	425
SDMF05	10/19/05 11:41	10/20/05 3:41	SF	21																			< 0.5	< 0.5	4.2	< 0.5	7.1	< 0.5	8.1	5.6	9.3	
SDMF05	10/21/05 9:43		SVC		2388	8.87	19.68	8.47																								
SDMF05	10/25/05 10:43		DT		2822	7.11	18.98	9.36	7.86	2710	8.07	38.4	0.5	0.8	0.92	0.21	18	6	< 10	< 10	< 10	< 10	< 0.5	0.86	2.7	0.5	8.5	< 0.5	9.8	6.7	17	1220
SDMF05	10/25/05 10:43		DF																				< 0.5	< 0.5	1.3	< 0.5	8.2	< 0.5	5.4	7.3	20	
SDMF05	11/1/05 10:07	11/2/05 9:07	DT	24	2752	8.85	18.78	12.34	14.1	3000	8.26	39.2	0.6	1.2	0.51	0.1	29	26	< 5	< 5	< 5	< 5	< 0.5	1.2	5.1	0.85	8.8	< 0.5	13	5.6	23	805
SDMF05	11/1/05 10:07	11/2/05 9:07	DF	24																			< 0.5	< 0.5	2.8	< 0.5	6.7	< 0.5	6.2		25	
SDMF05	11/1/05 10:50		SVC		3188	9.26	19.84	13.37																								
SDMF05	11/8/05 10:40		DT		2891	8.81	18.4	10.48	14.4	3040	8.04	38.5	0.5	1.1	0.42	0.05	36	7	< 10	< 10	< 10	< 10	< 0.5	1.4	3.5	1	8.3	< 0.5	11	5.3	18	1215
SDMF05	11/8/05 10:40		DF																				< 0.5	< 0.5	1.3	< 0.5	7.1	< 0.5	3.6	6	24	
SDMF05	11/14/05 9:30		DT		2537	8.62	17.56	11.7	8.61	2590	8.27	37.4	0.2	1.2	0.77	0.08	54	12	< 5	< 5	< 5	< 5	< 0.5	2.1	5.6	1.1	8.3	< 0.5	15	6	19	675
SDMF05	11/14/05 9:30		DF																				< 0.5	< 0.5	2.7	< 0.5	7.7	< 0.5	6.1	5.4	19	
SDMF05	11/22/05 11:10		DT						14.7	2950	8.25	43.5	0.2	1	0.52	0.06	33	6	< 10	< 10	< 10	< 10	0.94	2	4.4	1.4	7.9	< 0.5	24	4.7	23	
SDMF05	11/22/05 11:10		DF																				< 0.5	< 0.5	2.1	< 0.5	7.9	< 0.5	4.9	4.8	26	
SDMF05	11/29/05 11:38	11/30/05 10:38	DT	24	2880	8.09	15.69	14.26	7.93	2950	8.22	46.8	< 0.1	1.6	0.54	0.05	40	6	< 5	< 5	< 5	< 5	< 0.5	1	5.7	1	7	< 0.5	11	5	25	730
SDMF05	11/29/05 11:38	11/30/05 10:38	DF	24																			< 0.5	0.52	3.9	< 0.5	7.2	< 0.5	5.4	5.9	26	
SDMF05	12/6/05 10:50		DT		2433	7.9	14.16	9.51	6.18	2620	7.93	36.5	0.4	1.2	0.51	0.09	15	4	< 5	< 5	< 5	52.9	< 0.5	0.85	3.8	< 0.5	11	< 0.5	10	4.8	18	1115
SDMF05	12/6/05 10:50		DF																				< 0.5	< 0.5	2.9	< 0.5	9.3	< 0.5	7.2	6.1	20	
SDMF05	12/13/05 9:08	12/14/05 8:08	DT	24					10.6	2990	8.05	32.8	< 0.1	1.4	0.55	0.04	25	5	< 5	< 5	32	20.2	< 0.5	1.7	5.1	0.79	8.3	< 0.5	9.4	4.5	15	815
SDMF05	12/13/05 9:08	12/14/05 8:08	DF	24																			< 0.5	1	3.5	< 0.5	7.6	< 0.5	4.4	4.3	17	
SDMF05	12/14/05 9:29		SVC		2818	7.95	12.83	15.65																								
SDMF05	12/20/05 9:34	12/21/05 8:34	DT	24					14.2	2650	8.12	28.5	< 0.1	1.7	0.44	< 0.02	24	8	< 5	< 5	< 5	< 5	< 0.5	1	8.2	0.66	10	< 0.5	7.8	4.5	20	
SDMF05	12/20/05 9:34	12/21/05 8:34	DF	24																			< 0.5	< 0.5	3.1	< 0.5	7.5	< 0.5	3.7	3.5	19	
SDMF05	12/28/05 10:20		DT		2892	7.9	16.02	12.87	10.7	2990	8.30	30	0.2	1.1	0.41	< 0.02	21	7	< 5	< 5	< 5	< 5	< 0.5	0.92	2.4	< 0.5	9.2	< 0.5	6.2	4	17	825
SDMF05	12/28/05 10:20		DF																				< 0.5	< 0.5	1.5	< 0.5	8.4	< 0.5	4.5	3.7	21	
SDMF05	1/4/06 11:11		ST		1052	7.99	14.42	10.82	39.1	955	7.78	18.3	0.5	0.8	1.47	0.33	45	7					< 0.5	2.3	6.3	1.3	6.9	< 0.5	17	4.3	3.9	190
SDMF05	1/4/06 11:11		SF																				< 0.5	0.56	3.6	< 0.5	6.3	< 0.5	7.8	4	4.4	
SDMF05	1/11/06 10:18	1/12/06 9:18	DT	24					13.7	3030	8.06	31.3	< 0.1	0.7	0.57	0.02	25	8	< 5	< 5	< 5	< 5	< 0.5	1	4.1	0.77	10	< 0.5	11	4.7	21	825
SDMF05	1/11/06 10:18	1/12/06 9:18	DF	24																			< 0.5	< 0.5	2	< 0.5	7.6	< 0.5	4.6	3.7	20	

ST - Stormwater total metals; SF - Stormwater, dissolved metals
DT - Dry weather, total metals; DF - Dry weather, dissolved metals
SVC - Autosampler service time

e- estimated

Aqueous Chemistry at Mass Loading Stations: 2005-06 SAR

Site	Composite or Grab Time		Samples		FieldMeasurements				Turbidity	Specific Conductance	pH	Nitrate as NO_3	Ammonia as N	TKN	Total Phosphate as PO_4	ortho phosphate as P	TSS	VSS	Diazinon	Chlorpyrifos	Dimethoate	Malathion	Cd	Cr	Cu	Pb	Ni	Ag	Zn	As	Se	Hardness as $CaCO_3$
	Start	End	Type	#	EC	pH	TEMP	DO											ng/L								ug/L					
					µS		C	mg/L	NTU	µS			mg/L																			mg/L
SDMF05	1/12/06 9:45		SVC		2891	8.12	13.6	13.74																								
SDMF05	1/19/06 11:05		DT		2851	7.36	13.96	15.07	12.1	2900	8.22	34.3	< 0.1	0.5	0.4	< 0.02	26	8	< 5	< 5	< 5	< 5	< 0.5	0.61	2.6	< 0.5	9.2	< 0.5	6.1	3.4	21	785
SDMF05	1/19/06 11:05		DF																				< 0.5	< 0.5	1.8	< 0.5	8.7	< 0.5	5.6	4.6	21	
SDMF05	1/23/06 10:40		DT		2654	8.11	11.35	12.84																								
SDMF05	1/24/06 9:11	1/25/06 8:11	DT	24					13.6	2750	8.20	32.5	< 0.1	0.9	0.38	< 0.02	27	7	< 5	< 5	< 5	< 5	< 0.5	2.1	6	0.83	8.3	< 0.5	9.9	4.4	18	740
SDMF05	1/24/06 9:11	1/25/06 8:11	DF	24																			< 0.5	0.57	4.7	< 0.5	7.4	< 0.5	5.9	3.6	18	
SDMF05	1/25/06 9:46		SVC		2451	7.91	11.69	12.04																								
SDMF05	2/1/06 8:50	2/2/06 7:50	DT	24					12.1	2910	8.16	31.3	< 0.1	0.6	0.32	< 0.02	27	17	< 5	< 5	< 5	< 5	< 0.5	0.75	5.4	0.66	8.9	< 0.5	8.6	4.6	19	1040
SDMF05	2/1/06 8:50	2/2/06 7:50	DF	24																			< 0.5	< 0.5	3.9	< 0.5	9.1	< 0.5	13	4.4	19	
SDMF05	2/2/06 8:37		SVC		2758	7.66	14.47	11.91											< 5	< 5	< 5	< 5	0.93	18.8	21.4	9.25	11.8	0.16	104	4.26	2.21	1040
SDMF05	2/7/06 9:08	2/8/06 8:08	DT	24					12.1	2660	8.05	30.7	0.1	0.8	0.37	< 0.02	21	6					< 0.5	0.93	4.5	0.59	8.7	< 0.5	7.5	4.8	18	795
SDMF05	2/7/06 9:08	2/8/06 8:08	DF	24																			< 0.5	< 0.5	3.2	< 0.5	8	< 0.5	5.8	4.1	19	
SDMF05	2/8/06 8:51		SVC		2713	7.57	14.94	12.06																								
SDMF05	2/15/06 9:57	2/16/06 8:57	DT	24					21.9	2800	8.13	27.9	0.2	0.6	0.41	< 0.02	37	7					< 0.5	0.67	3.3	0.94	6.9	< 0.5	8.3	3.8	18	935
SDMF05	2/15/06 9:57	2/16/06 8:57	DF	24																			< 0.5	< 0.5	2.1	< 0.5	6.6	< 0.5	7.3	3.3	17	
SDMF05	2/16/06 10:05		SVC		2874	7.74	15.75	10.92																								
SDMF05	2/22/06 8:54	2/23/06 7:54	DT	24					9.93	2710	7.84	23.4	0.1	0.8	0.45	0.05	21	5					< 0.5	0.64	5.5	0.65	8.6	< 0.5	11	3.3	15	560
SDMF05	2/22/06 8:54	2/23/06 7:54	DF	24																			< 0.5	< 0.5	4.1	< 0.5	7.9	< 0.5	8.9	3.5	15	
SDMF05	2/23/06 8:17		SVC		2397	7.45	13.58	13.61																								
SDMF05	2/27/06 18:08	2/27/06 19:08	ST	6					20.4	4100	8.11	24.5	< 0.1	0.7	0.5	< 0.02	50	10	< 5	< 5	< 5	< 5	< 0.5	0.98	5.4	0.74	8.4	< 0.5	11	3.7	18	640
SDMF05	2/27/06 18:08	2/27/06 19:08	SF	6																			< 0.5	< 0.5	3.3	< 0.5	7.8	< 0.5	4.3	3.5	17	
SDMF05	2/27/06 21:08	2/28/06 19:08	ST	12					99	507	7.45	11.9	0.2	0.9	1.68	0.29	188	28	< 5	< 5	121	96.4	1.1	3.6	19	4.8	6.3	< 0.5	61	3.5	1.8	120
SDMF05	2/27/06 21:08	2/28/06 19:08	SF	12																			< 0.5	0.59	6.9	< 0.5	3.2	< 0.5	11	2.6	1.6	
SDMF05	2/28/06 13:12		SVC		437	7.87	16.33	11.54																								
SDMF05	2/28/06 21:08	3/1/06 13:08	ST	9					52	1000	7.64	19.3	0.2	0.9	1.63	0.32	82	13	< 5	< 5	276	95	0.5	2	10	2	6	< 0.5	24	3.6	4.5	470
SDMF05	2/28/06 21:08	3/1/06 13:08	SF	9																			< 0.5	< 0.5	6.5	< 0.5	5.5	< 0.5	9.9	3.1	4.2	
SDMF05	3/1/06 15:08	3/2/06 9:08	ST	10					19.1	1450	7.95	26	< 0.1	0.9	1.23	0.27	38	6	< 5	< 5	237	25.6	< 0.5	1.2	7	1.1	6.6	< 0.5	17	4.1	7.4	490
SDMF05	3/1/06 15:08	3/2/06 9:08	SF	10																			< 0.5	< 0.5	4.8	< 0.5	6	< 0.5	7.9	3.7	6.6	
SDMF05	3/2/06 11:03		SVC		1650	7.63	16.15	10.27																								
SDMF05	3/2/06 11:08	3/3/06 9:08	ST	12					18.5	1910	7.90	28.7	< 0.1	1	1.01	0.21	27	5	< 5	< 5	64.5	12.5	< 0.5	0.86	5.1	0.74	7	< 0.5	12	4.9	11	452
SDMF05	3/3/06 11:08	3/4/06 9:08	ST	12					87.5	810	7.59	9.4	< 0.1	0.6	1.44	0.17	128	20	< 5	< 5	21.6	121	< 0.5	2.8	13	4.3	5.8	< 0.5	45	3.8	3.5	192
SDMF05	3/3/06 11:08	3/4/06 9:08	SF	12																			< 0.5	< 0.5	4.8	< 0.5	3.3	< 0.5	6.1	2.4	2.3	
SDMF05	3/4/06 11:19		SVC		780	7.8	15.05	9.84																								
SDMF05	3/15/06 10:55		ST		1789	7.83	14.69	12.47	15	1830	9.56	20.1	0.2	0.8	0.63	0.06	29	6					< 0.5	0.57	3.5	0.64	6.2	< 0.5	7.6	3.7	9	455
SDMF05	3/15/06 10:55		SF																				< 0.5	< 0.5	2.4	< 0.5	6.2	< 0.5	3.1	3.2	8.6	
SDMF05	3/21/06 8:07	3/22/06 7:07	DT	24					79	712	7.66	8.6	0.3	0.7	1.47	0.19	101	15	11.4	< 1	23.4	90.6	< 0.5	1.6	7.4	2.5	4.4	< 0.5	29	2.5	2.7	190
SDMF05	3/21/06 8:07	3/22/06 7:07	DF	24																			< 0.5	< 0.5	2.4	< 0.5	3	< 0.5	5.2	2	2.4	
SDMF05	3/21/06 9:47		SVC		938	7.8	15.68	10.02																								
SDMF05	3/27/06 11:05		ST		2161	8.09	18.49	11.44	19.3	2190	7.84	22.8	< 0.1	0.7	0.48	0.02	33	9					< 0.5	0.64	3.1	0.77	7.3	< 0.5	8.7	4.6	15	600
SDMF05	3/27/06 11:05		SF																				< 0.5	< 0.5	1.6	< 0.5	7	< 0.5	3.4	4.6	16	
SDMF05	4/10/06 9:48	4/11/06 8:48	DT	24					25.5	1900	8.39	15.8	< 0.1	0.5	0.97	< 0.02	45	11					< 0.5	1	3.7	0.87	9.2	< 0.5	11	4.2	11	490
SDMF05	4/10/06 9:48	4/11/06 8:48	DF	24																			< 0.5	< 0.5	2.1	< 0.5	9.3	< 0.5	4	3.7	11	
SDMF05	4/11/06 10:00		SVC		1980	8.19	18.85	13.9																								
SDMF05	4/18/06 8:52	4/19/06 7:52	DT	24					13.6	1770	8.15	14.7	0.1	0.6	0.86	0.03	42	10	< 2	< 1	< 3	30.4	< 0.5	0.94	4.7	0.95	8.7	< 0.5	12	3.9	9.2	395
SDMF05	4/18/06 8:52	4/19/06 7:52	DF	24																			< 0.5	< 0.5	2.4	< 0.5	8.3	< 0.5	6.1	3.6	9.9	
SDMF05	4/19/06 9:35		SVC		1764	8.38	20.34	13.56																								
SDMF05	4/25/06 9:50	4/26/06 8:50	DT	24					26.4	1740	8.11	11.3	< 0.1	0.8	0.66	< 0.02	43	10	< 2	< 1	< 3	25.2	< 0.5	1.5	4.6	1.1	7.4	< 0.5	12	4	9	440
SDMF05	4/25/06 9:50	4/26/06 8:50	DF	24																			< 0.5	< 0.5	2.4	< 0.5	6.8	< 0.5	3.7	3.2	8.1	
SDMF05	4/26/06 10:43		SVC		1962	7.89	19.1	9.68																								
SDMF05	5/3/06 10:47		DT		2466	8.22	20.94	7.26	20.3	2430	8.06	17.9	< 0.1	1.3	0.55	< 0.02	22	7					< 0.5	1.1	3.3	0.86	8.8	< 0.5	9.1	3.9	16	628
SDMF05	5/3/06 10:47		DF																				< 0.5	< 0.5	2.4	< 0.5	8.7	< 0.5	5.1	3.1	15	

ST - Stormwater total metals; SF - Stormwater, dissolved metals
DT - Dry weather, total metals; DF - Dry weather, dissolved metals
SVC - Autosampler service time

e- estimated

Aqueous Chemistry at Mass Loading Stations: 2005-06 SAR

Site	Composite or Grab Time		Samples		FieldMeasurements				Turbidity	Specific Conductance	pH	Nitrate as NO_3	Ammonia as N	TKN	Total Phosphate as PO_4	ortho phosphate as P	TSS	VSS	Diazinon	Chlorpyrifos	Dimethoate	Malathion	Cd	Cr	Cu	Pb	Ni	Ag	Zn	As	Se	Hardness as $CaCO_3$
	Start	End	Type	#	EC	pH	TEMP	DO																								
					µS		C	mg/L	NTU	µS			mg/L						ng/L				ug/L									mg/L
SDMF05	5/10/06 9:18	5/11/06 8:18	DT	24					21.2	2740	8.08	20.8	0.13	0.69	0.58	< 0.02	30	10					0.55	1.1	5.1	0.97	10	< 0.5	13	4.5	16	620
SDMF05	5/10/06 9:18	5/11/06 8:18	DF	24																			< 0.5	< 0.5	3.3	< 0.5	9.8	< 0.5	7.7	3.9	15	
SDMF05	5/11/06 9:11		SVC		2623	8.13	21.46	12.33																								
SDMF05	5/17/06 10:18	5/18/06 9:18	DT	24					15.2	2890	8.26	16	0.11	0.86	0.46	< 0.02	33	7	< 2	< 1	< 3	< 3	< 0.5	0.67	4	0.92	10	< 0.5	9.6	4.9	19	690
SDMF05	5/17/06 10:18	5/18/06 9:18	DF	24																			< 0.5	< 0.5	2.6	< 0.5	9.9	< 0.5	4.3	4.6	18	
SDMF05	5/18/06 9:26		SVC		2692	8.18	23.1	11.93																								
SDMF05	5/24/06 13:48	5/25/06 12:50	DT	24					20.8	2030	8.33	21.3	0.12	1.31	1.01	0.06	37	30	< 2	< 1	189	106	< 0.5	1	6	1.1	8	< 0.5	14	5.8	12	498
SDMF05	5/24/06 13:48	5/25/06 12:50	DF	24																			< 0.5	< 0.5	3.8	< 0.5	7.1	< 0.5	4.7	4.8	11	
SDMF05	5/29/06 8:39	5/29/06 15:39	DT	7					46	2560	8.16	13.9	0.17	0.51	1.09	< 0.02	78	21					0.8	1.5	6.2	1.9	9.2	< 0.5	17	6.1	18	750
SDMF05	5/29/06 8:39	5/29/06 15:39	DF	7																			< 0.5	< 0.5	2.7	< 0.5	8.4	< 0.5	2.9	5.2	17	
SDMF05	5/30/06 9:30		SVC		2781	8.21	23.52	14.05																								
SDMF05	6/7/06 8:57	6/8/06 7:57	DT	24					28.4	2650	8.14	25.5	0.22	0.92	0.67	0.06	47	14					0.62	1.5	5.5	1.4	11	< 0.5	14	7.4	19	705
SDMF05	6/7/06 8:57	6/8/06 7:57	DF	24																			< 0.5	< 0.5	2.5	< 0.5	8.9	< 0.5	4.7	6	17	
SDMF05	6/8/06 9:54		SVC		2799	8.03	22.52	8.34																								
SDMF05	6/13/06 9:35	6/14/06 8:35	DT	14					15.4	2660	8.24	23.5	0.52	1.12	0.59	< 0.02	38	24					< 0.5	0.81	5.8	0.8	8.3	< 0.5	11	6	16	680
SDMF05	6/13/06 9:35	6/14/06 8:35	DF	14																			< 0.5	< 0.5	3.8	< 0.5	7.6	< 0.5	3.8	5.1	15	
SDMF05	6/14/06 9:45		SVC		2782	8.27	24.34	14.13																								
SDMF05	6/21/06 10:20	6/22/06 9:20	DT	24					4.15	2910	8.15	19.2	< 0.1	0.91	0.52	< 0.02	22	8	< 2	< 1	< 3	< 3	< 0.5	0.62	5.4	0.55	9.1	< 0.5	9.8	6.5	16	608
SDMF05	6/21/06 10:20	6/22/06 9:20	DF	24																			< 0.5	< 0.5	4	< 0.5	9.1	< 0.5	4.5	6.2	17	
SDMF05	6/22/06 12:15		SVC		2896	8.5	26.3	13.52																								
SDMF05	6/26/06 9:03	6/27/06 1:03	DT	17					9.2	2750	8.03	12.1	0.35	0.89	0.66	< 0.02	25	11	< 2	< 1	< 3	< 3	< 0.5	0.62	3.4	< 0.5	9.3	< 0.5	8.4	6.2	13	625
SDMF05	6/26/06 9:03	6/27/06 1:03	DF	17																			< 0.5	< 0.5	2.2	< 0.5	7.4	< 0.5	3.8	6	12	
SDMF05	6/27/06 10:05		SVC		2868	7.84	25.71	12.41																								
TBTD02	11/15/05 12:09		DT		52494	7.88	18.69	3.87	1.75	52000	7.82	< 0.4	< 0.1	< 0.2	0.13	< 0.02	27	23	< 5	< 5	< 5	< 5	0.017	0.59	17.3	0.216	10.7	0.37	4.45	2.89	0.54	
TBTD02	11/15/05 12:09		DF																				0.217	0.34	0.307	0.024	0.334	< 0.005	3.29	1.63	< 10	
TBTD02	2/9/06 9:50		DT		51348	7.14	14.68	11.6	4.6	51800	7.78	0.4	< 0.1	0.8	0.31	< 0.02	33	11	< 5	< 5	< 5	< 5	0.09	1.35	1.46	0.802	18.7	0.25	102	7.44	0.033	5650
TBTD02	2/9/06 9:50		DF																				0.089	0.27	0.682	0.013	0.54	< 0.005	2.85	0.983	0.007	
WYLSED	7/5/05 7:59	7/6/05 6:59	DT	24					2.7	2210	8.21	81.1	< 0.1	0.6	0.23	0.03	11	7	< 10	< 10	< 10	< 10	< 0.5	1.1	4.2	< 0.5	7.5	< 0.5	8.3		4.8	560
WYLSED	7/5/05 7:59	7/6/05 6:59	DF	24																			< 0.5	0.97	3.9	< 0.5	7.5	< 0.5	8		4.8	
WYLSED	7/6/05 7:49		SVC		2281	8.83	19.66	11.02																								
WYLSED	7/12/05 8:40	7/13/05 7:40	DT	24					1.4	2240	8.19	81.4	< 0.1	< 0.5	0.19	0.07	< 5	< 1	< 10	< 10	< 10	< 10	0.66	1.3	6	0.66	9.7	< 0.5	4.5		5.8	615
WYLSED	7/12/05 8:40	7/13/05 7:40	DF	24																			0.68	1.3	5.5	0.67	10	< 0.5	4.4		6.5	
WYLSED	7/13/05 10:57		SVC		2230	8.26	28.6	4.1																								
WYLSED	8/4/05 12:29		DT		2263	9.12	31.28	14.68	2.04	2090	8.52	70.3	< 0.1	0.9	0.32	0.07	5	3	< 10	< 10	< 10	< 10	< 0.5	0.7	1.9	< 0.5	6.9	< 0.5	4		4	585
WYLSED	8/4/05 12:29		DF																				< 0.5	0.66	1.6	< 0.5	7.2	< 0.5	5.3		3.8	
WYLSED	8/8/05 9:15	8/9/05 8:15	DT	24					1.53	3090	8.11	65.4	0.2	0.8	0.31	< 0.02	5	2	< 10	< 10	< 10	< 10	< 0.5	0.81	5.6	< 0.5	7.1	< 0.5	6.9		3.8	584
WYLSED	8/8/05 9:15	8/9/05 8:15	DF	24																			< 0.5	0.82	6.1	< 0.5	7.8	< 0.5	6.5		5.4	
WYLSED	8/9/05 8:57		SVC		2278	9.01	21.84	22.7																								
WYLSED	8/21/05 9:37	8/22/05 8:37	DT	24					0.75	2370	8.13	72.5	0.1	0.7	0.37	< 0.02	< 5	< 1	< 10	< 10	< 10	< 10	< 0.5	0.78	2.5	< 0.5	8.6	< 0.5	3.5	4.9	4.4	720
WYLSED	8/21/05 9:37	8/22/05 8:37	DF	24																			< 0.5	0.78	2.3	< 0.5	8.6	< 0.5	4.5	4.5	4.4	
WYLSED	8/22/05 8:45		SVC		2356	9.26	20.28	12.91																								
WYLSED	9/6/05 8:18	9/6/05 19:18	DT	12					0.56	220	8.12	18.9	0.1	0.6	0.28	0.07	< 5	< 1	< 10	< 10	< 10	< 10	< 0.5	0.77	5.4	< 0.5	10	< 0.5	5.5		5.5	635
WYLSED	9/6/05 8:18	9/6/05 19:18	DF	12																			< 0.5	0.74	4.9	< 0.5	8.7	< 0.5	5		4.5	
WYLSED	9/7/05 8:52		SVC		2241	8.94	19.71	11.27																								
WYLSED	9/20/05 13:50		DT		1881	7.74	22.88	19.24	3.6	2040	7.69	42.9	0.7	3.8	1.17	0.2	40	8	< 5	< 5	< 5	< 5	< 0.5	1.6	10	0.96	15	< 0.5	32		3.6	
WYLSED	9/20/05 13:50		DF																				< 0.5	0.88	6.8	< 0.5	13	< 0.5	21		3.7	
WYLSED	10/5/05 8:30	10/6/05 7:30	DT	24					0.57	2470	8.06	71.5	< 0.1	0.8	0.51	0.13	< 5	< 1	< 10	< 10	< 10	< 10	< 0.5	0.79	5.2	< 0.5	8.9	< 0.5	5.7		4.1	660
WYLSED	10/5/05 8:30	10/6/05 7:30	DF	24																			< 0.5	0.63	4.2	< 0.5	6.9	< 0.5	2.9		4.8	
WYLSED	10/6/05 8:54		SVC		2360	8.42	16.46	13.73																								
WYLSED	10/17/05 0:13	10/17/05 1:13	ST	6					25	912	7.51	18.9	0.8	3.9	2.55	0.39	191	171	< 5	< 5	< 5	17.5	0.97	4.8	26	3.8	13	< 0.5	77	5.4	1.2	805
WYLSED	10/17/05 0:13	10/17/05 1:13	SF	6																			< 0.5	0.77	9.3	< 0.5	7.8	< 0.5	15	4.2	1.8	

ST - Stormwater total metals; SF - Stormwater, dissolved metals
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e- estimated

Aqueous Chemistry at Mass Loading Stations: 2005-06 SAR

Site	Composite or Grab Time		Samples		FieldMeasurements				Turbidity	Specific Conductance	pH	Nitrate as NO_3	Ammonia as N	TKN	Total Phosphate as PO_4	ortho phosphate as P	TSS	VSS	Diazinon	Chlorpyrifos	Dimethoate	Malathion	Cd	Cr	Cu	Pb	Ni	Ag	Zn	As	Se	Hardness as $CaCO_3$
	Start	End	Type	#	EC	pH	TEMP	DO											ng/L				ug/L									mg/L
WYLSED	10/17/05 3:13	10/18/05 21:13	ST	22					39.1	971	7.60	24.1	0.6	2.9	1.83	0.32	120	25	< 10	< 10	< 10	< 10	0.79	4.5	18	3.2	11	< 0.5	52	5.3	1.8	268
WYLSED	10/17/05 3:13	10/18/05 21:13	SF	22																			< 0.5	0.64	8.7	< 0.5	7.9	< 0.5	12	4.7	1.5	
WYLSED	10/17/05 9:49		ST		1275	7.07	18.45	9.36																								
WYLSED	10/18/05 23:13	10/21/05 3:13	ST	27					4.3	2150	8.12	40.6	0.2	1	1.1	0.31	26	6	< 10	< 10	< 10	< 10	< 0.5	0.7	6	< 0.5	8.8	< 0.5	9.5	5.1	2.7	510
WYLSED	10/18/05 23:13	10/21/05 3:13	SF	27																			< 0.5	< 0.5	4.9	< 0.5	8.4	< 0.5	6.7	5.6	3	
WYLSED	10/19/05 9:15		SVC		1595	8.78	16.25	11.83																								
WYLSED	10/21/05 9:01		SVC		2007	8.84	18.21	9.52																								
WYLSED	11/1/05 9:33	11/2/05 8:33	DT	24					2.7	2000	8.35	67.9	< 0.1	0.7	1.01	0.28	< 5	2	< 5	< 5	< 5	< 5	< 0.5	0.73	3.1	< 0.5	7.9	< 0.5	6.9		3.5	710
WYLSED	11/1/05 9:33	11/2/05 8:33	DF	24																			< 0.5	0.78	2.7	< 0.5	10	< 0.5	6.1	5.2	5.1	
WYLSED	11/2/05 10:25		SVC		2212	8.95	20.51	15.56											< 1	< 1	< 1	< 1	0.24	0.64	1.63	0.92	1.23	0.8	10.1	0.77	0.42	710
WYLSED	11/29/05 11:08	11/30/05 10:08	DT	24	2317	8.27	17.53	14.19	0.73	2410	8.18	87.7	< 0.1	0.5	0.49	0.1	< 5	1	< 5	< 5	< 5	< 5	< 0.5	0.91	4.7	< 0.5	6.7	< 0.5	6.2		5.1	678
WYLSED	11/29/05 11:08	11/30/05 10:08	DF	24																			< 0.5	0.96	4.5	< 0.5	8.5	< 0.5	6		6.7	
WYLSED	12/22/05 9:04		DT		2360	7.94	13.73	14.75	1.24	2260	8.24	74.5	< 0.1	0.6	0.36	< 0.02	6	3	< 5	< 5	< 5	< 5	< 0.5	0.97	3.2	< 0.5	10	< 0.5	6		3.8	687.5
WYLSED	12/22/05 9:04		DF																				< 0.5	0.8	2.6	< 0.5	9.8	< 0.5	3.6		4.4	
WYLSED	12/28/05 10:40		DT		2330	8.01	16.58	13.67											< 5	< 5	< 5	< 5	< 0.5	0.69	1.4	< 0.5	9.2	< 0.5	3.6		4.3	705
WYLSED	12/28/05 10:40		DF						0.72	2400	8.37	71.9	< 0.1	0.6	0.41	0.12	< 5	< 1					< 0.5	0.66	1.3	< 0.5	8.3	< 0.5	2.7		3.6	
WYLSED	1/11/06 10:31	1/12/06 9:31	DT	24					1.02	2350	8.10	72.9	< 0.1	0.5	0.67	0.2	< 5	< 1	< 5	e 6.25	< 5	< 5	< 0.5	0.68	3.1	< 0.5	8.3	< 0.5	4.9		4.9	620
WYLSED	1/11/06 10:31	1/12/06 9:31	DF	24																			< 0.5	0.68	2.7	< 0.5	8.2	< 0.5	4		4	
WYLSED	1/12/06 9:30		SVC		2248	8.12	11.78	15.59																								
WYLSED	2/1/06 8:08	2/2/06 7:08	DT	24					0.92	2350	8.22	77.5	< 0.1	0.4	0.36	0.1	< 5	< 1	< 5	< 5	7.6	< 5	< 0.5	0.74	2.8	< 0.5	9.6	< 0.5	5.9	5	4.1	4310
WYLSED	2/1/06 8:08	2/2/06 7:08	DF	24																			< 0.5	0.79	2.5	< 0.5	9	< 0.5	5.6	3.7	3.7	
WYLSED	2/2/06 9:30		SVC		2290	8.17	12.35	17.89											< 5	< 5	< 5	< 5	0.15	2.07	1.15	1.11	0.98	0.08	8.03	0.79	0.14	4310
WYLSED	2/27/06 19:18	2/27/06 20:18	SF	6																			< 0.5	0.82	8.6	< 0.5	6	< 0.5	12	3.8	0.77	
WYLSED	2/27/06 22:18	2/28/06 20:18	ST	12					200	488	7.58	14.2	0.3	0.9	2.56	0.36	411	56	< 5	< 5	507	192	1.2	6.7	24	6.4	11	< 0.5	79	4.4	0.75	125
WYLSED	2/27/06 22:18	2/28/06 20:18	SF	12																			< 0.5	0.53	13	< 0.5	4.2	< 0.5	11	2.6	< 0.5	
WYLSED	2/28/06 11:56		SVC		478	7.9	16.69	10.84																								
WYLSED	2/28/06 19:18		ST						55.2	790	7.46	17.5	0.3	1.4	1.81	0.15	190	31	< 5	< 5	< 5	38.5	0.74	3.1	20	2.7	8	< 0.5	55	3.8	1.1	180
WYLSED	3/1/06 12:18	3/2/06 12:18	ST	13					2.56	1610	8.13	36.3	0.2	0.7	0.87	0.22	13	3	< 5	< 5	151	< 5	< 0.5	0.79	4.5	< 0.5	8.4	< 0.5	10	5.1	2.8	405
WYLSED	3/1/06 12:18	3/2/06 12:18	SF	13																			< 0.5	0.53	3.7	< 0.5	7.6	< 0.5	7.6	3.9	2.5	
WYLSED	3/2/06 10:40		SVC		1673	7.88	17.61	13.11																								
WYLSED	3/2/06 14:18	3/3/06 12:18	ST	12					1.74	1880	8.15	53.9	< 0.1	0.5	0.73	0.21	< 5	< 1	< 5	< 5	44.6	< 5	< 0.5	0.71	3.6	< 0.5	8.1	< 0.5	6.2	6.8	3.3	500
WYLSED	3/3/06 14:18	3/4/06 12:18	ST	12					110	890	7.69	20.8	< 0.1	0.7	1.84	0.2	434	235	< 5	< 5	720	89.2	1.1	3.4	18	5.4	8.4	< 0.5	94	4.8	1.1	240
WYLSED	3/3/06 14:18	3/4/06 12:18	SF	12																			< 0.5	< 0.5	3.6	< 0.5	5.1	< 0.5	15	3.1	1.2	
WYLSED	3/4/06 10:33		SVC		1292	8	16.03	11.51																								
WYLSED	3/21/06 7:24	3/22/06 6:24	DT	24					26.2	1070	7.89	20.5	0.2	0.5	1.19	0.21	66	11	< 2	< 1	79	54.8	< 0.5	1.4	5.9	1.1	5.8	< 0.5	17		2	275
WYLSED	3/21/06 7:24	3/22/06 6:24	DF	24																			< 0.5	< 0.5	3.2	< 0.5	4.4	< 0.5	3.8		1.2	
WYLSED	3/21/06 9:00		SVC		1472	7.74	15.3	6.05																								
WYLSED	4/17/06 12:00	4/18/06 11:00	DT	24					1.12	1880	8.27	57.6	0.1	0.7	0.74	0.21	< 5	< 1					< 0.5	0.69	3.5	< 0.5	12	< 0.5	6.4		3.5	595
WYLSED	4/17/06 12:00	4/18/06 11:00	DF	24																			< 0.5	0.73	3.2	< 0.5	9.7	< 0.5	5.8		3.6	
WYLSED	4/18/06 11:59		SVC		1862	8.17	24.66	14.15																								
WYLSED	4/24/06 9:00	4/25/06 8:00	DT	24					1.81	2480	8.20	74.8	< 0.1	0.7	0.65	0.14	5	3					< 0.5	0.78	3.4	< 0.5	11	< 0.5	7.5		3.9	550
WYLSED	4/24/06 9:00	4/25/06 8:00	DF	24																			< 0.5	0.73	2.9	< 0.5	9.7	< 0.5	5.1		3.8	
WYLSED	4/25/06 11:29		SVC		2048	8.41	20.71	16.34																								
WYLSED	5/1/06 9:00	5/2/06 8:00	DT	24					1.02	2110	8.26	76.5	0.1	0.6	0.44	0.11	5	2					0.86	0.96	4.5	< 0.5	10	< 0.5	7.3		4.1	575
WYLSED	5/1/06 9:00	5/2/06 8:00	DF	24																			0.8	0.95	4	< 0.5	10	< 0.5	6		4.3	
WYLSED	5/2/06 9:46		SVC		2097	8.32	18.58	12.91																								
WYLSED	5/17/06 9:33	5/18/06 8:33	DT	24					0.53	2360	8.21	70.9	< 0.1	0.59	0.4	0.1	< 5	1	< 2	< 1	< 3	< 3	< 0.5	0.89	3.6	< 0.5	11	< 0.5	5.7		4	600
WYLSED	5/17/06 9:33	5/18/06 8:33	DF	24																			< 0.5	0.86	3.2	< 0.5	11	< 0.5	5.5		4	
WYLSED	5/18/06 9:02		SVC		2225	8.21	19.84	10.54																								
WYLSED	6/13/06 8:55	6/14/06 7:55	DT	24					0.85	2200	8.15	72.7	0.17	0.54	0.32	0.06	< 5	1					< 0.5	0.88	3.2	< 0.5	8.3	< 0.5	4.5		4.5	610
WYLSED	6/13/06 8:55	6/14/06 7:55	DF	24																			< 0.5	0.78	2.7	< 0.5	8.7	< 0.5	4		4	

ST - Stormwater total metals; SF - Stormwater, dissolved metals
DT - Dry weather, total metals; DF - Dry weather, dissolved metals
SVC - Autosampler service time

e- estimated

Aqueous Chemistry at Mass Loading Stations: 2005-06 SAR

Site	Composite or Grab Time		Samples		FieldMeasurements				Turbidity	Specific Conductance	pH	Nitrate as NO_3	Ammonia as N	TKN	Total Phosphate as PO_4	ortho phosphate as P	TSS	VSS	Diazinon	Chlorpyrifos	Dimethoate	Malathion	Cd	Cr	Cu	Pb	Ni	Ag	Zn	As	Se	Hardness as $CaCO_3$
	Start	End	Type	#	EC	pH	TEMP	DO																								
					µS		C	mg/L	NTU	µS			mg/L						ng/L				ug/L									mg/L
WYLSED	6/14/06 9:12		SVC		2123	8.27	22.59	12.37																								
WYLSED	6/26/06 7:58	6/27/06 6:58	DT	24					1.27	2280	8.23	79.5	0.12	0.55	0.38	0.06	10	2	< 2	< 1	< 3	< 3	< 0.5	0.83	3.9	< 0.5	11	< 0.5	6.5	4.7	5.3	590
WYLSED	6/26/06 7:58	6/27/06 6:58	DF	24																			< 0.5	0.7	3.1	< 0.5	9.9	< 0.5	5.8	4.4	5	
WYLSED	6/27/06 9:16		SVC		2381	7.99	24.14	11.74											< 5	< 5	< 5	< 5	0.1	1	0.7	0.73	0.7	0.2	6.2	0.5	0.1	590

ST - Stormwater total metals; SF - Stormwater, dissolved metals
DT - Dry weather, total metals; DF - Dry weather, dissolved metals
SVC - Autosampler service time

e- estimated

Sediment Chemistry in Lower Newport Bay

	Site	LNBHIR					LNBRIN					LNBSBI	LNBTUB				
	Date	8/26/05	11/17/05	3/8/06	4/20/06	6/21/06	8/26/05	11/17/05	3/8/06	4/20/06	6/21/06	3/8/06	8/26/05	11/17/05	3/8/06	4/20/06	6/21/06
	Time	9:30	12:40	12:26	9:13	9:30	8:40	13:30	12:47	10:47	10:20	11:30	7:50	14:10	13:06	9:59	11:00
10-day Amphipod Surv.	% Survival	3	3		12	13	66	88		97	66		77	78		90	36
Nitrogen	mg/kg		835		690	785		1180		988	764			1260		941	1030
Phosphorus	mg/kg		626		564	538		42.3		607	572			358		62	551
TOC-S	%C	1.49	1.38	1.46	1.44	1.54	1.38	1.88	2.25	2.05	1.8	0.17	2.01	2.05	2.11	1.94	2.09
%Clay	%	30.38		31.27	10.04	28.65	19.96		46.97	36.04	30.19	4.78	50.57		47.63	44.69	53.7
%Silt + Clay	%	89.48		91.84	28.84	78.48	33.95		72.76	69.04	48.97	13.19	97.07		92.21	86.27	96.07
Metals																	
Ag	mg/kg	0.48	1.44	0.24	0.08	<0.025	0.3	1.78	0.34	0.14	<0.025	0.06	0.53	1.78	0.3	0.19	<0.025
Al	mg/kg	>50000	>50000	>50000	>50000	22800	>50000	34300	>50000	>50000	18000	>50000	>50000	>50000	>50000	>50000	2320
As	mg/kg	9.44	13.4	4.65	9.28	6.41	11.4	13.7	13.5	8.38	8.24	2.31	11.8	15.1	9.96	12.2	0.86
Ba	mg/kg	186	172	86.3	148	140	124	104	146	71.9	77.9	23.3	173	153	161	134	11.3
Be	mg/kg	1.02	1.44	0.43	1.03	1.08	0.8	1.07	0.88	0.61	0.86	0.09	1.22	1.59	0.94	1.14	0.13
Cd	mg/kg	1.77	1.8	0.86	1.86	1.64	0.69	0.69	0.93	0.8	0.58	0.11	1.2	1.03	0.91	1.12	0.08
Co	mg/kg	10.1	13.6	5.13	10.6	9.03	7.91	9.76	9.94	5.75	0.78	1	11.3	13.6	10.1	10.5	0.96
Cr	mg/kg	52.2	59.2	23.6	51.2	33.2	52.1	52.3	60.2	37.3	36	4.43	67.7	74.3	59	59.4	3.54
Cu	mg/kg	60	62.5	32.5	58.6	41.7	491	603	657	365	415	6.84	107	13	107	120	10.4
Fe	mg/kg	41100	43100	23700	38900	30500	35900	43900	52800	25400	27900	5730	48200	48600	51900	46700	3660
Hg	mg/kg	0.1003	0.0773	0.035	0.0462	0.0447	5.4275	2.88	9.83	4.13	5.92	0.0363	1.1964	0.0689	0.434	0.266	0.437
Mn	mg/kg	337	359	162	320	259	242	259	270	158	178	51.4	329	339	289	310	26.5
Mo	mg/kg	2.32	2.95	1.27	2.35	1.98	2.47	4.3	3.09	2.04	1.93	0.31	2.56	2.57	2.18	3.29	0.23
Ni	mg/kg	25.5	29.7	11.8	26.2	21.1	21.6	25.4	25.6	15.7	17.2	2.45	31	33.1	26	27	2.46
Pb	mg/kg	17.8	20.6	9.5	17	17.6	78.9	87.6	76.2	51.1	75.6	3.06	56	57.6	35.5	48.2	5.48
Sb	mg/kg	0.42	0.35	0.46	0.71	0.51	0.66	0.48	1.15	0.83	0.68	0.17	0.42	0.18	0.89	0.98	e 0.04
Se	mg/kg	1.1	2.2	0.46	1.05	<0.025	1.5	1.53	1.27	1.1	<0.025	0.14	1.4	2.48	0.85	1.11	<0.025
Sn	mg/kg	3.24	3	1.77	2.84	2.32	10.1	9.82	12.6	6.39	7.83	0.4	5.35	6.37	5.05	4.77	0.43
Sr	mg/kg	115	102	53.5	89.1	66.7	88.4	81.3	84	51.1	76.8	30.3	88.7	94.4	91.8	77.1	7.05
Ti	mg/kg	2210	2510	1100	2150	405	1740	711	2000	1260	498	421	2230	2520	1990	2200	50.4
Tl	mg/kg		0.45	0.22	0.41	0.36		0.39	0.37	0.23	0.29	e 0.04		0.5	0.38	0.42	e 0.04
V	mg/kg	119	137	57.1	108	65.2	98.8	89.3	111	67.6	56.1	6.96	140	155	117	129	7.8
Zn	mg/kg	178	190	84.2	175	137	325	380	320	221	240	16.6	228	237	200	225	19.3

Exceeds NOAA Effects Range Median Value

Anthropogenically enriched based on SCCWRP Iron Normalization Equation

Pyrethroid Pesticides																	
Allethrin	ug/Kg				<5	<5				<5	<5					<5	<5
Bifenthrin	ug/Kg				e 7.1	J 17.5				<5	<5					<5	<5
Cyfluthrin	ug/Kg				<5	<5				<5	<5					<5	<5
Cypermethrin	ug/Kg				<5	<5				<5	<5					<5	<5
Deltamethrin	ug/Kg				<5	<5				<5	<5					<5	<5
L-Cyhalothrin	ug/Kg				<5	<5				<5	<5					<5	<5
Permethrin	ug/Kg				<5	<5				<5	<5					<5	<5
Prallethrin	ug/Kg				<5	<5				<5	<5					<5	<5
Triazine Pesticides																	
Ametryn	ug/Kg	<5	<5		<5	<5	<5	<5		<5	<5		<5	<5		<5	<5
Atraton	ug/Kg	<5	<5		<5	<5	<5	<5		<5	<5		<5	<5		<5	<5
Atrazine	ug/Kg	<5	<5		<5	<5	<5	<5		<5	<5		<5	<5		<5	<5
Prometon	ug/Kg	<5	<5		<5	<5	<5	<5		<5	<5		<5	<5		<5	<5
Prometryn	ug/Kg	<5	<5		<5	<5	<5	<5		<5	<5		<5	<5		<5	<5
Propazine	ug/Kg	<5	<5		<5	<5	<5	<5		<5	<5		<5	<5		<5	<5
Secbumeton	ug/Kg	<5	<5		<5	<5	<5	<5		<5	<5		<5	<5		<5	<5
Simazine	ug/Kg	<5	<5		<5	<5	<5	<5		<5	<5		<5	<5		<5	<5
Simetryn	ug/Kg	<5	<5		<5	<5	<5	<5		<5	<5		<5	<5		<5	<5
Terbuthylazine	ug/Kg	<5	<5		<5	<5	<5	<5		<5	<5		<5	<5		<5	<5
Tertbutryn	ug/Kg	<5	<5		<5	<5	<5	<5		<5	<5		<5	<5		<5	<5

Sediment Chemistry in Lower Newport Bay

	Site	LNBHIR					LNBRIN					LNBSBI	LNBTUB				
	Date	8/26/05	11/17/05	3/8/06	4/20/06	6/21/06	8/26/05	11/17/05	3/8/06	4/20/06	6/21/06	3/8/06	8/26/05	11/17/05	3/8/06	4/20/06	6/21/06
	Time	9:30	12:40	12:26	9:13	9:30	8:40	13:30	12:47	10:47	10:20	11:30	7:50	14:10	13:06	9:59	11:00
Organochlorine Pesticides and PCB Arochlors																	
2,4 DDD	ug/Kg	<1	<1	<1	e 1.1	<1	<1	<1	<1	e 1.5	<1	<1	<1	<1	<1	<1	<1
2,4 DDE	ug/Kg	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
2,4 DDT	ug/Kg	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	e 1.8	<1
4,4'-DDD	ug/Kg	10.2	e 2.53	<1	e 1.6	e 3.1	<1	<1	<1	5.5	6.3	<1	6.2	<1	<1	e 3.5	e 2.1
4,4'-DDE	ug/Kg	34.2	16.7	7.9	15.3	15.4	32.3	12.8	9.6	12	14.6	e 1.4	47.6	24.7	e 4	28.5	17.5
4,4'-DDT	ug/Kg	<1	<1	<1	5	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
alpha-BHC	ug/Kg	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
beta-BHC	ug/Kg	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
delta-BHC	ug/Kg	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
gamma-BHC (Lindane)	ug/Kg	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Aldrin	ug/Kg	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Chlordane	ug/Kg		<1	<1	2.3	1.3		<1	<1	<1	<1	<1		<1	<1	3.5	<1
Chlordane-alpha	ug/Kg		<1	<1	e 1.1	<1		<1	<1	<1	<1	<1		<1	<1	<1	<1
Chlordane-gamma	ug/Kg			<1	<1	e 1.3			<1	<1	<1	<1			<1	e 1.1	<1
OxyChlordane	ug/Kg	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
cis-Nonachlor	ug/Kg		<1	<1	<1	<1		<1	<1	<1	<1	<1		<1	<1	e 1.4	<1
Dieldrin	ug/Kg	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Endosulfan I	ug/Kg	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Endosulfan II	ug/Kg	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Endosulfan Sulfate	ug/Kg	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Endrin	ug/Kg	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Endrin aldehyde	ug/Kg	<1	<1		<1	<1	<1	<1		<1	<1		<1	<1		<1	<1
Endrin Ketone	ug/Kg	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Heptachlor	ug/Kg	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Heptachlor Epoxide	ug/Kg	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Methoxychlor	ug/Kg	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Mirex	ug/Kg		<1	<1	<1	<1		<1	<1	<1	<1	<1		<1	<1	<1	<1
PCB-1016	ug/Kg	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10
PCB-1221	ug/Kg	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10
PCB-1232	ug/Kg	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10
PCB-1242	ug/Kg	<10	<10	<10	<10	<10	34	<10	<10	e 13.6	40.3	<10	<10	<10	<10	<10	<10
PCB-1248	ug/Kg	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10
PCB-1254	ug/Kg	<10	<10	<10	<10	<10	118	51.8	25.7	27.4	42.4	<10	<10	<10	<10	<10	e 15.9
PCB-1260	ug/Kg	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10
Perthane	ug/Kg	<5	<5		<5	<5	<5	<5		<5	<5		<5	<5		<5	<5
Toxaphene	ug/Kg	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10
Trans-Nonachlor	ug/Kg		<1	<1	e 1.2	<1		<1	<1	<1	<1	<1		<1	<1	1	<1
Organophosphate Pesticides																	
Bolstar	ug/Kg	<10	<10		<10	<10	<10	<10		<10	<10		<10	<10		<10	<10
Chlorpyrifos	ug/Kg	<5	<5		<5	<5	<5	<5		<5	<5		<5	<5		<5	<5
Demeton	ug/Kg	<10	<10		<10	<10	<10	<10		<10	<10		<10	<10		<10	<10
Diazinon	ug/Kg	<5	<5		<5	<5	<5	<5		<5	<5		<5	<5		<5	<5
Dichlorvos	ug/Kg	<10	<10		<10	<10	<10	<10		<10	<10		<10	<10		<10	<10
Dimethoate	ug/Kg	<5	<5		<5	<5	<5	<5		<5	<5		<5	<5		<5	<5
Disulfoton	ug/Kg	<10	<10		<10	<10	<10	<10		<10	<10		<10	<10		<10	<10
Ethoprop	ug/Kg	<10	<10		<10	<10	<10	<10		<10	<10		<10	<10		<10	<10
Fenchlorphos	ug/Kg	<10	<10		<10	<10	<10	<10		<10	<10		<10	<10		<10	<10
Fensulfothion	ug/Kg	<10	<10		<10	<10	<10	<10		<10	<10		<10	<10		<10	<10
Fenthion	ug/Kg	<10	<10		<10	<10	<10	<10		<10	<10		<10	<10		<10	<10
Malathion	ug/Kg	<5	<5		<5	<5	<5	<5		<5	<5		<5	<5		<5	<5
Merphos	ug/Kg	<10	<10		<10	<10	<10	<10		<10	<10		<10	<10		<10	<10
Mevinphos	ug/Kg	<10	<10		<10	<10	<10	<10		<10	<10		<10	<10		<10	<10
Parathion-Methyl	ug/Kg	<10	<10		<10	<10	<10	<10		<10	<10		<10	<10		<10	<10
Phorate	ug/Kg	<10	<10		<10	<10	<10	<10		<10	<10		<10	<10		<10	<10
Tetrachlorvinphos	ug/Kg	<10	<10		<10	<10	<10	<10		<10	<10		<10	<10		<10	<10
Tokuthion	ug/Kg	<10	<10		<10	<10	<10	<10		<10	<10		<10	<10		<10	<10
Trichloronate	ug/Kg	<10	<10		<10	<10	<10	<10		<10	<10		<10	<10		<10	<10

Sediment Chemistry in Lower Newport Bay

	Site	LNBHIR					LNBRIN					LNBSBI	LNBTUB				
	Date	8/26/05	11/17/05	3/8/06	4/20/06	6/21/06	8/26/05	11/17/05	3/8/06	4/20/06	6/21/06	3/8/06	8/26/05	11/17/05	3/8/06	4/20/06	6/21/06
	Time	9:30	12:40	12:26	9:13	9:30	8:40	13:30	12:47	10:47	10:20	11:30	7:50	14:10	13:06	9:59	11:00
PCB Congeners																	
PCB018	ug/Kg	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
PCB028	ug/Kg	<1	<1	<1	<1	<1	<1	<1	<1	<1	e 2.9	<1	<1	<1	<1	<1	<1
PCB031	ug/Kg	<1	<1	<1	<1	<1	e 3.9	<1	<1	e 1.6	e 1.8	<1	<1	<1	<1	<1	<1
PCB033	ug/Kg	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
PCB037	ug/Kg	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
PCB044	ug/Kg	<1	<1	<1	<1	<1	<1	<1	<1	<1	e 2.2	<1	<1	<1	<1	<1	<1
PCB049	ug/Kg	<1	<1	<1	<1	<1	<1	<1	<1	e 2.6	<1	<1	<1	<1	<1	<1	<1
PCB052	ug/Kg	<1	<1	<1	<1	<1	5.1	<1	<1	e 2.2	e 2.8	<1	<1	<1	<1	<1	<1
PCB066	ug/Kg	<1	<1	<1	<1	<1	12.6	e 4.65	<1	e 3.2	5.8	<1	<1	<1	<1	<1	<1
PCB070	ug/Kg	<1	<1	<1	<1	<1	10.3	e 2.73	<1	e 2.8	e 3.6	<1	<1	<1	<1	<1	<1
PCB074	ug/Kg	<1	<1	<1	<1	<1	<1	<1	<1	e 1.3	e 2.2	<1	<1	<1	<1	<1	<1
PCB077	ug/Kg	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
PCB081	ug/Kg	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
PCB087	ug/Kg	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
PCB095	ug/Kg	<1	<1	<1	<1	<1	<1	e 1.86	e 2.6	e 2.7	e 3.6	<1	<1	<1	<1	e 1.5	<1
PCB097	ug/Kg	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
PCB099	ug/Kg	<1	<1	<1	<1	<1	11.1	e 3.92	<1	e 3.3	e 4.6	<1	<1	<1	<1	<1	<1
PCB101	ug/Kg	<1	<1	<1	<1	<1	17.1	6.41	e 4.4	e 4.6	6.5	<1	<1	<1	<1	e 1.5	<1
PCB105	ug/Kg	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
PCB110	ug/Kg	<1	<1	<1	<1	<1	14.4	6.35	e 3.2	e 3.4	5.2	<1	<1	<1	<1	1	e 2
PCB114	ug/Kg	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
PCB118	ug/Kg	<1	<1	<1	<1	<1	21.4	e 4.62	e 2.3	e 3.5	e 3.6	<1	<1	<1	<1	<1	<1
PCB119	ug/Kg	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
PCB123	ug/Kg	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
PCB126	ug/Kg	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
PCB128+167	ug/Kg	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
PCB138	ug/Kg	<1	<1	<1	<1	<1	<1	e 4.57	<1	e 4.1	7	<1	<1	<1	<1	<1	e 3.3
PCB141	ug/Kg	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
PCB149	ug/Kg	<1	<1	<1	<1	<1	11.4	e 2.41	e 2.9	e 2.3	e 3.2	<1	<1	<1	<1	e 1.1	<1
PCB151	ug/Kg	<1	<1	<1	<1	<1	<1	<1	<1	<1	1	<1	<1	<1	<1	<1	<1
PCB153	ug/Kg	<1	<1	<1	<1	<1	12.5	6.71	e 3.5	5.6	6.9	<1	<1	<1	<1	e 1.8	e 2.2
PCB156	ug/Kg	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
PCB157	ug/Kg	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
PCB158	ug/Kg	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
PCB168+132	ug/Kg	<1	<1	<1	<1	<1	<1	<1	<1	e 1.3	e 2.2	<1	<1	<1	<1	<1	<1
PCB169	ug/Kg	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
PCB170	ug/Kg	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
PCB177	ug/Kg	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
PCB180	ug/Kg	<1	<1	<1	<1	<1	<1	<1	<1	e 1.6	e 3	<1	<1	<1	<1	<1	e 1.3
PCB183	ug/Kg	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
PCB187	ug/Kg	<1	<1	<1	<1	<1	<1	5.16	e 3.1	e 1.3	e 1.4	<1	<1	<1	<1	e 1.4	<1
PCB189	ug/Kg	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
PCB194	ug/Kg	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
PCB200	ug/Kg	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
PCB201	ug/Kg	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
PCB206	ug/Kg	<1	<1	<1	<1	<1	<1	<1	<1	e 1.4	<1	<1	<1	<1	<1	<1	<1
Polynuclear Aromatic Hydrocarbons																	
1-Methylnaphthalene	ug/Kg																
1-Methylphenanthrene	ug/Kg																
(1,2,3-CE)Pyrene	ug/Kg																
1,2,5,6- Dibenzanthracene	ug/Kg																
2,3,5-TriMethylnaphthalene	ug/Kg																
2,6-Dimethylnaphthalene	ug/Kg																
2-Methylnaphthalene	ug/Kg																
Acenaphthene	ug/Kg																
Acenaphthylene	ug/Kg																
Anthracene	ug/Kg																
Benzo (A) Anthracene	ug/Kg																
Benzo (A) Pyrene	ug/Kg																
Benzo (k) Fluoranthene	ug/Kg																
Benzo (GHI) Perylene	ug/Kg																
Benzo(b)fluoranthene	ug/Kg																
Benzo(e)pyrene	ug/Kg																
Biphenyl	ug/Kg																
Chrysene	ug/Kg																
Dibenzothiophene	ug/Kg																
Fluoranthene	ug/Kg																
Fluorene	ug/Kg																
Naphthalene	ug/Kg																
Perylene	ug/Kg																
Phenanthrene	ug/Kg																
Pyrene	ug/Kg																
Chlorinated Herbicides																	
2,4,5 TP-Silvex	ug/Kg	<14	<10		nr	<10	<10	<10		nr	<10		<10	<10		nr	<10
2,4-D	ug/Kg	<140	<100		nr	<100	<100	<100		nr	<100		<100	<100		nr	<100

Sediment Chemistry in Upper Newport Bay

	Site	UNBBCW	UNBJAM					
	Date	3/8/06	7/29/05	8/26/05	11/17/05	3/8/06	4/19/06	6/20/06
	Time	10:02	10:52	13:15	9:09	9:18	10:00	9:47
Eohaustorius	% Survival			0	0		0	3
Nitrogen	mg/kg		1100	327	587		1040	1080
Phosphorus	mg/kg		5.28	189	254		387	492
TOC-S	%C	1.23	1.07	0.13	1.01	2.01	2.57	2.4
%Clay	%	7.1	17.61	1.46		20.32	17.1	28.39
%Silt + Clay	%	16.78	70.85	4.57		55.99	72.6	86.17
Metals								
Ag	mg/kg	0.24	1.34	0.06	1.23	0.29	e 0.03	<0.025
Al	mg/kg	>50000	>1	8690	24500	>50000	>50000	17600
As	mg/kg	3.62	5.65	1.78	5.51	6.36	8.78	4.74
Ba	mg/kg	65.2	119	38.9	78	150	133	129
Be	mg/kg	0.28	0.72	0.18	0.62	0.66	0.93	0.79
Cd	mg/kg	0.68	1.31	0.46	1.04	1.66	1.3	1.82
Co	mg/kg	3.89	31.3	2.14	5.86	8.05	9.27	8.2
Cr	mg/kg	17.9	7.36	8.1	24.7	34.3	47.8	27.7
Cu	mg/kg	27.8	30	6.74	24.9	39.2	102	40.3
Fe	mg/kg	16500	26900	7110	18400	34100	37600	24900
Hg	mg/kg	0.0202	0.01253	0.01387	0.0231	0.0346	0.0245	0.147
Mn	mg/kg	133	284	81.9	182	261	297	291
Mo	mg/kg	1.48	2.52	0.82	2.4	3.91	1.87	2.86
Ni	mg/kg	9.28	16.6	4.6	13.5	17.8	23.3	18.7
Pb	mg/kg	8.85	9.29	3.4	9.68	12.6	18.9	15.6
Sb	mg/kg	0.47	0.6	<0.025	0.19	1.37	0.79	15
Se	mg/kg	0.85	1.13	0.35	1.62	1.66	1.49	<0.025
Sn	mg/kg	1.4	2.23	0.65	1.91	3.06	2.93	8.85
Sr	mg/kg	72.2	81.2	26.5	44	110	89.4	118
Ti	mg/kg	1050	1780	445	1410	1700	1930	421
Tl	mg/kg	0.18	0.23		0.2	0.27	0.33	<0.025
V	mg/kg	41.6	77.4	20.3	59.9	82.8	105	53.7
Zn	mg/kg	77.5	12	33	103	158	202	179
Pyrethroid Pesticides								
Allethrin	ug/Kg						<5	<5
Bifenthrin	ug/Kg						28.5	52.7
Cyfluthrin	ug/Kg						<5	<5
Cypermethrin	ug/Kg						<5	<5
Deltamethrin	ug/Kg						<5	<5
L-Cyhalothrin	ug/Kg						<5	<5
Permethrin	ug/Kg						<5	53.9
Prallethrin	ug/Kg						<5	<5
Triazine Pesticides								
Ametryn	ug/Kg		<5	<5	<5		<5	<5
Atraton	ug/Kg		<5	<5	<5		<5	<5
Atrazine	ug/Kg		<5	<5	<5		<5	<5
Prometon	ug/Kg		<5	<5	<5		<5	<5
Prometryn	ug/Kg		<5	<5	<5		<5	<5
Propazine	ug/Kg		<5	<5	<5		<5	<5
Secbumeton	ug/Kg		<5	<5	<5		<5	<5
Simazine	ug/Kg		<5	<5	<5		<5	<5
Simetryn	ug/Kg		<5	<5	<5		<5	<5
Terbuthylazine	ug/Kg		<5	<5	<5		<5	<5
Tertbutryn	ug/Kg		<5	<5	<5		<5	<5

Sediment Chemistry in Upper Newport Bay

	Site	UNBBCW	UNBJAM					
	Date	3/8/06	7/29/05	8/26/05	11/17/05	3/8/06	4/19/06	6/20/06
	Time	10:02	10:52	13:15	9:09	9:18	10:00	9:47
Organochlorine Pesticides and PCB Arochlors								
2,4 DDD	ug/Kg	<1	<1	<1	<1	<1	<1	<1
2,4 DDE	ug/Kg	<1	<1	<1	<1	<1	<1	<1
2,4 DDT	ug/Kg	<1	<1	<1	<1	<1	<1	<1
4,4'-DDD	ug/Kg	<1	<1	e 1.9	<1	<1	7.5	6.5
4,4'-DDE	ug/Kg	9.2	18.7	6.9	9.19	10.6	33.3	21.8
4,4'-DDT	ug/Kg	<1	<1	<1	<1	<1	<1	<1
alpha-BHC	ug/Kg	<1	<1	<1	<1	<1	<1	<1
beta-BHC	ug/Kg	<1	<1	<1	<1	<1	<1	<1
delta-BHC	ug/Kg	<1	<1	<1	<1	<1	<1	<1
gamma-BHC (Lindane)	ug/Kg	<1	<1	<1	<1	<1	<1	<1
Aldrin	ug/Kg	<1	<1	<1	<1	<1	<1	<1
Chlordane	ug/Kg	<1	0		<1	3	9	4.8
Chlordane-alpha	ug/Kg	<1	<1		e 2.85	<1	e 2.7	e 1.4
Chlordane-gamma	ug/Kg	<1	<1			e 1.8	e 2.6	e 1.6
OxyChlordane	ug/Kg	<1	<1	<1	<1	<1	<1	<1
cis-Nonachlor	ug/Kg	<1	<1		<1	<1	e 1.4	<1
Dieldrin	ug/Kg	<1	<1	<1	<1	<1	<1	<1
Endosulfan I	ug/Kg	<1	<1	<1	<1	<1	<1	<1
Endosulfan II	ug/Kg	<1	<1	<1	<1	<1	<1	<1
Endosulfan Sulfate	ug/Kg	<1	<1	<1	<1	<1	<1	<1
Endrin	ug/Kg	<1	<1	<1	<1	<1	<1	<1
Endrin aldehyde	ug/Kg		<1	<1	<1			<1
Endrin Ketone	ug/Kg	<1	<1	<1	<1	<1	<1	<1
Heptachlor	ug/Kg	<1	<1	<1	<1	<1	<1	<1
Heptachlor Epoxide	ug/Kg	<1	<1	<1	<1	<1	<1	<1
Methoxychlor	ug/Kg	<1	<1	<1	<1	<1	<1	<1
Mirex	ug/Kg	<1	<1		<1	<1	<1	<1
PCB-1016	ug/Kg	<10	<10	<10	<10	<10	<10	<10
PCB-1221	ug/Kg	<10	<10	<10	<10	<10	<10	<10
PCB-1232	ug/Kg	<10	<10	<10	<10	<10	<10	<10
PCB-1242	ug/Kg	<10	<10	<10	<10	<10	<10	<10
PCB-1248	ug/Kg	<10	<10	<10	<10	<10	<10	<10
PCB-1254	ug/Kg	<10	<10	<10	<10	<10	<10	<10
PCB-1260	ug/Kg	<10	<10	<10	<10	<10	<10	<10
Perthane	ug/Kg		<5	<5	<5		<5	<5
Toxaphene	ug/Kg	<10	<10	<10	<10	<10	<10	<10
Trans-Nonachlor	ug/Kg	<1	<1		<1	e 1.2	e 2.3	e 1.8
Organophosphate Pesticides								
Bolstar	ug/Kg		<10	<10	<10		<10	<10
Chlorpyrifos	ug/Kg		<5	<5	<5		<5	<5
Demeton	ug/Kg		<10	<10	<10		<10	<10
Diazinon	ug/Kg		<5	<5	<5		<5	<5
Dichlorvos	ug/Kg		<10	<10	<10		<10	<10
Dimethoate	ug/Kg		<5	<5	<5		<5	<5
Disulfoton	ug/Kg		<10	<10	<10		<10	<10
Ethoprop	ug/Kg		<10	<10	<10		<10	<10
Fenchlorphos	ug/Kg		<10	<10	<10		<10	<10
Fensulfothion	ug/Kg		<10	<10	<10		<10	<10
Fenthion	ug/Kg		<10	<10	<10		<10	<10
Malathion	ug/Kg		<5	<5	<5		<5	<5
Merphos	ug/Kg		<10	<10	<10		<10	<10
Mevinphos	ug/Kg		<10	<10	<10		<10	<10
Parathion-Methyl	ug/Kg		<10	<10	<10		<10	<10
Phorate	ug/Kg		<10	<10	<10		<10	<10
Tetrachlorvinphos	ug/Kg		<10	<10	<10		<10	<10
Tokuthion	ug/Kg		<10	<10	<10		<10	<10
Trichloronate	ug/Kg		<10	<10	<10		<10	<10

Sediment Chemistry in Upper Newport Bay

	Site	UNBBCW	UNBJAM					
	Date	3/8/06	7/29/05	8/26/05	11/17/05	3/8/06	4/19/06	6/20/06
	Time	10:02	10:52	13:15	9:09	9:18	10:00	9:47
PCB Congeners								
PCB018	ug/Kg	<1	<1	<1	<1	<1	<1	<1
PCB028	ug/Kg	<1	<1	<1	<1	<1	<1	<1
PCB031	ug/Kg	<1	<1	<1	<1	<1	<1	<1
PCB033	ug/Kg	<1	<1	<1	<1	<1	<1	<1
PCB037	ug/Kg	<1	<1	<1	<1	<1	<1	<1
PCB044	ug/Kg	<1	<1	<1	<1	<1	<1	<1
PCB049	ug/Kg	<1	<1	<1	<1	<1	<1	<1
PCB052	ug/Kg	<1	<1	<1	<1	<1	<1	<1
PCB066	ug/Kg	<1	<1	<1	<1	<1	<1	<1
PCB070	ug/Kg	<1	<1	<1	<1	<1	<1	<1
PCB074	ug/Kg	<1	<1	<1	<1	<1	<1	<1
PCB077	ug/Kg	<1	<1	<1	<1	<1	<1	<1
PCB081	ug/Kg	<1	<1	<1	<1	<1	<1	<1
PCB087	ug/Kg	<1	<1	<1	<1	<1	<1	<1
PCB095	ug/Kg	<1	<1	<1	<1	<1	<1	<1
PCB097	ug/Kg	<1	<1	<1	<1	<1	<1	<1
PCB099	ug/Kg	<1	<1	<1	<1	<1	<1	<1
PCB101	ug/Kg	<1	<1	<1	<1	<1	<1	<1
PCB105	ug/Kg	<1	<1	<1	<1	<1	<1	<1
PCB110	ug/Kg	<1	<1	<1	<1	<1	<1	<1
PCB114	ug/Kg	<1	<1	<1	<1	<1	<1	<1
PCB118	ug/Kg	<1	<1	<1	<1	<1	<1	<1
PCB119	ug/Kg	<1	<1	<1	<1	<1	<1	<1
PCB123	ug/Kg	<1	<1	<1	<1	<1	<1	<1
PCB126	ug/Kg	<1	<1	<1	<1	<1	<1	<1
PCB128+167	ug/Kg	<1	<1	<1	<1	<1	<1	<1
PCB138	ug/Kg	<1	<1	<1	<1	<1	<1	<1
PCB141	ug/Kg	<1	<1	<1	<1	<1	<1	<1
PCB149	ug/Kg	<1	<1	<1	<1	<1	<1	<1
PCB151	ug/Kg	<1	<1	<1	<1	<1	<1	<1
PCB153	ug/Kg	<1	<1	<1	<1	<1	<1	<1
PCB156	ug/Kg	<1	<1	<1	<1	<1	<1	<1
PCB157	ug/Kg	<1	<1	<1	<1	<1	<1	<1
PCB158	ug/Kg	<1	<1	<1	<1	<1	<1	<1
PCB168+132	ug/Kg	<1	<1	<1	<1	<1	<1	<1
PCB169	ug/Kg	<1	<1	<1	<1	<1	<1	<1
PCB170	ug/Kg	<1	<1	<1	<1	<1	<1	<1
PCB177	ug/Kg	<1	<1	<1	<1	<1	<1	<1
PCB180	ug/Kg	<1	<1	<1	<1	<1	<1	<1
PCB183	ug/Kg	<1	<1	<1	<1	<1	<1	<1
PCB187	ug/Kg	<1	<1	<1	<1	<1	<1	<1
PCB189	ug/Kg	<1	<1	<1	<1	<1	<1	<1
PCB194	ug/Kg	<1	<1	<1	<1	<1	<1	<1
PCB200	ug/Kg	<1	<1	<1	<1	<1	<1	<1
PCB201	ug/Kg	<1	<1	<1	<1	<1	<1	<1
PCB206	ug/Kg	<1	<1	<1	<1	<1	<1	<1
Polynuclear Aromatic Hydrocarbons								
1-Methylnaphthalene	ug/Kg						<1	<1
1-Methylphenanthrene	ug/Kg						5.1	7.4
(1,2,3-CE)Pyrene	ug/Kg						17.5	30.7
1,2,5,6- Dibenzanthracene	ug/Kg						e 4.1	9.1
2,3,5-TriMethylnaphthalene	ug/Kg						e 2.1	3
2,6-Dimethylnaphthalene	ug/Kg						13.1	4.9
2-Methylnaphthalene	ug/Kg						<1	<1
Acenaphthene	ug/Kg						e 1.4	2.9
Acenaphthylene	ug/Kg						e 1.3	2.7
Anthracene	ug/Kg						8.6	8.4
Benzo (A) Anthracene	ug/Kg						20.1	34.3
Benzo (A) Pyrene	ug/Kg						22.3	48.5
Benzo (k) Fluoranthene	ug/Kg						25.3	46.2
Benzo (GHI) Perylene	ug/Kg						29.4	54.3
Benzo(b)fluoranthene	ug/Kg						28	56.6
Biphenyl	ug/Kg						<1	<1
Benzo(e)pyrene	ug/Kg							49.4
Chrysene	ug/Kg						48	71.6
Dibenzothiophene	ug/Kg						6.4	3.9

Sediment Chemistry in Upper Newport Bay

	Site	UNBNSB						UNBSDC					
	Date	7/29/05	8/26/05	11/17/05	3/8/06	4/19/06	6/20/06	7/29/05	8/26/05	11/17/05	3/8/06	4/19/06	6/20/06
	Time	11:55	12:05	10:45	10:30	12:05	11:20	11:15	14:00	9:56	9:37	10:45	10:25
Eohaustorius	% Survival		20	13		16	84		5	44		21	6
Nitrogen	mg/kg	780	430	1380		1720	226	670	626	796		1240	917
Phosphorus	mg/kg	NR	356	396		748	327	NR	562	369		544	503
TOC-S	%C	0.97	0.62	1.41	0.97	1.64	0.76	1.63	1.26	2.04	2.03	1.85	2.1
%Clay	%	7.88	8.6		35.66	24.33	9.74	13.88	7.83		27.49	19.57	31.64
%Silt + Clay	%	22.54	25.56		73.68	54.93	26.26	66.41	45.02		73.99	79.38	82.19
Metals													
Ag	mg/kg	0.63	0.19	0.85	0.16	0.09	<0.025	1.12	0.23	0.7	15	e 0.04	<0.025
Al	mg/kg	18000	>50000	>50000	>50000	25900	7420	>1	>50000	18400	>50000	29500	16300
As	mg/kg	6.31	4.84	6.91	5.46	4.61	3.08	5.19	5.05	4.47	6.85	7.44	4.4
Ba	mg/kg	93.7	81.6	96.4	112	93.9	42.3	132	147	80.1	148	139	96.2
Be	mg/kg	0.5	0.41	0.75	0.44	0.53	0.33	0.67	0.59	0.52	0.6	0.83	0.77
Cd	mg/kg	0.78	0.83	0.87	0.88	1.65	0.44	1.13	1.17	0.75	1.46	1.78	1.34
Co	mg/kg	30.7	4.62	7.45	5.7	6.27	3.51	29.7	7.11	5.88	8.58	9.79	7.07
Cr	mg/kg	7.52	22.3	32.2	27.7	27.6	14	7.65	28.2	22.1	36.8	37.7	27.8
Cu	mg/kg	38.9	19.1	46.3	47.4	33.6	12.9	27.6	23.3	28.5	54.3	38.2	40.1
Fe	mg/kg	52400	17600	23600	27000	21200	12100	27300	24800	17300	36900	33300	24300
Hg	mg/kg	0.0146	0.06316	0.0491	0.0264	e 0.0197	0.0699	0.0137	0.03923	0.0327	0.0298	0.0257	0.102
Mn	mg/kg	591	165	21	212	206	107	265	248	177	260	322	211
Mo	mg/kg	78.8	1.15	1.48	1.68	3.15	1.47	1.96	2.5	3.26	3.02	2.57	1.6
Ni	mg/kg	15.5	11.4	15.7	13.2	14.2	9.8	15.3	15.1	13	18.6	20	16.8
Pb	mg/kg	9.69	11.3	13.2	12.5	10.1	6.21	11.3	16.1	16	17.5	15.9	21.9
Sb	mg/kg	0.25	e 0.04	0.09	0.46	1.09	0.21	0.38	0.51	0.32	0.79	0.71	16.1
Se	mg/kg	0.98	0.78	1.74	1.17	1.6	<0.025	1.14	1.06	1.54	1.3	1.25	<0.025
Sn	mg/kg	1.86	1.42	2.1	2.11	2.09	0.67	2.19	2.31	2.36	3.09	2.41	8.99
Sr	mg/kg	218	128	180	1030	89.6	290	84	71.7	50.2	90.7	81.6	56.2
Ti	mg/kg	999	1120	1560	1320	1330	291	1820	1720	1330	1660	2060	394
Tl	mg/kg	0.22		0.25	0.25	0.21	0.14	0.26		0.17	0.3	0.31	<0.025
V	mg/kg	60.6	51	73.7	66.5	58.9	23.9	77.4	70.2	52.9	86.4	93.3	48.4
Zn	mg/kg	92.6	67.2	115	88	139	38.7	117	116	114	178	157	139
Pyrethroid Pesticides													
Allethrin	ug/Kg					<5	<5					<5	<5
Bifenthrin	ug/Kg					e 17	<5					e 11.1	J 8.3
Cyfluthrin	ug/Kg					<5	<5					<5	<5
Cypermethrin	ug/Kg					<5	<5					<5	<5
Deltamethrin	ug/Kg					<5	<5					<5	<5
L-Cyhalothrin	ug/Kg					<5	<5					<5	<5
Permethrin	ug/Kg					<5	<5					<5	<5
Prallethrin	ug/Kg					<5	<5					<5	<5
Triazine Pesticides													
Ametryn	ug/Kg	<5	<5	<5		<5	<5	<5	<5	<5		<5	<5
Atraton	ug/Kg	<5	<5	<5		<5	<5	<5	<5	<5		<5	<5
Atrazine	ug/Kg	<5	<5	<5		<5	<5	<5	<5	<5		<5	<5
Prometon	ug/Kg	<5	<5	<5		<5	<5	<5	<5	<5		<5	<5
Prometryn	ug/Kg	<5	<5	<5		<5	<5	<5	<5	<5		<5	<5
Propazine	ug/Kg	<5	<5	<5		<5	<5	<5	<5	<5		<5	<5
Secbumeton	ug/Kg	<5	<5	<5		<5	<5	<5	<5	<5		<5	<5
Simazine	ug/Kg	<5	<5	<5		<5	<5	<5	<5	<5		<5	<5
Simetryn	ug/Kg	<5	<5	<5		<5	<5	<5	<5	<5		<5	<5
Terbuthylazine	ug/Kg	<5	<5	<5		<5	<5	<5	<5	<5		<5	<5
Tertbutryn	ug/Kg	<5	<5	<5		<5	<5	<5	<5	<5		<5	<5

Sediment Chemistry in Upper Newport Bay

	Site	UNBNSB						UNBSDC					
	Date	7/29/05	8/26/05	11/17/05	3/8/06	4/19/06	6/20/06	7/29/05	8/26/05	11/17/05	3/8/06	4/19/06	6/20/06
	Time	11:55	12:05	10:45	10:30	12:05	11:20	11:15	14:00	9:56	9:37	10:45	10:25
Organochlorine Pesticides and PCB Arochlo													
2,4 DDD	ug/Kg	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
2,4 DDE	ug/Kg	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
2,4 DDT	ug/Kg	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
4,4'-DDD	ug/Kg	<1	e 4.3	<1	<1	10.2	e 1.1	e 3.6	<1	<1	e 4.7	e 4.6	5.8
4,4'-DDE	ug/Kg	12.1	30	6.49	6.5	40.8	7.4	17.1	18.7	9.68	20	22	13.2
4,4'-DDT	ug/Kg	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
alpha-BHC	ug/Kg	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
beta-BHC	ug/Kg	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
delta-BHC	ug/Kg	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
gamma-BHC (Lindane)	ug/Kg	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Aldrin	ug/Kg	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Chlordane	ug/Kg	0		<1	<1	6.4	<1	0		e 2.34	5.2	5.4	<1
Chlordane-alpha	ug/Kg	<1		<1	<1	e 1.3	<1	<1		5.88	<1	e 1.3	<1
Chlordane-gamma	ug/Kg	<1			<1	e 1.3	<1	<1			e 2	e 1.8	<1
OxyChlordane	ug/Kg	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
cis-Nonachlor	ug/Kg	<1		<1	<1	e 1.4	<1	<1		<1	e 1.7	1	<1
Dieldrin	ug/Kg	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Endosulfan I	ug/Kg	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Endosulfan II	ug/Kg	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Endosulfan Sulfate	ug/Kg	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Endrin	ug/Kg	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Endrin aldehyde	ug/Kg	<1	<1	<1			<1	<1	<1	<1			<1
Endrin Ketone	ug/Kg	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Heptachlor	ug/Kg	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Heptachlor Epoxide	ug/Kg	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Methoxychlor	ug/Kg	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Mirex	ug/Kg	<1		<1	<1	<1	<1	<1		<1	<1	<1	<1
PCB-1016	ug/Kg	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10
PCB-1221	ug/Kg	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10
PCB-1232	ug/Kg	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10
PCB-1242	ug/Kg	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10
PCB-1248	ug/Kg	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10
PCB-1254	ug/Kg	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10
PCB-1260	ug/Kg	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10
Perthane	ug/Kg	<5	<5	<5		<5	<5	<5	<5	<5		<5	<5
Toxaphene	ug/Kg	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10
Trans-Nonachlor	ug/Kg	<1		<1	<1	e 2.4	<1	<1		e 1.16	e 1.5	e 1.3	<1
Organophosphate Pesticides													
Bolstar	ug/Kg	<10	<10	<10		<10	<10	<10	<10	<10		<10	<10
Chlorpyrifos	ug/Kg	<5	<5	<5		<5	<5	<5	<5	<5		<5	<5
Demeton	ug/Kg	<10	<10	<10		<10	<10	<10	<10	<10		<10	<10
Diazinon	ug/Kg	<5	<5	<5		<5	<5	<5	<5	<5		<5	<5
Dichlorvos	ug/Kg	<10	<10	<10		<10	<10	<10	<10	<10		<10	<10
Dimethoate	ug/Kg	<5	<5	<5		<5	<5	<5	<5	<5		<5	<5
Disulfoton	ug/Kg	<10	<10	<10		<10	<10	<10	<10	<10		<10	<10
Ethoprop	ug/Kg	<10	<10	<10		<10	<10	<10	<10	<10		<10	<10
Fenchlorphos	ug/Kg	<10	<10	<10		<10	<10	<10	<10	<10		<10	<10
Fensulfothion	ug/Kg	<10	<10	<10		<10	<10	<10	<10	<10		<10	<10
Fenthion	ug/Kg	<10	<10	<10		<10	<10	<10	<10	<10		<10	<10
Malathion	ug/Kg	<5	<5	<5		<5	<5	<5	<5	<5		<5	<5
Merphos	ug/Kg	<10	<10	<10		<10	<10	<10	<10	<10		<10	<10
Mevinphos	ug/Kg	<10	<10	<10		<10	<10	<10	<10	<10		<10	<10
Parathion-Methyl	ug/Kg	<10	<10	<10		<10	<10	<10	<10	<10		<10	<10
Phorate	ug/Kg	<10	<10	<10		<10	<10	<10	<10	<10		<10	<10
Tetrachlorvinphos	ug/Kg	<10	<10	<10		<10	<10	<10	<10	<10		<10	<10
Tokuthion	ug/Kg	<10	<10	<10		<10	<10	<10	<10	<10		<10	<10
Trichloronate	ug/Kg	<10	<10	<10		<10	<10	<10	<10	<10		<10	<10

Sediment Chemistry in Upper Newport Bay

	Site	UNBNSB						UNBSDC					
	Date	7/29/05	8/26/05	11/17/05	3/8/06	4/19/06	6/20/06	7/29/05	8/26/05	11/17/05	3/8/06	4/19/06	6/20/06
	Time	11:55	12:05	10:45	10:30	12:05	11:20	11:15	14:00	9:56	9:37	10:45	10:25
PCB Congeners													
PCB018	ug/Kg	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
PCB028	ug/Kg	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
PCB031	ug/Kg	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
PCB033	ug/Kg	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
PCB037	ug/Kg	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
PCB044	ug/Kg	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
PCB049	ug/Kg	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
PCB052	ug/Kg	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
PCB066	ug/Kg	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
PCB070	ug/Kg	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
PCB074	ug/Kg	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
PCB077	ug/Kg	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
PCB081	ug/Kg	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
PCB087	ug/Kg	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
PCB095	ug/Kg	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
PCB097	ug/Kg	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
PCB099	ug/Kg	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
PCB101	ug/Kg	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
PCB105	ug/Kg	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
PCB110	ug/Kg	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
PCB114	ug/Kg	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
PCB118	ug/Kg	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
PCB119	ug/Kg	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
PCB123	ug/Kg	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
PCB126	ug/Kg	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
PCB128+167	ug/Kg	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
PCB138	ug/Kg	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
PCB141	ug/Kg	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
PCB149	ug/Kg	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
PCB151	ug/Kg	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
PCB153	ug/Kg	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
PCB156	ug/Kg	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
PCB157	ug/Kg	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
PCB158	ug/Kg	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
PCB168+132	ug/Kg	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
PCB169	ug/Kg	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
PCB170	ug/Kg	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
PCB177	ug/Kg	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
PCB180	ug/Kg	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
PCB183	ug/Kg	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
PCB187	ug/Kg	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
PCB189	ug/Kg	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
PCB194	ug/Kg	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
PCB200	ug/Kg	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
PCB201	ug/Kg	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
PCB206	ug/Kg	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Polynuclear Aromatic Hydrocarbons													
1-Methylnaphthalene	ug/Kg											<1	<1
1-Methylphenanthrene	ug/Kg											e 4	2
(1,2,3-CE)Pyrene	ug/Kg											27.2	13.8
1,2,5,6- Dibenzanthracene	ug/Kg											6.5	3
2,3,5-TriMethylnaphthalene	ug/Kg											6	<1
2,6-Dimethylnaphthalene	ug/Kg											7.9	3.4
2-Methylnaphthalene	ug/Kg											<1	<1
Acenaphthene	ug/Kg											e 4.9	1
Acenaphthylene	ug/Kg											1	1
Anthracene	ug/Kg											17.8	2.6
Benzo (A) Anthracene	ug/Kg											35	10.2
Benzo (A) Pyrene	ug/Kg											37.1	15.1
Benzo (k) Fluoranthene	ug/Kg											37.1	16.3
Benzo (GHI) Perylene	ug/Kg											36.6	19.5
Benzo(b)fluoranthene	ug/Kg											34.9	16.3
Biphenyl	ug/Kg											<1	<1
Benzo(e)pyrene	ug/Kg												15
Chrysene	ug/Kg											53.3	18.3
Dibenzothiophene	ug/Kg											5.6	1.3

Sediment Chemistry in Huntington Harbour, Bolsa Bay and Talbert Marsh

	Site	HUNBCC		HUNCRB		HUNWAR		TGDC05		BBOLR		TBTD02		TBTMAR	
	Date	8/18/05	6/22/06	8/18/05	6/22/06	8/18/05	6/22/06	8/18/05	6/22/06	8/18/05	6/22/06	11/15/05	2/9/06	8/18/05	6/22/06
	Time	11:28	9:10	10:28	10:17	9:30	11:09	14:30	10:23	13:31	9:41	12:09	9:50	15:30	11:35
Eohaustorius	% Survival	85	3	54	52	45	82	68	68	90	79			77	88
Nitrogen	mg/kg														
Phosphorus	mg/kg														
TOC-S	%C	1.54	5.21	2.09	2.12	2.63	0.9	0.9	3.56	1.53	0.56	0.89	1.01	0.62	1
%Clay	%	23.78	22.86	34.8	34.91	6.36	7.09	1.6	25.05	8.67	5.51	4.91	9.21	3.19	8.89
%Silt + Clay	%	62.65	95.43	93.06	88.05	25.48	17.93	8.15	54.52	23.66	15.19	16.28	32.49	15.44	27.08
Metals															
Ag	mg/kg	<0.025	0.3	<0.025	0.2	<0.025	0.1	<0.025	0.1	<0.025	0.1	0.37	0.25	<0.025	0.1
Al	mg/kg	>50000	18930	>50000	24780	9630	8730	>50000	10500	7880	4151	16200	>50000	5460	8792
As	mg/kg	7.21	6.3	7.58	8	5.04	3.6	2.8	5.3	5.88	3.3	2.89	7.44	2.54	3.1
Ba	mg/kg	101	153.6	156	112	104	53.6	65.8	61.1	247	447.8	53.8	157	62.1	59
Be	mg/kg	0.62	0.5	0.83	0.8	0.4	0.2	0.23	0.3	0.33	0.1	0.32	0.65	0.21	0.2
Cd	mg/kg	0.32	0.5	0.37	<0.025	0.73	0.1	0.32	0.2	0.56	0.1	0.44	2.64	1.87	0.2
Co	mg/kg	10.6	10.2	12.2	11.5	6.93	4.7	4.92	5	5.52	2.3	5.6	9.69	3.73	4.7
Cr	mg/kg	37.4	33.3	50.1	42.8	24.6	15.3	14.9	19.1	22.2	9.2	22.2	45.6	23.9	15.6
Cu	mg/kg	27.2	78.1	112	112	52.6	39.8	16.9	54.7	30.2	13.4	17.3	41.9	28.7	14.4
Fe	mg/kg	33300	30040	42100	40280	22500	16010	15100	18700	18900	8733	21500	33300	13300	15620
Hg	mg/kg	0.0121	0.0675	0.0906	0.117	0.0318	0.0317	0.0149	0.0461	0.0193	e 0.0162	0.029	0.0991	0.147	0.025
Mn	mg/kg	328	393.5	405	402.4	278	188.3	274	187.5	260	95.2	275	417	159	166.9
Mo	mg/kg	4.09	5	1.45	1.7	2.5	0.9	1.7	2.6	2.07	2.2	0.8	2.64	0.93	1.1
Ni	mg/kg	20.8	21.3	26.4	23.5	14.9	9	9.18	11.2	12.5	5.4	10.7	18.7	9.04	8.8
Pb	mg/kg	11.6	37.81	84	78.28	36.3	22.18	20.9	48.03	60.7	19.62	9.41	28.5	20.7	9.04
Sb	mg/kg	0.21	2.9	0.43	0.5	0.66	0.5	0.31	0.7	0.55	0.3	0.27	0.52	0.12	0.2
Se	mg/kg	0.67	1	0.65	0.7	0.75	0.5	0.5	0.6	0.75	0.4	0.54	0.59	0.49	0.6
Sn	mg/kg	2.01	4.9	4.77	4.2	3.38	1.9	2.4	2.8	2.07	0.8	1.88	4.39	5.71	1.2
Sr	mg/kg	75.9	234.7	101	78.8	108	59.9	58.4	46.4	81.3	29.6	55.5	95.5	57.2	177
Ti	mg/kg	2270	1558	2590	1601	1740	864.5	1450	776.1	1620	383	2150	2290	1200	813.9
Tl	mg/kg	0.29	0.2	0.39	0.2	0.25	0.1	0.15	0.1	0.22	0.1	0.15	0.28	0.13	0.1
V	mg/kg	82.3	55.7	88.8	69.8	48.5	29.3	33	35	40.7	16.5	53.9	77.9	30.5	29
Zn	mg/kg	91.6	347.2	270	254.1	214	132.2	106	200.3	153	63	62.8	102	70.6	55.8
Pyrethroid Pesticides															
Allethrin	ug/Kg		<5		<5		<5		<5		<5				<5
Bifenthrin	ug/Kg		J 21.1		<5		<5		<5		<5				<5
Cyfluthrin	ug/Kg		<5		<5		<5		<5		<5				<5
Cypermethrin	ug/Kg		<5		<5		<5		<5		<5				<5
Deltamethrin	ug/Kg		<5		<5		<5		<5		<5				<5
L-Cyhalothrin	ug/Kg		<5		<5		<5		<5		<5				<5
Permethrin	ug/Kg		<5		<5		<5		<5		<5				<5
Prallethrin	ug/Kg		<5		<5		<5		<5		<5				<5
Triazine Pesticides															
Ametryn	ug/Kg	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5
Atraton	ug/Kg	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5
Atrazine	ug/Kg	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5
Prometon	ug/Kg	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5
Prometryn	ug/Kg	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5
Propazine	ug/Kg	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5
Secbumeton	ug/Kg	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5
Simazine	ug/Kg	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5
Simetryn	ug/Kg	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5
Terbuthylazine	ug/Kg	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5
Tertbutryn	ug/Kg	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5

Sediment Chemistry in Huntington Harbour, Bolsa Bay and Talbert Marsh

	Site	HUNBCC		HUNCRB		HUNWAR		TGDC05		BBOLR		TBTD02		TBTMAR	
	Date	8/18/05	6/22/06	8/18/05	6/22/06	8/18/05	6/22/06	8/18/05	6/22/06	8/18/05	6/22/06	11/15/05	2/9/06	8/18/05	6/22/06
	Time	11:28	9:10	10:28	10:17	9:30	11:09	14:30	10:23	13:31	9:41	12:09	9:50	15:30	11:35
Organochlorine Pesticides and PCB Arochlors															
2,4 DDD	ug/Kg	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	1.1	<1	<1
2,4 DDE	ug/Kg	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
2,4 DDT	ug/Kg	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
4,4'-DDD	ug/Kg	<1	<1	7.6	<1	<1	<1	<1	<1	<1	<1	<1	6.2	<1	<1
4,4'-DDE	ug/Kg	6.3	<1	57.2	13.9	59.4	7.8	15.2	16.3	7.9	<1	<1	4.6	7.6	<1
4,4'-DDT	ug/Kg	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
alpha-BHC	ug/Kg	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
beta-BHC	ug/Kg	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
delta-BHC	ug/Kg	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
gamma-BHC (Lindane)	ug/Kg	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Aldrin	ug/Kg	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Chlordane	ug/Kg		<1		<1		<1		<1		<1	4.3	5.4		<1
Chlordane-alpha	ug/Kg		<1		<1		<1		<1		<1	4.3	2.1		<1
Chlordane-gamma	ug/Kg	<1	<1	<1	<1	5.7	<1	<1	<1	<1	<1	<1		e 2.8	<1
OxyChlordane	ug/Kg	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
cis-Nonachlor	ug/Kg	<1	<1	<1	<1	e 2.3	<1	<1	<1	<1	<1	<1	<1	<1	<1
Dieldrin	ug/Kg	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Endosulfan I	ug/Kg	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Endosulfan II	ug/Kg	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Endosulfan Sulfate	ug/Kg	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Endrin	ug/Kg	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Endrin aldehyde	ug/Kg	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1		<1	<1
Endrin Ketone	ug/Kg	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Heptachlor	ug/Kg	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Heptachlor Epoxide	ug/Kg	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Methoxychlor	ug/Kg	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Mirex	ug/Kg	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
PCB-1016	ug/Kg	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10
PCB-1221	ug/Kg	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10
PCB-1232	ug/Kg	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10
PCB-1242	ug/Kg	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10
PCB-1248	ug/Kg	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10
PCB-1254	ug/Kg	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	224	59	<10
PCB-1260	ug/Kg	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	107	<10	<10
Perthane	ug/Kg	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5
Toxaphene	ug/Kg	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10
Trans-Nonachlor	ug/Kg	<1	<1	<1	<1	e 3.5	<1	<1	<1	<1	<1	e 4.3	1.4	<1	<1
Organophosphate Pesticides															
Bolstar	ug/Kg	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10
Chlorpyrifos	ug/Kg	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5
Demeton	ug/Kg	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10
Diazinon	ug/Kg	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5
Dichlorvos	ug/Kg	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10
Dimethoate	ug/Kg	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5
Disulfoton	ug/Kg	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10
Ethoprop	ug/Kg	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10
Fenchlorphos	ug/Kg	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10
Fensulfothion	ug/Kg	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10
Fenthion	ug/Kg	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10
Malathion	ug/Kg	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5
Merphos	ug/Kg	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10
Mevinphos	ug/Kg	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10
Parathion-Methyl	ug/Kg	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10
Phorate	ug/Kg	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10
Tetrachlorvinphos	ug/Kg	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10
Tokuthion	ug/Kg	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10
Trichloronate	ug/Kg	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10

Sediment Chemistry in Huntington Harbour, Bolsa Bay and Talbert Marsh

	Site	HUNBCC		HUNCRB		HUNWAR		TGDC05		BBOLR		TBTD02		TBTMAR	
	Date	8/18/05	6/22/06	8/18/05	6/22/06	8/18/05	6/22/06	8/18/05	6/22/06	8/18/05	6/22/06	11/15/05	2/9/06	8/18/05	6/22/06
	Time	11:28	9:10	10:28	10:17	9:30	11:09	14:30	10:23	13:31	9:41	12:09	9:50	15:30	11:35
PCB Congeners															
PCB018	ug/Kg	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
PCB028	ug/Kg	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
PCB031	ug/Kg	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
PCB033	ug/Kg	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
PCB037	ug/Kg	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
PCB044	ug/Kg	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	e 3.8	<1
PCB049	ug/Kg	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	e 2.5	<1
PCB052	ug/Kg	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	5.3	<1
PCB066	ug/Kg	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	e 4.5	<1
PCB070	ug/Kg	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	e 2.1	<1
PCB074	ug/Kg	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	e 1.7	<1
PCB077	ug/Kg	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
PCB081	ug/Kg	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
PCB087	ug/Kg	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
PCB095	ug/Kg	<1	<1	e 1.9	<1	<1	<1	<1	<1	<1	<1	<1	<1	e 2.7	<1
PCB097	ug/Kg	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
PCB099	ug/Kg	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	e 2.4	<1
PCB101	ug/Kg	<1	<1	5.5	<1	<1	<1	<1	<1	<1	<1	<1	<1	e 4.9	<1
PCB105	ug/Kg	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	e 3.9	<1
PCB110	ug/Kg	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	1	7.2	<1
PCB114	ug/Kg	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
PCB118	ug/Kg	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	e 3.6	<1
PCB119	ug/Kg	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
PCB123	ug/Kg	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
PCB126	ug/Kg	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
PCB128+167	ug/Kg	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
PCB138	ug/Kg	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	6.6	<1
PCB141	ug/Kg	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
PCB149	ug/Kg	<1	<1	e 4.3	<1	<1	<1	<1	<1	<1	<1	<1	<1	e 2.3	<1
PCB151	ug/Kg	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
PCB153	ug/Kg	<1	<1	5.7	<1	<1	<1	<1	<1	<1	<1	<1	<1	e 4	<1
PCB156	ug/Kg	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
PCB157	ug/Kg	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
PCB158	ug/Kg	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
PCB168+132	ug/Kg	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
PCB169	ug/Kg	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
PCB170	ug/Kg	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
PCB177	ug/Kg	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
PCB180	ug/Kg	<1	<1	e 4.3	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
PCB183	ug/Kg	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
PCB187	ug/Kg	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
PCB189	ug/Kg	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
PCB194	ug/Kg	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
PCB200	ug/Kg	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
PCB201	ug/Kg	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
PCB206	ug/Kg	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Polynuclear Aromatic Hydrocarbons															
1-Methylnaphthalene	ug/Kg														
1-Methylphenanthrene	ug/Kg														
(1,2,3-CE)Pyrene	ug/Kg														
1,2,5,6- Dibenzanthracene	ug/Kg														
2,3,5-TriMethylnaphthalene	ug/Kg														
2,6-Dimethylnaphthalene	ug/Kg														
2-Methylnaphthalene	ug/Kg														
Acenaphthene	ug/Kg														
Acenaphthylene	ug/Kg														
Anthracene	ug/Kg														
Benzo (A) Anthracene	ug/Kg														
Benzo (A) Pyrene	ug/Kg														
Benzo (k) Fluoranthene	ug/Kg														
Benzo (GHI) Perylene	ug/Kg														
Benzo(b)fluoranthene	ug/Kg														
Benzo(e)pyrene	ug/Kg														
Biphenyl	ug/Kg														
Chrysene	ug/Kg														
Dibenzothiophene	ug/Kg														
Fluoranthene	ug/Kg														
Fluorene	ug/Kg														
Naphthalene	ug/Kg														
Perylene	ug/Kg														
Phenanthrene	ug/Kg														
Pyrene	ug/Kg														
Chlorinated Herbicides															
2,4,5 TP-Silvex	ug/Kg	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10
2,4-D	ug/Kg	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100

Sediment Chemistry in the Newport Bay Watershed

	Site	BARSED				CICF25			CMCG02	
	Date	8/22/05	11/2/05	2/2/06	6/27/06	8/22/05	11/2/05	2/2/06	8/22/05	11/2/05
	Time	8:19	9:50	8:05	8:42	7:20	9:00	8:30	10:41	12:45
TOC-S	%C	0.36	2.6	0.72	0.22	0.52	1.81	3.29	17.61	13.06
%Clay	%	0.79	6.89	5.87	1.91	1.01	20.52	23.76	3.33	10.66
%Silt + Clay	%	3.75	33.54	34.95	7.1	14.19	74.49	82.21	12.45	42.22
Metals										
Ag	mg/kg	<0.025	1.06	0.09	0.2	<0.025	1.22	0.3	<0.025	1.87
Al	mg/kg	5170	>50000	16900	1556	7990	>50000	63500	6340	17600
As	mg/kg	3.27	12.6	4.63	1.7	3.38	12.5	10.8	3.73	6.74
Ba	mg/kg	80.6	221	165	20.4	101	372	357	117	173
Be	mg/kg	0.13	0.97	0.37	0.1	0.19	1.94	1.4	0.15	0.51
Cd	mg/kg	0.66	0.88	0.32	0.5	0.58	1.75	1.77	1.53	2.48
Co	mg/kg	2.33	40.1	4.72	1.1	2.97	21.7	15	4.01	42.4
Cr	mg/kg	6.07	12	17.5	2.7	9.88	57.4	48.6	17.4	11.1
Cu	mg/kg	7.74	42	19.3	3.4	9.03	43	39.2	81.2	238
Fe	mg/kg	7470	32700	13500	3161	10800	63300	50000	10100	19700
Hg	mg/kg	0.0148	44.8	0.0146	<0.01	0.00638	31.4	0.0402	0.0147	0.0194
Mn	mg/kg	208	814	372	97.3	195	1001	735	352	450
Mo	mg/kg	1.73	13.6	3.21	1.4	0.87	2.4	3	1.93	2.64
Ni	mg/kg	4.44	21.8	9.33	2.6	4.79	29.1	25.7	17.5	43.4
Pb	mg/kg	4.79	15.6	5.48	2.09	9.64	21.7	18.3	130	199
Sb	mg/kg	0.18	0.97	0.51	0.2	0.21	0.22	1.43	1.31	3.01
Se	mg/kg	1.31	13.8	3.31	1.1	0.35	2.04	1.21	1.69	3.65
Sn	mg/kg	0.64	2.94	1.16	0.2	1.1	3.58	3.17	4.19	9.18
Sr	mg/kg	196	318	187	61	42.4	148	169	154	136
Ti	mg/kg	300	1310	591	48.5	831	3900	2740	621	1370
Tl	mg/kg		0.31	0.16	<0.025		0.55	0.58		0.2
V	mg/kg	19.3	105	41.6	6.7	29	172	137	26.9	58.4
Zn	mg/kg	46.2	174	54.2	17	44.1	218	217	260	688
Pyrethroid Pesticides										
Allethrin	ug/Kg		<5		<5		<5			<5
Bifenthrin	ug/Kg		e 14		10		e 10			95.3
Cyfluthrin	ug/Kg		<5		<5		<5			<5
Cypermethrin	ug/Kg		<5		<5		<5			<5
Deltamethrin	ug/Kg		<5		<5		<5			<5
L-Cyhalothrin	ug/Kg		<5		<5		<5			<5
Permethrin	ug/Kg		<5		<5		<5			<5
Prallethrin	ug/Kg		<5		<5		<5			<5
Triazine Pesticides										
Ametryn	ug/Kg	<5	<1	<5	<5	<5		<5	<5	
Atraton	ug/Kg	<5	<5	<5	<5	<5		<5	<5	
Atrazine	ug/Kg	<5	<5	<5	<5	<5		<5	<5	
Prometon	ug/Kg	<5	<5	<5	<5	<5		<5	<5	
Prometryn	ug/Kg	<5	<5	<5	<5	<5		<5	<5	
Propazine	ug/Kg	<5	<5	<5	<5	<5		<5	<5	
Secbumeton	ug/Kg	<5	<5	<5	<5	<5		<5	<5	
Simazine	ug/Kg	<5	<5	<5	<5	<5		<5	<5	
Simetryn	ug/Kg	<5	<5	<5	<5	<5		<5	<5	
Terbuthylazine	ug/Kg	<5	<5	<5	<5	<5		<5	<5	
Tertbutryn	ug/Kg	<5	<5	<5	<5	<5		<5	<5	

Sediment Chemistry in the Newport Bay Watershed

	Site	BARSED				CICF25			CMCG02	
	Date	8/22/05	11/2/05	2/2/06	6/27/06	8/22/05	11/2/05	2/2/06	8/22/05	11/2/05
	Time	8:19	9:50	8:05	8:42	7:20	9:00	8:30	10:41	12:45
Organochlorine Pesticides and PCB Arochlors										
2,4 DDD	ug/Kg	<1	<1	<1	<1	<1		<1	6.3	
2,4 DDE	ug/Kg	<1	<1	<1	<1	<1		<1	e 3.8	
2,4 DDT	ug/Kg	<1	<1	<1	<1	<1		<1	<1	
4,4'-DDD	ug/Kg	<1	<1	<1	2	e 2.4		e 2.9	37.9	
4,4'-DDE	ug/Kg	e 2.1	e 2.8	e 1.3	4.7	21.2		36.5	45.6	
4,4'-DDT	ug/Kg	<1	<1	<1	<1	<1		<1	188	
alpha-BHC	ug/Kg	<1	<1	<1	<1	<1		<1	<1	
beta-BHC	ug/Kg	<1	<1	<1	<1	<1		<1	<1	
delta-BHC	ug/Kg	<1	<1	<1	<1	<1		<1	<1	
gamma-BHC (Lindane)	ug/Kg	<1	<1	<1	<1	<1		<1	<1	
Aldrin	ug/Kg	<1	<1	<1	<1	<1		<1	<1	
Chlordane	ug/Kg		1.3	<1	2.3			5.7		
Chlordane-alpha	ug/Kg		<1	<1	1.2			<1		
Chlordane-gamma	ug/Kg		<1		1.1					
OxyChlordane	ug/Kg	<1	<1	<1	<1	<1		<1	<1	
cis-Nonachlor	ug/Kg		<1	<1	<1			<1		
Dieldrin	ug/Kg	<1	<1	<1	<1	<1		<1	<1	
Endosulfan I	ug/Kg	<1	<1	<1	<1	<1		<1	<1	
Endosulfan II	ug/Kg	<1	<1	<1	<1	<1		<1	<1	
Endosulfan Sulfate	ug/Kg	<1	<1	<1	<1	<1		<1	<1	
Endrin	ug/Kg	<1	<1	<1	<1	<1		<1	<1	
Endrin aldehyde	ug/Kg	<1	NR		<1	<1			<1	
Endrin Ketone	ug/Kg	<1	<1	<1	<1	<1		<1	<1	
Heptachlor	ug/Kg	<1	<1	<1	<1	<1		<1	<1	
Heptachlor Epoxide	ug/Kg	<1	<1	<1	<1	<1		<1	13.7	
Methoxychlor	ug/Kg	<1	<1	<1	<1	<1		<1	<1	
Mirex	ug/Kg		<1	<1	<1			<1		
PCB-1016	ug/Kg	<10	<10	<10	<10	<10		<10	<10	
PCB-1221	ug/Kg	<10	<10	<10	<10	<10		<10	<10	
PCB-1232	ug/Kg	<10	<10	<10	<10	<10		<10	<10	
PCB-1242	ug/Kg	<10	<10	<10	<10	<10		<10	<10	
PCB-1248	ug/Kg	<10	<10	<10	<10	<10		<10	<10	
PCB-1254	ug/Kg	<10	<10	<10	<10	<10		<10	<10	
PCB-1260	ug/Kg	<10	<10	<10	<10	<10		<10	<10	
Perthane	ug/Kg	<5	<5	<5	<5	<5		<5	<5	
Toxaphene	ug/Kg	<10	<10	<10	<10	<10		<10	<10	
Trans-Nonachlor	ug/Kg		E 1.3	<1	<1			e 3.8		
Organophosphate Pesticides										
Bolstar	ug/Kg	<10	<10	<10	<10	<10		<10	<10	
Chlorpyrifos	ug/Kg	<5	<5	<5	<5	<5		<5	<5	
Demeton	ug/Kg	<10	<10	<10	<10	<10		<10	<10	
Diazinon	ug/Kg	<5	<5	<5	<5	<5		<5	<5	
Dichlorvos	ug/Kg	<10	<10	<10	<10	<10		<10	<10	
Dimethoate	ug/Kg	<5	<5	<5	<5	<5		<5	<5	
Disulfoton	ug/Kg	<10	<10	<10	<10	<10		<10	<10	
Ethoprop	ug/Kg	<10	<10	<10	<10	<10		<10	<10	
Fenchlorphos	ug/Kg	<10	<10	<10	<10	<10		<10	<10	
Fensulfothion	ug/Kg	<10	<10	<10	<10	<10		<10	<10	
Fenthion	ug/Kg	<10	<10	<10	<10	<10		<10	<10	
Malathion	ug/Kg	<5	<5	<5	<5	<5		<5	<5	
Merphos	ug/Kg	<10	<10	<10	<10	<10		<10	<10	
Mevinphos	ug/Kg	<10	<10	<10	<10	<10		<10	<10	
Parathion-Methyl	ug/Kg	<10	<10	<10	<10	<10		<10	<10	
Phorate	ug/Kg	<10	<10	<10	<10	<10		<10	<10	
Tetrachlorvinphos	ug/Kg	<10	<10	<10	<10	<10		<10	<10	
Tokuthion	ug/Kg	<10	<10	<10	<10	<10		<10	<10	
Trichloronate	ug/Kg	<10	<10	<10	<10	<10		<10	<10	
PCB Congeners										
PCB018	ug/Kg	<1	<1	<1	<1	<1		<1	<1	
PCB028	ug/Kg	<1	<1	<1	<1	<1		<1	<1	
PCB031	ug/Kg	<1	<1	<1	<1	<1		<1	<1	
PCB033	ug/Kg	<1	<1	<1	<1	<1		<1	<1	
PCB037	ug/Kg	<1	<1	<1	<1	<1		<1	<1	
PCB044	ug/Kg	<1	<1	<1	<1	<1		<1	<1	
PCB049	ug/Kg	<1	<1	<1	<1	<1		<1	<1	
PCB052	ug/Kg	<1	<1	<1	<1	<1		<1	<1	
PCB066	ug/Kg	<1	<1	<1	<1	<1		<1	<1	
PCB070	ug/Kg	<1	<1	<1	<1	<1		<1	<1	
PCB074	ug/Kg	<1	<1	<1	<1	<1		<1	<1	
PCB077	ug/Kg	<1	<1	<1	<1	<1		<1	<1	
PCB081	ug/Kg	<1	<1	<1	<1	<1		<1	<1	
PCB087	ug/Kg	<1	<1	<1	<1	<1		<1	<1	
PCB095	ug/Kg	<1	<1	<1	<1	<1		<1	<1	
PCB097	ug/Kg	<1	<1	<1	<1	<1		<1	<1	
PCB099	ug/Kg	<1	<1	<1	<1	<1		<1	<1	

Sediment Chemistry in the Newport Bay Watershed

	Site	BARSED				CICF25			CMCG02	
	Date	8/22/05	11/2/05	2/2/06	6/27/06	8/22/05	11/2/05	2/2/06	8/22/05	11/2/05
	Time	8:19	9:50	8:05	8:42	7:20	9:00	8:30	10:41	12:45
PCB101	ug/Kg	<1	<1	<1	<1	<1		<1	<1	
PCB105	ug/Kg	<1	<1	<1	<1	<1		<1	<1	
PCB110	ug/Kg	<1	<1	<1	<1	<1		<1	<1	
PCB114	ug/Kg	<1	<1	<1	<1	<1		<1	<1	
PCB118	ug/Kg	<1	<1	<1	<1	<1		<1	<1	
PCB119	ug/Kg	<1	<1	<1	<1	<1		<1	<1	
PCB123	ug/Kg	<1	<1	<1	<1	<1		<1	<1	
PCB126	ug/Kg	<1	<1	<1	<1	<1		<1	<1	
PCB128+167	ug/Kg	<1	<1	<1	<1	<1		<1	<1	
PCB138	ug/Kg	<1	<1	<1	<1	<1		<1	<1	
PCB141	ug/Kg	<1	<1	<1	<1	<1		<1	<1	
PCB149	ug/Kg	<1	<1	<1	<1	<1		<1	<1	
PCB151	ug/Kg	<1	<1	<1	<1	<1		<1	<1	
PCB153	ug/Kg	<1	<1	<1	<1	<1		<1	<1	
PCB156	ug/Kg	<1	<1	<1	<1	<1		<1	<1	
PCB157	ug/Kg	<1	<1	<1	<1	<1		<1	<1	
PCB158	ug/Kg	<1	<1	<1	<1	<1		<1	<1	
PCB168+132	ug/Kg	<1	<1	<1	<1	<1		<1	<1	
PCB169	ug/Kg	<1	<1	<1	<1	<1		<1	<1	
PCB170	ug/Kg	<1	<1	<1	<1	<1		<1	<1	
PCB177	ug/Kg	<1	<1	<1	<1	<1		<1	<1	
PCB180	ug/Kg	<1	<1	<1	<1	<1		<1	<1	
PCB183	ug/Kg	<1	<1	<1	<1	<1		<1	<1	
PCB187	ug/Kg	<1	<1	<1	<1	<1		<1	<1	
PCB189	ug/Kg	<1	<1	<1	<1	<1		<1	<1	
PCB194	ug/Kg	<1	<1	<1	<1	<1		<1	<1	
PCB200	ug/Kg	<1	<1	<1	<1	<1		<1	<1	
PCB201	ug/Kg	<1	<1	<1	<1	<1		<1	<1	
PCB206	ug/Kg	<1	<1	<1	<1	<1		<1	<1	
Polynuclear Aromatic Hydrocarbons										
1-Methylnaphthalene	ug/Kg									
1-Methylphenanthrene	ug/Kg									
(1,2,3-CE)Pyrene	ug/Kg									
1,2,5,6- Dibenzanthracene	ug/Kg									
2,3,5-TriMethylnaphthalene	ug/Kg									
2,6-Dimethylnaphthalene	ug/Kg									
2-Methylnaphthalene	ug/Kg									
Acenaphthene	ug/Kg									
Acenaphthylene	ug/Kg									
Anthracene	ug/Kg									
Benzo (A) Anthracene	ug/Kg									
Benzo (A) Pyrene	ug/Kg									
Benzo (k) Fluoranthene	ug/Kg									
Benzo (GHI) Perylene	ug/Kg									
Benzo(b)fluoranthene	ug/Kg									
Benzo(e)pyrene	ug/Kg									
Biphenyl	ug/Kg									
Chrysene	ug/Kg									
Dibenzothiophene	ug/Kg									
Fluoranthene	ug/Kg									
Fluorene	ug/Kg									
Naphthalene	ug/Kg									
Perylene	ug/Kg									
Phenanthrene	ug/Kg									
Pyrene	ug/Kg									
Chlorinated Herbicides										
2,4,5 TP-Silvex	ug/Kg	<10		<10	<10	<10		<10	<10	
2,4-D	ug/Kg	<100		<100	<100	<100		<100	<100	

Sediment Chemistry in the Newport Bay Watershed

	Site	SADF01				SDMF05				WYLSED			
	Date	8/22/05	11/2/05	2/2/06	6/27/06	8/22/05	11/2/05	2/2/06	6/27/06	8/22/05	11/2/05	2/2/06	6/27/06
	Time	10:07	12:05	9:03	10:48	9:26	11:40	8:37	10:05	8:45	10:25	9:30	9:16
TOC-S	%C	0.45	0.51	6.61	0.34	0.18	3.58	2.05	0.31	0.16	0.17	0.28	0.04
%Clay	%	0	0	4.97	0	16.01	10.53	2.75	3.89	0	0	0	0
%Silt + Clay	%	0.49	0.2	15.69	0.1	77.89	50.76	14.99	12.61	0.71	0.53	1.42	0.15
Metals													
Ag	mg/kg	<0.025	0.8	0.2	0.2	<0.025	1.34	0.16	0.1	<0.025	0.8	0.08	0.2
Al	mg/kg	2790	3860	7850	1572	>50000	22200	17800	1171	2240	2620	2320	521
As	mg/kg	2.2	1.42	3.59	1.5	2.87	8.32	4.26	0.7	0.987	0.77	0.79	0.5
Ba	mg/kg	174	50.5	142	16.4	89.1	1.22	111	17.9	39.9	20.1	18.8	12.1
Be	mg/kg	0.08	0.13	0.2	0.1	0.3	0.6	0.43	0.1	0.067	0.09	0.08	<0.025
Cd	mg/kg	0.34	0.22	1.07	0.2	0.59	2.15	0.93	0.2	0.476	0.24	0.15	0.1
Co	mg/kg	2.44	10.1	3.53	1.7	5.18	26.8	5.17	0.9	0.585	1.49	0.66	0.2
Cr	mg/kg	6.49	2.69	15.8	3.4	18	8.04	18.8	2.4	2.09	0.64	2.07	1
Cu	mg/kg	24.2	17.1	61.2	10.9	9.04	46.3	21.4	3	1.35	1.63	1.15	0.7
Fe	mg/kg	7330	7680	10700	4540	14200	20000	14800	2070	3140	2560	2660	1162
Hg	mg/kg	0.0129	0.0251	0.0243	e 0.01135	0.00842	19.6	0.0214	<0.01	0.7435	2.42	0.00121	<0.01
Mn	mg/kg	244	151	582	115.2	267	308	351	62.2	80	73.2	67	51.6
Mo	mg/kg	1.36	0.76	5.5	0.2	0.64	13	1.41	0.2	0.39	0.67	0.28	0.2
Ni	mg/kg	5.48	7.14	10.2	3	10.5	18.8	11.8	1.8	1.27	1.23	0.98	0.7
Pb	mg/kg	10.3	37.7	27.7	7.17	4.31	16.8	9.25	1.04	1.27	0.92	1.11	0.73
Sb	mg/kg	0.09	<0.025	5.21	0.2	<0.025	0.73	0.76	0.1	<0.025	<0.025	0.13	0.1
Se	mg/kg	1.23	0.74	3.39	0.5	0.24	6.23	2.21	0.2	0.285	0.42	0.14	0.1
Sn	mg/kg	0.44	1.49	2.46	0.2	0.81	2.5	1.69	0.2	0.757	0.5	0.35	0.1
Sr	mg/kg	227	72.8	852	56.2	43.7	167	161	31.1	43.2	32.4	14.2	8.7
Ti	mg/kg	252	198	567	58.5	665	1440	990	36.6	536	495	451	21.5
Tl	mg/kg		e 0.04	0.09	<0.025		0.22	0.18	<0.025		e 0.03	0.03	<0.025
V	mg/kg	15.7	13.8	26.9	6.1	30.4	70.9	44.4	4.4	9.64	10.2	7.39	2.9
Zn	mg/kg	50.4	91.1	247	42.8	33.7	193	104	10.8	9.47	10.1	8.03	6.2
Pyrethroid Pesticides													
Allethrin	ug/Kg		<5		<5		<5		<5		<5		<5
Bifenthrin	ug/Kg		<5		<5		59.3		3.3		<5		<5
Cyfluthrin	ug/Kg		<5		<5		<5		<5		<5		<5
Cypermethrin	ug/Kg		<5		<5		<5		<5		<5		<5
Deltamethrin	ug/Kg		<5		<5		<5		<5		<5		<5
L-Cyhalothrin	ug/Kg		<5		<5		<5		<5		<5		<5
Permethrin	ug/Kg		<5		<5		<5		<5		<5		<5
Prallethrin	ug/Kg		<5		<5		<5		<5		<5		<5
Triazine Pesticides													
Ametryn	ug/Kg	<5		<5	<5	<5		<5	<5	<5		<5	<5
Atraton	ug/Kg	<5		<5	<5	<5		<5	<5	<5		<5	<5
Atrazine	ug/Kg	<5		<5	<5	<5		<5	<5	<5		<5	<5
Prometon	ug/Kg	<5		<5	<5	<5		<5	<5	<5		<5	<5
Prometryn	ug/Kg	<5		<5	<5	<5		<5	<5	<5		<5	<5
Propazine	ug/Kg	<5		<5	<5	<5		<5	<5	<5		<5	<5
Secbumeton	ug/Kg	<5		<5	<5	<5		<5	<5	<5		<5	<5
Simazine	ug/Kg	<5		<5	<5	<5		<5	<5	<5		<5	<5
Simetryn	ug/Kg	<5		<5	<5	<5		<5	<5	<5		<5	<5
Terbuthylazine	ug/Kg	<5		<5	<5	<5		<5	<5	<5		<5	<5
Tertbutryn	ug/Kg	<5		<5	<5	<5		<5	<5	<5		<5	<5

Sediment Chemistry in the Newport Bay Watershed

	Site	SADF01				SDMF05				WYLSED			
	Date	8/22/05	11/2/05	2/2/06	6/27/06	8/22/05	11/2/05	2/2/06	6/27/06	8/22/05	11/2/05	2/2/06	6/27/06
	Time	10:07	12:05	9:03	10:48	9:26	11:40	8:37	10:05	8:45	10:25	9:30	9:16
Organochlorine Pesticides and PCB Arochlc													
2,4 DDD	ug/Kg	<1		<1	<1	<1		<1	<1	<1		<1	<1
2,4 DDE	ug/Kg	<1		<1	<1	<1		<1	<1	<1		<1	<1
2,4 DDT	ug/Kg	<1		<1	<1	<1		<1	<1	<1		<1	<1
4,4'-DDD	ug/Kg	<1		<1	<1	<1		e 2.2	<1	<1		<1	<1
4,4'-DDE	ug/Kg	<1		e 4.5	6.3	5.8		e 5	2.4	<1		<1	<1
4,4'-DDT	ug/Kg	<1		<1	<1	<1		<1	<1	<1		<1	<1
alpha-BHC	ug/Kg	<1		<1	<1	<1		<1	<1	<1		<1	<1
beta-BHC	ug/Kg	<1		<1	<1	<1		<1	<1	<1		<1	<1
delta-BHC	ug/Kg	<1		<1	<1	<1		<1	<1	<1		<1	<1
gamma-BHC (Lindane)	ug/Kg	<1		<1	<1	<1		<1	<1	<1		<1	<1
Aldrin	ug/Kg	<1		<1	<1	<1		<1	<1	<1		<1	<1
Chlordane	ug/Kg			<1	2.3			<1	<1			<1	<1
Chlordane-alpha	ug/Kg			<1	1.2			<1	<1			<1	<1
Chlordane-gamma	ug/Kg				1.1				<1				<1
OxyChlordane	ug/Kg	<1		<1	<1	<1		<1	<1	<1		<1	<1
cis-Nonachlor	ug/Kg			<1	<1			<1	<1			<1	<1
Dieldrin	ug/Kg	<1		<1	<1	<1		<1	<1	<1		<1	<1
Endosulfan I	ug/Kg	<1		<1	<1	<1		<1	<1	<1		<1	<1
Endosulfan II	ug/Kg	<1		<1	<1	<1		<1	<1	<1		<1	<1
Endosulfan Sulfate	ug/Kg	<1		<1	<1	<1		<1	<1	<1		<1	<1
Endrin	ug/Kg	<1		<1	<1	<1		<1	<1	<1		<1	<1
Endrin aldehyde	ug/Kg	<1			<1	<1			<1	<1			<1
Endrin Ketone	ug/Kg	<1		<1	<1	<1		<1	<1	<1		<1	<1
Heptachlor	ug/Kg	<1		<1	<1	<1		<1	<1	<1		<1	<1
Heptachlor Epoxide	ug/Kg	<1		<1	<1	<1		<1	<1	<1		<1	<1
Methoxychlor	ug/Kg	<1		<1	<1	<1		<1	<1	<1		<1	<1
Mirex	ug/Kg			<1	<1			<1	<1			<1	<1
PCB-1016	ug/Kg	<10		<10	<10	<10		<10	<10	<10		<10	<10
PCB-1221	ug/Kg	<10		<10	<10	<10		<10	<10	<10		<10	<10
PCB-1232	ug/Kg	<10		<10	<10	<10		<10	<10	<10		<10	<10
PCB-1242	ug/Kg	<10		<10	<10	<10		<10	<10	<10		<10	<10
PCB-1248	ug/Kg	<10		<10	<10	<10		<10	<10	<10		<10	<10
PCB-1254	ug/Kg	<10		<10	<10	<10		<10	<10	<10		<10	<10
PCB-1260	ug/Kg	<10		<10	<10	<10		<10	<10	<10		<10	<10
Perthane	ug/Kg	<5		<5	<5	<5		<5	<5	<5		<5	<5
Toxaphene	ug/Kg	<10		<10	<10	<10		<10	<10	<10		<10	<10
Trans-Nonachlor	ug/Kg			<1	<1			<1	<1			<1	<1
Organophosphate Pesticides													
Bolstar	ug/Kg	<10		<10	<10	<10		<10	<10	<10		<10	<10
Chlorpyrifos	ug/Kg	<5		<5	<5	<5		<5	<5	<5		<5	<5
Demeton	ug/Kg	<10		<10	<10	<10		<10	<10	<10		<10	<10
Diazinon	ug/Kg	<5		<5	<5	<5		<5	<5	<5		<5	<5
Dichlorvos	ug/Kg	<10		<10	<10	<10		<10	<10	<10		<10	<10
Dimethoate	ug/Kg	<5		<5	<5	<5		<5	<5	<5		<5	<5
Disulfoton	ug/Kg	<10		<10	<10	<10		<10	<10	<10		<10	<10
Ethoprop	ug/Kg	<10		<10	<10	<10		<10	<10	<10		<10	<10
Fenchlorphos	ug/Kg	<10		<10	<10	<10		<10	<10	<10		<10	<10
Fensulfothion	ug/Kg	<10		<10	<10	<10		<10	<10	<10		<10	<10
Fenthion	ug/Kg	<10		<10	<10	<10		<10	<10	<10		<10	<10
Malathion	ug/Kg	<5		<5	<5	<5		<5	<5	<5		<5	<5
Merphos	ug/Kg	<10		<10	<10	<10		<10	<10	<10		<10	<10
Mevinphos	ug/Kg	<10		<10	<10	<10		<10	<10	<10		<10	<10
Parathion-Methyl	ug/Kg	<10		<10	<10	<10		<10	<10	<10		<10	<10
Phorate	ug/Kg	<10		<10	<10	<10		<10	<10	<10		<10	<10
Tetrachlorvinphos	ug/Kg	<10		<10	<10	<10		<10	<10	<10		<10	<10
Tokuthion	ug/Kg	<10		<10	<10	<10		<10	<10	<10		<10	<10
Trichloronate	ug/Kg	<10		<10	<10	<10		<10	<10	<10		<10	<10
PCB Congeners													
PCB018	ug/Kg	<1		<1	<1	<1		<1	<1	<1		<1	<1
PCB028	ug/Kg	<1		<1	<1	<1		<1	<1	<1		<1	<1
PCB031	ug/Kg	<1		<1	<1	<1		<1	<1	<1		<1	<1
PCB033	ug/Kg	<1		<1	<1	<1		<1	<1	<1		<1	<1
PCB037	ug/Kg	<1		<1	<1	<1		<1	<1	<1		<1	<1
PCB044	ug/Kg	<1		<1	<1	<1		<1	<1	<1		<1	<1
PCB049	ug/Kg	<1		<1	<1	<1		<1	<1	<1		<1	<1
PCB052	ug/Kg	<1		<1	<1	<1		<1	<1	<1		<1	<1
PCB066	ug/Kg	<1		<1	<1	<1		<1	<1	<1		<1	<1
PCB070	ug/Kg	<1		<1	<1	<1		<1	<1	<1		<1	<1
PCB074	ug/Kg	<1		<1	<1	<1		<1	<1	<1		<1	<1
PCB077	ug/Kg	<1		<1	<1	<1		<1	<1	<1		<1	<1
PCB081	ug/Kg	<1		<1	<1	<1		<1	<1	<1		<1	<1
PCB087	ug/Kg	<1		<1	<1	<1		<1	<1	<1		<1	<1
PCB095	ug/Kg	<1		<1	<1	<1		<1	<1	<1		<1	<1
PCB097	ug/Kg	<1		<1	<1	<1		<1	<1	<1		<1	<1
PCB099	ug/Kg	<1		<1	<1	<1		<1	<1	<1		<1	<1

Sediment Chemistry in the Newport Bay Watershed

	Site	SADF01				SDMF05				WYLSED			
	Date	8/22/05	11/2/05	2/2/06	6/27/06	8/22/05	11/2/05	2/2/06	6/27/06	8/22/05	11/2/05	2/2/06	6/27/06
	Time	10:07	12:05	9:03	10:48	9:26	11:40	8:37	10:05	8:45	10:25	9:30	9:16
PCB101	ug/Kg	<1		<1	<1	<1		<1	<1	<1		<1	<1
PCB105	ug/Kg	<1		<1	<1	<1		<1	<1	<1		<1	<1
PCB110	ug/Kg	<1		<1	<1	<1		<1	<1	<1		<1	<1
PCB114	ug/Kg	<1		<1	<1	<1		<1	<1	<1		<1	<1
PCB118	ug/Kg	<1		<1	<1	<1		<1	<1	<1		<1	<1
PCB119	ug/Kg	<1		<1	<1	<1		<1	<1	<1		<1	<1
PCB123	ug/Kg	<1		<1	<1	<1		<1	<1	<1		<1	<1
PCB126	ug/Kg	<1		<1	<1	<1		<1	<1	<1		<1	<1
PCB128+167	ug/Kg	<1		<1	<1	<1		<1	<1	<1		<1	<1
PCB138	ug/Kg	<1		<1	<1	<1		<1	<1	<1		<1	<1
PCB141	ug/Kg	<1		<1	<1	<1		<1	<1	<1		<1	<1
PCB149	ug/Kg	<1		<1	<1	<1		<1	<1	<1		<1	<1
PCB151	ug/Kg	<1		<1	<1	<1		<1	<1	<1		<1	<1
PCB153	ug/Kg	<1		<1	<1	<1		<1	<1	<1		<1	<1
PCB156	ug/Kg	<1		<1	<1	<1		<1	<1	<1		<1	<1
PCB157	ug/Kg	<1		<1	<1	<1		<1	<1	<1		<1	<1
PCB158	ug/Kg	<1		<1	<1	<1		<1	<1	<1		<1	<1
PCB168+132	ug/Kg	<1		<1	<1	<1		<1	<1	<1		<1	<1
PCB169	ug/Kg	<1		<1	<1	<1		<1	<1	<1		<1	<1
PCB170	ug/Kg	<1		<1	<1	<1		<1	<1	<1		<1	<1
PCB177	ug/Kg	<1		<1	<1	<1		<1	<1	<1		<1	<1
PCB180	ug/Kg	<1		<1	<1	<1		<1	<1	<1		<1	<1
PCB183	ug/Kg	<1		<1	<1	<1		<1	<1	<1		<1	<1
PCB187	ug/Kg	<1		<1	<1	<1		<1	<1	<1		<1	<1
PCB189	ug/Kg	<1		<1	<1	<1		<1	<1	<1		<1	<1
PCB194	ug/Kg	<1		<1	<1	<1		<1	<1	<1		<1	<1
PCB200	ug/Kg	<1		<1	<1	<1		<1	<1	<1		<1	<1
PCB201	ug/Kg	<1		<1	<1	<1		<1	<1	<1		<1	<1
PCB206	ug/Kg	<1		<1	<1	<1		<1	<1	<1		<1	<1
Polynuclear Aromatic Hydrocarbons													
1-Methylnaphthalene	ug/Kg												
1-Methylphenanthrene	ug/Kg												
(1,2,3-CE)Pyrene	ug/Kg												
1,2,5,6- Dibenzanthracene	ug/Kg												
2,3,5-TriMethylnaphthalene	ug/Kg												
2,6-Dimethylnaphthalene	ug/Kg												
2-Methylnaphthalene	ug/Kg												
Acenaphthene	ug/Kg												
Acenaphthylene	ug/Kg												
Anthracene	ug/Kg												
Benzo (A) Anthracene	ug/Kg												
Benzo (A) Pyrene	ug/Kg												
Benzo (k) Fluoranthene	ug/Kg												
Benzo (GHI) Perylene	ug/Kg												
Benzo(b)fluoranthene	ug/Kg												
Benzo(e)pyrene	ug/Kg												
Biphenyl	ug/Kg												
Chrysene	ug/Kg												
Dibenzothiophene	ug/Kg												
Fluoranthene	ug/Kg												
Fluorene	ug/Kg												
Naphthalene	ug/Kg												
Perylene	ug/Kg												
Phenanthrene	ug/Kg												
Pyrene	ug/Kg												
Chlorinated Herbicides													
2,4,5 TP-Silvex	ug/Kg	<10		<10	<10	<10		<10	<10	<10		<10	<10
2,4-D	ug/Kg	<100		<100	<100	<100		<100	<100	<100		<100	<100

Sediment Chemistry in the North Orange County Watershed

	Site	BCC02			CARB01			CCBA01			EGWC05			FULA03		
	Date	8/24/05	11/15/05	2/9/06	8/24/05	11/15/05	2/9/06	8/24/05	11/15/05	2/9/06	8/24/05	11/15/05	2/9/06	8/24/05	11/15/05	2/9/06
	Time	9:32	11:03	10:30	8:52	10:26	10:29	8:17	9:45	9:52	10:04	11:32	11:00	7:50	9:06	9:13
Hyallela Azteca Sed. Tox.	% Survival															
Nitrogen	mg/kg															
Phosphorus	mg/kg															
TOC-S	%C	1.06	0.99	0.68	0.26	0.72	0.37	0.79	0.45	0.53	0.28	0.67	0.34	6.25	0.36	1.4
Clay		2.16	2.4	1.59	1.27	0		0.2	0	0.76	0	4.92	0.67	16.62	0.32	0
Silt + Clay		17.29	16.53	11.47	23.02	0.48		3.9	0.19	5.45	0.3	34.43	4.23	55.31	0.91	0.17
Metals																
Ag	mg/kg	< 0.025	0.27	0.07	< 0.025	0.19	0.04	< 0.025	0.21	0.1	< 0.025	0.24	0.04	< 0.025	0.16	0.04
Al	mg/kg	> 50000	16300	> 50000	2090	5460	3600	2320	4780	5910	2200	7820	5310	12000	4130	2890
As	mg/kg	3.17	2.3	2.16	3.79	1.16	1.25	1.35	1.94	1.5	1.43	1.96	1.46	3.65	0.91	0.96
Ba	mg/kg	137	106	101	60.4	57.9	26.6	129	41.3	78	27.3	61.9	38.6	225	31.3	25.2
Be	mg/kg	0.26	0.36	0.32	0.06	0.12	0.1	e 0.05	0.12	0.13	0.06	0.18	0.14	0.224	0.09	0.07
Cd	mg/kg	0.47	0.39	0.34	0.23	0.22	0.12	0.58	0.34	0.57	0.25	0.35	0.2	1.52	0.23	0.27
Co	mg/kg	6.87	7.29	6.29	1.23	1.99	1.44	1.38	1.88	2.12	1.99	3.1	2.45	5.45	1.7	1.03
Cr	mg/kg	19.6	22.2	20	3.32	8.6	3.27	5.64	6.76	10.6	2.47	8.6	5.41	29.9	9.99	4.74
Cu	mg/kg	22.7	20.5	20.3	5.85	17.6	4.76	8.12	9.12	9.16	4.97	18.7	6.45	41.1	8.46	14.4
Fe	mg/kg	20100	22300	21300	5040	10800	5680	5590	7670	7750	4570	8620	7060	17000	9590	4740
Hg	mg/kg	0.00044	0.0235	0.0288	0.00014	0.00748	0.0041	0.0001	0.014	0.0182	0.00023	0.0175	0.0135	0.00031	0.00942	0.0121
Mn	mg/kg	459	575	455	124	234	125	240	253	13.8	76.4	377	212	279	344	42.9
Mo	mg/kg	2.05	5.95	2.72	3.28	1.79	0.43	1.34	2.23	1.71	0.74	1.18	0.4	4.17	0.68	0.93
Ni	mg/kg	12.6	12.8	11.3	3.19	3.98	2.72	5.17	5.92	6.34	3.83	6.3	4.06	19.5	4.14	3.58
Pb	mg/kg	23.2	21.3	20.5	6.5	25.4	4.26	4.54	8.09	5.86	11.9	9.8	36	50.4	48.9	5.58
Sb	mg/kg	0.53	0.33	0.5	0.23	0.17	0.16	0.12	0.23	0.33	0.18	0.39	0.19	1.22	0.26	0.42
Se	mg/kg	0.71	1.15	0.63	0.62	0.94	0.22	1.47	0.63	0.76	0.41	1	0.38	1.82	0.35	0.22
Sn	mg/kg	2.49	1.77	2.04	0.68	0.66	0.37	0.53	1.79	0.81	0.32	1.04	0.59	3.09	1.38	3.9
Sr	mg/kg	276	332	233	368	296	59.2	570	69	185	45	268	82.1	376	28.2	25.1
Ti	mg/kg	1690	2370	1990	267	875	269	279	325	395	157	647	480	913	409	151
Tl	mg/kg	0.18	0.16	0.16	e 0.04	e 0.04	0.08	e 0.05	e 0.05	0.11	e 0.04	0.06	0.06	0.18	e 0.04	0.04
V	mg/kg	42.5	50.7	41.6	11.1	25.5	11.1	15.1	18.4	22.4	9.01	19.9	14.4	52.2	15.3	11.2
Zn	mg/kg	149	128	124	49.8	75.1	37.4	31.9	58.4	56.1	36.8	85.4	42.1	230	59.4	57.6
Pyrethroid Pesticides																
Allethrin	ug/Kg															
Bifenthrin	ug/Kg															
Cyfluthrin	ug/Kg															
Cypermethrin	ug/Kg															
Deltamethrin	ug/Kg															
L-Cyhalothrin	ug/Kg															
Permethrin	ug/Kg															
Prallethrin	ug/Kg															
Triazine Pesticides																
Ametryn	ug/Kg	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5
Atraton	ug/Kg	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5
Atrazine	ug/Kg	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5
Prometon	ug/Kg	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5
Prometryn	ug/Kg	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5
Propazine	ug/Kg	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5
Secbumeton	ug/Kg	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5
Simazine	ug/Kg	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5
Simetryn	ug/Kg	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5
Terbuthylazine	ug/Kg	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5
Tertbutryn	ug/Kg	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5

Sediment Chemistry in the North Orange County Watershed

	Site	BCC02			CARB01			CCBA01			EGWC05			FULA03		
	Date	8/24/05	11/15/05	2/9/06	8/24/05	11/15/05	2/9/06	8/24/05	11/15/05	2/9/06	8/24/05	11/15/05	2/9/06	8/24/05	11/15/05	2/9/06
	Time	9:32	11:03	10:30	8:52	10:26	10:29	8:17	9:45	9:52	10:04	11:32	11:00	7:50	9:06	9:13
Organochlorine Pesticides and PCB Arochlors																
2,4 DDD	ug/Kg	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1
2,4 DDE	ug/Kg	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1
2,4 DDT	ug/Kg	5.2	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1
4,4'-DDD	ug/Kg	6.8	< 1	1.4	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1
4,4'-DDE	ug/Kg	15.5	11	5.7	< 1	< 1	1.1	< 1	< 1	< 1	6.9	11.2	9	< 1	e 2	< 1
4,4'-DDT	ug/Kg	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1
alpha-BHC	ug/Kg	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1
beta-BHC	ug/Kg	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1
delta-BHC	ug/Kg	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1
gamma-BHC (Lindane)	ug/Kg	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1
Aldrin	ug/Kg	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1
Chlordane	ug/Kg	8.1	7.8	1.2	< 1	0	< 1	< 1	3.5	< 1	< 1		< 1	< 1	4.6	1.1
Chlordane-alpha	ug/Kg	e 3.1	7.8	< 1	< 1	< 1	< 1	nr	3.5	< 1	< 1	< 1	< 1	< 1	4.6	< 1
Chlordane-gamma	ug/Kg	e 2.7	e 2.1		< 1	< 1		< 1	e 1.1		< 1	< 1		< 1	e 1.1	
OxyChlordane	ug/Kg	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1
cis-Nonachlor	ug/Kg	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	e 1	< 1
Dieldrin	ug/Kg	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1
Endosulfan I	ug/Kg	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1
Endosulfan II	ug/Kg	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1
Endosulfan Sulfate	ug/Kg	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1
Endrin	ug/Kg	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1
Endrin aldehyde	ug/Kg	< 1	< 1		< 1	< 1		< 1	< 1		< 1	< 1		< 1	< 1	
Endrin Ketone	ug/Kg	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1
Heptachlor	ug/Kg	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1
Heptachlor Epoxide	ug/Kg	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1
Methoxychlor	ug/Kg	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1
Mirex	ug/Kg	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1
PCB-1016	ug/Kg	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10
PCB-1221	ug/Kg	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10
PCB-1232	ug/Kg	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10
PCB-1242	ug/Kg	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10
PCB-1248	ug/Kg	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10
PCB-1254	ug/Kg	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10
PCB-1260	ug/Kg	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10
Perthane	ug/Kg	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5
Toxaphene	ug/Kg	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10
Trans-Nonachlor	ug/Kg	e 2.3	e 3.7	1.2	< 1	< 1	< 1	< 1	e 1.3	< 1	< 1	< 1	< 1	< 1	e 1.3	1.1
Organophosphate Pesticides																
Bolstar	ug/Kg	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10
Chlorpyrifos	ug/Kg	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5
Demeton	ug/Kg	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10
Diazinon	ug/Kg	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5
Dichlorvos	ug/Kg	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10
Dimethoate	ug/Kg	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5
Disulfoton	ug/Kg	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10
Ethoprop	ug/Kg	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10
Fenchlorphos	ug/Kg	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10
Fensulfothion	ug/Kg	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10
Fenthion	ug/Kg	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10
Malathion	ug/Kg	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5
Merphos	ug/Kg	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10
Mevinphos	ug/Kg	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10
Parathion-Methyl	ug/Kg	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10
Phorate	ug/Kg	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10
Tetrachlorvinphos	ug/Kg	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10
Tokuthion	ug/Kg	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10
Trichloronate	ug/Kg	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10
PCB Congeners																
PCB018	ug/Kg	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1
PCB028	ug/Kg	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1
PCB031	ug/Kg	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1
PCB033	ug/Kg	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1
PCB037	ug/Kg	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1
PCB044	ug/Kg	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1
PCB049	ug/Kg	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1
PCB052	ug/Kg	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1
PCB066	ug/Kg	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1
PCB070	ug/Kg	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1
PCB074	ug/Kg	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1
PCB077	ug/Kg	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1
PCB081	ug/Kg	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1
PCB087	ug/Kg	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1
PCB095	ug/Kg	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1
PCB097	ug/Kg	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1
PCB099	ug/Kg	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1

Sediment Chemistry in the North Orange County Watershed

	Site	BCC02			CARB01			CCBA01			EGWC05			FULA03		
	Date	8/24/05	11/15/05	2/9/06	8/24/05	11/15/05	2/9/06	8/24/05	11/15/05	2/9/06	8/24/05	11/15/05	2/9/06	8/24/05	11/15/05	2/9/06
	Time	9:32	11:03	10:30	8:52	10:26	10:29	8:17	9:45	9:52	10:04	11:32	11:00	7:50	9:06	9:13
PCB101	ug/Kg	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1
PCB105	ug/Kg	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1
PCB110	ug/Kg	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1
PCB114	ug/Kg	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1
PCB118	ug/Kg	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1
PCB119	ug/Kg	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1
PCB123	ug/Kg	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1
PCB126	ug/Kg	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1
PCB128+167	ug/Kg	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1
PCB138	ug/Kg	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1
PCB141	ug/Kg	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1
PCB149	ug/Kg	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1
PCB151	ug/Kg	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1
PCB153	ug/Kg	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1
PCB156	ug/Kg	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1
PCB157	ug/Kg	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1
PCB158	ug/Kg	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1
PCB168+132	ug/Kg	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1
PCB169	ug/Kg	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1
PCB170	ug/Kg	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1
PCB177	ug/Kg	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1
PCB180	ug/Kg	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1
PCB183	ug/Kg	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1
PCB187	ug/Kg	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1
PCB189	ug/Kg	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1
PCB194	ug/Kg	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1
PCB200	ug/Kg	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1
PCB201	ug/Kg	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1
PCB206	ug/Kg	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1
Polynuclear Aromatic Hydrocarbons																
1-Methylnaphthalene	ug/Kg															
1-Methylphenanthrene	ug/Kg															
(1,2,3-CE)Pyrene	ug/Kg															
1,2,5,6- Dibenzanthracene	ug/Kg															
2,3,5-TriMethylnaphthalene	ug/Kg															
2,6-Dimethylnaphthalene	ug/Kg															
2-Methylnaphthalene	ug/Kg															
Acenaphthene	ug/Kg															
Acenaphthylene	ug/Kg															
Anthracene	ug/Kg															
Benzo (A) Anthracene	ug/Kg															
Benzo (A) Pyrene	ug/Kg															
Benzo (k) Fluoranthene	ug/Kg															
Benzo (GHI) Perylene	ug/Kg															
Benzo(b)fluoranthene	ug/Kg															
Benzo(e)pyrene	ug/Kg															
Biphenyl	ug/Kg															
Chrysene	ug/Kg															
Dibenzothiophene	ug/Kg															
Fluoranthene	ug/Kg															
Fluorene	ug/Kg															
Naphthalene	ug/Kg															
Perylene	ug/Kg															
Phenanthrene	ug/Kg															
Pyrene	ug/Kg															
Chlorinated Herbicides																
2,4,5 TP-Silvex	ug/Kg	< 10	< 10	< 10	< 11	< 10	< 10	< 14	< 10	< 10	< 10	< 10	< 10	< 19	< 10	< 10
2,4-D	ug/Kg	< 100	< 100	< 100	< 110	< 100	< 100	< 140	< 100	< 100	< 100	< 100	< 100	< 190	< 100	< 100

Aqueous Chemistry at Estuary / Wetlands Sites

			FieldMeasurements																								
Location	Date Time	Type	EC	pH	TEMP	DO	Turbidity	Specific Conductance	pH	Nitrate as NO_3	Ammonia as N	TKN	Total Phosphate as PO_4	ortho phosphate as P	TSS	VSS	Diazinon	Chlorpyrifos	Dimethoate	Malathion	Cd	Cr	Cu	Pb	Ni	Ag	Zn	As	Se
			µS		C	mg/L	NTU	µS		mg/L							ng/L				µg/L								
BBOLR	8/18/05 13:31	DT	51560	9.58	25.03	5.66	5.22	45900	8.02	< 0.4	< 0.1	0.6	0.48	0.06	17	5	< 10	< 10	< 10	< 10	0.068	1.44	3.77	2.4	1.35	< 0.005	12.7	2.23	0.036
BBOLR	8/18/05 13:31	DF																			0.051	0.25	1.56	0.11	0.888	< 0.005	5.06	2.04	0.034
BBOLR	3/29/06 11:45	ST	35969	7.76	16.52	7.94	3.64	36900	7.88	0.5	< 0.1	0.8	0.32	0.05	10	4	< 2	< 1	< 3	26.1	0.065	0.58	3.43	0.986	1.04	< 0.02	13.6	1.3	0.056
BBOLR	3/29/06 11:45	SF																			0.053	0.26	2.25	0.052	0.828	< 0.02	9.77	1.14	0.039
BBOLR	3/31/06 11:42	ST	39533	7.84	16.46	7.74	1.72	43200	8.1	< 0.4	< 0.1	0.7	0.22	0.03	< 5	< 1	< 2	< 1	< 3	< 3	0.29	0.405	2.4	0.63	0.859	< 0.02	9.47	1.09	0.037
BBOLR	3/31/06 11:42	SF																			0.372	0.285	1.94	0.061	0.803	< 0.02	6.86	0.947	0.035
BBOLR	4/2/06 11:40	ST	41972	8.31	17.79	10.6	1.67	41000	8.28	< 0.4	< 0.1	0.4	0.26	< 0.02	12	4	< 2	< 1	< 3	< 3	0.03	0.34	2.23	0.41	0.949	< 0.02	4.92	1.11	< 0.01
BBOLR	4/2/06 11:40	SF																			0.043	0.22	1.8	0.039	0.965	< 0.02	1.53	1.04	0.017
BBOLR	5/22/06 11:28	ST	50674	7.58	19.55	7.84	1.93	53100	7.81	< 0.4	< 0.1	0.49	0.31	0.03	< 5	2	< 2	< 1	< 3	< 3	< 0.005	0.215	1.77	0.392	0.61	< 0.02	6.37	1	0.056
BBOLR	5/22/06 11:28	SF																			< 0.005	0.155	1.38	0.049	0.632	< 0.02	5.25	0.945	0.031
BBOLR	5/24/06 11:30	ST	44507	7.59	21.94	5.33	2.37	49200	7.96	< 0.4	< 0.1	0.44	0.26	0.04	< 5	< 1	< 2	< 1	< 3	< 3	0.025	0.33	2.692	0.491	0.689	< 0.02	6.436	1.189	0.03
BBOLR	5/24/06 11:30	SF																			0.799	0.49	1.818	0.049	0.847	< 0.02	3.573	1.095	0.034
BBOLR	5/26/06 10:40	ST	49667	7.74	22.15	6.74	1.98	50800	8.38	< 0.4	< 0.1	0.62	0.23	0.07	< 5	< 1	< 2	< 1	< 3	< 3	0.031	0.295	1.608	0.464	0.553	< 0.02	4.984	1.014	0.027
BBOLR	5/26/06 10:40	SF																			0.152	0.235	1.186	0.068	0.597	< 0.02	3.185	0.841	0.037
BBOLR	6/22/06 9:41	DT	51240	8.21	24.12	6.56	1.15	53100	7.82	< 0.4	< 0.1	0.5	0.41	0.08	< 5	1	< 2	< 1	< 3	< 3	< 0.005	0.48	2.375	0.307	0.452	< 0.02	5.914	1.802	0.056
BBOLR	6/22/06 9:41	DF																			< 0.005	0.21	2.066	0.06	0.464	< 0.02	4.925	1.774	0.03
HUNBCC	8/18/05 11:28	DT	53000	7.97	19.8	3.6															0.033	0.43	2.28	0.31	0.578	< 0.005	7.75	1.47	< 0.01
HUNBCC	8/18/05 11:28	DF																			0.051	0.25	1.46	0.024	0.5	< 0.005	6.9	1.3	< 0.01
HUNBCC	8/19/05 11:28	DT					0.69	46800	7.6	< 0.4	< 0.1	0.5	0.31	0.04	5	4	< 10	< 10	< 10	< 10									
HUNBCC	3/29/06 9:15	ST	2554	8.08	14.14	9.02	25	2320	7.86	1.5	< 0.1	0.6	0.66	0.12	30	5	14.6	< 1	< 3	25.6	0.076	1.01	3.61	1.29	0.96	< 0.02	15.2	1.39	0.023
HUNBCC	3/29/06 9:15	SF																			0.062	0.37	1.82	0.088	0.719	< 0.02	8.74	1.19	0.028
HUNBCC	3/31/06 9:00	ST	43329	7.68	15.19	7.25	1.47	43400	7.8	0.7	0.2	0.7	0.25	0.05	12	5	< 2	< 1	< 3	< 3	0.058	0.605	2.33	0.538	0.625	< 0.02	9.87	1.17	0.04
HUNBCC	3/31/06 9:00	SF																			0.089	0.285	1.61	0.068	0.465	< 0.02	5.71	1.11	0.017
HUNBCC	4/2/06 9:00	ST	36792	7.7	16.34	6.1	3.11	28100	7.67	3.2	0.2	1.1	0.34	0.05	6	2	< 2	< 1	< 3	< 3	0.044	0.69	4.15	0.507	0.958	< 0.02	13.3	1.27	0.015
HUNBCC	4/2/06 9:00	SF																			0.043	0.25	2.46	0.042	0.875	< 0.02	12	1.08	0.032
HUNBCC	5/22/06 9:03	ST	6810	7.73	18.09	7.88	10.5	5500	7.1	5.43	0.53	1.97	1.05	0.08	35	12	< 2	< 1	< 3	< 3	0.015	0.995	7.96	1.05	2.25	< 0.02	46.4	1.17	0.051
HUNBCC	5/22/06 9:03	SF																			< 0.005	0.395	3.87	0.213	1.89	< 0.02	29.3	1.06	0.052
HUNBCC	5/24/06 8:45	ST	49090	7.66	20.05	5.18	1.84	51000	7.62	< 0.4	0.14	0.6	0.23	0.04	< 5	< 1	< 2	< 1	< 3	< 3	0.027	0.53	2.607	0.407	0.588	< 0.02	6.709	1.05	0.03
HUNBCC	5/24/06 8:45	SF																			0.024	0.18	1.219	0.027	0.453	< 0.02	4.616	0.969	0.032
HUNBCC	5/26/06 8:55	ST	50269	7.78	20.11	5.91	2.82	52600	7.95	< 0.4	0.13	0.66	0.24	0.05	5	2	< 2	< 1	< 3	< 3	0.031	0.545	2.496	0.397	0.509	< 0.02	10.566	1.018	0.034
HUNBCC	5/26/06 8:55	SF																			e 0.006	0.225	1.085	0.036	0.343	< 0.02	4.64	0.863	0.022
HUNBCC	6/22/06 9:10	DT	50040	7.84	21.88	6.32	1.85	52700	7.54	< 0.4	< 0.1	0.43	0.18	0.04	< 5	1	< 2	< 1	< 3	< 3	< 0.005	0.36	2.152	0.304	0.372	< 0.02	14.669	1.323	0.073
HUNBCC	6/22/06 9:10	DF																			< 0.005	0.18	1.395	0.03	0.355	< 0.02	8.799	1.24	0.038
HUNCRB	8/18/05 10:28	DT	40320	8.93	21.64	3.7	0.89	47500	7.7	< 0.4	< 0.1	0.3	0.34	0.06	< 5	< 1	< 10	< 10	< 10	< 10	0.083	0.2	2.92	0.093	0.719	< 0.005	12.4	1.41	< 0.01
HUNCRB	8/18/05 10:28	DF																			0.06	0.67	4.11	0.767	0.828	< 0.005	14.5	1.57	< 0.01
HUNCRB	3/29/06 10:00	ST	20584	7.92	15.36	8.55	12.4	20600	7.83	1.1	< 0.1	0.3	0.52	0.09	15	4	< 2	< 1	< 3	21	0.076	0.6	4.56	0.737	0.871	< 0.02	18.3	1.4	0.04
HUNCRB	3/29/06 10:00	SF																			0.075	0.3	3.22	0.066	0.828	< 0.02	12.7	1.31	0.052
HUNCRB	3/31/06 9:47	ST	36468	7.7	16.27	6.92	1.43	35700	7.71	0.9	0.2	0.4	0.23	0.05	< 5	< 1	< 2	< 1	< 3	< 3	0.062	0.525	2.86	0.579	0.651	< 0.02	13.6	1.15	0.016
HUNCRB	3/31/06 9:47	SF																			0.056	0.365	2.06	0.067	0.516	< 0.02	12.2	1.11	e 0.014
HUNCRB	4/2/06 9:40	ST	40633	7.73	15.7	6.71	1.73	40100	7.58	0.6	0.1	0.5	0.27	0.03	8	4	< 2	< 1	< 3	< 3	0.045	0.42	3.5	0.291	0.647	< 0.02	17.1	1.09	< 0.01
HUNCRB	4/2/06 9:40	SF																			0.072	0.26	3.2	0.046	0.696	< 0.02	12.3	1.05	< 0.01

Aqueous Chemistry at Estuary / Wetlands Sites

Location	Date Time	Type	FieldMeasurements				Turbidity	Specific Conductance	pH	Nitrate as NO_3	Ammonia as N	TKN	Total Phosphate as PO_4	ortho phosphate as P	TSS	VSS	Diazinon	Chlorpyrifos	Dimethoate	Malathion	Cd	Cr	Cu	Pb	Ni	Ag	Zn	As	Se
			EC	pH	TEMP	DO				mg/L							ng/L				µg/L								
			µS		C	mg/L	NTU	µS																					
HUNCRB	5/22/06 9:40	ST	43178	7.66	19.21	7.5	3.81	44700	7.54	1.47	0.19	0.69	0.47	0.05	7	3	< 2	< 1	< 3	< 3	0.14	0.325	5.62	0.572	0.697	< 0.02	20	1.23	0.028
HUNCRB	5/22/06 9:40	SF																			0.041	0.195	4.25	0.051	0.558	< 0.02	16.5	1.14	0.029
HUNCRB	5/24/06 9:20	ST	42620	7.65	21.56	6.27	2.32	42300	7.6	0.57	< 0.1	0.52	0.24	< 0.02	< 5	< 1	< 2	< 1	< 3	< 3	0.034	0.26	3.88	0.304	0.63	< 0.02	13.199	1.196	0.037
HUNCRB	5/24/06 9:20	SF																			0.034	0.14	3.161	0.03	0.603	< 0.02	11.989	1.096	0.024
HUNCRB	5/26/06 9:30	ST	47484	7.75	20.98	6.96	1.44	49100	7.9	< 0.4	0.12	0.18	0.2	0.06	< 5	< 1	< 2	< 1	< 3	< 3	0.03	1.015	4.505	1.545	0.765	< 0.02	17.036	1.372	0.034
HUNCRB	5/26/06 9:30	SF																			0.487	0.205	2.437	0.045	0.478	< 0.02	7.696	1.026	0.026
HUNCRB	6/22/06 10:17	DT	49710	8.03	23.29	7.38	0.84	52400	7.61	< 0.4	< 0.1	0.51	0.19	0.04	< 5	< 1	< 2	< 1	< 3	< 3	< 0.005	0.38	3.965	0.421	0.425	< 0.02	16.649	1.373	0.025
HUNCRB	6/22/06 10:17	DF																			< 0.005	0.18	3.01	0.042	0.468	< 0.02	16.769	1.38	0.051
HUNWAR	8/18/05 9:30	DT	51120	6.75	21.66	3.12	1.09	45600	7.71	< 0.4	< 0.1	< 0.2	0.33	0.07	< 5	< 1	< 10	< 10	< 10	< 10	0.189	1.45	7.19	1.96	4.6	< 0.005	21.3	1.79	0.035
HUNWAR	8/18/05 9:30	DF																			0.204	0.22	2.44	0.081	3.94	< 0.005	13	1.4	< 0.01
HUNWAR	3/29/06 10:30	ST	28416	7.92	15.59	8.5	9.97	28500	7.84	0.9	< 0.1	0.4	0.41	0.06	17	4	< 2	< 1	< 3	20.6	0.061	0.63	3.24	0.887	0.794	< 0.02	13.9	1.43	0.051
HUNWAR	3/29/06 10:30	SF																			0.068	0.32	2.46	0.066	0.688	< 0.02	10.4	1.29	0.033
HUNWAR	3/31/06 10:18	ST	38852	7.75	15.86	6.58	1.36	39900	7.72	0.6	0.1	0.6	0.24	0.04	< 5	< 1	< 2	< 1	< 3	< 3	0.04	0.435	2.26	0.37	0.54	< 0.02	8.46	1.11	0.028
HUNWAR	3/31/06 10:18	SF																			0.056	0.315	2.21	0.069	0.585	< 0.02	7.47	1.09	0.041
HUNWAR	4/2/06 10:10	ST	39519	7.77	16.2	7.2	2.8	38400	7.68	0.7	0.1	0.9	0.23	< 0.02	9	4	< 2	< 1	< 3	< 3	0.041	0.4	2.68	0.319	0.703	< 0.02	10.7	1.25	< 0.01
HUNWAR	4/2/06 10:10	SF																			0.041	0.25	1.85	0.029	0.666	< 0.02	7.08	1.09	< 0.01
HUNWAR	5/22/06 10:15	ST	24958	7.51	18.95	7.27	7.69	24300	6.97	4.15	0.57	1.73	0.67	< 0.02	15	7	< 2	< 1	< 3	170	< 0.005	0.615	6.53	1.14	1.94	< 0.02	23.4	1.41	0.158
HUNWAR	5/22/06 10:15	SF																			< 0.005	0.225	2.96	0.143	1.68	< 0.02	16.2	1.18	0.074
HUNWAR	5/24/06 9:50	ST	42610	7.56	21.02	5.04	1.82	42900	7.46	0.77	0.12	0.61	0.25	< 0.02	< 5	< 1	< 2	< 1	< 3	< 3	0.072	0.28	4.287	0.249	0.64	< 0.02	11.889	1.157	0.025
HUNWAR	5/24/06 9:50	SF																			0.027	0.16	3.497	0.028	0.633	< 0.02	11.109	1.06	0.029
HUNWAR	5/26/06 9:50	ST	49580	7.74	20.67	6.05	1.93	50800	7.91	< 0.4	0.14	0.61	0.24	0.07	5	2	< 2	< 1	< 3	< 3	0.027	0.435	2.598	0.428	0.515	< 0.02	10.956	1.149	0.028
HUNWAR	5/26/06 9:50	SF																			0.018	0.205	1.64	0.043	0.422	< 0.02	7.266	0.972	0.029
HUNWAR	6/22/06 11:09	DT	49780	8.21	23.01	7.85	1.07	52500	7.65	< 0.4	< 0.1	0.82	0.22	0.04	< 5	< 1	< 2	< 1	< 3	< 3	< 0.005	0.31	2.276	0.282	0.365	< 0.02	12.299	1.415	< 0.01
HUNWAR	6/22/06 11:09	DF																			< 0.005	0.17	1.954	0.039	0.531	< 0.02	10.869	1.364	< 0.01
TGDC05	8/18/05 14:30	DT	50760	9.3	24.18	6.24	1.92	46700	7.93	< 0.4	0.1	0.3	0.37	0.06	9	3	< 10	< 10	< 10	< 10	0.075	0.58	3.45	1.02	0.851	< 0.005	12.5	1.73	0.03
TGDC05	8/18/05 14:30	DF																			0.085	0.25	2.32	0.067	0.696	< 0.005	10.5	1.57	0.025
TGDC05	3/29/06 12:15	ST	1639	8.3	14.73	10.94	23.4	1680	8.1	1.3	< 0.1	0.5	0.81	0.09	46	10	< 2	< 1	< 3	70.3	0.119	1.87	8.4	5.47	2.19	< 0.02	44.4	0.888	0.113
TGDC05	3/29/06 12:15	SF																			0.019	0.22	1.99	0.227	0.652	< 0.02	5.84	0.25	0.074
TGDC05	3/31/06 12:23	ST	38166	7.76	16.42	7.97	1.64	40200	7.79	0.5	0.2	0.3	0.24	0.04	6	6	< 2	< 1	< 3	< 3	0.068	0.425	2.59	0.492	0.71	< 0.02	10.1	1.23	0.234
TGDC05	3/31/06 12:23	SF																			0.13	0.295	2.18	0.08	0.842	< 0.02	9.04	1.04	0.129
TGDC05	4/2/06 12:11	ST	43144	7.83	17.22	10.3	0.79	43200	7.78	< 0.4	< 0.1	0.4	0.28	< 0.02	4	2	< 2	< 1	< 3	< 3	0.137	0.4	2.48	0.461	0.996	< 0.02	8.24	1.1	e 0.011
TGDC05	4/2/06 12:11	SF																			0.147	0.24	2.06	0.056	0.944	< 0.02	7.12	1.02	0.024
TGDC05	5/22/06 12:02	ST	2064	8.14	19.33	10.79	10.2	1560	6.8	4.84	0.68	2.05	1.14	0.03	33	9	62.7	< 1	< 3	417	< 0.005	1.57	13.3	3.82	4.93	< 0.02	49.2	0.833	0.159
TGDC05	5/22/06 12:02	SF																			< 0.005	0.485	**5.96**	0.413	3.34	< 0.02	22.2	0.669	0.127
TGDC05	5/24/06 10:45	ST	47256	7.74	22.45	6	1.64	45900	7.52	< 0.4	0.13	0.47	0.27	0.05	< 5	< 1	< 2	< 1	< 3	< 3	0.03	0.23	3.302	0.281	0.792	< 0.02	8.559	1.282	0.047
TGDC05	5/24/06 10:45	SF																			0.036	0.13	2.883	0.025	0.807	< 0.02	9.009	1.132	0.036
TGDC05	5/26/06 11:10	ST	49660	7.74	20.92	9.15	1.78	51000	7.92	< 0.4	0.14	0.58	0.24	0.07	< 5	< 1	< 2	< 1	< 3	< 3	0.064	0.355	2.232	0.377	0.572	< 0.02	9.876	1.174	0.036
TGDC05	5/26/06 11:10	SF																			0.074	0.185	1.729	0.038	0.569	< 0.02	8.726	1.1	0.025
TGDC05	6/22/06 10:23	DT	48419	8.03	22.48	5.52	0.7	49600	7.63	< 0.4	< 0.1	0.58	0.33	0.07	< 5	< 1	< 2	< 1	< 3	< 3	< 0.005	0.33	2.235	0.46	0.465	< 0.02	13.619	1.584	0.044
TGDC05	6/22/06 10:23	DF																			< 0.005	0.17	1.595	0.021	0.367	< 0.02	9.959	1.443	0.019

Aqueous Chemistry at Estuary / Wetlands Sites

			FieldMeasurements																									
Location	Date Time	Type	EC	pH	TEMP	DO	Turbidity	Specific Conductance	pH	Nitrate as NO_3	Ammonia as N	TKN	Total Phosphate as PO_4	ortho phosphate as P	TSS	VSS	Diazinon	Chlorpyrifos	Dimethoate	Malathion	Cd	Cr	Cu	Pb	Ni	Ag	Zn	As	Se
			µS		C	mg/L	NTU	µS		mg/L							ng/L				µg/L								
TBTMAR	8/18/05 15:30	DT	53110	9.2	23.3	6.51	2.5	45200	7.84	< 0.4	< 0.1	0.3	0.32	0.02	14	5	< 10	< 10	< 10	< 10	0.098	0.92	1.04	0.58	0.641	< 0.005	5.01	1.33	< 0.01
TBTMAR	8/18/05 15:30	DF																			0.088	0.38	0.463	0.111	0.565	< 0.005	4.04	1.33	< 0.01
TBTMAR	3/29/06 12:45	ST	28952	8.07	16.49	11.91	11.6	29200	8.06	0.9	< 0.1	0.5	0.56	0.08	23	7	17.6	< 1	< 3	70.8	0.534	0.97	3.38	1.36	1.06	< 0.02	10.9	1.62	0.043
TBTMAR	3/29/06 12:45	SF																			0.057	0.24	1.11	0.017	0.647	< 0.02	3.37	1.26	0.05
TBTMAR	3/31/06 10:59	ST	52413	8.06	13.49	11.13	1.49	55200	7.94	< 0.4	< 0.1	0.5	< 0.06	< 0.02	7	2	< 2	< 1	< 3	< 3	0.039	0.485	0.613	0.14	0.321	< 0.02	1.78	1.21	0.017
TBTMAR	3/31/06 10:59	SF																			0.048	0.295	0.343	0.027	0.299	< 0.02	3.25	1.18	< 0.01
TBTMAR	4/2/06 12:15	ST	31655	8.08	17.18	10.38	4.35	29700	7.92	1.2	0.1	0.3	0.38	< 0.02	12	5	< 2	< 1	< 3	39.9	0.093	0.87	3.87	0.67	1.63	< 0.02	6.84	1.25	0.033
TBTMAR	4/2/06 12:15	SF																			0.073	0.3	2.55	0.02	1.4	< 0.02	4.82	1.27	0.022
TBTMAR	5/22/06 11:51	ST	11140	7.85	21.3	6.29	11.4	11100	7.54	5.86	0.61	2.09	0.62	< 0.02	18	6	< 2	< 1	< 3	152	e 0.005	0.725	6.16	0.958	2.72	< 0.02	22.8	1.56	0.178
TBTMAR	5/22/06 11:51	SF																			< 0.005	0.195	2.25	0.089	2.09	< 0.02	9.89	1.36	0.164
TBTMAR	5/24/06 12:15	ST	41513	7.81	22.74		2.61	46600	7.79	0.47	0.25	0.68	0.37	0.05	< 5	< 1	< 2	< 1	< 3	< 3	0.029	0.5	1.178	0.261	0.577	< 0.02	3.396	1.179	0.026
TBTMAR	5/24/06 12:15	SF																			0.023	0.2	0.757	0.053	0.583	< 0.02	3.584	1.038	0.036
TBTMAR	5/26/06 11:52	ST	52648	8.13	19.15	8.25	1.84	54300	8.28	0.43	< 0.1	0.41	0.1	0.03	5	2	< 2	< 1	< 3	< 3	0.018	0.505	0.522	0.173	0.302	< 0.02	1.83	0.909	0.026
TBTMAR	5/26/06 11:52	SF																			0.037	0.275	0.446	0.025	0.355	< 0.02	1.982	0.857	< 0.01
TBTMAR	6/22/06 11:35	DT	52642	8.25	21.25	8.4	0.61	54000	7.86	< 0.4	< 0.1	0.61	0.11	< 0.02	9	2	< 2	< 1	< 3	< 3	< 0.005	1.54	1.356	0.875	0.589	< 0.02	7.511	1.312	< 0.01
TBTMAR	6/22/06 11:35	DF																			< 0.005	0.26	0.223	0.018	0.162	< 0.02	2.877	1.062	< 0.01
LNBHIR	7/29/05 9:20	DT	52120	8.01	23	7.02	2.61	48800	8.09	< 0.4	< 0.1	< 0.2	0.18	0.04	9	5	< 10	< 10	< 10	< 10	0.608	1.56	4.07	0.399	0.771	< 0.005	14.1		
LNBHIR	7/29/05 9:20	DF																			0.608	0.265	2.72	0.108	0.701	< 0.005	10.1		
LNBHIR	8/26/05 9:30	DT	51210	8.51	21.69	7.65	2.12	51000	7.94	< 0.4	0.1	0.3	0.17	0.03	5	3	< 10	< 10	< 10	< 10	0.082	1.37	2.77	0.458	0.761	< 0.005	8.12	1.29	0.016
LNBHIR	8/26/05 9:30	DF																			0.062	0.275	0.87	0.028	0.478	< 0.005	5.03	1.06	e 0.015
LNBHIR	9/28/05 12:23	DT	51170	8.06	18.58	5.42	1.64	54500	7.76	< 0.4	< 0.1	0.2	0.18	0.04	5	2													
LNBHIR	10/28/05 12:27	DT	51114	7.25	18.47	6.39	1.48	61600	7.74	< 0.4	0.2	0.3	0.27	0.06	< 5	< 1													
LNBHIR	11/17/05 12:40	DT	50960	7.85	18.28	7.56	1.87	50300	8.15	< 0.4	< 0.1	0.4	0.2	0.04	< 5	1	< 5	< 5	< 5	< 5	0.12	2.63	6.45	1.24	1.22	< 0.005	19	2.02	0.042
LNBHIR	11/17/05 12:40	DF																			0.038	0.19	1.24	0.035	0.392	< 0.005	7.12	1.5	0.027
LNBHIR	12/21/05 12:20	DT	51830	6.45	14.89	6.25	0.77	51400	7.81	< 0.4	< 0.1	0.4	0.15	0.04	6	4													
LNBHIR	1/26/06 11:50	DT					1.65	50100	7.81	0.6	< 0.1	0.4	0.25	0.05	< 5	1													
LNBHIR	2/22/06 12:00	DT	46490	7.87	15.83	5.83																							
LNBHIR	2/28/06 12:42	ST	33680	5.81	15.59	7.13	11.3	36900	7.89	3.8	0.2	< 0.2	0.51	0.1	19	4	< 5	< 5	< 5	17.3	0.314	2.27	7.88	1.06	2.18	< 0.005	20.3	1.61	0.184
LNBHIR	2/28/06 12:42	SF																			0.183	0.4	3.13	0.07	1.68	< 0.005	9.91	1.32	0.195
LNBHIR	3/2/06 12:30	ST	43650	7.93	16.33	5.86	1.41	45300	7.86	1.8	< 0.1	0.3	0.27	0.06	< 5	< 1	< 5	< 5	< 5	< 5	0.121	0.54	3.68	0.149	0.827	< 0.005	10.7	0.987	< 0.01
LNBHIR	3/2/06 12:30	SF																			0.169	0.37	2.62	0.3	0.871	< 0.005	9.16	0.917	< 0.01
LNBHIR	3/4/06 10:35	ST	41740	7.05	15.32	5.38											< 5	< 5	< 5	< 5	0.061	0.63	1.93	0.151	0.472	< 0.005	7.03	1.24	0.051
LNBHIR	3/4/06 10:35	SF																			0.041	0.28	0.845	0.026	0.454	< 0.005	5.69	1.17	0.109
LNBHIR	3/8/06 12:26	DT	44450	8.73	16.23	4.8																							
LNBHIR	4/20/06 9:13	DT	47172	7.85	17.07	8.01	2.65	47800	7.61	0.9	0.1	0.7	0.28	0.05	36	12	< 2	< 1	< 3	< 3	0.105	0.885	2.09	0.33	0.923	< 0.02	10.3	1.26	0.069
LNBHIR	4/20/06 9:13	DF																			0.088	0.345	1.46	0.048	0.809	< 0.02	7.01	1.19	0.065
LNBHIR	5/31/06 12:30	DT	53034	7.87	22.34	7.16	3.6	46100	7.84	< 0.4	< 0.1	0.37	0.16	0.03	< 5	1													
LNBHIR	6/21/06 9:30	DT	51562	8.22	22.01	7.11	2.59	52900	7.87	< 0.4	< 0.1	< 0.4	0.14	0.02	8	2	< 2	< 1	< 3	< 3	0.079	0.975	3.217	0.28	0.684	< 0.02	10.396	1.215	0.103
LNBHIR	6/21/06 9:30	DF																			0.064	0.245	1.882	0.033	0.617	< 0.02	8.371	1.069	0.097

Aqueous Chemistry at Estuary / Wetlands Sites

			FieldMeasurements																									
Location	**Date Time**	**Type**	**EC**	**pH**	**TEMP**	**DO**	**Turbidity**	**Specific Conductance**	**pH**	**Nitrate as NO_3**	**Ammonia as N**	**TKN**	**Total Phosphate as PO_4**	**ortho phosphate as P**	**TSS**	**VSS**	**Diazinon**	**Chlorpyrifos**	**Dimethoate**	**Malathion**	**Cd**	**Cr**	**Cu**	**Pb**	**Ni**	**Ag**	**Zn**	**As**	**Se**
			µS		C	mg/L	NTU	µS		mg/L							ng/L				µg/L								
LNBRIN	8/26/05 8:40	DT	50968	8.49	21.1	7.48	0.68	51200	7.92	< 0.4	< 0.1	0.5	0.17	0.04	< 5	< 1	< 10	< 10	< 10	< 10	0.067	0.335	8.81	0.196	0.594	< 0.005	24.1	1.15	0.039
LNBRIN	8/26/05 8:40	DF																			0.077	0.245	**6.95**	0.054	0.706	< 0.005	26.8	1.2	0.04
LNBRIN	11/17/05 13:30	DT	50990	7.55	18.47	4.98	0.95	50500	8.06	< 0.4	0.3	0.2	0.29	0.08	< 5	< 1	< 5	< 5	< 5	< 5	0.027	0.98	10.3	1.24	0.567	< 0.005	18.4	1.76	0.043
LNBRIN	11/17/05 13:30	DF																			0.12	0.19	2.46	0.061	0.515	< 0.005	14.5	1.49	0.027
LNBRIN	2/28/06 13:20	ST	46530	4.74	16.45	7.19	1.74	43700	8	1.1	< 0.1	0.7	0.29	0.07	< 5	< 1	< 5	< 5	< 5	< 5	0.163	0.83	19.9	0.641	1.13	< 0.005	28.8	1.32	0.099
LNBRIN	3/2/06 13:15	ST	43170	8.17	16.33	5.32	1.24	44200	7.83	1.8	< 0.1	0.3	0.27	0.06	7	3	< 5	< 5	< 5	< 5	0.137	5.14	63	5.87	2.36	< 0.005	53.4	1.93	< 0.01
LNBRIN	3/2/06 13:15	SF																			0.082	0.34	3.13	0.358	0.872	< 0.005	13.9	0.847	< 0.01
LNBRIN	3/4/06 11:20	ST	41700	7.78	15.17	5.5											< 5	< 5	< 5	< 5	0.058	0.94	7.9	0.818	0.658	< 0.005	17.3	1.28	0.081
LNBRIN	3/4/06 11:20	SF																			0.037	0.25	2.31	0.058	0.477	< 0.005	13.6	1.15	0.069
LNBRIN	3/8/06 12:47	DT	39730	7.13	15.91	4.74																							
LNBRIN	4/20/06 10:47	DT	53369	7.99	17.33	8.39	1.18	50100	7.78	0.4	< 0.1	0.7	0.22	0.03	5	3	< 2	< 1	< 3	< 3	0.104	0.97	11.8	1.17	0.822	< 0.02	19.7	1.24	0.095
LNBRIN	4/20/06 10:47	DF																			0.112	0.255	3.22	0.089	0.733	< 0.02	16.4	1.06	0.043
LNBRIN	6/21/06 10:20	DT	54476	8.33	22.35	8.44	1.79	53000	7.74	< 0.4	< 0.1	< 0.4	0.18	0.03	12	5	< 2	< 1	< 3	< 3	0.071	0.715	10.841	0.944	0.652	< 0.02	21.356	1.232	0.075
LNBRIN	6/21/06 10:20	DF																			0.076	0.245	4.645	0.087	0.5	< 0.02	16.916	1.116	0.088
LNBSBI	3/8/06 11:30	DT	48790	8.04	15.41	5.35																							
LNBTUB	8/26/05 7:50	DT	49963	8.31	21.16	6.9	1.3	51100	7.92	< 0.4	0.1	0.5	0.13	0.03	< 5	< 1	< 10	< 10	< 10	< 10	0.156	1.04	4.99	0.302	0.722	< 0.005	15.5	1.18	0.043
LNBTUB	8/26/05 7:50	DF																			0.3	0.495	3.57	0.08	0.867	< 0.005	15.4	1.07	0.026
LNBTUB	11/17/05 14:10	DT	51100	7.43	18.19	6.98	1.22	50700	8.16	< 0.4	< 0.1	0.2	0.19	0.04	4	3	< 5	< 5	< 5	< 5	0.044	1.22	3.16	0.695	0.773	< 0.005	9.17	1.74	0.02
LNBTUB	11/17/05 14:10	DF																			0.148	0.59	1.32	0.379	0.695	< 0.005	7.08	1.43	0.021
LNBTUB	2/28/06 14:03	ST	40140	7.76	15.99	8.18	1.87	48300	7.96	0.8	< 0.1	0.6	0.2	0.04	< 5	< 1	< 5	< 5	< 5	< 5	0.151	0.56	6.92	0.267	0.942	< 0.005	17	1.15	0.084
LNBTUB	2/28/06 14:03	SF																			0.15	0.33	3.87	0.052	1.01	< 0.005	16	1.18	0.068
LNBTUB	3/2/06 13:45	ST	45350	8.04	15.97	5.73	1.59	46100	7.86	1.5	< 0.1	0.6	0.25	0.05	< 5	< 1	< 5	< 5	< 5	< 5	0.103	0.59	3.53	0.479	0.763	< 0.005	11.4	0.897	< 0.01
LNBTUB	3/2/06 13:45	SF																			0.083	0.36	1.9	0.301	0.727	< 0.005	8.89	0.85	< 0.01
LNBTUB	3/4/06 11:53	ST	43070	7.67	15.69	6.11											< 5	< 5	< 5	< 5	0.062	0.75	2.78	0.178	0.477	< 0.005	12	1.21	0.054
LNBTUB	3/4/06 11:53	SF																			0.057	0.28	1.85	0.027	0.531	< 0.005	10.2	1.16	0.053
LNBTUB	3/8/06 13:06	DT	50140	7.36	15.52	5.57																							
LNBTUB	4/20/06 9:59	DT	52055	8.11	17.29	10.81	0.96	49500	7.82	< 0.4	< 0.1	0.4	0.17	0.02	13	5	< 2	< 1	< 3	< 3	0.081	0.405	2.49	0.1	0.479	< 0.02	6.96	1.18	0.048
LNBTUB	4/20/06 9:59	DF																			0.162	0.285	1.86	0.033	0.466	< 0.02	7.63	1.14	0.025
LNBTUB	6/21/06 11:00	DT	56549	8.16	22.45	7.13	2	52900	7.79	< 0.4	< 0.1	0.23	0.11	< 0.02	19	8	< 2	< 1	< 3	< 3	0.077	1.075	5.383	0.818	0.852	< 0.02	14.226	1.247	0.087
LNBTUB	6/21/06 11:00	DF																			0.058	0.245	2.125	0.05	0.471	< 0.02	10.716	1.018	0.058
UNBBCW	3/8/06 10:02	DT	25930	6.45	15.22	5																							
UNBCHB	7/29/05 9:50	DT	51140	7.96	24.06	6.64	2.05	47400	8.08	< 0.4	< 0.1	0.3	0.22	0.06	< 5	< 1	< 10	< 10	< 10	< 10	0.094	0.455	3.59	0.145	0.615	< 0.005	12.7		
UNBCHB	7/29/05 9:50	DF																			0.095	0.265	2.92	0.036	0.629	< 0.005	11.4		
UNBCHB	8/26/05 10:50	DT	50830	8.58	22.47	9.35	1.28	50700	7.91	< 0.4	0.2	0.2	0.2	0.05	6	2	< 10	< 10	< 10	< 10	0.072	0.455	3.22	0.131	0.641	< 0.005	10.2	1.21	0.068
UNBCHB	8/26/05 10:50	DF																			0.074	0.265	2.57	0.038	0.586	< 0.005	9.88	1.11	0.057
UNBCHB	9/28/05 11:45	DT	50490	7.31	19.13	5.48	1.23	54000	7.77	< 0.4	0.1	0.2	0.2	0.04	11	4													
UNBCHB	10/28/05 11:59	DT	50225	7.24	18.49	6.14	1.16	60900	7.78	0.6	0.4	0.4	0.29	0.07	< 5	< 1													
UNBCHB	11/17/05 11:55	DT	50760	7.7	17.59	6.59															0.03	0.7	1.98	0.234	0.506	< 0.005	7.23	1.54	0.047
UNBCHB	11/17/05 11:55	DF																			0.019	0.18	1.05	0.024	0.465	< 0.005	5.23	1.47	0.038
UNBCHB	12/21/05 11:10	DT	52030	6.62	14.95	6.2	1.3	49500	7.82	< 0.4	0.2	0.5	0.2	0.04	< 5	< 1													
UNBCHB	1/26/06 11:30	DT					1.32	49500	7.78	1	0.1	0.7	0.28	0.07	< 5	2													
UNBCHB	2/22/06 11:45	DT	41650	7.45	15.93	7.09																							

Aqueous Chemistry at Estuary / Wetlands Sites

Location	Date Time	Type	FieldMeasurements				Turbidity	Specific Conductance	pH	Nitrate as NO_3	Ammonia as N	TKN	Total Phosphate as PO_4	ortho phosphate as P	TSS	VSS	Diazinon	Chlorpyrifos	Dimethoate	Malathion	Cd	Cr	Cu	Pb	Ni	Ag	Zn	As	Se
			EC	pH	TEMP	DO				mg/L							ng/L				µg/L								
			µS		C	mg/L	NTU	µS																					
UNBCHB	2/28/06 12:05	ST	25480	8.04	15.75	10.49	12.5	26000	7.78	5.1	0.3	0.9	0.68	0.14	41	6	< 5	< 5	< 5	27.8	0.358	1.93	8.19	1.18	0.468	< 0.005	22.2	1.66	0.21
UNBCHB	2/28/06 12:05	SF																			0.165	0.46	3.18	0.076	1.99	< 0.005	9.41	1.38	0.25
UNBCHB	3/2/06 11:35	ST	47820	7.32	15.31	7.04	1	48100	7.89	1	< 0.1	0.3	0.21	0.04	< 5	< 1	< 5	< 5	< 5	< 5	0.116	0.47	3.08	0.15	0.996	< 0.005	9.13	0.987	< 0.01
UNBCHB	3/2/06 11:35	SF																			0.092	0.27	1.88	0.299	0.728	< 0.005	7.51	0.9	< 0.01
UNBCHB	3/4/06 10:06	ST	34480	6.28	15.05	6.49											< 5	< 5	< 5	< 5	0.072	0.62	3	0.206	0.637	< 0.005	12.1	1.23	0.094
UNBCHB	3/4/06 10:06	SF																			0.063	0.29	2.02	0.029	0.544	< 0.005	10.7	1.22	0.033
UNBCHB	3/8/06 10:50	DT	39730	7.13	16.12	4.74																							
UNBCHB	4/19/06 13:06	DT	50970	7.83	18.21	7.65	0.95	47300	7.74	0.8	0.1	0.6	0.26	0.05	4	3	< 2	< 1	< 3	< 3	0.066	1.02	3.28	0.215	1.32	< 0.02	12.2	1.29	0.07
UNBCHB	4/19/06 13:06	DF																			0.065	0.325	2.2	0.045	1.42	< 0.02	11.3	1.17	0.029
UNBCHB	5/31/06 12:00	DT	53590	7.87	21.56	8.26	3.7	46900	7.88	< 0.4	< 0.1	0.47	0.13	0.02	5	2													
UNBCHB	6/20/06 12:30	DT	54765	8.14	23.77	8.08	4.21	51600	7.8	< 0.4	< 0.1	0.33	0.16	0.03	9	3	< 2	< 1	< 3	< 3	0.083	0.515	2.796	0.29	0.716	< 0.02	10.366	1.145	0.156
UNBCHB	6/20/06 12:30	DF																			0.083	0.225	1.818	0.035	0.828	< 0.02	8.853	1.115	0.139
UNBJAM	7/29/05 10:52	DT	24120	8.62	26.8	8.43	7.48	23500	8.22	3.2	< 0.1	0.8	0.49	0.07	6	3	< 10	< 10	< 10	< 10	0.098	0.505	2.56	0.165	0.999	< 0.005	5.92		
UNBJAM	7/29/05 10:52	DF																			0.13	0.215	2.19	0.033	1.11	< 0.005	5.33		
UNBJAM	8/26/05 13:15	DT	40233	8.8	27.3	17.37	3.43	40000	8.48	< 0.4	0.2	0.2	0.33	< 0.02	6	3	< 10	< 10	< 10	< 10	0.089	0.395	1.71	0.136	0.969	< 0.005	3.86	1.72	0.454
UNBJAM	8/26/05 13:15	DF																			0.071	0.205	1.36	0.35	0.926	< 0.005	2.06	1.6	0.43
UNBJAM	9/28/05 9:55	DT	34260	7.45	22.71	13.98	3.59	35900	8.32	1.9	< 0.1	1.3	0.33	< 0.02	9	3													
UNBJAM	10/28/05 10:16	DT	34740	7.11	19.51	4.92	3.23	36200	7.92	11.9	0.4	1.1	0.61	0.16	6	4													
UNBJAM	11/17/05 9:09	DT	44530	7.34	18.05	6.37	1.62	43900	8.1	3	0.3	0.7	0.37	0.08	< 5	< 1	< 5	< 5	< 5	< 5	0.049	0.4	1.45	0.153	0.424	< 0.005	5.92	1.61	0.144
UNBJAM	11/17/05 9:09	DF																			0.019	0.14	0.887	0.03	0.56	< 0.005	4.38	1.55	0.125
UNBJAM	12/21/05 9:30	DT	49160	5.73	15.16	6.18	1.95	48200	7.73	1.9	0.4	0.8	0.34	0.07	< 5	< 1													
UNBJAM	1/26/06 9:45	DT	44162	7.45	14.06		1.42	46900	7.75	1.9	0.3	0.9	0.34	0.08	< 5	2													
UNBJAM	2/22/06 10:00	DT	26990	8.06	15.41	11.26																							
UNBJAM	2/28/06 10:00	ST	5650	4.31	15.24	11.51	60	5080	7.46	8.9	0.3	1	1.38	0.25	204	36	< 5	< 5	38.4	32.4	0.689	7.04	13.6	3.44	4.05	< 0.005	61	2.82	0.264
UNBJAM	2/28/06 10:00	SF																			0.179	0.41	2.84	0.114	2.15	< 0.005	8.57	1.48	0.225
UNBJAM	3/2/06 9:21	ST	26150	6.69	16.14	4.66	4.68	17500	7.37	9.9	0.3	0.7	0.83	0.22	13	3	< 5	< 5	19.9	< 5	0.15	1.12	4.13	0.578	1.79	< 0.005	14.4	1.45	0.081
UNBJAM	3/2/06 9:21	SF																			0.151	0.28	1.86	0.309	1.5	< 0.005	10.8	1.16	0.084
UNBJAM	3/4/06 8:12	ST	7550	6.17	14.79	7.09											< 5	< 5	< 5	61.1	0.145	1.56	4.04	0.847	1.58	< 0.005	19.5	1.8	0.232
UNBJAM	3/4/06 8:12	SF																			0.299	0.34	1.8	0.044	1.08	< 0.005	9.99	1.59	0.212
UNBJAM	3/8/06 9:18	DT	22520	5.92	16.19	5.11																							
UNBJAM	4/19/06 10:00	DT	20791	7.94	20.39	8.5	4.24	20700	7.73	6.2	0.2	0.7	0.59	0.1	9	5	< 2	< 1	< 3	< 3	0.111	1.15	3.21	0.623	1.73	< 0.02	14.3	1.96	0.195
UNBJAM	4/19/06 10:00	DF																			0.05	0.245	1.21	0.039	1.45	< 0.02	7.66	1.71	0.231
UNBJAM	5/31/06 10:15	DT	31847	4.93	24.2	10.31	6.58	29600	7.84	2.29	0.12	1.05	0.55	0.03	18	9													
UNBJAM	6/20/06 9:47	DT	29510	8.36	24.17	8.86	3.06	24500	8.17	7.43	0.12	0.54	0.25	< 0.02	< 5	< 1	< 2	< 1	< 3	< 3	0.064	0.365	1.826	0.286	1.336	< 0.02	5.275	1.867	0.621
UNBJAM	6/20/06 9:47	DF																			0.064	0.235	1.607	0.063	1.28	< 0.02	3.857	1.941	0.606
UNBNSB	7/29/05 11:55	DT	48830	8.07	25.81	6.92	1.88	45900	8.14	< 0.4	< 0.1	0.4	0.31	0.09	< 5	< 1	< 10	< 10	< 10	< 10	0.08	0.465	3.5	0.156	0.752	< 0.005	10.8		
UNBNSB	7/29/05 11:55	DF																			0.083	0.225	2.96	0.039	0.714	< 0.005	9.4		
UNBNSB	8/26/05 12:05	DT	51477	8.55	24.3	8.66	0.88	49500	8.02	< 0.4	0.1	0.5	0.25	0.05	< 5	< 1	< 10	< 10	< 10	< 10	0.067	0.345	3.12	0.092	0.558	< 0.005	10.3	1.18	0.094
UNBNSB	8/26/05 12:05	DF																			0.095	0.275	2.46	0.041	0.693	< 0.005	10.9	1.19	0.1
UNBNSB	9/28/05 11:15	DT	49430	7.79	19.46	5.67	1.28	52800	7.78	0.5	< 0.1	0.4	0.25	0.05	< 5	1													
UNBNSB	10/28/05 11:19	DT	46850	7.25	18.52	6.77	1.53	56100	7.78	1.4	0.3	0.6	0.36	0.1	7	3													
UNBNSB	11/17/05 10:45	DT	51420	7.29	17.36	6.05	1.67	50400	8.13	< 0.4	< 0.1	0.2	0.2	0.05	< 5	3	< 5	< 5	< 5	< 5	0.033	0.56	1.73	0.168	0.538	< 0.005	6.79	1.55	0.041

Aqueous Chemistry at Estuary / Wetlands Sites

			FieldMeasurements																									
Location	Date Time	Type	EC	pH	TEMP	DO	Turbidity	Specific Conductance	pH	Nitrate as NO_3	Ammonia as N	TKN	Total Phosphate as PO_4	ortho phosphate as P	TSS	VSS	Diazinon	Chlorpyrifos	Dimethoate	Malathion	Cd	Cr	Cu	Pb	Ni	Ag	Zn	As	Se
			µS		C	mg/L	NTU	µS		mg/L							ng/L				µg/L								
UNBNSB	11/17/05 10:45	DF																			0.027	0.2	1.05	0.31	0.527	< 0.005	5.86	1.48	0.047
UNBNSB	12/21/05 10:40	DT	51420	6.64	14.59	6.16	1.87	48400	7.77	< 0.4	0.2	0.4	0.26	0.05	8	3													
UNBNSB	1/26/06 11:00	DT	47928	7.48	13.18		1.21	48100	7.76	1.2	0.2	0.9	0.31	0.07	6	2													
UNBNSB	2/22/06 11:10	DT	33450	5.89	14.87	8.42																							
UNBNSB	2/28/06 11:27	ST	14900	5.49	15.8	11.02	14.4	14600	7.6	7	0.3	1.1	0.88	0.18	45	8	< 5	< 5	25.5	38.5	0.392	2.38	8.2	1.37	2.52	< 0.005	25.3	1.85	0.21
UNBNSB	2/28/06 11:27	SF																			0.155	0.44	3.05	0.084	1.83	< 0.005	10.5	1.46	0.218
UNBNSB	3/2/06 10:55	ST	43950	8.26	15.63	5.51	1.08	44400	7.81	1.7	< 0.1	0.4	0.28	0.07	5	3	< 5	< 5	< 5	< 5	0.138	0.55	3.21	0.159	0.86	< 0.005	10.1	0.975	< 0.01
UNBNSB	3/2/06 10:55	SF																			0.107	0.33	2.14	0.31	0.8	< 0.005	8.76	0.889	< 0.01
UNBNSB	3/4/06 9:15	ST	17280	6.09	14.44	5.91											< 5	< 5	< 5	< 5	0.082	0.61	2.82	0.231	0.728	< 0.005	11.9	1.27	0.122
UNBNSB	3/4/06 9:15	SF																			0.063	0.29	1.59	0.034	0.598	< 0.005	10.1	1.3	0.101
UNBNSB	3/8/06 10:30	DT	10010	6.51	15.8	5.17																							
UNBNSB	4/19/06 12:05	DT	38590	7.88	19.84	7.08	1.34	36600	7.68	3.3	0.2	0.8	0.47	0.09	6	5	< 2	< 1	< 3	< 3	0.073	0.825	2.7	0.431	1.07	< 0.02	11.9	1.3	0.111
UNBNSB	4/19/06 12:05	DF																			0.049	0.205	1.08	0.043	0.869	< 0.02	8.98	1.16	0.085
UNBNSB	5/31/06 11:35	DT	49838	7.63	23.28	6.36	3.69	43500	7.73	0.57	0.1	0.67	0.27	0.05	< 5	1													
UNBNSB	6/20/06 11:20	DT	46355	8.38	24.68	8.25	6.63	45100	8.03	0.79	< 0.1	0.48	0.24	< 0.02	12	3	< 2	< 1	< 3	< 3	0.105	0.745	2.704	0.599	1.094	< 0.02	9.656	1.384	0.266
UNBNSB	6/20/06 11:20	DF																			0.083	0.235	1.51	0.062	1.013	< 0.02	7.64	1.291	0.279
UNBSDC	7/29/05 11:15	DT	38290	7.92	26.82	7.71	2.79	35300	8.3	< 0.4	< 0.1	0.7	0.39	0.09	< 5	< 1	< 10	< 10	< 10	< 10	0.087	0.335	2.54	0.121	1.22	< 0.005	5.37		
UNBSDC	7/29/05 11:15	DF																			0.085	0.235	2.89	0.043	1.55	< 0.005	7.12		
UNBSDC	8/26/05 14:00	DT	45920	8.7	26.62	13.82	1.57	46700	8.27	< 0.4	< 0.1	< 0.2	0.3	0.06	< 5	< 1	< 10	< 10	< 10	< 10	0.075	0.335	2.12	0.104	0.837	< 0.005	4.43	1.47	0.278
UNBSDC	8/26/05 14:00	DF																			0.069	0.225	1.83	0.015	0.821	< 0.005	4.37	1.47	0.277
UNBSDC	9/28/05 10:40	DT	39940	8.39	21.2	9.55	1.84	43000	8.17	0.5	< 0.1	0.9	0.34	< 0.02	< 5	2													
UNBSDC	10/28/05 10:45	DT	36480	7.17	18.89	7.25	1.98	45900	7.88	5.2	0.3	0.7	0.5	0.14	< 5	< 1													
UNBSDC	11/17/05 9:56	DT	45130	6.68	17.01	5.79	1.61	42700	8.12	4.9	0.4	0.7	0.38	0.09	8	5	< 5	< 5	< 5	< 5	0.034	0.33	1.43	0.102	0.453	< 0.005	6.52	1.55	0.086
UNBSDC	11/17/05 9:56	DF																			0.016	0.2	0.853	0.023	0.443	< 0.005	5.02	1.53	0.068
UNBSDC	12/21/05 10:10	DT	48560	5.77	14.16	6.39	1.71	43900	7.74	0.9	0.3	0.8	0.29	0.06	< 5	< 1													
UNBSDC	1/26/06 10:30	DT	46790	7.24	13.28		1.48	46700	7.82	1.7	0.3	0.8	0.35	0.08	< 5	1													
UNBSDC	2/22/06 10:40	DT	29240	6.94	15.19	11.48																							
UNBSDC	2/28/06 10:40	ST	6130	5.42	15.86	10.86	29.8	6600	7.48	8	0.3	0.8	0.83	0.24	62	12	< 5	< 5	23.8	25.9	0.336	2.25	8.19	1.47	2.41	< 0.005	27	1.72	0.185
UNBSDC	2/28/06 10:40	SF																			0.153	0.42	3.01	0.111	1.79	< 0.005	11.2	1.35	0.198
UNBSDC	3/2/06 9:57	ST	31700	7.52	15.72	4.8	4.96	27700	7.56	5.5	0.3	0.6	0.65	0.15	12	3	< 5	< 5	26.6	< 5	0.164	0.67	3.47	0.308	1.57	< 0.005	12.4	1.18	0.069
UNBSDC	3/2/06 9:57	SF																			0.149	0.29	1.83	0.299	1.05	< 0.005	9.05	0.981	e 0.011
UNBSDC	3/4/06 8:45	ST	13520	6.18	13.87	5.62											19.2	< 5	< 5	40.5	0.096	1.1	3.26	0.668	1.2	< 0.005	16.3	1.63	0.229
UNBSDC	3/4/06 8:45	SF																			0.065	0.32	1.49	0.51	1.09	< 0.005	10.3	1.47	0.245
UNBSDC	3/8/06 9:37	DT	27390	6.38	16.58	4.03																							
UNBSDC	4/19/06 10:45	DT	27591	7.97	19.92	8.34	2.64	26800	7.77	5.2	0.1	0.8	0.94	0.1	7	5	< 2	< 1	< 3	21.3	0.062	0.465	2.21	0.258	1.27	< 0.02	10.7	1.62	0.201
UNBSDC	4/19/06 10:45	DF																			0.048	0.225	1.52	0.038	1.15	< 0.02	6.5	1.51	0.168
UNBSDC	5/31/06 10:52	DT	41789	7.75	24.1	8.96	7.41	38600	7.83	0.89	< 0.1	0.74	0.52	0.04	18	4													
UNBSDC	6/20/06 10:25	DT	34065	8.53	23.64	10.34	2.99	33000	8.29	3.82	< 0.1	0.64	0.22	< 0.02	< 5	2	< 2	< 1	< 3	< 3	0.092	0.805	2.33	0.715	1.39	< 0.02	6.978	1.688	0.479
UNBSDC	6/20/06 10:25	DF																			0.064	0.215	1.501	0.07	1.207	< 0.02	4.356	1.575	0.521

Attachment C-11-V
Pathogen Indicator Monitoring in the Santa Ana Region

		Upcoast			Stormdrain				Downcoast		
		TC	FC	ENT	TC	FC	ENT		TC	FC	ENT
Site	Date	CFU/100 ml)									
BCC02	8/17/05 8:47				> 220	40	30	30			
BCC02	8/31/05 11:51				> 600	200	40	40			
BCC02	9/7/05 10:26				> 1500	250	60	60			
BCC02	9/14/05 11:39				> 8500	3900	2300	2300			
BCC02	9/23/05 9:45				32000	2400	510	510			
BCC02	9/28/05 10:52				> 9600	1400	400	400			
BCC02	10/6/05 10:47				> 4800	1500	580	580			
BCC02	10/14/05 8:40				> 3800	210	300	300			
BCC02	10/18/05 10:54				3600000	270000	740000	740000			
BCC02	10/27/05 7:50				3900	380	560	560			
BCC02	11/1/05 9:30				> 13000	2000	520	520			
BCC02	11/7/05 8:55				7800	330	600	600			
BCC02	11/15/05 9:10				> 7300	740	1270	1270			
BCC02	11/22/05 8:20				> 8600	950	2000	2000			
BCC02	11/28/05 8:51				> 7600	390	2500	2500			
BCC02	12/5/05 8:50				8900	2400	2600	2600			
BCC02	12/12/05 8:50				20000	760	3400	3400			
BCC02	12/19/05 8:35				14600	2100	3800	3800			
BCC02	12/28/05 7:55				5600	810	3100	3100			
BCC02	1/4/06 9:11				35000	8900	34000	34000			
BCC02	1/9/06 9:20				35000	2400	18000	18000			
BCC02	1/17/06 11:56				56000	1600	13400	13400			
BCC02	1/18/06 14:25				40000	3300	36000	36000			
BCC02	1/19/06 8:57				55000	3400	20000	20000			
BCC02	1/23/06 9:20				> 9800	880	29000	29000			
BCC02	1/31/06 9:45				22000	3600	10500	10500			
BCC02	2/6/06 9:30				> 7100	760	9900	9900			
BCC02	2/9/06 10:30				20000	1090	4300	4300			
BCC02	2/14/06 9:20				> 7000	1400	6500	6500			
BCC02	2/21/06 9:36				78000	2700	8600	8600			
BCC02	3/1/06 9:00				38000	4200	6800	6800			
BCC02	3/7/06 9:08				3400000	3400	6500	6500			
BCC02	3/15/06 8:30				> 7700	2300	700	700			
BCC02	3/27/06 9:15				> 9600	2000	690	690			
BCC02	3/28/06 12:50				130000	5100	6200	6200			
BCC02	3/29/06 9:56				134000	28000	16600	16600			
BCC02	3/31/06 9:15				24000	2900	610	610			
BCC02	4/2/06 10:30				25000	5800	270	270			
BCC02	4/3/06 9:25				6600	570	2000	2000			
BCC02	4/12/06 9:30				> 7100	1180	490	490			
BCC02	4/17/06 9:45				> 6900	760	340	340			
BCC02	4/24/06 9:45				16000	2200	410	410			
BCC02	5/1/06 9:25				> 6000	2800	400	400			
BCC02	5/9/06 9:30				> 3100	420	430	430			
BCC02	5/15/06 9:30				> 8000	380	180	180			
BCC02	5/22/06 10:38				112000	22000	8300	8300			
BCC02	5/24/06 10:45				15000	2800	300	300			
BCC02	5/25/06 8:22				> 4800	2200	480	480			
BCC02	5/26/06 10:30				2900	440	270	270			
BCC02	6/2/06 9:35				> 210	430	100	100			
BCC02	6/6/06 9:20				> 500	380	170	170			
BCC02	6/16/06 9:40				> 780	210	99	99			
BCC02	6/23/06 9:50				5800	980	190	190			
BCC02	6/29/06 9:28				> 3900	700	130	130			
BGC	8/9/05 10:45	390	< 9	20	22000	70	360	360	< 9	< 9	< 9
BGC	8/16/05 11:00	340	40	< 9	6300	240	550	550	20	< 9	< 9
BGC	8/23/05 10:15	150	20	9	5800	100	510	510	9	< 9	9
BGC	8/30/05 11:10	90	< 9	< 9	5900	210	510	510	< 9	< 9	< 9
BGC	9/7/05 10:40	40	20	9	4100	220	420	420	70	30	20
BGC	9/13/05 10:45	< 9	< 9	< 9	4500	270	230	230	9	< 9	< 9
BGC	9/21/05 10:25	200	< 9	9	14000	390	< 9	9	> 140	30	350
BGC	9/27/05 10:35	< 9	< 9	< 9	4100	320	470	470	40	< 9	< 9
BGC	10/5/05 9:20	20	< 9	< 9	> 1600	140	150	150	50	9	20

Bold entries in surfzone exceed AB-411 single sample standard for ocean water sports contact

Attachment C-11-V
Pathogen Indicator Monitoring in the Santa Ana Region

		Upcoast			Stormdrain				Downcoast		
		TC	FC	ENT	TC	FC	ENT		TC	FC	ENT
Site	Date	CFU/100 ml)									
BGC	10/13/05 11:10	20	< 9	< 9	3900	210	210	210	< 9	< 9	< 9
BGC	10/19/05 10:58	330	30	40	> 7500	470	730	730	50	9	9
BGC	10/24/05 9:10	220	20	30	3100	370	340	340			
BGC	11/1/05 12:00	190	50	< 9	4700	350	290	290	9	9	< 9
BGC	11/9/05 10:05	80	< 9	< 9	> 3900	260	520	520	< 9	< 9	< 9
BGC	11/15/05 10:20	70	9	< 9	2800	550	690	690	50	20	9
BGC	11/21/05 8:50	70	<9	40	2800	260	360	360	30	**<9**	< 9
BGC	11/30/05 9:30	90	20	30	2600	890	620	620	120	40	40
BGC	12/8/05 9:35	80	20	30	660	150	280	280	9	< 9	20
BGC	12/13/05 9:20	50	30	9	> 1060	410	200	200	140	20	80
BGC	12/19/05 9:55	99	30	**160**	800	270	80	80	290	99	90
BGC	12/29/05 9:25	20	< 9	< 9	4000	940	340	340	250	99	40
BGC	1/3/06 9:20	200	9	20	6100	2100	3400	3400	> 500	40	60
BGC	1/11/06 8:45	20	< 9	20	> 590	160	350	350	90	40	40
BGC	1/19/06 8:20	9	< 9	< 9	2300	230	360	360	490	190	70
BGC	1/23/06 9:30	70	50	50	280	110	240	240	9	30	9
BGC	2/1/06 10:50	70	90	9	660	130	190	190	90	70	**130**
BGC	2/7/06 11:05	9	< 9	< 9	240	220	110	110	< 9	< 9	< 9
BGC	2/15/06 9:40	30	20	< 9	> 730	200	180	180	180	70	50
BGC	2/23/06 8:30	40	9	< 9	> 560	40	220	220	9	< 9	9
BGC	2/27/06 9:00	80	9	30	1000	220	440	440	100	40	40
BGC	3/6/06 8:40	160	40	30	2700	230	450	450	40	9	20
BGC	3/13/06 10:00	40	9	9	2100	210	480	480	9	< 9	< 9
BGC	3/21/06 9:45	130	60	80	2100	450	760	760	< 9	< 9	< 9
BGC	3/31/06 9:45	410	80	**120**	6400	1460	1680	1680	270	240	**120**
BGC	4/6/06 10:30	740	200	30	3300	550	880	880	580	140	40
BGC	4/12/06 9:25	> 190	9	9	3300	210	210	210	9	< 9	< 9
BGC	4/17/06 9:55	150	< 9	100	2300	280	2400	2400	160	30	**240**
BGC	4/26/06 10:15	270	40	30	6700	360	640	640	40	9	30
BGC	5/2/06 0:00	440	40	40	3200	280	400	400	190	40	20
BGC	5/8/06 10:20	210	20	**130**	3000	510	200	200	330	40	70
BGC	5/17/06 12:00										
BGC	5/25/06 7:54	30	30	< 9	4500	280	270	270	40	50	60
BGC	5/30/06 10:25	1400	**990**	**600**	> 6600	130	170	170	440	290	**140**
BGC	6/5/06 10:10	> 330	150	70	730	680	920	920	200	130	60
BGC	6/14/06 9:40										
BGC	6/19/06 9:35	> 99	30	9	2300	200	410	410	> 250	80	70
BGC	6/27/06 9:10	290	210	60	5800	200	580	580	560	99	50
CMCG02	7/6/05 8:39				350000	63000	14800	14800			
CMCG02	7/13/05 10:04				460000	28000	16000	16000			
CMCG02	7/28/05 9:26				700000	12000	20000	20000			
CMCG02	8/4/05 13:35				950000	2300	5700	5700			
CMCG02	8/9/05 9:32				69000	19000	7100	7100			
CMCG02	8/17/05 12:53				25000	4500	4400	4400			
CMCG02	8/22/05 10:41				76000	5900	3000	3000			
CMCG02	8/31/05 11:14				21000	4800	2500	2500			
CMCG02	9/7/05 9:53				420000	21000	3000	3000			
CMCG02	9/14/05 11:03				> 67000	7000	8300	8300			
CMCG02	9/23/05 10:45				63000	2800	1080	1080			
CMCG02	9/28/05 10:12				430000	5500	2400	2400			
CMCG02	10/6/05 10:15				200000	6000	3700	3700			
CMCG02	10/14/05 10:55				93000	6900	2800	2800			
CMCG02	10/17/05 11:51				> 800000	38000	18000	18000			
CMCG02	10/19/05 10:31				92000	4900	1320	1320			
CMCG02	10/21/05 10:53				> 74000	4600	2500	2500			
CMCG02	10/27/05 10:04				600000	4500	2800	2800			
CMCG02	11/1/05 11:40				30000	1200	2500	2500			
CMCG02	11/2/05 12:45				64000	570	2300	2300			
CMCG02	11/7/05 10:45				96000	540	2000	2000			
CMCG02	11/14/05 11:22				26000	380	1120	1120			
CMCG02	11/15/05 11:00				73000	840	520	520			
CMCG02	11/22/05 10:30				540000	6000	2800	2800			
CMCG02	11/28/05 11:01				280000	23000	1010	1010			

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Attachment C-11-V
Pathogen Indicator Monitoring in the Santa Ana Region

		Upcoast			Stormdrain				Downcoast		
		TC	FC	ENT	TC	FC	ENT		TC	FC	ENT
Site	Date	CFU/100 ml)									
CMCG02	11/30/05 11:05				440000	7500	3200	3200			
CMCG02	12/5/05 11:00				2400000	1400	1040	1040			
CMCG02	12/12/05 11:15				400000	1600	4100	4100			
CMCG02	12/19/05 10:40				86000	8700	580	580			
CMCG02	12/28/05 9:25				940000	5200	2100	2100			
CMCG02	1/4/06 12:07				22000	590	2100	2100			
CMCG02	1/9/06 11:10				> 84000	6400	1800	1800			
CMCG02	1/19/06 12:02				63000	230	850	850			
CMCG02	1/23/06 11:15				39000	480	790	790			
CMCG02	1/31/06 11:55				168000	2200	2300	2300			
CMCG02	2/2/06 9:23				360000	2600	2800	2800			
CMCG02	2/6/06 11:10				3800000	56000	5700	5700			
CMCG02	2/14/06 11:00				300000	3000	21000	21000			
CMCG02	2/21/06 11:05				59000	280	420	420			
CMCG02	3/1/06 11:57				24000	1800	760	760			
CMCG02	3/2/06 12:01				> 5600	99	230	230			
CMCG02	3/7/06 10:38				118000	2000	3300	3300			
CMCG02	3/15/06 11:36				1070000	530	1050	1050			
CMCG02	3/20/06 10:50				> 167000	24000	2600	2600			
CMCG02	3/27/06 9:51				> 113000	590	2600	2600			
CMCG02	4/3/06 10:55				> 2800	520	1310	1310			
CMCG02	4/12/06 10:55				6500000	3000	3400	3400			
CMCG02	4/17/06 11:28				23000	380	340	340			
CMCG02	4/24/06 11:10				46000	1200	1060	1060			
CMCG02	5/1/06 11:00				> 138000	5600	2800	2800			
CMCG02	5/9/06 11:10				109000	6400	2900	2900			
CMCG02	5/15/06 11:07				1640000	31000	26000	26000			
CMCG02	5/25/06 10:05				9600000	35000	4100	4100			
CMCG02	6/2/06 11:17				102000	5500	3700	3700			
CMCG02	6/6/06 11:35				10000000	30000	5700	5700			
CMCG02	6/16/06 11:05				> 69000000	57000	5700	5700			
CMCG02	6/23/06 11:15				1100000	52000	12000	12000			
CMCG02	6/27/06 11:35				310000	48000	16000	16000			
CMCG02	6/29/06 11:50				680000	105000	7600	7600			
EGWC05	8/17/05 9:12				> 920	250	70	70			
EGWC05	8/24/05 10:04				> 520	150	30	30			
EGWC05	8/31/05 12:21				> 400	110	< 9	9			
EGWC05	9/7/05 11:02				> 7900	910	9	9			
EGWC05	9/14/05 12:00				> 700	9	< 9	9			
EGWC05	9/23/05 10:25				> 5900000	36000	1230	1230			
EGWC05	9/28/05 11:15				27000	3600	230	230			
EGWC05	10/6/05 11:21				> 6700	390	180	180			
EGWC05	10/14/05 9:25				10400	2200	670	670			
EGWC05	10/18/05 11:38				1200000	250000	200000	200000			
EGWC05	10/27/05 8:35				46000	7100	2000	2000			
EGWC05	11/1/05 10:10				31000	1400	260	260			
EGWC05	11/7/05 9:30				12000	1200	320	320			
EGWC05	11/15/05 9:49				12900	1000	640	640			
EGWC05	11/22/05 9:10				> 10000	760	680	680			
EGWC05	11/28/05 9:45				14000	1260	450	450			
EGWC05	12/5/05 9:45				27000	860	270	270			
EGWC05	12/12/05 9:50				4500	400	610	610			
EGWC05	12/19/05 9:15				26000	740	310	310			
EGWC05	12/28/05 8:30				51000	1700	180	180			
EGWC05	1/4/06 9:35				48000	1180	2400	2400			
EGWC05	1/9/06 9:55				< 10000	250	760	760			
EGWC05	1/19/06 9:34				> 9000	250	1110	1110			
EGWC05	1/23/06 10:00				4200	200	280	280			
EGWC05	1/31/06 10:20				36000	310	760	760			
EGWC05	2/6/06 10:05				64000	1400	2200	2200			
EGWC05	2/9/06 11:00				26000	230	140	140			
EGWC05	2/14/06 10:00				18000	710	390	390			
EGWC05	2/21/06 10:03				> 136000	1900	2800	2800			

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Attachment C-11-V
Pathogen Indicator Monitoring in the Santa Ana Region

		Upcoast			Stormdrain				Downcoast		
		TC	FC	ENT	TC	FC	ENT		TC	FC	ENT
Site	Date	CFU/100 ml)									
EGWC05	3/1/06 9:45				52000	2300	3400	3400			
EGWC05	3/7/06 9:40				3600000	12800	2800	2800			
EGWC05	3/15/06 9:15				8000	700	450	450			
EGWC05	3/20/06 10:00				49000	450	180	180			
EGWC05	3/27/06 9:50				> 10700	660	240	240			
EGWC05	3/28/06 13:30				1520000	9500	11800	11800			
EGWC05	3/29/06 10:32				53000	4700	7800	7800			
EGWC05	3/31/06 9:39				63000	2400	6200	6200			
EGWC05	4/2/06 11:10				27000	5100	100	100			
EGWC05	4/3/06 10:00				6100	360	300	300			
EGWC05	4/12/06 9:56				4000	150	50	50			
EGWC05	4/17/06 10:22				> 7200	270	80	80			
EGWC05	4/24/06 10:15				114000	3000	60	60			
EGWC05	5/1/06 10:00				> 5500	1500	150	150			
EGWC05	5/9/06 10:05				2800	340	200	200			
EGWC05	5/15/06 10:05				> 2100	220	280	280			
EGWC05	5/22/06 11:20				680000	34000	8100	8100			
EGWC05	5/24/06 11:22				20000	3200	390	390			
EGWC05	5/25/06 8:55				16000	480	350	350			
EGWC05	5/26/06 11:00				4200	360	140	140			
EGWC05	6/2/06 10:10				> 3600	760	90	90			
EGWC05	6/6/06 9:50				> 7200	670	240	240			
EGWC05	6/16/06 10:20				> 5500	590	170	170			
EGWC05	6/23/06 10:25				10600	930	310	310			
EGWC05	6/29/06 9:57				> 12500	4900	590	590			
HB1	8/9/05 9:17	20	9	9	39000	8000	33000	33000	< 9	< 9	< 9
HB1	8/16/05 9:15	40	9	9	36000	7400	15400	15400	30	40	9
HB1	8/23/05 8:40	20	20	9	36000	13000	16500	16500	40	< 9	9
HB1	8/30/05 9:40	9	< 9	< 9	> 36000	17000	10200	10200	9	< 9	< 9
HB1	9/7/05 9:10	9	< 9	< 9	> 28000	3800	9500	9500	9	< 9	< 9
HB1	9/13/05 9:25	9	< 9	9	32000	17000	6800	6800	< 9	< 9	< 9
HB1	9/21/05 8:45	**260000**	**51000**	**740**	> 120000	48000	9	9	**2800000**	**41000**	**240**
HB1	9/27/05 9:00	9	< 9	9	> 260000	16000	17000	17000	< 9	< 9	< 9
HB1	10/5/05 7:58	9	9	9	> 42000	2200	2300	2300	9	< 9	9
HB1	10/13/05 8:55	< 9	< 9	< 9	22000	2100	14600	14600	< 9	< 9	< 9
HB1	10/19/05 9:01	680	170	30	105000	4100	8400	8400	810	80	40
HB1	10/24/05 7:25	30	9	< 9	> 42000	9360	750	750	40	< 9	< 9
HB1	11/1/05 10:15	40	40	< 9	> 35000	15000	9	9	< 9	9	< 9
HB1	11/9/05 8:05	> 50	40	40	> 24000	9000	28000	28000	> 30	< 9	< 9
HB1	11/15/05 8:45	> 30	20	40	> 3500	2400	3600	3600	**40**	**60**	99
HB1	11/21/05 7:25	20	< 9	50	> 5800	560	2800	2800	< 9	< 9	< 9
HB1	11/30/05 7:45	340	400	30	> 13000	3500	5800	5800	> 40	40	**140**
HB1	12/8/05 8:10	< 9	< 9	< 9	4500	2100	1110	1110	< 9	< 9	< 9
HB1	12/13/05 7:55	20	< 9	30	> 7500	1900	2300	2300	9	< 9	40
HB1	12/19/05 8:40	20	< 9	< 9	15000	3400	2800	2800	9	< 9	9
HB1	12/29/05 7:55	70	9	80	20000	7300	660	660	80	40	**130**
HB1	1/3/06 7:40	4700	120	**290**	270000	4400	4600	4600	**7000**	80	**470**
HB1	1/11/06 7:25	30	20	99	49000	2400	280	280	70	20	70
HB1	1/19/06 7:30	20	< 9	< 9	> 92000	22000	890	890	40	< 9	< 9
HB1	1/23/06 7:50	20	< 9	30	5800	680	2000	2000	9	9	< 9
HB1	2/1/06 9:20	9	30	10	30000	2400	4800	4800	< 9	< 9	< 9
HB1	2/7/06 9:35	< 9	< 9	< 9	> 220000	54000	3300	3300	< 9	< 9	< 9
HB1	2/15/06 8:10	< 9	< 9	< 9	> 4900	120	830	830	9	20	9
HB1	2/23/06 7:00	30	30	< 9	810000	3600	3700	3700	190	30	9
HB1	2/27/06 7:45	330	210	**900**	99000	930	590	590	80	30	70
HB1	3/6/06 7:30	20	< 9	< 9	820000	20000	27000	27000	< 9	< 9	< 9
HB1	3/13/06 8:20	20	9	9	380000	3000	57000	57000	< 9	< 9	< 9
HB1	3/21/06 8:00	< 9	< 9	< 9	15000	2000	43000	43000	9	< 9	< 9
HB1	3/31/06 8:30	70	9	< 9	32000	12800	630	630	9	< 9	< 9
HB1	4/6/06 8:35	> 980	60	9	26000	390	540	540	1000	60	40
HB1	4/12/06 7:50								> 370	9	30
HB1	4/17/06 8:30	20	< 9	< 9	> 55000	880	2000	2000	40	< 9	< 9
HB1	4/26/06 8:40	< 9	9	< 9	> 21000	3200	5500	5500	20	< 9	< 9

Bold entries in surfzone exceed AB-411 single sample standard for ocean water sports contact

Attachment C-11-V
Pathogen Indicator Monitoring in the Santa Ana Region

		Upcoast			Stormdrain				Downcoast		
		TC	FC	ENT	TC	FC	ENT		TC	FC	ENT
Site	Date	CFU/100 ml)									
HB1	5/2/06 0:00	< 9	< 9	< 9	> 10000	5000	14300	14300	20	< 9	< 9
HB1	5/8/06 8:30	40	9	< 9	> 26000	2800	5800	5800	9	20	9
HB1	5/23/06 9:05	**51000**	**1700**	< 9	580000	45000	7500	7500	**38000**	**3100**	9
HB1	5/30/06 9:00	9	9	< 9	> 36000	7000	7100	7100	20	< 9	< 9
HB1	6/5/06 8:30	> 20	20	< 9	> 26000	8200	8900	8900	> 40	20	< 9
HB1	6/19/06 8:15	20	< 9	< 9					20	9	< 9
HB1	6/27/06 7:40	30	9	< 9	> 4500	2800	7100	7100	20	9	9
HB2	8/9/05 9:44	< 9	9	20	118000	72000	8400	8400	30	< 9	< 9
HB2	8/16/05 9:25	40	9	< 9	230000	30000	9100	9100	< 9	9	< 9
HB2	8/23/05 8:35	40	< 9	20	74000	41000	9910	9910	30	< 9	30
HB2	8/30/05 9:30	< 9	< 9	< 9	48000	16000	6400	6400	< 9	< 9	< 9
HB2	9/7/05 9:00	9	< 9	9	68000	27000	11300	11300	9	< 9	9
HB2	9/13/05 9:30	40	< 9	9	44000	25000	12200	12200	20	9	< 9
HB2	9/21/05 8:30	**550000**	**43000**	**2300**	220000	86000	24000	24000	**310000**	**38000**	**750**
HB2	9/27/05 9:05	9	< 9	< 9	29000	5300	5500	5500	9	< 9	< 9
HB2	10/5/05 7:55	< 9	< 9	9	> 38000	5600	7700	7700	< 9	9	< 9
HB2	10/13/05 9:05	< 9	< 9	< 9	16000	2400	5400	5400	< 9	< 9	< 9
HB2	10/19/05 9:13	600	110	30	> 20000	4200	4500	4500	680	60	40
HB2	10/24/05 7:30	9	< 9	< 9	64000	40000	6600	6600	< 9	< 9	9
HB2	11/1/05 10:05	< 9	< 9	9	> 17000	3300	2500	2500	20	9	< 9
HB2	11/9/05 8:18	> 80	9	30	19000	3800	3900	3900	> 20	30	< 9
HB2	11/15/05 8:55	> 20	80	60	34000	5300	11300	11300	50	40	40
HB2	11/21/05 0:00								> 3900	260	40
HB2	11/30/05 7:55	70	40	60	> 5500	700	2700	2700	> 90	90	99
HB2	12/8/05 8:15	< 9	< 9	< 9	29000	350	190	190	< 9	< 9	< 9
HB2	12/13/05 8:05	20	9	20	20000	4700	3200	3200	9	< 9	< 9
HB2	12/19/05 8:45	< 9	9	< 9	> 4300	370	540	540	< 9	< 9	< 9
HB2	12/29/05 8:00	80	40	**120**	> 8000	2900	3400	3400	120	100	**130**
HB2	1/3/06 7:45	5300	110	**340**	> 44000	10000	3300	3300	6200	110	**470**
HB2	1/11/06 7:30	40	30	50	66000	3800	27000	27000	30	20	50
HB2	1/19/06 7:35	30	< 9	< 9	> 5500	200	200	200	30	< 9	< 9
HB2	1/23/06 8:00	9	< 9	9	490000	820	2600	2600	9	< 9	40
HB2	2/1/06 9:25	< 9	< 9	9	93000	740	1570	1570	< 9	< 9	9
HB2	2/7/06 9:45	< 9	< 9	< 9	1400	770	990	990	< 9	< 9	< 9
HB2	2/15/06 8:15	30	< 9	< 9	> 4800	1600	2400	2400	< 9	< 9	< 9
HB2	2/23/06 7:05	50	40	20	19000	2300	2000	2000	40	40	40
HB2	2/27/06 7:50	130	80	30	> 9900	670	340	340	210	120	70
HB2	3/6/06 7:35	9	9	< 9	4700	920	2000	2000	30	< 9	< 9
HB2	3/13/06 8:25	< 9	< 9	9	< 48000	1500	2800	2800	20	< 9	9
HB2	3/21/06 8:05	< 9	< 9	< 9	32000	11000	2900	2900	9	< 9	< 9
HB2	3/31/06 8:40	80	9	20	31000	1630	3300	3300	70	< 9	< 9
HB2	4/6/06 8:45	1100	60	20	65000	5200	3000	3000	> 850	60	60
HB2	4/12/06 7:55	> 340	9	9	37000	4200	31000	31000	300	30	30
HB2	4/17/06 8:35	40	< 9	< 9	70000	4000	2100	2100	9	< 9	< 9
HB2	4/26/06 9:00	< 9	9	< 9	> 11000	8000	3300	3300	< 9	< 9	< 9
HB2	5/2/06 0:00	9	< 9	< 9	> 10000	4100	4500	4500	9	20	< 9
HB2	5/8/06 8:45	40	< 9	9	> 44000	2300	5100	5100	30	9	< 9
HB2	5/23/06 9:14	**26000**	**1500**	20	250000	17000	21000	21000	**37000**	**2900**	< 9
HB2	5/30/06 9:15	9	< 9	< 9	220000	9000	6600	6600	9	< 9	9
HB2	6/19/06 8:20	40	9	< 9	62000	23000	10900	10900	9	20	< 9
HB2	6/27/06 7:50	30	< 9	< 9	> 3400	3500	1180	1180	9	30	< 9
HB3	8/16/05 9:40	9	30	< 9	128000	64000	30000	30000	20	9	9
HB3	8/23/05 8:55	40	< 9	30	> 57000	26000	20000	20000	< 9	9	50
HB3	8/30/05 9:55	< 9	9	< 9	61000	18000	23000	23000	9	< 9	< 9
HB3	9/7/05 9:20	< 9	< 9	9	> 146000	36000	33000	33000	< 9	< 9	< 9
HB3	9/13/05 9:45	9	< 9	9	46000	15000	20000	20000	< 9	9	< 9
HB3	9/21/05 9:00	**220000**	**21000**	30	> 123000	78000	38000	38000	**300000**	**28000**	**410**
HB3	9/27/05 9:15	< 9	< 9	< 9	> 49000	12000	17000	17000	< 9	< 9	< 9
HB3	10/5/05 8:10	< 9	< 9	9	> 580000	140000	42000	42000	9	9	< 9
HB3	10/13/05 9:20	< 9	< 9	< 9	32000	3500	8600	8600	< 9	< 9	< 9
HB3	10/19/05 9:30	590	70	40	> 39000	4600	2500	2500	630	60	30
HB3	10/24/05 7:50	< 9	9	9	250000	97000	7200	7200	20	< 9	< 9
HB3	11/1/05 10:30	< 9	< 9	< 9	30000	3700	2800	2800	20	< 9	< 9

Bold entries in surfzone exceed AB-411 single sample standard for ocean water sports contact

Attachment C-11-V
Pathogen Indicator Monitoring in the Santa Ana Region

		Upcoast			Stormdrain				Downcoast		
		TC	FC	ENT	TC	FC	ENT		TC	FC	ENT
Site	Date	CFU/100 ml)									
HB3	11/9/05 8:38	> 30	20	9	> 29000	2100	7400	7400	> 30	30	< 9
HB3	11/15/05 9:10	50	40	**110**	>28000	4900	16100	16100	50	70	**140**
HB3	11/21/05 0:00								> 260	30	**140**
HB3	11/30/05 8:05	60	30	60	> 46000	1600	6000	6000	99	40	**120**
HB3	12/8/05 0:00								99	40	**120**
HB3	12/13/05 0:00								< 9	< 9	< 9
HB3	12/19/05 8:55								< 9	< 9	9
HB3	12/29/05 8:10	90	30	**140**	> 31000	200	350	350	99	90	30
HB3	1/3/06 7:50	5600	110	**250**	27000	4600	> 500	500	4500	100	**270**
HB3	1/11/06 7:40	20	< 9	90	490000	12500	3800	3800	9	9	40
HB3	1/19/06 7:45	30	< 9	< 9	> 6400	660	990	990	40	9	< 9
HB3	1/23/06 8:15	9	< 9	30	> 3600	680	2200	2200	9	9	< 9
HB3	2/1/06 9:40	30	< 9	< 9	6200	210	490	490	9	20	< 9
HB3	2/7/06 10:00	< 9	< 9	< 9	> 26000	4800	7100	7100	< 9	< 9	< 9
HB3	2/15/06 8:25	9	9	< 9	450000	13200	1260	1260			
HB3	2/23/06 7:15	40	60	60	> 72000	2300	7800	7800	60	50	30
HB3	2/27/06 7:55	120	20	20	230000	16400	21000	21000	99	40	70
HB3	3/6/06 7:40	< 9	< 9	< 9	> 44000	4700	40000	40000	9	9	< 9
HB3	3/13/06 8:30	9	< 9	< 9	> 58000	2800	5800	5800	9	< 9	< 9
HB3	3/21/06 8:15	< 9	< 9	< 9	32000	15700	9100	9100	40	9	30
HB3	3/31/06 8:55	9	9	< 9	60000	8000	2800	2800	70	< 9	< 9
HB3	4/6/06 9:00	> 850	20	9	> 5500	500	2600	2600	> 850	30	20
HB3	4/12/06 8:00	380	< 9	< 9	> 9800	1230	13300	13300	370	40	9
HB3	4/17/06 8:45								50	< 9	< 9
HB3	4/26/06 9:10								< 9	< 9	< 9
HB3	5/2/06 0:00								< 9	9	< 9
HB3	5/8/06 8:55								< 9	9	9
HB3	5/23/06 9:23	**44000**	**2400**	9	100000	24000	8400	8400	**43000**	**3300**	< 9
HB3	6/5/06 9:00								< 9	9	< 9
HB3	6/19/06 8:30								9	9	< 9
HB3	6/27/06 8:00	40	20	< 9	> 420000	39000	34000	34000	9	20	< 9
HB4	8/9/05 9:59	9	9	< 9	> 32000	9000	9700	9700	30	< 9	20
HB4	8/16/05 9:55	< 9	< 9	< 9	36000	5500	6000	6000	40	< 9	< 9
HB4	8/23/05 9:15	9	9	20	22000	5600	3700	3700	60	9	20
HB4	8/30/05 10:10	20	< 9	< 9	64000	25000	20000	20000	< 9	< 9	< 9
HB4	9/7/05 9:45	9	< 9	< 9	24000	3600	2700	2700	< 9	< 9	9
HB4	9/13/05 9:50	< 9	< 9	< 9	25000	6900	4200	4200	9	30	9
HB4	9/21/05 9:15	**310000**	**23000**	**260**	> 3800000	230000	20000	20000	**82000**	**10700**	**530**
HB4	9/27/05 9:35	< 9	< 9	< 9	19800000	3300000	8000	8000	< 9	< 9	< 9
HB4	10/5/05 8:25	9	< 9	< 9	420000	58000	40	40	9	< 9	< 9
HB4	10/13/05 9:40	< 9	< 9	< 9	1150000	71000	4100	4100	< 9	< 9	< 9
HB4	10/19/05 9:55	540	20	30	> 130000	18000	4800	4800	> 780	60	70
HB4	11/1/05 10:45	20	40	< 9	48000	5000	9	9	20	< 9	< 9
HB4	11/15/05 9:25	40	30	30	890000	43000	24000	24000	20	50	40
HB4	11/30/05 8:25	30	30	40	340000	32000	10000	10000	20	9	9
HB4	12/8/05 8:35	< 9	< 9	< 9	22000	5200	6200	6200	< 9	9	< 9
HB4	12/13/05 8:25	9	9	9	6300	2900	3800	3800	9	< 9	9
HB4	12/19/05 9:05	< 9	< 9	< 9	5900	2900	960	960	< 9	< 9	< 9
HB4	12/29/05 8:20	40	9	90	16000	2600	940	940	20	20	99
HB4	1/3/06 8:05	3500	**90**	**200**	320000	15000	19000	19000	4500	120	**340**
HB4	1/11/06 7:50								30	20	20
HB4	1/19/06 7:50	20	< 9	< 9	400000	7400	5700	5700	20	9	< 9
HB4	2/15/06 8:35	< 9	< 9	< 9					20	30	< 9
HB4	2/23/06 7:25	30	40	9	> 9200	1150	720	720	40	9	< 9
HB4	2/27/06 8:05								230	180	30
HB4	3/6/06 7:50								< 9	< 9	9
HB4	3/13/06 8:50	< 9	< 9	< 9	> 28000	700	3200	3200	9	< 9	< 9
HB4	3/21/06 8:40	9	< 9	< 9	> 9400	4600	6300	6300	9	< 9	< 9
HB4	3/31/06 9:10								20	< 9	9
HB4	4/6/06 9:20	> 800	40	< 9	> 141000	3000	3700	3700	> 1000	20	20
HB4	4/12/06 8:15	> 240	20	20	660000	1730	20000	20000	> 270	< 9	9
HB4	4/17/06 8:55	60	< 9	< 9	> 48000	4600	8100	8100	50	< 9	< 9
HB4	4/26/06 9:25	< 9	< 9	< 9	4800	540	220	220	< 9	< 9	< 9

Bold entries in surfzone exceed AB-411 single sample standard for ocean water sports contact

Attachment C-11-V
Pathogen Indicator Monitoring in the Santa Ana Region

		Upcoast			Stormdrain				Downcoast		
		TC	FC	ENT	TC	FC	ENT		TC	FC	ENT
Site	Date	CFU/100 ml)									
HB4	5/2/06 0:00								< 9	9	< 9
HB4	5/8/06 9:11								20	9	< 9
HB4	5/23/06 9:37	**37000**	**3400**	< 9	360000	42000	10700	10700	**28000**	**2600**	20
HB4	5/30/06 9:50	30	< 9	< 9	> 29000	13000	17200	17200	< 9	< 9	9
HB4	6/5/06 9:10	> 20	20	< 9	28000	4900	4700	4700	< 9	20	< 9
HB4	6/19/06 8:45	40	20	< 9	> 5800	2100	2400	2400	< 9	9	< 9
HB4	6/27/06 8:10	40	< 9	9	2800	840	880	880	30	< 9	20
HB5	8/9/05 10:12	40	< 9	< 9	11200000	100000	17800	17800	30	9	9
HB5	8/16/05 10:10	9	9	< 9	8600000	198000	45000	45000	30	20	9
HB5	8/23/05 9:35	20	< 9	40	16300000	173000	15900	15900	9	< 9	< 9
HB5	8/30/05 10:30	< 9	20	20	11500000	136000	25000	25000	9	< 9	< 9
HB5	9/7/05 9:55	9	< 9	< 9	9800000	760000	34000	34000	9	< 9	< 9
HB5	9/13/05 10:05	< 9	9	40	> 19200000	2500000	123000	123000	9	9	< 9
HB5	9/21/05 9:35	**88000**	**5800**	**230**	19800000	5300000	9	9	**119000**	**5900**	**150**
HB5	9/27/05 9:45	< 9	< 9	< 9	10700000	58000	29000	29000	< 9	< 9	< 9
HB5	10/5/05 8:43	30	9	< 9	5900000	32000	28000	28000	9	< 9	< 9
HB5	10/13/05 10:13	< 9	< 9	< 9	10200000	48000	5600	5600	< 9	< 9	< 9
HB5	10/19/05 10:09	2300	120	60	1240000	20000	8600	8600	2000	70	40
HB5	10/24/05 8:30	40	30	30	6300000	40000	5800	5800	60	20	< 9
HB5	11/1/05 11:00	9	< 9	< 9	68000000	730000	34000	34000	100	20	20
HB5	11/9/05 9:30	> 240	9	9	1690000	24000	5200	5200	> 20	< 9	< 9
HB5	11/15/05 9:45	30	< 9	< 9	109000000	163000	15000	15000	20	9	< 9
HB5	11/21/05 8:05	> 980	200	20	19700000	240000	52000	52000	< 9	9	< 9
HB5	11/30/05 8:50	20	30	< 9	> 1880000	220000	25000	25000	< 9	< 9	9
HB5	12/8/05 8:50	9	9	< 9	1360000	36000	5800	5800	9	< 9	< 9
HB5	12/13/05 8:40	9	9	9	10800000	69000	3000	3000	20	9	< 9
HB5	12/19/05 9:20	30	20	< 9	14000000	40000	13400	13400	9	< 9	20
HB5	12/29/05 8:40	70	30	**150**	23000	2400	600	600	40	20	50
HB5	1/3/06 8:30	3000	40	**230**	4000000	77000	192000	192000	3700	70	**190**
HB5	1/11/06 8:10	40	50	20	1240000	28000	8400	8400	60	40	30
HB5	1/19/06 8:00	9	< 9	< 9	32000000	83000	20000	20000	9	< 9	< 9
HB5	1/23/06 8:45	60	40	20	55000000	110000	12600	12600	40	9	20
HB5	2/1/06 10:15	1760	**2400**	**320**	53000000	110000	24000	24000	40	80	9
HB5	2/7/06 10:35	30	< 9	< 9	37000000	57000	19000	19000	40	20	9
HB5	2/15/06 8:55				57000000	100000	3200	3200	30	< 9	< 9
HB5	2/23/06 7:45	690	150	20	4800000	9000	8600	8600	30	< 9	< 9
HB5	2/27/06 8:20	590	280	20	3900000	17300	5800	5800	40	20	< 9
HB5	3/6/06 8:10	30	9	< 9	36000000	740000	136000	136000	9	< 9	< 9
HB5	3/13/06 9:15	40	< 9	< 9	22000000	4200	21000	21000	< 9	< 9	< 9
HB5	3/21/06 9:10	< 9	9	< 9	1310000	4300	2600	2600	20	30	< 9
HB5	3/31/06 9:25	30	< 9	< 9	2300000	8300	29000	29000	50	< 9	< 9
HB5	4/6/06 9:45	610	9	9	1360000	3600	3300	3300	650	40	9
HB5	4/12/06 8:40	250	9	< 9	29000000	66000	11300	11300	220	< 9	< 9
HB5	4/17/06 9:20	90	< 9	< 9	36000000	330000	21000	21000	280	9	< 9
HB5	4/26/06 9:45	< 9	< 9	< 9	67000000	210000	540000	540000	20	< 9	< 9
HB5	5/2/06 0:00	9	< 9	< 9	59000000	7900000	149000	149000	140	40	< 9
HB5	5/8/06 9:35	60	30	< 9	6800000	109000	28000	28000	< 9	9	9
HB5	5/30/06 10:05	40	20	9	14800000	116000	37000	37000	20	20	< 9
HB5	6/5/06 9:25	9	9	< 9	152000000	3400000	320000	320000	40	30	< 9
HB5	6/19/06 9:10	< 9	< 9	< 9	156000000	3900000	66000	66000	20	< 9	< 9
HB5	6/27/06 8:35	140	140	**1000**	48000000	2400000	370000	370000	9	< 9	< 9
MDC	8/9/05 12:04	< 9	< 9	< 9	> 200	190	< 9	9	< 9	< 9	< 9
MDC	8/16/05 12:15	< 9	20	< 9	> 5000	40	30	30	< 9	20	< 9
MDC	8/23/05 11:30	< 9	< 9	9	< 1000	< 9	9	9	9	< 9	< 9
MDC	8/30/05 12:30	< 9	< 9	< 9	210	170	< 9	9	< 9	< 9	< 9
MDC	9/7/05 11:40	30	9	9	> 900	< 9	< 9	9	> 50	20	< 9
MDC	9/13/05 11:50	< 9	< 9	< 9	3000	40	40	40	< 9	< 9	< 9
MDC	9/21/05 11:30	80	30	40	2300	200	2600	2600	9	9	< 9
MDC	9/27/05 11:35	< 9	< 9	< 9	1300	20	30	30	< 9	< 9	< 9
MDC	10/5/05 10:30	< 9	< 9	9	> 1000	30	30	30	< 9	9	9
MDC	10/13/05 12:42	< 9	< 9	< 9	> 280	< 9	20	20	< 9	< 9	< 9
MDC	10/19/05 12:35	160	9	9	> 7900	1600	430	430	520	80	20
MDC	10/24/05 10:35	< 9	< 9	< 9	> 2200	210	300	300	< 9	< 9	< 9

Bold entries in surfzone exceed AB-411 single sample standard for ocean water sports contact

Attachment C-11-V
Pathogen Indicator Monitoring in the Santa Ana Region

		Upcoast			Stormdrain				Downcoast		
		TC	FC	ENT	TC	FC	ENT		TC	FC	ENT
Site	Date	CFU/100 ml)									
MDC	11/1/05 1:15	9	20	< 9	200	9	20	20	40	< 9	70
MDC	11/9/05 11:40	20	< 9	< 9	3000	160	140	140	9	< 9	< 9
MDC	11/15/05 11:35	9	<9	< 9	> 3900	830	390	390	9	<9	< 9
MDC	11/30/05 10:55	20	9	9	3900	310	150	150	20	< 9	30
MDC	12/8/05 11:10	< 9	20	< 9	> 650	70	99	99	< 9	< 9	< 9
MDC	12/13/05 11:00	< 9	20	9	3000	450	60	60	20	< 9	< 9
MDC	12/19/05 11:30	20	< 9	9	2600	90	330	330	60	9	< 9
MDC	12/29/05 11:00	30	< 9	< 9	> 5500	2700	880	880	30	9	< 9
MDC	1/3/06 10:50	260	**<9**	80	46000	2000	9700	9700	> 960	60	**220**
MDC	1/11/06 10:30	40	9	< 9	3900	120	380	380	30	< 9	< 9
MDC	1/19/06 9:50	30	< 9	9	5900	70	400	400	20	< 9	< 9
MDC	2/1/06 11:55	< 9	< 9	< 9	> 700	210	99	99	< 9	< 9	< 9
MDC	2/7/06 11:30	< 9	< 9	< 9	380	290	9	9	< 9	< 9	< 9
MDC	2/15/06 11:20	< 9	< 9	< 9	> 2300	160	580	580	< 9	< 9	< 9
MDC	2/23/06 9:35	20	9	< 9	> 1700	30	130	130	9	< 9	< 9
MDC	2/27/06 10:30	< 9	< 9	9	4700	250	60	60	9	9	< 9
MDC	3/6/06 9:40	50	< 9	< 9	> 6100	320	910	910	20	< 9	< 9
MDC	3/13/06 11:20	9	< 9	< 9	> 3100	280	2100	2100	70	40	**140**
MDC	3/21/06 11:20	380	90	**280**	4800	790	3100	3100	350	40	**140**
MDC	3/31/06 11:00	670	50	20	25000	860	900	900	3100	220	99
MDC	4/6/06 11:50	2300	300	**140**	16000	2600	990	990	> 6100	**910**	**480**
MDC	4/12/06 11:00	40	< 9	< 9	> 3400	250	200	200	9	< 9	< 9
MDC	4/17/06 11:40	< 9	< 9	< 9	> 3100	310	150	150	40	< 9	< 9
MDC	4/26/06 11:45	> 20	20	< 9	> 1600	270	60	60	9	9	< 9
MDC	5/2/06 0:00	30	< 9	9	> 4700	160	570	570	20	< 9	50
MDC	5/8/06 11:30	< 9	< 9	< 9	> 1300	220	99	99	30	< 9	< 9
MDC	5/25/06 8:55	< 9	< 9	< 9	> 20000	350	350	350	< 9	< 9	< 9
MDC	5/30/06 11:45	30	< 9	30	> 1700	950	50	50	30	20	20
MDC	6/5/06 11:30	9	< 9	< 9	7900	6000	660	660	< 9	< 9	9
MDC	6/19/06 10:55	9	20	< 9	> 2200	420	250	250	20	< 9	< 9
MDC	6/27/06 11:00	130	60	< 9	> 3600	580	60	60	< 9	9	< 9
PPC	8/9/05 11:35								< 9	< 9	< 9
PPC	8/16/05 11:40	< 9	< 9	< 9	22000	11700	1870	1870	9	< 9	< 9
PPC	8/23/05 10:55	9	20	< 9	31000	2600	6900	6900	110	< 9	70
PPC	8/30/05 11:50	< 9	< 9	< 9	3600	680	790	790	9	< 9	< 9
PPC	9/7/05 11:15	80	20	20	26000	1900	2700	2700	> 50	9	80
PPC	9/13/05 11:20	< 9	< 9	< 9	> 5200	770	860	860	< 9	< 9	< 9
PPC	9/21/05 11:00	80	30	< 9	16000	12000	< 9	9	< 9	< 9	< 9
PPC	9/27/05 11:15	9	< 9	< 9	4900	340	640	640	30	< 9	< 9
PPC	10/5/05 9:55	< 9	< 9	< 9	> 3500	580	590	590	60	40	30
PPC	10/13/05 11:59	9	< 9	< 9	6400	350	1290	1290	< 9	< 9	< 9
PPC	10/19/05 11:53	40	9	9	> 4700	550	370	370	30	< 9	< 9
PPC	10/24/05 10:00	40	9	< 9	> 55000	5000	2600	2600	9	< 9	< 9
PPC	11/1/05 12:40	9	< 9	< 9	137000	5700	2500	2500	20	< 9	< 9
PPC	11/9/05 10:57	< 9	< 9	< 9	4800	140	280	280	< 9	< 9	< 9
PPC	11/15/05 11:05	9	<9	< 9	> 2800	430	760	760	9	<9	< 9
PPC	11/21/05 9:30	< 9	< 9	< 9	3500	160	240	240	9	**<9**	< 9
PPC	11/30/05 10:25	20	< 9	9	5000	310	110	110	20	9	< 9
PPC	12/8/05 10:35	< 9	9	< 9	> 1700	80	230	230	< 9	< 9	< 9
PPC	12/13/05 10:10	70	9	< 9	28000	800	2200	2200	40	< 9	< 9
PPC	12/19/05 10:55	20	9	9	> 17000	90	260	260	40	9	< 9
PPC	12/29/05 10:25	20	< 9	< 9	15000	160	350	350	20	30	< 9
PPC	1/3/06 10:15	100	20	9	53000	5600	2900	2900	210	30	< 9
PPC	1/11/06 9:50	20	9	< 9	4200	220	320	320	30	< 9	< 9
PPC	1/19/06 9:20	9	< 9	< 9	12300	1800	850	850	30	9	< 9
PPC	1/23/06 10:15	20	< 9	< 9	5600	140	220	220	9	9	< 9
PPC	2/1/06 11:30	9	< 9	< 9	33000	720	6200	6200	40	< 9	< 9
PPC	2/7/06 11:40	20	< 9	< 9	45000	42000	760	760	30	9	9
PPC	2/15/06 10:50	< 9	< 9	< 9	1600	70	140	140	9	< 9	< 9
PPC	2/23/06 9:30	20	< 9	< 9	2000	20	110	110	30	< 9	< 9
PPC	2/27/06 9:55	20	< 9	9	4800	110	160	160	20	< 9	9
PPC	3/6/06 9:30	40	9	< 9	10000	1130	1140	1140	300	20	40
PPC	3/13/06 10:55	20	< 9	< 9	4200	870	480	480	30	< 9	< 9

Bold entries in surfzone exceed AB-411 single sample standard for ocean water sports contact

Attachment C-11-V
Pathogen Indicator Monitoring in the Santa Ana Region

		Upcoast			Stormdrain				Downcoast		
		TC	FC	ENT	TC	FC	ENT		TC	FC	ENT
Site	Date	CFU/100 ml)									
PPC	3/21/06 10:40	110	9	< 9	23000	7500	2600	2600	40	< 9	< 9
PPC	3/31/06 10:30	420	30	< 9	43000	2100	2500	2500	110	9	9
PPC	4/6/06 11:25	200	30	< 9	> 6400	760	1520	1520	260	70	< 9
PPC	4/12/06 10:25	30	< 9	9	> 12400	410	2100	2100	9	< 9	< 9
PPC	4/17/06 10:50	9	20	< 9	210000	131000	41000	41000	640	320	< 9
PPC	4/26/06 11:20	110	< 9	< 9	29000	470	1170	1170	9	< 9	< 9
PPC	5/2/06 0:00	30	< 9	< 9	6800	280	870	870	40	< 9	< 9
PPC	5/8/06 11:05	99	< 9	< 9	75000	4900	2600	2600	20	< 9	< 9
PPC	5/25/06 8:29	40	9	< 9	68000	4200	1100	1100	220	70	40
PPC	5/30/06 11:10	30	< 9	< 9	30000	2400	810	810	9	< 9	< 9
PPC	6/5/06 11:00	30	20	< 9	6200	370	710	710	20	40	60
PPC	6/19/06 10:30	20	< 9	< 9	> 3800	1000	3800	3800	40	< 9	< 9
PPC	6/27/06 10:10	99	30	< 9	18000	710	900	900	50	9	< 9
SADF01	8/17/05 12:50				> 2000	800	140	140			
SADF01	8/22/05 10:07				2100000	4500	520	520			
SADF01	8/31/05 10:49				> 3700	430	140	140			
SADF01	9/7/05 9:39				> 12200	460	510	510			
SADF01	9/14/05 10:41				97000	41000	460	460			
SADF01	9/23/05 11:00				> 93000	38000	1170	1170			
SADF01	9/28/05 10:01				> 6000	5100	710	710			
SADF01	10/6/05 10:06				> 11000	3200	320	320			
SADF01	10/14/05 10:35				> 11100	500	110	110			
SADF01	10/17/05 11:08				22000000	680000	310000	310000			
SADF01	10/19/05 10:07				250000	20000	2500	2500			
SADF01	10/21/05 10:26				> 29000	4300	1120	1120			
SADF01	10/27/05 9:41				27000	1200	770	770			
SADF01	11/1/05 11:20				29000	3900	60	60			
SADF01	11/2/05 12:05				13000	310	9	9			
SADF01	11/7/05 10:25				7600	370	180	180			
SADF01	11/15/05 10:44				22000	440	210	210			
SADF01	11/22/05 10:15				> 37000	12000	20000	20000			
SADF01	11/28/05 10:42				6600	810	80	80			
SADF01	12/5/05 10:40				27000	1100	410	410			
SADF01	12/12/05 10:45				> 7500	210	130	130			
SADF01	12/19/05 10:10				8000	260	110	110			
SADF01	12/28/05 9:16				5800	3800	320	320			
SADF01	1/4/06 11:40				112000	3500	1400	1400			
SADF01	1/9/06 10:50				> 9300	220	220	220			
SADF01	1/19/06 11:30				10300	150	70	70			
SADF01	1/23/06 11:00				> 5500	170	200	200			
SADF01	1/31/06 11:15				3900	50	40	40			
SADF01	2/2/06 9:03				20000	180	260	260			
SADF01	2/6/06 10:55				3800	110	20	20			
SADF01	2/14/06 10:45				17000	190	40	40			
SADF01	2/21/06 10:51				40000	280	160	160			
SADF01	3/1/06 10:45				108000	2200	320	320			
SADF01	3/2/06 11:30				40000	220	140	140			
SADF01	3/7/06 10:23				112000	3200	910	910			
SADF01	3/15/06 11:15				4300	90	20	20			
SADF01	3/20/06 10:30				81000	1100	40	40			
SADF01	3/27/06 10:21				96000	11500	30	30			
SADF01	4/3/06 10:45				6600	110	80	80			
SADF01	4/12/06 10:38				450	40	120	120			
SADF01	4/17/06 11:05				> 8200	460	40	40			
SADF01	4/24/06 10:57				135000	2200	440	440			
SADF01	5/1/06 10:40				31000	2500	99	99			
SADF01	5/9/06 11:00				86000	560	120	120			
SADF01	5/15/06 10:55				7000	420	60	60			
SADF01	5/25/06 9:50				36000	2400	230	230			
SADF01	6/2/06 11:00				32000	1070	40	40			
SADF01	6/6/06 11:15				31000	3500	630	630			
SADF01	6/16/06 10:55				27000	790	120	120			
SADF01	6/23/06 11:30				25000	6900	80	80			

Bold entries in surfzone exceed AB-411 single sample standard for ocean water sports contact

Attachment C-11-V
Pathogen Indicator Monitoring in the Santa Ana Region

		Upcoast			Stormdrain				Downcoast		
		TC	FC	ENT	TC	FC	ENT		TC	FC	ENT
Site	Date	CFU/100 ml)									
SADF01	6/27/06 10:48				> 7300	840	140	140			
SADF01	6/29/06 11:41				> 12300	3000	110	110			
SDMF05	8/17/05 11:45				> 420	30	< 9	9			
SDMF05	8/22/05 9:26				> 2200	9	< 9	9			
SDMF05	8/31/05 10:36				> 1200	< 9	< 9	9			
SDMF05	9/7/05 9:17				> 1200	40	20	20			
SDMF05	9/14/05 9:35				> 900	20	< 9	9			
SDMF05	9/23/05 11:20				3200000	138000	3300	3300			
SDMF05	9/28/05 9:27				4300	380	20	20			
SDMF05	10/6/05 9:51				3000	140	20	20			
SDMF05	10/14/05 10:05				3700	260	80	80			
SDMF05	10/17/05 10:28				2500000	270000	78000	78000			
SDMF05	10/19/05 9:49				100000	14000	4500	4500			
SDMF05	10/21/05 9:43				7800	2700	260	260			
SDMF05	10/27/05 9:15				> 5600	280	90	90			
SDMF05	11/1/05 10:50				3600	440	40	40			
SDMF05	11/2/05 11:40				3000	330	80	80			
SDMF05	11/7/05 10:10				1580	220	80	80			
SDMF05	11/15/05 10:23				36000	490	140	140			
SDMF05	11/22/05 9:40				> 7900	350	30	30			
SDMF05	11/28/05 10:16				5200	230	70	70			
SDMF05	12/5/05 10:21				36000	200	9	9			
SDMF05	12/12/05 10:20				> 7400	200	60	60			
SDMF05	12/19/05 9:55				2900	20	30	30			
SDMF05	12/28/05 9:00				> 780	120	140	140			
SDMF05	1/4/06 11:10				36000	12000	26000	26000			
SDMF05	1/9/06 10:32				> 6900	280	480	480			
SDMF05	1/19/06 11:00				2600	60	40	40			
SDMF05	1/23/06 10:40				2500	99	200	200			
SDMF05	1/31/06 11:00				> 420	20	20	20			
SDMF05	2/2/06 8:37				60	40	< 9	9			
SDMF05	2/6/06 10:30				> 750	40	30	30			
SDMF05	2/14/06 10:30				> 5400	20	30	30			
SDMF05	2/21/06 10:33				52000	730	40	40			
SDMF05	3/1/06 10:20				92000	14000	7500	7500			
SDMF05	3/2/06 11:03				> 62000	2200	520	520			
SDMF05	3/7/06 10:05				> 4800	160	240	240			
SDMF05	3/15/06 10:50				22000	200	99	99			
SDMF05	3/20/06 10:10				860000	3500	5500	5500			
SDMF05	3/27/06 11:10				> 2900	40	100	100			
SDMF05	4/3/06 10:25				> 9200	310	80	80			
SDMF05	4/12/06 10:25				> 8800	480	360	360			
SDMF05	4/17/06 10:47				63000	670	130	130			
SDMF05	4/24/06 10:40				350000	6600	660	660			
SDMF05	5/1/06 10:23				1100	50	20	20			
SDMF05	5/9/06 10:35				1600	30	20	20			
SDMF05	5/15/06 10:28				400	< 9	< 9	9			
SDMF05	5/25/06 9:30				28000	2800	240	240			
SDMF05	6/2/06 10:30				> 1900	40	20	20			
SDMF05	6/6/06 10:30				> 1700	40	90	90			
SDMF05	6/16/06 10:40				> 680	30	9	9			
SDMF05	6/23/06 11:00				> 640	100	< 9	9			
SDMF05	6/27/06 10:05				> 1500	30	9	9			
SDMF05	6/29/06 11:14				> 1500	20	40	40			
SUNC07	8/17/05 8:59				> 3800	610	1000	1000			
SUNC07	8/24/05 9:49				> 3500	570	850	850			
SUNC07	8/31/05 12:05				2000	240	150	150			
SUNC07	9/7/05 10:47				300	70	130	130			
SUNC07	9/14/05 11:50				> 2900	510	410	410			
SUNC07	9/23/05 10:05				> 6800	3700	4300	4300			
SUNC07	9/28/05 11:09				29000	28000	2500	2500			
SUNC07	10/6/05 11:05				1300	120	50	50			
SUNC07	10/14/05 9:00				4600	40	100	100			

Bold entries in surfzone exceed AB-411 single sample standard for ocean water sports contact

Attachment C-11-V
Pathogen Indicator Monitoring in the Santa Ana Region

		Upcoast			Stormdrain				Downcoast		
		TC	FC	ENT	TC	FC	ENT		TC	FC	ENT
Site	Date	CFU/100 ml)									
SUNC07	10/18/05 11:27				370000	120000	48000	48000			
SUNC07	10/27/05 8:15				3000	490	370	370			
SUNC07	11/1/05 9:50				> 2100	300	160	160			
SUNC07	11/7/05 9:15				2500	90	370	370			
SUNC07	11/15/05 9:30				200	30	30	30			
SUNC07	11/22/05 8:40				> 12800	2000	2600	2600			
SUNC07	11/28/05 9:15				910	110	450	450			
SUNC07	12/5/05 9:20				140	60	110	110			
SUNC07	12/12/05 9:20				> 1500	90	210	210			
SUNC07	12/19/05 8:50				410	< 9	140	140			
SUNC07	12/28/05 8:10				2400	480	220	220			
SUNC07	1/4/06 9:25				> 98000	12900	41000	41000			
SUNC07	1/9/06 9:40				> 9100	320	680	680			
SUNC07	1/19/06 9:12				19000	280	2000	2000			
SUNC07	1/23/06 9:40				> 6600	480	8100	8100			
SUNC07	1/31/06 10:05				60	9	9	9			
SUNC07	2/6/06 9:45				49000	2100	3400	3400			
SUNC07	2/14/06 9:40				150	20	20	20			
SUNC07	2/21/06 9:45				> 65000	> 600	2100	2100			
SUNC07	3/1/06 9:20				56000	1500	640	640			
SUNC07	3/7/06 9:23				> 22000	2800	5700	5700			
SUNC07	3/15/06 8:50				> 780	210	230	230			
SUNC07	3/20/06 9:35				> 6800	310	2100	2100			
SUNC07	3/27/06 9:35				3000	370	150	150			
SUNC07	4/3/06 9:45				40000	9000	22000	22000			
SUNC07	4/12/06 9:42				4100	100	99	99			
SUNC07	4/17/06 10:05				52000	2400	1900	1900			
SUNC07	4/24/06 10:00				45000	1400	1080	1080			
SUNC07	5/1/06 9:48				16000	6100	8800	8800			
SUNC07	5/9/06 9:40				> 6700	3800	2500	2500			
SUNC07	5/15/06 9:45				> 4300	910	2400	2400			
SUNC07	5/25/06 8:35				2200	280	830	830			
SUNC07	6/2/06 9:50				30000	8500	140	140			
SUNC07	6/6/06 9:35				> 6500	1400	690	690			
SUNC07	6/16/06 9:55				> 560	310	100	100			
SUNC07	6/23/06 10:00				2600	900	400	400			
SUNC07	6/29/06 9:44				> 5900	6400	290	290			
WFC	8/9/05 11:23	9	< 9	< 9	> 260	< 9	160	160	9	< 9	< 9
WFC	8/16/05 11:30	< 9	< 9	< 9	> 700	20	80	80	20	< 9	< 9
WFC	8/23/05 10:45	9	9	< 9	> 230	20	150	150	< 9	< 9	< 9
WFC	8/30/05 11:40	< 9	< 9	< 9	> 400	< 90	700	700	< 9	< 9	< 9
WFC	9/7/05 11:00	< 9	< 9	< 9	> 190	30	140	140	9	< 9	< 9
WFC	9/13/05 11:15	20	< 9	< 9	> 160	< 9	60	60	9	< 9	20
WFC	9/21/05 10:45	20	< 9	20	> 200	< 9	140	140	9	< 9	< 9
WFC	9/27/05 10:55	< 9	< 9	< 9	> 100	40	160	160	40	< 9	< 9
WFC	10/5/05 9:45	< 9	< 9	< 9	> 100	40	70	70	< 9	< 9	< 9
WFC	10/13/05 11:44	< 9	< 9	< 9	> 30	9	99	99	< 9	< 9	< 9
WFC	10/19/05 11:39	30	< 9	< 9	> 1700	140	380	380	20	< 9	< 9
WFC	10/24/05 9:50	20	< 9	< 9	> 1100	9	140	140	< 9	< 9	< 9
WFC	11/1/05 12:30	9	9	< 9	3000	290	40	40	< 9	< 9	< 9
WFC	11/9/05 10:48	30	< 9	< 9	> 260	30	40	40	9	< 9	< 9
WFC	11/15/05 10:55	< 9	<9	< 9	> 160	20	< 9	9	9	<9	<9
WFC	11/21/05 9:20	20	< 9	9	> 250	<9	30	30	< 9	<9	< 9
WFC	11/30/05 10:35	30	< 9	< 9	> 200	30	140	140	20	9	< 9
WFC	12/8/05 10:20	9	< 9	< 9	110	9	60	60	< 9	< 9	9
WFC	12/13/05 9:45	9	< 9	< 9	370	40	9	9	< 9	< 9	< 9
WFC	12/19/05 10:25	9	40	9	> 220	40	30	30	40	20	< 9
WFC	12/29/05 10:00	9	9	9	> 250	< 9	40	40	30	< 9	< 9
WFC	1/3/06 10:00	230	9	9	> 6100	510	1230	1230	380	20	40
WFC	1/11/06 9:20	20	< 9	< 9	40	< 9	60	60			
WFC	1/19/06 8:50	9	< 9	9	160	< 9	40	40	20	< 9	< 9
WFC	1/23/06 10:05	30	50	< 9	170	20	150	150	70	60	< 9
WFC	2/1/06 11:15	9	< 9	< 9	> 150	9	40	40	< 9	< 9	< 9

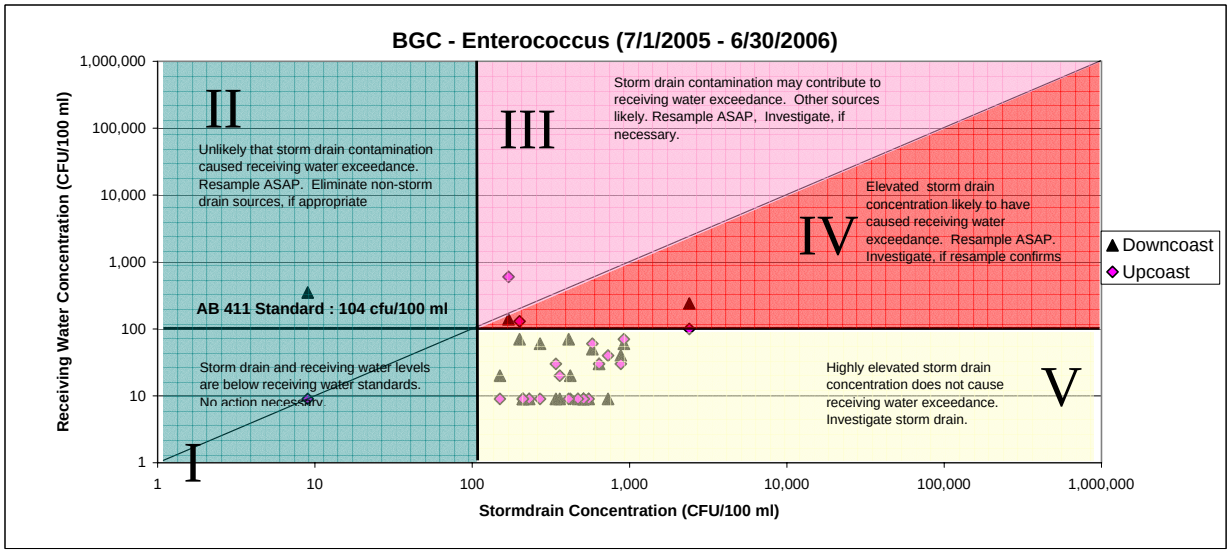
Bold entries in surfzone exceed AB-411 single sample standard for ocean water sports contact

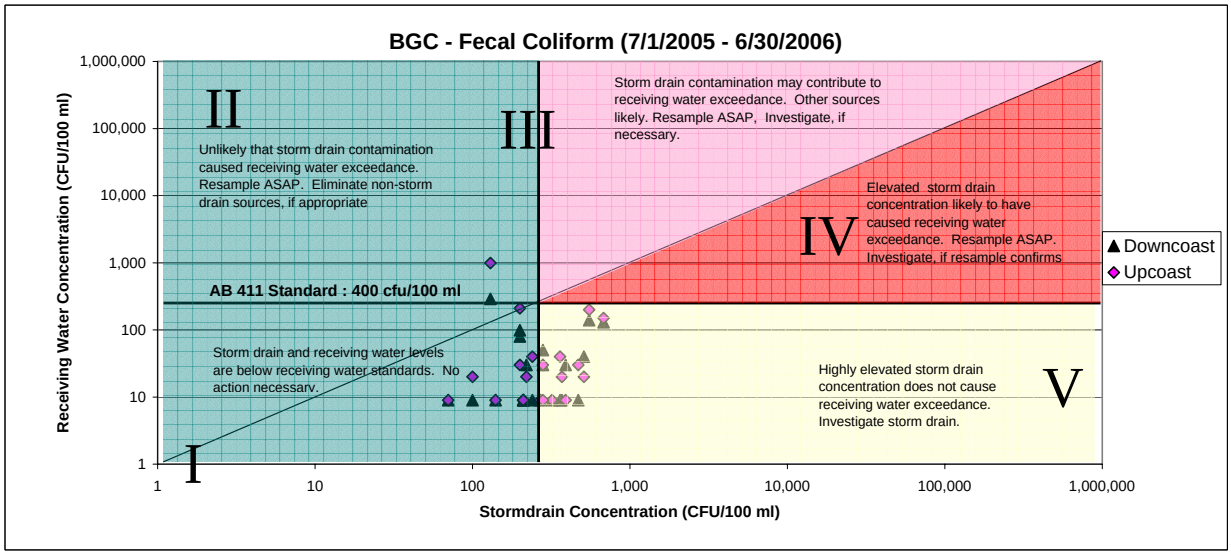
Attachment C-11-V
Pathogen Indicator Monitoring in the Santa Ana Region

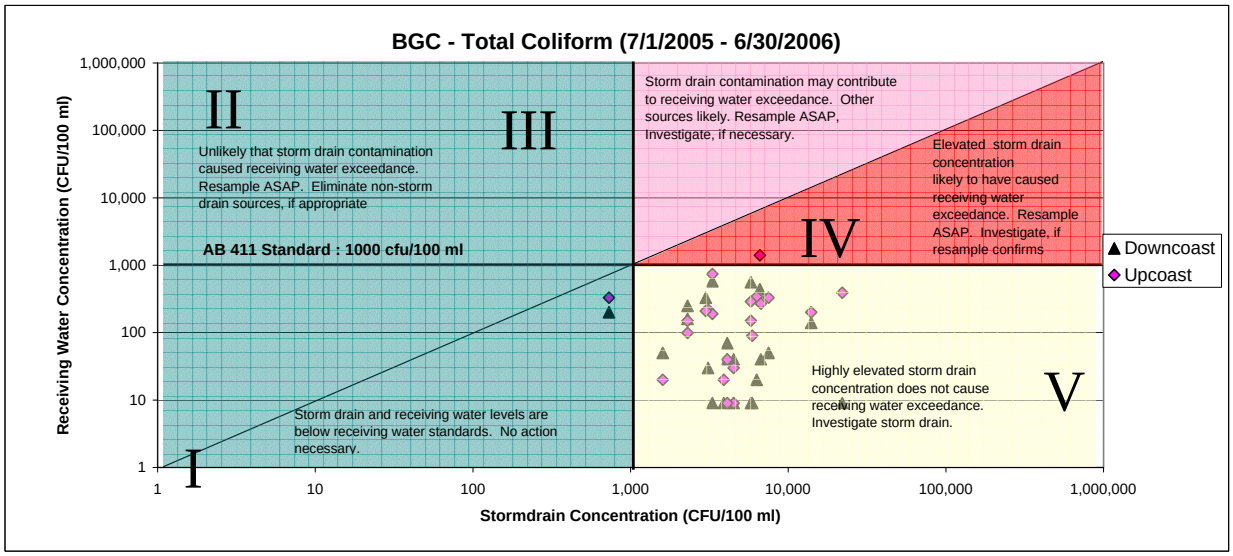
		Upcoast			Stormdrain				Downcoast		
		TC	FC	ENT	TC	FC	ENT		TC	FC	ENT
Site	Date	CFU/100 ml)									
WFC	2/7/06 11:30	20	< 9	9	> 230	< 9	100	100	< 9	9	< 9
WFC	2/15/06 10:20	120	80	< 9	> 50	9	60	60	1360	**1000**	< 9
WFC	2/23/06 9:00	20	< 9	< 9	> 9	< 9	< 9	9	9	< 9	< 9
WFC	2/27/06 9:35	9	< 9	< 9	> 130	< 9	70	70	< 9	< 9	< 9
WFC	3/6/06 9:10	20	9	9	2200	40	240	240	20	< 9	< 9
WFC	3/13/06 10:25	< 9	< 9	9	> 290	40	140	140	< 9	9	9
WFC	3/21/06 10:10	20	< 9	< 9	1700	400	760	760	< 9	< 9	30
WFC	3/31/06 10:15	20	< 9	< 9	2600	140	130	130	20	< 9	< 9
WFC	4/6/06 11:00	340	30	< 9	> 1200	340	290	290	360	30	9
WFC	4/12/06 9:55	< 9	< 9	< 9	> 1200	30	90	90	20	< 9	< 9
WFC	4/17/06 10:25	9	< 9	< 9	> 300	40	50	50	< 9	< 9	< 9
WFC	4/26/06 10:45	70	< 9	9	2200	290	140	140	30	< 9	< 9
WFC	5/2/06 0:00	20	< 9	< 9	> 400	< 9	160	160	9	< 9	< 9
WFC	5/8/06 10:50	9	< 9	< 9	> 410	260	70	70	460	9	40
WFC	5/25/06 8:21	9	9	< 9	> 710	50	380	380	20	< 9	< 9
WFC	5/30/06 10:55	< 9	< 9	< 9	> 470	20	320	320	9	< 9	< 9
WFC	6/5/06 10:40	20	9	9	> 580	190	350	350	20	20	< 9
WFC	6/19/06 10:10	9	< 9	< 9	> 380	220	480	480	9	< 9	< 9
WFC	6/27/06 9:40	9	20	20	> 170	50	120	120	< 9	< 9	< 9

Bold entries in surfzone exceed AB-411 single sample standard for ocean water sports contact

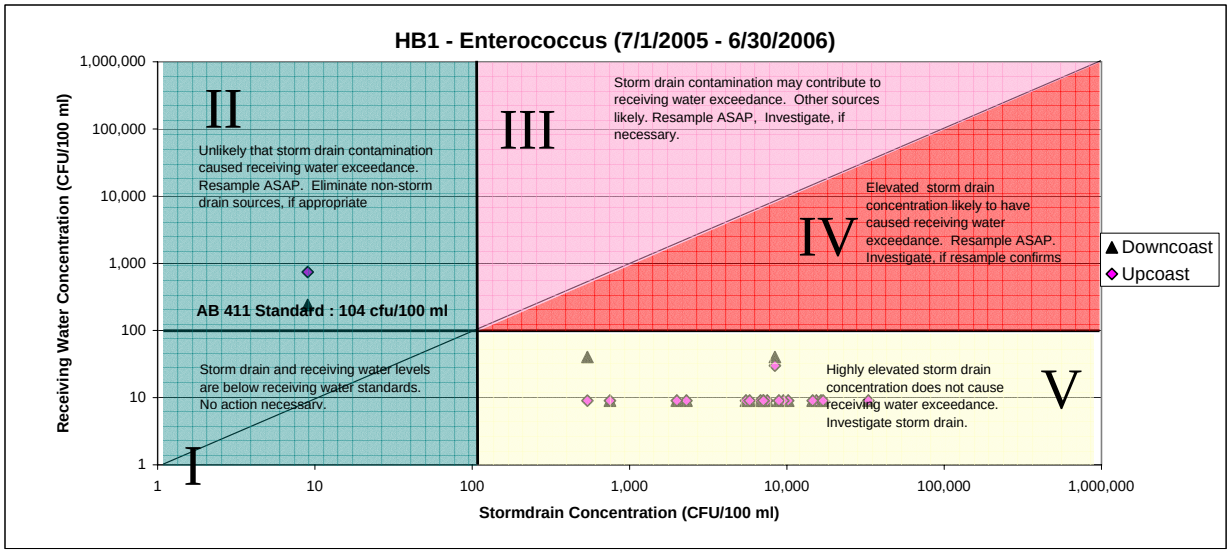
Relationship between Bacterial Concentrations in the Stormdrain and Receiving Waters

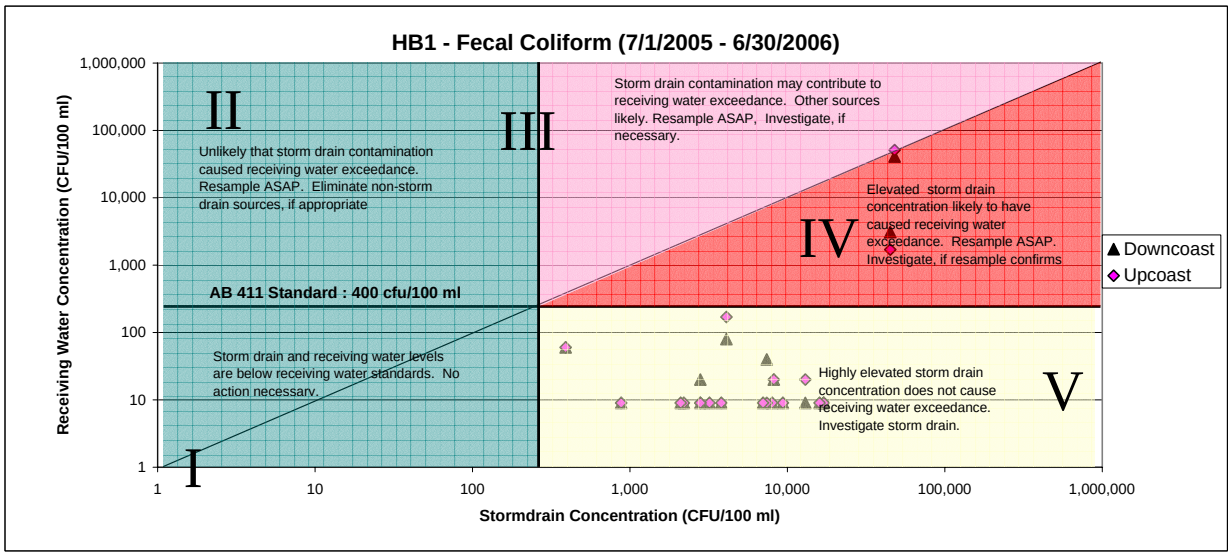


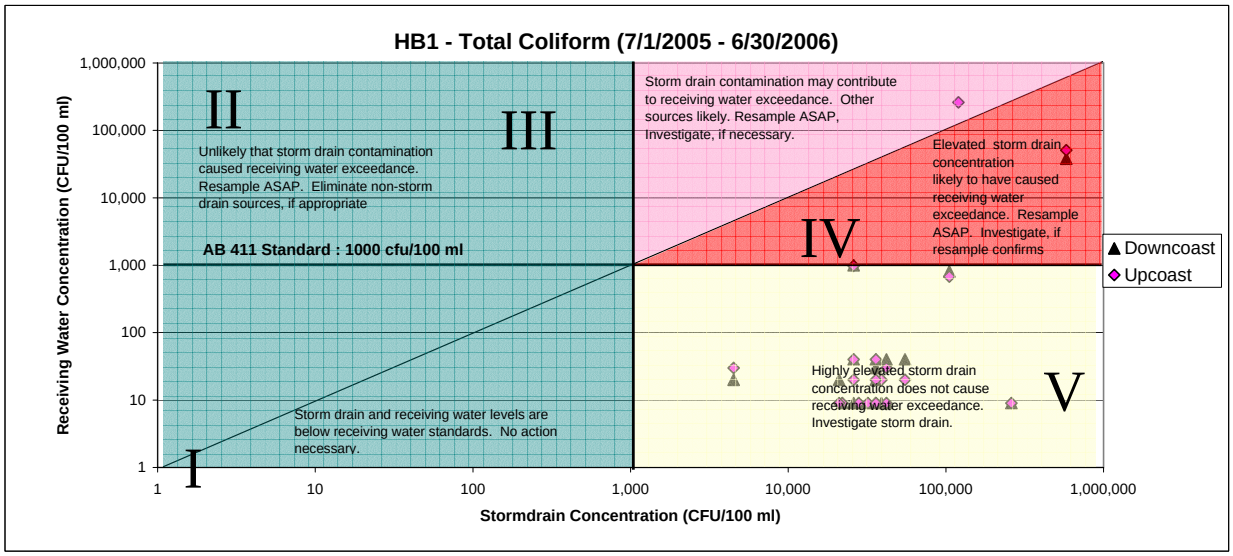




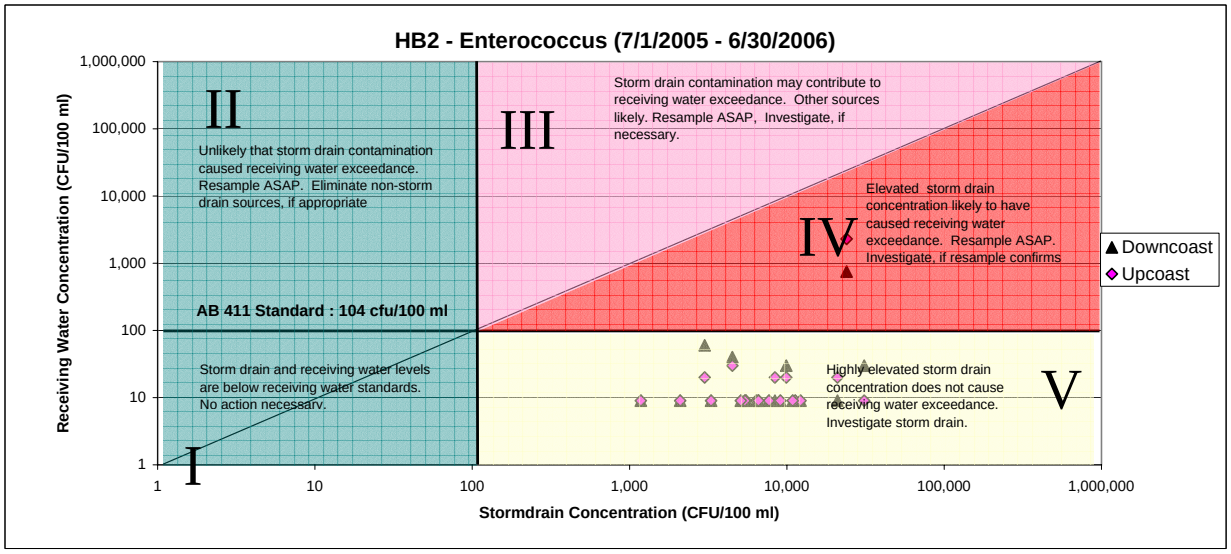
Relationship between Bacterial Concentrations in the Stormdrain and Receiving Waters

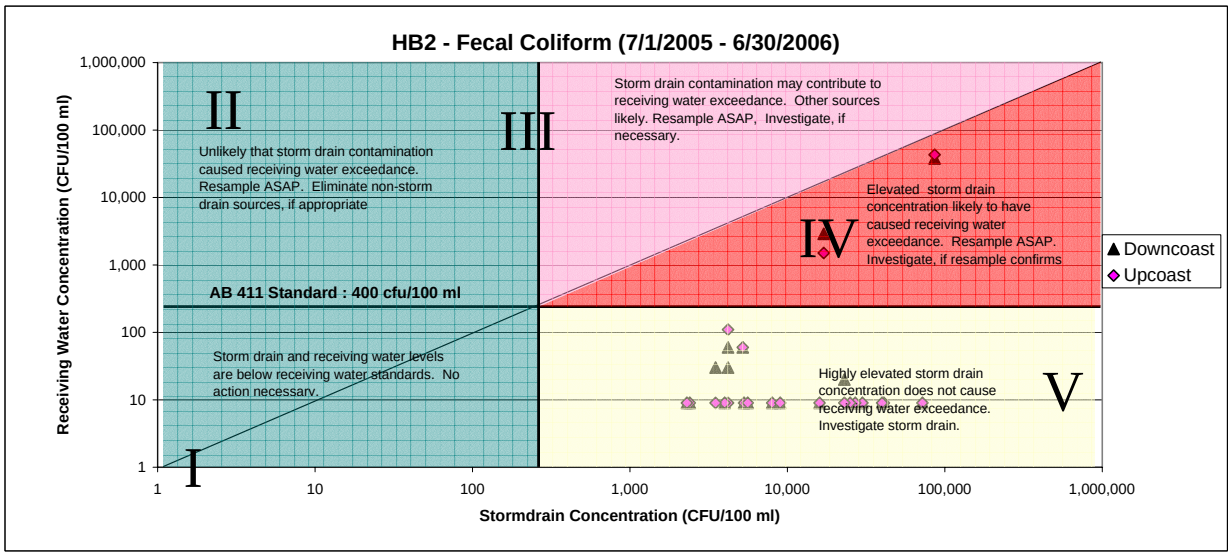


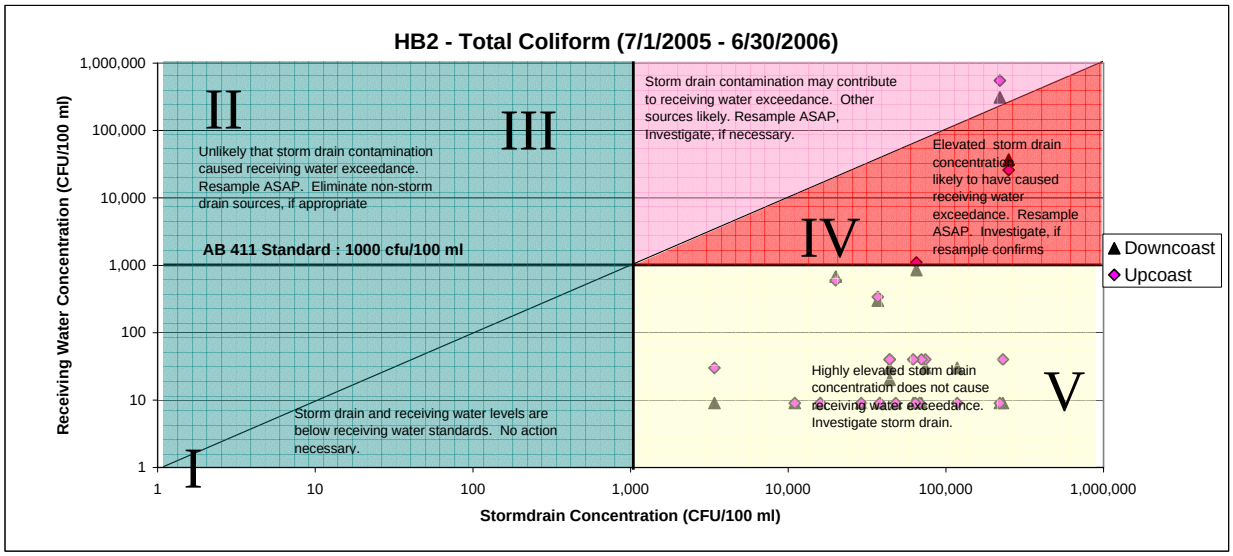




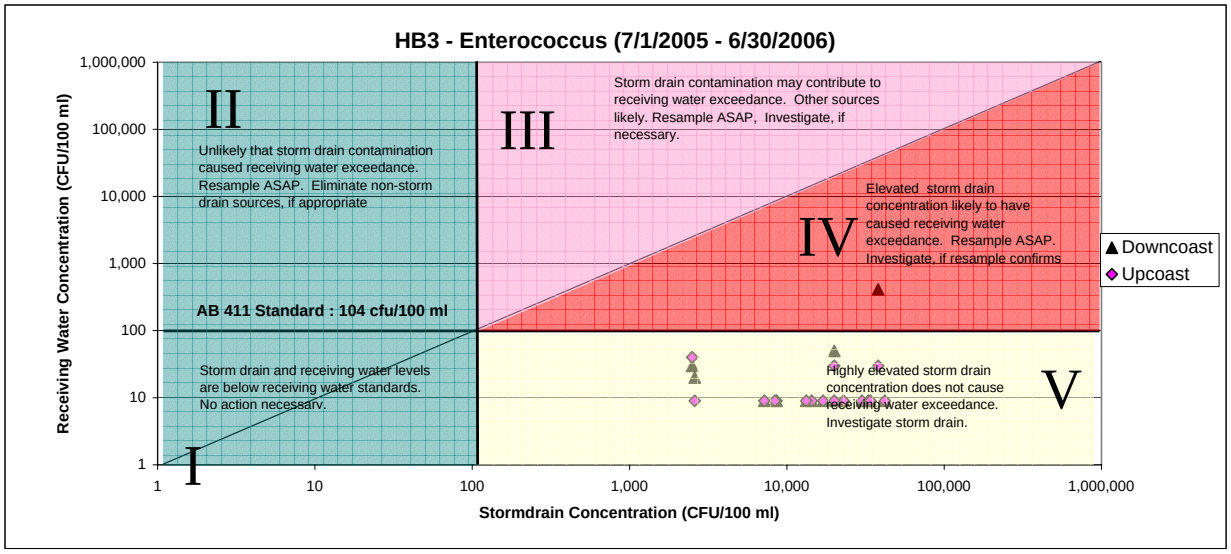
Relationship between Bacterial Concentrations in the Stormdrain and Receiving Waters

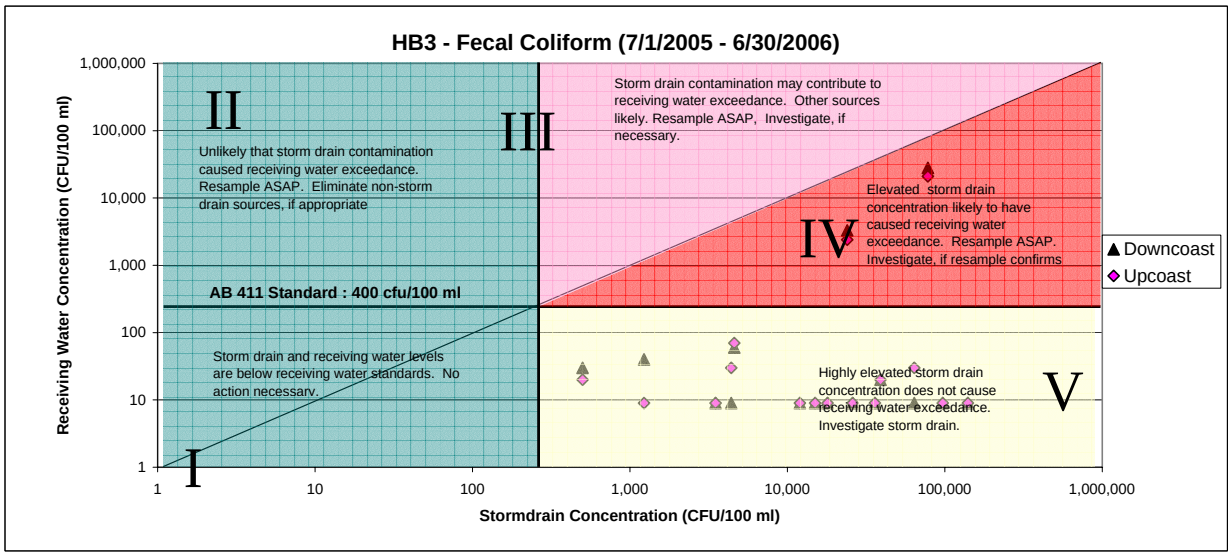


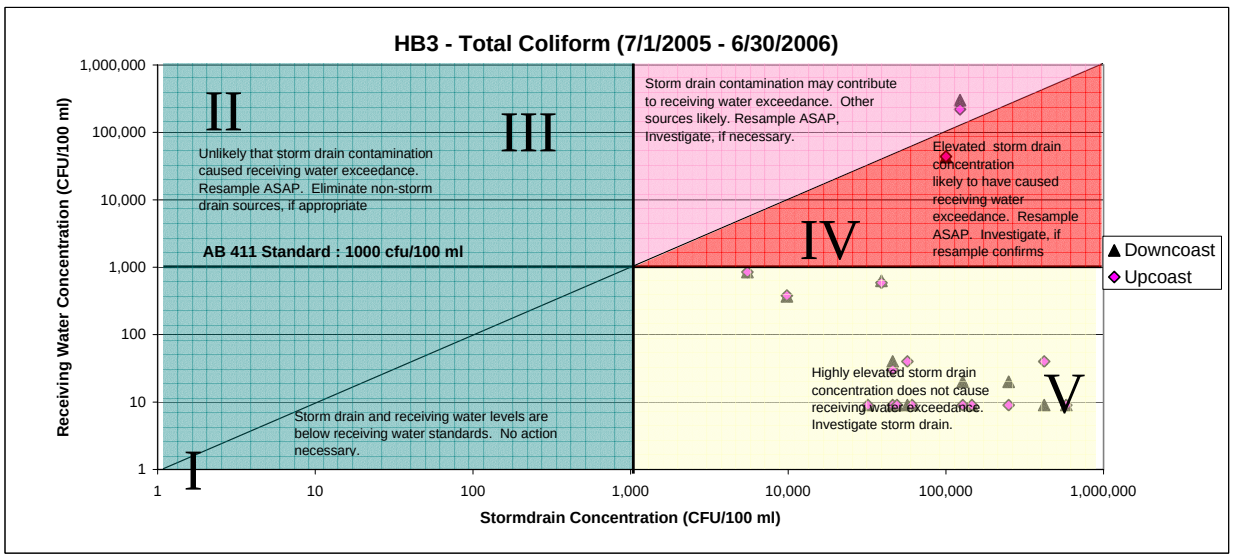




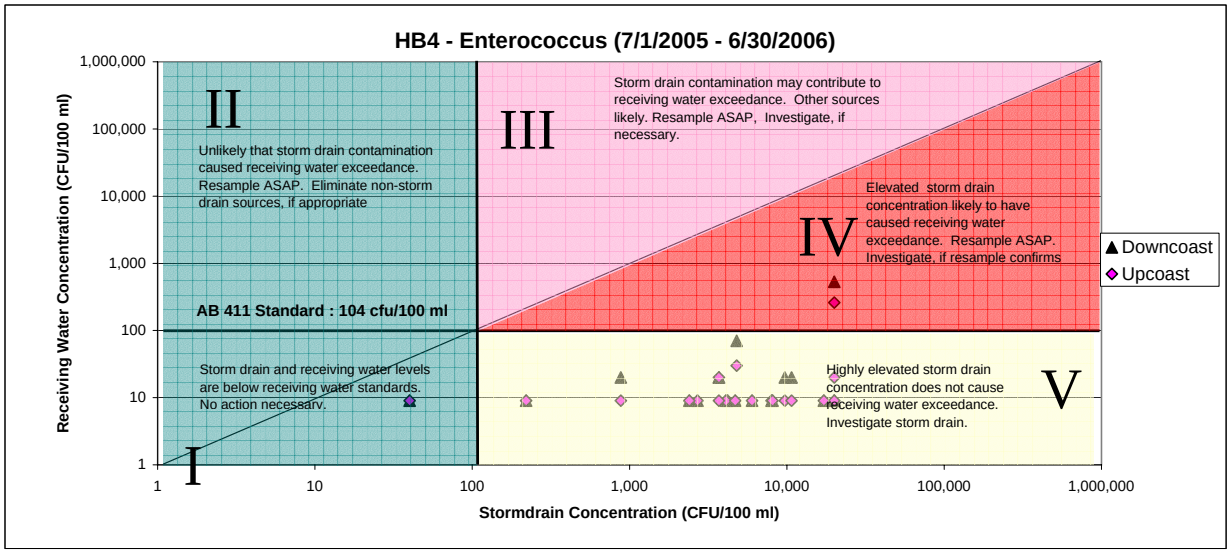
Relationship between Bacterial Concentrations in the Stormdrain and Receiving Waters

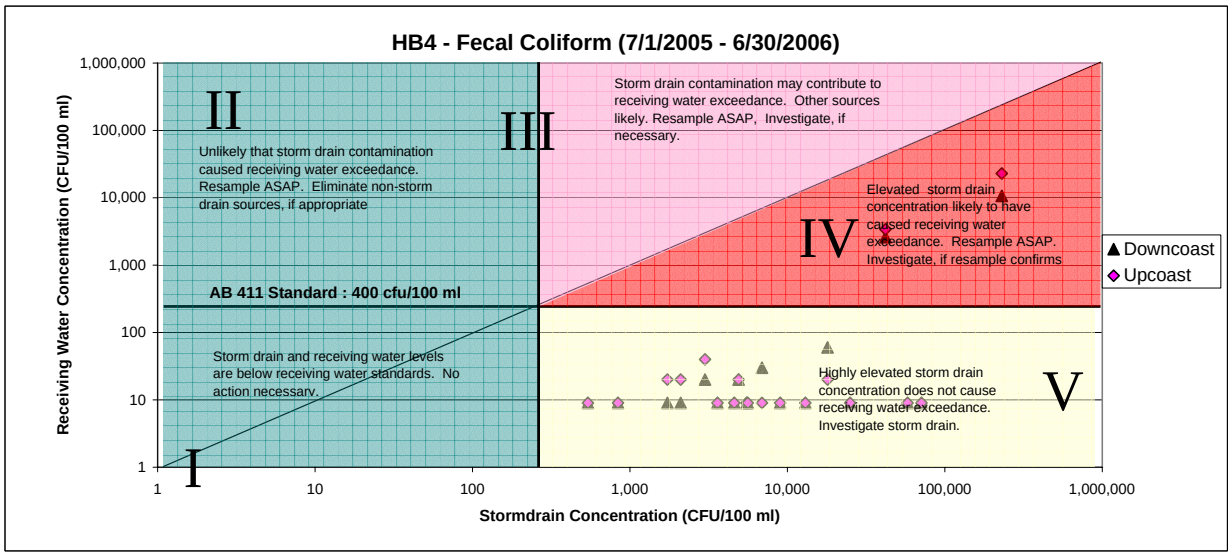


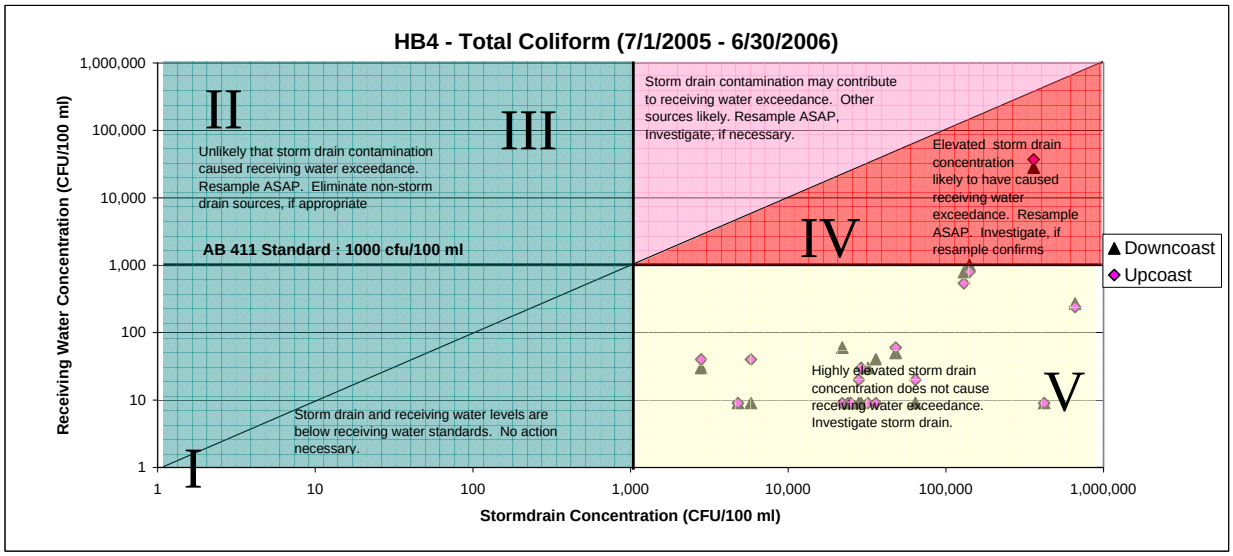




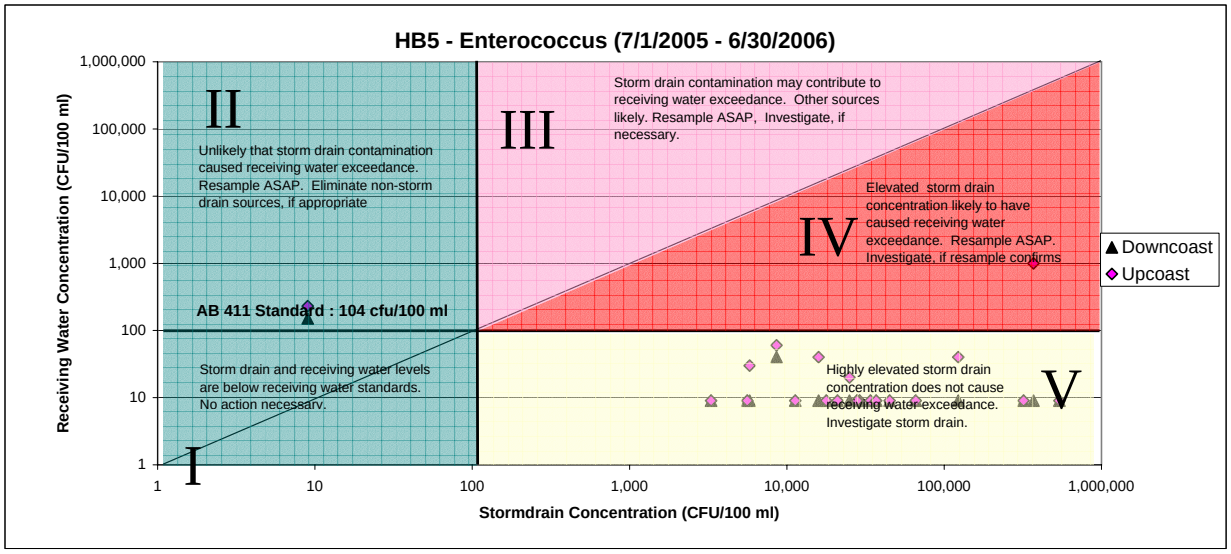
Relationship between Bacterial Concentrations in the Stormdrain and Receiving Waters

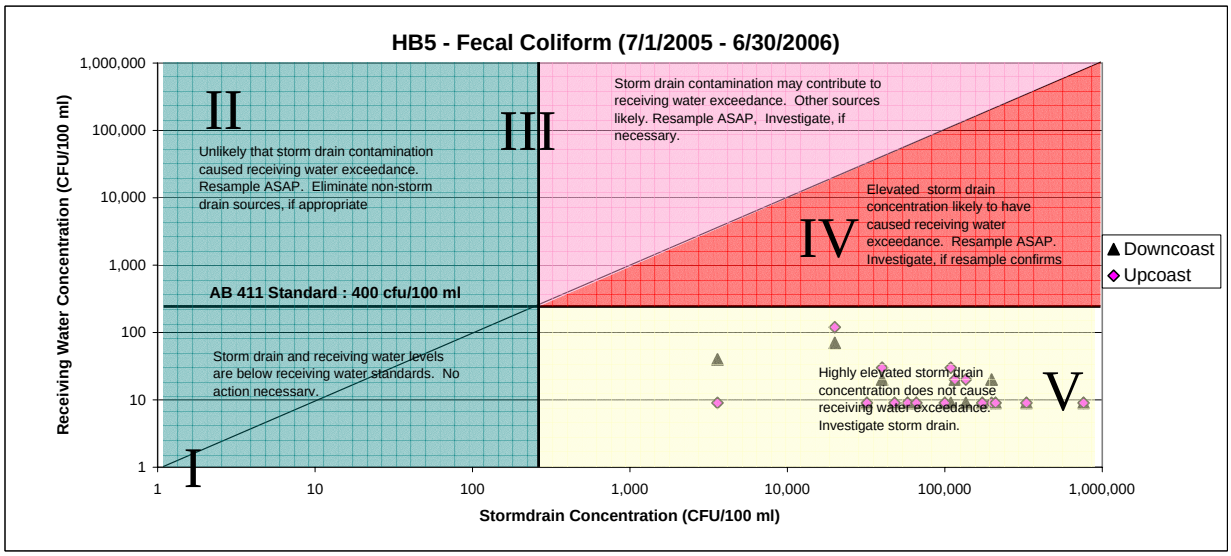


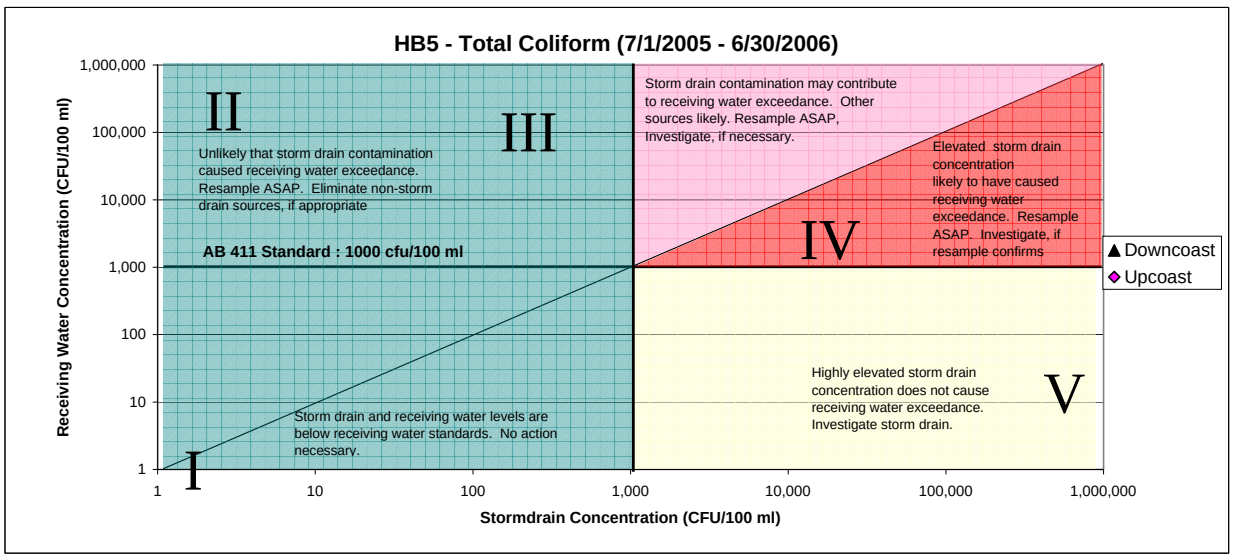




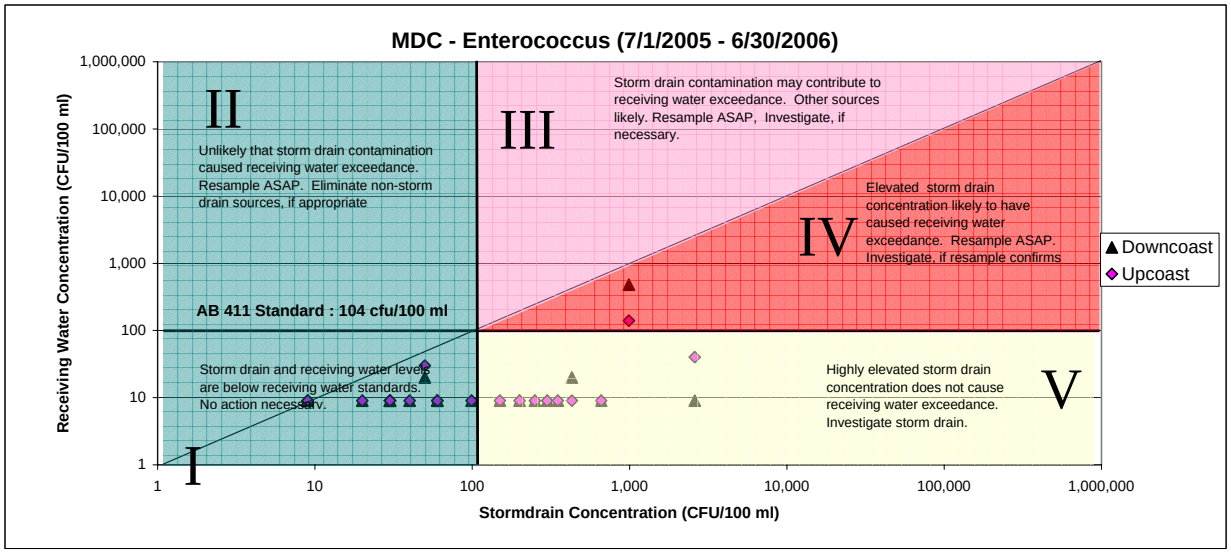
Relationship between Bacterial Concentrations in the Stormdrain and Receiving Waters

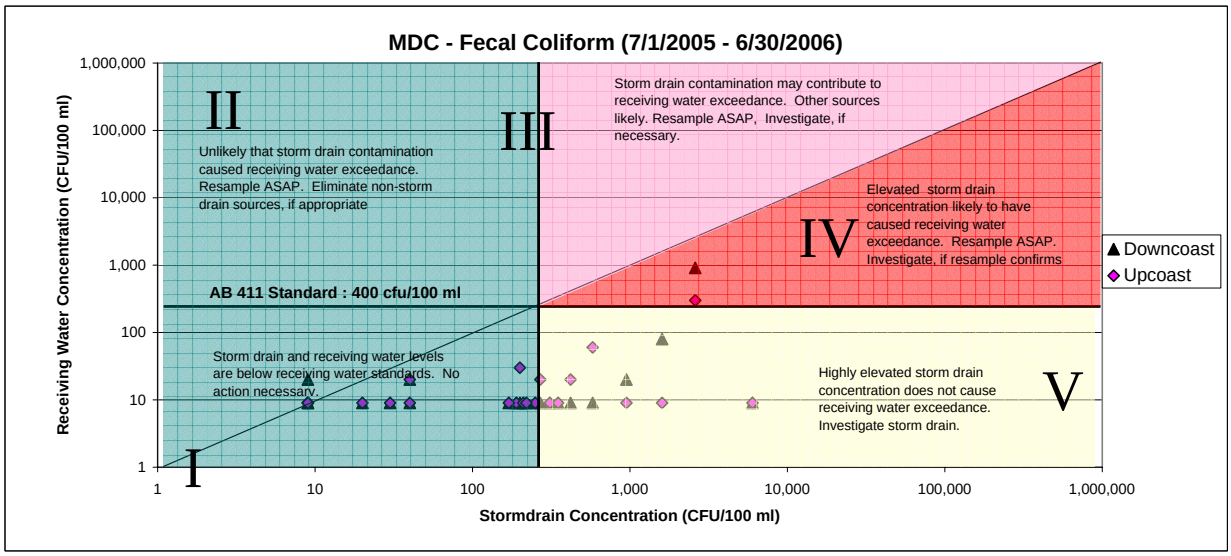


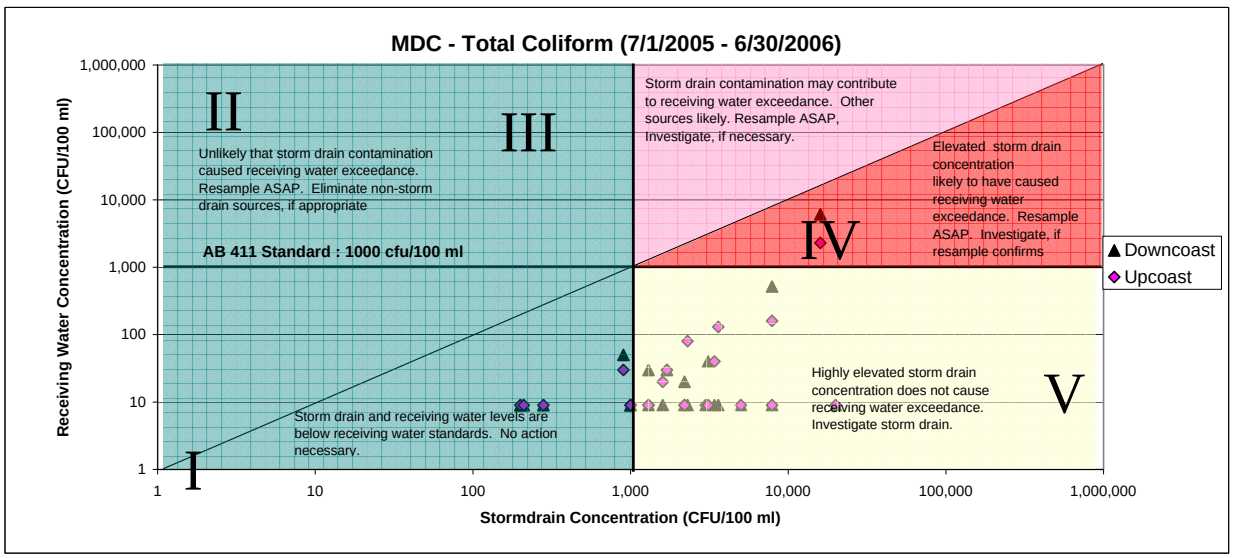




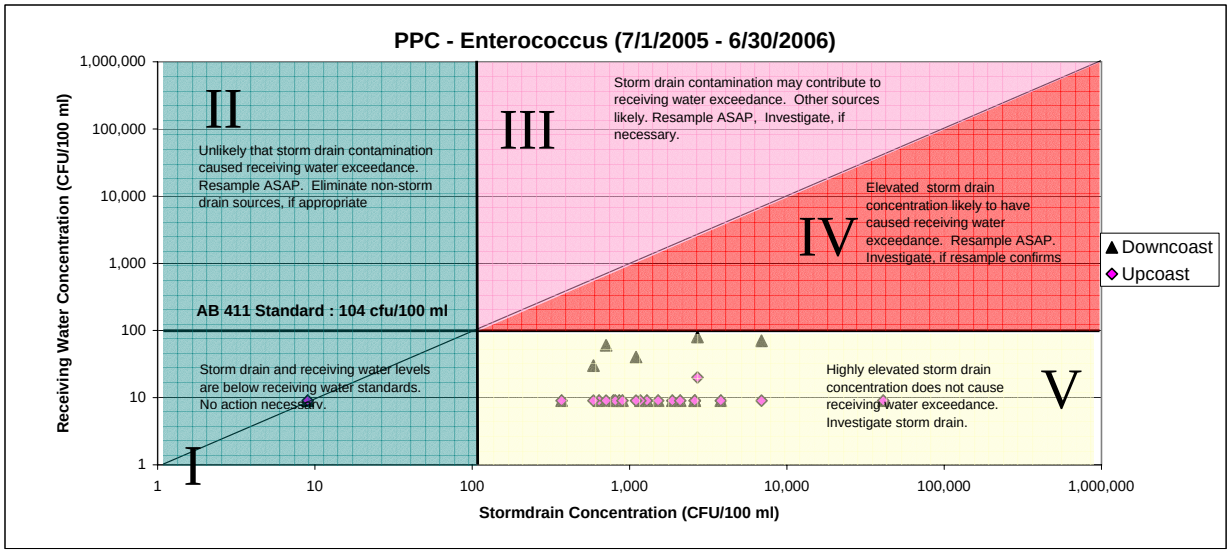
Relationship between Bacterial Concentrations in the Stormdrain and Receiving Waters

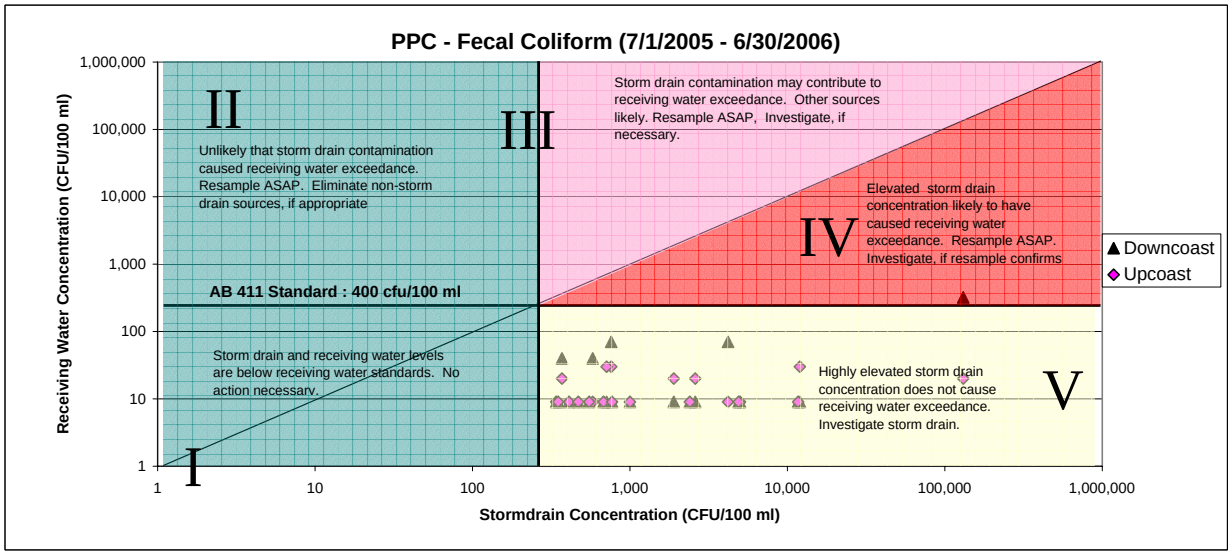


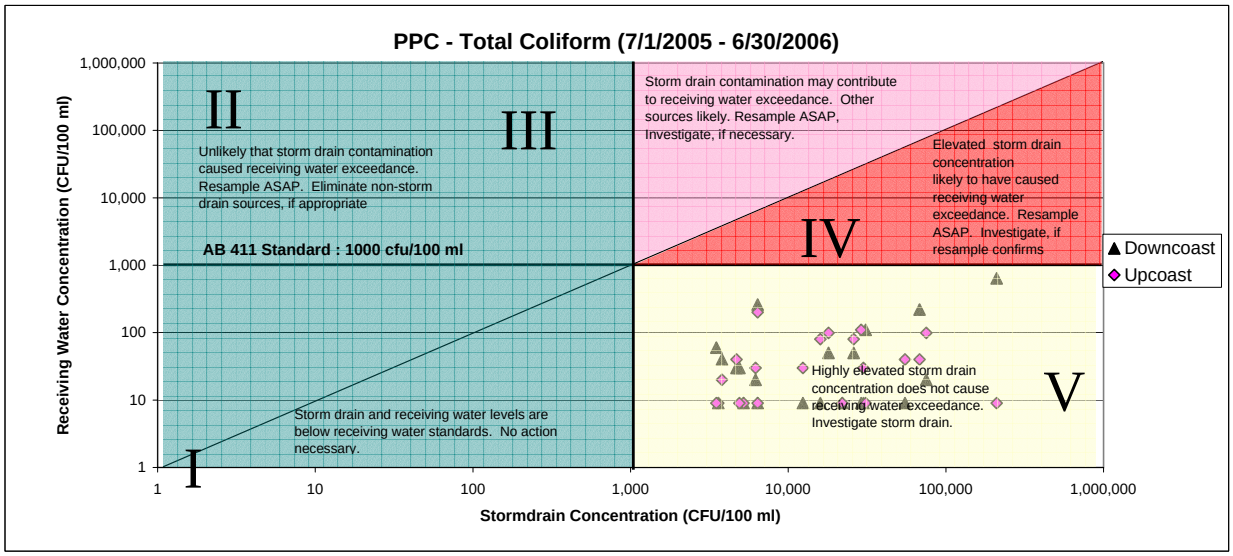




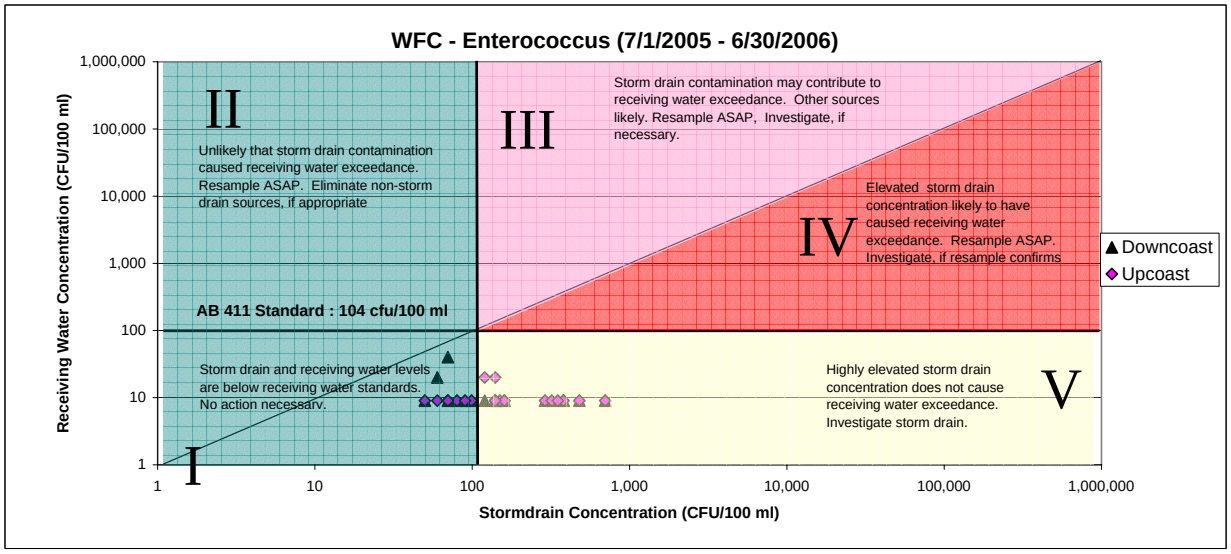
Relationship between Bacterial Concentrations in the Stormdrain and Receiving Waters

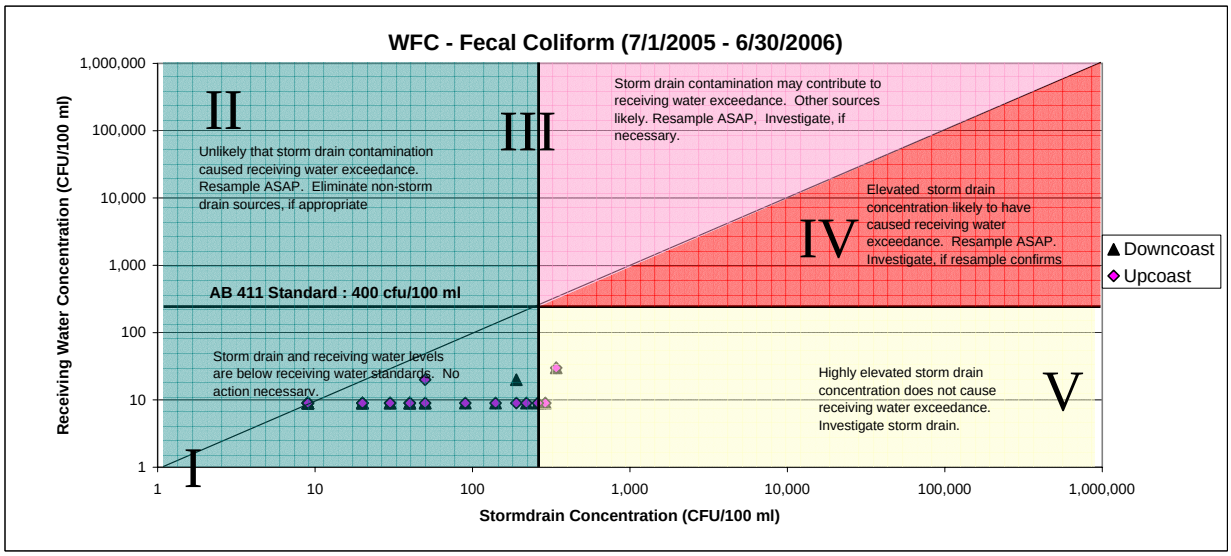


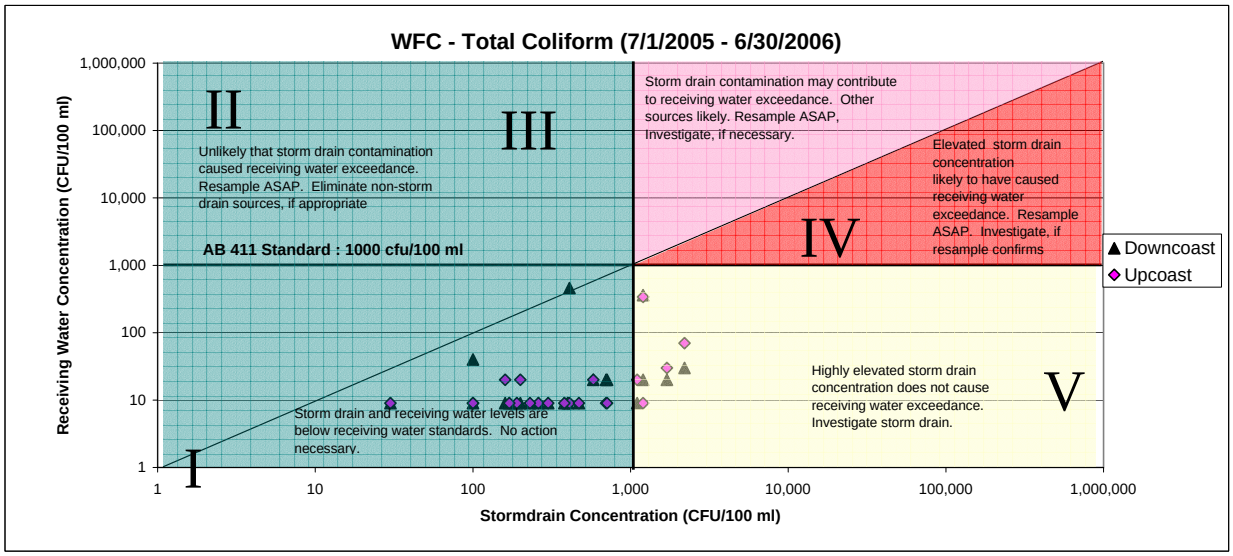




Relationship between Bacterial Concentrations in the Stormdrain and Receiving Waters

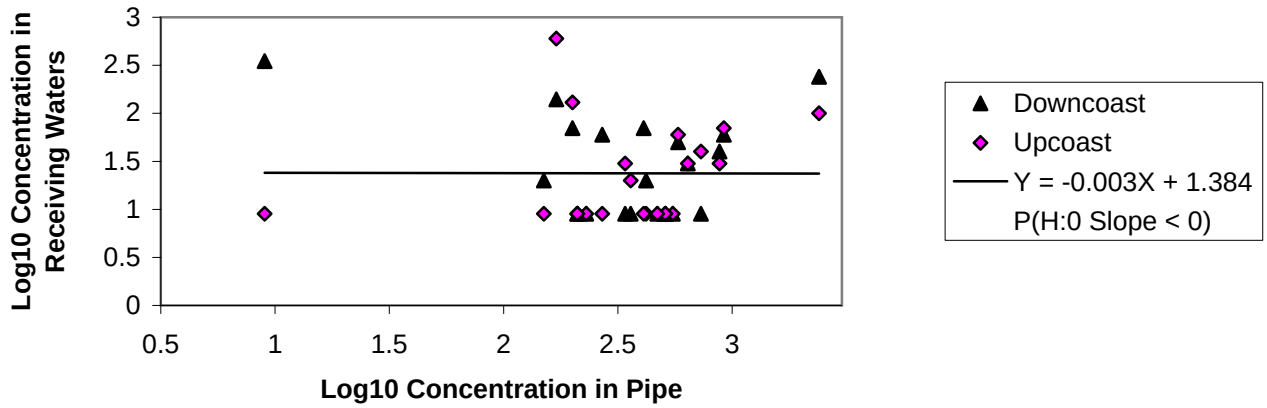




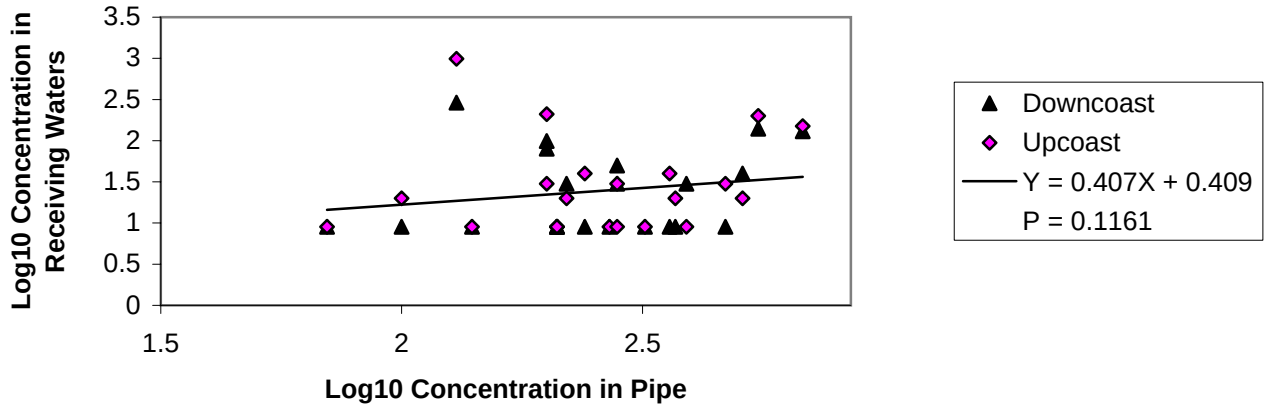


Regression Analysis for Relationship between Receiving Waters and Stormdrain Discharge - AB411 Months Only

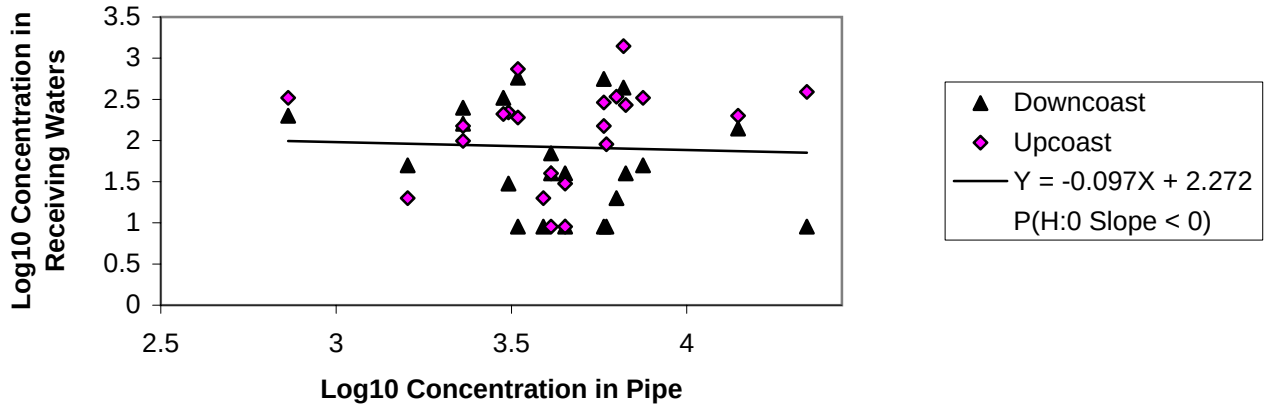
BGC - Enterococcus (7/1/2005 - 6/30/2006)



BGC - Fecal Coliform (7/1/2005 - 6/30/2006)



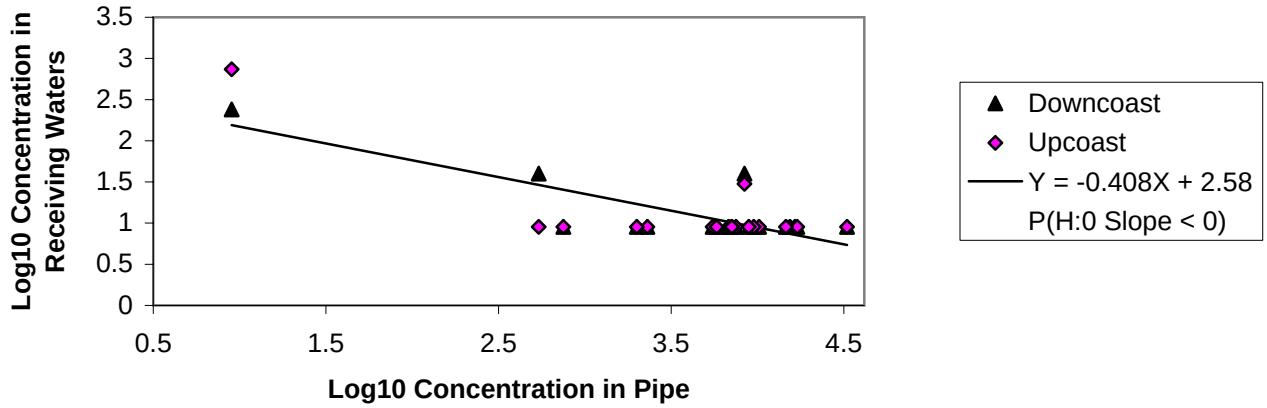
BGC - Total Coliform (7/1/2005 - 6/30/2006)



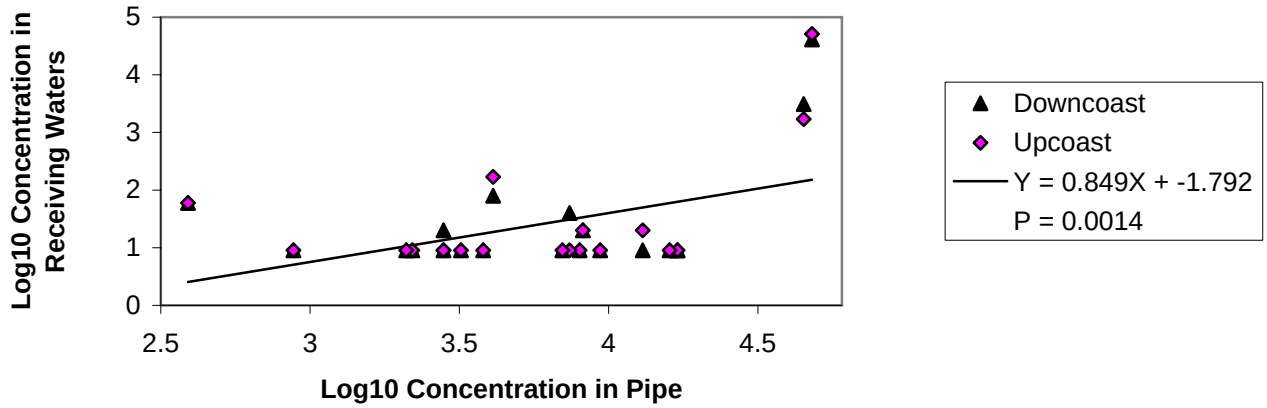
Null Hypothesis: slope<or=0 (i.e. no relationship)
P values: Probability that null hypothesis is true given the data

Regression Analysis for Relationship between Receiving Waters and Stormdrain Discharge - AB411 Months Only

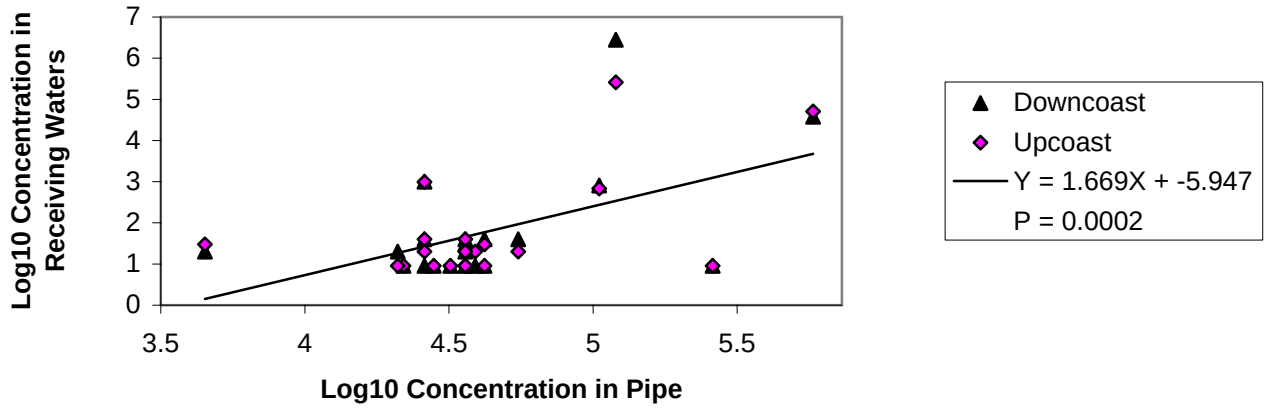
HB1 - Enterococcus (7/1/2005 - 6/30/2006)



HB1 - Fecal Coliform (7/1/2005 - 6/30/2006)



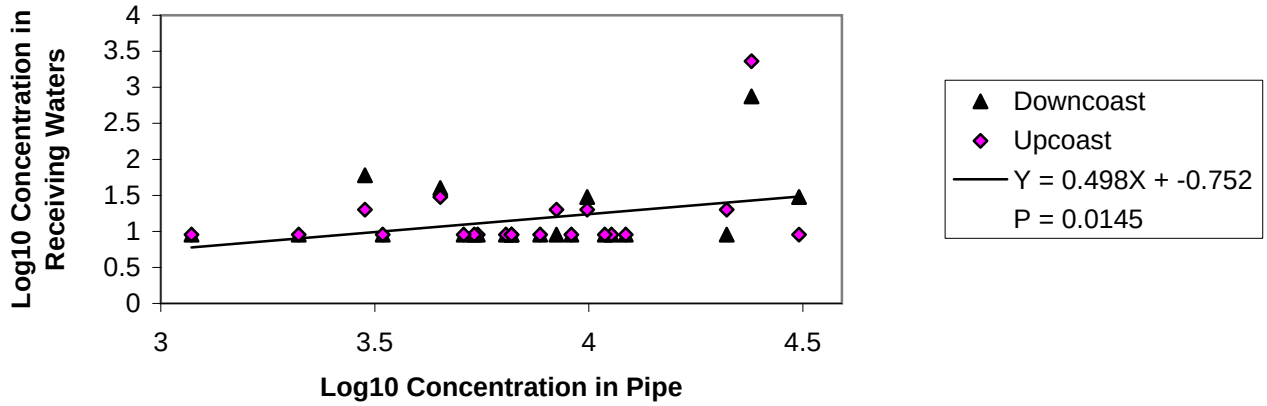
HB1 - Total Coliform (7/1/2005 - 6/30/2006)



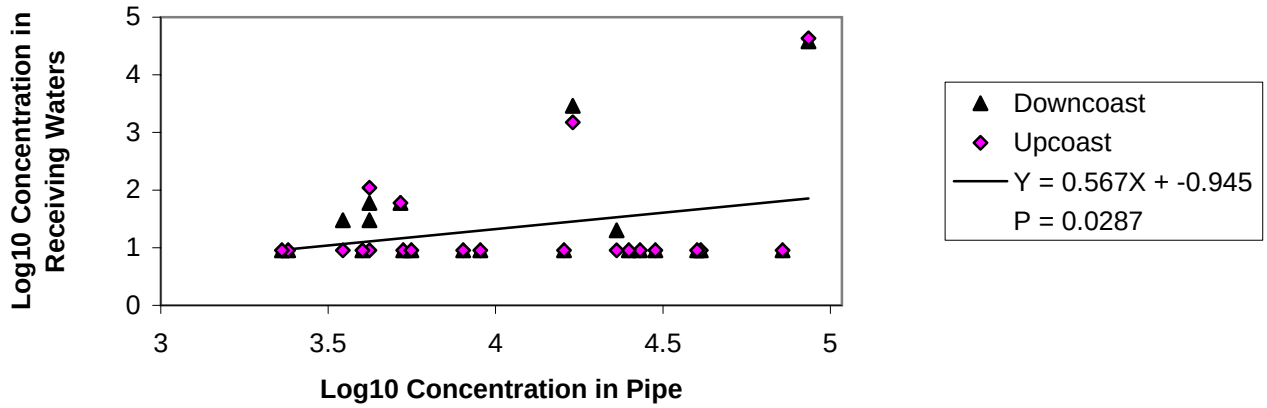
Null Hypothesis: slope<or=0 (i.e. no relationship)
P values: Probability that null hypothesis is true given the data

Regression Analysis for Relationship between Receiving Waters and Stormdrain Discharge - AB411 Months Only

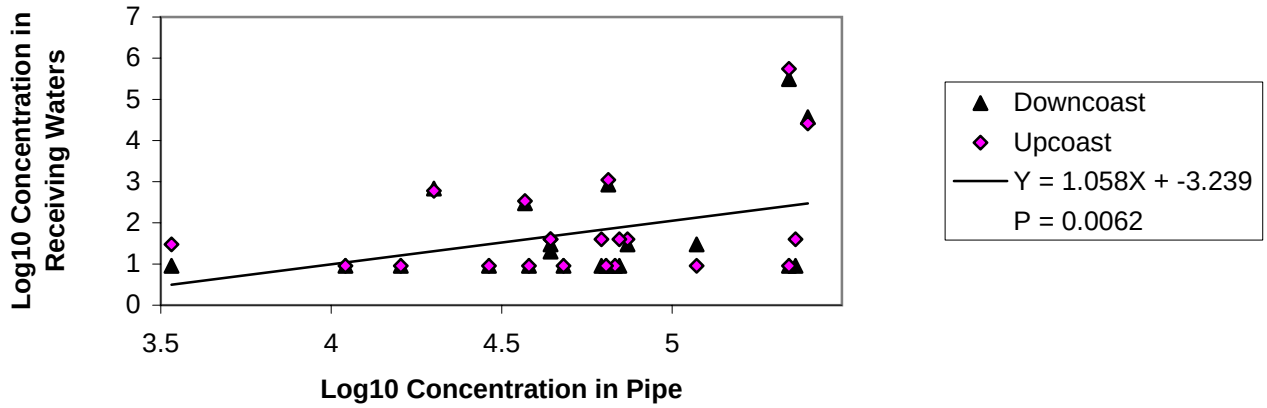
HB2 - Enterococcus (7/1/2005 - 6/30/2006)



HB2 - Fecal Coliform (7/1/2005 - 6/30/2006)



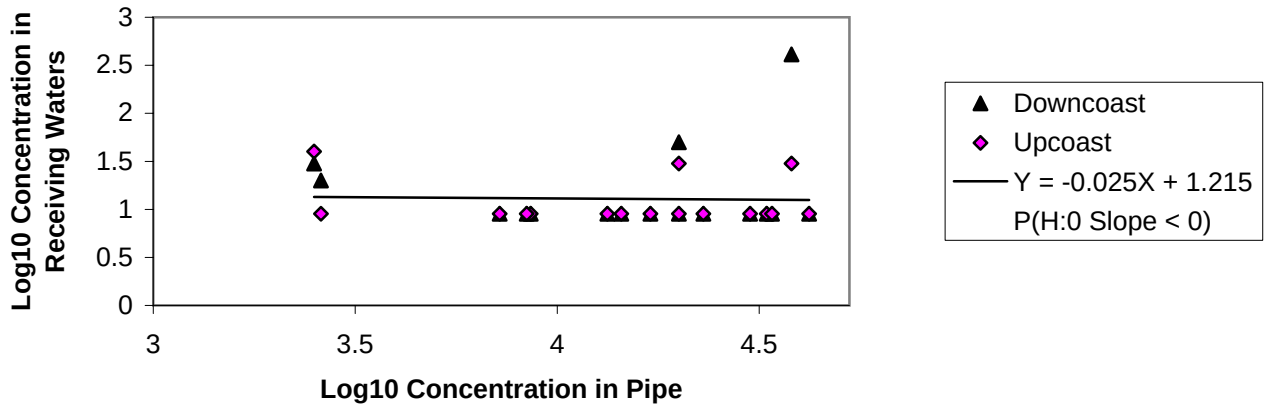
HB2 - Total Coliform (7/1/2005 - 6/30/2006)



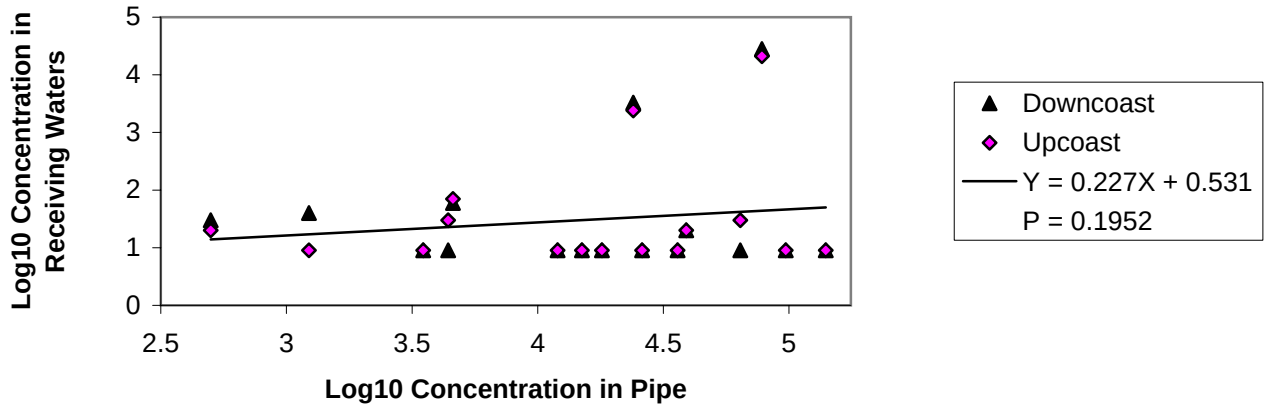
Null Hypothesis: slope<or=0 (i.e. no relationship)
P values: Probability that null hypothesis is true given the data

Regression Analysis for Relationship between Receiving Waters and Stormdrain Discharge - AB411 Months Only

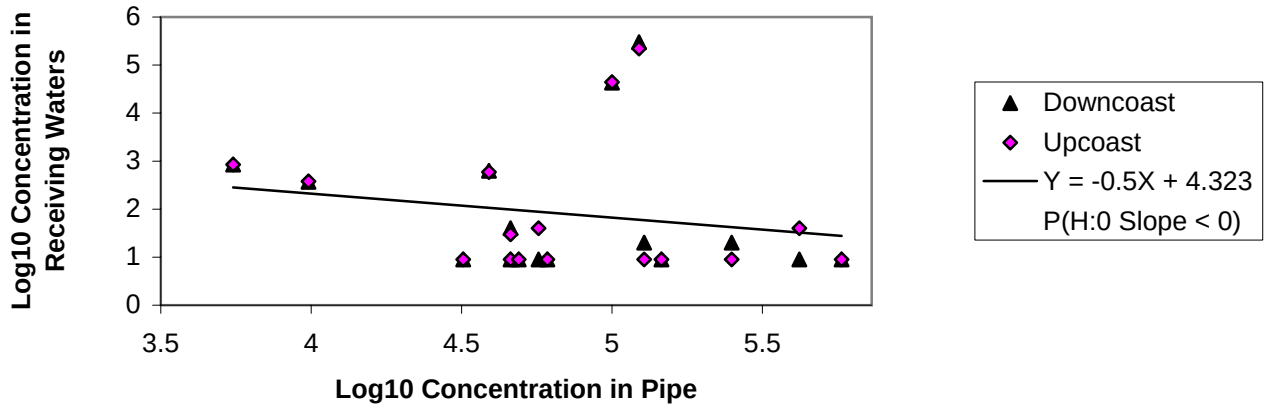
HB3 - Enterococcus (7/1/2005 - 6/30/2006)



HB3 - Fecal Coliform (7/1/2005 - 6/30/2006)



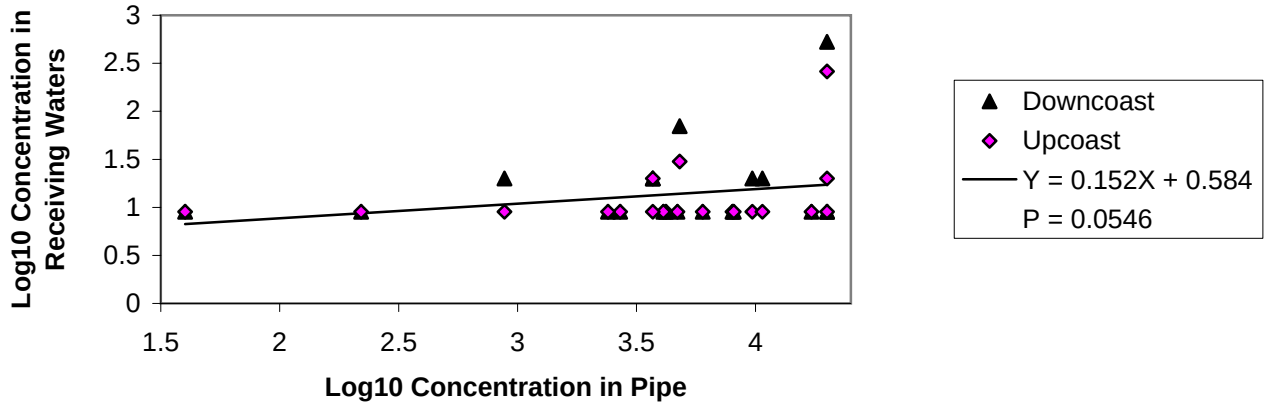
HB3 - Total Coliform (7/1/2005 - 6/30/2006)



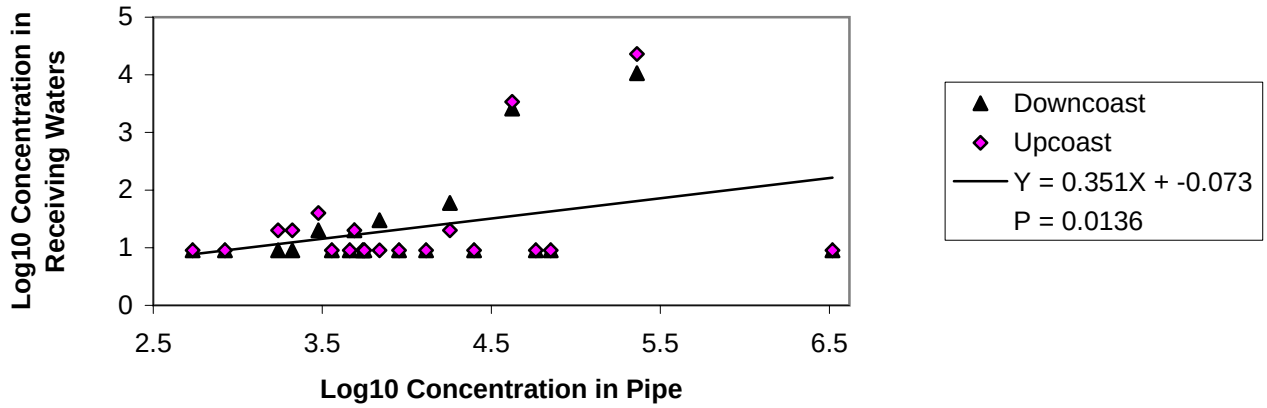
Null Hypothesis: slope<or=0 (i.e. no relationship)
P values: Probability that null hypothesis is true given the data

Regression Analysis for Relationship between Receiving Waters and Stormdrain Discharge - AB411 Months Only

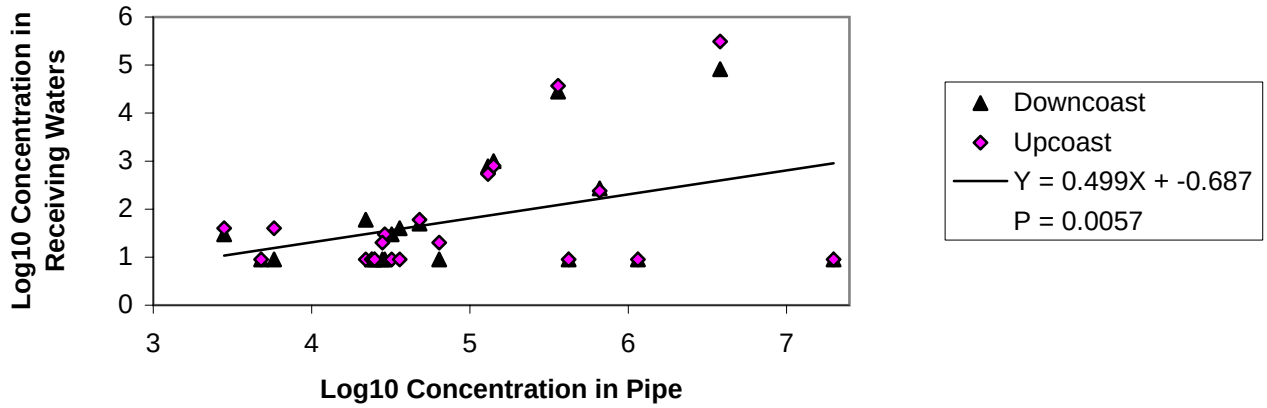
HB4 - Enterococcus (7/1/2005 - 6/30/2006)



HB4 - Fecal Coliform (7/1/2005 - 6/30/2006)



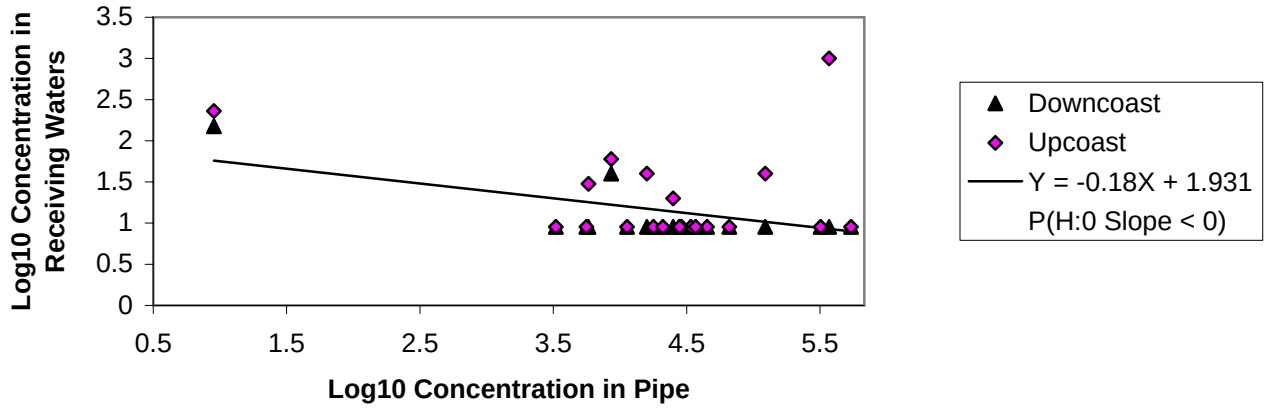
HB4 - Total Coliform (7/1/2005 - 6/30/2006)



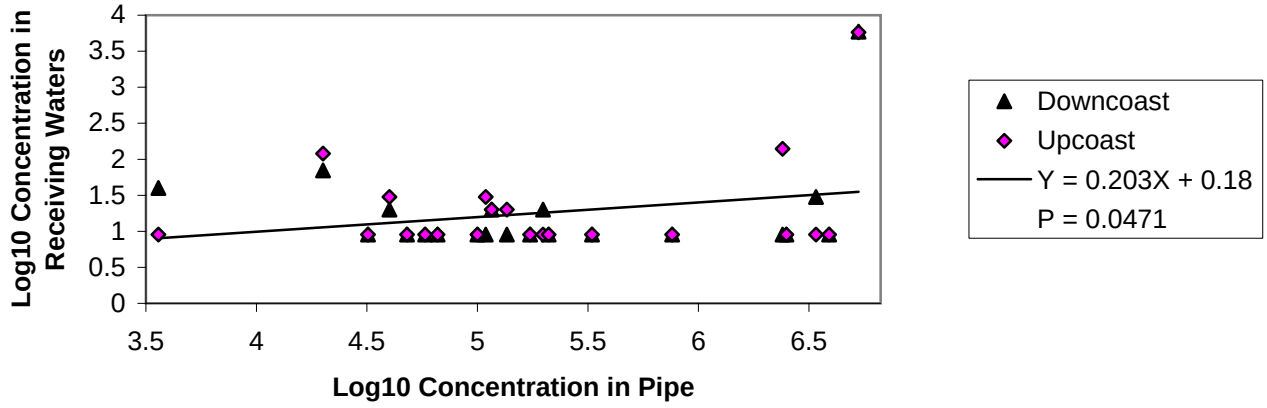
Null Hypothesis: slope<or=0 (i.e. no relationship)
P values: Probability that null hypothesis is true given the data

Regression Analysis for Relationship between Receiving Waters and Stormdrain Discharge - AB411 Months Only

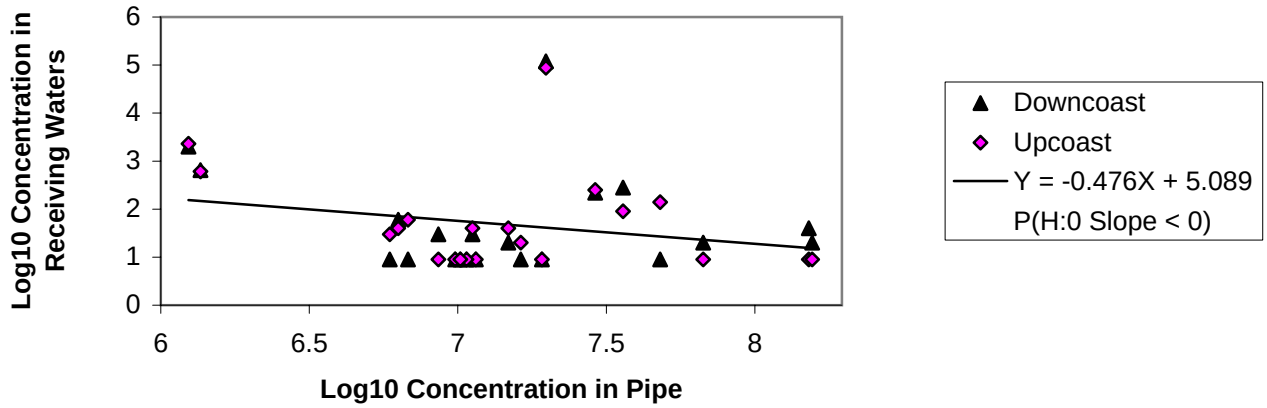
HB5 - Enterococcus (7/1/2005 - 6/30/2006)



HB5 - Fecal Coliform (7/1/2005 - 6/30/2006)



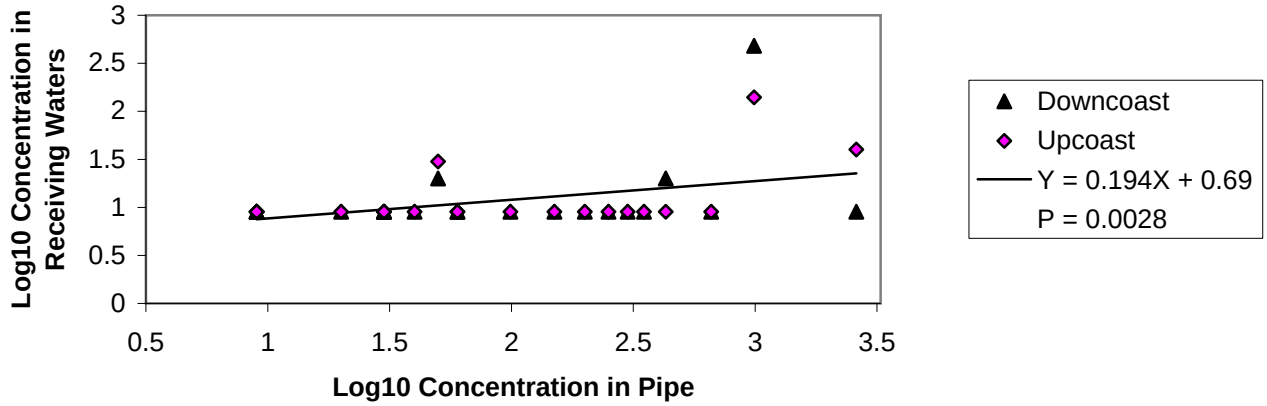
HB5 - Total Coliform (7/1/2005 - 6/30/2006)



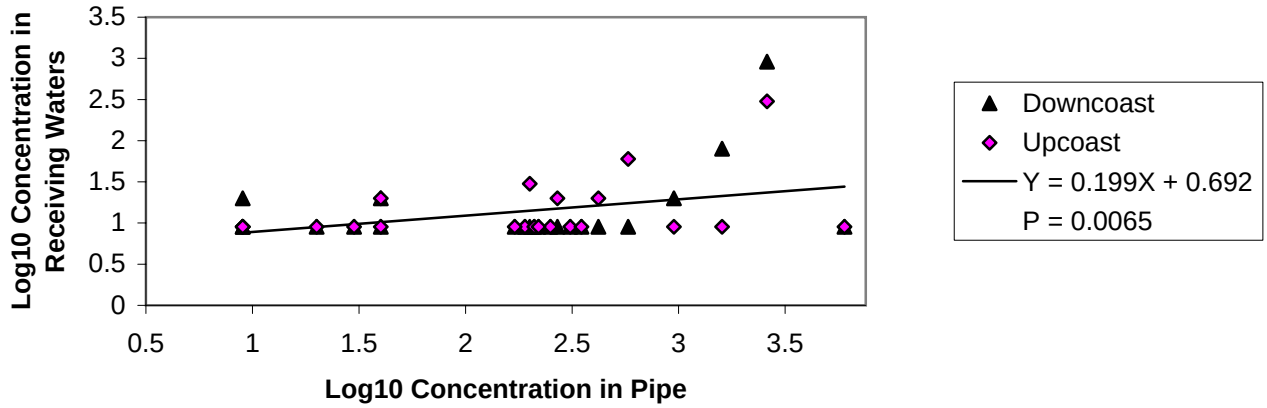
Null Hypothesis: slope<or=0 (i.e. no relationship)
P values: Probability that null hypothesis is true given the data

Regression Analysis for Relationship between Receiving Waters and Stormdrain Discharge - AB411 Months Only

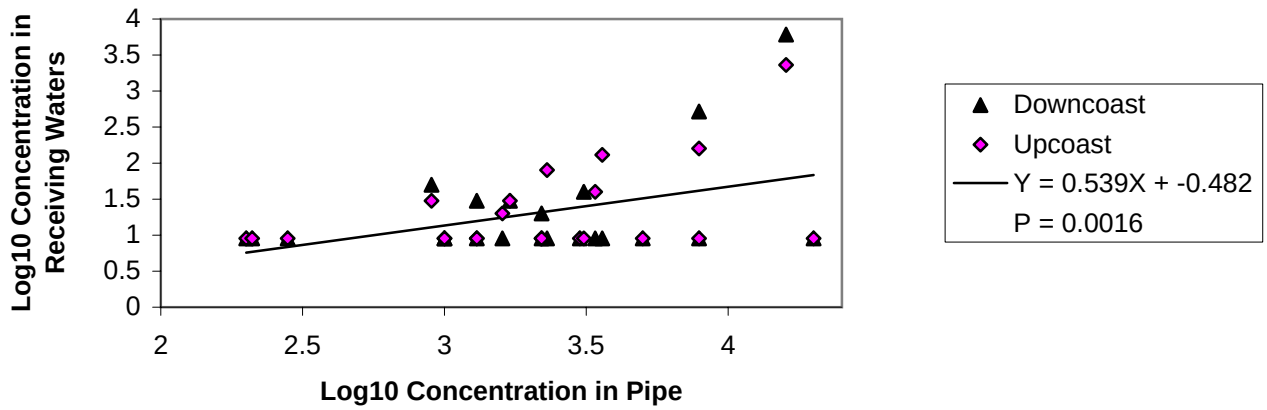
MDC - Enterococcus (7/1/2005 - 6/30/2006)



MDC - Fecal Coliform (7/1/2005 - 6/30/2006)



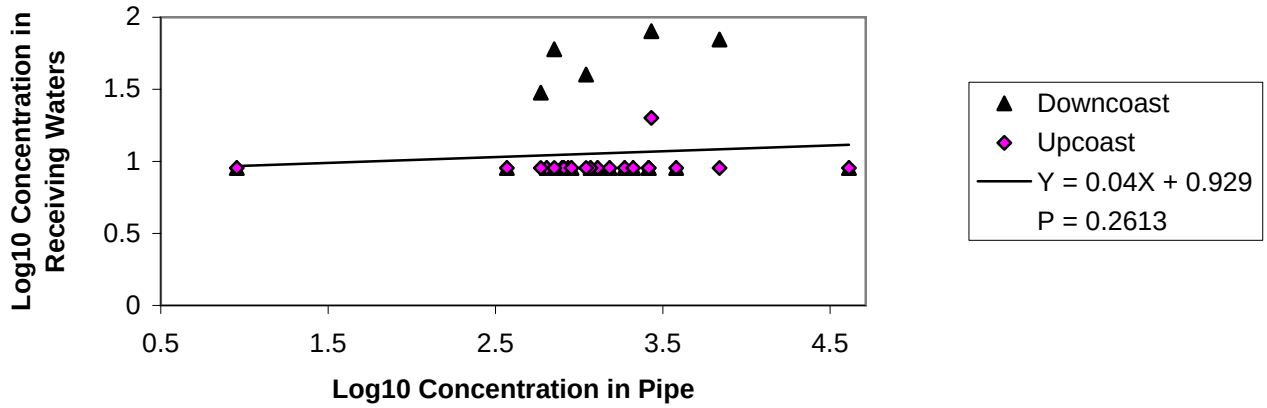
MDC - Total Coliform (7/1/2005 - 6/30/2006)



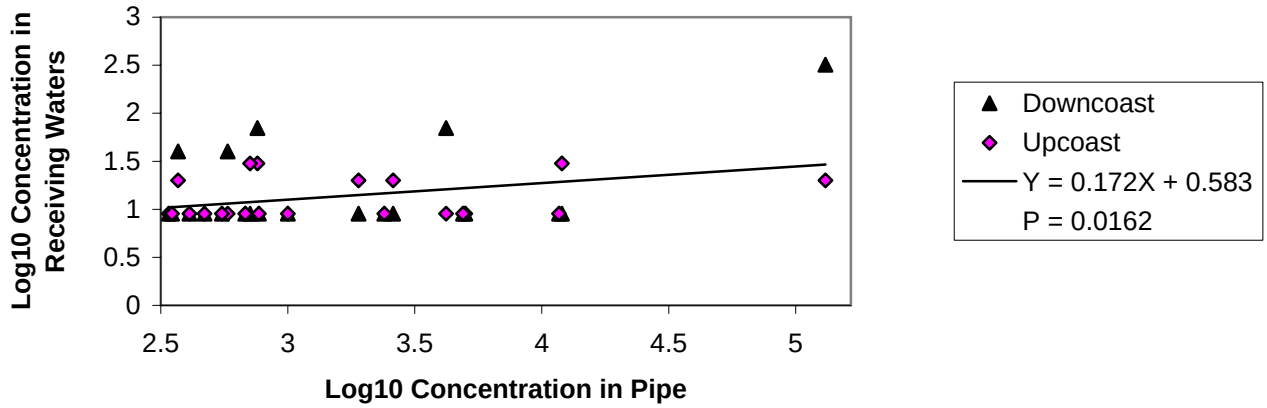
Null Hypothesis: slope<or=0 (i.e. no relationship)
P values: Probability that null hypothesis is true given the data

Regression Analysis for Relationship between Receiving Waters and Stormdrain Discharge - AB411 Months Only

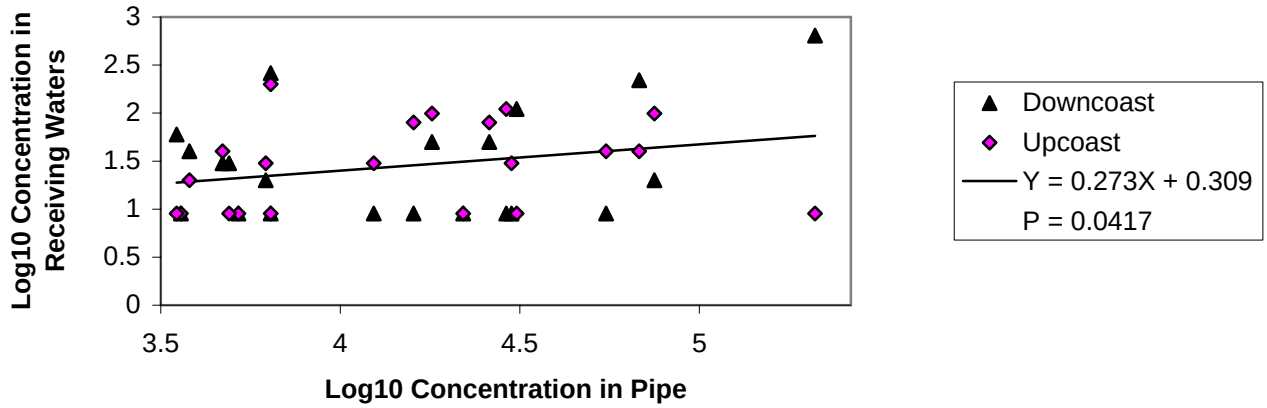
PPC - Enterococcus (7/1/2005 - 6/30/2006)



PPC - Fecal Coliform (7/1/2005 - 6/30/2006)



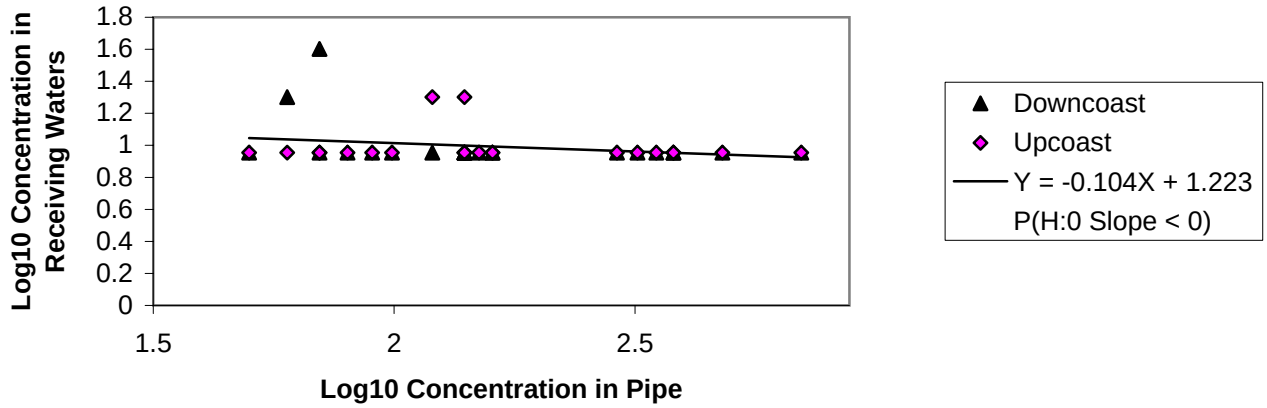
PPC - Total Coliform (7/1/2005 - 6/30/2006)



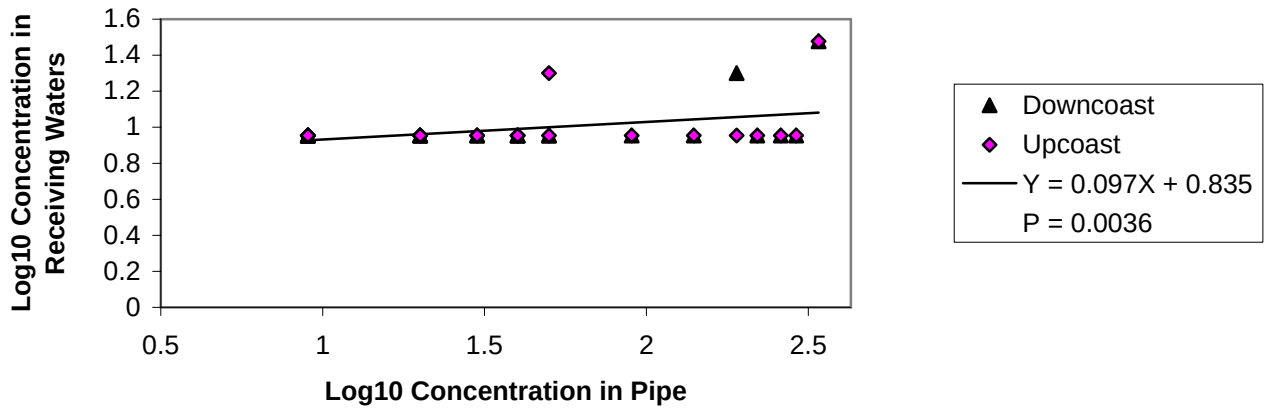
Null Hypothesis: slope<or=0 (i.e. no relationship)
P values: Probability that null hypothesis is true given the data

Regression Analysis for Relationship between Receiving Waters and Stormdrain Discharge - AB411 Months Only

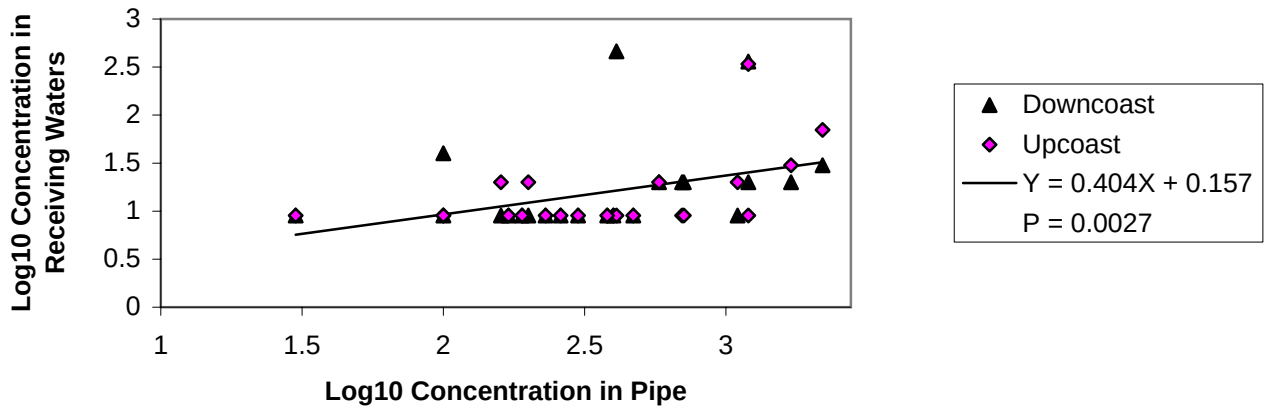
WFC - Enterococcus (7/1/2005 - 6/30/2006)



WFC - Fecal Coliform (7/1/2005 - 6/30/2006)



WFC - Total Coliform (7/1/2005 - 6/30/2006)



Null Hypothesis: slope<or=0 (i.e. no relationship)
P values: Probability that null hypothesis is true given the data

Dry Weather Reconnaissance Monitoring Data: 2005-06 SAR

Random or Targeted Site	Site Name	Date	Time	Watershed	Physicals								Chemical									Bacteria			Pesticides					Dissolved Metals						
					Discharge Rate	Dissolved Oxygen	Electrical Conductivity	pH	Water Temperature	Turbidity	Air Temperature	Hardness as $CaCO_3$	Phenols	Ammonia as N	Nitrate as N	Surfactsnats (MBAS)	Reactive Phosphorous	Total Chlorine	Total Suspended Solids (TSS)	Oil & Grease	Dissolved Copper	Dissolved Hexa Chrom.	Total Coliform	Fecal Coliform	Enterococcus	Diazinon	Chlorpyrifos	Malathion	Dimethoate	Disulfoton	Chromium	Nickel	Copper	Zinc	Silver	Cadmium	Lead
					cfs	mg/L	µS/cm		^{0}C	NTU	^{0}C	mg/L	mg/L										CFU/100mL			ng/L					µg/L						
	Outside Tolerance Interval					**6.11**		**7.03-8.2**	**23.44**	**16.7**	**18.14**		**0.01-0.0**	**1.16**	**5.3**	**0.45**	**2.92**	**0.13**	**78.08**				**330,000**	**106,000**	**55,000**	**271**	**10**	**57.4**	**10**			**88**	**15**	**75**		**9**	**2**
	Basin Plan Objective					5		6.5-9		20						0.5			75																	
	Warning Level based on Experience						6000		40				>0.02	0.65	10			1																		
	CTR Acute Criterion																													1708	1513	49.6	379	37.4	19.1	280
	CTR Chronic Criterion																													554	168	29.3	382		6.25	10.9
	LC_{50} for Toxicity Test Organism																								450	570	5,000	43,000								
T	ANACIT@B01	5/3/06	10:10	SGR	4.095	9.51	827	**8.35**	18.78	1.93	19	218	0	0.05	4.1	0.07	1.03	0.05	5	<5		0.01	13,000	6,000	200	<2	<1	<3	<3	<1	<0.50	4.6	2.9	11	<0.50	<0.50	<0.50
T	ANACIT@B01	6/16/06	08:25	SGR	0.129	7.72	1069	**8.49**	21.9	0.76	22	295	0	0.01	3.1	0.05	1.46	0.03	<5	<5		0	2,500	1,600	620	33.8	<1	<3	<3	<1	<0.50	6.3	2.5	15	<0.50	<0.50	<0.50
T	ANACIT@B01	7/20/06	09:20	SGR	0.499	10.57	1144	**8.41**	**24.34**	1.37	24	335	0	0.06	1.4	0.11	1.98	0.03	<5	<5		0	21,000	370	1,500	25.7	<1	<3	<3	<1	<0.50	4.4	5.9	26	<0.50	<0.50	<0.50
T	ANACIT@B01	8/11/06	09:15	SGR	1.68	7.37	551	8.24	**24.7**	1.31	25	140	0	0.04	0.7	0	0.59	0.03	<5	<5		0	30,000	8,000	300	<2	<1	<3	<3	<1	<0.50	1.6	3	9.2	<0.50	<0.50	<0.50
T	ANACIT@B01	9/11/06	11:45	SGR	0.053	7.04	1402	**8.37**	**23.97**	7.12	33	370	0	0.03	1.8	**0.6**	1.14	0.04	15	<5		0.01	**>1,200,000**	**700,000**	10,000	<2	<1	<3	<3	<1	4.2	13	**23**	44	<0.50	<0.50	1.5
T	ANAE12@ E01	5/3/06	11:35	Santa Ar	0.576	**5.57**	1360	7.66	17.47	**21.3**	19	308	0	0	1	0.11	0.39	0	<5	<5			**>1,200,000**	**>1,200,000**	25,000	<2	<1	<3	<3	<1	0.62	6.6	5.3	33	<0.50	<0.50	<0.50
T	ANAE12@ E01	6/16/06	11:30	Santa Ar	0.004	7.5	1544	7.47	**26.59**	**23.5**	30	345	0	0.04	1	0.17	1.66	0.05	11	<5		0	**>1,200,000**	**390,000**	30,000	<2	<1	<3	<3	<1	0.99	7.9	5.1	21	<0.50	<0.50	0.53
T	ANAE12@ E01	7/20/06	10:50	Santa Ar	0.713	**3.94**	1000	7.45	**23.79**	11	24	335	0	0.01	0.7	0.14	1.5	0.02	15	6		0	**>1,200,000**	**640,000**	55,000	<2	<1	<3	<3	<1	0.88	3.9	6.3	32	<0.50	<0.50	<0.50
T	ANAE12@ E01	8/11/06	12:28	Santa Ar	0.33	8.72	1095	8.03	**25.79**	8.77	30	360	0	0.31	1	0.2	0.91	0.04	10	<5		0	**790,000**	**350,000**	12,000	<2	<1	<3	<3	<1	0.57	2.4	5.3	35	<0.50	<0.50	<0.50
T	ANAE12@ E01	9/11/06	11:05	Santa Ar	0.104	11.37	1140	**8.43**	**24.59**	1.97	25	390	0	0.02	2	0.08	0.94	0.03	<5	5		0.01	**>1,200,000**	**570,000**	14,000	17	<1	<3	<3	<1	<0.50	5.3	7.5	14	<0.50	<0.50	<0.50
T	ANAHGC03	5/3/06	08:34	Anaheim	0.143	8.05	960	7.95	19.47	0.9	19	248	0	0.05	2.7	0.08	0.76	0.06	<5	<5		0.05	12,000	6,800	110	<2	<1	<3	<3	<1	0.52	9.7	10	**120**	<0.50	<0.50	<0.50
T	ANAHGC03	6/16/06	10:00	Anaheim	0.272	8.09	1030	8.17	**24.88**	3.85	30	295	0	0.07	2.9	0.08	0.82	0.03	<5	<5		0.01	13,000	1,800	60	<2	<1	<3	<3	<1	0.66	12	13	**88**	<0.50	<0.50	<0.50
T	ANAHGC03	7/20/06	08:30	Anaheim	0.254	9.28	1055	8.03	**25.24**	0.9	24	285	0	0.06	2.5	0.07	1.05	0.03	<5	<5		0	12,000	3,000	660	<2	<1	<3	<3	<1	0.62	8.3	11	**110**	<0.50	<0.50	<0.50
T	ANAHGC03	8/11/06	10:37	Anaheim	1.08	7.79	755	8.24	**26.42**	4.15	28	340	0	0.04	3	0	1.35	0.04	9	<5		0	26,000	9,000	1,500	<2	<1	24.2	<3	<1	0.61	5.7	9.3	31	<0.50	<0.50	<0.50
T	ANAHGC03	9/11/06	13:40	Anaheim	0.091	12.34	1030	**8.53**	**27.35**	4.1	26	355	0	0.01	3.1	0.05	0.96	0.05	14	5		0	11,000	4,300	2,000	<2	<1	<3	<3	<1	1.7	7.9	**55**	**97**	<0.50	<0.50	<0.50
T	BPARA01	5/4/06		SGR	DRY																															
T	BPARA01	6/2/06	08:40	SGR		10.78	598	**8.33**	21	1.96	21	195	0	0.03	0.5	0.11	0.47	0.02	<5	<5		0.01	220,000	7,000	20,000	<2	<1	<3	<3	<1	<0.50	3.4	4.7	21	<0.50	<0.50	<0.50
T	BPARA01	6/29/06	08:45	SGR		6.53	572	8.21	22.74	1.36	25	145	0	1	1.2	0.02	0.28	0.03	7	8		0	86,000	46,000	12,000	<2	<1	<3	<3	<1	<0.50	3.5	3.1	35	<0.50	<0.50	<0.50
T	BPARA01	8/2/06	08:30	SGR	0.017	7.87	658	**8.29**	**24.37**	2.11	25	180	0	0	0.5	0.15	0.85	0.01	5	<5		0	260,000	**160,000**	9,000	<2	<1	<3	<3	<1	<0.50	4.1	11	30	<0.50	<0.50	<0.50
T	BPARA01	8/25/06	09:45	SGR		8.22	552	**8.33**	**23.59**	0.47	23	160	0	0.01	0.4	0	0.31	0.01	<5	<5		0	14,000	4,400	2,900	<2	<1	<3	<3	<1	<0.50	1.3	5.3	15	<0.50	0.61	<0.50
T	BPDSA01	5/4/06		SGR	DRY																															
T	BPDSA01	6/2/06		SGR	DRY																															
T	BPDSA01	6/29/06	08:10	SGR		**3.73**	643	7.77	21.37	5	20	165	0	0.17	0.8	0.14	0.76	0.03	36	<5		0	30,000	2,400	9,700	<2	<1	<3	<3	<1	<0.50	4.2	1.8	8.3	<0.50	<0.50	<0.50
T	BPDSA01	8/2/06	10:05	SGR		7.22	911	8.25	**26.04**	4.79	25	230	0	0.21	0.2	0.19	1.5	0.02	58	<5		0	48,000	12,000	6,000	<2	<1	<3	<3	<1	0.63	5.7	5	11	<0.50	<0.50	0.61
T	BPDSA01	8/25/06	08:25	SGR		**0.93**	715	7.77	22.14	4.04	23	210	0	0	0.2	0.25	2.1	0.01	7	<5		0	80,000	41,000	28,000	<2	<1	<3	<3	<1	0.5	3.9	4.3	11	<0.50	<0.50	<0.50
T	BRRC@I-90	5/4/06	10:45	SGR		**4.85**	633				**18**			0.22		0.34						0.01	**690,000**	**180,000**	15,000	<2	<1	<3	<3	<1	1.7	5.8	3.1	22	<0.50	<0.50	<0.50
T	BRRC@I-90	6/2/06	09:45	SGR	0.234	8.17	661	7.26	19.38	3.02	21	230	0	0.28	2.8	0.14	1.16	0.02	<5	<5		0.01	300,000	37,000	7,600	<2	<1	<3	<3	<1	1.2	5.4	11	34	<0.50	<0.50	<0.50
T	BRRC@I-90	6/29/06	10:15	SGR	0.143	**2.78**	823	7.34	21.23	4.69	27	220	0	0.68	2.2	0.01	1.25	0.03	6	7		0	270,000	27,000	46,000	<2	<1	<3	<3	<1	0.6	5.4	2.9	22	<0.50	<0.50	<0.50
T	BRRC@I-90	8/2/06	12:05	SGR	0.242	**3.67**	790	7.48	23.09	4.04	27	270	0	0.41	1.5	0.13	1.5	0.04	21	5		0	**380,000**	65,000	15,000	<2	<1	<3	<3	<1	0.6	4.5	3.4	25	<0.50	<0.50	<0.50
T	BRRC@I-90	8/25/06	11:35	SGR	0.75	**2.84**	608	7.22	22.23	3.46	26	205	0	0.61	1.7	0.1	1.34	0.02	<5	<5		0.02	68,000	49,000	50,000	<2	<1	<3	<3	<1	<0.50	3.6	3.1	17	<0.50	<0.50	<0.50
T	CM15NB	5/5/06	09:30	Newport	0.15	**4.93**	2220	7.33	19.09	9.17	19	396	0	0.07	1.8	0.35	0.25	0	8	<5		0	86,000	33,000	1,300	<2	<1	<3	<3	<1	<0.50	13	14	57	<0.50	1	**6.1**
T	CM15NB	6/1/06	09:20	Newport	0.129	9.21	1998	7.19	20.3	3.53	21	385	0	0.05	1.5	0.22	1.27	0				0.01	137,000	12,000	2,500	<2	<1	<3	<3	<1							
T	CM15NB	6/28/06	08:40	Newport	0.156	**4.15**	1996	7.26	21.14	5.27	23	355	0	0.23	1.3	**0.46**	1.94	0.01	<5	6		0.02	260,000	17,000	5,800	<2	<1	<3	<3	<1	0.58	13	13	60	<0.50	<0.50	0.84
T	CM15NB	8/1/06	10:05	Newport	1.371	**3.5**	2042	7.26	22.79	4.73	25	390	0	0.25	0.5	0.19	1.73	0.04	<5	<5		0	44,000	15,000	40,000	<2	<1	<3	<3	<1	0.52	5.3	3.8	16	<0.50	<0.50	<0.50
T	CM15NB	8/24/06	08:45	Newport	0.225	**4.62**	604	7.43	22.67	10.1	23	450	0	0.4	2	0.1	2.02	0	27	<5		0	52,000	12,000	3,500	<2	<1	<3	<3	<1	<0.50	3.6	3.6	18	<0.50	<0.50	<0.50
T	CMNBG02P01	5/5/06	12:35	Newport	0.18	15.1	1391	**8.45**	19.3	2.06	20	224	0	0.03	2.9	0.4	1.07	0.01	8	<5		0.02	2,900	2,100	140	<2	<1	<3	<3	<1	<0.50	5.2	6	16	<0.50	<0.50	<0.50
T	CMNBG02P01	6/1/06	12:00	Newport	0.613	20.3	800	**8.57**	22.96	0.76	24	255	0	0.05	2.5	0.06	0.88	0.07				0.01	18,000	9,300	550	<2	<1	<3	<3	<1							
T	CMNBG02P01	6/28/06	11:00	Newport	0.034	8.18	1068	**8.74**	**27.8**	2	26	225	0	0.01	1.1	0	1.71	0.05	<5	<5		0	12,000	6,100	1,400	<2	<1	<3	<3	<1	<0.50	5.6	15	13	<0.50	<0.50	0.62
T	CMNBG02P01	8/1/06	13:45	Newport	0.179	7.75	1688	8.04	**25.07**	1.75	25	295	0	0.35	3.9	0.1	0.92	0.01	<5	<5		0	7,100	4,000	6,100	<2	<1	<3	<3	<1	0.55	1	6.3	14	<0.50	<0.50	<0.50
T	CMNBG02P01	8/24/06	11:10	Newport	0.24	11.66	1215	**9.07**	**28.1**	1.72	23	315	0	0	1.7	0	1.69	0.06	9	<5		0	6,700	2,300	1,400	<2	<1	<3	<3	<1	<0.50	3.6	10	**90**	<0.50	<0.50	0.9
T	CMNBG02P02	5/5/06	11:30	Newport	0.007	8.13	762	7.77	17.5	8.65	20	160	0	1.06	1.1	0.4	0.97	0.02	14	<5		0.02	**>1,200,000**	**>1,200,000**	2,800	<2	<1	<3	<3	<1	<0.50	4.2	7	56	<0.50	<0.50	0.8
T	CMNBG02P02	6/1/06	10:15	Newport	0.016	14.3	747	7.66	19.7	3.2	26	185	0	0.03	0.8	**0.83**	0.91	0.08				0.01	**>1,200,000**	43,000	11,600	<2	<1	<3	<3	<1							
T	CMNBG02P02	6/28/06	09:15	Newport	0.009	**5.29**	1049	7.97	21.48	5.76	26	220	0	0.33	0.7	0.33	1.23	0.11	41	9		0	**>1,200,000**	44,000	**76,000**	<2	<1	<3	<3	<1	0.58	9.5	11	**76**	<0.50	<0.50	0.87
T	CMNBG02P02	8/1/06	11:00	Newport	0.01	**1.92**	1173	7.65	23.34	5.4	26	240	0	**1.18**	0.5	**4**	**3.43**	0.02	<5	<5		0	**>1,200,000**	**400,000**	11,000	<2	<1	<3	<3	<1	0.87	10	**23**	**240**	<0.50	<0.50	**2.7**
T	CMNBG02P02	8/24/06	10:15	Newport	0.07	**5.96**	1792	7.8	23.18	2.98	24	310	0	0.17	0.8	0.2	1.02	0.03	<5	<5		0	51,000	6,000	5,400	<2	<1	<3	<3	<1	<0.50	5.5	6	**81**	<0.50	<0.50	0.84
R	COF13@FH	5/30/06	11:45	Newport	0.36	15.58	2093	7.93	19.68	3.26	22	730	0	0.06	3.5	**0.57**	0.72	0.03	<5	<5		0.02	26,000	7,000	1,500	<2	<1	<3	<3	<1	<0.50	12	3.8	10	<0.50	0.77	<0.50
R	COF13@FH	7/21/06	08:45	Newport	0.63	12.21	1754	8.03	22.02	4.67	24	608	0	0.04	2.7	0.07	0.83	0.05	14	<5		0	70,000	30,000	29,000	<2	<1	<3	<3	<1	<0.50	1.9	2.5	6.9	<0.50	<0.50	<0.50
R	COF13@FH	9/15/06	08:55	Newport	0.78	8.74	1121	8.2	20.6	4.25	**16**	625	0	0.03	3.5	0.02	0.62	0.03	9	<5		0.01	130,000	51,000	19,000	<2	<1	<3	<3	<1	<0.50	4.2	2.2	4.7	<0.50	<0.50	<0.50

Dry Weather Reconnaissance Monitoring Data: 2005-06 SAR

Random or Targeted Site	Site Name	Date	Time	Watershed	Physicals								Chemical									Bacteria			Pesticides					Dissolved Metals						
					Discharge Rate	Dissolved Oxygen	Electrical Conductivity	pH	Water Temperature	Turbidity	Air Temperature	Hardness as $CaCO_3$	Phenols	Ammonia as N	Nitrate as N	Surfactsnats (MBAS)	Reactive Phosphorous	Total Chlorine	Total Suspended Solids (TSS)	Oil & Grease	Dissolved Copper	Dissolved Hexa Chrom.	Total Coliform	Fecal Coliform	Enterococcus	Diazinon	Chlorpyrifos	Malathion	Dimethoate	Disulfoton	Chromium	Nickel	Copper	Zinc	Silver	Cadmium	Lead
					cfs	mg/L	µS/cm		°C	NTU	°C	mg/L	mg/L										CFU/100mL			ng/L					µg/L						
	Outside Tolerance Interval					**6.11**		**7.03-8.2**	**23.44**	**16.7**	**18.14**		**0.01-0.0**	**1.16**	**5.3**	**0.45**	**2.92**	**0.13**	**78.08**				**330,000**	**106,000**	**55,000**	**271**	**10**	**57.4**	**10**			**88**	**15**	**75**		**9**	**2**
	Basin Plan Objective					5		6.5-9		20						0.5			75																	
	Warning Level based on Experience						6000		40				>0.02	0.65	10			1																		
	CTR Acute Criterion																													1708	1513	49.6	379	37.4	19.1	280
	CTR Chronic Criterion																													554	168	29.3	382		6.25	10.9
	LC_{50} for Toxicity Test Organism																								450	570	5,000	43,000								
R	CYPB00P01	5/9/06	12:15	SGR		11.85	958	**8.3**	19.26	0.79	24	228	0	**2.02**	2.9	0.11	**2.94**	0.06	<5	<5	0.02	5,700	5,000	1,300	<2	<1	<3	<3	<1	<0.50	4.4	5.7	8.3	<0.50	<0.50	<0.50
R	CYPB00P01	7/7/06	08:25	SGR	0.024	7.89	2984	8.26	22.4	11.49	23	305	0	0.03	**6.2**	0	1.75	0.08	<5	<5	0	3,200	260	390	<2	<1	<3	<3	<1	2.8	5.2	3.3	10	<0.50	<0.50	<0.50
R	CYPB00P01	9/7/06		SGR	DRY																															
T	CYPB01S01	5/9/06	11:00	SGR	3.12	11.42	2156	**8.41**	18.4	1.81	22	404	0	0.03	3.3	0.06	0.12	0.03	9	<5	0.01	2,000	1,000	1,000	<2	<1	<3	<3	<1	<0.50	5.4	3.6	3.8	<0.50	<0.50	<0.50
T	CYPB01S01	6/13/06	08:25	SGR	0.453	10.52	1028	**8.38**	18.76	1.02	24	405	0	0.01	4.7	0.08	0.14	0.04	<5	<5	0.02	24,000	440	1,200	13.1	<1	42	<3	<1	<0.50	4.9	4.9	6.1	<0.50	<0.50	<0.50
T	CYPB01S01	7/7/06	08:50	SGR	0.405	8.32	1833	**8.56**	22.54	1.69	25	295	0	0.5	1.8	**3.76**	0.14	0.08	<5	<5	0	38,000	740	1,700	183	<1	<3	<3	<1	<0.50	6	5.3	8.7	<0.50	<0.50	<0.50
T	CYPB01S01	8/9/06	08:57	SGR	0.6	7.02	2019	8.19	21.13	2.88	24	390	0	0.17	1.8	0.1	0.12	0.04	5	<5	0	5,100	5,000	1,100	16.8	<1	<3	<3	<1	<0.50	2.3	4.2	8.7	<0.50	<0.50	<0.50
T	CYPB01S01	9/7/06	11:00	SGR	0.63	11.94	1840	**8.89**	**24.24**	2.38	24	345	0	0.06	2.1	0.05	0.13	0.03	<5	<5	0.01	2,400	1,000	430	<2	<1	<3	<3	<1	<0.50	2.4	5.7	5	<0.50	<0.50	<0.50
T	FULA03S05	5/10/06	13:15	SGR	0.018	11.97	1190	**10.21**	**30.24**	8.92	30	256	0	0.04	0.9	**0.66**	0.24	0.05			0	80	<10	70	<2	<1	<3	<3	<1	1.5	15	**82**	16	<0.50	0.56	1.2
T	FULA03S05	6/13/06	10:20	SGR	0.099	12.93	1005	**8.71**	22.77	5.12	27	290	0	0	3	0.09	0.36	0.07	<5	<5	0.05	20,000	7,000	560	<2	<1	**154**	<3	<1	<0.50	6.1	7	9.8	<0.50	<0.50	<0.50
T	FULA03S05	7/11/06	11:50	SGR	0.005	9.27	932	**9.62**	**30.28**	2.93	35	190	0	0	1.9	**0.73**	0.22	0.06	<5	<5	0	450	30	310	<2	<1	<3	<3	<1	0.84	9.2	**22**	10	<0.50	<0.50	<0.50
T	FULA03S05	8/9/06	11:17	SGR	0.048	8.63	1187	**8.95**	**25.4**	8.13	37	295	0	0	2.1	**0.47**	0.46	0.11	10	<5	0	4,200	1,200	780	<2	<1	**1950**	<3	<1	6.2	12	**32**	27	<0.50	<0.50	0.7
T	FULA03S05	9/7/06	09:25	SGR	0.029	10.99	1082	**9.18**	22.47	2.93	32	350	0	0	0	**0.8**	0.21	0.11	<5	<5	0.01	8,000	1,900	<10	<2	<1	<3	<3	<1	<0.50	5.9	11	21	<0.50	<0.50	1.1
T	FULB01@SCO	5/10/06	11:45	SGR	14.7	11.07	900	**8.62**	21.36	3.74	24	312	0	0.01	3	0.07	0.43	0.03			0	6,500	830	70	<2	<1	<3	<3	<1	<0.50	4.2	2.3	4.3	<0.50	<0.50	<0.50
T	FULB01@SCO	6/13/06	11:30	SGR	0.615	9.47	696	**8.87**	23.29	3.02	27	270	0	0	3	0.03	1.63	0.09	<5	<5	0.01	26,000	2,500	290	<2	<1	<3	<3	<1	<0.50	5.3	4.4	8.4	<0.50	<0.50	<0.50
T	FULB01@SCO	7/11/06	09:45	SGR	1.309	9.93	952	8.03	**24.97**	2.43	25	215	0	0.31	1.5	0.34	1.25	0.04	<5	<5	0	56,000	11,000	2,500	<2	<1	<3	<3	<1	<0.50	6.4	6.4	21	<0.50	<0.50	<0.50
T	FULB01@SCO	8/9/06	12:40	SGR	31.2	**6.05**	427	**8.68**	**26.87**	1.74	37	150	0	0.03	0.5	0.05	0.42	0.04	<5	<5	0	6,400	1,700	700	<2	<1	<3	<3	<1	<0.50	1.3	2.7	3	<0.50	<0.50	<0.50
T	FULB01@SCO	9/7/06	08:10	SGR	0.8	7.83	1080	**8.93**	23.36	2.15	22	450	0	0	0.8	0.05	0.19	0.04	<5	<5	0.02	80,000	2,700	5,800	<2	<1	<3	<3	<1	<0.50	1.8	1.8	3.2	<0.50	<0.50	<0.50
T	FVES@D05	5/9/06	09:10	SAR	1.08	8.6	915	7.91	20.59	0.49	19	238	0	0.01	4	0.03	0.31	0.08	<5	<5	0.01	860	290	170	<2	<1	<3	<3	<1	1.1	3.9	2.2	9.3	<0.50	<0.50	<0.50
T	FVES@D05	6/15/06	10:30	SAR	1.867	6.31	832	7.74	21.55	0.55	26	235	0	0.02	3.9	0.07	0.34	0.04	<5	<5	0.02	11,000	2,600	450	<2	<1	<3	<3	<1	1.2	3.3	2.4	8.3	<0.50	<0.50	<0.50
T	FVES@D05	7/7/06	10:50	SAR	3	7.3	966	**8.31**	22.41	0.36	35	265	0	0.02	3.4	0.01	0.35	0.06	<5	<5	0.01	13,000	360	1,100	<2	<1	<3	<3	<1	1.4	4.6	2.2	5.4	<0.50	<0.50	<0.50
T	FVES@D05	8/23/06	12:20	SAR	4.05	7.25	1218	7.71	22.54	0.95	32	275	0	0	**7.2**	0.05	0.42	0.03	<5	<5	0	700	10	200	<2	<1	<3	<3	<1	0.87	5.7	2.9	4.6	<0.50	<0.50	<0.50
T	FVES@D05	9/13/06	14:40	SAR	3.15	7.15	788	7.83	**23.75**	1.03	25	255	0	0	3.4	0.3	0	0.03	<5	<5	0.01				<2	<1	<3	<3	<1	1.1	2.4	3.1	10	<0.50	<0.50	<0.50
R	GGC04@MAL	5/10/06	09:05	AB/HH	0.016	7.44	615	8.04	17.3	2.24	20	254	0	**0.71**	2.5	0.13	1.41	0.04			0.02	240,000	16,000	4,000	<2	<1	<3	<3	<1	0.6	7	11	50	<0.50	<0.50	<0.50
R	GGC04@MAL	7/11/06	08:55	AB/HH	0.178	7.25	1066	7.97	**24.09**	1.26	22	255	0	0.05	2.2	0.19	0.63	0.03	<5	<5	0	320,000	13,000	2,300	<2	<1	<3	<3	<1	0.6	6.2	**24**	33	<0.50	<0.50	<0.50
R	GGC04@MAL	8/29/06	11:30	AB/HH	0.048	7.56	962	**8.67**	22.85	3.99	27	335	0	0.06	2.6	0.1	2.37	0.04	7	<5	0	160,000	**130,000**	2,500	<2	<1	<3	<3	<1	0.52	6	8.4	27	<0.50	<0.50	<0.50
T	GGHKWC02S01	5/11/06	11:00	AB/HH	0	11.8	903	**8.6**	20.9	1.49	21	336	0	0.02	3	0.13	1.48	0.06	<5	<5	0.04	5,500	3,000	1,100	<2	<1	<3	<3	<1	1.2	6	7.4	30	<0.50	<0.50	<0.50
T	GGHKWC02S01	6/6/06		AB/HH	DRY																															
T	GGHKWC02S01	6/30/06		AB/HH	DRY																															
T	GGHKWC02S01	8/3/06		AB/HH	DRY																															
T	GGHKWC02S01	8/29/06		AB/HH	DRY																															
T	GGKHC02S01	5/11/06	10:00	AB/HH	0.386	**4.61**	1293	7.7	19.3	**22.2**	20	458	0	**1.68**	1.1	0.15	0.09	0.01	<5	<5	0	**980,000**	**700,000**	200	<2	<1	<3	<3	<1	0.97	9	2.5	19	0.87	<0.50	**9.3**
T	GGKHC02S01	6/6/06	09:45	AB/HH	0.06	**2.77**	1105	7.55	22.53	2.77	23	365	0	0.5	0.7	0.07	1.3	0.03	<5	<5	0	**1,270,000**	**110,000**	2,700	<2	<1	<3	<3	<1	0.76	9.5	2.4	33	<0.50	<0.50	<0.50
T	GGKHC02S01	6/30/06	10:30	AB/HH	0.068	**3.24**	1205	7.34	**24.27**	**38.7**	28	390	0	**1.21**	0.9	0.13	**2.95**	0.03	8	5	0	**>1,200,000**	**670,000**	2,300	<2	<1	<3	<3	<1	1.3	10	4.8	24	<0.50	<0.50	1
T	GGKHC02S01	8/3/06	10:50	AB/HH	0.021	**2.02**	1045	7.73	**24.85**	**17.3**	25	330	0	**1.46**	0.8	0.2	2.13	0	11	<5	0	**710,000**	91,000	3,500	<2	<1	<3	<3	<1	1	4.1	7.2	25	<0.50	<0.50	<0.50
T	GGKHC02S01	8/29/06	08:55	AB/HH	0.049	**3.95**	1053	7.99	**24.15**	3.79	25	390	0	1.08	0.7	0.11	1.93	0.04	<5	<5	0	270,000	**170,000**	900	<2	<1	<3	<3	<1	0.9	4.3	4.8	22	<0.50	<0.50	<0.50
T	GGKNOTT@BEL	5/11/06	12:05	AB/HH	0.188	19.54	200	**8.7**	**23.9**	2.23	22	250	0	0.32	3.1	0.1	0.72	0.1	<5	<5	0.01	5,600	2,800	1,120	<2	<1	<3	<3	<1	0.8	4.6	5.3	13	<0.50	<0.50	<0.50
T	GGKNOTT@BEL	6/6/06	10:00	AB/HH	0.035	14.07	768	**8.45**	22.07	1.14	23	255	0	0.07	1.3	0.09	0.51	0.05	<5	<5	0.01	260,000	6,000	6,000	<2	<1	<3	<3	<1	1	5.2	5.9	12	<0.50	<0.50	<0.50
T	GGKNOTT@BEL	6/30/06	11:00	AB/HH	1.309	8	1154	**6.97**	21.63	0.18	28	630	0	0.02	4.2	0.13	0.38	0.05	<5	<5	0	3,100	2,800	390	<2	<1	<3	<3	<1	<0.50	9.5	1.3	7.3	<0.50	<0.50	<0.50
T	GGKNOTT@BEL	8/3/06	12:05	AB/HH	1.44	8.82	1924	7.99	22.67	1.27	24	540	0	0.12	4.2	0.05	0.11	**0.4**	<5	<5	0	2,000	1,900	790	<2	<1	<3	<3	<1	<0.50	2.4	2.8	7.9	<0.50	<0.50	<0.50
T	GGKNOTT@BEL	8/29/06	09:55	AB/HH	0.669	8.95	1955	8	22.23	0.39	23	620	0	0.03	3.8	0.05	0.29	0.06	<5	<5	0	8,000	4,000	2,500	<2	<1	<3	<3	<1	<0.50	4.4	2.2	5.9	<0.50	<0.50	<0.50
T	HBBA@C02	5/12/06	09:10	AB/HH	0.018	8.24	1698	**8.28**	18.25	1.71	**13**	204	0	0	**8.2**	0.08	0.74	0.08	15	<5	0.02	**380,000**	**210,000**	34,000	<2	<1	<3	<3	<1	0.97	4.8	**16**	20	<0.50	0.51	0.97
T	HBBA@C02	6/23/06	08:15	AB/HH	0.003	**5.46**	2176	7.9	20.52	3.53	21	235	0	0	**7.7**	0.02	0.9	0.13	8	<5	0.01	6,200	380	1,800	<2	<1	<3	<3	<1	0.95	4.9	7.6	11	<0.50	<0.50	<0.50
T	HBBA@C02	7/26/06	09:20	AB/HH	0.024	6.22	2086	8.22	23.39	1.27	27	222	0	0.12	4.9	0.05	1.33	0.04	6	<5	0	35,000	32,000	20	<2	<1	<3	<3	<1	4.4	8.1	13	14	<0.50	0.5	<0.50
T	HBBA@C02	8/18/06	09:00	AB/HH	0.009	**2.86**	2773	7.89	21.4	1.38	23	280	0	0.12	**7.1**	0.02	0.78	0.03	<5	<5	0	240,000	**120,000**	7,300	<2	<1	<3	<3	<1	1.6	3.4	7.2	12	<0.50	<0.50	<0.50
T	HBBA@C02	9/21/06	08:40	AB/HH	0.014	7.37	2637	**8.65**	20.56	3.8	20	350	0	0.2	**8**	0.01	1.36	0.07			0.02															

Dry Weather Reconnaissance Monitoring Data: 2005-06 SAR

Random or Targeted Site	Site Name	Date	Time	Watershed	Physicals								Chemical									Bacteria			Pesticides					Dissolved Metals						
					Discharge Rate	Dissolved Oxygen	Electrical Conductivity	pH	Water Temperature	Turbidity	Air Temperature	Hardness as $CaCO_3$	Phenols	Ammonia as N	Nitrate as N	Surfactsnats (MBAS)	Reactive Phosphorous	Total Chlorine	Total Suspended Solids (TSS)	Oil & Grease	Dissolved Copper	Dissolved Hexa Chrom.	Total Coliform	Fecal Coliform	Enterococcus	Diazinon	Chlorpyrifos	Malathion	Dimethoate	Disulfoton	Chromium	Nickel	Copper	Zinc	Silver	Cadmium	Lead
					cfs	mg/L	µS/cm		^{0}C	NTU	^{0}C	mg/L	mg/L										CFU/100mL			ng/L					µg/L						
	Outside Tolerance Interval					**6.11**		**7.03-8.2**	**23.44**	**16.7**	**18.14**		**0.01-0.0**	**1.16**	**5.3**	**0.45**	**2.92**	**0.13**	**78.08**				**330,000**	**106,000**	**55,000**	**271**	**10**	**57.4**	**10**			**88**	**15**	**75**		**9**	**2**
	Basin Plan Objective					5		6.5-9		20						0.5			75																	
	Warning Level based on Experience						6000		40				>0.02	0.65	10			1																		
	CTR Acute Criterion																													1708	1513	49.6	379	37.4	19.1	280
	CTR Chronic Criterion																													554	168	29.3	382		6.25	10.9
	LC_{50} for Toxicity Test Organism																								450	570	5,000	43,000								
T	HBC05S04@BRG	5/12/06		AB/HH	DRY																															
T	HBC05S04@BRG	5/30/06	09:20	AB/HH	40.11	13.76	2454	7.23	**23.8**	15.7	22	715	0	0.09	0.07	0.02	0.45	**0.26**	13	<5		0.03	4,200	1,000	80	<2	<1	<3	<3	19.4	<0.50	13	1.7	8.2	<0.50	0.67	<0.50
T	HBC05S04@BRG	6/23/06	09:35	AB/HH		7.25	2763	7.48	**25.3**	13.8	22	720	0	0.02	0.6	0.02	0.42	**0.26**	13	<5		0.01	3,000	700	230	<2	<1	<3	<3	<1	<0.50	13	0.89	5.8	<0.50	<0.50	<0.50
T	HBC05S04@BRG	7/26/06	11:44	AB/HH	34.2	8.49	2960	7.39	**28.69**	15.9	30	654	0	0.04	0	0.04	0.32	**0.43**	31	<5		0	**860,000**	**300,000**	**120,000**	<2	<1	<3	<3	<1	<0.50	2.4	3	13	<0.50	<0.50	<0.50
T	HBC05S04@BRG	8/18/06	10:00	AB/HH	12.6	**4.29**	3286	7.63	**24.99**	1.38	23	860	0	0.01	0.8	0.05	0.12	**0.16**	11	<5		0	1,300	300	<10	<2	<1	<3	<3	<1	<0.50	1.8	2.1	3.5	<0.50	<0.50	<0.50
T	HBC05S04@BRG	9/21/06	09:45	AB/HH		13.69	3308	**8.42**	23.37	7.95	21	910	0	0	0.6	0.02	0.2	**0.15**				0															
T	HBMC@C05	5/12/06	13:10	AB/HH	16.8	11.98	2003	7.9	20.5	4.49	22	724	0	0.22	1.9	0.06	0.22	0.07	<5	<5		0.02	2,000	320	80	<2	<1	<3	<3	<1	<0.50	12	2.9	10	<0.50	<0.50	<0.50
T	HBMC@C05	6/23/06	11:00	AB/HH	0.45	10.96	2091	7.99	**26.45**	9.41	24	780	0	0.63	2	0.03	0.28	0.06	21	<5		0.01	20,000	190	330	<2	<1	<3	<3	<1	<0.50	13	4.8	5.7	<0.50	<0.50	<0.50
T	HBMC@C05	7/26/06	10:20	AB/HH	0.149	6.11	2347	7.94	**29.33**	373	29	692	0	**2.41**	0.7	0.06	1.65	0	**170**	7		0	160,000	14,000	31,000	<2	<1	<3	<3	<1	<0.50	4.7	6	10	<0.50	<0.50	<0.50
T	HBMC@C05	8/18/06	12:00	AB/HH	0.375	10.09	2130	7.51	**29.16**	3.23	24	880	0	0.45	1.7	0.05	0.22	0.06	<5	<5		0.02	2,400	1,800	100	<2	<1	<3	<3	<1	<0.50	5.9	3.4	7.2	<0.50	<0.50	<0.50
T	HBMC@C05	9/21/06	11:30	AB/HH	0.773	13.41	2294	**8.37**	**23.83**	3.57	22	810	0	0.01	5.2	0.01	0.11	0.06				0															
R	IRVF05P07	5/17/06	10:10	NB	0.086	8.29	1469	7.92	18.58	1.93	19	216	0	0.01	**5.9**	**0.62**	2.45	**0.15**	<5	<5		0.02	230,000	38,000	1,100	<2	<1	<3	<3	<1	0.58	8.6	10	25	<0.50	<0.50	<0.50
R	IRVF05P07	7/12/06	10:20	NB	0.111	7.69	1092	7.69	**23.59**	2.53	33	245	0	0.19	2.9	0.16	**3.59**	0.04	<5	<5		0	35,000	40	1,800	<2	<1	<3	<3	<1	0.71	8.6	6.5	22	<0.50	<0.50	<0.50
R	IRVF05P07	9/12/06	11:30	NB	0.045	6.69	1009	8	22.08	3.85	25	255	0	0.09	2.4	0.07	1.85	0.04	<5	<5		0.02	**610,000**	98,000	1	<2	<1	<3	<3	<1	<0.50	4.4	5.7	25	<0.50	<0.50	<0.50
T	IRVF06P06	6/7/06	09:45	NB	0.004	7.47	3075	7.62	20.94	14.2	23	645	0	0.04	0.8	**0.81**	0.76	0.04	10	<5		0	**1,380,000**	2,000	**102,000**	45.4	<1	**470**	<3	<1	0.87	8.3	4.9	24	<0.50	<0.50	0.5
T	IRVF06P06	7/5/06	09:00	NB	1.2	8.09	3920	8.07	**25.02**	**31.1**	26	1705	0	0.1	**8.2**	0.39	0.15	0.04	44	<5		0	40,000	3,400	4,000	<2	<1	<3	<3	<1	<0.50	22	1.7	4.4	<0.50	<0.50	<0.50
T	IRVF06P06	8/4/06	08:50	NB	2.4	7.13	3383	7.19	22.94	**21.8**	23	1545	0	0.04	**8.9**	0.1	0.14	0.02	31	<5		0	41,000	25,000	6,500	<2	<1	<3	<3	<1	<0.50	2.2	1.1	3.1	<0.50	<0.50	<0.50
T	IRVF06P06	9/12/06	09:05	NB	0.042	**4.86**	2548	8.14	21.49	**62.6**	23	460	0	0	1.6	**0.65**	1.54	0.01	46	<5		0.02	280,000	45,000	21,000	27.4	<1	**96.5**	<3	<1	1.1	9.9	4.3	13	<0.50	<0.50	0.7
T	IRVF06S03	5/2/06		NB	DRY																															
T	IRVF06S03	6/7/06		NB	DRY																															
T	IRVF06S03	7/5/06		NB	DRY																															
T	IRVF06S03	9/12/06		NB	DRY																															
R	IRVF08P01	7/12/06	09:15	NB	0.012	9.83	1446	8.13	21.54	4.92	25	275	0	0.06	2.5	0.17	**3.93**	0.07	5	<5		0	61,000	1,800	13,000	<2	<1	<3	<3	<1	1.4	6.1	14	36	<0.50	<0.50	<0.50
R	IRVF08P01	9/19/06	13:15	NB	0.18	9.65	1006	7.6	22.66	3.96	23	300	0	0.05	1.2	0.1	0.96	0.08	6	<5		0.03	43,000	10,000	4,000	<2	<1	<3	<3	<1	1.2	2.4	4.8	9.6	<0.50	<0.50	<0.50
R	IRVF09P03	5/17/06		NB	DRY																															
R	IRVF09P03	7/12/06		NB	DRY																															
R	IRVF09P03	9/22/06		NB	DRY																															
T	IRVF20@ETGCC	5/2/06	11:50	NB	0.003	9.53	693	7.98	16.93	1.4	21	153	0	0.01	2.3	0.03	0.76	0.01				0.01	26,000	2,600	480	<2	<1	<3	<3	<1	<0.50	3	3.8	44	<0.50	<0.50	<0.50
T	IRVF20@ETGCC	6/7/06	10:45	NB	0.012	7.78	665	7.92	20.23	3.24	24	145	0	0.22	5	**0.79**	0.47	0.01	<5	<5		0.01	44,000	3,000	3,000	<2	<1	**1450**	<3	<1	3.2	15	**56**	**1,700**	<0.50	1.3	1.7
T	IRVF20@ETGCC	7/5/06	10:15	NB	0.006	8.5	591	**8.77**	22.88	1.02	27	95	0	0.11	1.2	0.23	2.39	0.07	<5	<5		0	37,000	30,000	3,800	<2	<1	<3	<3	<1	0.72	4.9	5	**430**	<0.50	0.64	**2.3**
T	IRVF20@ETGCC	8/4/06	10:50	NB	0.048	7.92	1543	7.99	22.55	4.68	27	1420	0	0.23	**13.9**	0.45	1.06	0	5	<5		0	**>1,200,000**	**>1,200,000**	**>120,000**	<2	<1	<3	<3	<1	13	43	**110**	**3,400**	<0.50	1.7	**10**
T	IRVF20@ETGCC	9/12/06	10:20	NB	0.005	9.01	530	8.13	21.55	2.34	25	110	0	0.01	1.2	0.15	1.19	0.03	<5	<5		0.02	2,000	2,000	10	<2	<1	<3	<3	<1	<0.50	1.8	3.7	17	<0.50	<0.50	<0.50
T	LAFPS@A01	5/18/06	09:13	AB/HH		**1.21**	790	7.49	18.21	2.62	20	220	0	**3**	1.1	0.16	2.78	0.02	<5	<5		0.01	22,000	1,400	390	<2	<1	<3	<3	<1	<0.50	6.8	14	23	<0.50	<0.50	<0.50
T	LAFPS@A01	6/22/06	10:15	AB/HH		**1.84**	795	**6.66**	20.9	4.24	25	170	0	**2.7**	0.6	0.04	2.54	0.04	10	<5		0.01	35,000	7,000	4,400	<2	<1	**263**	<3	<1	<0.50	6.7	13	27	<0.50	<0.50	<0.50
T	LAFPS@A01	7/27/06	12:45	AB/HH		**3.32**	914	7.67	**24.35**	2.95	33	300	0	**1.2**	0.4	0.03	1.73	0.07	<5	<5		0	24,000	8,000	870	<2	<1	<3	<3	<1	0.5	3.6	11	22	<0.50	<0.50	0.78
T	LAFPS@A01	8/17/06	10:50	AB/HH		**2.06**	764	7.75	21.87	1.79	25	185	0	**1.18**	1.1	0.1	2.02	0.04	<5	<5		0	51,000	23,000	11,000	<2	<1	<3	<3	<1	0.5	3.8	7.1	20	<0.50	<0.50	0.5
T	LAFPS@A01	9/20/06	10:40	AB/HH		**3.38**	635	8.05	**25.69**	1.28	23	250	0	0.55	1.4	0.15	1.44	0.05				0	14,000	7,000	990	<2	<1	<3	<3	<1							
T	LFDIM@LFD	5/16/06		NB	DRY																															
T	LFDIM@LFD	6/14/06	11:00	NB		7.32	937	7.65	19.28	0.55	28	210	0	**6.1**	2.6	0.01	0.95	0.06	6	<5		0	**1,050,000**	**750,000**	5,700	<2	<1	<3	<3	<1	<0.50	5.7	10	45	<0.50	<0.50	<0.50
T	LFDIM@LFD	7/14/06	09:45	NB		**2.88**	1064	7.35	21.1	4.9	29	215	0	**12**	1.7	0.21	1.38	0.04	<5	<5		0	140,000	20	11,700	<2	<1	<3	<3	<1	<0.50	7.2	6.2	49	<0.50	0.64	<0.50
T	LFDIM@LFD	8/10/06	09:30	NB	0.015		1258	7.85	21.66	3.99	26	275	0	**5.4**	1.4	0	0.97	0.03	6	<5		0	**430,000**	**110,000**	19,000	30.3	<1	<3	<3	<1	<0.50	4.2	6.9	40	<0.50	<0.50	<0.50
T	LFDIM@LFD	9/8/06	09:40	NB	0.004	**4.67**	1040	**8.66**	21.24	3.83	23	225	0	**6.8**	1.2	0.2	1.08	0.02	40	<5		0.03	170,000	57,000	4,200	<2	<1	<3	<3	<1	<0.50	4.9	7.7	38	<0.50	<0.50	<0.50
T	LFF19S02@PB	5/16/06	02:00	NB	0.09	11.55	1060	**8.78**	**28.39**	4.87	28	272	0	0.17	2.2	0.01	0.89	0.1	6	<5		0.1	180,000	**160,000**	24,000	<2	<1	<3	<3	<1	<0.50	6.5	7.3	21	<0.50	<0.50	<0.50
T	LFF19S02@PB	6/14/06	12:30	NB	0.108	11.62	1107	**8.76**	**28.66**	3.44	36	295	0	0.01	**5.7**	0.13	0.83	0.07	17	<5		0.02	15,000	3,000	3,700	34	<1	<3	<3	<1	0.8	7.5	**25**	22	<0.50	<0.50	0.54
T	LFF19S02@PB	7/14/06	10:35	NB	0.056	10.59	1122	8.26	**27.02**	7.47	32	265	0	0.02	**10.6**	0.36	1.85	0.06	12	<5		0	33,000	260	3,100	<2	<1	<3	<3	<1	1.1	7.8	**20**	29	<0.50	<0.50	<0.50
T	LFF19S02@PB	8/10/06	11:05	NB	0.5		1326	**8.3**	**24.8**	5.91	30	336	0	0.2	**30**	0.38	0.51	0.07	7	<5		0	330,000	30,000	8,000	28	<1	<3	<3	<1	1.1	5	15	31	<0.50	<0.50	<0.50
T	LFF19S02@PB	9/8/06	10:55	NB	0.66	9.33	1654	**8.83**	22.46	2.87	25	525	0	0.25	**36.8**	0.15	**4.35**	0.06	5	<5		0.02	39,000	20,000	6,300	38.7	**90.9**	<3	**1560**	<1	0.71	7.1	**19**	55	<0.50	0.6	0.56

Dry Weather Reconnaissance Monitoring Data: 2005-06 SAR

Random or Targeted Site	Site Name	Date	Time	Watershed	Physicals								Chemical									Bacteria			Pesticides					Dissolved Metals						
					Discharge Rate	Dissolved Oxygen	Electrical Conductivity	pH	Water Temperature	Turbidity	Air Temperature	Hardness as $CaCO_3$	Phenols	Ammonia as N	Nitrate as N	Surfactsnats (MBAS)	Reactive Phosphorous	Total Chlorine	Total Suspended Solids (TSS)	Oil & Grease	Dissolved Copper	Dissolved Hexa Chrom.	Total Coliform	Fecal Coliform	Enterococcus	Diazinon	Chlorpyrifos	Malathion	Dimethoate	Disulfoton	Chromium	Nickel	Copper	Zinc	Silver	Cadmium	Lead
					cfs	mg/L	µS/cm		°C	NTU	°C	mg/L	mg/L										CFU/100mL			ng/L					µg/L						
	Outside Tolerance Interval					**6.11**		**7.03-8.2**	**23.44**	**16.7**	**18.14**		**0.01-0.0**	**1.16**	**5.3**	**0.45**	**2.92**	**0.13**	**78.08**				**330,000**	**106,000**	**55,000**	**271**	**10**	**57.4**	**10**			**88**	**15**	**75**		**9**	**2**
	Basin Plan Objective					5		6.5-9		20						0.5			75																	
	Warning Level based on Experience						6000		40				>0.02	0.65	10			1																		
	CTR Acute Criterion																													1708	1513	49.6	379	37.4	19.1	280
	CTR Chronic Criterion																													554	168	29.3	382		6.25	10.9
	LC_{50} for Toxicity Test Organism																								450	570	5,000	43,000								
T	LGHF23@MP	5/17/06	11:00	NB	DRY						19																									
T	LGHF23@MP	6/27/06		NB	DRY																															
T	LGHF23@MP	7/27/06		NB	DRY																															
T	LGHF23@MP	8/22/06		NB	DRY																															
T	LGHF23@MP	9/22/06		NB	DRY																															
R	LGHF23S02	5/17/06	08:30	NB	0.28	8.84	3734	7.62	19.18	1.12	19	1032	0	0.01	3.9	0.03	0.79	0.04	<5	<5	0	32,000	32,000	3,100	<2	<1	<3	<3	<1	<0.50	35	2.7	12	<0.50	2.1	<0.50
R	LGHF23S02	7/13/06	10:35	NB	0.437	8.89	3577	7.51	21.23	1.02	37	985	0	0.02	2.9	0.05	1.43	0.09	<5	<5	0	14,000	2,200	520	<2	<1	<3	<3	<1	0.54	32	3.5	8.5	<0.50	1.8	<0.50
R	LGHF23S02	9/6/06	11:30	NB	0.468	8.4	343	**8.32**	21.87	0.95	32	940	0	0.02	2.9	0.05	1.35	0.06	<5	<5	0.01	27,000	4,000	1,000	<2	<1	**102**	<3	<1	<0.50	16	3.2	8.9	<0.50	1.7	<0.50
T	LHA01P10	5/4/06	02:00	SGR	0.012					1.03		332	0	0.06	**7**	0.13	2	0.04												0.95	6.8	5.2	22	<0.50	<0.50	<0.50
T	LHA01P10	5/4/06	14:00	San Gab	0.012					1.03		332	0	0.06	**7**	0.13	2	0.04				19,000	4,800	960	<2	<1	<3	<3	<1							
T	LHA01P10	6/8/06	09:30	San Gab	0.024	8.35	1276	**8.35**	20.1	1.03	23	380	0	0.05	**5.4**	0.17	2.23	0.04	<5	<5	0.01	50,000	870	8,300	<2	<1	<3	<3	<1	0.52	8.8	4.8	23	<0.50	<0.50	<0.50
T	LHA01P10	7/6/06	09:30	San Gab	0.006	9.45	1109	8.22	22.4	1.54	29	320	0	0.04	4.1	0.18	2.67	0.08	<5	<5	0	4,500	1,900	90	<2	<1	<3	<3	<1	0.59	8.3	5.3	57	<0.50	<0.50	<0.50
T	LHA01P10	8/8/06	11:51	San Gab	0.2	6.99	618	7.9	21.66	0.43	31	200	0	0.03	3.1	0.05	0.25	0.03	<5	<5	0	20,000	12,000	3,800	<2	<1	<3	<3	<1	0.89	1.1	1.8	21	<0.50	<0.50	<0.50
T	LHA01P10	9/13/06	12:30	San Gab	0.054	8.03	567	7.85	23.42	2.67	28	225	0	0.03	**5.6**	**0.6**	1.69	0.02	<5	<5	0.02				<2	<1	<3	<3	<1	2.3	3.9	5.9	25	<0.50	<0.50	0.63
T	LHA07XXX	5/4/06		SGR	DRY																															
T	LHA07XXX	6/8/06	09:00	SGR	0.108	**5.32**	844	7.91	21.35	3.59	20	195	0	**1.57**	1.6	0.11	1.42	0.05	<5	<5	0	19,000	190	1,800	<2	<1	**526**	<3	<1	<0.50	5.3	14	18	<0.50	<0.50	<0.50
T	LHA07XXX	7/6/06	08:45	SGR	0.039	6.34	1095	8.08	22.86	3.52	23	220	0	0.4	1	**1.74**	2.65	0.09	<5	<5	0	**>1,200,000**	**120,000**	**67,000**	<2	<1	<3	<3	<1	<0.50	5.9	12	13	<0.50	<0.50	<0.50
T	LHA07XXX	8/8/06	10:50	SGR	0.066	**4.33**	876	7.58	23.25	4.35	30	260	0	0.2	0.9	0.1	1.16	0.02	13	<5	0	28,000	15,000	6,000	<2	<1	49.7	<3	<1	<0.50	3.6	9.9	11	<0.50	<0.50	<0.50
T	LHA07XXX	9/13/06	11:20	SGR	0.259	**4.46**	598	7.79	22.67	9.82	25	218	0	0.19	0.9	0.05	1.23	0.02	<5	<5	0.02				98.7	<1	36.7	<3	<1	<0.50	4.4	8.5	16	<0.50	<0.50	0.55
R	LPB02P04	5/26/06	11:30	SGR	0.24	7.74	2085	**8.28**	21.58	2.31	24	410	0	0.02	4.6	0.09	0.71	0.03	<5	<5	0.01				<2	<1	<3	<3	<1	4.7	8.2	12	33	<0.50	<0.50	<0.50
R	LPB02P04	7/6/06	11:00	SGR	0.134	7.53	1694	7.78	**26.16**	2.16	36	330	0	0.05	2.1	0.19	1.3	0.1	<5	<5	0.01	**460,000**	1,000	1,300	**2,690**	<1	<3	<3	<1	0.71	8.4	8.5	**87**	<0.50	<0.50	0.8
R	LPB02P04	8/15/06		SGR	DRY																															
R	LWF23P07@SM	5/16/06	09:40	NB	0.05	8.06	2830	7.77	20.1	1.24	21	792	0	0.02	**7.5**	0.04	0.36	0.11	<5	<5	0.02	30,000	10,000	1,200	<2	<1	<3	<3	<1	<0.50	13	2.3	9.4	<0.50	<0.50	<0.50
R	LWF23P07@SM	7/13/06	08:40	NB	0.02	8.15	2420	7.83	**24.59**	1.01	23	645	0	0.06	2.1	0.02	**3.7**	0.07	<5	<5	0	42,000	12,000	12,000	<2	<1	<3	<3	<1	<0.50	12	1.7	8.9	<0.50	<0.50	<0.50
R	LWF23P07@SM	9/6/06	09:30	NB	0.075	8	2470	**8.63**	**25.96**	1.05	26	640	0	0	2.6	0.05	0.28	0.04	<5	<5	0	7,000	4,000	2,000	<2	<1	<3	<3	<1	<0.50	4.8	1.6	4.2	<0.50	<0.50	<0.50
T	LWF23P09XXX	5/16/06	10:30	NB	0.252	8.49	3988	7.54	19.6	0.59	27	288	0	0	3.8	0.06	1.1	0.1	<5	<5	0.01	31,000	14,000	2,200	<2	<1	<3	<3	<1	<0.50	36	2.4	9.3	<0.50	2.4	<0.50
T	LWF23P09XXX	6/14/06	09:20	NB	0.135	8.74	3661	7.23	19.61	1.39	23	1010	0	0.02	4.3	0.09	0.8	0.05	<5	<5	0.02	47,000	31,000	12,000	<2	<1	<3	<3	<1	<0.50	31	3.6	11	<0.50	2	<0.50
T	LWF23P09XXX	7/13/06	10:30	NB	0.128	8.78	3733	7.13	21.12	0.79	35	1155	0	0	3.8	0.07	1.16	0.07	7	<5	0	5,100	1,900	650	<2	<1	<3	<3	<1	<0.50	35	2.6	8.3	<0.50	2	<0.50
T	LWF23P09XXX	8/10/06	12:45	NB	0.3		3741	7.51	22.1	0.88	30	1005	0	0.06	3.5	0.05	0.98	**0.16**	<5	<5	0	8,000	2,600	400	7.6	<1	7.9	<3	<1	<0.50	20	4.1	8.7	<0.50	2	<0.50
T	LWF23P09XXX	9/6/06	10:50	NB	0.3	8.05	3542	**8.28**	22.53	0.97	32	980	0	0	3.5	0.05	1.16	0.07	<5	<5	0.02	22,000	3,100	100	<2	<1	<3	<3	<1	<0.50	19	3	5.6	<0.50	1.9	<0.50
T	ORGBGE07S03	5/23/06		SAR	DRY																															
T	ORGBGE07S03	5/26/06		SAR	DRY																															
T	ORGBGE07S03	5/31/06	08:40	SAR	0.004	13.27	717	8.06	19.75	1.36	19	185	0	0.83	1.6	0.14	1.06	0.04	<5	<5	0	120,000	1,500	16,000	<2	<1	<3	<3	<1	<0.50	4.5	3.2	32	<0.50	0.6	<0.50
T	ORGBGE07S03	6/27/06	08:20	SAR	0.036	**5.77**	834	7.97	23.36	13.2	22	255	0	0.14	1.8	0.06	1.23	0.02	7	<5	0.02	68,000	27,000	7,700	<2	<1	<3	<3	<1	0.52	7	3.9	35	<0.50	<0.50	<0.50
T	ORGBGE07S03	7/28/06	08:10	SAR	0.014	**5.23**	982	7.78	**25.75**	2.92	25	372	0	0	0.7	0.11	2.43	0.01	29	<5	0	**400,000**	**170,000**	**90,000**	<2	<1	**181**	<3	<1	0.5	6.2	5	**79**	<0.50	<0.50	<0.50
T	ORGBGE07S03	8/22/06	08:20	SAR	0.014	**3.06**	1166	8.27	23.08	9.32	20	340	0	0.56	1.4	0.1	1.02	0.02	11	<5	0	90,000	12,000	**77,000**	39.5	<1	<3	<3	<1	<0.50	5.2	5.4	34	<0.50	<0.50	<0.50
T	ORGBGE07S03	9/22/06	08:30	SAR	0.003	8.6	1628	**8.99**	21.36	5.52	**16**	225	0	0.16	2.2	0.01	2.2	0.01			0															
T	ORGKAT@E07	5/3/06		SAR	DRY																															
T	ORGKAT@E07	6/8/06		SAR	DRY																															
T	ORGKAT@E07	7/14/06		SAR	DRY																															
T	ORGKAT@E07	8/8/06		SAR	DRY																															
T	ORGKAT@E07	9/8/06		SAR	DRY																															
T	PLSE03S01@MJ	5/19/06	12:30	SAR		9.8	1357	7.8	21.54	3.78	24	275	0	0.21	2.8	0.09	1.83	0.03	<5	<5	0.04	65,000	33,000	4,900	<2	<1	<3	<3	<1	0.57	6.2	13	14	<0.50	<0.50	<0.50
T	PLSE03S01@MJ	5/23/06	12:30	SAR		9.8	1357	7.8	21.54	3.78	24	275	0	0.21	2.8	0.09	1.83	0.03			0.04															
T	PLSE03S01@MJ	6/21/06	12:05	SAR	0.095	9.94	1048	7.72	22.8	3.84	28	230	0	0.13	1.3	0.14	1.27	0.04	<5	<5	0.2	48,000	20,000	10,000	26.2	<1	21.7	<3	<1	1.1	5.9	10	12	<0.50	<0.50	<0.50
T	PLSE03S01@MJ	7/19/06	09:20	SAR	2.25	8.89	1080	7.84	**23.49**	3.04	23	270	0	0.1	1.4	0.08	2.17	0.03	11	<5	0	72,000	32,000	25,000	<2	<1	<3	<3	<1	0.68	6.1	6.8	10	<0.50	<0.50	<0.50
T	PLSE03S01@MJ	8/16/06	13:00	SAR	0.18	**5.68**	1035	7.62	21.86	**22.1**	26	350	0	0.24	1.9	0.2	1.41	0.02			0	65,000	6,200	4,900	22.7	<1	<3	<3	<1							
T	PLSE03S01@MJ	9/19/06	11:25	SAR	0.545	7.11	1404	7.8	20.62	2.17	22	400	0	0.17	2.7	0.2	1.96	0.05	<5	<5	0.02	64,000	18,000	14,000	<2	<1	<3	<3	<1	<0.50	4.4	6.2	11	<0.50	<0.50	<0.50

Dry Weather Reconnaissance Monitoring Data: 2005-06 SAR

Random or Targeted Site	Site Name	Date	Time	Watershed	Physicals								Chemical									Bacteria			Pesticides					Dissolved Metals						
					Discharge Rate	Dissolved Oxygen	Electrical Conductivity	pH	Water Temperature	Turbidity	Air Temperature	Hardness as $CaCO_3$	Phenols	Ammonia as N	Nitrate as N	Surfactsnats (MBAS)	Reactive Phosphorous	Total Chlorine	Total Suspended Solids (TSS)	Oil & Grease	Dissolved Copper	Dissolved Hexa Chrom.	Total Coliform	Fecal Coliform	Enterococcus	Diazinon	Chlorpyrifos	Malathion	Dimethoate	Disulfoton	Chromium	Nickel	Copper	Zinc	Silver	Cadmium	Lead
					cfs	mg/L	µS/cm		°C	NTU	°C	mg/L	mg/L										CFU/100mL			ng/L					µg/L						
	Outside Tolerance Interval					**6.11**		**7.03-8.2**	**23.44**	**16.7**	**18.14**		**0.01-0.0**	**1.16**	**5.3**	**0.45**	**2.92**	**0.13**	**78.08**				**330,000**	**106,000**	**55,000**	**271**	**10**	**57.4**	**10**			**88**	**15**	**75**		**9**	**2**
	Basin Plan Objective					5		6.5-9		20						0.5			75																	
	Warning Level based on Experience						6000		40				>0.02	0.65	10			1																		
	CTR Acute Criterion																													1708	1513	49.6	379	37.4	19.1	280
	CTR Chronic Criterion																													554	168	29.3	382		6.25	10.9
	LC_{50} for Toxicity Test Organism																								450	570	5,000	43,000								
T	SACC@F01	5/26/06	09:45	NB	0.002	7.46	322	**8.35**	18.94	9.63	20	115	0	**1.84**	1.8	0.13	2.38	0.01	33	<5	0.02				<2	<1	35.6	<3	<1	1.1	4.1	12	18	<0.50	<0.50	<0.50
T	SACC@F01	6/27/06	10:00	NB	0.002	7.54	363	8.13	22.07	2.72	25	125	0	0.11	1.1	0.01	1.7	0.04	6	<5	0	54,000	7,400	550	<2	<1	<3	<3	<1	1	3.1	5.3	14	<0.50	<0.50	0.57
T	SACC@F01	7/27/06	10:25	NB	0.003	8.19	831	8.12	**24.79**	2.88	26	180	0	0.34	**8**	0.07	**3.33**	0.06	7	<5	0	140,000	35,000	**58,000**	<2	<1	<3	<3	<1	<0.50	2.7	4.6	12	<0.50	<0.50	<0.50
T	SACC@F01	8/22/06	10:30	NB	0.009	6.46	694	**8.32**	**23.66**	14.4	23	195	0	**2.9**	1	**1.3**	**6.96**	0.03	17	<5	0.02	45,000	6,000	22,000	<2	<1	<3	<3	<1	0.76	6	**17**	34	<0.50	<0.50	0.67
T	SACC@F01	9/22/06	11:50	NB	0	8.53	762	**8.55**	21.84	3.2	20	325	0	0.12	0.4	0.01	1.47	0.01			0.01															
T	SB1EA@C01	5/18/06		AH/NB	DRY																															
T	SB1EA@C01	5/31/06	11:10	AH/NB	0.016	17.58	830	7.65	**23.98**	8.22	30	115	0	0.01	1.1	0.08	2.32	**0.16**	<5	<5	0.01	79,000	60,000	23,000	<2	<1	<3	<3	<1	0.52	3.7	11	46	<0.50	<0.50	0.75
T	SB1EA@C01	6/22/06	09:15	AH/NB		7.4	1268	7.21	21.99	7.64	25	245	0	0.11	2.7	0.19	1.16	0.08	12	<5	0.01	65,000	25,000	4,000	<2	<1	<3	<3	<1	<0.50	6.5	8.2	49	<0.50	<0.50	0.68
T	SB1EA@C01	7/28/06	09:30	AH/NB	0.057	6.25	1151	7.52	**26.97**	1.8	30	200	0	0.15	0.7	0.02	2.28	0.04	<5	<5	0	**670,000**	**400,000**	**120,000**	<2	<1	<3	<3	<1	0.6	4.9	8.1	27	<0.50	<0.50	<0.50
T	SB1EA@C01	8/17/06	09:00	AH/NB		6.78	1401	7.96	22.63	**24.6**	21	215	0	0.35	1.7	0	2.34	0.04	55	15	0.01	**360,000**	12,000	9,000	<2	<1	<3	<3	<1	0.5	2.9	4.7	12	<0.50	<0.50	<0.50
T	SB1EA@C01	9/20/06	08:50	AH/NB		6.9	1475	8.18	21.63	3.77	21	300	0	0.2	0.9	0.1	1.73	0.03			0	39,000	16,000	4,000	**388**	<1	<3	<3	<1							
T	SBMD@C01	5/18/06		AH/HB	DRY																															
T	SBMD@C01	6/22/06		AH/HB	DRY																															
T	SBMD@C01	7/28/06		AH/HB	DRY																															
T	SBMD@C01	8/17/06		AH/HB	DRY																															
T	SBMD@C01	9/20/06		AH/HB	DRY																															
T	STBB@PAC	5/25/06	09:15	AH/HB	0.017	9.17	333	**8.69**	19.63	4.56	22	85	0	0	0.7	0.36	0.51	0.06	7	<5	0.02	20,000	4,300	1,100	<2	<1	<3	<3	<1	0.64	11	**23**	45	<0.50	<0.50	1.9
T	STBB@PAC	6/20/06	12:10	AH/HB	0.001	8.2	1018	**8.67**	**24.1**	9.47	31	290	0	0	0.8	0.38	0.85	0.03	30	<5	0	**410,000**	**320,000**	5,000	<2	<1	<3	<3	<1	0.65	18	14	**110**	<0.50	<0.50	**2.9**
T	STBB@PAC	7/21/06		AH/HB	DRY																															
T	STBB@PAC	8/15/06		AH/HB	DRY																															
T	STBB@PAC	9/15/06		AH/HB	DRY																															
T	TTF07P01	5/19/06		NB	DRY																															
T	TTF07P01	6/15/06		NB	DRY																															
T	TTF07P01	7/18/06	08:40	NB	0.042	10.49	755	8.11	**26.12**	1	35	160	0	0.01	2.8	0.19	0.98	0.06	<5	<5	0	140,000	16,000	4,400	<2	<1	<3	<3	<1	<0.50	3.9	3.8	17	<0.50	<0.50	<0.50
T	TTF07P01	8/23/06	10:10	NB	0.024	7.05	916	8.16	**25.32**	1.53	30	255	0	0.35	3.9	0.1	1.48	0.06	<5	<5	0	84,000	30,000	4,700	<2	<1	<3	<3	<1	<0.50	7.1	9.2	27	<0.50	<0.50	0.51
T	TTF07P01	9/20/06	12:40	NB	0.053	8.28	830	7.99	**24.17**	2.99	30	200	0	0.11	3.4	0.1	1.59	0.06			0	220,000	59,000	8,000	<2	<1	<3	<3	<1							
R	TTF07P04	5/17/06	12:30	NB	0.024	10.18	696	**9.48**	**26.53**	4.85	21	192	0	0.05	**5.4**	0.14	0.86	0.06	10	<5	0.01	110,000	45,000	270	<2	<1	<3	<3	<1	<0.50	5.2	12	52	<0.50	<0.50	0.75
R	TTF07P04	7/18/06	09:50	NB	0.007	8.25	876	7.89	**25.46**	6.21	28	245	0	0.7	0.9	**0.51**	2.34	0.01	14	<5	0	**470,000**	**200,000**	4,300	<2	<1	<3	<3	<1	<0.50	7.4	5	17	<0.50	<0.50	0.52
R	TTF07P04	8/23/06	09:05	NB	0.003	**2.23**	906	7.96	**23.71**	4.33	23	285	0	0.25	3.4	0.41	1.11	0.06	9	<5	0	44,000	20,000	33,000	<2	<1	<3	<3	<1	<0.50	7.6	7.2	26	<0.50	<0.50	0.72
T	VPRCP@CYNCIR	5/18/06	12:30	SAR	0.054	9.44	806	8.17	18.54	5.52	24	340	0	0.04	1.5	0.01	0.72	0.04	<5	<5	0.03	28,000	19,000	2,500	<2	<1	<3	<3	<1	1.6	7.3	**32**	19	<0.50	<0.50	<0.50
T	VPRCP@CYNCIR	6/21/06	10:30	SAR	0.126	8.46	1015	**8.36**	21.73	1.97	27	355	0	0.1	1.8	0.07	1.29	0.04	8	<5	0.01	31,000	19,000	12,000	29.2	<1	35.3	<3	<1	<0.50	6.5	**23**	15	<0.50	<0.50	<0.50
T	VPRCP@CYNCIR	7/18/06	11:45	SAR	0.252	12.24	979	7.96	**24.2**	5.16	30	345	0	0.05	1.7	0.16	1.68	0.09	14	<5	0	83,000	79,000	9,500	70.1	<1	27.2	<3	<1	<0.50	2.8	5.1	12	<0.50	<0.50	<0.50
T	VPRCP@CYNCIR	8/16/06	10:40	SAR	0.08	**4.36**	1504	8.02	21.18	3.31	23	445	0	0.08	3.6	0.12	1.53	**0.25**			0	80,000	29,000	18,000	<2	<1	<3	<3	<1							
T	VPRCP@CYNCIR	9/19/06	09:50	SAR	0.33	8.59	1049	**8.31**	20.2	4.43	21	405	0	0.1	1.5	0.02	1.29	0.05	11	<5	0.02	110,000	8,000	**91,000**	<2	<1	25.5	<3	<1	<0.50	3.7	5.2	7	<0.50	<0.50	<0.50
T	WMC03HEFRCP	5/25/06	12:15	AH/HB	0.017	7.4	1578	7.73	19.6	0.36	22	530	0	0.03	**6**	0.07	0.53	0.05	15	<5	0	5,900	2,800	1,000	<2	<1	<3	<3	<1	0.73	5.1	4.1	8.3	<0.50	<0.50	<0.50
T	WMC03HEFRCP	6/20/06	11:15	AH/HB	0.012	7.39	1587	7.12	22.85	0.46	24	520	0	0.75	**6**	0.06	0.45	**0.15**	<5	<5	0.01	40,000	30,000	4,200	<2	<1	<3	<3	<1	0.68	6	2.9	5.8	<0.50	<0.50	<0.50
T	WMC03HEFRCP	7/21/06	10:55	AH/HB	0.037	11.18	1517	7.85	22.73	0.2	27	536	0	0.4	3.8	0.03	0.63	0.02	<5	<5	0	15,000	9,000	2,000	<2	<1	<3	<3	<1	0.83	0.92	3	9.5	<0.50	<0.50	<0.50
T	WMC03HEFRCP	8/15/06	10:03	AH/HB	0.027	**5.6**	1494	7.67	21.56	0.3	21	490	0	0.04	5.1	0	0.47	0.06	<5	<5	0	20,000	5,100	9,300	<2	<1	<3	<3	<1	0.85	0.89	4.7	3.8	<0.50	<0.50	<0.50
T	WMC03HEFRCP	9/15/06	10:20	AH/HB	0.021	7.45	1250	8.09	22.42	1.09	20	440	0	0	3.6	0.05	0.53	0.04	<5	<5	0.03	21,000	9,800	6,100	<2	<1	<3	<3	<1	0.7	2.3	2.6	5.4	<0.50	<0.50	<0.50
T	WMC04PASD	5/30/06	10:20	AH/HB	0.003	11.5	1184	**8.42**	**29.1**	5.02	25	505	0	0.25	2.7	0.09	0.93	0.04	7	<5	0.01	61,000	8,400	1,300	<2	<1	<3	<3	<1	1.7	9.1	15	**91**	<0.50	<0.50	0.71
T	WMC04PASD	6/20/06	10:30	AH/HB	0.003	6.24	1462	8.11	**25.01**	8.97	23	345	0	0.34	1.5	0.31	1.41	0.03	57	<5	0.01	37,000	20,000	20,000	<2	<1	<3	<3	<1	1.7	9.1	**26**	67	<0.50	<0.50	1.2
T	WMC04PASD	7/21/06		AH/HB	DRY																															
T	WMC04PASD	8/15/06		AH/HB	DRY																															
T	WMC04PASD	9/15/06		AH/HB	DRY																															
T	YLE01MIROUT	5/19/06	10:30	SAR	0.026	**4.9**	1636	7.51	18.9	2.53		165	0	0.17	0.9	0.38	1.22	0.02	7	18	0.02	**370,000**	**270,000**	16,000	<2	<1	<3	<3	<1	<0.50	4.8	6.9	**170**	<0.50	0.74	1.4
T	YLE01MIROUT	5/23/06	10:30	SAR	0.026	**4.9**	1636	7.51	18.9	2.53	25	165	0	0.17	0.9	0.38	1.22	0.02			0.02																
T	YLE01MIROUT	6/21/06	08:45	SAR	0.072	**4.72**	1847	7.64	20.39	3.03	22	195	0	**6.2**	0.6	0.21	**5.4**	0.05	7	<5	0	280,000	4,000	29,000	<2	<1	<3	<3	<1	<0.50	5.8	5	37	<0.50	<0.50	<0.50
T	YLE01MIROUT	7/19/06	08:40	SAR	0.074	6.34	1413	7.56	**23.65**	2.32	23	220	0	0.32	0.5	0.13	1.16	0.02	<5	<5	0	210,000	**150,000**	17,000	<2	<1	<3	<3	<1	<0.50	5.1	4	42	<0.50	<0.50	<0.50
T	YLE01MIROUT	8/16/06	08:30	SAR	0.158	**3.15**	1425	7.89	22.44	6.41	20	385	0	0.34	1.6	0.2	1.57	0.03			0	**450,000**	**140,000**	4,700	<2	<1	<3	<3	<1							
T	YLE01MIROUT	9/19/06	08:20	SAR	0.06	**5.85**	2763	**8.47**	18.86	2.96	**18**	390	0	0.56	1.2	0.1	0.89	0.02	9	<5	0.03	130,000	20,000	21,000	<2	<1	<3	<3	<1	<0.50	4.2	2.3	16	<0.50	<0.50	<0.50

Aqueous Chemistry at Landuse Monitoring Sites

			Field Measurements																																
			EC	pH	Temp	DO	Turbidity	Spec Conductance	pH	Nitrate as NO_3	Ammonia as N	TKN	Total Phosphorus as PO_4	Ortho Phosphate as P	TSS	VSS	OilAndGrease	SO4	Cl	TOC	DOC	Chlorpyrifos	Diazinon	Dimethoate	Malathion	Cd	Cr	Cu	Pb	Ni	Ag	Zn	Se	As	Hardness
Site	Date		uS		C	mg/L	NTU	µS		mg/L												ng/L				µg/L										mg/L
BORF20	4/4/06 14:51	ST	158	8.28	18.21	10.04	1040	171	7.45	13.6	0.7	1.5	9.53	0.9	2580	351		22.5	6.7	14	12	< 1	< 2	< 3	<3	11	13	46	22	43	<0.5	330	0.52		125
BORF20	4/4/06 14:51	SF																								<1	<8	13	<2	<4	<2	24			
HINF25d	7/13/05 8:30	DT	1407	9.15	21.14	16.14	10.5	1380	8.51	<0.4	<0.1	1	1.69	1.61	33	6						< 10	< 10	< 10	<10	0.89	2.1	17	3.5	12	<0.5	93	2.9		500
HINF25d	7/13/05 8:30	DF																								<0.5	0.82	18	<0.5	11	<0.5	5.3	1.4		
HINF25d	8/11/05 11:50	DT	961	9.25	29.7	13.88	39.2	1000	8.49	1	0.3	1.3	1.69	0.4	56	12						< 10	< 10	< 10	<10	<0.5	2.2	33	1.2	13	<0.5	15	1.4		472
HINF25d	8/11/05 11:50	DF																								0.69	1.2	8.3	<0.5	18	<0.5	15	0.92		
HINF25d	9/8/05 8:25	DT	1635	8.81	20.33	9.81	21.6	1640	6.57	2.3	0.4	2.8	1.81	0.17	113	29						< 10	< 10	< 10	<10	0.87	2.9	11	1.4	19	<0.5	21	1.2		530
HINF25d	9/8/05 8:25	DF																								<0.5	0.75	5.2	<0.5	9.3	<0.5	4.1	1.3		
HINF25d	10/6/05 8:30	DT	1282	8.18	17.79	11.63	10.2	1320	7.76	2.1	<0.1	1.4	0.77	0.12	24	3						< 10	< 10	< 10	<10	<0.5	1.2	6.3	<0.5	9.2	<0.5	11	1.5		845
HINF25d	10/6/05 8:30	DF																								<0.5	3.8	21	<0.5	15	<0.5	10	0.85		
HINF25d	11/10/05 9:30	DT	1118	8.64	17.48	9.62	18.5	1000	8	30.6	0.8	4.4	1.62	0.22	30	10						< 5	< 5	< 5	<5	<0.5	5.5	26	0.85	17	<0.5	19	1.1		410
HINF25d	11/10/05 9:30	DF																								<0.5	1.4	10	<0.5	9.8	<0.5	5.4	1.2		
HINF25d	12/20/05 10:30	DT	1504	8.43	15.25	17.74	18.2	1490	8.6	33.9	0.2	3.2	1.9	0.22	86	18						< 5	< 5	< 5	<5	0.61	2.8	15	1.3	15	<0.5	26	1.3		695
HINF25d	12/20/05 10:30	DF																					< 5	< 5		<0.5	1.3	8.4	<0.5	7.7	<0.5	8.5	1.1		
HINF25d	1/20/06 9:14	DT	1717	6.81	10.14	13.07	24.6	1710	7.88	213	13.1	16.9	2.16	0.65	26	6						< 5			<5	<0.5	2.1	11	0.75	8.2	<0.5	16	1.3		620
HINF25d	1/20/06 9:14	DF																								<0.5	2.3	1.9	<0.5	2.1	<0.5	5.2	0.8		
HINF25d	3/24/06 9:15	DT	714	7.9	17.39	9.75	24.3	734	7.73	2.8	<0.1	0.3	0.57	0.06	48	7	<5	120	79.1	2.6	3.3	< 1	< 2	< 3	<3	<0.5	2.8	4.4	0.9	2.9	<0.5	12	<0.5		170
HINF25d	3/24/06 9:15	DF																								<0.5	0.91	5.9	<0.5	3.6	<0.5	4.1	<0.5		
HINF25d	4/4/06 15:26	ST	375	8.1	17.74	10.4	374	360	6.98	23.6	0.6	1.3	5	0.41	640	82		80.2	15.6	22	19	< 1	< 2	< 3	<3	1.8	11	27	10	15	<0.5	110	<0.5		125
HINF25d	4/4/06 15:26	SF																								<0.5	2.2	9.1	<0.5	12	<0.5	10	0.94		
HINF25d	5/23/06 9:15	DT	834	7.71	17.86	7.8	32.9	882	7.52	17.7	0.19	4.32	4.93	0.75	68	23	<5	169	35.6	35	31	< 1	< 2	< 3	244	<0.5	4.1	13	1.4	14	<0.5	25	0.94		345
HINF25d	5/23/06 9:15	DF																								<0.5	3	14	<0.5	13	<0.5	10	1.1		
HINF25d	6/9/06 9:45	DT	1247	8.21	20.01	8.85	18.5	1180	8.03	59.5	1.83	5.75	2.64	0.61	22	5	<5	234	69.6	51	47	< 1	< 2	< 3	58.4	<0.5	3.8	17	0.7	14	<0.5	17	0.91		390
HINF25d	6/9/06 9:45	DF																								<1	<8	9.3	<2	<4	<2	10			
HINF25u	9/8/05 8:47		1510	8.69	22.94	9.25																< 10													790
HINF25u	4/4/06 15:05	ST	512	8.05	17.32	10.48	1100	498		37.6	0.9	1.8	6.43	0.83	1870	289		125	20.5	15	13	< 1	< 2	< 3	<3	3.7	28	81	60	36	<0.5	310	0.75		170
HINF25u	4/4/06 15:05	SF																								<1	<8	8.5	<2	<4	<2	44			
SASF10	7/13/05 11:20	DT	1990	8.89	26.48	21.37	2.4	1960	7.76	52.3	<0.1	<0.5	0.21	0.1	<5	<1						< 10	< 10	< 10	<10	0.58	0.92	3.3	0.86	8.2	<0.5	19	22		525
SASF10	7/13/05 11:20	DF																								<0.5	<0.5	3.4	<0.5	5.7	<0.5	12	25		
SASF10	8/11/05 14:38	DT	1863	8.86	30.88	27.46	3.5	1900	7.85	54.2	0.2	0.7	0.31	0.02	8	4						< 10	< 10	< 10	<10	<0.5	<0.5	5	0.62	6.1	<0.5	16	22		730
SASF10	8/11/05 14:38	DF																								<0.5	<0.5	1.3	<0.5	5.7	<0.5	11	20		
SASF10	9/8/05 10:29	DT	1913	8.66	23.41	16.5	1.11	1840	7.52	49.2	0.2	4.5	0.4	0.03	25	7						< 10			<10	<0.5	<0.5	2.7	0.7	5.7	<0.5	11	20		780
SASF10	9/8/05 10:29	DF																								<0.5	<0.5	1	<0.5	6.4	<0.5	7.3	26		
SASF10	10/6/05 11:15	DT	1986	7.12	22.78	21.85	1.51	2070	7.51	56	<0.1	0.9	0.32	<0.02	10	5						< 10	< 10	< 10	<10	<0.5	<0.5	1.6	<0.5	5.5	<0.5	16	21		1160
SASF10	10/6/05 11:15	DF																								<0.5	0.98	13	1.2	6.1	<0.5	71	1.3		
SASF10	11/10/05 13:00	ST	327	8.82	19.05	8.54	37.3	364	6.81	14.2	1.3	3.3	1.76	0.16	86	36						< 5			<5	<0.5	4.7	40	15	9.5	<0.5	190	1.8		200
SASF10	11/10/05 13:00	SF																					< 5	< 5		<0.5	<0.5	1.3	<0.5	7.8	<0.5	9.5	20		
SASF10	12/20/05 13:25	DT	1962	7.74	19.57	17.23	1.45	1900	7.45	54.9	<0.1	0.6	0.23	0.04	8	4						< 5	< 5	< 5	<5	<0.5	0.57	2.5	0.73	11	<0.5	13	24		775
SASF10	12/20/05 13:25	DF																								<0.5	<0.5	1.3	<0.5	10	<0.5	13	25		
SASF10	1/20/06 12:00	DT	2103	7.38	18.88	19.94	1.27	2380	7.58	58.5	<0.1	0.4	0.23	0.03	6	5						< 5	< 5	< 5	<5	<0.5	<0.5	2	<0.5	9	<0.5	14	25		900
SASF10	1/20/06 12:00	DF																								<0.5	<0.5	1.5	<0.5	7.3	<0.5	10	17		
SASF10	2/15/06 9:30	DT	1853	7.1	17.16	12.73	1.16	1750	7.45	49.3	<0.1	0.4	0.29	0.05	<5	<1	<5	432	130	2.4	2.8	< 5	< 5	< 5	<5	<0.5	<0.5	2.1	<0.5	7	<0.5	11	19		940
SASF10	2/15/06 9:30	DF																								<0.5	<0.5	1.5	<0.5	9	<0.5	7.1	23		
SASF10	3/24/06 12:10	DT	2096	7.77	25.59	24.34	0.6	2100	7.88	58.9	<0.1	0.4	0.13	<0.02	<5	<1	<5	496	148	2.6	2.5	< 1	< 2	< 3	<3	<0.5	<0.5	1.9	<0.5	8.9	<0.5	8.9	23		850
SASF10	3/24/06 12:10	DF																								<0.5	<0.5	6.2	<0.5	10	<0.5	28	20		
SASF10	4/4/06 13:00	ST	1888	7.44	19.15	12.43	9.02	1740	7.46	58.9	<0.1	0.4	0.27	0.03	8	2		455	122	10	8.8	< 1	< 2	< 3	<3	<0.5	0.91	8.6	1.1	10	<0.5	37	19		775
SASF10	4/4/06 13:00	SF																								<0.5	<0.5	3.3	<0.5	11	<0.5	27	20		
SASF10	5/23/06 11:30	DT	1883	7.33	24.6	13.18	2.01	1930	7.3	53.6	<0.1	0.88	0.29	0.05	<5	<1	<5	463	123	6	6	< 1	< 2	< 3	<3	2.8	<0.5	4.4	<0.5	11	<0.5	28	21		1110
SASF10	5/23/06 11:30	DF																								<0.5	<0.5	2.9	<0.5	8.7	<0.5	11	20		
SASF10	6/9/06 11:45	DT	2034	7.5	23.38	15.88	1.38	1960	7.54	53.1	<0.1	0.86	0.32	0.02	4	1	<5	513	140	6.2	6.1	< 1	< 2	< 3	<3	<0.5	<0.5	3.7	<0.5	8.5	<0.5	12	22		1130

Aqueous Chemistry at Landuse Monitoring Sites

			Field Measurements																																		
			EC	pH	Temp	DO	Turbidity	Spec Conductance	pH	Nitrate as NO_3	Ammonia as N	TKN	Total Phosphorus as PO_4	Ortho Phosphate as P	TSS	VSS	OilAndGrease	SO4	Cl	TOC	DOC	Chlorpyrifos	Diazinon	Dimethoate	Malathion	Cd	Cr	Cu	Pb	Ni	Ag	Zn	Se	As	Hardness
Site	Date		uS		C	mg/L	NTU	µS		mg/L												ng/L				µg/L										mg/L
SASF10	6/9/06 11:45	DF																								<1	<8	2.7	<2	<4	<2	<10			
SCIL1E08	8/11/05 10:24	DT	940	8.96	22.78	10.34	0.6	921	8.03	0.6	0.2	<0.2	<0.06	<0.02	< 5	< 1						< 10	< 10	< 10	< 10	<0.5	<0.5	0.6	<0.5	3.7	<0.5	3.6	1.1	1	
SCIL1E08	8/11/05 10:24	DF																								<0.5	<0.5	0.62	<0.5	3.1	<0.5	2.4	0.89	0.9	
SCIL1E08	9/9/05 10:00	DT	998	7.63	19.2	9.12	35	981	7.66	<0.4	0.2	1.8	<0.06	<0.02	< 5	< 1						< 10	< 10	< 10	< 10	<0.5	<0.5	0.56	<0.5	3.2	<0.5	< 2	0.86	0.92	
SCIL1E08	9/9/05 10:00	DF																								<0.5	<0.5	0.58	<0.5	3.7	<0.5	2.7	0.57	0.89	
SCIL1E08	10/7/05 9:55	DT	1010	7.84	18.01	11.38	0.37	1080	7.37	<0.4	<0.1	0.2	<0.06	<0.02	< 5	< 1						< 10	< 10	< 10	< 10	<0.5	<0.5	<0.5	<0.5	3.6	<0.5	< 2	<0.5	1.3	
SCIL1E08	10/7/05 9:55	DF																								<0.5	<0.5	<0.5	<0.5	3.5	<0.5	< 2	<0.5	1.2	
SCIL1E08	11/10/05 10:23	DT					0.3	1000	7.88	<0.4	0.1	0.2	<0.06	<0.02	< 5	< 1						< 5	< 5	< 5	< 5	<0.5	<0.5	0.7	<0.5	3.9	<0.5	3	<0.5		
SCIL1E08	11/10/05 10:23	DF																								<0.5	<0.5	0.68	<0.5	3.5	<0.5	2.4	<0.5		
SCIL1E08	12/15/05 10:45	DT	998	7.99	14.25	11.27	0.32	1020	7.93	<0.4	<0.1	0.2	<0.06	<0.02	< 5	< 1						< 5	< 5	< 5	< 5	<0.5	<0.5	<0.5	<0.5	4.2	<0.5	< 2	<0.5	1	
SCIL1E08	12/15/05 10:45	DF																								<0.5	<0.5	<0.5	<0.5	4.2	<0.5	< 2	<0.5	0.86	
SCIL1E08	1/17/06 9:30	DT	1032	7.33	1126	12.6	0.28	920	7.96	<0.4	<0.1	<0.2	<0.06	<0.02	< 5	< 1						< 5	< 5	< 5	< 5	<0.5	<0.5	<0.5	<0.5	3.1	<0.5	2.3	<0.5	0.66	
SCIL1E08	1/17/06 9:30	DF																								<0.5	<0.5	<0.5	<0.5	3.5	<0.5	2.4	0.55	0.63	
SCIL1E08	2/16/06 10:00	DT	978	7.57	12.98	12.19	0.41	1020	8.01	<0.4	<0.1	<0.2	<0.06	<0.02	< 5	< 1	< 5	291	30	1.5	1.7	< 5	< 5	< 5	< 5	<0.5	<0.5	1.2	<0.5	4.2	<0.5	4	0.68		
SCIL1E08	2/16/06 10:00	DF																								<0.5	<0.5	0.68	<0.5	4.4	<0.5	3.1	0.7		
SCIL1E08	3/30/06 10:30	DT	964	7.78	15.33	11.22	4.77	1000	8.07	0.5	<0.1	<0.2	<0.06	<0.02	13	2	< 5	245	23.2	2.1	2.3	< 1	< 2	< 3	< 3	<0.5	<0.5	1.1	<0.5	5	<0.5	3.1	1.4	0.6	
SCIL1E08	3/30/06 10:30	DF																								<0.5	<0.5	0.86	<0.5	4.9	<0.5	2.1	1.2	0.54	
SCIL1E08	4/4/06 13:38	DT	987	7.81	17.34	11.32	0.84	945	7.94	<0.4	<0.1	<0.2	0.08	<0.02	< 5	< 1		265	26	2.1	1.8	< 1	< 2	< 3	< 3	<0.5	<0.5	0.8	<0.5	5.3	<0.5	3.5	1.2	0.65	
SCIL1E08	4/4/06 13:38	DF																								<0.5	<0.5	0.54	<0.5	5.2	<0.5	3.3	1.4	0.64	
SCIL1E08	5/25/06 8:30	DT	1039	8.07	18.28	10.45	0.34	1040	8.33	<0.4	<0.1	<0.2	<0.06		< 5	< 1	< 5	257	25.3	1.1	1.2	< 1	< 2	< 3	< 3	<0.5	<0.5	0.98	<0.5	6.9	<0.5	3.1	0.88	1	
SCIL1E08	5/25/06 8:30	DF																								<0.5	<0.5	1	<0.5	11	<0.5	4.4	0.79	0.89	
SCIL1E08	6/8/06 9:00	DT	994	8.08	18.76	9.97	0.36	978	8.17	<0.4	<0.1	<0.2	<0.06	<0.02	< 5	< 1	< 5	260	25.9	1.7	1.6	< 1	< 2	< 3	< 3	<0.5	<0.5	0.72	<0.5	5.6	<0.5	2.2	0.75	0.88	
SCIL1E08	6/8/06 9:00	DF																								<0.5	<0.5	0.64	<0.5	5.7	<0.5	2.4	0.56	0.83	
SCIL2E08	3/30/06 11:00	DT	683	8.06	16.17	10.74	1.2	685	8.04	0.5	<0.1	<0.02	<0.06	<0.2	< 5	< 1	< 5	116	17.9	1.8	1.9	< 1	< 2	< 3	< 3	<0.5	<0.5	0.67	<0.5	3.4	<0.5	< 2	<0.5		1.3
SCIL2E08	3/30/06 11:00	DF																								<0.5	<0.5	0.64	<0.5	3.3	<0.5	2	<0.5		1
SCIL2E08	4/4/06 14:05	DT	667	8.19	17.5	11.62	0.48	624	8.15	<0.4	<0.1	<0.02	<0.06	<0.2	< 5	< 1		122	20	1.8	2.1	< 1	< 2	< 3	< 3	<0.5	<0.5	<0.5	<0.5	3.4	<0.5	3	<0.5		1.1
SCIL2E08	4/4/06 14:05	DF																								<0.5	<0.5	<0.5	<0.5	3.4	<0.5	3.1	<0.5		0.92
SCIL2E08	5/25/06 8:00	DT	829	8.15	16.13	10.01	0.3	811	8.46	0.58	<0.1		<0.06	<0.2	< 5	< 1	< 5	148	22.1	1	1.3	< 1	< 2	< 3	< 3	<0.5	<0.5	1.2	<0.5	4.4	<0.5	2.7	0.51		1.1
SCIL2E08	5/25/06 8:00	DF																								<0.5	<0.5	0.81	<0.5	4.2	<0.5	2.3	0.5		1
SCIL2E08	6/8/06 9:35	DT	751	8.35	20.11	11.42	0.3	729	8.26	<0.4	<0.1	<0.02	<0.06	<0.2	< 5	< 1	< 5	155	22.8	1.4	1.4	< 1	< 2	< 3	< 3	<0.5	<0.5	0.52	<0.5	4	<0.5	< 2	0.57		0.78
SCIL2E08	6/8/06 9:35	DF																								<0.5	<0.5	<0.5	<0.5	4.1	<0.5	< 2	0.55		0.81
SJQF14d	7/13/05 10:00	DT	2334	9.14	24.15	11.63	6.8	2280	8.31	17.3	<0.1	1.2	0.21	<0.06	18	5						< 10	< 10	< 10	<10	0.64	1.1	3.9	1.1	9.8	<0.5	22	5		710
SJQF14d	7/13/05 10:00	DF																								<0.5	<0.5	3	<0.5	6.5	<0.5	5.1	6.3		
SJQF14d	8/11/05 14:14	DT	1574	9.17	28.06	10.04	2.83	2120	8.51	16.4	0.3	1.6	0.2	<0.02	15	7						< 10	< 10	< 10	<10	<0.5	0.51	3.8	<0.5	6.8	<0.5	8.5	4.5		680
SJQF14d	8/11/05 14:14	DF																								<0.5	0.65	4.5	<0.5	7.1	<0.5	5.1	2.5		
SJQF14d	12/20/05 12:20	DT	1233	9.5	14.82	21.19	39.3	1550	8.95	681	0.3	5.3	3.01	<0.02	1160	62						< 5	< 5	< 5	<5	<0.5	4.2	8.3	<0.5	11	<0.5	29	3.4		535
SJQF14d	12/20/05 12:20	DF																								<0.5	0.79	4.1	<0.5	6.8	<0.5	<2	1.8		
SJQF14d	1/20/06 10:55	DT	903	8.84	12.99	14.82	5.95	1560	8.81	23.6	<0.1	1.2	0.95	<0.02	18	13						< 5	< 5	< 5	<5	<0.5	0.92	5.1	<0.5	6.8	<0.5	8.3	1.9		470
SJQF14d	1/20/06 10:55	DF															<5									<0.5	11	4.5	<0.5	3.3	<0.5	3.5	1.7		
SJQF14d	3/24/06 11:10	DT	598	10.06	26.47	11.31	2.71	591	10.12	<0.4	<0.1	0.9	0.37	<0.02	8	4		99.7	66.7	7.4	6.7	< 1	< 2	< 3	<3	<0.5	11	4.6	<0.5	3.2	<0.5	8.7	1.3		225
SJQF14d	3/24/06 11:10	DF																								<0.5	2.1	10	<0.5	2.5	<0.5	6.4	<0.5		
SJQF14d	4/4/06 14:00	ST	217	9.53	20.34	10.72	55	195	8.42	4.5	0.6	0.9	0.97	0.02	214	62		26.8	12.3	13	11	< 1	< 2	< 3	<3	<0.5	5.4	34	16	5.8	<0.5	160	<0.5		110
SJQF14d	4/4/06 14:00	SF															<5									<0.5	0.93	5	<0.5	4.4	<0.5	3.8	1.8		
SJQF14d	5/23/06 10:30	DT	770	9.27	25.57	12.75	4.93	770	9.12	13.3	0.15	0.92	0.54	0.22	5	3		141	81.1	11	10	< 1	< 2	< 3	23	<0.5	1.1	5.1	<0.5	4.4	<0.5	7.6	1.9		295
SJQF14d	5/23/06 10:30	DF															<5									<0.5	<0.5	6.5	<0.5	6.9	<0.5	15	3.3		
SJQF14d	6/9/06 10:40	DT	1565	9.14	20.18	9.76	5.25	1510	9	13.6	0.24	2.26	1.25	0.18	17	9		304	209	14	13	< 1	< 2	< 3	<3	<0.5	0.63	7.4	<0.5	6.8	<0.5	20	3.3		445
SJQF14d	6/9/06 10:40	DF																								1.1	<8	7.2	<2	6.9	<2	<10			
SJQF14u	7/13/05 9:30	DT	3238	8.61	19.67	5.47	16.4	3340	7.46	<0.4	<0.1	1.2	1.19	0.17	91	26						< 10	< 10	< 10	<10	0.92	2.2	9.6	1.9	29	<0.5	51	1.2		1350
SJQF14u	7/13/05 9:30	DF																								<0.5	<0.5	1.3	<0.5	22	<0.5	4.2	0.63		
SJQF14u	11/10/05 10:45	DT	4265	8.18	16.99	7.29	5.6	5000	7.33	<0.4	0.1	1.6	1.19	0.05	83	25						< 5	< 5	< 5	<5	<0.5	1.3	2	0.6	26	<0.5	9	<0.5		1500

Aqueous Chemistry at Landuse Monitoring Sites

			Field Measurements																																
			EC	pH	Temp	DO	Turbidity	Spec Conductance	pH	Nitrate as NO_3	Ammonia as N	TKN	Total Phosphorus as PO_4	Ortho Phosphate as P	TSS	VSS	OilAndGrease	SO4	Cl	TOC	DOC	Chlorpyrifos	Diazinon	Dimethoate	Malathion	Cd	Cr	Cu	Pb	Ni	Ag	Zn	Se	As	Hardness
Site	Date		uS		C	mg/L	NTU	µS		mg/L												ng/L				µg/L									mg/L
SJQF14u	11/10/05 10:45	DF																								<0.5	<0.5	0.68	<0.5	20	<0.5	<2	<0.5		
SJQF14u	12/20/05 11:40	DT	3696	7.46	14.68	7.67	6.41	3660	7.13	<0.4	<0.1	1.2	0.83	0.03	68	22						< 5	< 5	< 5	<5	<0.5	1.4	2	0.57	32	<0.5	10	<0.5		1395
SJQF14u	12/20/05 11:40	DF																								<0.5	<0.5	<0.5	<0.5	22	<0.5	2.9	<0.5		
SJQF14u	1/20/06 10:30	DT	3818	6.22	10.94	9.61	84.9	4210	7.12	<0.4	0.2	0.6	2.91	<0.02	84	17						< 5	< 5	< 5	<5	<0.5	1.2	0.92	0.51	22	<0.5	6.3	0.59		1420
SJQF14u	1/20/06 10:30	DF															<5									<0.5	<0.5	0.91	<0.5	16	<0.5	2.1	<0.5		
SJQF14u	2/15/06 11:15	DT	3489	6.82	15.02	8.61	8.3	3470	7.3	<0.4	<0.1	0.6	0.98	0.04	18	6		587	513	7.4	8.8	< 5	< 5	< 5	<5	<0.5	0.57	<0.5	<0.5	18	<0.5	4.3	<0.5		1305
SJQF14u	2/15/06 11:15	DF															<5									<0.5	<0.5	0.82	<0.5	17	<0.5	2.6	<0.5		
SJQF14u	3/24/06 10:25	DT	3429	7.27	17.76	24.34	9.66	3600	7.37	<0.4	0.3	0.5	0.92	0.03	22	6		555	477	6.6	6.8	< 1	< 2	< 3	<3	<0.5	<0.5	0.95	<0.5	17	<0.5	3.6	<0.5		1200
SJQF14u	3/24/06 10:25	DF																								<0.5	<0.5	1	<0.5	16	<0.5	4.7	<0.5		
SJQF14u	4/4/06 14:25	ST	2863	7.28	16.46	7.26	9.49	2850	7.47	<0.4	<0.1	0.5	0.5	0.04	5	3		481	399	18	17	< 1	< 2	< 3	<3	<0.5	<0.5	1.1	<0.5	17	<0.5	4.9	<0.5		1020
SJQF14u	4/4/06 14:25	SF																								<1	<8	5.7	<2	<4	<2	27			
TABF09	7/13/05 10:45	DT	2476	9.06	26.2	11.58	25.5	2400	7.98	6.4	<0.1	0.8	0.25	<0.02	30	6						< 10	< 10	< 10	<10	0.63	1.5	15	1.5	10	<0.5	100	16		880
TABF09	7/13/05 10:45	DF																								<0.5	<0.5	2.4	<0.5	8.2	<0.5	5.4	25		
TABF09	8/11/05 14:49	DT	2885	8.98	30.98	17.34	18.4	2950	7.99	8.5	0.3	1.4	0.25	<0.02	29	11						< 10	< 10	< 10	<10	<0.5	<0.5	3.3	0.5	8.5	<0.5	11	19		1125
TABF09	8/11/05 14:49	DF																								<0.5	<0.5	2.4	<0.5	8	<0.5	11	13		
TABF09	9/8/05 10:57	DT	2830	8.75	23.85	7.5	1.79	2720	7.18	11.6	0.3	0.9	0.51	0.04	20	7						< 10	< 10	< 10	<10	<0.5	<0.5	3.8	<0.5	8.4	<0.5	15	11		960
TABF09	9/8/05 10:57	DF																								<0.5	<0.5	1.3	<0.5	8.9	<0.5	16	5.5		
TABF09	10/6/05 10:45	DT	1947	7.36	20.4	9.32	11.9	2080	7.67	<0.4	<0.1	1.2	0.53	<0.02	33	14						< 10	< 10	< 10	<10	<0.5	0.75	3.2	0.98	11	<0.5	26	4		980
TABF09	10/6/05 10:45	DF																								<0.5	4.1	30	7.6	7.2	<0.5	150	0.64		
TABF09	11/10/05 12:30	DT	242	8.87	18.91	8.46	56.5	256	7.16	7.2	1	2.3	1.52	0.12	94	29						< 5	< 5	< 5	<5	0.55	4.8	33	8.8	7.5	<0.5	180	0.78		250
TABF09	11/10/05 12:30	DF																								<0.5	<0.5	1.9	<0.5	8.8	<0.5	22	5.3		
TABF09	12/20/05 13:00	DT	2287	8.26	13.65	15.01	3.76	2180	7.97	5.9	<0.1	0.6	0.16	<0.02	8	3						< 5	< 5	< 5	<5	<0.5	<0.5	2.9	0.53	11	<0.5	26	5.6		780
TABF09	12/20/05 13:00	DF																								<0.5	<0.5	2	<0.5	12	<0.5	17	19		
TABF09	1/20/06 11:30	DT	2978	6.94	11.97	15.03	3.91	3580	7.89	23.9	<0.1	0.7	0.13	<0.02	9	2						< 5	< 5	< 5	<5	<0.5	<0.5	3.1	0.58	12	<0.5	24	20		1113
TABF09	1/20/06 11:30	DF															<5									<0.5	<0.5	2.3	<0.5	13	<0.5	11	24		
TABF09	2/15/06 10:15	DT	3429	7.39	15.65	11.54	3.52	3320	7.77	29.4	<0.1	0.8	0.21	<0.02	8	2		1350	234	5.5	5.1	< 5	< 5	< 5	<5	<0.5	<0.5	3.7	<0.5	11	<0.5	14	25		1250
TABF09	2/15/06 10:15	DF															<5									<0.5	<0.5	2	<0.5	7.8	<0.5	6.6	14		
TABF09	3/24/06 12:50	DT	2320	7.98	21.08	13.28	7.62	2220	7.26	14.7	<0.1	0.7	0.17	<0.02	9	2		774	128	5.3	5.1	< 1	< 2	< 3	<3	<0.5	<0.5	2.7	0.51	8	<0.5	11	13		725
TABF09	3/24/06 12:50	DF																								<0.5	<0.5	3.2	<0.5	13	<0.5	19	25		
TABF09	4/4/06 13:30	ST	2654	8.01	17.42	12.02	110	2810	7.78	41.3	0.1	1	0.68	<0.02	175	28		1030	170	9.9	8.8	< 1	< 2	< 3	<3	0.5	3.9	16	5.3	16	<0.5	96	27		1120
TABF09	4/4/06 13:30	SF															<5									<0.5	<0.5	3.5	<0.5	10	<0.5	20	15		
TABF09	5/23/06 11:05	DT	1815	7.72	23.1	7.6	15.2	1850	7.39	7.26	0.18	0.96	0.29	<0.02	20	6		678	92.8	13	12	< 1	< 2	< 3	<3	<0.5	1	5.8	0.8	11	<0.5	30	16		745
TABF09	5/23/06 11:05	DF															<5									<0.5	<0.5	1.8	<0.5	13	<0.5	11	38		
TABF09	6/9/06 11:15	DT	3264	7.97	22.03	11.71	8.65	3280	7.95	21.5	0.18	0.84	0.38	<0.02	16	8		1280	212	5.6	5.5	< 1	< 2	< 3	<3	<0.5	<0.5	2.8	<0.5	13	<0.5	17	36		1320
TABF09	6/9/06 11:15	DF																																	

Priority Pollutants in Stormwater - Newport Bay Watershed

		Site	BARSED	CMCG02	CICF25	HCWF27	SADF01	SDMF05	WYLSED
		Date	9/20/05	9/20/05	9/20/05	12/13/05	9/20/05	9/20/05	9/20/05
		Start Time	13:34	15:15	13:12	8:08	14:45	14:16	13:50
		Length of Composite Period	hrs	grab	grab	grab	24.0	grab	grab	grab
Acid Extractable Compounds									
2,4,6-Trichlorophenol	ng/L		< 50	< 50	< 50		< 50	< 50	< 50
2,4-Dichlorophenol	ng/L		< 50	< 50	< 50		< 50	< 50	< 50
2,4-Dimethylphenol	ng/L		< 100	235	253		< 100	< 100	< 100
2,4-Dinitrophenol	ng/L		< 100	< 100	1000		< 100	< 100	< 100
2-Chlorophenol	ng/L		< 50	< 50	< 50		< 50	< 50	< 50
2-Nitrophenol	ng/L		< 100	< 100	e149		< 100	< 100	< 100
4-Nitrophenol	ng/L		< 100	< 100	< 100		< 100	< 100	< 100
Pentachlorophenol	ng/L		< 50	208	166		257	< 50	< 50
Phenol	ng/L		< 100	489	232		491	< 100	< 100
Base/Neutral Extractable Compounds									
1,2,4-Trichlorobenzene	ng/L		< 10	< 10	< 10		< 10	< 10	< 10
1,2-Dichlorobenzene	ng/L		< 10	< 10	< 10		e46.4	< 10	< 10
1,3-Dichlorobenzene	ng/L		< 10	< 10	< 10		< 10	< 10	< 10
1,4-Dichlorobenzene	ng/L		< 10	< 10	< 10		< 10	< 10	< 10
2-Chloronaphthalene	ng/L		< 50	< 50	< 50		< 50	< 50	< 50
2,4-Dinitrotoluene	ng/L		< 50	< 50	< 50		< 50	< 50	< 50
2,6-Dinitrotoluene	ng/L		< 50	< 50	< 50		< 50	< 50	< 50
3,3'-Dichlorobenzidine	ng/L		< 50	< 50	< 50		< 50	< 50	< 50
4-Bromophenyl phenyl ether	ng/L		< 50	< 50	< 50		< 50	< 50	< 50
4-Chlorophenyl phenyl ether	ng/L		< 50	< 50	< 50		< 50	< 50	< 50
Benzidine	ng/L		< 50	< 50	< 50		< 50	< 50	< 50
Bis(2-Chloroethoxy)methane	ng/L		< 50	< 50	< 50		< 50	< 50	< 50
Bis(2-chloroethyl)ether	ng/L		< 50	< 50	< 50		< 50	< 50	< 50
Bis(2-chloroisopropyl)ether	ng/L		< 50	< 50	< 50		< 50	< 50	< 50
Hexachlorobenzene	ng/L		< 1	< 1	< 1		< 1	< 1	< 1
Hexachlorobutadiene	ng/L		< 50	< 50	< 50		< 50	< 50	< 50
Hexachlorocyclopentadiene	ng/L		< 50	< 50	< 50		< 50	< 50	< 50
Hexachloroethane	ng/L		< 50	< 50	< 50		< 50	< 50	< 50
Isophorone	ng/L		< 50	< 50	< 50		< 50	< 50	< 50
Nitrobenzene	ng/L		< 50	< 50	< 50		< 50	< 50	< 50
N-Nitrosodi-n-propylamine	ng/L		< 50	< 50	< 50		< 50	< 50	< 50
N-Nitrosodiphenylamine	ng/L		< 50	< 50	< 50		< 50	< 50	< 50
Polynuclear Aromatic Hydrocarbons									
Acenaphthene	ng/L		< 5	<1	<1	< 1	<1	< 1	< 1
Acenaphthylene	ng/L		< 5	10.1	<1	< 1	< 1	< 1	< 1
Anthracene	ng/L		< 5	13.3	<1	< 1	66.8	< 1	< 1
Chrysene	ng/L		66.4	108	164	< 1	804	< 1	< 1
Fluoranthene	ng/L		46.3	160	113	e 1.7	1310	< 1	< 1
Fluorene	ng/L		13.8	9.6	<1	< 1	28.4	< 1	< 1
Indeno[1,2,3-c,d]pyrene	ng/L		28.3	51.8	57.2	< 1	357	< 1	< 1
Naphthalene	ng/L		< 1	47.1	27.7	6.7	76.8	< 1	< 1
Phenanthrene	ng/L		26.2	86.1	97.2	< 1	491	< 1	< 1
Pyrene	ng/L		64.8	146	208	e 3.6	1240	< 1	< 1
Phthalates									
Bis(2-ethylhexyl) phthalate	ng/L		2430	3480	8700		13000	1010	633
Butyl benzyl Phthalate	ng/L		131	732	1210		2350	102	110
Diethyl phthalate	ng/L		273	445	769		210	266	227
Dimethyl phthalate	ng/L		71.7	254	256		396	68.5	62.1
Di-n-butyl phthalate	ng/L		103	263	442		617	101	125
Di-n-octyl phthalate	ng/L		248	631	1650		1920	46.8	20.7

Priority Pollutants in Stormwater - Newport Bay Watershed

	Site	BARSED	CMCG02	CICF25	HCWF27	SADF01	SDMF05	WYLSED
	Date	9/20/05	9/20/05	9/20/05	12/13/05	9/20/05	9/20/05	9/20/05
	Start Time	13:34	15:15	13:12	8:08	14:45	14:16	13:50
	Length of Composite Period hrs	grab	grab	grab	24.0	grab	grab	grab
Metals								
Ag	ug/L		< .5	< .5	< 0.5	0.64	< .5	< .5
Ag (Dissolved)	ug/L		< .5	< .5	< 0.5	< .5	< .5	< .5
As	ug/L							
As (Dissolved)	ug/L							
Be	ug/L							
Be (Dissolved)	ug/L							
Cd	ug/L		0.51	< .5	< 0.5	2.1	0.64	< .5
Cd (Dissolved)	ug/L		< .5	< .5	< 0.5	< .5	< .5	< .5
Cr	ug/L		4.6	4.7	0.5	17	2.8	1.6
Cr (Dissolved)	ug/L		2.5	2	< 0.5	2.5	2	0.88
Cu	ug/L		66	55	7.7	180	15	10
Cu (Dissolved)	ug/L		47	39	7.8	29	8.4	6.8
Hg	ug/L			19				
Hg (Dissolved)	ug/L							
Ni	ug/L		13	17	4.7	31	15	15
Ni (Dissolved)	ug/L		11	5.7	4.6	17	15	13
Pb	ug/L		14	1.3	< 0.5	57	1.7	0.96
Pb (Dissolved)	ug/L		4.7	1.7	< 0.5	4.4	0.6	< .5
Sb	ug/L							
Sb (Dissolved)	ug/L							
Se	ug/L		< .5	170	0.98	2.2	15	3.6
Se (Dissolved)	ug/L		< .5	1.6	1	1.2	16	3.7
Tl	ug/L							
Tl (Dissolved)	ug/L							
Zn	ug/L		360	100	7.9	870	65	32
Zn (Dissolved)	ug/L		260	1.7	7.9	220	50	21
Cyanide	mg/L							
Organochlorine Pesticides and PCB Arochlors								
4,4'-DDD	ng/L	< 1	< 1	< 1	< 1	< 1	< 1	< 1
4,4'-DDE	ng/L	< 1	< 1	< 1	< 1	< 1	< 1	< 1
4,4'-DDT	ng/L	< 1	< 1	< 1	< 1	< 1	< 1	< 1
Aldrin	ng/L	< 1	< 1	< 1	< 1	< 1	< 1	< 1
Dieldrin	ng/L	< 1	< 1	< 1	< 1	< 1	< 1	< 1
Endrin	ng/L	< 1	< 1	< 1	< 1	< 1	< 1	< 1
Endrin aldehyde	ng/L	< 1	< 1	< 1	< 1	< 1	< 1	< 1
Heptachlor	ng/L	< 1	< 1	< 1	< 1	< 1	< 1	< 1
Heptachlor Epoxide	ng/L	< 1	< 1	< 1	< 1	< 1	< 1	< 1
PCB-1016	ng/L	10	10	10		10	10	10
PCB-1221	ng/L	< 10	< 10	< 10		< 10	< 10	< 10
PCB-1232	ng/L	< 10	< 10	< 10		< 10	< 10	< 10
PCB-1242	ng/L	< 10	< 10	< 10		< 10	< 10	< 10
PCB-1248	ng/L	< 10	< 10	< 10		< 10	< 10	< 10
PCB-1254	ng/L	< 10	< 10	< 10		< 10	< 10	< 10
PCB-1260	ng/L	< 10	< 10	< 10		< 10	< 10	< 10
Toxaphene	ng/L	< 10	< 10	< 10	< 10	< 10	< 10	< 10

Priority Pollutants in Stormwater - North Orange County Watersheds

Site		BCC02	BCC02	BCC02	EGWC05	EGWC05	EGWC05
Date		5/22/06	5/22/06	5/23/06	5/22/06	5/22/06	5/23/06
Start Time		2:11	5:11	11:11	1:37	4:37	12:37
Length of Composite Period	hrs	1.0	28.0	22.0	1.0	30.0	22.0
Acid Extractable Compounds							
2,4,6-Trichlorophenol	ng/L	< 50	< 50	< 50	< 50	< 50	< 50
2,4-Dichlorophenol	ng/L	< 50	< 50	< 50	< 50	< 50	< 50
2,4-Dimethylphenol	ng/L	< 100	< 100	< 100	< 100	< 100	< 100
2,4-Dinitrophenol	ng/L	< 100	< 100	< 100	< 100	< 100	< 100
2-chlorophenol	ng/L	< 50	< 50	< 50	< 50	< 50	< 50
2-Nitrophenol	ng/L		< 100	< 100		420.3	< 100
4-Nitrophenol	ng/L	< 100	< 100	< 100	< 100	< 100	< 100
Pentachlorophenol	ng/L	< 50	< 50	< 50	< 50	e 69.1	< 50
Phenol	ng/L	e 131	< 100	< 100	e 159	< 100	< 100
Base/Neutral Extractable Compounds							
1,2,4-Trichlorobenzene	ng/L	< 10	< 10	< 10	< 10	< 10	< 10
1,2-Dichlorobenzene	ng/L	< 10	< 10	< 10	< 10	< 10	< 10
1,3-Dichlorobenzene	ng/L	< 10	< 10	< 10	< 10	< 10	< 10
1,4-Dichlorobenzene	ng/L	< 10	< 10	< 10	< 10	< 10	< 10
2,4-Dinitrotoluene	ng/L	< 50	< 50	< 50	< 50	< 50	< 50
2,6-Dinitrotoluene	ng/L	< 50	< 50	< 50	< 50	< 50	< 50
2-Chloronaphthalene	ng/L	< 50	< 50	< 50	< 50	< 50	< 50
3,3'-Dichlorobenzidine	ng/L	< 50	< 50	< 50	< 50	< 50	< 50
4-Bromophenyl phenyl ether	ng/L	< 50	< 50	< 50	< 50	< 50	< 50
4-Chlorophenyl phenyl ether	ng/L	< 50	< 50	< 50	< 50	< 50	< 50
Benzidine	ng/L	< 50	< 50	< 50	< 50	< 50	< 50
Bis(2-Chloroethoxy)methane	ng/L	< 50	< 50	< 50	< 50	< 50	< 50
Bis(2-chloroethyl)ether	ng/L	< 50	< 50	< 50	< 50	< 50	< 50
Bis(2-chloroisopropyl)ether	ng/L	< 50	< 50	< 50	< 50	< 50	< 50
Hexachlorobenzene	ng/L	< 1	< 1	< 1	< 1	< 1	< 1
Hexachlorobutadiene	ng/L	< 50	< 50	< 50	< 50	< 50	< 50
Hexachlorocyclopentadiene	ng/L	< 50	< 50	< 50	< 50	< 50	< 50
Hexachloroethane	ng/L	< 50	< 50	< 50	< 50	< 50	< 50
Isophorone	ng/L	< 50	< 50	< 50	< 50	< 50	< 50
Nitrobenzene	ng/L	< 50	< 50	< 50	< 50	< 50	< 50
N-Nitrosodi-n-propylamine	ng/L	< 50	< 50	< 50	< 50	< 50	< 50
N-Nitrosodiphenylamine	ng/L	< 50	< 50	< 50	< 50	< 50	< 50
Polynuclear Aromatic Hydrocarbons							
Acenaphthene	ng/L	< 1	8.8	< 1	< 1	5.8	< 1
Acenaphthylene	ng/L	8.3	< 1	< 1	e 4.1	< 1	< 1
Anthracene	ng/L	18	e 4.9	< 1	11.1	9.3	< 1
Chrysene	ng/L	220	17.3	e 3.6	125	33.2	e 4.5
Fluoranthene	ng/L	242	19.6	7.7	143	44.2	5.5
Fluorene	ng/L	e 4.9	< 1	< 1	< 1	e 4.8	< 1
Indeno[1,2,3-c,d]pyrene	ng/L	95.2	< 1	< 1	65.4	16.1	< 1
Naphthalene	ng/L	28	29.7	10.2	21.1	11.3	6.5
Phenanthrene	ng/L	102	15.3	9.7	60	27.5	6.8
Pyrene	ng/L	264	23.2	6.5	142	49.7	7
Phthalates							
Bis(2-ethylhexyl) phthalate	ng/L	6580	721	249	5770	1580	290
Butyl benzyl Phthalate	ng/L	812	119	76.2	737	243	55.1
Diethyl phthalate	ng/L	309	292	306	340	248	204
Dimethyl phthalate	ng/L	154	121	114	158	94.8	37.9
Di-n-butyl phthalate	ng/L	574	134	95.2	669	328	249
Di-n-octyl phthalate	ng/L	602	101	19.9	402	198	29.2

Priority Pollutants in Stormwater - North Orange County Watersheds

Site		BCC02	BCC02	BCC02	EGWC05	EGWC05	EGWC05
Date		5/22/06	5/22/06	5/23/06	5/22/06	5/22/06	5/23/06
Start Time		2:11	5:11	11:11	1:37	4:37	12:37
Length of Composite Period	hrs	1.0	28.0	22.0	1.0	30.0	22.0
Metals							
Ag	ug/L	0.64	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5
Ag (Dissolved)	ug/L	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5
As	ug/L	6.3	2.8	3.8	5.1	2.6	3.5
As (Dissolved)	ug/L	2.2	2.3	3.9	2.3	2.1	3.3
Be	ug/L	0.36	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2
Be (Dissolved)	ug/L	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2
Cd	ug/L	1	< 0.5	< 0.5	0.52	< 0.5	< 0.5
Cd (Dissolved)	ug/L	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5
Cr	ug/L	17	1.6	0.65	4.5	1.2	< 0.5
Cr (Dissolved)	ug/L	1.1	0.65	< 0.5	0.72	< 0.5	< 0.5
Cu	ug/L	56	12	7.5	39	15	6.2
Cu (Dissolved)	ug/L	8.2	8.4	6.6	14	8.6	5.2
Hg	ug/L	0.11	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1
Hg (Dissolved)	ug/L	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1
Ni	ug/L	20	7	10	13	7.3	8.6
Ni (Dissolved)	ug/L	7.4	6.7	9.9	11	6.4	8.2
Pb	ug/L	36	4	0.9	14	4.4	0.81
Pb (Dissolved)	ug/L	< 0.5	< 0.5	< 0.5	0.76	< 0.5	< 0.5
Sb	ug/L	1.6	1.1	1.2	2.2	1.5	1
Sb (Dissolved)	ug/L	1.3	1.3	1.2	1.7	1.5	1.1
Se	ug/L	1.4	0.81	1.7	1.2	0.84	1.9
Se (Dissolved)	ug/L	1.3	0.68	1.5	1.3	0.72	1.4
Tl	ug/L	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2
Tl (Dissolved)	ug/L	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2
Zn	ug/L	350	57	22	210	60	18
Zn (Dissolved)	ug/L	25	28	19	58	23	12
Cyanide	mg/L						
Organochlorine Pesticides and PCB Arochlors							
4,4'-DDD	ng/L						
4,4'-DDE	ng/L						
4,4'-DDT	ng/L						
Aldrin	ng/L						
Dieldrin	ng/L						
Endrin	ng/L						
Endrin aldehyde	ng/L						
Heptachlor	ng/L						
Heptachlor Epoxide	ng/L						
PCB-1016	ng/L						
PCB-1221	ng/L						
PCB-1232	ng/L						
PCB-1242	ng/L						
PCB-1248	ng/L						
PCB-1254	ng/L						
PCB-1260	ng/L						
Toxaphene	ng/L						

Priority Pollutants in Stormwater - North Orange County Watersheds

		Site	CARB01	CARB01	CARB01	CCBA01	CCBA01	CCBA01	FULA03	FULA03
		Date	5/22/06	5/22/06	5/23/06	5/22/06	5/22/06	5/22/06	5/22/06	5/22/06
		Start Time	1:29	4:17	4:17	1:39	4:39	22:39	1:57	4:57
		Length of Composite Period hrs	0.4	22.0	28.0	1.0	16.0	34.0	1.0	38.0
Acid Extractable Compounds										
2,4,6-Trichlorophenol	ng/L		< 50	< 50	< 50	< 50	< 50	< 50	< 50	< 50
2,4-Dichlorophenol	ng/L		< 50	< 50	< 50	< 50	< 50	< 50	< 50	< 50
2,4-Dimethylphenol	ng/L		< 100	< 100	< 100	< 100	< 100	< 100	< 100	< 100
2,4-Dinitrophenol	ng/L		< 100	< 100	< 100	< 100	< 100	< 100	< 100	< 100
2-chlorophenol	ng/L		< 50	< 50	< 50	< 50	< 50	< 50	< 50	< 50
2-Nitrophenol	ng/L			< 100	< 100		< 100	< 100	nr	< 100
4-Nitrophenol	ng/L		< 100	< 100	< 100	< 100	< 100	< 100	< 100	< 100
Pentachlorophenol	ng/L		< 50	e 67.1	< 50	< 50	e 54	< 50	e 74.1	< 50
Phenol	ng/L		e 174	< 100	< 100	< 100	< 100	< 100	292	< 100
Base/Neutral Extractable Compounds										
1,2,4-Trichlorobenzene	ng/L		< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10
1,2-Dichlorobenzene	ng/L		< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10
1,3-Dichlorobenzene	ng/L		< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10
1,4-Dichlorobenzene	ng/L		< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10
2,4-Dinitrotoluene	ng/L		< 50	< 50	< 50	< 50	< 50	< 50	< 50	< 50
2,6-Dinitrotoluene	ng/L		< 50	< 50	< 50	< 50	< 50	< 50	< 50	< 50
2-Chloronaphthalene	ng/L		< 50	< 50	< 50	< 50	< 50	< 50	< 50	< 50
3,3'-Dichlorobenzidine	ng/L		< 50	< 50	< 50	< 50	< 50	< 50	< 50	< 50
4-Bromophenyl phenyl ether	ng/L		< 50	< 50	< 50	< 50	< 50	< 50	< 50	< 50
4-Chlorophenyl phenyl ether	ng/L		< 50	< 50	< 50	< 50	< 50	< 50	< 50	< 50
Benzidine	ng/L		< 50	< 50	< 50	< 50	< 50	< 50	< 50	< 50
Bis(2-Chloroethoxy)methane	ng/L		< 50	< 50	< 50	< 50	< 50	< 50	< 50	< 50
Bis(2-chloroethyl)ether	ng/L		< 50	< 50	< 50	< 50	< 50	< 50	< 50	< 50
Bis(2-chloroisopropyl)ether	ng/L		< 50	< 50	< 50	< 50	< 50	< 50	< 50	< 50
Hexachlorobenzene	ng/L		< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1
Hexachlorobutadiene	ng/L		< 50	< 50	< 50	< 50	< 50	< 50	< 50	< 50
Hexachlorocyclopentadiene	ng/L		< 50	< 50	< 50	< 50	< 50	< 50	< 50	< 50
Hexachloroethane	ng/L		< 50	< 50	< 50	< 50	< 50	< 50	< 50	< 50
Isophorone	ng/L		< 50	< 50	< 50	< 50	< 50	< 50	e 62.6	< 50
Nitrobenzene	ng/L		< 50	< 50	< 50	< 50	< 50	< 50	< 50	< 50
N-Nitrosodi-n-propylamine	ng/L		< 50	< 50	< 50	< 50	< 50	< 50	< 50	< 50
N-Nitrosodiphenylamine	ng/L		< 50	< 50	< 50	< 50	< 50	< 50	< 50	< 50
Polynuclear Aromatic Hydrocarbon										
Acenaphthene	ng/L		< 1	< 1	< 1	e 2.8	12.7	6.2	8.7	11.2
Acenaphthylene	ng/L		e 2.3	< 1	< 1	e 4.4	< 1	< 1	12.3	< 1
Anthracene	ng/L		5.6	8.5	e 3.3	11.3	10.2	e 3.6	37.3	7.5
Chrysene	ng/L		99	16.4	< 1	182	24.7	e 3.9	356	16.2
Fluoranthene	ng/L		117	21.9	e 4.4	170	28.2	6.6	439	18
Fluorene	ng/L		< 1	< 1	< 1	e 2.3	6.4	< 1	13.1	< 1
Indeno[1,2,3-c,d]pyrene	ng/L		55.6	10.6	< 1	91	12	< 1	190	5.1
Naphthalene	ng/L		16.4	10.6	8	23.8	13.3	12.1	32	7.9
Phenanthrene	ng/L		49.5	151.1	7.1	79.2	22.7	11.1	162	12.1
Pyrene	ng/L		123	25	e 4.3	195	33	5.7	418	19.9
Phthalates										
Bis(2-ethylhexyl) phthalate	ng/L		3290	841	304	4140	1180	634	11600	966
Butyl benzyl Phthalate	ng/L		251	118	39	508	193	52.3	1120	153
Diethyl phthalate	ng/L		171	263	163	327	476	217	593	270
Dimethyl phthalate	ng/L		46.4	166	61.6	88	68.7	27.7	323	129
Di-n-butyl phthalate	ng/L		186	181	84.7	524	244	159	517	202
Di-n-octyl phthalate	ng/L		191	95.9	25.5	303	136	14.5	665	69.8

Priority Pollutants in Stormwater - North Orange County Watersheds

		Site	CARB01	CARB01	CARB01	CCBA01	CCBA01	CCBA01	FULA03	FULA03
		Date	5/22/06	5/22/06	5/23/06	5/22/06	5/22/06	5/22/06	5/22/06	5/22/06
		Start Time	1:29	4:17	4:17	1:39	4:39	22:39	1:57	4:57
		Length of Composite Period hrs	0.4	22.0	28.0	1.0	16.0	34.0	1.0	38.0
Metals										
Ag	ug/L		< 0.5	< 0.5	< 0.5	3.9	< 0.5	< 0.5	< 0.5	< 0.5
Ag (Dissolved)	ug/L		< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5
As	ug/L		4.6	2.3	4	2.3	1.7	2	4	1.8
As (Dissolved)	ug/L		2.5	2.2	3.8	0.86	1.5	2.3	1.7	1.9
Be	ug/L		< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	0.36	< 0.2
Be (Dissolved)	ug/L		< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2
Cd	ug/L		< 0.5	< 0.5	< 0.5	0.64	< 0.5	0.65	1.6	1.3
Cd (Dissolved)	ug/L		< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	0.6	< 0.5	2.7
Cr	ug/L		3.7	0.89	< 0.5	6.1	1.1	0.58	16	1.1
Cr (Dissolved)	ug/L		< 0.5	0.58	< 0.5	< 0.5	0.56	< 0.5	1.2	< 0.5
Cu	ug/L		30	15	9.7	30	12	6.8	90	12
Cu (Dissolved)	ug/L		7.8	12	9	6.3	8.2	6.5	16	8.7
Hg	ug/L		< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1
Hg (Dissolved)	ug/L		< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1
Ni	ug/L		9.2	4.8	5.7	9.9	5.8	7.6	34	6.7
Ni (Dissolved)	ug/L		5.7	4.7	5.9	2.8	5.1	7	16	5.8
Pb	ug/L		10	2.3	0.62	13	2.2	< 0.5	34	2.4
Pb (Dissolved)	ug/L		< 0.5	0.5	< 0.5	< 0.5	< 0.5	< 0.5	1.2	< 0.5
Sb	ug/L		1.3	1.6	1.4	1.2	1.5	1.2	2.2	1.4
Sb (Dissolved)	ug/L		0.98	1.6	1.5	0.73	1.5	1.1	2	1.5
Se	ug/L		2.1	0.59	2.26	0.59	0.72	2.1	0.81	0.69
Se (Dissolved)	ug/L		1.5	0.61	2.2	< 0.5	0.75	1.9	0.71	< 0.5
Tl	ug/L		< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	0.21	< 0.2
Tl (Dissolved)	ug/L		< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2
Zn	ug/L		150	53	20	200	47	12	580	43
Zn (Dissolved)	ug/L		19	34	17	15	25	9	100	20
Cyanide	mg/L									
Organochlorine Pesticides and PCB A										
4,4'-DDD	ng/L									
4,4'-DDE	ng/L									
4,4'-DDT	ng/L									
Aldrin	ng/L									
Dieldrin	ng/L									
Endrin	ng/L									
Endrin aldehyde	ng/L									
Heptachlor	ng/L									
Heptachlor Epoxide	ng/L									
PCB-1016	ng/L									
PCB-1221	ng/L									
PCB-1232	ng/L									
PCB-1242	ng/L									
PCB-1248	ng/L									
PCB-1254	ng/L									
PCB-1260	ng/L									
Toxaphene	ng/L									

Summary of Sample Submittals

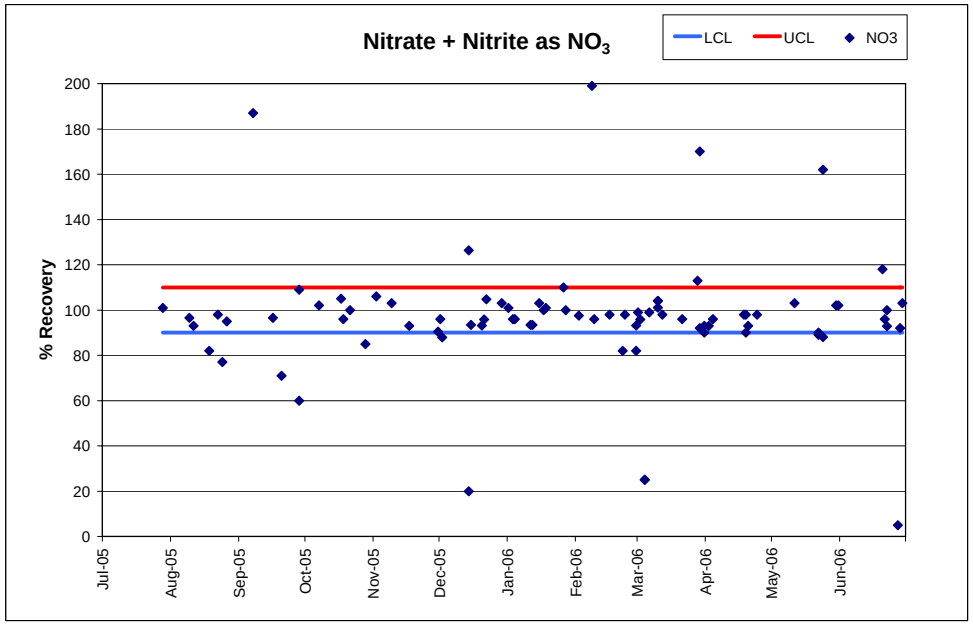
	Trace Metals			Nutrients		Organic Carbon		General Mineral	Rain	Cl, SO4	Organophosphate Pesticides	Semivolatile Organic Carbon	Glyphosate	Oil & Grease	Pesticides		BactiMF	Grand Total
Matrix	FW	SW	SED	FW	SW	WATER	SED	FW	FW	FW	WATER	WATER	WATER	WATER	WATER	SED	WATER	
Total Sanples Submitted*	3432	322	281	816	428	739	120	10	14	502	1178	36	271	495	53	227	6445	15369
Lab Control Standards	151	17	1	62	23	31	8	3	3	34	79	3	2	12	0	7	54	490
Dupl./Splits	208	10	0	46	17	29	2	0	0	18	74	0	8	36	3	0	164	615
Equipment Blanks	191	7	0	65	5	39	0	1	0	30	40	2	8	5	2	0	0	395
Trip Blanks	115	17	0	53	19	26	0	1	0	34	62	3	14	14	0	0	185	543

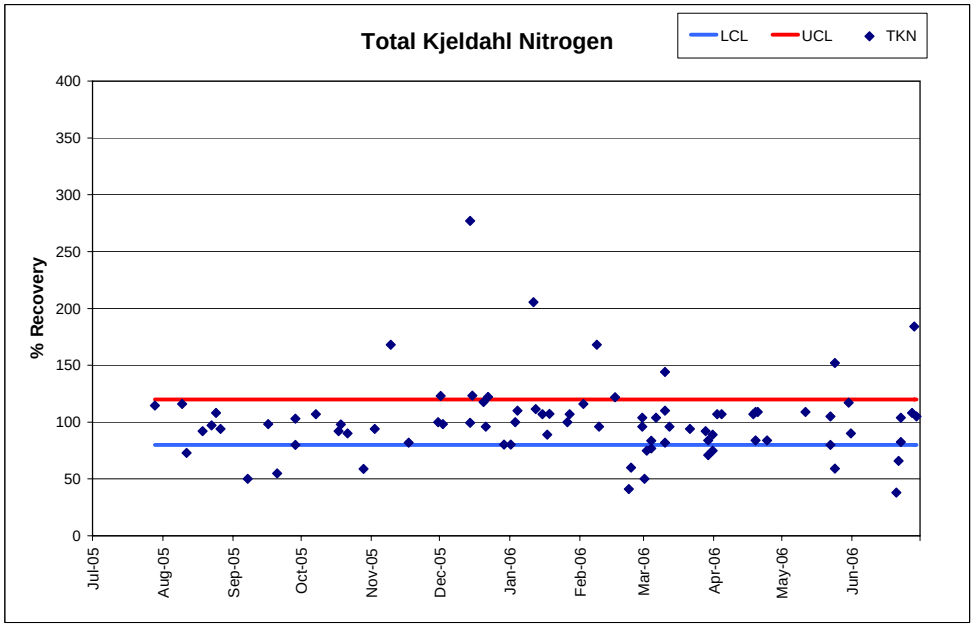
Percentage of QA Samples by type

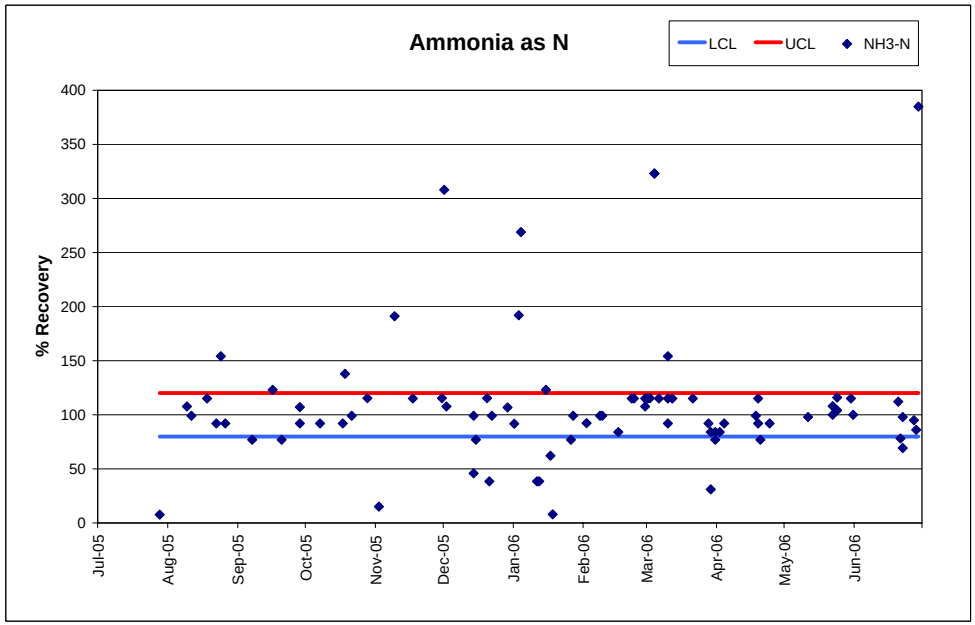
Lab Control Standard	4.4	5.3	0.4	7.6	5.4	4.2	6.7	30.0	21.4	6.8	6.7	8.3	0.7	2.4	0.0	3.1	0.8	3.2
Dupl./Splits	6.1	3.1	0.0	5.6	4.0	3.9	1.7	0.0	0.0	3.6	6.3	0.0	3.0	7.3	5.7	0.0	2.5	4.0
Equipment Blanks	5.6	2.2	0.0	8.0	1.2	5.3	0.0	10.0	0.0	6.0	3.4	5.6	3.0	1.0	3.8	0.0	0.0	2.6
Trip Blanks	3.4	5.3	0.0	6.5	4.4	3.5	0.0	10.0	0.0	6.8	5.3	8.3	5.2	2.8	0.0	0.0	2.9	3.5
Total	19.4	15.8	0.4	27.7	15.0	16.9	8.3	50.0	21.4	23.1	21.6	22.2	11.8	13.5	9.4	3.1	6.3	13.3

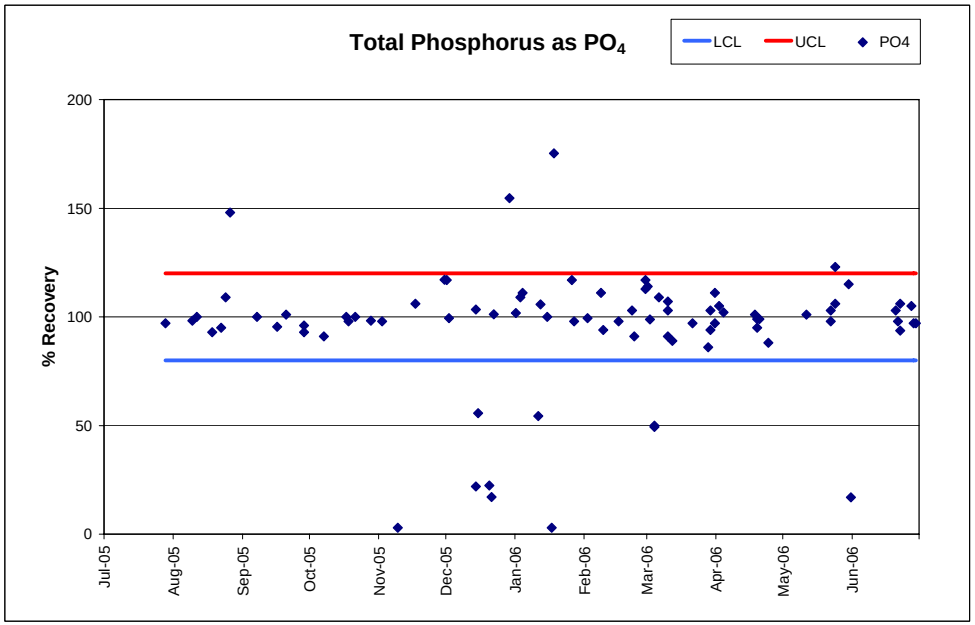
* Environmental + Quality Assurance Samples from Santa Ana and San Diego Region NPDES Programs

Accuracy of Analyses : Nutrients in Freshwater and Saltwater

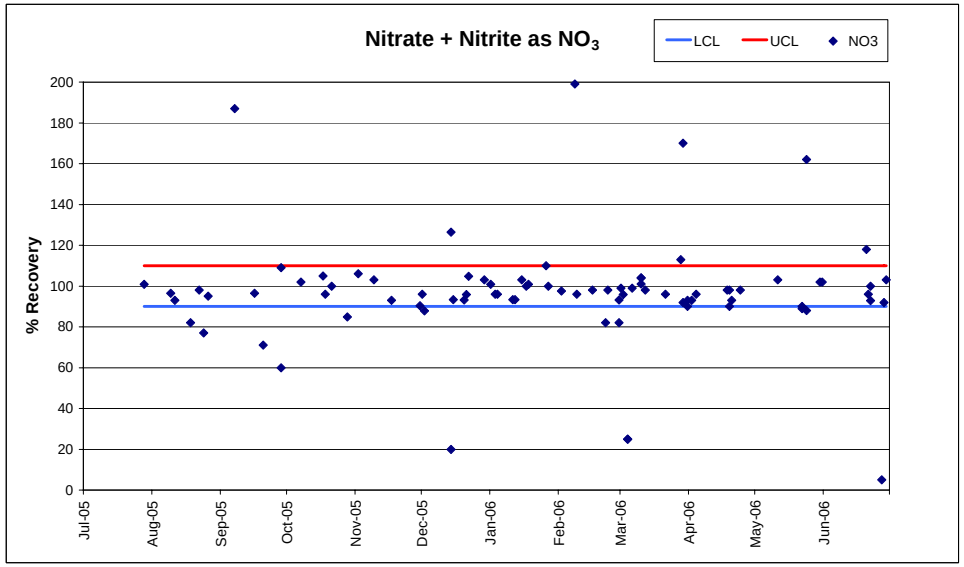


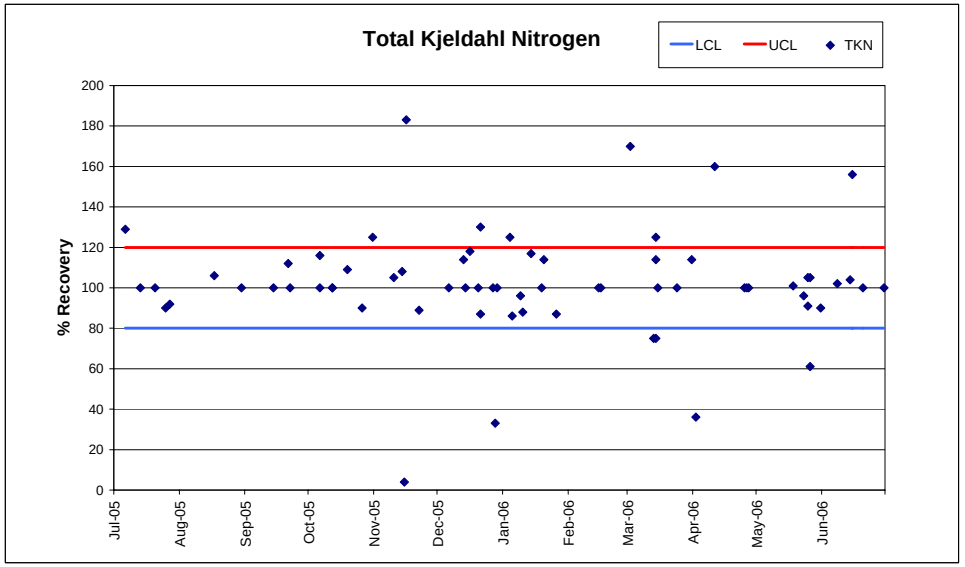


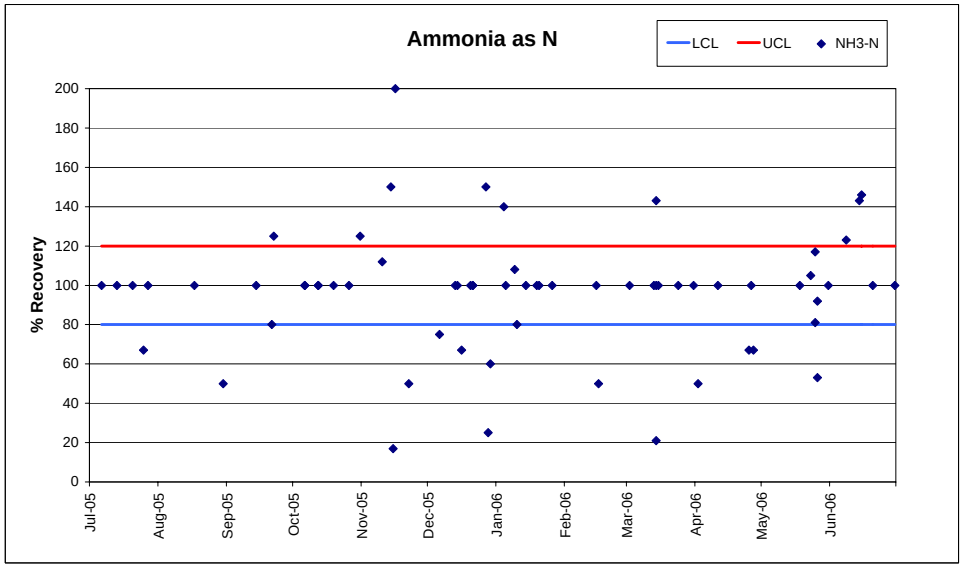


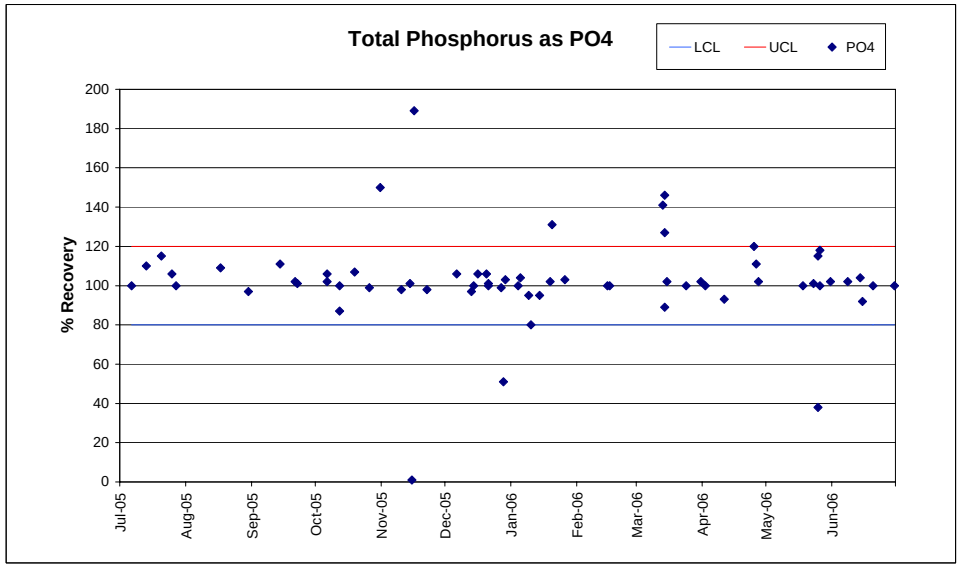


Precision of Analyses: Nutrients in Freshwater and Saltwater

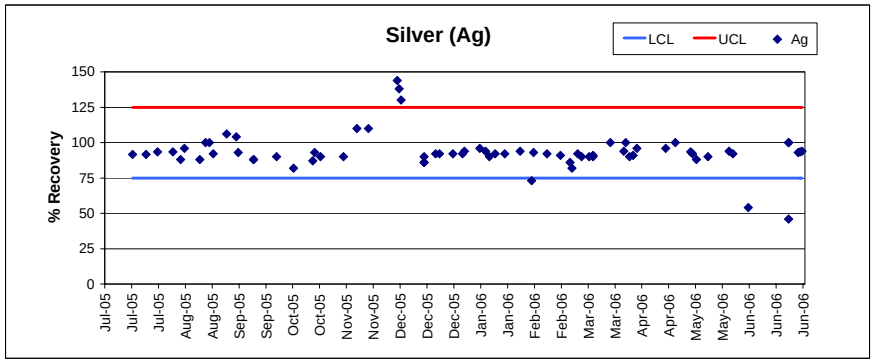


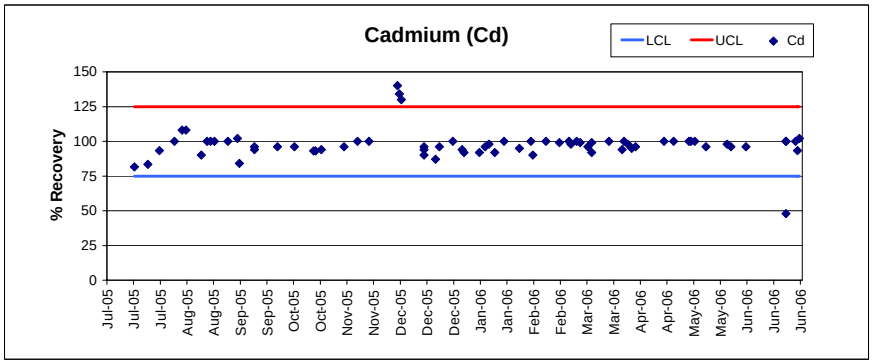


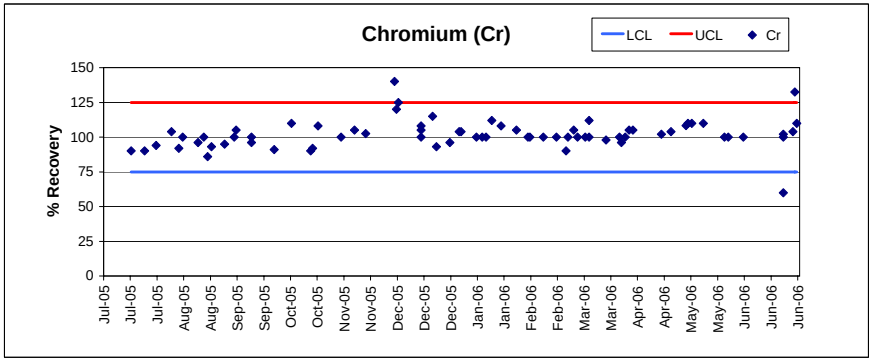


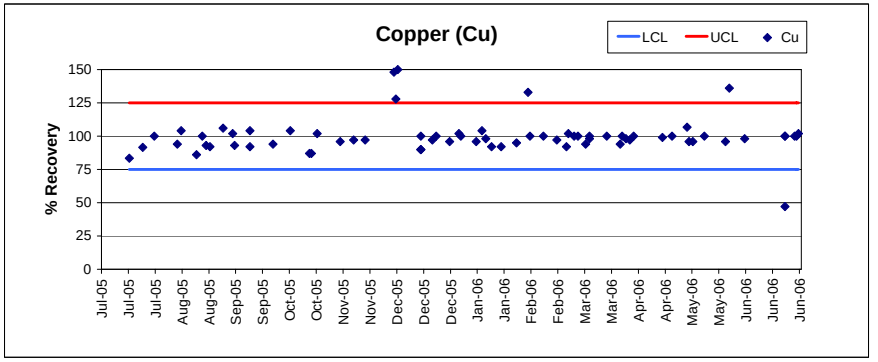


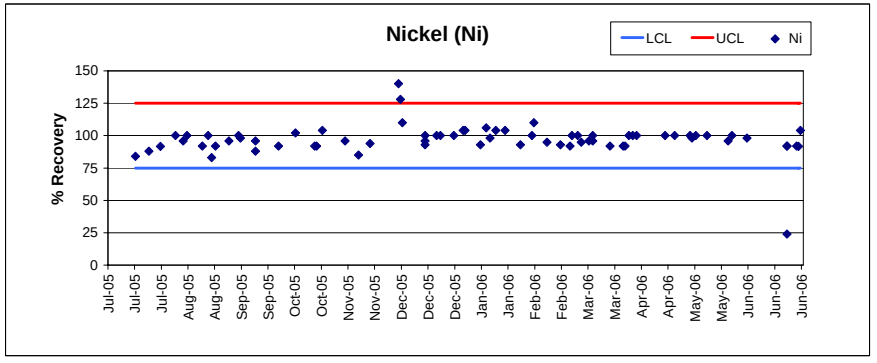
Accuracy of Analyses : Trace Elements in Freshwater

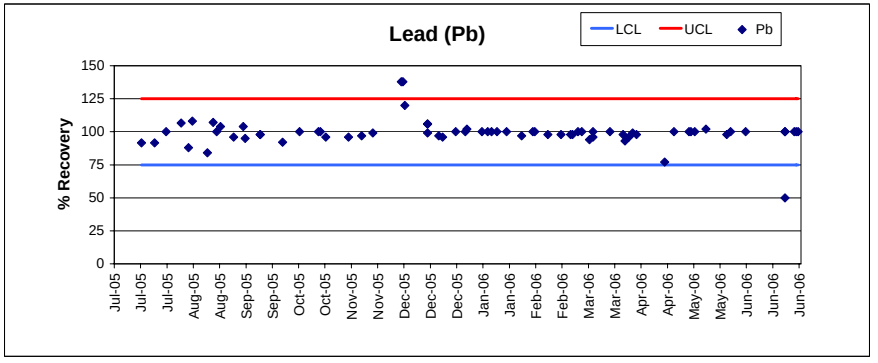


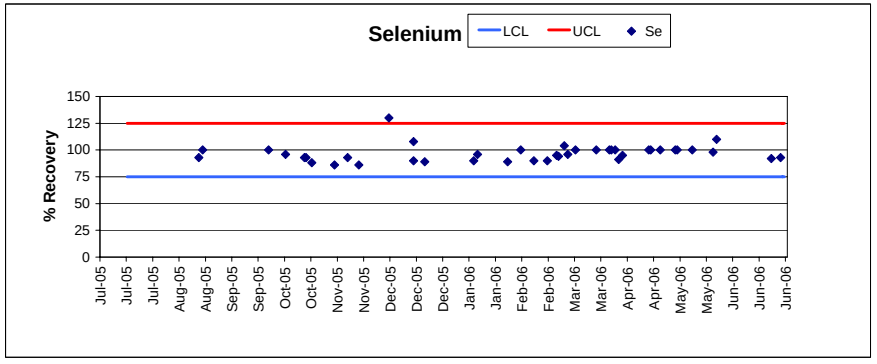


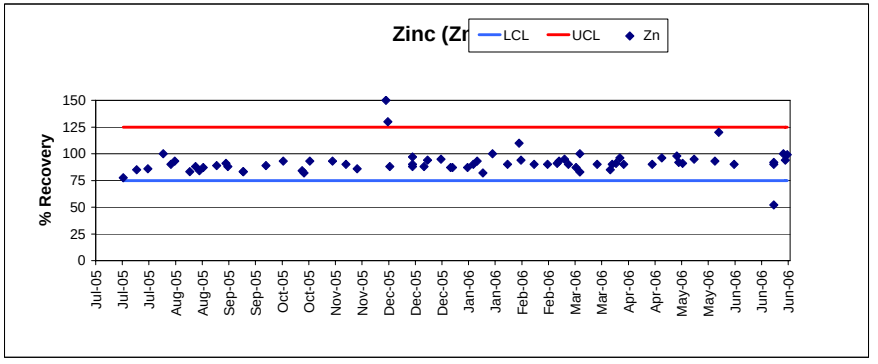






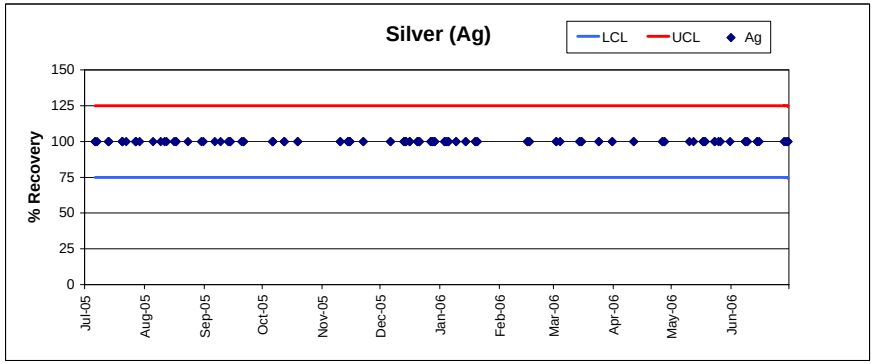


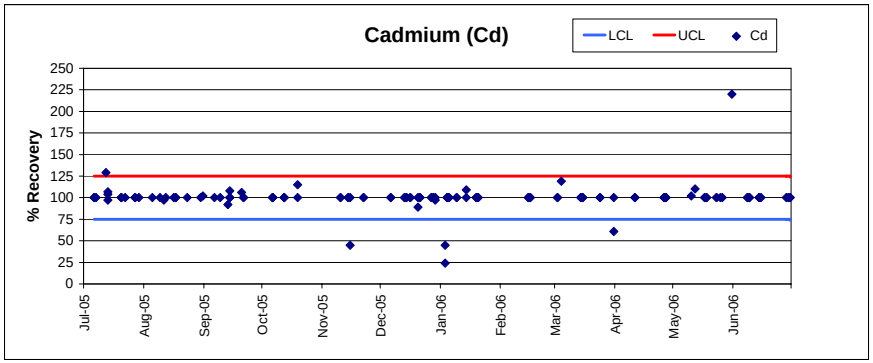


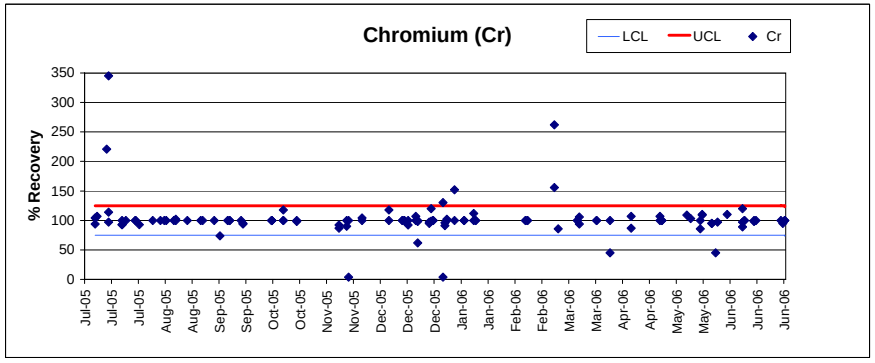


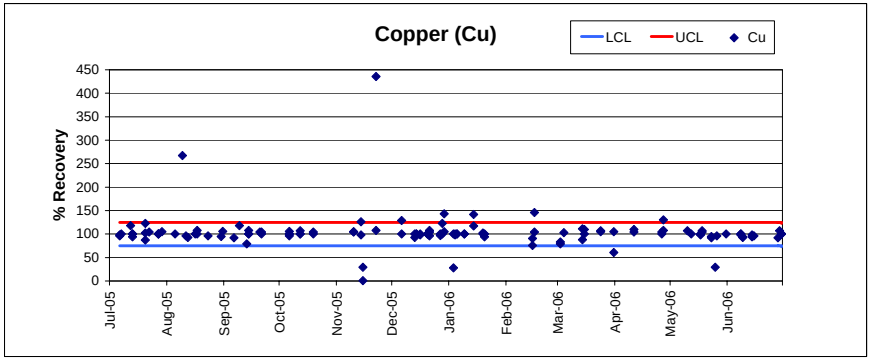
SARB_002652

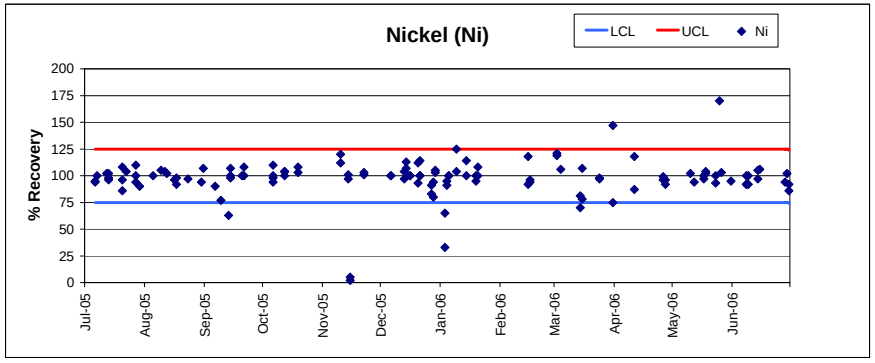
Precision of Analyses: Trace Elements in Freshwater

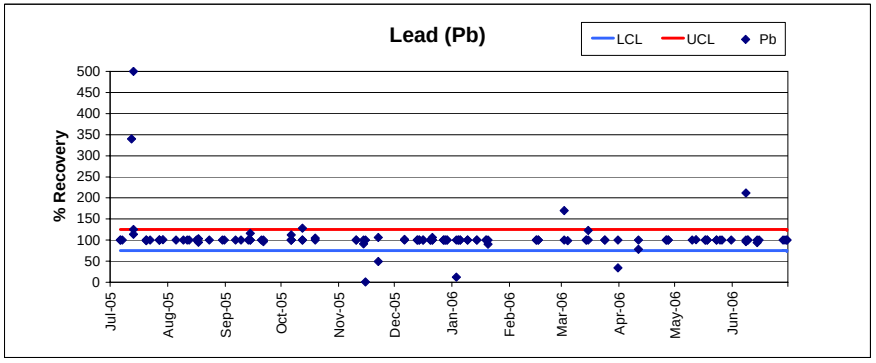


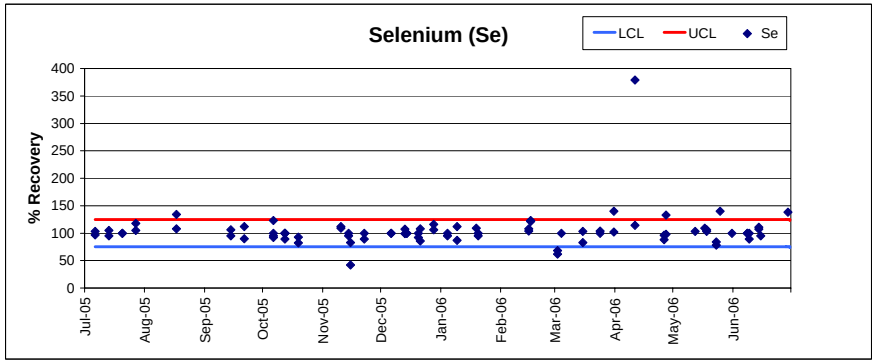


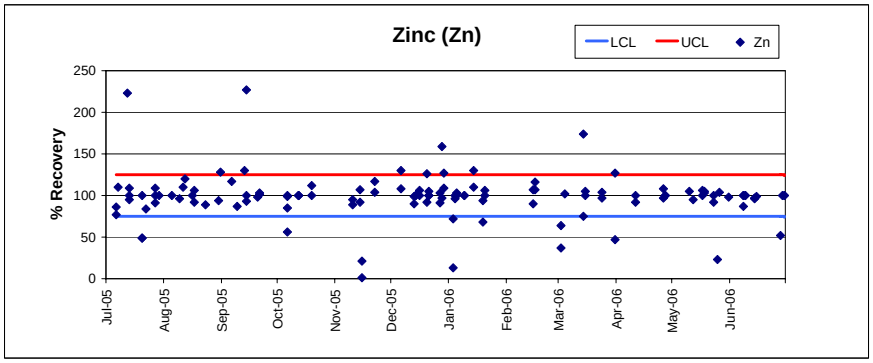








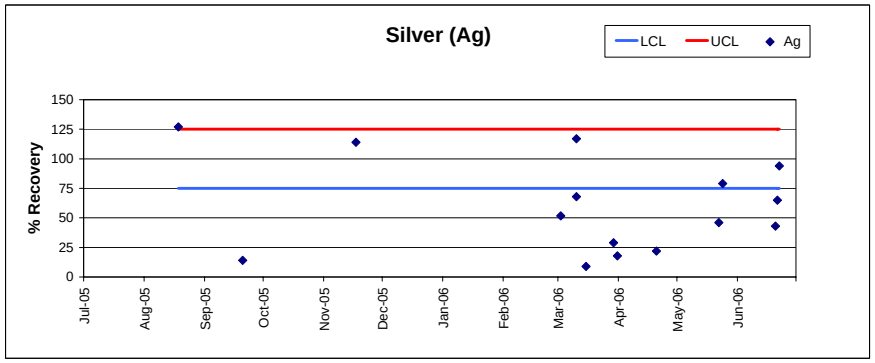


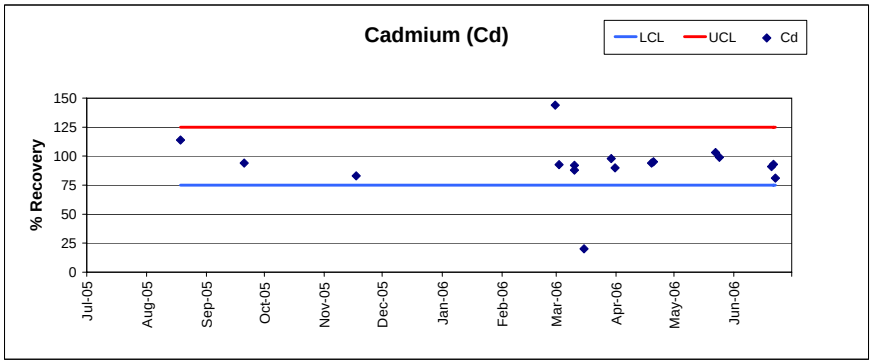


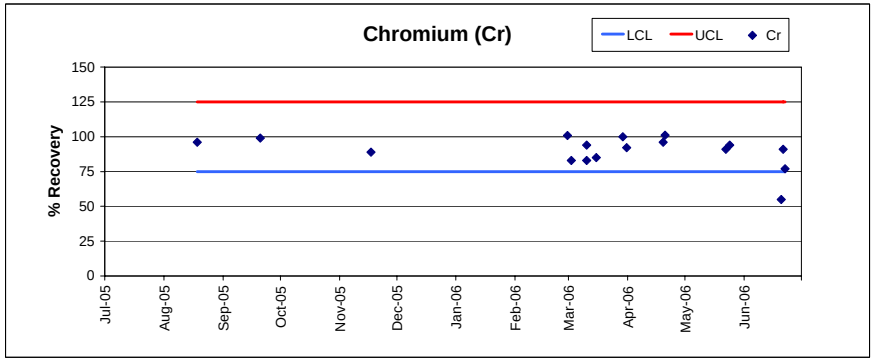
SARB_002653

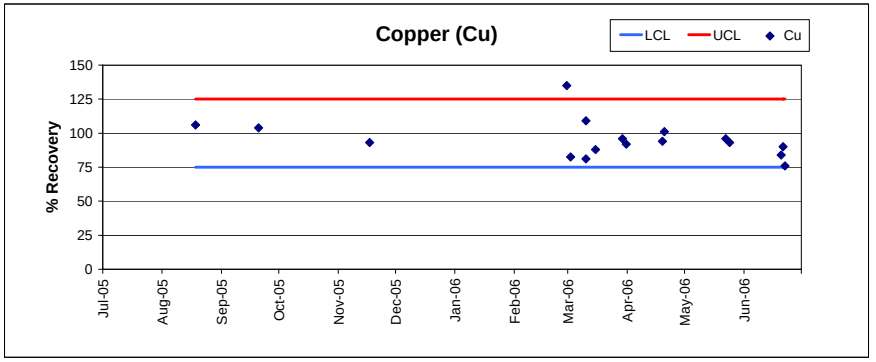
Attachment C-11-XI

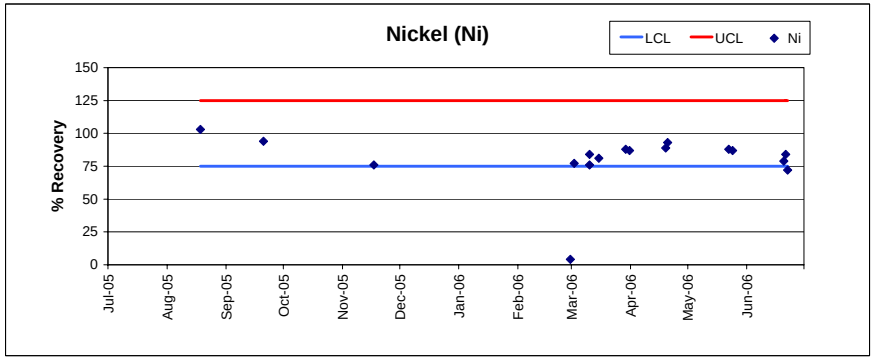
Accuracy of Analyses : Trace Elements in Saltwater

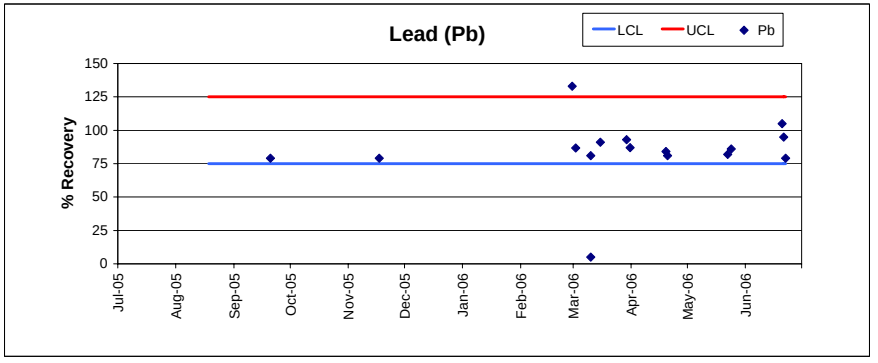


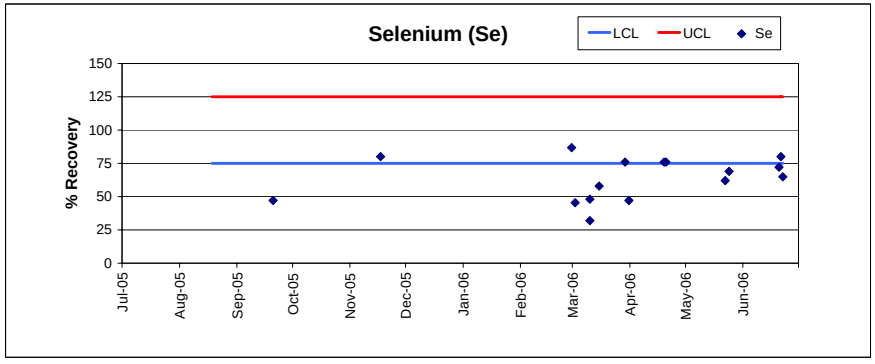


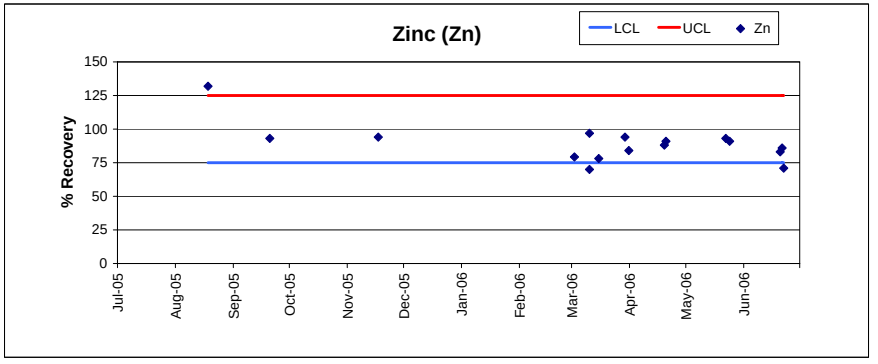




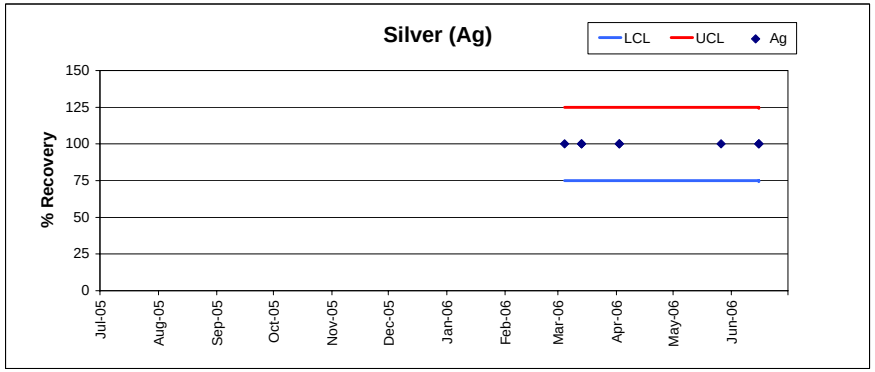


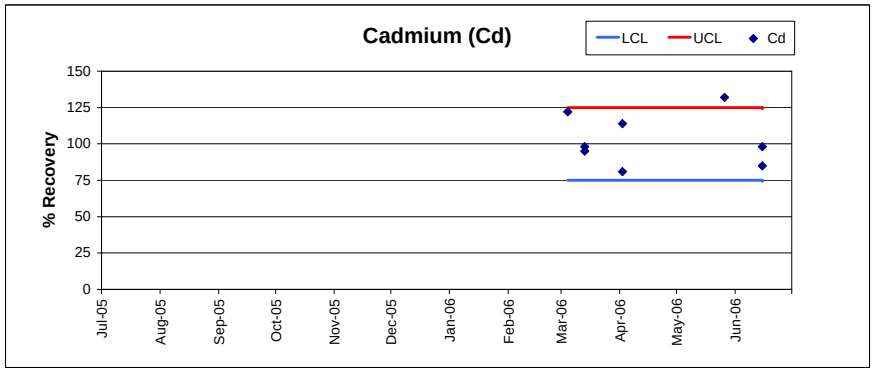


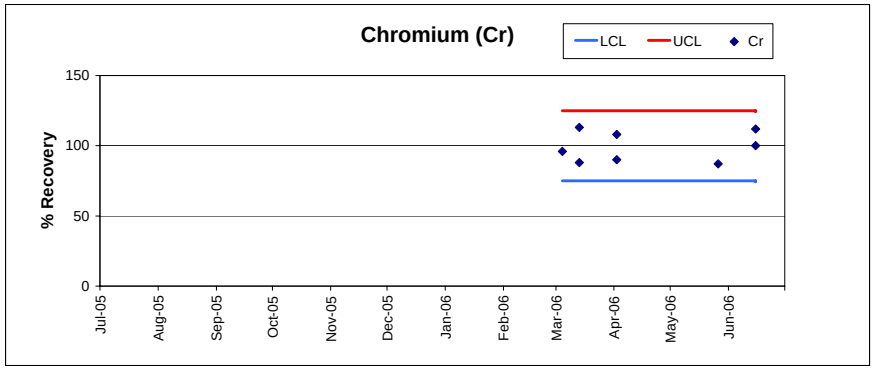


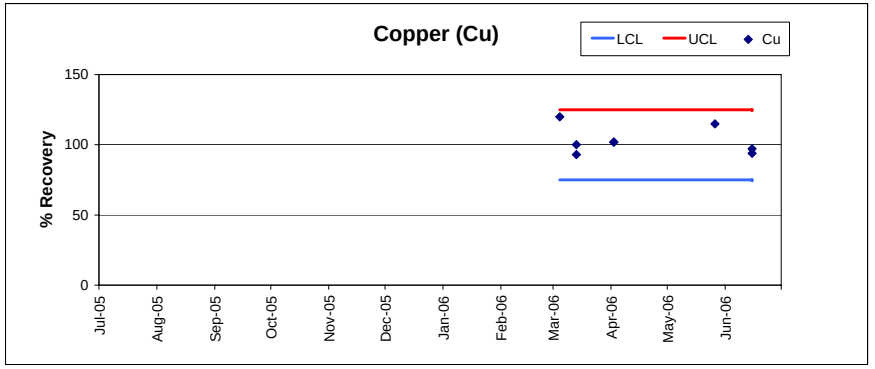


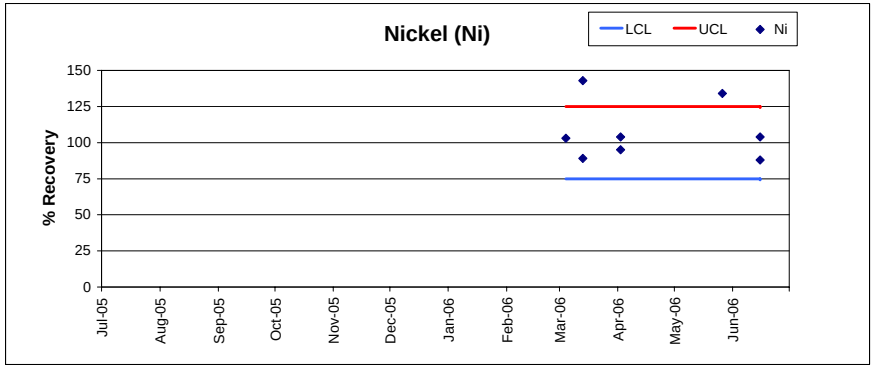
Precision of Analyses: Trace Elements in Saltwater

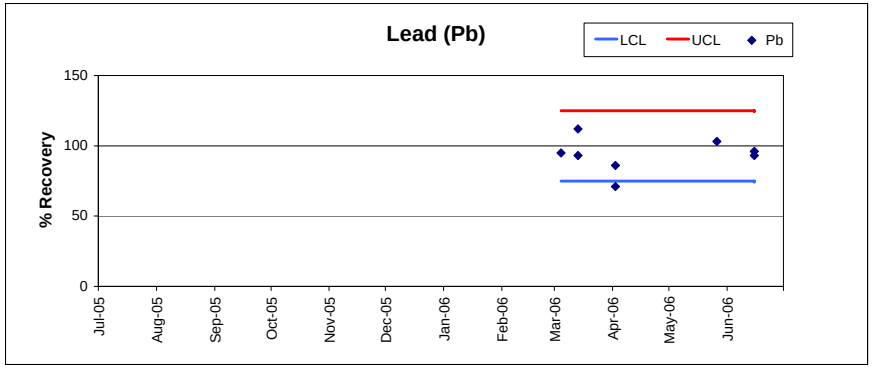


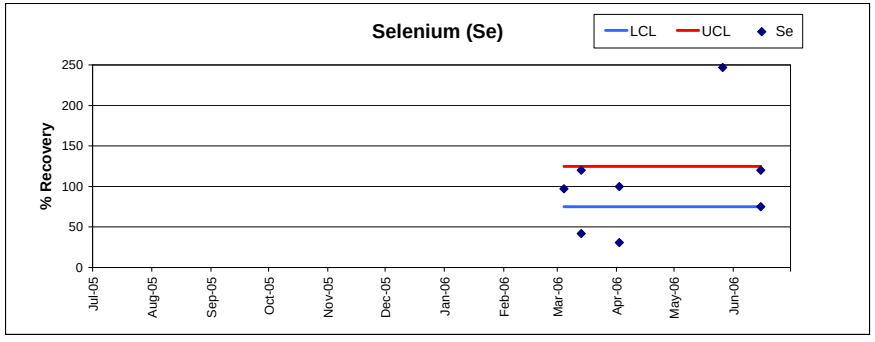


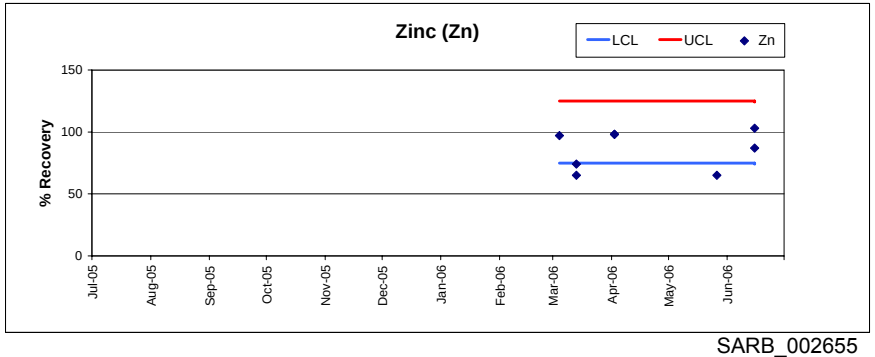






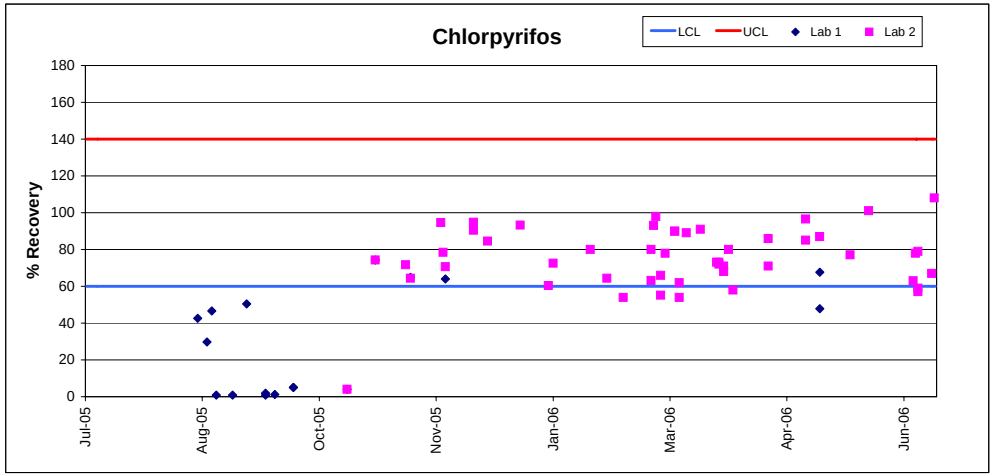


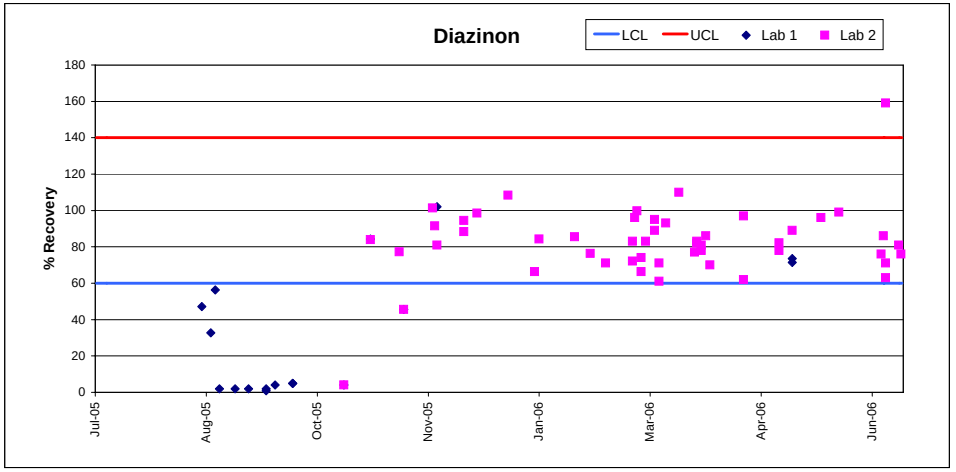


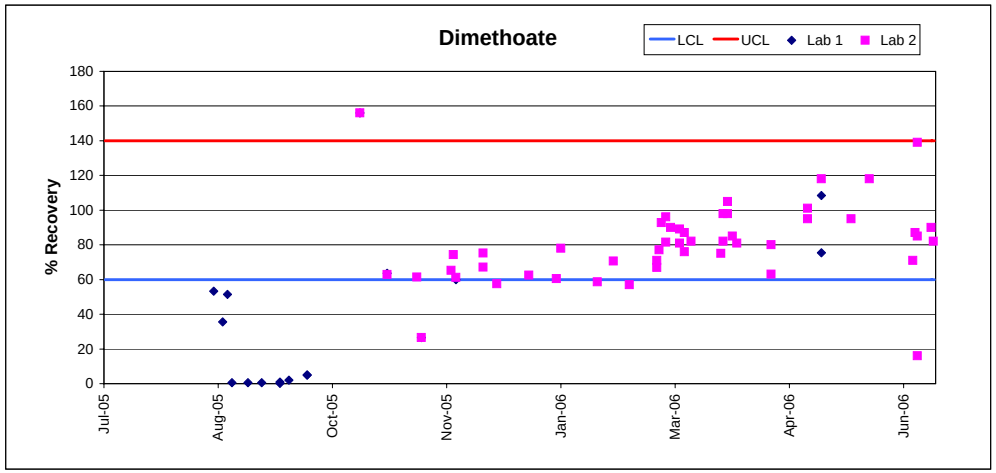


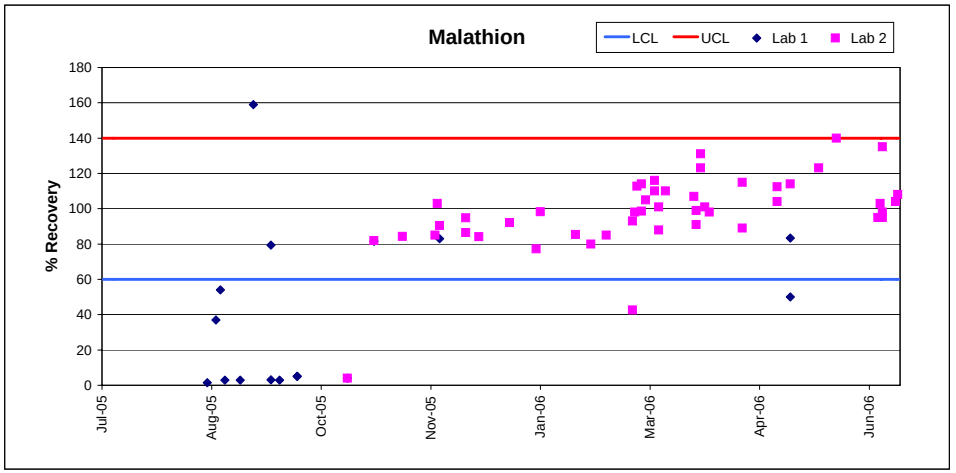
SARB_002655

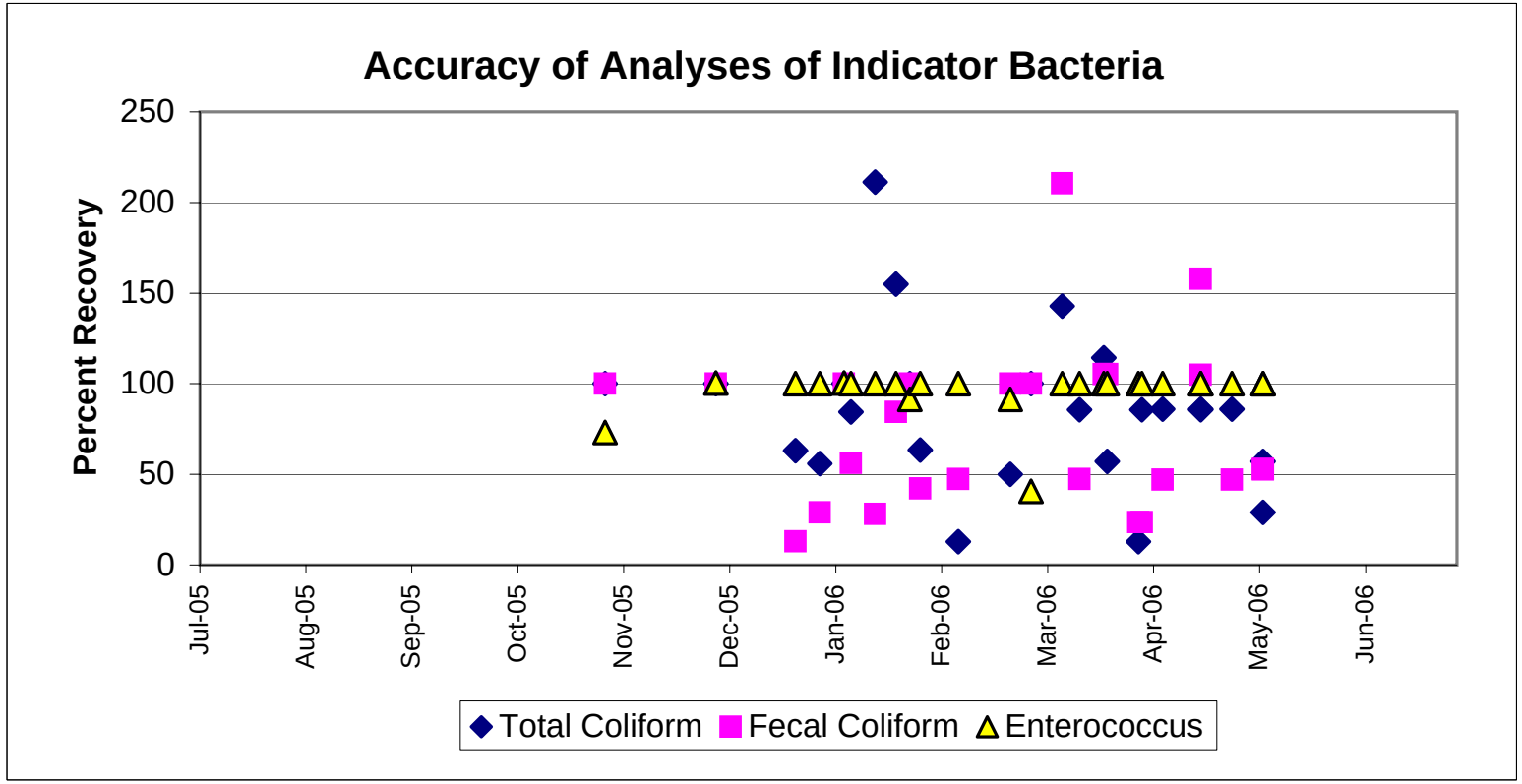
Accuracy of Analyses: Organophosphate Pesticides in Freshwater











All results within acceptance criteria provided by QA sample provider

QA Summary for Dry Weather Reconnaissance Programs

Region	Date	Ammonia	Nitrate + Nitrite	Reactive Phosphorus	Copper	Hexavalent Chromium	Hardness	MBAS	Total Chlorine	Turbidity
		% Recovery								
Santa Ana	4/20/06	103.0	106.0	99.0	103.0	102.0				98.5
	5/12/06	61.1	99.5	92.0	106.0	91.4	99.3	100.0	86.3	93.9
	6/8/06	80.0	80.0	115.0	71.0	5.0	99.0	80.0	60.0	94.0
	6/29/06	116.9	121.4	99.4						
	7/14/06	104.4	100.7	101.7	106.0	160.0	90.6	80.0	98.7	95.5
	8/24/06	93.0	105.0	105.0	95.6	95.7	94.3	85.0	70.6	120
	10/3/06	95.0	126.0	106.0	100.8	92.9	99.3	50.0	15.7	90.0
San Diego	4/20/06	101.0	104.0	97.0	NA	NA				98.5
	5/12/06	109.2	123.8	94.8	NA	NA	92.3	80.0	86.3	92.8
	6/8/06	105.0	120.0	140.0	NA	NA	96.5	1800.0	100.0	98.5
	6/29/06	107.7	150.5	93.7	NA	NA				
	7/14/06	96.2	109.2	88.8	NA	NA	86.8	86.0	93.5	90.0
	8/24/06	100.0	108.0	100.0	NA	NA	88.1	96.0	70.6	100.0
	10/3/06	100.0	110.0	101.0	NA	NA	96.8	103.0	98.0	96.5

Analyses of Laboratory Control Standards for Organic Compounds in Sediment

Sample Number	WR96860	ERA Sediment QC				WR97737	NIST SRM 1944		WR101680	ERA Sediment QC			
Date	8/22/05	Lot D037-720				9/6/05			11/15/05	Lot D037-720			
	Target	Result	%REC	QC Limits		Target	Result	%REC	Target	Result	%REC	QC Limits	
Analyte	ug/kg	ug/kg		LCL	UCL	ug/kg	ug/kg		ug/kg	ug/kg		LCL	UCL
2,4 DDD						38	41.4	109					
2,4 DDE						19	18.9	99					
2,4 DDT						<1	<1						
4,4'-DDD	324	262	81	155	445	108	90.9	84	324	<1	0	155	445
4,4'-DDE	208	164	79	99.2	273	86	84.1	98	208	<1	0	99.2	273
4,4'-DDT	210	245	117	89.6	291	119	112	94	210	150	71	89.6	291
2,4,5 TP-Silvex													
Aldrin	153	111	73	72.1	196	<1	<1		153	97	63	72.1	196
BHC-alpha	455	312	69	195	604	6.03	<1	8	455	249	55	195	604
BHC-beta	393	280	71	120	507	6.03	<1	8	393	285	73	120	507
BHC-delta	<1	<1				6.03	<1	8	<1	<1			
BHC-gamma	144	109	76	59.9	195	<1	<1		144	88.9	62	59.9	195
Chlordane	149.3	118.5	79			25	32	128	149.3	<1	0		
Chlordane-alpha	84.3	66.5	79	38.8	108	16.51	16.5	100	84.3	<1	0	38.8	108
Chlordane-gamma	65	52	80	29.6	82.7	8	10.3	129	65	<1	0	29.6	82.7
Total Chlordane													
cis-Nonachlor						3.7	<1	14					
Dieldrin	157	118	75	73.4	207	<1	<1		157	153	97	73.4	207
Endosulfan I													
Endosulfan II													
Endosulfan Sulfate	164	139	85	59.3	229	<1	<1		164	129	79	59.3	229
Endrin	180	190	106	93.9	251	<1	<1		180	1.8	1	93.9	251
Endrin Aldehyde	259	<1	0	54	310	<1	<1		259	<1	0	54	310
Endrin Ketone	260	168	65	102	346	<1	<1		260	149	57	102	346
Heptachlor	296	305	103	137	379	<1	<1		296	178	60	137	379
Heptachlor Epoxide	64.3	54	84	32.8	89.5	<1	<1		64.3	<1	2	32.8	89.5
Methoxychlor	232	262	113	58.9	348	<1	<1		232	181	78	58.9	348
Mirex													
Nonachlor													
OxyChlordane	<1	<1				<1	<1			42.2			
Perthane	<5	<5				<5	<5		<5	<5			
Toxaphene	<10	<10				<10	<10		<10	<10			
Trans-Nonachlor	<1	<1				82	8.3	10					
1-Methylnaphthalene						520	211	41					
1-Methylphenanthrene						1700	1310	77					
1,2,5,6- Dibenzanthracene													
2-Methylnaphthalene						950	368	39					
2,3,5-TriMethylnaphthalene													
2,6-Dimethylnaphthalene													
Acenapthene						570	204	36					
Acenapthylene													
Anthracene						1770	1220	69					
Benzo (A) Anthracene						4720	5030	107					
Benzo (A) Pyrene						4300	4390	102					
Benzo (B) Fluoranthene						3870	4430	114					
Benzo (GHI) Perylene						2840	2540	89					
Benzo(b)Fluoranthene						3870	4530	117					
Benzo(e)pyrene						3280	3370	103					
Biphenyl						320	126	39					
Chrysene						4860	6350	131					
Fluoranthene						8920	9120	102					
Fluorene						850	283	33					
Indeno(1,2,3-CE)Pyrene						2780	2660	96					
Naphthalene						1650	565	34					
Phenanthrene						5270	4840	92					
Pyrene						9700	9520	98					
Perylene						1117	1090	98					

Analyses of Laboratory Control Standards for Organic Compounds in Sediment

Sample Number	WR96860	ERA Sediment QC				WR97737	NIST SRM 1944		WR101680	ERA Sediment QC			
Date	8/22/05	Lot D037-720				9/6/05			11/15/05	Lot D037-720			
	Target	Result	%REC	QC Limits		Target	Result	%REC	Target	Result	%REC	QC Limits	
Analyte	ug/kg	ug/kg		LCL	UCL	ug/kg	ug/kg		ug/kg	ug/kg		LCL	UCL
PCB018						51	44.8	88					
PCB028						80.8	64.9	80					
PCB031						78.7	61.4	78					
PCB033													
PCB037						<1	<1						
PCB044						60.2	50.7	84					
PCB049						53	35.6	67					
PCB052						79.4	58	73					
PCB066						71.9	60.8	85					
PCB070						<1	<1						
PCB074						<1	<1						
PCB077						<1	<1						
PCB081						<1	<1						
PCB087						29.9	26.4	88					
PCB095						65	38.2	59					
PCB097						<1	<1						
PCB099						37.5	30	80					
PCB101						73.4	53.3	73					
PCB-1016						<10	<10						
PCB105						24.5	21.2	87					
PCB110						63.5	47.3	74					
PCB114						<1	<1						
PCB118						58	25.6	44					
PCB119						<1	<1						
PCB-1221						<10	<10						
PCB123						<1	<1						
PCB-1232						<10	<10						
PCB-1242						<10	<10						
PCB-1248						<10	<10						
PCB-1254						<10	<10						
PCB126						<1	<1						
PCB-1260						<10	<10						
PCB128+167						8.47	<1	12					
PCB138						62.1	36.8	59					
PCB141						<1	<1						
PCB149						49.7	43.7	88					
PCB151						16.93	11.2	66					
PCB153						74	49.4	67					
PCB156						65.2	4.2	6					
PCB157						<1	<1						
PCB158						<1	<1						
PCB168+132						<1	<1						
PCB169						<1	<1						
PCB170						22.6	20.1	89					
PCB177						<1	<1						
PCB180						44.3	33.2	75					
PCB183						12.19	10.7	88					
PCB187						25.1	23.9	95					
PCB189						<1	<1						
PCB194						11.2	8.6	77					
PCB200						<1	<1						
PCB201						<1	<1						
PCB206						9.21	7.9	86					

Analyses of Laboratory Control Standards for Organic Compounds in Sediment

Sample Number	WR102917 ERA Sediment QC					WR104795 ERA Sediment QC					WR104984 ERA Sediment QC				
Date	12/20/05 Lot D037-720					2/2/06 Lot D037-720					2/9/06 Lot D037-720				
Analyte	Target ug/kg	Result ug/kg	%REC	QC Limits LCL	UCL	Target ug/kg	Result ug/kg	%REC	QC Limits LCL	UCL	Target ug/kg	Result ug/kg	%REC	QC Limits LCL	UCL
2,4 DDD															
2,4 DDE															
2,4 DDT															
4,4'-DDD				155	445				155	445				155	445
4,4'-DDE	324	220	68	99.2	273	324	179	55	99.2	273	324	141	44	99.2	273
4,4'-DDT	208	141	68	89.6	291	208	104	50	89.6	291	208	105	50	89.6	291
2,4,5 TP-Silvex	210	92	44			210	111	53			210	75.7	36		
Aldrin				72.1	196				72.1	196				72.1	196
BHC-alpha	153	96.7	63	195	604	153	54.9	36	195	604	153	59.7	39	195	604
BHC-beta	455	261	57	120	507	455	180	40	120	507	455	209	46	120	507
BHC-delta	393	210	53			393	196	50			393	71.4	18		
BHC-gamma	<1	<1		59.9	195	<1	<1		59.9	195	<1	<1		59.9	195
Chlordane	144	75	52			144	62.9	44			144	181	126		
Chlordane-alpha	149.3	93	62	38.8	108	149.3	89.1	60	38.8	108	149.3	60.6	41	38.8	108
Chlordane-gamma	84.3	41	49	29.6	82.7	84.3	26.2	31	29.6	82.7	84.3	34.6	41	29.6	82.7
Total Chlordane	<5	<5				<5	<5				<5	<5			
cis-Nonachlor	65	52	80			65	62.9	97			65	26	40		
Dieldrin				73.4	207				73.4	207				73.4	207
Endosulfan I	157	105	67			157	70.1	45			157	80.9	52		
Endosulfan II															
Endosulfan Sulfate				59.3	229				59.3	229				59.3	229
Endrin	164	<1	1	93.9	251	164	85.5	52	93.9	251	164	82.4	50	93.9	251
Endrin Aldehyde	180	123	68	54	310	180	103	57	54	310	180	95.7	53	54	310
Endrin Ketone	259	99	38	102	346	259	NR	0	102	346	259	NR	0	102	346
Heptachlor	260	107	41	137	379	260	93.6	36	137	379	260	102	39	137	379
Heptachlor Epoxide	296	165	56	32.8	89.5	296	124	42	32.8	89.5	296	116	39	32.8	89.5
Methoxychlor	64.3	40	62	58.9	348	64.3	26.7	42	58.9	348	64.3	35.4	55	58.9	348
Mirex	232	108	47			232	133	57			232	86.9	37		
Nonachlor															
OxyChlordane															
Perthane	<1	<1				<1	<1				<1	<1			
Toxaphene															
Trans-Nonachlor	<10	<10				<10	<10				<10	<10			
1-Methylnaphthalene	<1	<1				<1	<1				<1	<1			
1-Methylphenanthrene															
1,2,5,6- Dibenzanthracene															
2-Methylnaphthalene															
2,3,5-TriMethylnaphthalene															
2,6-Dimethylnaphthalene															
Acenapthene															
Acenapthylene															
Anthracene															
Benzo (A) Anthracene															
Benzo (A) Pyrene															
Benzo (B) Fluoranthene															
Benzo (GHI) Perylene															
Benzo(b)Fluoranthene															
Benzo(e)pyrene															
Biphenyl															
Chrysene															
Fluoranthene															
Fluorene															
Indeno(1,2,3-CE)Pyrene															
Naphthalene															
Phenanthrene															
Pyrene															
Perylene															

Analyses of Laboratory Control Standards for Organic Compounds in Sediment

Sample Number	WR111082	ERA Sediment QC			
Date	6/27/06	Lot D037-720			
	Target	Result	%REC	QC Limits	
Analyte	ug/kg	ug/kg		LCL	UCL
2,4 DDD					
2,4 DDE					
2,4 DDT					
4,4'-DDD				155	445
4,4'-DDE	324	<1	0	99.2	273
4,4'-DDT	208	189	91	89.6	291
2,4,5 TP-Silvex	210	169	80		
Aldrin				72.1	196
BHC-alpha	153	146	95	195	604
BHC-beta	455	472	104	120	507
BHC-delta	393	396	101		
BHC-gamma	<1	<1		59.9	195
Chlordane	144	161	112		
Chlordane-alpha	149.3	143.6	96	38.8	108
Chlordane-gamma	84.3	80.5	95	29.6	82.7
Total Chlordane	<5	<5			
cis-Nonachlor	65	63.1	97		
Dieldrin				73.4	207
Endosulfan I	157	165	105		
Endosulfan II					
Endosulfan Sulfate				59.3	229
Endrin	164	<1	0	93.9	251
Endrin Aldehyde	180	236	131	54	310
Endrin Ketone	259	368	142	102	346
Heptachlor	260	233	90	137	379
Heptachlor Epoxide	296	368	124	32.8	89.5
Methoxychlor	64.3	69.5	108	58.9	348
Mirex	232	<1	0		
Nonachlor					
OxyChlordane					
Perthane	<1	<1			
Toxaphene					
Trans-Nonachlor	<10	<10			
1-Methylnaphthalene	<1	<1			
1-Methylphenanthrene					
1,2,5,6- Dibenzanthracene					
2-Methylnaphthalene					
2,3,5-TriMethylnaphthalene					
2,6-Dimethylnaphthalene					
Acenapthene					
Acenapthylene					
Anthracene					
Benzo (A) Anthracene					
Benzo (A) Pyrene					
Benzo (B) Fluoranthene					
Benzo (GHI) Perylene					
Benzo(b)Fluoranthene					
Benzo(e)pyrene					
Biphenyl					
Chrysene					
Fluoranthene					
Fluorene					
Indeno(1,2,3-CE)Pyrene					
Naphthalene					
Phenanthrene					
Pyrene					
Perylene					

Received
March 9, 2011
Commission on
State Mandates

9.2.1.3 Inventory Database Protocols and Maintenance

The Permittee will be inspecting commercial/industrial facilities at the frequencies specified in **Section 9.2.4** of this Model Program. The inspections provide current information on commercial/industrial facilities that is used to annually update the inventory database and map of commercial/industrial facilities. Information that should be collected during the inspection and included in the inventory database includes:

Characteristic or Criteria	Information Collected or Verified
Business Name	Business Name
Physical Address Information	Street Number, Street Direction, Street Name, Street Suffix, City or Unincorporated Area, Zip Code, Business Phone Number, Business Fax Number, email address, APN.
Mailing Address Information	Street Number, Direction, Street Name, Street Suffix, Suite Number/Letter, City or Unincorporated Area, Zip.
Business Contact Name	Full Name of Owner, Operator, Manager, etc.
Emergency Contact	24 hour Emergency Contact Phone Number
Lot Size	Total Square Feet of Lot (or if Multi-Tennant Lot: Enter Total Square Feet of Business).
SIC Code	SIC Code 1 and Other Pertinent SIC Codes if Applicable.
Industrial-Specific Info	WDID Number (Statewide Industrial Permit), Is Facility Subject to SARA Sect. 313, Title III?
Commercial-Specific Info	Description of Commercial Activity
Watershed	The hydrologic unit within the Permittee's jurisdiction where the facility resides, Longitude and Latitude.
GIS Information (optional)	Latitude, Longitude, etc.
Local Licensing/Permits	Business License Number, Special Permits, etc.
Potential pollutants	Outcome of Step 3
Adjacent to and/or Discharge to ESA/ASBS	Outcome of Step 4
Pollutants of concern into an ESA	Outcome of Step 4 (SDRWQCB only)
Comments/Notes	

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9.2.2 Prioritization for Inspection

9.2.2.1 Introduction

This section outlines the procedures for prioritizing commercial/industrial facilities for inspection frequency, based on the threat to water quality. Potential threats to water quality at each commercial/industrial facility can be determined by evaluating a variety of site-specific factors according to the criteria outlined below. Priorities may be high, medium or low.

The prioritization processes for commercial and industrial facilities are discussed separately in this section. Although the processes are similar, specific permit requirements necessitate that commercial and industrial facilities be prioritized separately.

9.2.2.2 Prioritization of Industrial Facilities

Prioritization involves two phases:

- Initially classifying a facility as being a high, medium or low priority for inspection based on site information; and
- Subsequently confirming or reclassifying the facility based on inspections, field observations and additional information.

The first phase can be accomplished administratively using the data provided in the inventory of industrial facilities. The latter phase is completed following the initial inspection of each industrial facility.

Initial Prioritization

The following industrial facilities are mandatory high priority facilities:

San Diego RWQCB Jurisdiction

- Facilities subject to section 313 of Title III of the Superfund Amendments and Reauthorization Act of 1986 (SARA).
- Facilities which are tributary to a Clean Water Act Section 303(d) impaired water body, where the facility generates pollutants for which the water body is impaired.
- Facilities within or directly adjacent to (i.e. within 200 feet) or discharging directly to a receiving water within an Environmentally Sensitive Area (ESA).
- Facilities subject to the state Industrial General Permit (excluding those facilities that have been approved for a No Exposure Certification).
- All other facilities that the Permittee determines are contributing significant pollutant loading to its MS4, regardless of whether such facilities are covered under the statewide General Industrial Permit or other NPDES permits.

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Santa Ana RWQCB Jurisdiction

- Facilities subject to section 313 of Title III of the Superfund Amendments and Reauthorization Act of 1986 (SARA).
- Facilities which are tributary to or directly adjacent to (i.e. within 500 feet) an area defined by the Ocean Plan as an Area of Special Biological Significance (ASBS).
- Facilities subject to the state Industrial General Permit.
- Facilities with a high potential for, or history of, unauthorized, non-storm water discharges.

In addition to the industrial facilities noted above, the Permittee should review other facilities to determine whether they should be high priority sites. In some cases, the Permittees may not have all the required information necessary to properly evaluate a facility for prioritization. In this case, a preliminary site visit may be warranted such that the Permittee can collect the needed information and verify the prioritization.

A ranking system using the following criteria is used to prioritize the sites:

- Type of activity (SIC code)
- Materials used in the industrial process
- Type(s) and quantities of waste products generated
- Potential for discharge of pollutants
- Non-stormwater discharges
- Size of the facility (% impervious surface)
- Proximity to a receiving water bodies

The ranking criteria and scores have been provided in **Table 9-7** below. The recommended prioritization may be adjusted within a LIP to fit the needs of individual Permittees. The sum from each line item is the total ranking for a specific Industrial Facility. If the total ranking is equal to or greater than 25, then a high priority is assigned. If the total ranking is less than 25 but equal to or greater than 15, then a medium priority is assigned. If the total ranking is less than 15, then a low priority is assigned. Each prioritized facility should be inspected at a minimum in accordance with the inspection schedule presented below in **Section 9.2.4.**

Field Verification of Prioritization

After initial prioritization, the Permittee should perform facility inspections; subsequently, each site is re-evaluated to determine whether the initial prioritization was adequate. Facilities possessing a No Exposure Certification (NEC) may be eligible for a lesser priority classification. Permittees should contact the RWQCB to obtain information regarding which facilities have NECs.

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9.2.2.3 Prioritization of Commercial Facilities

San Diego RWQCB Jurisdiction

Permittees within the San Diego RWQCB jurisdiction are **NOT** required to prioritize commercial facilities. However, they are required to inventory a set of pre-determined high priority commercial facilities/activities. See **Table 9-2** for a list of those commercial facilities/activities that are automatically considered "high priority" within the San Diego RWQCB jurisdiction. However, if field observations, monitoring data or complaints indicate that another commercial site/source may contribute a significant pollutant load, the site should be inspected and ranked in accordance with the prioritization scheme outlined below, or as adjusted within an individual LIP.

Santa Ana RWQCB Jurisdiction

Permittees within the Santa Ana RWQCB jurisdiction are required to prioritize commercial facilities. See **Table 9-3** for a list of those commercial facilities/activities that must be inventoried and prioritized within the Santa Ana RWQCB jurisdiction. However, these are NOT automatically considered "high priority".

Prioritization for commercial facilities in the Santa Ana RWQCB jurisdiction involves two phases:

- Initially classifying a facility as being a high, medium or low priority for inspection based on site information; and
- Subsequently confirming or reclassifying the facility based on inspections, field observations and additional information.

Initial Prioritization

The first phase can be accomplished administratively using the data provided in the inventory of commercial/industrial facilities. The latter phase will be completed following the initial inspection of each commercial/industrial facility.

Santa Ana RWQCB Permittees must consider the following site attributes to evaluate the potential threat to water quality and subsequent inspection priority for commercial facilities:

- Type of Commercial Activity
- Magnitude of Commercial Activity
- Location of Commercial Activity
- Potential for Discharge of Pollutants to the MS4
- History of Un-Authorized Stormwater Discharges

The ranking criteria and scores have been provided in **Table 9-8** below. The recommended prioritization may be adjusted within a LIP to fit the needs of individual Permittees. The sum from each line item is the total ranking for a specific Commercial

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facility. If the total ranking is equal to or greater than 20, then a high priority is assigned. If the total ranking is less than 20 but equal to or greater than 10, then a medium priority is assigned. If the total ranking is less than 10, then a low priority is assigned. Each prioritized facility should be inspected at a minimum in accordance with the inspection schedule presented below in **Section 9.2.4.1**.

Field Verification of Prioritization

Initially, the Permittees may not have all the required information necessary to properly evaluate a facility for prioritization. In this case, a preliminary site visit may be warranted such that the Permittee can collect the needed information and verify the prioritization. Facilities possessing a No Exposure Certification (NEC) may be eligible for a lesser priority classification. An NEC designation must be accomplished through the jurisdictional regional board and is awarded if the facility meets the No Exposure criterion.

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9.5.3.1 Prioritization Procedure for Implementation

The creation of geographic information system (GIS) maps identifying common interest developments characterizes the prioritization procedure for CIAs/HOAs. These maps are used in conjunction with the residential overlays developed as part of the Residential Program (**Section 9.4**). The County has developed GIS maps that identify ESAs and 303(d) listed water bodies.

Each Permittee should incorporate GIS based overlays of CIA/HOA areas with watershed boundaries. Locating the CIA/HOA areas within a particular watershed will allow for assessment of proximity to 303(d) listed water bodies in that watershed. Refer to **Table 9-4** for a listing of major watersheds within the County of Orange and to **Figure 9-3** for the map of these watersheds.

The threat prioritization procedure for CIA/HOA areas can be summarized as follows:

STEP 1: Locate all CIA/HOA areas on a GIS overlay (may be accomplished as part of the Existing Residential Program JURMP) that shows watershed boundaries.

STEP 2: Overlay County-generated GIS maps that identify ESAs and 303(d) listed water bodies.

STEP 3: Identify receiving waters for all CIAs/HOAs.

STEP 4: Determine if a CIA/HOA area is considered high priority through answering the following questions:

- Is the CIA/HOA directly tributary to a 303(d) listed water body? Water bodies in Orange County that are listed on the 2002 303(d) list of impaired water bodies are shown in **Table 9-6**.

  If YES, then CIA/HOA is high priority.

- Does the CIA/HOA discharge directly to an ESA? Comparison of drainage facility maps with an ESA map will allow determination of discharge areas.

  If YES, then CIA/HOA is high priority.

- Does the CIA/HOA contribute significant pollutant loads to the storm drain system via evaluation of IDIC and receiving water monitoring data?

  Significant pollutant load should be interpreted to mean any discharge that causes or contributes to a violation of a receiving water quality standard. The results from the ID/IC and Receiving Water Monitoring programs should be used to determine if significant pollutant loads occur as a result of CIA/HOA activities or discharges from residential areas. Results from dry weather monitoring may be used in an effort to isolate additional CIA/HOA activities and areas for follow-up investigation. Any residential activity or area found to cause or contribute to a water quality objective violation should be categorized as high priority.

  If YES, then CIA/HOA is high priority.

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- Is the CIA/HOA responsible for street and storm drain maintenance?

  If YES, then CIA/HOA is high priority.

STEP 5: Implement best management practices as described in **Section 9.5.4.**

Note that Steps 1 – 4 occur throughout a Permittee's jurisdiction, whereas Step 5 is reserved for those CIA/HOA areas within that jurisdiction that are considered high priority.

9.5.3.2 Ongoing Determinations

The Receiving Water Monitoring program established in compliance with the San Diego Permit, Attachment B, should be used as one facet of determining the effectiveness of the Common Interest Area/Homeowners Associations Activities JURMP, and if CIA/HOA activities and areas are in compliance with the Permit Orders and DAMP commitments.

Permittees should ensure that the dry weather monitoring program developed as part of Illegal Discharge/Illicit Connection Program (ID/IC), **Section 10**, is of sufficient scope (i.e., with samples taken at outfalls exclusively serving CIAs/HOAs) to aid in assessment of Permittee efforts and actions as part of the CIA/HOA Program. Coordination between the CIA/HOA program and the ID/IC program is necessary to determine permit compliance and the need for further investigation.

9.5.4 Best Management Practices Implementation

This section presents the best management practices and procedures that Permittees can provide to CIAs/HOAs in order to protect receiving water quality.

CIA/HOA areas can be divided in terms of activities of concern based on those common interest developments that have publicly-owned and maintained streets and storm drains and those in which these facilities are owned and maintained by the maintenance association. Likewise, the best management practice programs for publicly-owned and maintained streets and storm drain systems within CIAs/HOAs differ from those used in CIA/HOA areas that have privately owned and maintained streets and storm drain systems.

The following sections describe a minimum set of BMPs appropriate for both types of common interest developments.

CIAs/HOAs with Publicly-owned and Maintained Streets and Storm Drains

CIAs/HOAs with publicly-owned and maintained streets and storm drains operate similarly to more traditional residential areas within a Permittee's jurisdiction, in that activities such as street sweeping, refuse removal and drainage and utility operation and maintenance are generally performed by the Permittee. Therefore, the BMPs appropriate to these types of CIAs/HOAs will not include practices for such typically Permittee-performed activities as street sweeping. BMP fact sheets, as identified in

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ATTACHMENT

Attachment I Proposed 2007 DAMP

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The Orange County Stormwater Program (the Program) is a cooperative municipal regulatory compliance initiative focused on the management of urban and stormwater runoff for the protection and enhancement of Orange County's creeks, rivers, streams, and coastal waters. The main objective of the Program is to fulfill the commitment of Orange County's cities, the County of Orange and the Orange County Flood Control District to develop and implement a program that satisfies the requirements of area-wide municipal National Pollutant Discharge Elimination System (NPDES) permits (subsequently referred to as the Third Term Permits).

The purpose of this document is to comply with the requirement of the Third Term Permits, Regional Water Quality Control Board Orders R8-2002-0010 (Santa Ana Regional Board) and R9-2002-0001 (San Diego Regional Board) to submit a Report of Waste Discharge 180 days prior to permit expiration. This Report discusses the Permittees' Third Term Permit compliance activities and includes a description of accomplishments, an assessment of program effectiveness, and a proposed management program (a draft 2007 Drainage Area Management Plan) for the period 2007-2012.

The Program's accomplishments represent the culmination of the development and three years of implementation of a program that was substantially revised to meet the requirements of the Third Term NPDES Permits. Notable programmatic accomplishments include:

- Completion of the 2003 DAMP including 34 jurisdictional Local Implementation Plans (LIPs) (**DAMP Appendix A**) , a formal training program (**DAMP Appendix B**) a program effectiveness assessment strategy (**DAMP Appendix C**), and 6 Watershed Action Plans (WAPs) (**DAMP Appendix D**) (**Section 2.0**);
- Establishment of 2 separate, but nonetheless similar and highly interdependent, planning processes targeting the control of pollutants in urban runoff and completion of studies to evaluate the effectiveness and applicability of various source control and treatment control Best Management Practices (**DAMP Appendix D**) (**Section 3.0**);
- Validation, through independent administrative and trial court review, of the robustness of the Permittees' local legal authority for DAMP implementation (**Section 4.0**);
- Development and implementation of (1) a Model Municipal Activities program at 2,302 municipal facilities, (2) Model Integrated Pest Management Guidelines which have reduced municipal fertilizer and pesticide use, and (3) an Established BMP performance reporting program that has indicated the increased effectiveness of street sweeping and trash and debris collection practices (**Section 5.0**);
- Development and implementation of a public education program that has created over 160,000,000 media impressions and produced measurable and positive changes in public awareness and behavior (**Section 6.0**);
- Development and implementation of a Model Water Quality Management Plan (WQMP) based program for new development, the approval of over 1,400 project WQMPs, and the creation and ongoing development of a web-based expert system to support coastal urban wetland management (**Section 7.0**);
- Development and implementation of a Model Construction Program under which 6,570 enforcement actions were taken within a pattern of increasing levels of compliance in the most recent annual reporting period (**Section 8.0**);
- Development and implementation of a Model Industrial/Commercial Program under which over 31,000 facilities have been subject to local regulatory review and 7,266

enforcement actions were taken within a pattern of increasing levels of compliance in the most recent annual reporting period (**Section 9.0**);
- The investigation of 8,866 complaints regarding illegal discharges or illicit connections, increased use of a telephone hotline for the reporting by the public of water quality concerns, and implementation of enhanced cooperative local agency procedures and practices for sewage spill response (**Section 10.0**);
- Development and approval of the Third Term Permit water quality monitoring program and development and implementation of a sophisticated environmental data management system (Labtrack) (**Section C-11.0**), and
- Implementation of the DAMP/Watershed Action Plans (WAPs) in the San Diego Regional Board area (**Section C-12.0)** and significant progress toward completion of WAPs for the Newport Bay and Santa Ana River watersheds**.**

In assessing the effectiveness of the Program, the Permittees evaluated a series of performance metrics termed Headline Measure, that are intended to confirm program implementation and validate achievement of outcomes. The basis of this approach draws on the hierarchical taxonomy of programmatic outcomes, being advocated by the California Stormwater Quality Association (CASQA), which creates a framework for defining the relationships between compliance actions and, ultimately, positive changes in water quality. In addition, the assessment has been informed by (1) the findings of the Countywide water quality monitoring programs, (2) a series of consultative workshops conducted with jurisdictional program coordinators, (3) reviews of audit reports and other Regional Water Quality Control Board (RWQCB) correspondence and meetings with RWQCB staff, and (4) the receiving water limitations provisions of the Permits.

In conducting the assessment, three major themes emerged during the review. These themes are:

Theme 1: Demonstrating the iterative management approach: Adapting the management program to more effectively address urban sources of pollutants that are causing or contributing to exceedances of water quality standards;

Theme 2: Enhancing Implementation: Improving program implementation through incorporation for auditable environmental management system concepts, and

Theme 3: Establishing watershed-based water quality planning: On a Countywide basis, creating 2 separate, but nonetheless highly inter-related, water quality planning processes, to address urban sources of pollutants.

The Program effectiveness assessment resulted in 2 types of programmatic recommendations, specifically (1) ROWD Commitments (New programmatic commitments to be developed and implemented over the period of the Fourth Term Permits) and (2) DAMP Modifications (Improvements to existing program commitments incorporated into the proposed 2007 DAMP). The ROWD Commitments comprise:

Iterative Management: Developing and implementing new BMP programs including Integrated Pest Management (IPM) approaches for pesticide toxicity, BMPs for the architectural use of copper and zinc in new development, and new BMPs and for municipal trash and debris

control.

Enhancing implementation: Defining the expertise and competencies of staff with program implementation responsibilities and to develop staff skills and expertise through a strategic approach to training. Also, commitments to develop program guidance documentation and standards for source and treatment control BMPs.

Enhancing watershed-based water quality planning: Completing 11 Watershed Action Plans to establish countywide and watershed-based water quality planning processes across Orange County.

1.0 INTRODUCTION

The cities of Anaheim, Brea, Buena Park, Costa Mesa, Cypress, Fountain Valley, Fullerton, Garden Grove, Huntington Beach, Irvine, La Habra, La Palma, Laguna Hills, Laguna Woods, Lake Forest, Los Alamitos, Newport Beach, Orange, Placentia, Santa Ana, Seal Beach, Stanton, Tustin, Villa Park, Westminster, and Yorba Linda (collectively the Santa Ana Region Permittees) and the cities of Aliso Viejo, Dana Point, Laguna Beach, Laguna Hills, Laguna Niguel, Laguna Woods, Lake Forest, Mission Viejo, Rancho Santa Margarita, San Clemente, and San Juan Capistrano (collectively the San Diego Region Permittees) operate municipal storm drain systems and discharge stormwater and urban runoff pursuant to National Pollutant Discharge Elimination System (NPDES) Permits.

These Permits require that the Permittees work together to:

- Effectively prohibit non-stormwater discharges to the stormdrain system, and
- Implement controls to reduce the discharge of pollutants in stormwater to the Maximum Extent Practicable (MEP).

The Permits were first adopted in 1990 and subsequently renewed in 1996 (Second Term) and 2002 (Third Term) (See **Table 1.1**). This **Report of Waste Discharge** has been prepared in anticipation of the expiration of the Third Term Permits in early 2007 and comprises:

- An evaluation of NPDES permit compliance over the period of the Third Term Permits;
- A proposed management program, the **2007 Drainage Area Management Plan (2007 DAMP)** (see **Appendix A**) for the Fourth Term Permits;
- A comparison of land use in Orange County in 2002 and 2005 (see **Appendix B**), and,
- A compendium of maps showing changes to the storm drain system infrastructure over the period of the Third Term Permits (see **Appendix C**).

1.1 Background

1.1.1 Drainage Area Management Plan

The **Drainage Area Management Plan (DAMP)** is the principal policy and program guidance document for the *Orange County Stormwater Program*, a cooperative municipal regulatory compliance initiative focused on the management and protection of Orange County's streams, rivers, creeks and coastal waters. The main objective of the DAMP is to fulfill the commitment of the Permittees to develop and implement a program that satisfies NPDES permit requirements.

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The DAMP describes the agreements, structures and programs that:

- Provide the framework for the program management activities and plan development (**DAMP Section 2.0** and **Section 3.0**);

- Provide the legal authority for prohibiting unpermitted discharges into the storm drain system and for requiring BMPs in new development and significant redevelopment (**DAMP Section 4.0**);

- Improve existing municipal pollution prevention and removal best management practices (BMPs) to further reduce the amount of pollutants entering the storm drain system. (**DAMP Section 5.0**);

- Educate the public about the issues of urban stormwater and non-stormwater pollution and obtain their support in implementing pollution prevention BMPs (**DAMP Section 6.0**);

- Ensure that all new development and significant redevelopment incorporates appropriate Site Design, Source Control and Treatment Control BMPs to address specific water quality issues. (**DAMP Section 7.0**);

- Ensure that construction sites implement control practices that address control of construction related pollutants discharges including an effective combination of erosion and sediment controls and on-site hazardous materials and waste management (**DAMP Section 8.0**);

- Ensure that existing development addresses discharges from industrial facilities, selected commercial businesses, residential development and common interest areas/homeowner associations (note: the San Diego permit explicitly outlines a residential component, but the Santa Ana permit is more general about residential requirements). (**DAMP Section 9.0**);

- Detect and eliminate illegal discharges/illicit connections to the municipal storm drain system (**DAMP Section 10.0**);

- Identify urban impacts on receiving waters; produce environmental quality information to direct management activities, including prioritization of pollutants to support the development of specific controls to address these problems; and determine pollutant load reductions and changes in the quality of receiving waters (**DAMP Section 11.0**); and

- Assess watershed constituents of concern and manage urban runoff on a watershed basis (**DAMP Section 12.0**).

1.1.2 Runoff from Urban Areas

The Program is concerned with the imprint of urban development on the landscape.

Urbanization creates rooftops, driveways, roads and parking lots (Schueler and Holland, 2000,[1] use the term *Imperviousness* as the unifying theme for understanding the adverse hydrologic impacts of urbanization), which (1) increase the timing and volume of rainfall runoff (compared to pre-development conditions) and (2) provide a source of pollutants that are flushed or leached by rainfall runoff into aquatic systems. The environmental consequences of these impacts are loss or impairment of aquatic beneficial uses due to:

- Water quality degradation resulting from increased loadings of sediment nutrients, metals hydrocarbons, pesticides and bacteria;
- Stream channel instability and habitat loss resulting from increased severity and frequency of floods;
- Increased water temperatures resulting from solar energy absorption by urban surfaces and elimination of riparian shading; and
- Loss of groundwater recharge.

1.1.3 Regulatory History

The Orange County Stormwater Program was initiated in 1990 as a cooperative local government response to a 1987 amendment to the federal Clean Water Act (CWA). This amendment extended the provisions of CWA Section 402 (National Pollutant Discharge Eliminations System permitting) to municipal storm drain system operators thereby making local governments (and some industrial activities) responsible for the quality of their stormwater discharges. Permit application requirements were promulgated by US Environmental Protection Agency (EPA) in 1990 (40 CFR 122) and form the basis of the current program.

Orange County's first NPDES Permits were issued in 1990 with renewals in 1996 and 2002. There are separate NPDES Permits administered by the Santa Ana and San Diego Regional Water Quality Control Boards (RWQCBs). The Permits prescribe that surface water quality protection be addressed in local governments' oversight of construction and development, its regulation of industry and commerce, and in its construction, operation and maintenance of the public urban infrastructure.

Program managers maintain the compliance of their jurisdiction with the applicable permit (or permits) through implementation of a BMP-based environmental management system (i.e. the DAMP) that is subject to both annual self auditing and reporting and external regulatory compliance audits which, in the Santa Ana Regional Board are, is an enforceable part of the Third Term Permit.

[1] Thomas R. Schuler and Heather K. Holland. *The Practice of Watershed Protection: Techniques for protecting our nation's streams, lakes, rivers and estuaries* (Maryland: Center for Watershed Protection, 2000).

1.2 Approach to Preparing Report of Waste Discharge

1.2.1 Themes

The immediate objective of the ROWD is to fulfill the commitment of the Permittees to undertake a program assessment and propose revisions to the management program in response to the information learned. While compliance with the Third Term Permits is maintained by implementation of prescribed management actions, program assessment must be undertaken with regard to the Permits' receiving water limitations provisions which require adaptation of the Orange County Stormwater Program where urban sources are causing or contributing to exceedances of applicable water quality standards. The first of the major themes that has framed preparation of the ROWD is a focusing of management efforts on identified water quality constituents of concern identified by the environmental monitoring programs.

The Third Term Permits transformed the Orange County Stormwater Program developed under the First and Second Permit Terms. The major escalation in compliance obligations prescribed new requirements for local governments' oversight of construction and development, regulation of industry and commerce, and its construction, operation and maintenance of the public urban infrastructure. These new compliance obligations required a major realignment of the program implemented over two years with the consequence that program performance metrics are generally available for three years. Program effectiveness assessments over the limited period of full implementation have indicated positive programmatic impacts, as detailed in subsequent sections of this report. However, annual assessments have also indicated significant variability in performance reporting between jurisdictions. In addition, regulatory agency reviews have identified differences in regulatory agency and Permittee expectations in key areas of the Program, particularly with respect to regulation and oversight. The second major theme of the ROWD is therefore a focus on enhancing existing program implementation rather than the proposed development of major new program initiatives.

The third major theme is a focus on the watershed approach and specific water quality constituents of concern. The Third Term Permits required the Permittees under the jurisdiction of the San Diego RWQCB to develop Watershed Urban Runoff Management Plans (WURMPs) to address priority water quality constituents of concern, and similar plans are being developed for watersheds in the Santa Ana Region. The WURMPs, termed DAMP Watershed Action Plans, while continuing to evolve, provide a basis for both cooperative targeted actions that complement the countywide approach and optimizing management actions on a regional, sub-regional or jurisdictional basis.

Major Themes of the ROWD

- Demonstrating the Iterative Management Approach: Implementing policy shifts based upon the findings of the environmental monitoring programs.

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- Enhancing Implementation: Focusing on program implementation through incorporation of environmental management system concepts.

- Emphasizing the Watershed Approach: Establishing and enhancing watershed–based water quality planning on a countywide basis.

1.2.2 Assessment

The DAMP incorporates three separate but nonetheless related water quality planning processes which are identified as "countywide," "jurisdictional," and "watershed-based" water quality management. Each process is iterative and incorporates annual phases of assessment focused on determining whether programmatic outcomes are being achieved (See **DAMP Appendix C – Program Effectiveness Assessment**). These annual assessments have previously been reported (see Unified and jurisdictional Annual Progress Reports).

DAMP Appendix C also recognizes the additional phase of assessment required in the ROWD every five years. While the longer term perspective of the ROWD allows a focus on environmental outcomes, both the annual and ROWD assessments necessarily consider the same performance metrics, both programmatic and environmental. In addition to considering these metrics, preparation of effectiveness assessments in the ROWD were additionally informed by:

- A longer term (rather than annual) review of the findings of the countywide water quality monitoring programs;

- Review of audit reports and other regulatory correspondence regarding the Program and meetings with RWQCB staff;

- A series of facilitated consultation meetings with jurisdictional program coordinators, including in-depth interviews on key program areas; and

- Input from the public at workshops.

The assessment has produced two types of programmatic recommendations:

1. ROWD Commitments, and
2. DAMP Modifications.

ROWD commitments represent shifts in programs that will be implemented upon completion of a development process with the Permittees, and are identified at the end of each program section of the ROWD. DAMP Modifications are characterized as programmatic modifications for improving program implementation and have been incorporated into the proposed 2007 DAMP.

Program Effectiveness

An activity, program element, or overall program is effective if it is producing a desired outcome. **Figure 1.1** shows that outcomes can be construed in terms of six levels and illustrates the progression of each successive level toward the ultimate goal of environmental improvement. In general, Levels 1 to 3 can be considered *Implementation Outcomes*, Levels 5 and 6 *Water Quality Outcomes* and Level 4 a combination of the two. Each level has value in informing the management process. However, it bears emphasis that not all are necessary or possible in every instance (CASQA, 2005).[2]
Assessment measures may be variously categorized. In this ROWD, two categories are recognized, related to (1) the shorter term confirmation of BMP implementation (Implementation or Process Measures, also termed Programmatic Indicators), corresponding to Levels 1-3 in **Figure 1.1**, and (2) the longer term verification of environmental improvement (Validation or Results Measures, typically actual indicators of environmental change). In essence, the categorization of measures reflects two basic assessment questions:

- Are program elements being implemented correctly?
- Are environmental improvements being realized?

Headline Indicators are intended to be a sub-set of measures that reflect in simple terms how a stormwater program is progressing towards its goals and are easily understandable. The Orange County Stormwater Program Headline Indicators that have been reported over the Third Term Permits are presented in **Table 1.2**.

Effectiveness assessment requires the establishment of a set of baseline conditions. Thereafter effectiveness can be determined by comparisons of successive years of indicator information against the baseline data. Where the period of evaluation is characterized by the implementation of new program requirements, determinations of program effectiveness will be limited to confirmation of program implementation. Indeed, it must be recognized that evidence of positive environmental outcomes can be elusive because:

- Water quality changes in response to program implementation are likely to be very slow; and
- Establishing a link between receiving water condition and program activities is difficult at the watershed scale when programs are being implemented incrementally.

While program effectiveness assessment is a key step in the iterative process of program

[2] California Stormwater Quality Association (CASQA). 2005. "An Introduction to Stormwater Program Effectiveness Assessment." Available at: http://www.scvurppp-w2k.com/pdfs/0405/CASQA%20White%20Paper_An%20Introduction%20to%20Stormwater%20Program%20Effectiveness%20Assessment4.pdf.

implementation, it should be realized that effectiveness assessment tools are still evolving. Assessing program effectiveness is recognized as a challenge for program managers across California, and the Orange County Stormwater Program is supporting the effort of the California Stormwater Quality Association (CASQA) to develop guidance in this area at a statewide level.

Environmental Assessment

A summary of the major findings of the water quality monitoring program is presented in **Section 11**. This summary has identified a number of water quality constituents of concern, specifically, metals (copper and zinc) and pesticides, based upon frequent exceedances of water quality standards and the occurrence of toxicity, respectively. In addition, Total Maximum Daily Loads (TMDL) and 13225 and 13267 Directives (see **Section 12**) for pathogen indicator bacteria and regulatory interventions regarding trash and debris require that these constituents also be considered water quality constituents of concern that will be the focus of targeted management efforts over the period of the Fourth Term Permits.

Regulatory Assessment

Over the period of the Third Term Permits, most of the municipal entities have been the subject of compliance audits which have served to highlight the successes (national recognition by USEPA) and shortcomings (three instances of administrative civil liabilities) of the Program. Since the primary objective of the DAMP is to fulfill the commitment of the Permittees to develop and implement a program that satisfies NPDES permit requirements, regulatory agency findings regarding permit compliance and the performance of the Orange County Stormwater Program must be considered in effectiveness assessments. Indeed, many of the commitments made in the subsequent sections follow from regulatory findings. In addition, current Total Maximum Daily Load (TMDL) development in the South County area and a regulatory intervention regarding trash and debris in the north County area, elevate fecal indicator bacteria and trash and debris to the status of Orange County Stormwater Program water quality constituents of concern.

Permittee Assessment

The Permittees have undertaken a comprehensive review of the current programs, identifying areas that are ineffective and require modification, and ones requiring additional emphasis. This assessment, coupled with the environmental and regulatory assessments, are the foundational underpinnings for this ROWD.

Table 1.1: Permit History

Permit Term	Santa Ana Regional Board			San Diego Regional Board		
	Order No.	NPDES No.	Date Adopted	Order No.	NPDES No.	Date Adopted
First (1990-1996)	90-71	CA 8000180	July 1990	90-38	CA 0108740	July 1990
Second (1996-2002)	96-31	CAS618030	March 1996	96-03	CAS0108740	August 1996
Third (2002-2007)	R8-2002-0010	CAS618030	January 2002	R9-2002-0001	CAS0108740	February 2002

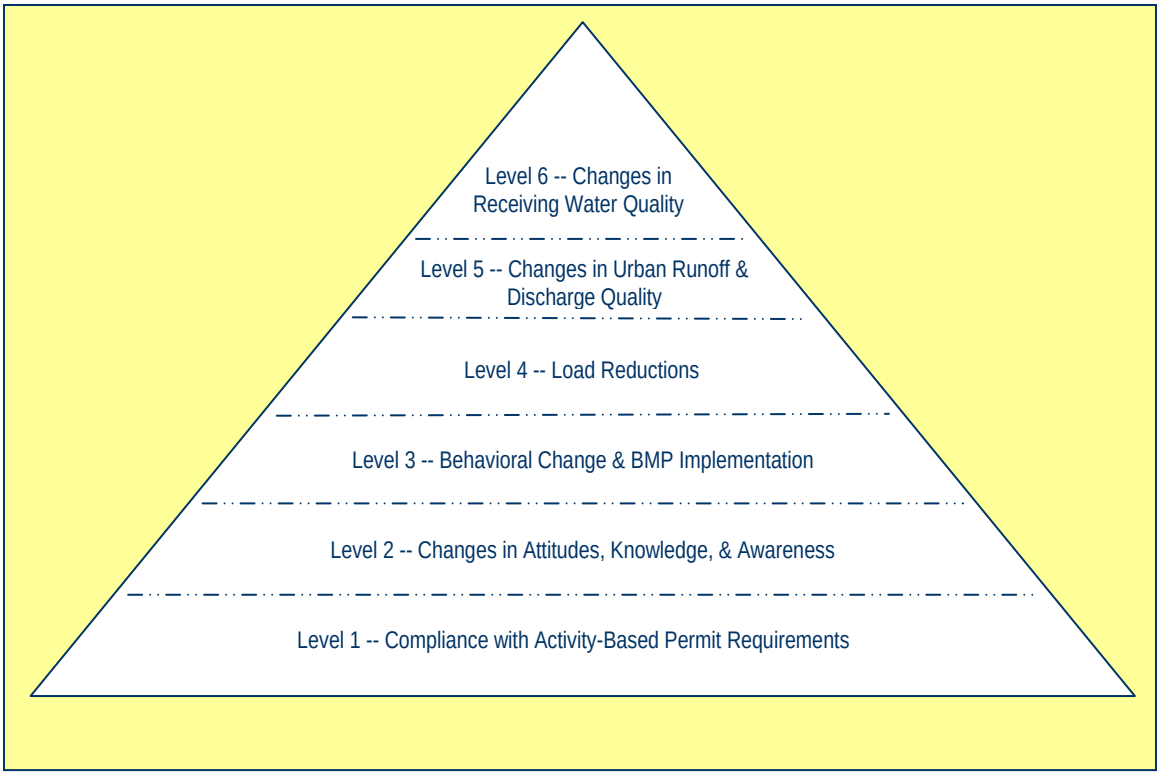
Table 1.2: Headline Measures

Program Element	Headline Measure	Process Measure	Result Measure	
			Indirect	Direct
2.0 Program Management	Participation in General Permittee Committee	X		
5.0 Municipal Activities	Solid Waste Collected		X	
	Drainage Facility Maintenance - Solid Waste Collected		X	
	Catchbasin Stenciling	X		
	Street Sweeping - Solid Waste Collected		X	
	Household Hazardous Waste Collected		X	
	Used Oil Collected		X	
	# of Facilities Inspected	X		
	Prioritization (High, Medium, Low) of Facilities		X	
	Reduction in Total Pesticide Application		X	
	Reduction in Total Fertilizer (Nitrogen) Application		X	
	Reduction in Total Fertilizer (Phosphorus) Application		X	
6.0 Public Education	# of Impressions	X		
	Changes in Public Awareness and Behavior		X	

Table 1.2: Headline Measures

Program Element	Headline Measure	Process Measure	Result Measure	
			Indirect	Direct
7.0 New Development	# of WQMPs processed	X		
	Area (Acreage) to which BMPs have been Applied		X	
	# of BMPs Implemented		X	
8.0 Construction	# of Sites Inspected	X		
	Extent of Compliance		X	
	# and Level of Enforcement Actions	X		
9.0 Existing Development	# of BMPs Implemented		X	
	Prioritization of Facilities		X	
	# and Level of Enforcement Actions	X		
10.0 ID/IC	# of Complaints		X	
	# and Level of Enforcement Actions	X		
11.0 Water Quality	Monitoring			X

Figure 1.1: General Classification of Outcome Types



2. 0 PROGRAM MANAGEMENT

2. 1 Introduction

The key elements of program management comprise the Principal Permittee and Permittee relationship, the Implementation Agreement, the structure and hierarchy of committees (termed Management Framework), and policy and program documentation (i.e. the DAMP). At the inception of the Orange County Stormwater Program, the Permittees in both Regional Board areas agreed that the County of Orange would be the Principal Permittee and the cities and the Orange County Flood Control District would be Co-Permittees on the permit (all parties are now collectively referred to as Permittees). Principal Permittee and Permittee responsibilities are specified in the Permits and reiterated in the NPDES Stormwater Permit Implementation Agreement (referred to as Implementation Agreement) which also provides a funding mechanism for the shared costs (administration, program development, public education, and environmental monitoring) of the Orange County Stormwater Program. To further support the development and implementation of a coordinated countywide program, a management framework was created during the First Permit Term. With the Third Term Permits this framework has evolved into a four tier structure (Permittees, City Managers' Water Quality Committee, Technical Advisory Committee (TAC) and Program Committees/Task Forces). Concurrently, the DAMP was substantially revised to address the significant escalation in compliance requirements prescribed in the Third Term Permits.

2. 2 Accomplishments

2.2.1 Implementation Agreement

The Implementation Agreement, originally entered into in December of 1990, was amended in October of 1993 to include two additional Permittees (Laguna Hills and Lake Forest) and formally establish the TAC.

- Implementation Agreement: On June 25, 2002, the Implementation Agreement was amended again and fully restated to include three additional Permittees (Aliso Viejo, Laguna Woods and Rancho Santa Margarita).

2.2.2 Management Framework

The Permittees established (in early 2002) and maintained a tiered management framework consisting of committees, task forces, sub-committees and ad hoc work groups to direct the development and implementation of the Orange County Stormwater Program (**Figure 2.1**). A greater level of participation in all aspects of the program has been evident by high Permittee participation in the management framework. This framework is composed of:

- City Manager's Water Quality Committee

The City Manager's Water Quality Committee meets as needed to provide budget and overall program review and governance direction.

- City Engineer's Technical Advisory Committee (TAC)

  The TAC serves in a program advisory role and provides policy direction on program budget and program development and implementation. It is comprised of one Public Works Director/City Engineer, or selected representative, from each of the County Supervisor Districts and a representative from the County of Orange. It meets 4-6 times annually.

- General Permittee Committee

  The General Permittee Committee is the principal forum for disseminating information for program coordinators. The Committee meets monthly (except November).

  In 2004-05, thirty four (34) out of thirty five (35) Permittees reported 80% or higher participation in the General Permittee Committee.

- Task Forces/ Sub-Committees

  The *Task Forces/ Sub-Committees* provide for the continued development of the program in a specified area of program responsibility and oversight. The Task Forces/ Sub-Committees which were active in 2004-05, are:

  - Trash and Debris Task Force

    - Purpose: To foster and sustain partnership approaches to dealing with trash and debris in stormwater and urban runoff (quarterly meeting schedule). Recent products include a strategic assessment of Orange County's trash and debris control efforts.

  - Legal/Regulatory Authority Task Force

    - Purpose: To review the legal authorities that the Permittees have in complying with the permit requirements and recommend changes as needed and to track stormwater related litigation that may affect the Orange County Stormwater Program (quarterly meeting schedule).

  - Water Use Efficiency Task force

    - Purpose: To study and support a comprehensive effort to curb urban runoff through efficient water usage in Orange County (quarterly meeting schedule).

- Data and Information Management Sub-Committee
  - Purpose: To oversee the development and implementation of information technology solutions to program data management and reporting requirements (monthly meeting schedule). Recent products include an internet-based system for preparation of the annual reports/Program Effectiveness Assessments (PEAs).
- LIP/PEA Sub-Committee
  - Purpose: To provide oversight and technical direction to the management of core DAMP/Local Implementation Plan (LIP) programs (bi-monthly meeting schedule).
- Public Education Sub-Committee
  - Purpose: To provide regional consistency and oversight for the stormwater public education program efforts (monthly meeting schedule). The sub-committee directs development and dissemination of all education and outreach materials.
- Inspection Sub-Committee
  - Purpose: To provide a forum for the coordination, investigation, enforcement and training aspects of the existing development inspection program and Illegal Discharges/Illicit Connections (ID/IC) programs (bi-monthly meeting schedule). Recent products include the Investigative Guidance Manual and self-audit checklist.
- Water Quality Sub-Committee
  - Purpose: To provide oversight and technical input for the revision of the water quality monitoring programs, ongoing water quality data evaluation, and special water quality investigations and BMP effectiveness studies (quarterly meeting schedule).
- Ad-Hoc Group – Wastewater Disposal
  - Purpose: To develop a list of BMPs for the disposal of washwater/ wastewater generated by mobile businesses. The Group was convened specifically to address wastewater disposal issues and worked cooperatively with the sewering agencies to produce best management practice guidance (BMP Fact Sheet IC24). This ad-hoc group has now sunsetted.

- Watershed Committees

  - Seven Watershed Committees (Newport Bay, Laguna Coastal streams, Aliso Creek, Dana Point Coastal Streams, San Juan Creek, San Clemente Coastal Streams, and San Mateo Creek) were established and have met regularly since their inception.

  - Other Watershed Committees/Work Groups

    The Permittees have also participated in the Newport Bay Executive and Management Committees (the latter held jointly for a period with the Army Corp of Engineers (ACOE) Study Management Team), the Huntington Harbour Water Quality Task Force, the Dana Point Harbor Water Quality Task Force, the Coastal Coalition, and the Aliso Creek Tier I and Tier II stakeholder meetings. These watershed groups focus their activities and discussions on broader watershed issues of concern, such as habitat restoration and flood control in addition to water quality issues resulting from Total Maximum Daily Loads (TMDLs) and special directives.

- Other Representation/Participation

  The Principal Permittee actively represents the Permittees on various advisory stormwater fora, including, California Stormwater Quality Association (CASQA), Southern California Coastal Water Research Project (SCCWRP) (the County, representing the Orange County Stormwater Program, joined SCCWRP in 2005-06), Plastic Debris – Rivers to Sea Project, Nitrogen and Selenium Management Program, and Waste Discharge Requirements (WDR) for Fats, Oils and Grease (FOG) Program.

2.2.3 Program Documentation

The completion of the 2003 DAMP marked the culmination of a major program documentation overhaul and revision that was initiated by the preparation of the Report of Waste Discharge submitted on September 1, 2000. In addition to the revised policy commitments and model programs, the DAMP was expanded through the addition of appendices to include 34 individual jurisdictional LIPs (the Permittees formally identified which departments have responsibility for implementation of each program element), an extensive compendium of training materials, regional and jurisdictional program effectiveness assessment and reporting, and six watershed management plans.

2.2.4 Watershed Mapping

To support the development of the DAMP/Watershed Chapters, GIS-based mapping was undertaken for the S. County area initially to define watershed boundaries. It will be completed for the entire County area by the end of 2006 and will, for the first time, establish definitive watershed and sub-watershed boundaries for Orange County.

Orange County Watersheds (See **Figure 12.1**)

Orange County – Santa Ana Region
San Gabriel /Coyote Creek Watershed (within Orange County)
Anaheim Bay/Huntington Harbour Watershed
Santa Ana River Watershed (within Orange County)
Newport Bay Watershed
Newport Coastal Streams Watershed

South Orange – San Diego Region
Laguna Coastal Streams Watershed
Aliso Creek Watershed
Dana Point Coastal Streams Watershed
San Juan Creek Watershed
San Clemente Coastal Streams Watershed
San Mateo Creek Watershed (within Orange County)

2.2.5 Fiscal Analyses

Annual fiscal analyses have been conducted since the inception of the Program. Each analysis identifies *shared costs* and *individual costs*. Shared costs are those that fund activities performed by the Principal Permittee. These activities include administration, program development, public education, and environmental monitoring. The projected-shared cost expenditures for the 2005-06 fiscal year, as approved by the Permittees, were $5,941,160.

Individual Costs are those incurred by each Permittee arising from its jurisdictional program implementation as documented in the LIPs and comprise capital and operation and maintenance costs. Capital Costs refers to expenditures for land, large equipment, and structures and Operations and Maintenance Costs refer to normal costs of operation including the cost of keeping equipment and facilities in working order. The total individual Permittee costs for the 2005-06 fiscal year were projected to be $91,868,883.

The fiscal analysis also requires the identification of funding sources. The funding sources used by the Permittees include: General Fund, Utility Tax, Separate Utility, Gas Tax, and Special District Fund, Others (Sanitation Fee, Fleet Maintenance, Community Services District, Water Fund, Sewer & Storm Drain Fee, Grants, and Used Oil Recycling Grants). **Figure 2.2** shows that general funds continue to support over half the cost of program implementation across Orange County.

2.3 Assessment

2.3.1 Implementation Agreement

Since the inception of the Program the Implementation Agreement has been amended to provide for the incorporation of new cities and to formally recognize the role of the TAC. The structure of the Agreement has accommodated the expansion of the program and the significant escalation of shared costs with the adoption of the Third Term Permits. More recently, the Agreement has served as a model for cost sharing collaboration related to the Newport Bay TMDL compliance effort (including the Nitrogen Selenium Management Program), Regional Harbor Monitoring Program, and

Aliso Creek 13255 Directive. Consequently, it is considered to be an effective basis for cooperation of the Program.

2.3.2 Management Framework

USEPA defines a management framework *"as a lasting process for partners working together. It's a support structure making it easier to coordinate efforts--a structure made of agreed upon standard operating procedures, timelines, and forums for communicating with each other"*. On the basis of this definition, the current framework continues to effectively serve the Permittees. The Management Framework has enabled 36 local government entities to develop, implement and sustain coordinated regional and watershed-based approaches to water quality protection and management. The Framework provides a basis for all parties, including staff, management, executive management and elected officials to be informed and involved in the planning processes.

In addition to the established framework, an alternate management framework was conceived during the Third Permit Term by County senior management and the City Managers Association Water Quality Committee in the context of developing a countywide strategic approach to water quality protection based upon three watershed management areas. Conceptually endorsed by the County of Orange Board of Supervisors, this alternate structure will continue to be developed over the course of the Fourth Term Permits.

Headline Indicator – Participation in General Permittee Committee: In 2004-05, thirty four (34) out of thirty five (35) Permittees reported 80% or higher participation in the General Permittee Committee compared to thirty two (32) Permittees reporting 80% or higher participation in 2003-04.

The management framework is reviewed annually to ensure it meets program needs. All the committees/task forces have been effective in bringing forward initiatives to meet the requirements of the Third Term Permits and to address program needs under a consensus building production process.

While these outcomes point to the value and robustness of the current Framework, there has been significant turnover of staff in jurisdictional program manager positions. This has lead to a regulatory agency perception that program managers lack the training and expertise necessary to effectively implement the "stormwater mandate."

ROWD Commitment:

- Prepare a training schedule and define expertise and competencies for jurisdictional program manager positions.

2.3.3 Program Documentation

International Organization for Standardization (ISO) 14000 provides criteria for evaluating the efficacy of management system documentation. The DAMP expresses the commitment of the Permittees to NPDES permit compliance and to addressing the adverse impacts of urban runoff on Orange County's creeks, rivers, streams and coastal waters. It establishes objectives, guides the participating organizations toward the development and implementation of BMPs, and commits the Permittees to an iterative process of improvement. It requires the designation of a program manager and assigns responsibilities (through the LIPs) for program implementation. Based upon these considerations, the DAMP meets formal environmental management system expectations for policy documentation. Moreover, the DAMP clearly identifies management procedures and provides for the internal and external communication of both policy and performance. The DAMP is also widely available to interested parties through its posting to www.ocwatersheds.com .

While the comprehensive nature of the current documentation supports the implementation of the Program, it can be perceived as overwhelming in its complexity to both jurisdictional program coordinators who lack a long period of program association and outside constituencies seeking insights into the program. Moreover, the active consideration being given by regulators (e.g. the SWRCB's Blue Ribbon Panel) to possible future inclusion in NPDES permits of quantitative measures, including effluent limitations, underscores regulatory agency and environmental advocate perception of there being undue complexity and challenge with respect to establishing discharger accountability. It is possibly a perception which is being reinforced by overly comprehensive and complex program documentation. The Permittees started to address this issue of accessibility with the publication of the "popular format" *Orange County Stormwater Program Progress in 2002-2003* report and this document's subsequent acclaim points to the need for the more regular use of "popular" format reports. However, to address both the need for the DAMP to be more "accessible" and the Permittees' interest in validating a regulatory framework for stormwater predicated upon an auditable management system, the DAMP must more succinctly demonstrate to all constituencies that policies, objectives, and targets are properly identified and are being met, that regulatory compliance is being achieved, and that the planning processes provide for iterative improvement.

DAMP Modification:

- Revise the DAMP for greater consistency with established Environmental Management System (EMS) principles and improved accessibility to different constituencies and levels or readership.

2.3.4 Fiscal Analyses

The significant year-to-year variability in reported program costs (**Figure 2.3**), which cannot be attributed to changes in program management, point to the clear need for an assessment of the fiscal reporting process.

ROWD Commitment:

- Prepare a fiscal reporting strategy based upon a review of the fiscal analysis reporting section of the PEA, to better define the expenditure and budget line items included in the fiscal report.

Figure 2.1: Orange County Municipal NPDES Management Framework

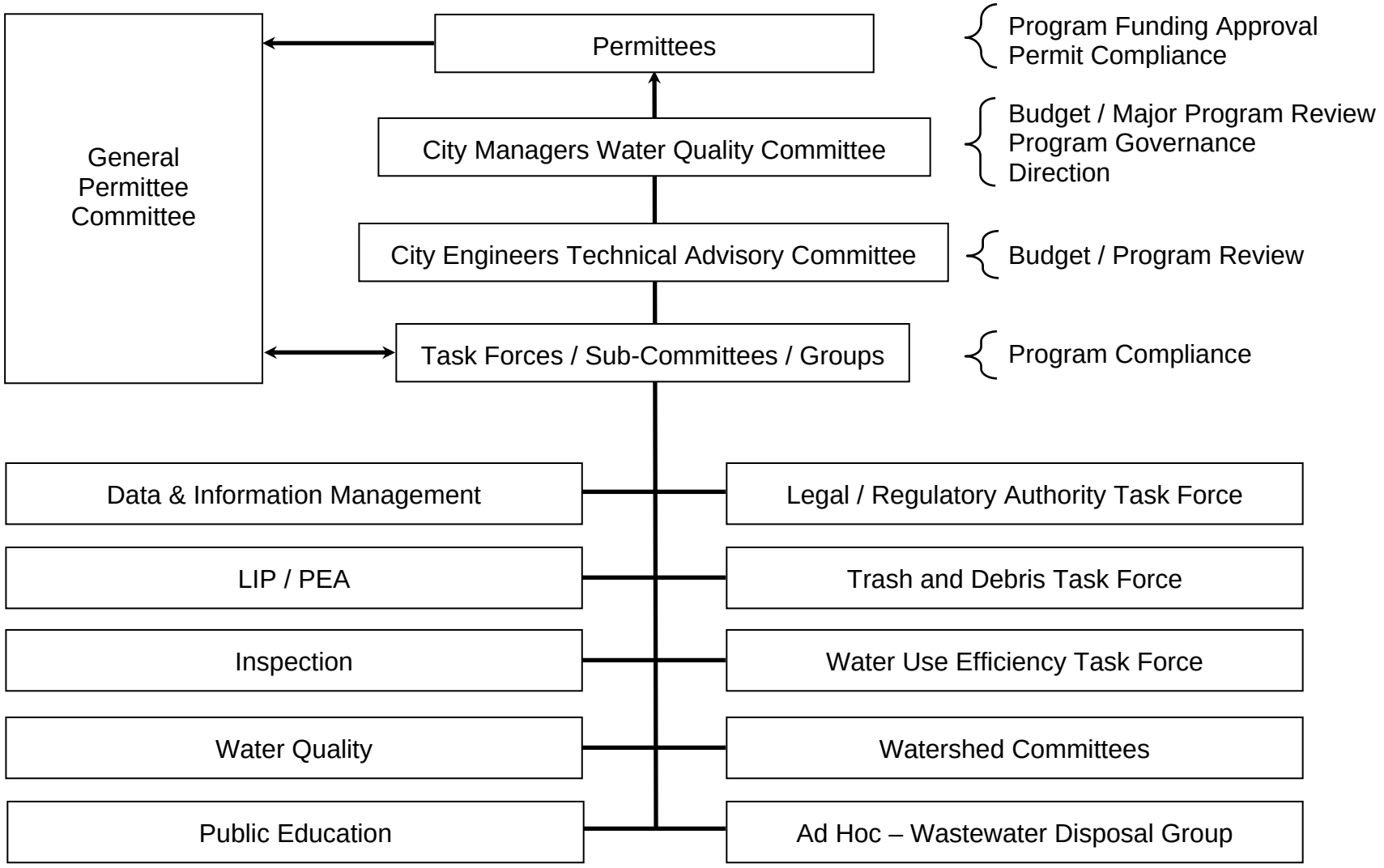


Figure 2.2: 2004-05 Funding Sources

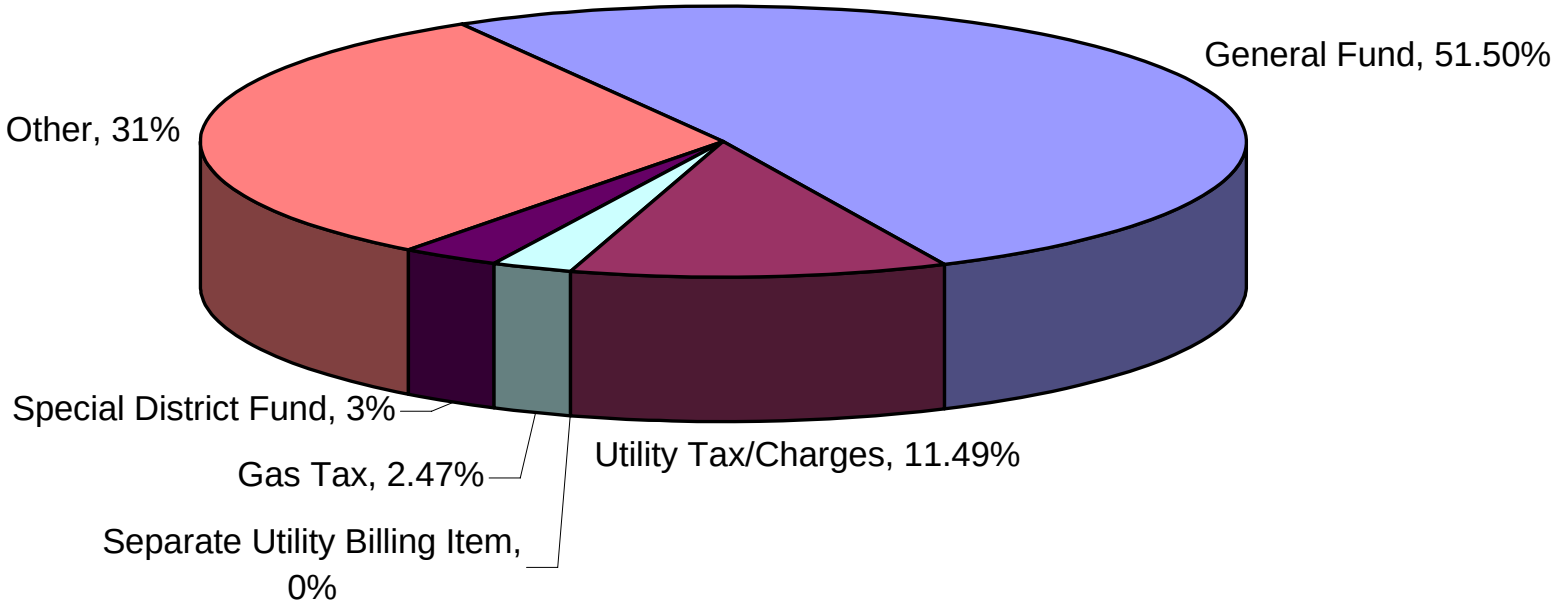
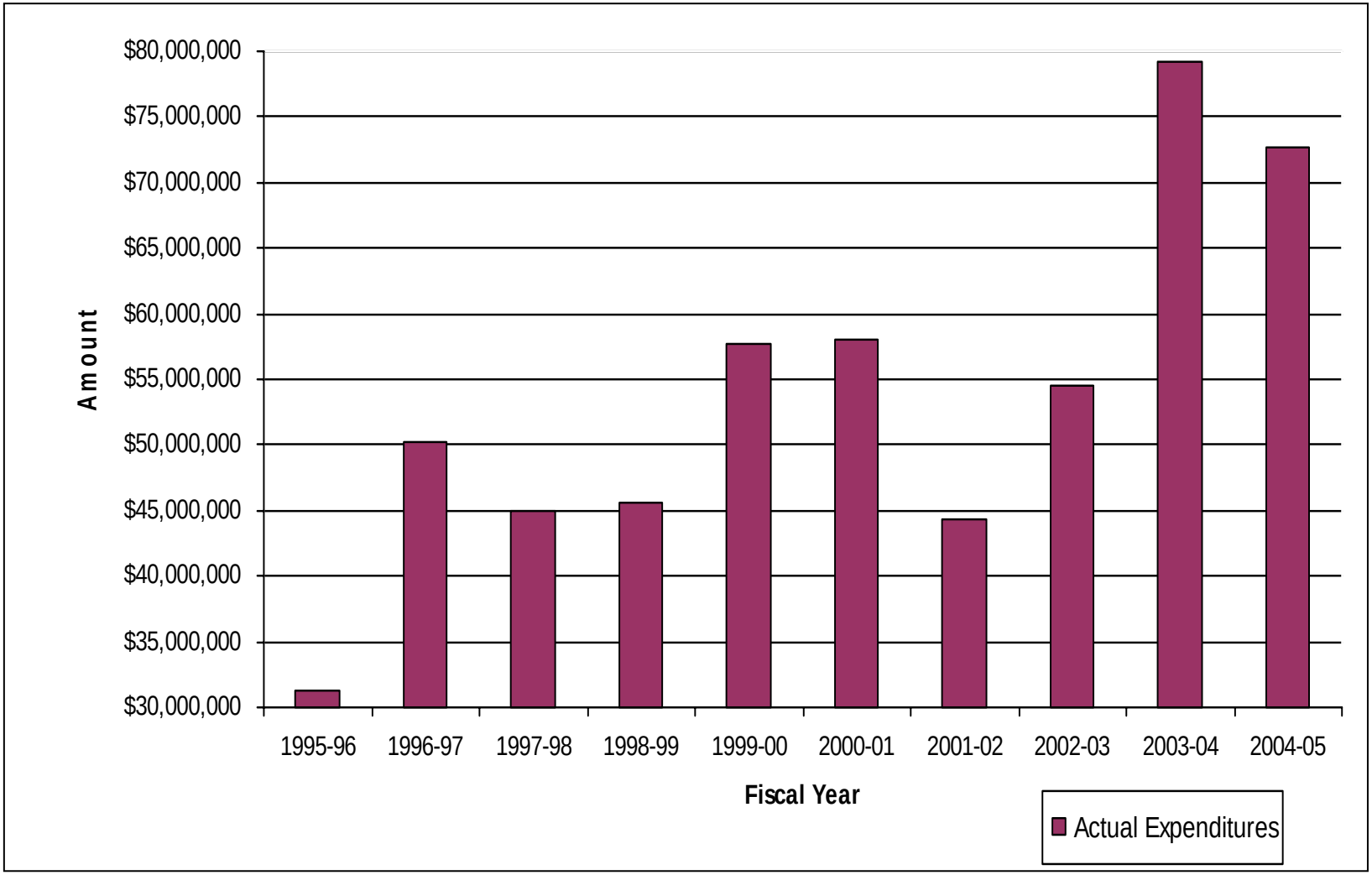


Figure 2.3: Historical Review of Total Individual Permittee Costs



3.0 PLAN DEVELOPMENT

3.1 Introduction

The DAMP sets forth a countywide approach for urban stormwater management by:

- Establishing a baseline set of BMPs that are applicable to all areas and that are proven and cost-effective;
- Monitoring water quality to assess progress and identify urban impacts on receiving water;
- Prioritizing waterbodies for corrective action, with those listed as impaired having a higher priority; and
- Focusing on enhanced BMPs for constituents of concern at a watershed or jurisdictional level, as appropriate.

The purpose of **DAMP Section 3.0** is to describe an iterative planning process, informed by programmatic BMP assessments and environmental monitoring, which support the progressive evolution attainment of water quality standards, as required by the NPDES Permits.

3.2 Accomplishments

3.2.1 Enhancements to DAMP: Iterative Planning Processes

A defining feature of the iterative planning process is the continual analysis, measurement and improvement through the quality loop which is illustrated in a simplified form in **Figure 3.1:**

Assessing: Assessing environmental conditions and programmatic performance, establishing the goals and targets to be achieved, and determining the route to be taken and the measurements to track success;

Planning: Designing activities to achieve the goal, identifying the needed skills and expertise, and designating responsibility for achieving desired outcomes;

Implementing: Striving to bring the process into effect in an efficient and effective manner, and

Monitoring: Evaluating the effectiveness of the *Implementing* stage.

With the adoption of the Third Term Permits, the DAMP which previously had presented policy and programmatic guidance, was revised to incorporate greater individual accountability through jurisdictional Local Implementation Plans (LIPs) (see **DAMP Appendix B**). The LIPs provide a flexible jurisdiction-specific plan within the broader policy and model program framework of the DAMP.

With additional permit mandates to institute watershed-based planning, water quality

planning in the context of the DAMP is now evident as two separate, but nonetheless similar and highly interdependent, processes targeting the control of pollutants in urban runoff. These processes (**Table 3.1; Figure 3.1**) are now recognized in the DAMP as:

- DAMP/LIP – Directed by jurisdictional assessments completed individually by each Permittee and a countywide assessment through a Unified Annual Progress Report.; and
- DAMP/Watershed Action Plan (WAD) (See **DAMP Appendix D**) – Directed by watershed scale assessments in Watershed Annual Reports.

3.2.2 Enhancements to DAMP: Programs and BMPs

Assessment is the part of the planning cycle that involves either initial investigation of the environmental conditions that are being addressed by the management program or, in subsequent iterations of the planning cycle, re-assessment to determine program effectiveness (i.e. if the actions being implemented are contributing to programmatic goals). It encompasses programmatic (including technology evaluations) and environmental enhancements and is itself an evolving area of stormwater management.

Programmatic Enhancements

To assist the Permittees with reporting the status of LIP implementation and the performance of the individual jurisdictional stormwater quality management programs, a Program Effectiveness Assessment (PEA) reporting framework (**DAMP Appendix C**) was developed in 2002-03. The PEA:

- Facilitates the collection and compilation of specific stormwater program implementation data and progress validation indicators;
    - A PEA template was created in 2003 and has been the basis of the 2002-03, 2003-04, and 2004-05 Annual Reports. In 2005, the template was converted into an internet-based reporting system.
- Provides for program effectiveness assessment by the individual Permittees and the Principal Permittee on a jurisdictional, watershed and/or countywide basis;
    - The PEA identifies specific programmatic and environmental performance metrics including specified validation indicators titled, "Headline Indicators." (See Section 1.2.2)
- Ensures that an evaluation and improvement process is applied on a jurisdictional, watershed and/or countywide level to determine where modifications within the DAMP, LIP or WAP may be necessary; and
- Provides a mechanism for the Permittee to identify and report modifications that have or will be made to their LIP.

Enhancements in BMP Knowledge

A number of BMP evaluations, with countywide application, have been undertaken. These studies include the *BMP Effectiveness and Applicability for Orange County* (see **DAMP Appendix E1**); Trash *and Debris BMP Evaluation* (see **DAMP Appendix E2**); *Erosion Control BMP Effectiveness Study* (see **DAMP Appendix E3**); *Septic System Inventory and Assessment* (see **DAMP Appendix E4**); *Portable Toilet Pollution Prevention Program* (see **DAMP Appendix E5**), *Dry Weather Diversion Study* (see **DAMP Appendix E6**), *BMP Retrofit Opportunity Study* (see **DAMP Appendix E7**), and *Tustin Area Spill Containment Project* (see **DAMP Appendix E8**).

- *BMP Effectiveness and Applicability for Orange County*

  This study was commissioned to review existing information on available structural BMPs and to organize and present specific information to facilitate the selection, siting, design, construction and maintenance of the most appropriate and cost-effective BMPs for a particular site in Orange County. The study recommended consideration be given to using extended detention basins, vegetated swales, vegetated buffer strips, bioretention, sand and organic filters, infiltration basins and infiltration trenches. In 2005, the study report was updated to include flow reduction BMPs developed in conjunction with the Nitrogen and Selenium Management Program.

- *Trash and Debris BMP Evaluation*

  The objectives of the study were to review characterization information on trash and debris in Orange County and to identify candidate structural BMPs. The study concluded that site characteristics such as hydraulic head or footprint may be the principal determinants of BMP selection. During the reporting period the findings of this study were developed into a BMP selection guide for retrofit applications to modify an existing facility to provide a water quality (trash/debris removal) function. This guide will be finalized in 2006-07 and incorporated into **DAMP Appendix E.**

- *Erosion Control BMP Effectiveness Study*

  The study was conducted to evaluate selected erosion methodologies for graded building pads with the goal of providing information on (1) the effect of time and weathering on product condition; (2) the frequency a product must be applied to be effective; (3) the maximum slope on which a product will perform effectively; and (4) how product performance is affected by soil types. The study comprised an evaluation of two types of hydraulic mulch (paper and wood based), two types of polyacrylimide (low and high molecular weights), and wood mulch (without a binding agent). The findings of the evaluation, which will be reported in the **2005-06 Unified Report** and incorporated into **DAMP Appendix E**, will be used to form the basis of a program recommendation on county pre-approved

BMPs.

- *Septic System Inventory and Assessment*

  The objectives of this study were to develop an inventory/database of the septic systems in Orange County and to estimate the potential impact of septic systems on the quality of selected receiving waters. The final inventory/database compilation resulted in a list of over 2776 active septic systems which are widely dispersed throughout the County but are found in the highest concentrations in the Santa Ana River watershed. In the course of conducting eighty field surveys, one failed system was noted, representing a failure rate of 1.25% which was consistent with a similar finding in the literature. The study concluded that septic systems do no represent a significant source of constituents of concern (particularly fecal indicator bacteria and nutrients) for Orange County receiving waters.

- *Portable Toilet Pollution Prevention Program*

  The objectives of the evaluation were to: (1) determine the nature of existing operational practices and regulatory oversight structure; (2) assess the extent to which the present practices associated with their use and maintenance were adversely impacting surface water quality; and (3) recommend appropriate revisions to current operational practices or regulatory oversight as warranted. The study determined that current standard industry practices for use, maintenance, transport and storage of portable toilets within Orange County are generally found to be sufficiently responsible to prevent impacts to receiving waters.

- *Dry Weather Diversion Study*

  The dry weather diversion study was prepared to evaluate the diversions to the sanitary sewer that are in place or proposed within Orange County and to identify decision-making criteria to be used in selecting diversions as a preferred BMP. A recommended procedure for prioritizing implementation of diversion facilities was developed for the area of Orange County served by the Orange County Sanitation District.

- *BMP Retrofit Opportunities Study*

  In 1997-98, the feasibility of incorporating BMP retrofits to optimize beneficial use attainment began to be addressed in the context of the long-term water quality planning initiatives being conducted within Orange County, a number of which were in cooperation with the Army Corps of Engineers. To supplement these earlier efforts, during 2003-04, a countywide evaluation was initiated using a GIS-based model to identify opportunities within the existing storm drain infrastructure for configuring/reconfiguring storm drains or channel segments in order to improve water quality and maintain the designated beneficial uses

(see **DAMP Appendix E**). This effort was continued in 2005-06 with further use of the GIS-based model.

- *Tustin Area Spill Control (TASC) Demonstration Project*

  To address the various regulatory, technical and coordination issues associated with preventing and planning for sanitary sewer overflows (SSOs), the County, as Principal Permittee, and the Orange County Sanitation District (OCSD) initiated a pilot project titled Tustin Area Spill Control (TASC) Demonstration Project. The project's accomplishments to date include:

  - Development of SSO response procedures;
  - Selection of primary and backup sewage spill response contractors for containment and recovery of sanitary sewer overflows;
  - Conducting SSO desktop and hands-on field response training with the contractors; and,
  - Development of a Memorandum of Understanding for delineating jurisdictional and financial responsibilities within the TASC project.

Enhancements in Technologies and Methodologies

A number of important initiatives are being supported by the Permittees aimed at the development of assessment techniques and methodologies to support more informed and consistent decision making across Southern California and statewide, including projects being undertaken with the Southern California Stormwater Monitoring Coalition, University of California, Irvine (UCI) for the development of the California Sustainable Watershed/Wetland Information Manager (CalSWIM) – prototype database, and the California Stormwater Quality Association (CASQA) initiative on program effectiveness assessment.
ings of the extensive water quality monitoring program during the reporting period are discussed in **Section 11.0**. However, concurrent with this data collection effort are a number of important initiatives, being supported by the Permittees, that are aimed at the development of assessment techniques and methodologies to support more informed and consistent decision making across Southern California. Notable amongst these initiatives are the Regional Research Monitoring Program (Stormwater Monitoring Coalition) and the Development of the California Sustainable Watershed/Wetland Information Manager (CalSWIM) – prototype Database.

- *Regional Research Monitoring Program (Stormwater Monitoring Coalition)*

  The goal of the Southern California Stormwater Monitoring Coalition (SMC) is to identify region-specific research needs to better understand stormwater mechanisms and impacts, and to collectively sponsor the development of assessment techniques and methodologies that will enable more informed and consistent stormwater management decision-making across the region.

  The SMC has initiated several of the 15 research projects identified in the research needs agenda, including: microbial source tracking method comparison,

development of standardized sampling and analysis protocols, implementation of a laboratory intercalibration program, peak flow impact assessment, and the development of a regional integrated freshwater stream bioassessment monitoring program.

- *Development of California Sustainable Watershed/Wetland Information Manager (CalSWIM) – Prototype Database*

  In response to a commitment to develop a prototype watershed database for cumulative impact assessment, the County of Orange as Principal Permittee has worked with UCI in developing and implementing a prototype database called the California Sustainable Watershed/Wetland Information Manager (CalSWIM). CalSWIM is a web-based expert system and database focused, initially, on Newport Bay and the Newport Bay watershed and can be viewed at www.calswim.org. The technical objective of CalSWIM is to provide an interactive platform for coastal wetland and watershed managers, planners, and engineers to explore alternative wetland and watershed management strategies.

- *CASQA Program Effectiveness Assessment White Paper*

  The preliminary *White Paper* introduced and discussed key concepts and provided a standardized terminology related to the development of a comprehensive framework for assessing the effectiveness of stormwater management programs. It briefly defined and categorized potential outcomes, measures, and methods to be used in conducting assessments, and provided examples of how several programs are already utilizing these tools to assess their effectiveness. It also discussed the current needs of stormwater program managers with respect to program assessment. The issues addressed in this paper will form the basis for more detailed guidance on effectiveness assessment that is being developed by the CASQA Effectiveness Assessment Subcommittee during 2006.

3.3 Assessment

The Permittees recognize that knowledge in the field of stormwater quality is rapidly evolving and that the BMPs within the DAMP/LIP must be revised, deleted or added to in order for the program to stay current. In addition, water quality problems caused by urban stormwater that are identified either through environmental monitoring or regulatory interventions will elevate the need for additional or new BMPs to be implemented.

3.3.1 Iterative Planning Processes

While the ROWD itself serves to identify new programmatic commitments (see **Sections 5.0** through **10.0**), and is thereby evidence of the iterative approach, the DAMP has not, to date, detailed a process for programmatic change in response to improved knowledge of water quality controls and best management practices.

DAMP Modification:

- Revise **DAMP Section 3.0** plan improvement process to detail the plan improvement process.

3.3.2 Programmatic Assessment

The PEA template created in 2003, and used as the basis of the 2002-03, 2003-04, and 2004-05 Annual Reports, has been helpful in establishing a series of metrics for spatial (i.e. jurisdictional comparisons) and temporal (i.e. year-to-year comparisons) assessments of program effectiveness. However, the reporting has highlighted significant inconsistencies in metric interpretation across the jurisdictions of the Orange County Stormwater Program that require further standardization.

ROWD Commitment:

- Prepare metric definitions and guidance to improve efficacy of the assessment process.

3.3.3 BMP Assessment

Over the course of the Third term Permits a number of BMP evaluations have been undertaken. The recommendations arising from these studies are presented as ROWD commitments or DAMP Modifications in the subsequent sections of this ROWD as appropriate.

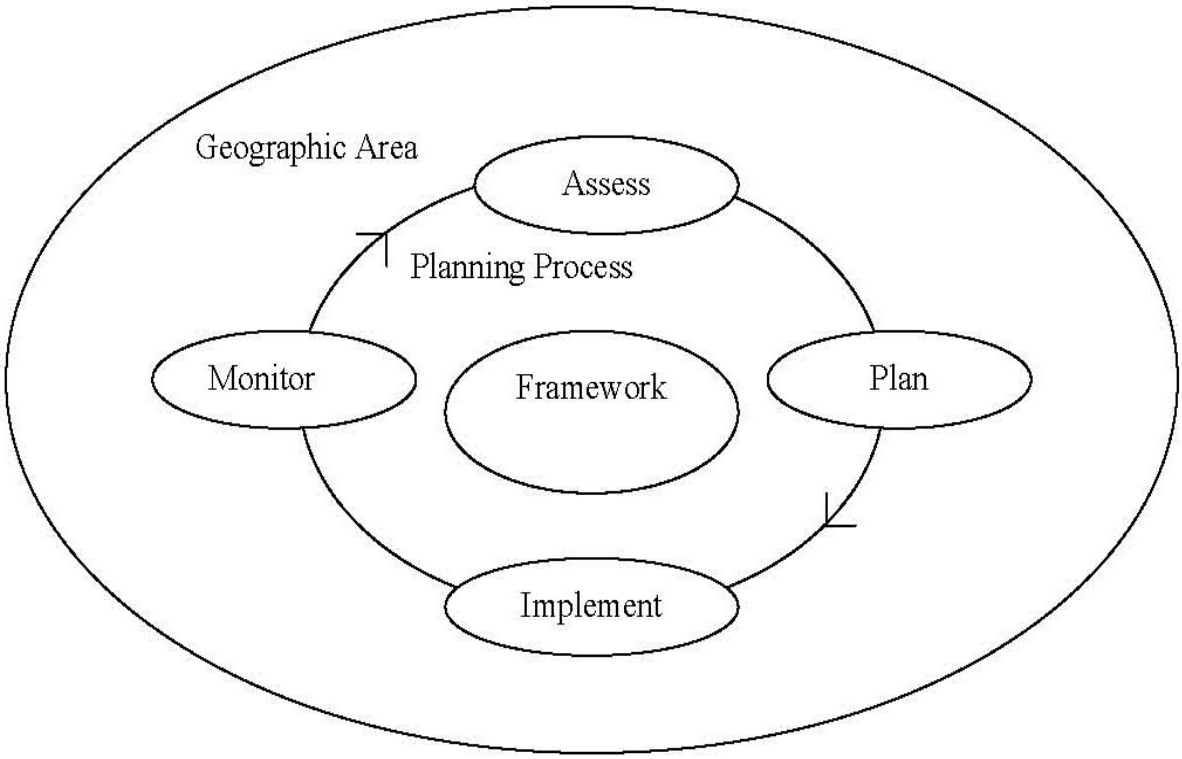
3.4 Summary

The Permittees consider **DAMP Section 3.0** to define the iterative planning processes, informed by programmatic and BMP assessments, that are the basis of the DAMP. Based upon this evaluation of the process, the principal finding is that the language of the DAMP can be revised to better define these processes at separate, but interrelated, jurisdictional, watershed and countywide levels. The Permittees have also identified a need to standardized annual reporting data further in order to enhance effectiveness assessment.

Table 3.1: Comparison of Water Quality Planning Processes

	DAMP/LIP	Watershed Action Plan
Geographic Area Covered by Plan	Defined by political (city/County) boundaries.	Defined by hydrologic boundaries.
Planning Process	Focused on reducing discharges of pollutants in urban runoff and stormwater pollution on a uniform countywide basis. Directed by DAMP/LIP in conformance with NPDES permits requirements.	Focused on improving local receiving water quality where it is adversely impacted by urban runoff and stormwater pollution. Directed by NPDES permits and 303(d) list.
Framework	Directed by Stormwater Program committee structure and Regional Board review. Public consultation principally through CEQA process/Regional Board review.	Directed by municipal and public agency stakeholders. Characterized by public participation.
Assessment	Based on countywide municipal and regional cooperative investigations of stormwater and receiving water quality. Assessments are undertaken annually (LIP) and every 5 year (DAMP).	Based on information from watershed specific investigations. Assessments are undertaken on an annual basis.
Planning	Broad based approach with emphasis on well established pollution prevention and source control measures.	Pollutant specific approach with emphasis on treatment controls and consideration of innovative regional solutions.
Implementation	Individually by Permittees.	Individually and collaboratively by Watershed Permittees and other agencies.
Monitoring	Considers pollutant load reduction.	Considers beneficial use attainment.

Figure 3.1: Water Quality Planning Process



4.0 LEGAL AUTHORITY

4.1 Introduction

The ability of the Permittees to comply with the requirements of the Third Term Permits is contingent upon the establishment, by each Permittee, of adequate legal authority to support control program implementation. **DAMP Section 4.0** discusses the development, starting in 1993, of a Model Water Quality Ordinance that was used by the Permittees as the basis of their local ordinances that were adopted by 1997. It also commits the Permittees to reviewing their ordinances to determine if any modifications are necessary in order to comply with new NPDES Permit requirements.

4.2 Accomplishments

With the adoption of the Third Term Permits in early 2002, the Permittees reviewed and verified the adequacy of their legal authority as the legal basis for the activities required for Third Term Permit compliance, primarily **DAMP Sections 7.0, 8.0, 9.0**, and **10.0**. Following this initial review and verification, the responsibility for maintaining the efficacy of this key program element has rested with the Legal and Regulatory Task Force (see **Section 2.3.1**). During the reporting period, this Task Force has focused on a number of key areas including:

- Review and revision of legal authority as necessary regarding the stipulation of mandatory minimum BMPs in the San Diego Region;
- Review of inspection authority and "right of entry" at industrial/commercial facilities;
- Identification and resolution of overlap in legal authority within requirements of the WDR FOG program;
- Examination of the various Total Maximum Daily Load (TMDL) initiatives and their relationship to NPDES permits; and
- Perpetuation of BMP upkeep and maintenance in Water Quality Management Plans (WQMPs) for New Development/Significant Redevelopment.

Arising from the work of the Task Force have been continued findings of legal authority adequacy and the development of a model approach to WQMP recordation.

4.3 Assessment

The program effectiveness assessment outcome level for the **DAMP Section 4.0** is presented in **Table 4.1**. However, beyond confirming compliance with the Permits, the Permittees' legal authority can also be assessed in the context of the sections of the DAMP that it primarily supports.

4.3.1 Legal Authority to Implement Existing Development and ID/IC Programs

In 2005, an action taken under the Ordinance requiring a property owner to effect the removal of manure from a creek under the authority of the jurisdiction's water quality

ordinance was formerly challenged under the ordinance's appeal provisions. The jurisdiction prevailed in the third party adjudicated appeal hearing and again at a subsequent trial in an action brought by the Orange County District Attorney. These results, in addition to the numerous successful administrative actions and citations detailed in **Sections 8.0**, **9.0** and **10.0** of this report, validate the robustness of the Permittees' legal basis for implementing **DAMP Sections 9.0** and **10.0**.

4.3.2 Legal Authority to Implement New Development Program

The New Development/Significant Redevelopment component of the Program ends with permit close-out and the BMPs implemented in conformance with DAMP Section 7.0 transition to the Existing Development component. As noted in **Section 7.3.1**, the Permittees believe that the BMP approach to stormwater management could be more effectively sustained by ensuring the longevity and enforcement of the approved WQMP against subsequent property owners for ongoing responsibility for BMP maintenance. The ROWD Commitment in **Section 7** to develop guidance on the recordation process and appropriate documentation to enable such enforcement will be fulfilled under the aegis of the Legal and Regulatory Task Force.

4.4 Summary

The Permittees validated the legal basis for implementing the DAMP in early 2002 and over the balance of the period of the Third term Permit continued to review aspects their legal authority under the aegis of the Legal and Regulatory Task Force. This review and the formal legal challenge to this authority in late 2005 and early 2006 have served to affirm the basic robustness of the Permittees' water quality ordinances.

Table 4.1: Current and Potential Outcome Levels (Legal Authority)

Legal Authority	Effectiveness Assessment Outcome Levels					
	Level 1	Level 2	Level 3	Level 4	Level 5	Level 6
	Implement Program	Increase Awareness	Behavior Change	Load Reduction	Runoff Quality	Receiving Water Quality
Water Quality Ordinance	✓ Adopt and Maintain Adequate Legal Authority					
Training	✓ Track number/type of training sessions	P Surveys show improved knowledge				

Key:

✓ = Currently Achieved Outcome Level

P = Potentially Achievable Outcome Level

5.0 MUNICIPAL ACTIVITIES

5.1 Introduction

The Permittees own and operate facilities and build and maintain much of the transportation, drainage and recreational infrastructure of the urban environment. The primary purpose of **DAMP Section 5.0** is to ensure that, through a systematic process of evaluation, BMPs are incorporated into these activities. **DAMP Section 5.0** also requires a commitment to implement Integrated Pest Management (IPM) approaches. In addition, **DAMP Appendix C** requires performance reporting related to a number of Established BMPs that have been recognized, since the inception of the Program, as significant contributors to pollutant load reduction.

5.2 Accomplishments

5.2.1 Model Municipal Activities Program

The Model Municipal Activities Program was developed and implemented in 2002-03 and replaced the environmental performance reporting program of the Second Term Permits. It establishes a framework for conducting a systematic program of evaluation and BMP implementation targeting fixed facilities, field programs and drainage facilities. The Model Municipal Activities Program requires the Permittees to:

- Compile facility and program inventories:

  2,302 facilities have been reported as inventoried (2004-05 reporting period) and are subject to the program (**Table 5.2; Figure 5.1**).

- Prioritize facilities and programs based upon water quality threat and receiving water sensitivity:

  There are a reported 1,070 high priority, 126 medium priority, and 1,106 low priority municipal facilities (**Table 5.2; Figure 5.1**)

- Establish model maintenance procedures:

  Sets of BMP factsheets were produced for Fixed Facilities (13 factsheets), Field Programs (7 fact sheets) and Drainage Facilities (1 fact sheet). The factsheets are available at http://www.ocwatersheds.com/StormWater/documents_damp_lip.asp (Section 5 of the County of Orange/Orange County Flood Control District 2005-06 Local Implementation Plan).

- Conduct inspections:

  Standard general and activity specific inspection forms have been developed for Fixed Facilities, Field Programs and Drainage Facilities. In addition, by the end

of 2006, 2,326 municipal facilities were reported as having been inspected for stormwater issues (**Table 5.3**).

- Implement BMPs:

  At the end of the 2004-05 reporting period, 1,968 municipal facilities were determined to have full BMP implementation (**Table 5.3**).

- Undertake training:

  Three training modules have been developed, specifically, Municipal Activities program Training, Fixed Facility Model Maintenance Procedure Training and Field Program Model Maintenance Procedure Training.

5.2.2 Model Integrated Pest Management, Pesticide and Fertilizer Guidelines

Landscaping is best managed using an integrated system of tactics that include biological, mechanical, physical, cultural, and chemical control. This system, known as IPM, relies on careful monitoring of the plants to identify when a chemical or other control action should be taken. In June 2001, the Principal Permittee entered into a five-year agreement with the University of California Cooperative Extension (UCCE) to conduct water quality monitoring studies and implement water quality improvement programs in areas where the University has special expertise, particularly related to fertilizer and pesticide applications (Note: On May 10, 2005, the agreement was revised and extended for up to six additional years). In close cooperation with the UCCE, Model IPM, Pesticide and Fertilizer Guidelines were completed in 2002-03. The Guidelines require the Permittees to:

- Conduct IPM self-audits:

  With oversight and assistance from UCCE, the Permittees have completed self-audits of the Model IPM, Pesticide and Fertilizer Management Guidelines implementation. Audits have been conducted annually as part of annual progress reporting.

- Implement the Model IPM, Pesticide and Fertilizer Management Guidelines based upon IPM principles:

  Fifty-seven percent (57%) of the Permittees are able to report that they operate under a formal written IPM policy.

  Thirty-five (35) Permittees reported that approximately 363,146 pounds of nitrogen were applied to 6,862 acres of public land during the 2004-05 reporting period representing a third consecutive year of reduction (the 2005-06 figure represents a 2% decrease from the pounds per acre of nitrogen usage in 2003-04; a decrease of 27% from 2002-03; and a 12% decrease from 2001-02) **(Table 5.4).**

During the 2004-05 reporting period, approximately 19,227 pounds of active ingredients (AI) of pesticides were applied by the Permittees representing a 30% reduction in use since the inception of the program **(Table 5.3)**.

- Undertake Training:

  Training has been provided annually.

5.2.3 Established BMPs

Performance indicators for certain Established BMPs have been tracked since the inception of the Model Municipal Activities Program. These BMPs are street sweeping, solid waste collection, catch basin stenciling, drainage facility maintenance, trash & debris Control (formerly litter control), household hazardous waste collection, and used oil grant participation.

- Street Sweeping:

  All Permittees maintain street sweeping programs in residential, commercial and/or industrial areas. In 1993 the Permittees compiled information regarding their existing street sweeping schedules and practices and have subsequently changed elements of their programs such as the types of sweepers purchased, the frequency of sweeping, and the use of parking restrictions in order for the street sweeping program to aid in water quality improvements.

  85,516 tons of material was removed from the streets and gutters during the 2004-05 reporting period. This effort appears to represent a 12% increase for weight of material collected over the previous reporting period and a 25% increase over the tons of material reported in 2002-03. This amount represents a 87% increase in the weight of material collected over the 2001-02 total, indicating a marked increase in effort in this area of infrastructure maintenance in the Third Term Permit cycle. **(Table 5.5; Figure 5.2)**.

- Solid Waste Collection:

  The Permittees have solid waste collection programs for public, residential, commercial and industrial areas.

  3,959,590 tons of solid waste was collected during the 2004-05 reporting period. This effort appears to represent a 9.1% increase in the amount of solid waste collected over the previous reporting period, an 8.8% increase over the reported total in 2002-03, and a 7.0% increase over the reported total in 2001-02 **(Table 5.6; Figure 5.3)**.

- Catchbasin Stenciling:

  Over 37,000 stormdrain inlets have been stenciled. Each year 6,000 – 9,000 inlets are re-stenciled.

- Drainage Facility Maintenance:

  The Permittees inspect the drainage system within their jurisdictions annually and clean out accumulated debris on an as needed basis. Removal of accumulated debris and sediment is carried out either manually or by mechanical methods using flushing – in emergency situations only – in accordance with established maintenance procedures (Model Maintenance Procedure DF-1). By removing this material from the catch basin inlets and stormdrain system, the Permittees make a significant contribution in preventing the passage of these materials in downstream receiving waters.

  5,612 tons of debris was removed from drainage facilities in 2004-05. This amount represents a 43% decrease in the amount of debris collected from drainage facilities when compared to the previous reporting period, a 77% decrease in the amount collected in 2002-03 and a 6.5% decrease in the amount collected in 2001-02 (The 2002-03 reported total suggests inconsistent reporting of this Indicator or other environmental factors such as Santa Ana winds) **(Table 5.7; Figure 5.2; Figure 5.3)**.

- Trash & Debris Control:

  Trash and debris control is an important element in the diversion of litter and other solid materials from the storm drain system. Although most Permittees historically viewed litter control as a public service program (i.e., preventing visual blight, etc.), rather than as a pollution control problem, it is now considered important as a visual indicator of water quality and an aspect of the recreational use of a waterbody.

  Eleven (11) trash and debris booms have been installed in flood control channels and harbors to recover floatable material.

  Inner-Coastal and Watershed Cleanup Day, which engages the public directly in the cleanup of trash and debris, has been heavily promoted by the Orange County Stormwater Program. In 2002, 1,722 volunteers joined in and collected 29,503 pounds of trash and 5,350 pounds of recyclables. In 2003, 2,473 volunteers collected 52,474 pounds of trash and 5,447 pounds of recyclables at 37 sites. In 2004, 6,001 volunteers collected 78,390 pounds of trash and 9,563 pounds of recyclables at 38 sites. In 2005 the number of clean-up sites increased to 43.

  The Permittees have participated in the preparation of a number of strategic assessments of litter control efforts including *A Review Of Current Trash Pollution and Mitigation Efforts in Orange County: Final Report January 2006* prepared under

the auspices of the Trash & Debris Task Force and the Algalita Marine Foundation/California Coastal Commission *Plastic Debris: Rivers To Sea* initiative in which the Principal Permittee was represented on the advisory board.

- Household Hazardous Waste Collection:

  Orange County has a household hazardous waste collection program administered by the Integrated Waste Management Department (IWMD). The program comprises four sites (Anaheim, Huntington Beach, San Juan Capistrano, and Irvine).

  A total of 6,303,938 pounds of household hazardous waste was collected in the 2004-05 reporting period representing a 9.8% increase from the previous reporting period, a 48.7% increase from the 2002-03 reporting period, and 68.7% increase from the 2001-02 reporting period **(Table 5.8; Figure 5.6)**.

- Used Oil Grant Participation:

  Most of the Permittees, as well as the County's Health Care Agency, currently implement used oil recycling programs. These programs involve comprehensive public outreach including television and newspaper advertising, displays at community events, and the distribution of used oil containers at no cost to residents.

  Twenty seven (27) Permittees reported having a Used Oil Grant participation program for 2004-05, 28 Permittees in 2003-04 and 27 Permittees in 2002-03 **(Table 5.9; Figure 5.7)**.

5.3 Assessment

The current and potential program effectiveness assessment outcome levels for the Municipal Activities Program are presented in **Table 5.1a** (Model Municipal Activities Program) and **Table 5.1b** (Model IPM and Fertilizer Guidelines).

5.3.1 Model Municipal Activities Program

The Model Municipal Activities Program superceded the Environmental Performance Reporting (EPR) program of the Second Term Permits. Nonetheless, elements of the EPR program were carried over into the **2003 DAMP**. The **ROWD** is therefore recognized by the Permittees as an opportunity to eliminate the redundant vestiges of the prior inspection and oversight program.

The fixed facility inventory has fluctuated significantly over the reporting period (see **Table 5.2**) pointing to the need for the better definition of key program terms.

Indicator – Prioritization of Facilities: For 2004-05, 2,302 industrial facilities were prioritized, 46% of which were ranked as high priority; for 2003-04, 2,418 industrial facilities were prioritized, 49% of which were ranked as high priority; and for 2002-03, 2,380 industrial facilities were prioritized, 46% of which were ranked as high priority **(Table 5.2)**.

☒ Level 1: Implement Program

☒ Level 3: Behavior Change

In addition, the number of designated "high priority" facilities has remained at approximately 1,100 annually (**Table 5.2**) despite the initial intention for the program to be risk-based and the significant level of BMP implementation (i.e. risk mitigation) that has occurred over the period of the Third Term Permits. It is also apparent that the application of a "high priority" designation has varied significantly between the Permittees, reflecting both different SAR and SDR Permit requirements and individual Permittee interpretations of the prioritization process.

DAMP Modification:

- Eliminate Environmental Performance Reporting (EPR) program (which is duplicative of Model Municipal Activities Program).
- Define "fixed facilities," "field programs," and "drainage facility sites."

ROWD Commitment:

- Standardize SDR and SAR definitions of "high priority" and develop prioritization process that is better predicated on the threat (diminished by BMP implementation) posed by the facility, and considers the presence of "constituents of concern."

5.3.2 Model Integrated Pest Management, Pesticide and Fertilizer Guidelines

The majority of fertilizers are applied to turfgrass with a smaller amount utilized on landscape material (trees, shrubs, groundcovers, and vines). Countywide, municipal fertilizer use has declined. However, other indicators of a shift toward more of an IPM-

oriented approach show little change; e.g. utilization of slow-release fertilizers, timing of fertilizer applications, and use of soil analyses.

Headline Indicator –Reduction in Total Fertilizer Usage (Nitrogen): Thirty-five Permittees (35) reported that approximately 363,146 pounds of nitrogen were applied to 6,862 acres of public land during the 2004-05 reporting period (53 lbs/acre). This figure represents a 2% decrease from the pounds per acre of nitrogen usage in 2003-04; a decrease of 27% from 2002-03; and a 12% decrease from 2001-05.

☒ Level 3: Behavior Change

Headline Indicator – Reduction in Total Fertilizer Application (Phosphorus): Thirty-five Permittees reported that 81,600 pounds of phosphorus were applied to 6,862 acres of public land during the 2004-05 reporting period (12 lbs/acre). This figure represents a 20% decrease from the pounds per acre of phosphorus applied in 2003-04; a decrease of 33% from 2002-03; and an 8% decrease from 2001-05.

☒ Level 3: Behavior Change

There also appears to have been an overall reduction in pesticide use. However, as with fertilizer use, other indicators (e.g. equipment calibration, clean-up of overspray, use of non-chemical pest control methods) show little change. The absence of a trend in these indicators shows that factors other than the adoption of IPM approaches (e.g. budgetary constraints) may be the more significant in explaining the overall reduction in pesticide use. Indeed, toward the end of the current Permit term, only fifty-seven percent (57%) of the Permittees are able to report that they operate under a formal written IPM policy.

Headline Indicator – Reduction in Pesticide Application: During the 2004-05 reporting period, approximately 19,227 pounds of active ingredient of pesticides was applied by Permittees. This represents an approximately 30% decrease in pounds of pesticide applied compared to 25,022 pounds of active ingredient pesticides applied in 2003-04, and 24,750 pounds of active ingredient applied in 2002-03.

☒ Level 3: Behavior Change

ROWD Commitment:

- Develop Model Integrated Pest Management, Pesticide and Fertilizer Guidelines into a Model Program (rather than guidelines) with implementation goals and including model contract language.
- Redefine IPM (pesticide use) indicators.

5.3.3 Established BMPs

An annual evaluation of the routine preventive maintenance activities is conducted and, where appropriate, improvements or new practices are implemented to further reduce the amount of pollutants discharged into the storm drain system. An important component of this evaluation process is the documentation and collection of data related to these selected activities.

Trash and Debris Controls (formerly Litter Control)

There are currently three aspects to trash and debris control that have been reported over the period of the Third Term Permits, specifically, the deployment of trash and debris booms, public participation in Inner-Coastal and Watershed Cleanup Day, and an enhanced program of catchbasin cleaning.

Currently, eleven (11) trash and debris booms have been installed in flood control channels and harbors to recover floatable material. However, the Permittees recognize that the stormdrain infrastructure provides for retrofit opportunities in other areas. Indeed, a number of recent technical reports prepared by the Permittees and Coastal Commission examining technologies for trash and debris control, as well as extensive independent jurisdictional experience with inlet devices, establish a basis for the development of policy recommendations in this area.

ROWD Commitment:

- Develop recommendations for the selection and installation of drain inlet screens.

Every year the California Coastal Commission and Trails-4-All sponsor the Inner-Coastal and Watershed Cleanup Day to help cleanup the trash and debris that accumulates along the coastline, fouling the beaches and tidal zone. This event has been sponsored and heavily promoted by the Orange County Stormwater Program. In 2002, 1,722 volunteers joined in and collected 29,503 pounds of trash and 5,350 pounds of recyclables. In 2003, 2,473 volunteers collected 52,474 pounds of trash and 5,447 pounds of recyclables. In 2004, 6,001 volunteers collected 78,390 pounds of trash and 9,563 pounds of recyclables. In 2005, the number of clean-up sites increased to 43. The sustained year-to-year increases in public participation and material recovery point to the effectiveness of the Permittees' efforts in promoting this event.

Catchbasins are inspected annually and cleaned as appropriate. In the 2004-05 reporting period 86% of the catchbasin inventory in Orange County was cleaned, the highest level in the first three years of the Third Term Permits.

Solid Waste Collection

During the last reporting period, 35 Permittees reported the collection of nearly 4.0 million tons of solid waste. This effort compares to the total of 3.62 million tons of solid waste reported by 30 Permittees in 2003-04, 3.64 million tons of solid waste reported by 26 Permittees in 2002-03, and 3.70 million tons of solid waste reported by 33 Permittees in 2001-05. While the Permittees encourage the public, through education and outreach, to properly dispose of their trash, and this encouragement may be contributing to the increased level of collection in the most recent reporting period, there are significant discrepancies in the year-to-year reporting of individual jurisdictions.

Headline Indicator – Solid Waste Collection: 3,959,590 tons of solid waste was collected during the 2004-05 reporting period. This effort appears to represent a 9.1% increase in the amount of solid waste collected over the previous reporting period, an 8.8% increase over the reported total in 2002-03, and a 7.0% increase over the reported total in 2001-05.

In addition to education, the Permittees have considered the extent to which the cradle-to-grave management of solid waste can be improved to increase the effectiveness of collection efforts. This consideration has identified municipal oversight of contract solid waste collection and disposal as another area for possible improvements in service effectiveness.

ROWD Commitment:

- Develop model language for municipal trash collection and haulage contracts that addresses water quality protection issues.

Drainage Facility Maintenance

Drainage facilities are an integral component of the Model Municipal Activities Program and, as high priority facilities, subject to annual inspection. While the reported total length of drainage facilities has increased over successive years, the amount of material recovered has decreased. This reduction may reflect the increasing effectiveness of source controls and the impact of changing management practices such as street sweeping on concrete channels. However, both inconsistent year-to-year reporting and the profound influence of environmental variables (e.g. prevalence of Santa Ana wind conditions and severity of the wet season) may also be explanatory factors.

Headline Indicator – Drainage Facility Maintenance: 5,612 tons of debris was removed from drainage facilities during the 2004-05 reporting period. This amount represents a 43% decrease in the amount of debris collected from drainage facilities when compared to the previous reporting period, a 77% decrease in the amount collected in 2002-03 and a 6.5% decrease in the amount collected in 2001-02.

Street Sweeping

The year-to-year increases in the amount of material recovered from the urban environment by street sweeping suggest success regarding the Permittees' efforts to continue to improve the effectiveness (e.g. increasing use of drain inlet screens, regenerative air sweepers, parking controls etc.) of this maintenance practice.

Headline Indicator – Street Sweeping: 85,516 tons of material was removed from the streets and gutters during the 2004-05 reporting period. This effort appears to represent a 12% increase for weight of material collected over the previous reporting period and a 25% increase over the tons of material reported in 2002-03. This amount represents an 87% increase in the weight of material collected over the 2001-02 total, indicating increasing effectiveness in this area of infrastructure maintenance in the Third Term Permit cycle.

Table 5.1a: Current and Potential Outcome Levels (Municipal Activities)

Model Municipal Activities Program	Effectiveness Assessment Outcome Levels					
	Level 1	Level 2	Level 3	Level 4	Level 5	Level 6
	Implement Program	Increase Awareness	Behavior Change	Load Reduction	Runoff Quality	Receiving Water Quality
Inventory	✓ Maintain Inventory					
Prioritization	✓ Assign Priorities		✓Change in prioritization level			
Inspection	✓Conduct and track # of inspections		✓ # BMPs implemented	P Load reduction associated with BMPs		
Training	✓ Track number/type of training sessions	P Surveys show improved knowledge				

Key:

✓ = Currently Achieved Outcome Level

P = Potentially Achievable Outcome Level

Table 5.1b: Current and Potential Outcome Levels (Municipal Activities)

Model IPM and Fertilizer Guidelines	Effectiveness Assessment Outcome Levels					
	Level 1	Level 2	Level 3	Level 4	Level 5	Level 6
	Implement Program	Increase Awareness	Behavior Change	Load Reduction	Runoff Quality	Receiving Water Quality
Model IPM	✓ Formal Policy		✓Reduction in pesticide use			
Fertlizer Guidelines	P Formal Policy		✓Reduction in fertilizer use			
Training	✓ Track number/type of training sessions	P Surveys show improved knowledge				

Key:

✓ = Currently Achieved Outcome Level

P = Potentially Achievable Outcome Level

Table 5.2: Countywide Permittees' Fixed Facility Inventory and Prioritization

Permittee	Low 2002-03	Low 2003-04	Low 2004-05	Medium 2002-03	Medium 2003-04	Medium 2004-05	High 2002-03	High 2003-04	High 2004-05	Total 2002-03	Total 2003-04	Total 2004-05
Aliso Viejo	0	1	0	0	0	0	1	0	1	1	1	1
Anaheim	99	63	0	0	0	0	15	0	62	114	63	62
Brea	27	30	31	0	0		1	1		28	31	31
Buena Park	3	14	14	15	0	0	2	5	5	20	19	19
Costa Mesa	51	51	51	0	0		10	10	10	61	61	61
Cypress	17	14	14	8	8	8	1	1	1	26	23	23
Dana Point	14	13	13	0	0	0	8	9	10	22	22	23
Fountain Valley	28	28	28	0	0		1	1		29	29	28
Fullerton	90	94	94	0	0		1	1	1	91	95	95
Garden Grove	55	55	55	1	1	1	0	0		56	56	56
Huntington Beach	66	78	79	2	7	7	12	8	8	80	93	94
Irvine	39	39	44	12	12	12	1	3	3	52	54	59
La Habra	39	31	31	0	15	15	3	7	7	42	53	53
La Palma	1	1	2	1	1	1	2	2	1	4	4	4
Laguna Beach	46	46	46	48	45	46	73	75	74	167	166	166
Laguna Hills	0	0	0	0	0	0	20	20	20	20	20	20
Laguna Niguel	15	15	18	0	0		19	19	39	34	34	57
Laguna Woods	3	3	3	0	0		1	34	1	4	37	4
Lake Forest	7	0	0	0	0	0	0	8	9	7	8	9
Los Alamitos	14	14	14	NA	0	0	116	127	0	130	141	14
Mission Viejo	40	40	40	2	2	2	25	23	22	67	65	64
Newport Beach	20	21	21	1	1	1	4	4	4	25	26	26
Orange	27	26	29	25	29	29	2	2	2	54	57	60
Placentia	25	35	35	9	0		1	1	1	35	36	36
R S Margarita	3	0	4	0	0		669	669	669	672	669	673
San Clemente	73	20	73	0	19	0	17	51	17	90	90	90
S J Capistrano	18	18	18	0	0	0	38	38	38	56	56	56
Santa Ana	108	112	116	1	1	1	1	1	1	110	114	118
Seal Beach	32	32	39	0	0	0	3	3	5	35	35	44
Stanton	NA	19	19	NA	0	0	NA	1	1	NA	20	20
Tustin	24	22	22	0	0	0	4	4	4	28	26	26
Villa Park	0	1	1	0	0	0	2	1	1	2	2	2
Westminster	28	28	28	0	0	0	1	1	1	29	29	29
Yorba Linda	34	29	29	0	3	3	3	2	2	37	34	34
County of Orange	102	101	95	0	0	0	50	48	50	152	149	145
TOTALS	**1,148**	**1,094**	**1,106**	**125**	**144**	**126**	**1,107**	**1,180**	**1,070**	**2,380**	**2,418**	**2,302**

NA = Not Available

Table 5.3: BMP Implementation

PERMITTEE	FULLY Implemented 2002-03	FULLY Implemented 2003-04	FULLY Implemented 2004-05	PARTIALLY Implemented 2002-03	PARTIALLY Implemented 2003-04	PARTIALLY Implemented 2004-05	No BMPs Implemented 2002-03	No BMPs Implemented 2003-04	No BMPs Implemented 2004-05
Aliso Viejo	5	11	9	NA	0	0	NA	0	
Anaheim	147	52	65	NA	9	13	NA	0	
Brea	18	NA		0	NA	1	0	NA	
Buena Park	756	16	151	0	2	102	0	0	29
Costa Mesa	7	8	8	3	2	2	0	0	
Cypress	21	0		2	1	1	NA	0	
Dana Point	NA	NA	19	NA	NA	4	NA	NA	
Fountain Valley	79	51	53	2	0		2	0	
Fullerton	84	95	95	NA	0		NA	0	
Garden Grove	6	53	55	0	3	1	0	0	
Huntington Bch.	69	4	79	5	9	19	1	5	3
Irvine	54	54	59	0	0		0	0	
La Habra	0	1	29	4	2	26	NA	0	16
La Palma	1	1	1	3	3	3	0	0	
Laguna Beach	NA	NA	74	NA	NA		NA	NA	
Laguna Hills	16	20	35	2	0		0	0	
Laguna Niguel	NA	6	7	NA	12	29	NA	0	
Laguna Woods	3	6	3	1	7	3	NA	0	
Lake Forest	7	8	9	0	0		0	0	
Los Alamitos	NA	140	141	NA	1		NA	0	
Mission Viejo	23	23	28	26	44	25	18	0	
Newport Beach	8	19	19	0	7	7	0	0	
Orange	39	58	63	0	0		0	0	
Placentia	28	0		7	34	32	NA	0	
R S Margarita	672	669	673	0	0		0	0	
San Clemente	NA	NA		NA	NA		NA	NA	
S J Capistrano	54	56	37	0	0		0	0	
Santa Ana	NA	114	117	NA	0	1	NA	0	
Seal Beach	NA	NA		NA	NA		NA	NA	
Stanton	NA	20	19	NA	0	1	NA	0	
Tustin	NA	12	20	NA	31	23	NA	0	
Villa Park	0	0	0	2	2	0	0	0	1
Westminster	28	29	29	1	0		0	0	
Yorba Linda	2	29	14	0	15		0	0	
County of Orange	9	19	57	7	57	16	0	5	0
TOTALS	**2,136**	**1,574**	**1,968**	**65**	**241**	**309**	**21**	**10**	**49**

NA = Not Available

Table 5.4: 2004-05 Fertilizers and Amounts Applied By Permittee

	2002-03					2003-04					2004-05				
Permittee	**Acres**	**Total N**	**Total P**	**N/acre**	**P/acre**	**Acres**	**Total N**	**Total P**	**N/acre**	**P/acre**	**Acres**	**Total N**	**Total P**	**N/acre**	**P/acre**
Aliso Viejo	6.0	0.0	0.0			6.0	220.0	30.0	36.7	5.0	6.0	220.0	30.0	36.7	5.0
Anaheim	771.0	19,197.6	3,826.0	3,199.6	637.7	609.0	16,895.6	3,977.9	27.7	6.5	311.0	13,852.0	3,429.4	44.5	11.0
Brea	75.0	1,955.4	692.4	325.9	115.4	84.0	808.7	205.9	9.6	2.5	118.7	1,049.3	247.5	8.8	2.1
Buena Park	162.0	160.0	60.0	26.7	10.0	125.0	4,405.0	855.0	35.2	6.8	55.0	23,505.0	855.0	427.4	15.5
Costa Mesa	200.0	11,340.0	3,780.0	1,890.0	630.0	200.0	23,450.8	5,700.0	117.3	28.5	200.0	12,127.0	1,878.0	60.6	9.4
Cypress	69.0	420.0	140.0	70.0	23.3	69.0	23,450.8	5,700.0	339.9	82.6	9.0	210.0	70.0	23.3	7.8
Dana Point	50.0	4,800.0	720.0	800.0	120.0	50.0	4,800.0	720.0	96.0	14.4	50.0	960.0	360.0	19.2	7.2
Fountain Valley	200.0	1,017.5	405.0	169.6	67.5	200.0	2,441.0	1,183.0	12.2	5.9	200.0	2,441.0	1,183.0	12.2	5.9
Fullerton	50.0	3,397.5	1,672.5	566.3	278.8	120.0	4,911.5	1,408.5	40.9	11.7	NA	3,414.0	1,303.5	NA	NA
Garden Grove	160.0	2,771.8	1,343.4	462.0	223.9	170.0	4,095.0	1,335.0	24.1	7.9	170.0	5,265.0	1,712.5	31.0	10.1
Huntington Beach	596.0	25,178.6	4,932.6	4,196.4	822.1	606.0	25,133.6	4,887.6	41.5	8.1	606.0	25,133.6	4,887.6	41.5	8.1
Irvine	736.5	70,139.5	14,755.5	11,689.9	2,459.2	773.0	74,070.6	24,712.2	95.8	32.0	846.6	61,240.4	14,516.2	72.3	17.1
La Habra	108.0	3,080.0	1,030.0	513.3	171.7	108.0	2,943.5	889.5	27.3	8.2	108.0	2,474.0	942.0	22.9	8.7
La Palma	30.0	1,280.0	480.0	213.3	80.0	15.0	640.0	240.0	42.7	16.0	15.0	640.0	240.0	42.7	16.0
Laguna Beach	42.0	1,350.0	525.0	225.0	87.5	42.0	881.4	330.9	21.0	7.9	50.0	1,000.6	375.6	20.0	7.5
Laguna Hills	125.0	8,170.8	2,181.4	1,361.8	363.6	125.0	8,125.8	2,181.4	65.0	17.5	125.0	8,155.7	2,196.4	65.2	17.6
Laguna Niguel	151.0	33,079.5	11,461.1	5,513.2	1,910.2	151.0	37,929.2	18,528.2	251.2	122.7	151.0	20,737.5	5,763.7	137.3	38.2
Laguna Woods	15.0	642.5	145.5	107.1	24.3	5.0	497.5	142.5	99.5	28.5	5.0	510.0	210.0	102.0	42.0
Lake Forest	187.0	7,680.0	2,880.0	1,280.0	480.0	72.0	8,040.0	3,015.0	111.7	41.9	71.8	13,803.0	4,803.0	192.2	66.9
Los Alamitos						15.0	100.0	20.0	6.7	1.3	14.3	100.0	20.0	7.0	1.4
Mission Viejo	975.0	100,678.1	17,453.1	16,779.7	2,908.9	975.0	76,503.0	9,042.0	78.5	9.3	702.0	78,611.0	7,995.0	112.0	11.4
Newport Beach	300.0	5,967.0	2,837.0	994.5	472.8	170.0	4,095.0	1,335.0	24.1	7.9	300.0	4,800.0	2,760.0	16.0	9.2
Orange	243.4	21,479.0	3,646.0	3,579.8	607.7	190.0	6,233.5	1,560.3	32.8	8.2	243.0	6,506.2	1,478.5	26.8	6.1
Placentia	140.0	2,340.0	580.0	390.0	96.7	40.0	1,510.0	330.0	37.8	8.3	108.0	2,760.0	580.0	25.6	5.4
Rancho Santa Margarita						NA	NA	NA	NA	NA	0.2	8.0	3.0	40.0	15.0
San Clemente	151.0	13,217.5	3,132.5	2,202.9	522.1	305.0	16,492.5	3,990.0	54.1	13.1	180.0	10,200.0	2,800.0	56.7	15.6
San Juan Capistrano	173.0	6,562.0	1,704.4	1,093.7	284.1	176.0	4,771.1	1,079.0	27.1	6.1	176.0	3,606.0	1,072.5	20.5	6.1
Santa Ana	400.0	8,022.5	2,476.5	1,337.1	412.8	400.0	9,766.8	2,985.0	24.4	7.5	400.0	9,754.3	2,985.0	24.4	7.5
Seal Beach	10.0	0.0	0.0	0.0	0.0	55.0	320.0	120.0	5.8	2.2	55.0	320.0	120.0	5.8	2.2
Stanton						NA	NA	NA	0.0	NA	10.0	471.0	228.0	47.1	22.8
Tustin	160.0	5,679.5	1,022.5	946.6	170.4	160.0	3,105.0	612.5	19.4	3.8	184.0	1,065.0	75.0	5.8	0.4
Villa Park						2.0	0.0	0.0	0.0	0.0	10.0	400.0	200.0	40.0	20.0
Westminster	15.0	675.0	375.0	112.5	62.5	15.0	605.0	305.0	40.3	20.3	15.0	605.0	305.0	40.3	20.3
Yorba Linda	722.0	22,524.6	7,604.0	3,754.1	1,267.3	722.0	22,511.5	11,636.0	31.2	16.1	699.0	34,325.3	10,661.8	49.1	15.3
County of Orange	967.6	30,283.3	10,471.4	5,047.2	1,745.2	819.5	17,025.8	6,274.0	20.8	7.7	667.0	12,875.8	5,312.4	19.3	8.0
Totals	**7,990.5**	**413,089.2**	**102,332.8**	**68,848.2**	**17,055.5**	**7,574.5**	**406,778.9**	**115,331.5**	**1,898.1**	**566.2**	**6,861.6**	**363,145.6**	**81,599.5**	**1,896.3**	**462.6**

NA = Not Available

Table 5.5: Volume of Street Sweeping Material Collected

PERMITTEE	Total Weight of Material Collected (Tons)* FY 2002-03	Total Weight of Material Collected (Tons)* FY 2003-04	Total Weight of Material Collected (Tons)* FY 2004-05
Aliso Viejo	96	120	110
Anaheim	4,500	4,500	4,500
Brea	800	800	1,179
Buena Park	1,830	1,475	1,475
Costa Mesa	1,730	1,810	1,846
Cypress	526	525	525
Dana Point	465	984	160
Fountain Valley	2,104	2,000	2,000
Fullerton	15,925	19,102	12,832
Garden Grove	NA	NA	2,940
Huntington Beach	3,282	3,434	3,516
Irvine	2,500	2,500	2,700
La Habra	7	5	5
La Palma	375	384	1,170
Laguna Beach	684	675	771
Laguna Hills	194	NA	315
Laguna Niguel	449	NA	423
Laguna Woods	3	62	14
Lake Forest	550	1,044	630
Los Alamitos	NA	3,500	
Mission Viejo	1,192	1,503	1,502
Newport Beach	4,044	4,150	28,800
Orange	11,880	12,000	3,000
Placentia	104	572	531
Rancho Santa Margarita	NA	12	92
San Clemente	1,164	1,177	523
San Juan Capistrano	525	605	676
Santa Ana	6,825	6,825	6,825
Seal Beach	2,085	2,084	
Stanton	NA	843	2,529
Tustin	874	904	1,025
Villa Park	89	134	135
Westminster	1,749	1,041	1,175
Yorba Linda	608	690	720
County of Orange/OCFCD	996	834	873
Totals	**68,155**	**76,294**	**85,516**

NA = Not Available

***Tons=3 cubic yards per Michigan Department of Environmental Quality, Waste and Hazardous Materials Division**

Table 5.6: Solid Waste Collection

PERMITTEE	Total Quantity of Solid Waste Collected 2002-03 (Tons)	Total Quantity of Solid Waste Collected 2003-04 (Tons)	Total Quantity of Solid Waste Collected 2004-05 (Tons)
Aliso Viejo	41,000	43,723	38,063
Anaheim	453,015	460,000	460,000
Brea	406,000	407,543	86,877
Buena Park	NA	80	100,000
Costa Mesa	287,090	279,850	186,753
Cypress	45,197	46,197	52,673
Dana Point	52,480	79,909	32,348
Fountain Valley	63,743	53,702	59,376
Fullerton	177,555	NA	187,385
Garden Grove	NA	NA	197,550
Huntington Beach	274,853	272,836	286,717
Irvine	295,000	292,600	287,500
La Habra	NA	31,043	37,000
La Palma	16,000	NA	18,000
Laguna Beach	48,390	58,550	47,700
Laguna Hills	43,783	39,803	56,031
Laguna Niguel	81,046	79,655	82,059
Laguna Woods	NA	23,000	25,000
Lake Forest	103,000	86,200	89,612
Los Alamitos	NA	NA	NA
Mission Viejo	105,600	108,000	108,252
Newport Beach	NA	39,992	40,000
Orange	234,040	210,836	215,400
Placentia	58,861	NA	63,000
Rancho Santa Margarita	NA	NA	63,356
San Clemente	85,339	85,339	88,956
San Juan Capistrano	68,417	76,166	81,652
Santa Ana	258,408	354,000	474,350
Seal Beach	45,292	45,000	26,136
Stanton	NA	35,004	41,500
Tustin	80,629	80,000	84,024
Villa Park	NA	10,200	10,500
Westminster	94,750	85,372	93,294
Yorba Linda	88,680	88,680	83,233
County of Orange/OCFCD	132,584	153,707	155,293
Total tons of solid waste collected	**3,640,752**	**3,626,987**	**3,959,590**

NA = Not Available

Table 5.7: Drainage Facility Maintenance

PERMITTEE	Total Length of Channel/Pipe Cleaned (in Miles)			Number of Catchbasins Within Jurisdiction			Number of Catchbasins Cleaned Within Jurisdiction			Percentage of Catchbasins Cleaned			Total Volume From Facilities (Tons)		
	2002-03	2003-04	2004-05	2002-03	2003-04	2004-05	2002-03	2003-04	2004-05	2002-03	2003-04	2004-05	2002-03	2003-04	2004-05
Aliso Viejo	0.23	0.24	0.24	625	625	625	625	625	625	100%	100%	100%	60.0	111.0	82
Anaheim	37.06	36.00	36	3,500	3,500	3,500	3,500	3,500	3,500	100%	100%	100%	1500.0	1500.0	1500
Brea	NA	NA	2.93	1,158	965	965	1,158	965	965	100%	100%	100%	50.5	50.0	50
Buena Park	0.01	2.25	2.25	20	857	758	20	28	949	100%	3%	125%	1.0	2.4	10.3
Costa Mesa	0.60	0.60	0.6	1,165	1,165	1,165	1,165	1,165	1,165	100%	100%	100%	25.0	25.0	20
Cypress	0.39	0.37	0.37	567	567	569	430	48	194	75%	8%	34%	2.0	0.5	1.5
Dana Point	0.03	0.00	0.29	430	555	526	386	446	459	90%	80%	87%	13.6	508.0	26.04
Fountain Valley	1.50	0.40	0.44	1,965	750	750	1,965	750	750	100%	100%	100%	422.0	217.0	281
Fullerton	7.82	5.90	6.5	1,255	1,322	3,424	3,268	2,216	3,424	50%	100%	100%	1697.0	1629.0	2.1
Garden Grove	0.01	0.01	0.01	907	907	936	907	907	936	100%	100%	100%	108.5	108.5	94
Huntington Beach	8.00	8.40	8.4	1,706	1,706	1,715	1,706	1,706	1,715	100%	100%	100%	934.4	894.9	687
Irvine	0.56	0.60	0.3	3,300	3,300	3,840	1,574	1,584	1,430	100%	48%	37%	14174.8	91.5	74.4
La Habra	NA	2.50	2.5	NA	545	545	NA	542	545	NA	99%	100%	NA	10.0	18
La Palma	5.00	4.70	5.2	201	201	201	201	201	201	100%	100%	100%	15.5	15.7	16
Laguna Beach	0.20	0.20	0.10	633	910	910	633	633	910	75%	70%	100%	227.9	NA	192
Laguna Hills	0.02	0.20	NA	521	515	487	481	304	472	92%	60%	97%	13.6	68.0	5.7
Laguna Niguel	0.73	0.20	0.6	NA	1,209	1,350	1,035	1,197	1,300	80%	99%	96%	1133.0	388.0	124
Laguna Woods	0.02	NA	NA	17	17	17	18	18	17	100%	100%	100%	0.2	NA	0.5
Lake Forest	0.00	0.00	0.03	438	483	1,082	200	331	1,042	47%	76%	96%	15.5	20.8	3.9
Los Alamitos	NA	NA		114	114	114	114	114	114	100%	100%	100%	DNR	15.5	15.5
Mission Viejo	0.02	0.02	3.63	1,800	1,830	1,830	360	651	781	10%	100%	43%	18.2	27.7	4.88
Newport Beach	1.45	3.33	3.33	2,853	3,057	3,087	2,551	2,733	3,087	89%	89%	100%	963.0	834.0	860
Orange	3.33	4.00	1.33	1,625	1,625	1,625	76	147	91	5%	9%	6%	1.9	2.0	12
Placentia	0.10	0.00	0	240	447	447	200	175	175	83%	39%	39%	7.8	0.5	0.5
Rancho Santa Margarita	NA	0.00	41.6	669	669	669	669	669	669	100%	100%	100%	NA	7.0	181.35
San Clemente	10.25	1.50	3.42	1,236	1,236	1,239	1,104	620	1,606	95%	50%	130%	NA	3.0	3
San Juan Capistrano	0.18	0.09	0.26	1,200	1,200	1,200	500	99	150	41%	9%	13%	37.0	28.0	45
Santa Ana	NA	2.10	10.1	1,500	1,270	1,665	129	1,175	1,586	9%	92%	95%	3058.0	3058.0	1042
Seal Beach	0.02	0.02	0.02	195	195	195	195	195	195	100%	100%	100%	4.5	16.8	32
Stanton	DNR	1.30	1.42	DNR	NA	145	DNR	142	145	DNR	99	100%	DNR	19.3	19.3
Tustin	NA	0.20	0.2	942	942	962	1,258	1,034	962	100%	>100%	100%	64.0	114.0	76
Villa Park	1.00	0.90	0.9	150	150	80	150	150	25	100%	100%	31%	NA	NA	70
Westminster	0.83	0.83	0.83	622	622	622	622	622	622	100%	100%	100%	6.0	5.0	5
Yorba Linda	1.06	1.06	0.8	1,550	1,575	1,728	1,500	1,575	1,728	97%	98%	100%	56.3	70.5	21
County of Orange/OCFCD	46.00	29.00	78	2,325	2,353	2,353	2,133	1,485	1,835	91%	63%	78%	52.0	36.0	36
Totals	**126**	**107**	**213**	**35,429**	**37,384**	**41,326**	**30,833**	**28,752**	**34,370**	**83% (Ave.)**	**80% (Ave.)**	**86% (Ave.)**	**24,663**	**9,878**	**5,612**

NA = Not Available
DNR = Did Not Report

Table 5.8: 2004-05 Integrated Waste Management Household Hazardous Waste Program Collection Totals

Category	Type Of Waste	Collection Center Waste Volumes Collected (pounds)											
		Anaheim			Huntington Beach			Irvine			San Juan Capistrano		
		2002-03	2003-04	2004-05	2002-03	2003-04	2004-05	2002-03	2003-04	2004-05	2002-03	2003-04	2004-05
1. Flammable & Poison	Flammable Solid/Liquid	202,451	218,456	247,962	236,740	282,013	279,665	99,074	151,510	170,366	70,550	99,450	99050
	Bulked Flammable Liquids	0	800	0	0	1,600	0	0	800	0	0	0	0
	Oil-Base Paint	346,307	395,469	512,372	327,172	347,123	387,257	213,166	247,271	249,331	162,400	245,700	221260
	Poison (Excl aerosols)	38,301	50,713	64,974	47,496	53,486	58,972	27,172	39,395	41,169	16,650	16,650	27720
	Reactive & Explosive	0	200	360	0	318	171	0	160	160	0	0	0
	Subtotal	**587,059**	**665,638**	**825,668**	**611,408**	**684,540**	**726,065**	**339,412**	**439,136**	**461,026**	**249,600**	**361,800**	**348,030**
2. Acid	Inorganic Acid	5,400	4,649	8,443	6,564	7,992	6,014	2,740	4,143	4,266	2,520	2,520	2520
	Organic Acid	5,191	5,597	5,514	7,560	7,173	7,790	3,908	6,372	7,281	2,310	2,970	2970
	Subtotal	**10,591**	**10,246**	**13,957**	**14,124**	**15,165**	**13,804**	**6,648**	**10,515**	**11,547**	**4,830**	**5,490**	**5,490**
3. Base	Inorganic Base	1,260	1,889	2,380	3,136	2,296	4,111	796	1,819	2,120	0	1,260	720
	Organic Base	7,555	10,117	4,070	10,168	12,282	13,802	3,810	6,896	7,462	2,640	4,950	2310
	Subtotal	**8,815**	**12,006**	**6,450**	**13,304**	**14,578**	**17,913**	**4,606**	**8,715**	**9,582**	**2,640**	**6,210**	**3,030**
4. Oxidizer	Neutral Oxidizer	1,055	2,243	1,977	2,076	2,733	2,207	1,276	1,665	3,164	400	1,000	800
	Organic Peroxides	20	0	10	45	0	0	10	0	20	20	0	10
	Oxidizing Acid	0	94	136	1,240	504	1,186	10	29	30	0	0	0
	Oxidizing Base	0	171	115	0	414	1,167	136	421	166	0	0	0
	Subtotal	**1,075**	**2,508**	**2,238**	**3,361**	**3,651**	**4,560**	**1,432**	**2,115**	**3,380**	**420**	**1,000**	**810**
5. PCBs (Containing)	PCB Containing Paint	0	0	0	0	0	0	0	0	0	0	0	0
	Other PCB Waste	0	1,300	1,000	200	200	4,000	100	200	500	0	0	500
	Subtotal	**0**	**1,300**	**1,000**	**200**	**200**	**4,000**	**100**	**200**	**500**	**0**	**0**	**500**
6. Aerosol	Corrosive Aerosols	400	1,232	3,066	3,584	3,145	2,955	236	693	805	200	0	400
	Flammable Aerosols	22,760	28,106	35,258	35,741	39,875	48,539	16,101	24,101	26,364	10,450	11,525	14250
	Poison Aerosols	1,810	4,033	5,592	7,196	5,903	7,685	2,128	4,338	5,161	800	1,200	100
	Subtotal	**24,970**	**33,371**	**43,916**	**46,521**	**48,923**	**59,179**	**18,465**	**29,132**	**32,330**	**11,450**	**12,725**	**14,750**

Table 5.8: 2004-05 Integrated Waste Management Household Hazardous Waste Program Collection Totals *(continued)*

Category	Type Of Waste	Collection Center Waste Volumes Collected (pounds)											
		Anaheim			Huntington Beach			Irvine			San Juan Capistrano		
		2002-03	2003-04	2004-05	2002-03	2003-04	2004-05	2002-03	2003-04	2004-05	2002-03	2003-04	2004-05
7. Reclaimable	Antifreeze	31,461	35,675	19,453	31,620	25,995	21,098	13,667	16,851	6,525	7,360	3,017	0
	Car Batteries	130,500	135,450	147,595	71,280	98,440	175,280	41,765	72,200	73,465	24,255	39,720	42605
	Fluorescent Bulbs	3,000	3,800	3,400	4,400	4,600	4,600	1,200	3,200	3,400	600	1,200	1800
	Latex Paint	268,300	349,243	379,840	315,558	358,846	410,495	159,584	269,382	294,413	135,090	97,470	182400
	Motor Oil/Oil Products	157,833	169,939	179,892	131,309	123,238	123,193	72,121	88,387	93,325	43,275	49,062	39975
	Oil Filters	5,000	4,600	5,800	4,600	4,000	4,000	2,200	2,600	2,600	1,000	1,400	1000
	Mercury (Metallic)	80	120	100	78	100	200	54	80	250	0	40	150
	Subtotal	**596,174**	**698,827**	**736,080**	**558,845**	**615,219**	**738,866**	**290,591**	**452,700**	**473,978**	**211,580**	**191,909**	**267,930**
8. Other	Medical Waste	0	0	0	0	0	0	0	0	0	0	0	-
	Household Batteries	2,370	3,750	6,871	2,556	3,108	6,571	2,700	3,630	8,858	600	3,035	4,631
	Other	316,052	567,729	22,254	178,783	387,154	27,682	80,394	273,493	12,785	36,858	171,835	7,650
	Subtotal	**318,422**	**571,479**	**29,125**	**181,339**	**390,262**	**34,253**	**83,094**	**277,123**	**21,643**	**37,458**	**174,870**	**12,281**
9. Propane	Propane	NR	NR	28,060	NR	NR	36,613	NR	NR	94,039	NR	NR	5164
	CRT	NR	NR	427,976	NR	NR	323,695	NR	NR	273,539	NR	NR	190971
	Subtotal	**0**	**0**	**456,036**	**0**	**0**	**360,308**	**0**	**0**	**367,578**	**0**	**0**	**196,135**
	Collection Center Totals	**1,547,106**	**1,995,375**	**2,114,470**	**1,429,102**	**1,772,538**	**1,958,948**	**744,348**	**1,219,636**	**1,381,564**	**517,978**	**754,004**	**848,956**

Grand Total Collected for FY 2002-03 = 4,238,534

Grand Total Collected for FY 2003-04 = 5,741,553

Grand Total Collected for FY 2004-05 = 6,303,938

NR = Not Reported

Table 5.9: Used Oil Grant Participation

PERMITTEE	Has or Participates in a Used Oil Grant	Amount Collected As a Result of the Used Oil Grant FY 2002-03		Amount Collected As a Result of the Used Oil Grant FY 2003-04		Amount Collected As a Result of the Used Oil Grant FY 2004-05	
		Motor Oil/Oil Products (Gallons)	Oil Filters (Units)	Motor Oil/Oil Products (Gallons)	Oil Filters (Units)	Motor Oil/Oil Products (Gallons)	Oil Filters (Units)
Aliso Viejo	X			NA	NA	63,647	27,109
Anaheim	No	135	74	0	0	NA	NA
Brea	X	900	165	720	144	31,680	3,867
Buena Park	X	NA	NA	9,495	NA	12,289	220
Costa Mesa	X	7,869	90	8,886	101	473	59
Cypress	X	NA	NA	43,000	0	75,000	NA
Dana Point	X	624	NA	28,930	NA	5,610	NA
Fountain Valley	X	1,834	27	74	15	147	28
Fullerton	X	15,840	35	50,856	132	79,942	NA
Garden Grove	X	31,837	1,154	19,471	NA	3,170	809
Huntington Beach	X	1,499	368	702	203	887	239
Irvine	X	71,784	NA	71,784	NA	59,645	NA
La Habra	X	NA	NA	7,630	NA	NA	NA
La Palma	No						
Laguna Beach	X	41	0	1,014	0	153	NA
Laguna Hills	X	DNR	DNR	NA	NA	44,800	11,000
Laguna Niguel	No	DNR	DNR	NA	NA	NA	NA
Laguna Woods	X	14,400	3,000	84	NA	25	6
Lake Forest	X	9,297	NA	NA	NA	63,614	NA
Los Alamitos	No						
Mission Viejo	X	12,145	147	14,280	NA	14,372	55
Newport Beach	X	NA	NA	19,471	NA		
Orange	X	2,966	NA	418	NA	2,158	554
Placentia	X	707	209	91	18	148	160
R S Margarita	X	NA	NA	NA	NA	33,544	133
San Clemente	X	19,455	2,500	19,455	2,500		
S J Capistrano	X	5,770	667	1,620	1,296	98,000	13,500
Santa Ana	X	5,804	3,815	12,037	3,698	12,583	4,004
Seal Beach	NA	NA	NA	NA	NA	NA	NA
Stanton	No	NA	NA	NA	NA	NA	NA
Tustin	X	NA	NA	NA	NA	NA	NA
Villa Park	No						
Westminster	X	64,100	NA	7,620	3,000	34,442	1,000
Yorba Linda	NA	NA	NA	NA	NA	NA	NA
County of Orange/OCFCD*	X	259,000	1,333	61,330	49,064	653,848	57,817
NA = Not Available		**526,007**	**13,584**	**378,967**	**60,171**	**1,290,177**	**93,451**

* The number of gallons of used oil collected dropped in 2003-04 and then dramatically increased for 2004-05 due to CIWMB regulations in 2003-04 when the CIWMB stated that only the used oil turned in by do-it-yourselfers could be counted. However, for the 2004-05 reporting year, the CIWMB reversed their decision and allowed all used oil to be counted, including oil from HHHCCs and certified collectors (Jiffy Lube, etc.).

Figure 5.1: Countywide Permittees' Fixed Facility Inventory and Prioritization

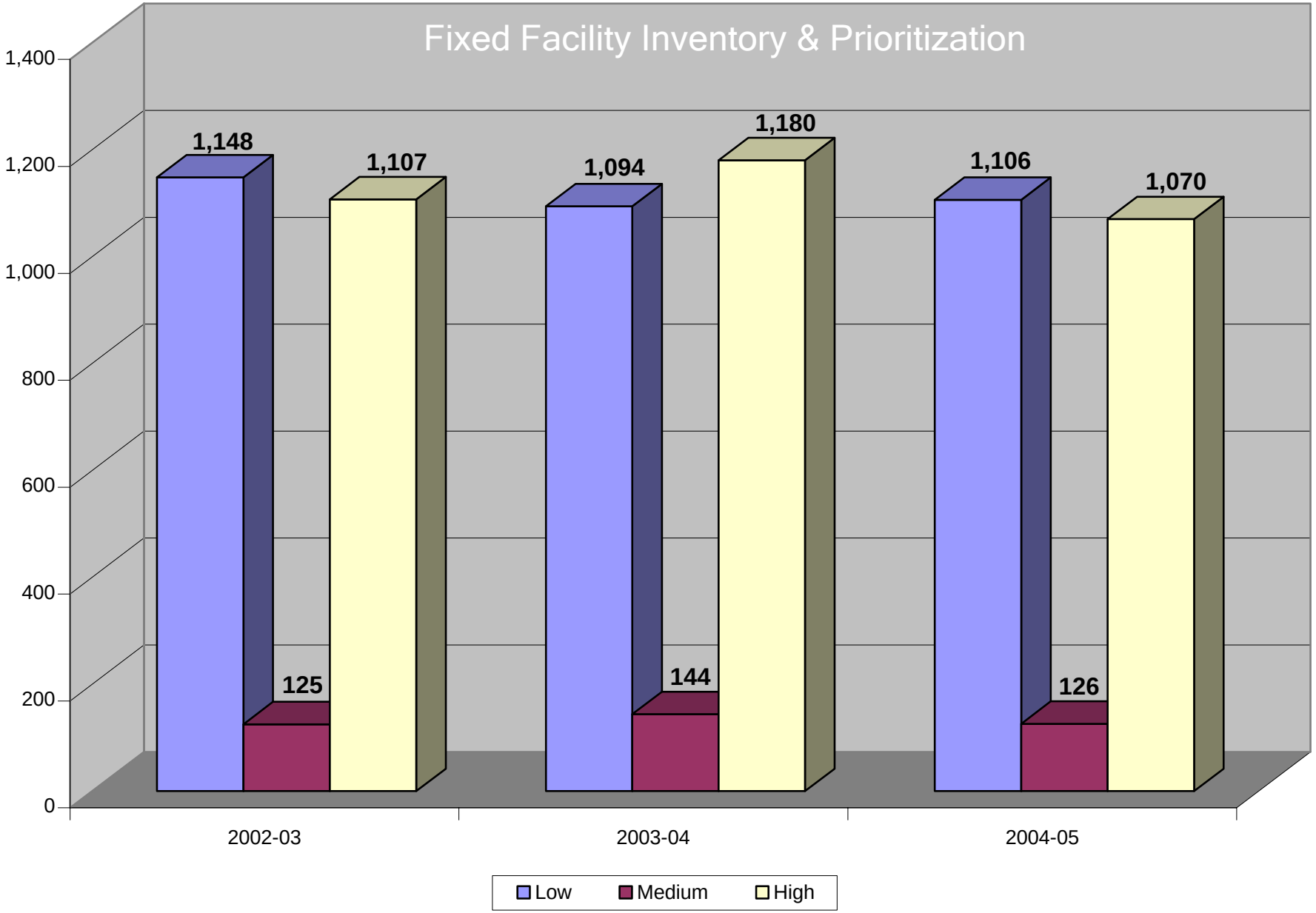


Figure 5.2: Volume of Street Sweeping Material Collected

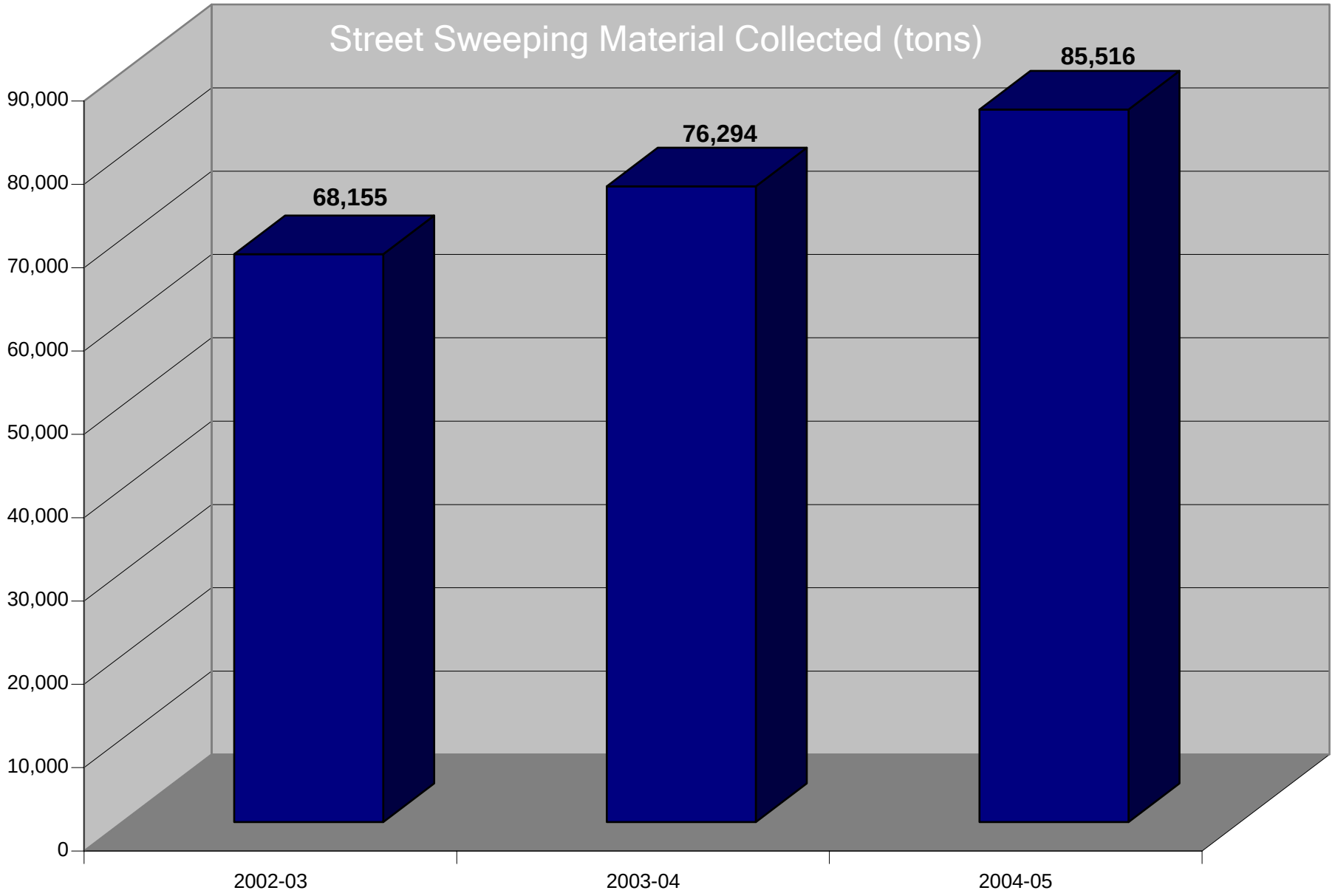


Figure 5.3: Solid Waste Collection (tons)

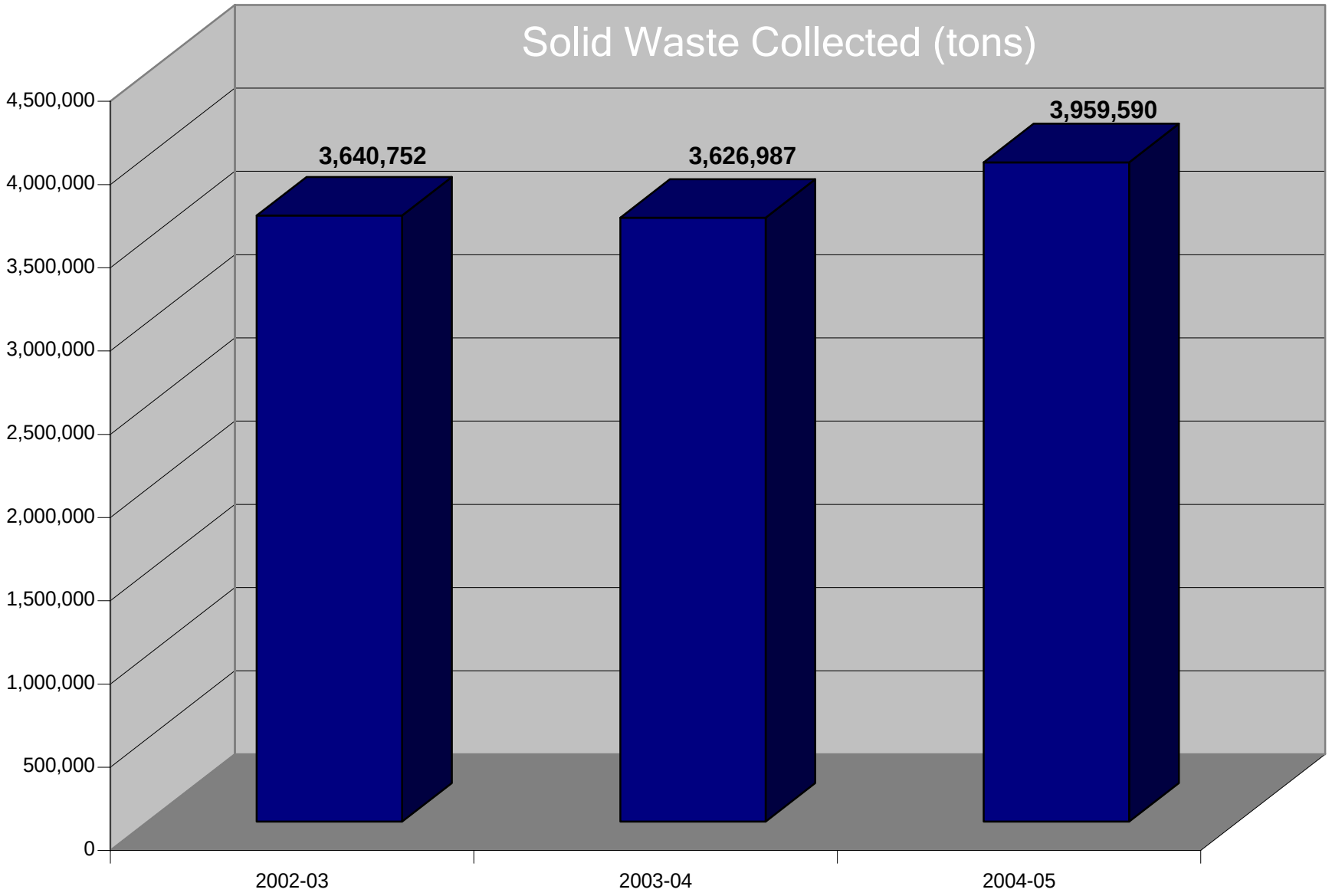


Figure 5.4: Drainage Facility Maintenance – Miles of Pipe Cleaned

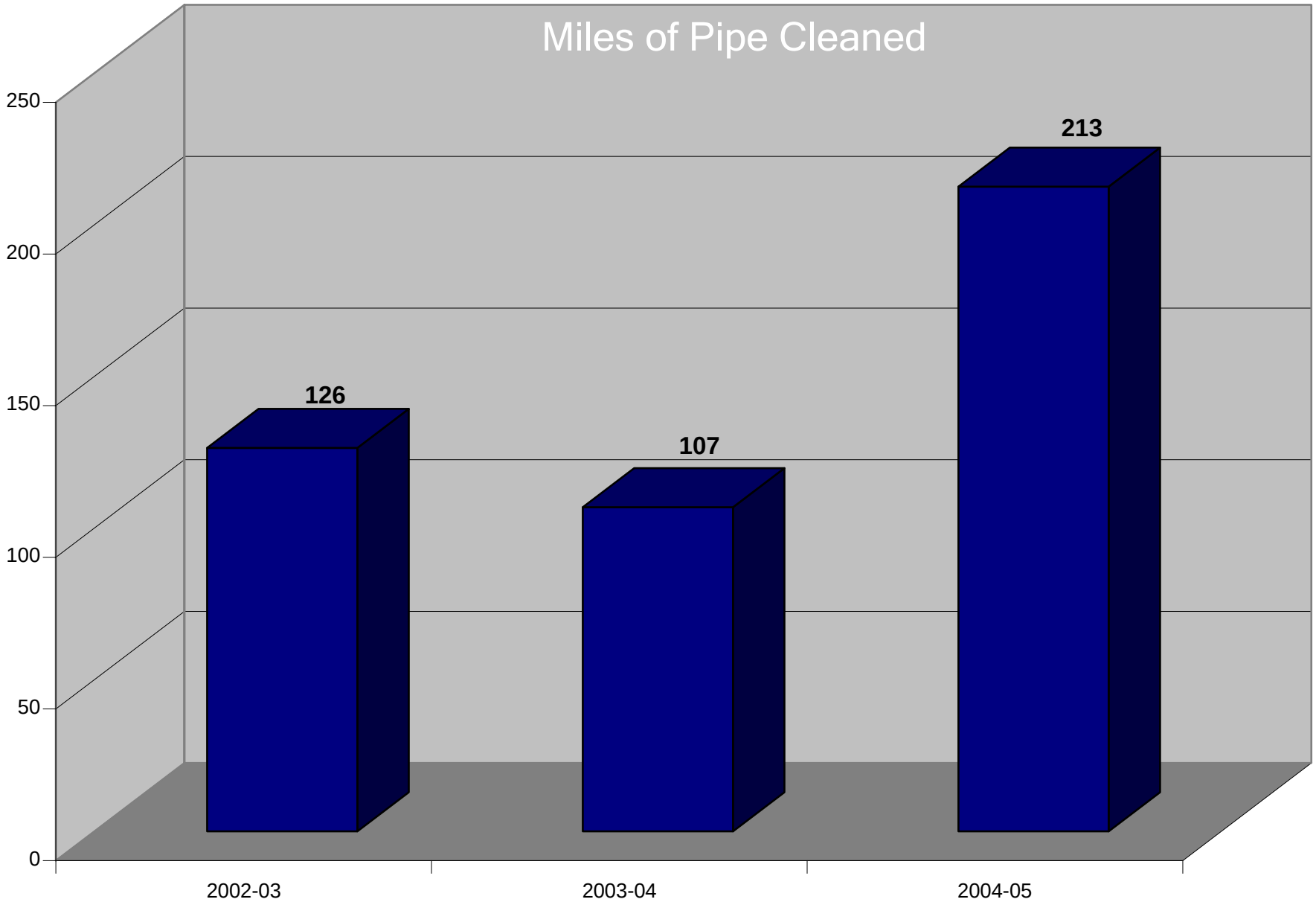


Figure 5.5: Drainage Facility Maintenance – Percentage of Catch Basins Cleaned

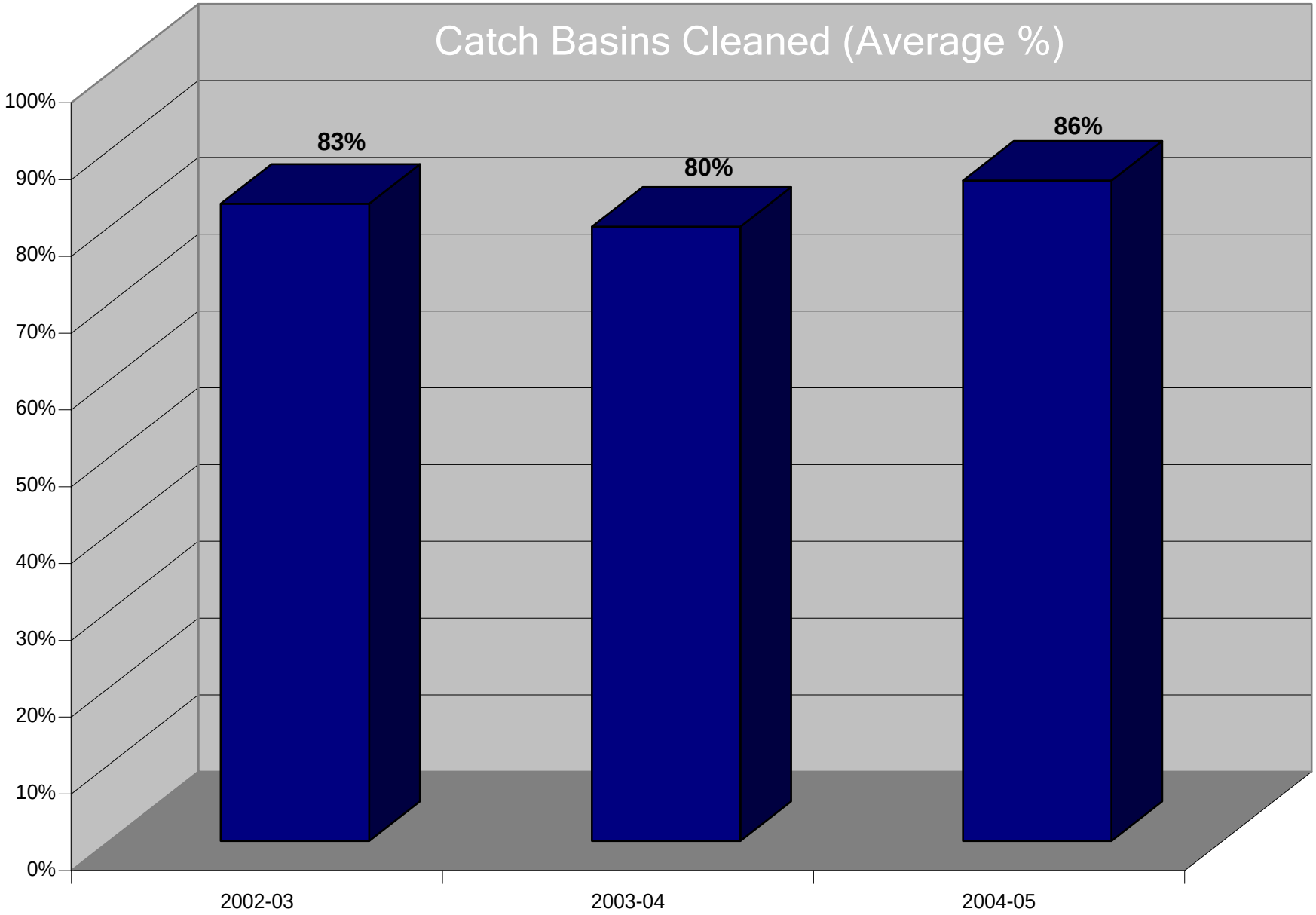


Figure 5.6: 2004-05 Integrated Waste Management Household Hazardous Waste Program Collection Totals

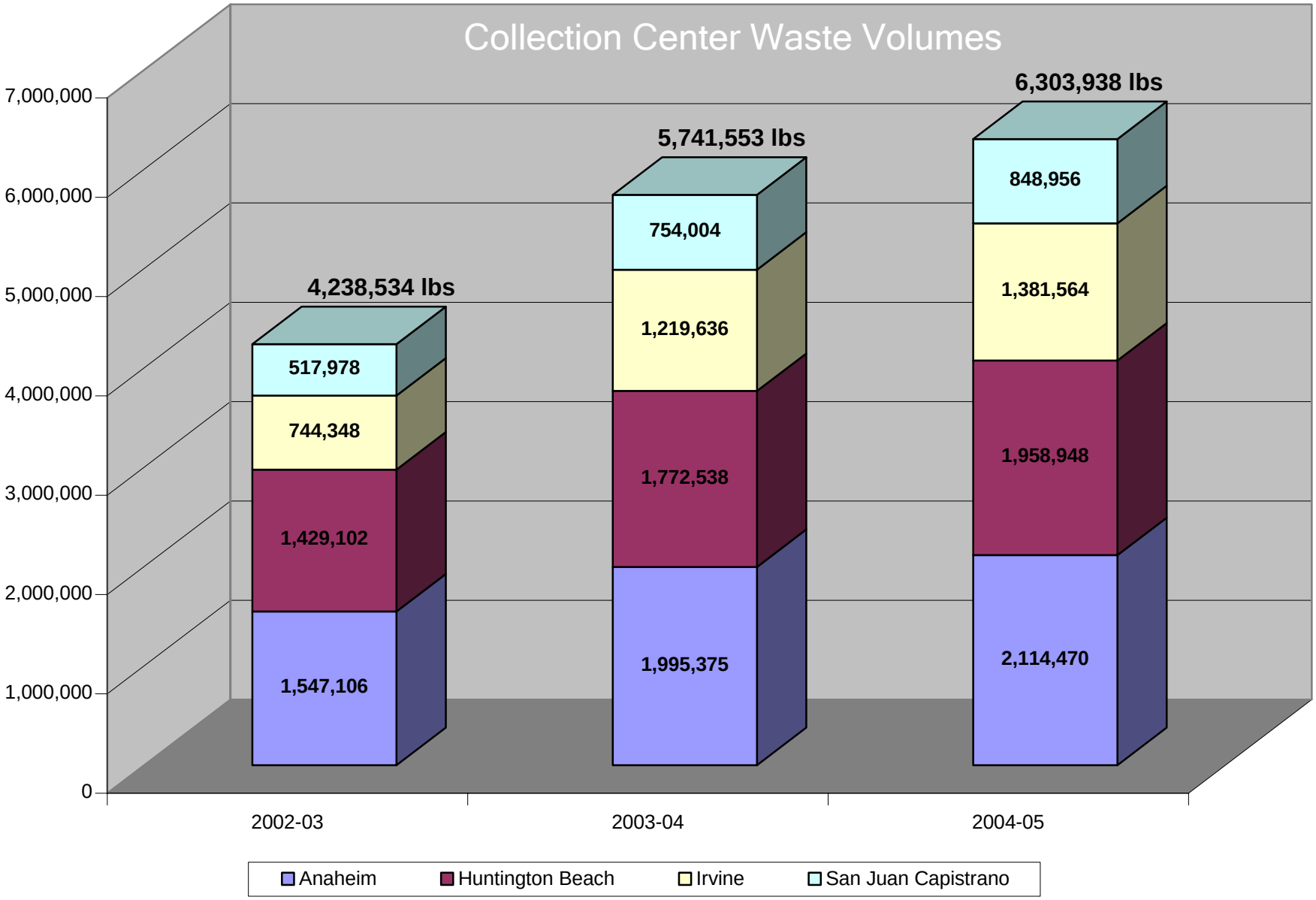
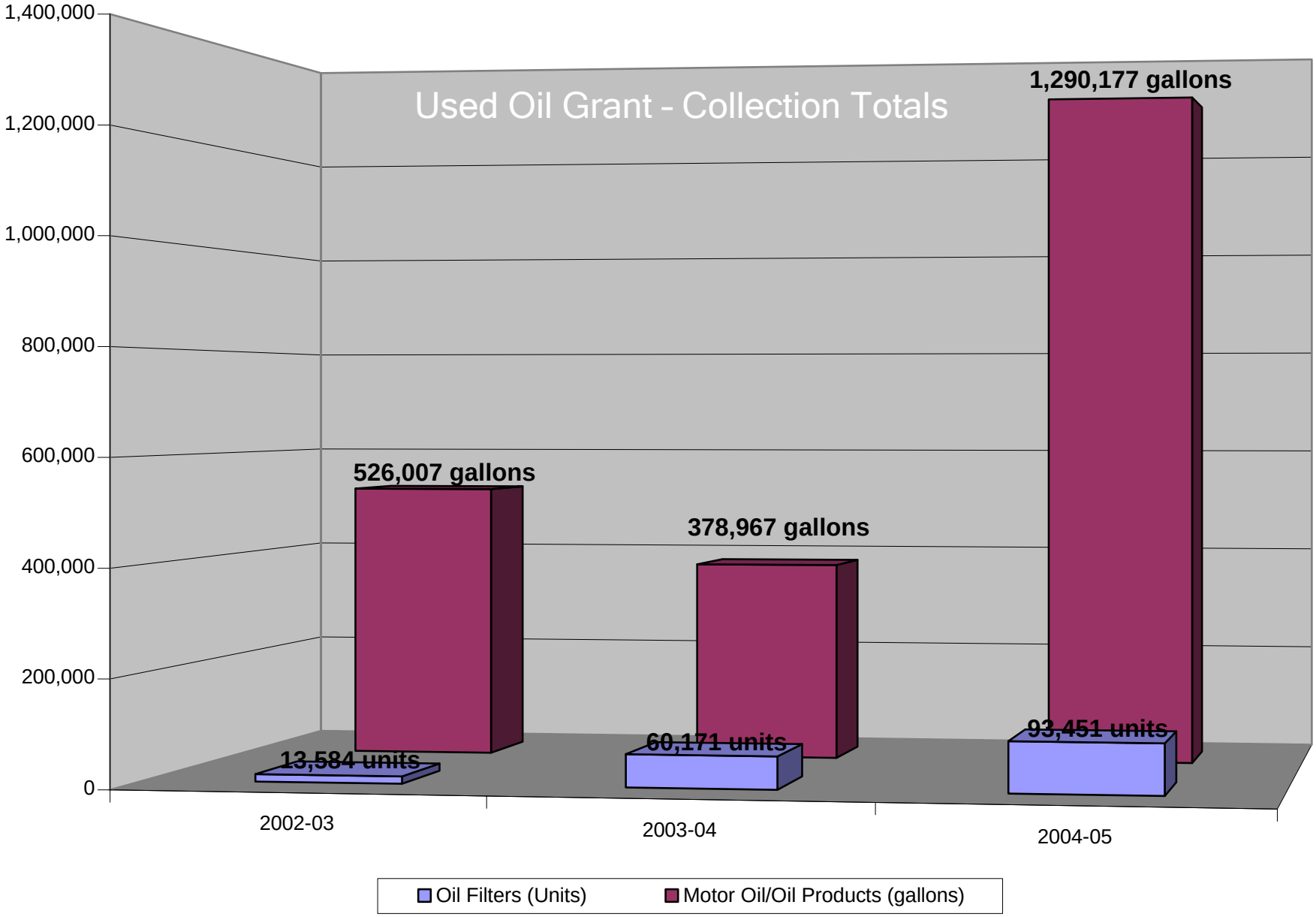


Figure 5.7: Used Oil Grant Participation



6.0 PUBLIC EDUCATION

6.1 Introduction

In 2002, the Permittees created a public and business outreach strategy - "Orange County Stormwater Public Education Program Recommendations." This strategy, which was updated in 2004, established a long-term, cost-effective approach to educate the public and targeted business groups about the effects of stormwater pollution and encourages their participation in the protection of surface waters. Key aspects of the strategy included conducting a survey to define the level of general knowledge held by people in Orange County, utilizing the survey results to develop campaign goals, determining the key messages, defining specific community outreach activities and approaches, preparing a master timeline, and creating a "brand" name for the Orange County Stormwater Program ("Project Pollution Prevention").

6.2 Accomplishments

The primary elements of the Third Term Permits public education program were a series of "Plans" that guided the program implementation, specifically:

- A "Materials Plan" that prioritized the educational materials necessary for revision/development and defined the common look and theme;
- A "Media Plan" that identified advertisement purchases in major publications, on Orange County Transit Authority buses and shelters, in movie theaters, on radio, and on cable television;
- A "Non-media Plan" which included the develop of a tool box for local outreach and building relationships with businesses, trade associations, chambers of commerce, utilities, and organizations that provided key opportunities for outreach;
- A "School Education Plan" to reach K-12 students in Orange County with pollution prevention messages; and
- An outreach plan for the approximate 10,000 food service facilities in Orange County.

Additional elements of the program include:

- An initial and follow-up public opinion/education survey (completed in 2003 and late 2005 respectively);
- Assistance with governmental and regulatory agency relations;
- Translation of all materials into Spanish and the creation of a Spanish webpage;
- Translation of key materials into Vietnamese;
- A "tool box" of materials for Permittee program coordinators to conduct local outreach efforts, based upon a quarterly "Quad Approach" including press releases, newsletter articles, fact sheets and billing inserts; and
- An employee-training program ("Stormwater 101") to educate all municipal employees about general stormwater principals.

6.2.1 Countywide Public and Business Education Materials Plan

A Materials Plan was developed that prioritizes the outreach materials necessary for revision/development and defined a common look and theme. Pursuant to this plan, the following materials were produced:

- Forty-three brochures; 22 in English, 18 in Spanish and four in Vietnamese.
- Sixteen print advertisements; eight in English, seven in Spanish and one in Vietnamese.
- Ten radio public service announcements; five in English and five in Spanish.
- Four movie/cable PSAs; three in English and one in Spanish.
- Three bus advertisements.
- Six quad outreach kits including a newsletter, press release, billing insert and fact sheet.
- Outreach kit for food service establishments including a BMP poster, four stickers, a PowerPoint presentation, fact sheet and CD-ROM.
- Stormwater 101 training kit including a pre/post training evaluation, fact sheet, PowerPoint presentation and 7-½ minute video.
- A municipal vehicle magnet.
- A door hanger notice for residential pollution problem correction.

6.2.2 Media Outreach Plan

A strategic media relations campaign was developed and implemented that included advertisements in major publications, on Orange County Transit Authority buses and shelters, in movie theaters, on radio, on cable television and online. The Permittees collectively purchased the following media during 2002-06:

Newspaper advertisements generated 46.5 million impressions

- Seven full-color ads in the Sunday *Orange County Register*
- Three full-color ads in the Sunday *Los Angeles Times* (Orange County Edition)
- Twenty-two full-page ads in 17 of the *Register's* community papers
- Fourteen full-page ads in four of the *Register's* community papers
- Eleven ¾-page ads in the *Los Angeles Times'* three Orange County community papers: the *Daily Pilot, Huntington Beach Independent* and *Laguna Beach Coastline Pilot*
- Nine full-page ads in the *News-Enterprise*
- Fourteen full-page ads in *OC Metro*
- Eleven full-page ads in *OC Weekly*
- Seventeen full-page ads in *Miniondas* (Spanish language)
- Fifteen full-page ads in *Excelsior* (Spanish language)

Radio advertising generated 27.6 million impressions

- Twenty 60-second spots on KLAC AM 570. The spots generated more than 120,000 impressions.
- One hundred and twenty- 60-second spots ran on JACK FM 93.1 generating 25 million impressions.

- One hundred and sixty 60-second spots ran on Sonido (Spanish language radio station) generating 2.5 million impressions.

OCTA bus advertising generated 71.5 million impressions

- Fifty-seven bus sides
- Fifty bus backs
- Fifty outdoor bus shelters

Movie theater advertising generated 11 million impressions

- The 30-second public service announcement ran on screen and in lobby kiosks for twenty weeks at 22 Edwards/Regal Cinemas, San Clemente's Krikorian Theater, twelve weeks at the Long Beach Town Center Theater and twelve weeks at AMC theaters.
- The sad fish poster was displayed at all 24 Orange County theaters.

Cable television advertising generated 1.4 million impressions on four cable stations (Adelphia, AT&T/Comcast, Time Warner and Cox Communications)

On-line banner advertising generated 2.35 million impressions

- Banner display on www.931jackfm.com for three months.
- Banner display on www.ocregister.com for two months.

Headline Indicator – Number of Media Impressions: The public education program generated over 160,000,000 media impressions over the period 2002-06.

ROWD Commitment

- Continue to "fine tune" the multi-media approach.
- Re-evaluate audiences & key messages for targeted behaviors.
- Pursue opportunities for regional collaboration.

6.2.3 Non-Media Outreach Plan

A Non-Media Outreach Plan was developed and implemented to complement the paid advertising media campaign. The plan utilized existing resources and partnerships to produce free or low-cost exposure for the program.

Outreach to Permittees

The plan included the development of a "tool box" of materials to enable the Permittees to conduct local outreach both directly and indirectly through businesses, trade associations, chambers of commerce, utilities, restaurants and other organizations.
Specifically, the "tool box" included:

- Outreach Materials - Artwork was created for use on outdoor locations such as bus shelters, streetlight banners, mouse pads and beach towels.

- The Quad - A series of newsletters, press releases, fact sheets and billing inserts were created that focused on seasonal stormwater themes. Six seasonal quads were created.
    - Spring Into Cleaning – Household Hazardous Waste
    - What's Summer Without The Beach
    - When It Rains It Pours Pollutants Into Our Storm drains
    - A Pollution Fix for 2006
    - Green Thumb Blue Ocean
    - Keeping Your Car and the Environment Sparkling Clean

- An Events Listing - Lists of upcoming utility, restaurant, city and organization sponsored events were developed where stormwater information could be provided to event participants.

- Employee Training Materials - Stormwater training materials were developed to educate all municipal employees about general stormwater pollution prevention principles.

Outreach to Businesses

The plan's proposed implementation of programs is based on relationships and partnerships that had been developed with groups who may have been receptive to partnering with the program..

- A list of key Orange County businesses that the Stormwater Program could potentially foster relationships with was developed. The list included top businesses and major Orange County employers. These businesses were contacted and the following is a list of the business partnerships developed:

- Point of Purchase - Partnerships with stores that sell auto supplies, hardware, pet supplies and gardening supplies were developed. The program has fostered relationships with:

    - PetsMart Inc.
    - Home Depot, Inc.,
    - Orchard Supply Hardware (OSH)
    - Wal-Mart,

  - The Pet Pantry
  - Huntington Garden Center
  - Flowerdale
  - De Nault's Hardware

- A list of major Orange County events such as the Orange County Auto Show and Southern California Home & Garden Show was created. Event coordinators were contacted with a letter introducing the program and asking for the opportunity to participate and/or distribute Orange County Stormwater Program materials.

Outreach to Utilities

Major non-city utilities providing water, electricity, cable and refuse services were contacted and provided sample newsletters for use in their publications. Several utilities printed stormwater education materials in their newsletters and billing inserts and posted information on their websites including:

  - Rainbow Disposal
  - Waste Management
  - Southern California Edison
  - Sempra Energy/The Gas Company
  - Orange County Water District
  - Orange County Fire Authority

The four major refuse companies in Orange County agreed to place a 12" x 24" Stormwater magnet on their trucks. More than 500 refuse trucks displayed the magnet during the 2002-06 reporting period.

Outreach to Organizations

A list of key Orange County organizations that the Stormwater Program could foster relationships with was developed. The list included organizations such as chambers of commerce, rotary clubs, and environmental groups.

- Chambers of Commerce - Several chambers provided Stormwater information to their members including the Brea Chamber of Commerce, Fountain Valley Chamber of Commerce, the Black Chamber of Commerce and the South Orange County Chambers of Commerce.

- Welcome Express - Welcome Express provides welcome packets to new homeowners in various communities throughout Orange County. Welcome Express provides the Household Tips brochure within their new homeowner's packet.

Media Relations Campaign

The media relations campaign centered on fostering relationships with reporters. Local newspapers are considered one of the most credible sources of information for Orange County residents and reach a large audience. Therefore, media relations were an invaluable component of the public education campaign.

The media relations campaign utilized the seasonal stormwater press releases created as part of "the Quad" to contact the media on a quarterly basis. The program also updated its media distribution lists quarterly.

Indicator – Number of Non-Media Impressions: The public education program generated 25 million non- media impressions during 2002-06.

Outreach to Restaurants

A specific outreach plan for the approximate 10,000 food service facilities in Orange County was developed and implemented. The outreach plan included the following efforts:

- The inspection and distribution of educational materials to the approximately 10,000 existing food facilities (the inventory is updated annually) countywide. Over 36,000 inspections for NPDES stormwater related issues were conducted.

- A focused public education outreach component was developed and implemented. This effort included:
    - A mass mailing to all corporate and food service facilities within Orange County. Over 9,000 letters were mailed.
    - Distribution of focused educational brochures, posters, stickers and CD-ROMs were distributed during inspections.
    - Presentation was given to the Food Sanitation Advisory Council.

Indicator – Number of Food Facility Outreach Impressions: The public education program generated over 45,000 food facility outreach impressions during the 2002-06.

ROWD Commitment

- Continue to foster new relationships and partnerships.

6.2.4 School Education Outreach Program

During the 2002-03, reporting period extensive meetings took place with representatives from

various educational programs and agencies throughout Orange County. A school education outreach plan was developed and implemented that included the following partnerships:

Orange County Department of Education (OCDE)

Inside the Outdoors is an environmental education program administered by the OCDE. There are three types of programs within *Inside the Outdoors* which are the:

- Outdoor Science School - This program includes information on sources of water for southern California, pollution prevention, and watershed information. 14,000 students participated in this program.

- School Program - A traveling scientist visits school sites providing the "Drip Drop" program - a 60-minute presentation about water quality. 3,000 students participated in this program.

- Field Program - Fifth grade students move into the real world of science and social science. During the "Where Do I Flow" program students learn about water pollution and prevention. 12,803 students participated in this program.

Approximately 30,000 students participated in the *Inside the Outdoors* Science Programs.

Municipal Water District of Orange County (MWDOC)/Discovery Science Center (DSC)

The partnership with MWDOC/DSC is focused on the Elementary Water Science Education Program, a water education course for teachers, and a public program for general visitors.

- Elementary Water Science Education Program – This program presents grade-specific science lessons, which incorporate water sources, water conservation, and water/trash pollution themes complementary to the science content standards.

  5th Grade Student Assemblies: This element of the program presents lessons to elementary school students in an assembly format. 17,200 fifth grade students and 500 fifth grade teachers participated in this program.

  5th Grade Students Attending the DSC Field Trip Program - For 5th grade students attending the DSC, field trip instructors screen the Project Pollution Prevention video entitled "Go With the Flow" and distribute the Project Pollution Prevention water education-based booklet. 25,827 fifth grade students and 2,000 fifth grade teachers participated in this program.

- Water Education Course for Middle and High School Teachers - The Water Education Course provides fifth through twelfth grade teachers Professional Development classes complete with curriculum and a kit of scientific equipment to conduct water-focused and pollution awareness activities in their classrooms. The Water Education Course was provided to 24 teachers reaching approximately 792

students.

- Public Program for General Visitors to the DSC - A demonstration and learning station for the general public visitors and students on field trips to the DSC was developed to further communicate the importance of water, water conservation, urban pollutants, and stormwater/urban runoff pollution. An estimated 76,000 visitors saw the station annually.

Project WET (Water Education for Teachers)

The Project WET (http://www.projectwet.org/index.html) is a water science and education program for teachers that provide classroom ready teaching aids including the Project WET Curriculum and Activity Guide. The guide is a collection of hands-on, innovative, interdisciplinary activities. Project WET developed curriculum specifically for the stormwater program.

Nearly two hundred teachers have participated in Stormwater Program sponsored workshops reaching 7,000 students per year.

California Regional Environmental Educational Community (CREEC) Network

The California Regional Environmental Education Community (CREEC) Network is an educational project whose mission is "to develop a communication network which provides educators with access to "high quality" environmental education resources to enhance the environmental literacy of California Students." It is an educational project supported by the California Department of Education, Environmental Education Program, in collaboration with state, regional and local partners. The CREEC Network provides information on all Orange County environmental school education outreach programs. To further publicize this information, links between the Permittees' website and CREEC were established.

Indicator – Number of School Outreach Impressions: The public education program generated 188,846 school outreach impressions during the 2002-06.

6.2.5 Other Countywide Initiatives

The Principal Permittee conducted a number of countywide public education initiatives on behalf of the Permittees. These initiatives included:

- Provision of brochures, magnets, bookmarks, manual, and posters to the Permittees, general public, businesses, schools, and other agencies. During 2002-06 over 450,000 educational materials were distributed.

- Management of the countywide 24-hr bilingual water pollution reporting hotline number, (714) 567-6363. During the 2002-06 the hotline received 927 water pollution calls. Water pollution complaints are also received through the County website.

- Advertisement of the 24-hour water pollution hotline number and web address, www.ocwatersheds.com, in all SBC Regional Phone Directories.

- Management of the County website, www.ocwatersheds.com. During 2002-06 the website received over 10,000,000 hits.

Indicator – Number of Other Countywide Initiative Impressions: The public education program generated 10,450,927 other impressions during the 2002-06.

Headline Indicator – Public Education Program Impressions: The public education program created over 195,684,773 impressions during the 2002-06 permit cycle. One of the goals of the public education program is to target 100% of the residents of Orange County. Orange County has a population of approximately 3 million people. Therefore, it can be deduced that every resident of Orange County received thousands of impressions during the reporting period. This achievement also far exceeds a Third Term Permit requirement to deliver a minimum of 10 million impressions per year within the Santa Ana Regional Board Area.

6.3 Assessment

In an effort to better understand the public's awareness regarding water quality issues, several surveys have been conducted. The surveys have incorporated a number of questions relating to pesticide, herbicide and fertilizer use, the sewer and storm drain system and the public's overall awareness of the County's public outreach campaign. Surveys conducted since the inception of the Orange County Stormwater Program include:

- 1994 Stormwater Pollution Prevention and Flood Awareness Survey
- 2000 County of Orange Fair Survey

- 2000 Orange County Sanitation District Fair Survey
- LA Times In Education Survey
- 2001 Public Awareness Survey
- 2003 Public Awareness Survey
- 2005 Public Awareness Survey

6.3.1 Public Awareness Surveys

In May 2003, the Permittees conducted a large sample (1,500 respondents) public awareness survey to measure the current level of knowledge held by residents of Orange County. In November 2005, after 30 months of the public education campaign, a follow-up to the baseline survey was conducted. The purpose of the second survey was to assess the extent to which public opinion and knowledge about urban runoff issues have changed and whether Orange County residents have made any behavioral changes as a result of the public education campaign.

The findings indicate that the public information campaign on stormwater and urban runoff has made initial inroads towards increasing awareness. In the majority of questions, awareness of the program and or its elements increased one to three percentage points.

Effectiveness of Educating on the Environmental Issue

Consistent with findings from 2003, education, traffic congestion, safety and employment continue to rank higher than pollution as top issues of concern with Orange County residents. In the last 30 months, residents concern regarding pollution of the ocean, rivers, creeks and bays increased 1%. When asked specifically about ocean, bay and harbor pollution, concern remained consistent with the baseline data with 85% to 87% concerned. However, the intensity of concern regarding pollution of creeks and rivers increased 6% (from 39% very concerned in 2003 to 45% in 2005).

During the 30-month stormwater outreach campaign, information never focused on the actual quality of Orange County water or the severity of the issues. Most elements of the program focused on particular activities that would "protect our creeks, rivers, bays and ocean." The result of the survey is consistent with the amount of prominence placed on this subject. If a greater emphasis was placed on this subject in the campaign, the numbers could have been higher.

Effectiveness of Educating on the Storm Drain System

Knowledge about urban runoff and storm drains has increased. In fact, 90% of residents know that water flowing in the street enters a storm drain and goes directly to a waterway. This is up six percentage points from 2003. However, there still is a lack of understanding regarding the storm drain system. When asked if water in the storm drains is tested and filtered, 4% more answered the question correctly in 2005, however, it was still less than half (46%) of the respondents. Similarly, when asked if sewer water and storm drain water

enter the same system, 3% more answered the question correctly, however, it was still less than half (44%) of the respondents.

During the education campaign, nearly all materials created mentioned that objects in the street flow through storm drains directly to the nearest waterway. However, only the brochures, fact sheets and newsletter articles went into depth regarding the difference between the sewer and storm drain system. The use of this information in all the materials shows in the increased level of awareness. Had the differences between the sewer system and storm drain system been illustrated in every piece, these numbers may have been higher.

Also, men tend to be very knowledgeable regarding the storm drain system while women were less knowledgeable according to the 2005 survey; therefore, materials targeted at women may be considered.

Effectiveness of Educating on Key Pollutants

The survey asked respondents if the following items contributed to polluting urban runoff: oil, toxic waste, Styrofoam cups, gardening products, cigarette butts, paint, dirty water/detergent, cleaning products, trash, pet waste, water from hoses, lawn clippings/dirt/leaves and pool water. In every case, respondents were very likely to say these items contributed to polluted runoff with nine of them increasing beyond the margin of error (oil, Styrofoam cups, cigarette butts, paint, cleaning products, trash, pet waste, lawn clippings/dirt/leaves and pool water).

The increased knowledge held regarding these 13 pollutants shows a strong upward trend and indicates that education materials are reaching the residents. For all but two pollutants (toxic waste and Styrofoam cups) a brochure has been created to educate the public. Also, seven of the pollutants (oil, gardening products, cigarette butts, dirty water/detergent, pet waste, hose water and lawn clippings/dirt/leaves) were covered in the print advertising campaign. The fact that public knowledge has increased regarding all 13 pollutants demonstrates that the education campaign is effective.

Effectiveness of Educating on Key Behaviors

Consistent with the first survey, roughly two thirds say that changing their personal behaviors would make a difference in cleaning up pollution (65%). This represents an increase of 2%. The survey revealed the following: 97% of people were either willing or did dispose of chemicals properly, 89% were willing to or did use fertilizers properly, 92% were either willing to or did keep yard clippings out of the street, 90% were willing to or currently adjust sprinklers to avoid overwatering; 79% were willing to or did pick up after their pet, 90% were willing to or currently use a broom to clean driveways, and 73% were willing to or eliminated washing cars at home.

When comparing seven actions that residents were already participating in, they were 4% more likely to dispose of chemicals properly and 3% more likely to pick up after a pet in 2005. However, less respondents were keeping yard clippings out of the street (-5%),

adjusting sprinklers (-1%), using a broom instead of a hose (-5%), properly using fertilizer (-1%) and eliminating car washing (-9%). Although participation in some of the seven actions decreased, roughly half of Orange County residents report taking part in all seven of the activities – making a significant increase over the 30 months (+37%) of the campaign (**Figure 6.1**).

During the course of the education campaign, the materials focused on what can be done to prevent urban runoff. All seven activities mentioned in the survey were addressed in brochures, newsletter articles, fact sheets, press releases and billing inserts.
The survey results indicate that the education campaign has penetrated the residents of Orange County and caused significant awareness of the activities that can reduce urban runoff. In all cases (except home car washing) at least eight in ten residents were either participating, or willing to participate in, activities that limit runoff. Despite a successful start to the campaign, residents appear to be obstinate when it comes to one behavior—eliminating home car washing.

Effectiveness of the School Outreach Program

A significant portion of parents of children under 19, roughly 25%, report that their children learned about urban runoff issues in school and came home and talked about it. It is safe to assume that the number of students who received the information, but did not share it with their parents is even higher.

Based on the significant number of students who have reported to a parent about having heard urban runoff prevention messages, it appears that the school outreach program has been effective.

Effectiveness of the Media Outreach Program

According to the 2005 survey, the most effective (most recognized by residents) form of advertising are the "No dumping, drains to ocean" stencils (81%) and newspaper articles (65%). Although part of the overall stormwater program, stencils were not an integral element of the education campaign. Their success can be attributed to a couple of factors. First, the stencils are on a large percentage of storm drains throughout the County. Nearly every resident has a stencil in his or her neighborhood. Also, the stencil program has been active in Orange County for many years. While other education programs were introduced in the last 30 months, residents have seen the stencils for more than a decade. The other very effective program has been newspaper articles. Similar to the stencils, articles on water pollution have been available to the public for decades and have had time to resonate.

Other effective aspects of the program (recognized by residents) were the PSAs on radio (39%), PSAs on cable (38%), newspaper advertising (35%), brochures (28%) and community events (20%). All five of these programs were initiated 30 months ago through the outreach campaign and have significantly resonated with residents. While most of these campaign elements were specific to Orange County, a few had the additional assistance from other regional campaigns such as "Don't Trash California" and the "Used

Oil" program.

Less effective aspects of the program (least recognized by residents) were movie theater advertising (14%), workplace information (14%), bus advertising (13%) door hangers (12%), and Spanish radio PSAs (6%). While Spanish radio was the least recognized program by all respondents to the survey, among Spanish speaking respondents it was substantially higher (18%). All of these specific campaign elements were created and implemented during the 30-month outreach campaign (**Figure 6.2**).

When determining whether an element should be eliminated from the campaign, it is important to evaluate the number of sources people received information from. According to the 2005 survey, 29% of people received stormwater information from one or two sources. If the majority of these people received information from a source that is eliminated, the campaign would be less effective. However, in this circumstance, only 2% of people who received information from one or two sources received information from theater ads or bus backs. In regarding to theater advertising, it is possible that residents confused cable PSAs with theater advertising because both played the same spot. Since cable advertising was highly recognized by residents, the campaign could have been less effective if it were removed. In the case of bus back advertising, the program would still have been effective without this element.

Another aspect of the program that was evaluated was the print advertising. While, 35% of people recalled seeing print advertising, it is important to note what papers residents are reading. While the largest percentage of advertising was in the Orange County Register, the program did advertise in the Los Angeles Times a half dozen times a year. According to the survey, the percentage of people who get most of their information on urban run-off from the Times dropped from 12% to 9% (Orange County Register is 28%). Also, only 5% of people who received information from one or two sources received the information from print advertising. Therefore, advertising in the Times could likely have been less frequent without affecting the effectiveness of the campaign (**Figure 6.3** Effectiveness of Print Advertising).

According to the 2005 survey, the percentage of voters saying there is enough information has increased (+1% and +5% from a split question). However, residents continue to believe that there is not enough information provided about how to stop urban runoff and ocean pollution in Orange County. So while some of the elements of the campaign could have been eliminated, the survey demonstrated that people need to receive information from a variety of sources. The Internet appears to be an emerging source of information, increasing 6% to 10% (third highest source of information).

6.4 Summary

Since the inception of the Orange County Stormwater Program outreach campaign, information on stormwater and urban runoff has made initial inroads in increasing awareness. This increase is seen in nearly every element of the program and demonstrates a great beginning to a program that was implemented in a short period of time.

Although all of the elements of the program contributed to the success of the campaign, the program could have considered eliminating bus back advertising. Print ads in the Los Angeles Times could have been reduced and ads in the full-run Orange County Register could have been increased. Another element that could have been added is online marketing. Overall the program demonstrated an effective start to the education campaign.

Figure 6.1: Resident Participation in Pollution Prevention Activities

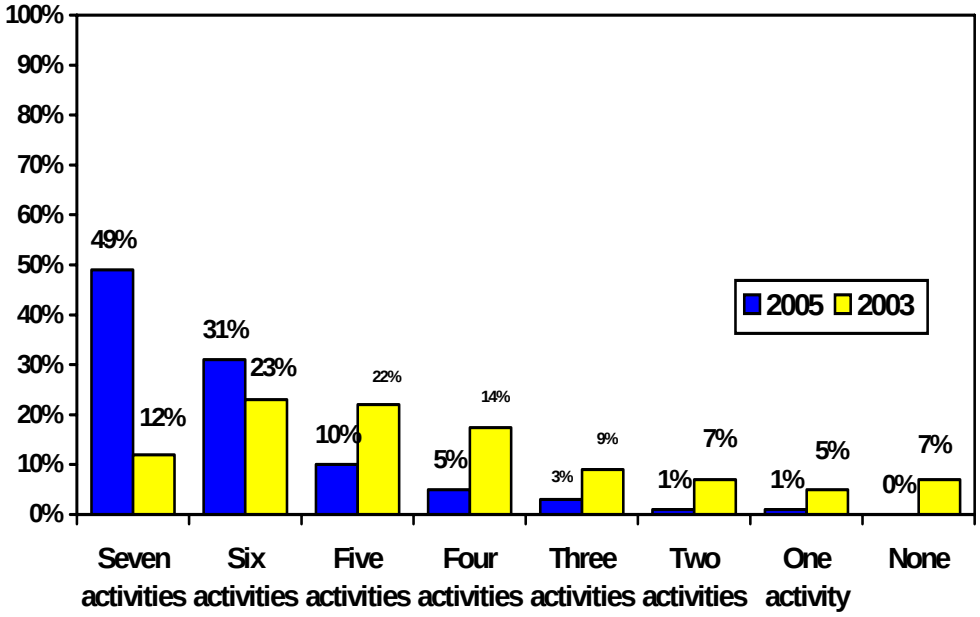


Figure 6.2: Effectiveness of Media Outreach Program

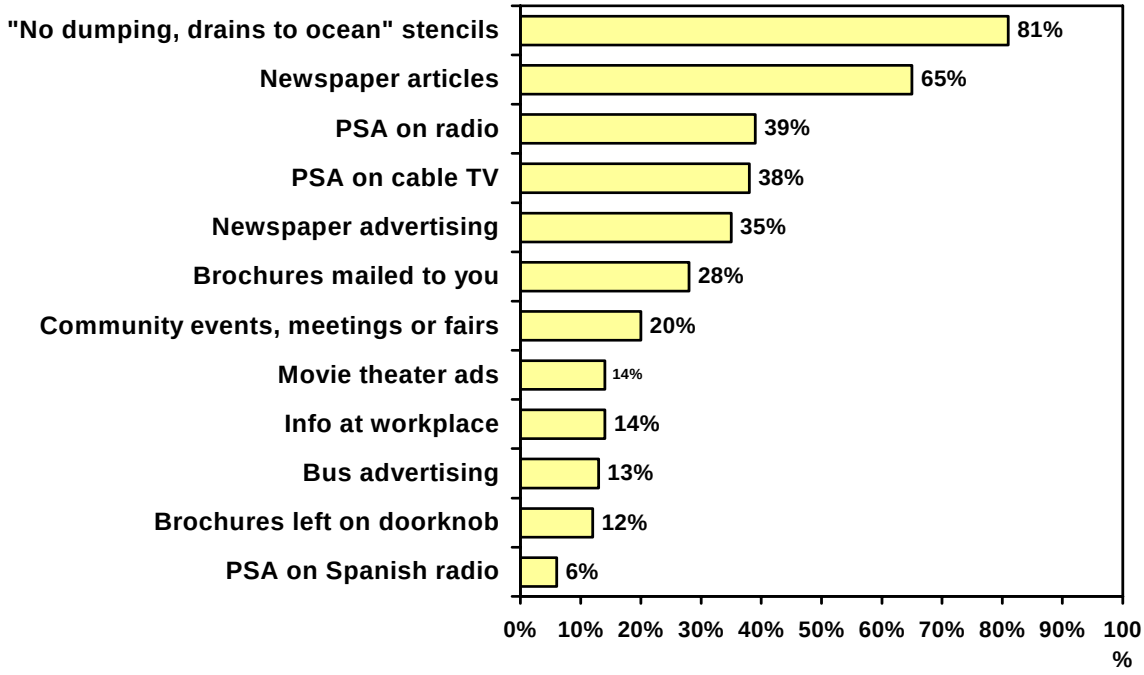
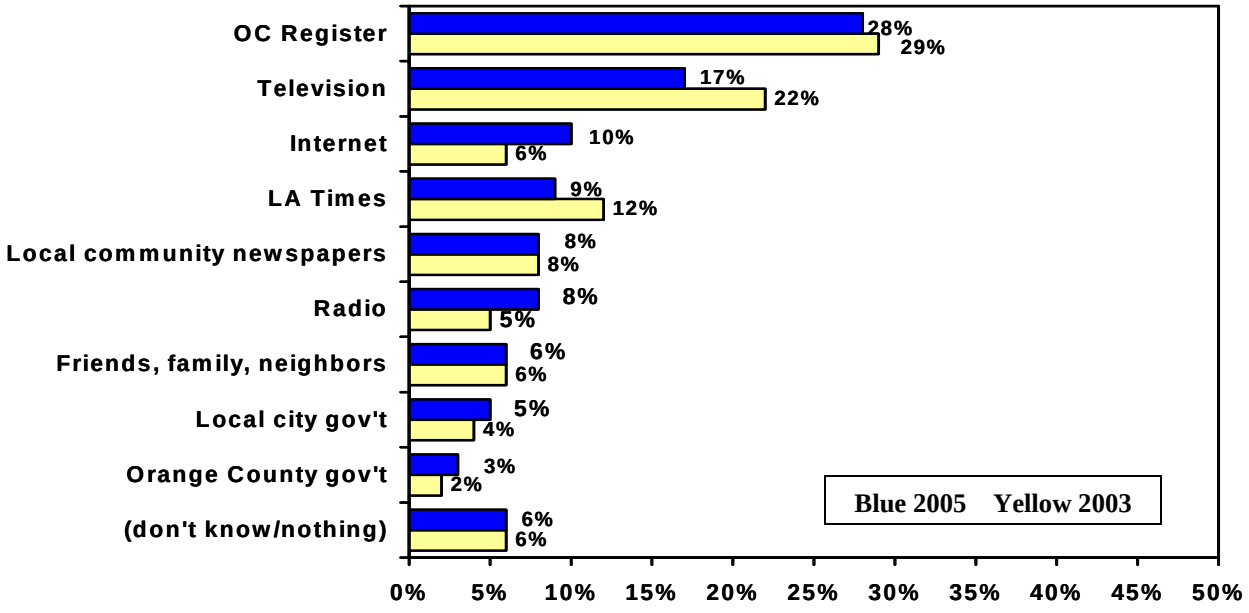


Figure 6.3: Effectiveness of Print Advertising



7.0 NEW DEVELOPMENT/SIGNIFICANT REDEVELOPMENT

7.1 Introduction

One of the most important responsibilities of local government is to provide a decision making and approval processing framework for new development and re-development. This framework ensures that (1) development occurs in an orderly and organized fashion in a manner that reflects the vision and needs of the community, (2) environmental issues associated with development are assessed, and (3) provides a regulatory framework to ensure that standards set by the jurisdiction are implemented.

Since the inception of the Program, it has been recognized that the incorporation of BMPs into a development project in its planning stages offers a unique opportunity to limit increases in pollutant loads. **DAMP Section 7.0** links new development BMP design, construction and operation to the earlier phases of new development project planning, encompassed by the jurisdictional General Plans environmental review and development permit approval processes.

7.2 Accomplishments

7.2.1 New Development/Significant Redevelopment Program

In 1993, the New Development/Construction Task Force, comprised of representatives from the Principal Permittee, Building Industry Association (BIA), Association of General Contractors (AGC) and Civil Engineers & Land Surveyors of California (CELSOC), completed a report - *Best Management Practices For New Development Including Nonresidential Construction Projects (1-5 acres)* - that provided the basis for requiring the incorporation of structural and non-structural BMPs into development. This report was the basis of the New Development component of the DAMP during the First and Second Term Permits.

The requirements of the Third Term permits significantly increased the complexity of the new development provisions of the DAMP. These provisions provide a framework and a process for integrating watershed protection/stormwater quality management principles into the Permittees' General Plans, environmental review processes, and development permit approval processes. The new development provisions also cover initial project planning and project design, construction and completion, including requirements for the selection, design and long-term maintenance of permanent BMPs. Specifically, the new development provisions require the Permittees to:

- Assess the need to revise and update General Plans to include watershed and stormwater quality and quantity management considerations.
- Review CEQA processes for potential stormwater quality impacts and mitigation.
- Review development planning/permit approval process for stormwater protection principles.

- Develop and implement a model Water Quality Management Plan (WQMP) (also referred to as a Standard Urban Stormwater Mitigation Plan – SUSMP) to address impact from new development and significant redevelopment.

  For the area of Orange County within the San Diego Regional Water Quality Control Board jurisdiction of Orange County (area south of El Toro Rd.), each municipality was required by the Permit to develop a Local WQMP, based on the model WQMP, to oversee new development and significant redevelopment within their local jurisdiction. These Local WQMPs were finalized for implementation on August 13, 2003.

  For the area of Orange County within the Santa Ana Regional Water Quality Control Board jurisdiction of Orange County (area north of El Toro Rd.), the Model WQMP explains the requirements placed upon all new development and significant redevelopment projects. The Model WQMP underwent a lengthy public review process and was approved for implementation by the Executive Officer of the Santa Ana Regional Water Quality Control Board on September 30, 2003.

  During the 2004-05 reporting period, 551 Project WQMPs were processed for 3,227 acres of development. Since 1997, a total of 3,193 Project WQMPs have been approved, covering 27,287 acres which represents approximately 6% of the area within Orange County subject to the Third Term Permits.

- Conduct education or training.

  Five training modules have been developed and have been given:

  1. General Plan Issues;
  2. New Development/Significant Program Management;
  3. Project Planning and Design: Environmental Review, Planning and Permitting and WQMP Development;
  4. Stormwater BMP Effectiveness and Applicability for Orange County, and
  5. Stormwater Treatment: How it Works (Or Does It?).

7.2.2 California Sustainable Watershed/Wetland Information Manager (CalSWIM)

CalSWIM (http://calswim.org/)is an Orange County Storm Water Program and University of California, Irvine (Departments of Engineering and Informatics) initiative to develop a web-based expert system and prototype database designed to support cost-effective and scientifically justifiable decisions regarding the monitoring, management, and alteration of coastal urban wetlands and their associated watersheds. Initiated in 2004, CalSWIM currently delivers:

- Forecasting and now-casting of nutrient levels, sediment supply, indicator bacteria, and pathogens in the Newport Bay Watershed, and

- Targeted evaluation of management decisions that affect the habitat quality and ecological function of coastal wetlands, and/or that directly bear on pollutants of concern.

7.2.3 Hydromodification

Hydromodification arises from changes in the volume, magnitude and duration of flows that can occur coincident with urbanization and is evident in the landscape as channel incision and bank erosion in the upper and middle portions of a watershed and as aggradation and increased channel meandering in the downstream areas of the watershed. In 2005, the Permittees supported, through the Stormwater Monitoring Coalition (SMC) and California Stormwater Quality Association (CASQA), a workshop that was convened to provide an overview of the key technical and managerial issues associated with hydromodification in S. California (see Stein and Zaleski, 2005[1]).

7.3 Assessment

The current and potential program effectiveness assessment outcome levels for the New Development /Significant Redevelopment Program are presented in **Table 7.1.**

7.3.1 New Development/Significant Redevelopment Program

CEQA review processes were reviewed for adequacy early in the period of the Third Term Permits. However, in preparing the ROWD, a number of Permittees commented that the overall planning approval process for projects needs to more effectively ensure that water quality protection is considered in the earliest phases of project consideration through further elaboration of the preliminary or conceptual WQMP concept in the DAMP.

ROWD Commitment:

- Prepare guidance documentation and clarify requirements for the preliminary or conceptual Project WQMP.

The Model WQMP identifies BMPs for new development and significant redevelopment projects that are subject to WQMP requirements pursuant to **DAMP Section 7**. Depending upon the project size and characteristics, these BMPs include Site Design BMPs, applicable Source Control BMPs and Project-based Treatment Control BMPs (and/or participation in an approved regional or watershed management program).

[1] Managing Runoff to Protect Natural streams: The Latest Developments on Investigation and Management of Hydromodification in California; Stein and Zaleski, SCCWRP Technical Report 475, December 2000.

The requirement for new developments/significant redevelopment projects to prepare a WQMP has been an established part of the planning approval process (See **Table 7.2**) since the **1993 DAMP** and all Permittees certified they were implementing this part of the Program in 1997. While there is considerable variation in the level of activity between the Permittees, this variability can be attributed to the availability of land for development/redevelopment within a particular jurisdiction. Indeed, the County of Orange and the cities of Irvine and Anaheim, with large swathes of undeveloped land, show the highest numbers of WQMPs processed.

Headline Indicator – Number of WQMPs processed and the area (acreage) to which BMPs have been applied: During the 2004-05 reporting period, 551 WQMPs were processed for 3,227 acres of development compared to 461 WQMPs processed for 1,595 acres of development in 2003-04, and 391 WQMPs processed for 2,836 acres of development in 2002-03 (**Table 7.2; Figure 7.1**).

☒ Level 1: Implement Program

Headline Indicator – Number of BMPs Implemented: A total of 5,061 BMPs were implemented in the 2004-05 reporting period. This total represents a 129% increase in the total number of BMPs implemented in 2003-04 (2,201) and a 112% increase from the total number of BMPS implemented in 2002-03 (2,389) (**Figure 7.2**).

☒ Level 3: Behavior Change

During the Third Term Permit term, the structural source controls used most often were: common area efficient irrigation systems and landscape design, filtration, storm drain stenciling, and trash storage area. The non-structural source controls used most often include: employee training, common area litter control, common area landscape management, street sweeping, education, BMP maintenance, and activity restrictions. The most common treatment control BMPs that have been implemented include catch basin screens, catch basin filters, and stormwater treatment units (hydro-dynamic separators).

In preparing the ROWD, a number of Permittees have commented that (1) the guidance for selecting BMPs needs to be updated and enhanced, particularly with regard to treatment control BMPs, (2) there is a possible inconsistency in provisions regarding site prioritization, and (3) adjacent municipal stormwater programs have more effective provisions regarding the consideration of Site Design BMPs.

DAMP Modification:

- Revise *Model WQMP Table 7.II.6* for latest information on BMPs and clarity.
- Evaluate and revise (as necessary) prioritization provisions for Countywide consistency.

ROWD Commitment:

- Develop recommendations (through cooperative Stormwater Monitoring Coalition project) for incorporation of LID techniques into resource and water quality protection requirements.
- Develop library of BMP performance reports.
- Develop standard design checklist/plans/details for selected Source Control and Treatment Control BMPs.
- Develop recommendations for enhanced Model WQMP language regarding Site Design BMPs.
- Develop and implement BMPs for architectural uses of copper and zinc.

In 2005 the Santa Ana Regional Board formally approved the Irvine Ranch Water District's Natural Treatment System as a regional treatment control BMP for a portion of the Newport Bay Watershed. The project is significant for it being the first expression in the area under the jurisdiction of the Santa Ana RWQCB of a regional approach to stormwater treatment.

ROWD Commitment:

- Evaluate the NTS approval process and develop recommendations for streamlining regulatory agency approval of regional Treatment Control BMPs.

The New Development/Significant Redevelopment component of the Program ends with permit close-out and the BMPs transition to the Existing Development component. The Permittees believe that the BMP approach to stormwater management is most effectively sustained by ensuring the longevity of the WQMP through successive ownerships. Additionally, the Permittees requested additional guidance on recording WQMPs in a manner that would enable them to enforce the approved WQMP against subsequent property owners and ensure ongoing

responsibility for BMP maintenance.

ROWD Commitment:

Prepare guidance and training as needed on the recordation process (timing and appropriate documents to use) and develop recommendations for appropriate methods to employ to enable the Permittees to enforce the approved WQMP against subsequent property owners.

Training: Both the Permittees and RWQCB staff has identified a need for updated and additional training regarding WQMP review and approval.

ROWD Commitment:

- Prepare a training schedule and curriculum including defined expertise and competencies for staff with WQMP review and approval responsibilities.
- Prepare a workshop schedule and curriculum for the private sector on WQMP preparation.

7.3.2 California Sustainable Watershed/Wetland Information Manager (CalSWIM)

This initial development and deployment of CalSWIM has focused on Newport Bay, the regionally important tidal saltwater marsh. However, CalSWIM will in the future be extended with an open and scalable architecture to facilitate its rapid redeployment at other coastal urban wetland sites in southern California and elsewhere.

7.3.3 Hydromodification

While the major development projects in Orange County have now been entitled, the Permittees recognize that hydromodification is an emerging issue of concern as the future regulation and management of runoff from urban areas is increasingly considered with respect to the overarching objective of the CWA i.e. maintenance of the chemical, physical and biological integrity of the nation's waters.

DAMP Modification:

- Revise *Model WQMP Section 7.II -3.2.4 Identify Hydrologic Conditions of Concern* to incorporate additional information from hydromodification study.

7.4 Summary

The Third Term Permits have required the Permittees to develop and implement a significantly revised SUSMP- equivalent program for new development/significant redevelopment. This effort was completed Countywide by the end of 2003 and has resulted in an enhanced a WQMP program that, since 1997, has resulted in a total of 3,193 approved Project WQMPs. While the WQMP program is long-established, the review points to a possible continuing emphasis on pollution prevention BMPs and less progress regarding Site Design BMPs using LID approaches. Consequently, the development of additional training and technical support documentation on these approaches is being proposed as an area for further development. In addition, the Permittees have provisionally identified an opportunity, possibly through a Notice of Transfer of Responsibility, recordation, or other means, to enhance efficacy of the WQMP. This opportunity will be the future subject of a formal recommendation to the Permittees.

Table 7.1: Current and Potential Outcome Levels (New Development/Significant Redevelopment)

Development Program Component	Effectiveness Assessment Outcome Levels					
	Level 1	Level 2	Level 3	Level 4	Level 5	Level 6
	Implement Program	Increase Awareness	Behavior Change	Load Reduction	Runoff Quality	Receiving Water Quality
WQMPs	✓ # of WQMPs approved		P # BMPs implemented	P Load reduction associated with BMPs		
Training	✓ Track number/type of training sessions	P Surveys show improved knowledge				

Key:

✓ = Currently Achieved Outcome Level

P = Potentially Achievable Outcome Level

Table 7.2: Historical WQMPs and Acreage Covered

Permittee	2002-03		2003-04		2004-05	
	# of WQMPs Approved	Acreage Covered by WQMP	# of WQMPs Approved	Acreage Covered by WQMP	# of WQMPs Approved	Acreage Covered by WQMP
Aliso Viejo	1	23	3	NA	8	60
Anaheim	38	100	16	41	33	67
Brea	2	NA	5	NA	6	58
Buena Park	14	NA	8	NA	3	18
Costa Mesa	27	93	10	3	157	38
Cypress	11	14	22	NA	8	76
Dana Point	NA	NA	6	NA	1	121
Fountain Valley	5	37	2	NA	5	9
Fullerton	18	145	23	65	10	NA
Garden Grove	28	NA	21	NA	18	42
Huntington Beach	19	133	16	104	20	110
Irvine	87	NA	120	NA	100	485
La Habra	7	NA	0	0	2	1
La Palma	0	0	0	0	2	3
Laguna Beach	0	NA	11	NA	12	22
Laguna Hills	2	NA	6	NA	8	9
Laguna Niguel	2	NA	3	NA	1	21
Laguna Woods	NA	NA	4	NA	3	21
Lake Forest	16	40	7	26	4	8
Los Alamitos	0	0	4	NA	NA	NA
Mission Viejo	8	236	10	246	5	10
Newport Beach	NA	NA	18	NA	15	25
Orange	3	11	14	116	10	58
Placentia	0	NA	0	0	2	3
Rancho Santa Margarita	0	0	4	NA	4	4
San Clemente	10	277	22	146	4	329
San Juan Capistrano	8	85	10	NA	9	102
Santa Ana	19	61	23	NA	12	28
Seal Beach	0	0	2	NA	1	NA
Stanton	NA	NA	6	NA	7	3
Tustin	3	1	9	105	4	5
Villa Park	0	0	0	0	0	0
Westminster	8	8	15	17	13	10
Yorba Linda	6	145	14	234	20	187
County of Orange	49	1,426	27	491	44	1,294
TOTALS	**391**	**2,836**	**461**	**1,595**	**551**	**3,227**

NA = Not Available

Figure 7.1: Historical WQMPs and Acreage Covered

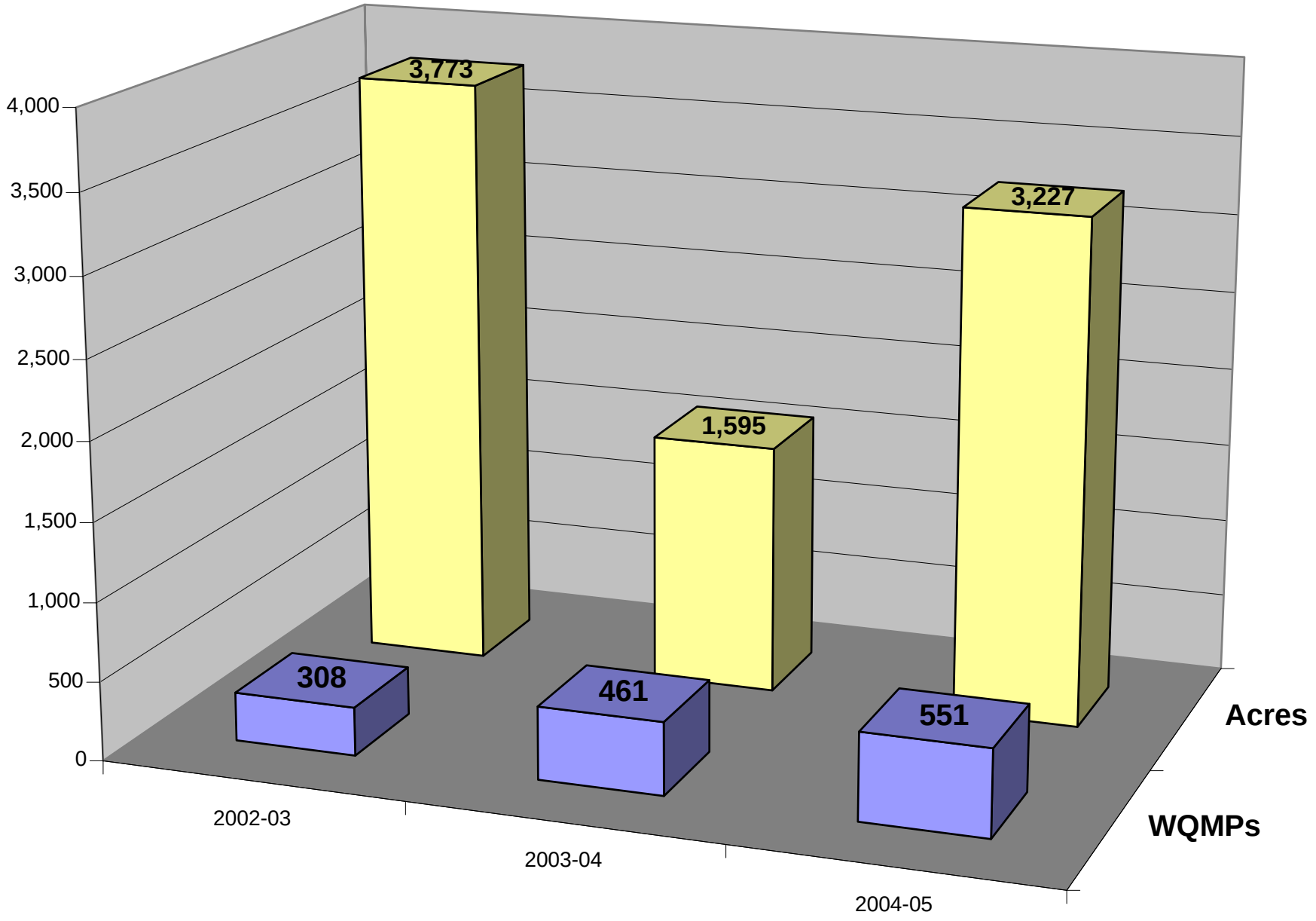
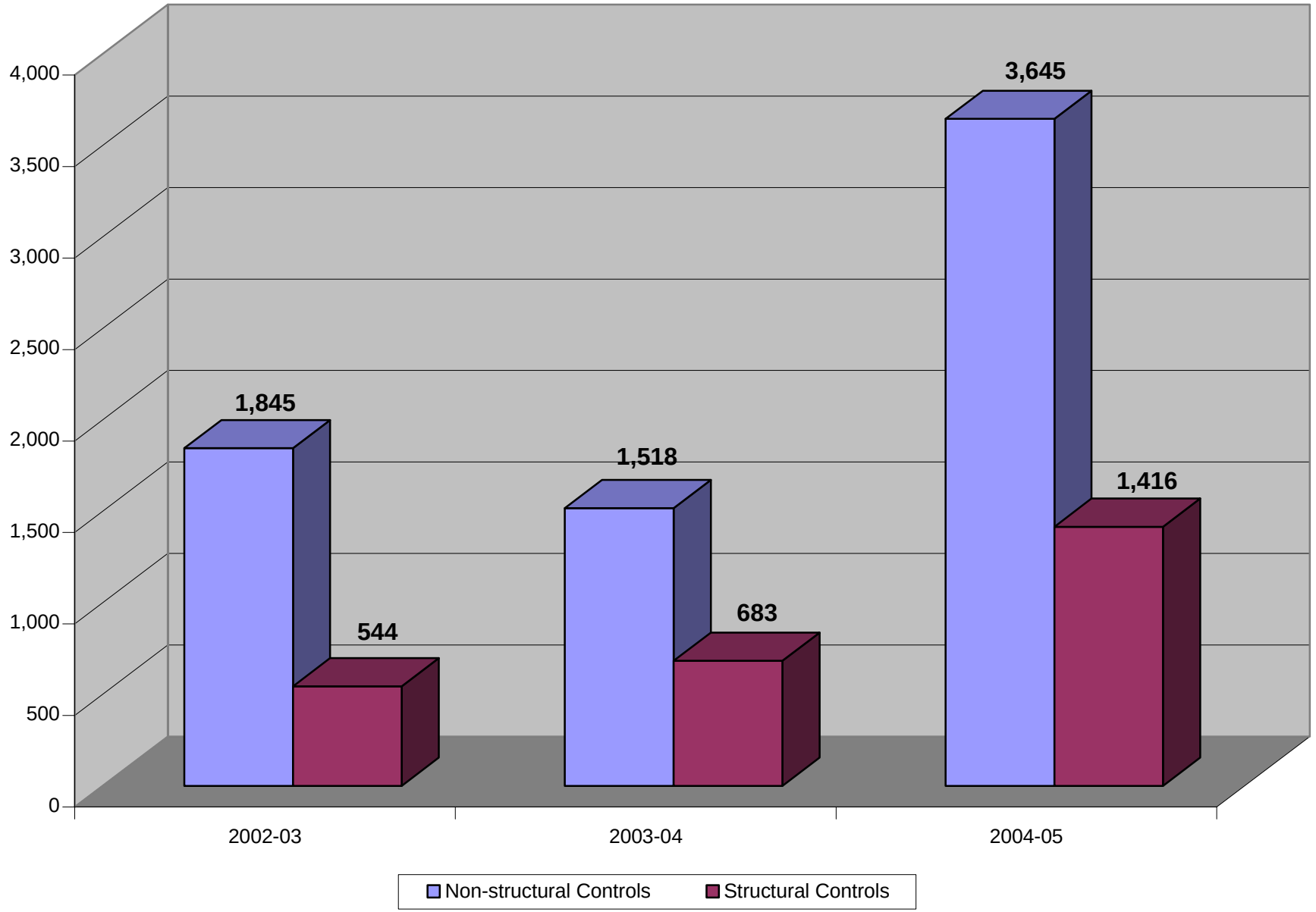


Figure 7.2: Structural and Non-Structural Source Control BMPs Implemented



8.0 CONSTRUCTION

8.1 Introduction

The Permittees regulate construction activities and have responsibility for the construction and reconstruction of municipal facilities and infrastructure. Concern over construction sites as a major source of sediment and other pollutants has meant that construction activity has been a focus of the Permittees' compliance program since the First Term Permits.

8.2 Accomplishments

8.2.1 Model Construction Program

This Model Construction Program was developed and implemented in 2002-03. It requires all construction projects regardless of size to implement an effective combination of erosion and sediment controls and waste and materials management BMPs. It also establishes inspection obligations on the Permittees. Previously, the Permittees' oversight of construction activities was based upon ensuring conformance of public works projects with the *Greenbook Standard Specifications for Public Works Construction*. Specifically, the Model Construction Program requires the Permittees to:

- Inventory construction sites

  In May 2002, a construction site inventory spreadsheet was finalized and distributed to the Permittees so that each municipality could develop their inventories by October 15, 2002, as required by Section VIII.1 of the 2002 Santa Ana Permit.

- Prioritize construction sites based upon water quality threat

  During 2004-05, thirty-four (34) Permittees reported conducting 15,067 construction site inspections comprising 5,504 high priority site inspections, 1,542 medium priority site inspections and 8,021 low priority site inspections.

- Prepare BMP Guidance

  The Permittees produced and distributed the *Construction Runoff Guidance Manual*.

- Conduct Inspections of construction sites

  During the Third Term Permits 25,831, 25,549 and 15,067 site inspections were conducted in the 2002-03, 2003-04 and 2004-05 reporting periods respectively.

- Undertake Enforcement

  As a result of the 2004-05 inspections, thirty-three (33) Permittees reported the issuance of 445 Educational Letters, 1,052 Notices of Non-compliance, 74 Administrative Compliance Orders, 81 Cease and Desist Orders, and 47 Misdemeanor/Infractions.

- Conduct Training

  To assist responsible municipal and contract/lease staff in understanding the Construction Program, two training modules have been developed:

  1) Construction Program Management.
  2) Inspecting Construction Site BMPs.

  In the 2004-05 reporting period Construction Inspection training was provided in two sessions to 167 inspectors.

8.3 Assessment

The current and potential Program effectiveness Assessment Outcome Levels for the current program are summarized in **Table 8.1**.

8.3.1 Model Construction Program

Inventories

The year-to-year status of the Permittees' inventories are not tracked at a Countywide level and consequently this aspect of the model program cannot be assessed.

Prioritization

The Permittees prioritize construction sites based upon a consideration of the size and type of construction, time of construction, location, and site topography. While the numbers of sites of each priority are not tracked at a Countywide level, the year-to-year changes in the level of inspection activity (**Table 8.2**) shows inconsistent reporting between the Permittees.

DAMP Modification:

- Provide definitive construction site prioritization and reporting guidance.

Inspection

The Permittees inspect construction sites to verify that the requirements of the DAMP are being implemented. The inspection frequency is determined by the season ("Wet" or "Dry") and a site's prioritization. The need for follow-up inspections also contributes significantly to the overall level of activity within a reporting period.

Headline Indicator – Inspection Activity: In 2004-05 thirty-four (34) Permittees completed 5,504 high priority, 1,542 medium priority, and 8,021 low priority construction site inspections. In 2003-04, 8,445 high priority, 5,731 medium priority, and 11,363 low priority construction site inspections were completed; and in 2002-03, 4,060 high priority, 15,937 medium priority, and 5,834 low priority construction site inspections were completed (**Table 8.2; Figure 8.1**).

☒ Level 1: Implement Program

While the level of inspection activity is significant (15,000 inspections in the last reporting period) there are disparities between the Permittees which indicates inconsistent reporting. A major component of this activity is re-inspection following a finding of non-compliance. The Permittees believe that the re-inspection obligation is not sufficiently sensitive to the severity of the non-compliance, and RWQCB staff is concerned that the mandated level of follow-up activity may be discouraging findings of non-compliance.

DAMP Modification:

- Clarify inspection frequencies, violation definitions and re-inspection requirements.

Enforcement

Inspectors enforce compliance with the Model Construction Program, grading or building permit, sediment and erosion control plan, and the Water Quality Ordinance. Enforcement steps that may be taken by inspectors include but are not limited to verbal warnings, administrative actions under the Water Quality Ordinance (notice of violation, administrative compliance order, etc.) and written actions under Building/Grading Ordinances (corrective action notice, stop work order, etc.).

Headline Indicator – Extent of Compliance: As a result of the 2004-05 inspections, thirty-three (33) Permittees reported 1,514 construction requiring 1,521 re-inspections compared to 1,066 construction sites requiring 1,072 re-inspections in 2003-04; and 408 construction requiring 542 re-inspections in 2002-03 (**Table 8.3; Figure 8.2**).

☒ Level 1: Implement Program

☒ Level 3: Behavior Change

Headline Indicator – Number and Level of Enforcement Actions: As a result of the 2004-05 inspections, thirty-three (33) Permittees reported taking a total of 1,699 enforcement actions. This compares to 3,475 enforcement actions taken in 2003-04, and 1,395 enforcement actions taken in 2002-03 (**Table 8.4; Figure 8.3**).

☒ Level 1: Implement Program

☒ Level 3: Behavior Change

The significant disparities in enforcement activity between the Permittees clearly indicate inconsistent reporting. However, the consistent pattern of a peak of activity in 2003-04 and a subsequent reduction in the 2004-05 reporting period in construction and other stormwater program areas (Existing Development and Illegal Discharges/Illicit Connections) suggests an increased level of compliance within the regulated community.

Training

The Permits require that staff is adequately trained. In response, the Permittees developed two training modules and a guidance manual. However, the training modules need to be updated frequently enough to keep pace with the developments in the field of construction site sediment and erosion control management, and to provide inspectors with a technical understanding of BMPs. In addition, the training of inspectors regarding construction site inspection and oversight has been identified as a particular area of concern for Regional Board staff.

ROWD Commitment:

- Prepare a training schedule including curriculum content and defined expertise and competencies for construction inspectors.

8.4 Summary

The Third Term Permits have required the Permittees to develop and implement a formal inspection program commencing with an initial prioritized inventory of construction sites. Over the first three years of this effort, there has been a clear trend in the level of inspection and enforcement activity that, despite some uncertainties with respect to reporting, suggests increased BMP implementation and compliance with local water quality and grading/building ordinances by the regulated community. Based upon perceived positive outcomes of the Construction elements of the DAMP, the Permittees are proposing minor program modifications based upon the need for the continued training of inspectors and the sensitizing of the prioritization and inspection process toward a more risk-based approach.

Table 8.1: Current and Potential Outcome Levels (Construction)

Construction Program Component	Effectiveness Assessment Outcome Levels					
	Level 1	Level 2	Level 3	Level 4	Level 5	Level 6
	Implement Program	Increase Awareness	Behavior Change	Load Reduction	Runoff Quality	Receiving Water Quality
Inventory	✓ Maintain inventory					
Prioritization	✓ Assign priorities		P Change in prioritization level			
Inspection	✓ Conduct and Track number of inspections	P Number of re-inspections	P # BMPs implemented	P Load reduction associated with BMPs		
Enforcement/ Reporting	✓ Conduct enforcement		✓ Extent and correction of problem level of enforcement			
Training	✓ Track number/type of training sessions	P Surveys show improved knowledge				

Key:

✓ = Currently Achieved Outcome Level

P = Potentially Achievable Outcome Level

Table 8.2: Construction Site Inspections Comparison of 2002-03, 2003-04 and 2004-05

PERMITTEES	Number of Sites Inspected								
	HIGH 2002-03	HIGH 2003-04	HIGH 2004-05	MEDIUM 2002-03	MEDIUM 2003-04	MEDIUM 2004-05	LOW 2002-03	LOW 2003-04	LOW 2004-05
Aliso Viejo	2	3	2	51	51	1	53	0	39
Anaheim	3	0	0	51	27	48	138	839	850
Brea	0	4	3	20	10	6	9	8	36
Buena Park	0	0	2	20	9	15	180	19	590
Costa Mesa	30	19	15	0	0	0	2,223	5,974	522
Cypress	1	2	5	0	1	0	7	9	1
Dana Point*	NA	16	24	NA	4	8	NA	1,077	182
Fountain Valley	25	5	6	0	0	0	163	353	87
Fullerton	84	17	1	3	34	0	30	67	10
Garden Grove	0	9	0	0	0	0	56	17	49
Huntington Beach	25	3	59	123	66	165	376	422	320
Irvine	132	67	114	1	41	99	2	63	175
La Habra	0	0	0	12	1	1	560	353	360
La Palma	25	0	6	123	0	0	376	5	0
Laguna Beach	1	1	2	32	47	111	0	0	0
Laguna Hills	210	183	209	0	0	0	0	0	0
Laguna Niguel	1	14	34	7	0	0	304	109	1,398
Laguna Woods	34	7	1	0	0	3	27	4	0
Lake Forest	4	2	1	21	9	13	18	5	1
Los Alamitos	0	0	NA	0	1	NA	0	292	NA
Mission Viejo	1,869	2,570	1,100	2,040	506	495	0	0	0
Newport Beach	4	3	2	54	23	0	162	270	648
Orange	3	7	7	20	40	37	563	193	153
Placentia	0	1	1	3	6	4	8	5	5
Rancho Santa Margarita	0	0	0	0	2	2	24	0	269
San Clemente	NA	34	276	NA	120	163	NA	0	0
San Juan Capistrano	1,304	199	48	12,595	4,674	300	0	0	400
Santa Ana	0	0	0	73	29	41	63	51	68
Seal Beach	NA	2	1	NA	0	0	NA	975	1,612
Stanton	NA	2	4	NA	0	4	NA	0	25
Tustin	5	6	13	1	7	4	49	56	4
Villa Park	0	0	0	0	0	0	127	166	175
Westminster	18	5	5	4	0	0	8	11	22
Yorba Linda	2	7	10	23	23	22	14	20	20
County of Orange/OCFCD	278	5,267	3,553	660	**See explanation below	**See explanation below	294	**See explanation below	**See explanation below
Totals	**4,060**	**8,455**	**5,504**	**15,937**	**5,731**	**1,542**	**5,834**	**11,363**	**8,021**

NA = Not Available

***includes undetermined amount and different categories**

****** the database system the County uses to track construction inspections does not differentiate between high, medium, and low priority construction sites; therefore, all sites are classified as "high" priority.**

Table 8.3: Inspection Results, Comparison of 2002-03, 2003-04 and 2004-05

	2002-03		2003-04		2004-05	
PERMITTEES	**Number of Construction Sites Out of Compliance**	**Number of Re-Inspections Due to Non-Compliance**	**Number of Construction Sites Out of Compliance**	**Number of Re-Inspections Due to Non-Compliance**	**Number of Construction Sites Out of Compliance**	**Number of Re-Inspections Due to Non-Compliance**
Aliso Viejo	27	27	45	33	21	21
Anaheim	4	4	55	14	33	48
Brea	1	1	0	0	2	3
Buena Park	0	0	5	5	29	15
Costa Mesa	2	3	NA	NA	0	0
Cypress	NA	NA	1	1	2	2
Dana Point	NA	NA	NA	NA	98	105
Fountain Valley	56	56	43	43	4	4
Fullerton	8	12	105	105	8	2
Garden Grove	3	3	4	4	1	1
Huntington Beach	54	130	23	39	150	54
Irvine	3	3	33	40	35	35
La Habra	14	17	18	18	68	81
La Palma	0	0	0	0	1	2
Laguna Beach	NA	NA	NA	NA	68	68
Laguna Hills	2	3	7	8	9	9
Laguna Niguel	14	26	24	24	23	23
Laguna Woods	1	1	0	0	6	6
Lake Forest	2	2	0	0	7	7
Los Alamitos	0	0	0	0	NA	NA
Mission Viejo	57	61	67	69	137	139
Newport Beach	0	0	NA	NA	67	75
Orange	0	0	7	7	8	8
Placentia	5	5	5	5	6	6
Rancho Santa Margarita	0	0	0	0	8	5
San Clemente	NA	NA	161	161	NA	NA
San Juan Capistrano	50	50	56	84	49	72
Santa Ana	13	23	7	7	12	22
Seal Beach	NA	NA	21	21	NA	NA
Stanton	NA	NA	0	0	2	8
Tustin	19	67	0	0	7	40
Villa Park	0	0	0	0	0	0
Westminster	1	2	5	10	5	12
Yorba Linda	7	6	4	4	6	6
County of Orange/OCFCD	65	40	370	370	642	642
Totals	**408**	**542**	**1,066**	**1,072**	**1,514**	**1,521**

NA = Not Available

Table 8.4: Enforcement Action Taken, Comparison of 2002-03, 2003-04 and 2004-05

PERMITTEES	FY 2002-03					FY 2003-04					FY 2004-05				
	Administrative Remedies				Criminal Remedies	Administrative Remedies				Criminal Remedies	Administrative Remedies				Criminal Remedies
	No. of EL/VW	No. of NON	No. of AC	Number of C&D Orders	Misdr, Infrct	No. of EL/VW	No. of NON	No. of AC	Number of C&D Orders	Misdr, Infrct	No. of EL/VW	No. of NON	No. of AC	Number of C&D Orders	Misdr, Infrct
Aliso Viejo	0	0	27	6	0	0	0	32	7	0	0	0	51	43	0
Anaheim	0	0	2	0	0	55	0	0	0	0	6	0	0	0	0
Brea	15	1	0	0	0	0	0	0	0	0	0	1	0	0	0
Buena Park	0	0	0	0	0	0	3	1	1	0	0	63	0	6	0
Costa Mesa	3	0	0	0	0	3	0	0	0	0	0	0	0	0	0
Cypress	0	4	0	0	0	1	10	0	0	0	1	4	0	0	0
Dana Point	2	32	0	0	1	7	36	0	3	0	29	61	3	5	0
Fountain Valley	400	4	21	6	0	27	12	15	9	0	168	0	5	2	0
Fullerton	0	5	1	0	0	51	44	0	5	0	NA	NA	NA	NA	NA
Garden Grove	2	1	0	0	0	3	4	0	0	0	0	1	0	0	0
Huntington Beach	0	16	1	1	0	0	23	1	0	0	0	80	0	0	24
Irvine	0	3	0	0	0	33	0	0	0	0	35	35	0	0	0
La Habra	0	14	0	0	0	0	18	0	0	0	52	7	2	6	0
La Palma	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
Laguna Beach	54	14	37	0	1	23	23	29	0	0	24	31	13	0	0
Laguna Hills	0	3	0	0	0	4	3	0	0	0	1	5	0	0	0
Laguna Niguel	0	26	0	0	0	0	24	0	0	0	0	14	0	0	0
Laguna Woods	2	0	0	0	0	0	0	0	0	0	8	8	0	0	0
Lake Forest	NA	NA	NA	NA	NA	0	0	0	0	0	0	2	0	0	0
Los Alamitos	4	0	0	0	0	0	0	0	0	0	NA	NA	NA	NA	NA
Mission Viejo	NA	NA	NA	NA	NA	238	93	0	0	0	0	21	0	0	0
Newport Beach	6	250	200	0	0	558	618	315	0	0	0	2	0	0	1
Orange	0	0	0	0	0	7	7	0	0	0	0	8	0	0	0
Placentia	0	5	0	1	0	0	0	1	0	0	0	1	0	1	0
Rancho Santa Margarita	0	0	0	0	0	0	0	0	0	0	9	5	0	1	0
San Clemente	1	2	0	1	0	142	71	7	33	0	34	20	0	11	21
San Juan Capistrano	50	50	0	0	0	50	6	0	0	0	8	35	0	6	0
Santa Ana	0	13	0	0	0	0	7	0	0	0	0	3	0	0	0
Seal Beach	NA	NA	NA	NA	NA	41	41	0	0	0	0	19	0	0	0
Stanton	NA	NA	NA	NA	NA	0	0	0	0	0	0	0	0	0	0
Tustin	0	19	0	0	0	0	0	0	0	0	0	0	0	0	1
Villa Park	15	0	0	0	0	12	0	0	0	0	0	0	0	0	0
Westminster	0	1	0	0	0	10	0	0	0	0	0	12	0	0	0
Yorba Linda	0	3	0	4	0	327	4	0	0	0	0	6	0	0	0
County of Orange/OCFCD	0	65	0	0	0	5	372	0	0	0	70	607	0	0	0
Totals	**554**	**531**	**289**	**19**	**2**	**1,597**	**1,419**	**401**	**58**	**0**	**445**	**1,052**	**74**	**81**	**47**

NA = Not Available
EL/VW = Educational Letter/Verbal Warning
NON = Notice of Non-Compliance
AC = Administrative Compliance Order
C&D = Cease and Desist
Misdr./Infrct = Misdemeanor/Infraction

Figure 8.1: Construction Site Inspections Comparison of 2002-03, 2003-04 and 2004-05

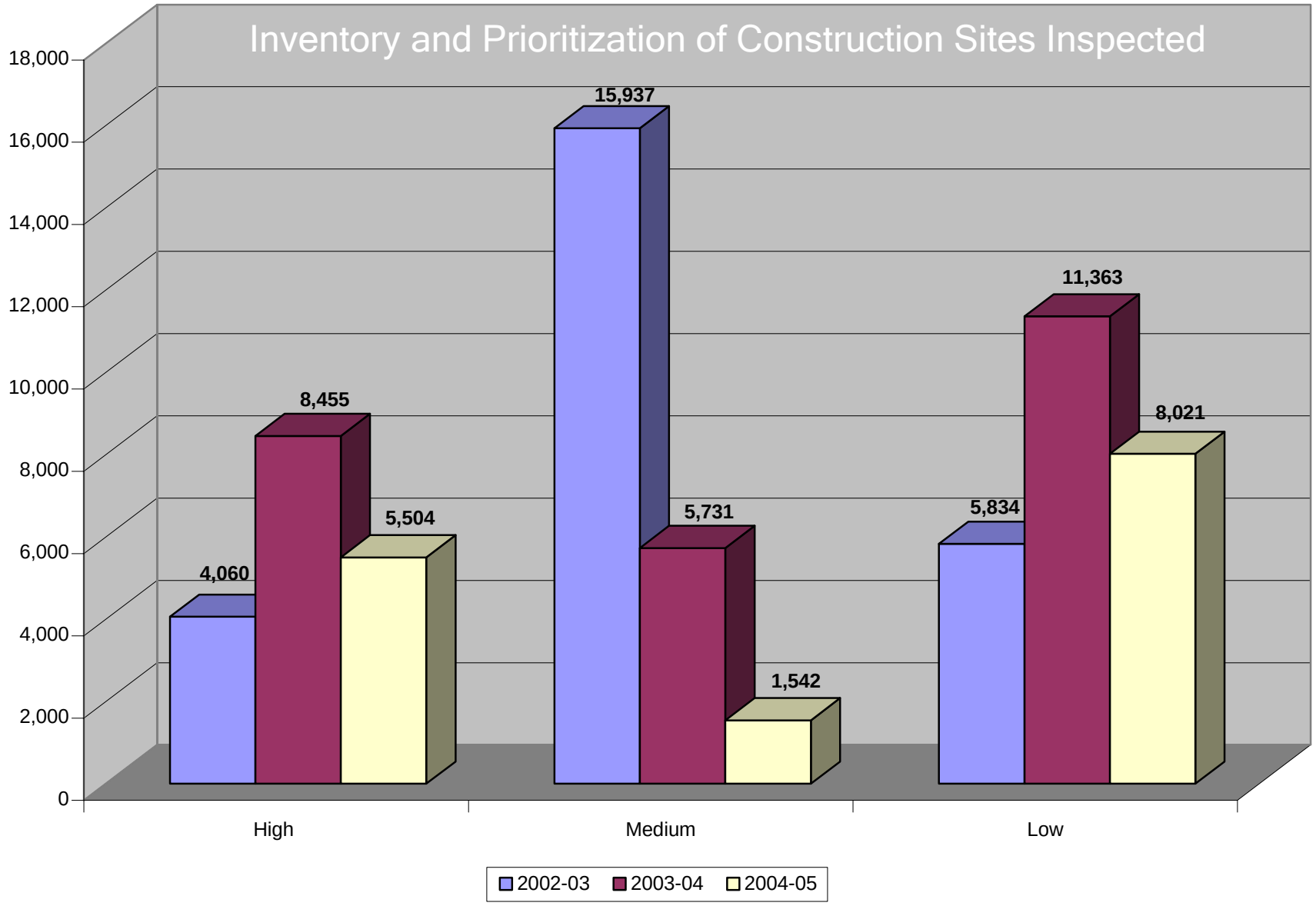


Figure 8.2: Inspection Results, Comparison of 2002-03, 2003-04 and 2004-05

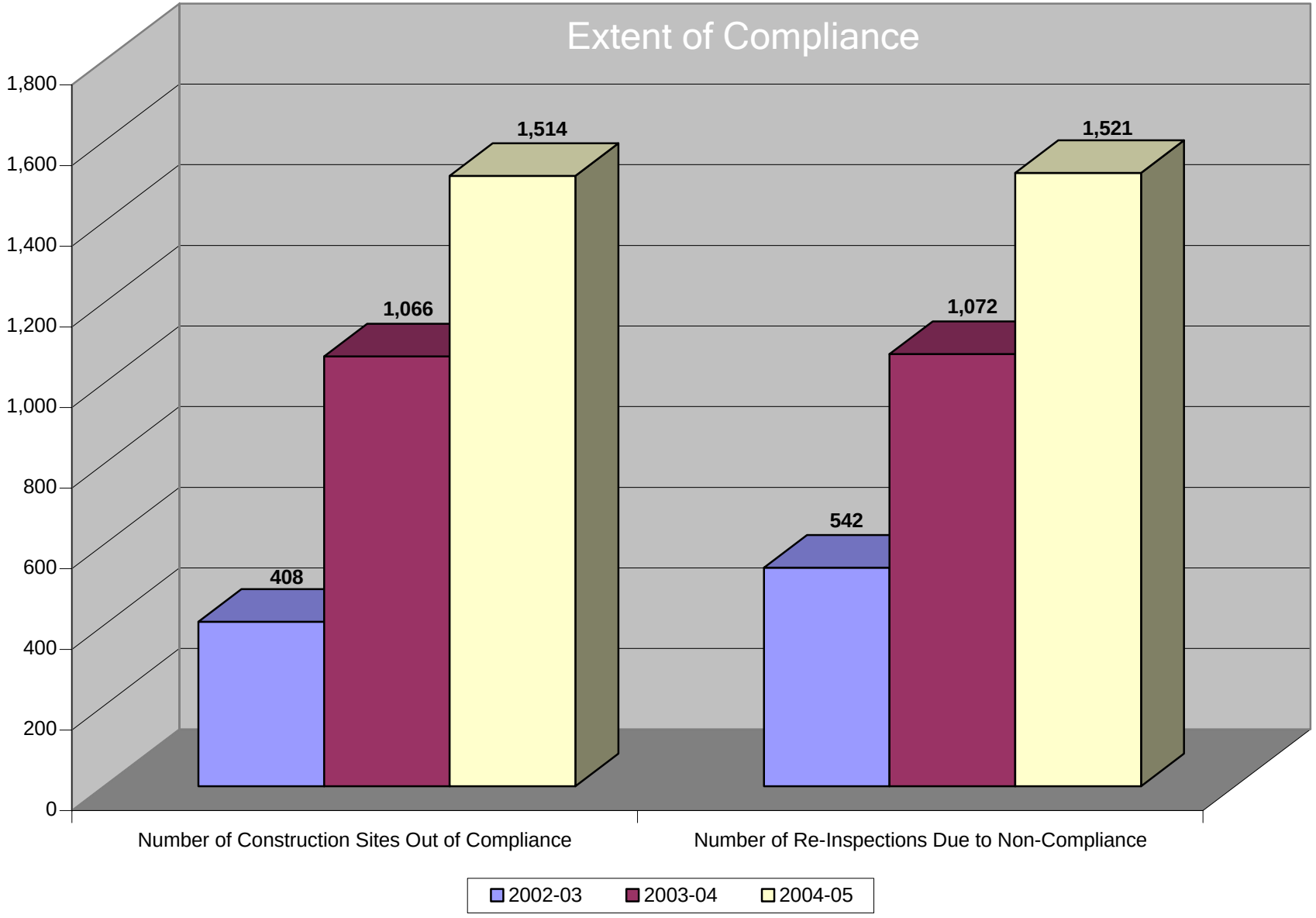
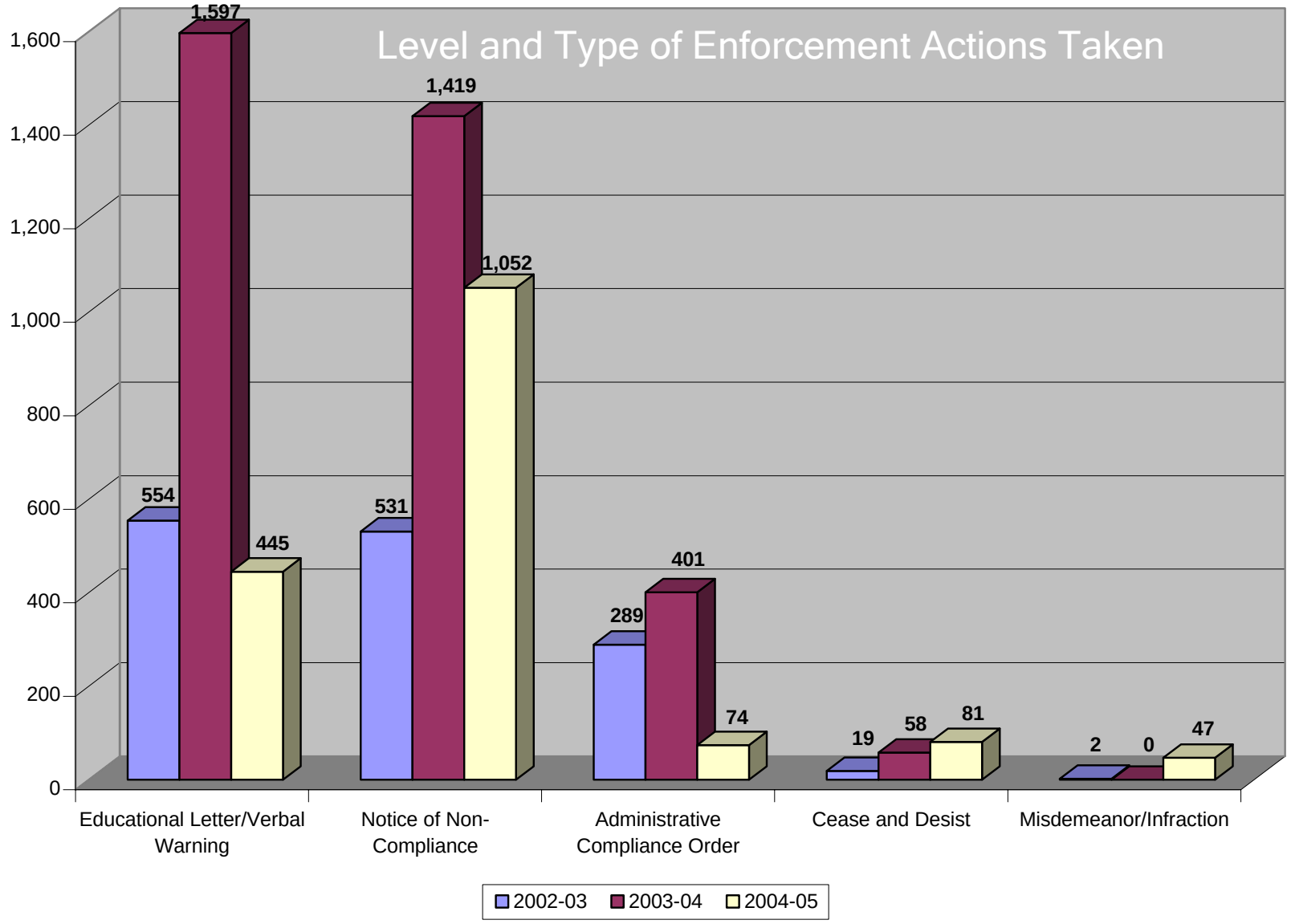


Figure 8.3: Enforcement Action Taken, Comparison of 2002-03, 2003-04 and 2004-05



9.0 EXISTING DEVELOPMENT

9.1 Introduction

Stormwater discharges from commercial and industrial facilities can become contaminated when material management practices allow exposure to stormwater and/or there is commingling of runoff with wastes. The purpose of **DAMP Section 9.0** is to provide a programmatic framework for the regulatory oversight of activities in commercial and industrial areas. Through inspections, outreach and requiring compliance with water quality ordinances, the Permittees are able to pro-actively address the quality of urban and stormwater runoff from industrial and commercial facilities. In addition, **DAMP Section 9.0** also provides a programmatic framework, based upon education and outreach approaches, for addressing activities in residential areas. Both the industrial/commercial and residential elements were added to the Program by the Third Term Permits.

9.2 Accomplishments

9.2.1 Model Industrial/Commercial Program

The Model Industrial/Commercial Program was developed and implemented in 2002-03. It transformed the Permittees oversight of commercial and industrial facilities/activities by establishing a formal inspection program where previously there had been a series of notifications and inspections initiated by complaints. The Model Industrial/Commercial Program requires the Permittees to:

- Identify and inventory facilities/activities with the potential to discharge pollutants:

  Initially, 8,546 industrial facilities **(Table 9.1; Figure 9.1)** and 22,789 commercial facilities were identified and inventoried **(Table 9.2; Figure 9.2).**

- Prioritize facilities based upon water quality threat and receiving water sensitivity:

  The Permittees prioritized 8,546, 8,604 and 2,821 industrial facilities in 2002-03, 2003-04 and 2004-05 respectively. Concurrently, 22,789, 23,778, and 25,411 commercial facilities were similarly evaluated and prioritized over the same respective periods.

- Establish Model Maintenance Procedures:

  Twenty-two (22) model BMP fact sheets have been prepared which include a description of specific minimum source control BMPs for common industrial and commercial activities that may discharge pollutants. Specific BMPs may be adjusted on a jurisdictional basis as necessary. Where applicable, optional controls have been identified that should be considered for implementation at high priority facilities.

  Typically each fact sheet contains the following sections:
  - Pollution Prevention

- Suggested Best Management Practices
- Training
- References and Resources

- Conduct inspections and monitoring to ensure that commercial and industrial facilities are minimizing their impacts on the environment:

  In the 2002-03, 2003-04 and 2004-05 reporting periods the Permittees completed 1,017, 4,029 and 2,706 inspections, respectively.

- Conduct inspections of food facilities:

  The Orange County Permittees developed and submitted a food facility inspection program to the Santa Ana Regional Board on July 1, 2002. This program, which also meets the inspection requirements of the San Diego Regional Board, involves inspections and the distribution of educational materials at the approximately 10,000 existing restaurants countywide. The implementation of the Program is an addition to the environmental health inspections conducted by the County of Orange Health Care Agency (HCA). The HCA inspectors identify NPDES issues during these inspections, and they are forwarded to the respective Permittees and addressed by Permittee staff.

  For the 2004-05 reporting period, 25,078 food facility inspections were conducted and 1,416 were reported to have NPDES issues **(Table 9.3)**.

- Undertake Non-compliance Notification and Enforcement:

  Enforcement for the industrial and commercial component of the Existing Development Program is the responsibility of individual Permittees. Each Permittee has several different levels of enforcement to choose from for different types of situations. This includes – from least severe to most severe – issuance of an educational letter, a notice of non-compliance, an administrative compliance order, a cease and desist order, or a misdemeanor/infraction.

  The Permittees reported a total of 371 enforcement actions against industrial facilities during the 2004-05 reporting period

- Participate in Training:

  To assist municipal staff in implementing the Existing Development Program for industrial and commercial facilities, five training modules were developed:

  1. Existing Development Program Management Module (targeting jurisdictional program coordinators and providing guidance regarding management of an inspection program;
  2. Field Implementation of Existing Development Program Module (targeting inspectors and providing guidance on conducting inspections);

3. Existing Development Program Training – Automobile Mechanical Repair, Maintenance, Fueling and Cleaning Businesses Module;
4. Existing Development Program Training – Landscape Maintenance Businesses Module, and
5. Existing Development Program Training – Industrial Stormwater Monitoring Module.

- Conduct Education and Outreach:

A number of education and outreach efforts, conducted under the overall public education element of the Program (see **DAMP Section 6.0**), directly supported implementation of the Model Industrial Commercial Program, specifically:

Mailings – During 2003-05 there was one mass mailing of an outreach letter for corporate environmental managers of food service establishments (FSE) and one mass mailing of education materials to all Orange County FSEs.

Outreach Materials –The following materials were developed by the Public Education Committee supportive of **Section 9.0:**

Brochures
- *Mobile Detailing and the Water Quality Act*
- *Water Quality Guidelines for Exterior Restaurant Cleaning Operations*
- *Water Quality Guidelines for Carpet Cleaning Activities*
- *Help Prevent Ocean Pollution: Tips for Hardscape and Landscape Drains*
- *Help Prevent Ocean Pollution: Tips for Home Improvement*

Posters
- Food/Restaurant Industry
- *"Help Prevent Ocean Pollution"* Food Facility BMPs Poster
- Auto Repair Industry
- Good Gas Station Operating Practices

"The Quad" - "The Quad" was developed as a tool to communicate with Cities, Businesses, Utilities and Organizations. Each Quad contains a newsletter, press release, fact sheet and billing insert focusing on a seasonal stormwater theme. Four seasonal quads were created during this reporting period, two of which were distributed in this reporting period. The following were the 2004-05 Quad themes:

- "Spring Into Cleaning – Disposal of Household Hazardous Waste"
- "Summer: Yard Care"
- "Fall: Prepare for the Rainy Season"
- "Winter: New Years Resolution – Green in the New Year"

FSE Outreach – The following materials were developed specifically for FSEs.

- *"Help Prevent Ocean Pollution": A Guide for Food Service Establishments*
- *"Help Prevent Ocean Pollution"* Food Facility BMPs Poster
- *"Help Prevent Ocean Pollution"* Food Facility BMPs Stickers
- Bilingual CD-Rom illustrating appropriate Food Facility BMPs
- Food Facility BMP PowerPoint Presentation
- Food Facility BMP Fact Sheet

Other: Developed an urban nutrient outreach program targeting independent gardeners operating in the San Diego Creek/Newport Bay Watershed with Proposition 13 funding awarded to the County to investigate the sources of nutrients from the urban environment and test the effectiveness of structural and non-structural BMPs.

9.2.2 Model Residential Program

The Model Residential Program was developed and implemented in 2002-03 to further reduce pollutants potentially released into the environment from residential activities, including efforts to reduce over-watering. The main thrust of the residential program is to advocate pollution prevention practices as the most effective method to protect receiving water quality. The Model Residential Program requires the Permittees under the jurisdiction of the San Diego Regional Board to:

- Develop a source identification procedure and prioritize residential areas based on proximity to Environmentally Sensitive Areas (ESAs) within the Permittee's jurisdiction.

- Identify Best Management Practices (BMPs) most appropriate for each area, based on residential activities:

  See discussion of Outreach Materials (below).

- Conduct public outreach and education:

  A number of education and outreach efforts, conducted under the overall public education element of the Program (see **DAMP Section 6.0**), directly supported implementation of the Model Residential Program, specifically:

  Outreach Materials –The following materials were developed by the Public Education Committee supportive of **Section 9.0:**

  Brochures
  - *Help Prevent Ocean Pollution: Tips for Hardscape and Landscape Drains*
    Help Prevent Ocean Pollution:Tips for Horse Care
  - *Help Prevent Ocean Pollution: Tips for Using Paint*
  - *Help Prevent Ocean Pollution: Tips for Home Improvement*

  "The Quad" - "The Quad" was developed as a tool to communicate with

cities, businesses, utilities and organizations such as home owner associations. Each Quad contains a newsletter, press release, fact sheet and billing insert focusing on a seasonal stormwater theme. Four seasonal quads were created during this reporting period, two of which were distributed in this reporting period. The following were the 2004-05 Quad themes:

- "Spring Into Cleaning – Disposal of Household Hazardous Waste"
- "Summer: Yard Care"
- "Fall: Prepare for the Rainy Season"
- "Winter: New Years Resolution – Green in the New Year"

9.2.3 Other Programs

During the reporting period, the Principal Permittee developed an urban nutrient outreach program targeting residential gardeners operating in the San Diego Creek/Newport Bay Watershed. The outreach program was one element of a Proposition 13 funded investigation of nutrient sources in an urban environment and structural and non-structural BMP effectiveness.

9.3 Assessment

The current and potential Program Effectiveness Assessment Outcome Levels that could be assessed within the current program are summarized in **Table 9-4** (Industrial/Commercial) **and Table 9.5** (Residential).

9.3.1 Model Industrial/Commercial Program

Inventories: Completing the inventory of industrial and commercial facilities has been problematic for some jurisdictions since the Standard Industrial Classification (SIC) codes on the business licenses (the primary source of this information for those jurisdictions with a business license program) have been incorrectly provided by businesses.[1] In addition, inventorying commercial facilities is extremely difficult because they are numerous, often transitory, and can only be identified through site visits. Mobile businesses are particularly problematic because they typically do not have a permanent facility location.

The Unified Annual Progress Reports include tables reporting the total number of commercial and industrial facilities and their respective prioritizations, organized by

[1] The Notice of Intent (NOI) form attached to the Draft Industrial General Permit (February 2005) and the SWRCB's NOI processing system have been modified to accept both Standard Industrial Classification (SIC) codes and North American Industrial Classification System (NAICS) codes. The USEPA has indicated it intends to incorporate the NAICS codes into the storm water regulations but has not yet done so. The Proposed 2006 Multi-Sector General Permits for Stormwater Discharges Associated with Industrial Activity (MSGP) contains a note that "a complete list of SIC Codes (and conversions from the newer North American Industry Classification System [NAICS]) can be obtained from the Internet at www.census.gov/epcd/www/naics.html or in paper form from various locations in the document titled Handbook of Standard Industrial Classifications, Office of Management and Budget, 1987."

Permittee. However, since the structure and content of the jurisdictional databases can differ between the Permittees, analysis of data on a regional or countywide basis is challenging. Indeed, there appears to be a persistent disparity between the number of industrial and commercial facilities inventoried and the number of industrial and commercial facilities that were prioritized over the reporting period (see **Tables 9.1** through **9.3** and **Figures 9.1** through **9.2**). This disparity points to the need to augment facility descriptions beyond SIC codes.

DAMP Modification:

- Provide more detailed industrial and commercial facility descriptions to assist in inventory standardization.

Prioritization: Commercial and industrial facilities must be classified as high, medium, or low priority to determine the frequency of inspection. The DAMP details a risk and receiving water sensitivity based point system for classification, the result of which is a total score indicating the facility priority. A change in facility prioritization can be indicative of programmatic success, since a finding that BMPs are being implemented (a behavior change) reduces the risk of pollutants being discharged which can result in a change in prioritization. However, both Permits specify mandatory high-priority commercial and industrial facilities. In addition, the San Diego Region Permittees are required to inventory only high-priority commercial facilities i.e. there are no designation of medium and low priority commercial facilities.

Headline Indicator – Prioritization of Facilities (Industrial Facilities): For 2004-05, 2,821 industrial facilities were prioritized, 27% of which were ranked as high priority; for 2003-04, 8,604 industrial facilities were prioritized, 13% of which were ranked as high priority; and for 2002-03, 8,546 industrial facilities were prioritized, 15% of which were ranked as high priority **(Table 9.1; Figure 9.1)**.

☒ Level 1: Implement Program

☒ Level 3: Behavior Change

Headline Indicator – Prioritization of Facilities (Commercial Facilities): For 2004-05, 25,411 commercial facilities were prioritized, 20% of which were ranked as high priority; for 2003-04, 23,778 commercial facilities were prioritized, 24% of which were ranked as high priority; and for 2002-03, 22,789 commercial facilities were prioritized, 22% of which were ranked as high priority **(Table 9.2; Figure 9.2)**.

☒ Level 1: Implement Program

☒ Level 3: Behavior Change

The year-to-year comparisons suggest some inconsistent reporting of this indicator. Part of this inconsistency arises from the interpretation of the extent to which a facility "tributary to" a sensitive receiving water, which is a key determinant in prioritization. From the Annual Progress Reports (See **DAMP Appendix C**), it is evident that "tributary to" is variously being interpreted as more than "next to" but "less than the whole watershed." Also, although the point system is used by many of the Permittees, some perceive it as time-consuming and too subjective, and, as a result, may rely primarily on professional judgment. In addition, the ability of the prioritization process to meaningfully provide for a risk-based approach is also dampened by the requirements for mandatory high priority sites. Despite these reservations, it is possible that the decreased numbers of high priority sites in the most recent annual reporting period may also reflect increased findings of no stormwater exposures and diminished site risk.

ROWD Commitment:

- Develop a more detailed prioritization process to improve standardized reporting and to support re-direction of inspection resources to significant sources of priority constituents of concern

Inspection: The Permittees generally conduct two types of inspections: compliance inspections and follow-up inspections. Should an inspected site demonstrate non-compliance, inspection frequency must be increased as specified in the Permits until compliance is achieved. Although these inspections are generally viewed as beneficial, there is a regulatory agency perception (highlighted in meetings with Regional Board staff) that the inspections may be missing key items of concern and discouraging findings of non-compliance which add to the inspection burden by requiring additional follow-up activity.

Headline Indicator – Number of BMPs Implemented (Industrial Facilities): For 2004-05, 2,706 industrial facilities were reported to have BMP implementation, 68% of which have full BMP implementation; for 2003-04, 4,029 industrial facilities were reported to have BMP implementation, 59% of which have full BMP implementation; and for 2002-03, 1,026 industrial facilities were reported to have BMP implementation, 53% of which have full BMP implementation **(Table 9.6; Figure 9.3)**.

☒ Level 1: Implement Program

☒ Level 3: Behavior Change

Headline Indicator – Number of BMPs Implemented (Commercial Facilities): For 2004-05, 5,566 commercial facilities were reported to have BMP implementation, 59% of which have full BMP implementation; for 2003-04, 8,484 commercial facilities were reported to have BMP implementation, 77% of which have full BMP implementation; and for 2002-03, 1,389 commercial facilities were reported to have BMP implementation, 63% of which have full BMP implementation **(Table 9.7; Figure 9.4)**.

☒ Level 1: Implement Program

☒ Level 3: Behavior Change

It is also proving difficult for the inspectors to categorize BMP implementation at commercial and industrial sites along a three-point scale (fully, partially, or not implemented) because such a scale requires overly subjective determinations. Lastly, the requirement for follow-up inspections of all non-compliant sites every month is perceived to be excessive due to the already large number of sites in many cities' inventories.

ROWD Commitment:

- Develop effective alternative to re-inspection such as self-certification.

Headline Indicator – Food Facility Inspections: For the 2004-05 reporting period, 25,078 food facility inspections were conducted and 1,416 were reported to have NPDES issues **(Table 9.3)**. For the 2003-04 reporting period, 12,635 food facility inspections were conducted and 1,298 were reported to have NPDES issues in the six month period of program implementation.

☒ Level 1: Implement Program

☒ Level 3: Behavior Change

The 2003-04 comparison suggests that food facility inspections and the associated education and outreach efforts are having a positive impact since the incidence of NPDES issues decreases from 1 in 10 inspections to 1 in 17 inspections .

Enforcement: Permittees are required to use a progressive enforcement approach and initiate enforcement actions where commercial and industrial facilities are found to be out of compliance. In general, specific facilities that are repeat offenders are identified through active database inventories and, in most cases, progressive enforcement is used to bring repeat offenders into compliance.

Headline Indicator – Number and Level of Enforcement Actions (Industrial Facilities): The Permittees reported a total of 371 enforcement actions against industrial facilities during the 2004-05 reporting period, 3,146 during the 2003-04 reporting period, and 533 during the 2002-03 reporting period **(Table 9.8)**. The 2004-05 figure represents an 89% decrease from the total reported in 2003-04.

☒ Level 1: Implement Program

☒ Level 3: Behavior Change

Headline Indicator – Number and Level of Enforcement Actions (Commercial Facilities): The Permittees reported a total of 1,192 enforcement actions against commercial facilities during the 2004-05 reporting period, 1,534 during the 2003-04 reporting period, and 490 during the 2002-03 reporting period **(Table 9.9)**. The 2004-05 figure represents a 22% decrease from the total reported in 2003-04.

☒ Level 1: Implement Program

☒ Level 3: Behavior Change

The 2003-04 comparison suggests some inconsistent reporting (e.g. Newport Beach, which compiled enforcement activity data in 2004-05 Unified Report, Section 2.10.0). However, the consistent pattern of reduced enforcement activity in the most recent reporting period across the Construction, Existing Development, and Illegal Discharges/Illicit Connections areas of the Program also suggests an increased level of compliance, also viewed as behavior change, by the regulated community.

Training: The Permits require that staff is adequately trained. In response, the Permittees developed several training modules, which are provided annually throughout the year. The training that has taken place has been deemed helpful. However, the training modules need to be updated frequently enough to keep pace with the developments in the field of stormwater management, maintain staff interest, and to provide inspectors with a technical understanding of a broad array of BMPs that can be shared with facility owner/operators.

ROWD Commitment:

- Prepare defined expertise and competencies for authorized inspector positions and develop a training schedule to meet these requirements

9.3.2 Model Residential Program

The Residential Model Program was developed to fulfill the residential activity and related commitments and requirements of Section F.3.d of the SDR Permit. The Common Interest Areas/Homeowners Associations (CIA/HOA) Activities Program was developed to fulfill the existing CIA/HOA activity commitments and requirements of Section F.6 of the SDR Permit.

Identification and Inventory: The SDR Permittees are required to identify high priority areas and activities as defined in the Permit. CIAs are considered to include high-priority areas and activities.

BMP Implementation: The SDR Permittees are required to identify minimum BMPs for high-priority areas and activities and, as necessary, additional controls. Some Permittees use a baseline BMP implementation approach for Residential areas and CIAs/HOAs unless inspectors notice a specific concern.

Enforcement and Reporting: SDR Permittees are required to enforce their stormwater ordinances for all residential areas and activities as necessary to maintain Permit compliance. The primary issue with residential areas and CIAs/HOAs concerns over irrigation. Enforcement actions taken against CIAs/HOAs include letters or notices, which generally leads to resolution of the issues. Some Permittees have reported some limited success using self certifications as a tool for effective implementation of the program within residential and CIA/HOA areas.

9.4 Summary

The Third Term Permits have required the Permittees to develop and implement a formal inspection program commencing with an initial inventory of potentially 30,000 facilities being subject to municipal oversight for stormwater and urban runoff issues. Over the first three years of this effort, there has been a clear trend in the level of inspection and enforcement activity that, despite some uncertainties with respect to reporting, suggests increased BMP implementation and compliance with local water quality ordinances by the existing industrial and commercial sector in Orange County. Based upon perceived positive outcomes of the Existing Development elements of the DAMP, the Permittees are proposing minor program modifications based upon the need for the continued training of inspectors and the sensitizing of the prioritization and inspection process toward a more effective risk-based approach.

Table 9.1: Countywide Permittees' Industrial Inventory and Prioritization, Comparison of 2002-03, 2003-04 and 2004-05

PERMITTEE	HIGH 2002-03	HIGH 2003-04	HIGH 2004-05	MEDIUM 2002-03	MEDIUM 2003-04	MEDIUM 2004-05	LOW 2002-03	LOW 2003-04	LOW 2004-05	TOTAL 2002-03	TOTAL 2003-04	TOTAL 2004-05
Aliso Viejo	2	2	2	65	65	42	0	0	0	67	67	44
Anaheim	129	115	93	419	45	0	868	1,126	299	1,416	1,286	392
Brea	11	14	13	32	28	27	167	137	111	210	179	151
Buena Park	24	184	115	52	18	17	0	17	27	76	219	159
Costa Mesa	489	287	13	329	475	2	0	40	128	818	802	143
Cypress	2	4	0	5	2	0	34	38	0	41	44	0
Dana Point	NA	0	0	NA	0	0	NA	0	0	NA	0	0
Fountain Valley	4	44	4	0	0	48	32	0	0	36	44	52
Fullerton	36	38	37	23	23	0	554	344	0	613	405	37
Garden Grove	25	41	30	35	51	11	310	296	25	370	388	66
Huntington Beach	30	25	30	38	69	13	645	529	23	713	623	66
Irvine	236	3	95	98	21	0	841	520	0	1,175	544	95
La Habra	NA	65	65	NA	249	48	NA	228	59	NA	542	172
La Palma	8	5	5	2	3	5	9	11	0	19	19	10
Laguna Beach	0	0	0	28	23		35	14		63	37	0
Laguna Hills	NA	1	0	NA	0	0	NA	0	0	NA	1	0
Laguna Niguel	2	1	0	0	0	0	0	0	0	2	1	0
Laguna Woods	0	0	0	0	0	0	0	0	0	0	0	0
Lake Forest	11	11	12	0	0		0	0		11	11	12
Los Alamitos	6	7	1	71	19	27	24	96	23	101	122	51
Mission Viejo	5	4	4	30	31		56	56		91	91	4
Newport Beach	2	2	2	0	0	0	11	11	11	13	13	13
Orange	69	52	72	422	416	228	256	249	0	747	717	300
Placentia	21	16	12	18	0		6	109	40	45	125	52
R S Margarita	1	1	3	10	10	10	19	19	19	30	30	32
San Clemente	2	3	2	72	72		0	0		74	75	2
S J Capistrano	1	1	1	11	5	5	15	8	4	27	14	10
Santa Ana	102	100	82	1,266	1,031	615	0	574	5	1,368	1,705	702
Seal Beach	2	2	2	0	0	0	0	0	0	2	2	2
Stanton	NA	18	18	NA	17	15	NA	118	0	NA	153	33
Tustin	9	11	13	59	6	7	0	49	55	68	66	75
Villa Park	NA	0	0	NA	0	0	NA	0	0	NA	0	0
Westminster	10	4	4	37	18	18	34	6	6	81	28	28
Yorba Linda	29	4	7	214	206	88	0	13	2	243	223	97
County of Orange	13	16	12	13	12	9	0	0	0	26	28	21
TOTALS	**1,281**	**1,081**	**749**	**3,349**	**2,915**	**1,235**	**3,916**	**4,608**	**837**	**8,546**	**8,604**	**2,821**

NA = Not Available

Table 9.2: Countywide Permittees' Commercial Inventory and Prioritization, Comparison of 2002-03, 2003-04 and 2004-05

PERMITTEE	HIGH 2002-03	HIGH 2003-04	HIGH 2004-05	MEDIUM 2002-03	MEDIUM 2003-04	MEDIUM 2004-05	LOW 2002-03	LOW 2003-04	LOW 2004-05	TOTAL 2002-03	TOTAL 2003-04	TOTAL 2004-05
Aliso Viejo	153	153	110	0	0		0	0		153	153	110
Anaheim	114	14	13	278	310	310	194	307	307	586	631	630
Brea	0	0	0	138	117	129	0	180	228	138	297	357
Buena Park	0	119	283	5	40	20	0	50	26	5	209	329
Costa Mesa	1,306	1,107	969	587	555	483	4,559	2,548	2,083	6,452	4,210	3,535
Cypress	0	56	2	38	162	19	39	6	203	77	224	224
Dana Point	238	205	228	0	0		0	0		238	205	228
Fountain Valley	0	112	40	0	0	77	314	139	139	314	251	256
Fullerton	7	7	126	23	23	164	639	631	116	669	661	406
Garden Grove	0	7	47	102	90	204	5,797	5,807	5,587	5,899	5,904	5,838
Huntington Beach	403	261	276	7	170	206	233	920	831	643	1,351	1,313
Irvine	0	0		105	103	148	1,040	1,038	1,132	1,145	1,141	1,280
La Habra	NA	378	414	NA	340	306	NA	177	254	NA	895	974
La Palma	0	0		17	18	12	25	30	31	42	48	43
Laguna Beach	336	356		0	2		0	7		336	365	0
Laguna Hills	NA	237	325	NA	0		NA	0		NA	237	325
Laguna Niguel	182	183	177	0	0		0	0		182	183	177
Laguna Woods	28	24	24	3	3	3	65	83	89	96	110	116
Lake Forest	10	124	150	17	68		50	182		77	374	150
Los Alamitos	NA	98		173	32		800	0		973	130	0
Mission Viejo	426	423	484	0	0		0	0		426	423	484
Newport Beach	41	41	41	40	40	40	40	40	42	121	121	123
Orange	269	0		241	311	311	54	700	725	564	1,011	1,036
Placentia	127	375		44	0		310	0	373	481	375	373
R S Margarita	126	146	141	13	0	0	377	0	438	516	146	579
San Clemente	463	688	626	0	0		0	0		463	688	626
S J Capistrano	248	316	216	0	0	277	0	0	1,401	248	316	1,894
Santa Ana	0	0		779	26	26	1	917	923	780	943	949
Seal Beach	NA	0	23	NA	183	2	NA	0	859	NA	183	884
Stanton	NA	31	31	NA	168	168	NA	476	476	NA	675	675
Tustin	1	0	1	103	104	39	0	0	40	104	104	80
Villa Park	0	0	0	0	1	1	0	6	6	0	7	7
Westminster	354	140	213	95	365	443	278	354	428	727	859	1,084
Yorba Linda	20	25	42	171	162	126	0	6	5	191	193	173
County of Orange	97	107	106	46	48	47	0	0	0	143	155	153
TOTALS	**4,949**	**5,733**	**5,108**	**3,025**	**3,441**	**3,561**	**14,815**	**14,604**	**16,742**	**22,789**	**23,778**	**25,411**

NA = Not Available

Table 9.3: Food Facility Inspections 2003-04 and 2004-05

PERMITTEE	2003-04		2004-05	
	No. of Routine Inspections	No. of NPDES Issues	No. of Routine Inspections	No. of NPDES Issues
Aliso Viejo	116	50	218	37
Anaheim	1721	40	3,285	22
Brea	256	19	506	23
Buena Park	301	91	686	12
Costa Mesa	724	98	1,412	74
Cypress	175	12	421	0
Dana Point	186	9	374	12
Fountain Valley	313	72	545	22
Fullerton	539	46	1,054	123
Garden Grove	738	2	1,412	280
Huntington Beach	691	64	1,420	17
Irvine	718	169	1,388	52
La Habra	273	11	548	40
La Palma	42	18	118	1
Laguna Beach	203	7	382	31
Laguna Hills	149	91	332	72
Laguna Niguel	193	21	406	16
Laguna Woods	24	18	59	13
Lake Forest	307	8	547	27
Los Alamitos	98	12	193	8
Mission Viejo	325	51	591	40
Newport Beach	501	33	1,037	20
Orange	725	25	1,451	61
Placentia	185	8	386	18
Rancho Santa Margarita	95	0	179	23
San Clemente	284	5	529	7
San Juan Capistrano	1261	111	302	17
Santa Ana	141	28	2,436	145
Seal Beach	122	13	217	3
Stanton	168	20	504	1
Tustin	377	12	648	60
Villa Park	18	1	26	1
Westminster	418	123	931	96
Yorba Linda	139	4	328	23
County of Orange	109	6	207	19
Totals	**12635**	**1298**	**25,078**	**1,416**

Table 9.4: Current and Potential Outcome Levels (Industrial/Commercial)

Industrial/Commercial Program Component	Effectiveness Assessment Outcome Levels					
	Level 1	Level 2	Level 3	Level 4	Level 5	Level 6
	Implement Program	Increase Awareness	Behavior Change	Load Reduction	Runoff Quality	Receiving Water Quality
Inventory	✓ Maintain inventory					
Prioritization	✓ Assign priorities		✓ Change in prioritization level			
Inspection	✓ Conduct and Track number of inspections		✓ # BMPs implement	P Load reduction associated with BMPs		
Enforcement/ Reporting	✓ Conduct enforcement		✓ Extent and correction of problem level of enforcement			
Training	✓ Track number/type of training sessions	P Surveys show improved knowledge				

Key:

✓ = Currently Achieved Outcome Level

P = Potentially Achievable Outcome Level

Table 9.5: Current and Potential Outcome Levels (Residential)

Residential & CIA/HOA Program Component	Effectiveness Assessment Outcome Levels					
	Level 1	Level 2	Level 3	Level 4	Level 5	Level 6
	Implement Program	Increase Awareness	Behavior Change	Load Reduction	Runoff Quality	Receiving Water Quality
Identification/Inventory	✓ Maintain inventory					
BMP Implementation	✓ Conduct Inspections	✓ BMP Implementation	✓ Track number of BMPs implemented	P Load reduction associated with BMPs		
Enforcement/ Reporting	✓ Issue EAs	✓ Track number of EAs issued & response	P Correction of problem			

Key:

✓ = Currently Achieved Outcome Level

P = Potentially Achievable Outcome Level

Table 9.6: Industrial Inventory and BMP Implementation, Comparison of 2002-03, 2003-04 and 2004-05

PERMITTEE	NUMBER OF FACILITIES WITH BMPs:												
	FULLY Implemented 2002-03	FULLY Implemented 2003-04	FULLY Implemented 2004-05	PARTIALLY Implemented 2002-03	PARTIALLY Implemented 2003-04	PARTIALLY Implemented 2004-05	NO BMPs Implemented 2002-03	NO BMPs Implemented 2003-04	NO BMPs Implemented 2004-05	Modify/Upgrade or Implement BMP's 2002-03[a]	TOTAL 2002-03	TOTAL 2003-04	TOTAL 2004-05
Aliso Viejo	2	49	31	1	15	11	0	0		1	4	64	42
Anaheim	0	160	312	0	82	80	0	0		0	0	242	392
Brea	NA	NA	15	NA	NA		NA	NA	10	NA	NA	NA	25
Buena Park	NA	188	151	NA	33	102	NA	0	29	NA	NA	221	282
Costa Mesa	142	530	115	0	168	28	0	0		193	335	698	143
Cypress	NA	0	NA	NA	4	NA	NA	0	NA	NA	0	4	NA
Dana Point	NA	0	NA	NA	0	NA	NA	0	NA	NA	NA	0	NA
Fountain Valley	10	36	52	5	8		5	0		5	25	44	52
Fullerton	36	38	34	NA	23	2	NA	344		NA	36	405	36
Garden Grove	NA	55	28	NA	43	38	NA	3	1	NA	NA	101	67
Huntington Bch	3	52	14	4	19	20	17	28	33	4	28	99	67
Irvine	136	132	37	31	467	58	12	68		26	205	667	95
La Habra	NA	8	49	NA	57	108	NA	28	15	NA	NA	93	172
La Palma	0	NA	1	0	NA	6	0	NA	1	0	0	NA	8
Laguna Beach	NA	21		NA	16		NA	0		NA	NA	37	0
Laguna Hills	NA	NA	0	NA	NA	0	NA	NA	0	NA	NA	NA	0
Laguna Niguel	3	0		0	0		0	0		0	3	0	0
Laguna Woods	NA	0	NA	NA	0	NA	NA	0	NA	NA	0	0	NA
Lake Forest	0	0	12	11	11		0	0		0	11	11	12
Los Alamitos	NA	8		NA	0		NA	0		NA	0	8	0
Mission Viejo	24	0	2	43	4	2	13	0		56	136	4	4
Newport Beach	4	1	1	0	1	2	0	0		0	4	2	3
Orange	NA	64	142	NA	2	149	NA	0	9	NA	NA	66	300
Placentia	16	0	3	14	19	7	12	2	1	14	56	21	11
R S Margarita	0	0	2	0	0	2	0	0	28	0	0	0	32
San Clemente	NA	NA	2	NA	NA	0	NA	NA	0	NA	NA	NA	2
S J Capistrano	1	10	8	2	4	2	0	0	0	1	4	14	10
Santa Ana	NA	818	639	NA	132	63	NA	0		NA	NA	950	702
Seal Beach	NA	0	1	NA	2	1	NA	0	0	NA	NA	2	2
Stanton	NA	28	28	NA	4	58	NA	1	1	NA	NA	33	87
Tustin	NA	17	17	NA	49		NA	0		NA	NA	66	17
Villa Park	0	0	0	1	0	0	0	0	0	0	1	0	0
Westminster	1	24	25	0	3	3	0	1		0	1	28	28
Yorba Linda	166	130	94	0	0	3	1	0		1	168	130	97
County of Orange	NA	19	16	NA	0	2	NA	0	0	NA	0	19	18
TOTALS	**544**	**2,388**	**1,831**	**112**	**1,166**	**747**	**60**	**475**	**128**	**301**	**1,017**	**4,029**	**2,706**

NA = Not Available

[a] Modifications/Upgrades only applicable to 2002-03 reporting year.

Table 9.7: Commercial Inventory and BMP Implementation, Comparison of 2002-03, 2003-04 and 2004-05

PERMITTEE	Number of Facilities with BMPs:											
	FULLY Implemented 2002-03	FULLY Implemented 2003-04	FULLY Implemented 2004-05	PARTIALLY Implemented 2002-03	PARTIALLY Implemented 2003-04	PARTIALLY Implemented 2004-05	NO BMPs Implemented 2002-03	NO BMPs Implemented 2003-04	NO BMPs Implemented 2004-05	TOTAL 2002-03	TOTAL 2003-04	TOTAL 2004-05
Aliso Viejo	69	35	35	4	64	75	8	4		81	103	110
Anaheim	0	35	46	0	2	27	0	0		0	37	73
Brea	NA	0	0	NA	0	0	NA	0	0	NA	0	0
Buena Park	0	183	98	5	29	60	0	0	43	5	212	201
Costa Mesa	623	3,298	64	0	665	2	0	0		623	3,963	66
Cypress	NA	0		NA	2	2	NA	0		0	2	2
Dana Point	NA	NA	25	NA	NA	145	NA	NA	11	NA	NA	181
Fountain Valley	0	251	225	0	0		0	0		0	251	225
Fullerton	NA	0		NA	0		NA	0		NA	0	0
Garden Grove	NA	66	824	NA	29	455	NA	3	4	NA	98	1,283
Huntington Bch	9	59	26	2	108	21	11	120	34	22	287	81
Irvine	NA	DNR		NA	DNR		NA	DNR		NA	DNR	0
La Habra	NA	28	85	NA	107	111	NA	36	77	NA	171	273
La Palma	0	24	22	0	18	13	0	0		0	42	35
Laguna Beach	NA	NA		NA	NA		NA	NA		NA	NA	0
Laguna Hills	31	150	222	0	0		3	10	5	34	160	227
Laguna Niguel	0	123	27	0	15	18	0	0		0	138	45
Laguna Woods	NA	0		NA	27	28	NA	0		0	27	28
Lake Forest	0	0		77	48	19	0	0		77	48	19
Los Alamitos	NA	86		NA	12		NA	0		0	98	0
Mission Viejo	68	164	268	314	51	29	57	0		439	215	297
Newport Beach	NA	NA	6	NA	NA	6	NA	NA		NA	NA	12
Orange	NA	207	0	NA	0	0	NA	0	0	NA	207	0
Placentia	NA	0	32	9	63	32	NA	0		9	63	64
R S Margarita	0	0	64	0	0	21	0	0	482	0	0	567
San Clemente	NA	139	NA	NA	12	NA	NA	0	NA	NA	151	NA
Santa Ana	NA	818	304	NA	132	109	NA	0		NA	950	413
S J Capistrano	75	139	132	7	12	0	15	0	0	97	151	132
Seal Beach	NA	0	0	NA	122	0	NA	0	0	NA	122	0
Stanton	NA	35	35	NA	10	10	NA	3	10	NA	48	55
Tustin	NA	0	NA	NA	0	NA	NA	0	NA	NA	0	NA
Villa Park	0	0	0	0	0	0	0	0	0	0	0	0
Westminster	0	633	675	0	219	409	0	7		0	859	1,084
Yorba Linda	NA	10	27	NA	27	7	NA	0		NA	37	34
County of Orange	2	41	49	NA	3	10	NA	NA	0	2	44	59
TOTALS	**877**	**6,524**	**3,291**	**418**	**1,777**	**1,609**	**94**	**183**	**666**	**1,389**	**8,484**	**5,566**

NA = Not Available **DNR = Did Not Report**

Table 9.8: Permittee Enforcement Actions for Industrial Facilities, Comparison of 2002-03, 2003-04 and 2004-05

PERMITTEE	EL 2002-03	EL 2003-04	EL 2004-05	NON 2002-03	NON 2003-04	NON 2004-05	ACO 2002-03	ACO 2003-04	ACO 2004-05	CDO 2002-03	CDO 2003-04	CDO 2004-05	M/I 2002-03	M/I 2003-04	M/I 2004-05	TOTAL 2002-03	TOTAL 2003-04	TOTAL 2004-05
Aliso Viejo	0	2	3	0	1	17	0	0	8	0	0		0	0		0	3	28
Anaheim	NA	0	0	NA	2	0	NA	1	0	NA	0	0	NA	0	0	NA	3	0
Brea	2	0	13	0	0	1	0	0		0	0		0	0		2	0	14
Buena Park	NA	0	2	NA	39	6	NA	5	13	NA	1	4	NA	0	1	NA	45	26
Costa Mesa	NA	0		NA	0		NA	0		NA	0		NA	0		NA	0	0
Cypress	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	2	0
Dana Point	NA	0	0	NA	0	0	NA	0	0	NA	0	0	NA	0	0	NA	0	0
Fountain Valley	5	393	52	0	8		0	12	1	0	6	1	0	0		5	419	54
Fullerton	36	0	NA	0	0	NA	0	0	NA	0	0	NA	0	0	NA	36	0	NA
Garden Grove	2	5	2	0	0		0	0		0	0		0	0		2	5	2
Huntington Beach	6	0		0	0	5	0	15		0	0		0	0	1	6	15	6
Irvine	NA	939	95	NA	0		NA	0		NA	0		NA	0		NA	939	95
La Habra	NA	0		NA	0	28	NA	0		NA	0		NA	0		NA	0	28
La Palma	0	19	10	0	0		0	0		0	0	1	0	0		0	19	11
Laguna Beach	NA	0		NA	0		NA	0		NA	0		NA	0		NA	0	0
Laguna Hills	NA	NA	0	NA	NA	0	NA	NA	0	NA	NA	0	NA	NA	0	NA	NA	0
Laguna Niguel	0	0		0	0		0	0	0	0	0		0	0		0	0	0
Laguna Woods	0	0	NA	0	0	NA	0	0	NA	0	0	NA	0	0	NA	0	0	NA
Lake Forest	11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	11	0	0
Los Alamitos	NA	0		NA	0		NA	0		NA	0		NA	0		NA	0	0
Mission Viejo^	NA	0		NA	103		NA	0		NA	0		NA	0		NA	103	0
Newport Beach	6	8	2	250	618	0	200	315	0	0	0	0	0	550	0	456	1491	2
Orange	NA	66	0	NA	4	1	NA	0	0	NA	0	0	NA	0	0	NA	70	1
Placentia	7	7	10	0	0		0	0		0	0		0	0		7	7	10
R S Margarita	0	0	2	0	0		0	0		0	0		0	0		0	0	2
San Clemente	NA	7	0	NA	2	0	NA	2	0	NA	0	0	NA	0	0	NA	11	0
S J Capistrano	1	14	10	1	0	2	0	0	0	0	0	0	0	0	0	2	14	12
Santa Ana	NA	0	1	NA	0	2	NA	0		NA	0		NA	0		NA	0	3
Seal Beach	NA	NA	5	NA	NA	0	NA	NA	0	NA	NA	0	NA	NA	0	NA	NA	5
Stanton	DNR	NA		NA	NA		NA	NA		NA	NA		NA	NA		NA	NA	0
Tustin	NA	0	0	NA	0	0	NA	0	0	NA	0	0	NA	0	0	NA	0	0
Villa Park	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Westminster	0	0	9	5	0	4	0	0		0	0		0	0		5	5	13
Yorba Linda	0	0	59	1	0	0	0	0	0	0	0	0	0	0	0	1	0	59
County of Orange	NA	0	0	NA	0	0	NA	0	0	NA	0	0	NA	0	0	NA	0	0
TOTALS	**76**	**1,460**	**275**	**257**	**779**	**66**	**200**	**350**	**22**	**0**	**7**	**6**	**0**	**550**	**2**	**533**	**3,151**	**371**

NA = Not Available **EL = Educational Letter** **ACO = Administrative Compliance Orde** **M/I = Misdemeanor/Infraction**

DNR = Did Not Report **NON = Notice of Non-Compliance** **CDO = Cease and Desist Order**

^ Enforcement actions against industrial facilities are included with commercial facilities.

Table 9.9: Permittee Enforcement Actions for Commercial Facilities, Comparison of 2002-03, 2003-04, and 2004-05

PERMITTEE	EL 2002-03	EL 2003-04	EL 2004-05	NON 2002-03	NON 2003-04	NON 2004-05	ACO 2002-03	ACO 2003-04	ACO 2004-05	CDO 2002-03	CDO 2003-04	CDO 2004-05	M/I 2002-03	M/I 2003-04	M/I 2004-05	TOTAL 2002-03	TOTAL 2003-04	TOTAL 2004-05
Aliso Viejo	70	3	4	0	0	4	2	13	2	0	0	2	0	0	1	72	16	13
Anaheim	NA	0		NA	0	0	NA	0	0	NA	0	0	NA	0	0	NA	0	0
Brea	NA	4	3	NA	1		NA	0		NA	0		NA	0		NA	5	3
Buena Park	5	0		0	87	16	0	19	33	0	4	16	0	0	4	5	110	69
Costa Mesa	2	10	6	3	3	67	0	10		0	0		0	0		5	23	73
Cypress	2	0		4	2		0	0		0	0		0	0		6	2	0
Dana Point	13	14	57	41	19	3	1	0	1	0	0		1	0	1	56	33	62
Fountain Valley	6	251	256	6	2	4	21	3	7	5	1	2	0	0		38	257	269
Fullerton	NA	0	NA	NA	0	NA	NA	0	NA	NA	0	NA	NA	0	NA	NA	0	NA
Garden Grove	5	37	5	2	8	1	0	0		0	0		0	0		7	45	6
Huntington Beach	16	0		3	10	13	0	80		1	0		0	0	5	20	90	18
Irvine	NA	NA		NA	NA		NA	NA		NA	NA		NA	NA		NA	NA	0
La Habra	NA	0		NA	0	25	NA	0	1	NA	0		NA	0		NA	0	26
La Palma	0	0	15	0	0		0	0		0	0		0	0		0	0	15
Laguna Beach	NA	0		NA	0		NA	0	2	NA	0		NA	0		NA	0	2
Laguna Hills	NA	11	6	NA	9	4	NA	1		NA	0		NA	0		NA	20	10
Laguna Niguel	0	127		1	15	32	0	0		0	0		0	0		1	142	32
Laguna Woods	3	0	15	4	0	18	1	0	10	0	0		0	0		8	0	43
Lake Forest	77	1		1	14	12	0	0		0	0	1	0	0		78	15	13
Los Alamitos	NA	0		NA	0		NA	0		NA	0		NA	0		NA	0	0
Mission Viejo	118	0	2	20	103	16	0	0	17	1	0	0	0	0	2	139	103	37
Newport Beach	NA	NA	2	NA	NA		NA	NA		NA	NA		NA	NA		NA	NA	2
Orange	NA	269	0	NA	13	0	NA	0	0	NA	0	0	NA	0	0	NA	283	0
Placentia	10	30	64	0	0	13	1	0	1	2	0	1	0	0	1	13	30	80
R S Margarita	10	0	32	0	0	7	0	0		0	0		0	0		10	0	39
San Clemente	NA	187	91	NA	82	63	NA	15		NA	2		NA	7	24	NA	293	178
S J Capistrano	25	10	150	7	2	5	0	0	0	0	0	0	0	0	0	32	12	155
Santa Ana	NA	0	1	NA	3	18	NA	0	1	NA	0		NA	0		NA	3	20
Seal Beach	NA	0	0	NA	0	0	NA	0	0	NA	0	0	NA	0	0	NA	0	0
Stanton	DNR	DNR		DNR	DNR		DNR	DNR		DNR	DNR		DNR	DNR		NA	DNR	0
Tustin	NA	0	0	NA	0	0	NA	0	0	NA	0	0	NA	0	0	NA	0	0
Villa Park	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Westminster	0	0	2	0	2	3	0	0		0	0		0	0		0	2	5
Yorba Linda	0	45	19	0	1	0	0	0	0	0	0	0	0	0	0	0	46	19
County of Orange	NA	0	0	NA	4	3	NA	0	0	NA	0	0	NA	0	0	NA	4	3
TOTALS	**362**	**999**	**730**	**92**	**380**	**327**	**26**	**141**	**75**	**9**	**7**	**22**	**1**	**7**	**38**	**490**	**1,534**	**1,192**

NA = Not Available **EL = Educational Letter** **ACO = Administrative Compliance Order** **M/I = Misdemeanor/Infraction**

DNR = Did Not Report **NON = Notice of Non-Compliance** **CDO = Cease and Desist Order**

Figure 9.1: Countywide Permittees' Industrial Inventory and Prioritization, Comparison of 2002-03, 2003-04 and 2004-05

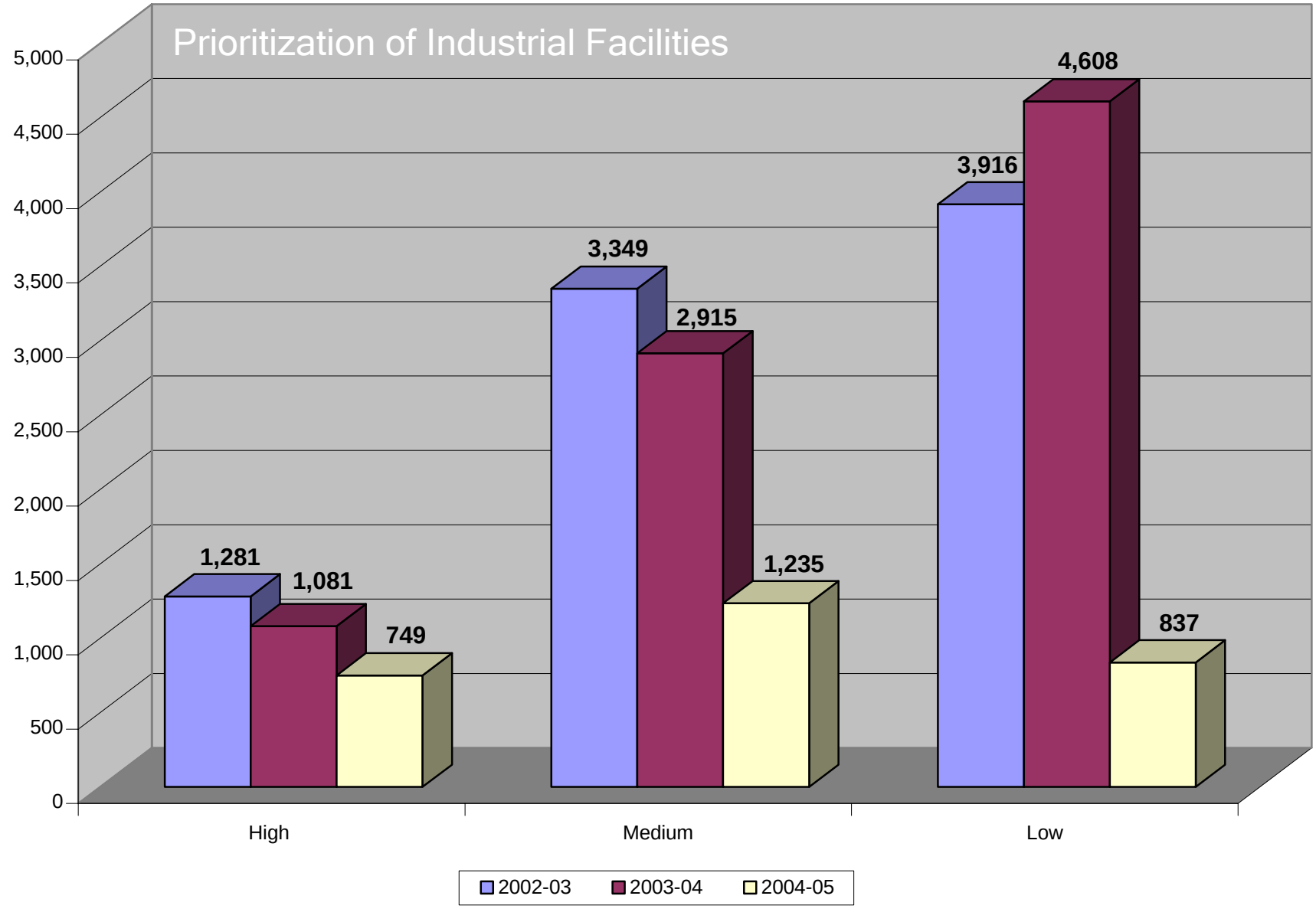


Figure 9.2: Countywide Permittees' Commercial Inventory and Prioritization, Comparison of 2002-03, 2003-04 and 2004-05

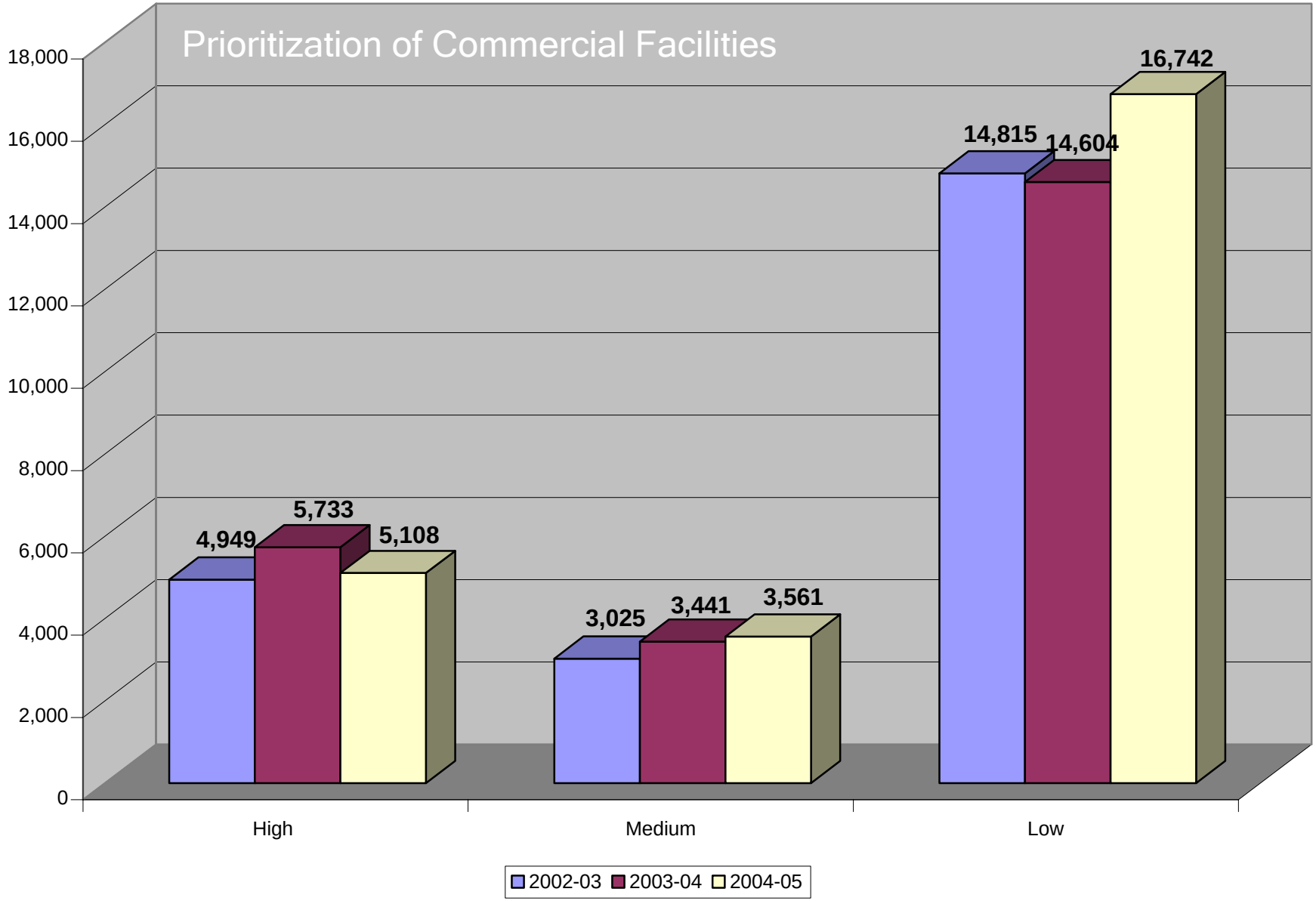


Figure 9.3: Industrial Inventory and BMP Implementation, Comparison of 2002-03, 2003-04 and 2004-05

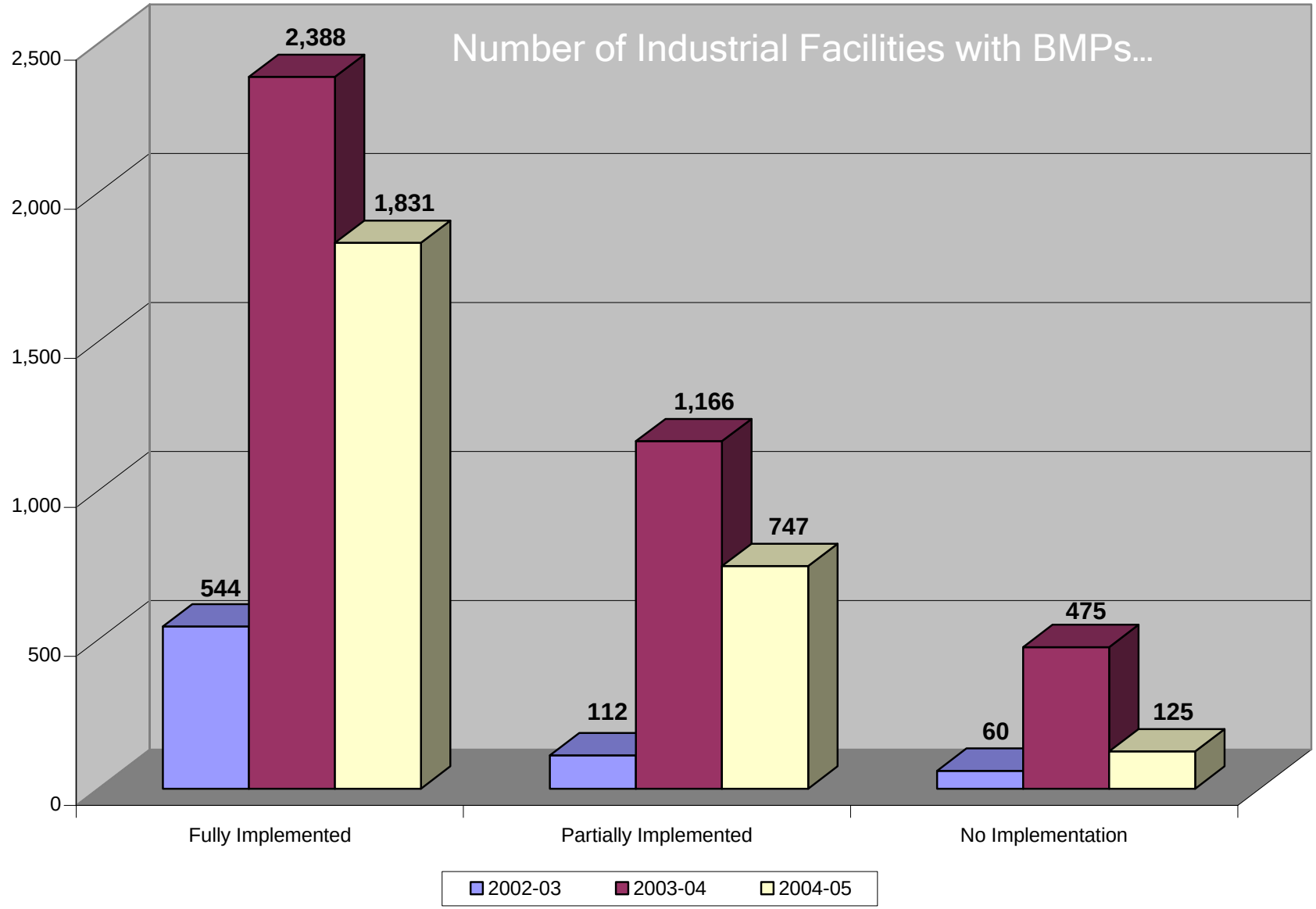
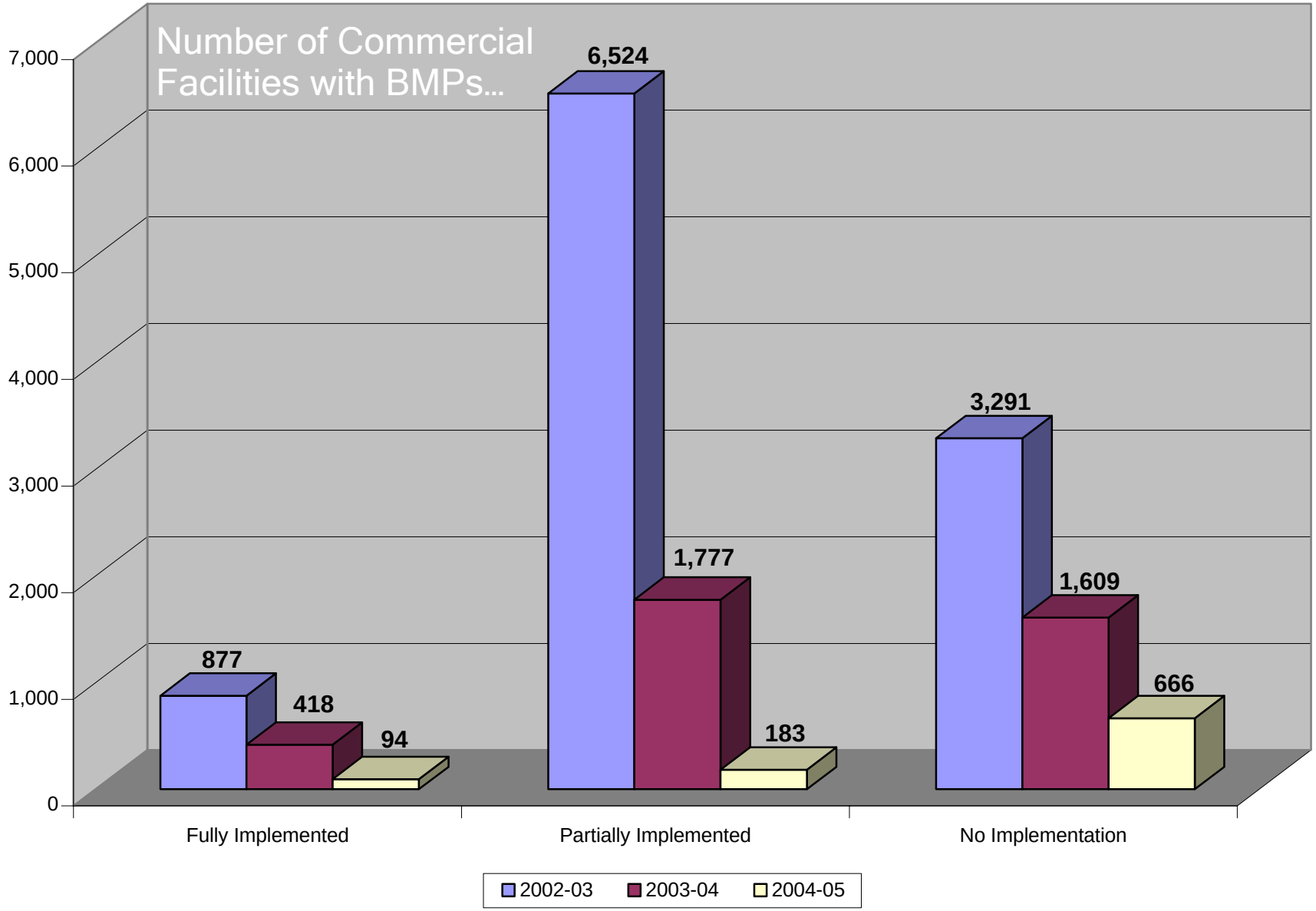


Figure 9.4: Commercial Inventory and BMP Implementation, Comparison of 2002-03, 2003-04 and 2004-05



10.0 ILLEGAL DISCHARGES/ILLICIT CONNECTIONS

10.1 Introduction

Illegal discharges/illicit connections (ID/IC) are potential sources of pollutants within municipal storm drain systems. The purpose of **DAMP Section 10.0** is to ensure that the Permittees have a programmatic framework for detecting and quickly responding to non-stormwater discharges to their storm drain systems. Since **DAMP Section 10.0** directly addresses one the basic objectives of the NPDES Permits, it is a long-established part of the Program. With the Third Term Permits, the key elements of ID/IC have been significantly enhanced. In addition, a model sewage spill response program has been developed and has begun to be implemented in conjunction with OCSD.

10.2 Accomplishments

10.2.1 Illegal Discharges/Illicit Connections Program

The ID/IC Program provides guidance for Permittees when identifying, responding to and mitigating the effects of non-stormwater discharges and enforcing the ID/IC component of the Program for the protection of the environment. **DAMP Section 10.0** requires the Permittees to:

- Detect illegal discharges and illicit connections

  A innovative Dry Weather Reconnaissance Program, based upon statistically derived benchmarks, was developed and implemented in both permit regions specifically to identify illegal discharges and illicit connections during the typically dry summer months of May through September using a suite of water quality analyses conducted in the field at designated random and targeted drains. The 2004-05 reporting period marked the third season of dry weather monitoring in the San Diego Region. With the approval of the Santa Ana Monitoring Program in July of 2005 by the Executive Officer of the Santa Ana Regional Board, dry weather monitoring in the Santa Ana Region commenced in May of 2006.

- Facilitate Public Reporting

  Telephone and web-based reporting systems for the general public have been established and are advertised in the Stormwater Program's public education materials, Orange County "White Pages" telephone directories, and Permittee websites. A total of 3,408 complaints were received during the 2004-05 reporting period.

- Investigate

  Each Permittee has designated Authorized Inspectors to investigate compliance with, detect violations of, and take actions pursuant to their Water Quality

Ordinance. During the 2004-05 reporting period, the Permittees encountered and sought to mitigate discharges involving hydrocarbons (296 incidents), inorganic materials (264 incidents), metals (6 incidents), nutrients (43 incidents), 73 organic materials (73 incidents), discharge exceptions (133 incidents), pathogens (156 incidents), wastewater (624 incidents), pesticides (2 incidents), sediment (680 incidents), trash and debris (376 incidents) , and 716 incidents involving miscellaneous types of materials for a total 3,369 incidents.

- Enforce

  Enforcement actions are undertaken according to the adopted Water Quality Ordinances and accompanying Enforcement Consistency Guide. The Permittees reported a total of 3,528 enforcement actions, associated with ID/IC investigations during the 2004-05 reporting period.

- Undertake Training

  To assist responsible municipal staff in understanding the Illegal Discharges/Illicit Connections Program, 10 training modules have been developed:

  1) Program Management Training - Introductory
  2) Program Management Training - Experienced
  3) Authorized Inspector Training[1]
  4) Authorized Inspector Training - Introductory
  5) Authorized Inspector – Field Implementation
  6) Sewage Spill Response Training
  7) Sewage Spill Response Training - Introductory
  8) "Hands-On" Sewage Spill Response Training - Experienced
  9) Fire Department Activities Training
  10) Investigative Guidance Manual Training

  In addition to the training modules, the Inspection Sub-Committee also provided training on various subjects relevant to the ID/IC program. This sub-committee meets bi-monthly to provide training to municipal inspectors and Authorized Inspectors in issues related to spill response, inspection and enforcement. In addition, this meeting serves as a forum for the coordination and discussion of ongoing difficult or new enforcement, investigation, or enforcement issues and to profile cases or incidents.

10.2.2 Model Sewage Spill Response Procedures

During the Third Permit term, the County and OCSD developed and implemented a coordinated sewage spill prevention and response demonstration project (The "Tustin

[1] This module was modified in the 2004-05 reporting period and divided into two modules, 1) Introductory and 2) Field Implementation.

Area Spill Control (TASC) Demonstration Project"). The TASC includes: 1) Development of sanitary sewer overflow (SSO) response procedures; 2) Selection of primary and backup sewage spill response contractors for containment and recovery of SSOs; and 3) SSO hands-on field response training for Permittee staff and municipal sewering agency staff.

The TASC model program is currently in use in a limited portion of the County, however; one of the goals for TASC is to gradually phase the implementation of the project throughout the County so that the proactive interagency planning and coordination for sewage spill response can be implemented and/or improved in other watersheds

10.3 Assessment

The current and potential Program Effectiveness Assessment Outcome Levels that could be assessed within the current program are summarized in **Table 10-1**.

10.3.1 Illegal Discharges/Illicit Connections Program

Detection: The San Diego Dry Weather Monitoring Program has been conducted over 3 summers. Over this period there have been 585 site visits to 67 locations comprising 3 visits to the random sites and five visits to the targeted sites each season. Investigations, prompted by findings of elevated contaminant concentrations, were triggered on 18 occasions. These results show that approximately 25% of the 67 monitoring sites have exhibited evidence of contamination in dry weather flow at levels significantly above background levels.

The approval of the Santa Ana Monitoring Program (including the Dry Weather Reconnaissance Program) in July of 2005 by the Executive Officer of the Santa Ana Regional Board meant that the dry weather monitoring in the Santa Ana Region commenced in May of 2006. The 2006-07 Unified Report will present the first opportunity to review the effectiveness of this monitoring effort through comparison of the North and South County efforts.

Reporting: RWQCB staff have acknowledged that the Permittees' field inspectors are trained to detect illegal discharges as part of their daily activities and, indeed, the majority of illegal discharges are detected by Permittee staff. The RWQCB staff also has noted that most Permittees have hotline numbers to receive water pollution complaints and incident information from the public and use database software to document the reported incidents which assists with the tracking of water pollution complaints by source. These RWQCB staff findings point to the overall robustness of the Permittees' efforts to facilitate reporting.

Headline Indicator – Number of Complaints: The Permittees reported a total of 3,408 complaints/incidents during the 2004-05 reporting period. This total represents an 11% decrease from 2003-04 (3,837 complaints), and a 110% increase from 2002-03 (1,621 complaints) **(Table 10.2; Figure 10.1)**.

☒ Level 1: Implement Program

☒ Level 3: Behavior Change

While the year-to-year comparison suggests some inconsistent reporting of this indicator, the overall pattern of a peak in the 2003-4 period (which is reproduced across other metrics) tends to suggest the positive impact of the Program (i.e. that there has been an overall reduction in the number of incidents and thereby a commensurate decline in the number of complaints). The increasing use of the "hotline" appears to indicate increasing awareness regarding this reporting mechanism.

Enforcement: Enforcement actions are undertaken according to the adopted Water Quality Ordinance and accompanying Enforcement Consistency Guide. In instances of noncompliance, the Permittee may adopt one of four types of remedies, including educational letters, administrative remedies, criminal remedies, or other civil or criminal remedies, as appropriate.

Headline Indicator – Number and Level of Enforcement Actions: The Permittees reported a total of 3,528 enforcement actions during the 2004-05 reporting period **(Table 10.3; Figure 10.2)**. This represents an 18.9% decrease from the total reported in 2003-04 (4,351 enforcement actions), and an increase of 63% from the total reported 2002-03 (2,167 enforcement actions).

☒ Level 1: Implement Program

☒ Level 3: Behavior Change

The pattern in the number of enforcement arising from ID/IC investigations follows the pattern observed in other metrics of a peak of activity in the 2003-04 reporting period. An increase in the use of citations over the Third Term permit term is one feature of the changing approach to enforcement representing a shift from the prior educational emphasis.

Training: The Permits require that staff be adequately trained. In response, the Permittees developed a number of training modules (as outlined in 10.2.1) that are offered by the County throughout the year. Although the Permittees stated that the training has been helpful, they noted that the modules need to be updated and that new training topics and more advanced training are desired.

ROWD Commitment:

- Prepare a defined expertise and competencies for Authorized Inspector positions and develop a training program to meet these requirements.

10.3.2 Model Sewage Spill Response Procedures

The 2006-07 Unified Report will present the first opportunity to review the effectiveness of initial implementation of the TASC model program. Based on field experience on actual spills, the intent is to expand the geographical implementation of the program, initially with the area coincident with the boundaries of OCSD.

10.4 Summary

The Permittees' program for responding to complaints regarding ID/IC is a long established element of the Program. The major efforts regarding this element over the period of the Third Term Permits relate to the Dry Weather Reconnaissance Program, the continued facilitation of public reporting of complaints, the designation and training of designated Authorized Inspectors, and the development of TASC.

The incidence of complaints appears to have peaked in the 2003-04 reporting period and subsequently declined, which suggest a positive overall Program impact. Based primarily upon the interest of the Permittees and of RWQCB staff, the sole commitment arising out of the effectiveness assessment is for the development of defined experience and competencies for Authorized Inspector positions and development of a training program to meet these requirements.

Table 10.1: Current Outcome Levels and Suggested Actions or Outcomes to Achieve Potential Outcome Levels

ID/IC Program Component	Effectiveness Assessment Outcome Levels					
	Level 1	Level 2	Level 3	Level 4	Level 5	Level 6
	Implement Program	Increase Awareness	Behavior Change	Load Reduction	Runoff Quality	Receiving Water Quality
Detection of ID/IC	✓ Identify ID/IC	✓ Track number of complaints by source, facility type, or pollutant	✓ Reduced occurrences of ID/IC			
Enforcement	✓ Issue EAs	✓ Track number of Enforcement Actions	✓ Track number and type of Enforcement Actions	P Discharge is eliminated	P Change in runoff quality	
Training	✓ Track # and type of training	P Surveys				

Key:

✓ = Currently Achieved Outcome Level

P = Potentially Achievable Outcome Level

Table 10.2: Source of Complaints/Incidents, Comparison of 2002-03, 2003-04, and 2004-05

PERMITTEE	City Staff 2002-03	City Staff 2003-04	City Staff 2004-05	Other Agencies 2002-03	Other Agencies 2003-04	Other Agencies 2004-05	Hotline 2002-03	Hotline 2003-04	Hotline 2004-05	Public 2002-03	Public 2003-04	Public 2004-05	Businesses 2002-03	Businesses 2003-04	Businesses 2004-05	Other 2002-03	Other 2003-04	Other 2004-05	TOTAL 2002-03	TOTAL 2003-04	TOTAL 2004-05
Aliso Viejo	21	38	11	2	3	2	6	4	7	2	12	15	4	3	2	0	0	0	35	60	37
Anaheim	34	117	156	3	45	2	0	95	56	19	0		0	26	13	0	0		56	283	227
Brea	NA	3	8	NA	1	20	NA	0	10	NA	0	16	NA	0		NA	0		NA	4	54
Buena Park	5	8	24	1	5	3	0	0	0	4	28	35	0	0	1	0	0	0	10	41	63
Costa Mesa	2	21		0	0	14	10	0		286	27	18	70	14		10	90		378	152	32
Cypress	5	18	14	0	2	3	11	0	7	1	10	7	0	3	4	0	0		17	33	35
Dana Point	NA	2	24	NA	13	7	NA	2	6	NA	12	33	NA	0	3	NA	6		NA	35	73
Fountain Valley	29	50	47	5	2	2	16	6	11	8	1	2	0	0		0	0		58	59	62
Fullerton	51	43	1	0	0		0	0		26	30	2	0	0		0	0		77	73	3
Garden Grove	26	15	208	2	5	41	4	10	2	19	84	89	3	6	12	0	0		54	120	352
Huntington Bch	108	387	140	9	11	10	9	0	0	323	51	59	9	1	1	0	0	0	458	450	210
Irvine	32	61	49	4	96	79	0	0	0	33	31	64	0	0	0	0	0		69	188	192
La Habra	0	6	32	0	0	1	0	0		21	19		0	0		0	0		21	25	33
La Palma	27	69	53	1	0	0	1	2	0	4	25	13	0	0	1	0	0	0	33	96	67
Laguna Beach	25	25	23	4	13	13	56	66	55	0	0	0	0	0	0	0	0	0	85	104	91
Laguna Hills	7	11	20	0	1	2	0	1	0	7	0	0	1	0	0	0	0	0	15	13	22
Laguna Niguel	NA	18	14	NA	1	6	NA	2	3	NA	10	2	NA	0	1	NA	0	0	NA	31	26
Laguna Woods	12	13	84	6	1	8	0	0	0	22	65	18	0	3	10	0	0	0	40	82	120
Lake Forest	2	27	35	4	6	16	0	3	3	11	16	44	0	2	7	0	0	0	17	54	105
Los Alamitos	0	0	0	1	12		0	3	0	2	0	0	0	0	0	0	0		3	15	0
Mission Viejo	NA	NA	0	NA	NA	0	NA	NA	0	NA	NA	111	NA	NA	0	NA	NA	0	NA	NA	111
Newport Beach	NA	NA	100	NA	NA	5	NA	NA	30	NA	NA	60	NA	NA	10	NA	NA	95	NA	NA	300
Orange	17	76	35	0	6	3	0	0	257	0	59	0	1	9	0	0	0	0	18	150	295
Placentia	9	58	50	0	1	1	0	1	1	5	13	24	0	0	2	0	0	69	14	73	147
R S Margarita	0	4	11	0	1	18	0	5	4	7	3	12	3	0	1	0	0	0	10	13	46
San Clemente	NA	581	NA	NA	6	NA	NA	0	NA	NA	92	NA	NA	0	NA	NA	0	NA	NA	679	NA
S J Capistrano	12	7	8	1	2	1	4	9	10	17	13	26	0	1	1	0	0		34	32	46
Santa Ana	7	6	37	6	7	7	0	0		7	3	6	0	0	2	0	0		20	16	52
Seal Beach	NA	NA	17	NA	NA		NA	NA		NA	NA	14	NA	NA		NA	NA		NA	NA	31
Stanton	NA	0	0	NA	8	0	NA	0		NA	40		NA	2		NA	0		NA	50	0
Tustin	9	19	37	0	0	0	0	0	0	4	8	9	1	0	0	13	0	0	27	27	46
Villa Park	NA	4	5	NA	0	0	NA	0	0	NA	6	10	NA	0	0	NA	0	0	NA	10	15
Westminster	0	26	18	8	8	3	0	19	7	0	65	21	0	33	3	0	0	0	8	151	52
Yorba Linda	6	23	5	1	1	0	0	0	0	23	26	13	0	1	0	0	0	1	30	51	19
County of Orange	12	494	273	1	40	24	4	15	94	17	85	53	0	25	0	0	8	0	34	667	444
TOTALS	**458**	**2,230**	**1,539**	**59**	**297**	**291**	**121**	**243**	**563**	**868**	**834**	**776**	**92**	**129**	**74**	**23**	**104**	**165**	**1,621**	**3,837**	**3,408**

NA = Not Available

Table 10.3: Permittee Enforcement Actions, Comparison of 2002-03, 2003-04 and 2004-05

Permittee	EL 02-03	EL 03-04	EL 04-05	NON 02-03	NON 03-04	NON 04-05	ACO 02-03	ACO 03-04	ACO 04-05	CDO 02-03	CDO 03-04	CDO 04-05	Mis 02-03	Mis 03-04	Mis 04-05	Inf 02-03	Inf 03-04	Inf 04-05	IOC 02-03	IOC 03-04	IOC 04-05	Other 02-03	Other 03-04	Other 04-05	TOTAL 02-03	TOTAL 03-04	TOTAL 04-05
Aliso Viejo	0	3	7	27	4	19	0	0	1	0	17	2	0	0	0	0	0	0	4	38	79	3	0	0	34	62	108
Anaheim	0	1	13	20	39	34	11	39	28	1	0	0	2	0	0	0	0	0	0	0	0	1	0	0	35	79	75
Brea	0	11	6	2	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	2	3	13	8
Buena Park	8	5	2	0	10	21	0	16	47	0	0	20	0	0	0	0	0	0	0	0	6	0	0	0	8	31	96
Costa Mesa	22	9	7	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	2	14	2	0	0	0	24	26	9
Cypress	5	10	3	10	21	25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	7	17	31	35
Dana Point	NA	14	24	NA	19	12	NA	0	9	NA	0	1	NA	0	0	NA	0	0	NA	0	1	NA	0	18	NA	33	65
Fountain Valley	12	391	71	4	8	6	21	12	15	6	6	9	0	0	0	0	0	0	0	0	0	40	0	50	83	417	151
Fullerton	0	0	NA	23	59	NA	5	0	NA	0	0	NA	0	0	NA	0	14	NA	26	0	NA	0	0	NA	54	73	NA
Garden Grove	21	19	75	2	11	39	0	0	0	0	1	0	0	1	0	0	0	0	0	0	1	0	0	0	23	32	115
Huntington Bch	60	61	96	54	47	127	5	5	0	1	0	0	0	0	0	0	0	0	0	0	30	0	0	2	120	113	255
Irvine	32	14	0	0	88	0	24	33	0	0	0	0	0	0	0	0	0	0	0	0	0	14	5	0	70	140	0
La Habra	0	0	0	0	1	15	0	0	1	0	0	3	0	0	0	0	0	0	0	0	0	50	19	32	50	20	51
La Palma	18	41	31	8	24	15	0	2	4	0	0	1	0	2	0	0	0	0	0	0	2	0	0	14	26	69	67
Laguna Beach	0	5	2	71	62		52	83	0	0	0	0	1	0	0	0	57	0	0	37	0	60	0	114	184	244	116
Laguna Hills	8	6	16	5	11	20	1	1	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	16	18	36
Laguna Niguel	NA	8	10	NA	1	4	NA	0	0	NA	0	0	NA	0	0	NA	0	0	NA	0	0	NA	0	0	NA	9	14
Laguna Woods	27	30	15	11	13	18	1	1	0	0	1	0	0	0	0	0	0	0	0	6	2	1	0	0	40	51	35
Lake Forest	90	2	2	3	23	42	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	93	25	45
Los Alamitos	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	0	0
Mission Viejo	134	15	5	58	139	31	0	0	0	1	0	1	0	0	0	0	0	0	0	0	2	0	0	0	193	154	39
Newport Beach	6	8	20	250	618	209	200	315	0	0	0	0	0	0	0	0	0	0	0	0	166	300	550	1100	756	1491	1495
Orange	0	75	0	0	4	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	79	2
Placentia	8	20	7	0	11	19	3	3	0	3	1	0	0	0	1	0	0	0	0	0	0	0	31	41	14	66	68
R S Margarita	10	7	48	0	0	13	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	5	10	8	66
San Clemente	72	430	175	37	160	98	0	10	0	1	9	11	0	0	0	0	0	0	2	0	45	8	10	2	120	619	331
S J Capistrano	24	6	0	9	2	0	0	7	0	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0	34	16	0
Santa Ana	1	4	1	2	9	18	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	14	2	0	19	16	20
Seal Beach	4	35	0	21	41	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	31	3	6	0	28	82	31
Stanton	NA	0	0	NA	0	0	NA	0	0	NA	0	0	NA	0	0	NA	0	0	NA	0	0	NA	0	0	NA	0	0
Tustin	0	169	38	16	27	21	0	5	0	0	0	0	0	0	0	0	0	0	0	0	1	11	0	0	27	201	60
Villa Park	15	0	3	0	0	12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10	0	15	10	15
Westminster	13	55	35	1	0	4	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0	52	15	55	92
Yorba Linda	1	2	0	21	34	9	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	22	41	9
County of Orange	5	4	3	20	12	12	2	9	4	0	0	0	0	0	0	0	0	0	0	0	0	3	2	0	30	27	19
TOTALS	**600**	**1,460**	**715**	**675**	**1,502**	**845**	**327**	**544**	**110**	**16**	**36**	**49**	**4**	**3**	**1**	**0**	**71**	**1**	**34**	**96**	**368**	**511**	**639**	**1,439**	**2,167**	**4,351**	**3,528**

NA = Not Available **EL = Educational Letter** **NON = Notice of Non-Compliance** **ACO = Administrative Compliance Order** **CDO = Cease and Desist Order** **Mis = Misdemeanor** **Inf = Infraction** **IOC = Issuance of Citation**

Figure 10.1: Source of Complaints/Incidents, Comparison of 2002-03, 2003-04, and 2004-05

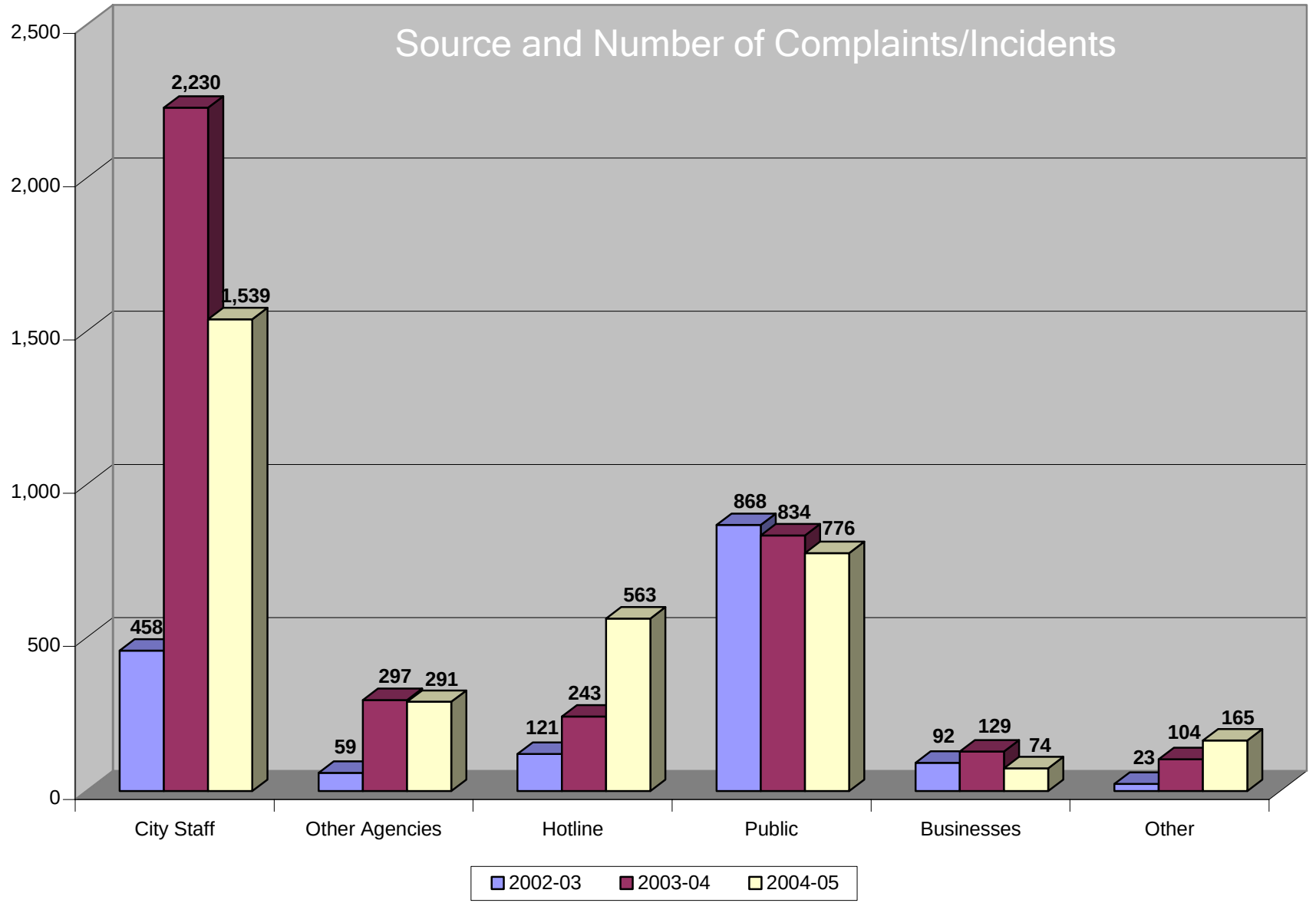
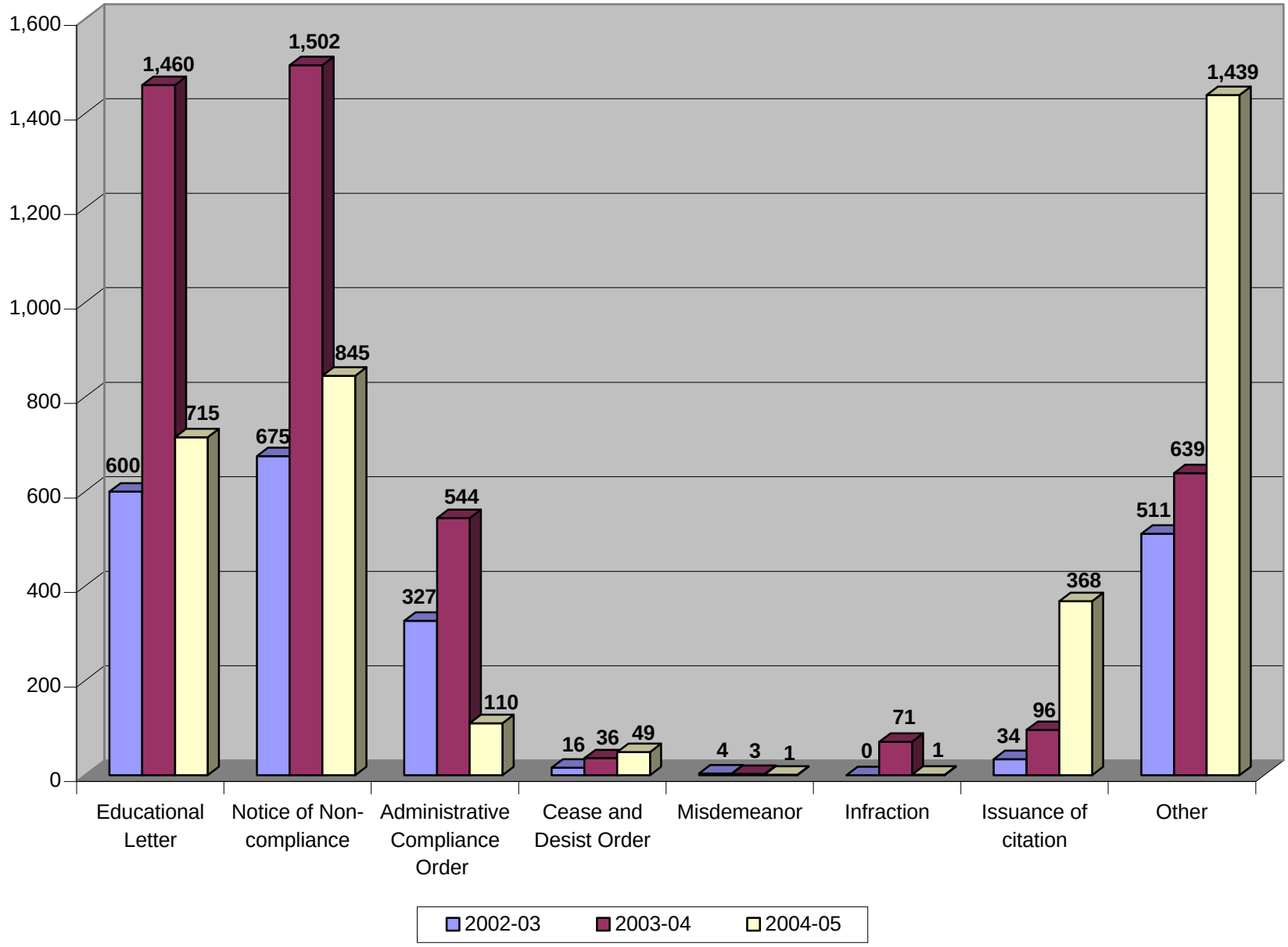


Figure 10.2: Permittee Enforcement Actions, Comparison of 2002-03, 2003-04 and 2004-05



11.0 WATER QUALITY MONITORING SUMMARY AND ANALYSES

11.1 Introduction

The goal of environmental monitoring is to support the management process.

> "monitoring is most useful when it results in more effective management decisions, specifically management decisions that protect or rehabilitate the environment."
> (NAS, 1991[1])

On July 1, 2003 the Permittees submitted a proposed monitoring plan to the Santa Ana Regional Board for the Third Term Permit. This monitoring plan design was based on the model stormwater monitoring plan developed by a subcommittee of the southern California Stormwater Monitoring Coalition (SMC). This subcommittee was comprised of representatives from southern California stormwater agencies, Regional and State Water Resources Control Board staff, EPA Region 9, and the Southern California Coastal Water Research Project (SCCWRP).

With input from Regional Board staff, many additions to the proposed plan for the Third Term permit were made to accommodate development of the Toxics TMDLs for San Diego Creek and Newport Bay. The plan was finally approved during the summer of 2005 and subsequently implemented.

In the interim period between issuance of the Third Term Permit and approval of the new monitoring plan, the program continued monitoring under the Second Term Permit plan (99-04 Plan). Under the 99-04 plan the Permittees identified a group of critical aquatic resources and conducted monitoring to evaluate environmental conditions relative to applicable water quality criteria. The 99-04 Plan also included mass emissions monitoring of stormwater runoff at several locations in the Newport Bay and Anaheim Bay/Huntington Harbour watersheds.

No evaluation is currently possible of data collection that was started under the Third Term Permit. This section will therefore focus on the results of monitoring critical aquatic resources and mass emissions monitoring under the 99-04 Plan.

11.2 Accomplishments

11.2.1 Completion of the 99-04 Monitoring Plan

Critical Aquatic Resources

The 99-04 Monitoring Plan identified critical aquatic resources in Orange County. In the Santa Ana Regional Board area these included the Newport Bay, Huntington Harbour, and Bolsa Bay. Monitoring during the First Term Permit included evaluations of water chemistry and physical characteristics during periods stormwater runoff, and semi-

[1] Managing Troubled Waters, National Academy of Sciences, 1991

annual (pre and post storm season) dry-weather assessments of water quality, physical characteristics, and benthic sediment chemistry. The water chemistry assessments included nutrients and trace metals. During the latter part of the First Term Permit dissolved metals were added to the suite of analyses in anticipation of the adoption of the California Toxics Rule (CTR).

Although the monitoring locations in these receiving waters have essentially remained the same from the start of the NPDES program, the most significant change has been the dramatic improvement in the reporting limits for trace metals. For some metals the reporting limits have dropped nearly two orders of magnitude from the early 1990's to 2005. This improvement has allowed more confidence in the assessment of potential aquatic toxicity with respect to the criteria from the CTR.

As in the prior monitoring program the goal at each harbor complex was to monitor two stormwater runoff events per year. Each monitored stormwater event included three separate visits: day 1 of stormwater runoff to receiving water, 2 days after initial sampling, and 4 days after initial sampling. The water chemistry from each sampling was compared to applicable acute saltwater criteria from the CTR. The mean concentrations of the 3 days of stormwater sampling were compared to the chronic saltwater criteria from the CTR.

The following is a summary of the number of stormwater runoff events monitored in the harbors during the last five reporting years. The 2001-02 and 2003-04 storm seasons did not present many monitoring opportunities because of the lower than average rainfall totals.

Reporting Year	Rainfall Total at Santa Ana	Huntington Harbour	Newport Bay
2000-01	14.87″	0	3
2001-02	3.82″	0	0
2002-03	14.57″	2	2
2003-04	8.41″	1	1
2004-05	28.44″	2	2

In order to put the critical aquatic resources sites in a broader regional perspective, aquatic chemistry samples from these locations (e.g., Newport Bay, Huntington Harbour, Bolsa Bay) were combined with aquatic chemistry samples from the mass emissions monitoring program and then evaluated in comparison to acute and chronic toxicity criteria established in the CTR. The data from the bays and harbors were compared to the saltwater criteria from the CTR. The data from the mass emissions sites were compared to the freshwater criteria and to the saltwater criteria if the channel directly discharges to a marine or estuarine receiving water. While such CTR criteria are available for only a portion of the constituents measured in the program's samples, the combination of all available CTR exceedance data provides an overview of patterns across the region. In addition to tabulating the number of exceedances at each station, the overall percentage of exceedances at each station (out of all samples collected at each station) was used to place stations into one of four categories representing relative

frequency of exceedances. These categories were then represented with colored symbols on maps (**Figure 11.1** and **Figure 11.2**) of the region.

Table 11.2 summarizes the patterns of exceedances of relevant acute toxicity CTR criteria at mass loading and bays/harbors monitoring stations in the Santa Ana region with more than one sampling event. These stations provide the most spatially distributed and consistently sampled set of data for assessing overall levels of specific pollutants in both dry and wet weather. **Table 11.3** summarizes the comparisons of stormwater data from the bays/harbors to relevant chronic toxicity criteria from the CTR.

It should be noted that the comparisons of the concentrations of dissolved metals at mass emission sites near estuarine receiving waters to saltwater criteria from the CTR assume no mixing zone dilution in the receiving waters. During dry weather conditions the impacts would be localized at the channel-receiving water interface. During stormwater runoff the spatial impacts would be greater.

The main findings from the data were that:

1. Exceedances of the acute toxicity criteria in channels and bay/harbors were predominantly due to dissolved copper, with much smaller percentages due to dissolved zinc in some channels.
2. Exceedances of the chronic toxicity criteria in the harbors were due to both dissolved copper and nickel.
3. Exceedances were more widespread during periods of stormwater water runoff compared to dry weather
4. There was a tendency for exceedances to be more frequent at stations nearer the bottom end of watersheds, along the coast, and particularly in embayments such as Huntington Harbour and Newport Bay.

Figures 11.1 and **11.2** visually summarize these regional patterns, using the data presented in **Table 11.2**.

Within these larger patterns, the CTR exceedance data help identify locations where targeted special studies to identify upstream sources should be implemented. The Third Term Monitoring Program has been designed to be adaptive to allow these special studies if warranted. These are stations where both the exceedance rate and/or the number of pollutants showing exceedances are among the highest:

Channels
CMCG02
SADF01
SDMF05

Bays/Harbors
HUNBCC
HUNCRB
HUNWAR
TGDC05
LNBHIR
LNBRIN
UNBCHB
UNBJAM
UNBNSB
UNBSDC

Stations with elevated exceedance rates in dry weather tend to have elevated rates in wet weather as well. However, there is not a readily apparent, consistent relationship between the overall levels of CTR exceedances at the mass loading stations and the loads of total metals. For example, both stations CMCG02 and SDMF05 showed persistent exceedances of the saltwater CTR criteria (**Table 11.2**), yet **Figures 11.5** and **Figure 11.5a** show that these two stations have very different baseline mass loads of copper, nickel, and zinc. Improved understanding of the potential impact of these elevated pollutant levels will stem from the addition of toxicity testing to the Third Term Monitoring Program. This will help to identify where and to what extent such pollutants are more likely to be bio-available.

Mass Emissions Monitoring

The long-term mass emissions component of the monitoring program is intended to evaluate changes in stormwater pollutant loadings over a number of permit terms. This is accomplished through wet weather monitoring of a number of flood channels in the Newport Bay and Anaheim Bay-Huntington Harbour watersheds. Monitored constituents include nutrients, trace elements (total recoverable and dissolved), and for some channels, organophosphate pesticides. The program is coordinated with elements of the San Diego Creek Nutrient TMDL, a dry-weather assessment of the inorganic nitrogen and total nitrogen loading to the Newport Bay.

For the stormwater assessments three storms are monitored at each location annually and for each storm the water chemistry is monitored with a series of 3 to 4 composite samples collectively spanning approximately 96-hours. This time period frequently extends beyond the end of stormwater runoff but provides for comparison of the time-weight average concentrations of dissolved metals to the 96-hour guidance criteria for chronic aquatic toxicity from the CTR. The concentrations of dissolved heavy metals in each of the composite samples are also compared to acute toxicity criteria from the CTR.

The concentrations of organophosphate pesticides are compared to literature values of LC_{50}s for toxicity testing organisms.

The dry-weather assessments usually involve a 24-hour composite sampling of the channels on a monthly basis. More frequent monitoring is also conducted at some stations for the Nutrient TMDL.

Mass Emissions monitoring during the Third Term Permit in the SAR was essentially an extension of monitoring conducted under the prior permits. Several sites, primarily in the Newport Bay watershed, have been monitored since the early 1990's. **Table 11.1** lists the mass emissions sites from which data were analyzed for this report.

The monitoring program utilizes continuous water level records from streamgages at each site are used to determine dry-weather and stormwater discharge rates. The streamgages on Costa Mesa , Central Irvine, and Lane Channels have not had sufficient numbers of stormwater discharge measurements made to accurately define the upper ranges of their respective channel ratings. To remedy this deficiency the program has recently invested in equipment utilizing acoustic Doppler current profiling technology in order to rapidly make discharge measurements during stormwater conditions.

The evolution of automatic sampling equipment and analytical methodologies has improved sampling efficiency and allowed more accurate assessments of potential aquatic toxicity. During the latter part of the 99-04 Monitoring Program Teflon-lined sampler tubing replaced plastic tubing to reduce the likelihood of cross contamination between samples. Detection limits of the analytical services providers improved dramatically for trace element and pesticide analyses.

The raw data for many constituents from the long-term mass loading stations in the Santa Ana Region (see **Figure 11.3** for the location of stations and **Figure 11.4** for an example raw data plot) show declining trends in event mean concentrations (EMCs) and loads over time. The legitimacy of these trends was investigated statistically[2] with a multiple regression analysis that included both the amount of rainfall in the three days preceding each sampling event and the amount of total suspended solids (TSS) in each sample. In order to increase the length of the time series back to the early 1990s, only total metals, phosphate (PO_4), and nitrate (NO_3) were used in the analysis.

The findings of this statistical analysis were as follows:

- There were no long-term trends in loads and event mean concentrations (EMCs) that were not accounted for by changes in TSS concentrations
- Mean levels of TSS differed among stations and so did underlying (baseline) levels of pollutants

The statistical analysis showed that the stormwater trends in metals, phosphate and nitrate concentrations were not a function of time but a function of TSS concentration.

[2] Mark Fitzgerald, Neptune and Company Inc.

This would suggest that TSS reduction would result in a reduction of the other constituents. This makes logical sense for metals and phosphate which are predominantly found in particulate form in stormwater. For nitrate however, the TSS correlation is not readily explainable since nitrate is a dissolved component.

The underlying differences among stations in both EMCs and loads (after TSS influences were statistically removed) are shown in **Figures 11.5** and **11.6**. San Diego Creek at Campus (station SDMF05) has the highest loads for the three metals and two nutrients, probably a reflection of its consistently higher flow. On the other hand, the rank order of stations after this changes depending on the pollutant. There was no single station that was consistently among the highest ranked in terms of EMCs.

11.2.2 Approval of the Third Term Monitoring Plan

On July 1, 2003, the Permittees submitted to the Regional Board a monitoring program proposal to address the requirements of the Third Term Permit. The design of the program was based on The Model Monitoring Program for Municipal Separate Storm Sewer Systems in Southern California, a report from the Southern California Stormwater Monitoring Coalition (SMC). The proposal contained several new assessment tools (relative to the 99-04 Plan) including expanded suites of monitored stormwater pollutants, dry-weather reconnaissance for illegal discharges/illicit connections, urban stream bioassessments, infaunal analyses of benthic sediment in the harbors and estuaries, and toxicity testing of water and benthic sediment. After lengthy discussions between the Permittees and Regional Board staff, the proposed monitoring plan was revised to incorporate several new elements to aid in the development of the Toxics TMDLs for San Diego Creek and the Newport Bay. The Executive Officer gave final approval of the plan in August 2005 and it was subsequently implemented.

While the 99-04 Plan has provided useful information with respect to regional patterns of water quality relative to the CTR and trends in stormwater EMCs and loads, the Third Term program will greatly expand the Permittees ability to assess the impacts of urban runoff. Since the Third Term program was implemented in August 2005 the Permittees have done the following:

- Conducted urban stream bioassessments in the Fall of 2005 and Spring of 2006
- Conducted toxicity testing of stormwater runoff at mass emissions and harbor/estuary sites
- Conducted infaunal analyses and toxicity testing of the benthic sediment in the Newport Bay and Huntington Harbour
- Initiated the weekly monitoring of bacterial indicators in coastal stormdrain discharges and their receiving waters
- Initiated the dry-weather reconnaissance program in May of 2006

Analysis of the data from this monitoring will be provided in the Performance Evaluation Assessment Report in November 2006.

11.2.3 Database Management

In 2004, a new computer program was developed for managing NPDES monitoring data. The intent of this program which has been called Labtrack, is to provide a single repository for all current NPDES data, to reduce the number of systematic errors in monitoring and laboratory analyses, and to increase the efficiency in processing invoices for the payment of analytical services. Some of the features of Labtrack include:

- Printing labels for sampling containers
- Printing and maintaining chain-of-custody documentation
- Checking laboratory results against quality assurance criteria
- Checking invoice pricing against price agreements
- Integrating discharge rate information from Hydstra (hydrologic database) to calculate load information for PEA and TMDL reports

11.2.4 Participation in Regional Monitoring Programs

Since 1997, the Permittees have been an active participant in the Regional Monitoring Program for the Southern California Bight. A Permittee representative has served on the steering committees for the 1998 Regional Assessment (Bight 98) and the 2003 Assessment (Bight 03). A representative has also served on several of the monitoring subcommittees on Bight 03.

The Permittees have also provided representation to the southern California Stormwater Monitoring Coalition. A Permittee representative was instrumental in the development of the Model Stormwater Monitoring Program guidance document mentioned in Section 11.2.2. A Permittee representative is currently on the working group with SCCWRP and the California Department of Fish and Game to improve the California Stream Bioassessment Procedure.

The knowledge gained from participation in these regional programs has enabled the Permittees to improve the monitoring program in many ways. The newly established price agreements for analytical services for the stormwater program required that the vendor had participated in the rigorous laboratory inter-calibration exercises for the Bight Regional Monitoring Program. These exercises, coordinated by SCCWRP, ensured that the accuracy and precision by each of the participating laboratories were maintained at a high standard.

11.2.5 Involvement in Research Level Investigations

The Permittees also contributed monitoring equipment and funding to UCI to conduct bacteriological investigations in the Santa Ana River and Huntington Beach surfzone. As a result of the study findings, the dry-weather discharges of several channels which drain to that area have been diverted to the Orange County Sanitation District. Since the diversions have been implemented there has been an improvement in scores for the surfzone in that area on Heal the Bay's Beach Water Quality Report Card.

11.3 Assessment

The Permittees have assessed the recently approved Third Term Permit Monitoring Program and are proposing no changes to this program.

The Permittees will continue to develop the capabilities to implement the program and assess the monitoring data to provide feedback to the management program. This will include the following:

- Continue to participate in Regional efforts to improve the quality and validity of stormwater monitoring data and provide a broader geographic context for monitoring results. These would include the Bight and SMC laboratory inter-calibrations, and Surface Water Ambient Monitoring Program (SWAMP) comparability studies.
- Continue to investigate improved GIS base data visualization tools for presenting monitoring information to a broader audience.
- Improve existing water quality database (Labtrack) to include automated report generation for:
    - Monthly updates to the Permittees pertaining to the Dry-weather Reconnaissance program
    - Quarterly data reports for the Nutrient TMDL
    - Integration of NPDES monitoring data with UCI's CalSWIM web-base GIS database
- Enhance training of monitoring staff by
    - Preparing standard operating procedures manuals for each monitoring program element
    - Providing opportunities for attending specialized training as provided by the USGS (streamgaging) and CaDFG (urban stream bioassessment)
- Evaluate new technologies for sampling and discharge monitoring

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Table 11.1: Mass Loading Stations Sampled During the Permit Term

Site Code	Channel	NPDES	Nutrient TMDL	Comments
SDMF05	San Diego Creek at Campus	X	X	
BARSED	Peters Canyon Wash at Barranca	X	X	
WYLSED	San Diego Creek at Harvard	X	X	
SADF01	Santa Ana Delhi at Irvine Ave	X	X	
CICF25	Central Irvine u/s Peters Cyn Wash	X		New site under 3rd term permit. Channel rating needs refining
BCF04	Bonita Cyn Wash u/s University		X	USGS gage
MIRF07	El Modena Irvine at Michelle		X	
LANF08	Lane Channel at Jamboree	X	X	Channel rating needs refining
ACWF18	Agua Chinon u/s San Diego Creek		X	USGS gage
CMCG02	Costa Mesa Channel at Highland	X	X	Channel rating needs refining
BCC02	Bolsa Chica at Westminster	X		
ABCC03	Anaheim Barber City at Rancho Rd	X		
WMCC04	Westminster Channel at Beach Blvd	X		
EGWC05	E. Garden Grove Wintersburg at Gothard	X		Gage removed during channel reconstruction 02-05

Table 11.2: Summary of Exceedances of Acute CTR Criteria Across the Region

						% Samples Exceeding CTR		
Weather	CTR Type	Site Code	Type	Watershed	# Samples	Cu	Ni	Zn
Storm	FW	ABCC03	Channel	Anaheim Bay-Huntington Harbour	25	40	0	4
Storm	FW	BCC02	Channel	Anaheim Bay-Huntington Harbour	11	18	0	0
Storm	FW	EGWC05	Channel	Anaheim Bay-Huntington Harbour	18	45	0	0
Storm	FW	WMCC04	Channel	Anaheim Bay-Huntington Harbour	16	50	0	6
Storm	SW	BCC02	Channel	Anaheim Bay-Huntington Harbour	11	100	0	0
Storm	SW	EGWC05	Channel	Anaheim Bay-Huntington Harbour	18	100	0	6
Dry	SW	BBOLR	Harbor	Anaheim Bay-Huntington Harbour	11	55	0	0
Dry	SW	HUNBCC	Harbor	Anaheim Bay-Huntington Harbour	11	73	0	0
Dry	SW	HUNCRB	Harbor	Anaheim Bay-Huntington Harbour	11	82	0	0
Dry	SW	HUNSUN	Harbor	Anaheim Bay-Huntington Harbour	11	45	0	0
Dry	SW	HUNWAR	Harbor	Anaheim Bay-Huntington Harbour	11	64	0	0
Dry	SW	TGDC05	Harbor	Anaheim Bay-Huntington Harbour	8	88	0	0
Storm	SW	BBOLR	Harbor	Anaheim Bay-Huntington Harbour	7	43	0	0
Storm	SW	HUNBCC	Harbor	Anaheim Bay-Huntington Harbour	9	67	0	10
Storm	SW	HUNCRB	Harbor	Anaheim Bay-Huntington Harbour	9	56	0	0
Storm	SW	HUNSUN	Harbor	Anaheim Bay-Huntington Harbour	9	56	0	0
Storm	SW	HUNWAR	Harbor	Anaheim Bay-Huntington Harbour	9	44	0	0
Storm	SW	TGDC05	Harbor	Anaheim Bay-Huntington Harbour	5	80	0	0
Dry	FW	BARSED	Channel	Newport Bay	8	0	0	0
Dry	FW	BCF04	Channel	Newport Bay	5	0	0	0
Dry	FW	CICF25	Channel	Newport Bay	7	0	0	0
Dry	FW	CMCG02	Channel	Newport Bay	137	5	0	1
Dry	FW	HCWF27	Channel	Newport Bay	5	0	0	0
Dry	FW	SADF01	Channel	Newport Bay	10	20	0	0
Dry	FW	SDMF05	Channel	Newport Bay	82	0	0	0
Dry	FW	WYLSED	Channel	Newport Bay	9	0	0	0
Dry	SW	CMCG02	Channel	Newport Bay	137	99	1	1
Dry	SW	SADF01	Channel	Newport Bay	10	90	0	0
Dry	SW	SDMF05	Channel	Newport Bay	82	48	0	0

						% Samples Exceeding CTR		
Weather	CTR Type	Site Code	Type	Watershed	# Samples	Cu	Ni	Zn
Dry	SW	LNBHIR	Harbor	Newport Bay	12	75	0	0
Dry	SW	LNBRIN	Harbor	Newport Bay	4	100	0	0
Dry	SW	LNBTUB	Harbor	Newport Bay	4	50	0	0
Dry	SW	UNBCHB	Harbor	Newport Bay	12	67	0	0
Dry	SW	UNBJAM	Harbor	Newport Bay	12	75	0	0
Dry	SW	UNBNSB	Harbor	Newport Bay	12	67	0	0
Dry	SW	UNBSDC	Harbor	Newport Bay	13	77	0	0
Storm	FW	ACWF18	Channel	Newport Bay	4	0	0	0
Storm	FW	BARSED	Channel	Newport Bay	61	5	0	0
Storm	FW	BCF04	Channel	Newport Bay	17	6	0	0
Storm	FW	CICF25	Channel	Newport Bay	8	13	0	0
Storm	FW	CMCG02	Channel	Newport Bay	58	48	0	26
Storm	FW	HCWF27	Channel	Newport Bay	7	0	0	0
Storm	FW	LANF08	Channel	Newport Bay	39	15	0	0
Storm	FW	MIRF07	Channel	Newport Bay	16	31	0	0
Storm	FW	SADF01	Channel	Newport Bay	57	28	0	0
Storm	FW	SDMF05	Channel	Newport Bay	50	4	0	0
Storm	FW	WYLSED	Channel	Newport Bay	52	2	0	0
Storm	SW	CMCG02	Channel	Newport Bay	58	97	0	22
Storm	SW	SADF01	Channel	Newport Bay	57	98	0	12
Storm	SW	SDMF05	Channel	Newport Bay	50	86	0	2
Storm	SW	LNBHIR	Harbor	Newport Bay	15	60	0	0
Storm	SW	LNBRIN	Harbor	Newport Bay	16	75	0	0
Storm	SW	LNBTUB	Harbor	Newport Bay	10	100	0	0
Storm	SW	UNBCHB	Harbor	Newport Bay	17	59	0	0
Storm	SW	UNBJAM	Harbor	Newport Bay	16	50	0	0
Storm	SW	UNBNSB	Harbor	Newport Bay	16	38	0	0
Storm	SW	UNBSDC	Harbor	Newport Bay	16	44	0	0

Table 11.3 Summary of Exceedances of CTR Chronic Criteria in Harbors and Bays

						% Samples Exceeding CTR		
Weather	CTR Type	Site Code	Type	Watershed	# Samples	Cu	Ni	Zn
Storm	SW	BBOLR	Harbor	Anaheim Bay-Huntington Harbour	4	75	50	0
Storm	SW	HUNBCC	Harbor	Anaheim Bay-Huntington Harbour	4	75	25	0
Storm	SW	HUNCRB	Harbor	Anaheim Bay-Huntington Harbour	4	100	25	0
Storm	SW	HUNSUN	Harbor	Anaheim Bay-Huntington Harbour	4	75	25	0
Storm	SW	HUNWAR	Harbor	Anaheim Bay-Huntington Harbour	4	100	0	0
Storm	SW	TGDC05	Harbor	Anaheim Bay-Huntington Harbour	3	100	33	0
Storm	SW	LNBHIR	Harbor	Newport Bay	7	86	29	0
Storm	SW	LNBRIN	Harbor	Newport Bay	6	100	50	0
Storm	SW	LNBTUB	Harbor	Newport Bay	4	100	75	0
Storm	SW	UNBCHB	Harbor	Newport Bay	7	86	29	0
Storm	SW	UNBJAM	Harbor	Newport Bay	8	100	25	0
Storm	SW	UNBNSB	Harbor	Newport Bay	8	75	50	0
Storm	SW	UNBSDC	Harbor	Newport Bay	7	71	29	0

Figure 11.1: Pattern of CTR Exceedances Across the Region During Dry Weather

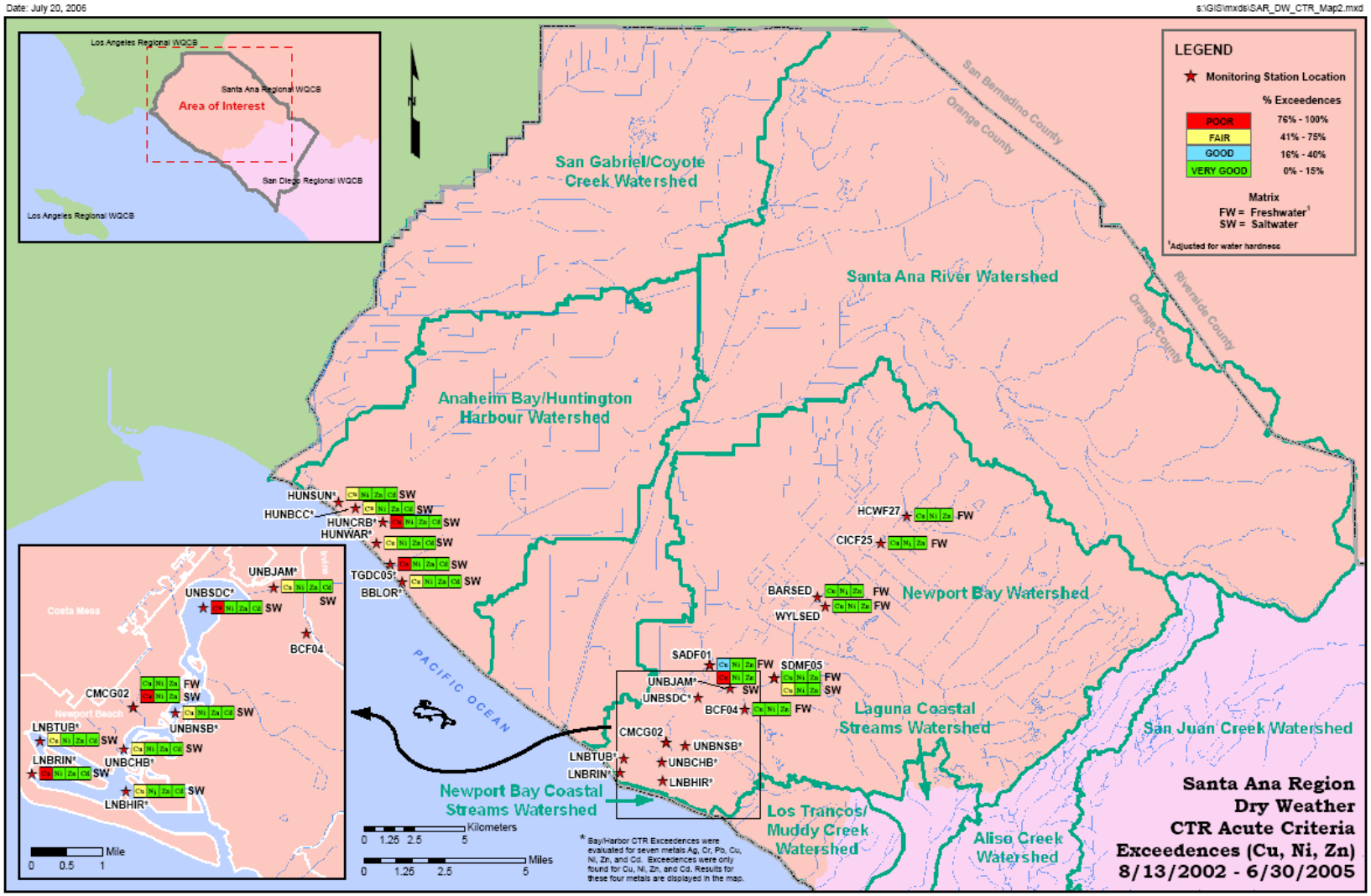


Figure 11.2: Pattern of CTR Exceedances Across the Region During Wet Weather

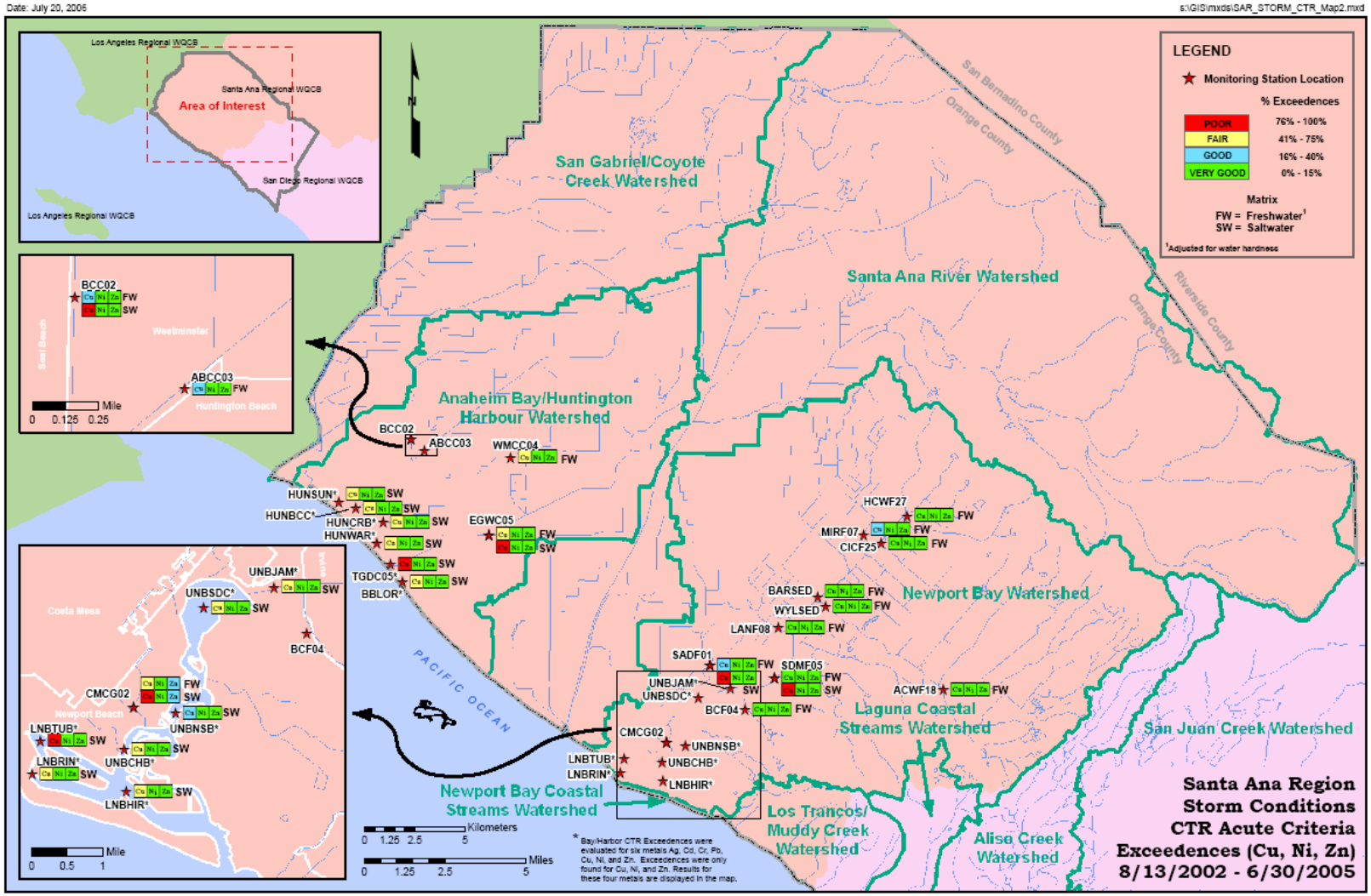
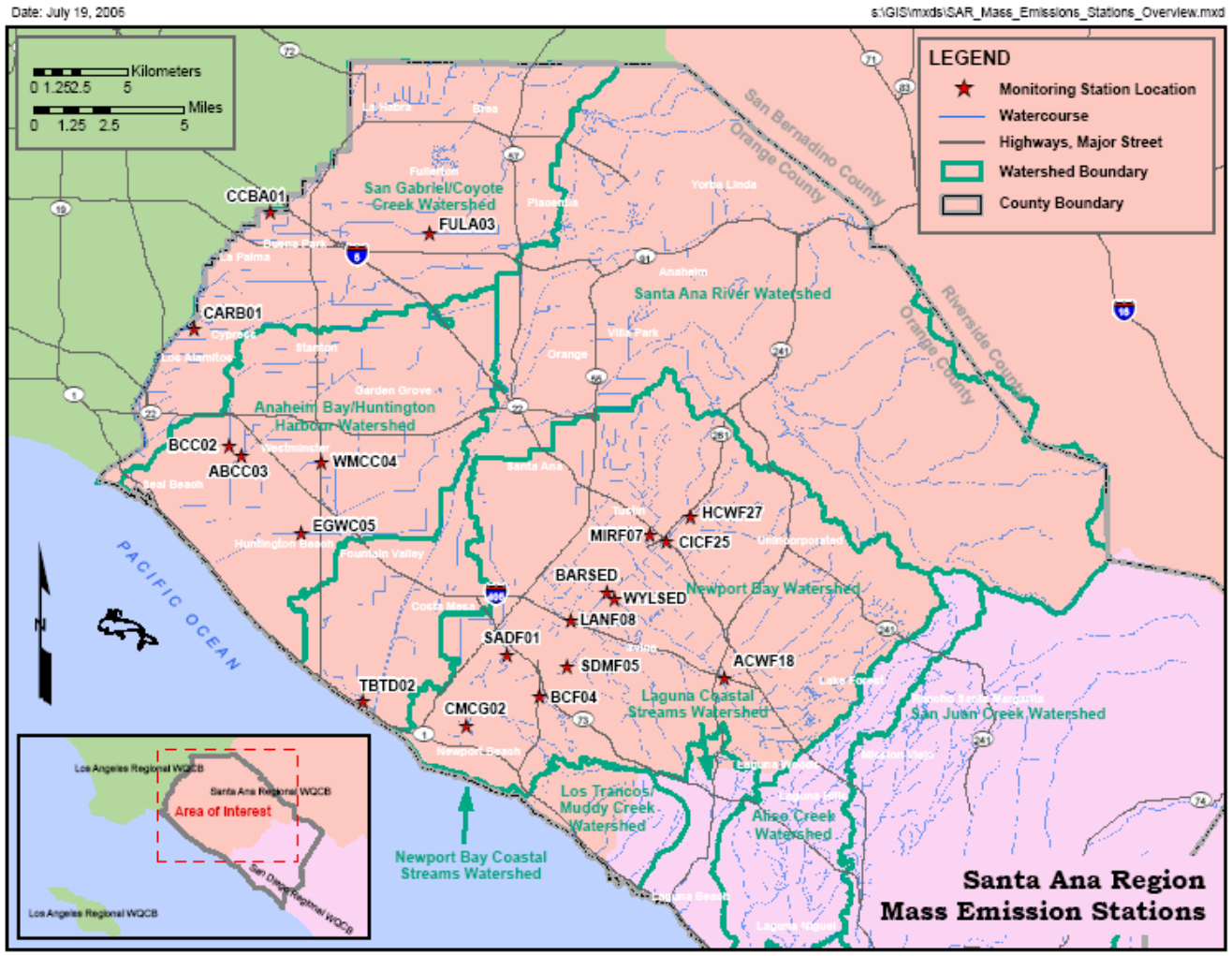
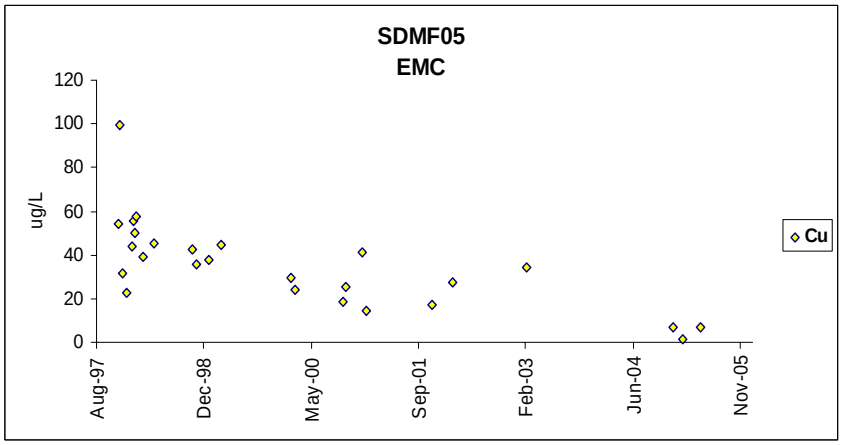


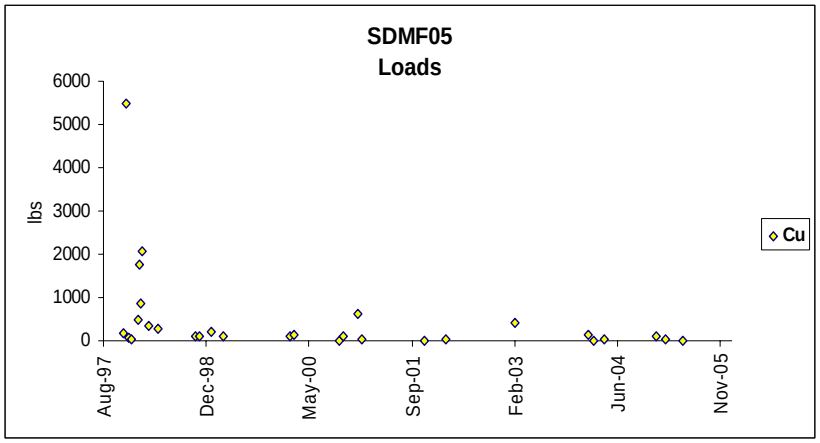
Figure 11.3: Location of the Long-Term Mass Loading Stations

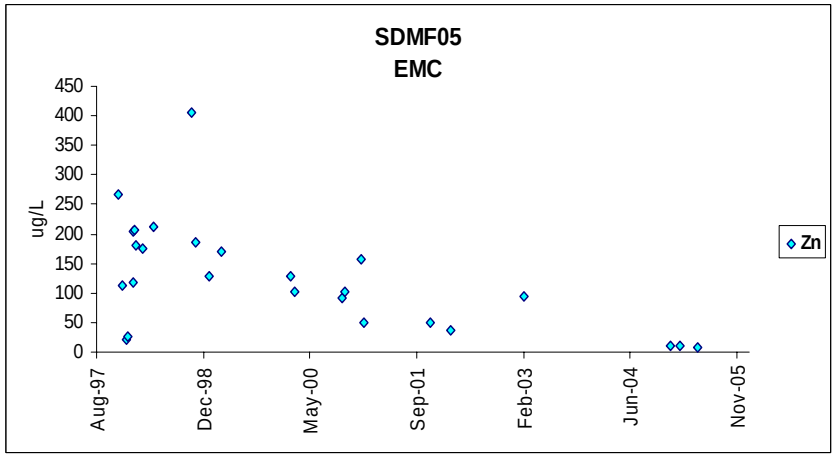


New stations (CARB01, CCBA01, FULA03) are not included in retrospective analyses.

Figure 11.4: Illustrative Trends in Raw EMCs and Loads of Copper and Zinc at San Diego Creek at Campus (SDMF05)







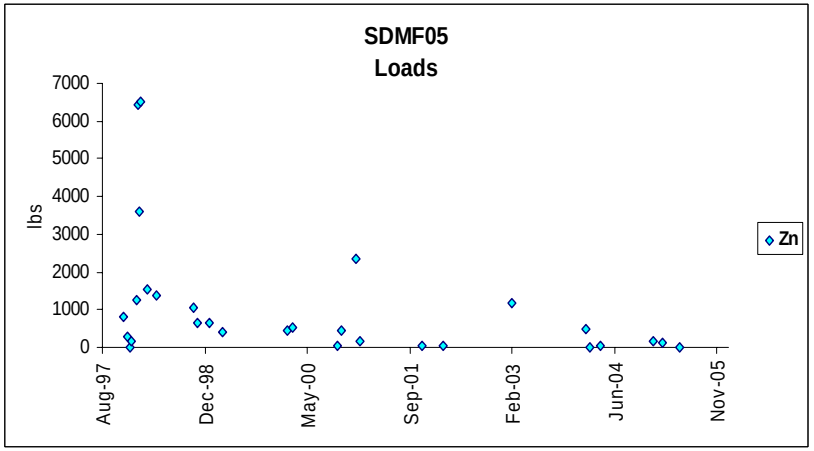
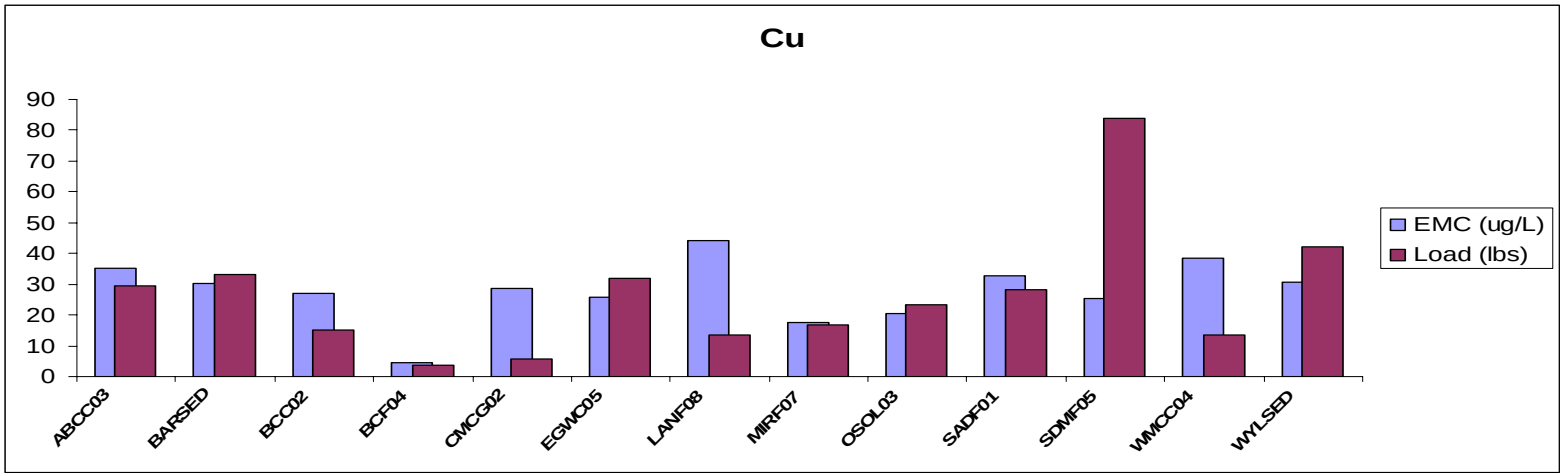
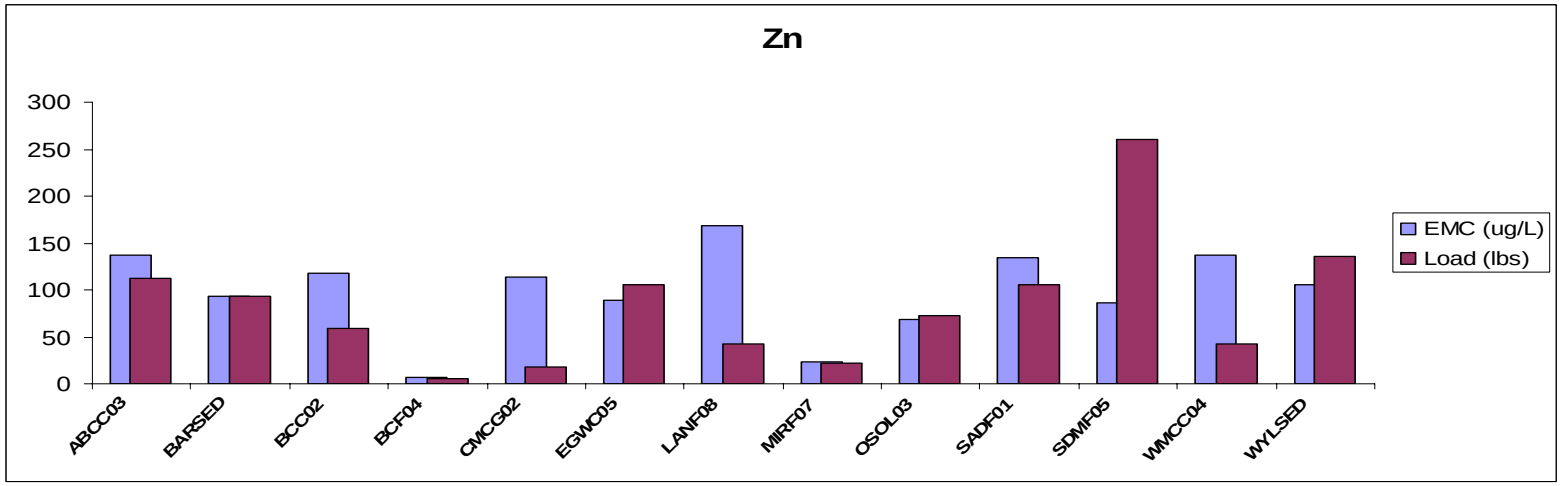


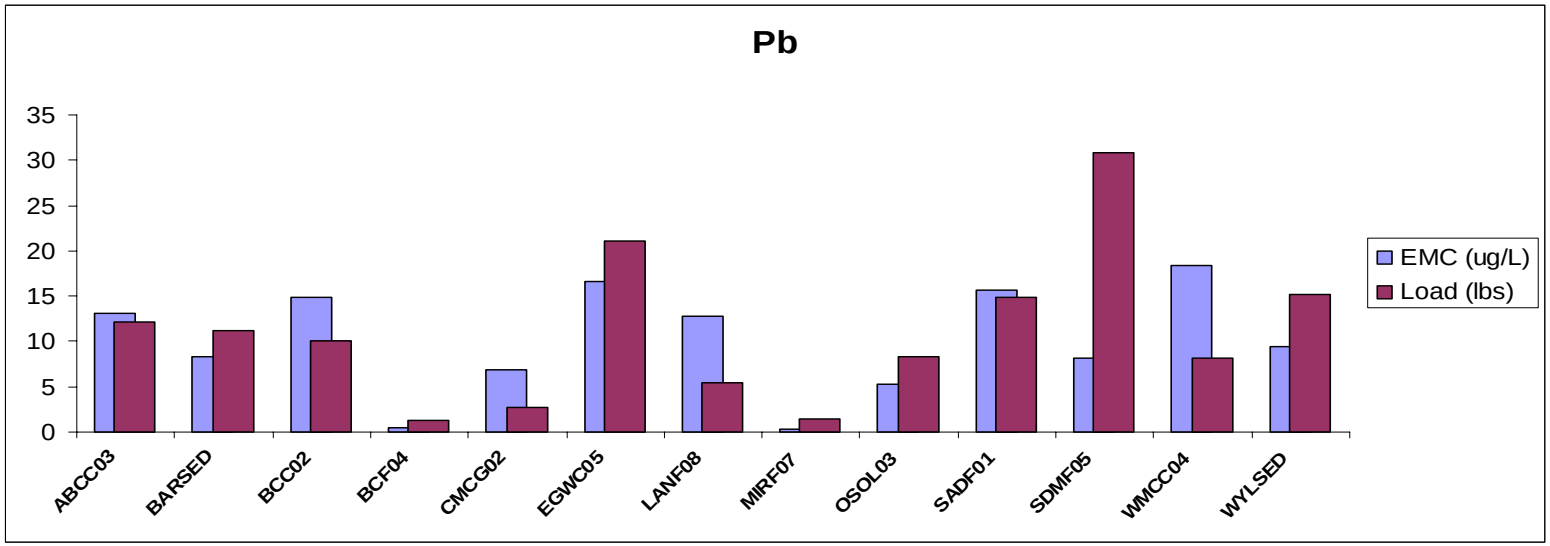
Figure 11.5a: Baseline Levels (Adjusted for TSS) of Total Metals at Long-Term Mass Loading Stations





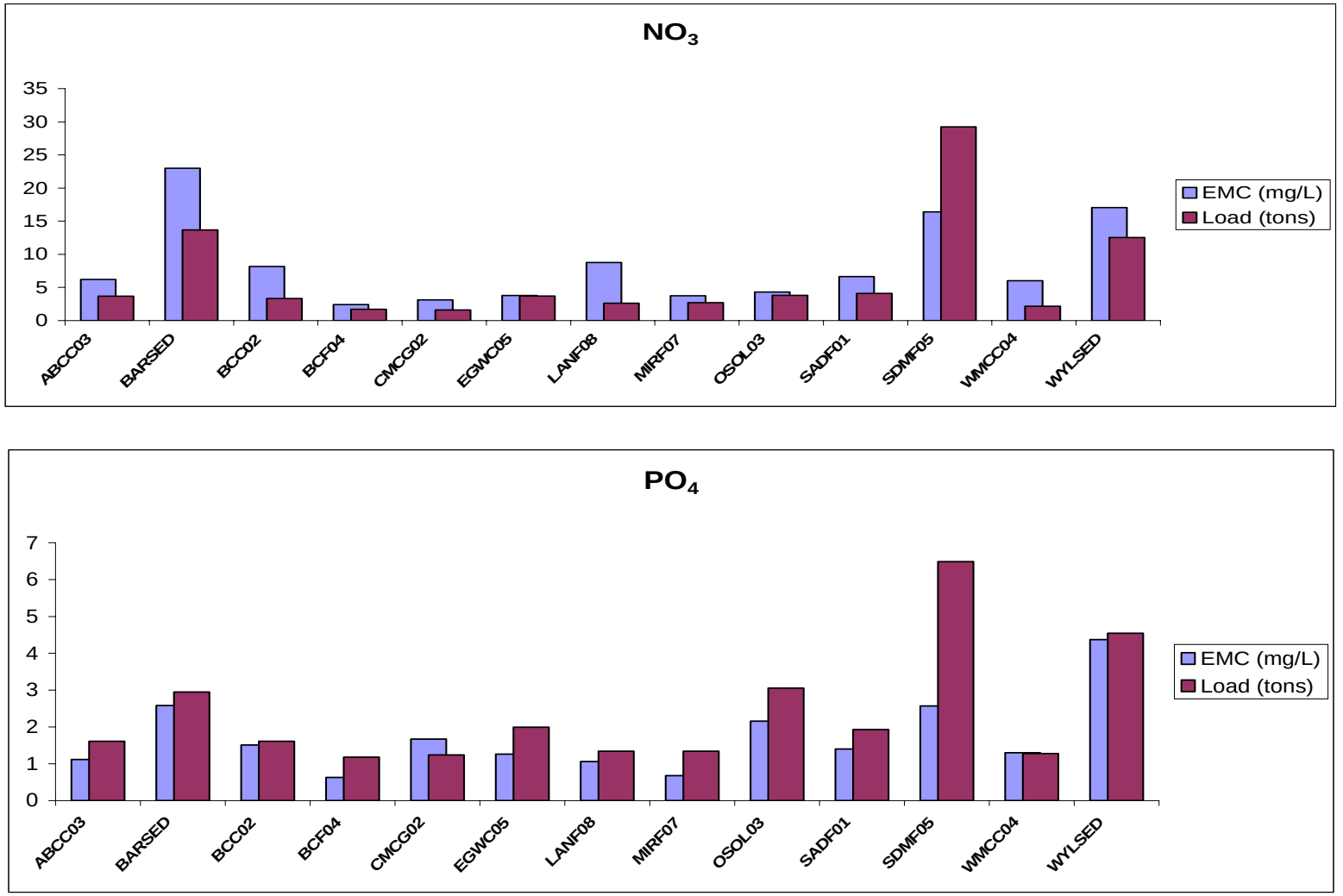
Loads are as pounds per sampling event.

Figure 11.5: Baseline Levels (Adjusted for TSS) of Total Metals at Long-Term Mass Loading Stations



Loads are as pounds per sampling event.

Figure 11.6: Baseline Levels (Adjusted for TSS) of Nutrients at Long-Term Mass Loading Stations



Loads are as tons per sampling event

12.0 WATERSHED ACTION PLANS

12.1 Introduction

The Third Term Permits have, with varying degrees of specificity, required the Permittees to develop and implement a watershed-based approach to urban stomwater management to complement the established jurisdictional-based approaches. In the area of the County under the jurisdiction of the San Diego Regional Board, Watershed Urban Runoff Management Plans (WURMPs) termed DAMP/Watershed Action Plans[1], have been prepared for each of the six principal watersheds. In the Santa Ana Regional Board area of the County, which has a long history of watershed planning focused on the Newport Bay, the Permittees were required to update Appendix N of the DAMP to reflect the implementation measures and schedules related to the fecal coliform TMDL.

Watershed management is the term used for the approach to water quality planning that places an emphasis on the watershed (the area draining into a river system, ocean or other body of water through a single outlet) as the planning area and looks to multi-jurisdictional solutions to problems that cut across programs and jurisdictions. In Orange County, these efforts focus additional effort on the highest priority water quality constituents of concern in each watershed.

The approach taken to develop the DAMP/Watershed Action Plans recognizes that the jurisdictional DAMP/LIPs and the DAMP/Watershed Action Plans represent the principal policy and program documents for two separate, but nonetheless similar and highly interdependent, water quality planning processes targeting the control of pollutants in urban runoff (see **Section 3.0, 2007 DAMP**). There is also recognition that these efforts are, in many watersheds in Orange County, supportive of a third planning process that is focused on achieving broader objectives such as watershed habitat restoration and connectivity rather than specific water quality outcomes.

There are 5 distinct watersheds within the Santa Ana Regional Board area which are identified below:

Region 8	Watershed Planning Area	Major Watercourses
Santa Ana	San Gabriel River/Coyote Creek	Coyote, Carbon, Fullerton, and Brea Creeks
	Anaheim Bay/Huntington Harbour	East Garden Grove Wintersburg Channel/Bolsa Chica Channel
	Santa Ana River (within Orange County)	Talbert Channel, Santiago Creek and Santa Ana River
	Newport Bay	San Diego Creek , Santa Ana Delhi Channel

[1] Previously termed DAMP/Watershed Chapters

	Newport Coastal Streams	Buck Gully, Los Trancos Canyon Creek, Muddy Canyon Creek

12.2 Accomplishments

Through the current Permit term, these watersheds (**Figure 12.1**) have been the focus of a number of continuing environmental restoration and watershed-based water quality planning efforts.

12.2.1 Environmental Restoration Planning Efforts

- **San Gabriel River - Coyote Creek**: Coyote Creek - Lower San Gabriel River Watershed Feasibility Study:

  The Army Corps of Engineers (ACOE) has commenced a Feasibility Study for the Coyote Lower San Gabriel River Watershed. The purpose and goal of the Study is to develop a rehabilitation plan and identify projects for ecosystem restoration, recreation, water quality improvement and resolve some flooding issues. The study will take approximately three years to complete and will be cost shared (50-50) by the Corps and the local sponsor (County of Orange). The watershed is divided between the County of Orange and the County of Los Angeles. Los Angeles County Department of Public Works has also agreed to contribute to the local cost share.

- **Anaheim Bay/Huntington Harbour**: Westminster Watershed Management Plan

  The ACOE is undertaking a comprehensive study of the Westminster Watershed including the East Garden Grove-Wintersburg Channel and the Bolsa Chica Channel in order to develop a rehabilitation plan that will investigate flood control, ecosystem restoration, recreation, water quality and shoreline protection. The Feasibility Study Phase is estimated to cost a total of $5,500,000 and will take approximately three years to complete.

- **Santa Ana River**: Orange Coast River Park

  The goal of the project, being promoted by Friends of Harbors, Beaches and Parks, is to create a shared management structure and identity for a 1000+ acre park at the mouth of the Santa Ana River. At the Park's upstream boundary, is Fairview Park located in the City of Costa Mesa. An extensive restoration project along with a proposed, water treatment and riparian habitat development is in the master plan for the park.

  The Fairview Park Wetlands and Riparian Habitat Project include the restoration of approximately 30 acres containing the following four major design elements:

- 17-acre riparian habitat area;
- 5-acre area of water treatment ponds for water quality improvement and percolation;
- 13-acre area of upland habitat including a 2-acre public park; and
- Water delivery system to the ponds and riparian area from a modified pump station along the Greenville-Banning Channel.

Existing dry weather flows, currently being pumped to Orange County Sanitation District (OCSD) from nearby Greenville-Banning Channel, will be diverted into the wetlands where it will flow through a series of engineered wetland channels and infiltration ponds. Water diverted into the wetlands will be infiltrated into the groundwater or removed through evapotranspiration as well as support riparian habitat throughout the park. The completed project will include walking paths, flow diversion structures and bridges located amongst a series of streams and channels covered with thick wetland vegetation.

- **Newport Bay**: Upper Newport Bay Ecosystem Restoration Project

  The project includes expanding and deepening the two In-Bay Basins and relocating a tern island from the upper basin to the lower basin. Restoration measures include wetland creation and restoring degraded habitat. In addition, the project will support sediment TMDL goals. The project is cost-shared with the ACOE. The cost apportionment for this ecosystem restoration project require Federal interests to provide 65% of the total costs, which is estimated to be $38.4 million, and the County of Orange as the local sponsor to pay 35% through California Coastal Conservancy Bond funds. Dredging commenced in spring 2006.

- **Newport Bay**: Newport Bay/San Diego Creek Watershed Management Plan and Feasibility Study

  The ACOE is conducting a study to develop a comprehensive framework to improve the health of the Newport Bay/San Diego Creek watershed. The process will address the protection and enhancement of watershed habitats, flood protection, water quality improvements, and reduction of erosion and sedimentation. A draft Newport Bay/San Diego Creek Watershed Feasibility Study Report was released in October 2005 and will be finalized in 2006-07.

12.2.2 Watershed-Based Water Quality Planning Efforts

- **San Gabriel River / Coyote Creek**: San Gabriel River Watershed Monitoring Workgroup

  The Los Angeles County Sanitation District is required, as a condition of its NPDES Permit, to work with all agencies and interested parties in developing a watershed-wide monitoring program for the San Gabriel River Watershed. The project's ongoing planning and implementation is coordinated by the Southern California

Coastal Water Research Project (SCCWRP) and Brock Bernstein, PhD. A first round of sampling was completed in 2005 and a second round was completed in June of 2006. The County, as Principal Permittee, is participating in this workgroup which is facilitated by the Los Angeles River – San Gabriel River Watershed Council.

- **Santa Ana River**: Talbert Channel and Lower Santa Ana River Water Quality Diversions and Investigation

  On October 15, 1999, the Santa Ana Regional Board issued a Section 13267 Directive to the County of Orange and five cities concerning bacteriological water quality impairments in the Talbert and Lower Santa Ana River watersheds that maybe affecting surfzone water quality. In response to the Regional Board's Directive, the County of Orange constructed dry weather urban runoff diversion projects in four flood control facilities [Huntington Beach Pump Station (D01PS1), Talbert Channel (D03), Santa Ana River (E01); and Greenville Banning Channel (D03)] for the diversion of all dry weather urban runoff in the Talbert – Lower Santa Ana River Watershed, an area of 16,575 acres. Similar diversion actions were taken by the City of Huntington Beach at a number of pump stations. The project goals were to divert dry weather urban runoff from the watershed year round and reduce the number of beach postings and closures due to high bacteria counts at the Huntington Beach State Beach.

  On December 24, 2003, the Santa Ana Regional Board issued a second California Water Code Section 13267 letter to the County of Orange and five cities in the area of the Talbert and Lower Santa Ana River watersheds. The letter specifically requested a special investigation into any drains downstream of the diversions to determine if these non-diverted drains were contributing to bacteriological water quality impairments at Huntington State Beach. This letter was subsequently revised by the Regional Board on February 3, 2004 to rescind the 13267 requirements on two of the cities as their land area is entirely upstream from the point of diversion. The requested investigation was conducted in the Spring of 2004 and a full report was delivered to the Regional Board. The investigation determined that there were twenty one (21) non-diverted drains, but the majority did not show any evidence of discharge. In a September 10, 2004 letter from the Regional Board, a few drains were identified for follow-up investigations to ensure that no discharge was occurring. These follow-up investigations were conducted from 2004 through 2005 and a final report was delivered to the Santa Ana Regional Water Quality Control Board on July 29, 2005.

- **Newport Bay**: Nitrogen and Selenium Management Program

  The Nitrogen and Selenium Management Program (NSMP) was launched by a group of watershed stakeholders, including all Watershed Permittees, in response to Order No. R8-2004-0021 (NPDES No. CAG998002) issued by the Santa Ana Regional Water Quality Control Board on December 20, 2004. Over the five year permit term, the NSMP Working Group is implementing a comprehensive work plan focusing on

developing watershed based management strategies for groundwater inputs of selenium and nitrogen in the Newport Bay watershed. This work plan has been approved by the Executive Officer of the Santa Ana Regional Board and the key elements of the work plan include, (1) collecting additional data to fill knowledge gaps regarding the movement and impacts and selenium and nitrogen in the watershed, (2) examining Best Management Practices (BMPs) and treatment technologies that can reasonably and effectively be applied in the watershed, (3) developing an offset, trading, or mitigation program for both selenium and nitrogen, (4) using the increased knowledge and treatment opportunities developed in previous tasks to evaluate the Nutrient TMDL, and (5) if appropriate, develop a site specific objective for selenium.

The National Water Research Institute (NWRI) has assembled an independent advisory panel to evaluate key work products and provide recommendations to the NSMP Working Group. In particular, the independent advisory panel will be providing a recommendation on whether or not a site specific objective for selenium is appropriate for the Newport Bay watershed.

In addition to entities regulated by the permit, the Santa Ana Regional Water Quality Control Board, Orange County Coastkeeper, and Stop Polluting Our Newport (Dr. Jack Skinner) are serving as Participatory Members of the NSMP Working Group. As Participatory Members, these three entities are providing key public input and feedback to the NSMP Working Group but are not financially responsible for implementing the work plan.

The NSMP Working Group currently consists of twenty members:

- County of Orange
- Orange County Flood Control District
- City of Costa Mesa
- City of Irvine
- City of Laguna Hills
- City of Laguna Woods
- City of Lake Forest
- City of Newport Beach
- City of Orange
- City of Santa Ana
11. City of Tustin
12. California Dept. of Transportation
13. Irvine Ranch Water District
14. The Irvine Company
15. Golden State Water Company
16. Tustin Legacy Community Partners
17. Lennar
18. The Great Park Corporation
19. Nexus Construction Services
20. Maguire Properties

In a separate, but related effort, the Newport Bay Watershed Permittees, the Irvine Ranch Water District, and The Irvine Company funded a special study in the San Joaquin Marsh and San Diego Creek to investigate concentrations of selenium in key parts of the food web, including benthic invertebrates, plants, sediment, and water. The study was conducted by Dr. Alex Horne and the final report has been completed.

- **Newport Bay**: Newport Bay Watershed Nutrient Total Maximum Daily Load

(TMDL)

The nutrient TMDL establishes targets for reducing the annual loading of nitrogen and phosphorus to Newport Bay by 50% and meeting the numeric and narrative water quality objectives by 2012. To achieve these targets, the TMDL establishes a number of interim targets requiring a 30% and 50% reduction in nutrients in summer flows by 2002 and 2007, respectively, and a 50% reduction in non-storm winter flows by 2012.

The Newport Watershed Permittees have evaluated compliance with the TMDL targets (Newport Bay Watershed TMDL Compliance Evaluation, Tetra Tech, July 2000). The report indicated significant compliance with the 2002 targets and slight nutrient loads in excess of the future targets. It concluded that current programs are working and that further minor program revisions will achieve all TMDL targets.

The findings of the compliance studies are further supported by nutrient loading studies that were conducted by the Principal Permittee in September 1999, June 2000, May 2001, and May 2003. These studies demonstrate compliance with the 2002 target based on extrapolation of the data collected to date. This assessment was verified when analysis of the summer 2002 water quality data illustrated the reduction of nutrient loading in the Newport Bay watershed was greater than the 30% reduction target.

In February 2000, the Principal Permittee on behalf of the Watershed Permittees, initiated the Regional Nutrient Monitoring Program (RMP) for the Newport Bay and its watershed pursuant to the requirements established by the Santa Ana Regional Board (Resolution 99-77 to establish an RMP pursuant to the TMDL). Annual data analysis reports have been submitted each November to document watershed nutrient concentrations and loadings, algal biomass and bay nutrient concentrations. Analysis of the RMP watershed and bay data indicate compliance with the 2002 and 2007 TMDL targets. At the request of the Regional Board, beginning in 2006, the Principal Permittee will begin submitting quarterly data analysis reports and data transmittals.

In addition to the routine watershed and bay monitoring, the RMP requires several special studies to be conducted. Progress on the special studies is described below.

° Newport Bay Watershed Nutrient TMDL – Dissolved Oxygen (DO) and Algae Distribution Grant Study

  In March 2005 the Principal Permittee on behalf of the Watershed Permittees was awarded a $250,300 Prop. 13 grant from the State Water Resources Control Board to conduct The Newport Bay Nutrient TMDL DO and Algae Distribution Study. The study characterized the dissolved oxygen and macroalgae regimes of Upper Newport Bay (UNB) by completing two special investigations identified in the Nutrient TMDL RMP. First, the spatial and temporal extent of hypoxia/anoxia

in UNB will be determined. Then, to determine if there is a quantitative relationship between intertidal macroalgal abundance and the frequency of hypoxic events, macroalgal abundance will be estimated using remote sensing techniques during the period of deployment of DO sensors in UNB. These data are essential in determining the relationship, if any, between hypoxia/anoxia and macroalgal abundance. A final report is due at the end of October 2006.

° Newport Bay Watershed Nutrient TMDL – Urban Nutrient Special Investigations

A Proposition 13 grant was received in 2003 to fund a characterization study of the sources and magnitude of urban nutrient loading. The specific study objectives were to: (1) Quantify nutrient loading of dry weather runoff from urban residential and business areas which drain to Upper Newport Bay; (2) Identify and characterize runoff quality of specific urban activities and sources which contribute to urban nutrient loading from each study area, and (3) Estimate to what extent urban runoff quality may be influenced or compromised by infiltration of shallow groundwater into the drainage network. The grant amount was $295,000 with $100,000 matching funds from the Watershed Permittees. Field work for these investigations was completed in 2004, and draft final reports of research findings and project accomplishments were completed in the spring of 2006.

Mean TIN areal loading rates ranged between 0.029 – 0.415 lb/acre-year across study areas, while TN loading rates ranged between 0.242 – 1.228 lb/acre-year. Mean TP areal loading rates varied between 0.019 - 0.232 lb/acre-year. Areal loading rates were substantially lower in the Costa Mesa study areas than in the San Diego Creek watershed study areas for all three parameters. There was no apparent meaningful difference between loading based on land use (residential vs. business).

Findings in the Como Channel study area demonstrated that dry weather discharge and related contaminant loadings from confined pipe systems in areas of the San Diego Creek watershed should not be presumed to be exclusively from surface runoff. It was conclusively demonstrated that shallow groundwater infiltration into the storm drain system contributed 27% of dry weather discharge from the study area, and comprised a disproportionately high 84% of the NO3/NO2-N load of what was ostensibly an urban area discharge. This finding likely applies to all urban areas which overlie the nitrate-rich shallow groundwater area in the center of the San Diego Creek - Peters Canyon Wash watershed.

- **Newport Bay**: Newport Bay Watershed Sediment TMDL

The TMDL allocation for sediment in the Newport Bay Watershed was approved in March 1999. The objectives of the TMDL are to reduce the annual average sediment

load in the San Diego Creek watershed from a total of 250,000 tons per year to 125,000 tons per year, thereby reducing the sediment load to Newport Bay to 62,500 tons per year and limiting sediment deposition in the drainages to 62,500 tons per year within 10 years (a 50% reduction) and to lower the frequency of dredging within the Bay.

To comply with the sediment TMDL, an annual report has to be submitted to the Santa Ana Regional Board by November 15 of each year verifying that the basins have at least 50% capacity and an annual compilation of sediment monitoring data and TMDL compliance analysis is required by February 27 of each year.

In general, the available data suggests that sediment loads in the San Diego Creek watershed have been reduced significantly from rates recorded in the pre-TMDL period. Since implementation of the TMDL, the average suspended sediment load measured at San Diego Creek at Campus Drive has been approximately 55,360 tons per year.

- **Newport Bay**: Newport Bay Watershed Fecal Coliform TMDL

The fecal coliform TMDL establishes a long-term, prioritized, phased approach to meeting recreational contact (REC1) and shellfish harvesting (SHELL) water quality standards in Newport Bay. In response to the 13267 letter, dated January 7, 2000, from the Santa Ana Regional Board, the Newport Watershed Permittees, IRWD and The Irvine Company are currently supporting studies and monitoring in the Bay that are expected to result in the development of a TMDL implementation plan.

To date, work has been carried out in a collaborative manner by the Newport Watershed Permittees with technical support from the Irvine Ranch Water District and their consultants, Eisenberg, Olivieri and Associates (EOA) and Resource Management Associates (RMA). In September 2001, EOA and RMA issued their final report entitled Public Health Risk Assessment for the Newport Bay Watershed: Recreational Contact and Microbial Risk. Reported findings are that exceedances of Basin Plan fecal coliform objectives for REC-1 beneficial use are temporally sporadic and geographically limited and that they generally occur during the time of year when REC-1 use is low or in areas of the bay where the level of body contact recreation is low or prohibited. Additionally, the risk of enteric viral disease from body contact recreation in Newport Bay is well below EPA's "accepted illness rate" of 19 illnesses per 1,000 swimmers for recreation in marine waters. The report also indicates that the urban runoff identified in the Clean Water Act 303(d) listing as the likely source of pathogens in Newport Bay do not substantially impact the risk to public health from body contact recreation.

A Proposition 13 Grant has been obtained to conduct a set of field studies that will provide data necessary to identify and prioritize urban and natural sources of fecal coliform to the Bay. This data will provide the basis for the formulation of a Fecal Coliform Source Management Plan needed to implement the fecal coliform TMDL

for Newport Bay. The field studies are designed to provide information on Bay-wide impact of fecal indicator bacteria from urban and natural sources, measurement and prioritization of specific urban sources in Lower Bay, estimates for the magnitude and kinetics of within-Bay natural sources and processes that affect the concentration of fecal indicator bacteria in the water column, and information on the communicy structures and species abundance of *Enterococcus* and relatedness of *E. Coli* strains in the bay. The grant award amount for the studies is $780,000 with a $50,000 match provided by the Watershed Permittees and others.

- **Newport Bay Fecal Coliform TMDL - Shellfish Harvesting Beneficial Use Assessment**

The shellfish harvesting beneficial use assessment was initiated in 2003 with the goal of developing recommendations for prioritizing areas within Newport Bay for purposes of evaluation and implementation of cost-effective and reasonable control actions. The primary objectives of the assessment are to: 1) Identify historic areas of bivalve mollusk shellfishing (shellfishing) in Newport Bay; 2) Establish the existing level of the shellfishing resource in Newport Bay; 3) Characterize current levels of shellfish collection (for consumption and bait) as a beneficial use in Newport Bay; 4) Investigate impediments to, and the possibility of enhancing the potential for, increased levels of shellfish collection in Newport Bay, and; 5) Document the results of the investigation in a manner that will be useful to the Regional Board for decision-making purposes.

Both qualitative and quantitative surveys were conducted to identify the current extent of intertidal shellfish resources in Newport Bay. The results of these surveys indicate large differences in the composition and abundance of shellfish in Lower Newport Bay compared to Upper Newport Bay. Shellfish species that are of potential interest to shellfisherman for consumption are predominantly located in Lower Newport Bay, despite the fact that this region has only 5 percent of the intertidal habitat found in Upper Newport Bay.

Two major factors were identified that prevent utilization of this resource by shellfishermen. The most significant is that the populations were found almost exclusively in areas with eelgrass. These areas are not open to shellfishing since Section 30.10 under Title 14, Chapter 4, Article 1 of the California Code of Regulations prohibits cutting or disturbance of eel grass. A second factor was the size composition in the Bay. Only three out of 419 littleneck clams collected from Lower Newport Bay met the legal minimum size of 38.1 mm (1.5 inches) under California's Ocean Fishing Regulations. One-third of the Venus clams that were collected from this region met the size limits for harvesting but overall abundances were 25% of the littleneck clam population. Many factors may have influenced the size composition of littleneck clams including possible differences in annual recruitment and survival of littleneck clams over the past five to 10 years.

The beneficial use data collection program surveyed 1,100 individuals. Over 99% of those respondents who collect shellfish in Newport Bay reported doing so for fishing bait. Mussels collected from piers, pilings, and docks are the most common shellfish targeted by fishermen. On rare occasions, fishermen were also observed to use clams as bait. Only two individuals interviewed reported that they had consumed shellfish. In both cases, the shellfish collected and consumed were mussels. Based upon the beneficial use surveys, it is clearly evident that intertidal clam populations in Newport Bay are not currently being used for human consumption.

The cost of the Beneficial Use Assessment was $453,000 provided by the Watershed Permittees and others.

- **Newport Bay**: Newport Bay Watershed Toxics TMDL

On June 14, 2002, EPA Region 9 established the Toxics TMDL for the Newport Bay Watershed. The Santa Ana Regional Board is currently splitting the EPA promulgated Toxics TMDL into five separate constituent and geographically specific TMDLs. The five resulting TMDLs will include (1) diazinon and chlorpyrifos, (2) organochlorine compounds, (3) selenium, (4) metals, and (5) Rhine Channel. Each of these individual TMDLs must proceed through the full approval process before they are officially adopted and made a part of the Basin Plan. Currently, the only TMDL to complete the approval process is the diazinon and chlorpyrifos TMDL. The Santa Ana Regional Board approved an amendment to include the diazinon and chlorpyrifos TMDL on April 4, 2003.

A Pesticide Research and Identification of Source and Mitigation (PRISM) grant was received in 2005 to evaluate legacy organochlorine pesticide mass loadings with respect to geographic location, flow, sediment particle size, and total organic carbon within the watersheds. The information gathered by the study will assist with the evaluation of waste load allocations and the development of an implementation plan for the Organochlorine Compounds TMDL. The PRISM Grant provides $188,254 for this study with a match of $9,906 by the Watershed Permittees and others.

Samples from approximately five storms were collected during the 2005-06 storm season (September – April). Storm and dry season sampling will conclude in 2006 with a final report due in 2007.

- **Newport Coastal Streams:** City of Newport Beach Initiatives

The Newport Coast Watershed area covers about 10 square miles and eight coastal canyons it extends south of Corona Del Mar in Newport Beach to El Morro Canyon in Crystal Cove State Park. Two of the canyons are 303(d) listed and the entire watershed drains to one of two ASBS's (the Newport Beach Marine Life Refuge and/or the Irvine Coast Marine Life Refuge). The following actions are under way by the City of Newport Beach to address canyon degradation, ASBS concerns and

the 303(d) listing:

- Initiated a erosion control project in Buck Gully;
- Performing canyon stability inspections of Buck Gully, Los Trancos and Muddy Creek;
- Preparing a Watershed Management Plan for each of the eight canyons;
- Performing a series of investigations to determine primary sources of degradation to the ASBS's (Public Use Study, Canyon flows and water quality, cross contamination investigation from Newport Bay);
- Reducing negative impacts to the two Marine Life Refuge Areas (ASBS's) by reducing unnatural dry-weather canyon flows and improving storm-flow water quality;
- Working with IRWD, Coastkeepers, California Department of Parks and Surfriders to expand educational and training programs and expanding the City's Tide Pool Ranger Program;
- Implementing a continuing program of flow and water quality monitoring for the canyons;
- Implementing a suite of canyon water quality BMP's (wetland improvements, native plantings, grade control structures, retention basins, a watershed ET controller retrofit program), and
- Implementing a series of structural and non-structural BMP's (increased WQ enforcement, increased street sweeping, installation of catch basin screens, and educating the community relative to over-watering and runoff)

In addition, the following actions have been competed:

- A canyon stabilization project in Morning Canyon;
- A draft groundwater seepage study;
- A draft Landscape and Irrigation Ordinance (to be reviewed with City Council), and
- A Runoff Reduction Program to address dry-weather runoff.

12.3 Assessment

Four separate, but nonetheless highly interrelated, planning processes have continued to develop through the period of the Third Term Permits. These processes are (1) DAMP/LIP focused Countywide implementation of a baseline of BMPs, (2) DAMP/Watershed Action Plan focused on enhanced BMP implementation targeting specific constituents of concern, (3) IRWD's Natural treatment system designed to treat dry weather runoff with man-made wetlands. The natural treatment system will rely on natural ecosystems to remove sediment, nutrients, pathogens and other contaminants from the runoff and prevent these contaminants from reaching Upper Newport Bay, and (4) a process that is focused on achieving broader objectives such as watershed habitat restoration and connectivity rather than specific water quality outcomes. The first three processes align with the CWA's interim goal, which is to attain water quality sufficient to provide for the protection and propagation of fish, shellfish, and wildlife and for recreation in and on the water. The third process aligns with the over-arching objective of the CWA which is to restore and maintain the chemical, physical

and biological integrity of the nation's waters. While the interim goal is subordinate to the broader objective, it nonetheless continues to be the primary focus of the Permittees efforts since it is the basis of the long-established NPDES permitting framework to which the Permittees, as a consequence of Section 402(p) of the CWA, are subject.

12.3.1 Environmental Restoration Planning Efforts

The Permittees' environmental restoration efforts focused on ecological outcomes are broad stakeholder initiatives rather than permit compliance driven planning processes, and are predominantly cooperative projects with the ACOE. Federal funding of ACOE watershed management and restoration initiative will continue to be a major determinant of progress with respect to these planning efforts.

12.3.2 Watershed-Based Water Quality Planning Efforts

The Permittees' watershed-based water quality planning efforts are focused on water quality standard attainment; involve the Permittees and other regulated entities, and represent collective and cooperative compliance efforts. In the Santa Ana Regional Board area of Orange County, TMDL promulgation (first addressed in **Appendix N** of the **DAMP**) has resulted in two regulatory approaches, specifically (1) California Water Code 13267 Directives and (2) the incorporation TMDL provisions for nutrients and fecal coliform in the Newport Bay Watershed into the Third Term Permit. The Permittees' response to (and full compliance with) these regulatory initiatives has preceded the development of **DAMP/Watershed Action Plans**. In south Orange County the reverse situation has occurred since the specific WURMP requirements of the Third Term Permits have preceded TMDL development and implementation and led to the creation of six DAMP/Watershed Action Plans**.** These plans are deemed to usefully provide:

- A holistic account of all water quality protection and management activities in the watershed;

- A basis for developing establishing and communicating common goals for the watershed with an action plan to achieve them, and

- A framework for monitoring and assessing the progress of projects individually and cumulatively at the watershed scale.

ROWD Commitment

- Complete **DAMP/Watershed Action Plans** for all 11 Orange County watersheds (See Appendix A: Model Watershed Action Plan prepared as Newport Bay Watershed Action Plan[2]).

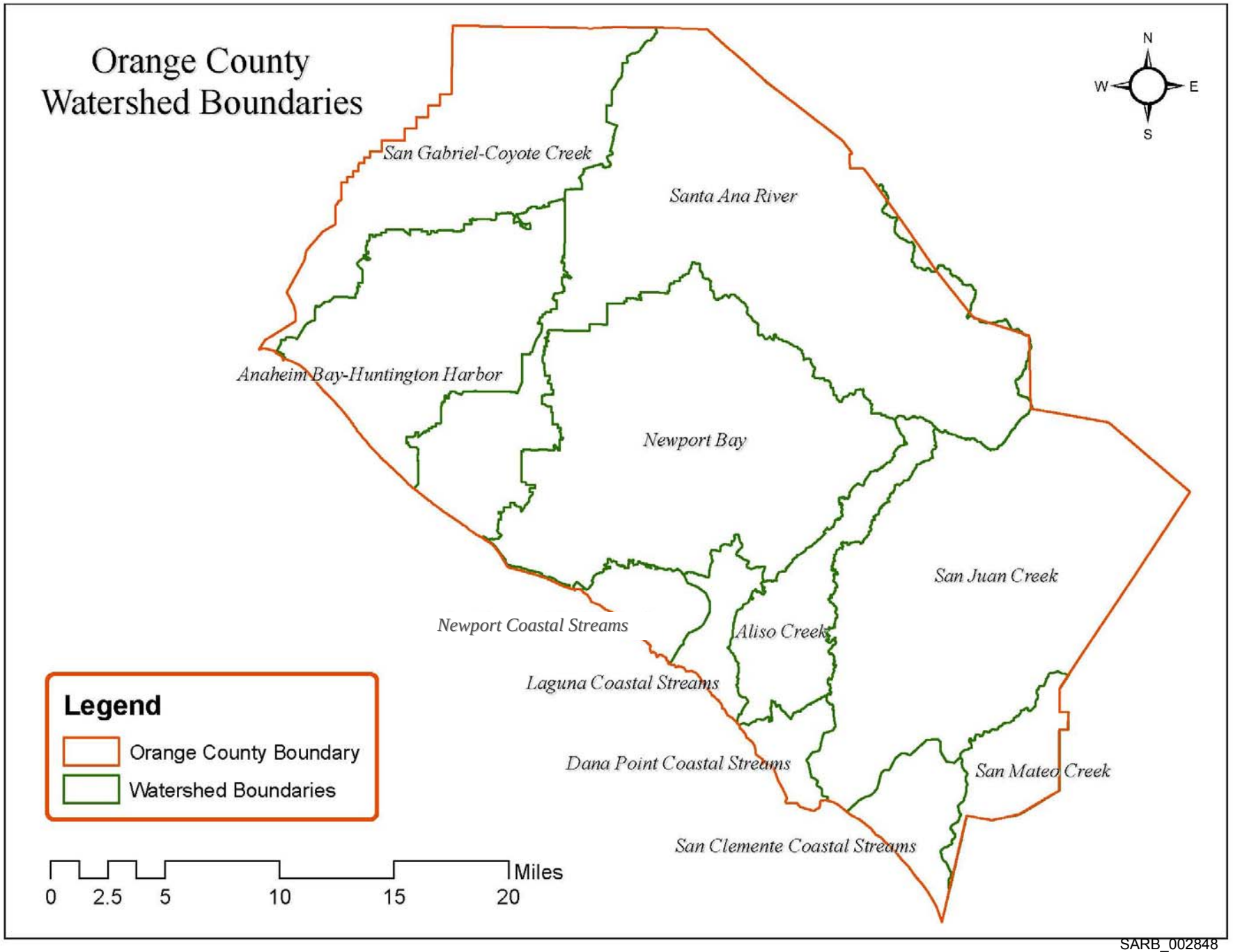
12.4 Summary

The watershed-based approach to water quality planning has been advocated by many constituencies for over 30 years. In Orange County, this approach has been the basis of efforts to protect and manage Newport Bay, notably for sediment, for almost the same period of time. With the completion of **DAMP/Watershed Action Plans** for the south Orange County watersheds and with a number of areas of Orange County facing TMDL implementation over the period of the Fourth Term Permits, these documents essentially represent implementation plans for urban sources of constituents of concern.

[2] The Newport Bay Watershed Action Plan is being presented as a Model DAMP/WAP. It will be presented as a final document with the Annual Progress Report in November, 2006.

SARB_002847

Figure 12.1



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13.0 SUMMARY

13.1 Introduction

From the various sources of information that were used to evaluate program effectiveness, three themes have emerged that frame the Permittees approach to developing the proposed 2007 DAMP. These themes are:

Demonstrating the iterative management approach: Adapting the management program to more effectively address urban sources of pollutants that are causing or contributing to exceedances of water quality standards;

Enhancing Implementation: Improving program implementation through incorporation of auditable environmental management system concepts; and,

Establishing watershed-based water quality planning: On a Countywide basis, creating two separate, but nonetheless highly inter-related, water quality planning processes to address urban sources of pollutants.

Each of these themes is the basis for two types of programmatic recommendations, specifically (1) ROWD Commitments (new programmatic commitments to be developed and implemented over the period of the Fourth Term Permits) and (2) DAMP Modifications (improvements to existing program commitments incorporated into the proposed 2007 DAMP).

13.2 Demonstrating Iterative Management

ROWD Commitments*:*

- Develop Model Integrated Pest Management, Pesticide and Fertilizer Guidelines into a Model Program (rather than guidelines) with implementation goals and including model contract language (see **Section 5.3.2**).

- Develop recommendations for the selection and installation of drain inlet screens (see **Section 5.3.3**).

- Develop model language for municipal trash collection and haulage contracts that address water quality protection issues (see **Section 5.3.3**).

- Develop and implement BMPs for architectural uses of copper and zinc (see **Section 7.3.1**).

13.3 Enhancing Implementation

ROWD Commitments:

- Prepare a training schedule and define expertise and competencies for

jurisdictional program manager positions (see **Section 2.3.2**).

- Prepare a fiscal reporting strategy based upon an audit of the fiscal analysis reporting section of the PEA, to better define the expenditure and budget line items included in the fiscal report (see **Section 2.3.4**).

- Prepare metric definitions and guidance to improve efficacy of the assessment process.

- Standardize SDR and SAR definitions of "High" priority and develop prioritization process that is better predicated on the threat (diminished by BMP implementation) posed by the facility, and consider the presence of "constituents of concern" (see **Section 5.3.1**).

- Redefine IPM (pesticide use) indicators (see **Section 5.3.1**).

- Prepare guidance documentation and clarify requirements or conceptual Project WQMP (see **Section 7.3.1**).

- Prepare guidance and training as needed on the recordation process (timing and appropriate documents to use) and develop recommendations for appropriate methods to employ to enable the Permittees to enforce the approved WQMP against subsequent property owners (see **Section 7.3.1**).

- Develop library of BMP performance reports (see **Section 7.3.1**).

- Develop standard design checklist/plans/details for source and treatment control BMPs (see **Section 7.3.1**).

- Develop recommendations/guidance for enhanced Model WQMP language regarding Site Design BMPs (see **Section 7.3.1**).
-
- Evaluate the NTS approval process and develop recommendations for streamling regulatory agency approval of regional treatment control BMPs (see **Section 7.3.1**).

- Prepare a training schedule including defined expertise and competencies for staff with WQMP review and approval responsibilities (see **Section 7.3.1**).

- Prepare a training schedule including defined expertise and competencies for construction inspectors (see **Section 8.3.1**).

- Develop a more detailed prioritization process to improve standardized reporting and to support re-direction of inspection resources to significant sources of priority constituents of concern (see **Section 9.3.1**).

- Develop effective alternative to re-inspection such as self-certification (see **Section 9.3.1**).

- Prepare defined expertise and competencies for authorized inspector positions and develop a training schedule to meet these requirements (see **Section 9.3.1**).

DAMP Modifications:

- Revised the DAMP for greater consistency with established Environmental Management System (EMS) principles and improved accessibility to different constituencies and levels or readership (see **Section 2.3.3**).

- Revised **DAMP Section 3.0 plan improvement process** to detail iterative process for DAMP improvement (see **Section 3.3.1**).

- Defined "fixed facilities," "field programs," and "drainage facility sites" (see **Section 5.3.1**)

- Eliminated Environmental Performance Reporting (EPR) program (which is duplicative of Model Municipal Activities Program) (see **Section 5.3.1**).

- Revised Model WQMP Table 7.II.6 for latest information on BMPs and clarity (see **Section 7.3.1**).

- Evaluated and revised (as necessary) prioritization provisions for Countywide consistency (see **Section 7.3.1**).

- Provided definitive construction site prioritization guidance (see **Section 8.3.1**).

- Clarified inspection frequencies; violation definitions and re-inspection (see **Section 9.3.1**).

- Provided definitive industrial and commercial facility descriptions (see **Section 9.3.1**).

13.4 Establishing Watershed-Based Water Quality Planning

ROWD Commitment:

- Complete DAMP/Watershed Action Plans for all 11 Orange County watersheds (see **Section 12.3.2**).

February 13, 2008

Mr. Michael Adackapara
Division Chief
Santa Ana Regional Water Quality Control Board
3737 Main Street, Suite 500,
Riverside, California 92501·3348

RE: Comments on Tentative Order No. R8-2008-0030

Dear Mr. Adackapara,

Thank you for accepting these comments on Tentative Order No. R8-2008-0030. There are commendable improvements in direction in the draft permit, notably the emphasis on low impact development (LID) and hydromodification. However, refinement of sections containing these new requirements is needed. In particular, reliance on a 5% Effective Impervious Area (EIA) standard to be applied on a site by site basis is inappropriate and without associated runoff reduction standards is likely to be counterproductive. Although the 5% EIA standard has been called a measurable performance standard it is more accurately described as a prescriptive site design criteria. Unfortunately this design criterion can be applied in lieu of actual treatment or runoff reduction standards in this permit. The water quality benefits of applying a 5% EIA standard on a site by site basis are unknown, and this standard should not be considered to provide adequate protection.

Rather than recounting the potential pitfalls of including this standard in the permit, and in the interest of brevity, I wish express my support for the approach outlined in the January 2009 white paper entitled "Low Impact Development Metrics in Stormwater Permitting" which has been circulated to the Board and permittees. In particular, the paper emphasizes the need for a measurable LID BMP performance standard which it defines as the difference between the pre-development and post-development runoff volume resulting from the water quality design storm event. This is a clear standard that will substantially mitigate hydromodification effects as well.

While control of the entire water quality event with LID BMPs will not be feasible on all sites, the alternatives proposed in the report provide sufficient off-ramps for those projects where site constraints limit their use. In particular, the proposed reductions in the LID design runoff volume for infill and redevelopment projects are important incentives that will encourage development in these areas.

The move toward on-site retention and beneficial reuse of stormwater is a critical part of a sustainable stormwater management strategy and also has well documented water supply and energy benefits. The approach outlined in the LID metrics paper makes important progress toward requiring that LID BMPs are given adequate consideration on all sites. However, there are additional components of the program that are given limited attention either in the paper or in the

CONTECH CMP DETENTION SYSTEMS
CDS
The Stormwater Management StormFilter
Vortechs
CONSPAN DETENTION SYSTEMS

report. Specifically water quality treatment and LID BMP inspection and maintenance requirements are not well developed.

Any BMP that removes pollutants must be maintained periodically to remove those accumulated pollutants. This requires regular inspection of those BMP processes that are relied upon to provide treatment or hydrologic control. For example, the infiltration rate of infiltration BMPs should periodically be investigated, and regeneration of the infiltrating surface should be scheduled when that infiltration rate drops below the initial design rate. In the draft permit, it is not clear that this kind of ongoing inspection and maintenance is required for LID BMPs. Sections XII.F-I only apply to "structural treatment controls". It is unclear if this category includes the pervious areas that are intended to reduce the EIA of the site or LID BMPs. All BMPs with a water quality or quantity control function should be subject to the requirements of sections XII.F-I.

Post construction treatment controls are addressed directly in section XII.C.3 of the permit which states that "pollutants in post-development runoff shall be reduced using controls that utilize best management practices." There is no guidance regarding which BMPs should be selected or what level of performance those BMPs must provide. This standard is clearly inadequate.

Minimum BMP based treatment requirements should be included in the permit to ensure that effective reduction of pollutants is provided prior to discharge of runoff. The current permit and companion Drainage Area Management Plan (DAMP) include the requirement to treat primary pollutants of concern with BMPs that "have been shown to have either medium or high effectiveness**" (**DAMP Page 7.II-36). DAMP Tables 7-II-2 and 7-II-6 are provided to guide the selection of pollutants of concern and those BMPs that are appropriate for their treatment. This process of identifying pollutants of concern and matching the unit processes inherent in specific BMPs to those pollutants is important, but it is not specifically required by the current permit.

My expectation is that a new and significantly improved draft of this permit will be released at a future date that reflects careful consideration of comments received on the current draft. The changes needed, especially modification or removal of the 5% effective impervious area standard, are substantial and have implications in other sections of the permit. Therefore, I will reserve comments on other issues in anticipation of a revised draft. In the mean time, please contact me if you have any questions.

Sincerely,

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APR 10 2008

Ms. Tam M. Doduc, Chair
Ms. Dorothy R. Rice, Executive Director
State Water Resources Control Board
1001 I Street
Sacramento, CA 95814

Dear Ms. Doduc and Ms. Rice:

I understand that certain specific provisions of the 2001 Municipal Separate Storm Sewer System ("MS4") permit for the County of Los Angeles have been called into question as going beyond what is required under section 402(p) of the CWA. (Commission on State Mandates, File Nos. 03-TC-04, 03-TC-19, 03-TC-20, and 03-TC-21.) The permit conditions at issue are: 1) the requirements for conducting inspections at industrial and commercial facilities including, restaurants and automobile servicing, [Parts 4.C.2.a. and b.] and, 2) the requirement for permittees not subject to the Trash TMDL to locate and maintain trash receptacles at transit stops [Part 4.F.5.c.3.]. California RWQCB, Los Angeles Region, Order No. 01-182, NPDES No. CAS004001 (Dec. 13, 2001). This letter discusses these permit conditions in the context of EPA's expectations for MS4 permits.

Section 402(p) of the Clean Water Act, 33 U.S.C. 1342(p), requires EPA (or authorized states) to issue National Pollutant Discharge Elimination System ("NPDES") permits to regulate the discharge of stormwater from MS4s. Typically, these MS4s are owned and operated by cities and counties. Pursuant to the Clean Water Act, these permits must require the MS4 to: 1) "effectively prohibit" non-stormwater discharges, and 2)"reduce the discharge of pollutants to the maximum extent practicable, including management practices, control techniques and system, design and engineering methods, and such other provisions as the Administrator or the State determines appropriate for the control of such pollutants." 33 U.S.C. 1342(p)(3)(B)(ii) and (iii).

The NPDES regulations require medium and large MS4s to develop stormwater management programs that the permitting authority will consider when developing permit conditions to reduce pollutants in discharges to the maximum extent practicable. Stormwater permitting has generally relied on the use of best management practices ("BMPs"), including both structural and non-structural controls, for achieving compliance with these requirements. The EPA also expects stormwater permits to follow an iterative process whereby each successive permit becomes more refined, detailed, and expanded as needed, based on experience under the previous permit. See, 55 Fed. Reg. 47990, 48052 ("EPA anticipates that storm water management programs will evolve and mature over time."); 64 Fed. Reg. 68722, 68754 (Dec. 8, 1999) ("EPA envisions application of the MEP standard as an iterative process."); Interim Permitting Approach for Water Quality-Based Effluent Limitations in Stormwater Permits (Sept. 1, 1996) ("The interim permitting approach uses BMPs in first-round storm water permits, and

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expanded or better-tailored BMPs in subsequent permits, where necessary, to provide for the attainment of water quality standards"). See also, "Evaluating the Effectiveness of Municipal Stormwater Programs" (January 2008) (http://www.epa.gov/npdes/pubs/region3_factsheet_swmp.pdf). While the standard of "maximum extent practicable" (MEP) allows for flexibility, that flexibility is not boundless and requires some level of vigor. EPA has created a national menu of stormwater BMPs to provide additional guidance concerning appropriate BMPs for stormwater management plans. Other factors to consider in ensuring appropriate controls include "technical feasibility, cost, public acceptance, regulatory compliance, and effectiveness." Building Indus. Ass'n v. State Water Res. Control Bd., 124 Cal. App. 4th 866, 889 (2004). See also "In re Cities of Bellflower, et al.", SWRCB 2000-11.

At the outset, I note the Los Angeles MS4 permit is a third generation Phase I MS4 permit that should be building upon the experiences from previous permits. Both of the provisions at issue here seem well within a reasonable expectation of controls that reduce pollutants to the "maximum extent practicable." EPA regulations at 40 C.F.R. §122.26(d)(2)(iv) set forth the basic elements to be included in a Phase I MS4's stormwater management program. Subparagraph (A) requires a description of "source control measures to reduce pollutants from runoff from commercial and residential areas that are discharged from the [MS4] that are to be implemented during the life of the permit." Subparagraph (B) requires a program for detection and removal of illicit discharges and improper disposal into the storm sewer, including a program for inspections and enforcement. A program for commercial and industrial facility inspection and enforcement that includes restaurants and automobile facilities, would appear to be both practicable and effective. Such an inspection program ensures that stormwater discharges from such facilities are reducing their contribution of pollutants and that there are no non-stormwater discharges or illicit connections. Thus these programs are founded in both 402(p)(3)(B)(ii) and (iii) and are well within the scope of 40 C.F.R. §122.26(d)(2)(iv)(A) and (B).[1]

Similarly, maintaining trash receptacles at all public transit stops is well within the scope of these regulations. Among the minimum controls required to reduce pollutants from runoff from commercial and residential areas are practices for "operating and maintaining public streets, roads, and highways . . . ." §122.26(d)(2)(iv)(A)(3). I believe these requirements are also practical and effective.[2] Moreover, this permit provision is consistent with EPA's national menu

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[1]EPA's "MS4 Program Evaluation Guidance" (January 2007) envisions that an MS4 permit would include a requirement for an inspection program for common industrial/commercial businesses, such as restaurants and gas stations, within the jurisdiction of the MS4. Id. at 76 - 77, 81. The inspection requirements of the LA MS4 permit are consistent with the recommended activities in the Guide.

[2]The provision applicable to the TMDL permittees is also clearly consistent with EPA's 2002 guidance on TMDLs and storm water permitting. "Establishing Total Maximum Daily Load (TMDL) Wasteload Allocations (WLAs) for Storm Water Sources and NPDES Permit

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of BMPs for stormwater management programs, which recommends a number of BMPs to reduce trash discharges. See http://cfpub.epa.gov/npdes/stormwater/menuofbmps/index.cfm?action=browse&Rbutton=detail&bmp=5. Among the recommendations is "improved infrastructure" for trash management when necessary, which includes the placement of trash receptacles at appropriate locations based on expected need. The requirements of the Los Angeles County MS4 permit are consistent with this recommendation. See also, "MS4 Program Evaluation Guidance" (January 2007) at pp. 50, 79. EPA's expectations of the programs to reduce pollutants to the maximum extent practicable specifically refer to control of litter and trash, regardless of whether the particular receiving water is already impaired for trash.

I hope that this explanation helps clarify EPA's expectations for MS4 permit requirements under the Clean Water Act. I look forward to continuing to work with the State on our shared goal of ensuring consistency and effectiveness in storm water permitting as a vital tool in protecting the quality of our waters. Should you have further questions about these issues, please have your staff contact Douglas Eberhardt of my staff at (415) 972-3420 or have your counsel's office contact Laurie Kermish of the Office of Regional Counsel at (415) 972-3917.

Sincerely,

Alexis Strauss 10 April 2008

Alexis Strauss
Director, Water Division

cc: Mr. Michael Lauffer, Chief Counsel
State Water Resources Control Board

Ms. Paula Higashi, Executive Director
Commission on State Mandates

Requirements Based on Those WLAs" (November 22, 2002) which is available at: http://cfpub.epa.gov/npdes/pubs.cfm?program_id=6

6/30/2008

Pesticide Runoff Management Plan

Newport Bay Watershed, Orange County, California

Darren L. Haver, Ph.D.
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Orange County

SARB_002857

Pesticide Runoff Management Plan

Newport Bay Watershed, Orange County, California

Section I. Introduction

On June 14, 2002, the United States Environmental Protection Agency established Total Maximum Daily Loads (TMDLs) for organophosphate pesticides, specifically diazinon and chlorpyrifos, in San Diego Creek and Upper Newport Bay (USEPA 2002). Investigative studies performed prior to establishment of the TMDLs, suggested diazinon and chlorpyrifos were significant contributors to toxicity, as determined by the use of indicator species, in Upper Newport Bay and its tributary, Upper San Diego Creek (Lee and Taylor, 1999, 2001).

On April 4, 2003, the Santa Ana Regional Water Quality Control Board (SARWQCB) adopted USEPA's Diazinon and Chlorpyrifos TMDL along with an implementation plan to reduce aquatic toxicity and thereby improve water quality and protect beneficial uses (SARWQCB, 2003). The implementation plan consists of several key tasks, including the development of a pesticide runoff management plan (PRMP). The objective of the PRMP is not to address specific pesticide active ingredients, such as diazinon and chlorpyrifos, but to propose guidelines for stakeholders to adopt in order to protect the Newport Bay and its tributaries from future pesticide-related impairments. The TMDL envisioned the PRMP as a cooperative project involving local stakeholders and the Regional Board.

In September 2004, the State Water Resources Control Board (SWRCB) awarded a grant to the South Coast Resource Conservation and Development Council (SCRCDC) in partnership with the University of California Cooperative Extension (UCCE), Orange County, to investigate and demonstrate strategies to reduce pesticide runoff from urban areas. The Santa Ana Regional Board requested UCCE to develop a PRMP for the Newport Bay Watershed as part of the grant, and this document is one of the deliverables required by the grant.

The PRMP briefly discusses pesticide use in the Newport Bay Watershed, and then provides recommended actions for reducing pesticide runoff. The recommendations are divided into two categories; broad recommendations targeted towards agencies and regulatory program administrators, and specific recommendations targeted towards pesticide users/applicators, including residents and homeowner associations (HOAs).

These recommendations are intended to address the following issues:

1. Identifying pesticides impacting the Newport Bay Watershed.
2. Eliminating or reducing usage of pesticides with high aquatic toxicity levels.
3. Implementing runoff mitigation strategies for key pesticide users.

Section II. Pesticide Use in the Newport Bay Watershed

Pesticide Use in the Newport Bay Watershed

The California Department of Pesticide Regulation (CDPR) requires records of all pesticide use other than residential use by homeowners. These Pesticide Use Records (PURs) are submitted to CDPR via the local county agricultural commissioner's office, and provide useful information on pesticide use. However, only agricultural production and professional pesticide applications to schools are reported by site. Pesticide applications made by structural pest control operators and professional landscape pest applicators are reported monthly on a county-wide scale and as a result, data are not available to the public on a finer scale, such as zip code or cross streets. In addition, tracking the pesticide use by retail consumers is not required and is often cited by professional pesticide applicators as the most likely source of pesticide impairments.

Prior to extensive development, pesticide use on production agriculture sites was responsible for the majority of pesticides applied in the Newport Bay Watershed. Urbanization of the watershed has resulted in a shift to most pesticide applications being applied by structural and landscape pest control businesses, municipalities, and retail consumers. However, because parks, golf courses, cemeteries, and right-of-ways are considered "agricultural use" for the purposes of CDPR, "agriculture use" is still a significant component of pesticide use reported in the Newport Bay Watershed.

Figure 1 shows the pounds of pesticide applied in Orange County during 2006 to a variety of different urban-related situations by sources required to report usage to CDPR. The largest usage category is Structural Pest Control, which refers to usage of pesticides to protect buildings (structures) against pest infestation. Landscape maintenance and rights of way account for the next largest categories of use. Public Health uses include pesticides used to control mosquito populations. Vertebrate pesticide use controls populations of nuisance pests, such as rats, gophers, voles, and ground squirrels.

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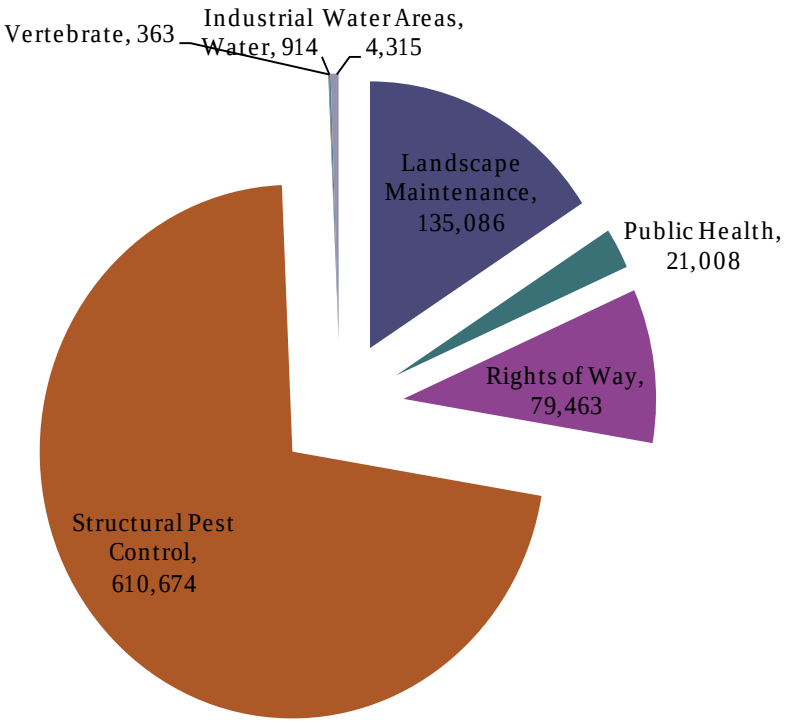
Figure 1. Pounds of Pesticide (A.I.) Applied in Urban-Related Situations in Orange County (2006)



Pesticide source tracking is complicated in urban settings because applications are made to control a variety of pests in complex environments. For example, herbicides are used to control weeds on right-of-ways, residential landscapes, and in water features. Structural pest control businesses treat for termites, household pests, and outdoor pests with the potential to enter structures, such as ants and cockroaches.

Pesticides of Concern

Although classes of pesticides (**Table 1**) exhibit many similar characteristics, toxicity to the target organism, longevity in the environment, and the ability of the pesticide to move from its point of application, may differ considerably. In order for a pesticide to gain federal and state registration, the manufacturer must demonstrate a thorough understanding of a pesticide's impacts on not only the pest but the environment.

Table 1: Pesticide Classes

Organochlorines (Historic use)	Spinosyns*
Organosulfurs	Fiproles
Organophosphates	Pyrroles
Pyrethroids	Pyrazoles
Carbamates	Pyridazinones
Nicotinoids	Quinazolines
Formamidines	Benzoylureas
Dinitrophenols	Botanicals*
Organotins	**Least Toxic Alternatives*

Unfortunately it is nearly impossible to study every possible scenario a pesticide will be utilized under, especially illegal uses, and as a result many unanticipated impacts to the environment will and do occur. For example, synthetic pyrethroids provided an alternative to the more water soluble organophosphate pesticides. Manufacturers, regulators, and consumers believed the strong adsorption properties of the pyrethroids to surfaces would minimize their movement in surface runoff into water bodies. Studies conducted over the last few years have shown that large amounts of sediment and dissolved organic matter containing pesticides with strong adsorptive properties have entered water conveyances where levels in the bed sediments can build up to high levels (Yang et al., Budd et al., Amweg et al., Gan et al.). Bioavailability and toxicology studies still need to be conducted in order to determine the impacts, if any, of these pesticide-laden sediments on aquatic organisms.

The task of managing pesticide runoff and its impact on water quality is more difficult because spatial pesticide data is only available from agricultural production sites and pesticide applications to school sites, which are a small percentage of total pesticide application sites in urban watersheds. Comprehensive pesticide use data of all sources at the watershed level would allow for the development of management strategies directly addressing the specific pesticide inputs at their sources. Without this key spatial data, pesticide management plans must use a less efficient and effective approach of addressing all possible pesticides utilized within the larger urban area to develop strategies to either eliminate/reduce use or implement cost-effective mitigation practices.

Section III. General Program-Level Recommendations

Pesticide Identification Recommendations

Changes to the current pesticide use reporting program administered by the CDPR would require the adoption of new regulations by CDPR. Although CDPR has revisited the pesticide reporting requirements several times, 100% reporting of all pesticide applications, including geo-referenced information, is unlikely to occur in the near future. The Urban Pest Management Working Group, established by CDPR's Pest Management Advisory Committee, to address urban pest management issues, reported a lack of consensus by the members of the work group on the adequacy of pesticide use reporting required by CDPR (CDPR, 2008). Some felt the requirements were not sufficient, while others felt additional requirements were not practical or detrimental to businesses. However, in critical watersheds where the presence of a Toxics TMDL and the extreme sensitivity of the Newport Bay Estuary it would be beneficial to request 100% reporting of pesticide applications made within the Newport Bay Watershed. This would provide the capability to identify sources and result in a higher probability of successful implementation of mitigation strategies. Without the ability to identify specific pesticides and application sites, mitigation strategies are mainly limited to regional approaches, such as Irvine Ranch Water District's Natural Treatment System. Long-term monitoring and tracking of pesticide influent and effluent levels in these treatment systems is required in order to ensure the ability to effectively breakdown and remove pesticides from water runoff.

The County of Orange's National Pollutant Discharge and Elimination System Permit (NPDES) requires that all municipalities provide a summary of the pesticide applications made to landscapes under their jurisdiction. This includes medians, parks, sports fields, and open space. In addition, a few municipalities internally track pesticide applications on a much finer scale in an effort to better manage landscapes and to ensure the safety of the general public. Municipalities with jurisdictions in the Newport Bay Watershed could utilize this tracking model in order to improve our ability to identify sources of pesticide runoff and successfully implement mitigation strategies.

Recommendation #1: Municipalities in the Newport Bay Watershed contracting pest control services should require contractors to specify the specific location (cross streets, park name, etc...) of pesticide applications to improve tracking procedures. A standard form developed for use by all municipalities would also reduce NPDES Annual Report errors.

Pesticide applications by structural pest control operators, contract landscape pesticide applicators applying to private landscapes, and homeowners present the most

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significant hurdle to improved pesticide use data. Structural and landscape pest control businesses are unlike agricultural production sites as pesticide applications are made to sites crossing many zip codes, municipalities, and counties. Reporting of actual sites would require a significant commitment on their part and a change in CDPR regulations. The majority of these businesses already internally track the location of pesticide applications for invoicing purposes and to protect themselves from any liability.

Recommendation #2: Suggest CDPR require sites of pesticide applications be identified by structural and landscape pest control businesses as an improvement to the existing pesticide use reporting program. Site identification would include the nearest cross streets or address of the application. Ultimately, the most useful site identification requirement would be to include GPS coordinates on the PUR form for traceback.

Elimination or Reduction of Pesticide Use

The choice to use a pesticide to control a pest requires the user to first determine the need to control the pest. Although the majority of the time the decision to apply a pesticide is due to a legitimate pest problem, often times it is a perceived problem. Pesticide use may be necessary to protect public health, such as when applications are made to control mosquito populations and reduce the risk of West Nile virus. However, the majority of pesticide use is simply in response to a nuisance caused by the pest.

In Southern California, ants are one of the major pests around structures in urban environments (Knight and Rust, 1990) and therefore the main reason for pesticide applications in urban areas. Tolerance levels vary among individuals, but in general, individuals do not tolerate ants in the home and outdoor living spaces. Commercial pest management companies throughout California report that 65-80% of their pest control services deal exclusively with ants and that Argentine ants make up 85% of the collections made by their service technicians, pest management professionals (PMPs) (Field et al. 2007). Telephone surveys in northern California indicate that ants are the most common pest treated by homeowners or PMPs (Flint 2003). Even though only a small percentage of homeowners use PMPs, the structural pest control industry accounts for > 90% of the insecticide applied in non-agricultural areas (Wilen et al. 2005). However, this varies widely across counties. For example in Sacramento County, 34% of non-agricultural pesticide use was applied by PMPs whereas it was 79% in Orange County. In addition to PMP's services, there is an even larger group of homeowners who attempt to control their own ant problems. Telephone surveys of 2,600 households indicated that in two northern California counties only 6.5 and 11.1% hire PMPs (Flint 2003). Approximately 40-47% of all products purchased were for ant

control. This was confirmed in a survey of residents living in a new housing development in southern California, where 72% did their own ant control, 23% hired an exterminator, and only 5% did nothing to control ants (Field and Klotz, unpublished data, 2007). The homeowners doing their own treatments indicated that it was necessary for them to make regular applications of over-the-counter insecticides, most commonly applying Home Defense® (bifenthrin) because "the ants keep coming back."

Recommendation #3: Encourage CDPR to continue to fund projects such as the Urban Pest Ant Pest Management Alliance project currently being conducted in Orange and San Diego County. (http://www.cdpr.ca.gov/docs/pestmgt/grants/ant_wp.pdf)

The goal of this alliance of research, government and industry is to significantly reduce the amount of pesticide applied for urban pest ant control, and to specifically reduce by 50% the amount of pyrethroid insecticide applied. Relevant and cost-effective IPM strategies that significantly minimize and measurably reduce the amount of pesticide applied around residences will be developed and implemented. Because commercial applicators (PMPs) apply most insecticide outdoors for urban pest ant control, emphasis will be on training PMPs and eliciting their support and participation. An interactive ant IPM website, an IPM training module, and printed material will be developed for the public and PMPs. A survey will be used to determine the level of acceptance of the program by residents and PMPs. Alternative ant IPM techniques that minimize dependence on pesticide will be promoted at industry conferences and used in a training module for businesses and individual PMPs. Reduction in pesticide use will be quantified and documented by the Pesticide Use Reports.

Recommendation #4: Encourage CDPR, Regional Water Quality Control Boards, county and city governments to fund IPM education programs for professional pest control applicators, beginning in critical watersheds, focusing specifically on minimizing the use of pesticides with high aquatic toxicities through the use of exclusion techniques, confinement of highly toxic pesticides in bait stations, and increasing the use of least toxic pesticides (botanicals, biological-based, etc...) when pesticide use is deemed necessary.

Recommendation #5: Suggest municipalities require Pest Control Advisers (PCAs) on staff or professionals contracted to apply pesticides within the city, specifically consider and address any pesticide recommendations potentially detrimental to water quality if used improperly or under circumstances where irrigation or storm runoff could easily transport the material into storm drains. Pest Control Advisers are licensed by CDPR to provide written recommendations for pest control. For more information on PCAs please visit the California Association of Pest Control Advisers at http://capca.com/.

Implementation of Mitigation Strategies by Key Pesticide Users

Many of the Urban Pest Management Working Group's recommendations provide an excellent framework of mitigation strategies for reducing the potential contamination of surface waters in the Newport Bay Watershed and other highly populated areas of Southern California. The Working Group agreed on the importance of improving educational outreach to the nonprofessional. Educating the general public on less toxic pest management practices will not only influence their own selection and use of pesticides, but also change what they demand of professional pest control applicators. Increased requests by homeowners for the use of least toxic pesticides or integrated pest management practices will alter the services offered by professional pest management companies.

Recommendation #6: Develop an IPM Certification Program, under the direction of the University of California Cooperative Extension, for professional pest control applicators. The certification will need to be recognized by CDPR, the Regional Water Quality Control Board, county and city government, and the pest control industry. Recognition by the county and municipalities could be obtained by limiting contracts to only those pest control contractors with the IPM Certification.

Recommendation #7: Suggest CDPR collaborate UC IPM and UC Cooperative Extension to develop a pilot consumer education program, delivered through point-of-sale outlets, on the proper selection of a pest control practices, choosing reduced-risk pesticides, and implementing mitigation strategies to minimize the impact of pesticide applications of the environment. A previous partnership between these groups resulted in development of pilot outreach materials targeting employees and customers of retail nurseries and box stores; however, funding for implementation of the program needs to be identified.

Section IV. Specific Source Control Recommendations

Urban Groups

Municipalities

1. Adopt a formal Integrated Pest Management Plan supported by the city council and city administrators. Download a free copy of the UC ANR publication 'Establishing Integrated Pest Management Policies and Programs: A Guide for Public Agencies' at http://anrcatalog.ucdavis.edu for assistance in developing a written policy.

2. Ensure pesticide applications are a result of a written recommendation by a Pest Control Adviser with a clear understanding of a pesticide's potential impact(s) on water quality. The impact of a pesticide on water quality can be found at www.pw.ucr.edu or within individual Pest Notes at www.ipm.ucdavis.edu.

3. Improve the general public's understanding of the use of pesticides in an Integrated Pest Management Program, especially as it relates to threshold pest populations that must be reached before pesticides are utilized in park and sport facilities. Contact UC Cooperative Extension for pesticide-related outreach materials directed at the general public and professional gardeners.

4. Reduce or eliminate pesticide applications resulting from poor cultural practices, such as poor irrigation and drainage, improper plant selection, soil compaction, etc...

5. Invest in training landscape personnel to recognize pest problems early through proper identification and regular monitoring. Require landscape personnel to track pest populations throughout the year in order to increase the effectiveness of least-toxic pesticide alternatives.

Property Management/Homeowner Associations (HOAs)

1. Require contractors, by including it in contract language, to employ Integrated Pest Management practices in order to decrease the use of broad spectrum pesticides in common landscaped areas.

2. Educate homeowners on the benefits of utilizing IPM practices, especially as it relates to less exposure to pets and children. Contact UC Cooperative Extension for pesticide-related outreach materials directed at the general public and professional gardeners.

3. Request a copy of all Pest Control Adviser recommendations be provided to the homeowner's association board to ensure homeowners are aware of the pesticides being utilized in landscaped common areas.

4. Reduce or eliminate pesticide applications resulting from poor cultural practices, such as poor irrigation and drainage, improper plant selection, thatch buildup in turfgrass and soil compaction.

5. Promote the installation of low impact landscapes; landscapes requiring less water, fertilizer, and pesticide applications. For more information on implementing low impact residential landscapes and to schedule a tour of demonstration landscapes in Irvine, contact UC Cooperative Extension's water resources/water quality program at (714) 708-1613.

Institutional

1. Adopt a formal Integrated Pest Management Plan supported by the city council and city administrators. Download a free copy of the UC ANR publication 'Establishing Integrated Pest Management Policies and Programs: A Guide for Public Agencies' at http://anrcatalog.ucdavis.edu for assistance in developing a written policy.

2. Ensure pesticide applications are a result of a written recommendation by a Pest Control Adviser with a clear understanding of a pesticide's potential impact(s) on water quality. The impact of a pesticide on water quality can be found at www.pw.ucr.edu or within individual Pest Notes at www.ipm.ucdavis.edu.

3. Reduce or eliminate pesticide applications resulting from poor cultural practices, such as poor irrigation and drainage, improper plant selection, soil compaction, etc...

4. Verify proper pesticide cleanup and disposal following applications of pesticides to not only outside landscaped areas, but interior applications as well.

Commercial

1. Require contractors, by including it in contract language, to employ Integrated Pest Management practices in order to decrease the use of broad spectrum pesticides in common areas.

2. Request a copy of all Pest Control Adviser recommendations be provided to the homeowner's association board.

3. Reduce or eliminate pesticide applications resulting from poor cultural practices, such as poor irrigation and drainage, improper plant selection, soil compaction, etc...

4. Verify proper pesticide cleanup and disposal following applications of pesticides to not only outside landscaped areas, but interior applications as well.

Residential

1. If you hire a pest control company, require they implement IPM programs to control pests.

2. Reduce or eliminate pesticide applications resulting from poor cultural practices, such as poor irrigation and drainage, improper plant selection, soil compaction, etc...

3. If pesticides, especially broadcast sprays and granules, are utilized around the home ensure surface runoff from irrigation, car washing, etc... does not leave the property by diverting runoff into vegetative areas, such as the lawn or a planter, refraining from washing down driveways and sidewalks, or improving irrigation to eliminate runoff from misdirected sprinklers, slow infiltration rates, and mismatched sprinkler heads.

4. Utilize bait stations to control ants as pesticide is protected from running off in irrigation and rain events.

5. Utilize least-toxic pesticide alternatives, such as soaps, botanical oils, bait stations, and barriers. For more information

6. Verify proper pesticide cleanup and disposal following applications of pesticides to outside landscaped areas.

7. Install infiltration devices (gravel pit, rain barrels, slot drains, perforated pipe, and impervious surfaces, such as decomposed granite pathways) in your landscape to retain runoff and applied pesticides on-site.

8. Locate landscape drains in landscape and ensure pesticide applications or runoff containing pesticides does not directly enter these drains by covering during pesticide application or directing low flows into a vegetated area or infiltration device listed in recommendation #7.

Agriculture and Nursery

1. Adopt a formal Integrated Pest Management Plan that includes documentation of practices addressing pest identification, pest population monitoring, establish action thresholds, prevention strategies, and pest control tactics.

2. Conduct an assessment of the agriculture or nursery operation to determine potential pathways for pesticide movement off-site, such as through erosion, surface runoff created by irrigation or precipitation events, drift during application, or leaching into groundwater. Self-evaluation techniques are available from the UC Cooperative Extension Farm Water Quality Planning Program's web site at http://fwqp.ucanr.org/.

3. Implement management practices to mitigate the impacts of pesticides in runoff. Examples of some pesticide mitigation practices include more efficient irrigation delivery methods, vegetative filters and swales, detention basins, use of reduced-risk pesticides, and polyacylamides. Additional information on implementing these and other management practices can be found at http://fwqp.ucanr.org/ or in the Natural Resources Conservation Service's (NRCS) National Conservation Practice Standards at http://www.nrcs.usda.gov/technical/standards/nhcp.

4. Particular attention should be paid to controlling the movement of legacy pesticides through the utilization of various erosion and sediment control practices. Free UC Agriculture and Natural Resources (UC ANR) publications describing specific sediment control measures for agriculture and nursery operations can also be found at http://fwqp.ucanr.org/.

5. Ensure pesticide applications are a result of a written recommendation by a Pest Control Adviser with a clear understanding of a pesticide's potential impact(s) on water quality. The impact of a specific pesticide on water quality can be found at *PesticideWise (*www.pw.ucr.edu) or within individual crop UC IPM *Pest Notes* at www.ipm.ucdavis.edu.

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Title: Resolution No. R8-2003-0039, Resolution Amending the Water Quality Control Plan for the Santa Ana River Basin to Incorporate a Diazinon and Chlorpyrifos Total Maximum Daily Load for San Diego Creek and Upper Newport Bay
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Title: Pyrethroid Insecticides and Sediment Toxicity in Urban Creeks from California and Tennessee
Author(s): Amweg EL, Weston DP, You J, et al.
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Title: Occurrence and Bioavailability of Pyrethroids in a Mixed Land Use Watershed
Author(s): Budd R, Bondarenko S, Haver D, et al.

Source: JOURNAL OF ENVIRONMENTAL QUALITY Volume: 36 Issue: 4 Pages: 1006-1012 Published: JUL-AUG 2007

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Author(s): Urban Pest Management Working Group
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POLLUTION CONTROL HEARINGS BOARD
STATE OF WASHINGTON

PUGET SOUNDKEEPER ALLIANCE; PEOPLE FOR PUGET SOUND; PIERCE COUNTY PUBLIC WORKS AND UTILITIES DEPARTMENT; CITY OF TACOMA; PORT OF SEATTLE; SNOHOMISH COUNTY; CLARK COUNTY; PACIFICORP; and PUGET SOUND ENERGY,

Appellants,

v.

STATE OF WASHINGTON, DEPARTMENT OF ECOLOGY,

Respondent,

CITY OF SEATTLE; KING COUNTY; PORT OF TACOMA; PACIFICORP; PUGET SOUND ENERGY; STATE OF WASHINGTON, DEPARTMENT OF TRANSPORTATION,

Intervenors.

FINDINGS OF FACT, CONCLUSIONS OF LAW, AND ORDER

PHASE I

PCHB NOS. 07-021, 07-026, 07-027
07-028, 07-029, 0-030,
07-037

These consolidated appeals involve the regulation of stormwater discharges from municipal storm sewer systems under a National Pollutant Discharge Elimination System (NPDES) and State Waste Discharge General Permit (State Waste Permit). In these appeals, multiple parties challenge the validity of the Department of Ecology's (Ecology) 2007 Phase I Municipal Stormwater General Permit (Phase I Permit). This permit was issued pursuant to the

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Federal Water Pollution Control Act, commonly known as the "Clean Water Act" (CWA), 33 U.S.C. § 1251 *et seq.* and the state Water Pollution Control Act, (WPCA), Chapter 90.48 RCW.

The Pollution Control Hearings Board (Board) held a multiple day hearing between April 29, 2008 and May 8, 2008. Attorneys Todd True and Jan Hasselman represented Appellants Puget Soundkeeper Alliance and People for Puget Sound (PSA). Attorney Tad H. Shimazu represented Appellant Pierce County. Assistant City Attorney Doug Mosich represented Appellant City of Tacoma. Attorneys Susan Ridgley and Tanya Barnett represented Appellant Port of Seattle. Catherine A. Drews and Elizabeth E. Anderson, Deputy Prosecuting Attorneys, represented Appellant Snohomish County. E. Bronson Potter, Senior Deputy Prosecuting Attorney and Rodney Swanson, Clark County Department of Public Works represented Appellant Clark County. Attorneys Loren R. Dunn and Blake Mark-Dias represented Appellants Pacificorp and Puget Sound Energy (Utilities). Ronald L. Lavigne, Senior Counsel, and Thomas J. Young, Assistant Attorney General represented Respondent Ecology. Assistant City Attorney Theresa R. Wagner represented Intervenor City of Seattle. Senior Deputy Prosecuting Attorney Joseph B. Rochelle and Deputy Prosecutor Verna P. Bromley represented Intervenor King County. Attorney Carolyn Lake represented Intervenor Port of Tacoma. Stephen Klasinski, Assistant Attorney General represented Intervenor Washington State Department of Transportation (WSDOT).

Chair, Kathleen D. Mix, William H. Lynch, and Andrea McNamara Doyle comprised the Board. Administrative Appeals Judge Kay M. Brown, presided for the Board. Randi Hamilton

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and Kim L. Otis of Gene Barker and Associates of Olympia, Washington provided court reporting services.

PROCEDURAL BACKGROUND

On January 17, 2007, Ecology issued the Phase I Permit for discharges from large and medium municipal separate storm sewer systems (called MS4s). The Phase I Permit went into effect on February 16, 2007.

PSA, Pierce County, City of Tacoma, Port of Seattle, Snohomish County, Clark County, and the Utilities appealed the Phase I Permit.[1] The Board conducted pre-hearing conferences, and entered pre-hearing orders for the Phase I Appeal. The parties raised multiple issues. The Board addressed many of these issues in a separate summary judgment order[2] and has resolved others through orders on summary judgment and after a hearing on the merits related to the Permit's Special Condition S4.[3] The parties also withdrew some of the issues. This decision resolves the remaining issues, which include the following:[4]

C. Special Condition 8 re: Monitoring (challenged only by Clark and Pierce County)[5]

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[1] City of Pacific (PCHB No. 07-031), Whatcom County (PCHB No. 07-032), and Sammamish Plateau Water & Sewer District (PCHB No. 07-024) filed additional appeals, but they are not part of this consolidated action.
[2] See Order on Dispositive Motions (Phase I Municipal Stormwater Permit), issued on April 7, 2008.
[3] See Order on Dispositive Motions: Condition S4, issued on April 2, 2008 and Findings of Fact, Conclusions of Law and Order, Condition S4, issued on August 7, 2008.
[4] The numbering of these issues was retained from the numbering system used in the Third Pre-Hearing Order issued on December 11, 2007.
[5] All of the permittee appellants initially raised issues related to the S8 monitoring provisions. These issues were resolved through an agreement between Ecology and all of the permittee appellants except Clark and Pierce County. *See* Ex. Ecy 11 (Phase I). The agreement also resolves issues raised by Snohomish County related to Special Condition S7.

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1. Whether the requirements imposed in Special Condition S8 are lawful, practicable, reasonable, and/or designed to achieve the goals of the statutory municipal stormwater permit program?

3. Whether the monitoring requirements imposed in Special Condition S8 are overly broad, overly prescriptive, and cost-ineffective so that requiring implementation of such requirements as written is unlawful, impracticable, and/or unreasonable?

E. Issues Specific to the Ports of Seattle and Tacoma

5. Whether the requirement in Special Condition S6.E.7 to prepare and implement SWPPP(s) for "all Port-owned lands," regardless of their capacity to generate pollutants or other site-specific characteristics, is unlawful, unreasonable, unjust, or invalid?

F. Joint Environmental Legal Issues

1. Low-Impact Development:

   a. Does the permit fail to require maximum on site dispersion and infiltration of stormwater, through the use of "low impact development" techniques, basin planning, and other appropriate technologies, and if so, does that failure unlawfully cause or contribute to violations of water quality standards?
   b. Does the permit fail to require maximum onsite dispersion and infiltration of stormwater, through the use of "low impact development" techniques, basin planning, and other appropriate technologies, and if so, does that failure unlawfully allow permittees to discharge pollutants that have not been treated with all known available and reasonable methods of treatment ("AKART"), and/or fail to reduce the discharge of pollutants to the maximum extent practicable ("MEP")?

2. Existing Development:

   a. Does the absence of any standard and/or technology requirements for reducing stormwater discharges from existing development and existing stormwater systems unlawfully cause or contribute to violations of water quality standards?

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b. Does the absence of any standard and/or technology requirements for reducing stormwater discharges from existing development and existing stormwater systems unlawfully allow permittees to discharge pollutants that have not been treated with AKART, and/or fail to reduce the discharge of pollutants to MEP?

3. Monitoring: Is the monitoring required under Permit Condition S.8 unlawful because it is inadequate to determine whether: (i) the permittee is in compliance with water quality standards; (ii) discharges are causing or contributing to violations of water quality standards; or (iii) discharges are being treated with AKART and/or MEP?[6]

4. Water Quality Standards Violations:

   a. Does the Phase I permit fail to ensure that discharges will not cause or contribute to violations of water quality standards?[7]

5. Compliance:

   a. Does the permit unlawfully provide for compliance with permit terms on a schedule that is indefinite and unenforceable, not as expeditious as possible, and/or in excess of statutory deadlines?
   b. Does the permit unlawfully allow a permittee to create and implement permit requirements without Ecology's oversight or involvement?

Based on pre-filed testimony, multiple days of sworn testimony of witnesses, extensive exhibits submitted into the record, and argument from counsel representing the numerous parties that participated in these consolidated appeals, and having fully considered the record, the Board enters the following decision:

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[6] PSA is not challenging the monitoring provisions of the permit. This issue is brought by the Utilities only.

[7] This issue also includes the issue originally stated as S4.6: Does the prohibition on violations of water quality standards contained in Permit Condition S4 unlawfully or unreasonably conflict with the other provisions of the permit?

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SUMMARY OF THE DECISION

The Board concludes that the monitoring program established in Special Condition S8 and required of all permittees is a valid exercise of Ecology's technical expertise and discretion. (Issues C.1 and 3, and F.5). The Board upholds the permit term requiring that Stormwater Pollution Prevention Plans (SWPPPs) be prepared on all port-owned lands, but directs that Ecology modify the condition to exempt environmental mitigation sites owned by the Port of Tacoma from the SWPPP preparation requirement. (Issue E.5). The Board concludes that the Phase I Permit fails to require that the municipalities control stormwater discharges to the maximum extent practicable, and does not require application of all known, available, and reasonable methods to prevent and control pollution, because it fails to require more extensive use of low impact development (LID) techniques. (Issue F.1.b). To remedy this problem, the Board directs Ecology to make specific changes to some provisions in the permit, and also remands the permit with direction to Ecology to require the permittees to develop methods for use of low impact development at parcel and subdivision levels in their jurisdictions. The Board concludes that permittees must provide information in their annual report to Ecology on the extent to which basin planning is being undertaken or should be considered in their jurisdiction in order to assist with future phases of the permit. The areas identified should be relatively undeveloped where new development is occurring, and from which discharges may impact aquatic resources. The Board concludes that the structural stormwater control program provisions of the permit, as drafted, constitute impermissible self regulation. (Issues F.2 and F.5.b). To remedy this deficiency, the Board directs modification of the permit to require

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permittees to describe the prioritization of their selected structural control projects. The Board affirms the source control program requirements without change. Finally, the Board concludes that PSA and the Utilities failed to prove that any of the conditions of the permit violate the timing requirements of 33 U.S.C. § 1342 (p)(4)(A) (Issue F.5.a).

FINDINGS OF FACT

A. History of Phase I Permit

1.

Ecology developed the current Phase I Permit through an eight year long process. The 2007 Phase I Permit replaced the first municipal stormwater NPDES and State Waste Permits, which were issued in 1995 and expired in July of 2000. *Testimony of Wessel, Moore, Exs. Muni 0002, p. 17, 0006, 0007, 0008, 0009.*

2.

On January 19, 1999, Ecology filed a Notice of Intent to reissue the 1995 permits. *Ex. Muni 0002, p. 6.* Ecology formed an advisory committee, which included representatives from cities, counties, state and federal agencies, environmental groups, and the public, to assist with development of the revised permit. This committee met several times during 1999 and 2000. *Testimony of Wessel, Moore, Exs. Muni 0002, p. 6-7.* The 1995 Phase I Permit closely followed the EPA Phase I Regulations, which allowed the permittees to propose what was contained within their own stormwater programs. Ecology was dissatisfied with this approach and decided that more detailed requirements were needed for the 2007 Phase I Permit. *Testimony of Moore.*

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3.

Completion of the new permit was delayed at several junctures as a result of a number of intervening events and shifting priorities, including the federal listing of Puget Sound Chinook Salmon in 1999, the adoption of EPA's Phase II rules, and Ecology's decision to revise the state's Stormwater Management Manuals and develop the first Phase II municipal stormwater permits in tandem with the Phase I permit update. *Testimony of Wessel, Moore, Exs. ECY 6 (Phase I), Muni 0002, p. 7.*

4.

In response to legislative interest in the new federal requirements for municipal stormwater permits, Ecology convened two advisory groups during the summer of 2003: one for Eastern Washington and one for Western Washington. Each advisory group submitted a report of its findings to Ecology in early December, 2003. Ecology developed its own recommendations and published these, together with the recommendations from both advisory groups, in a report to the Legislature dated January, 2004. *Testimony of Moore, Exs. ECY 6 (Phase I), Muni 0002, p. 7.*

5.

Ecology filed a notice of intent to issue the Phase I and Phase II Permits in June of 2004. The agency released the first preliminary draft of the Phase I Permit for public comment in May, 2005, and the first formal draft in February, 2006. *Exs. PSA 018, Muni-0100.* Ecology received and reviewed thousands of pages of public comment, and responded to those comments in a 205 page document when it released the revised, final permit in January, 2007. *Exs. Muni 002, p. 7-*

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8, ECY 3 (Phase I). Ecology issued the Phase I permit, in its current form, on January 17, 2007. It became effective on February 16, 2007, and expires on February 15, 2012. *Ex. Muni 001, Testimony of Moore.*

B. Overview of the permit

6.

The Phase I Permit regulates discharges from municipal separate storm sewer systems (MS4s) owned or operated by the following large and medium municipalities statewide: City of Seattle, City of Tacoma, Clark County, King County,[8] Pierce County and Snohomish County.[9] It also allows coverage of "secondary permittees," including the Ports of Seattle and Tacoma, for discharges from other publicly owned or operated municipal separate sewer systems located within the primary permittee cities and counties. Secondary permittees as a group are subject to somewhat different terms under the permit than primary permittees, and the permit also has specific terms applicable only to the Ports of Seattle and Tacoma and not other secondary permittees. The Phase I permit does not cover direct discharges into waters of the state from privately owned stormwater systems, nor does it cover the storm sewers owned and operated by the Washington State Department of Transportation (WSDOT).[10] Unlike traditional NPDES permits, the Phase I permit is a "programmatic permit," meaning it requires the municipal

[8] King County Department of Metropolitan Services (METRO) is covered as a "co-permittee" with the City of Seattle for discharges from outfalls King County owns or operates in the City of Seattle. *Special Condition S1.C., Exs. Muni 0001, p. 1, Muni 0002, p. 21.*

[9] An MS4 consists of all of the conveyances, or systems of conveyances (including roads with drainage systems, municipal streets, catch basins, curbs gutters, ditches manmade channels or storm drains) designed or used for collecting or conveying stormwater. By definition, these systems cannot be combined with sanitary sewer systems. *Exs. Muni 0001, p. 61, 63, Muni 0002, p. 22-24.*

[10] The Phase I permit does not cover the storm sewers owned and operated by the Washington State Department of Transportation (WSDOT). WSDOT's system is covered under an individual permit. *Ex. Muni 0002, p. 19, 21.*

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permittees to implement area-wide stormwater management programs rather than establishing benchmarks or other numeric or narrative effluent limits for stormwater discharges from individual outfalls. *Testimony of Moore, Exs. Muni 0001, p. 1, 2, 60-65, Muni 0002, p 20-24.*

7.

The heart of the Phase I Permit requires that permittees implement a Stormwater Management Program (SWMP). Special Condition S5 contains the SWMP requirements for the primary permittees, and Special Condition S6 sets out the SWMP requirements for secondary and co-permittees. The required elements of the SWMP track closely with EPA's Part II Application rules but contain much more detailed minimum performance standards for the municipalities' programs. This approach avoids the need for separate review and approval by Ecology of each SWMP prior to coverage under the Phase I Permit. Instead, a permittee is required to submit the SWMP with the permittee's first year annual report. S5.A. *Testimony of Moore, Wessel; Exs. Muni 0001, p. 6-25; Muni 0002, p. 18, 28-42.*

8.

Ecology views these SWMP requirements, in the aggregate, to represent the MEP standard; that is, permittees who implement all of the program requirements in combination with one another are considered by Ecology to be reducing the discharge of pollutants to the maximum extent practicable, even though it may be possible for a permittee to do more in a specific program element or at a specific outfall if the individual requirements were evaluated in isolation from the rest of the program requirements. *Testimony of Moore.*

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9.

Under Special Condition S5 the SWMP must include ten component parts, which are mandatory to the extent allowable under state and federal law. These program components address the following topics, and the minimum requirements for each are set out in S5.C. 1 through 10 of the Phase I Permit: (1) Legal authority; (2) System mapping and documentation; (3) Coordination; (4) Public involvement; (5) Controlling runoff from new development, redevelopment, and construction; (6) Structural stormwater controls (retrofits); (7) Source control for existing development; (8) Illicit connections, illicit discharge detection and elimination; (9) Operations and maintenance; and (10) Education and outreach. *Muni 0001, p. 6-25.*

10.

More specifically, S5.C.1 requires the permittee to demonstrate by the effective date of the Phase I Permit that it has the legal authority to control discharges to and from its MS4s. S5.C.2 requires the permittee to map, by specific dates, prescribed parts of its MS4. S5.C.3 requires the permittee to establish coordination mechanisms to remove barriers to stormwater management created by the need to coordinate efforts both internally within one governmental entity, and externally with jurisdictions that share drainage basins. S5.C.4 requires the permittee to provide ongoing opportunities for public involvement in its stormwater management program. S5.C.5 requires the permittee to develop a program to prevent and control impacts of runoff from new development, redevelopment, and construction activities. S5.C.6 requires the permittee to

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include a program to construct structural stormwater controls to prevent or reduce impacts from discharges from its MS4s. This element is applicable to existing development, as well as new development, and addresses impacts that are not already adequately controlled by other required actions under the SWMP. S5.C.7 requires the permittee to include a source control program for existing development that reduces pollutants in runoff from these areas. S5.C.8 requires the permittee to have an ongoing program to detect, remove and prevent illicit connections and illicit discharges, including spills, into its MS4s.[11] S5.C.9 requires the inclusion of a program to regulate maintenance activities and to conduct maintenance activities by the permittee that prevent or reduce stormwater impacts. S5.C.10 requires that the permittee's SWMP include an education program with the goal of reducing or eliminating behaviors and practices that cause or contribute to adverse stormwater impacts. The performance measures associated with S5.C.2 through 10 must be completed within specific time periods. *Testimony of Moore, Wessel, Exs. Muni 0001, p. 6-25, Muni 0002, p. 28-42.*

11.

Special Condition S6 (S6), which is similar but not identical to S5, establishes the components required for SWMPs from secondary permittees. Parts of this condition apply to all secondary permittees (S6.A, B and C), all secondary permittees other than the Ports of Seattle

[11] An illicit connection is any man-made conveyance that is connected to a MS4 without a permit, excluding roof drains and other similar type connections. An illicit discharge is any discharge to a MS4 that is not composed entirely of stormwater except discharges pursuant to a NPDES permit and discharges resulting from fire fighting activities. *Ex. Muni 0001, p. 61.*

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and Tacoma (S6.D), and just the Ports of Seattle and Tacoma (S6.E). *Testimony of Moore, Exs. Muni 0001, p. 25-39, Muni 0002, p. 42-47.*

12.

Special Condition S8 (S8) addresses monitoring. It requires the primary permittees and the Ports to develop and implement long-term monitoring programs for the purpose of meeting two of the four monitoring objectives identified in the first round of the Phase I municipal stormwater permits issued in 1995: (1) estimating pollutant concentrations and loads from representative areas or basins; and (2) evaluating the effectiveness of selected Best Management Practices (BMP). The permit does not require monitoring to identify specific sources of pollutants or the degree to which stormwater discharges are impacting selected receiving waters and sediments. *Testimony of Moore, O'Brien, Exs. Muni 0001 p. 40-49; Muni 0002, p. 49-50.*

C. Monitoring provisions in S8

13.

Special Condition S8.C.1 specifies that the primary permittees' and the Ports' monitoring programs must contain three components: 1) stormwater outfall monitoring, which is intended to characterize stormwater runoff quantity and quality at a limited number of locations 2) Targeted stormwater management program effectiveness monitoring, which is intended to improve stormwater management efforts by evaluating at least two stormwater management practices that significantly affect the success of, or confidence in, stormwater controls, and 3) BMP evaluation monitoring, which is intended to evaluate the effectiveness and operation and maintenance requirements of stormwater treatment and hydrologic management BMPs. S8.D, E, and F set out

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the requirements for each of the three components. *Testimony of Moore, O'Brien, Exs. Muni 0001, p. 40-49; Muni 0002, p. 49-56.* A Quality Assurance Project Plan (QAPP) must be prepared for each of the components of the monitoring program in accordance with Ecology guidelines and submitted to Ecology for review. Ecology must review and approve the QAPPs for stormwater monitoring conducted under S8.D and F prior to monitoring. *Ex. Muni 0001, p. 40-41.*

14.

The first component of the Special Condition S8 monitoring involves outfall monitoring for the purpose of developing local knowledge of pollutant loads and average event mean concentrations from representative areas drained by MS4s. Developing a baseline of local data is important because some variations are emerging between stormwater characterization data from the Pacific Northwest and other areas around the county and world, with examples of both higher and lower concentration levels present regionally, differing from national averages. To accomplish this objective, the Permit requires permittees to select three sites that represent different land uses and then to monitor a certain percentage of storm events per year for a wide range of constituents and parameters. The permit requires storm events to be sampled using flow-weighted composite storm sampling. S8.D.2.b. The seasonal first-flush must be tested for toxicity. S8.D.2.d. Grab samples from each storm must be taken and tested for total petroleum hydrocarbon and fecal coliform bacteria, and one to three sediment samples must be collected each year at each site and analyzed for a variety of parameters. S8.D.2.e, f. *Testimony of O'Brien, Moore, Ex. Muni 0001, p. 41-45.*

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15.

The number of samples is intended to establish a sufficient database from which to discern annual and seasonal loading trends over a long time period. Performing a toxicity test on the "seasonal first-flush storm" provides an annual worst case scenario. Ecology believes this data is necessary to evaluate whether stormwater management programs are making progress towards the goal of reducing pollutants discharged and protecting water quality. The data would also be useful when establishing Water Clean-up Plans (TMDLs) for water bodies not currently achieving water quality standards, and in other efforts to identify sources of toxicant loading to Puget Sound. *Testimony of O'Brien, Ex. Muni 0002, p. 49-53.*

16.

The second component of the S8 required monitoring, described in detail in S8.E, is the targeted stormwater management program effectiveness monitoring. In this section, each permittee must conduct monitoring designed to determine the effectiveness of (1) a targeted action (or narrow suite of actions) from their SWMP, and (2) achieving a targeted environmental outcome. The monitoring must, at a minimum, include stormwater, sediment or receiving water monitoring of physical, chemical and/or biological characteristics, and may also include other kinds of data collection and analysis. Ecology anticipates that the targeted environmental outcomes permittees will chose to evaluate will be measured in the receiving water and, therefore, may involve receiving water monitoring. *Testimony of O'Brien, Moore, Exs. Muni 0001, p. 45-46; Muni 0002, p. 53-54.*

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17.

The third component of the S8 monitoring provisions is BMP effectiveness monitoring, the requirements of which are set out in S8.F. The purpose of this third component of the S8 monitoring is to develop local performance data on the effectiveness of specific treatment BMPs in reducing pollutant discharges and the effectiveness of various low impact development (LID) practices in reducing the quantity of runoff. This section requires the primary permittees and Ports to select and monitor two treatment BMPs in use at a minimum of two sites in their jurisdiction. S8.F.2. The permittees are also required to monitor the effectiveness of one flow reduction strategy[12] that is in use or planned for installation in their jurisdiction. S8.F.7. Though many of these treatment BMPs have been in common use for many years, and the 2005 Stormwater Management Manual for Western Washington relies on them as presumptively effective, Ecology has only incomplete information about their actual pollutant removal capabilities. *Testimony of O'Brien, Exs. Muni 0001, p. 46-47; Muni 0002, p. 54-56.*

18.

In the absence of local data, Ecology had relied on an existing national stormwater treatment BMP database, [13]as its primary source of BMPs for the 2005 Stormwater Management Manual for Western Washington (The Manual) *Testimony of O'Brien, Tobiason, Exs. PI 0059, 0060, 0064 and 0065.* The national database is of limited utility, however, in evaluating the

[12] A flow reduction strategy is an approach that reduces the volume of runoff coming off a landscape. Ecology witness Ed O'Brien indicated in his testimony that this referred to the use of low impact development techniques.
[13] The purpose of the database, called the International Stormwater Treatment Database, is to facilitate understanding about how particular BMPs perform database and contains studies from both inside and outside the United States. *Testimony of O'Brien.*

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effectiveness of BMPs because the performance of treatment BMPs varies greatly depending on specific design criteria, loading criteria, different rainfall patterns, and the types and sizes of solids to which a site gets exposed. These factors vary widely across the country, and therefore BMP performance data from one area is not always useful for another area. This has been a specific concern for Washington because, until recently, there has been little Washington data in the database. In some instances, this national database lacks also data quality, and relies on an insufficient number of samples at a particular site or from a particular BMP to be statistically useful. So, while there exists national data that allows Ecology to make some general assumptions about how well BMPs perform, Ecology still lacks site-specific, region-specific data to verify that the BMPs perform the way Ecology anticipates they will perform. As a result, Ecology required permittees to evaluate BMP effectiveness in an effort to learn and apply the information in future settings and permit iterations. *Testimony of O'Brien, Tobiason, Kibbey, Exs. PI 0059, 0060, 0064, 0065, Muni 0002, p.* 54-56.

19.

Ecology considered requiring receiving water monitoring in the Phase I Permit, but the municipalities as a group opposed the requirement. The 1995 Phase I Permit identified one monitoring objective as evaluating the degree to which stormwater discharges impact selected receiving waters and sediments, and Ecology concedes this continues to be a valid long-term objective for the municipal stormwater general permits. In the current iteration of the Phase I Permit Ecology decided, however, that receiving water monitoring data would not be the most helpful monitoring data because 1) receiving water monitoring data is more complex data to

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obtain, 2) samples can be hard to collect during storms, and 3) it is difficult to tie the receiving water data back to a specific discharger. Ecology agreed with the municipalities that certain receiving waters may receive pollution from multiple upland sources, and monitoring the receiving water would not provide permittees with useful data by which they could develop or tailor their stormwater management programs. Ecology also does not typically require receiving water monitoring under several other general stormwater discharge permits, including the construction and industrial permits, except for certain impaired water bodies where there have been violations of discharge limitations. *Testimony of Moore, O'Brien. Ex. Muni 0002, p. 49.*

20.

The monitoring required by S8 is primarily aimed at developing a uniform baseline of information about the pollutant loading discharging from MS4s, and evaluating the effectiveness of the BMPs that permittees use to control and reduce the pollutants discharging from those systems. Ecology determined this data will be the most useful for establishing what constitutes maximum extent practicable reduction in pollutants from MS4 discharges for future iterations of the municipal stormwater permits. Allowing some municipalities to opt out of these requirements, by substituting different kinds of monitoring, would reduce the robustness of the data set Ecology seeks for establishing this baseline for future permits. *Testimony of Moore, O'Brien.*

21.

Ecology intends to rely on its own monitoring programs, coordinated with and supplemented by other monitoring efforts, to accomplish the receiving water monitoring

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objectives identified in the 1995 permit. Ecology received an $800,000 state appropriation to begin work with a collaborative monitoring consortium to identify the elements of a comprehensive receiving water monitoring program, outside of the permit process. Such a monitoring consortium could more fairly distribute the cost of monitoring among all of the entities with an interest in receiving water data and form the basis for effective, region-wide monitoring of receiving water quality in relation to discharge points. Although Ecology is currently organizing the consortium, no water monitoring has been started to date through this program, and inadequate funding currently exists to do so. Outside the consortium, some receiving water monitoring occurs through statewide ambient water quality monitoring and pollutant specific monitoring where a water body is subject to a TMDL. *Testimony of Moore, O'Brien, Wessel.*

D. Pierce and Clark Counties Monitoring Plans

22.

Two primary permittees, Pierce and Clark Counties, already have water quality monitoring programs which differ significantly from the monitoring required in the Phase I Permit. The key difference between both of the counties' programs, and the Phase I Permit monitoring requirements, is that the county programs focus on monitoring in the receiving water environment. However, neither of the County programs monitors the chemical composition or toxicity of stormwater discharges from their MS4, nor relates stormwater management actions to a reduction in the pollutant characteristics of stormwater. *Testimony of Tobiason, O'Brien, Exs. PSA 018, PI 0042.*

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23.

Pierce County began working with a consultant in 2004 to develop its monitoring program. The County developed the program based on the proposed monitoring requirements in an early draft of the Phase I permit, which included a receiving water monitoring component, as well as ongoing communications with Ecology personnel. The 2005 draft of the Phase I permit prescribed two of the five monitoring methods that Pierce County incorporated into its monitoring plan. *Ex. PI 0041.* Pierce County published its final program in March, 2007. *Testimony of Tobiason, O'Brien, Ex. PI 0042.*

24.

The overall goal of the Pierce County monitoring program is to implement a comprehensive monitoring program that will provide meaningful data to support the County's efforts to protect receiving waters from stormwater impacts. Although developed primarily in anticipation of the NPDES permit requirements, it also serves other county water quality objectives. In order to accomplish its goal, the program uses a three level receiving water monitoring approach. It includes long term status and trends monitoring, which includes a triad of bioassessments, physical channel characterization, and in-situ bioassays at existing County monitoring sites in selected streams, and may also include flow monitoring where gauges exist. Pierce County includes the sampling of the stream bottom as part of this long-term monitoring in order to determine the presence and health of benthic invertebrates. Monitoring benthic invertebrates provides a good indicator of watershed health because these organisms respond to physical and chemical stresses at the stream bottom. Pierce County applies these monitoring

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methods over a five year period to characterize the receiving waters in up to nine watersheds with regards to the receiving waters' physical stability, habitat, biological health, and susceptibility to toxicants in stormwater. This will enable Pierce County to prioritize responses to watersheds that exhibit vulnerability. It also includes targeted development monitoring, which compares upstream and downstream conditions to assess impacts of stormwater discharges on the receiving waters over finite periods before and after specific development. Targeted development monitoring includes continuous turbidity, conductivity and hydraulic stage monitoring and *in-situ* bioassay upstream and downstream of discharges from targeted development, and assessment of physical channel conditions downstream. Some aspects of the County's monitoring program, particularly the real-time data, will also assist the county in detecting spills and illicit discharges. The third level of receiving water monitoring included is a special studies monitoring. This method provides for adaptive management to be employed as needed on a site specific basis to develop cause-effect relationships that lead to focused stormwater management response. As part of this method, chemical analysis may be conducted if other programs indicate a need for such study to determine the cause of a problem discovered through receiving water monitoring. This is the only aspect of the Pierce County Program that provides for the use of chemical analysis. *Testimony of Tobiason, Kibbey, Exs. PI 0042, Ex. PI 0055, PI 0094.*

25.

Clark County, like Pierce County, has its own monitoring plan which is focused on receiving water monitoring. Clark County developed its plan in response to its first

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NPDES/State Waste permit which was issued July, 1999 and expired December, 2000.[14] *Muni 0140, Special Condition S5.B.4, p. 7, 8.* Its plan has three elements: a long-term index site project, hydrologic monitoring, and a stormwater needs assessment program. The index site project involves nine stream stations which are influenced by stormwater, and a forested reference site. A suite of stream health characteristics are monitored at each site. Water quality monitoring takes place on a monthly basis. The hydrologic monitoring consists of monitoring stream flow continuously through the use of storm gauges at several locations, including some of the site index locations. The stormwater needs assessment program is a system created to make an assessment of needs for each sub-basin in the county that contains parts of the MS4. Currently, Clark County is in the process of completing reports on 12 urbanizing and rural sub-watersheds. *Testimony of Swanson, Ex. Muni 0140, p. 7-8.*

26.

The monitoring required under the Phase I Permit is fundamentally different than the monitoring contained in the Pierce and Clark County monitoring programs. The Counties' monitoring programs do not routinely look at the chemical content or toxicity of stormwater discharges, nor do they look at the effectiveness of treatment BMPs. *Testimony of O'Brien, Tobiason, Kibbey.*

[14] Clark County was not informed of the need to submit a permit application until January of 1995, because of confusion over whether Clark County met the requirements of the Phase I Permit, i.e. urbanized area with a population greater than 100,000.. *Ex. Muni 0141, p. 8.*

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27.

Ecology stated that it was extremely important to be able to answer whether our stormwater programs are adequate to protect aquatic resources and uses in its 2004 report to the Legislature. Therefore, Ecology included recommendations that certain types of environmental monitoring be conducted at the local and regional levels, including monitoring of the biological, chemical, and physical health of receiving waters. *Ex. ECY 6 (Phase I), p. 31-32.*

28.

Ecology does not oppose the Counties continuing on with their own monitoring programs in addition to the S8 monitoring. However, it has not allowed Pierce and Clark Counties to substitute their programs for the required S8 monitoring. Ecology witness Edward O'Brien did not rule out the possibility that Ecology could allow Pierce and Clark to substitute their monitoring programs for some parts of the required S8 monitoring. Pierce County witness Heather Kibbey testified that Pierce County could not afford to do both its receiving monitoring program and the required S8 monitoring. *Testimony of O'Brien, Tobiason, Kibbey.*

E. Ports

29.

One of the required elements of the SWMP for all Phase I permittees is the preparation of a stormwater pollution prevention plan (SWPPP). The permit requires all primary permittees to prepare SWPPS for "all heavy equipment maintenance or storage yards, and material storage facilities owned or operated by the Permittee(s)" that are not already covered by another stormwater discharge permit. S5.C.9.b.xi, p. 23, 24. The primary permittees are allowed 24

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months to complete the development of their SWPPPs. The secondary permittees, other than the Ports, are required to prepare SWPPPS for "material storage areas, heavy equipment storage areas, and maintenance areas" not covered by another stormwater discharge permit. S6.D.6.a.vi, p. 32. Their SWPPPs must also be completed within three years from the date of permit coverage. *Testimony of Moore, Ex. Muni 0001, p. 23, 24, 32.* In contrast, the Ports' SWPPP preparation requirement, found in S6.E.7, requires the Ports to prepare SWPPPs "all Port-owned lands" that are not covered by another stormwater discharge permit. The Ports are allowed 24 months to develop and implement their SWPPPs. *Ex. Muni 0001, p. 38.*

30.

The Port of Seattle estimates this requirement will involve the preparation of SWPPPs for approximately 44 properties covering approximately 27 percent of its total Seaport acreage (286 acres).[15] Some of these sites include port-controlled and operated facilities with multiple tenants, such as Shilshole Marina and Fisherman's Terminal, and several others consist of tenant-controlled container areas. *Testimony of Guthrie, Exs. PI 0020, 0022.* The Port of Tacoma has identified several port-owned sites that are not covered by other stormwater discharge permits, some of which include buildings and parking lots leased to other businesses, others of which consist of environmental mitigation sites. *Testimony of Graves, Ex. PI 0039.*

31.

The Phase I fact sheet explains Ecology's general thinking regarding SWPPP preparation

[15] By agreement with Ecology, SWPPPs will not be required on "no discharge" properties, which include Port-owned parks and properties with connections to Metro Stormwater Conveyances.

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for the primary permittees. It states:

> Ecology has determined that activities at certain sites owned or operated by permittees are potentially similar to activities at sites regulated under the Industrial Stormwater General Permit. For this reason this provision of the permit calls for developing Stormwater Pollution Prevention Plans (SWPPPs) for these sites.
>
> *Ex. Muni 0002, p. 41.*

32.

In the 2005 draft of the Phase I Permit, Ecology required SWPPP preparation for "all Port-owned lands with potential pollutant-generating sources." *Ex. PSA 018, p. 37.* The final permit eliminated the qualifier because Ecology expected that all port-owned lands would be pollutant-generating sources, although Ecology did not consider wetland mitigation areas owned by the Port of Tacoma when it made this decision. *Testimony of Graves, Moore, Exs. PSA 018, p. 37; PI 0022, 0025-0027.*

33.

The Port of Tacoma owns several environmental mitigation sites (i.e. wetlands). Most of these sites probably discharge directly to surface or ground waters of the state, and not to the MS4. For the ones that do discharge to the MS4, there is only a small potential that the discharges would carry pollutants. Therefore, preparation of SWPPPs on these sites is unlikely to result in any corresponding water-quality benefits. *Testimony of Moore, Graves.*

34.

Ecology also explains in the fact sheet its reasons for providing a slightly different

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standard for the Ports regarding SWPPP preparation. It states:

> Ecology has determined that special consideration is needed for the Ports of Seattle and Tacoma, distinguishing them from the broader group of Secondary permittees such as diking and drainage districts and public universities. These ports are both located on urban bays with documented water quality and sediment contamination problems that may be linked to stormwater discharges. The infrastructure in both Seattle and Tacoma is fairly old and the MS4s are heavily interconnected between each port and the respective city. Also, both ports lease properties to tenants, of whom many, but not all, are required to have coverage under the Industrial Stormwater General Permit. For these reasons this permit establishes SWMP components that are specific to these two entities.
>
> *Ex. Muni 0002, p. 43.*

35.

In general, the permit has more requirements for primary permittees SWMPs than it does for the Ports. *Contrast* S5.C. 1 through 10 (establishing 10 components for primary permittees SWMPs) p. 6-25 with S6.E (establishing 7 components for Ports SWMPs) p. 32-39. The source control program for existing development, which is a component of both primary permittees and the Ports SWMPs, also imposes more requirements on the primary permittees than it does the Ports. *Contrast* S5.C.7, p. 13-15, with S6.E.7, p. 38-39. Further, the scope of the primary permittees source control obligation is much wider than that of the Ports, because the primary permittees are dealing with thousands of different sources, compared to a much more limited number for the Ports. Therefore, the Ports will be preparing a much smaller number of SWPPPs than the primary permittees. While Ecology suggests that the Guidance Manual for Preparation of SWPPPs for Industrial Facilities can be used to assist in preparation of Port SWPPPs, it also encourages the use of generic SWPPP provisions for sites grouped by type of activity, such as

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parking lots. *Testimony of Moore, Guthrie, Exs. Muni 0001, p. 6-25, 33-39, Muni 0002, p. 44, PI 0021.*

36.

The Port of Seattle expects its tenant businesses to be involved in the preparation of the required SWPPPs because they have the most familiarity with the pollution-generating activities and source control opportunities at the individual sites, but the port, in its role as property manager, will work cooperatively with tenants through its routine compliance assessment process. For example, it has already provided its tenants with templates for preparing the SWPPPs. This process will involve some cost and effort on the part of the tenants, but can also serve as an opportunity for educating and training tenants in issues related to stormwater management. *Testimony of Guthrie.* The Port of Tacoma intends to prepare the SWPPPS for its existing tenant facilities which will require the port to become better informed about the details of its tenant operations and pollutant-generating activities. For new facilities, the Port of Tacoma intends to direct tenants to prepare the SWPPPs. *Testimony of Graves.*

F. Low Impact Development (LID)

37.

The major contention of PSAs' challenge to the Phase I permit is that traditional structural engineered stormwater management practices are inadequate to address the municipal stormwater problem and that the Permit should have also required greater use of Low Impact Development (LID) practices on a broader and more comprehensive scale.

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38.

In the Phase I Permit, Ecology chose to regulate stormwater discharges from new development and redevelopment primarily through the imposition of a flow control standard. S5.C.5.b.i. *Ex. Muni 0001, p. 9, Testimony of O'Brien.* The flow control standard generally requires new and redeveloped sites that discharge to surface waters to control the rate at which stormwater is released from their sites so that the discharges do not cause accelerated stream channel erosion. The flow control standard is not a LID concept, because, in contrast to LID techniques, it is based on the premise that there will be discharges of stormwater from particular sites, and it attempts to control the duration and frequency of high stormwater runoff flows. Conventional stormwater management criteria frequently incorporate a post development peak discharge rate for a 2- and 10-year storm event based upon possible property damage due to flooding and stream bank erosion. These are becoming more recognized as insufficient because they do not address the loss of storage volume to provide for groundwater recharge, they do not adequately protect downstream channels from accelerated erosion, and the inspection and maintenance costs are an increasing burden for local governments. The goal of LID, on the other hand, is to minimize or prevent entirely the discharge of stormwater from the site. While utilization of LID techniques may be useful (or even in some cases necessary) to meet the flow control standard on a particular site, the flow control standard does not require the use of LID techniques. *Testimony of O'Brien, Booth, Exs. ECY 4 (Phase I) p. 2-30 through 2-35, Ex. PSA-053, p. 7.*

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39.

In order to meet the Permit's flow control standard(s), facilities must be engineered so that discharges are not predicted to exceed the predevelopment flow "durations" for a range of storm events. The Stormwater Management Manual gives detailed design specifications for sizing and constructing detention/retention facilities to meet the flow control standard. The Manual itself recognizes the shortcomings of the use of engineered stormwater conveyance, treatment and detention systems to control stormwater. It states, at page 1-25:

> [These techniques] can reduce the impacts of development to water quality and hydrology. But they cannot replicate the natural hydrologic functions of the natural watershed that existed before development, nor can they remove sufficient pollutants to replicate the water quality of pre-development conditions.

The primary focus of detention standards is on mitigating the worst impacts of large storm events. These standards have little or no effect on small storm events, which can also cause damaging increase in flows. Stated another way, the flow control standard addresses large stormwater flow rates only, which occur only a small percentage of time (1%), and provides only residual control to runoff the remainder of the time. *Testimony of O'Brien, Booth, Ex. ECY 4 (Phase I), p. 1-25, 2-30 through 2-35.*

40.

Another limitation of the flow control standard comes from a significant exception to the requirement to achieve pre-developed discharge rates for basins that have had at least 40 percent total impervious area since 1985. Phase I permit, Appendix 1, p. 25-27, and Manual, Section 2.5.7 Minimum Requirement # 7, pp. 2-33. For sites in these basins, the pre-developed condition

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to be matched is the existing land cover. Most areas located within the Seattle city limits, many areas within the City of Tacoma, and some areas in Bellevue and Everett would qualify for this exception. *Testimony of O'Brien, Booth, Exs. ECY 4 (Phase I), p. 2-33, Muni 0001, Appendix 1, p. 25-27.*

41.

The Phase I Permit defines LID as follows:

> stormwater management and land development strategy applied at the parcel and subdivision scale that emphasizes conservation and use of on-site natural features integrated with engineered, small-scale hydrologic controls to more closely mimic pre-development hydrologic functions.

Ex. Muni 0001, p. 62. Ecology adopted this definition from the Puget Sound Action Team's Low Impact Development Manual (PSAT Manual), which is a technical manual published in 2005 to "provide stormwater managers and site designers with a common understanding of LID goals, objectives, specifications for individual practices, and flow reduction credits that are applicable to the Puget Sound region." *Ex. PSA 050, p.2.*[16] Other definitions of LID offered in testimony at the hearing differ from this definition primarily in the scale of application of LID. Thomas Holz offers an almost identical definition to the one quoted above, but includes application at the watershed scale in addition to the parcel or subdivision scale. *Testimony of Holz, Ex. PSA 050, p.11.*

[16] The advisory committee for the development of the PSAT Manual included Edward O'Brien, Tom Holz, and Derek Booth. These three experts also testified at the Phase I hearing, *Testimony of Moore, Ex. PSA 050, Acknowledgements page and p. 2.*

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42.

While specific definitions of LID may vary, the concept of LID is well-established, and the basic BMPs that constitute LID are well-defined. LID techniques emphasize protection of the natural vegetated state, relying on the natural properties of soil and vegetation to remove pollutants. LID techniques seek to mimic natural hydraulic conditions, reducing pollutants that go into stormwater in the first instance, by reducing the amount of stormwater that reaches surface waters. *Testimony of Horner, Booth, Holz.*

43.

LID techniques store, infiltrate and evaporate stormwater where it falls rather than collect and convey it to surface waters off site, and can be implemented at an individual development site level, as well as part of a broader strategy employed at a basin or watershed level. Site-level LID BMPs include, but are not limited to, maintenance of natural vegetation on site; reduction of impervious surfaces; protection of natural drainage patterns, use of minimal excavation foundations such as pin foundation for structures; use of vegetated swales to capture and retain runoff; use of green roofs, and storage and reuse of runoff. At a watershed or landscape scale, LID strategies can include basin planning, watershed-wide limits on imperviousness, and protection of sensitive areas like riparian zones, wetland and steep slopes. *Testimony of Holz, Booth, Ex. PSA 050.*

44.

Although many LID techniques are not new ideas (i.e. grass roofs, rain gardens), LID as a formal stormwater management concept was developed in the late 1980's. *Testimony of Booth,*

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Holz. Prince George's County, Maryland, a pioneer in the area of LID in the United States, began working on bioretention or rain gardens during the 1980's, and published a comprehensive LID technical manual and an accompanying volume providing detailed hydrologic analysis and computational procedures in 1999. *Exs. PSA 052 and 053.* Two federal agencies, the U.S. Department of Defense and Department of Housing and Urban Development, adopted LID Manuals in 2003 and 2004. *Exs. PSA 054 and 055.* The Puget Sound Action Team and the Washington State University Pierce County Extension published The PSAT Manual, a 247 page, comprehensive, technical guidance manual for the use of LID in the Puget Sound Area, in January of 2005 with funding provided by the Ecology. *Ex. PSA 050.* The PSAT Manual was intended to provide a menu of treatment options and direction for site design techniques, but it does not attempt to identify a performance standard for any of the included LID strategies. *Testimony of O'Brien.*

45.

The Environmental Protection Agency (EPA) has not required the use of LID in its stormwater rules or EPA permits, but it is increasingly supporting and encouraging the use of LID approaches in municipal stormwater programs on its website and thorough numerous publications. *See for example, Ex. PSA 057(EPA National Pollutant Discharge Elimination System (NPDES), Post-Construction Stormwater Management in New Development and Redevelopment)(posted on EPA's website); PSA Ex. 058, (EPA National Pollutant Discharge Elimination System (NPDES), Low Impact Development (LID) and Other Green Design Strategies)(posted on EPA's website); PSA 056 (EPA Fact Sheet for Stormwater Phase II Final*

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Rule, Post-Construction Runoff Control Minimum Control Measure (Jan. 2000, rev'd 2005); Ex. PSA 066 (EPA Low Impact Development (LID), A Literature Review (Oct. 2000); Ex. PSA 059 (EPA 833-F-04-033, Resource List for Stormwater Management Programs (May 2004); Ex. PSA 060 (EPA National Management Measures to Control Nonpoint source Pollution for Urban Areas (Excerpts: Cover, Table of Content, Chapters 1-4, 10); Ex. PSA 061 (Memorandum from Benjamin Grumbles (Assistant Administrator, EPA) to EPA Regional Administrators Re: Using Green Infrastructure to Protect Water Quality in Stormwater, CSO, Nonpoint Source and Other Water Programs (Mar. 5, 2007); Testimony of Holz.

46.

Ecology's 2005 Stormwater Management Manual addresses the use of LID techniques in several ways, as part of the manual's Minimum Technical Requirements and Site Planning (Volume I), its Hydrologic Analysis and Flow Control Design/BMPs (Volume III), and its Runoff Treatment BMPs (Volume V). *Ex. ECY 4.*[17] One of the most significant changes during the 2005 update to the Manual included the addition of a "credit" system for projects that use LID techniques. *Ex. PSA 064.*

[17] The Manual is not a regulation but rather a guidance document that presents a presumptive approach to meeting requirements established through other means, such as permits. Washington is somewhat unique in its reliance on the Stormwater Management Manual for directing how stormwater management is to be conducted. *Testimony of Moore. Testimony of O'Brien.* The Manual represents Ecology's generalized determination of what constitutes AKART for stormwater management, without regard to how much horizontal development should be allowed (*i.e.*, whether a particular parcel, subdivision, or watershed should be developed or a particular project should be undertaken). The manual is also considered by the Department of Community, Trade, and Economic Development, the agency charged with state oversight of the implementation of the GMA, to constitute the best available science for use by local governments planning under the GMA. *Testimony of O'Brien.*

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47.

Volume I covers several key elements of developing a stormwater site plan, including identifying the minimum requirements for stormwater management at all new development and redevelopment projects. Minimum Requirement #5, which directs on-site stormwater management for the purpose of using inexpensive practices on individual properties to reduce the amount of disruption of the natural hydrological characteristics of the site, requires the use of certain LID BMPs such as roof downspout control and dispersion and soil quality BMPs. This minimum requirement applies to single-family home sites and larger properties. *Testimony of O'Brien, Ex. ECY 4 (Phase 1), Vol I, at 2-26; Ex. Muni 0001, Appendix I at p.10 and 19.* The Phase I permit requires that permittees' local ordinances must meet Minimum Requirement #5, including requiring specified LID BMPs to reduce the hydrologic disruption of developed sites. *Testimony of O'Brien, Ex. Muni 0001, Condition S5.C.5 (at p. 9) and Appendix 1(at p.19).*

48.

Stormwater site planning requirements, also contained in Volume I, direct that site layouts minimize land disturbance and maximize on-site filtration by considering a number of LID strategies and techniques such as preserving areas with natural vegetation (especially forested areas) as much as possible, minimizing impervious areas, and maintaining and utilizing natural drainage patterns. *Testimony of O'Brien, Ex. ECY 4 (Phase I), Vol I, at 3-2.*

49.

Volume III of the Manual focuses primarily on BMPs to address the volume and timing of stormwater flows from developed sites, for the purpose of providing guidance on the

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estimation and control of stormwater runoff quantity. Appendix III-C of this volume is Ecology's guidance explaining how Low Impact Development techniques can be represented in approved runoff models so that their benefits in reducing surface runoff can be estimated and credited in the flow duration model. It identifies seven categories of LID techniques, including permeable pavements, vegetated roofs, rainwater harvesting, reverse slope sidewalks, minimal excavation foundations, and rain gardens, and lists the basic design criteria Ecology considers necessary in order to justify use of the suggested runoff credit. *Testimony of O'Brien, Ex. ECY 4 (Phase I), Vol III, at Appendix III-C.*

50.

Finally, Volume V of the Manual identifies and discusses BMPs designed to treat runoff to remove sediment and other pollutants at developed sites, for the purpose of providing guidance on the selection, design and maintenance of permanent runoff treatment facilities. LID techniques are included in both the basic and advanced treatment options available to developers, and the method for determining the treatment credits for each technique is explained. Chapter 5 of this volume is devoted to the methods for analysis and design of on-site LID BMPs that serve to both control runoff flow rates as well as provide runoff treatment and, since 2005, has directed readers to use the PSAT Manual for various LID BMPs. *Testimony of O'Brien, Ex. ECY 4, Vol V.*

51.

Ecology wrote the first draft of the current Phase I Permit in 1999. At that time, LID was recognized as a stormwater management strategy, but there was not the same body of work

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available on its use as there is today. Although much of the work and literature cited above post-dated the initial draft of the current Phase I Permit, Ecology recognized that a large body of work existed on LID as it finalized the Phase I permit. Despite the existence of many LID source or reference materials, Ecology believed that it could not at that time define minimum LID requirements, and was unable to define a regulatory performance standard to hold municipalities to, should LID requirements be imposed by the permit. The agency also recognized that local governments had adopted other land use and development standards that were obstacles to the implementation of LID on a broader scale. Some local governments also have limited experience with LID techniques and are reluctant to approve them. *Testimony of O'Brien.*

52.

Early drafts of the permit included requirements for basin or watershed planning as a LID technique. Use of a basin planning approach in the permit would, among other things, require municipalities to consider the effects of loss of impervious cover to water quality in larger, watershed, basin, and sub-basin areas (potentially measured in many square miles). The ideal area size for basin planning is two to ten acres. WRIA-scale (Water Resources Inventory Area) planning efforts are too large to address the impervious surface problem. *Testimony of Wessel.* Basin planning can also lead to the development of better site specific strategies, and some Ecology staff advocated for its inclusion into the Permit. *Testimony of O'Brien.*

53.

Ultimately, Ecology drafted a permit that requires municipalities to identify barriers to use of LID, and to take steps to also "allow" LID. Specific requirements for basin planning were

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not included in the final permit, although the Endangered Species Act listing of various salmon species, and efforts of the Puget Sound Partnership are reasons to reexamine the need for basin planning as a permit requirement. *Testimony of Wessel, Moore; Ex. PSA 31.* Ecology rejected basin or watershed planning as a permit requirement, in part because the agency could not require a comprehensive planning effort, given that not all jurisdictions within a given watershed or basin were covered by the Phase I permit. Ecology also concluded that imposing both site level LID and basin planning requirements would move the agency too far into the land use regulatory arena, although Ecology witnesses conceded that imposition of more detailed LID requirements and a basin planning process could be harmonized with a parallel Growth Management Act land use process, thereby elevating water quality as a growth management planning priority. *Testimony of Moore, Wessel, O'Brien.*

54.

Ecology stated in its 2004 report to the Legislature that:

> Compact style development, with a smaller footprint, reduced impervious surfaces, natural areas within the urban core, and improved water detention can help local communities meet the Growth Management Act's goals of accommodating growth while protecting the environment.

Ex. ECY 6 (Phase I), p. 31. This same 2004 report to the Legislature highlighted the importance of stormwater basin planning in areas which are relatively undeveloped where new development is occurring. Ecology stated that in these areas:

> site specific controls alone cannot prevent impacts and preserve aquatic resources. Recent research should be used to identify development strategies that may protect the resources. Scientific modeling of the basin can help predict the extent of potential

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> impacts and the effectiveness of alternative land development options to help avoid or minimize those impacts.

Id. at 28. Ecology also recommended in its report to the Legislature that state and local governments consider basin planning to address the known shortcomings of the stormwater permits. Ecology stated that:

> Stormwater basin planning is needed to quantify flow-related impacts and sources of pollution to urban water bodies. This information is needed to target resources spent on structural and non-structural controls (such as maintenance and public education) so that goals for urban water bodies can be met. In many basins, this planning can be combined with the planning for new development described earlier.

Id. at 30. Other types of water quality planning are taking place on a WRIA basis. The Board finds that information developed by permittees regarding their use of basin planning, and its possible interface with other planning efforts, would be very valuable to Ecology in its development of the next phase of the Permit.

55.

The Phase I Permit includes several conditions that address LID in various ways, nearly all of which are in the nature of encouraging or promoting rather than requiring LID by municipalities. In contrast to other permit terms, the final permit does not require municipalities to implement ordinances or other measures to use LID as a primary tool to manage stormwater within their jurisdictions. *See* S5.C.5.b.i (allowing local governments to tailor certain requirements applicable to new development through the use of basin plans or other similar water quality and quantity planning efforts); S5.C.5.b.iii (requiring SWMPs to allow non-structural preventative actions and source reduction approaches such as LID techniques);

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S5.C.6.a (stating that permittees should consider other means to address impacts from existing development "such as reduction or prevention of hydrologic changes through the use of on-site (infiltration and dispersion) stormwater management BMPs and site design techniques, riparian habitat acquisition, or restoration of forest cover and riparian buffers . . ."); S5.C.10.b.(3) and (4) (requiring the inclusion of LID techniques in education and outreach programs); S8.F.1 and 7 (requiring monitoring of the effectiveness of one flow reduction strategy that is in use or planned for installation in their jurisdiction); and Appendix 1 § 4.5 (imposing, as a minimum requirement, on-site stormwater management where feasible, including use of roof downspout controls and dispersion and soil quality BMPs or their functional equivalent).[18] *Exs. Muni 0001, p. 9, 10, 12, 24, 25, 46, 47, and Appendix 1, p. 19.*

56.

Some commentors on the draft Phase I Permit criticized the lack of more mandatory LID requirements. The National Marine Fisheries Service and the U.S. Fish and Wildlife Service (jointly the Services) offered comments on the Draft Phase I Permit in May, 2006. While they supported many elements of the draft Permit, the Services recommended that the Permit employ methods to help ensure that several LID projects are completed within the permit term and strongly encouraged the use of basin planning to make better linkage with salmonid recovery plans organized at the watershed level. *Ex. PSA 030.* EPA offered its comments on the draft Phase I Permit in October, 2006. *Ex. PSA 067.* While EPA praised many aspects of the permit, it also recommended strengthening the permit by "promot[ing] the implementation of low impact

[18] This same requirement is included in The Manual. *Ex. ECY 0004 (Phase I), Vol. 1, p. 2-26.*

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development and non-structural best management practices," and "add[ing] a basin planning program requirement." Similarly, a group of Washington Scientists sent an "open letter" to Ecology on October 26, 2006, in which they criticized the draft Phase I Permit for its continued focus on "end of pipe" management of stormwater, emphasizing the need to preserve existing "least-disturbed" watersheds, to limit forest loss, and to halt runoff from new impervious areas in the Puget Sound Basin. They recommended broad application of LID principles within the context of land use planning and development regulations efforts to prevent runoff to surface water. *Ex. PSA 010.*

57.

Ecology staff who developed the Phase I permit, as well as a number of stormwater experts who testified before the Board, agreed that no one stormwater management technique could solve the problem of polluted runoff from municipal stormwater systems. Even the extensive use of site-level LID is not sufficient, on its own, to fully protect aquatic resources. Rather, a combination of aggressive use of LID techniques, best conventional engineering techniques to manage high flows (such as the flow duration standard), and land use actions to preserve a high percentage of native land cover, are necessary to reduce pollutants in stormwater to the maximum extent, and to preserve water quality. Although the there is considerable dispute about the attainable performance of particular LID strategies and engineering techniques, there is no dispute that *in combination* these approaches offer the best available, known and tested methods to address stormwater runoff. *Testimony of O'Brien, Holtz, Booth.*

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58.

There are existing design criteria for many LID techniques, just as there are for traditional BMPs employed to manage stormwater run-off used at the parcel or subdivision scale (for example, pond size or thickness of a liner). These aspects of LID can be employed at a site specific level. However, at this time there are no universal or broadly endorsed performance standards for LID, at either the parcel, subdivision, or watershed scale. Nor were experts before the Board willing to endorse or recommend such standards from among the many potential options identified, although it was undisputed that any permit condition requiring permittees to meet a new stormwater performance standard based on LID would implicate many other local government regulatory schemes, and require modification to local government GMA planning processes and requirements, zoning and development regulations, and building codes. *Testimony of Holz.*

59.

A zero runoff outcome from the use of LID techniques is one such performance standard, but actions to meet that standard would implicate a range of land use planning actions and watershed level assessments. It is possible to create other, more specific performance standards for LID, although the process would involve time and effort. Other jurisdictions are currently using such standards, or have proposed standards for use. For example, jurisdictions can require that LID BMPs be designed in accordance with guidelines in technical manuals, impose specific minimum technical requirements for buildings or roads, require protection of a specific amount of native vegetation at the site or basin level, limit the amount of effective impervious surface,

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protect the natural hydrograph through various parameters, require maintenance of a certain percentage of predevelopment evapotranspiration capacity or minimize or eliminate surface runoff, or require that developers prioritize LID BMPs as the first choice before conventional BMPs. The Phase I Municipal Stormwater Permit for San Diego County, which was reissued in January, 2007, requires all new and redevelopment projects to implement LID BMPs where feasible. The Permittees are given the responsibility of defining the applicability and feasibility of LID BMPs, including the minimum standards to ensure maximum implementation. Another example of an NPDES permit from another jurisdiction that incorporates a LID performance criteria is the Ventura County MS4 Permit. This permit, which was in draft form at the time of the hearing, requires that developers prioritize LID BMPs as the first choice before conventional BMPS. *Testimony of Booth, Holz, Horner, Exs. PSA 048, p. 13-18; PSA 069, p. 49; PSA 070, 072, 080, Snohomish County Code 30.63C.*

60.

Requiring municipalities to impose parcel and subdivision-level LID best management practices represents a cost effective, practical advancement in stormwater management. Use of LID techniques at the parcel and subdivision level would not be feasible on every type of site, or under all rainfall conditions present in Western Washington. Use of LID techniques could in some instances allow pollutants to enter groundwater. LID BMPs require maintenance. All of these limitations are also applicable to the more traditional end of pipe BMPs. In fact, site attributes that make implementation of LID techniques difficult also typically make implementation of conventional techniques difficult. In the absence of watershed or basin level

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efforts to utilize LID, parcel and subdivision-level use of LID will be less effective in overall stormwater management efforts, but still a substantial advancement. *Testimony of O'Brien, Booth, Holz, Horner, Exs. ECY 3 (Phase I), p. 34-36, PSA 066, p. 2, 3.*

61.

In many cases, implementation of LID techniques on the ground for new or redevelopment, or even retrofitting existing development, is less costly, or no more costly, than conventional engineered BMPS. Structural stormwater controls, such as detention ponds, curbs, gutters and pipes, require significant hardware and capital investment. LID techniques eliminate or reduce the need for these structural controls by reducing the volume of water to be managed. LID techniques may also require less space than these traditional methods. *Testimony of Holz, Booth, Horner, Exs. PSA 047, p. 6-10, PSA 066, p.1, ECY 3 (Phase I), p. 35-36.*

62.

A major cost consideration in utilizing LID techniques at a site level is not the engineering or construction associated with the LID techniques, but rather the costs associated with navigating a system of regulation and development that was not created with LID in mind. To fully incorporate LID principles into this system will require review, consideration, and in some instances modification, of existing zoning and building regulations that create obstacles to the use of LID. Some examples of common local government ordinances that could make it difficult to utilize certain LID techniques include requirements related to road width, curbs and gutters, vegetation clearing, and parking spaces. *Testimony of Holz, Horner.* The cost of implementing LID across a broader land use spectrum, through basin or watershed planning is

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more speculative, and the Board was presented with no clear evidence on costs associated with broader scale implementation of LID in this manner. Although such planning is underway in certain areas, a longer public and political process could be expected to accompany such an effort.

63.

The cost of not expanding the application of LID strategies to manage municipal stormwater is very high. The biological health of Puget Sound is declining, and a significant cause of the decline is stormwater run-off. This decline carries with it a variety of environmental, economic, and social costs. *Ex. PSA 087, p. 1.* The Puget Sound Water Quality Plan, which is a plan mandated by the Legislature to be the state's long term strategy for protecting and restoring the Puget Sound, stated as early as 2000 that local governments needed to adopt ordinances that allow and encourage LID practices. *Ex. PSA 078, p. 101.* Many leading scientists concluded, in a paper submitted to the Puget Sound Partnership in July of 2007, that the problem of stormwater must be addressed in the land use context if the health of Puget Sound, the species that inhabit it, and its various important beneficial uses to the region, are to be protected and/or recovered. The group concluded that:

> We have well documented evidence that the impairment associated with stormwater runoff is primarily a **land use problem,** and that we cannot fully mitigate its effects if we approach it only site-by-site. We know that the problems must be addressed at a basin or landscape level-but we continue to manage land use and stormwater primarily on a site-by-site, end of pipe basis. At the same time, we also know that current site-by-site development techniques that result typically in wholesale loss of vegetation, compaction of native soils and connected impervious surfaces, can and should be improved upon significantly if we are to address stormwater problems.

Ex. PSA -012, p. 3 (emphasis in original).

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64.

Recently, many local governments have begun incorporating LID techniques into their stormwater manuals, and/or adopting LID stormwater requirements. *Exs. PSA 072 (City of Olympia, Engineering Design and Development Standards, Ch. 9, Green Cove Basin); PSA 073 (Graham Community Plan, A Component of the Pierce County Comprehensive Plan, Excerpts: pp. Cover, Table of Contents, p. 70, 87, 109, 149, 208); PSA 074 (Gig Harbor Peninsula Community Plan, Excerpts: pp. cover, 29, 41, 63, 117, 210); PSA 076 (King County, Washington, Surface Water Design Manual, Jan. 4, 2005, Excerpts: pp. cover, Table of Contents, 5-1 through 5-16); PSA 051 (Pierce County, Stormwater Management and Site Development Manual, Excerpts: Ch. 10, p. 10-1 to 10-82).*

65.

Examples of the approaches already being used by Phase I Permittees to encourage or require the use of LID techniques include reducing charges for surface water rates with the use of an approved LID stormwater and surface water runoff systems (*City of Tacoma, Ex. PSA 085, p. 4);* promoting LID during project scoping meetings with potential developers (*City of Tacoma, Ex. PSA 085, p. 4);* adopting LID Ordinances (*Snohomish County, PSA Ex. 077, p. 8);* incorporating LID Development Design concepts into existing regulations (*Snohomish County, Ex. PSA 077, p. 9*); and providing public outreach and education about LID (*City of Tacoma, Ex. PSA 085, p. 5, Snohomish County, Ex. PSA 077, p. 10-14, City of Seattle, Ex.PSA 079, p. 12, 13*). Other, more stringent examples include requiring project proponents to use LID techniques for all proposed Fully Contained Community developments in rural areas (*Snohomish County, Ex.*

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PSA 077, p. 9); requiring LID for any UGA docket expansions proposals within the Little Bear Creek watershed (*Snohomish County, Ex. PSA 077, p. 10*); and requiring LID to be used on a large project in the Mill Creek pocket expansion (*Snohomish County, Ex. PSA 077, p. 9*).

66.

The Board finds that LID methods are at this time a known and available method to address stormwater runoff at the site, parcel, and subdivision level. Numerous reference documents, technical manuals, expert testimony, and Ecology's own Stormwater Management Manual, discussed above, support this finding. The Board also finds that LID methods are technologically and economically feasible and capable of application at the site, parcel, and subdivision level at this time. Because application of these methods at the basin and watershed level involves additional cost and practical considerations, we find Ecology must ready for the eventual use of this known and available method of stormwater treatment for future iterations of the permit, consistent with its obligation to impose increasingly stringent requirements on discharges covered by NPDES permits.

G. Existing development

67.

The Phase I Permit addresses stormwater runoff from existing development through the implementation of structural stormwater controls and source controls. Both of these are required components of Permittees' SWMPs, and the Permit includes minimum requirements for each

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which are based on EPA's stormwater rules.[19] *Testimony of Wessel, Ex. Muni 0001, p. 12-15, Ex. Muni 0002, p. 34-36.*

68.

The structural stormwater control program, also referred to as the "retrofit" component, is targeted at discharges not adequately controlled by other aspects of the SWMP. S5.C.6. Through this program, permittees must consider construction of stormwater control projects, as well as other means to address impacts to state waters caused by MS4 discharges. The permit directs that the program "shall consider the construction of projects such as: regional flow control facilities; water quality treatment facilities; facilities to trap and collect contaminated particulates, retrofitting of existing stormwater facilities; and rights-of-way, or other property acquisition to provide additional water quality and flow control benefits." The Permit also provides that permittees "should consider" other means to address impacts, including LID techniques such as "reduction or prevention of hydrologic changes through the use of on-site (infiltration and dispersion) stormwater management BMPs and site design techniques. . ." S5.C.6.a. *Testimony of Wessel, Ex. Muni 0001, p. 12, 13.*

69.

The permit establishes minimum performance measures for the structural stormwater control program, including development of the program within 1 year of the effective date of the

[19] The Fact Sheet's reference to 40 C.F.R. 122.26(b)(2) appears to be a typographical error. Ecology's pre-hearing brief properly cites the applicable federal regulation for these program elements as 40 C.F.R. 122.26(d)(2). A portion of this federal rule, unrelated to municipal stormwater, was recently invalidated in Natural Resources Defense Council v. U.S. E.P.A., 526 F.3d 591 (9th Cir. 2008).

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permit, and implementation of the program within 18 months from the effective date of the permit. S5.C.6.b.i. Permittees are required to provide a list of planned individual projects that are scheduled for implementation during the term of the permit. Municipalities are not required to prioritize the planned projects in any manner. Permittees are required to submit a description of their structural stormwater control program to Ecology along with the written documentation of their SWMP, but the permit does not set a minimum level of effort for this requirement or provide for Ecology review and/or approval of the structural stormwater control program. S5.C.6.b.ii. *Testimony of Wessel, Dalton, Ex. Muni 0001, p. 12, 13, Ex. Muni 0002, p. 35.*

70.

The requirements for the Source Control Program for existing development are set out in S5.C.7. Through this program, the permittee must "reduce" pollutants in runoff from areas that discharge to MS4s, through application of operational and structural source control BMPs, and if necessary treatment BMPs to pollution generating sources associated with existing land uses and activities. S5.C.7.a. The program required in this section also must include inspections, application and enforcement of local ordinances at applicable sites, and reduction of pollutants associated with application of pesticides, herbicides and fertilizer discharging to MS4s. S5.C.7.b.ii-iv. While reduction of pollutants is mandated, no objective standard is set for the amount of reduction, although Ecology must review and approve the source control program. S5.C.7.b.i. *Testimony of Wessel, Muni 0001, p. 13-15.* Under this section of the permit, permittees must also implement a progressive enforcement policy to assure compliance with

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stormwater requirements within a reasonable time period. S5.C.7.b.iv. *Testimony of Wessel, Ex. Muni 0001, p. 13-15.*

H. Timing of Compliance

71.

PSA challenges the validity of several Phase I Permit provisions on the grounds that they do not require implementation of the permit within three years. PSA provides several examples of permit conditions that allow implementation after three years. Some of these examples include S5.C.2.b.ii (requiring outfalls to be mapped no later than four years from the effective date of the permit); S5.C.8.b.vi (requiring screening for illicit discharges in portion of each jurisdictions to be completed within four years.); and S.5.C.9.b.ii (3) (allowing permittees up to four years after the effective date of the permit to develop a schedule to inspect treatment and flow control facilities). PSA also provides examples of conditions that impose duties that are tied to the expiration of the permit. Some examples of these conditions include Condition S6.A.3 (full development of the co-permittee and secondary permittees' SWMPs no later than 180 days prior to the expiration of the permit); and S6.D.1. a.ii (Secondary permittees shall label all inlets 180 days prior to expiration of the permit). *Ex. Muni 0001, p. 7, 18, 20-21, 25, and 27.*

72.

Any Conclusion of Law deemed to be a Finding of Fact is hereby adopted as such.

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CONCLUSIONS OF LAW

1.

The Board has jurisdiction over the parties and the issues in the case pursuant to RCW 43.21B.110(1)(c). The burden of proof is on the appealing party(s) as to each of the legal issues, and the Board considers the matter *de novo,* giving deference to Ecology's expertise in administering water quality laws and on technical judgments, especially where they involve complex scientific issues. *Port of Seattle v. Pollution Control Hearings Board*, 151 Wn.2d 568, 593-594, 90 P.3d 659 (2004). Pursuant to WAC 371-08-540(2), "In those cases where the board determines that the department issued a permit that is invalid in any respect, the board shall order the department to reissue the permit as directed by the board and consistent with all applicable statutes and guidelines of the state and federal governments."

A. Monitoring (Issues C.1, C3, and F.3.)

2.

Two counties, Pierce and Clark, challenge the monitoring requirements imposed by Special Condition S8.[20] They contend that their own monitoring programs, which focus on receiving water monitoring, are more advanced than the monitoring required by S8. While they support Ecology's S8 monitoring approach as a starting point for municipalities that do not already have well developed receiving water monitoring programs, Pierce and Clark Counties

[20] Issues C.1 and C.3.

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argue that compliance with the S8 monitoring will hinder their own efforts to protect water quality.

3.

The Utilities also challenge the validity of the S8 monitoring program. They contend that it is deficient because it does not require receiving water or "compliance" monitoring. They argue that receiving water monitoring is necessary to establish whether the permittees have complied with water quality standards and whether they have treated their discharges with AKART or to the maximum extent practicable.[21]

4.

WAC 173-226-090(1) establishes monitoring requirements for general waste discharge permits. The Board has concluded in its past decisions that this regulation provides Ecology with the discretion to impose *reasonable* monitoring requirements. WAC 173-226-090(1); *Puget Soundkeeper Alliance v. Ecology*, PCHB Nos. 05-150, 0151, 06-034, -040 (Jan. 26, 2007) (CL 22). Further, since a decision pertaining to monitoring requirements in a general permit falls within an area of Ecology's technical expertise, and involves complex scientific issues, the agency's decision is entitled to deference. *Port of Seattle* at 593-594. The disagreement between appellants and Ecology reflects different sides of a long-standing debate regarding the relative merits of instream versus outfall monitoring, and the most advantageous sequencing of the two. *Ex. P1 0048*. It is clear there is no one right approach, as the type and timing of monitoring that is best

[21] Issue F.3.

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in any given situation depends on the particular purpose, context, and available resources, among other factors.

5.

Neither the Utilities nor the Counties have cited to any law requiring the Phase I Permit to require receiving water monitoring. The federal stormwater rules require only that municipalities propose a monitoring program for the term of the permit, but list few specific requirements. 40 C.F.R. 122.26(d)(2)(iii)(D).[22] The Board concludes that Ecology's decision not to require receiving water monitoring during this permit cycle is lawful and reasonable. Ecology's decision to require monitoring designed to understand the pollutants discharging from MS4s, and to evaluate the effectiveness of the BMP's in use, will provide the most useful data to establish what constitutes maximum extent practicable reduction in pollutants in discharges from MS4s for future permits. Further, as pointed out by Ecology, the counties are not prohibited from conducting receiving water monitoring in addition to the S8 monitoring required under the permit.[23]

6.

In light of the discretion Ecology has in this area, the deference its technical decisions are entitled to, and the fact that the burden of proof rests on the party challenging the permit, neither the Counties nor the Utilities have presented a sufficient case to convince the Board that it should

[22] A portion of this federal rule, unrelated to municipal stormwater, was recently invalidated in Natural Resources Defense Council v. U.S. E.P.A., 526 F.3d 591 (9th Cir. 2008).

[23] It is also possible that parts of the Pierce and Clark County programs could be used to satisfy the targeted effectiveness component of the S8 monitoring (S8.E). *Ex. Muni 0001, p. 45-46.* The Board encourages Ecology to work with Pierce and Clark Counties to find ways to make parts of their current monitoring programs satisfy some of the requirements under S8.

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reverse Ecology's decision to select the S8 monitoring program and require all permittees to participate in it.

B. Ports (Issue E.5)

7.

The Ports contend that it is "unlawful, unreasonable, unjust, or invalid" to require them to prepare SWPPPs on all port owned land not covered by another discharge permit. The Ports argue that the primary permittees have to prepare SWPPPs only on areas on which industrial type activities occur (maintenance areas and material and heavy equipment storage) that are not covered by another discharge permit. The Ports assert that it is unreasonable to require SWPPPs without consideration to how property is used, it is unreasonably burdensome to the Ports because of the cost to prepare SWPPPs, and it is unnecessary because not all port-owned lands have polluting generating characteristics. The evidence presented, however, does not support these arguments.

8.

The evidence presented at the hearing establishes that lands owned by the Ports of Seattle and Tacoma are located close to vulnerable urban waters with documented water quality and sediment contamination problems. Almost all of the port-owned lands that discharge to MS4s have pollutant-generating characteristics. Therefore preparation of SWPPPs for these properties will have environmental benefits. The only exception is those few environmental mitigation sites owned by the Port of Tacoma. Most of these environmental mitigation sites probably do not discharge to the MS4s, and therefore would not require coverage under the Phase I Permit.

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For the ones that do, however, there is no environmental benefit gained by requiring the preparation of a SWPPP, and it is appropriate to exempt these sites from preparation of SWPPPs.

9.

The Board concludes that it not an unreasonable burden to require the Ports to prepare a SWPPP for all port-owned lands which discharge to the MS4 and are not already covered by another discharge permit. Based on the permit's inventory of types of sites with potential pollutant generating sources (*Muni 0001, Appendix 8*), it was reasonable for Ecology to conclude that the Ports owned most or all of these type of pollution sources, and that the Ports needed to prepare plans to manage stormwater from such port-owned property. The Ports also have fewer requirements under the Phase I Permits than other primary permittees. They will have fewer SWPPPs to prepare than the primary permittees. For SWPPP preparation, they can use some generic conditions for sites with identical uses, such as commercial buildings or parking lots. This will reduce the amount of time it takes to prepare each SWPPP and the cost of preparation. The ports can also work cooperatively with their tenants who share some responsibility for the proper management of stormwater on port-owned properties, which will have the added environmental benefit of educating site operators about stormwater BMPs.

10.

The Board concludes that Special Condition S6.E.7, which requires the Ports to prepare SWPPPs on all port-owned lands is appropriate and valid. However, the permit should not mandate SWPPP preparation for environmental mitigation sites owned by the Port of Tacoma, as

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the Port of Tacoma has shown that such sites are unlikely to generate untreated stormwater pollution.

C. LID (Issue F.1.a & .b)

11.

The LID issues raised in this appeal involve the question of whether the Phase I Permit fails to meet the required treatment standard of reducing pollutants to the "maximum extent practicable"(MEP) and applying "all known, available and reasonable methods of treatment" (AKART), because the permit does not require more extensive use of LID techniques.

12.

The Board has previously ruled in this appeal (on summary judgment in the Special Condition S4 proceeding) the CWA requires that NPDES permits issued for discharges from MS4s must reduce pollution to the maximum extent practicable (the "MEP" standard). The Board also concluded the WPCA contains a similar requirement, in that all wastewater discharge permits must incorporate permit conditions requiring all known, available and reasonable methods of treatment to control the discharge of toxicants and protect water quality (the "AKART" standard). Order on Dispositive Motions: S.4 issued on April 2, 2008.

13.

The MEP standard in the CWA provides:

> Permits for discharges from municipal stormsewers . . . (iii) shall require controls to reduce the discharge of pollutants to the maximum extent practicable, including management practices, control techniques and system, design and engineering methods, and such other provisions as the Administrator or the State determines appropriate for the control of such pollutants.

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33 U.S.C. § 1342(p)(3)(B)(iii).

Neither Congress nor the EPA have defined the meaning of MEP in the municipal stormwater context, nor do the parties cite to federal court cases interpreting the MEP standard in the municipal stormwater context.[24] The Board, in a prior decision pertaining to the first round of the municipal stormwater permits, stated:

> The MEP standard is unique under water pollution laws and applicable only to municipal stormwater discharges. MEP reflects the difficulty of addressing stormwater on a system wide basis and the focus of regulating municipal stormwater discharges on prevention and control. This approach by its nature requires extensive planning and *prioritization* to achieve the underlying of goal of meeting water quality standards.

Save Lake Sammamish v. Ecology, PCHB Nos. 95-78 & 121, Order Granting Summary Judgment (Dec. 12, 1995) (emphasis added).

14.

The AKART standard originates in state law, but the Legislature has not explicitly defined the term. Ecology has incorporated the state AKART standard into several of its regulatory programs (*e.g.*, the state surface and ground water quality standards, state waste discharge and NPDES permit programs, sediment management standards, and domestic wastewater facilities regulations), and has defined the AKART standard through rulemaking. In the state's surface water quality standards, "AKART" is defined as "the most current methodology that can be reasonably required for preventing, controlling, or abating the

[24] The term "practicable" as used in a different section of the CWA, 33 USC § 1311(b)(1)(a), has been defined as meaning that technology is required unless the costs are "wholly disproportionate" to pollution reduction benefits. *Rybacheck v. U.S. EPA,* 904 F.2d 1276, 1289 (9th Cir. 1990).

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pollutants associated with a discharge." WAC 173-201A-020. The Washington Supreme Court has further clarified that the "reasonableness" prong of AKART involves both technological and economic feasibility. *Puget Soundkeeper Alliance v. Ecology,* 102 Wn. App. 783, 792-793, 9 P.3d 892, 897 (2000).

15.

In evaluating MEP and AKART for the Phase I Permit, we start with the context that this is a "programmatic" permit that regulates the discharge from MS4 systems on a jurisdiction-wide basis, through the municipalities' implementation of their Stormwater Management Programs. In several instances the permit requires that through these Stormwater Management Programs, municipalities enact ordinances or orders, or adopt other enforceable documents, to control pollution in stormwater. *See, e.g.*, Condition S5.C.1. The nature and scope of the LID provisions in the Permit, and what can be required through the permit, must therefore be evaluated within the broader context of the SWMP requirements and the programmatic nature of this permit.

16.

The permit's reliance on a flow control standard as the primary method to control stormwater runoff from MS4s fails to reduce pollutants to the federal MEP standard, and without greater reliance on LID, does not represent AKART under state law. The permit's reliance on terms that simply require "removal of obstacles" and actions to "allow" use of LID is insufficient to meet these same federal and state pollution control standards. The testimony presented by PSA, the Utilities, and Ecology's technical experts leads to the indisputable conclusion that

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application of LID techniques, at the parcel and subdivision level, is a currently known and existing methodology that is reasonable both technologically and economically to control discharges entering into MS4s covered by the Phase I Permit. The great weight of testimony before the Board, from various experts and Ecology witnesses, was that in order to reduce pollution in urban stormwater to the maximum extent practicable, and to apply AKART, it is necessary to aggressively employ LID practices *in combination with* conventional stormwater management methods. Thus, we conclude that under state law, the permit must require greater application of LID techniques, where feasible, in combination with the flow control standard, to meet the AKART standard. The permit must also require the application of LID, where feasible, and conventional engineered stormwater management techniques to remove pollutants from stormwater to the maximum extent practicable in order to comply with federal law. Our recognition that use of LID is to be employed where feasible recognizes that, like all stormwater management tools, it too is subject to limitations in its practical application by site or other constraints. *See* Findings of Fact 49-51. We do not change the applicable legal standard by use of this term. Accordingly, the permit must be remanded for modification in light of this conclusion.

17.

Although we conclude that the permit must require municipalities to employ broader use of LID at the parcel and subdivision level, we stop short of concluding that the permit must, at this time, require use of LID at a basin and watershed level. Based on the evidence before the Board, we cannot conclude that the current iteration of the permit must require implementation

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of LID on a basin or watershed scale in order to meet federal and state water quality standards. Little evidence was presented as to the elements and cost of basin or watershed planning that would be necessary to implement LID at this level. Ecology testified that the current Phase I and Phase II permits result in a patchwork of regulation of municipal stormwater, and jurisdictions are at greatly varying degrees of readiness to manage stormwater on basin or watershed levels. The Phase II permittees themselves are at greatly varying degrees of readiness and capacity to undertake LID on a basin and watershed level, and would need to work with Phase I and other jurisdictions to do so. Given these several factors, the Board concludes that a permit condition requiring municipalities to implement LID at a basin or watershed level is not, at this time, reasonable or practicable. This is not to say that no steps can or should be taken at this time. Ecology has identified the particular importance of basin planning in areas which are relatively undeveloped where new development is occurring. The Board concludes that city and county permittees should identify such areas where potential basin planning would assist in reducing the harmful impacts of stormwater discharges upon aquatic resources. This will assist Ecology in readying for the next round of permits when such a requirement may be necessary to meet the state AKART standard and, under federal law, to reduce pollutants in municipal stormwater to MEP. As we discuss in further conclusions, we do not find the Growth Management Act to be an impediment to Ecology requiring greater use of LID than represented by the current permit, including at the basin and watershed planning level. Because the CWA and state water quality laws anticipate that there will be increasingly stringent requirements imposed on those that discharge pollutants to the state's waters, including municipalities, efforts to further basin and

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watershed planning efforts in order to incorporate the known and available LID techniques should begin in anticipation of the next permit cycle.

18.

No party challenges Ecology's authority to require LID techniques if they are necessary to meet the AKART or MEP standards. The Board affirmed this point in its summary judgment order. Order on Dispositive Motions: (Phase I Municipal Stormwater Permit) (April 8, 2008). The Board further stated:

> As pointed out by PSA, it is impossible to untangle stormwater management from land use. Even the commonly accepted water quality technique of requiring a stormwater retention pond at a site takes up significant area in a development, potentially reducing the number of buildable sites and constituting a land use restriction. The challenge, as recognized by both Ecology and PSA, is to most effectively harmonize Ecology's authority over site design and land use standards under the water pollution laws with other state laws that are specifically aimed at addressing land use on a broader scale.

Id. While Ecology does not dispute that it has the authority to require the use of LID techniques, it was constrained in the full exercise of this authority because of concerns about intruding too far into local government land use planning efforts under the Growth Management Act. Ecology's position is somewhat puzzling, as it has, through various requirements of its Stormwater Management Manual, and the permit itself, already required a number of LID techniques, and has required local government to remove obstacles to use of the same.[25] The

[25] We also note that, in another context, Ecology has recently adopted rules for the implementation of the Shoreline Management Act which outline a comprehensive process for preparing or amending shoreline master programs that requires, among other things, local governments to incorporate the most current, accurate, and complete scientific and technical information available that is applicable to the issues of concern; prepare a characterization of shoreline ecological functions, including hydrologic functions; identify water quality and quantity issues relevant to master

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Board concludes that contrary to the concerns raised by Ecology during permit development, that the GMA is not a barrier to greater use of LID but rather complements the efforts of Ecology to move forward with requiring the use of LID techniques under the Phase I Permit.

19.

The Legislature enacted the Growth Management Act (GMA), Ch. 36.70A RCW in 1990 and 1991, largely "in response to public concerns about rapid population growth and increasing development pressures in the state, especially in the Puget Sound region." *Quadrant Corp. v. State Growth Management Hearings Bd.*, 154 Wn.2d 224, 231-232, 110 P.3d 1132, 1136 (2005) (citations deleted). The GMA includes a broad statement of goals to guide local governments in their development and adoption of comprehensive plans including a goal to "Protect the environment and enhance the state's high quality of life, including air and water quality. . ." RCW 36.70A.020(10).

20.

The GMA mandates that local governments adopt comprehensive plans which include, among other elements, a land use element addressing, "drainage, flooding, and stormwater run-off in the area and nearby jurisdictions" and providing "guidance for corrective action to mitigate or cleanse those discharges that pollute waters of the state, including Puget Sound or waters entering Puget Sound." RCW 36.70A.070(1); *Swinomish Indian Tribal Community v. Skagit*

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program provisions; identify important ecological functions that have been degraded through loss of vegetation; and identify measures to ensure that new development meets vegetation conservation objectives. WAC 173-26-201.

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Co., 138 Wn. App. 771, 774, 158 P.3d 1179 (2007) (concluding that the GMA mandates that local governments adopt comprehensive plans to protect surface and ground water resources.)

21.

The state WPCA predated the GMA, with the specific purpose of protecting the waters of the state. RCW 90.48.010. The Legislature tasked Ecology with the job of implementing the WPCA. RCW 90.48.030, .035. Clearly, there is an area of interface and overlap between the GMA and the WPCA.

22.

The Washington Courts have stated that statutes are to be read together harmoniously whenever possible. "The construction of two statutes shall be made with the assumption that the Legislature does not intend to create an inconsistency." *Peninsula Neighborhood Ass'n v. Dep't of Transportation*, 142 Wn.2d 328, 342, 12 P.3d 134 (2000). Further, as the Washington Supreme Court recently stated: "We do not favor repeal by implication, and where potentially conflicting acts can be harmonized, we construe each to maintain the integrity of the other". *Anderson v. State, Dept. of Corrections,* 159 Wash.2d 849, 859, 154 P.3d 220, 225 (2007)(citing *Misterek v. Washington Mineral Products, Inc.*, 85 Wn.2d 166, 168, 531 P.2d 805 (1975)). *See also Kariah Enterprises, LLC v. Ecology*, PCHB No. 05-021, Corrected Order Granting Partial Summary Judgment (Jan. 6, 2005).

23.

The Board has addressed the interface between the GMA and the WPCA in the *Kariah* decision, cited above. In that case, the appellant challenged Ecology's denial of a CWA Section

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401 Water Quality Certification for a proposed residential development. The Appellant argued that the Legislature, through GMA, had delegated Ecology's authority over wetlands under the WPCA to local governments. The Board rejected this argument, concluding that neither chapter 90.48 RCW nor 36.70A RCW contained any express provisions delegating Ecology's authority over protecting water quality in wetlands to cities and counties. The Board went on to conclude that the WPCA and the GMA should be harmonized, and that:

> The legislative policy articulated in RCW 36.70A.010 indicates the GMA was directed at addressing uncoordinated and unplanned growth, not at shifting the responsibility to regulate wetlands from the state government to local governments.

Kariah, CL 33.

24.

Similarly, in a Shoreline Hearings Board decision addressing the interaction between the Shoreline Management Act (SMA) and the GMA, the Board concluded that Ecology's newly adopted shoreline rules did not improperly usurp the authority of local governments planning under the GMA, despite venturing into land use controls. *Association of Washington Businesses v. Ecology*, SHB No. 00-037, Order granting and denying appeal (2001)(Issue 9).[26]

[26] Although this decision was split on several issues, the holding on the GMA issue was unanimous. We note that even prior to the GMA, the Shoreline Management Act (SMA), Ch. 90.58 RCW, was enacted by initiative of the people in 1971 after recognizing the "ever increasing pressures of additional uses ... being placed on the shorelines necessitate[e] increased coordination in the management and development of the shorelines of the state." RCW 90.58.020. The SMA includes a broad policy to protect the waters of the state and gives preference to uses that protect water quality and the natural environment. *Id.* The SMA establishes a balance of authority between local and state government, where cities and counties have the primary responsibility for initiating the planning required by the Act and administering the regulatory program, and Ecology is tasked with providing assistance to local governments in the development of their shoreline master programs and "insuring compliance with the policy and provisions of [the Act]." RCW 90.58.050.

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25.

The Legislature has not expressed any intent, either through the GMA, SMA, or amendments to the WPCA, to redirect Ecology's role in water quality protection to the local governments. The Department of Community, Trade and Economic Development (CTED), the agency charged with implementing and interpreting the GMA, has considered the interaction between the GMA and pre-existing laws not specifically addressed in the GMA. In WAC 365-195-700, CTED's GMA regulations state:

> For local jurisdictions subject to its terms, the Growth Management Act mandates the development of comprehensive plans and development regulations that meet statutory goals and requirements. These plans and regulations will take their place among existing laws relating to resource management, environmental protection, regulation of land use, utilities and public facilities. Many of these existing laws were neither repealed nor amended by the act.
>
> This circumstance places responsibilities both on local growth management planners and on administrators of preexisting programs to work toward producing a single harmonious body of law.

WAC 365-195-700 (emphasis added).[27]

CTED's regulations further explain that:

> Overall, the broad sweep of policy contained in the act implies a requirement that all programs at the state level accommodate the outcomes of the growth management process wherever possible. State agencies are rarely concerned solely with the rote application of fixed standards. The exercise of statutory powers, whether in permit functions, grant funding, property acquisition or otherwise, routinely involves such agencies in discretionary decision-making. The discretion they exercise should now take into account the new reality of legislatively mandated local growth management

[27] Ecology's SMA rules recognize a similar responsibility to harmonize overlapping bodies of law and regulation, which now provide: "It is the responsibility of the local government to assure consistency between the master program and other elements of the comprehensive plan and development regulations." WAC 173-26-191(e).

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programs.

WAC 365-195-765(4).

26.

The Phase I permittees are all cities and counties required to plan under the GMA. RCW 36.70A.040. Their planning must address protection of surface and ground water. RCW 36.70A.070(1). CTED has identified the Ecology Stormwater Management Manual as best available science in regard to stormwater management under the GMA. Ecology, as a state agency, must also work toward implementation of the GMA. We conclude that there is no conflict between GMA and the WPCA, nor the roles of local governments and Ecology under these statutes. These roles support and complement each other and can be harmonized to allow water quality efforts to be considered and integrated into the growth management process outlined in the GMA.

27.

The Board concludes Ecology may, within the bounds of the GMA, require use of LID as a water quality management tool. The Board further concludes that the Phase I Permit must be modified to require use of LID where feasible, as it is necessary to meet the MEP and AKART standards of federal and state law, respectively. RCW 36.70A.070(1) already provides the mandate for local governments planning under the GMA to address drainage, flooding, and stormwater runoff in order to mitigate or cleanse discharges of water pollution. The Permit, including the Manual, merely sets forth the methods to accomplish this requirement.

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D. Existing Development (Issue F.2)

28.

PSA and the Utilities contend that the permit provisions addressing existing development are inadequate to meet the MEP and AKART standards. Their primary complaint is that both the structural and source control provisions applicable to existing development require only that programs "reduce" impacts from discharges (S5.C.6) or that the permittees "reduce" pollutants in runoff (S5.C.7). They contend that these sections do not set any minimum expectation for the level of effort required and allow the permittees to make deminimus reductions in polluting discharges, and thus constitute impermissible self regulation. *PSA v. Ecology*, PCHB Nos. 02-162, -163, and -164, Order Granting Partial Summary Judgment (June 6, 2003)(CL XVI)(citing *Environmental Defense Center v. Environmental Protection Agency*, at U.S. App. 497, at 57-62 (9th Cir., Jan. 14, 2003)).

29.

The Board agrees the structural stormwater control program, as drafted, amounts to impermissible self-regulation. First, the permit fails to require a minimum level of effort for the permittees in the selection and prioritization of structural stormwater projects, and provides no review and approval role for Ecology. Second, the permit fails to comply with the applicable EPA rule and therefore amounts to impermissible self regulation on this basis as well. 40 C.F.R 122.26(d)(2)(iv) requires that "Proposed management programs shall describe priorities for implementing controls." Condition S5.C.6 merely requires the permittees to develop a program within 12 months and provide Ecology a "list of planned individual projects that are scheduled

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for implementation" during the term of the permit. S5.C.6.b.i. While initial project selection is presumably subject to the MEP and AKART standard of the permit, Ecology plays no role in ensuring these standards are met, even through simple review of the selected projects. The permit does not contain any requirement that permittees describe their project priorities or require that Ecology review the permittees' structural stormwater control program. Ecology is not expected to approve the municipalities' prioritization of projects in relation to the pollution reduction requirements of the permit. While Ecology testified that the permit "implied" there needs to be a prioritization of planned structural stormwater control projects, and a schedule reviewed by Ecology *(Moore testimony)*, the permit does not expressly state this requirement and the fact sheet explicitly states that "review and approval by Ecology is not a permit requirement." *Ex. Muni 0002, p. 35.* Thus, the structural stormwater control program is left entirely to the discretion of the municipalities, not only with respect to which projects they initially select, but also in the timing and manner in which they implement the selected projects. Prioritization of projects is particularly important given that Conditions S5 and S6 are based upon actions taken by the permittees and not outcomes, and this structural stormwater control provision is to "address impacts that are not adequately controlled by the other required actions of the SWMP." Prioritization helps to ensure that the sites where the permittees choose to "act" are meaningful in providing environmental protection. It can also assist to engage the public as a partner in reducing pollutants in discharges and the overall volume of discharges. A community, for example, could request a permittee to focus a project in an area which discharges near shellfish beds. While the Board recognizes that local funding will influence the selection of planned

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projects and that municipalities must therefore retain local control in the selection process, we conclude that the permit must require permittees to describe the prioritization of their selected projects in order to comply with federal rules, demonstrate compliance with the MEP and AKART standards, and facilitate oversight by Ecology to ensure the legal standards of the permit are applied on a programmatic level. *See Save Lake Sammamish v. Ecology*, PCHB Nos. 95-78 & -121, Order Granting Summary Judgment (Dec. 12, 1995).

30.

In contrast to the structural stormwater control program provisions, the source control program for existing development requires a more rigorous program to reduce pollutants in runoff from areas that discharge to MS4s owned or operated by the permittee, and does not suffer from the same flaws as the structural stormwater control program. The permit requires that Ecology must review and approve the source control program. S5.C.7.b.i. Therefore, the Board concludes that the source control program as drafted meets the MEP and AKART standard.

E. Water quality violations (Issues F.1.a., F.2.a., and F.4)

PSA and PSE argue, through several different issues, that the permit fails to prevent discharges that violate water quality. *See* F.1.a (permit fails to require LID techniques which results in discharges that violate water quality); F.2.a (permit allows discharges from existing development that violate water quality); F.4 (Permit as a whole allows discharges that violate water quality standards; Prohibition on violations of water quality standards contained in Special Condition S4 conflicts with other provisions of the permit). The Board concludes that the

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permit, with the amendments directed by the Board to meet AKART and MEP, and with the amendments directed by the Board to the S4.F compliance process,[28] is adequately conditioned to comply with state law.

F. Timelines for Compliance (Issue F.5)

31.

The CWA sets out a number of deadlines related to NPDES permits for industrial and large municipal dischargers, including a deadline for EPA to establish regulations setting forth permit application requirements, a deadline for filing permit applications, and a deadline for EPA's approval or denial of the permits. 33 U.S.C. § 1342 (p)(4)(A). The final sentence in 33 U.S.C. § 1342 (p)(4)(A) states: "Any such permit shall provide for compliance as expeditiously as practicable, but in no event later than 3 years after the date of issuance of such permit." PSA contends that the Phase I Permit violates this provision.

32.

The Board has addressed this specific sentence before, in a case involving a challenge to a renewal of the Industrial Stormwater General NPDES Permit. *PSA v. Ecology*, PCHB Nos. 02-162, -163, -164, Order Granting Partial Summary Judgment (June 6, 2003). In that case, involving industrial stormwater discharges, the Board concluded that the reference to "compliance" in the sentence referred to compliance with the permit requirement contained in 33 U.S.C. § 1342 (p)(3)(A)(the provision pertaining to industrial stormwater discharges). *PSA* at CL XXI. Applying that same analysis to this case, involving municipal stormwater discharges,

[28] These modifications are ordered in the Board's Findings, Conclusions and Order on S4, issued on August 7, 2008.

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the reference to "compliance" is to 33 U.S.C. § 1342 (p)(3)(B)(the provision establishing the MEP standard for municipal stormwater discharges). Therefore, the question becomes whether the permit allows any actions to occur later than three years after the date of issuance of the permit that are necessary to reduce discharges of pollutants to the maximum extent practicable.

33.

Several of the conditions of the Phase I Permit allow actions required by the permit to occur more than three years after the date of issuance of the permit. PSA and the Utilities contend that this establishes that the permit violates 33 U.S.C. § 1342 (p)(4)(A). However, this fact alone does not establish a violation of 33 U.S.C. § 1342 (p)(4). PSA and the Utilities, as the parties with the burden of proof, must bring forth evidence establishing that earlier compliance with one of the permit provisions currently allowing implementation outside of the three year statutory window is necessary to meet the MEP standard. Ecology has developed a programmatic permit with multiple components to be implemented throughout the permit cycle which, collectively, represent MEP and AKART. To read the statute as suggested by PSA and the Utilities would inappropriately limit Ecology's ability to include within the permit additional conditions or requirements that may not be practicable within three years but which are reasonable within a longer time frame. The Board concludes that PSA and the Utilities have failed to meet their burden on this issue. The record does not contain sufficient evidence on any specific permit condition to convince the Board that the permit violates 33 U.S.C. § 1342 (p)(4)(A).

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Any Finding of Fact deemed to be a Conclusion of Law is hereby adopted as such.

Having so found and concluded, the Board enters the following

ORDER

Having concluded that portions of the Phase I Permit are invalid, the Board remands the Phase I Permit to Ecology pursuant to WAC 371-08-540, for modifications consistent with this opinion.

1. Ecology shall modify Special Condition S6.E.7 as follows:

> 7. Source Control in existing Developed Areas
>
> The SWMP shall include the development and implementation of one or more Stormwater Pollution Prevention Plans (SWPPPs). A SWPPP is a documented plan to identify and implement measures to prevent and control the contamination of discharges of stormwater to surface or ground water. SWPPP(s) shall be prepared and implemented for all Port-owned lands, **except environmental mitigation sites owned by the Port of Tacoma,** that are not covered by either a General Permit or an individual NPDES permit issued by Ecology that covers stormwater discharges.
>
> (modified language is in bold and underlined)

2. With respect to the use of LID, in addition to the specific modifications identified in No. 1 above, Ecology shall also modify the permit consistent with this opinion as follows :

a. Modify Permit Condition S5.C.5.b to read as follows:

> iii. The program must ((~~allow~~)) **require** non-structural preventive actions and source reduction approaches ((~~such as~~)), **including** Low Impact Development Techniques (LID), to minimize the creation of impervious surfaces, and measures to minimize the disturbance of soils and vegetation **where feasible**.

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b. Require permittees to identify barriers to implementation of LID and, in each annual report, identify actions taken to remove barriers identified.

c. Require permittees to adopt enforceable ordinances that require use of LID techniques where feasible in conjunction with conventional stormwater management methods.

d. Require permittees to address in their annual report to Ecology under the Phase I Permit, information on the extent to which basin planning is being conducted in their jurisdiction, either voluntarily, or pursuant to GMA or any other requirement.

e. Require permittees to identify, prior to the next permit cycle or renewal, areas for potential basin or watershed planning that can incorporate development strategies as a water quality management tool to protect aquatic resources.

3. Ecology shall modify Special Condition S5.C.6.b.ii, related to structural Stormwater control programs minimum performance measures, to require that permittees describe the prioritization of their selected projects as required by federal rules, in order to facilitate oversight by Ecology to ensure that the MEP and AKART standards are met on a programmatic level.

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SO ORDERED this 7th day of August, 2008.

POLLUTION CONTROL HEARINGS BOARD

Kathleen D. Mix, Chair

see concurrence/dissent
William H. Lynch, Member

Andrea McNamara Doyle, Member

Kay M. Brown, Presiding
Administrative Appeals Judge

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POLLUTION CONTROL HEARINGS BOARD
STATE OF WASHINGTON

PUGET SOUNDKEEPER ALLIANCE; PEOPLE FOR PUGET SOUND; PIERCE COUNTY PUBLIC WORKS AND UTILITIES DEPARTMENT; CITY OF TACOMA; PORT OF SEATTLE; SNOHOMISH COUNTY; CLARK COUNTY; PACIFICORP; and PUGET SOUND ENERGY, Appellants, v. STATE OF WASHINGTON, DEPARTMENT OF ECOLOGY, Respondent, CITY OF SEATTLE; KING COUNTY; PORT OF TACOMA; PACIFICORP; PUGET SOUND ENERGY; STATE OF WASHINGTON, DEPARTMENT OF TRANSPORTATION, Intervenors.	FINDINGS OF FACT, CONCLUSIONS OF LAW, AND ORDER **PHASE I** PCHB NOS. 07-021, 07-026, 07-027 07-028, 07-029, 0-030, 07-037 CONCURRENCE AND DISSENT

I write separately for the purpose of disagreeing with my colleagues on one portion of the decision. I would allow Pierce County to substitute its monitoring program for the monitoring required under Special Condition S8 (S8). Pierce County provided testimony that it was unable to afford both monitoring programs. Pierce County has established an extensive monitoring program that will allow the County to assess the impacts of stormwater discharges in the

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receiving water over an extended period of time. Portions of the monitoring program include continuous monitoring, so that a more accurate assessment can be made of the impact of development on the physical channel conditions and aquatic organisms. Ecology has recognized the importance of this type of monitoring in its 2004 report to the Legislature. Ecology's efforts to collect data regarding the effectiveness of BMPs would not significantly suffer from the absence of BMP effectiveness data from Pierce County. To the contrary, I believe that Pierce County's monitoring program would yield information that would be quite valuable to Ecology and assist in the development of future phases of the permit. The one modification I would require to Pierce County's monitoring regime is for Pierce County to test for the full range of chemical pollutants required of other permittees under S8.

For this reason, I concur with the remainder of the decision but respectively dissent regarding Pierce County's monitoring program.

Dated this 7th day of August 2008.

POLLUTION CONTROL HEARINGS BOARD

William H. Lynch

William H. Lynch, Member

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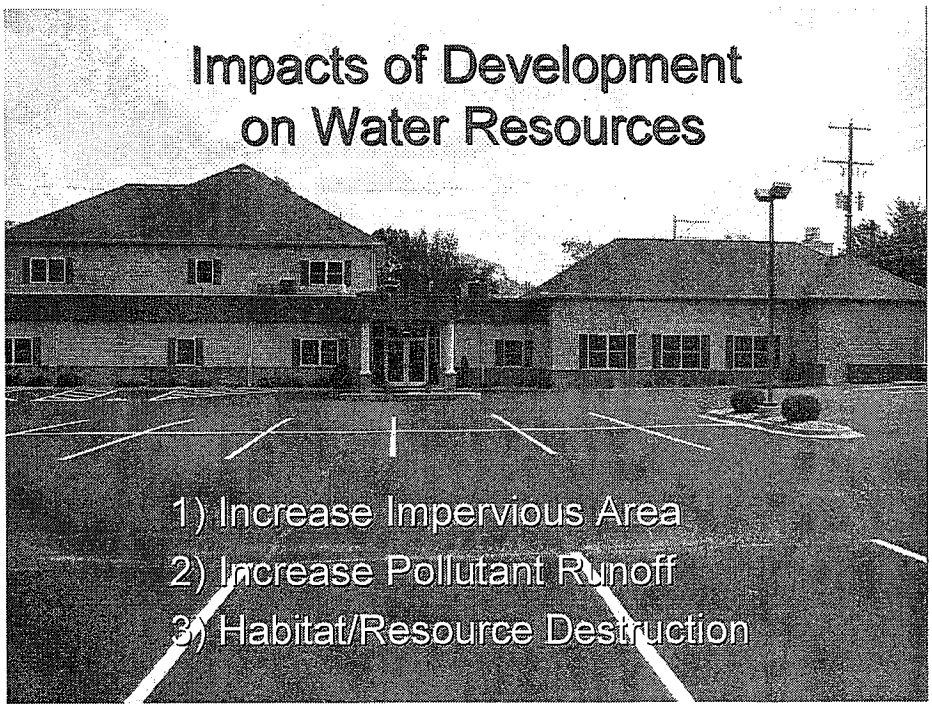
Hydromodification: A Regulatory Perspective

Dr. Cindy Lin
US EPA Region 9
Sept 4, 2008

Impacts of Development on Water Resources



1) Increase Impervious Area
2) Increase Pollutant Runoff
3) Habitat/Resource Destruction

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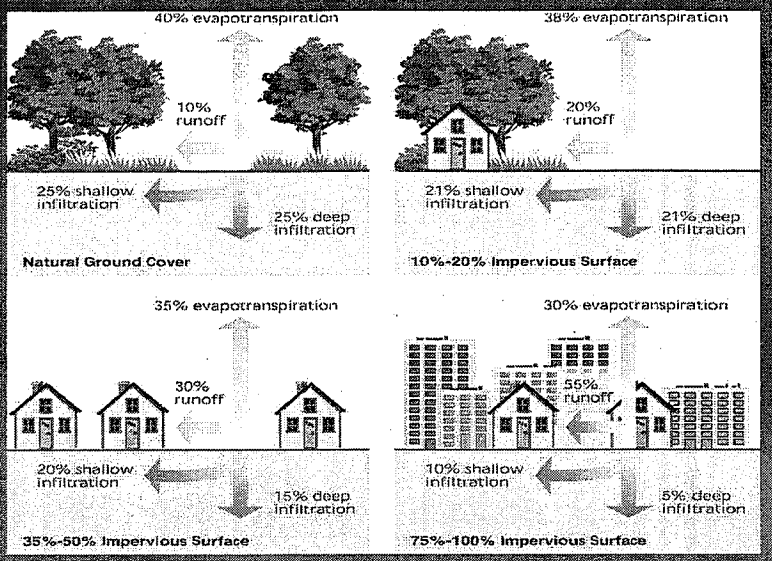
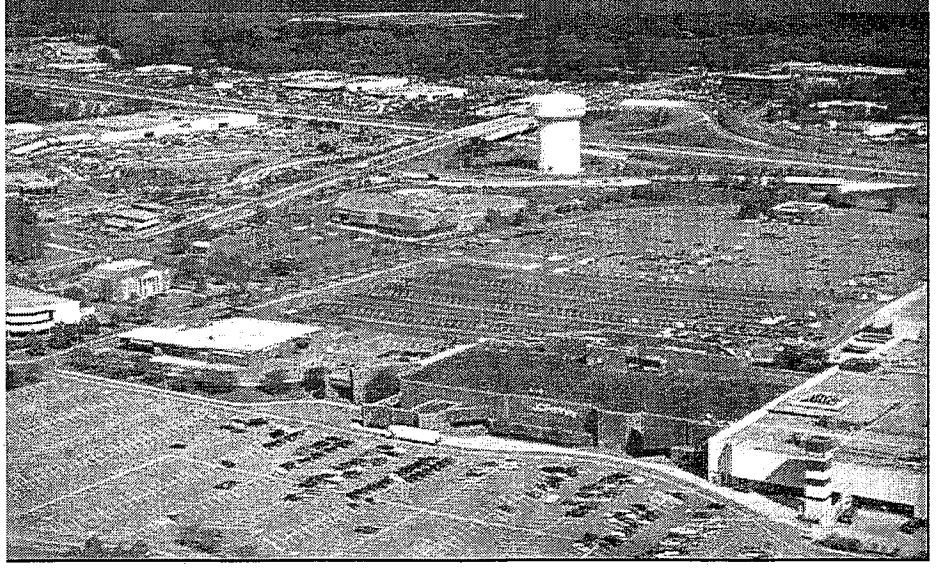
Increase in Impervious Area



Habitat/Resource Destruction



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Pollutants in Storm Water Runoff

- oil, grease
- heavy metals
- sediment, trash
- temperature
- pesticides, herbicides

Impacts

- Changes to the natural hydrology, drainage
- Land cover changes, increased overland flow
- Physical impacts on receiving streams
- Transports pollutants that have collected on impervious surfaces
- Diminished Infiltration, interception and evapotranspiration rates

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Increase in Impervious Area

- Erosion
- Loss of pool & riffles
- Loss of vegetation & riparian canopy
- Decrease in dry weather flow regime

Storm Water Management

- Management of storm water has primarily relied on BMP implementation for limiting pollutant levels in MS4 effluent.
- No specificity in permits on the compliance requirements.
- Appropriate in the past because lack of knowledge on tools and technology.
- But, storm water control efforts have not been successful; water quality goals not achieved

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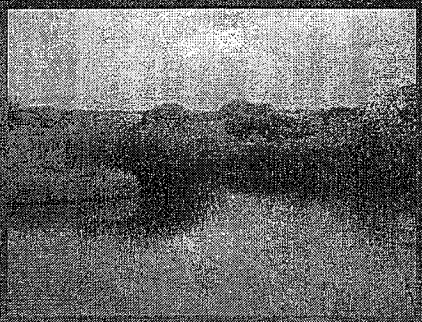
Objectives

- Achieve **water quality** improvements
- **Reduce** pollutant discharges
- Improve management of storm water (**LID** tools)
- **Minimize alteration** of hydrologic characteristics of waters (storm water discharge, velocities, or duration are maintained or reduced)
- **Minimize flow**
- **Prevent** increased erosion, protect habitat in natural drainage systems



EPA Recommendations

- Use Low Impact Development to minimize storm water generation, thus reducing storm water pollution, mimic natural hydrology
- Advocate green infrastructure as an approach to wet weather management that is cost-effective, sustainable, and environmentally sound

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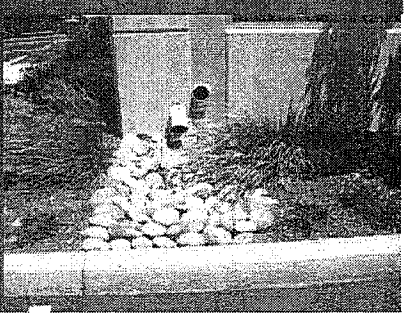
Low Impact Development (Green Infrastructure)

- New approach to stormwater management
- Cost-effective
- Sustainable
- Environmentally friendly

Low Impact Development Concepts

- Preserve environmentally sensitive areas
- Reduce sources of pollution
- Minimize impervious areas
- Remove direct connections
- Utilize Natural systems



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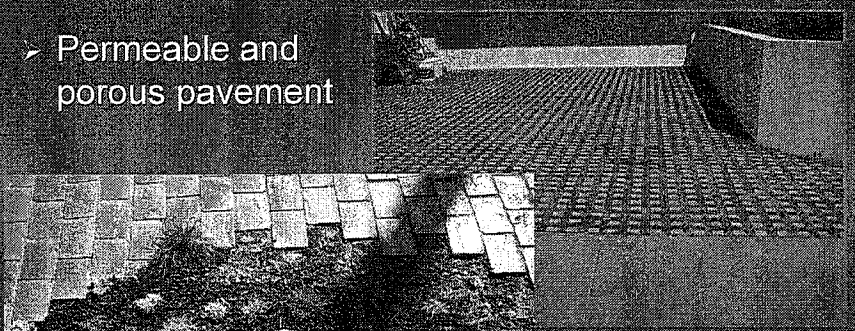
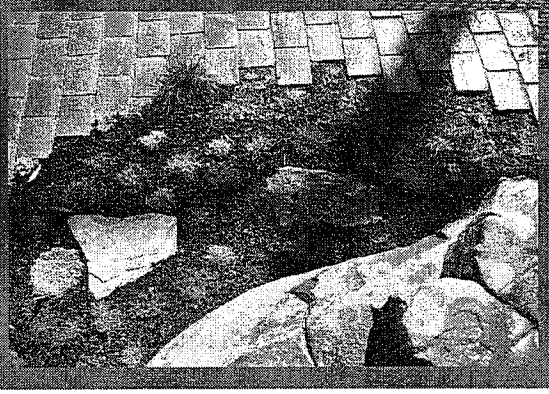
LID: Minimize impervious areas

- Permeable and porous pavement





Porous pavement & raingarden

LID: Parking Lots Infiltration, Retention

Parking lot treatment- vegetative buffer strip

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Green Infrastructure

- Utilize natural systems & engineered systems to:
  - mimic natural landscapes,
  - capture, cleanse and reduce stormwater runoff using plants, soils and microbes
- Maximize Stormwater
  - Infiltration
  - Evapotranspiration
  - Storage for re-use

Tools to Minimize Hydromodification

- Implement LID strategies to increase infiltration (limits on effective impervious area)
- Hydromodification BMPs (e.g., post construction BMPs)
- In-stream restoration
- Develop, implement watershed-specific hydromodification control strategies

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Metrics to Minimize Hydromodification

- New developments include buffer zones a certain distance from riparian zones or water.
- New development, redevelopment projects mush establish a post-development water balance which replicates pre-project runoff (e.g., porous pavements, tree planting)

Examples

- No change Pre- and Post- Development (RB 8)
- 5% EIA (Ventura County MS4 Permit)
- Hydromodification Management Plan (SD County MS4 Permit)
- 12% impervious cover cap (Barberry Creek TMDL, Maine)
- New Jersey, Portland, Seattle, Washington D.C., Maryland

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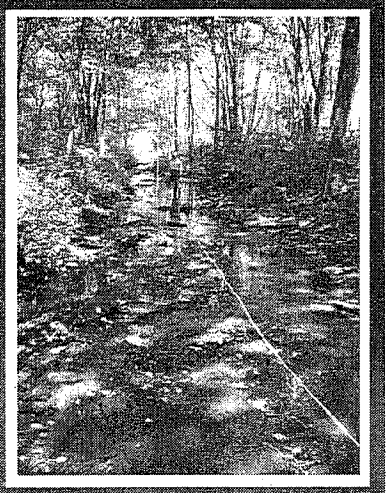
Barberry Creek TMDL, Maine

- Impairment due to pollutant (metals) and non-pollutant (stream habitat, baseflow) stressors related to storm water runoff from developed areas
- Sources of storm water from City of South Portland & overland runoff from a highly urbanized drainage area
- Existing Load = 23% IC
- **TMDL: Total extent of impervious cover (%IC) in watershed capped at 12%**



EPA Region 9

- **<u>Advocates LID strategies</u>**:
- Infiltrate, evapotranspire, capture and reuse storm water to maintain or restore natural hydrologies and improve water quality
- **Encourage permitting agencies to incorporate LID provisions into MS4 permits as clear, enforceable, measurable requirements which result in water quality improvements**

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LID Resources

- www.epa.gov/NPDES/GreenInfrastructure
- California Stormwater Quality Association BMP Handbooks. www.CASQA.org
- www.lowimpactdevelopment.org
- "Start at the Source" - Bay Area Stormwater Management Agencies
- Alameda Countywide Clean Water Program Site Design Guidebook
  - www.BASMAA.org

Thank You

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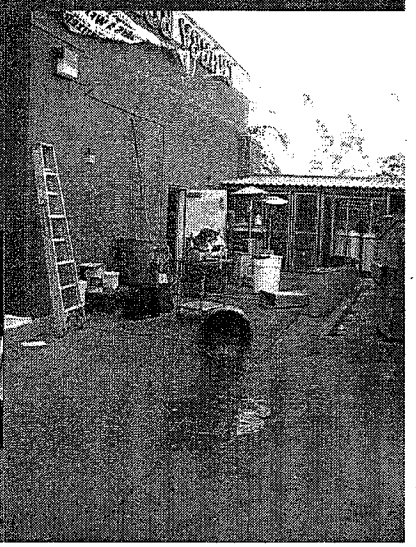
LID: Reduce sources of pollution

Site design to contain or treat/recycle washwater

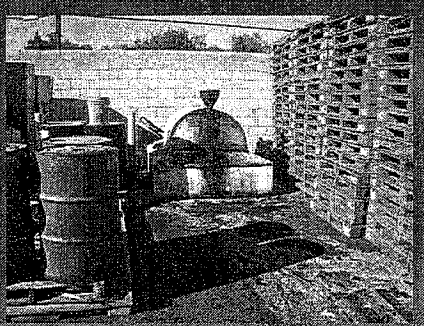
- Restaurant Areas –
- Vehicle washing area –



LID: Reduce sources of pollution

Site Design to prevent exposure (shed/cover) or contain and treat washwater

- Material Storage -
- Trash dumpsters -
- Fueling area -



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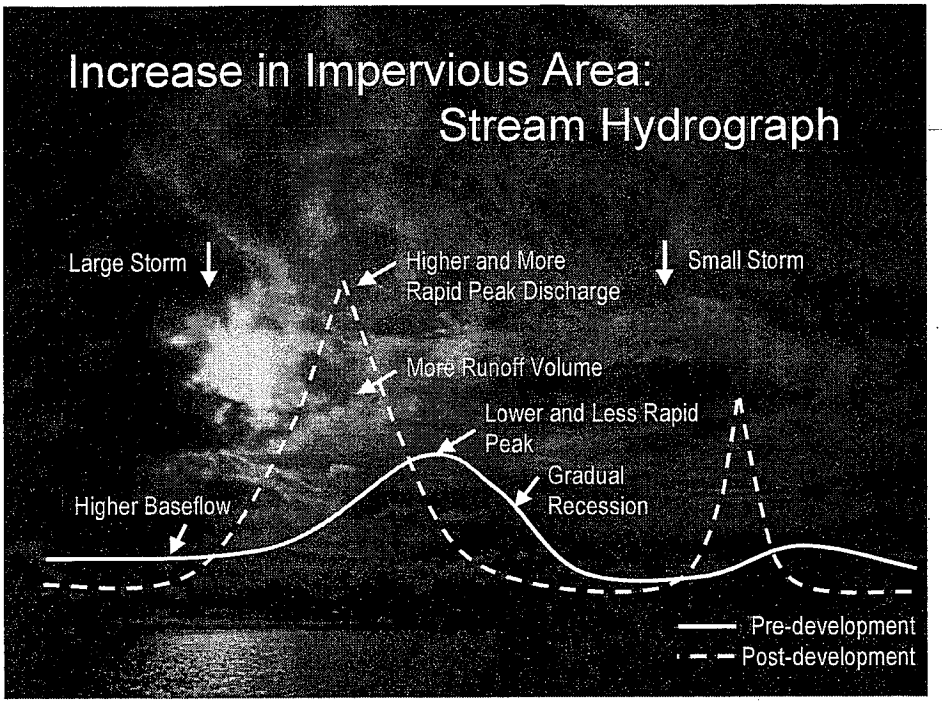

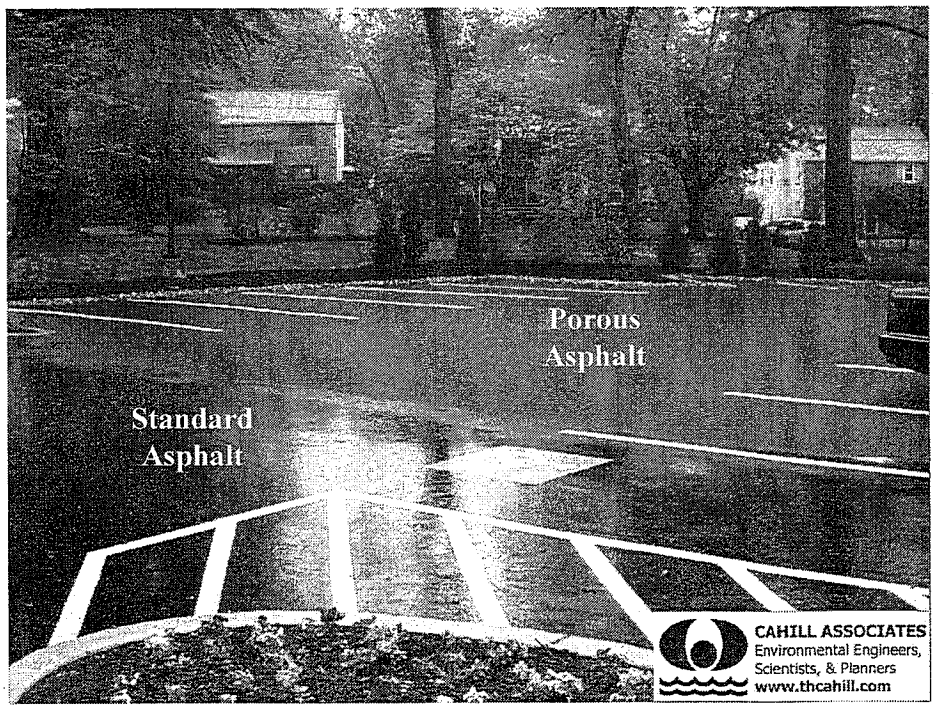

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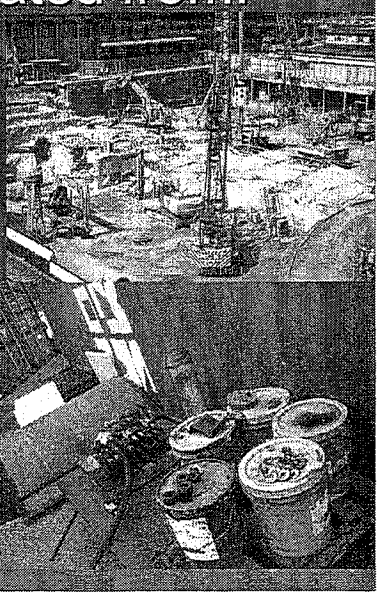
LID: Preserve environmentally sensitive areas

- Wetlands
- Stream Buffers
- Springs
- Habitat areas/native vegetation
- Maintain natural drainage paths
- Mature trees

Pollutants Generated from:

- Construction
- Parking lots
- Maintenance areas
- Material storage areas
- Restaurant washing
- Trash storage



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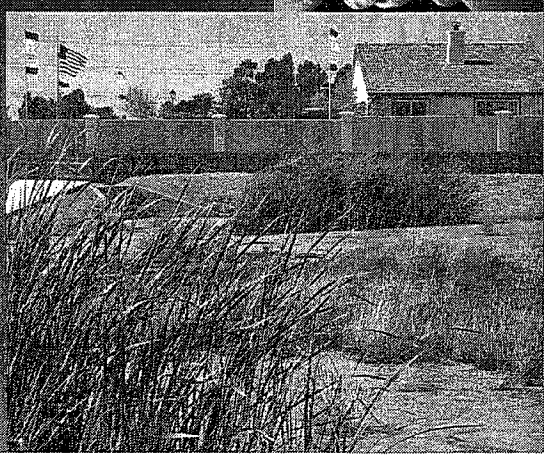
- Photo: California Nevada Cement Council

Multiple Benefits

- Reduce pollutants
- Maintain natural hydrograph
- Cost Effective
- Increase property values
- Climate change
- Maintain habitat



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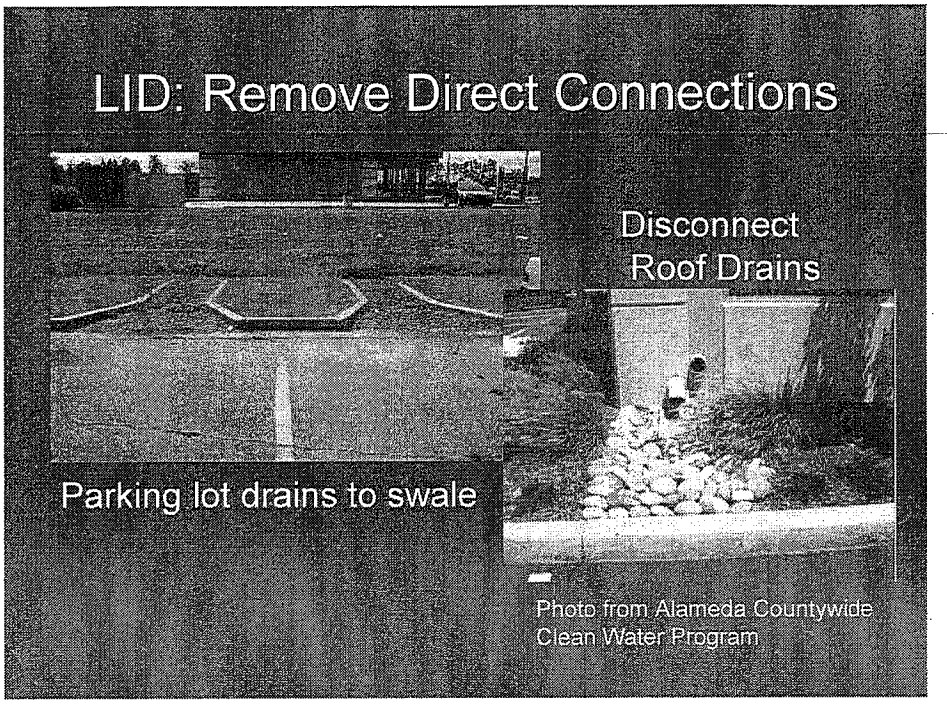

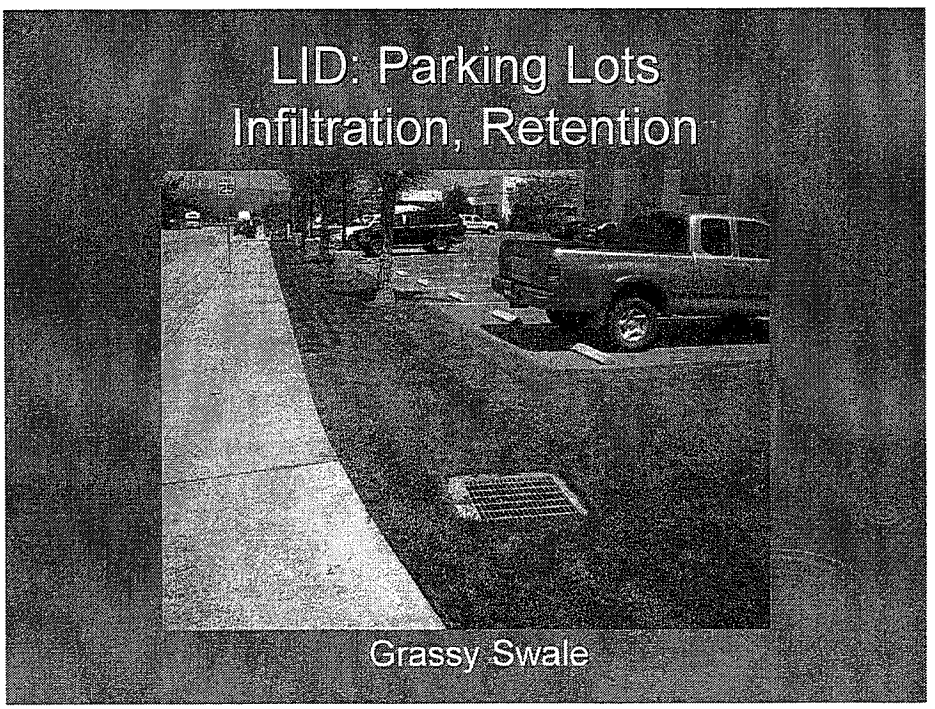

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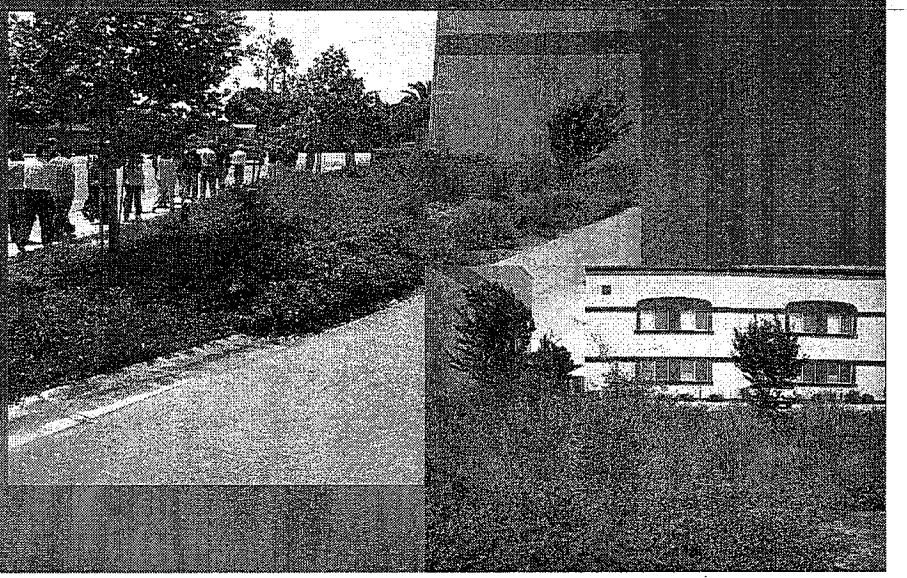
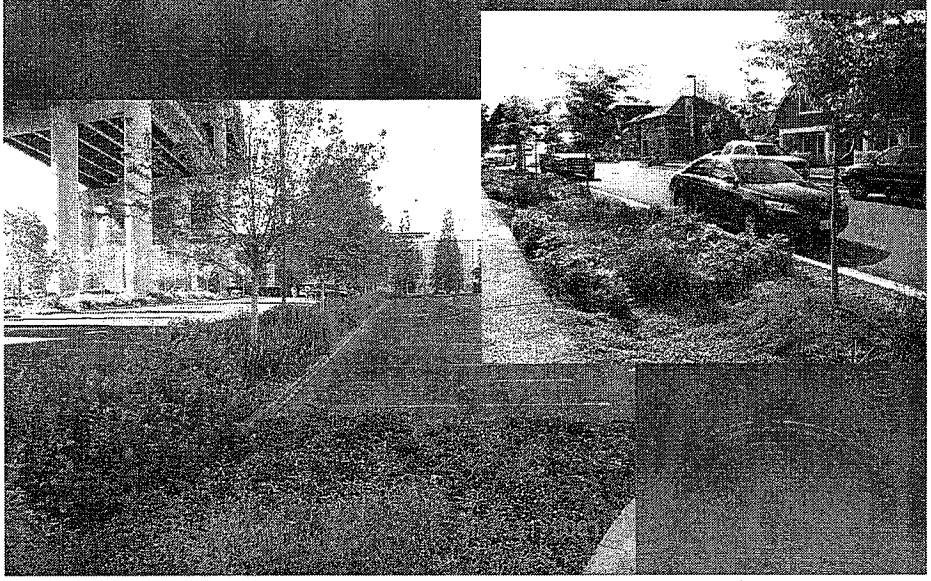
LID: Bioretention, Raingardens



LID: Bioretention, Raingardens



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Committee on Reducing Stormwater Discharge Contributions to Water Pollution

Water Science and Technology Board

Division on Earth and Life Studies

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Preface

Stormwater runoff from the built environment remains one of the great challenges of modern water pollution control, as this source of contamination is a principal contributor to water quality impairment of waterbodies nationwide. In addition to entrainment of chemical and microbial contaminants as stormwater runs over roads, rooftops, and compacted land, stormwater discharge poses a physical hazard to aquatic habitats and stream function, owing to the increase in water velocity and volume that inevitably result on a watershed scale as many individually managed sources are combined. Given the shift of the world's population to urban settings, and that this trend is expected to be accompanied by continued wholesale landscape alteration to accommodate population increases, the magnitude of the stormwater problem is only expected to grow.

In recognition of the need for improved control measures, in 1987 the U.S. Congress mandated the U.S. Environmental Protection Agency (EPA), under amendments to the Clean Water Act, to control certain stormwater discharges under the National Pollutant Discharge Elimination System. In response to this federal legislation, a permitting program was put in place by EPA as the Phase I (1990) and Phase II (1999) stormwater regulations, which together set forth requirements for municipal separate storm sewer systems and industrial activities including construction. The result of the regulatory program has been identification of hundreds of thousands of sources needing to be permitted, which has put a strain on EPA and state administrative systems for implementation and management. At the same time, achievement of water quality improvement as a result of the permit requirements has remained an elusive goal.

To address the seeming intractability of this problem, the EPA requested that the National Research Council (NRC) review its current permitting program for stormwater discharge under the Clean Water Act and provide suggestions for improvement. The broad goals of the study were to better understand the links between stormwater pollutant discharges and ambient water quality, to assess the state of the science of stormwater management, and to make associated policy recommendations. More specifically, the study was asked to:

(1) Clarify the mechanisms by which pollutants in stormwater discharges affect ambient water quality criteria and define the elements of a "protocol" to link pollutants in stormwater discharges to ambient water quality criteria.

(2) Consider how useful monitoring is for both determining the potential of a discharge to contribute to a water quality standards violation and for determining the adequacy of stormwater pollution prevention plans. What specific parameters should be monitored and when and where? What effluent limits and benchmarks are needed to ensure that the discharge does not cause or contribute to a water quality standards violation?

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(3) Assess and evaluate the relationship between different levels of stormwater pollution prevention plan implementation and in-stream water quality, considering a broad suite of best management practices (BMPs).

(4) Make recommendations for how to best stipulate provisions in stormwater permits to ensure that discharges will not cause or contribute to exceedances of water quality standards. This should be done in the context of general permits. As a part of this task, the committee will consider currently available information on permit and program compliance.

(5) Assess the design of the stormwater permitting program implemented under the Clean Water Act.

There are a number of related topics that one might expect to find in this report that are excluded, because EPA requested that the study be limited to problems addressed by the agency's stormwater regulatory program. Specifically, nonpoint source pollution from agricultural runoff, septic systems, combined sewer overflows, sanitary sewer overflows, and concentrated animal feeding operations are not addressed in this report. In addition, alteration of the urban base-flow hydrograph from a number of causes that are not directly related to storm events (e.g., interbasin transfers of water, leakage from water supply pipes, lawn irrigation, and groundwater withdrawals) is a topic outside the scope of the report and therefore not included in any depth.

In developing this report, the committee benefited greatly from the advice and input of EPA representatives, including Jenny Molloy, Linda Boornazian, and Mike Borst; representatives from the City of Austin; representatives from King County, Washington, and the City of Seattle; and representatives from the Irvine Ranch Water District. The committee heard presentations by many of these individuals in addition to Chris Crockett, City of Philadelphia Water Department; Pete LaFlamme and Mary Borg, Vermont Department of Environmental Conservation; Michael Barrett, University of Texas at Austin; Roger Glick, City of Austin; Michael Piehler, UNC Institute of Marine Sciences, Keith Stolzenbach, UCLA; Steve Burges, University of Washington; Wayne Huber, Oregon State University; Don Theiler, King County; Charlie Logue, Clean Water Services, Hillsboro, Oregon; Don Duke, Florida Gulf Coast University; Mike Stenstrom, UCLA; Gary Wolff, California Water Board; Paula Daniels, City of Los Angeles Public Works; Mark Gold, Heal the Bay; Geoff Brosseau, California Stormwater Quality Association; Steve Weisberg, Southern California Coastal Water Research Project; Chris Crompton, Southern California Stormwater Monitoring Coalition; David Beckman, NRDC; and Eric Strecker, GeoSyntec. We also thank all those stakeholders who took time to share with us their perspectives and wisdom about the various issues affecting stormwater.

The committee was fortunate to have taken several field trips in conjunction with committee meetings. The following individuals are thanked for their participation in organizing and guiding these trips: Austin (Kathy Shay, Mike Kelly, Matt Hollon, Pat Hartigan, Mateo Scoggins, David Johns, and Nancy McClintock); Seattle (Darla Inglis, Chris May, Dan Powers,

Scott Bawden, Nat Scholz, John Incardona, Kate McNeil, Bob Duffner, Curt Crawford); and Los Angeles (Peter Postlmayr, Matthew Keces, Alan Bay, and Sat Tamarieuchi).

Completion of this report would not have been possible without the Herculean efforts of project study director Laura Ehlers. Her powers to organize, probe, synthesize, and keep the committee on track with completing its task were simply remarkable. Meeting logistics and travel arrangements were ably assisted by Ellen De Guzman and Jeanne Aquilino.

This report has been reviewed in draft form by individuals chosen for their diverse perspectives and technical expertise, in accordance with procedures approved by the NRC's Report Review Committee. The purpose of this independent review is to provide candid and critical comments that will assist the institution in making its published report as sound as possible and to ensure that the report meets institutional standards for objectivity, evidence, and responsiveness to the study charge. The review comments and draft manuscript remain confidential to protect the integrity of the deliberative process. We wish to thank the following individuals for their review of this report: Michael Barrett, University of Texas; Bruce Ferguson, University of Georgia; James Heaney, University of Florida; Daniel Medina, CH2MHILL; Margaret Palmer, University of Maryland Chesapeake Biological Laboratory; Kenneth Potter, University of Wisconsin; Joan Rose, Michigan State University; Eric Strecker, Geosyntec Consultants; and Bruce Wilson, Minnesota Pollution Control Agency.

Although the reviewers listed above have provided many constructive comments and suggestions, they were not asked to endorse the conclusions and recommendations nor did they see the final draft of the report before its release. The review of this report was overseen by Michael Kavanaugh, Malcolm Pirnie, Inc., and Richard Conway, Union Carbide Corporation, retired. Appointed by the NRC, they were responsible for making certain that an independent examination of this report was carried out in accordance with institutional procedures and that all review comments were carefully considered. Responsibility for the final content of this report rests entirely with the authoring committee and institution.

Claire Welty,

Committee Chair

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Summary

Urbanization is the changing of land use from forest or agricultural uses to suburban and urban areas. This conversion is proceeding in the United States at an unprecedented pace, and the majority of the country's population now lives in suburban and urban areas. The creation of impervious surfaces that accompanies urbanization profoundly affects how water moves both above and below ground during and following storm events, the quality of that stormwater, and the ultimate condition of nearby rivers, lakes, and estuaries.

The National Pollutant Discharge Elimination System (NPDES) program under the Clean Water Act (CWA) is the primary federal vehicle to regulate the quality of the nation's waterbodies. This program was initially developed to reduce pollutants from industrial process wastewater and municipal sewage discharges. These point sources were known to be responsible for poor, often drastically degraded conditions in receiving waterbodies. They were easily regulated because they emanated from identifiable locations, such as pipe outfalls. To address the role of stormwater in causing or contributing to water quality impairments, in 1987 Congress wrote Section 402(p) of the CWA, bringing stormwater control into the NPDES program, and in 1990 the U.S. Environmental Protection Agency (EPA) issued the Phase I Stormwater Rules. These rules require NPDES permits for operators of municipal separate storm sewer systems (MS4s) serving populations over 100,000 and for runoff associated with industry, including construction sites five acres and larger. In 1999 EPA issued the Phase II Stormwater Rule to expand the requirements to small MS4s and construction sites between one and five acres in size.

With the addition of these regulated entities, the overall NPDES program has grown by almost an order of magnitude. EPA estimates that the total number of permittees under the stormwater program at any time exceeds half a million. For comparison, there are fewer than 100,000 non-stormwater (meaning wastewater) permittees covered by the NPDES program. To manage the large number of permittees, the stormwater program relies heavily on the use of general permits to control industrial, construction, and Phase II MS4 discharges. These are usually statewide, one-size-fits-all permits in which general provisions are stipulated.

To comply with the CWA regulations, industrial and construction permittees must create and implement a stormwater pollution prevention plan, and MS4 permittees must implement a stormwater management plan. These plans documents the stormwater control measures (SCMs) (sometimes known as best management practices or BMPs) that will be used to prevent stormwater emanating from these sources from degrading nearby waterbodies. These SCMs range from structural methods such as detention ponds and bioswales to nonstructural methods such as designing new development to reduce the percentage of impervious surfaces.

A number of problems with the stormwater program as it is currently implemented have been recognized. First, there is limited information available on the effectiveness and longevity of many SCMs, thereby contributing to uncertainty in their performance. Second, the requirements for monitoring vary depending on the regulating entity and the type of activity. For example, a subset of industrial facilities must conduct "benchmark monitoring" and the results often exceed the values established by EPA or the states, but it is unclear whether these exceedances provide useful indicators of potential water quality problems. Finally, state and local stormwater programs are plagued by a lack of resources to review stormwater pollution

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prevention plans and conduct regular compliance inspections. For all these reasons, the stormwater program has suffered from poor accountability and uncertain effectiveness at improving the quality of the nation's waters.

In light of these challenges, EPA requested the advice of the National Research Council's Water Science and Technology Board on the federal stormwater program, considering all entities regulated under the program (i.e., municipal, industrial, and construction). The following statement of task guided the work of the committee:

(1) Clarify the mechanisms by which pollutants in stormwater discharges affect ambient water quality criteria and define the elements of a "protocol" to link pollutants in stormwater discharges to ambient water quality criteria.
(2) Consider how useful monitoring is for both determining the potential of a discharge to contribute to a water quality standards violation and for determining the adequacy of stormwater pollution prevention plans. What specific parameters should be monitored and when and where? What effluent limits and benchmarks are needed to ensure that the discharge does not cause or contribute to a water quality standards violation?
(3) Assess and evaluate the relationship between different levels of stormwater pollution prevention plan implementation and in-stream water quality, considering a broad suite of SCMs.
(4) Make recommendations for how to best stipulate provisions in stormwater permits to ensure that discharges will not cause or contribute to exceedances of water quality standards. This should be done in the context of general permits. As a part of this task, the committee will consider currently available information on permit and program compliance.
(5) Assess the design of the stormwater permitting program implemented under the CWA.

Chapter 2 of this report presents the regulatory history of stormwater control in the United States, focusing on relevant portions of the CWA and the federal and state regulations that have been created to implement the Act. Chapter 3 reviews the scientific aspects of stormwater, including sources of pollutants in stormwater, how stormwater moves across the land surface, and its impacts on receiving waters. Chapter 4 evaluates the current industrial and MS4 monitoring requirements, and it considers the multitude of models available for linking stormwater discharges to ambient water quality. Chapter 5 considers the vast suite of both structural and nonstructural measures designed to control stormwater and reduce its pollutant loading to waterbodies. In Chapter 6, the limitations and possibilities associated with a new regulatory approach are explored, as are those of a more traditional but enhanced scheme. This new approach, which rests on the broad foundation of correlative studies demonstrating the effects of urbanization on aquatic ecosystems, would reduce the impact of stormwater on receiving waters beyond any efforts currently in widespread practice.

THE CHALLENGE OF REGULATING STORMWATER

Although stormwater has been long recognized as contributing to water quality impairment, the creation of federal regulations to deal with stormwater quality has occurred only in the last 20 years. Because this longstanding environmental problem is being addressed so late

in the development and management of urban areas, the laws that mandate better stormwater control are generally incomplete and are often in conflict with state and local rules that have primarily stressed the flood control aspects of stormwater management (i.e., moving water away from structures and cities as fast as possible). Many prior investigators have observed that stormwater discharges would ideally be regulated through direct controls on land use, strict limits on both the quantity and quality of stormwater runoff into surface waters, and rigorous monitoring of adjacent waterbodies to ensure that they are not degraded by stormwater discharges. Future land-use development would be controlled to minimize stormwater discharges, and impervious cover and volumetric restrictions would serve as proxies for stormwater loading from many of these developments. Products that contribute pollutants through stormwater—like de-icing materials, fertilizers, and vehicular exhaust—would be regulated at a national level to ensure that the most environmentally benign materials are used.

Presently, however, the regulation of stormwater is hampered by its association with a statute that focuses primarily on specific pollutants and ignores the volume of discharges. Also, most stormwater discharges are regulated on an individualized basis without accounting for the cumulative contributions from multiple sources in the same watershed. Perhaps most problematic is that the requirements governing stormwater dischargers leave a great deal of discretion to the dischargers themselves in developing stormwater pollution prevention plans and self-monitoring to ensure compliance. These problems are exacerbated by the fact that the dual responsibilities of land-use planning and stormwater management within local governments are frequently decoupled.

EPA's current approach to regulating stormwater is unlikely to produce an accurate or complete picture of the extent of the problem, nor is it likely to adequately control stormwater's contribution to waterbody impairment. The lack of rigorous end-of-pipe monitoring, coupled with EPA's failure to use flow or alternative measures for regulating stormwater, make it difficult for EPA to develop enforceable requirements for stormwater dischargers. Instead, the stormwater permits leave a great deal of discretion to the regulated community to set their own standards and to self-monitor. Current statistics on the states' implementation of the stormwater program, discharger compliance with stormwater requirements, and the ability of states and EPA to incorporate stormwater permits with Total Maximum Daily Loads are uniformly discouraging. Radical changes to the current regulatory program (see Chapter 6) appear necessary to provide meaningful regulation of stormwater dischargers in the future.

Flow and related parameters like impervious cover should be considered for use as proxies for stormwater pollutant loading. These analogs for the traditional focus on the "discharge" of "pollutants" have great potential as a federal stormwater management tool because they provide specific and measurable targets, while at the same time they focus regulators on water degradation resulting from the increased volume as well as increased pollutant loadings in stormwater runoff. Without these more easily measured parameters for evaluating the contribution of various stormwater sources, regulators will continue to struggle with enormously expensive and potentially technically impossible attempts to determine the pollutant loading from individual dischargers or will rely too heavily on unaudited and largely ineffective self-reporting, self-policing, and paperwork enforcement.

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EPA should engage in much more vigilant regulatory oversight in the national licensing of products that contribute significantly to stormwater pollution. De-icing chemicals, materials used in brake linings, motor fuels, asphalt sealants, fertilizers, and a variety of other products should be examined for their potential contamination of stormwater. Currently, EPA does not apparently utilize its existing licensing authority to regulate these products in a way that minimizes their contribution to stormwater contamination. States can also enact restrictions on or tax the application of pesticides or other particularly toxic products. Even local efforts could ultimately help motivate broader scale, federal restrictions on particular products.

The federal government should provide more financial support to state and local efforts to regulate stormwater. State and local governments do not have adequate financial support to implement the stormwater program in a rigorous way. At the very least, Congress should provide states with financial support for engaging in more meaningful regulation of stormwater discharges. EPA should also reassess its allocation of funds within the NPDES program. The agency has traditionally directed funds to focus on the reissuance of NPDES wastewater permits, while the present need is to advance the NPDES stormwater program because NPDES stormwater permittees outnumber wastewater permittees more than five fold, and the contribution of diffuse sources of pollution to degradation of the nation's waterbodies continues to increase.

EFFECTS OF URBANIZATION ON WATERSHEDS

Urbanization causes change to natural systems that tends to occur in the following sequence. First, land use and land cover are altered as vegetation and topsoil are removed to make way for agriculture, or subsequently buildings, roads, and other urban infrastructure. These changes, and the introduction of a constructed drainage network, alter the hydrology of the local area, such that receiving waters in the affected watershed experience radically different flow regimes than prior to urbanization. Nearly all of the associated problems result from one underlying cause: loss of the water-retaining and evapotranspirating functions of the soil and vegetation in the urban landscape. In an undeveloped area, rainfall typically infiltrates into the ground surface or is evapotranspirated by vegetation. In the urban landscape, these processes of evapotranspiration and water retention in the soil are diminished, such that stormwater flows rapidly across the land surface and arrives at the stream channel in short, concentrated bursts of high discharge. This transformation of the hydrologic regime is a wholesale reorganization of the processes of runoff generation, and it occurs throughout the developed landscape. When combined with the introduction of pollutant sources that accompany urbanization (such as lawns, motor vehicles, domesticated animals, and industries), these changes in hydrology have led to water quality and habitat degradation in virtually all urban streams.

The current state of the science has documented the characteristics of stormwater runoff, including its quantity and quality from many different land covers, as well as the characteristics of dry weather runoff. In addition, many correlative studies show how parameters co-vary in important but complex and poorly understood ways (e.g., changes in macroinvertebrate or fish communities associated with watershed road density or the percentage of impervious cover). Nonetheless, efforts to create mechanistic links between population growth, land-use change, hydrologic alteration, geomorphic adjustments, chemical contamination in stormwater, disrupted

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energy flows and biotic interactions, and changes in ecological communities are still in development. Despite this assessment, there are a number of overarching truths that remain poorly integrated into stormwater management decision-making, although they have been robustly characterized for more than a decade and have a strong scientific basis that reaches even farther back through the history of published investigations.

There is a direct relationship between land cover and the biological condition of downstream receiving waters. The possibility for the highest levels of aquatic biological condition exists only with very light urban transformation of the landscape. Conversely, the lowest levels of biological condition are inevitable with extensive urban transformation of the landscape, commonly seen after conversion of about one-third to one-half of a contributing watershed into impervious area. Although not every degraded waterbody is a product of intense urban development, all highly urban watersheds produce severely degraded receiving waters.

The protection of aquatic life in urban streams requires an approach that incorporates all stressors. Urban Stream Syndrome reflects a multitude of effects caused by altered hydrology in urban streams, altered habitat, and polluted runoff. Focusing on only one of these factors is not an effective management strategy. For example, even without noticeably elevated pollutant concentrations in receiving waters, alterations in their hydrologic regimes are associated with impaired biological condition. More comprehensive biological monitoring of waterbodies will be critical to better understanding the cumulative impacts of urbanization on stream condition.

The full distribution and sequence of flows (i.e., the flow regime) should be taken into consideration when assessing the impacts of stormwater on streams. Permanently increased stormwater volume is only one aspect of an urban-altered storm hydrograph. It contributes to high in-stream velocities, which in turn increase streambank erosion and accompanying sediment pollution of surface water. Other hydrologic changes, however, include changes in the sequence and frequency of high flows, the rate of rise and fall of the hydrograph, and the season of the year in which high flows can occur. These all can affect both the physical and biological conditions of streams, lakes, and wetlands. Thus, effective hydrologic mitigation for urban development cannot just aim to reduce post-development peak flows to predevelopment peak flows.

Roads and parking lots can be the most significant type of land cover with respect to stormwater. They constitute as much as 70 percent of total impervious cover in ultra-urban landscapes, and as much as 80 percent of the directly connected impervious cover. Roads tend to capture and export more stormwater pollutants than other land covers in these highly impervious areas, especially in regions of the country having mostly small rainfall events. As rainfall amounts become larger, pervious areas in most residential land uses become more significant sources of runoff, sediment, nutrients, and landscaping chemicals. In all cases, directly connected impervious surfaces (roads, parking lots, and roofs that are directly connected to the drainage system) produce the first runoff observed at a storm-drain inlet and outfall because their travel times are the quickest.

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MONITORING AND MODELING

The stormwater monitoring requirements under the EPA Stormwater Program are variable and generally sparse, which has led to considerable skepticism about their usefulness. This report considers the amount and value of the data collected over the years by municipalities (which are substantial on a nationwide basis) and by industries, and it makes suggestions for improvement. The MS4 and particularly the industrial stormwater monitoring programs suffer from a paucity of data, from inconsistent sampling techniques, and from requirements that are difficult to relate to the compliance of individual dischargers. For these reasons, conclusions about stormwater management are usually made with incomplete information. Stormwater management would benefit most substantially from a well-balanced monitoring program that encompasses chemical, biological, and physical parameters from outfalls to receiving waters.

Many processes connect sources of pollution to an effect observed in a downstream receiving water—processes that can be represented in watershed models, which are the key to linking stormwater dischargers to impaired receiving waters. The report explores the current capability of models to make such links, including simple models and more involved mechanistic models. At the present time, stormwater modeling has not evolved enough to consistently say whether a particular discharger can be linked to a specific waterbody impairment. Some quantitative predictions can be made, particularly those that are based on well-supported causal relationships of a variable that responds to changes in a relatively simple driver (e.g., modeling how a runoff hydrograph or pollutant loading change in response to increased impervious land cover). However, in almost all cases, the uncertainty in the modeling and the data (including its general unavailability), the scale of the problems, and the presence of multiple stressors in a watershed make it difficult to assign to any given source a specific contribution to water quality impairment.

Because of a 10-year effort to collect and analyze monitoring data from MS4s nationwide, the quality of stormwater from urbanized areas is well characterized. These results come from many thousands of storm events, systematically compiled and widely accessible; they form a robust dataset of utility to theoreticians and practitioners alike. These data make it possible to accurately estimate stormwater pollutant concentrations from various land uses. Additional data are available from other stormwater permit holders that were not originally included in the database and from ongoing projects, and these should be acquired to augment the database and improve its value in stormwater management decision-making.

Industry should monitor the quality of stormwater discharges from certain critical industrial sectors in a more sophisticated manner, so that permitting authorities can better establish benchmarks and technology-based effluent guidelines. Many of the benchmark monitoring requirements and effluent guidelines for certain industrial subsectors are based on inaccurate and old information. Furthermore, there has been no nationwide compilation and analysis of industrial benchmark data, as has occurred for MS4 monitoring data, to better understand typical stormwater concentrations of pollutants from various industries.

Continuous, flow-weighted sampling methods should replace the traditional collection of stormwater data using grab samples. Data obtained from too few grab samples are highly variable, particularly for industrial monitoring programs, and subject to greater

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uncertainly because of experimenter error and poor data-collection practices. In order to use stormwater data for decision making in a scientifically defensible fashion, grab sampling should be abandoned as a credible stormwater sampling approach for virtually all applications. It should be replaced by more accurate and frequent continuous sampling methods that are flow weighted. Flow-weighted composite monitoring should continue for the duration of the rain event. Emerging sensor systems that provide high temporal resolution and real-time estimates for specific pollutants should be further investigated, with the aim of providing lower costs and more extensive monitoring systems to sample both streamflow and constituent loads.

Watershed models are useful tools for predicting downstream impacts from urbanization and designing mitigation to reduce those impacts, but they are incomplete in scope and do not offer definitive causal links between polluted discharges and downstream degradation. Every model simulates only a subset of the multiple interconnections between physical, chemical, and biological processes found in any watershed, and they all use a grossly simplified representation of the true spatial and temporal variability of a watershed. To speak of a "comprehensive watershed model" is thus an oxymoron, because the science of stormwater is not sufficiently far advanced to determine causality between all sources, resulting stressors, and their physical, chemical, and biological responses. Thus, it is not yet possible to create a protocol that mechanistically links stormwater dischargers to the quality of receiving waters. The utility of models with more modest goals, however, can still be high—as long as the questions being addressed by the model are in fact relevant and important to the functioning of the watershed to which that model is being applied, and sufficient data are available to calibrate the model for the processes included therein.

STORMWATER MANAGEMENT APPROACHES

A fundamental component of EPA's stormwater program is the creation of stormwater pollution prevention plans that document the SCMs that will be used to prevent the permittee's stormwater discharges from degrading local waterbodies. Thus, a consideration of these measures—their effectiveness in meeting different goals, their cost, and how they are coordinated with one another—is central to any evaluation of the stormwater program. The statement of task asks for an evaluation of the relationship between different levels of stormwater pollution prevention plan implementation and in-stream water quality. Although the state of knowledge has yet to reveal the mechanistic links that would allow for a full assessment of that relationship, enough is known to design systems of SCMs, on a site-scale or local watershed scale, that can substantially reduce the effects of urbanization.

The characteristics, applicability, goals, effectiveness, and cost of nearly 20 different broad categories of SCMs to treat the quality and quantity of stormwater runoff are discussed in Chapter 5, organized as they might be applied from the rooftop to the stream. SCMs, when designed, constructed, and maintained correctly, have demonstrated the ability to reduce runoff volume and peak flows and to remove pollutants. A multitude of case studies illustrates the use of SCMs in specific settings and demonstrates that a particular SCM can have a measurable positive effect on water quality or a biological metric. However, the implementation of SCMs at the watershed scale has been too inconsistent and too recent to be able to definitively link their

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performance to the prolonged sustainment—at the watershed level—of receiving water quality, in-stream habitat, or stream geomorphology.

Individual controls on stormwater discharges are inadequate as the sole solution to stormwater in urban watersheds. SCM implementation needs to be designed as a system, integrating structural and nonstructural SCMs and incorporating watershed goals, site characteristics, development land use, construction erosion and sedimentation controls, aesthetics, monitoring, and maintenance. Stormwater cannot be adequately managed on a piecemeal basis due to the complexity of both the hydrologic and pollutant processes and their effect on habitat and stream quality. Past practices of designing detention basins on a site-by-site basis have been ineffective at protecting water quality in receiving waters and only partially effective in meeting flood control requirements.

Nonstructural SCMs such as product substitution, better site design, downspout disconnection, conservation of natural areas, and watershed and land-use planning can dramatically reduce the volume of runoff and pollutant load from a new development. Such SCMs should be considered first before structural practices. For example, lead concentrations in stormwater have been reduced by at least a factor of 4 after the removal of lead from gasoline. Not creating impervious surfaces or removing a contaminant from the runoff stream simplifies and reduces the reliance on structural SCMs.

SCMs that harvest, infiltrate, and evapotranspirate stormwater are critical to reducing the volume and pollutant loading of small storms. Urban municipal separate stormwater conveyance systems have been designed for flood control to protect life and property from extreme rainfall events, but they have generally failed to address the more frequent rain events (<2.5 cm) that are key to recharge and baseflow in most areas. These small storms may only generate runoff from paved areas and transport the “first flush” of contaminants. SCMs designed to remove this class of storms from surface runoff (runoff-volume-reduction SCMs—rainwater harvesting, vegetated, and subsurface) can also help address larger watershed flooding issues.

Performance characteristics are starting to be established for most structural and some nonstructural SCMs, but additional research is needed on the relevant hydrologic and water quality processes within SCMs across different climates and soil conditions. Typical data such as long-term load reduction efficiencies and pollutant effluent concentrations can be found in the International Stormwater BMP Database. However, understanding the processes involved in each SCM is in its infancy, making modeling of these SCMs difficult. Seasonal differences, the time between storms, and other factors all affect pollutant loadings emanating from SCMs. Research is needed that moves away from the use of percent removal and toward better simulation of SCM performance. Research is particularly important for nonstructural SCMs, which in many cases are more effective, have longer life spans, and require less maintenance than structural SCMs. EPA should be a leader in SCM research, both directly by improving its internal modeling efforts and by funding state efforts to monitor and report back on the success of SCMs in the field.

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The retrofitting of urban areas presents both unique opportunities and challenges. Promoting growth in these areas is desirable because it takes pressure off the suburban fringes, thereby preventing sprawl, and it minimizes the creation of new impervious surfaces. However, it is more expensive than Greenfields development because of the existence of infrastructure and the limited availability and affordability of land. Both innovative zoning and development incentives, along with the careful selection SCMs, are needed to achieve fair and effective stormwater management in these areas. For example, incentive or performance zoning could be used to allow for greater densities on a site, freeing other portions of the site for SCMs. Publicly owned, consolidated SCMs should be strongly considered as there may be insufficient land to have small, on-site systems. The performance and maintenance of the former can be overseen more effectively by a local government entity. The types of SCMs that are used in consolidated facilities—particularly detention basins, wet/dry ponds, and stormwater wetlands—perform multiple functions, such as prevention of streambank erosion, flood control, and large-scale habitat provision.

INNOVATIVE STORMWATER MANAGEMENT AND REGULATORY PERMITTING

There are numerous innovative regulatory strategies that could be used to improve the EPA's stormwater program. The course of action most likely to check and reverse degradation of the nation's aquatic resources would be to **base all stormwater and other wastewater discharge permits on watershed boundaries instead of political boundaries.** Watershed-based permitting is the regulated allowance of discharges of water and wastes borne by those discharges to waters of the United States, with due consideration of: (1) the implications of those discharges for preservation or improvement of prevailing ecological conditions in the watershed's aquatic systems, (2) cooperation among political jurisdictions sharing a watershed, and (3) coordinated regulation and management of all discharges having the potential to modify the hydrology and water quality of the watershed's receiving waters.

Responsibility and authority for implementation of watershed-based permits would be centralized with a municipal lead permittee working in partnership with other municipalities in the watershed as co-permittees. Permitting authorities (designated states or, otherwise, EPA) would adopt a minimum goal in every watershed to avoid any further loss or degradation of designated beneficial uses in the watershed's component waterbodies and additional goals in some cases aimed at recovering lost beneficial uses. Permittees, with support by the states or EPA, would then move to comprehensive impact source analysis as a foundation for targeting solutions. The most effective solutions are expected to lie in isolating, to the extent possible, receiving waterbodies from exposure to those impact sources. In particular, low-impact design methods, termed Aquatic Resources Conservation Design in this report, should be employed to the fullest extent feasible and backed by conventional SCMs when necessary.

The approach gives municipal co-permittees more responsibility, with commensurately greater authority and funding, to manage all of the sources discharging, directly or through municipally owned conveyances, to the waterbodies comprising the watershed. This report also outlines a new monitoring program structured to assess progress toward meeting objectives and the overlying goals, diagnosing reasons for any lack of progress, and determining compliance by dischargers. The proposal further includes market-based trading of credits among dischargers to

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achieve overall compliance in the most efficient manner and adaptive management to determine additional actions if monitoring demonstrates failure to achieve objectives.

As a first step to taking the proposed program nationwide, a pilot program is recommended that will allow EPA to work through some of the more predictable impediments to watershed-based permitting, such as the inevitable limits of an urban municipality's authority within a larger watershed.

Short of adopting watershed-based permitting, other smaller-scale changes to the EPA stormwater program are possible. These recommendations do not preclude watershed-based permitting at some future date, and indeed they lay the groundwork in the near term for an eventual shift to watershed-based permitting.

Integration of the three permitting types is necessary, such that construction and industrial sites come under the jurisdiction of their associated municipalities. Federal and state NPDES permitting authorities do not presently have, and can never reasonably expect to have, sufficient personnel to inspect and enforce stormwater regulations on more than 100,000 discrete point source facilities discharging stormwater. A better structure would be one where the NPDES permitting authority empowers the MS4 permittees to act as the first tier of entities exercising control on stormwater discharges to the MS4 to protect water quality. The National Pretreatment Program, EPA's successful treatment program for municipal and industrial wastewater sources, could serve as a model for integration.

To improve the industrial, construction, and MS4 permitting programs in their current configuration, EPA should (1) issue guidance for MS4, industrial, and construction permittees on what constitutes a design storm for water quality purposes; (2) issue guidance for MS4 permittees on methods to identify high-risk industrial facilities for program prioritization such as inspections; (3) support the compilation and collection of quality industrial stormwater effluent data and SCM effluent quality data in a national database; and (4) develop numerical expressions of the MS4 standard of "maximum extent practicable." Each of these issues is discussed in greater detail in Chapter 6.

***

Watershed-based permitting will require additional resources and regulatory program support. Such an approach shifts more attention to ambient outcomes as well as expanded permitting coverage. Additional resources for program implementation could come from shifting existing programmatic resources. For example, some state permitting resources may be shifted away from existing point source programs toward stormwater permitting. Strategic planning and prioritization could shift the distribution of federal and state grant and loan programs to encourage and support more watershed-based stormwater permitting programs. However, securing new levels of public funds will likely be required. All levels of government must recognize that additional resources may be required from citizens and businesses (in the form of taxes, fees, etc.) in order to operate a more comprehensive and effective stormwater permitting program.

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Chapter 1
Introduction

URBANIZATION AND ITS IMPACTS

The influence of humans on the physical and biological systems of the Earth's surface is not a recent manifestation of modern societies; instead, it is ubiquitous throughout our history. As human populations have grown, so has their footprint, such that between 30 and 50 percent of the Earth's surface has now been transformed (Vitousek et al., 1997). Most of this land area is not covered with pavement; indeed, less than 10 percent of this transformed surface is truly "urban" (Grübler, 1994). However, urbanization causes extensive changes to the land surface beyond its immediate borders, particularly in ostensibly rural regions, through alterations by agriculture and forestry that support the urban population (Lambin et al., 2001). Within the immediate boundaries of cities and suburbs, the changes to natural conditions and processes wrought by urbanization are among the most radical of any human activity.

In the United States, population is growing at an annual rate of 0.9 percent (U.S. Census Bureau, http://www.census.gov/compendia/statab/2007edition.html); the majority of the population of the United States now lives in suburban and urban areas (Figure 1-1). Because the area appropriated for urban land uses is growing even faster, these patterns of growth all but guarantee that the influences of urban land uses will continue to expand over time. Cities and suburbia obviously provide the homes and livelihood for most of the nation's population. But, as this report makes clear, these benefits have been accompanied by significant environmental change. Urbanization of the landscape profoundly affects how water moves both above and below ground during and following storm events; the quality of that stormwater (defined in Box 1-1); and the ultimate condition of nearby rivers, lakes, and estuaries. Unlike agriculture, which can display significant interchange with forest cover over time scales of a century (e.g., Hart, 1968), there is no indication that once-urbanized land ever returns to a less intensive state. Urban land, however, does continue to change over time; by one estimate, 42 percent of land currently considered "urban" in the United States will be redeveloped by 2030 (Brookings Institute, 2004). In their words, "nearly half of what will be the built environment in 2030 doesn't even exist yet" (p. vi). This truth belies the common belief that efforts to improve management of stormwater are doomed to irrelevancy because so much of the landscape is already built. Opportunities for improvement have indeed been lost, but many more still await an improved management approach.

Measures of urbanization are varied, and the disparate methods of quantifying the presence and influence of human activity tend to confound analyses of environmental effects. Population density is a direct metric of human presence, but it is not the most relevant measure of the influence of those people on their surrounding landscape. Expressions of the built environment, most commonly road density or pavement coverage as a percentage of gross land area, are more likely to determine stormwater runoff-related consequences. An inverse metric, the percentage of mature vegetation or forest across a landscape, expresses the magnitude of related, but not identical, impacts to downstream systems. Alternatively, these measures of land cover can be replaced by measures of land use, wherein the types of human activity (e.g.,

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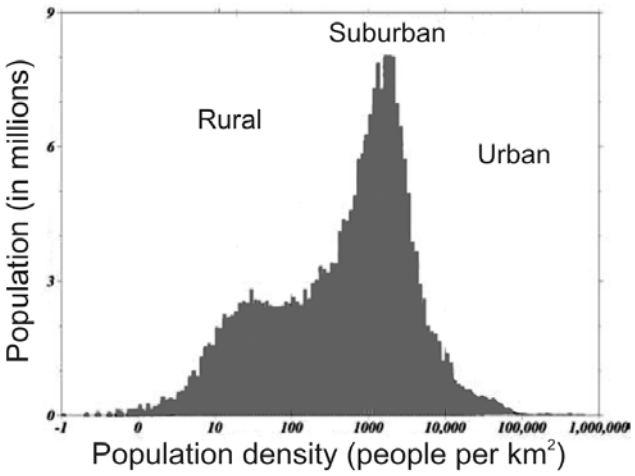

FIGURE 1-1 Histogram of population for the United States, based on 2000 census data. The median population density is about 1,000 people/km^2. SOURCE: Modified from Pozzi and Small (2005), who place the rural–suburban boundary at 100 people/km^2. Reprinted, with permission, from ASPRS (2005). Copyright 2005 by the American Society for Photogrammetry and Remote Sensing.

BOX 1-1
What Is "Stormwater"?

"Stormwater" is a term that is used widely in both scientific literature and regulatory documents. It is also used frequently throughout this report. Although all of these usages share much in common, there are important differences that benefit from an explicit discussion.

Most broadly, stormwater runoff is the water associated with a rain or snow storm that can be measured in a downstream river, stream, ditch, gutter, or pipe shortly after the precipitation has reached the ground. What constitutes "shortly" depends on the size of the watershed and the efficiency of the drainage system, and a number of techniques exist to precisely separate stormwater runoff from its more languid counterpart, "baseflow." For small and highly urban watersheds, the interval between rainfall and measured stormwater discharges may be only a few minutes. For watersheds of many tens or hundreds of square miles, the lag between these two components of storm response may be hours or even a day.

From a regulatory perspective, stormwater must pass through some sort of engineered conveyance, be it a gutter, a pipe, or a concrete canal. If it simply runs over the ground surface, or soaks into the soil and soon reemerges as seeps into a nearby stream, it may be water generated by the storm but it is not regulated stormwater.

This report emphasizes the first, more hydrologically oriented definition. However, attention is focused mainly on that component of stormwater that emanates from those parts of a landscape that have been affected in some fashion by human activities ("urban stormwater"). Mostly this includes water that flows over the ground surface and is subsequently collected by natural channels or artificial conveyance systems, but it can also include water that has infiltrated into the ground but nonetheless reaches a stream channel relatively rapidly and that contributes to the increased stream discharge that commonly accompanies almost any rainfall event in a human-disturbed watershed.

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residential, industrial, commercial) are used as proxies for the suite of hydrologic, chemical, and biological changes imposed on the surrounding landscape.

All of these metrics of urbanization are strongly correlated, although none can directly substitute for another. They also are measured differently, which renders one or another more suitable for a given application. Land use is a common measure in the realm of urban planning, wherein current and future conditions for a city or an entire region are characterized using equivalent categories across parcels, blocks, or broad regions. Road density can be reliably and rapidly measured, either manually or in a Geographic Information System environment, and it commonly displays a very good correlation with other measures of human activity. "Land cover," however, and particularly the percentage of impervious cover, is the metric most commonly used in studying the effects of urban development on stormwater, because it clearly expresses the hydrologic influence and watershed scale of urbanization. Box 1-2 describes the ways in which the percent of impervious cover in a watershed is measured.

There is no universally accepted terminology to describe land-cover or land-use conditions along the rural-to-urban gradient. Pozzi and Small (2005), for example, identified "rural," "suburban," and "urban" land uses on the basis of population density and vegetation cover, but they did not observe abrupt transitions that suggested natural boundaries (see Figure 1-1). In contrast, the Center for Watershed Protection (2005) defined the same terms but used impervious area percentage as the criterion, with such labels as "rural" (0 to 10 percent imperviousness), "suburban" (10 to 25 percent imperviousness), "urban" (25 to 60 percent imperviousness) and "ultra-urban" (greater than 60 percent imperviousness).

Beyond the problems posed by precise yet inconsistent definitions for commonly used words, none of the boundaries specified by these definitions are reflected in either hydrologic or ecosystem responses. Hydrologic response is strongly dependent on both land cover and drainage connectivity (e.g., Leopold, 1968); ecological responses in urbanizing watersheds do not show marked thresholds along an urban gradient (e.g., Figure 1-2) and they are dependent on not only the sheer magnitude of urban development but also the spatial configuration of that development across the watershed (Alberti et al., 2006). This report, therefore, uses such terms as "urban" and "suburban" under their common usage, without implying or advocating for a more precise (but ultimately limited and discipline-specific) definition.

Changing land cover and land use influence the physical, chemical, and biological conditions of downstream waterways. The specific mechanisms by which this influence occurs vary from place to place, and even a cursory review of the literature demonstrates that many different factors can be important, such as changes to flow regime, physical and chemical constituents in the water column, or the physical form of the stream channel itself (Paul and Meyer, 2001). Not all of these changes are present in any given system—lakes, wetlands, and streams can be altered by human activity in many different ways, each unique to the activity and the setting in which it occurs. Nonetheless, direct influences of land-use change on freshwater systems commonly include the following (Naiman and Turner, 2000):

- Altering the composition and structure of the natural flora and fauna,
- Changing disturbance regimes,
- Fragmenting the land into smaller and more diverse parcels, and
- Changing the juxtaposition between parcel types.

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BOX 1-2
Measures of Impervious Cover

The percentage of impervious surface or cover in a landscape is the most frequently used measure of urbanization. Yet this parameter has its limitations, in part because it has not been consistently used or defined. Most significant is the distinction between ***total*** impervious area (TIA) and ***effective*** impervious area (EIA). TIA is the "intuitive" definition of imperviousness: that fraction of the watershed covered by constructed, non-infiltrating surfaces such as concrete, asphalt, and buildings. Hydrologically, however, this definition is incomplete for two reasons. First, it ignores nominally "pervious" surfaces that are sufficiently compacted or otherwise so low in permeability that the rate of runoff from them is similar or indistinguishable from pavement. For example, Burges and others (1998) found that the impervious unit-area runoff was only 20 percent greater than that from pervious areas—primarily thin sodded lawns over glacial till—in a western Washington residential subdivision. Clearly, this hydrologic contribution cannot be ignored entirely.

The second limitation of TIA is that it includes some paved surfaces that may contribute nothing to the stormwater-runoff response of the downstream channel. A gazebo in the middle of parkland, for example, probably will impose no hydrologic changes into the catchment except for a very localized elevation of soil moisture at the edge of its roof. Less obvious, but still relevant, would be the different downstream consequences of rooftops that drain alternatively into a piped storm-drain system with direct discharge into a natural stream or onto splash blocks that disperse the runoff onto the garden or lawn at each corner of the building. This metric therefore cannot recognize any stormwater mitigation that may result from alternative runoff-management strategies, for example, pervious pavements or rainwater harvesting.

The first of these TIA limitations, the production of significant runoff from nominally pervious surfaces, is typically ignored in the characterization of urban development. The reason for such an approach lies in the difficulty in identifying such areas and estimating their contribution, and because of the credible belief that the degree to which pervious areas shed water as overland flow should be related, albeit imperfectly, with the amount of *impervious* area: where construction and development are more intense and cover progressively greater fractions of the watershed, it is more likely that the intervening green spaces have been stripped and compacted during construction and only imperfectly rehabilitated for their hydrologic functions during subsequent "landscaping."

The second of these TIA limitations, inclusion of non-contributing impervious areas, is formally addressed through the concept of EIA, defined as the impervious surfaces with direct hydraulic connection to the downstream drainage (or stream) system. Thus, any part of the TIA that drains onto pervious (i.e., "green") ground is excluded from the measurement of EIA. This parameter, at least conceptually, captures the hydrologic significance of imperviousness. EIA is the parameter normally used to characterize urban development in hydrologic models.

The direct measurement of EIA is complicated. Studies designed specifically to quantify this parameter must make direct, independent measurements of both TIA and EIA (Alley and Veenhuis, 1983; Laenen, 1983; Prysch and Ebbert, 1986). The results can then be generalized either as a correlation between the two parameters or as a "typical" value for a given land use. Sutherland (1995) developed an equation that describes the relationship between EIA and TIA. Its general form is:

$$EIA = A\ (TIA)^B$$

where A and B are a unique combination of numbers that satisfy the following criteria:

TIA = 1 then EIA = 0%
TIA = 100 then EIA = 100%

A commonly used version of this equation ($EIA = 0.15\ TIA^{1.41}$) was based on samples from highly urbanized land uses in Denver, Colorado (Alley and Veenhuis, 1983; Gregory et al., 2005). These results, however, are almost certainly region- and even neighborhood-specific, and, although highly relevant to watershed studies, they can be quite laborious to develop.

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Historically, human-induced alteration was not universally seen as a problem. In particular, dams and other stream-channel "improvements" were a common activity of municipal and federal engineering works of the mid-20th century (Williams and Wolman, 1984). "Flood control" implied a betterment of conditions, at least for streamside residents (Chang, 1992). And fisheries "enhancements," commonly reflected by massive infrastructure for hatcheries or artificial spawning channels, were once seen as unequivocal benefits for fish populations (White, 1996; Levin et al., 2001).

By almost any currently applied metric, however, the net result of human alteration of the landscape to date has resulted in a degradation of the conditions in downstream watercourses. Many prior researchers, particularly when considering ecological conditions and metrics, have recognized a crude but monotonically declining relationship between human-induced landscape alteration and downstream conditions (e.g., Figure 1-2; Horner et al., 1997; Davies and Jackson, 2006). These include metrics of physical stream-channel conditions (e.g., Bledsoe and Watson, 2001), chemical constituents (e.g., Figure 1-3; House et al., 1993), and biological communities (e.g., Figure 1-4; Steedman, 1988; Wang et al., 1997).

The association between watercourse degradation and landscape alteration in general, and urban development in particular, seems inexorable. The scientific and regulatory challenge of the last three decades has been to decouple this relationship, in some cases to reverse its trend and in others to manage where these impacts are to occur.

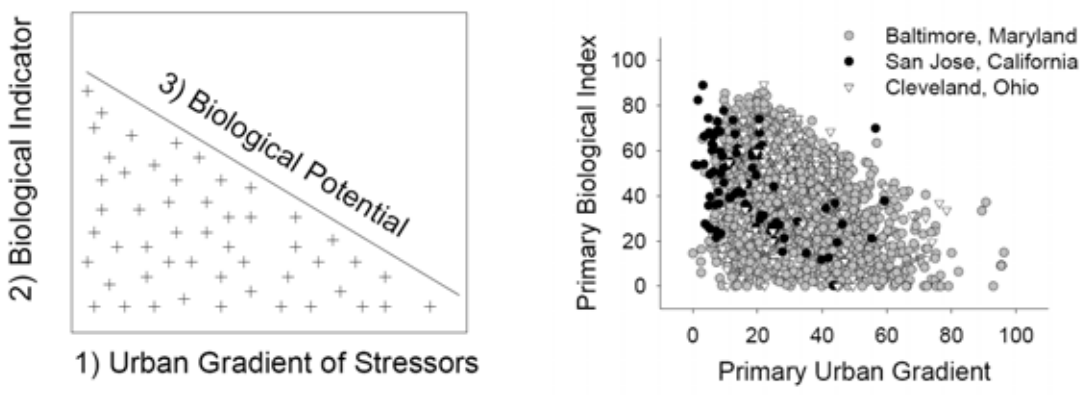

FIGURE 1-2 Conceptual model (left) and actual response (right) of a biological system's response to stress. The "Urban Gradient of Stressors" might be a single metric of urbanization, such as percent watershed impervious or road density; the "Biological Indicator" may be single-metric or multi-metric measures of the level of disturbance in an aquatic community. The right-declining line traces the limits of a "factor-ceiling distribution" (Thomson et al., 1986), wherein individual sites (i.e., data points) have a wide range of potential values for a given position along the urban gradient but are not observed above a maximum possible limit of the biological index. The right-hand graph illustrates actual biological responses, using a biotic index developed to show responses to urban impacts plotted against a standardized urban gradient comprising urban land use, road density, and population. SOURCE: Davies and Jackson (2006) (left) and Barbour et al. (2006) (right). Left figure, reprinted, with permission, Davies and Jackson (2006). Copyright by the Ecological Society of America. Right figure, reprinted, with permission, Barbour et al. (2006). Copyright by the Water Environment Research Foundation.

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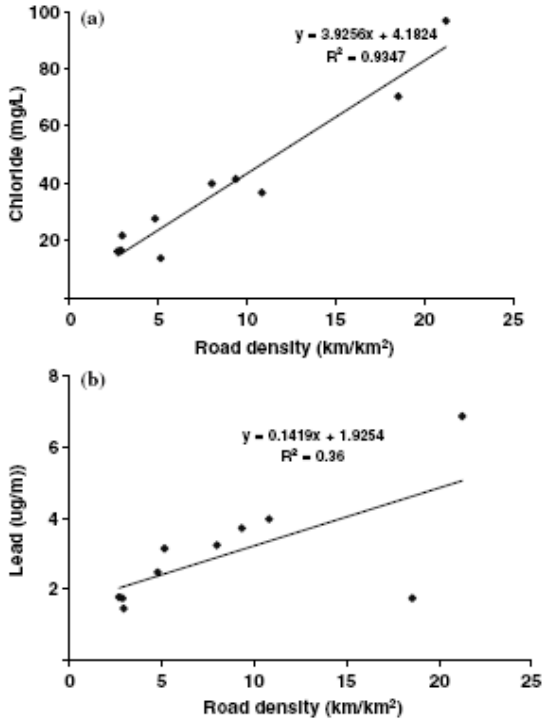

FIGURE 1-3 Example relationships between road density (a surrogate measure of urban development) and common water quality constituents. Direct causality is not necessarily implied by such relationships, but the monotonic increase in concentrations with increasing "urbanization," however measured, is near-universal. SOURCE: Reprinted, with permission, from Chang and Carlson (2005). Copyright 2005 by Springer.

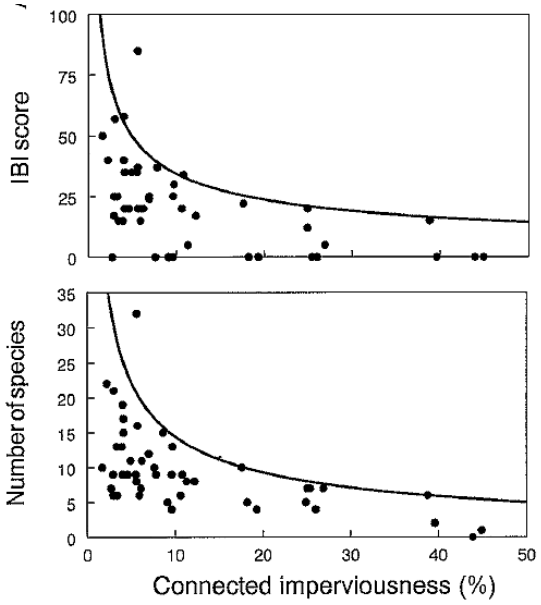

FIGURE 1-4 Plots of Effective Impervious Area (EIA, or "connected imperviousness") against metrics of biologic response in fish populations. SOURCE: Reprinted, with permission, from Wang et al. (2001). Copyright 2001 by Springer.

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WHAT'S WRONG WITH THE NATION'S WATERS?

Since passage of the Water Quality Act of 1948 and the Clean Water Act (CWA) of 1972, 1977, and 1987, water quality in the United States has measurably improved in the major streams and rivers and in the Great Lakes. However, substantial challenges and problems remain. Major reporting efforts that have examined state and national indicators of condition, such as CWA 305(b) reports (EPA, 2002) and the Heinz State of the Nation's Ecosystem report (Heinz Center, 2002), or environmental monitoring that was designed to provide statistically valid estimates of condition (e.g., National Wadeable Stream Assessment; EPA, 2006), have confirmed widespread impairments related to diffuse sources of pollution and stressors.

The National Water Quality Inventory (derived from Section 305b of the CWA) compiles data in relation to use designations and water quality standards. As discussed in greater detail in Chapter 2, such standards include both (1) a description of the use that a waterbody is supposed to achieve (such as a source of drinking water or a cold water fishery) and (2) narrative or numeric criteria for physical, chemical, and biological parameters that allow the designated use to be achieved. As of 2002, 45 percent of assessed streams and rivers, 47 percent of assessed lakes, 32 percent of assessed estuarine areas, 17 percent of assessed shoreline miles, 87 percent of near-coastal ocean areas, 51 percent of assessed wetlands, 91 percent of assessed Great Lakes shoreline miles, and 99 percent of assessed Great Lakes open water areas were not meeting water quality standards set by the states (2002 EPA Report to Congress).[1]

The U.S. Environmental Protection Agency (EPA) has also embarked on a five-year statistically valid survey of the nation's waters (http://www.epa.gov/owow/monitoring/guide.pdf). To date, two waterbody types—coastal areas and wadeable streams—have been assessed. The most recent data indicate that 42 percent of wadeable streams are in poor biological condition and 25 percent are in fair condition (EPA, 2006). The overall condition of the nation's estuaries is generally fair, with Puerto Rico and Northeast Coast regions rated poor, the Gulf Coast and West Coast regions rated fair, and the Southeast Coast region rated good to fair (EPA, 2007). These condition ratings for the National Estuary Program are based on a water quality index, a sediment quality index, a benthic index, and a fish tissue contaminants index.

The impairment of waterbodies is manifested in a multitude of ways. Indeed, EPA's primary process for reporting waterbody condition (Section 303(d) of the CWA—see Chapter 2) identifies over 200 distinct types of impairments. As shown in Table 1-1, these have been categorized into 15 broad categories, encompassing about 94 percent of all impairments. 59,515 waterbodies fall into one of the top 15 categories, while the total reported number of waterbodies impaired from all causes is 63,599 (which is an underestimate of the actual total because not all waterbodies are assessed). Mercury, microbial pathogens, sediments, other metals, and nutrients are the major pollutants associated with impaired waterbodies nationwide. These constituents have direct impacts on aquatic ecosystems and public health, which form the basis of the water quality standards set for these compounds. Sediments can harm fish and macroinvertebrate communities by introducing sorbed contaminants, decreasing available light in streams, and smothering fish eggs. Microbial pathogens can cause disease to humans via both ingestion and dermal contact and are frequently cited as the cause of beach closures and other recreational

[1] EPA does not yet have the 2004 assessment findings compiled in a consistent format from all the states. EPA is also working on processing the states 2006 Integrated Reports as the 303(d) portions are approved and the states submit their final assessment findings. Susan Holdsworth, EPA, personal communication, September 2007.

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water hazards in lakes and estuaries. Nutrient over-enrichment can promote a cascade of events in waterbodies from algal blooms to decreases in dissolved oxygen and associated fish kills. Metals like mercury, pesticides, and other organic compounds that enter waterways can be taken up by fish species, accumulating in their tissues and presenting a health risk to organisms (including humans) that consume the fish.

However, Table 1-1 can be misleading if it implies that degraded *water quality* is the primary metric of impairment. In fact, many of the nation's streams, lakes, and estuaries also suffer from fundamental changes in their flow regime and energy inputs, alteration of aquatic habitats, and resulting disruption of biotic interactions that are not easily measured via pollutant concentrations. Such waters may not be listed on State 303(d) lists because of the absence of a corresponding water quality standard that would directly indicate such conditions (like a biocriterion). Figure 1-5A, B, and C show examples of such impacted waterbodies.

Over the years, the greatest successes in improving the nation's waters have been in abating the often severe impairments caused by municipal and industrial point source discharges. The pollutant load reductions required of these facilities have been driven by the National Pollutant Discharge Elimination System (NPDES) permit requirements of the CWA (see Chapter 2). Although the majority of these sources are now controlled, further declines in water quality remain likely if the land-use changes that typify more diffuse sources of pollution are not addressed (Palmer and Allan, 2006). These include land-disturbing agricultural, silvicultural, urban, industrial, and construction activities from which hard-to-monitor pollutants emerge during wet-weather events. Pollution from these landscapes has been almost universally acknowledged as the most pressing challenge to the restoration of waterbodies and aquatic

TABLE 1-1 Top 15 Categories of Impairment Requiring CWA Section 303(d) Action

Cause of Impairment	Number of Waterbodies	Percent of the Total
Mercury	8,555	14%
Pathogens	8,526	14%
Sediment	6,689	11%
Metals (other than mercury)	6,389	11%
Nutrients	5,654	10%
Oxygen depletion	4,568	8%
pH	3,389	6%
Cause unknown - biological integrity	2,866	5%
Temperature	2,854	5%
Habitat alteration	2,220	4%
PCBs	2,081	3%
Turbidity	2,050	3%
Cause unknown	1,356	2%
Pesticides	1,322	2%
Salinity/TDS/chlorides	996	2%

Note: "Waterbodies" refers to individual river segments, lakes, and reservoirs. A single waterbody can have multiple impairments. Because most waters are not assessed, however, there is no estimate of the number of unimpaired waters in the United States. SOURCE: EPA, National Section 303(d) List Fact Sheet (http://iaspub.epa.gov/waters/national_rept.control). The data are based on three-fourths of states reporting from 2004 lists, with the remaining from earlier lists and one state from a 2006 list.

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FIGURE 1-5A Headwater tributary in Philadelphia suffering from Urban Stream Syndrome. SOURCE: Courtesy of Chris Crockett, City of Philadelphia Water Department (2007).

FIGURE 1-5B A destabilized stream in Vermont. SOURCE: Courtesy of Pete LaFlamme, Vermont Department of Environmental Conservation.

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FIGURE 1-5C An urban stream, the Lower Oso Creek in Orange County, California, following a storm event. Oso Creek was formerly an ephemeral stream, but heavy development in the contributing watershed has created perennial flow—stormwater flow during wet weather and minor wastewater discharges and authorized non-stormwater discharges such as landscape irrigation runoff during dry weather. Courtesy of Eric Stein, Southern California Coastal Research Water Project.

ecosystems nationwide. All population and development forecasts indicate a continued worsening of the environmental conditions caused by diffuse sources of pollution under the nation's current growth and land-use trajectories.

Recognition of urban stormwater's role in the degradation of the nation's waters is but the latest stage in the history of this byproduct of the human environment. Runoff conveyance systems have been part of cities for centuries, but they reflected only the desire to remove water from roads and walkways as rapidly and efficiently as possible. In some arid environments, rainwater has always been collected for irrigation or drinking; elsewhere it has been treated as an unmetered, and largely benign, waste product of cities. Minimal (unengineered) ditches or pipes drained developed areas to the nearest natural watercourse. Where more convenient, stormwater shared conveyance with wastewater, eliminating the cost of a separate pipe system but commonly resulting in sewage overflows during rainstorms. Recognition of downstream flooding that commonly resulted from upstream development led to construction of stormwater storage ponds or vaults in many municipalities in the 1960s, but their performance has typically fallen far short of design objectives (Booth and Jackson, 1997; Maxted and Shaver, 1999; Nehrke and Roesner, 2004). Water-quality treatment has been a relatively recent addition to the management of stormwater, and although a significant fraction of pollutants can be removed through such efforts (e.g., Strecker et al., 2004; see http://www.bmpdatabase.org), the constituents remaining even in "treated" stormwater represent a substantial, but largely unappreciated, impact to downstream watercourses.

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Of the waterbodies that have been assessed in the United States, impairments from urban runoff are responsible for about 38,114 miles of impaired rivers and streams, 948,420 acres of impaired lakes, 2,742 square miles of impaired bays and estuaries, and 79,582 acres of impaired wetlands (2002 305(b) report). These numbers must be considered an underestimate, since the urban runoff category does not include stormwater discharges from municipal separate storm sewer systems (MS4s) and permitted industries, including construction. Urban stormwater is listed as the "primary" source of impairment for 13 percent of all rivers, 18 percent of all lakes, and 32 percent of all estuaries (2000 305(b) report). Although these numbers may seem low, urban areas cover just 3 percent of the land mass of the United States (Loveland and Auch, 2004), and so their influence is disproportionately large. Indeed, developed and developing areas that are a primary focus of stormwater regulations contain some of the most degraded waters in the country. For example, in Ohio few sites with greater than 27 percent imperviousness can meet interim CWA goals in nearby waterbodies, and biological degradation is observed with much less urban development (Miltner et al., 2004). Numerous authors have found similar patterns (see Meyer et al., 2005).

Although no water quality inventory data have been made available from the EPA since 2002, the dimensions of the stormwater problem can be further gleaned from several past regional and national water quality inventories. Many of these assessments are somewhat dated and are subject to the normal data and assessment limitations of national assessment methods, but they indicate that stormwater runoff has a deleterious impact on nearly all of the nation's waters. For example:

- Harvesting of shellfish is prohibited, restricted, or conditional in nearly 40 percent of all shellfish beds nationally due to high bacterial levels, and urban runoff and failing septic systems are cited as the prime causes. Reopening of shellfish beds due to improved wastewater treatment has been more than offset by bed closures due to rapid coastal development (NOAA, 1992; EPA, 1998).

- In 2006 there were over 15,000 beach closings or swimming advisories due to bacterial levels exceeding health and safety standards, with polluted runoff and stormwater cited as the cause of the impairment 40 percent of the time (NRDC, 2007).

- Pesticides were detected in 97 percent of urban stream water samples across the United States, and exceeded human health and aquatic life benchmarks 6.7 and 83 percent of the time, respectively (USGS, 2006). In 94 percent of fish tissues sampled in urban areas nationwide, organochlorine compounds were detected.

- Urban development was responsible for almost 39 percent of freshwater wetland loss (88,960 acres) nationally between 1998 and 2004 (Dahl, 2006), and the direct impact of stormwater runoff in degrading wetland quality is predicted to affect an even greater acreage (Wright et al., 2006).

- Eastern brook trout are present in intact populations in only 5 percent of more than 12,000 subwatersheds in their historical range in eastern North America, and urbanization is cited as a primary threat in 25 percent of the remaining subwatersheds with reduced populations (Trout Unlimited, 2006).

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- Increased flooding is common throughout urban and suburban areas, sometimes as a consequence of improperly sited development (Figure 1-6A) but more commonly as a result of increasing discharges over time resulting from progressive urbanization farther upstream (Figure 1-6B). According to FEMA (undated), property damage from all types of flooding, from flash floods to large river floods, averages $2 billion a year.

- The chemical effects of stormwater runoff are pervasive and severe throughout the nation's urban waterways, and they can extend far downstream of the urban source. Stormwater discharges from urban areas to marine and estuarine waters cause greater water column toxicity than similar discharges from less urban areas (Bay et al., 2003).

- A variety of studies have shown that stormwater runoff is a vector of pathogens with potential human health implications in both freshwater (Calderon et al., 1991) and marine waters (Dwight et al., 2004; Colford et al., 2007).

FIGURE 1-6 (A) New residential construction in the path of episodic stream discharge (Issaquah, Washington); (B) recent flooding of an 18th-century tavern in Collegeville, Pennsylvania following a storm event in an upstream developing watershed. SOURCES: Derek Booth, Stillwater Sciences, Inc., and Robert Traver, Villanova University.

WHY IS IT SO HARD TO REDUCE THE IMPACTS OF STORMWATER?

"Urban stormwater" is the runoff from a landscape that has been affected in some fashion by human activities, during and immediately after rain. Most visibly, it is the water flow over the ground surface, which is collected by natural channels and artificial conveyance systems (pipes, gutters, and ditches) and ultimately routed to a stream, river, lake, wetland, or ocean. It also includes water that has percolated into the ground but nonetheless reaches a stream channel relatively rapidly (typically within a day or so of the rainfall), contributing to the high discharge in a stream that commonly accompanies rainfall. The subsurface flow paths that contribute to this stormflow response are typically quite shallow, in the upper layers of the soil, and are sometimes termed "interflow." They stand in contrast to deeper groundwater paths, where water moves at much lower velocities by longer paths and so reaches the stream slowly, over periods of days, weeks, or months. This deeper flow sustains streamflow during rainless periods and is usually called baseflow, as distinct from "stormwater." A formal distinction between these types

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of runoff is sometimes needed for certain computational procedures, but for most purposes a qualitative understanding is sufficient.

These runoff paths can be identified in virtually all modified landscapes, such as agriculture, forestry, and mining. However, this report focuses on those settings with the particular combination of activities that constitute "urbanization," by which we mean to include the commonly understood conversion (whether incremental or total) of a vegetated landscape to one with roads, houses, and other structures.

Although the role of urban stormwater in degrading the nation's waters has been recognized for decades (e.g., Klein, 1979), reducing that role has been notoriously difficult. This difficulty arises from three basic attributes of what is commonly termed "stormwater":

1. It is produced from literally everywhere in a *developed* landscape;
2. Its production and delivery are episodic, and these fluctuations are difficult to attenuate; and
3. It accumulates and transports much of the collective waste of the urban environment.

Wherever grasslands and forest are replaced by urban development in general, and impervious surfaces in particular, the movement of water across the landscape is radically altered (see Figure 1-7). Nearly all of the associated problems result from one underlying cause: loss of the water-retaining function of the soil and vegetation in the urban landscape. In an undeveloped, vegetated landscape, soil structure and hydrologic behavior are strongly influenced by biological activities that increase soil porosity (the ratio of void space to total soil volume) and the number and size of macropores, and thus the storage and conductivity of water as it moves through the soil. Leaf litter on the soil surface dissipates raindrop energy; the soil's organic content reduces detachment of small soil particles and maintains high surface infiltration rates. As a consequence, rainfall typically infiltrates into the ground surface or is evapotranspired by vegetation, except during particularly intense rainfall events (Dunne and Leopold, 1978).

In the urban landscape, these processes of evapotranspiration and water retention in the soil may be lost for the simple reason that the loose upper layers of the soil and vegetation are gone—stripped away to provide a better foundation for roads and buildings. Even if the soil still exists, it no longer functions if precipitation is denied access because of paving or rooftops. In either case, a stormwater runoff reservoir of tremendous volume is removed from the stormwater runoff system; water that may have lingered in this reservoir for a few days or many weeks, or been returned directly to the atmosphere by evaporation or transpiration by plants, now flows rapidly across the land surface and arrives at the stream channel in short, concentrated bursts of high discharge.

This transformation of the hydrologic regime from one where subsurface flow once dominated to one where overland flow now dominates is not simply a readjustment of runoff flow paths, and it does not just result in a modest increase in flow volumes. It is a wholesale reorganization of the processes of runoff generation, and it occurs throughout the developed landscape. As such, it can affect every aspect of that runoff (Leopold, 1968)—not only its rate of production, its volume, and its chemistry, but also what it indirectly affects farther downstream (Walsh et al., 2005a). This includes erosion of mobile channel boundaries, mobilization of once-static channel elements (e.g., large logs), scavenging of contaminants from the surface of the urban landscape, and efficient transfer of heat from warmed surfaces to receiving waterbodies. These changes have commonly inspired human reactions—typically with narrow objectives but carrying

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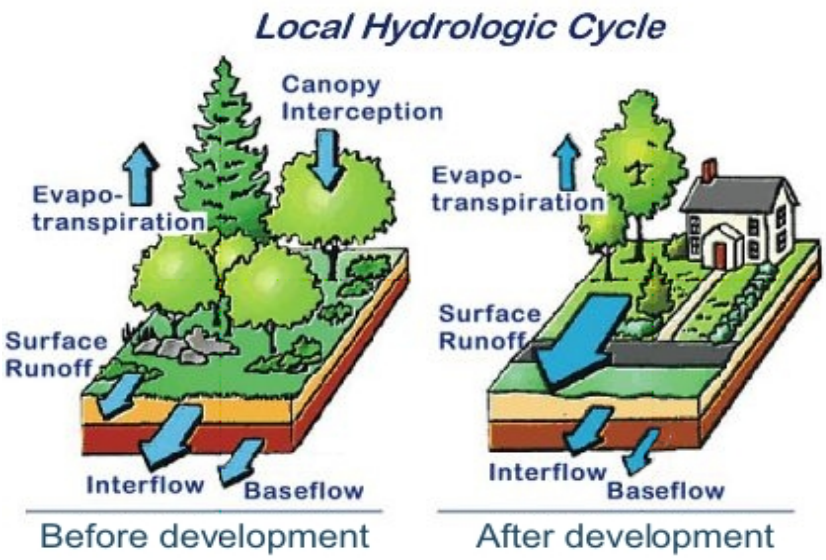

FIGURE 1-7 Schematic of the hydrologic pathways in humid-region watersheds, before and after urban development. The sizes of the arrows suggest relative magnitudes of the different elements of the hydrologic cycle, but conditions can vary greatly between individual catchments and only the increase in surface runoff in the post-development condition is ubiquitous. SOURCE: Adapted from Schueler (1987) and Maryland Department of the Environment; http://www.mde.state.md.us/Programs/WaterPrograms.

additional, far-ranging consequences—such as the piping of once-exposed channels, bank armoring, and construction of large open-water detention ponds (e.g., Lieb and Carline, 2000).

This change in runoff regime is also commonly accompanied by certain land-use activities that have the potential to generate particularly harmful or toxic discharges, notably those commercial activities that are the particular focus of the industrial NPDES permits. These include manufacturing facilities, transport of freight or passengers, salvage yards, and a more generally defined category of "sites where industrial materials, equipment, or activities are exposed to stormwater" (e.g., EPA, 1992).

Other human actions are associated with urban landscapes that do not affect stormwater directly, but which can further amplify the negative consequences of altered flow. These actions include clearing of riparian vegetation around streams and wetlands, introduction of atmospheric pollutants that are subsequently deposited, inadvertent release of exotic chemicals into the environment, and channel crossings by roads and utilities. Each of these additional actions further degrades downstream waterbodies and increases the challenge of finding effective methods to reverse these changes (Boulton, 1999). There is little doubt as to why the problem of urban stormwater has not yet been "solved"—because every functional element of an aquatic ecosystem is affected. Urban stormwater has resulted in such widespread impacts, both physical and biological, in aquatic systems across the world that this phenomenon has been termed the "Urban Stream Syndrome" (see Figure 1-5; Walsh et al., 2005b).

Of the many possible ways to consider these conditions, Karr (1991) has recommended a simple yet comprehensive grouping of the major stressors arising from urbanization that influence aquatic assemblages (Figure 1-8). These include chemical pollutants (water quality and toxicity); changes to flow magnitude, frequency, and seasonality of various discharges; the

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physical aspects of stream, lake, or wetland habitats; the energy dynamics of food webs, sunlight, and temperature; and biotic interactions between native and exotic species. Stormwater and stormwater-related impacts encompass all of these categories, some directly (e.g., water chemistry) and some indirectly (e.g., habitat, energy dynamics). Because of the wide-ranging effects of stormwater, programs to abate stormwater impacts on aquatic systems must deal with a broad range of impairments far beyond any single altered feature, whether traditional water-chemistry parameters or flow rates and volumes.

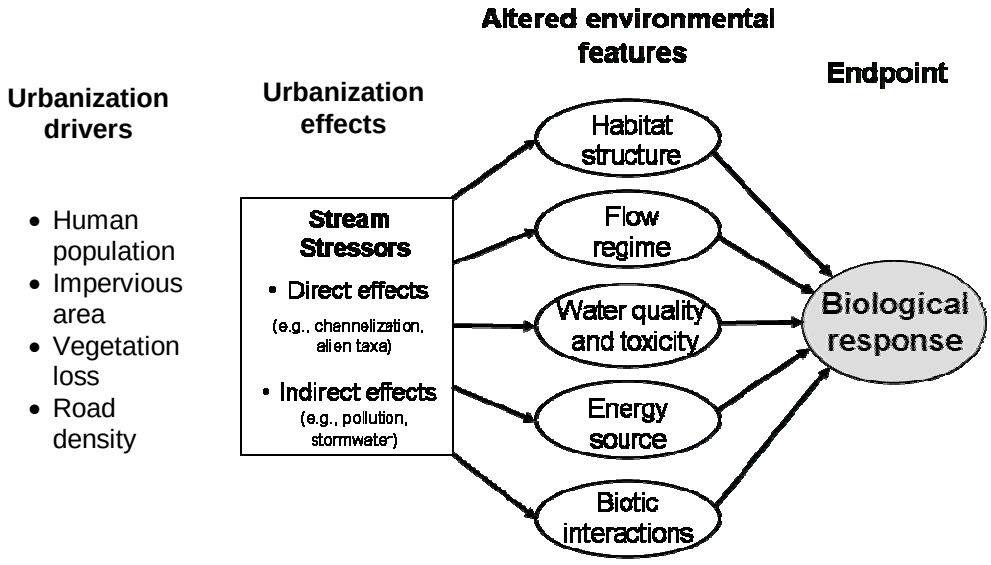

FIGURE 1-8 Five features that are affected by urban development and, in turn, affect biological conditions in urban streams. SOURCES: Modified from Karr (1991), Karr and Yoder (2004), and Booth (2005). Reprinted, with permission, from Karr (1991). Copyright 2001 by Ecological Society of America. Reprinted, with permission, from Karr and Yoder (2004). Copyright 2004 by American Society of Civil Engineers. Reprinted, with permission, from Booth (2005). Copyright 2005 by the North American Benthological Society.

The broad spatial scale of where and how these impacts are generated suggests that solutions, if effective, should be executed at an equivalent scale. Although the "problem" of stormwater runoff is manifested most directly as an altered hydrograph or elevated concentrations of pollutants, it is ultimately an expression of land-use change at a landscape scale. Symptomatic solutions, applied only at the end of a stormwater collection pipe, are not likely to prove fully effective because they are not functioning at the scale of the original disturbance (Kloss and Calarusse, 2006).

The landscape-scale generation of stormwater has a number of consequences for any attempt to reduce its effects on receiving waters, as described below.

Sources and Volumes

The "source" of stormwater runoff is dispersed, making collection and centralized treatment challenging. To the extent that collection is successful, however, the flip side of this

condition—very large volumes—becomes manifest. Either an extensive infrastructure brings stormwater to centralized facilities, whose operation and maintenance may be relatively straightforward (e.g., Anderson et al., 2002) but of modest effectiveness, or stormwater remains dispersed for management, treatment, or both across the landscape (e.g., Konrad and Burges, 2001; Holman-Dodds et al., 2003; Puget Sound Action Team, 2005; Walsh et al., 2005a; Bloom, 2006; van Roon, 2007), better mimicking the natural processes of runoff generation but requiring a potentially unlimited number of "facilities" that may have their own particular needs for space, cost, and maintenance.

Treatment Challenges

Regardless of the scale at which treatment is attempted, technological difficulties are significant because of the variety of "pollutants" that must be addressed. These include physical objects, from large debris to microscopic particles; chemical constituents, both dissolved and immiscible; and less easily categorized properties such as temperature. Wastewater treatment plants manage a similarly broad range of pollutants, but stormwater flows have highly unsteady inflows and, when present, typically much greater volumes to treat.

Industrial sources of stormwater pose a particularly challenging problem because potential generators of polluted or toxic runoff are widespread and are regulated under NPDES permitting by their *activities*, not by the specific category of industrial activity under which they fall. This complicates any systematic effort to identify those entities that should be regulated (Duke et al., 1999). Even for the limited number of regulated generators, pollution prevention measures are of uncertain effectiveness.

Soil erosion from construction sites is another pollution source that has proven difficult to effectively control. Although most bare sites are relatively small and only short-lived, at any given time there can be many sites under construction, each of which can deliver sediment loads to downstream waterbodies at rates that exceed background levels by many orders of magnitude (e.g., Wolman and Schick, 1967). Relatively effective approaches and technologies exist to dramatically reduce the magnitude of these sediment discharges (e.g., Raskin et al., 2005), but they depend on conscientious installation and regular maintenance. Enforcement of such requirements, normally a low-priority activity of local departments of building or public works, is commonly lacking.

Another difference between the stormwater and wastewater streams is that stormwater treatment must address not only "pollutants" but also physically and ecologically deleterious changes in flow rate and total runoff volume. Treating these changes constitutes a particularly difficult task for two reasons. First, there is simply more runoff, as a rule, and so replicating the predevelopment hydrograph is not an option—the increased volume of runoff guarantees that some discharges, some of the time, must be allowed to increase. Second, there is little agreement on what constitutes "adequate" or "effective" treatment for the various attributes of flow. Even the most basic metrics, such as the magnitude of peak flow, can require extensive infrastructure to achieve (e.g., Booth and Jackson, 1997); other flow metrics that correlate more directly with undesired effects on physical and biological systems can require even greater efforts to match. In many cases, the urban-induced transformation of the flow regime makes true "mitigation" virtually impossible.

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Widespread Cause and Effects

The spatial scale of stormwater generation and its impacts is wide-ranging. "Generators" are literally landscape-wide, and impacts can occur at every location in the path followed by urban runoff, from source to receiving waterbody (Hamilton et al., 2004). There are few ways to demonstrate causal connections between distributed landscape sources and cumulative downstream effects (Allan, 2004), and so site-specific mitigation typically provides little lasting improvement in the watershed as a whole (Maxted and Shaver, 1997).

Stormwater Measurements

The desired attributes of stormwater runoff are normally expressed through a combination of physical and chemical parameters. These parameters are commonly presumed to have direct correlation to attributes of human or ecological concern, such as the condition of human or fish communities, or the stability of a stream channel, even though these parameters do not directly measure those effects. The most commonly measured physical parameters are hydrologic and simply measure the rate of flow past a specified location. Both the absolute, instantaneous magnitude of that flow rate (i.e., the discharge) and the variations in that rate over multiple time scales (i.e., how rapidly the discharge varies over an hour, a day, a season, etc.) can be captured by analysis of a continuous time series of a flow. Obviously, however, a nearly unlimited number of possible metrics, capturing a multitude of temporal scales, could be defined (Poff et al., 1997, 2006; Cassin et al., 2004; Konrad et al., 2005; Roy et al., 2005; Chang, 2007). Commonly only a single parameter—the peak storm discharge for a given return period (Hollis, 1975)—has been emphasized in the past. Mitigation of urban-induced flow increases have followed this narrow approach, typically by endeavoring to reduce peak discharge by use of detention ponds but leaving the underlying increase in runoff volumes—and the associated augmentation of both frequency and duration of high discharges—untouched. This partly explains why evaluation of downstream conditions commonly document little improvement resulting from traditional flow-mitigation measures (e.g., Maxted and Shaver, 1997; Roesner et al., 2001; May and Horner, 2002).

Other physical parameters, less commonly measured or articulated, can also express the conditions of downstream watercourses. Measures of size or complexity, particularly for stream channels, are particularly responsive to the changes in flow regime and discharge. Booth (1990) suggested that discriminating between *channel expansion*, the proportional increase in channel cross-sectional area with increasing discharge, and *channel incision*, the catastrophic vertical downcutting that sometimes accompanies urban-induced flow increases, captures important end-members of the physical response to hydrologic change. The former (proportional expansion) is more thoroughly documented (Hammer, 1972; Hollis and Luckett, 1976; Morisawa and LaFlure, 1982; Neller, 1988; Whitlow and Gregory, 1989; Booth and Jackson, 1997; Moscrip and Montgomery, 1997; Booth and Henshaw, 2001); the latter (catastrophic incision) is more difficult to quantify but has been recognized in both urban and agricultural settings (e.g., Simon, 1989). Both types of changes result not only in a larger channel but also in substantial simplification and loss of features normally associated with high-quality habitat for fish and other in-stream biota. The sediment released by these "growing channels" also can be the largest

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component of the overall sediment load delivered to downstream waterbodies (Trimble, 1997; Nelson and Booth, 2002).

Chemical parameters (or, historically, "water-quality parameters"; see Dinius, 1987; Gergel et al., 2002) cover a host of naturally and anthropogenically occurring constituents in water. In flowing water these are normally expressed as instantaneous measurements of concentration. In waterbodies with long residence times, such as lakes, these may be expressed as either concentrations or as loads (total accumulated amounts, or total amounts integrated over an extended time interval). The CWA defined a list of priority pollutants, of which a subset is regularly measured in many urban streams (e.g., Field and Pitt, 1990). Parameters that are not measured may or may not be present, but without assessment they are rarely recognized for their potential (or actual) contribution to waterbody impairment.

Other attributes of stormwater do not fit as neatly into the categories of water quantity or water quality. Temperature is commonly measured and is normally treated as a water quality parameter, although it is obviously not a chemical property of the water (LeBlanc et al., 1997; Wang et al., 2003). Similarly, direct or indirect measures of suspended matter in the water column (e.g., concentration of total suspended solids, or secchi disk depths in a lake) are primarily physical parameters but are normally included in water quality metrics. Flow velocity is rarely measured in either context, even though it too correlates directly to stream-channel conditions. Even more direct expressions of a flow's ability to transport sediment or other debris, such as shear stress or unit stream power, are rarely reported and virtually never regulated.

***

Urban runoff degrades aquatic systems in multiple ways, which confounds our attempts to define causality or to demonstrate clear linkages between mitigation and ecosystem improvement. It is generally recognized from the conceptual models that seek to describe this system that no single element holds the key to ecosystem condition. All elements must be functional, and yet every element can be affected by urban runoff in different ways. These impacts occur at virtually all spatial scales, from the site-specific to the landscape; this breadth and diversity challenges our efforts to find effective solutions.

This complexity and the continued growth of the built environment also present fundamental social choices and management challenges. Stormwater control measures entail substantial costs for their long-term maintenance, monitoring to determine their performance, and enforcement of their use—all of which must be weighed against their (sometimes unproven) benefits. Furthermore, the overarching importance of impervious surfaces inextricably links stormwater management to land-use decisions and policy. For example, where a reversal of the effects of urbanization cannot be realized, more intensive land-use development in certain areas may be a paradoxically appropriate response to reduce the overall impacts of stormwater. That is, increasing population density and impervious cover in designated urban areas may reduce the creation of impervious surface and the associated ecological impacts in areas that will remain undeveloped as a result. In these highly urban areas (with very high percentages of impervious surface), aquatic conditions in local streams will be irreversibly changed and the Urban Stream Syndrome may be unavoidable to some extent. Where these impacts occur and what effort and cost will be used to avoid these impacts are both fundamental issues confronting the nation as it attempts to address stormwater.

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IMPETUS FOR THE STUDY AND REPORT ROADMAP

In 1972 Congress amended the Federal Water Pollution Control Act (subsequently referred to as the Clean Water Act) to require control of discharges of pollutants to waters of the United States from point sources. Initial efforts to improve water quality using NPDES permits focused primarily on reducing pollutants from industrial process wastewater and municipal sewage discharges. These point source discharges were clearly and easily shown to be responsible for poor, often drastically degraded conditions in receiving waterbodies because they tended to emanate from identifiable and easily monitored locations, such as pipe outfalls.

As pollution control measures for industrial process wastewater and municipal sewage were implemented and refined during the 1970s and 1980s, more diffuse sources of water pollution have become the predominant causes of water quality impairment, including stormwater runoff. To address the role of stormwater in causing water quality impairments, Congress included Section 402(p) in the CWA; this section established a comprehensive, two-phase approach to stormwater control using the NPDES program. In 1990 EPA issued the Phase I Stormwater Rule (55 Fed. Reg. 47990; November 16, 1990) requiring NPDES permits for operators of municipal separate storm sewer systems (MS4s) serving populations over 100,000 and for runoff associated with industrial activity, including runoff from construction sites five acres and larger. In 1999 EPA issued the Phase II Stormwater Rule (64 Fed. Reg. 68722; December 8, 1999), which expanded the requirements to small MS4s in urban areas and to construction sites between one and five acres in size.

Since EPA's stormwater program came into being, several problems inherent in its design and implementation have become apparent. As discussed in more detail in Chapter 2, problems stem to a large extent from the diffuse nature of stormwater discharges combined with a regulatory process that was created for point sources (the NPDES permitting approach). These problems are compounded by the shear number of entities requiring oversight. Although exact numbers are not available, EPA estimates that the number of regulated MS4s is about 7,000, including 1,000 Phase I municipalities and 6,000 from Phase II. The number of industrial permittees is thought to be around 100,000. Each year, the construction permit covers around 200,000 permittees each for both Phase I (five acres or greater) and Phase II (one to five acres) projects. Thus, the total number of permittees under the stormwater program at any time numbers greater than half a million. There are fewer than 100,000 non-stormwater (meaning wastewater) permittees covered by the NPDES program, such that stormwater permittees account for approximately 80 percent of NPDES-regulated entities. To manage this large number of permittees, the stormwater program relies heavily on the use of general permits to control industrial, construction, and Phase II MS4 discharges, which are usually statewide, one-size-fits-all permits in which general provisions are stipulated.

An example of the burden felt by a single state is provided by Michigan (David Drullinger, Michigan Department of Environmental Quality Water Bureau, personal communication, September 2007). The Phase I Stormwater regulations that became effective in 1990 regulate 3,400 industrial sites, 765 construction sites per year, and five large cities in Michigan. The Phase II regulations, effective since 1999, have extended the requirements to 7,000 construction sites per year and 550 new jurisdictions, which are comprised of about 350 "primary jurisdictions" (cities, villages, and townships) and 200 "nested jurisdictions" (county drains, road agencies, and public schools). Often, only a handful of state employees are allocated to administer the entire program (see the survey in Appendix C).

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In order to comply with the CWA regulations, permittees must fulfill a number of requirements, including the creation and implementation of a stormwater pollution prevention plan, and in some cases, monitoring of stormwater discharges. Stormwater pollution prevention plans document the stormwater control measures (SCMs; sometimes known as best management practices or BMPs) that will be used to prevent or slow stormwater from quickly reaching nearby waterbodies and degrading their quality. These include structural methods such as detention ponds and nonstructural methods such as designing new development to reduce the percentage of impervious surfaces. Unfortunately, data on the degree of pollutant reduction that can be assigned to a particular SCM are only now becoming available (see Chapter 5).

Other sources of variability in EPA's stormwater program are that (1) there are three permit types (municipal, industrial, and construction), (2) some states and local governments have assumed primacy for the program from EPA while others have not, and state effluent limits or benchmarks for stormwater discharges may differ from the federal requirements, and (3) whether there are monitoring requirements varies depending on the regulating entity and the type of activity. For industrial stormwater there are 29 sectors of industrial activity covered by the general permit, each of which is characterized by a different suite of possible contaminants and SCMs.

Because of the industry-, site-, and community-specific nature of stormwater pollution prevention plans, and because of the lack of resources of most NPDES permitting authorities to review these plans and conduct regular compliance inspections, water quality-related accountability in the stormwater program is poor. Monitoring data are minimal for most permittees, despite the fact that they are often the only indicators of whether an adequate stormwater program is being implemented. At the present time, available monitoring data indicate that many industrial facilities routinely exceed "benchmark values" established by EPA or the states, although it is not clear whether these exceedances provide useful indicators of stormwater pollution prevention plan inadequacies or potential water quality problems. These uncertainties have led to mounting and contradictory pressure from permittees to eliminate monitoring requirements entirely as well as from those hoping for greater monitoring requirements to better understand the true nature of stormwater discharges and their impact.

To improve the accountability of it Stormwater Program, EPA requested advice on stormwater issues from the National Research Council's (NRC's) Water Science and Technology Board as the next round of general permits is being prepared. Although the drivers for this study have been in the industrial stormwater arena, this study considered all entities regulated under the NPDES program (municipal, industrial, and construction). The following statement of task guided the work of the committee:

> (1) Clarify the mechanisms by which pollutants in stormwater discharges affect ambient water quality criteria and define the elements of a "protocol" to link pollutants in stormwater discharges to ambient water quality criteria.
>
> (2) Consider how useful monitoring is for both determining the potential of a discharge to contribute to a water quality standards violation and for determining the adequacy of stormwater pollution prevention plans. What specific parameters should be monitored and when and where? What effluent limits and benchmarks are needed to ensure that the discharge does not cause or contribute to a water quality standards violation?

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(3) Assess and evaluate the relationship between different levels of stormwater pollution prevention plan implementation and in-stream water quality, considering a broad suite of SCMs.

(4) Make recommendations for how to best stipulate provisions in stormwater permits to ensure that discharges will not cause or contribute to exceedances of water quality standards. This should be done in the context of general permits. As a part of this task, the committee will consider currently available information on permit and program compliance.

(5) Assess the design of the stormwater permitting program implemented under the CWA.

The report is intended to inform decision makers within EPA, affected industries, public stormwater utilities, other government agencies and the private sector about potential options for managing stormwater.

EPA requested that the study be limited to those issues that fall under the agency's current regulatory scheme for stormwater, which excludes nonpoint sources of pollution such as agricultural runoff and septic systems. Thus, these sources are not extensively covered in this report. The reader is referred to NRC (2000, 2005) for more detailed information on the contribution of agricultural runoff and septic systems to waterbody impairment and on innovative technologies for treating these sources. Also at the request of EPA, concentrated animal feeding operations and combined sewer overflows were not a primary focus. However, the committee felt that in order to be most useful it should opine on certain critical effects of regulated stormwater beyond the delivery of traditional pollutants. Thus, changes in stream flow, streambank erosion, and habitat alterations caused by stormwater are considered, despite the relative inattention given to them in current regulations.

Chapter 2 presents the regulatory history of stormwater control in the United States, focusing on relevant portions of the CWA and the regulations that have been created to implement the Act. Federal, state, and local programs for or affecting stormwater management are described and critiqued. Chapter 3 deals with the first item in the statement of task. It reviews the scientific aspects of stormwater, including sources of pollutants in stormwater, how stormwater moves across the land surface, and its impacts on receiving waters. It reflects the best of currently available science, and addresses biological endpoints that go far beyond ambient water quality criteria. Methods for monitoring and modeling stormwater (the subject of the second item in the statement of task) are described in Chapter 4. The material evaluates the usefulness of current benchmark and MS4 monitoring requirements, and suggestions for improvement are made. The latter half of the chapter considers the multitude of models available for linking stormwater discharges to ambient water quality. This analysis makes it clear that stormwater pollution cannot yet be treated as a deterministic system (in which the contribution of individual dischargers to a waterbody impairment can be identified) without significantly greater investment in model development. Addressing primarily the third item in the statement of task, Chapter 5 considers the vast suite of both structural and nonstructural measures designed to control stormwater and reduce its pollutant loading to waterbodies. It also takes on relevant larger-scale concepts, such as the benefit of stormwater management within a watershed framework. In Chapter 6, the limitations and possibilities associated with a new

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regulatory approach are explored, as are those of an enhanced but more traditional scheme. Numerous suggestions for improving the stormwater permitting process for municipalities, industrial sites, and construction are made. Along with Chapter 2, this chapter addresses the final two items in the committee's statement of task.

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Chapter 2
The Challenge of Regulating Stormwater

Although stormwater has long been regarded as a major culprit in urban flooding, only in the past 30 years have policymakers appreciated the significant role stormwater plays in the impairment of urban watersheds. This recent rise to fame has led to a cacophony of federal, state, and local regulations to deal with stormwater, including the federal Clean Water Act (CWA) implemented by the U.S. Environmental Protection Agency (EPA). Perhaps because this longstanding environmental problem is being addressed so late in the development and management of urban watersheds, the laws that mandate better stormwater control are generally incomplete and were often passed for other purposes, like industrial waste control.

This chapter discusses the regulatory programs that govern stormwater, particularly the federal program, explaining how these programs manage stormwater only impartially and often inadequately. While progress has been made in the regulation of urban stormwater—from the initial emphasis on simply moving it away from structures and cities as fast as possible to its role in degrading neighboring waterbodies—a significant number of gaps remain in the existing system. Chapter 6 returns to these gaps and considers the ways that at least some of them may be addressed.

FEDERAL REGULATORY FRAMEWORK FOR STORMWATER

The Clean Water Act

The CWA is a comprehensive piece of U.S. legislation that has a goal of restoring and maintaining the chemical, physical, and biological integrity of the nation's waters. Its long-term goal is the elimination of polluted discharges to surface waters (originally by 1985), although much of its current effort focuses on the interim goal of attaining swimmable and fishable waters. Initially enacted as the Federal Water Pollution Control Act in 1948, it was revised by amendments in 1972 that gave it a stronger regulatory, water chemistry-focused basis to deal with acute industrial and municipal effluents that existed in the 1970s. Amendments in 1987 broadened its focus to deal with more diffuse sources of impairments, including stormwater. Improved monitoring over the past two decades has documented that although discharges have not been eliminated, there has been a widespread lessening of the effects of direct municipal and industrial wastewater discharges.

A timeline of federal regulatory events over the past 125 years relevant to stormwater, which includes regulatory precursors to the 1972 CWA, is shown in Table 2-1. The table reveals that while there was a flourish of regulatory activity related to stormwater during the mid-1980s to 1990s, there has been much less regulatory activity since that time.

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TABLE 2-1 Legal and Regulatory Milestones for the Stormwater Program

1886	**Rivers and Harbors Act.** A navigation-oriented statute that was used in the 1960s and 1970s to challenge unpermitted pollutant discharges from industry.
1948 *1952* *1955*	**Federal Water Pollution Control Act.** Provided matching funds for wastewater treatment facilities, grants for state water pollution control programs, and limited federal authority to act against interstate pollution.
1965	**Water Quality Act.** Required states to adopt water quality standards for interstate waters subject to federal approval. It also required states to adopt state implementation plans, although failure to do so would not result in a federally implemented plan. As a result, enforceable requirements against polluting industries, even in interstate waters, was limited.
1972	**Federal Water Pollution Control Act.** First rigorous national law prohibiting the discharge of pollutants into surface waters without a permit. • Goal is to restore and maintain health of U.S. waters • Protection of aquatic life and human contact recreation by 1983 • Eliminate discharge of pollutants by 1985 • Wastewater treatment plant financing
	Clean Water Act Section 303(d) • Contains a water quality-based strategy for waters that remain polluted after the implementation of technology-based standards. • Requires states to identify waters that remain polluted, to determine the total maximum daily loads that would reverse the impairments, and then to allocate loads to sources. If states do not perform these actions, EPA must.
	Clean Water Act Section 208 • Designated and funded the development of regional water quality management plans to assess regional water quality, propose stream standards, identify water quality problem areas, and identify wastewater treatment plan long-term needs. These plans also include policy statements which provide a common consistent basis for decision making.
1977 *1981*	**Clean Water Act Sections 301 and 402** • Control release of toxic pollutants to U.S. waters • Technology treatment standards for conventional pollutants and priority toxic pollutants. • Recognition of technology limitations for some processes.
1977	*NRDC vs. Costle.* Required EPA to include stormwater discharges in the National Pollution Discharge Elimination System (NPDES) program.
1987	**Clean Water Act Amended Sections 301 and 402** • Control toxic pollutants discharged to U.S. waters. • Manage urban stormwater pollution. • Numerical criteria for all toxic pollutants. • Integrated control strategies for impaired waters. • Stormwater permit programs for urban areas and industry. • Stronger enforcement penalties. • Anti-backsliding provisions.

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1990	**EPA's Phase I Stormwater Permit Rules are Promulgated** • Application and permit requirements for large and medium municipalities • Application and permit requirements for light and heavy industrial facilities based on Standard Industrial Classification (SIC) Codes, and construction activity ≥ 5 acres
1999	**EPA's Phase II Stormwater Permit Rules are Promulgated** • Permit requirements for census-defined urbanized areas • Permit requirements for construction sites 1 to 5 acres
1997-2001	**Total Maximum Daily Load (TMDL) Program Litigation** • Courts order EPA to establish TMDLs in a number of states if the states fail to do so. The TMDLs assign Waste Load Allocations for stormwater discharges which must be incorporated as effluent limitations in stormwater permits.
2006-2008	**Section 323 of the Energy Policy Act of 2005** • EPA promulgates rule (2006) to exempt stormwater discharges from oil and gas exploration, production, processing, treatment operations, or transmission facilities from NPDES stormwater permit program. • In 2008, courts order EPA to reverse the rule which exempted certain activities in the oil and gas exploration industry from storm water regulations. In *Natural Resources Defense Council vs. EPA* (9th Cir. 2008), the court held that it was "arbitrary and capricious" to exempt from the Clean Water Act stormwater discharges containing sediment contamination that contribute to a violation of water quality standards.
2007	**Energy Independence and Security Act of 2007** • Requires all federal development and redevelopment projects with a footprint above 5,000 square feet to achieve predevelopment hydrology to the "maximum extent technically feasible."

The Basic NPDES Program: Regulating Pollutant Discharges

The centerpiece of the CWA is its mandate "that all *discharges* into the nation's waters are unlawful, unless specifically authorized by a permit" [42 U.S.C. §1342(a)]. Discharges do not include all types of pollutant flows, however. Instead, "discharges" are defined more narrowly as "point sources" of pollution, which in turn include only sources that flow through a discrete conveyance, like a pipe or ditch, into a lake or stream [33 U.S.C. §§ 1362(12) and (14)]. Much of the focus of the CWA program, then, is on limiting pollutants emanating from these discrete, point sources directly into waters of the United States. Authority to control nonpoint sources of pollution, like agricultural runoff (even when drained via pipes or ditches), is generally left to the states with more limited federal oversight and direction.

All point sources of pollutants are required to obtain a National Pollutant Discharge Elimination System (NPDES) permit and ensure that their pollutant discharges do not exceed specified effluent standards. Congress also commanded that rather than tie effluent standards to the needs of the receiving waterbody—an exercise that was far too scientifically uncertain and time-consuming—the effluent standards should first be based on the best available pollution technology or the equivalent. In response to a very ambitious mandate, EPA has promulgated very specific, quantitative discharge limits for the wastewater produced by over 30 industrial categories of sources based on what the best pollution control technology could accomplish, and

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it requires at least secondary treatment for the effluent produced by most sewage treatment plants. Under the terms of their permits, these large sources are also required to self-monitor their effluent at regular intervals and submit compliance reports to state or federal regulators.

EPA quickly realized after passage of the CWA in 1972 that if it were required to develop pollution limits for all point sources, it would need to regulate hundreds of thousands and perhaps even millions of small stormwater ditches and thousands of small municipal stormwater outfalls, all of which met the technical definition of "point source". It attempted to exempt all these sources, only to have the D.C. Circuit Court read the CWA to permit no exemptions [*NRDC vs. Costle*, 568 F.2d 1369 (D.C. Cir. 1977)]. In response, EPA developed a "general" permit system (an "umbrella" permit that covers multiple permittees) for smaller outfalls of municipal stormwater and similar sources, but it generally did not require these sources to meet effluent limitations or monitor their effluent.

It should be noted that, while the purpose of the CWA is to ensure protection of the physical, biological, and chemical integrity of the nation's waters, the enforceable reach of the Act extends only to the discharges of "pollutants" into waters of the United States [33 U.S.C. § 1311(a); cf. PUD No. 1 of Jefferson County v. Washington Department of Ecology, 511 U.S. 700 (1994) (providing states with broad authority under section 401 of the CWA to protect designated uses, not simply limit the discharge of pollutants)]. Even though "pollutant" is defined broadly in the Act to include virtually every imaginable substance added to surface waters, including heat, it has not traditionally been read to include water volume [33 U.S.C. § 1362(6)]. Thus, the focus of the CWA with respect to its application to stormwater has traditionally been on the water quality of stormwater and not on its quantity, timing, or other hydrologic properties. Nonetheless, because the statutory definition of "pollutant" includes "industrial, municipal, and agricultural waste discharged into water," using transient and substantial increases in flow in urban watersheds as a proxy for pollutant loading seems a reasonable interpretation of the statute. EPA Regions 1 and 3 have considered flow control as a particularly effective way to track sediment loading, and they have used flow in TMDLs as a surrogate for pollutant loading (EPA Region 3, 2003). State trial courts have thus far ruled that municipal separate storm sewer system (MS4) permits issued under delegated federal authority can impose restrictions on flow where changes in flow impair the beneficial uses of surface waters (Beckman, 2007). EPA should consider more formally clarifying that significant, transient increases in flow in urban watersheds serve as a legally valid proxy for the loading of pollutants. This clarification will allow regulators to address the problems of stormwater in more diverse ways that include attention to water volume as well as to the concentration of individual pollutants.

Stormwater Discharge Program

By 1987, Congress became concerned about the significant role that stormwater played in contributing to water pollution, and it commanded EPA to regulate a number of enumerated stormwater discharges more rigorously. Specifically, Section 402(p), introduced in the 1987 Amendments to the CWA, directs EPA to regulate some of the largest stormwater discharges—those that occur at industrial facilities and municipal storm sewers from larger cities and other significant sources (like large construction sites)—by requiring permits and promulgating discharge standards that require the equivalent of the best available technology [42 U.S.C. §

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1342(p)(3)]. Effectively, then, Congress grafted larger stormwater discharges onto the existing NPDES program that was governing discharges from manufacturing and sewage treatment plants.

Upon passage of Section 402(p), EPA divided the promulgation of its stormwater program into two phases that encompass increasingly smaller discharges. The first phase, finalized in 1990, regulates stormwater discharges from ten types of industrial operations (this includes the entire manufacturing sector), construction occurring on five or more acres, and medium or large storm sewers in areas that serve 100,000 or more people [40 C.F.R. § 122.26(a)(3) (1990); 40 C.F.R. § 122.26 (b)(14) (1990)]. The second phase, finalized in 1995, includes smaller municipal storm sewer systems and smaller construction sites (down to one acre) [60 Fed. Reg. 40,230 (Aug. 7, 1995) (codified at 40 C.F.R. Parts 122, 124 (1995)]. If these covered sources fail to apply for a permit, they are in violation of the CWA.

Because stormwater is more variable and site specific with regard to its quality and quantity than wastewater, EPA found it necessary to diverge in two important ways from the existing NPDES program governing discharges from industries and sewage treatment plants. First, stormwater discharge limits are not federally specified in advance as they are with discharges from manufacturing plants. Even though Congress directed EPA to require stormwater sources to install the equivalent of the best available technology or "best management practices," EPA concluded that the choice of these best management practices (referred to in this report as stormwater control measures or SCMs) would need to be source specific. As a result, although EPA provides constraints on the choices available, it generally leaves stormwater sources with responsibility for developing a stormwater pollution prevention plan and the state with the authority to approve, amend, or reject these plans (EPA, 2006a, p. 15).

Second, because of the great variability in the nature of stormwater flow, some sources are not required to monitor the pollutants in their stormwater discharges. Even when monitoring is required, there is generally a great deal of flexibility for regulated parties to self-monitor as compared with the monitoring requirements applied to industrial waste effluent (not stormwater from industries). More specifically, for a small subset of stormwater sources such as Phase I MS4s, some monitoring of effluent during a select number of storms at a select number of outfalls is required (EPA, 1996a, p. VIII-1). A slightly larger number of identified stormwater dischargers, primarily industrial, are only required to collect grab samples four times during the year and visually sample and report on them (so-called benchmark monitoring). The remaining stormwater sources are not required to monitor their effluent at all (EPA, 1996a). States and localities may still demand more stringent controls and rigorous stormwater monitoring, particularly in areas undergoing a Total Maximum Daily Load (TMDL) assessment, as discussed below. Yet, even for degraded waters subject to TMDLs, any added monitoring that might be required will be limited only to the pollutants that cause the degraded condition [40 C.F.R. §§ 420.32-420.36 (2004)].

Water Quality Management

Since technology-based regulatory requirements imposed on both stormwater and more traditional types of discharges are not tied to the conditions of the receiving water—that is, they require sources only to do their technological best to eliminate pollution—basic federal effluent limits are not always adequate to protect water quality. In response to this gap in protection,

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Congress has developed a number of programs to ensure that waters are not degraded below minimal federal and state goals [e.g., 33 U.S.C. §§ 1288, 1313(e), 1329, 1314(l)]. Among these, the TMDL program involves the most rigorous effort to control both point and nonpoint sources to ensure that water quality goals are met [33 U.S.C. § 1313(d)].

Under the TMDL program, states are required to list waterbodies not meeting water quality standards and to determine, for each degraded waterbody, the "total maximum daily load" of the problematic pollutant that can be allowed without violating the applicable water quality standard. The state then determines what types of additional pollutant loading reductions are needed, considering not only point sources but also nonpoint sources. It then promulgates controls on these sources to ensure further reductions to achieve applicable water quality goals.

The TMDL process has four separate components. The first two components are already required of the states through other sections of the CWA: (1) identify beneficial uses for all waters in the state and (2) set water quality standards that correlate with these various uses. The TMDL program adds two components by requiring that states then (3) identify segments where water quality goals have not been met for one or more pollutants and (4) develop a plan that will ensure added reductions are made by point and/or nonpoint sources to meet water quality goals in the future. Each of these is discussed below.

Beneficial Uses. States are required to conduct the equivalent of "zoning" by identifying, for each water segment in the state, a beneficial use, which consists of ensuring that the waters are fit for either recreation, drinking water, aquatic life, or agricultural, industrial, and other purposes [33 U.S.C. § 1313(c)(2)(A)]. All states have derived "narrative definitions" to define the beneficial uses of waterbodies that are components of all water quality standard programs. Many of these narrative criteria are conceptual in nature and tend to define general aspects of the beneficial uses. For categories such as *aquatic life uses,* most states have a single metric for differentiating uses by type of stream (e.g., coldwater vs. warmwater fisheries). In general, the desired biological characteristics of the waterbody are not well defined in the description of the beneficial use. Some states, such as Ohio, have added important details to their beneficial uses by developing tiered aquatic life uses that recognize a strong gradient of anthropogenic background disturbance that controls whether a waterbody can attain a certain water quality and biological functioning (see Box 2-1; Yoder and Rankin, 1998). Any aquatic life use tier less stringent than the CWA interim goal of "swimmable–fishable" requires a Use Attainability Analysis to support a finding that restoration is not currently feasible and recovery is not likely in a reasonable period of time. This analysis and proposed designation must undergo public comment and review and are always considered temporary in nature. More importantly, typically one or more tiers above the operative interim goal of "swimmable–fishable" are provided. This method typically will protect the highest attainable uses in a state more effectively than having only single uses.

The concept of tiered beneficial uses and use attainability is especially important with regard to urban stormwater because of the potential irreversibility of anthropogenic development and the substantial costs that might be incurred in attempting to repair degraded urban watersheds to "swimmable–fishable" or higher status. Indeed, it is important to consider what public benefits and costs might occur for different designated uses. For example, large public benefits (in terms of aesthetics and safety) might be gained from initial improvements in an urban stream (e.g., restoring base flow) that achieve modest aquatic use and protect secondary human contact. However, achieving designated uses associated with primary human contact or

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BOX 2-1
Ohio's Tiered Aquatic Life Uses

"Designated" or "beneficial" uses for waterbodies are an important aspect of the CWA because they are the explicit water quality goals or endpoints set for each water or class of waters. Ohio was one of the first states to implement tiered aquatic life uses (TALUs) in 1978 as part of its water quality standards (WQS). Most states have a single aquatic life use for a class of waters based on narrative biological criteria (e.g., warmwater or coldwater fisheries) although many states now collect data that would allow identification of multiple tiers of condition. EPA has recognized the management advantages inherent to tiered aquatic life uses and has developed a technical document on how to develop the scientific basis that would allow States to implement tiered uses (EPA, 2005a; Davies and Jackson, 2006).

Ohio's TALUs reflect the mosaic of natural features across Ohio and over 200 years of human changes to the natural landscape. Widespread information on Ohio's natural history (e.g., Trautman's 1957 *Fishes of Ohio*) provided strong evidence that the potential fauna of streams was not uniform, but varied geographically. Based on this knowledge, Ohio developed a more protective aquatic life use tier to protect streams of high biological diversity that harbored unique assemblages of rare or sensitive aquatic species (e.g., fish, mussels, invertebrates). In its WQS in 1978, Ohio established a narrative Exceptional Warmwater Habitat (EWH) aquatic life use to supplement its more widespread general or "Warmwater Habitat" aquatic life use (WWH) (Yoder and Rankin, 1995).

The CWA permits states to assign aquatic life uses that do not meet the baseline swimmable-fishable goals of the CWA under specific circumstances after conducting a Use Attainability Analysis (UAA), which documents that higher CWA aquatic life use goals (e.g., WWH and EWH in Ohio) are not feasibly attainable. These alternate aquatic life uses are always considered temporary in case land use changes or technology changes to make restoration feasible. The accrual of more than ten years of biological assessment data by the late 1980s and extensive habitat and stressor data provided a key link between the stressors that limited attainment of a higher aquatic life use in certain areas and reaches of Ohio streams. This assessment formed the basis for several "modified" (physical) warmwater uses for Ohio waters and a "limited" use (limited resource water, LRW) for mostly small ephemeral or highly artificial waters (Yoder and Rankin, 1995). Table 2-2 summarizes the biological and physical characteristics of Ohio TALUs and the management consequences of these uses. Channelization typically maintained by county or municipal drainage and flood control efforts, particularly where such changes have been extensive, are the predominant cause of Modified and Limited aquatic life uses. Extensive channel modification in urban watersheds has led to some modified warmwater habitat (MWH) and LRW uses in urban areas. There has been discussion of developing specific "urban" aquatic life uses; however the complexity of multiple stressors and the need to find a clear link between the sources limiting aquatic life and feasible remediation is just now being addressed in urban settings (Barbour et al., 2006).

The TALUs in Ohio (EWH→LRW) reflect a gradient of landscape and direct physical changes, largely related to changes to instream habitat and associated hydrological features. Aquatic life uses and the classification strata based on ecoregion and stream size (headwater, wadeable, and boatable streams) provide the template for the biocriteria expectations for Ohio streams (see Box 2-2). Identification of the appropriate tiers for streams and UAA are a routine part of watershed monitoring in Ohio and are based on biological, habitat, and other supporting data. Any recommendations for changes in aquatic life uses are subject to public comment when the Ohio WQS are changed.

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BOX 2-1 Continued

Aquatic Life Use	Key Attributes	Why a Waterbody Would Be Designated	Practical Impacts (compared to a baseline of WWH)
Warmwater Habitat (WWH)	Balanced assemblages of fish/invertebrates comparable to least impacted *regional* reference condition	Either supports biota consistent with numeric biocriteria for that ecoregion **or** exhibits the habitat potential to support recovery of the aquatic fauna	Baseline regulatory requirements consistent with the CWA "fishable" and "protection & propagation" goals; criteria consistent with EPA guidance with State/regional modifications as appropriate
Exceptional Warmwater Habitat (EWH)	Unique and/or diverse assemblages; comparable to upper quartile of *statewide* reference condition	Attainment of the EWH biocriteria demonstrated by both organism groups	More stringent criteria for D.O., temperature, ammonia, and nutrient targets; more stringent restrictions on dissolved metals translators; restrictions on nationwide dredge & fill permits; may result in more stringent wastewater treatment requirements
Coldwater Habitat (CWH)	Sustained presence of Salmonid or non-salmonid coldwater aquatic organisms; bonafide trout fishery	Bioassessment reveals coldwater species as defined by Ohio EPA (1987); put-and-take trout fishery managed by Ohio DNR	Same as above except that common metals criteria are more stringent; may result in more stringent wastewater treatment requirements
Modified Warmwater Habitat (MWH)	Warmwater assemblage dominated by species tolerant of low D.O., excessive nutrients, siltation, and/or habitat modifications	Impairment of the WWH biocriteria; existence and/or maintenance of hydrological modifications that cannot be reversed or abated to attain the WWH biocriteria; a use attainability analysis is required	Less stringent criteria for D.O., ammonia, and nutrient targets; less restrictive applications of dissolved metals translators; Nationwide permits apply without restrictions or exception; may result in less restrictive wastewater treatment requirements
Limited Resource Waters (LRW)	Highly degraded assemblages dominated exclusively by tolerant species; *should not* reflect acutely toxic conditions	Extensive physical and hydrological modifications that cannot be reversed and which preclude attainment of higher uses; a use attainability analysis is required	Chemical criteria are based on the prevention of acutely lethal conditions; may result in less restrictive wastewater treatment requirements

TABLE 2-2 Key features associated with tiered aquatic life uses in the Ohio WQS. SOURCE: EPA (2005a Appendix B).

Ohio's water quality standards contain specific listings by stream or stream reach with notations about the appropriate aquatic life use as well as other applicable uses (e.g., recreation). Much of the impact of tiered uses on regulated entities or watershed management efforts arises from the tiered chemical and stressor criteria associated with each TALU. Criteria for compounds such as ammonia and dissolved oxygen vary with aquatic life use (see Table 2-2). Furthermore, application of management actions in Ohio, ranging from assigning antidegradation tiers, awarding funding for wastewater infrastructure and other projects, to issuing CWA Section 401/404 permits, are influence by the TALU and the biological assemblages present.

Ohio has been expanding its use of tiered uses by proposing tiered uses for wetlands (http://www.epa.state.oh.us/dsw/rules/draft_1-53_feb06.pdf) and developing new aquatic life uses for very small (primary headwater, PHW) streams. Both of these water types have a strong intersection with urban construction and stormwater practices. In Ohio this is especially so because the proposed mitigation standards for steams and wetlands are linked to TALUs (Ohio EPA, 2007).

Davies and Jackson (2006) present a good summary of the Maine rationale for TALUs: "(1) identifying and preserving the highest quality resources, (2) more accurately depicting existing conditions, (3) setting realistic and attainable management goals, (4) preserving incremental improvements, and (5) triggering management action when conditions decline" (Davies et al., 1999). Appendices A and B of EPA (2005a) provide more detailed information about the TALUs in Maine and Ohio, respectively.

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exceptional aquatic habitat may be much more costly, such that the perceived incremental public gains may be much lower than the costs that must be expended to achieve that more ambitious designation.

Water Quality Criteria. Once a state has created a list of beneficial uses for its waters, water quality criteria are then determined that correspond with these uses. These criteria can target chemical, biological, or physical parameters, and they can be either numeric or narrative.

In response to the acute chemical water pollution that existed when the CWA was written, the primary focus of water quality criteria was the control of toxic and conventional pollutants from wastewater treatment plants. EPA developed water quality criteria for a wide range of conventional pollutants and began working on criteria for a list of priority pollutants. These were generally in the form of numeric criteria that are then used by states to set their standards for the range of waterbody types that exist in that state. While states do not have to adopt EPA water quality criteria, they must have a scientific basis for setting their own criteria. In practice, however, states have promulgated numerical water quality standards that can vary by as much as 1,000-fold for the same contaminant but are still considered justified by the available science [e.g., the water quality criteria for dioxin—*Natural Resources Defense Council, Inc. vs. EPA*, 16 F.3d 1395, 1398, 1403-05 (4th Cir. 1993)].

The gradual abatement of point source impairments and increased focus on ambient monitoring and nonpoint source pollutants has led to a gradual, albeit inconsistent, shift by states toward (1) biological and intensive watershed monitoring and (2) consideration of stressors that are not typical point source pollutants including nutrients, bedded sediments, and habitat loss. For these parameters, many states have developed narrative criteria (e.g., "nutrients levels that will not result in noxious algal populations"), but these can be subjective and hard to enforce.

The use of biological criteria (biocriteria) has gained in popularity because traditional water quality monitoring is now perceived as insufficient to answer questions about the wide range of impairments caused by activities other than wastewater point sources, including stormwater (GAO, 2000). As described in Box 2-2, Ohio has defined biocriteria in its water quality standards based on multimetric indices from reference sites that quantify the baseline expectations for each tier of aquatic life use.

Antidegradation. The antidegradation provision of the water quality standards deals with waters that already achieve or exceed baseline water quality criteria for a given designated use. Antidegradation provisions must be considered before any regulated activity can be authorized that may result in a lowering of water quality which includes biological criteria. These provisions protect the existing beneficial uses of a water and only allow a lowering of water quality (but never lower than the baseline criteria associated with the beneficial use) where necessary to support important social and economic development. It essentially asks the question: is the discharge or activity necessary? States with refined designated uses and biological criteria have used these programs to their advantage to craft scientifically sound, protective, yet flexible antidegradation rules (see Ohio and Maine). Antidegradation is not a replacement for tiered uses, which provide a permanent floor against lowering water quality protection. Tiered beneficial uses and refined antidegradation rules can have substantial influence on stormwater programs because they influence the goals and levels of protection assigned to each waterbody.

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BOX 2-2
Ohio's Biocriteria

After it implemented tiered aquatic life uses in 1978, Ohio developed numeric biocriteria in 1990 (Ohio WQS; Ohio Administrative Code 3745-1) as part of its WQS. Since designated uses were formulated and described in ecological terms, Ohio felt that it was natural that the criteria should be assessed on an ecological basis (Yoder, 1978). Subsequent to the establishment of the EWH tier in its WQS, Ohio expanded its biological monitoring efforts to include both macroinvertebrates and fish (Yoder and Rankin, 1995) and established consistent and robust monitoring methodologies that have been maintained to the present. This core of consistently collected data has allowed the application of analytical tools, including multimetric indices such as the Index of Biotic Integrity (IBI), the Invertebrate Community Index (ICI), and other multivariate tools. The development of aquatic ecoregions (Omernik, 1987, 1995; Gallant et al., 1989), a practical definition of biological integrity (Karr and Dudley, 1981), multimetric assessment tools (Karr, 1981; Karr et al., 1986), and reference site concepts (Hughes et al., 1986) provided the basis for developing Ohio's ecoregion-based numeric criteria.

Successful application of biocriteria in Ohio was dependent on the ability to accurately classify aquatic ecosystem changes based on primarily natural abiotic features of the environment. Ohio's reference sites, on which the biocriteria are based, reflect spatial differences that were partially explained by aquatic ecoregions and stream size. Biological indices were calibrated and stratified on this basis to arrive at biological criteria that present minimally acceptable baseline ecological index scores (e.g., IBI, ICI). Ohio biocriteria stratified by ecoregion aquatic life use and stream size are depicted in Figure 2-1.

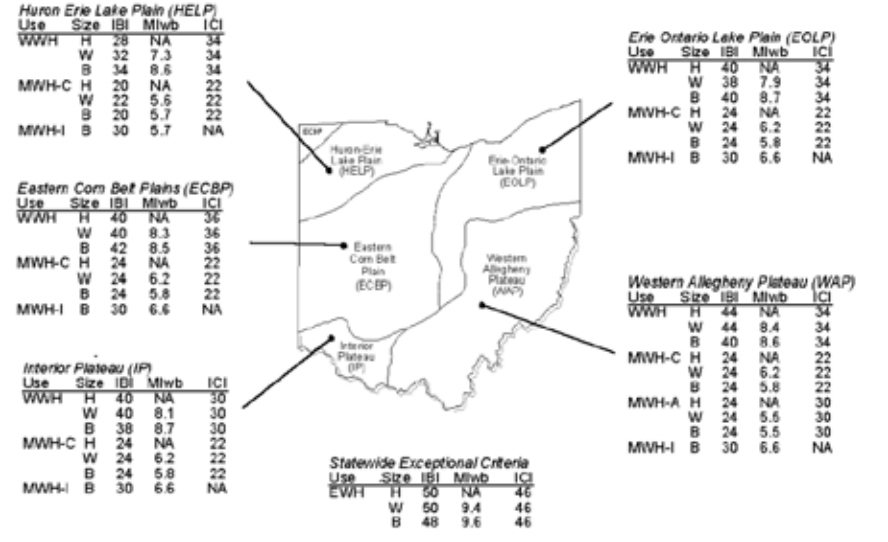

FIGURE 2-1 Numeric biological criteria adopted by Ohio EPA in 1990, using three biological indices [IBI, ICI, and the Modified Index of well-being (Mlwb), which is used to assessed fish assemblages] and showing stratification by stream size, ecoregion, and designated use (warmwater habitat, WWH; modified warmwater habitat-channelized, MWH-C; modified warmwater habitat-impounded, MWH-I; and exceptional warmwater habitat, EWH). SOURCE: EPA (2006, Appendix B). The basis for the Ohio biocriteria and sampling methods is found in Ohio EPA (1987, 1989a,b), DeShon (1995), and Yoder and Rankin (1995).

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Monitoring Programs to Identify Degraded Segments. Monitoring strategies by the states generally follow the regulatory efforts of EPA and seek to identify those waterbodies where one or more water quality standards are not being met. Much of the initial ambient monitoring (i.e., monitoring of receiving waterbodies) was chemical based and focused on documenting changes in pollutant concentrations and exceedances of water quality criteria. Biological monitoring techniques have a long history of use as indicators of water quality impacts. However, it was not until such tools became more widespread—initially in states like Maine, North Carolina, and Ohio—that the extent of stormwater and other stressor effects on waterbodies became better understood. The biological response to common nonpoint stressors has driven the consideration of new water quality criteria (e.g., for nutrients, bedded sediments) that were not major considerations under an effluent-dominated paradigm of water management.

In parallel with the increase in biocriteria has been the development of biological monitoring to measure beneficial use attainment. Integrated biological surveys have revealed impairments of waterbodies that go beyond those caused by typical point sources (EPA, 1996b; Barbour et al., 1999a). The substantial increase in biological assemblage monitoring during the 1980s was enhanced by the development of more standard methods (Davis, 1995; Barbour et al., 1999a,b; Klemm et al., 2003) along with conceptual advances in the development of assessment tools (Karr, 1981; Karr and Chu, 1999). Development of improved classification tools (e.g., ecoregions, stream types), the reference site concept (Stoddard et al., 2006), and analytical approaches including multivariate (e.g., discriminant analysis) and multimetric indices such as IBI and ICI (see Box 2-3; Karr et al., 1986; DeShon, 1995) resulted in biological criteria being developed for several states. Biological monitoring approaches are becoming a widespread tool for assessing attainment of aquatic life use designation goals inherent to state water quality standards. Development of biocriteria represents a maturation of the use of biological data and provides institutional advantages for states in addressing pollutants without numeric criteria (e.g., nutrients) and non-chemical stressors such as habitat (Yoder and Rankin, 1998).

Setting Loads and Restricting Loading. Section 303d of the CWA requires that states compare existing water quality data with water quality standards set by the states, territories, and tribes. For those waters found to be in violation of their water quality standards, Section 303d requires that the state develop a TMDL. Currently, approximately 20,000 of monitored U.S. waters are in non-attainment of water quality standards, as evidenced by not meeting at least one specific narrative or numeric physical, chemical, or biological criterion, and thus require the development of a TMDL.

The TMDL process includes an enforceable pollution control plan for degraded waters based on a quantification of the loading of pollutants and an understanding of problem sources within the watershed [33 U.S.C. § 1313(d)(1)(C)]. Both point and nonpoint sources of the problematic pollutants, including runoff from agriculture, are typically considered and their contributions to the problem are assessed. A plan is then developed that may require these sources to reduce their loading to a level (the TMDL) that ensures that the water will ultimately meet its designated use. Most of the TMDL requirements have been developed through regulation. Additional effluent limits for point sources discharging into segments subject to TMDLs are incorporated into the NPDES permit.

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BOX 2-3
Commonly Used Biological Assessment Indices

Much of the initial work using biological data to assess the effects of pollution on inland streams and rivers was a response to Chicago's routing of sewage effluents into the Illinois River in the late 1800s. Early research focused on the use of indicator species, singly or in aggregate, and how they changed along gradients of effluent concentrations (Davis, 1990, 1995). In the 1950s Ruth Patrick used biological data to assess rivers by observing longitudinal changes in taxonomic groups, and later in the 1950s and 1960s "diversity indices" (e.g., Shannon-Wiener index, Shannon and Weaver, 1949) were used to assess aquatic communities (Washington, 1984; Davis 1990, 1995). These indices were various mathematical constructs that measured attributes such as richness and evenness of species abundance in samples and are still widely used today in ecological studies. Similarity indices are another approach that is used to compare biological assemblages between sites. There are a wide multitude of such indices (e.g., Bray-Curtis, Jaccard) and all use various mathematical constructs to examine species in common and absent between samples.

Biotic indices are generally of more recent origin (1970s to the present). Hilsenhoff (1987, 1988) assigned organic pollution tolerances to macroinvertebrate taxa and then combined these ratings in a biotic index that is still widely used for macroinvertebrates. Karr (1981) developed the Index of Biotic Integrity (IBI), a "multimetric" index that is composed of a series of 12 metrics of a Midwest stream fish community. This approach has been widely adopted and adapted to many types of waterbodies (streams, lakes, rivers, estuaries, wetlands, the Great Lakes, etc.) and organism groups and is probably the most widely used biotic index approach in the United States. Examples include the periphyton IBI (PIBI; Hill et al., 2000) for algal communities, the Invertebrate Community Index (ICI; DeShon, 1995) and benthic IBI (B-IBI, Kerans and Karr, 1994) for macroinvertebrates, a benthic IBI for estuaries (B-IBI; Weisberg et al., 1997), and a vegetative IBI for wetlands (VIBI-E; Mack, 2007).

Various multivariate statistical approaches have also been used to assess aquatic assemblages, often concurrently with multimetric indices. Maine, for example, uses a discriminant analysis that assesses stream stations by comparison to reference sites (Davies and Tsomides, 1997). Predictive modeling approaches, incorporating both biotic and environmental variables, have been widely used in Great Britain and Europe (River Invertebrate Prediction and Classification System, RIVPACS; Wright et al., 1993), Australia (AUSRIVAS; Simpson and Norris, 2000), and more recently in the United States by Hawkins et al. (2000).

All of these approaches now have a wide scientific literature supporting their use and application. EPA (2002a) reports that most states have a biomonitoring program with at least one organism group to assess key waters in their states, although the level of implementation and sophistication varies by state. For example, only four states have numeric biocriteria in their state water quality standards, although 11 more are developing such biocriteria based on one or more of the above monitoring approaches (EPA, 2002a). The key to implementation of any of these approaches is to set appropriate goals for waters that can be accurately measured and then to use this type of information to identify limiting stressors (e.g., EPA Stressor Identification Process; EPA, 2000a).

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Total Maximum Daily Load Program and Stormwater

The new emphasis on TMDLs and the revelation that impacts are primarily from diffuse sources has increased the attention given to stormwater. If a TMDL assigns waste load allocations to stormwater discharges, these must be incorporated as effluent limitations into stormwater permits. In addition, the TMDL program provides a new opportunity for states to regulate stormwater sources more vigorously. In degraded waterbodies, effluent reductions for point sources are not limited by what is economically feasible but instead include requirements that will ensure that the continued degradation of the receiving water is abated. If a permitted stormwater source is contributing pollutants to a degraded waterbody and the state believes that further reductions in pollution from that source are needed, then more stringent discharge limitations are required. For example, in *City of Arcadia vs. State Water Resources Control Board* [135 Cal. App. 4th 1392 (Ca. Ct. App. 2006)], the court held in part that California's zero trash requirements for municipal storm drains, resulting from state TMDLs, were not inconsistent with TMDL requirements or the CWA. Thus, the maximum-extent-practicable standard for MS4s, as well as other technology-based requirements for other stormwater permittees, are a floor, not a ceiling, for permit requirements when receiving waters are impaired (Beckman, 2007). Finally, since the TMDL program expects the states to regulate any source—point or nonpoint—that it considers problematic, any source of stormwater is fair game, regardless of whether it is listed in Section 402p, and regardless of whether it is a "point source." Nonpoint source runoff from agricultural and silvicultural operations is in fact a common target for TMDL-driven restrictions [see, e.g., *Pronsolino vs. Nastri*, 291 F.3d 1123, 1130 (9th Cir. 2002), upholding restrictions on nonpoint sources, such as logging, compelled by State's TMDLs)].

Despite the potential for positive interaction between stormwater regulation and the TMDL program, there appears to be little activity occurring at the stormwater–TMDL interface. This is partly because the TMDL program itself has been slow in developing. In 2000, the National Wildlife Federation applied 36 criteria to the 50 states' water quality programs and concluded that 75 percent of the states had failed to develop meaningful TMDL programs (National Wildlife Federation, 2000, pp. 1–2). The General Accounting Office (GAO, 1989) identified the lack of implementation of TMDLs as a major impediment to attaining the goals of the CWA, which led to a spate of lawsuits filed by environmental groups to reverse this pattern. The result was numerous settlements with ambitious deadlines for issuing TMDLs.

Commentators blame the delays in these TMDL programs on inadequate ambient monitoring data and on the technical and political challenges of causally linking individual sources to problems of impairment. In a 2001 report, for example, the National Research Council (NRC) noted that unjustified and poorly supported water quality standards, a lack of monitoring, uncertainty in the relevant models, and a failure to use biocriteria to assess beneficial uses directly all contributed to the delays in states' abilities to bring their waters into attainment through the TMDL program (NRC, 2001). Each of these facets is not only technically complicated but also expensive. The cost of undertaking a rigorous TMDL program in a single state has been estimated to be about $4 billion per state, assuming that each state has 100 watersheds in need of TMDLs (Houck, 1999, p. 10476).

As a result, the technical demands of the TMDL program make for a particularly bad fit with the technical impediments already present in monitoring and managing stormwater. As mentioned earlier, the pollutant loadings in stormwater effluent vary dramatically over time and

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stormwater is notoriously difficult to monitor for pollutants. It is thus difficult to understand how much of a pollutant a stormwater point source contributes to a degraded waterbody, much less determine how best to reduce that loading so that the waterbody will meet its TMDL. As long as the focus in these TMDLs remains on pollutants rather than flow (a point raised earlier that will be considered again), the technical challenges of incorporating stormwater sources in a water quality-based regulatory program are substantial. Without considerable resources for modeling and monitoring, the regulator has insufficient tools to link stormwater contributions to water quality impairments.

These substantial challenges in linking stormwater sources back to TMDLs are reflected by the limited number of reports and guidance documents on the subject. In one recent report, for example, EPA provides 17 case studies in which states and EPA regions incorporated stormwater control measures into TMDL plans, but it is not at all clear from this report that these efforts are widespread or indicative of greater statewide activity (EPA, 2007a). Indeed, it almost appears that these case studies represent the universe of efforts to link TMDLs and stormwater management together. The committee's statement of task also appears to underscore, albeit implicitly, EPA's difficulty in making scientific connections between the TMDL and stormwater programs. This challenge is returned to in Chapter 6, which suggests some ways that the two can be joined together more creatively.

Other Statutory Authorities that Control Stormwater

Although the CWA is by far the most direct statutory authority regulating stormwater discharges, there are other federal regulatory authorities that could lead to added regulation of at least some stormwater sources of pollution.

Critical Resources

If there is evidence that stormwater flows or pollutants are adversely impacting either endangered species habitat or sensitive drinking water sources, federal law may impose more stringent regulatory restrictions on these activities. Under the Endangered Species Act, stormwater that jeopardizes the continued existence of endangered species may need to be reduced to the point that it no longer threatens the endangered or threatened populations in measurable ways, especially if the stormwater discharge results from the activity of a federal agency [16 U.S.C. §§ 1536(a), 1538(a)].

Under the Safe Drinking Water Act, a surface water supply of drinking water must conduct periodic "sanitary surveys" to ensure the quality of the supply (see 40 C.F.R. § 142.16). During the course of these surveys, significant stormwater contributions to pollution may be discovered that are out of compliance or not regulated under the Clean Water Act because they are outside of an MS4 area. Such a discovery could lead to more rigorous regulation of stormwater discharges. For a groundwater source that supplies 50 percent or more of the drinking water for an area and for which there is no reasonably available alternative source, the aquifer can be designated as a "Sole Source Aquifer" and receive greater protection under the Safe Drinking Water Act [42 U.S.C. § 300(h)-3(e)]. Stormwater sources that result from

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federally funded projects are also more closely monitored to ensure they do not cause significant contamination to these sole source aquifers.

Some particularly sensitive water supplies are covered by both programs. The Edwards Aquifer underlying parts of Austin and San Antonio, Texas, for example, is identified as a "Sole Source Aquifer." There are also several endangered species of fish and salamander in that same area. As a result, both the Safe Drinking Water Act and the Endangered Species Act demand more rigorous stormwater management programs to protect this delicate watershed.

Stormwater is also regulated indirectly by floodplain control requirements promulgated by the Federal Emergency Management Agency (FEMA). In order for a community to participate in the FEMA National Flood Insurance Program, it must fulfill a number of requirements, including ensuring that projects will not increase flood heights, including flood levels adjacent to the project site [see, e.g., 44 C.F.R. § 60.3(d)].

Contaminated Sites

Continuous discharges of contaminated stormwater and other urban pollutants (particularly through combined sewer overflows) have led to highly contaminated submerged sediments in many urban bays and rivers throughout the United States. In several cases where the sediment contamination was perceived as presenting a risk to human health or has led to substantial natural resource damages, claims have been filed under the federal hazardous waste cleanup statute commonly known as Superfund (42 U.S.C. § 9601 et seq.). This liability under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) technically applies to any area—whether submerged or not—as long as there is a "release or a threat of release of a hazardous substance" and the hazardous substances have accumulated in such a way as to lead to the "incurrence of response [cleanup] costs" or to "natural resource damages" [42 U.S.C. §9607(a)]. Although only a few municipalities and sewer systems have been sued, Superfund liability is theoretically of concern for possibly a much larger number of cities or even industries whose stormwater contains hazardous substances and when at least some of the discharges were either in violation of a permit or unpermitted. The National Oceanic and Atmospheric Administration brought suit against the City of Seattle and the Municipality of Metropolitan Seattle alleging natural resource damages to Elliott Bay resulting from pollution in stormwater and combined sewer overflows; the case was settled in 1991 (***United States vs. City of Seattle***, No. C90-395WD, http://www.gc.noaa.gov/natural-office1.html). While some of the elements for liability remain unresolved by the courts, such as whether some or all of the discharges are exempted under the "federally permitted release" defense of CERCLA [42 U.S.C. § 9601(10)(H)], which exempts surface water discharges that are covered by a general or NPDES permit from liability, the prospect of potential liability is still present.

Diversion of Stormwater Underground or into Wetlands

In some areas, stormwater is eliminated by discharging it into wetlands. If done through pipes or other types of point sources, these activities require a permit under the CWA. Localities or other sources that attempt to dispense with their stormwater discharges in this fashion must thus first acquire an NPDES permit.

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Even without a direct discharge into wetlands, stormwater can indirectly enter wetland systems and substantially impair their functioning. In a review of more than 50 studies, the Center for Watershed Protection found that increased urbanization and development increased the amount of stormwater to wetlands, which in turn "led to increased ponding, greater water level fluctuation and/or hydrologic drought in urban wetlands" (Wright et al., 2006). They found that, in some cases, the ability of the wetlands to naturally remove pollutants became overwhelmed by pollutant loadings from stormwater.

An even more common method of controlling stormwater is to discharge it underground. Technically, these subsurface discharges of stormwater, including dry wells, bored wells, and infiltration galleries, are considered by EPA to be infiltration or "Class V" wells, which require a permit under the CWA as long as they are in proximity to an underground source of drinking water (40 C.F.R. Parts 144, 146). While EPA's definition excludes surface impoundments and excavated trenches lined with stone (provided they do not include subsurface fluid distribution systems or amount to "improved sinkholes" that involve the man-made modification of a naturally occurring karst depression for the purpose of stormwater control), most other types of subsurface drainage systems are covered regardless of the volume discharged (40 C.F.R. § 144.81(4)).

Given EPA's recent description of SCMs considered to be Class V injection wells (EPA, 2008), most SCMs that rely on infiltration are exempted. For example, if an infiltration trench is wider than it is deep, it is exempted from the Class V well regulations. Residential septic systems are also exempted [see 40 C.F.R. §§ 144.1(g)(1)(ii) and (2)(iii)]. However, those that involve deeper dry wells or infiltration galleries appear to require Class V well permits under the Safe Drinking Water Act. Because the use of these SCMs is likely to involve expensive compliance requirements, dischargers may steer away from them.

Air Contaminants

Air pollutants from vehicular exhaust and industrial sources that precipitate on roads and parking lots can also be collected in stormwater and increase pollutant loading (see Chapter 3 discussion of atmospheric deposition). While the Clean Air Act regulates these sources of air contamination, it does not eliminate them. Stormwater that is contaminated with air pollutants may consist of both "legal" releases of air pollutants, as well as "illegal" releases emitted in violation of a permit, although the distinction between the two groups of pollutants is effectively impossible to make in practice.

Pesticides and Other Chemical Products Applied to Land and Road Surfaces

EPA regulates the licensing of pesticides as well as chemicals and chemical mixtures, although its actual authority to take action, such as restricting product use or requiring labeling, varies according to the statute and whether the product is new or existing. Although EPA technically is allowed to consider the extent to which a chemical is accumulating in stormwater in determining whether additional restrictions of the chemical are needed, EPA is not aware of any instances in its Toxic Substances Control Act (TSCA) chemical regulatory decision-making

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in which it actually used this authority to advance water quality protection (Jenny Molloy, EPA, personal communication, March 13, 2008).

In its pesticide registration program, EPA does routinely consider a pesticide's potential for adverse aquatic effects from stormwater runoff in determining whether the pesticide constitutes an unreasonable risk (Bill Jordan, EPA, personal communication, March 14, 2008). EPA has imposed use restrictions on a number of individual pesticides, such as prohibiting aerial applications, requiring buffer strips, or reducing application amounts. Presumably states and localities are tasked with primary enforcement responsibility for most of these use restrictions. EPA has also required a surface water monitoring program as a condition of the re-registration for atrazine and continues to evaluate available surface water and groundwater data to assess pesticide risks (Bill Jordan, EPA, personal communication, March 14, 2008).

EPA STORMWATER PROGRAM

Stormwater is defined in federal regulations as "storm water runoff, snow melt runoff, and surface runoff and drainage" [40 CFR §122.26(b)(13)]. EPA intended that the term describe runoff from precipitation-related events and not include any type of non-stormwater discharge (55 Fed. Reg. 47995). A brief discussion of the evolution of the EPA's stormwater program is followed by an explanation of the permitting mechanisms and the various ways in which the program has been implemented by the states. As shown in Figure 2-2, the entire NPDES program has grown by almost an order of magnitude over the past 35 years in terms of the number of regulated entities, which explains the reliance of the program on general rather than individual permits. Both phases of the stormwater program have brought a large number of new entities under regulation.

Historical Background

States like Florida, Washington, Maryland, Wisconsin, and Vermont and some local municipalities such as Austin, Texas, Portland, Oregon, and Bellevue, Washington, preceded the EPA in implementing programs to mitigate the adverse impacts of stormwater quality and quantity on surface waters. The State of Florida, after a period of experimentation in the late 1970s, adopted a rule that required a state permit for all new stormwater discharges and for modifications to existing discharges if flows or pollutants increased (Florida Administrative Code, Chapter 17-25, 1982). The City of Bellevue, WA, established a municipal utility in 1974 to manage stormwater for water quality, hydrologic balance, and flood management purposes using an interconnected system of natural areas and existing drainage features.

EPA first considered regulating stormwater in 1973. At that time, it exempted from NPDES permit coverage conveyances carrying stormwater runoff not contaminated by industrial or commercial activity, unless the discharge was determined by the Administrator to be a significant contributor of pollutants to surface waters (38 Fed. Reg. 13530, May 22, 1973). EPA reasoned that while these stormwater conveyances were point sources, they were not suitable for end-of-pipe, technology-based controls because of the intermittent, variable, and less predictable nature of stormwater discharges. Stormwater pollution would be better managed at the local agency level through nonpoint source controls such as practices that prevent pollutants from

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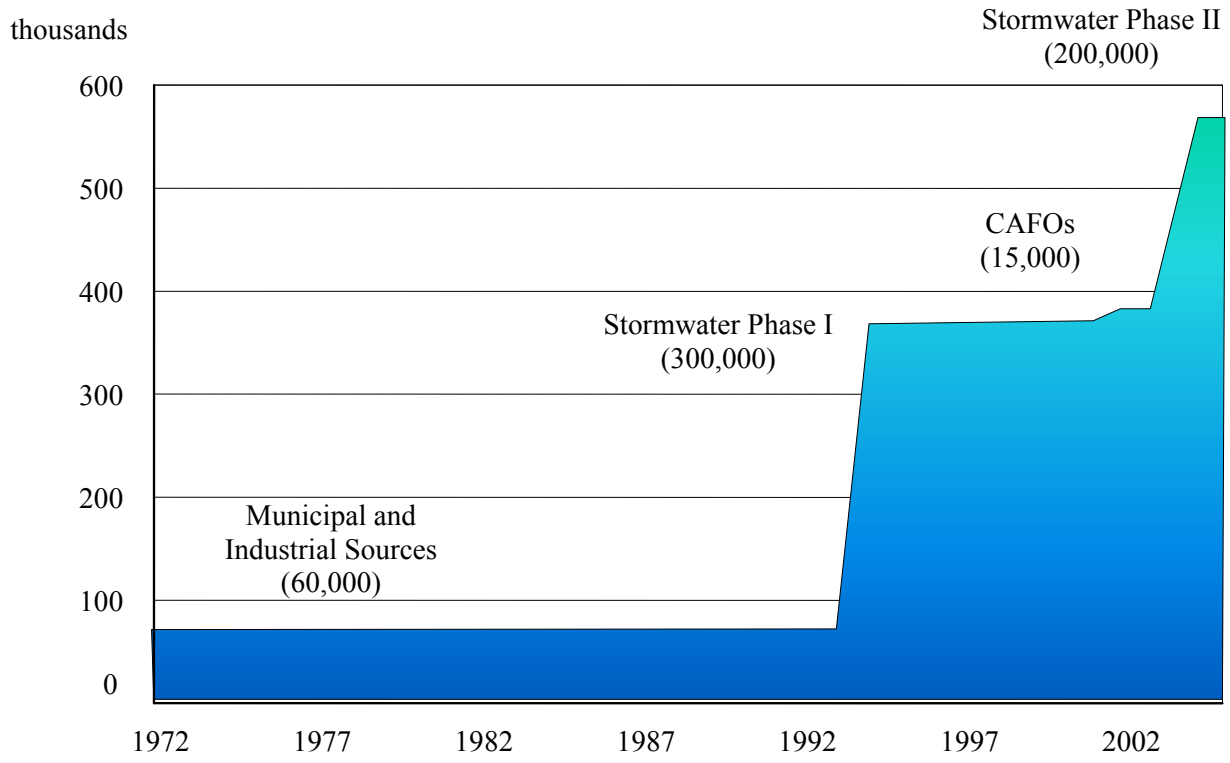

FIGURE 2-2 The number of permittees under the NPDES program of the Clean Water Act from 1972 to the present. Note that concentrated Animal Feeding Operations (CAFOs) are not considered in this report.

entering the runoff. Further, EPA justified its decision by noting that the enormous numbers of individual permits that the Agency would have to issue would be administratively burdensome and divert resources from addressing industrial process wastewater and municipal sewage discharges, which presented more identifiable problems.

The Natural Resources Defense Council (NRDC) successfully challenged the EPA's selective exemption of stormwater point sources from the NPDES regulatory permitting scheme in federal court [*NRDC vs. Train*, 396 F.Supp. 1393 (D.D.C. 1975), *aff'd NRDC vs. Costle* 568 F.2d. 1369 (D.C. Cir. 1977)]. The court ruled that EPA did not have the authority to exempt point source discharges from the NPDES permit program, but recognized the Agency's discretion to use reasonable procedures to manage the administrative burden and to define what constitutes a stormwater point source. Consequently, EPA issued a rule establishing a comprehensive permit program for all stormwater discharges (except rural runoff) including municipal separate storm sewer systems (MS4s), which were to be issued "general" or area permits after a period of study (41 Fed. Reg. 11307, March 18, 1976). Individual permits were required for stormwater discharges from industrial or commercial activity, or where the stormwater discharge was designated by the permitting authority to be a significant contributor of pollutants. Comprehensive revisions to the NPDES regulations were published next, retaining the broad definition of stormwater discharges subject to the NPDES permit program and requiring permit application requirements similar to those for industrial wastewater discharges,

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including testing for an extended list of pollutants (44 Fed. Reg. 32854, June 7, 1979; 45 Fed. Reg. 33290, May 19, 1980).

The new NPDES regulations resulted in lawsuits filed in federal courts by a number of major trade associations, member companies, and environmental groups challenging several aspects of the NPDES program, including the stormwater provisions. The cases were consolidated in the D.C. Circuit Court of Appeals, and EPA reached a settlement with the industry petitioners on July 7, 1982, agreeing to propose changes to the stormwater regulations to balance environmental concerns with the practical limitations of issuing individual NPDES permits and limited resources. The Agency significantly narrowed the definition of stormwater point sources to conveyances contaminated by process wastes, raw materials, toxics, hazardous pollutants, or oil and grease, and it reduced application requirements by dividing stormwater discharges into two groups based on their potential for significant pollution problems (47 Fed. Reg. 52073, November 18, 1982). EPA issued a final rule retaining the broad coverage of stormwater point sources, and a two-tiered classification to administratively regulate these stormwater discharges (49 Fed. Reg. 37998, September 26, 1984).

The rule generated considerably controversy; trade associations and industry contended that application deadlines would be impossible to meet and that the sampling requirements were excessive, while the environmental community expressed a concern that additional changes or delays would exacerbate the Agency's failure to regulate sources of stormwater pollution. On the basis of the post-promulgation comments received, EPA determined that it was necessary to obtain additional data on stormwater discharges to assess their significance, and it conducted meetings with industry groups, who indicated an interest in providing representative data on the quality of stormwater discharges of their membership. The Agency determined that the submission of representative data was the most practical and efficient means of determining appropriate permit terms and conditions, as well as priorities for the multitude of stormwater point source discharges that needed to be permitted (50 Fed. Reg. 32548, August 12, 1985).

In the mean time, the U.S. House of Representatives and the Senate both passed bills to amend the CWA in mid-1985. The separate bills were reconciled in Conference Committee, and on February 4, 1987, Congress passed the Water Quality Act (WQA), which specifically addressed stormwater discharges. The WQA added Section 402(p) to the CWA, which requires stormwater permits to be issued prior to October 1992 for (i) municipal stormwater discharges from large and medium municipalities based on the 1990 census; (ii) discharges associated with industrial activity; and (iii) a stormwater discharge that the Administrator determines contributes to the violation of a water quality standard or is a significant contributor of pollutants to waters of the United States. MS4s were required to reduce pollutants in stormwater discharges to the "maximum extent practicable" (MEP). Industrial and construction stormwater discharges must meet the best conventional technology (BCT) standard for conventional pollutants and the best available technology economically achievable (BAT) standard for toxic pollutants. EPA and the NPDES-delegated states were given the flexibility to issue municipal stormwater permits on a system-wide or jurisdiction-wide basis. In addition, the WQA amended Section 402(l)(2) of the CWA to not require a permit for stormwater discharges from mining and oil and gas operations if the stormwater discharge is not contaminated by contact, and it amended Section 502(14) of the CWA to exclude agricultural stormwater discharges from the definition of point source.

These regulations had been informed by the National Urban Runoff Program, conducted from 1978 to 1983 to characterize the water quality of stormwater runoff from light industrial, commercial, and residential areas (Athayde et al., 1983). The majority of samples collected were

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analyzed for eight conventional pollutants and three heavy metals, and a subset was analyzed for 120 priority pollutants. The study indicated that on an annual loading basis, some of the conventional pollutants were greater than the pollutant loadings resulting from municipal wastewater treatment plants. In addition, the study found that a significant number of samples exceeded EPA's water quality criteria for freshwater.

The Federal Highway Administration conducted studies over a ten-year period ending in 1990 to characterize the water quality of stormwater runoff from roadways (Driscoll et al., 1990). A total of 993 individual stormwater events at 31 highway sites in 11 states were monitored for eight conventional pollutants and three heavy metals. In addition, a subset of samples was analyzed for certain other conventional pollutant parameters. The studies found that urban highways had significantly higher pollutant concentrations and loads than non-urban highway sites. Also, sites in relatively dry semi-arid regions had higher concentrations of many pollutants than sites in humid regions.

Final Stormwater Regulations

EPA issued final regulations in 1990 establishing a process for stormwater permit application, the required components of municipal stormwater management plans, and a permitting strategy for stormwater discharges associated with industrial activities (55 Fed. Reg. 222, 47992, November 16, 1990). Stormwater discharges associated with industrial activity that discharge to MS4s were required to obtain separate individual or general NPDES permits. Nevertheless, EPA recognized that medium and large MS4s had a significant role to play in source identification and the development of pollution controls for industry, and thus municipalities were obligated to require the implementation of controls under local government authority for stormwater discharges associated with industrial activity in their stormwater management program. The final regulations also established minimum sampling requirements during permit application for medium and large MS4s (serving a population based on the 1990 census of 100,000 to 250,000, and 250,000 or more, respectively). MS4s were required to submit a two-part application over two years with the first part describing the existing program and resources and the second part providing representative stormwater quality discharge data and a description of a proposed stormwater management program, after which individual MS4 NPDES permits would be issued for medium and large MS4s.

In addition, the regulations identified ten industry groups and construction activity disturbing land area five acres or greater as being subject to stormwater NPDES permits. These industries were classified as either heavy industry or light industry where industrial activities are exposed to stormwater, based on the Office of Management and Budget Standard Industrial Classifications (SIC). The main industrial sectors subject to the stormwater program are shown in Table 2-3 and include 11 regulatory categories: (i) facilities with effluent limitations, (ii) manufacturing, (iii) mineral, metal, oil and gas, (iv) hazardous waste treatment, storage, or disposal facilities, (v) landfills, (vi) recycling facilities, (vii) steam electric plants, (viii) transportation facilities, (ix) treatment works, (x) construction activity, and (xi) light industrial activity.

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TABLE 2-3 Sectors of Industrial Activity Covered by the EPA Stormwater Program

Category (see above)	**Sector**	**SIC Major Group**	**Activity Represented**
(i)	A	24	Timber products
(ii)	B	26	Paper and allied products
(ii)	C	28 and 39	Chemical and allied products
(i), (ii)	D	29	Asphalt paving and roofing materials and lubricants
(i) (ii)	E	32	Glass, clay, cement, concrete, and gypsum products
(i) (iii)	F	33	Primary metals
(i), (iii)	G	10	Metal mining (ore mining and dressing)
(i), (iii)	H	12	Coal mines and coal mining-related facilities
(i), (iii)	I	13	Oil and gas refining
(i), (iii)	J	14	Mineral mining and dressing
(iv)	K	HZ	Hazardous waste, treatment, storage, and disposal
(v)	L	LF	Landfills, land application sites, and open dumps
(vi)	M	50	Automobile salvage yards
(vii)	N	50	Scrap recycling facilities
(vii)	O	SE	Steam electric generating facilities
(viii)	P	40, 41, 42, 43, 51	Land transportation and warehousing
(viii)	Q	44	Water transportation
(viii)	R	37	Ship and boat building or repairing yards
(viii)	S	45	Air transportation
(ix)	T	TW	Treatment works
(xi)	U	20, 21	Food and kindred products
(xi)	V	22, 23, 31	Textile mills, apparel, and other fabric product manufacturing, leather and leather products
(xi)	W	24, 25	Furniture and fixtures
(xi)	X	27	Printing and publishing
(xi)	Y	30, 39, 34	Rubber, miscellaneous plastic products, and miscellaneous manufacturing industries
(xi)	AB	35, 37	Transportation equipment, industrial or commercial machinery
(xi)	AC	35, 36, 38	Electronic, electrical, photographic, and optical goods
(x)			Construction activity
	AD		Non-classified facilities designated by Administrator under 40 CFR §122.26(g)(1)(l)

SOURCE: 65 Fed. Reg. 64804, October 30, 2000.

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The second phase of final stormwater regulations promulgated on December 8, 1999 (64 Fed. Reg. 68722) required small MS4s to obtain permit coverage for stormwater discharges no later than March 10, 2003. A small MS4 is defined as an MS4 not already covered by an MS4 permit as a medium or large MS4, or is located in "urbanized areas" as defined by the Bureau of the Census (unless waived by the NPDES permitting authority), or is designated by the NPDES permitting authority on a case-by-case basis if situated outside of urbanized areas. Further, the regulations lowered the construction activities regulatory threshold for permit coverage for stormwater discharges from five acres to one acre.

To give an idea of the administrative burden associated with the stormwater program and the different types of permits, Table 2-4 shows the number of regulated entities in the Los Angeles region that fall under either individual or general permit categories. Industrial and construction greatly outweigh municipal permittees, and stormwater permittees are vastly more numerous that traditional wastewater permittees.

TABLE 2-4 Number of NPDES wastewater and stormwater entities regulated by the CalEPA, Los Angeles Regional Water Board, as of May 2007

Waste Type	Individual Permittees	General Permittees
Wastewater and Non-stormwater Industry	103	574
Combined Wastewater and Stormwater	23	0
Stormwater (pre-1990)	45	0
Industrial Stormwater (post-1990)	0	2990
Construction Stormwater (post-1990)	0	2551
Municipal Stormwater (post-1990)	100	0
Total	271	6215

Municipal Permits

States with delegated NPDES permit authority (all except Alaska, Arizona, Idaho, Massachusetts, New Hampshire, and New Mexico) issued the first large and medium MS4 permits beginning in 1990, some of which are presently in their fourth permit term. These MS4 permits require large and medium municipalities to implement programmatic control measures (the six minimum measures) in the areas of (1) public education and outreach, (2) public participation and involvement, (3) illicit discharge detection and elimination, (4) construction site runoff control, (5) post-construction runoff control, and (6) pollution prevention and good housekeeping—all to reduce the discharge of pollutants in stormwater to the *maximum extent practicable*. Efforts to meet the six minimum measures are documented in a stormwater management plan. Non-stormwater discharges to the MS4 are prohibited unless separately permitted under the NPDES, except for certain authorized non-stormwater discharges, such as landscape irrigation runoff, which are deemed innocuous nuisance flows and not a source of pollutants. MS4 permits generally require analytic monitoring of pollutants in stormwater discharges for all Phase I medium and large MS4s from a subset of their outfalls that are 36 inches or greater in diameter or drain 50 acres or more. These data, at the discretion of the permitting authority, may be compared with water quality standards and considered (by default) to be effluent limitations, which refer to any restriction, including schedules of compliance, established by a state or the Administrator pursuant to CWA Section 304(b) on quantities, rates,

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and concentrations of chemical, physical, biological, and other constituents discharged from point sources into navigable waters, the waters of the contiguous zone, or the ocean (40 CFR §401.11). A future exceedance of an effluent limitation constitutes a permit violation. However, permitting authorities have so far not taken this approach to interpreting MS4 stormwater discharge data.

The Phase I stormwater regulations require medium and large MS4s to inspect "high-risk" industrial facilities and construction sites within their jurisdictions. Certain industrial facilities and construction sites of a minimum acreage are also subject to separate EPA/state permitting under the industrial and construction general permits (see below). While EPA envisioned a partnership with municipalities on these inspections in its Phase I Rule Making, it provided no federal funding to build these partnerships. Both industry and municipalities have argued that the dual inspection responsibilities are duplicative and redundant. Municipalities have further contended that the inspection of Phase I industrial facilities and construction sites are solely an EPA/state obligation, although state and federal courts have ruled otherwise. In the committee's experience, many MS4s do not oversee or regulate industries within their boundaries.

As part of the Phase II program, small MS4s are covered under general permits and are required to implement a stormwater management program to meet the six minimum measures mentioned above. Unlike with Phase I, Phase II MS4 stormwater discharge monitoring was made discretionary, and inspection of industrial facilities within the boundary of a Phase II MS4 is not required.

Industrial Permits

EPA issued the first nationwide multi-sector industrial stormwater general permit (MSGP) on September 29, 1995 (60 Fed. Reg. 50804), which was reissued on October 30, 2000 (65 Fed. Reg. 64746). A proposed new MSGP was released for public comment in 2005 (EPA, 2005b). The proposed MSGP requires that industrial facility operators prepare a stormwater pollution prevention plan (similar to an MS4's stormwater management plan) that documents the SCMs that will be implemented to reduce pollutants in stormwater discharges. They must achieve technology-based requirements using BAT or BCT or water quality-based effluent limits, which is the same requirement as for process wastewater permits.

All industrial sectors covered under the MSGP must conduct visual monitoring four times a year. The visual monitoring is performed by collecting a grab sample within the first hour of stormwater discharge and observing its characteristics qualitatively. A subset of MSGP industrial categories is required to perform analytical monitoring for benchmark pollutant parameters four times in Year 2 of permit coverage and again in Year 4 if benchmarks were exceeded in Year 2. The benchmark pollutant parameters, listed in Table 2-5, were selected based on the sampling data included with group permit applications submitted after the EPA issued its stormwater regulations in 1990. To comply with the benchmark monitoring requirements, a grab sample must be collected within the first hour of stormwater discharge after a rainfall event of 0.1 inch or greater and with an interceding dry period of at least 72 hours. A benchmark exceedance is not a permit violation, but rather is meant to trigger the facility operator to investigate SCMs and make necessary improvements.

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TABLE 2-5 Industry Sectors and Sub-Sectors Subject to Benchmark Monitoring

MSGP Sector	Industry Sub-sector	Required Parameters for Benchmark Monitoring
C	Industry organic chemicals	Al, Fe, nitrate and nitrite N
	Plastics, synthetic resins, etc.	Zn
	Soaps, detergents, cosmetics, perfumes	Zn, nitrate and nitrite N
	Agricultural chemicals	Pb, Fe, Zn, P, nitrate and nitrite N
D	Asphalt paving and roofing materials	TSS
E	Clay products	Al
	Concrete products	TSS and Fe
F	Steel works, blast furnaces, rolling and finishing mills	Al, Zn
	Iron and steel foundries	Al, Cu, Fe, Zn, TSS
	Non-ferrous rolling and drawing	Cu, Zn
	Non-ferrous foundries (casting)	Cu, Zn
G	Copper ore mining and dressing	COD, TSS, nitrate and nitrite N
H	Coal mines and coal mining related facilities	TSS
J	Dimension stone, crushed stone, and non-metallic minerals (except fuels)	TSS, Al, Fe
	Sand and gravel mining	Nitrate and nitrite N, TSS
K	Hazardous waste treatment, storage, or disposal	NH_3, Mg, COD, Ar, Cd, CN, Pb, Hg, Se, Ag
L	Landfills, land application sites, and open dumps	Fe, TSS
M	Automobile salvage yards	TSS, Al, Fe, Pb
N	Scrap recycling	Cu, Al, Fe, Pb, Zn, TSS, COD
O	Steam electric generating facilities	Fe
Q	Water transportation facilities	Al, Fe, Pb, Zn
S	Airports with deicing activities	BOD, COD, NH_3, pH
U	Grain mill products	TSS
	Fats and oils	BOD, COD, nitrate and nitrite N, TSS
Y	Rubber products	Zn
AA	Fabricated metal products except coating	Fe, Al, Zn, nitrate and nitrite N
	Fabricated metal coating and engraving	Zn, nitrate and nitrite N

NOTE: BOD, biological oxygen demand; COD, chemical oxygen demand; TSS, total suspended solids.
SOURCE: 65 Fed. Reg. 64817, October 30, 2000.

EPA had already established technology-based effluent limitations for stormwater discharges for eight subcategories of industrial discharges prior to 1987, namely, for cement manufacturing, feedlots, fertilizer manufacturing, petroleum refining, phosphate manufacturing, steam electric, coal mining, and ore mining and dressing (see Table 2-6). Most of these facilities were covered under individual permits prior to 1987 and are generally required to stay covered under individual stormwater permits. Facilities in these sub-categories that had not been issued a stormwater discharge permit prior to 1992 are allowed to be covered under the MSGP, but they still have analytical monitoring requirements that must be compared to effluent limitation guidelines. An exceedance of the effluent limitation constitutes a permit violation.

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TABLE 2-6 Select Stormwater Effluent Limitation Guidelines for Illustrative Purposes

Discharges	**Design Storm**	**Pollutant Parameters**	**Effluent Limitations (max per day)**
Phosphate Fertilizer Manufacturing Runoff (40 C.F.R. 418)	Not specified	Total P Fluoride	105 mg/L 75 mg/L
Petroleum Refining (40 C.F.R. 419)	Not specified	O&G TOC BOD5 COD Phenols Cr Hex Cr pH	15 mg/L 110 mg/L 48 kg/1000 m^3 flow 360 mg/1000 m^3 flow 0.35 mg/1000 m^3 flow 0.73 mg/1000 m^3 flow 0.062 mg/1000 m^3 flow 6–9
Asphalt Paving and Roofing Emulsion Products Runoff (40 C.F.R. 443)	Not specified	TSS O&G pH	0.023 kg/m^3 0.015 kg/m^3 6.0–9.0
Cement Manufacturing Material Storage Piles Runoff (40 C.F.R. 411)	10 yr, 24 hour	TSS pH	50 mg/L 6.0–9.0
Coal Mining (40 C.F.R. 434 Subpart B)	1 yr, 24 hour	Fe Mn TSS pH	7.0 mg/L 4 mg/L 70 mg/L 6.0–9.0
Steam Electric Power Generating (40 C.F.R. 423)	10 yr, 24 hour	TSS pH PCBs	50 mg/L 6.0–9.0 No discharge

NOTE: BOD5, biological oxygen demand; COD, chemical oxygen demand; O&G, oil and grease; PCBs, polychlorinated biphenyls; TOC, total organic carbon; TSS, total suspended solids. SOURCE: 40 C.F.R.

At the issuance of the Final Storm Water Rule in 1990, EPA envisioned the use of a mix of general permits and individual permits to better manage the administrative burden associated with permitting thousands of industrial stormwater point sources. In its original permitting strategy for industrial stormwater discharges, EPA articulated a four-tier strategy with the nationwide general permits: Tier 1 was baseline permitting, Tier 2 would incorporate watershed permits, Tier 3 would be industry category-specific permitting, and Tier 4 would encompass facility-specific individual permits. In reality, individual permits, which would allow for the crafting of permit conditions to be better structured to the specific industrial facility based on its higher potential risk to water quality, and could include adequate monitoring for purposes of compliance and enforcement, have been sparsely used. Similarly, neither the watershed permitting strategy nor the industry category-specific permitting strategy has found favor in the absence of better federal guidance and funding.

Industrial stormwater general permits are issued by the State NPDES Permitting Authority in NPDES-delegated states, and may be in the form a single statewide permit covering thousands of industrial permittees or sector-specific stormwater general permits covering less than a hundred facilities. EPA Regions issue the MSGP in states without NPDES-delegated authority and for facilities on Native Indian and Tribal Lands. EPA's nationwide 2000 MSGP presently covers 4,102 facilities.

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Construction Permits

EPA issued the first nationwide construction stormwater general permit (CGP) in February 1998 (63 Fed. Reg. 7858). The permits are valid for five-year terms. The most recent CGP was issued in 2005 (68 Fed. Reg. 39087), and the EPA in 2008 administratively continued the CGP until the end of 2009, when it is expected to have developed effluent guidelines for construction activity (73 Fed. Reg. 40338). The EPA is presently under court order to develop effluent limitation guidelines for stormwater discharges from the construction and land development industry. The construction general permit requires the implementation of stormwater pollution prevention plans to prevent erosion, control sediment in stormwater discharges, and manage construction waste materials. Operators of the construction activity are required to perform visual inspections regularly, but no sampling of stormwater discharge during rainfall events is required. As with the industrial and municipal permittees, an exceedance of an effluent limitation incorporated in a permit would be a violation of the CWA and is subject to penalties.

EPA's CGP covers construction activity in areas where EPA is the permitting authority, including Indian lands, Puerto Rico, the District of Columbia, Massachusetts, New Hampshire, New Mexico, Idaho, Arizona, and Alaska. All other states have been delegated the authority to issue NPDES permits, and these states issue CGPs based on the EPA model but with subtle variations. For example the California and Georgia CGPs include monitoring requirements for construction sites discharging to sediment-impaired waterbodies. Wisconsin requires weekly inspections and an inspection within 24 hours of a rain event of 0.5 inches or greater. Georgia imposes discharge limits of an increase of no more than 10 Nephelometric Turbidity Units (NTU) above background in trout streams and no more than 25 NTU above background in other types of streams.

Permit Creation, Administration, and Requirements

For individual permits, the entity seeking coverage submits an application and one permit is issued. The conditions of the permit are based on an analysis of information provided in a rather lengthy permit application by the facility operator about the facility and the discharge. Generally, it takes six to 18 months for the permittee to compile the application information and for the permitting authority to finalize the permit. Individual permits are common for medium and large MS4s (Phase I), small MS4s in a few states (Phase II), and a few industrial activities.

General permits, on the other hand, are issued by the permitting authority, and interested parties then submit an Notice of Intent (NOI) to be covered. This mechanism is used where large numbers of dischargers require permit coverage, such as construction activities, most industrial activities, and most small MS4s (Phase II). The permit must identify the area of coverage, the sources covered, and the process for obtaining coverage. Once the permit is issued, a permittee may submit a NOI and receive coverage either immediately or within a very short time frame (e.g., 30 days).

All permits contain "effluent limitations" or "effluent guidelines," adherence to which is required of the permittee. However, the terms (which are synonymous) are agonizingly broad and encompass (1) meeting numeric pollutant limits in the discharge, (2) using certain SCMs, and (3) meeting certain design or performance standards. Effluent limitations may be expressed

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as SCMs when numeric limits are infeasible or for stormwater discharges where monitoring data are insufficient to carry out the purposes and intent of the CWA [122.44(k)]. If EPA has promulgated numerical "effluent guidelines" for existing and new stormwater sources under CWA Sections 301, 304, or 306, then the permits must incorporate the "effluent guidelines" as permit limits.

Effluent limitations can be either technology-based or water quality-based requirements. Technology-based requirements establish pollutant limits for discharges on what the best pollution control technology installed for that industry would normally accomplish. Water-quality based requirements, by contrast, look to the receiving waters to determine the level of pollution reduction needed for individual sources. There are national technology-based standards available for many categories of point sources, including many industrial sectors and municipal wastewater treatment plants. In the absence of national standards, technology-based requirements are developed on a case-by-case basis using best professional judgment. In general, BAT is the standard for toxic and non-conventional pollutants, while BCT is the standard for conventional pollutants. Water quality-based effluent limitations are required where technology-based limits are found to be insufficient to achieve applicable water quality standards, including restoring impaired waters, preventing impairments, and protecting high-quality waters. Limitations must control all pollutants or pollutant parameters that are or may be discharged at a level which will *cause, have reasonable potential to cause, or contribute to* an excursion above any applicable water quality standard. To distinguish between technology-based and water quality-based effluent limits, consider that a permittee is required to meet a numeric pollutant limit in their stormwater discharge. A technology-based limit would be based on studies of effluent concentrations coming from that technology, while a water quality-based limit would be based on some assessment of the impact of the discharge on a nearby receiving water (with the applicable water quality standard being the most conservative choice).

EPA is presently writing stormwater "effluent guidelines" for airport de-icing operations and construction/development activity, with an estimated final action date of December 2009.

Permits Prior to 1990

A limited number of individual stormwater permits (perhaps in the low thousands) were first issued prior to 1990, the period before EPA promulgated regulations specific to stormwater discharges, and before EPA first received the authority to issue general NPDES permits. These individual NPDES permits for industrial stormwater discharges, like traditional individual wastewater NPDES permits, incorporate numerical effluent limits and they impose discharge monitoring requirements to demonstrate compliance. These facilities were selected for permitting before 1990, presumably because of the risk they presented to causing or contributing to the exceedance of water quality standards.

Do Permittees Have to Meet Water Quality Standards in their Effluent?

It is unclear as to whether municipal, industrial, and construction stormwater discharges must meet water quality standards. Furthermore, even if such discharges were required to meet water quality standards, the absence of monitoring found within the permits means that

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enforcement of the requirement would be difficult at best. Nonetheless, some sources suggest that, with the exception of Phase II MS4 discharges, EPA's intent is that stormwater discharges comply with water quality standards, especially where a TMDL is in place.

First, the EPA Office of General Counsel issued a memorandum in 1991 stating that municipal stormwater permits must require that MS4s reduce stormwater pollutant discharges to the maximum extent practicable and must also comply with water quality standards. Recognizing the complexity of stormwater, EPA's 1996 Interim Permitting Approach for Water Quality-Based Effluent Limitations in Storm Water Permits (61 Fed. Reg. 43761) stated that stormwater permits should use SCMs in first-term stormwater permits and expanded or better-tailored SCMs in subsequent term permits to provide for the attainment of water quality standards. However, where adequate information existed to develop more specific conditions or limitations to meet water quality standards, these conditions or limitations are to be incorporated into stormwater permits as necessary and appropriate.

As permitting authorities began to develop TMDL waste load allocations to address impaired receiving waters, and waste load allocations were assigned to stormwater discharges, EPA issued a TMDL Stormwater Policy. It stated that stormwater permits must include permit conditions consistent with the assumptions and requirements of available waste load allocations (EPA, 2002b). Since waste load allocations derive directly from water quality standards, this could be interpreted as saying that stormwater discharges must meet water quality standards. However, EPA expected that most water quality-based effluent limitations for NPDES-regulated stormwater discharges that implement TMDL waste load allocations would be expressed as SCMs, and that numeric limits would be used only in rare instances. This is understandable, given that storm events are dynamic and variable and it would be expensive to monitor all storm events and discharge points, particularly for MS4s, to demonstrate compliance with a waste load allocation expressed as a numeric effluent limitation. Effluent limitations expressed as SCMs appear to be the best interim approach to demonstrate compliance with TMDLs, provided that these SCMs are reasonably expected to satisfy the waste load allocation in the TMDL. As part of the TMDL, the NPDES permit must also specify the monitoring necessary to determine compliance with effluent limitations. Where effluent limits are specified as SCMs, the permit should specify the monitoring necessary to assess if the load reductions expected from SCM implementation are achieved (e.g., SCM performance data).

Implementation of the Stormwater Program by States and Municipalities

NPDES-delegated states and Indian Tribes generally utilize the CGP and the MSGP as model templates for adopting their respective general permits to regulate stormwater discharges associated with industrial activity, including construction, within their jurisdictions. Nevertheless, some variations exist. For example, the California CGP requires sampling of stormwater at construction sites that discharge to surface waters that are listed as being impaired for sediment. Connecticut's MSGP regulates stormwater discharges associated with commercial activity, in addition to industrial activity. With respect to the municipal permits, the variability with which the stormwater program is implemented reflects the flexibility inherent in the MEP standard. In the absence of a definite description of MEP or nationwide effluent guidelines issued by EPA, states and municipalities have not been very rigorous in determining what

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constitutes an adequate level of compliance. This self-defined compliance threshold has been translated into a wide range of efforts at program implementation.

A number of MS4 programs have been leaders in some areas of program implementation. For example, Prince George's County, Maryland, was a pioneer in implementing low impact development (LID) techniques. Notable efforts have been made by states and municipalities in the Pacific Northwest, such as Oregon and Washington. California and Florida also are in the forefront of implementing comprehensive and progressive stormwater programs.

Greater implementation is evident in states that had state stormwater regulations in place prior to the advent of the national stormwater program (GAO, 2007). Some states issued early MS4 permits (e.g., California, Florida, Washington, and Wisconsin) prior to the promulgation of the national stormwater program, while a number of MS4s (e.g., Austin, Texas,; Santa Monica, California; and Bellevue, Washington) were already implementing comprehensive stormwater management programs. In addition, some MS4s conducted individual stormwater management activities, such as street-sweeping, household hazardous waste collection, construction site plan review, and inspections, prior to the national stormwater program. These areas are more likely than areas without a stormwater program that predated the EPA program to be successfully meeting the requirements of the current program.

One of the obvious differences is the level of interest and effort exercised by coastal communities or communities in close proximity to a water resource that have immediate access to the beneficial uses of those resources but also have an immediate view of the impacts of polluted runoff. That interest may contrast with the less active posture of upstream or further inland communities that may not be as sensitive and willing to implement more stringent stormwater programs. A recent report has found that programs with more specific permit requirements generally result in more comprehensive and progressive stormwater management programs (TetraTech, 2006a). The report concluded that permittees should be required to develop measurable goals based on the desired outcomes of the stormwater program. Furthermore, additional stormwater permit requirements can be expected as more TMDLs are developed and wasteload allocations must be translated into permit conditions.

GAO Report on Current Status of Implementation

In 2007, the GAO issued a report to determine the impact of EPA's Stormwater Program on communities (GAO, 2007). Some of the relevant findings are that urban stormwater runoff continues to be a major contributor to the nation's degraded waters and that stormwater program implementation has been slow for both Phase I and Phase II communities, with almost 11 percent of all communities not yet permitted as of fall 2006. Litigation, among other reasons, delayed the issuance of some permits for years after the application deadlines. As a result, almost all Phase II and some Phase I communities are still in the early stages of program implementation although deadlines for permit applications were years ago—16 years for Phase I and six years for Phase II. EPA has acknowledged that it does not currently have a system in place to measure the success of the Phase I program on a national scale (EPA, 2000b). Therefore, it is reasonable to conclude that the level of implementation of the stormwater program ranges widely, from municipalities having completed a third-term permit (such as Los Angeles County MS4 permit) to municipalities not yet covered by a Phase II MS4 permit.

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The GAO report also indicates that communities' inconsistent reporting of activities makes it difficult to evaluate program implementation nationwide. Based on the report's findings it seems that little auditing activity has been performed to gauge the status of implementation and effectiveness in achieving water quality improvements. Most often cited is the effort by EPA's Region 9 and the State of California auditors that recently discovered, among other things, that some MS4s (1) had not developed stormwater management plans, (2) were not properly performing an adequate number of inspections to enforce their stormwater ordinances, and (3) were lax in implementing SCMs at publicly owned construction sites. They also found that some MS4s were not adequately controlling stormwater runoff at municipally owned and operated facilities, such as maintenance yards. In response to these findings, EPA issued in January 2007 an MS4 Program Evaluation Guidance document (EPA, 2007b).

In the absence of a nationwide perspective of the implementation of the stormwater program, it is hard to make a determination about the program's success. There are communities and states that seem to have made great strides in implementing progressive stormwater programs, but it also seems that overall many programs are still in the early stages of implementation, while a number of communities are still waiting to obtain coverage under the MS4 permits. In addition, it appears that there is no national uniform system of tracking success or cost data. All these unknowns make it very difficult to formulate any definite statements about how successful the implementation of the program is on a national perspective.

Committee Survey

In order to get a better understanding of how the stormwater program is implemented by the states, during 2007 the committee conducted two surveys asking states about their monitoring requirements, compliance determination, and other facts for each program (municipal, industrial, and construction). For the larger survey, 18 states representing all ten EPA regions responded to the survey. Both surveys and all responses are found in Appendix C.

As expected, the responding states reported that Phase I MS4s are required to sample their stormwater discharges for pollutants, although the frequency of sampling and the number of pollutants being sampled tended to vary. No state reported requiring Phase II MS4s to sample stormwater discharges. Monitoring requirements for industrial stormwater varied by state from none in Minnesota, Nebraska, and Maine to benchmark monitoring required under the MSGP in Virginia, New York, and Wyoming. California, Connecticut, and Washington require all industrial facilities to monitor for select chemical pollutants. Connecticut, additionally, requires sampling for aquatic toxicity. Most of the responding states do not require construction sites to do much more than visual monitoring periodically and after rain events. Georgia and Washington require construction sites to monitor for parameters such as turbidity and pH. California and Oregon require sampling when the discharge is to a waterbody impaired by sediment.

As mentioned previously, Phase I MS4s (but not Phase II MS4s) are required to address industrial dischargers within their boundaries. There was considerable variability regarding the survey questions of whether MS4s can conduct inspections of industrial facilities and what industries are considered high risk. In all of the responding states except Virginia, the responders think that MS4s have the authority to inspect industries within their boundaries, although the extent to which this is done is not clear and, in the committee's experience, is quite

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rare. Many of the responding states have not identified "high-risk" facilities and targeted them for compliance scrutiny, although certain categories were felt to be problematic by the state employee responding to the survey, such as metal foundries, auto salvage yards, metal recyclers, cement plants, and saw mills. In California and Washington, however, some of the Phase I MS4 permits have identified high-risk facilities for the municipal permittee to inspect.

Georgia, Maine, Minnesota, Nevada, New York, Vermont, and Washington have State Guidance Manuals for MS4 implementation, while in California a coalition of municipalities and the California Department of Transportation have developed MS4 guidance manuals. The rest of the responding states rely on general guidance provided by the EPA. State guidance manuals for the implementation of the industrial stormwater program were less common than guidance manuals for construction activity, with only California and Washington having such guidance manuals. In contrast, except for Nebraska and Oklahoma, statewide guidance manuals for erosion and sediment control were available. This may have resulted from the fact that many states had laws in place that required erosion and sediment control practices during land development, timber harvesting, and agricultural farming that predated the EPA stormwater regulations.

In an attempt to determine the level of oversight that a state provides for industrial and construction operations, the survey asked whether and to whom stormwater pollution prevention plans (SWPPPs) are submitted. Most of the responding states require the stormwater pollution prevention plans that industrial facilities prepare to be retained at the facility and produced when requested by the state. Only Oregon, Vermont, Washington, and Hawaii required industrial SWPPPs to be submitted to the state when seeking coverage under the MSGP. The practice for the submittal of construction SWPPPs was similar, except that some states required that SWPPPs for large construction projects be submitted to the state.

Compliance with the MS4 permit in the responding States is mainly determined through the evaluation of annual reports and program audits, although no indication was given of the frequency of audits. Regulators in Maine have monthly meetings with municipalities. The responding states evaluate compliance with the MSGP by reviewing annual monitoring reports and conducting inspections of industrial facilities. Connecticut characterized its industrial inspections as "regular," Maine inspects industrial facilities twice per five-year permit cycle, while Vermont performs visual inspections four times a year. No other responding states specified the frequency of inspections. Inspections and reviews of the SWPPPs constitute the main ways for responding states to determine the compliance of sites and facilities covered under the CGP.

With respect to the extent of actual compliance, few states have such information, partly because it has not routinely been collected and analyzed. West Virginia has found that, of the 871 permitted industrial facilities in the state, 576 were delinquent in submitting the results of their benchmark monitoring. Several case studies of compliance rates for municipal, industrial, and construction sites in Southern California are presented in Box 2-4. The data suggest that compliance in all three groups is poor, particularly for industrial sites. This may be partly explained by the preponderance of small businesses covered by the MSGP, whose operators may have financial difficulty in committing funds to SCMs, or lack a recognition and knowledge of the stormwater program and its requirements.

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BOX 2-4
Compliance with Stormwater Permits in Southern California

Construction General Permits

In order to determine the compliance of construction sites with the general stormwater permit, data were collected and analyzed from three sources: (1) an audit performed in June 2004 of the development construction program of five cities that are permittees in the Los Angeles County MS4 permit (about 44 sites), (2) an audit performed in February 2002 of the development construction program (among others) of five Ventura County MS4 permittees (about 32 sites), and (3) a review and inspection of 24 large construction sites (50 acres or greater of disturbed land). These sites accounted for about 5 percent of all construction sites in the region at the time, and they represent both small and large construction sites. The most common violations on construction sites were paper violations, such as incomplete SWPPPs and a lack of record keeping. Forty (40) percent of the sites had some type of paper deficiency. A close second is the absence of erosion and/or sediment control, observed on 30 percent of the sites. SOURCE: TetraTech (2002, 2006b,c).

Industrial Multi-Sector General Permit

For industrial sites, information was obtained from the following sources: (1) a review of SCM inspections performed in February 2005 which consisted of 38 sites in the transportation sector; (2) a review of inspections and non-filer identification information in the plastics sector performed in 2007, which consisted of about 100 permitted sites among a large number of non-filer sites; and (3) a review of 13 area airport inspections and 55 port tenant inspections at the ports of Los Angeles and Long Beach. The sites are about 6 percent of the total number of permittees covered by California's MSGP and represent some of the major regulated industrial sectors. The most common violations observed at industrial sites were the lack of implementation of SCMs such as overhead cover, secondary containment and/or spill control. Sixty (60) percent of the sites had poor housekeeping problems. This was followed by incomplete stormwater pollution prevention plans (40 percent). (SOURCE: E. Solomon, California EPA, Los Angeles Regional Water Board, personal communication, 2008).

In another study, the California Water Boards with the assistance of an EPA contractor conducted inspections of 1,848 industrial stormwater permittees (21 percent of permitted facilities) between 2001 and 2005 (TetraTech, 2006d). Seventy-one (71) percent of the industrial facilities inspected were not in compliance with the MSGP and 18 percent were identified as a threat to water quality. Fifty-six (56) percent of facilities that collected one or more water quality samples reported an exceedance of a benchmark. Facility follow-up inspections indicated that field presence of the California Water Boards inspectors improved facility compliance with the MSGP.

Municipal Permits

An audit similar to the TetraTech study described above was conducted for 84 Phase I and Phase II MS4s in California during the same period (TetraTech, 2006e). The audits found that municipal maintenance facilities were often deficient in implementing SCMs, MS4 permittees did not obtain adequate legal authority to implement the program, they were not inspecting industrial facilities and construction sites or were inspecting them inadequately, and they were unable to evaluate program effectiveness in improving water quality. Overall, the audits found that programs with more specific permit requirements generally resulted in more comprehensive and progressive stormwater management programs. For example, the Los Angeles or San Diego MS4 permits enumerate in detail the permit tasks such as the frequency of inspection, the types of facilities, and the SCMs to be inspected that permittees must perform in implementing their stormwater program. The auditors concluded that the specificity of the provisions enabled the permitting authorities to enforce the MS4 permits and improve the quality of MS4 discharges.

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Box 2-4 Continued

Compliance with Industrial Permits within MS4s

The EPA and the California EPA Los Angeles Regional Water Board conducted a limited audit of the inspection program requirements of the Los Angeles County MS4 Permit and the City of Long Beach MS4 Permit in conjunction with industrial facilities covered under the MSGP within the Ports of Los Angeles and Long Beach (EPA, 2007c). The Port of Long Beach is covered under a single NOI for its 53 tenant facilities that discharge stormwater associated with industrial activity, while 137 industrial facilities within the Port of Los Angeles file independent NOIs. At the Port of Los Angeles, of the 23 facilities that were inspected, 30 percent were judged to pose a significant threat to water quality, 43 percent were determined to have some violations with regard to implementation of SCMs or paperwork requirements, and 26 percent appeared to be in compliance with the MSGP. At the Port of Long Beach, of the 21 tenant facilities that were inspected, 14 percent were judged to pose a significant threat to water quality, 52 percent were determined to have some deficiencies with regard to implementation of SCMs or paperwork requirements, and 33 percent appeared to be in full compliance with general permit requirements. The Port of Long Beach had a more comprehensive stormwater monitoring program which indicated that several pollutant parameters were above EPA benchmark values. Communication between the MS4 departments and the ports in both programs appeared deficient. The EPA issued 20 compliance orders for violations of the MSGP, but it did not pursue any action against the MS4s overseeing the industries because it was outside the scope of the EPA audit.

Another aspect of compliance is the extent to which industrial facilities have identified themselves and applied for coverage under the state MSGP. Six states responded to the committee's survey about that topic; only two of the six (California and Vermont) have made efforts to determine the numbers of non-filers of an NOI to be covered by the MSGP. In both cases, the efforts, which involved mailings, telephone calls, and file review, found that the number of non-filing facilities that should be subject to the MSGP was substantial (see Box 2-5 for California's data). Duke and Augustenborg (2006) studied this level of compliance (whether industries are filing an NOI for permit coverage) and found incomplete compliance that is variable among states and urbanized areas. Texas and Oklahoma had higher levels of permit coverage than California or Florida.

LOCAL CODES AND ORDINANCES THAT AFFECT STORMWATER MANAGEMENT

Zoning and building standards, codes, and ordinances have been the basis for city building in the United States for almost a century. They define how to build to protect the health, safety, and welfare of the public, and to establish a predictable, although often lengthy and cumbersome, process for ensuring that built improvements become a well-integrated part of the larger urban environment. Review processes can be as simple as a walk-through in a local building department for a minor house remodeling project. In other cases, extended rezoning processes for larger projects can require several years of planning; multiple public meetings; multiple reviews by city, state, and federal agencies; and specialized studies to determine impacts on the natural environment and water, sewer, and transportation systems.

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BOX 2-5
Searching for Non-Filers Under the Industrial MSGP in Southern California

The California Water Boards conducted an industrial non-filer identification study between 1995 and 1998 (CA SWB, 1999). The study had three components: (1) to develop a mechanism to identify facilities subject to the industrial stormwater general permit that had not filed an NOI, which involved a comparison of commercially available and agency databases with that maintained by the California Water Boards; (2) to communicate with operators of these facilities to inform them of their responsibility to comply, which was done using post-mail, telephone calls, and filed verification; and (3) to refer responses to the communication efforts to the Water Boards for any appropriate follow-up.

About 9 percent of the potential non-filers submitted an NOI after the initial mail contact. About 52 percent of facilities indicated that they were exempt. About 37 percent failed to respond and 16 percent of mailed packages were returned unopened. A follow-up on facilities that claimed they were exempt indicated that 16 percent of them indeed needed to comply. Similarly 33 percent of facilities that failed to respond were determined as needing to file NOIs. The study suggested that only half of facilities considered heavy industrial had filed NOIs through the first five years of the program (Duke and Shaver, 1999).

The California EPA Los Angeles Regional Water Board and the City of Los Angeles conducted a study in the City of Los Angeles between January 1998 and June 2000 to identify non-filers and evaluate compliance by door-to-door visits in industrially zoned areas of the city (Swamikannu et al., 2001). The field investigations covered industrial zones totaling about 4.2 square miles, or about 22 percent of the area in the City of Los Angeles zoned for industrial land use. A total of 1,103 of suspected non-filer facilities were subject to detailed on-site facility investigation. Ninety-three (93) were determined to have already have submitted NOIs, and 436 were determined not to be subject to the industrial stormwater general permit. The site visits identified 223 potential non-filers, or industrial facilities where site-visit evidence suggested the facilities probably needed to comply with relevant regulations but that had not filed NOIs or recognized their duty to comply at the time of the visit. Of the facilities identified as potential non-filers, 202 were identified during detailed on-site investigations, or 18 percent of facilities inspected with that methodology; and 21 were identified during the less-detailed non-filer assessment visits, or 6 percent of the 379 facilities inspected with that methodology. In total, 295 of the 1,103 facilities visited under the project (about 27 percent) were known or suspected to be required to file NOIs under the permit, including 93 facilities that had previously filed NOIs and 202 facilities identified as probably required to file NOIs based on visual evidence of industrial activities exposed to stormwater. Thus, prior to the project, only 31 percent of all facilities in the project area needing to comply had submitted an NOI.

There is an overlapping and conflicting maze of codes, regulations, ordinances, and standards that have a profound influence on the ability to implement stormwater control measures, although they can be loosely categorized into three areas. Land-use zoning is the first type of control. Zoning, which was developed in response to unsanitary and unhealthy living conditions in 19th-century cities, prescribes permitted land uses, building heights, setbacks, and the arrangement of different types of land uses on a given site. Zoning often requires improvements that enhance the aesthetic and functional qualities of communities. For example, ordinances prescribing landscaping, minimum parking requirements, paving types, and related requirements have been developed to improve the livability of cities. These ordinances have a significant impact on both how stormwater affects waterbodies and on attempts to mitigate its impacts.

The second category involves the design and construction of buildings. National and international building codes and standards, such as the International Building Code, and Uniform Plumbing, Electrical, and Fire Codes, for example, allow local governments to establish

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minimum requirements for building construction. Because these controls primarily affect building construction, they have less effect on stormwater discharges than zoning.

The third category includes engineering and infrastructure standards and practices that govern the design and maintenance of the public realm—streets, roads, utilities rights-of-way, and urban waterways. Roadway design standards and emergency access requirements have resulted in contemporary cities that are 30 percent or more pavement, just to accommodate the movement and storage of vehicles in the public right-of-way. The standards for the construction of deep utilities—water and sewer lines that are typically located underneath streets—are often the reason that streets are wider than necessary to safely carry traffic.

Over time, these codes, standards, and practices have become more complex, and they may no longer support the latest innovations in planning practices. The past 10 to 20 years have seen a number of innovations in zoning and related building standards. Mixed-use, mixed-density communities that incorporate traditional patterns of community development (often described as "New Urbanism"), low impact development (LID), and transit-oriented development are examples of building patterns that challenge traditional zoning and city design standards. With the exception of LID, proposed new patterns of development and regulations connected with their implementation rarely incorporate specific guidelines for innovations in stormwater management, other than to have general references to environmental responsibility, ecological restoration, and natural area protection.

The following sections describe in more detail the codes, ordinances, and standards that affect stormwater and our ability to control it, and alternative approaches to developing new standards and practices that support and encourage effective stormwater management.

Zoning

The primary, traditional purpose of zoning has been to segregate land uses thought to be incompatible. In practice, zoning is used as a permitting system to prevent new development from harming existing residents or businesses. Zoning is commonly controlled by local governments such as counties or cities, though the specifics of the zoning regime are determined primarily by state planning laws (see Box 2-6 for a discussion of land use acts in Oregon and Washington).

Zoning involves regulation of the kinds of activities that will be acceptable on particular lots (such as open space, residential, agricultural, commercial or industrial), the densities at which those activities can be performed (from low-density housing such as single-family homes to high-density housing such as high-rise apartment buildings), the height of buildings, the amount of space structures may occupy, the location of a building on the lot (setbacks), the proportions of the types of space on a lot (for example, how much landscaped space and how much paved space), and how much parking must be provided. Thus, zoning can have a significant impact on the amount of impervious area in a development and on what constitutes allowable stormwater management.

As an example, local parking ordinances are often found within zoning that govern the size, number, and surface material of parking spaces, as well as the overall geometry of the parking lot as a whole. The parking demand requirements are tied to particular land uses and

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Box 2-6
Growth Management in the Pacific Northwest

In Oregon, the 1973 Legislative Assembly enacted the Oregon Land Use Act, which recognized that the uncoordinated use of lands threatens orderly development of the environment, the health, safety, order, convenience, prosperity and welfare of the people of Oregon. The state required all of Oregon's 214 cities and 36 counties to adopt comprehensive plans and land-use regulations. It specified planning concerns that had to be addressed, set statewide standards that local plans and ordinances had to meet, and established a review process to ensure that those standards were met. Aims of the program are to conserve farm land, forest land, coastal resources, and other important natural resources; encourage-efficient development; coordinate the planning activities of local governments and state and federal agencies; enhance the state's economy; and reduce the public costs that result from poorly planned development. Setting urban growth boundaries is a major mechanism for implementing the act.

The Washington State Legislature followed in 1990 with the Growth Management Act (GMA), adopted on grounds similar to Oregon's act. The GMA requires state and local governments to manage Washington's growth by identifying and protecting critical areas and natural resource lands, designating urban growth areas, preparing comprehensive plans, and implementing them through capital investments and development regulations. Similar again to Oregon, rather than centralize planning and decision-making at the state level, the GMA established state goals, set deadlines for compliance, offered direction on how to prepare local comprehensive plans and regulations, and set forth requirements for early and continuous public participation. Urban growth areas (UGAs) are those areas, designated by counties pursuant to the GMA, "within which urban growth shall be encouraged and outside of which growth can occur only if it is not urban in nature." Within these UGAs, growth is encouraged and supported with adequate facilities. Areas outside of the UGAs are reserved for primarily rural and resource uses. Urban growth areas are to be based on population forecasts made by counties, which are required to have a 20-year supply of land for future residential development inside the boundary—a time frame also pertaining in the Oregon system. In both states urban growth boundaries are reconsidered and sometimes adjusted to meet this criterion.

It is important to note that the growth management efforts in the two states have no direct relationship to stormwater management. Rather, the laws control development density, which has implications for how stormwater should be managed (see discussion in Chapter 5). The local jurisdictions in Washington have reacted in different ways to link growth management and stormwater management. For example, the King County, Washington, stormwater code requires drainage review to evaluate and deal with stormwater impacts for development that adds 2,000 square feet or more of impervious surface or clears more than 7,000 square feet. For rural residential lots outside the UGA, the impervious threshold is reduced to 500 square feet.

Sources:
http://bluebook.state.or.us/state/executive/Land_Conservation/land_conservation_history.htm
http://www.oregonmetro.gov/index.cfm/go/by.web/id=277
http://www.gmhb.wa.gov/gma/ and http://www.mrsc.org/Subjects/Planning/compfaqs.aspx

zoning categories, and can create needless impervious cover. Most local parking codes are overly generous and have few, if any, provisions to treat stormwater at the source (Wells, 1995). For example, in a co-housing project under construction in Fresno, California, current city codes require 27-foot-long parking spaces. The developer, in an effort to reduce construction costs, requested that the length of spaces be reduced to 24 feet. The city agreed to the smaller spaces if the developer would sign an indemnity clause guaranteeing that the local government would not be sued in case of an accident (Wenz, 2008).

Similarly, landscaping ordinances apply to certain commercial and institutional zoning categories and specify that a fixed percentage of site area be devoted to landscaping, screening,

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or similar setbacks. These codes may require as much as 5 to 10 percent of the site area to be landscaped, but seldom reference opportunities to capture and store runoff at the source, despite the fact that the area devoted to landscaping is often large enough to meet some or all of their stormwater treatment needs.

Zoning codes have evolved over the years as urban planning theory has changed, legal constraints have fluctuated, and political priorities have shifted. The various approaches to zoning can be divided into four broad categories: Euclidean, performance, planned unit development, and form-based.

Euclidean Zoning

Named for the type of zoning code adopted in the town of Euclid, Ohio, Euclidean zoning codes are by far the most prevalent in the United States, used extensively in small towns and large cities alike. Euclidean zoning is characterized by the segregation of land uses into specified geographic districts and dimensional standards stipulating limitations on the magnitude of development activity that is allowed to take place on lots within each type of district. Typical land-use districts in Euclidean zoning are residential (single- or multi-family), commercial, and industrial. Uses within each district are usually heavily prescribed to exclude other types of uses (for example, residential districts typically disallow commercial or industrial uses). Some "accessory" or "conditional" uses may be allowed in order to accommodate the needs of the primary uses. Dimensional standards apply to any structures built on lots within each zoning district and typically take the form of setbacks, height limits, minimum lot sizes, lot coverage limits, and other limitations on the building envelope.

Although traditional Euclidean zoning does not include any significant requirements for stormwater drainage, there is no reason that it could not. Modern Euclidean ordinances include a broad list of "development standards" that address topics like signage, lighting, steep slopes, and other topics, and that list could be expanded to included stormwater standards for private development.

Euclidean zoning is used almost universally across the country (with rare exceptions) because of its relative effectiveness, ease of implementation (one set of explicit, prescriptive rules), long-established legal precedent, and familiarity to planners and design professionals. However, Euclidean zoning has received heavy criticism for its unnecessary separation of land uses, its lack of flexibility, and its institutionalization of now-outdated planning theory. . In response, variances and other methods have been used to modify Euclidean zoning so that it is better adapted to localized conditions and existing patterns of development. The sections below briefly describe a range of innovations in local zoning regulations that have potential for incorporating stormwater controls into existing regulations.

Incentive Zoning. Incentive zoning systems are typically an add-on to Euclidean zoning systems. First implemented in Chicago and New York City in 1961, incentive zoning is intended to provide a reward-based system to encourage development that meets established urban development goals. Typically, a base level of prescriptive limitations on development will be established and an extensive list of incentive criteria with an associated reward scale will be established for developers to adopt at their discretion. Common examples include floor-area-

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ratio bonuses for affordable housing provided on-site and height-limit bonuses for the inclusion of public amenities on-site.

With incentive zoning, developers are awarded additional development capacity in exchange for a public benefit, such as a provision for low- or moderate-income housing, or an amenity, such as additional open space. Incentive zoning is often used in more highly urbanized areas. Consideration for water quality treatment and innovative SCMs fits well within the incentive zoning model. For example, redevelopment sites in urbanized areas are often required to incorporate stormwater control measures into developments to minimize impacts on aging, undersized stormwater systems in that area, and to meet new water quality requirements. An incentive could be to allow greater building height, and therefore higher density, than under existing zoning, freeing up land area for SCMs that could also serve as a passive park area. Another example would be to allow a higher density on the site and to require not an on-site system but a cash payment to the governing entity to provide for consolidated stormwater management and treatment. Off-site consolidated systems, discussed more extensively in Chapter 5, may require creation of a localized maintenance district or an increase in stormwater maintenance fees to offset long-term maintenance costs.

Incentive zoning could be used to preserve natural areas or stream corridors as part of a watershed enhancement strategy. For example, transferrable development rights (TDR) could be used in the context of the urban or semi-urban interface with rural lands. Many of the formal TDR programs in Colorado (such as Fruita/Mesa County and Aspen/Pitkin) involve cities or counties seeking to preserve sensitive areas in the county, or outlying areas of the city, including the floodplain, in exchange for urban-level density on a more appropriate site (David D. Smith, Garfield & Hecht P.C., personal communication, 2008).

Incentive zoning allows for a high degree of flexibility, but it can be complex to administer. The more a proposed development takes advantage of incentive criteria, the more closely it has to be reviewed on a discretionary basis. The initial creation of the incentive structure can also be challenging and often requires extensive ongoing revision to maintain balance between incentive magnitude and value given to developers.

Performance Zoning

Performance zoning uses performance-based or goal-oriented criteria to establish review parameters for proposed development projects in any area of a municipality. At its heart, performance zoning deemphasizes the specific land uses, minimum setbacks, and maximum heights applicable to a development site and instead requires that the development meet certain performance standards (usually related to noise, glare, traffic generation, or visibility). Performance zoning sometimes utilizes a "points-based" system whereby a property developer can apply credits toward meeting established zoning goals through selecting from a menu of compliance options (some examples include mitigation of environmental impacts, providing public amenities, and building affordable housing units). Additional discretionary criteria may also be established as part of the review process.

The appeal of performance zoning lies in its high level of flexibility, rationality, transparency, and accountability. Because performance zoning is grounded in specific and in many cases quantifiable goals, it better accommodates market principles and private property rights with environmental protection. However, performance zoning can be extremely difficult

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to implement and can require a high level of discretionary activity on the part of the supervising authority. City staff must often be trained to use specialized equipment to measure the performance of the development, and sometimes those impacts cannot be measured until the building is completed and the activity operating, by which time it may be difficult and expensive to modify a building that turns out not to meet the required performance standards. Because stormwater performance is measurable (especially the amounts of water retained/detained and rates and amounts of water discharge), stormwater regulations could be integrated into a performance zoning system. As with other topics, however, it might be time-consuming or require special equipment to measure compliance (particularly before the building is built).

Planned Unit Development (Including Cluster Development and Conservation Design)

A planned unit development (PUD) is generally a large area of land under unified control that is planned and developed as a whole through a single development operation or series of development phases, in accord with a master plan. In California, these are known as Specific Plans. More specialized forms of PUDs include clustered subdivisions where density limitations apply to the development site as a whole but provide flexibility in the lot size, setback, and other standards that apply to individual house lots. These PUDs provide considerable flexibility in locating building sites and associated roads and utilities, allowing them to be concentrated in parts of the site, with the remaining land use for agriculture, recreation, preservation of sensitive areas, or other open-space purposes.

PUDs are typically, although not exclusively, found in new development areas and have significant open space and park areas that are often 25 percent or more of the total land area. This large amount of open space provides considerable opportunity for the use of consolidated, multifunctional stormwater controls.

Form-Based Zoning

Form-based zoning relies on rules applied to development sites according to both prescriptive and potentially discretionary criteria. These criteria are typically dependent on lot size, location, proximity, and other various site- and use-specific characteristics. Form-based codes offer considerably more flexibility in building uses than do Euclidean codes, but, as they are comparatively new, may be more challenging to create. When form-based codes do not contain appropriate illustrations and diagrams, they are criticized as being difficult to interpret.

One example of a recently adopted code with form-based features is the Land Development Code adopted by Louisville, Kentucky, in 2003. This zoning code creates "form districts" for Louisville Metro. Each form district intends to recognize that some areas of the city are more suburban in nature, while others are more urban. Building setbacks, heights, and design features vary according to the form district. As an example, in a "traditional neighborhood" form district, a maximum setback might be 15 feet from the property line, while in a suburban "neighborhood" there may be no maximum setback. Narrower setbacks allow increased density, requiring less land area for the same number of housing units and resulting in a smaller development footprint.

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In rural and suburban areas, form-based codes can often reinforce the "open" character of development by preserving open site areas, which could be used for on-site stormwater management. In denser, urban areas, however, some form-based ordinances favor shorter, more pedestrian-scale buildings that cover more of the site than taller buildings of the same square footage, on the basis that keeping activity closer to the ground and enclosing street frontages results in a better pedestrian environment and urban form. One result of this preference is that there may be less of the site left potentially available for on-site stormwater detention or infiltration. Integrating stormwater management considerations into form-based codes may require a cash payment system where the developer contributes to financing of a district or regional stormwater treatment facility because on-site solutions are not available.

Building Codes

Building codes define minimum standards for the construction of virtually all types and scales of structures. With a few exceptions, building codes have limited direct impact on stormwater management. The main example is where structural and geotechnical design standards, which stem from the need to protect buildings and infrastructure from water damage, discourage or prohibit the potential infiltration of water adjacent to building foundations. Such standards can make it difficult to use landscape-based SCMs, such as porous pavement, bioinfiltration, and extended detention. There is a need to examine and redefine structural and geotechnical "standards of care" that ensure the structural integrity of buildings and other infrastructure like buried utilities, in order for landscaped areas adjacent to structures to be utilized more effectively for SCMs. For example, a developer building a mixed-use, medium-density infill development in Denver intended to incorporate innovative approaches to stormwater management by infiltrating stormwater in a number of areas around the site. The standard of care for the geotechnical design of building foundations typically requires that positive drainage be maintained a minimum of 5 feet from the building edge. The geotechnical engineer required, when informed that water might be infiltrated in the area of the building and without further study, that the minimum distance to an infiltration area must be at least to 20 feet from the building, greatly limiting the potential for using the building landscape areas as SCMs. The City of Los Angeles is in the process of updating its Building Code, but it is not clear if it will be sufficiently comprehensive to address the use of some LID practices, such as on-site infiltration. The 2002 Building Code now in effect is written to require the builder to convey water away from the building using concrete or some other "non-erosive device."

Engineering and Infrastructure Standards and Practices

Engineering standards and practices for public rights-of-way complement building and zoning codes which control development on private property. Engineering standards and practices typically describe requirements for public utilities such as stormwater and wastewater, roadways, and related basic services. For example, there are standards for parking and roadway design that typically describe the specific type of roadway and parking surfacing requirements. Regulations and standards often require minimum gradients for surface drainage, site grading, and drainage pipe size, all of which play an important role in how stormwater is transported. There are also often landscape planting requirements, including the requirement to mound

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landscape areas to screen cars, which can preclude the opportunity to incorporate SCMs into landscape areas.

Unless right-of-way improvements are constructed as part of the subdivision process by private developers, improvements in the right-of-way are typically provided for by city government and public agencies. Because engineering standards are often based on decades of refinement and have evolved regionally and nationally, they are difficult to change. For example, street widths are determined more by the ability to maneuver emergency equipment and to accommodate water and sewer easements than the need for adequate lane widths for vehicles. Street lane-width requirements might be as narrow as 11 feet for each travel lane, resulting in a street width of 22 to 24 feet. This could accommodate emergency vehicle access, which typically can require a minimum of 20 feet of unobstructed street. However, because most streets also include potable water distribution lines and easement requirements for the lines, which are a minimum of 30 feet in width, this results in a minimum roadway width of 30 feet.

Local drainage codes govern the disposal of stormwater and essentially dictate the nature and capacity of the stormwater infrastructure from the roof to the floodplain. Like many codes, they were developed over time to address problems such as basement flooding, nuisance drainage problems, maintenance of floodplain boundaries, and protection of infrastructure such as bridges and sewers from storm damage. Local drainage codes, many of which predate the EPA's stormwater program, often involve peak discharge control requirements for a series of design storm events ranging from the 2-year storm up to the 100-year event. Traditional drainage codes can often conflict with effective approaches to reducing runoff volume or removing pollutants from stormwater. Examples of such codes include requirements for positive drainage, directly connected roof leaders, curbs and gutters, lined channels, storm-drain inlets, and large-diameter storm-drain pipes discharging to a downstream detention or flood control basins.

Often, standards have been tested through legal precedent, and case law has developed around certain standards of care, which can further deter innovation. Changes in design standards could result in unknown legal exposure and liability. Specific types of equipment, maintenance protocols and procedures, and extensive training further discourage changes in established standards and procedures.

Innovations in Codes and Regulations to Promote Better Stormwater Management

A number of innovations have been developed in the previously described zoning, building codes, and infrastructure and engineering standards that make them more amenable to stormwater management. These are described in detail below.

Separate Ordinances for New and Infill Development

Redevelopment of existing urban areas is almost universally more difficult and expensive than Greenfield development because of the deconstruction costs of the former, higher costs of designing around existing infrastructure, upgrading existing infrastructure, and higher costs and risks associated with assuming liability of pre-existing problems (contamination, etc). Redevelopment often occurs in areas of medium to high levels of impervious surface (e.g.,

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downtown areas). Such severely space-limited areas with high land costs drive up stormwater management costs. Consequently, holding developers of such areas to the same stormwater standard as for Greenfield developments creates a financial disincentive for redevelopment. Without careful application, stormwater requirements may discourage needed redevelopment in existing urban areas. This would be unfortunate because redevelopment can take pressure off of the development of lands at the urban fringe, it can accommodate growth without introducing new impervious surfaces, and it can bring improvements in stormwater management to areas that had previously had none.

Stormwater planning can include the development of separate ordinances for infill and new developments. Wisconsin has administrative rules that establish specific requirements for stormwater management based on whether the site is new development, redevelopment, or infill. Requirements for new development include reducing total suspended solids (TSS) by 80 percent, maintaining the pre-development peak discharge for the 2-year, 24-hour storm, infiltrating 90 percent of the pre-development infiltration volume for residential areas, and infiltrating 60 percent of the pre-development infiltration volume for non-residential areas. Redevelopment varies from new development only in that the TSS requirement is less at 40 percent reduction. Requirements for existing developed areas in incorporated cities, villages, and towns do not include peak flow reduction or infiltration performance standards, but the municipalities must achieve a 40 percent reduction in their TSS load by 2013. Other requirements unique to developed areas include public education activities, proper application of nutrients on municipality property, and elimination of illicit discharges (www.dnr.state.wi.us/org/water/wm/nps/stormwater/post-constr/). Chapter 5 makes recommendations for the specific types of SCMs that should be used for new, low-density residential development as opposed to redevelopment of existing urban and industrial areas.

Integrated Stormwater Management and Growth Policies

In the city of San Jose, California, an approach was taken to link water quality and development policies that emphasized higher density in-fill development and performance-based approaches to achieving water quality goals. The city's approach encourages stormwater practices such as minimizing impervious surface and incorporating swales as the preferred means of conveyance and treatment. In urbanized areas, the policy then goes on to define criteria to determine the practicability of meeting numeric sizing requirements for stormwater control measures, and identifies Equivalent Alternative Compliance Measures for cases where on-site controls are impractical. Equivalent Measures can include regional stormwater treatment and other specific projects that "count" as SCMs, including certain affordable and senior housing projects, significant redevelopment within the urban core, and Brownfield projects. This is similar to in lieu fee programs that are sometimes implemented by municipalities to provide additional regulated parties with compliance options (see discussion in Chapter 6).

This approach is a breakthrough in terms of measuring environmental performance, which is now focused only on what happens within the boundaries of a site for a project. This myopic view tends to allow many environmentally unfriendly projects that encourage sprawl and expand the city's boundaries to qualify as "low impact," while more intense projects on a small footprint appear to have a much higher impact because they cover so much of the site. San Jose brought several other layers of review, including location in the watershed (close to other uses or

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not) as a means of estimating performance. A PowerPoint presentation describing their approach in greater detail is linked here (http://www.cmcgc.com/media/handouts/260126/THR-PDF/040-Ketchum.PDF, Lisa Nisenson, Nisenson Consulting, LLC, personal communication, May 8, 2007).

Unified Development Codes

A unified development code (UDC) consolidates development-related regulations into a single code that represents a more consistent, logical, integrated, and efficient means of controlling development. UDCs integrate zoning and subdivision regulations, simplifying development controls that are often conflicting, confusing, and that require multiple layers of review and administration. UDC development standards may include circulation standards that address how vehicles and pedestrians move, including provision for adequate emergency access. Utility standards are described for water distribution and sewage collection, and necessary utility easements are prescribed. Because of the integrated nature of the code, efficiencies in requirements for right-of-way can reduce street widths or the reduction in setbacks, for example, resulting in more compact development.

Design Review Incentives to Speed Permitting

A number of incentives have been put in place to promote innovative stormwater control measures in cities such as Portland and Chicago, where environmental concerns have been identified as a key goal for development and redevelopment. Practices such as the waiver or reduction of development fees, preferential treatment and review and approval of innovative plans, reduction in stormwater fees, and related incentives encourage the use of innovative stormwater practices. In Chicago, the Green Permit Program initiated in April 2005 has proven attractive to many developers as it speeds up the permitting process. Under the Green Permit Program, a green building adviser reviews design plans under an aggressive schedule long before a permit application is submitted. There is one point of contact with intimate knowledge about the project to help speed up the permit process. Projects going through the Green Permit Program receive benefits based on their "level of green." Tier I commercial projects are designed to be Leadership in Energy and Environmental Design (LEED) certified (see Box 2-7). Tier II projects must obtain LEED silver rating. At this level, outside consultant review fees, which range from $5,000 to $50,000, are waived. Tier III projects must earn LEED gold. The goal for a Tier III project is to issue a permit in three weeks for a small project such as a 12-unit condo building. Thus, there is both time and money saved. Private developers are interested in the time savings because they can pay less interest on their construction loans by completing the building faster. By the end of 2005, 19 green permits were issued. The program's director estimated that about 50 would be issued in 2006, which exceeds the city's goal of 40.

In Portland, Oregon, the city's Green Building Program is considering instituting a new High-Performance Green Building Policy. Along with goals for reducing global warming pollution, it proposes (1) waiving development fees if goals are exceeded by specified percentages and (2) eligibility for cash rewards and qualification for state and federal financial incentives and tax credits if even higher goals are achieved. Developers can earn credits by

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Box 2-7
Innovative Building Codes

An increased interest in energy conservation and more environmentally friendly building practices in general has led to various methods by which buildings can be evaluated for environmentally friendly construction, in addition to conventional code compliance. The most popular system in the United States is the Leadership in Energy and Environmental Design (LEED) system developed in 2000.

The LEED Green Building Rating System is a voluntary, consensus-based national rating system for developing high-performance, sustainable buildings. LEED addresses all building types and emphasizes state-of-the-art strategies in five areas: sustainable site development, water savings, energy efficiency, materials and resources selection, and indoor environmental quality. The U.S. Green Building Council is a 501(c)(3) nonprofit organization that certifies sustainable businesses, homes, hospitals, schools, and neighborhoods.

The LEED system encourages progressive stormwater management practices as part of its rating system. The LEED system has identified specific criteria, with points assigned to each of the criteria, to assess the success of stormwater strategies. Generally, the criteria are based on LID principles and practices and relate directly to the *Better Site Design Handbook* of the Center for Watershed Protection (CWP, 1998). The system identifies eight categories by which building sites and site-planning practices are evaluated. Of the 69 points possible to achieve the highest LEED rating, 16 points are directly related to innovative site design and stormwater management practices. Six of the eight criteria describing sound site-planning practices relate directly to good stormwater practices, including the following:

Erosion and sediment control;
Site selection to protect farmland, wetlands, and watercourses;
Site design to encourage denser infill development to protect Greenfield sites;
Limitations on site disturbance;
Specific requirements for the management of stormwater rate and quantity; and
Specific requirements for the treatment of stormwater for TSS and phosphorous removal.

The LEED rating system has been criticized because it focuses on individual buildings in building sites. A new category, LEED neighborhood development, was developed in response to consider the interrelationship of buildings and building sites and connections to existing urban infrastructure. The category is currently in pilot testing. Evaluation criteria related directly to stormwater include

All requirements of the original site design criteria,
A reduced requirement for parking based on access to transit and reduced auto use, and
Site planning that emphasizes compact development.

incorporating enhanced stormwater management and water conservation features into their projects, including the use of green roofs (Wenz, 2008).

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There are parallel challenges in the realm of community development and city building that tend to discourage innovative stormwater management policies and practices. Building codes and zoning have evolved to reflect the complex relationship of legal, political, and social processes and frequently do not promote or allow the most innovative stormwater management. Engineering standards and practices that guide the development of roads and utilities present equal and possibly greater challenges, in that legal and technical precedents and large investments in public equipment and infrastructure present even more intractable reasons to resist change.

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The difficulty of implementing stormwater control measures cannot be attributed to an individual code, standard, or regulation. It is important to unravel the complexities of codes, regulations, ordinances, and standards and practices that discourage innovative stormwater management and target the particular element (or multiple elements) that is a barrier to innovation. Elements that are barriers might not have been considered previously. For example, roadway design is controlled more by access for emergency equipment and utilities rights-of-way than by the need for wide travel lanes; it is the fire marshal and the water department that should be the focus of attention, rather than the transportation engineer.

LIMITATIONS OF THE FEDERAL STORMWATER PROGRAM

The regulation of stormwater discharges seems an inevitable next step to the CWA's objective of "restoring the nation's waters," and EPA's stormwater program is still evolving. Yet, in its current configuration EPA's approach seems inadequate to overcome the unique challenges of stormwater and therefore runs the risk of only being partly effective in meeting its goals. A number of regulatory, institutional, and societal obstacles continue to hamper stormwater management in the United States, as described below.

The Poor Fit Between the Clean Water Act's Regulatory Approach and the Realities of Stormwater Management

Controlling stormwater discharges with the CWA introduces a number of obstacles to effective stormwater regulation. Unlike traditional industrial effluent, stormwater introduces not only contaminants but also surges in volume that degrade receiving waterbodies; yet the statute appears focused primarily on the "discharge" of "pollutants." Moreover, unlike traditional effluent streams from manufacturing processes, the pollutant loadings in stormwater vary substantially over time, making effluent monitoring and the development of enforceable control requirements considerably more challenging. Traditional use of end-of-pipe control technologies and automated effluent monitors used for industrial effluent do not work for the episodic and variable loading of pollutants in stormwater unless they account for these eccentricities by adjustments such as flow-weighted measurements. Finally, at the root of the stormwater problem is increasingly intensive land use. Yet the CWA contains little authority for regulators to directly limit land development, even though the discharges that result from these developments increase stormwater loading at a predictably rapid pace. The CWA thus expects regulators to reduce stormwater loadings, but gives them incomplete tools for effectuating this goal.

A more straightforward way to regulate stormwater contributions to waterbody impairment would be to use flow or a surrogate, like impervious cover, as a measure of stormwater loading (such as in the Barberry Creek TMDL [Maine DEP, 2003, pp. 16–20] or the Eagle Brook TMDL [Connecticut DEP, 2007, pp. 8–10]). Flow from individual stormwater sources is easier to monitor, model, and even approximate as compared to calculating the loadings of individual contaminants in stormwater effluent. Efforts to reduce stormwater flow will automatically achieve reductions in pollutant loading. Moreover, flow is itself responsible for additional erosion and sedimentation that adversely impacts surface water quality. Flow

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provides an inexpensive, convenient, and realistic means of tracking stormwater contributions to surface waters. Congress itself recently underscored the usefulness of flow as a measure for aquatic impairments by requiring that all future developments involving a federal facility with a footprint larger than 5,000 square feet ensure that the development achieves predevelopment hydrology to the maximum extent technically feasible "with regard to the temperature, rate, volume, and duration of flow" (Energy Independence and Security Act of 2007, § 438). Several EPA regions have also used flow in modeling stormwater inputs for TMDL purposes (EPA, 2007a, Potash Brook TMDL, pp. 12–13).

Permitting and Enforcement

For industrial wastewater discharged directly from industrial operations (rather than indirectly through stormwater), the CWA requirements are relatively straightforward. In these traditional cases, EPA essentially identifies an average manufacturer within a category of industry, like iron and steel manufacturers engaged in coke-making, and then quantifies the pollutant concentrations that would result in the effluent if the industry installed the best available pollution control technology. EPA promulgates these effluent standards as national, mandatory limits (e.g., see Table 2-7).

TABLE 2-7 Effluent Limits for Best Available Technology Requirements for By-product Coke-making in Iron and Steel Manufacture.

SUBPART A—EFFLUENT LIMITATIONS (BAT)

Regulated parameter	Maximum daily [1]	Maximum monthly avg.[1]
Ammonia-N	0.00293	0.00202
Benzo(a)pyrene	0.0000110	0.00000612
Cyanide	0.00297	0.00208
Naphthalene	0.0000111	0.00000616
Phenols (4AAP)	0.0000381	0.0000238

[1] Pounds per thousand lb of product.

SOURCE: 40 C.F.R. § 420.13(a).

By contrast, the uncertainties and variability surrounding both the nature of the stormwater discharges and the capabilities of various pollution controls for any given industrial site, construction site, or municipal storm sewer make it much more difficult to set precise numeric limits in advance for stormwater sources. The quantity and quality of stormwater are quite variable over time and vary substantially from one property to another. Natural causes of variation in the pollutant loads in stormwater runoff include the topography of a site, the soil conditions, and of course, the nature of storm flows in intensity, frequency, and volume. In addition, the manner in which the facility stores and uses materials, the amount of impervious cover, and sometimes even what materials the facility uses can vary and affect pollutant loads in runoff from one site to another. Together, these sources of variability, particularly the natural features, make it much more difficult to identify or predict a meaningful "average" pollutant load

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of stormwater runoff from a facility. As a result, EPA generally leaves it to the regulated facilities, with limited oversight from regulators, to identify the appropriate SCMs for a site. Unfortunately, this deferential approach makes the permit requirements vulnerable to significant ambiguities and difficult to enforce, as discussed below for each permit type.

Municipal Stormwater Permits. MS4 permits are difficult to enforce because the permit requirements have not yet been translated into standardized procedures to establish end-of-pipe numerical effluent limits for MS4 stormwater discharges. CWA Section 402(p) requires that pollutants in stormwater discharges from the MS4 be reduced to the maximum extent practicable and comply with water quality standards (when so required by the permitting authority). However, neither EPA nor NPDES-delegated states have yet expressed these criteria for compliance in numerical form.

The EPA has not yet defined MEP in an objective manner that could lead to convergence of MS4 programs to reduce stormwater pollution. Thus, at present MS4 permittees have no more guidance on the level of effort expected other than what is stated in the CWA:

> [S]hall require controls to reduce the discharge of pollutants to the maximum extent practicable, including management practice, control techniques and system, design and engineering methods, and such other provisions as the Administrator or the State determines appropriate for the control of such pollutants. [CWA Section 402(p)(3)(B)(iii)]

A legal opinion issued by the California Water Board's Office of Chief Counsel in 1993 stated that MEP would be met if MS4 permittees implemented technically feasible SCMs, considering costs, public acceptance, effectiveness, and regulatory compliance (Memorandum from Elizabeth Miller Jennings, Office of Chief Counsel, to Archie Matthews, Division of Water Quality, California Water Board, February 11, 1993). In its promulgation of the Phase II Rule in 1999, the EPA described MEP as a flexible site-specific standard, stating that:

> The pollutant reductions that represent MEP may be different for each [MS4 Permittee] given the unique local hydrological and geological concerns that may exist and the differing possible pollutant control strategies. (64 Fed. Reg. 68722, 68754)

As matters stand today, MS4 programs are free to choose from the EPA's menu of SCMs, with MEP being left to the discretionary judgment of the implementing municipality. Similarly, there are no clear criteria to be met for industrial facilities that discharge to MS4s in order for the MS4s to comply with MEP. The lack of federal guidance for MS4s is understandable. A stormwater expert panel convened by the California EPA State Water Board in 2006 (CA SWB, 2006) concluded that it was not yet feasible to establish strictly enforceable end-of-pipe numeric effluent limits for MS4 discharges. The principal reasons cited were (1) the lack of a design storm (because in any year there are few storms sufficiently large in volume and/or intensity to exceed the design volume capacity or flow rates of most treatment SCMs) and (2) the high variability of stormwater quality influenced by factors such as antecedent dry periods, extent of connected impervious area, geographic location, and land use.

Industrial and Construction Stormwater Permits. The industrial and construction stormwater programs suffer from the same kind of deficiencies as the municipal stormwater

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program. These stormwater discharges are not bound by the MEP criterion, but they are required to comply with either technology-based or, less often, water quality-based effluent limitations. In selecting SCMs to comply with these limitations, the industrial discharger or construction operator similarly selects from a menu of options devised by the EPA or, in some cases, the states or localities for their particular facility (EPA, 2006a, p. 15). For example, the regulated party will generally identify structural SCMs, such as fences and impoundments that minimize runoff, and describe how they will be installed. The SWPPP must also include nonstructural SCMs, like good housekeeping practices, that require the discharger to minimize the opportunity for pollutants to be exposed to stormwater. The SWPPP and the accompanying SCMs constitute the compliance requirements for the stormwater discharger and are essentially analogous to the numeric effluent limits listed for industrial effluents in the Code of Federal Regulations.

This set of requirements leaves considerable discretion to regulated parties in several important ways. First, the regulations require the discharger to evaluate the site for problematic pollutants; but where the regulated party does not have specific knowledge or data, they need only offer "estimates" and "predictions" of the types of pollutants that might be present at the site (EPA, 1996a, pp. IV-3, V-3). With the exception of visible features, the deferential site investigation requirements allow regulated parties to describe site conditions in ways that may effectively escape accountability unless there is a vigorous regulatory presence.

Second, dischargers enjoy considerable discretion in drafting the SWPPP (EPA, 1996a, p. IV-3). Despite EPA's instructions to consider a laundry list of considerations that will help the facility settle on the most effective plan (EPA, 2006a, p. 20), rational operators may take advantage of the wiggle room and develop ambiguous requirements that leave them with considerable discretion in determining whether they are in compliance (EPA, 2006a, pp. 15, 20, 132). Indeed, the federal regulations do little to prevent regulated parties from devising requirements that maximize their discretion. Instead, EPA describes many of the permit requirements in general terms. For example, in its industrial stormwater permit program the EPA commands the regulated party to "implement any additional SCMs that are economically reasonable and appropriate in light of current industry practice, and are necessary to eliminate or reduce pollutants in . . . stormwater discharges" (EPA, 2006a, p. 23).

EPA's program provides few rewards or incentives for dischargers to go beyond the federal minimum and embrace rigorous or innovative SCMs. In fact, if the regulated party invests resources to measure pollutant loads on their property, they are creating a paper trail that puts them at risk of greater regulation. Under the EPA's regulations, a regulated party "must provide a summary of existing stormwater discharge sampling data previously taken at [its] facility," but if there are no data or sampling efforts, then the facility is off the hook (EPA, 2006a, p. 20). Quantitative measures can thus be incriminating, particularly in a regulatory setting where the regulator is willing to settle for estimates.

Dilemma of Self-Monitoring

Unlike the wastewater program where there are relatively rigid self-monitoring requirements for the end-of-pipe effluent, self-monitoring is much more difficult to prescribe for stormwater discharges, which are variable over time and space. [For example, *compare* 33 U.S.C. § 1342(a)(2)-(b)(2) (2000) (outlining requirements for compliance under NPDES) *with* EPA, 2006a, p. 26 (outlining requirements for self-compliance under EPA regulations.)] EPA's

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middle ground, in response to these challenges, requires self-monitoring of select chemicals in stormwater for only a subset of regulated parties—Phase I MS4 permittees and a limited number of industrial facilities (see Table 2-8, EPA, 2006a, pp. 93-94). Yet even for these more rigid monitoring requirements, the discharger enjoys some discretion in sampling. The EPA's sampling guidelines do prescribe regular intervals for sampling but ultimately must defer to the discharger insofar as requiring only that the samples should be taken within 30 minutes after the storm begins, and only if it is the first storm in three days (EPA, 2006a, p. 33).

TABLE 2-8 Effluent Monitoring Requirements for Various Dischargers of Stormwater

Source Category	**Type of Effluent Monitoring Required by EPA**
Phase I MS4	Municipality must develop a monitoring plan that provides for representative data collection. This requires the municipality, at the very least, to select at least 5 to 10 of its most representative outfalls for regular sampling and sample for selected conventional pollutants and heavy metals in its effluent.
Phase II MS4	None
Small subset of highest risk industries, like hazardous waste landfills	Must conduct compliance monitoring as specified in effluent guidelines and ensure compliance with these effluent limits. Must also conduct visual monitoring and benchmark monitoring.
Larger subset of higher risk industrial dischargers	Benchmark monitoring: Must conduct analytic monitoring to determine whether effluent exceeds numeric benchmark values; compliance with the numeric values is not required, however. Must also conduct visual monitoring.
Remaining set of industry except construction	Visual monitoring: Must take four grab samples of stormwater effluent each year during first 30 minutes of a storm event and inspect the sample visually for contamination.
Construction (larger than 5 acres)	Visual monitoring: Must take four grab samples of stormwater effluent each year during first 30 minutes of a storm event and inspect the sample visually for contamination.
Construction (between 1 and 5 acres)	Visual monitoring: Must take four grab samples of stormwater effluent each year during first 30 minutes of a storm event and inspect the sample visually for contamination.

Note: State regulators can and sometimes do require more—see Appendix C.

Moreover, while the monitoring itself is mandatory, the legal consequences of an exceedance of a numerical limit vary and may be quite limited. For a small number of identified industries, exceedances of effluent limits established by EPA are considered permit violations (65 Fed. Reg. 64766). For the other high-risk industries subject to benchmark monitoring requirements (see Table 2-5), the analytical limits do not lead to violations per se, but only serve to "flag" the discharger that it should consider amending its SWPPP to address the problematic pollutant (EPA, 2006a, pp. 10, 30, 34). Although municipalities are required to do more extensive sampling of stormwater runoff and enjoy less sampling discretion, even municipalities are allowed to select what they believe are their most representative outfalls for purposes of monitoring pollutant loads (EPA, 1996a. p. VIII-1).

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A large subset of dischargers—the remaining industrial dischargers and construction sites—are subject to much more limited monitoring requirements. They are not required to sample contaminant levels, but instead are required only to conduct a visual inspection of a grab sample of their stormwater runoff on a quarterly basis and describe the visual appearance of the sample in a document that is kept on file at the site (EPA, 2006a, p. 28). Certainly a visual sample is better than nothing, but the requirement allows the discharger not only some discretion in determining how and when to take the sample (explained below), but also discretion in how to describe the sample.

A final set of regulated parties, the Phase II MS4s, are not required to perform any quantitative monitoring of runoff to test the effectiveness of SCMs (EPA, 1996a, p. 3).

Making matters worse, in some states there appear to be limited regulatory resources to verify compliance with many of these permit requirements. Thus, even though monitoring plans are subject to review and approval by permitting agencies, there may be insufficient resources to support this level of oversight. As shown in Appendix C, the total number of staff associated with state stormwater programs is usually just a handful, except in cases of larger states (California and Georgia) or those where there is a longer history of stormwater management (Washington and Minnesota). In its survey of state stormwater programs, the committee asked states how they tracked sources' compliance with the stormwater permits. For the 18 states responding to the questionnaire, review of (1) monitoring data, (2) annual reports, and (3) SWPPP as well as on-site inspections were the primary mechanisms. However, several states indicated that they conduct an inspection only after receiving complaints. West Virginia tracked whether industrial facilities submitted their required samples and followed up with a letter if they failed to comply, but in 2006 it found that over 65 percent of the dischargers were delinquent in their sampling. Although the states were not asked in the survey to estimate the overall compliance rate, Ohio admitted that at least for construction, "the general sense is that no site is 100 percent in compliance with the Construction General Permit" (see Appendix C).

Even where considerable regulatory resources are dedicated to ensuring that dischargers are in compliance, it is not clear how well regulators can independently assess compliance with the permit requirements. For example, some of the permits will require "good housekeeping" practices that should take place daily at the facility. Whether or how well these practices are followed cannot be assessed during a single inspection. While a particularly non-compliant facility might be apparent from a brief visual inspection, a facility that is mildly sloppy**,** or at least has periods during which it is not careful**,** can escape detection on one of these pre-announced audits. Facilities also know best the pollutants they generate and how or whether those pollutants might make contact with stormwater. Inspectors might be able to notice some of these problems, but because they do not have the same level of information about the operations of the facility, they can be expected to miss some problems.

Identifying Potentially Regulatable Parties

Evidence suggests that a sizable percentage of industrial and construction stormwater dischargers are also failing to self-identify themselves to regulators, and hence these unreported dischargers remain both unpermitted and unregulated (GAO, 2005; Duke and Augustenborg, 2006). In contrast to industrial pipes that carry wastes from factories out to receiving waters, the physical presence of stormwater dischargers may be less visible or obvious. Thus, particularly

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for some industries and construction, if a stormwater discharger does not apply for a permit, the probability of detecting it is quite low.

In Maine, less than 20 percent of the stormwater dischargers that fall within the regulatory jurisdiction of the federal stormwater program actually applied for permits before 2005—more than a decade after the federal regulations were promulgated (Richardson, 2005). Yet there is no record of enforcement action taken by Maine against the unpermitted dischargers during that interim period. Indeed, in the one enforcement action brought by citizens in Maine for an unpermitted discharge, the discharger claimed ignorance of the stormwater program. In Washington, the State Department of Ecology speculates that between 10 and 25 percent of all businesses that should be covered by the federal stormwater permit program are actually permitted (McClure, 2004). In a four-state study, Duke and Augustenborg (2006) found a higher percentage of stormwater dischargers—between 50 and 80 percent—had applied for permits by 2004, but they concluded that this was still "highly incomplete" compliance for an established permit program.

In 2007, the committee sent a short survey to each state stormwater program inquiring as to whether and how they tracked non-filing stormwater dischargers, but only six states replied to the questions and only two of the six states had any methods for tracking non-filers or conducting outreach to encourage all covered parties to apply for permits (see Appendix C). While the low response rate cannot be read to mean that the states do not take the stormwater program seriously, the responses that were received lend some support to the possibility that there is substantial noncompliance at the filing stage.

In response to this problem of unpermitted discharges, the EPA appears to be targeting enforcement against stormwater dischargers that do not have permits. In several cases, the EPA pursued regulated industries that failed to apply for stormwater permits (EPA Region 9, 2005; Kaufman et al., 2005). The EPA has also brought enforcement actions against at least three construction companies for failing to apply for a stormwater permit for their construction runoff (EPA Region 1, 2004). Such enforcement actions help to make the stormwater program more visible and give the appearance of a higher probability of enforcement associated with non-compliance. Nevertheless, the non-intuitive features of needing a permit to discharge stormwater, coupled with a rational perception of a low probability of being caught, likely encourage some dischargers to fail to enter the regulatory system.

Absence of Regulatory Prioritization

Many states have been overwhelmed with the sheer numbers of permittees, particularly industry and construction sites, and lack a prioritization strategy to identify high-risk sources in particular need of rigorous and enforceable permit conditions. For example, in California major facilities like the Los Angeles International Airport and the Los Angeles and Long Beach ports are covered under California's MSGP along with a half-acre metal plating facility in El Segundo—all subject to the same level of compliance scrutiny even after nearly two decades of implementation! Similarly, a multiphase, 20-year, thousand-acre residential development such as Newhall Land Development in North Los Angeles County is covered by the same California CGP as a one-acre residential home construction project in West Los Angeles, and subject to the same level of compliance scrutiny. The lack of an EPA strategy to identify and address high-risk industrial facilities and construction sites (i.e., those that pose the greatest risk of discharging

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polluted stormwater) remains an enormous deficiency. Phase I MS4s, for example, are left to their own devices to determine how to identify the most significant contributors to their stormwater systems (Duke, 2007).

Limited Public Participation

Public participation is more limited in the stormwater program in comparison to the wastewater permit program, providing less citizen-based oversight over stormwater discharges. Typically, during the issuance of an individual NPDES permit (for either wastewater or stormwater) the public has a chance to comment and review the draft permit requirements that are specifically prescribed for a certain site and discharge. While the same is true about the public participation during the adoption of a general stormwater permit, those general permits contain only the framework of the requirements and the menu of conditions, but do not prescribe specific requirements. Instead, it is up to the permittee to tailor the compliance to the specific conditions of the site in the form of a SWPPP. However, at this phase neither the public nor the regulators have access to the site-specific plan developed by the permittee to comply with the obligations of the permit. In the case of general permits, then, the discharger has enormous flexibility in designing its compliance activities.

Citizens also encounter difficulties in enforcing stormwater permit requirements. Citizens have managed to sue facilities for unpermitted stormwater discharges: this is a straightforward process because citizens need only verify that the facility should be covered and lacks a permit (Richardson, 2005). Overseeing facility compliance with stormwater permit requirements is a different story, however, and citizens are stymied at this stage of ensuring facility compliance. Citizens can access a facility's SWPPP, but only if they request the plan from the facility in writing (EPA, 2006a, p. 25). Moreover, the facility is given the authority to make a determination—apparently without regulator oversight—of whether the plan contains confidential business information and thus cannot be disclosed to citizens (EPA, 2006a, p. 26). But, even if the facility sends the plan to the citizens, it will be nearly impossible for them to independently assess whether the facility is in compliance unless the citizens station telescopes, conduct air surveillance of the site, or are allowed to access the facility's records of its own self-inspections. Moreover, to the extent that the stormwater outfalls are on the facility's property**,** citizens might not be able to conduct their own sampling without trespassing.

Not surprisingly, significant progress has nevertheless been made in reducing stormwater pollution when stormwater becomes a visible public issue. This increased visibility is often accomplished with the help of local environmental advocacy groups who call attention to the endangered species, tourism, or drinking water supplies that are jeopardized by stormwater contamination. Box 2-8 describes two cases of active public participation in the management of stormwater.

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BOX 2-8
Citizen Involvement/Education in Stormwater Regulations

The federal Clean Water Act, under Section 505, authorizes citizen groups to bring an action in U.S. or state courts if the EPA or a state fails to enforce water quality regulations. Unsurprisingly, the few areas nationally where stormwater quality has become a visible public issue and significant progress has been made in reducing stormwater pollution have prominent local environmental advocacy groups actively involved.

Heal the Bay, Santa Monica, California. In Southern California, Santa Monica-based Heal the Bay has utilized research, education, community action, public advocacy, and political activism to improve the quality of stormwater discharges from MS4s in Southern California. Heal the Bay operates an aquarium to educate the public, conducts stream teams to survey local streams, posts a beach report card on the web to inform swimmers on beach quality, appears before the California Water Boards to comment on NPDES stormwater permits, and works with lawmakers to sponsor legislative bills that protect water quality.

In 1998, the organization helped co-author legislation to notify the public when shoreline water samples show that water may be unsafe for swimming. California regulations (AB411) require local health agencies (county or city) to monitor water quality at beaches that are adjacent to a flowing storm drain and have 50,000 visitors annually (from April 1 to October 31). At a minimum, these beaches are tested on a weekly basis for three specific bacteria indicators: total coliform, fecal coliform, and *enterococcus*. Local health officials are required to post or close the beach, with warning signs, if state standards for bacterial indicators are exceeded. The monitoring data collected are available to the public.

In order to better inform and engage the public, Heal the Bay has followed up with a web-based Weekly Beach Report Card (http://healthebay.org/brc/statemap.asp) and the release of an Annual California Beach Report Card assigning an "A" to "F" letter grade to more than 500 beaches throughout the state based on their levels of bacterial pollution. Heal the Bay's Annual Beach Report Card is a comprehensive evaluation of California coastal water quality based on daily and weekly samples gathered at beaches from Humboldt County to the Mexican border. A poor grade means beachgoers face a higher risk of contracting illnesses such as stomach flu, ear infections, upper respiratory infections, and skin rashes than swimmers at cleaner beaches.

Heal the Bay was instrumental in passing Proposition O in the City of Los Angeles which sets aside half a billion dollars to improve the quality of stormwater discharges. In the 2007 term of the California Legislature, the organization has sponsored five legislative bills to address marine debris, including plastic litter transported in stormwater runoff, that foul global surface waters (*Currents*, Vol. 21, No. 2, p.8, 2007). Heal the Bay also coordinates its actions and partners with other regional and national environmental organizations, such as the WaterKeepers and the NRDC, in advancing water quality protection nationally.

Save Our Springs, Austin, Texas. Citizen groups have played a very influential role in the development of a rigorous stormwater control program in the City of Austin, Texas. Catalyzed in 1990 by a proposal for extensive development that threatened the fragile Barton Springs area, a citizens group named Save Our Springs Legal Defense Fund (later renamed Save our Springs Alliance) formed to oppose the development. It orchestrated an infamous all-night council meeting, with 800 citizens registering in opposition to the proposed development and ultimately led to the City Council's rejection of the 4,000-acre proposal and the formulation of a "no degradation" policy for the Barton Creek watershed. The nonprofit later sponsored the Save Our Springs Ordinance, a citizen initiative supported by 30,000 signatures, which passed by a 2 to 1 margin in 1992 to further strengthen protection of the area. The Save Our Springs Ordinance limits impervious cover in the Barton Springs watershed to a maximum of between 15 and 25 percent, depending on the location of the development in relation to the recharge and contributing zones. The ordinance also mandates that stormwater runoff be as clean after development as before. The ordinance was subject to a number of legal challenges, all of which were successfully defended by the nonprofit in a string of court battles.

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Box 2-8 Continued

Since its initial formation in 1990, the Save Our Springs Alliance has continued to serve a vital role in educating the community about watershed protection and organizing citizens to oppose development that threatens Barton Springs. The organization has also been instrumental in working with a variety of government and nonprofit organizations to set aside large areas of parkland and open spaces within the watershed. Other citizen groups, like the Save Barton Creek Association, also play a very active, complementary role to the Save Our Springs Alliance in protecting the watershed. These other nonprofits are sometimes allied and sometimes diverge to take more moderate stances to development proposals. The resulting constellation of citizen groups, citizen outreach, and community participation is very high in the Austin area and has unquestionably led to a much more informed citizenry and a more rigorous watershed protection program than would exist without such grassroots leadership.

Accounting for Future Land Use

One of the challenges of managing stormwater from urban watersheds thus involves anticipating and channeling future urban growth. Currently, the CWA does little to anticipate and control for future sources of stormwater pollution in urban watersheds. Permits are issued individually on a technology-based basis, allowing for uncontrolled cumulative increases in pollutant and volume loads over time as individual sources grow in number. The TMDL process in theory requires states to account for future growth by requiring a "margin of safety" in loading projections. However, it is not clear how frequently future growth is included in individual TMDLs or how vigorous the growth calculations are (for example, see EPA [2007a, pp. 12, 37], mentioning considerations of future land use as a consideration in stormwater related TMDLs for only a few—Potash Brook and the lower Cuyahoga River—of the 17 TMDLs described in the report). In any event, as already noted a TMDL is generally triggered only after waters have been impaired, which does nothing to anticipate and channel land development before waters become degraded.

The fact that stormwater regulation and land-use regulation are largely decoupled in the federal regulatory system is understandable given the CWA's industrial and municipal wastewater focus and concerns about federalism, but this limited approach is not a credible approach to stormwater management in the future. Federal incentives must be developed to encourage states and municipalities to channel growth in a way that acknowledges, estimates, and minimizes stormwater problems.

Picking up the Slack at the Municipal and State Level

Because it involves land use, any stormwater discharge program strikes at a target that is traditionally within the province of state and even more likely local government regulation. Indeed, it is possible that part of the reason for the EPA's loosely structured permit program is its concern about intruding on the province of state and local governments, particularly given their superior expertise in regulating land-use practices through zoning, codes, and ordinances.

In theory, it is perfectly plausible that some state and local governments will step into the void and overcome some of the problems that afflict the federal stormwater discharge program. If local or state governments required mandatory monitoring or more rigorous and less

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ambiguous SCMs, they would make considerable progress in developing a more successful stormwater control program. In fact, some states and localities have instituted programs that take these steps. For example, Oregon has established its own benchmarks based on industrial stormwater monitoring data, and it uses the benchmark exceedances to deny industries coverage under Oregon's MSGP. In such cases, the facility operator must file for an individual stormwater discharge NPDES permit. Some municipalities are also engaging in these problems, such as the City of Austin and its ban on coal tar sealants.

Despite these bursts of activity, most state and local governments have not taken the initiative to fill the gaps in the EPA's federal program (see Tucker [2005] for some exceptions). Because they involve some expense, stormwater discharge requirements can increase resident taxes, anger businesses, and strain already busy regulatory staff. Moreover, if the benefits of stormwater controls are not going to materialize in waters close to or of value to the community instituting the controls, then the costs of the program from the locality's standpoint are likely to outweigh its benefits. Federal financial support for state and local stormwater programs is very limited (see section below). Until serious resources are allocated to match the seriousness and complexity of the problem and the magnitude of the caseload, it seems unlikely that states and local communities will step in to fill the gaps in EPA's program. These impediments help explain why there appear to be so many stormwater sources out of compliance with the stormwater discharge permit program as discussed above, at least in the few states that have gone on record.

Funding Constraints

Without a doubt, the biggest challenge for states, regions, and municipalities is having adequate fiscal resources dedicated to implement the stormwater program. Box 2-9 highlights the costs of the program for the State of Wisconsin, which has been traditionally strong in stormwater management. Phase I regulations require that a brief description of the annual proposed budget for the following year be included in each annual report, but this requirement has been dispensed with entirely for Phase II.

Ever since the promulgation of the stormwater amendments to the CWA and the issuance of the stormwater regulations, the discharger community pointed out that this statutory requirement had the flavor of an unfunded mandate. Unlike the initial CWA that provided significant funding for research, design, and construction of wastewater treatment plants, the stormwater amendments did not provide any funding to support the implementation of the requirements by the municipal operators. The lack of a meaningful level of investment in addressing the more complex and technologically challenging problem of cleaning up stormwater has left states and municipalities in the difficult position of scrambling for financial support in an era of multiple infrastructure funding challenges.

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BOX 2-9
Preliminary Cost Estimates for Complying with Stormwater Discharge Permits in Wisconsin

The Wisconsin Department of Natural Resources (WDNR) was delegated authority under the CWA to administer the stormwater permit program under Chapter NR 216. There are 75 municipalities regulated under individual MS4 permits and 141 MS4s regulated under a general permit for a total of 216 municipalities with stormwater discharge permits.

As part of the "pollution prevention" minimum measure the municipalities are required to achieve compliance with the developed urban area performance standards in Chapter NR 151.13. By March 10, 2008, municipalities subject to a municipal stormwater permit under NR 216 must reduce their annual TSS loads by 20 percent. These same permitted municipalities are required to achieve an annual TSS load reduction of 40 percent by March 10, 2013. The reduction in TSS is compared to no controls, and any existing SCMs will be given credit toward achieving the 20 or 40 percent. As part of their compliance with NR151.13 developed area performance standards, the municipalities are preparing stormwater plans describing how they will achieve the 20 and 40 percent TSS reduction. They are required to use an urban runoff model, such as WinSLAMM or P8, to do the pollutant load analysis.

As the permitted municipalities comply with the six minimum control measures and submit the stormwater plans for their developed area urban areas, the WDNR is learning how much it is going to cost to achieve the requirements in the stormwater discharge permits. Some cities have already been submitting annual reports that include the cost of the six minimum measures. Nine of the permitted municipalities in the southeast part of Wisconsin have been submitting their annual reports for at least four years. The average population of these nine communities is 17,700 with a range of about 6,000 to 65,000. The average cost of the six minimum measures in 2007 for the nine municipalities is $162,900 with a range of $11,600 to $479,000. These costs have not changed significantly from year to year. The average per capita cost is $9 with a range of $1 to $16 per person. Street cleaning and catch basin cleaning (Figures 2-3 and 2-4) cost are included in the cost for the pollution prevention measure, and most of the cities were probably incurring costs for these two activities before the issuing of the permit. On average the street cleaning and catch basin cleaning represent about 40 percent of the annual cost for the six minimum measures. These two activities will help the cities achieve the 20 and 40 percent TSS performance standards for developed urban areas.

Information is available on the preliminary cost of achieving the 40 percent TSS performance standard for selected cities in Wisconsin. The costs were prepared for 15 municipalities by Earth Tech Inc. in Madison, Wisconsin. Areas of the municipality developed after October 2004 are not included in the TSS load analysis. At this point in the preparation of the stormwater plans the costs are just capital cost estimates done at the planning level (Table 2-9). Because the municipalities receive credit for their existing practices, these capital costs represent the additional practices needed to achieve the annual 40 percent TSS reduction. The costs per capita appear to decline for cities with a population over 50,000. All of the costs in Table 2-9 will increase when other costs, such as maintenance and land cost, are included.

TABLE 2-9 Planning-Level Capital Cost Estimate to Meet 40 Percent TSS Reduction

Population	Number of Cities	Average Cost ($)	Minimum Cost ($)	Maximum Cost ($)	Avg. Cost per Capita per Year over 5 Years ($)
5,000 to 10,000	5	1,380,000	425,000	2,800,000	34
10,000 to 50,000	6	4,600,00	2,700,00	9,200,000	35
50,000 to 100,000	4	9,200,000	7,000,000	12,500,000	26

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Box 2-9 Continued

For most of the 15 municipalities, the capital costs are for retrofitting dry ponds with permanent pools, installing new wet detention ponds, and improved street cleaning capabilities. Because of their lower cost, the regional type practices have received more attention in the stormwater plans than the source area practices, such as proprietary devices and biofilters. Municipalities with a higher percentage of newer areas will usually have lower cost because the newer developments tend to have stormwater control measures designed to achieve a high level of TSS control, such as wet detention ponds. Older parts of a municipality are usually limited to practices with a lower TSS reduction, such as street cleaning and catch basin cleaning. Of course, retrofitting older areas with higher efficiency practices is expensive, and the cost can go higher than expected when unexpected site limitations occur, such as the presence of underground utilities.

Over the next five years all of the 15 municipalities must budget the costs in Table 2-9. It is not clear yet how much of a burden these costs represent to the taxpayers in each municipality. All the permits will be reviewed for compliance with the performance standards in 2013.

FIGURE 2-3 Catch basin cleaning. Courtesy of Robert Pitt.

FIGURE 2-4 Street cleaning. SOURCE: Selbig and Bannerman (2007).

While a number of communities have passed stormwater fees linked to water quality as described below, a significant number of communities still do not have that financial resource. Municipalities that have not formed utility districts or imposed user fees have had to rely on general funds, where stormwater permit compliance must compete with public safety, fire protection, and public libraries. This circumstance explains why elected local government officials have been reluctant to embrace the stormwater program. Stormwater quality management is often not regarded as a municipal service, unlike flood control or wastewater conveyance and treatment. A concerted effort will need to be made by all stakeholders to make the practical and legal case that stormwater quality management is truly another municipal service like trash collection, wastewater treatment, flood control, etc. Even in states that do collect fees to finance stormwater permit programs, the programs appear underfunded relative to other types of water pollution initiatives. Table 2-10 shows the water quality budget of the California EPA, Los Angeles Regional Water Board. The amount of money per regulated entity (see Table 2-4) dedicated to the stormwater program pales in comparison to the wastewater portion of the NPDES program, and it has declined over time. Furthermore, of the more than $5 billion dollars in low-interest loans provided in 2006 for investments in water quality improvements, 96 percent of that total funding went to wastewater treatment (EPA, 2007d).

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TABLE 2-10 Comparison of Fiscal Year (FY) 02–03 Budget with FY 06–07 Budget for Water Quality Programs at the California EPA, Los Angeles Regional Water Board

Program	Funding Source	2002–2003	2006–2007
NPDES[1]	Federal	$2.8 mil	$2.6 mil
Stormwater	State	$2.3 mil	$2.1 mil
TMDLs	Federal	$1.47 mil	$1.38 mil
Spills, Leaks, Investigation Cleanup	State	$1.32 mil.	$2.87 mil.
Underground Storage Tanks	State	$2.78 mil.	$2.74 mil.
Non-Chapter 15 (Septics)	State	$0.93 mil.	$0.93 mil.
Water Quality Planning	Federal	$0.2 mil.	$0.21 mil.
Well Investigation	State	$1.36 mil.	$0.36 mil.
Water Quality Certification	Federal	$0.2 mil.	$0.23 mil.
Total		$17.1 mil.	$15.82 mil.

[1]The NPDES row is entirely wastewater funding, as there is no federal money for implementing the stormwater program. Note that the stormwater program in the table is entirely state funded.

There are a number of potential methods that agencies can use to collect stormwater quality management fees, as described more extensively in Chapter 5. A number of states now levy permit fees, with some permits costing in excess of $10,000, to help defray the costs of implementation and enforcement of their stormwater programs. The State of Colorado, for example, has developed an elaborate fee structure for separate types of general permits for industry and construction, as well as MS4s (see http://www.cdphe.state.co.us/wq/permitsunit/stormwater/StormwaterFees.pdf). The ability of a state agency to collect fees generally must first be authorized by the state legislatures (see, e.g., Revised Code of Washington 90.48.465, providing the state agency with the authority to "collect expenses for issuing and administering each class of permits"). The lack of state legislative authorization may limit some state agencies from creating such programs on their own. In fact, in those states where fees cannot be levied against permittees, the stormwater programs appear to be both underfinanced and understaffed. Some municipalities have even experienced political backlash because of the absence of a strong state or federal program requiring them to engage in rigorous stormwater management (see Box 2-10).

Stormwater Management Expertise

Historically, engineering curriculum dealt with stormwater management by focusing on the flood control aspects, with little attention given to the water quality aspects. Thus, there has been a significant gap in knowledge and a lack of qualified personnel. In areas where SCMs are just beginning to be introduced, many municipalities, industrial operators, and construction site operators are not prepared to address water quality issues; the problem is especially difficult for smaller municipalities and operators. The profession and academia are moving to correct this shortfall. Professional associations such as the Water Environment Federation (WEF) and the American Society for Civil Engineers (ASCE) are co-authoring an update of the WEF/ASCE Manual of Practice "Design of Urban Runoff Controls" that integrates quality and quantity, after years of issuing separate manuals of design and operation for the water quality and water quantity elements of stormwater management.

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BOX 2-10
A City's Ability to Pay for Stormwater, Water, and Sewage Utility Fees

With the implementation of the stormwater permit program of the CWA, stormwater utilities are becoming more common as a way to jointly address regional stormwater quality and drainage issues. One such program is the Jefferson County, Alabama, Storm Water Management Authority (SWMA), formed in 1997 under state legislation that enables local governments to pool their resources in a regional stormwater authority to meet regulations required by the CWA. Jefferson County, the City of Birmingham, and 22 other regional municipalities in Jefferson, part of Shelby and part of St. Clair counties, Alabama, were required to comply with CWA regulations. The act gave the stormwater program the ability to develop a funding mechanism for the program and to form a Public Corporation.

Over the years, SWMA has been responsible for many activities. One of their first goals was to develop a comprehensive GIS database to map outfalls, land uses, stormwater practices, and many other features that were required as part of the permit program. Another major activity conducted by SWMA was the collection of water samples from about 150 sites in the authority's jurisdiction, both during wet and dry weather. SWMA also inspects approximately 4,000 outfalls during dry weather to check for inappropriate connections to the storm drainage system. SWMA coordinates public volunteer efforts with local environmental groups, including the Alabama Water Watch, the Alabama River Alliance, the Black Warrior Riverkeeper, and the Cahaba River Society. SWMA also inspects businesses and industries (including construction sites) within their jurisdictions that are not permitted by the Alabama Department of Environmental Management (ADEM). SWMA does not enforce rules or issue fines, although it can report violators to the state. In its most famous case, it reported McWane Inc. for pollution that led to investigations by the state and the federal government, and ultimately a trial and criminal convictions.

The Birmingham News (Bouma, 2007) reported that from 1997 to 2005, SWMA's responsibilities under the CWA increased substantially, although their fees did not rise. In late 2005, SWMA proposed that member cities increase their stormwater charges from $5 a year to $12 a year per household for residences and from $15 to $36 per year for businesses. At that point, the Business Alliance for Responsible Development (BARD), a group of large businesses, utilities, mining interests, developers and landowners, began to argue that the group was financially irresponsible, and its attorneys convinced member cities that they could save money by withdrawing from SWMA. Even though SWMA withdrew its fee increase request, many local municipalities have pulled out of SWMA, significantly reducing the agency's budget and ability to conduct comprehensive monitoring and reporting. BARD claims the pollution control programs of the ADEM are sufficient. In their countersuit, several environmental groups maintain that ADEM has failed to adequately protect the state's waters because the agency is underfunded, understaffed, and ineffective at enforcement. Much of the Cahaba and Black Warrior River systems within Jefferson County have such poor water quality that they frequently violate water quality standards (http://www.southernenvironment.org). SWMA has been significantly impaired in its ability to monitor and report water quality violations with the withdrawal of many of its original member municipalities and the associated reduced budget.

At the same time, the sewer bill for a family of four in the region is expected to be about $63 per month in 2008. Domestic water rates have also increased, up to about $32 per month (*The Birmingham News*, Barnett Wright, December 30, 2007). Domestic water rates have increased in recent years in attempts to upgrade infrastructure in response to widespread and long-lasting droughts and to cover rising fuel costs. It is ironic that stormwater management agency fees are very small compared to these other urban water agency fees per household by orders of magnitude. The $12 per year stormwater fee was used to justify the dismantling of an agency that was doing its job and identifying CWA violators. In order to bring some reasonableness to the stormwater management situation and expected fees, it may be possible for the EPA to re-examine its guidelines of 2 percent of the household income for sewer fees to reflect other components of the urban water system, and to ensure adequate enforcement of existing regulations, especially by underfunded state environmental agencies.

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The split between water quantity and quality is evident in municipal efforts that have focused primarily on flood control issues and design of appropriate appurtenances tailored for this purpose. As discussed earlier, most municipal codes specify practices to collect and move water away as fast as possible from urbanized areas. Very little focus has been put on practices to mitigate the quality of the stormwater runoff. This is especially true in urbanized areas with separate municipal storm sewer systems. Even the designation "sewer" is borrowed from the sanitary sewer conveyance system terminology. In arid or semi-arid areas, these flood control systems have been maximally engineered such that river beds have become concrete channels. A typical example is the Los Angeles River, which most of the year resembles an empty freeway. This analysis does not intend to minimize the engineering feat of designing a robust and reliable flood control system. For example, during the unusually wet 2005 season in Southern California, the Los Angeles area did not have any major flooding incidents. However, based on recent studies (Stein and Ackerman, 2007) up to 80 percent of the annual metals loading from six watersheds in the Los Angeles area was transported by stormwater events.

Because of the historical lack of focus on stormwater quality, municipal departments in general are not designed to address the issue of pollution in urban runoff. Just recently and due to the stormwater regulations, cities have been adding personnel and creating new sections to deal with the issue. However, because of the complexities of the task, many duties are spread among various municipal departments, and more often than not coordination is still lacking. Perhaps most problematic is the fact that the local governmental entities in charge of stormwater management are often different from those that oversee land-use planning and regulation. This disconnect between land-use planning and stormwater management is especially true for large cities. It is not unusual for program responsibilities to be compartmentalized, with industrial aspects of the program handled by one group, construction by another, and planning and public education by other distinct units. Smaller cities may have one person handling all aspects of the program assisted by a consulting firm. While coordination may be ensured, the task can be overwhelming for a single staff person.

Beyond water quality issues, training to better understand the importance of volume control and the role of LID has not yet reached many practitioners. Many established practices and industry standards in the fields of civil, geotechnical, and structural engineering were developed prior to the introduction of the current group of SCMs and can unnecessarily limit their use. Indeed, certain SCMs such as porous landscape detention, extended detention, and vegetated swales require special knowledge about soils and appropriate plant communities to ensure their longevity and ease of maintenance.

Supplementing the Clean Water Act with Other Federal Authorities that Can Control Stormwater Pollutants at the Source

EPA does have other supplemental authorities that are capable of making significant progress in reducing or even eliminating some of the problematic stormwater pollutants at the national level. Under both the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) and the TSCA, for example, EPA could restrict some of the most problematic pollutants at their source by requiring labels that alert consumers to the deleterious water quality impacts caused by widely marketed chemical products, restricting their use, or even banning them. This source-

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based regulation bypasses the need of individual dischargers or governments to be concerned with reducing the individual contaminants in stormwater.

The City of Austin's encounter with coal tar-based asphalt sealants provides an illustration of the types of products contributing toxins to stormwater discharges that could be far better controlled at the production or marketing stage. Through detective work, the City of Austin learned that coal tar-based asphalt sealants leach high levels of polycyclic aromatic hydrocarbons (PAHs) into surface waters (Mahler et al., 2005; Van Metre et al., 2006). The city discovered this because the PAHs were found in sediments in Barton Springs, which were in turn leading to the decline of the endangered Barton Creek salamander (Richardson, 2006). By tracing upstream, the city was able to find the culprit—a parking lot at the top of the hill that was recently sealed with coal tar sealant and produced very high PAH readings. Further tests revealed that coal tar sealants typically leach very high levels of PAHs, but other types of asphalt sealants that are not created from coal tar are much less toxic to the environment and are no more expensive than the coal tar-based sealants (City of Austin, 2004). As a result of its findings, the City of Austin banned the use of coal tar-based asphalt sealants. Several retailers, including Lowes and Home Depot followed the city's lead and refused to carry coal tar sealants. Dane County in the State of Wisconsin has now also banned coal tar sealants[1].

For reasons that appear to inure to the perceived impotency of TSCA and the enormous burdens of restricting chemicals under that statute, EPA declined to take regulatory action under TSCA against coal tar sealants (Letter from Brent Fewell, Acting Assisting Administrator, U.S. EPA, to Senator Jeffords, October 16, 2006, p. 3). Yet, it had authority to consider whether this particular chemical mixture presents an "unreasonable risk" to health and the environment, particularly in comparison to a substitute product that is available at the same or even lower price [15 U.S.C. § 2605(a); *Corrosion Proof Fittings vs. EPA*, 947 F.2d 1201 (5th Cir. 1991)]. Indeed, if EPA had undertaken such an assessment, it might have even discovered that the coal tar sealants are not as inferior as Austin and others have concluded; alternatively it could reveal that these sealants do present an "unreasonable risk" since there are substantial risks from the sealant without corresponding benefits, given the availability of a less risky substitute.

A similar situation holds for other ubiquitous stormwater pollutants, such as the zinc in tires, roof shingles, and downspouts; the copper in brake pads; heavy metals in fertilizers; creosote- and chromated copper arsenate (CCA)-treated wood; and de-icers, including road salt. Each of these sources may be contributing toxins to stormwater in environmentally damaging amounts, and each of these products might have less deleterious and equally cost-effective substitutes available, yet EPA and other federal agencies seem not to be undertaking any analysis of these possibilities. The EPA's phase-out of lead in gasoline in the 1970s, which led to measurable declines in the concentrations of lead in stormwater by the mid-1980s (see Figure 2-5), may provide a model of the type of gradual regulatory ban EPA could use to reduce contaminants in products that are non-essential.

[1] See, e.g., Coal Tar-based pavement sealants studied, Science Daily, February 12, 2007, available at http://www.sciencedaily.com/upi/index.php?feed=Science&article=UPI-1-20070212-10255500-bc-us-sealants.xml; Matthew DeFour, Dane County bans Sealants with Coal Tar, Wisconsin State Journal, April 6, 2007, available at http://www.madison.com/wsj/home/local/index.php?ntid=128156&ntpid=5.

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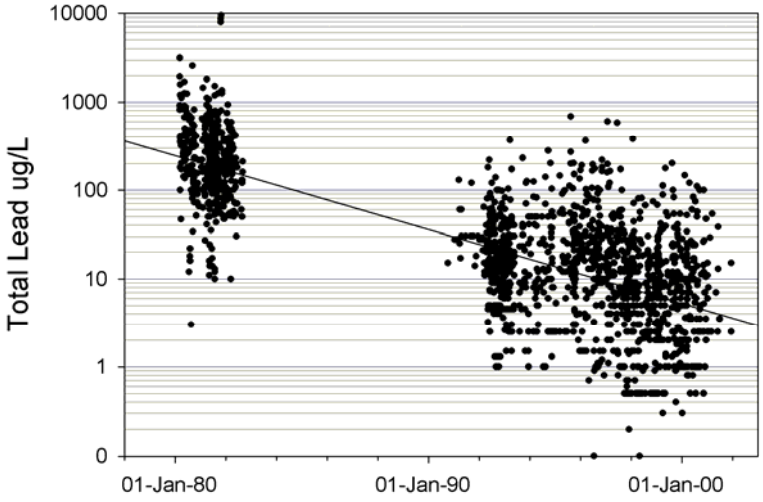

FIGURE 2-5 Trend of lead concentrations in stormwater in EPA rain zone 2 from 1980 to 2001. Although the range of lead concentrations for any narrow range of years is quite large, there is a significant and obvious trend in concentration for these 20 years. SOURCE: National Stormwater Quality Database (version 3).

Some states are taking more aggressive forms of product regulation. For example, in the mid-1990s, numerous scientific studies conducted in California by stormwater programs, wastewater treatment plants, the University of California, California Water Boards, the U.S. Geological Survey, and EPA showed widespread toxicity in local creeks, stormwater runoff, and wastewater treatment plant effluent from pesticide residues, particularly diazinon and chlopyrifos (which are commonly used organophosphate pesticides available in hundreds of consumer products) (Kuivila and Foe, 1995; MacCoy et al., 1995). As a result, the California Water Boards and EPA listed many waters in urban areas of California as being impaired in accordance with CWA Section 303(d). Many cities and counties were required to implement expensive programs to control the pollution under the MS4 NPDES permits to restore the designated beneficial uses of pesticide-impaired waters. Figure 2-6 shows the results of one such action—a ban on diazinon.

In sum, even though there are a number of sources of pollutants—from roof tiles to asphalt sealants to de-icers to brake linings—that could be regulated more restrictively at the product and market stage, EPA currently provides little meaningful regulatory oversight of these sources with regard to their contribution to stormwater pollution. The EPA's authority to prioritize and target products that increase pollutants in runoff, both for added testing and regulation, seems clear from the broad language of TSCA [15 U.S.C. § 2605(a)]. The underutilization of this national authority to regulate environmentally deleterious stormwater pollutants thus seems to be a remediable shortcoming of EPA's current stormwater regulatory program.

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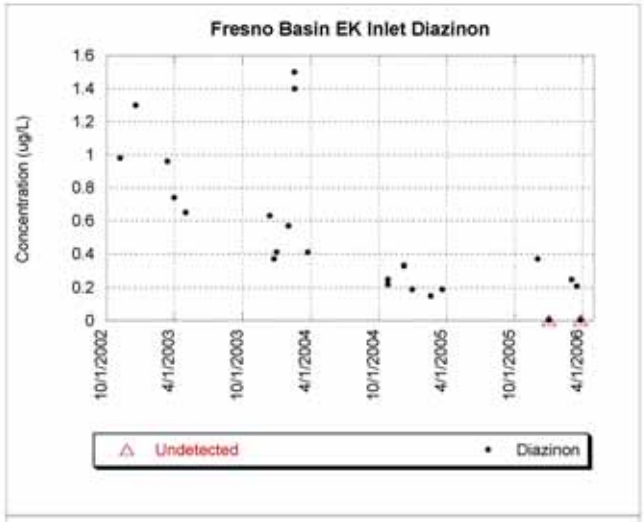

FIGURE 2-6 Trend of the organophosphate pesticide diazinon in MS4 discharges that flow into a stormwater basin in Fresno County, California, following a ban on the pesticide. The figure shows the significant drop in the diazinon concentration in just four years to levels where it is no longer toxic to freshwater aquatic life. EPA prohibited the retail sale of diazinon for crack and crevice and virtually all indoor uses after December 31, 2002, and non-agriculture outdoor use was phased out by December 31, 2004. Restricted use for agricultural purposes is still allowed. SOURCE: Reprinted, with permission, from Brosseau (2007). Copyright 2006 by Fresno Metropolitan Flood Control District.

CONCLUSIONS AND RECOMMENDATIONS

In an ideal world, stormwater discharges would be regulated through direct controls on land use, strict limits on both the quantity and quality of stormwater runoff into surface waters, and rigorous monitoring of adjacent waterbodies to ensure that they are not degraded by stormwater discharges. Future land-use development would be controlled to prevent increases in stormwater discharges from predevelopment conditions, and impervious cover and volumetric restrictions would serve as a reliable proxy for stormwater loading from many of these developments. Large construction and industrial areas with significant amounts of impervious cover would face strict regulatory standards and monitoring requirements for their stormwater discharges. Products and other sources that contribute significant pollutants through stormwater—like de-icing materials, urban fertilizers and pesticides, and vehicular exhaust—would be regulated at a national level to ensure that the most environmentally benign materials are used when they are likely to end up in surface waters.

In the United States, the regulation of stormwater looks quite different from this idealized vision. Since the primary federal statute—the CWA—is concerned with limiting pollutants into surface waters, the volume of discharges are secondary and are generally not regulated at all. Moreover, given the CWA's focus on regulating pollutants, there are few if any incentives to anticipate or limit intensive future land uses that generate large quantities of stormwater. Most stormwater discharges are regulated instead on an individualized basis with the demand that existing point sources of stormwater pollutants implement SCMs, without accounting for the cumulative contributions of multiple sources in the same watershed. Moreover, since individual stormwater discharges vary with terrain, rainfall, and use of the land, the restrictions governing

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regulated parties are generally site-specific, leaving a great deal of discretion to the dischargers themselves in developing SWPPPs and self-monitoring to ensure compliance. While states and local governments are free to pick up the large slack left by the federal program, there are effectively no resources and very limited infrastructure with which to address the technical and costly challenges faced by the control of stormwater. These problems are exacerbated by the fact that land use and stormwater management responsibilities within local governments are frequently decoupled. The following conclusions and recommendations are made.

EPA's current approach to regulating stormwater is unlikely to produce an accurate or complete picture of the extent of the problem, nor is it likely to adequately control stormwater's contribution to waterbody impairment. The lack of rigorous end-of-pipe monitoring, coupled with EPA's failure to use flow or alternative measures for regulating stormwater, make it difficult for EPA to develop enforceable requirements for stormwater dischargers. Instead, under EPA's program, the stormwater permits leave a great deal of discretion to the regulated community to set their own standards and self-monitor.

Implementation of the federal program has also been incomplete. Current statistics on the states' implementation of the stormwater program, discharger compliance with stormwater requirements, and the ability of states and EPA to incorporate stormwater permits with TMDLs are uniformly discouraging. Radical changes to the current regulatory program (see Chapter 6) appear necessary to provide meaningful regulation of stormwater dischargers in the future.

Future land development and its potential increases in stormwater must be considered and addressed in a stormwater regulatory program. The NPDES permit program governing stormwater discharges does not provide for explicit consideration of future land use. Although the TMDL program expects states to account for future growth in calculating loadings, even these more limited requirements for degraded waters may not always be implemented in a rigorous way. In the future, EPA stormwater programs should include more direct and explicit consideration of future land developments. For example, stormwater permit programs could be predicated on rigorous projections of future growth and changes in impervious cover within an MS4. Regulators could also be encouraged to use incentives to lessen the impact of land development (e.g., by reducing needless impervious cover within future developments).

Flow and related parameters like impervious cover should be considered for use as proxies for stormwater pollutant loading. These analogs for the traditional focus on the "discharge" of "pollutants" have great potential as a federal stormwater management tool because they provide specific and measurable targets, while at the same time they focus regulators on water degradation resulting from the increased volume as well as increased pollutant loadings in stormwater runoff. Without these more easily measured parameters for evaluating the contribution of various stormwater sources, regulators will continue to struggle with enormously expensive and potentially technically impossible attempts to determine the pollutant loading from individual dischargers or will rely too heavily on unaudited and largely ineffective self-reporting, self-policing, and paperwork enforcement.

Local building and zoning codes, and engineering standards and practices that guide the development of roads and utilities, frequently do not promote or allow the most

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innovative stormwater management. Fortunately, a variety of regulatory innovations—from more flexible and thoughtful zoning to using design review incentives to guide building codes to having separate ordinances for new versus infill development can be used to encourage more effective stormwater management. These are particularly important to promoting redevelopment in existing urban areas, which reduces the creation of new impervious areas and takes pressure off of the development of lands at the urban fringe (i.e., reduces sprawl).

EPA should provide more robust regulatory guidelines for state and local government efforts to regulate stormwater discharges. There are a number of ambiguities in the current federal stormwater program that complicate the ability of state and local governments to rigorously implement the program. EPA should issue clarifying guidance on several key areas. Among the areas most in need of additional federal direction are the identification of industrial dischargers that constitute the highest risk with regard to stormwater pollution and the types of permit requirements that should apply to these high-risk sources. EPA should also issue more detailed guidance on how state and local governments might prioritize monitoring and enforcement of the numerous and diverse stormwater sources within their purview. Finally, EPA should issue guidance on how stormwater permits could be drafted to produce more easily enforced requirements that enable oversight and enforcement not only by government officials, but also by citizens. Further detail is found in Chapter 6.

EPA should engage in much more vigilant regulatory oversight in the national licensing of products that contribute significantly to stormwater pollution. De-icing chemicals, materials used in brake linings, motor fuels, asphalt sealants, fertilizers, and a variety of other products should be examined for their potential contamination of stormwater. Currently, EPA does not apparently utilize its existing licensing authority to regulate these products in a way that minimizes their contribution to stormwater contamination. States can also enact restrictions on or tax the application of pesticides or even ban particular pesticides or other particularly toxic products. Austin, for example, has banned the use of coal-tar sealants within city boundaries. States and localities have also experimented with alternatives to road salt that are less environmentally toxic. These local efforts are important and could ultimately help motivate broader scale, federal restrictions on particular products.

The federal government should provide more financial support to state and local efforts to regulate stormwater. State and local governments do not have adequate financial support to implement the stormwater program in a rigorous way. At the very least, Congress should provide states with financial support for engaging in more meaningful regulation of stormwater discharges. EPA should also reassess its allocation of funds within the NPDES program. The agency has traditionally directed funds to focus on the reissuance of NPDES wastewater permits, while the present need is to advance the NPDES stormwater program because NPDES stormwater permittees outnumber wastewater permittees more than five fold, and the contribution of diffuse sources of pollution to degradation of the nation's waterbodies continues to increase.

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Chapter 3
Hydrologic, Geomorphic, and Biological Effects of Urbanization on Watersheds

A watershed is defined as the contributing drainage area connected to an outlet or waterbody of interest, for example a stream or river reach, lake, reservoir, or estuary. Watershed structure and composition include both naturally formed and constructed drainage networks, and both undisturbed areas and human dominated landscape elements. Therefore, the watershed is a natural geographic unit to address the cumulative impacts of urban stormwater. Urbanization has affected change to natural systems that tends to occur in the following sequence. First, land use and land cover are altered as vegetation and topsoil are removed to make way for agriculture or subsequently buildings, roads, and other urban infrastructure. These changes, and the introduction of a built drainage network, alter the hydrology of the local area, such that receiving waters in the affected watershed can experience radically different flow regimes than they did prior to urbanization. This altered hydrology, when combined with the introduction of pollutant sources that accompany urbanization (such as people, domesticated animals, industries, etc.), has led to water quality degradation of many urban streams.

This chapter first discusses the typical land-use and land-cover composition of urbanized watersheds. This is followed by a description of changes to the hydrologic and geomorphic framework of the watershed that result from urbanization, including altered runoff, streamflow mass transport, and stream-channel stability. The chapter then discusses the characteristics of stormwater runoff, including its quantity and quality from different land covers, as well as the characteristics of dry weather runoff. Finally, the effects of urbanization on aquatic ecosystems and human health are explored.

LAND-USE CHANGES

Land use has been described as the human modification of the natural environment into the built environment, such as fields, pastures, and settlements. Important characteristics of different land uses are the modified surface characteristics of the land and the activities that take place within that land use. From a stormwater viewpoint, land uses are usually differentiated by building density and comprised of residential, commercial, industrial, institutional, recreational, and open-space land uses, among others. Each of these land uses usually has distinct activities taking place within it that affect runoff quality. In addition, each land use is comprised of various amounts of surface land cover, such as roofs, roads, parking areas, and landscaped areas. The amount and type of each cover also affect the quality and quantity of runoff from urban areas. Changes in land use and in the land covers within the land uses associated with development and redevelopment are therefore important considerations when studying local receiving water problems, the sources of these problems within the watershed, and the stormwater control opportunities.

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Land-Use Definitions

Although there can be many classifications of residential land use, a crude and common categorization is to differentiate by density. High-density residential land use refers to urban single-family housing at a density of greater than 6 units per acre, including the house, driveway, yards, sidewalks, and streets. Medium density is between 2 and 6 units per acre, while low density refers to areas where the density is 0.7 to 2 units per acre. Another significant residential land use is multiple-family housing for three or more families and from one to three stories in height. These units may be adjoined up-and-down, side-by-side, or front-and-rear.

There are a variety of commercial land uses common in the United States. The strip commercial area includes those buildings for which the primary function is the sale of goods or services. This category includes some institutional lands found in commercial strips, such as post offices, court houses, and fire and police stations. This category does not include warehouses or buildings used for the manufacture of goods. Shopping centers are another common commercial area and have the unique distinction that the related parking lot that surrounds the buildings is at least 2.5 times the area of the building roof area. Office parks are a land use on which non-retail business takes place. The buildings are usually multi-storied and surrounded by larger areas of lawn and other landscaping. Finally, downtown central business districts are highly impervious areas of commercial and institutional land use.

Industrial areas can be differentiated by the intensity of the industry. For example, "manufacturing industrial" is a land use that encompasses those buildings and premises that are devoted to the manufacture of products, with many of the operations conducted outside, such as power plants, steel mills, and cement plants. Institutional areas include a variety of buildings, for example schools, churches, and hospitals and other medical facilities that provide patient overnight care.

Roads constitute a very important land use in terms of pollutant contributions. The "freeway" land use includes limited-access highways and the interchange areas, including any vegetated rights-of-ways. Finally, there are a variety of open-space categories, such as cemeteries, parks, and undeveloped land. Parks include outdoor recreational areas such as municipal playgrounds, botanical gardens, arboretums, golf courses, and natural areas. Undeveloped lands are private or publicly owned with no structures and have a complete vegetative cover. This includes vacant lots, transformer stations, radio and TV transmission areas, water towers, and railroad rights-of-way.

The preceding land-use descriptions are the traditional categories that make up the vast majority of the land in U.S. cities. However, there are emerging categories of land use, such as those espoused under the term New Urbanism, which combine several area types (such as commercial and high-density residential areas). Although land use can be broadly and generally categorized, local variations can be extremely important such that locally available land-use data and definitions should always be used. For example, local planning agencies typically do not separate the medium-density residential areas into subcategories. However, this may be necessary to represent different development trends that have occurred with time, and to represent newly emerging types of land uses for an area. Box 3-1 discusses the subtle influence that tree canopy could have on the residential land-use classification.

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BOX 3-1
The Role of Tree Cover in Residential Land Use

Figure 3-1 shows two medium-density residential neighborhoods, one older and one newer. Tree canopy is obviously different in each case, and it may have an effect on seasonal organic debris in an area and possibly on nutrient loads (although nutrient discharges appear to be more related to homeowner fertilizer applications). Increased tree canopy cover also has a theoretical benefit in reducing runoff quantities due to increased interception losses. In both cases, however, monitoring data to quantify these benefits are sparse. Xiao (1998) examined the effect urban tree cover had on the rainfall volume striking the ground in Sacramento, California. The results indicated that the type of tree or type of canopy cover affected the amount of rainfall reduction measured during a rain event, such that large broad-leafed evergreens and conifers reduced the rainfall that reached the ground by 36 percent, while medium-sized conifers and deciduous trees reduced the rainfall by 18 percent. Cochran (2008) compared the volume and intensity of rain that reached the ground in an open area (no canopy cover) versus two areas with intact canopy covers in Shelby County, Alabama, over a year. The sites were sufficiently close to each other to assume that the rainfall characteristics were the same in terms of the intensity and the variation of intensity and volume during the storm. Rainfall "throughfall" was reduced by about 13.5 percent during the spring and summer months when heavily wooded cover existed. The rainfall characteristics at the leafless tree sites (winter deciduous trees) were not significantly different from the parking lot control sites. In many locations around the county, very high winds are associated with severe storms, significantly decreasing the interception losses. Of course, mature trees are known to provide other benefits in urban areas, including shading to counteract stormwater temperature increases and massive root systems that help restore beneficial soil structure conditions. Additional research is needed to quantify the benefits of urban trees through a comprehensive monitoring program.

FIGURE 3-1 Two medium-density residential areas (no alleys); the area on the right is older.

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Trends in Urbanization

Researchers at Columbia University (de Sherbinin, 2002) state that 83 percent of the Earth's land surface has been affected by human settlements and activities, with the urbanized areas comprising about 4 percent of the total land use of the world. Urban areas are expanding world-wide, especially in developing countries. The United Nations Population Division estimates suggest that the world's population will become mostly urbanized by 2010, whereas only 37 percent of the world's population was urbanized in 1970. De Sherbinin (2002) concludes that although the extent of urban areas is not large when compared with other land uses (such as agriculture or forestry) their environmental impact is significant. Population densities in the cities are large, and their political, cultural, and economic influence is great. Most industrial activity is also located near cities. The influence of urban areas extends beyond their boundaries due to the need for large amounts of land for food and energy production, to generate raw materials for industry, for building water supplies, for obtaining other resources such as construction materials, and for recreational areas. One study estimated that the cities of Baltic Europe require from 500 to more than 1,000 times the urbanized land area (in the form of forests, agricultural, marine, and wetland areas) to supply their resources and to provide for waste disposal (de Sherbinin, 2002).

Currently, considerable effort is being spent investigating land-use changes world-wide and in the United States in support of global climate change research. The U.S. Geological Survey (USGS, 1999) has prepared many research reports describing these changes; Figure 3-2 shows the results for one study in the Chicago and Milwaukee areas, and Figure 3-3 shows the results for a study in the Chesapeake Bay area. These maps graphically show the dramatic rate of change in land use in these areas. The very large growth in urban areas during the 20 years between 1975 and 1995 is especially astonishing. By 1995, Milwaukee and Chicago's urbanized areas more than doubled in size from prior years. Even more rapid growth has occurred in the Washington, D.C.–Baltimore area.

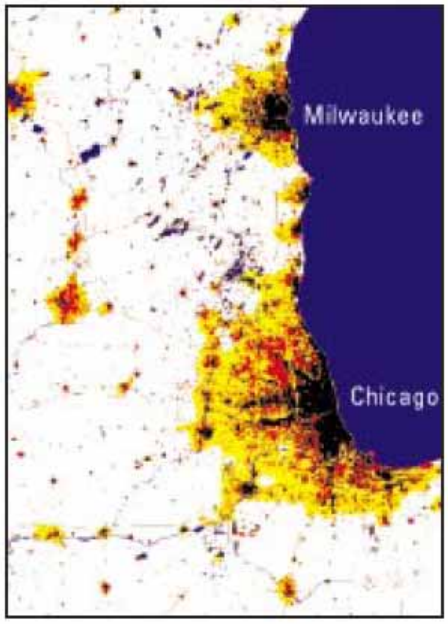

FIGURE 3-2 The extent of urban land in Chicago and Milwaukee in 1955 (black), 1975 (red), and 1995 (yellow). SOURCE: USGS (1999).

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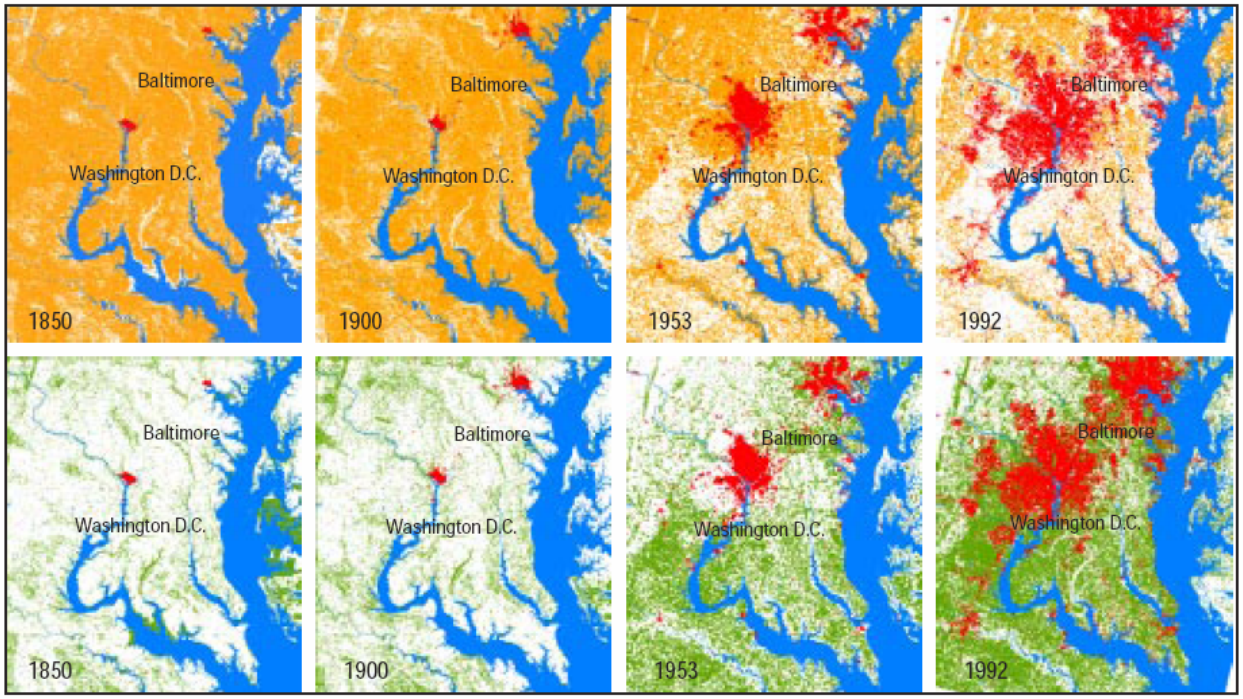

FIGURE 3-3 This series of maps compares changes in urban, agricultural, and forested lands in the Patuxent River watershed over the past 140 years. The top series shows the extent of urban areas (red) along with agriculture (gold), which was at its peak in the mid- to late 1800s. Since 1900, the amount of agricultural land has declined as urban and forested land (green) has increased. SOURCE: USGS (1999).

Many different metrics can be used to measure the rate of urbanization in the United States, including the number of housing starts and permits and the level of new U.S. development. The latter is tracked by the U.S. Department of Agriculture's (USDA) National Resources Inventory (USDA, 2000). The inventory, conducted every five years, covers all non-federal lands in the United States, which is 75 percent of the U.S. total land area. The inventory uses land-use information from about 800,000 statistically selected locations. From 1992 to 1997, about 2.2 million acres per year were converted from non-developed to developed status. According to the USDA (2000), the per capita developed land use (acres per person, a classical measure of urban sprawl) has increased in the United States between the years of 1982 and 1997 from about 0.43 to about 0.49 acres per person. The smallest amount of developed land used per person was for New York and Hawaii (0.15 acres), while the largest land consumption rate was for North Dakota, at about 10 times greater. Surprisingly, Los Angeles is the densest urban area in the country at 0.11 acres per person. The amount of urban sprawl is also directly proportionate to the population growth. According to Beck et al. (2003):

> In the 16 cities that grew in population by 10 percent or less between 1970 and 1990 (but whose population did not decline), developed area expanded 38 percent—more than in cities that declined in population but considerably less than in the cities where population increased more dramatically. Cities that grew in population by between 10 and 30 percent sprawled 54 percent on average. Cities that grew

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> between 31 and 50 percent sprawled 72 percent on average. Cities that grew in population by more than 50 percent sprawled on average 112 percent. These findings confirm the common sense, but often unacknowledged proposition, that there is a strong positive relationship between sprawl and population growth.

In most areas, the per capita use of developed land has increased, along with the population growth. However, even some cities that had no population growth or had negative growth, such as Detroit, still had large amounts of sprawl (increased amounts of developed land used per person), but usually much less than cities that had large population growth. Los Angeles actually had an 8 percent decreased rate of land consumption per resident during this period, but the city still experienced tremendous growth in land area due to its very large population growth. The additional 3.1 million residents in the Los Angeles area during this time resulted in the development of almost an additional 400 square miles.

Land-Cover Characteristics in Urban Areas

As an area urbanizes, the land cover changes from pre-existing rural surfaces, such as agricultural fields or forests, to a combination of different surface types. In municipal areas, land cover can be separated into various common categories—pictured and described in Box 3-2—that include roofs, roads, parking areas, storage areas, other paved areas, and landscaped or undeveloped areas.

Most attention is given to impervious cover, which can be easily quantified for different types of land development. Given the many types of land cover described in Box 3-2, impervious cover is composed of two principal components: building rooftops and the transportation system (roads, driveways, and parking lots). Compacted soils and unpaved parking areas and driveways also have "impervious" characteristics in that they severely hinder the infiltration of water, although they are not composed of pavement or roofing material. In terms of total impervious area, the transportation component often exceeds the rooftop component (Schueler, 1994). For example, in Olympia, Washington, where 11 residential multifamily and commercial areas were analyzed in detail, the areas associated with transportation-related uses comprised 63 to 70 percent of the total impervious cover (Wells, 1995). A significant portion of these impervious areas—mainly parking lots, driveways, and road shoulders—experience only minimal traffic activity. Most retail parking lots are sized to accommodate peak parking usage, which occurs only occasionally during the peak holiday shopping season, leaving most of the area unused for a majority of the time. On the other hand, many business and school parking areas are used to their full capacity nearly every work day and during the school year. Other differences at parking areas relate to the turnover of parking during the day. Parked vehicles in business and school lots are mostly stationary throughout the work and school hours. The lighter traffic in these areas results in less vehicle-associated pollutant deposition and less surface wear in comparison to the greater parking turnover and larger traffic volumes in retail areas (Brattebo and Booth, 2003).

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BOX 3-2
Land Cover in Urban Areas

For any given land use, there is a range of land covers that are typical. Common land covers are described below, along with some indication of their contribution to stormwater runoff and their pollutant-generating ability.

Roofs. These are usually either flat or pitched, as both have significantly different runoff responses. Flat roofs can have about 5 to 10 mm of detention storage while pitched roofs have very little detention storage. Roofing materials are also usually quite different for these types of roofs, further affecting runoff quality. In addition, roof flashing and roof gutters may be major sources of heavy metals if made of galvanized metal or copper. Directly connected roofs have their roof drains efficiently connected to the drainage system, such as direct connections to the storm drainage itself or draining to driveways that lead to the drainage system. These directly connected roofs have much more of their runoff waters reaching the receiving waters than do partially connected roofs, which drain to pervious areas.

A directly connected roof drain

A disconnected roof drain (drains to pervious area)

Parking Areas. These can be asphalt or concrete paved (impervious surface) or unpaved (traditionally considered a pervious surface) and are either directly connected or drain to adjacent pervious areas. Areas that have rapid turnover of parked cars throughout the day likely have greater levels of contamination due to the frequent starting of the vehicles, an expected major source of pavement pollutants. Unpaved parking areas actually should be considered impervious surfaces, as the compacted surface does not allow any infiltration of runoff. Besides automobile activity in the parking areas, other associated activities contribute to contamination. For example, parked cars in disrepair awaiting service can contribute to parking area runoff contamination. In addition, maintenance of the pavement surface, such as coal-tar seal coating, can be significant sources of polycyclic aromatic hydrocarbons (PAHs) to the runoff.

Paved parking area with frequent automobile movement

Contamination of paved parking areas due to commercial activities

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BOX 3-2 Continued

Storage Areas. These can also be paved, unpaved, directly connected, or drained to pervious areas. As with parking areas, unpaved storage areas should not be considered pervious surfaces because the compacted material effectively hinders infiltration. Detention storage runoff losses from unpaved storage areas can be significant. In storage areas (especially in commercial and industrial land uses), activities in the area can have significant effects on runoff quality.

Contaminated paved storage area at vehicle junk yard

Heavy equipment storage area on concrete surface

Streets. Streets in municipal areas are usually paved and directly connected to the storm drainage system. In municipal areas, streets constitute a significant percentage of all impervious surfaces and runoff flows. Features that affect the quality of runoff from streets include the varying amounts of traffic on different roads and the amount and type of roadside vegetation. Large seasonal phosphorus loads can occur from residential roads in heavily wooded areas, for example.

Wide arterial street with little roadside vegetation

Narrow residential street with substantial vegetation

Other Paved Areas. Other paved areas in municipal regions include driveways, playgrounds, and sidewalks. Depending on their slopes and local grading, these areas may drain directly to the drainage system or to adjacent pervious areas. In most cases, the runoff from these areas contributes little to the overall runoff for an area, and the runoff quality is of relatively better quality than from the other "hard" surfaces.

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BOX 3-2 Continued

Landscaped and Turf Areas. Although these are some of the only true pervious surfaces in municipal areas, disturbed urban soils can be severely compacted, with much more reduced infiltration rates than are assumed for undisturbed regional soils. Besides the usually greater than expected quantities of runoff of pervious surfaces in urban areas, they can also contribute high concentrations of various pollutants. In areas with high rain intensities, erosion of sediment can be high from pervious areas, resulting in much higher concentrations of total suspended solids (TSS) than from paved areas. Also, landscaping chemicals, including fertilizers and pesticides, can be transported from landscaped urban areas. Undeveloped woods in urban areas can have close to natural runoff conditions, but many parks and other open-space areas usually have degraded runoff compared to natural conditions. Turf grass has unique characteristics compared to other landscaped areas in that the soil structure is usually more severely degraded compared to natural conditions. The normally shallower root systems are not as effective in restoring compacted soils and they can remain compacted due to some activities (pathways, parked cars, playing fields, etc.) that do not occur on areas planted with shrubs and trees.

Soil erosion from turf areas with fine-grained soils during periods of high rain intensities

Undeveloped Areas. Undeveloped areas in otherwise urban locations differ from natural areas. In many situations, they can be previously disturbed (cleared and graded) areas that have not been sold or developed. They may be overgrown with various local vegetation types that thrive in disturbed locations. In other situations, undeveloped areas may be small segments of natural areas that have not been disturbed or revegetated. In this case, their stormwater characteristics may approach natural conditions but still be degraded due to adjacent activities and atmospheric deposition.

SOURCE: Pitt and Voorhees (1995, 2002).

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As described in Box 1-1, impervious cover is broken down into two main categories: directly connected impervious areas (or effective impervious area) and non-directly connected (disconnected) impervious areas (Sutherland, 2000; Gregory et al., 2005) (although it is recognized that these two states are end-members of a range of conditions). Directly connected impervious area includes impervious surfaces which drain directly to the sealed drainage system without flowing appreciable distances over pervious surfaces (usually a flow length of less than 5 to 20 feet over pervious surfaces, depending on soil and slope characteristics and the amount of runoff). Those areas are the most important component of stormwater runoff quantity and quality problems. Approximately 80 percent of directly connected impervious areas are associated with vehicle use such as streets, driveways, and parking (Heaney, 2000).

Values of imperviousness can vary significantly according to the method used to estimate the impervious cover. In a detailed analysis of urban imperviousness in Boulder, Colorado, Lee and Heaney (2003) found that hydrologic modeling of the study area resulted in large variations (265 percent difference) in the calculations of peak discharge when impervious surface areas were determined using different methods. They concluded that the main focus should be on effective impervious area (EIA) when examining the effects of urbanization on stormwater quantity and quality.

Runoff from disconnected impervious areas can be spread over pervious surfaces as sheet flow and given the opportunity to infiltrate before reaching the drainage system. Therefore, there can be a substantial reduction in the runoff volume and a delay in the remaining runoff entering the storm drainage collection system, depending on the soil infiltration rate, the depth of the flow, and the available flow length. Examples of disconnected impervious surfaces are rooftops that discharge into lawns, streets with swales, and parking lots with runoff directed to adjacent open space or swales. From a hydrologic point of view, road-related imperviousness usually exerts a larger impact than rooftop-related imperviousness, because roadways are usually directly connected whereas roofs can be disconnected (Schueler, 1994).

Methods for Determining Land Use and Land Cover

Historically, land-use and land-cover information was acquired by a combination of field measurements and aerial photographic analyses—methods that required intensive interpretation and cross validation to guarantee that the analyst's interpretations were reliable (Goetz et al., 2003). Figure 3-4 is an example of a high-resolution panchromatic aerial photograph that was taken from an airplane in Toronto and used for measurements of urban surfaces (Pitt and McLean, 1986). Most recently, satellite images have become available at high spatial resolution for many areas (<1 to 5 m resolution) and have the advantage of digital multi-spectral information more complete than even that provided by digital orthophotographs. Minnesota has one of the longest records (over 20 years) of continuously recorded statistics on land cover and impervious surfaces derived from satellite images—information which has been incorporated into the Minnesota Statewide Conservation and Preservation Plan. Some of the remaining problems to be overcome with satellite imagery include difficulties in obtaining consistent sequential acquisition dates, intensive computer processing time requirements, and large computer storage space requirements to store massive amounts of image information.

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FIGURE 3-4 Example of a high-resolution panchromatic aerial photograph of an industrial area used for measurements of urban surfaces. SOURCE: Pitt and McLean (1986).

The recommended approach for conducting a survey of land uses and development characteristics (land cover and activities) for an area is to use both aerial photography and site surveys. Aerial photography has improved greatly in recent years, but it is still not suitable for obtaining all the information needed for developing a comprehensive stormwater management plan. Initially, aerial photos should be used to identify the locations and extents of the various land uses in the study area. Neighborhoods representing homogenous land uses should then be identified for site surveys. Usually, about 10 to 15 neighborhoods for each land use are sufficient for a community being studied (Burton and Pitt, 2002). After the field surveys are conducted, the aerials are again used to measure the actual areas associated with land surface cover. This information can be used with field survey data to separate the surfaces into the appropriate categories for analyses and modeling.

Box 3-3 presents a detailed study of land cover for several land uses in the southern United States using satellite imagery and ground surveys (Bochis, 2007; Bochis et al., 2008). The results presented here have been found to be broadly similar to other areas studied in the United States, although few studies have been as detailed, and there are likely to be regional differences.

The general conclusion of many land-use and land-cover studies is that in urban areas, the amount of impervious surfaces has increased since the early years of the 20th century because of the tendency toward increased automobile use and bigger houses, which is associated with an increase in the facilities necessary to accommodate them (wider streets, more parking lots, and garages). As shown in later sections of this report, the construction of impervious surfaces leads to multiple impacts on stream systems. Therefore, future development plans and water resource protection programs should consider reducing impervious cover in the potential expansion of communities. Wells (1995), Booth (2000), Stone (2004), and Gregory et al. (2005) show that reducing the size and dimensions of residential parcels, promoting cluster developments (clustered medium-density residential areas in conjunction with open space, instead of large

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BOX 3-3
Land Use and Land Cover for the Little Shades Creek Watershed

Data collected by Bochis-Micu and Pitt (2005) and Bochis (2007) for the Little Shades Creek watershed near Birmingham, Alabama, were acquired using IKONOS satellite imagery (provided by the Jefferson County Storm Water Management Authority) as an alternative to classical aerial photography to map the characteristics of the land uses in the monitored watershed areas, supplemented with verified ground truth surveys. IKONOS is the first commercially owned satellite that provides 1-m-resolution panchromatic image data and 4-m multi-spectral imagery (Goetz et al., 2003).

This project was conducted to evaluate the effects of variable site conditions associated with each land-use category. About 12 homogeneous neighborhoods were investigated in each of the 16 major land uses in this 2,500-hectare watershed. Detailed land-cover measurements were made using a variety of techniques, as listed above, including field surveys for small details that were not visible with remote sensing tools (such as roof drain connectiveness, pavement texture, and landscaping maintenance practices). Each of these individual neighborhoods was individually modeled to investigate the resultant variability in runoff volume and pollutant discharges. These were statistically evaluated to determine if the land-use categories properly stratified these data by explaining significant fractions of the variability. Bochis-Micu and Pitt (2005) and Bochis (2007) concluded that land-use categories were an appropriate surrogate that can be used to describe the observed combinations of land surfaces. However, proper stormwater modeling should examine the specific land surfaces in each land-use category in order to better understand the likely sources of the pollutants and the effectiveness of candidate stormwater control measures (SCMs).

This watershed has an overall impervious cover of about 35 percent, of which about 25 percent is directly connected to the drainage system. Table 3-1 shows the average land covers for each of the surveyed land uses, along with the major source areas in each of the directly connected and disconnected impervious and pervious surface categories. The impervious covers include streets, driveways, parking, playgrounds, roofs, walkways, and storage areas. The directly connected areas are indicated as “connected” or “draining to impervious” and do not include the pervious area or the impervious areas that drain to pervious areas. As expected, the land uses with the least impervious cover are open space (vacant land, cemeteries, golf courses) and low-density residential, and the land uses with the largest impervious covers are commercial areas, followed by industrial areas. For a typical high-density residential land use in this region (having 15 or more units per hectare), the major land cover was found to be landscaped areas, subdivided into front- and backyard categories, while 25 percent of this land-use area is covered by impervious surfaces broken down into three major subcategories: roofs, streets, and driveways. The subareas making up each land use show expected trends, with roofs and streets being the predominant directly connected impervious covers in residential areas, and parking and storage areas also being important in commercial and industrial areas.

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BOX 3-3 Continued

TABLE 3-1 Little Shades Creek Watershed Land Cover Information (percent and the predominant land cover)

Land Use	Directly Connected Impervious Cover (%)	Disconnected Impervious Cover (%)	Pervious Cover (%)
High-Density Residential	14 (streets and roof)	10 (roofs)	76 (front and rear landscaping)
Medium-Density Residential (<1960 to 1980)	11 (streets and roofs)	8 (roofs)	81 (front and rear landscaping)
Medium-Density Residential (>1980)	14 (streets and roofs)	5 (roofs)	80 (front and rear landscaping)
Low-Density Residential	6 (streets)	4 (roofs)	89 (front and rear landscaping)
Apartments	21 (streets and parking)	22 (roofs)	58 (front and rear landscaping)
Multiple Families	28 (roofs, parking , and streets)	7 (roofs)	65 (front and rear landscaping)
Offices	59 (parking, streets, and roofs)	3 (parking)	39 (front and rear landscaping)
Shopping Centers	64 (parking, roofs, and streets)	4 (roofs)	31 (front landscaping)
Schools	16 (roofs and parking)	20 (playground)	64 (front and rear landscaping, large turf)
Churches	53 (parking and streets)	7 (parking)	40 (front landscaping)
Industrial	39 (storage, parking, and streets)	18 (storage and roofs)	44 (front and rear landscaping)
Parks	32 (streets and parking)	33 (playground)	34 (large turf and undeveloped)
Cemeteries	7 (streets)	15 (parking)	78 (large turf)
Golf Courses	2 (streets)	4 (roofs)	95 (large turf)
Vacant	5 (streets)	1 (driveways)	94 (undeveloped and large turf)

SOURCE: Bochis-Micu and Pitt (2005) and Bochis (2007). Reprinted, with permission, from Bochis (2007). Copyright 2007 by Celina Bochis.

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tracts of low-density areas), building taller buildings, reducing the residential street width (local access streets), narrowing the width and/or building one-side sidewalks, reducing the size of paved parking areas to reflect the average parking needs instead of peak needs, and using permeable pavement for intermittent/overflow parking can reduce the traditional impervious cover in communities by 10 to 50 percent. Many of these benefits can also be met by paying better attention to how the pavement and roof areas are connected to the drainage system. Impervious surfaces that are "disconnected" by allowing their drainage water to flow to adjacent landscaped areas can result in reduced runoff quantities.

HYDROLOGIC AND GEOMORPHIC CHANGES

The watershed provides an organizing framework for the management of stormwater because it determines the natural patterns of water flow as well as the constituent sediment, nutrient, and pollutant loads. In undeveloped watersheds, hillslope hydrologic flow-path systems co-evolve with microclimate, soils, and vegetation to form topographic patterns within which ecosystems are spatially arranged and adjusted to the long-term patterns of water, energy, and nutrient availability. The landforms that comprise the watershed include the network patterns of streams, rivers, and their associated riparian zones and floodplains, as well as component freshwater lakes, reservoirs, wetlands, and estuaries.

This section starts with a discussion of precipitation measurement and characteristics before turning to the typical changes in hydrology and geomorphology of the watershed brought on by urbanization. In both the terrestrial and aquatic phases, retention and residence time of sediment and solutes decreases with increasing flow volume and velocity. This results in relatively high retention and low export of water and nutrients in undeveloped watersheds compared to decreasing retention and greater pollutant export in disturbed or developed systems.

The Storm in Stormwater

The magnitude and frequency of stormwater discharges are not just determined by rainfall. Instead, they are the combined product of storm and inter-storm characteristics, land use, the natural and built drainage system, and any stormwater control measures (SCMs) that have been implemented. The total volume and peak discharge of runoff, as well as the mobilization and transport of pollutants, are dependent on all aspects of the storm magnitude, catchment antecedent moisture conditions, and the interstorm period. Therefore, information on the frequency distribution of storm events and properties is an important aspect of understanding the distribution of pollutant concentrations and loads in stormwater discharges. In northern climates, runoff production from precipitation can be significantly delayed by the accumulation, ripening, and melt of snowpacks, such that much of the annual load of certain pollutants may be mobilized in peak flow from snowmelt events. Therefore, measurement of precipitation and potential accumulation in both liquid and solid form is critical for stormwater assessment.

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Precipitation Measurements

Any given storm is characterized by the storm's total rainfall (depth), its duration, and the average and peak intensity. A *storm hyetograph* depicts measured precipitation depth (or intensity) at a precipitation gauge as a function of time; an example is shown in Figure 3-5. This figure illustrates the typical high degree of variability of precipitation over the total duration of a storm. In this example, the total storm depth is 50.9 mm, the duration is 19 hours, and the peak intensity is 0.56 mm/minute (peak depth of 2.79 mm divided by the measurement increment of 5 minutes). The average intensity is 0.045 mm/minute, quite a bit lower than the peak intensity, since the storm duration is punctuated by periods of low and no measurable precipitation.

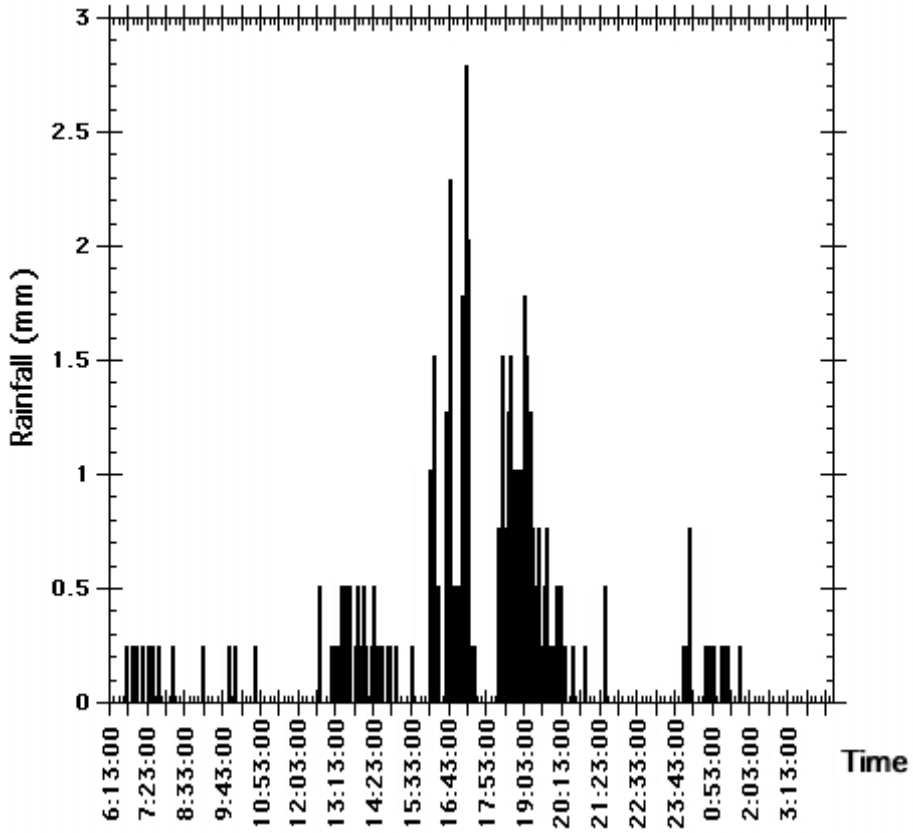

FIGURE 3-5 Example of a storm hyetograph at location RG2, September 20–21, 2001, Valley Creek watershed, Chester County, Pennsylvania. The time increment of measurement is 5 minutes, while the entire duration of this storm is about 16 hours.

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In addition to measurements of individual storm events, precipitation data are routinely collected for longer time periods and compiled and analyzed annually when trying to understand local rainfall patterns and their impact on baseflow, water quality, and infrastructure design. Figure 3-6 shows the rainfall during 2007 at both humid (Baltimore) and arid (Phoenix) locations. Especially apparent in the Baltimore data is the fact that the majority of storm events are less than 20 mm in depth.

Several networks of precipitation gauges are available in the United States; gauge data are available online from the National Climatic Data Center (NCDC) (http://ncdc.nws.noaa.gov). High-resolution precipitation data (i.e., with measurement intervals of an hour or less) are typically not recorded except at primary weather service meteorological stations, while daily precipitation records are more extensively collected and available through the Cooperative Weather Observer Program (http://www.nws.noaa.gov/om/coop/). This distinction is important to stormwater managers because most stormwater applications require short-duration measurements or model results (minutes to hours). Fortunately, a combination of precipitation gauges and precipitation radar estimates are available to estimate precipitation depth and duration, as well as additional methods to estimate snowfall and snowpack water equivalent depth and conditions. (A thorough description of precipitation measurement by radar is given by Krajewski and Smith [2001]). While most of the conterminous United States is covered by NEXRAD radar for estimation of high-temporal-resolution precipitation at current resolutions of ~4 km, the radar backscatter information requires calibration and correction with precipitation gauge data, and satellite estimates of precipitation are generally not sufficiently reliable for stormwater applications. It goes without saying that the measurement, quality assurance, and maintenance of long-term precipitation records are both vital and nontrivial to stormwater management.

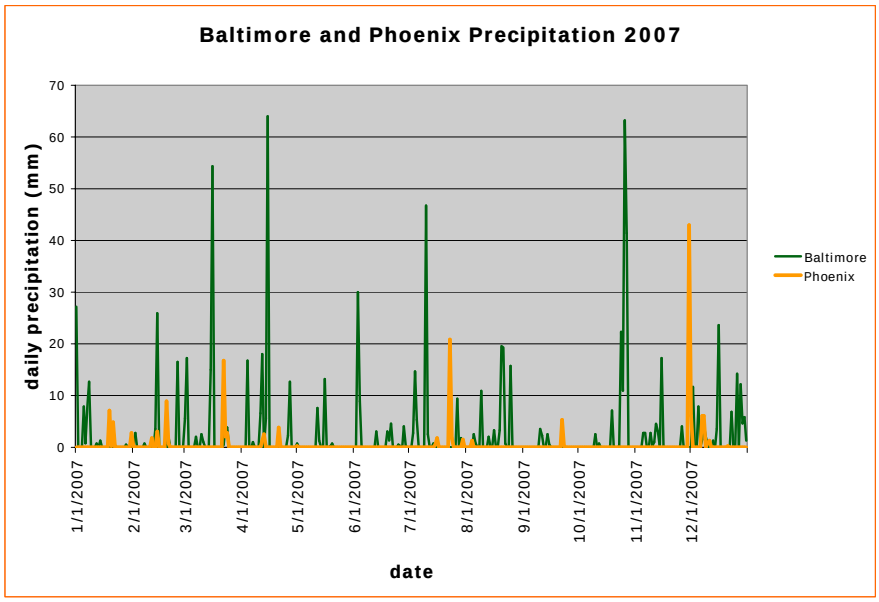

FIGURE 3-6 Daily precipitation totals for the Baltimore-Washington and Phoenix airports for 2007.

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Precipitation Statistics

The basic characterization of precipitation is by depth-duration-frequency curves, which describe the return period, recurrence interval, and exceedance probability (terms all denoting frequency) of different precipitation intensities (depths) over different durations. The methodology for determining the curves is described in Box 3-4. Precipitation durations of interest in stormwater management range from a few minutes (important for determining peak discharge from small urban drainage areas) to a year (where the interest is in the total annual volume of runoff production). As an example, one might be interested in the return period of the 1-inch, 1-hour event, or the 1-inch, 24-hour event; the latter would have a much shorter return period, because accumulating an inch of rain over a day is much more common than accumulating the same amount over just an hour.

The National Weather Service has developed an online utility to estimate the return period for a range of depth–duration events for any place in the conterminous United States (http://hdsc.nws.noaa.gov/hdsc/pfds/). Figures 3-7 and 3-8 show examples of precipitation depth-duration-frequency curves for a humid location (Baltimore, Maryland) and an arid site (Phoenix, Arizona). As an illustration of the climatic influence on the depth-duration-frequency curves, the 2-year, 1-hour storm is associated with a depth of 1.2 inches of precipitation in Baltimore, whereas this same recurrence interval and duration are associated with a depth of only 0.6 inch of precipitation in Phoenix. Durations from 5 minutes to one day are shown because

BOX 3-4
Determining Depth-Duration-Frequency Curves

Depth-duration-frequency curves are developed from precipitation records using either annual maximum data series or annual exceedance data series. Annual maximum data series are calculated by extracting the annual maximum precipitation depths of a chosen duration from a record. In cases where there are only a few years of data available (less than 20 to 25 years), then an annual exceedance series (a type of "partial duration series") for each storm duration can be calculated, where N largest values from N years are chosen. An annual maximum series excludes other extreme values of record that may occur in the same year. For example, the second highest value on record at an observing station may occur in the same year as the highest value on record but will not be included in the annual maximum series. The design precipitation depths determined from the annual exceedance series can be adjusted to match those derived from an annual maximum series using empirical factors (Chow et al., 1988; NOAA Atlas data series, see http://www.weather.gov/oh/hdsc/currentpf.htm, e.g., Bonnin et al., 2006). Hydrologic frequency analysis is then applied the data series to determine desired return periods by fitting a probability distribution to the data to determine the return periods[1] of interest. The process is repeated for other chosen storm durations.

[1]Analysis of annual maximum series produces estimates of the average period between years when a particular value is exceeded ("average recurrence interval"). Analysis of partial duration (annual exceedance) series gives the average period between cases of a particular magnitude ("annual exceedance probability"). The two results are numerically similar at rarer average recurrence intervals but differ at shorter average recurrence intervals (below about 20 years). NOAA (e.g., Bonnin et al., 2006) notes that the use of the terminology "average recurrence interval" and "annual exceedance probability" typically reflects the analysis of the two different series, but that sometimes the term "average recurrence interval" is used as a general term for ease of reference.

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this is the range typically used in the design of stormwater management facilities. The shorter durations provide expected magnitude and frequency for brief but significant precipitation intensity peaks that can mobilize and transport large amounts of pollutants and erode soil, and they are used in high-resolution stormwater models. More commonly, however, stormwater regulations are written for 24-hour durations at 2-, 10-, 25-, 50-, or 100-year recurrence intervals.

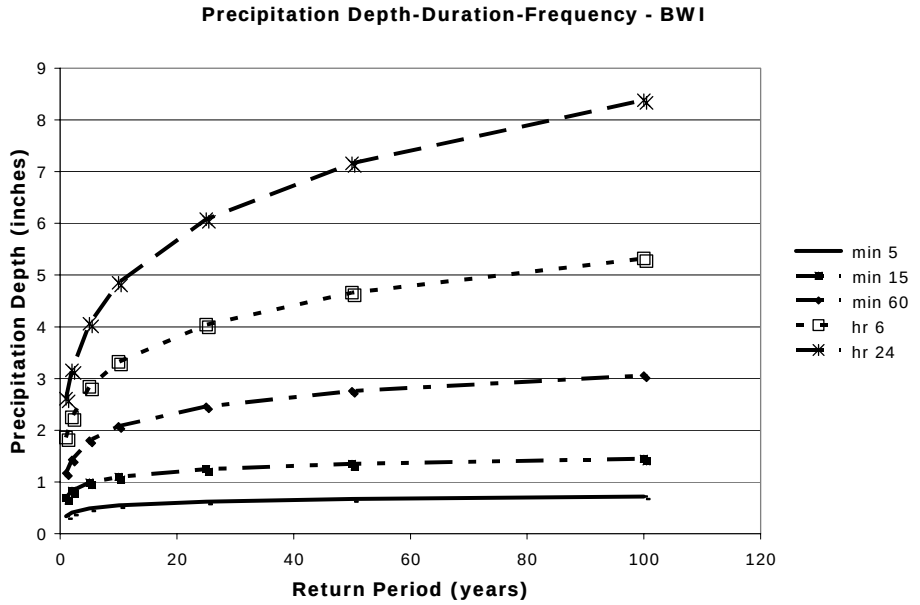

FIGURE 3-7 Depth-duration-frequency curves for Baltimore, Maryland.

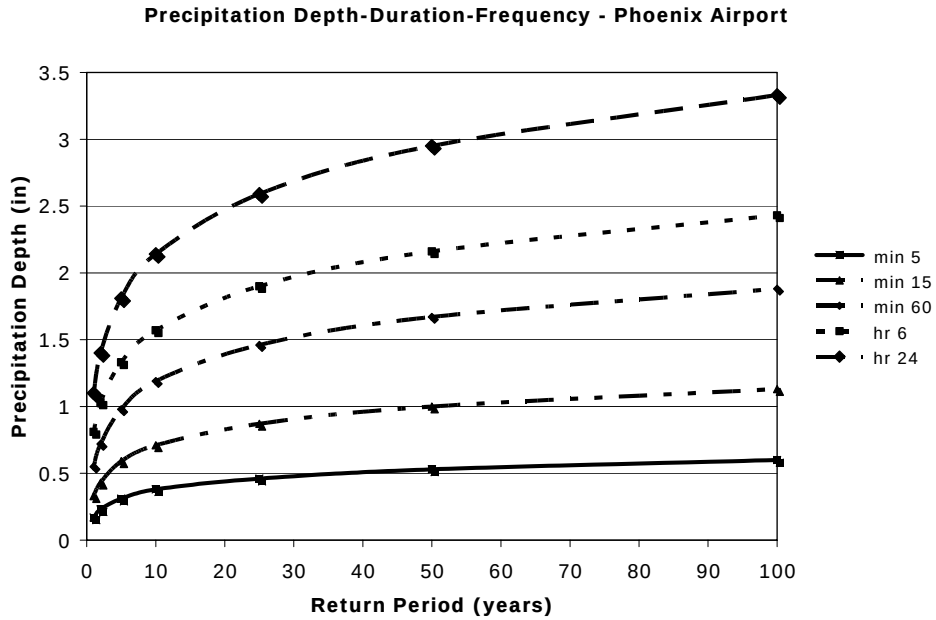

FIGURE 3-8 Depth-duration-frequency curves for Phoenix, Arizona.

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Because storm magnitudes and frequencies vary by climatic region, it is reasonable to expect them to change during recurring climate events (e.g., El Niño) or over the long term by climate change. Alteration in convective precipitation by major urban centers has been documented for some time (Huff and Changnon, 1973). Some evidence exists that precipitation regimes are shifting systematically toward an increase in more intense rainfall events, which is consistent with modeled projections of global climate change increases in hydrologic extremes. Kunkel et al. (1999) analyzed precipitation data from 1,295 weather stations from 1931 to 1996 across the contiguous United States and found that storms with extreme levels of precipitation have increased in frequency. The analysis considered short-duration events (1, 3, and 7 days) of 1-year and 5-year return intervals. A linear trend analysis using Kendall's slope estimator statistic indicated that the overall trend in 7-day, 1-yr events for the conterminous United States is upward at a rate of about 3 percent per decade for 1931 to 1996; the upward trend in 7-day, 5-year events is about 4 percent per decade. These two time series are shown in Figure 3-9. An increased frequency of intense precipitation events will shift depth-frequency-duration curves for a given location, with a given return period being associated with a more intense event. Alternatively, the return period for a given intensity (or depth) of an event will be reduced if the event is occurring more frequently. In light of climate change, depth-duration-frequency curves will need to be updated regularly in order to ensure that stormwater management facilities are not underdesigned for an increasing intensity of precipitation. Additional implications of climate change for stormwater management are discussed in Box 3-5.

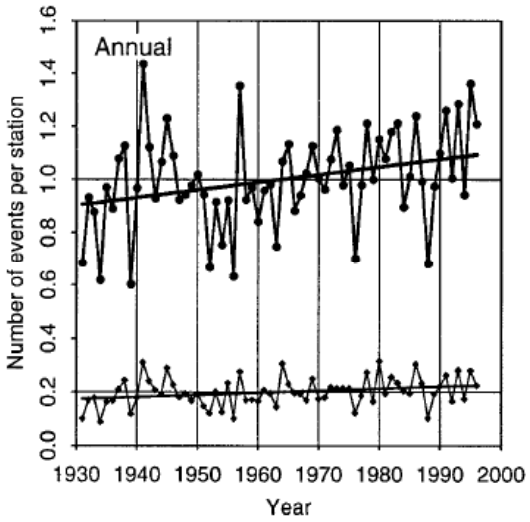

FIGURE 3-9 Nationally averaged annual U.S. time series of the number of precipitation events of 7-day duration exceeding 1-year (dots) and 5-year (diamonds) recurrence intervals. SOURCE: Reprinted, with permission, from Kunkel et al. (1999). Copyright 1999 by American Meteorological Society.

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BOX 3-5
Climate Change and Stormwater Management

An ongoing report series issued by the U.S. Climate Change Science Program and the Subcommittee on Global Change Research summarizes the evidence for climate change to date and expected impacts of climate change, including impacts on the water resources sector (http://www.climatescience.gov/). According to the Intergovernmental Panel on Climate Change (IPCC 2007), annual precipitation will likely increase in the northeastern United States and will likely decrease in the southwestern United States over the next 100 years. In the western United States, precipitation increases are projected during the winter, whereas decreases are projected for the summer. As temperatures warm, precipitation will increasingly fall as rain rather than snow, and snow season length and snow depth are very likely to decrease in most of the country. More extreme precipitation events are also projected, which, when coupled with an anticipated increase in rain-on-snow events, would contribute to more severe flooding due to increases in extreme stormwater runoff.

The predictions for increases in the intensity and frequency of extreme events have significant implications for future stormwater management. First, many of the design standards currently in use will need to be revised, since they are based on historical data. For example, depth-duration-frequency curves used for design storm data will need to be updated, because the magnitude of the design storms will change. Even with revised design standards, in light of future uncertainty, new SCMs will need to be designed conservatively to allow for additional storage that will be required for regions with predicted trends in increased precipitation. In addition, existing SCM designs based on old standards may prove to be undersized in the future. Implementation of a monitoring program to check existing SCM inflows against original design inflows may be prudent to aid in judging whether retrofit of existing facilities or additional stormwater infrastructure is needed.

Design Storms

Given that only daily precipitation records are widely available, but short-duration data are required for stormwater analysis and prediction, *design storms* have been developed for the different regions of the United States by different state and federal resource agencies. A *design storm* is a specified temporal pattern of rainfall at a location, created using an overall storm duration and frequency relevant to the design problem at hand. Examples of design storms include the 24-hour, 100-year event for flood control and the 24-hour, 2-year event for channel protection. The magnitude of the design storm can be derived from data at a single gauge, or from synthesized regional data published by state or federal agencies. The simplest form of a design storm is a triangular hyetograph where the base is the duration and the height is adjusted so that the area under the curve equals the total precipitation. In instances where the hyetograph is to be used to estimate sequences of shorter duration intensities (i.e., minutes to a few hours) within larger duration events, depth-duration-frequency curve data can be used to synthesize a design storm hyetograph (see Chow et al., 1988). An example design storm for the 100-year storm event for St. Louis based on NOAA Atlas 14 depth-duration-frequency data is shown in Figure 3-10.

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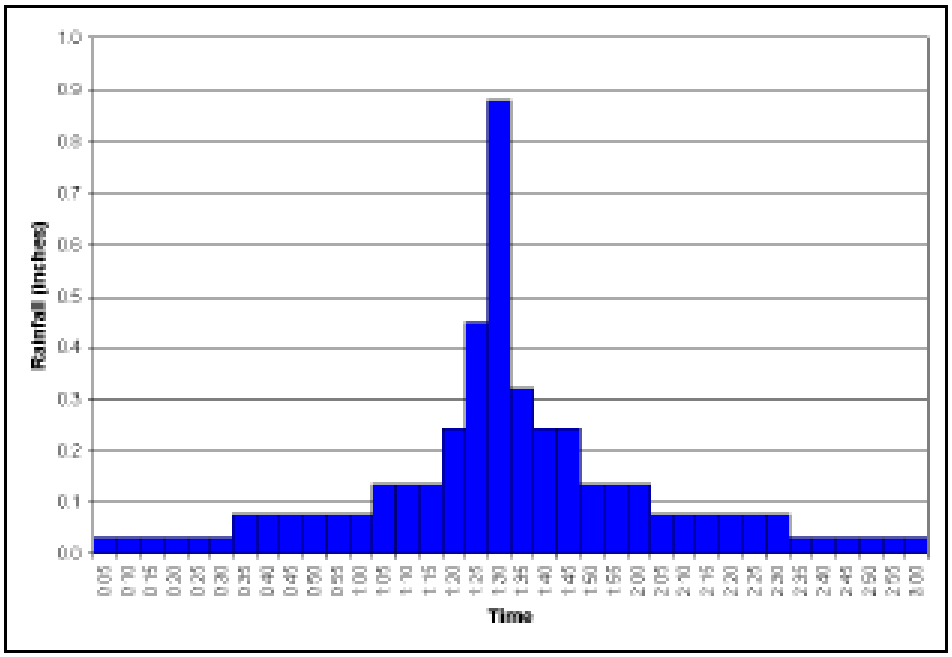

FIGURE 3-10 Hundred-year design storm for St. Louis based on NOAA Atlas 14 data.

Conversion of Precipitation to Runoff

Dynamics of Watershed Flowpaths

Precipitation falling on the land surface is subject to evaporative loss to the atmosphere by vegetation canopy and leaf litter interception, evaporation directly from standing water on the surface and upper soil layers or impervious surfaces, and later transpiration through root uptake by vascular plants. Snowpack is also subject to sublimation (conversion of snow or ice directly to vapor), which results in the loss of a portion of the snow prior to melt. The rate of evaporative loss depends on local weather conditions (temperature, humidity, wind speed, solar radiation) and the rate and duration of precipitation. Precipitation (or snowmelt) in excess of interception and potential evaporative loss rates is then partitioned into infiltration and direct runoff.[1]

There is a gradation of flowpaths transporting water, sediment, and solutes through a watershed, ranging from rapid surface flowpaths through generally slower subsurface flowpaths. Residence times generally increase from surface to subsurface flowpaths, with rapid surface flow

[1] The term *runoff* is often used in two senses. For a given precipitation event, direct *storm runoff* refers to the rainfall (minus losses) that is shed by the landscape to a receiving waterbody. In an area of 100 percent imperviousness, the runoff nearly equals the rainfall (especially for larger storms). Over greater time and space scales, *surface water runoff* refers to streamflow passing through the outlet of a catchment, including base flow from groundwater that has entered the stream channel. The raw units of runoff in either case are volume per time, but the volumetric flowrate (discharge) is often divided by contributing area to express runoff in units of depth per time. In this way, unit runoff rates from various-sized watersheds can be compared to account for differences other than the contributing area.

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providing the major contribution to flood flow while subsurface flowpaths contribute to longer-term patterns of surface wetness. Watershed characteristics that influence the relative dominance of surface versus subsurface flowpaths include infiltration capacity as affected by land cover, soil properties, and macropores; subsurface structure or soil horizons with varying conductivity; antecedent soil moisture and groundwater levels; and the precipitation duration and intensity for a particular storm.

The distribution and activity of flowpaths result in changing patterns of soil moisture and groundwater depth, which result in patterns of soil properties, vegetation, and microbial communities. These ecosystem patterns, in turn, can have strong influences on the hydraulics of flow and biogeochemical transformations within the flowpaths, with important implications for sources, sinks, and transport of solutes and sediment in the watershed. Riparian areas, wetlands, and the benthos of streams and waterbodies are nodes of interaction between surface and groundwater flowpaths, yielding reactive environments in which "hot spots" of biogeochemical transformation develop (McClain et al., 2003). Thus, any alteration of surface and subsurface hydrologic flowpaths, for example due to urbanization, not only alters the properties of soil and vegetation canopy but also reforms the ecosystem distribution of biogeochemical transformations.

Runoff Measurements

Surface water runoff for a given area is measured by dividing the discharge at a given point in the stream channel by the contributing watershed area. The basic variables describing channel hydraulics include width, mean depth, slope, roughness, and velocity. Channel discharge is the product of width, depth, and velocity and is typically estimated by either directly measuring each of these three components, or by development of a rating curve of measured discharge as a function of water depth, or stage relative to a datum, of the channel that is more easily estimated by a staff gauge or pressure transducer. The establishment of a gauging station to measure discharge typically requires a stable cross section so that stage can be uniquely related to discharge. Maintenance of reliable, long-term gauge sites is expensive and requires periodic remeasurement to update rating curves, as well as to remove temporary obstructions that may raise stage relative to unobstructed conditions.

Most stream gauging in the United States is carried out by the USGS, and can be found on-line at http://waterdata.usgs.gov/nwis. Recent reviews of standard methods of stream gauging and the status of the USGS stream gauging network are given by the USGS (1998) and the National Research Council (NRC, 2004). A major concern is the overall decline in the number of active gauges, particularly long-term gauges, as well as the representativeness of the stream gauge network relative to the needs of stormwater permitting. For example, restored streams typically lack any gauged streamflow or water quality information prior to or following restoration. This makes it very difficult to assess both the potential for successful restoration and whether project goals are met.

Support of existing and development of new gauges is often in collaboration through a co-funding mechanism with other agencies. Municipal co-funding for stations in support of National Pollutant Discharge Elimination System (NPDES) permitting is common and has tended to shift the concentration of active gauges toward more urban areas. Note that the USGS river monitoring system was originally designed for resource inventory, and therefore did not

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originally sample many headwater streams, particularly intermittent and ephemeral channels that are typically most proximal to stormwater discharges. While this is beginning to change with municipal co-funding, headwater streams are still underrepresented in the National Water Information System relative to their ecological significance.

Reliable records for stream discharge are vital because the frequency distribution and temporal trends of flows must be known to evaluate long-term loading to waterbodies. Magnitude and frequency analysis of sediment and other stream constituent loads consists of a transport equation as a function of discharge, integrated over the discharge frequency distribution (e.g., Wolman and Miller, 1960). Different constituent loads have different forms of dependency on discharge, but are often nonlinear such that long-term or expected loads cannot be simply evaluated from mean flow conditions. Similar to precipitation, discharge levels often follow an Extreme Value distribution, dependent on climate, land use, and hydrogeology, but which is typically dampened compared to precipitation due to the memory effects of subsurface storage and flows (e.g., Winter, 2007).

Impacts of Urbanization on Runoff

Shift from Infiltration and Evapotranspiration to Surface Runoff

Replacement of vegetation with impervious or hardened surfaces affects the hydrologic budget—the quantity of water moving through each component of the hydrologic cycle—in a number of predictable ways. As the percent of the landscape that is paved over or compacted is increased, the land area available for infiltration of precipitation is reduced, and the amount of stormwater available for direct surface runoff becomes greater, leading to increased frequency and severity of flooding. Reduced infiltration of precipitation leads to reduced recharge of the groundwater reservoir; absent new sources of recharge, this can lead to reduction in base flow of streams (e.g., Simmons and Reynolds, 1982; Rose and Peters, 2001). Vegetation removal also results in a lower amount of evapotranspiration compared to undeveloped land. This can have particularly profound hydrologic effects in those regions of the country where a significant percent of precipitation is evapotranspirated, such as the arid Southwest (Ng and Miller, 1980). Figure 3-11 illustrates the changes to these components of the hydrologic budget as the percent of impervious area is increased.

It should be noted that the conversion in hydrology from infiltrated water to surface runoff following urbanization is not entirely straightforward in all cases. Leaking pressurized water supply pipes and sanitary sewers, subsurface discharge of septic system effluent (Burns et al., 2005), infiltration of stormwater from unlined detention ponds, and lawn irrigation can offset reduced infiltration of precipitation, such that stream baseflow levels may actually be increased, especially during low base flow months, when such effects would be most pronounced (Konrad and Booth, 2005; Meyer, 2005). Cracks in sealed surfaces can also provide concentrated points of infiltration (Sharp et al., 2006).

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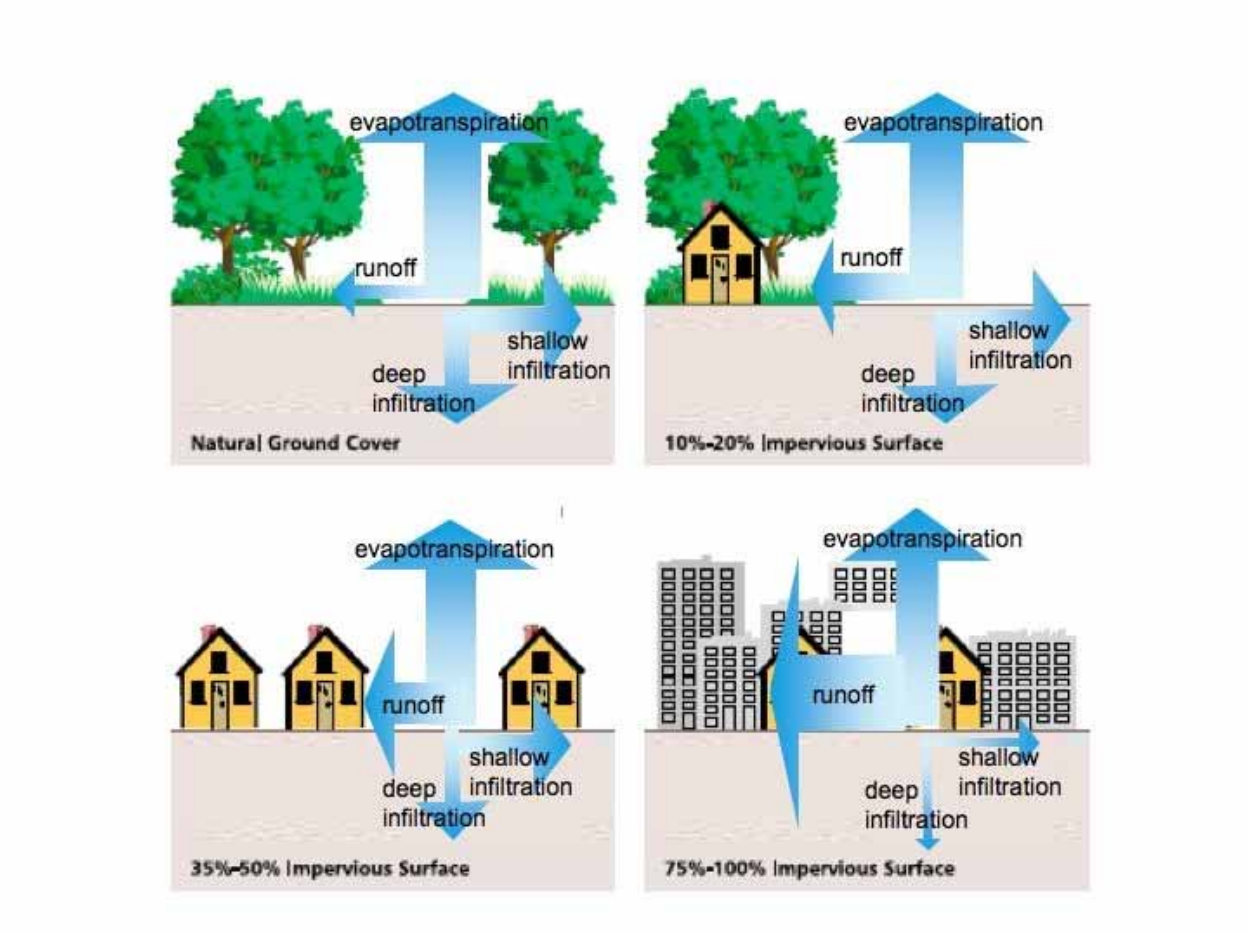

FIGURE 3-11 As land cover changes from vegetated and undeveloped (upper left) to developed with increased connected impervious surfaces (lower right), the partitioning of precipitation into other components of the hydrologic cycle is shifted. Evapotranspiration and shallow and deep infiltration are reduced, and surface runoff is increased. SOURCE: Adapted from the Federal Interagency Stream Restoration Working Group (FISRWG, 2000).

Relationship Between Imperviousness, Drainage Density, and Runoff

Excess runoff due to urbanization is a direct reflection of the land uses onto which the precipitation falls, as well as the presence of drainage systems that receive stormwater from many separate source areas before it enters receiving waters. Thus, a functional way of partitioning urban areas is by the nature of the impervious cover and by its connection to the drainage system, underlying the differentiation of total impervious area and effective impervious area discussed in Box 1-2.

As examples of how runoff changes with urbanization, Figure 3-12 shows daily stream flow values for a low-density suburban catchment and a high-density urban catchment in the Baltimore, Maryland area. The low-density site (Figure 3-12A) shows a strong seasonal signal and a marked decline in flow during an extreme drought in 2002. In contrast, the more densely urbanized catchment (Figure 3-12B) shows a much greater variability in flow that is dominated

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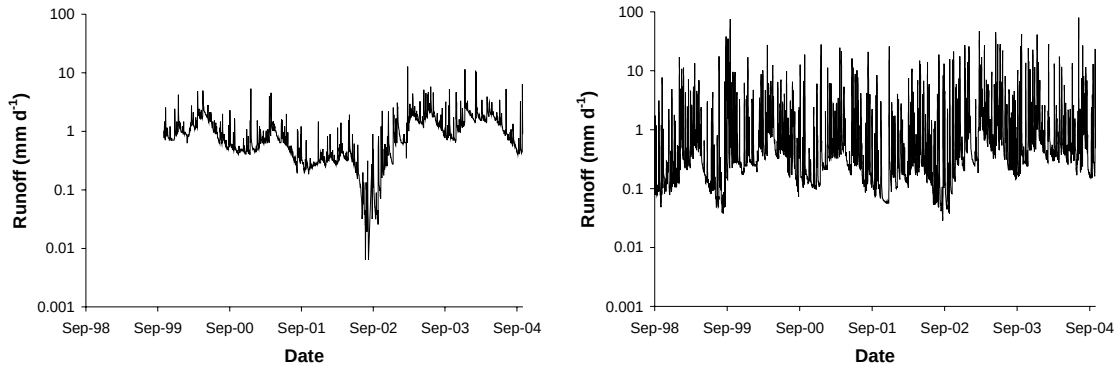

FIGURE 3-12 Daily time series of flows in (A) a low-density suburban and forested catchment (Baisman Run, http://waterdata.usgs.gov/md/nwis/uv/?site_no=01583580) and (B) a catchment dominated by medium- to high-density residential and commercial land uses (Dead Run, http://waterdata.usgs.gov/md/nwis/uv/?site_no=01589330). Both lie within the Piedmont physiographic province.

by impervious surface runoff, and a dampened response to the drought because natural groundwater flow is a much smaller component of the total discharge.

The percentage of time a discharge level is equaled or exceeded is displayed by flow duration curves, which show the cumulative frequency distributions of flows for a given duration. Examples for three catchments in the Baltimore area are given in Figure 3-13, showing the tendency for urban areas to produce high flows with much longer aggregate durations.

As another example of how runoff changes with imperviousness, a locally calibrated version of WinSLAMM was used to investigate the relationships between watershed and runoff characteristics for 125 individual neighborhoods in Jefferson County, Alabama (Bochis-Micu and Pitt, 2005). Figure 3-14 shows the relationships between the directly connected impervious area values and the calculated volumetric runoff coefficient (R_v, which is the volumetric fraction of the rainfall that occurs as runoff), based on 43 years of local rain data. As expected, there is a strong relationship between these parameters for both sandy and clayey soil conditions. It is interesting to note that the R_v values are relatively constant until values of directly connected impervious cover of 10 to 15 percent are reached (at R_v values of about 0.07 for sandy soil areas and 0.16 for clayey soil areas)—the point where receiving water degradation typically has been observed to start (as discussed later in the chapter). The 25 to 30 percent directly connected impervious levels (where significant degradation is usually observed) is associated with R_v values of about 0.14 for sandy soil areas and 0.25 for clayey soil areas; this is where the curves start to greatly increase in slope.

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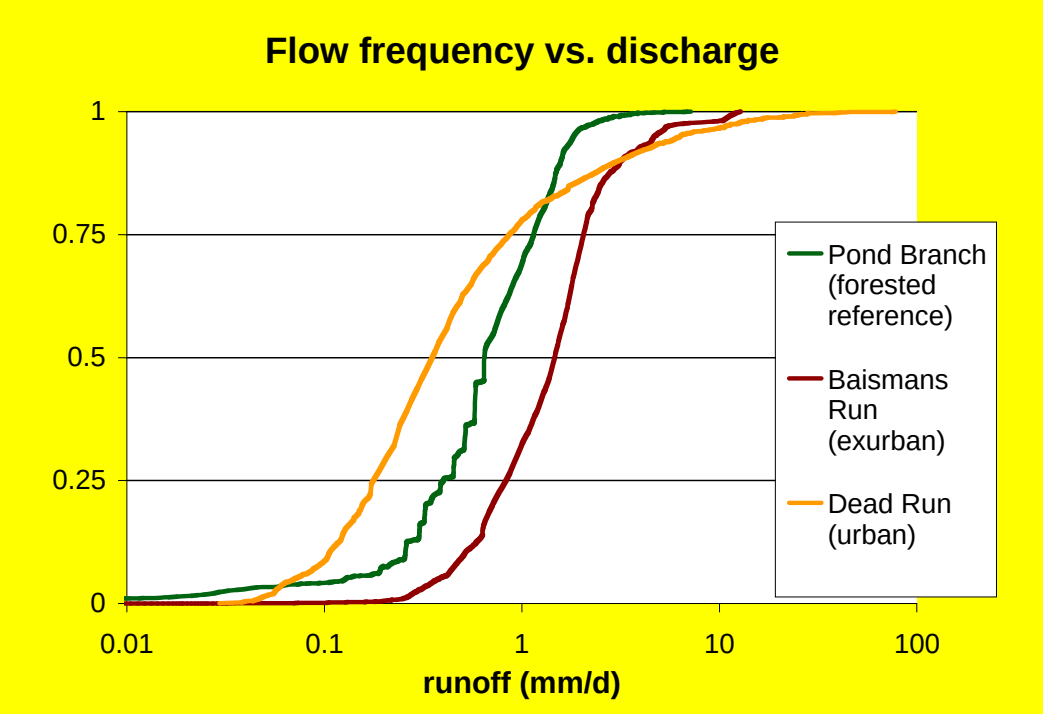

FIGURE 3-13 Flow duration curves for three watersheds with distinct land use in the Baltimore, Maryland area. Urban areas have flashier runoff with greater frequency of low and high extreme flows.

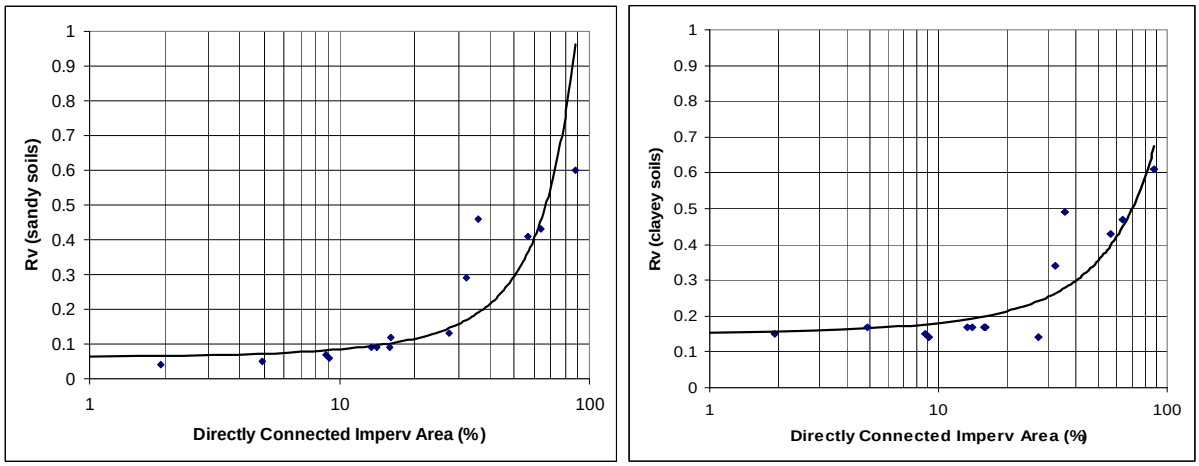

FIGURE 3-14 Relationships between the directly connected impervious area (%) and the calculated volumetric runoff coefficients (R_v) for (A) sandy soil and (B) clayey soil. SOURCE: Reprinted, with permission, from Bochis-Micu and Pitt (2005). Copyright 2005 by Water Environment Federation, Alexandria, Virginia.

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Relationship Between Runoff and Rainfall Conditions

The runoff that results from various land uses also varies depending on rainfall conditions. For small rain depths, almost all the runoff originates solely from directly connected impervious areas, as disconnected areas have most of their flows infiltrated (Pitt, 1987). For larger storms, both directly connected and disconnected impervious areas contribute runoff to the stormwater management system. For example, Figure 3-15 (created using WinSLAMM; Pitt and Voorhees, 1995) shows the relative runoff contributions for a large commercial/mall area in Hoover, Alabama, for different rains (Bochis, 2007). In this example, about 80 percent of the runoff originates from the parking areas for the smallest runoff-producing rains. This contribution decreases to about 55 percent at rain depths of about 0.5 inch (13 mm). This decrease in the importance of parking areas as a source of runoff volume is associated with an increase in runoff contributions from streets and directly connected roofs. In many areas, pervious areas are not hydrologically active until the rain depths are relatively large and are not significant runoff contributors until the rainfall exceeds about 25 mm for many land uses and soil conditions. However, compacted urban soils can greatly increase the flow contributions from pervious areas during smaller rains. Burges and others (1998), for example, found that more than 60 percent of the storm runoff in a suburban development in western Washington State originated from nominally "green" parts of the landscape, primarily lawns.

A further example illustrating the relationship between rainfall and runoff is given for Milwaukee, summarized in Box 3-6. The two curves of Figure 3-16 show a relationship between rainfall and runoff that is typical of urban areas. Very small storms (< 0.05 inch) produce no measurable runoff, owing to removal by interception storage and evaporation. Storms that deposit up to one inch of rainfall constitute about 90 percent of the storm events in this region, but these events produced only about 50 percent of the runoff. Very large events (greater than 3 inches of precipitation) are rare and destructive, accounting for only a few percent of the annual rainfall events.

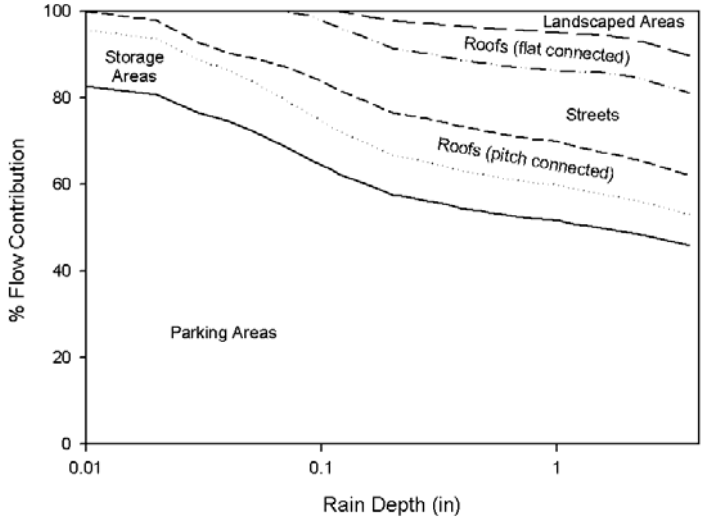

FIGURE 3-15 Surfaces contributing to runoff for an example commercial/mall area. SOURCE: Reprinted, with permission, from Bochis (2007). Copyright 2007 by Celina Bochis.

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BOX 3-6
Example Rainfall and Runoff Distributions

Figure 3-16 is an example of rainfall and runoff observed at Milwaukee, Wisconsin (Bannerman et al., 1983), as monitored during the Nationwide Urban Runoff Program (NURP) (EPA, 1983). This observed distribution is interesting because of the unusually large rains that occurred twice during the monitoring program. These two major rains would be in the category of design storms for conventional drainage systems. These plots indicate that these very large events, in the year they occurred, caused a measureable fraction of the annual pollutant loads and runoff volume discharges, but smaller events were responsible for the vast majority of the discharges. In typical years, when these rare design events do not occur, their pro-rated contributions would be even smaller.

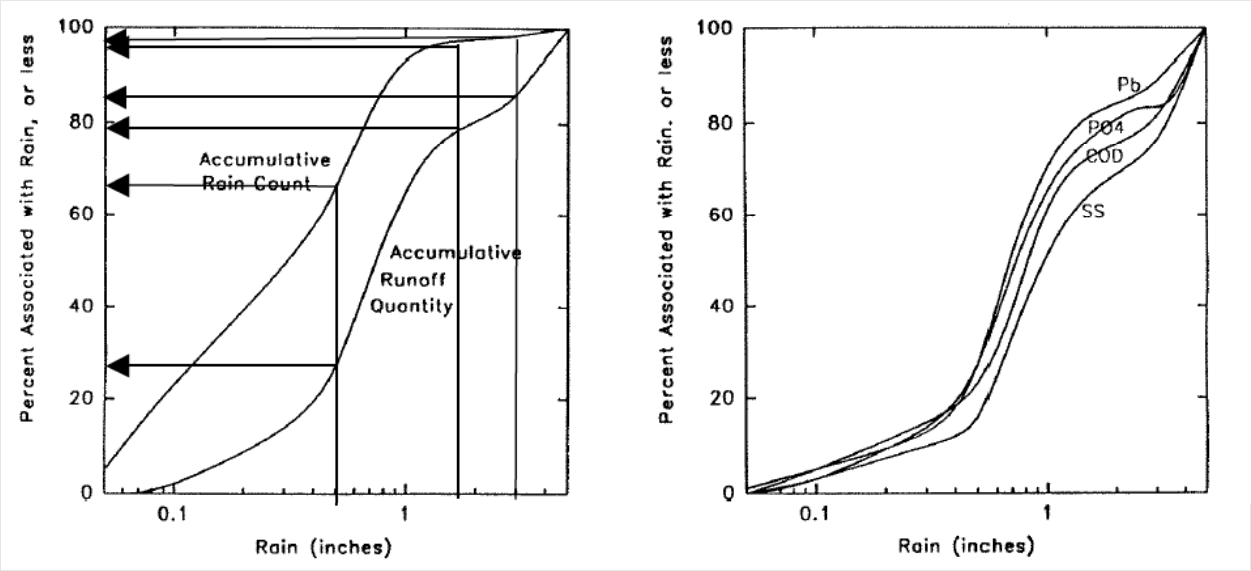

FIGURE 3-16 Milwaukee rainfall and runoff probability distributions, and pollutant mass discharge probability distributions (1981 to 1983). Rain count refers to the number of rain events. SOURCE: Data from Bannerman et al. (1983).

More than half of the runoff from this typical medium-density residential area was associated with rain events that were smaller than 0.75 inch. Two large storms (about 3 and 5 inches in depth), which are included in the figure, distort this figure because, on average, the Milwaukee area only expects one 3.5-inch storm about every five years, and 5-inch storms even less frequently. If these large rains did not occur, such as for most years, then the significance of the smaller rains would be even greater. The figure also shows the accumulated mass discharges of different pollutants (suspended solids, chemical oxygen demand [COD], phosphates, and lead) monitored during the Milwaukee NURP project. When these figures are compared, it is seen that the runoff and pollutant mass discharge distributions are very similar and that variations in the runoff volume are much more important than variations in pollutant concentrations (the mass divided by the runoff volume) for determining pollutant mass discharges.

These rainfall and runoff distributions for Milwaukee can thus be divided into four regions:

- **Less than 0.5 inch.** These rains account for most of the events, but little of the runoff volume, and they are therefore easiest to control. They produce much less pollutant mass discharge and probably have less receiving water effects than other rains. However, the runoff pollutant concentrations likely exceed regulatory standards for several categories of critical pollutants (bacteria and some total recoverable heavy metals). They also cause large numbers of overflow events in uncontrolled combined

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BOX 3-6 Continued

sewers. These rains are very common, occurring once or twice a week (accounting for about 60 percent of the total rainfall events and about 45 percent of the total runoff-generating events), but they only account for about 20 percent of the annual runoff and pollutant discharges. Rains less than about 0.05 inch did not produce noticeable runoff.

- **0.5 to 1.5 inches**. These rains account for the majority of the runoff volume (about 50 percent of the annual volume for this Milwaukee example) and produce moderate to high flows. They account for about 35 percent of the annual rain events, and about 20 percent of the annual runoff events, by number. These rains occur on average about every two weeks from spring to fall and subject the receiving waters to frequent high pollutant loads and moderate to high flows.

- **1.5 to 3 inches**. These rains produce the most damaging flows from a habitat destruction standpoint and occur every several months (at least once or twice a year). These recurring high flows, which were historically associated with much less frequent rains, establish the energy gradient of the stream and cause unstable streambanks. Only about 2 percent of the rains are in this category, but they are responsible for about 10 percent of the annual runoff and pollutant discharges.

- Greater than **3 inches.** The rains in this category are included in design storms used for traditional drainage systems in Milwaukee, depending on the times of concentration and rain intensities. These rains occur only rarely (once every several years to once every several decades, or less frequently) and produce extremely large flows that greatly exceed the capacities of the storm drainage systems, causing extensive flooding. The monitoring period during the Milwaukee NURP was unusual in that two of these events occurred. Less than 2 percent of the rains were in this category (typically <<1 percent would be in this category), and they produced about 15 percent of the annual runoff quantity and pollutant discharges. However, when they do occur, substantial property and receiving water damage results (mostly associated with habitat destruction, sediment scouring, and the flushing of organisms great distances downstream and out of the system). The receiving water can conceivably recover naturally to pre-storm conditions within a few years. These storms, while very destructive, are sufficiently rare that the resulting environmental problems do not justify the massive controls that would be necessary to decrease their environmental effects.

Alteration of the Drainage Network

As shown in Figure 3-17, urbanization disrupts natural systems in ways that further complicate the hydrologic budget, beyond the imperviousness effects on runoff discussed earlier. As an area is urbanized, lower-order stream channels are typically re-routed or encased in pipes and paved over, resulting in a highly altered drainage pattern. The buried stream system is augmented by an extensive system of storm drains and pipes, providing enhanced drainage density (total lengths of pipes and channels divided by drainage area) compared to the natural system. Figure 3-18 shows how the drainage density of Baltimore today compares to the natural watershed before the modern stormwater system was fully developed. The artificial drainage system occupies a greater percentage of the landscape compared to natural conditions, permanently altering the terrestrial component of the hydrologic cycle.

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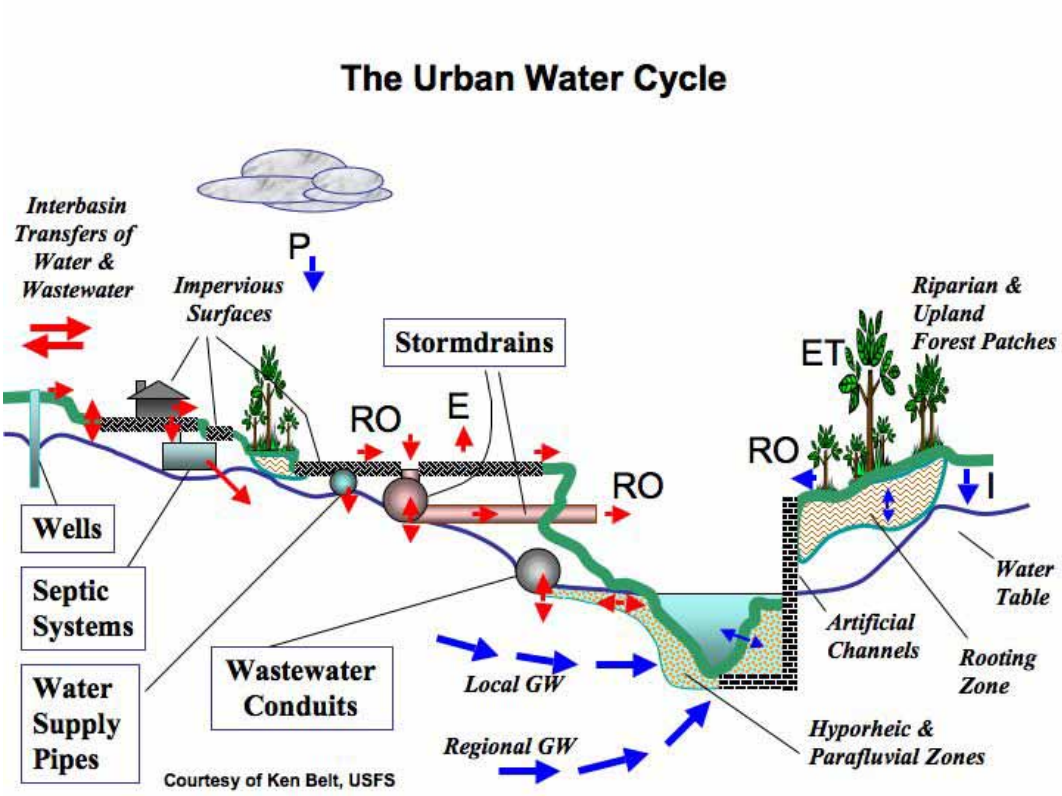

FIGURE 3-17 Alteration of the natural hydrologic cycle by the presence of piped systems. Blue arrows represent the natural system; red arrows indicate short-circuiting due to piped systems. Note that several elements of the water cycle shown in this diagram are not considered in this report, such as septic systems, interbasin transfers of water and wastewater, and the influence of groundwater withdrawals. SOURCE: Courtesy of Kenneth Belt, USDA Forest Service, Baltimore, Maryland.

Flowpaths are altered in other ways by urban infrastructure. Buried stormwater and sewer pipes can act as infiltration galleries for groundwater, causing shortened groundwater flowpaths between groundwater reservoirs and stream systems. Natural surface water pathways are often interrupted or reversed, as shown by the blue lines in Figure 3-19 for a drainage system in Baltimore. Understanding how the system operates as a whole can often require knowledge of the history of construction conditions and field verification of the actual flow paths.

Large-scale infrastructure such as dams, ponds, and bridges can also have a major impact on stormwater flows. Figure 3-20 illustrates the interruption of the drainage network by bridges and culverts, even in places where there have been attempts to keep excessive development out of the riparian corridor. Simulations and post-flood mapping in areas around Baltimore have shown that bridge abutments such as those shown in Figure 3-20 can slow down channel floodwaters during storms. This is because water backs up behind bridges constructed across the floodplain and spreads out over land surfaces and then flows back into channels as floodwaters subside. Although reducing the severity of downstream flooding, this phenomenon also interrupts the transport of sediment, leading to local zones of both enhanced deposition and downstream scour.

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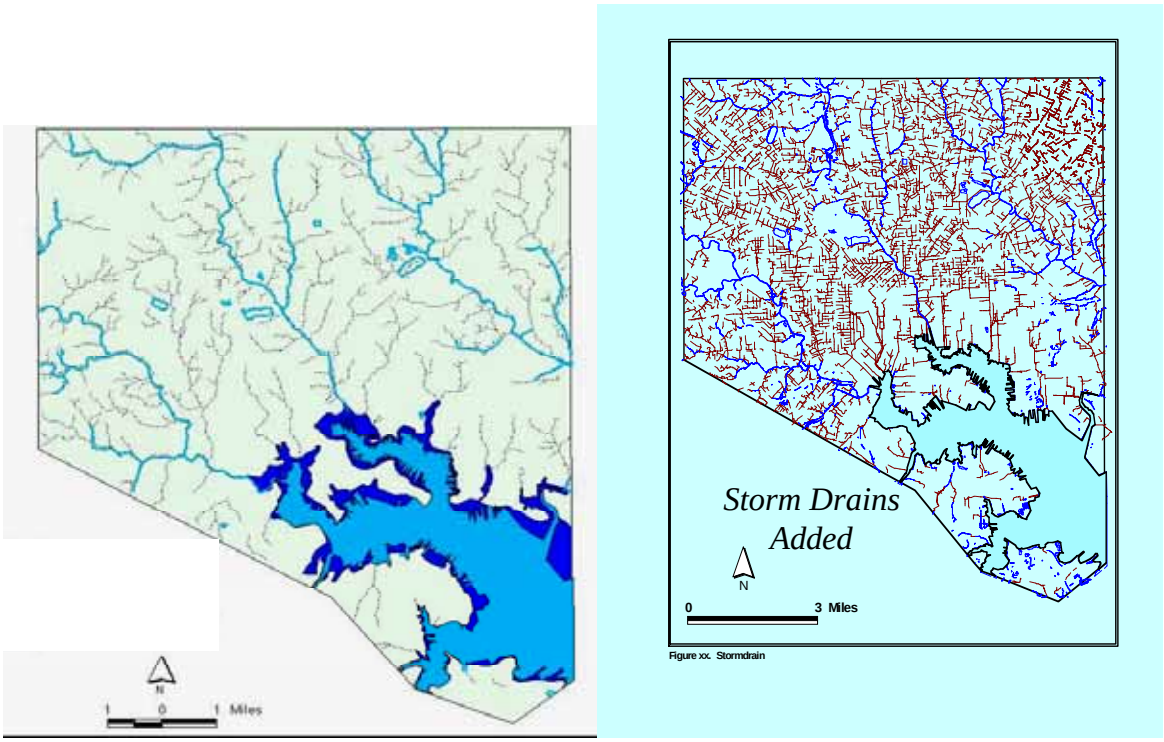

FIGURE 3-18 Baltimore City before and after development of its stormwater system. The left-hand panel shows first- and second-order streams lost to development. The right-hand panel shows the increase in drainage density resulting from construction of the modern storm-drain network. SOURCE: Courtesy of William Stack, Baltimore Department of Public Works.

Alteration of Travel Times

The combination of impervious surface and altered drainage density provides significantly more rapid hydraulic pathways for stormwater to enter the nearest receiving waterbody compared to a natural landscape. This is illustrated quantitatively by Figure 3-21, which shows that the lag time—the difference in time between the center of mass of precipitation and the center of mass of the storm response hydrograph—is reduced for an urbanized landscape compared to a natural one.

The increase in surface runoff volumes and reduction in lag times between precipitation and a waterbody's response give rise to greater velocities and volumetric discharges in receiving waters. Storm hydrographs in a developed setting peak earlier and higher than they do in undeveloped landscapes. This altered flow regime is of concern to property owners because upstream development can increase the probability of a flood-prone property being inundated. Properties in the floodplain and near stream channels are particularly susceptible to flooding from upstream development. Such increased flood risk is accompanied by associated potential property damages and costs of replacement or repair.

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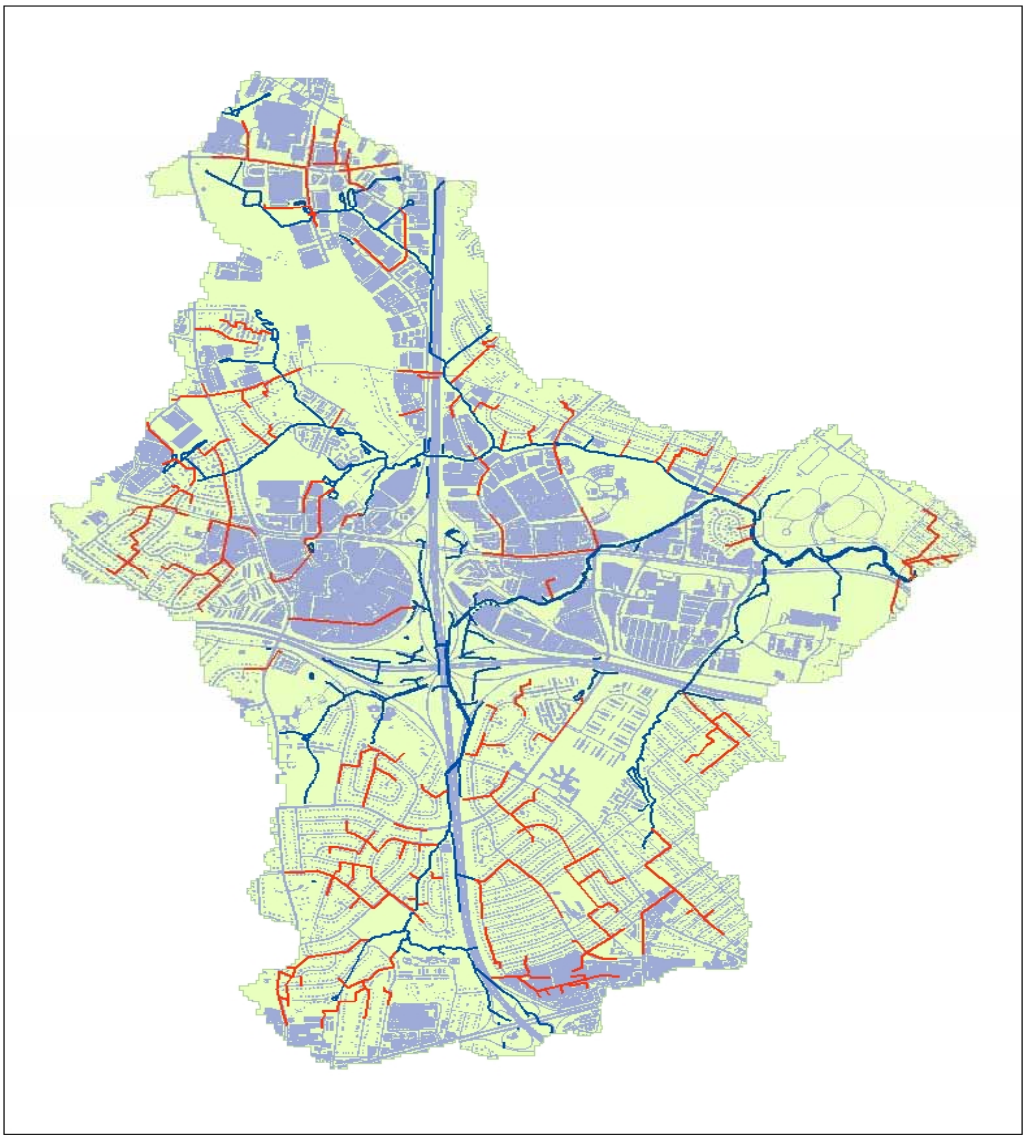

FIGURE 3-19 Dead Run drainage system, Baltimore, Maryland. Blue lines indicate surface (daylighted) drainage; orange indicates the subsurface storm-drain system. The surface drainage system is highly disconnected. From the coverage it is difficult to impossible to discern the flow direction of some of the surface drainage components. SOURCE: Reprinted, with permission, from Meierdierks et al. (2004). Copyright 2004 by the American Geophysical Union.

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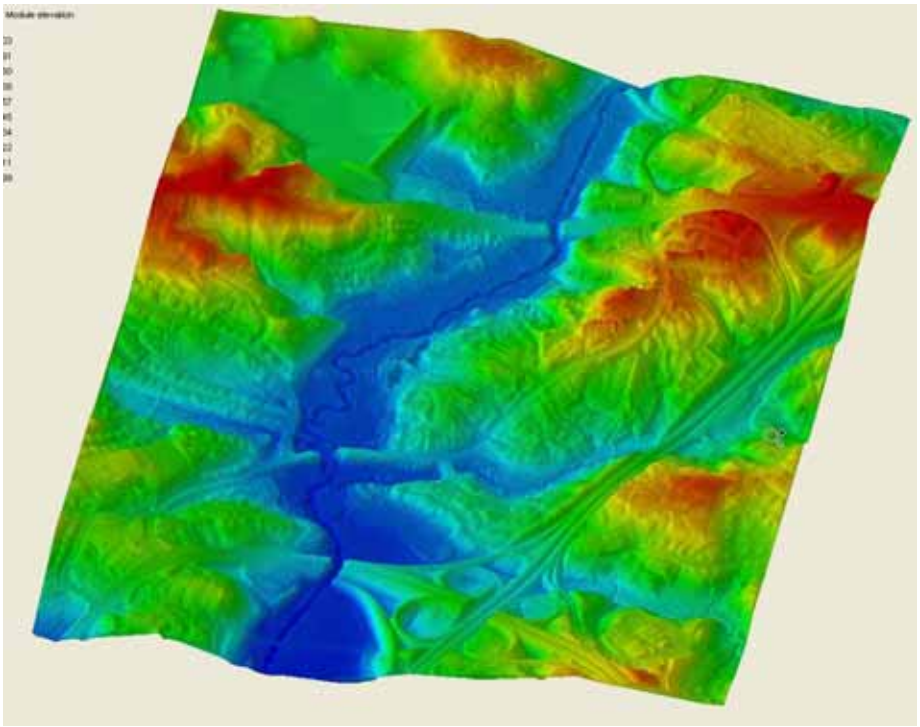

FIGURE 3-20 Shaded-relief lidar image of a portion of the Middle Patuxent River valley in Howard County, Maryland, showing the pervasive interruption of the drainage network by bridges and culverts, even in places where there is an attempt to keep excessive development out of the riparian corridor. SOURCE: Reprinted, with permission, from Miller, University of Maryland, Baltimore County. Copyright 2006 by Andrew J. Miller.

Various descriptors can be used to quantify the effects of urbanization on streamflow including flood frequency, flow duration, mean annual flood, discharge at bankfull stage, and frequency of bankfull stage. The "classic" view of urban-induced changes to runoff was presented by Leopold (1968), who provided several quantitative descriptors of the effects of urbanization on the mean annual flood. For example, Figure 3-22 shows the ratio of discharge before and after urbanization for the mean annual flood for a 1-square-mile area as a function of percentage of impervious area and percentage area served by a storm-drain system. This shows that for unsewered areas, increases from 0 to 100 percent impervious area will increase the peak discharge by a factor of 2.5. However, for 100 percent sewered areas, the ratio of peak discharges ranges from 1.7 to 8 for 0 to 100 percent impervious area. Clearly both impervious surfaces and the presence of a storm-drain system combine to increase discharge rates in receiving waters. Combining this information with regional flood frequency data, a discharge–frequency relationship can be developed that shows the expected discharge and recurrence interval for varying degrees of storm-drain coverage and impervious area coverage. An example is shown in Figure 3-23, using data from the Brandywine Creek watershed in Pennsylvania (Leopold, 1968). Bankfull flow for undeveloped conditions in general has a recurrence interval of about 1.5 years (which, in the particular case of the Brandywine, was 67 cubic feet per second); with 40 percent of the watershed area paved, this discharge would occur about three times as often.

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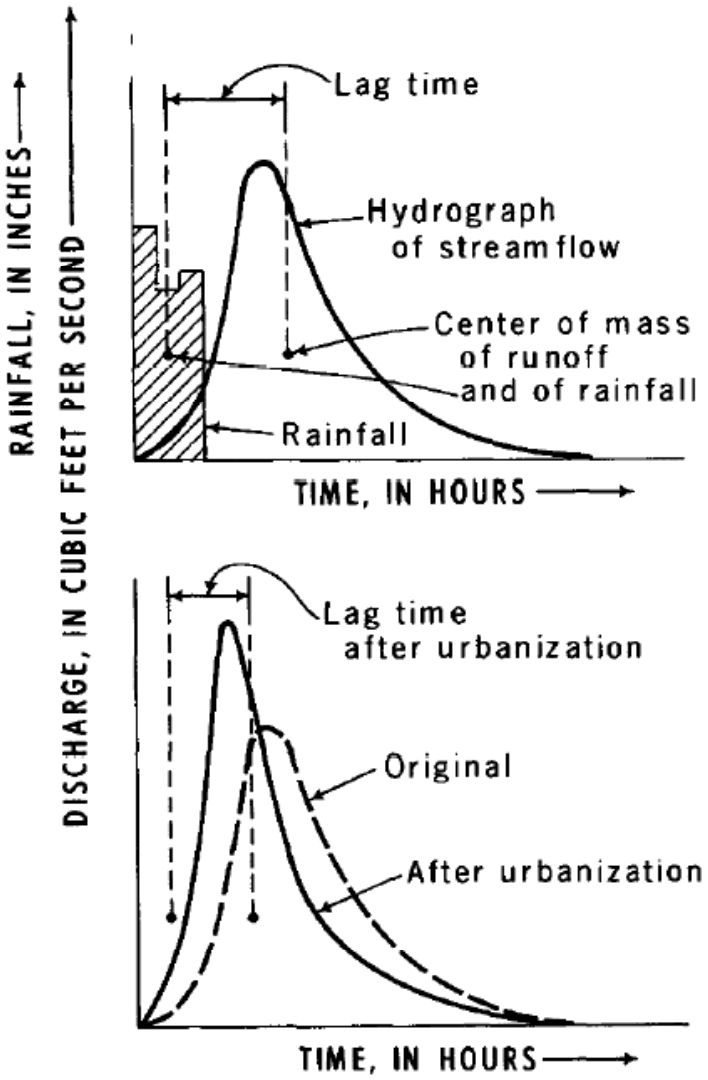

FIGURE 3-21 Illustration of the effect of urbanization on storm hydrograph lag time, the difference in time between the center of mass of rainfall and runoff response before and after urbanization. SOURCE: Leopold (1968).

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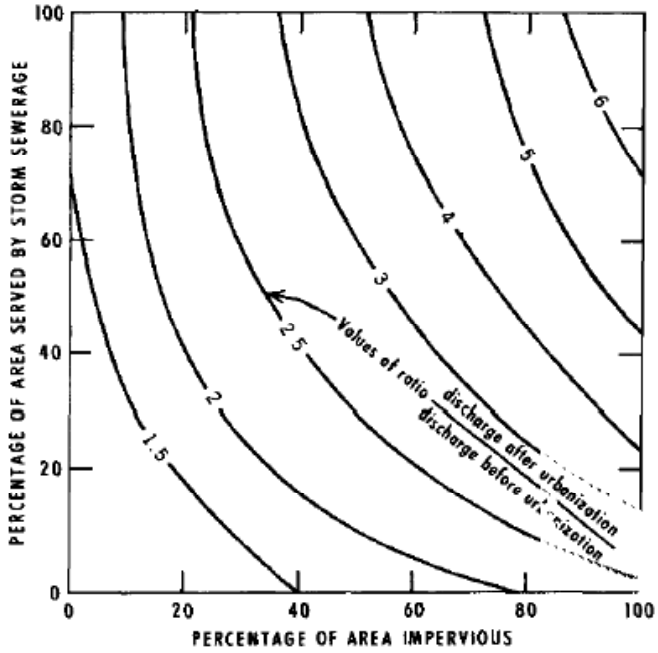

FIGURE 3-22 Ratio of peak discharge after urbanization to peak discharge before urbanization for the mean annual flood for a 1-square-mile drainage area, as a function of percent impervious surface and percent area drained by storm sewers. SOURCE: Leopold (1968).

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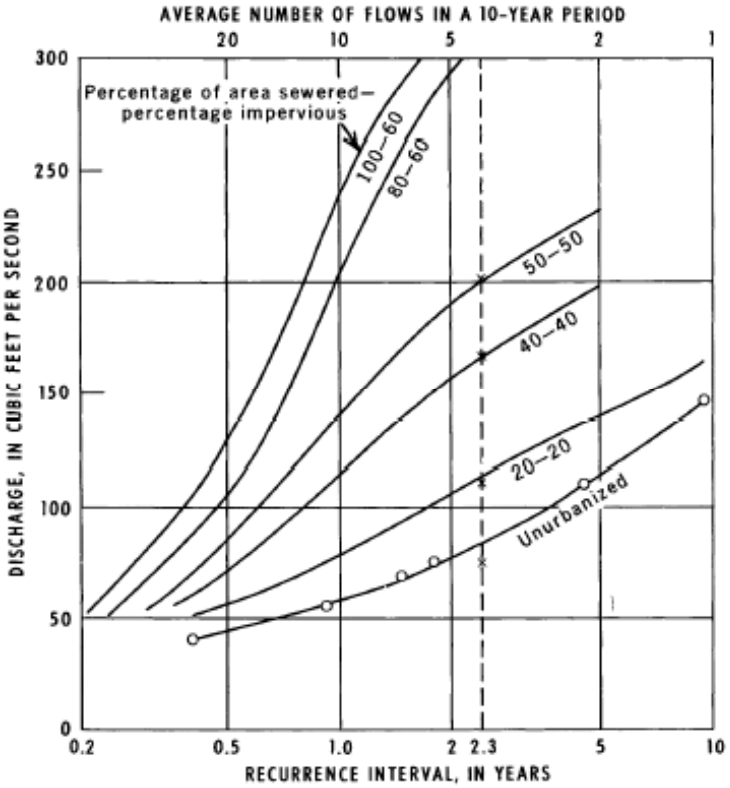

FIGURE 3-23 Flood frequency curves as a function of percent impervious area and percent of area serviced by storm sewers. The unurbanized data are from Brandywine Creek, Pennsylvania. SOURCE: Leopold (1968).

Over the past four decades since this first quantitative characterization of urban hydrology, a much greater variety of hydrologic changes resulting from urbanization has been recognized. Increases in peak discharge are certainly among those changes, and they will always gather attention because of their direct impact on human infrastructure and potential for more frequent and more severe flooding. The extended duration of flood flows, however, also affects natural channels because of the potential increase in erosion. Ecological effects of urban-altered flow regimes are even more diverse, because changes in the sequence and frequency of high flows, the rate of rise and fall of the hydrograph, and even the season of the year in which high flows can occur all have significant ecological effects and can be dramatically altered by watershed urbanization (e.g., Rose and Peters, 2001; Konrad et al., 2005; Roy et al., 2005; Poff et al., 2006).

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The overarching conclusion of many studies is that the impact of urbanization on the hydrologic cycle is dramatic. Increased impervious area and drainage connectedness decreases stormwater travel times, increases flow rates and volumes, and increases the erosive potential of streams. The flooding caused by increased flows can be life-threatening and damaging to property. As described below, changes to the hydrologic flow regime also can have deleterious

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effects on the geomorphic form of stream channels and the stability of aquatic ecosystems. Although these impacts are commonly ignored in efforts to improve "water quality," they are inextricably linked to measured changes in water chemistry and must be part of any attempt to recover beneficial uses that have been lost to upstream urbanization.

Geomorphology

Watershed geomorphology is determined by the arrangement, interactions, and characteristics of component landforms, which include the stream-channel network, the interlocking network of ridges and drainage divides, and the set of hillslopes between the channel (or floodplain) and ridge. The stream and ridge systems define complementary networks, with the ridge (or drainage divide) network separating the drainage areas contributing to each reach in the stream network. At the hillslope scale, the ridges provide upper boundaries of all surface flowpaths which converge into the complementary stream reaches. A rich literature describes the topology and geometry of stream and ridge networks (e.g., Horton, 1945; Strahler, 1957, 1964; Shreve, 1966, 1967, 1969; Smart, 1968; Abrahams, 1984; Rodriguez-Iturbe et al., 1992).

Besides stream channels, a variety of other water features and landforms make up a watershed. Fresh waterbodies (ponds, lakes, and reservoirs) are typically embedded within the stream network, while wetlands may be either embedded within the stream network or separated and upslope from the channels. Estuaries represent the interface of the stream network with the open ocean. Additional fluvial and colluvial landforms include alluvial fans, landslide features, and a set of smaller features within or near the channels and floodplains including bar deposits, levees, and terraces. Each of these landforms are developed and maintained by the fluvial and gravitational transport and deposition of sediment, and are therefore potentially sensitive to disruption or alteration of flowpaths, hydrologic flow regimes, and sediment supply.

Stream Network Form and Ordering Methods

Most watersheds are fully convergent, with tributary streams combining to form progressively larger channels downstream. The manner is which streams from different source areas join to produce mainstreams strongly influences the propagation of stormwater discharge and pollutant concentrations, and the consequent level of ecological impairment in the aquatic ecosystem.

Methods for indexing the topologic position of individual reaches within the drainage network have been introduced by Horton (1945), Strahler (1957), Shreve (1966, 1967) and others. All stream topologic systems are dependent on the identification of first-order streams—the most upstream element of the network—and their lengths and drainage areas. Unfortunately, no universal standards exist to define where the stream head is located, or whether perennial, intermittent, and ephemeral channels should be considered in this determination. While this may seem like a trivial process, the identification and delineation of these sources effectively determines what lengths and sections of channels are defined to be *waterbodies* and, thus, the classification of all downstream waterbodies.

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Nadeau and Rains (2007) have recently reviewed stream-channel delineation in the United States using standardized maps and hydrographic datasets to better relate climate to the extent of perennial, intermittent, and ephemeral channel types. Because this may influence the set of stream channels that are regulated by the Clean Water Act (CWA), it is the subject of current legal arguments in courts up to and including the Supreme Court (e.g., *Solid Waste Agency of Northern Cook County v. U.S. Army Corps of Engineers*, 531 U.S. 159 [2001], *John A. Rapanos et al. vs. United States* [U.S., No. 04-1034, 2005]). In addition to the stream-channel network, additional features (discussed below) that are embedded in or isolated from the delineated stream network (lakes, ponds, and wetlands) are subject to regulation under the CWA based on their proximity or interaction with the defined stream and river network. Therefore, definition of the extent and degree of connectivity of the nation's stream network, with an emphasis on the headwater region, is a critical determinant of the set of waterbodies that are regulated for stormwater permitting (Nadeau and Rains, 2007).

Stream Reach Geomorphology

Within the channel network, stream reaches typically follow a regular pattern of changes in downstream channel form. Hydraulic geometry equations, first introduced by Leopold and Maddock (1953), describe the gross geomorphic adjustment of the channel (in terms of average channel depth and width) to the flow regime and sometimes the sediment supply. Within this general pattern of larger flows producing larger channels, variations in channel form are evident, particularly the continuum among straight, meandering, or braided patterns. These forms are dependent on the spatial and temporal patterns of discharge, sediment supply, transport capacity, and roughness elements.

Most natural channels have high width-to-depth ratios and complexity of channel form compared with engineered channels. Meanders are ubiquitous self-forming features in channels, created as accelerated flow around the outside of the meander entrains and transports more sediment, producing greater flow depths and eroding the bank, while decelerated flow on the inside of the meander results in deposition and the formation of lower water depth and bank gradients. These channels typically show small-scale alternation between larger cross sections with lower velocities and defining pools, and smaller cross sections with higher velocity flow in riffles. Braided streams form repeated subdivision and reconvergence of the channel in multiple threads, with reduced specific discharge compared to a single channel. Natural obstructions including woody debris, boulders, and other large (relative to channel dimensions) features all contribute to hydraulic and habitat heterogeneity. The complexity of these channel patterns contributes to hydraulic roughness, further dissipating stream energy by increasing the effective wetted perimeter of the channel through a valley and deflecting flow between banks.

Embedded Standing Waterbodies

Standing waterbodies include natural, constructed, or modified ponds and lakes and are characterized by low or near-zero lateral velocity. They can be thought of as extensions of pools within the drainage network, although there is no clear threshold at which a pool can be defined as a pond or lake. When they are embedded within the channel network, they are characterized

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with much greater cross-sectional area (width x depth), lower surface water slopes (approaching flat), and lower velocities than a stream reach of similar length. Therefore, standing waterbodies function as depositional zones, have higher residence times, and provide significant storage of water, sediment, nutrients, and other pollutants within the stream network.

Riparian Zone

The riparian area is a transitional zone between the active channel and the uplands, and between surface water and groundwater. The area typically has shallower groundwater levels and higher soil moisture than the surrounding uplands, and it may support wetlands or other vegetation communities that require higher soil moisture. Riparian zones provide important ecosystem functions and services, such as reducing peak flood flows, transforming bioavailable nutrients into organic matter, and providing critical habitat.

In humid landscapes, a functioning riparian area commonly is an area where shallow groundwater forms discharge seeps, either directly to the surface and then to the stream channel or through subsurface flowpaths to the stream channel. The potential for high moisture and organic material content provides an environment conducive to anaerobic microbial activity, which can provide effective sinks for inorganic nitrogen by denitrification, reducing nitrate loading to the stream channel. However, the width of the effective riparian zone depends on local topographic gradients, hydrogeology, and the channel geomorphology (Lowrance et al., 1997). In steeply incised channels and valleys, or areas with deeper flowpaths, the riparian zone may be narrow and relatively well drained.

Under more arid conditions with lower groundwater levels, riparian areas may be the only areas within the watershed with sufficient moisture levels to support significant vegetation canopy cover, even though saturation conditions may occur only infrequently. Subsurface flowpaths may be oriented most commonly from the channel to the bed and banks, forming the major source of recharge to this zone from periodic flooding. In monsoonal climates in the U.S. southwest, runoff generated in mountainous areas or from storm activity may recharge riparian aquifers well downstream from the storm or snowmelt activity. Channelization that reduces this channel-to-riparian recharge may significantly impair riparian and floodplain ecosystems that provide critical habitat and other ecosystem services (NRC, 2002).

Floodplains

The presence and distribution of alluvial depositional zones, including floodplains, is dependent on the distribution and balance of upstream sediment sources and sediment transport capacity, the temporal and spatial variability of discharge, and any geological structural controls on valley gradient. Lateral migration of streams contributes to the development of floodplains as the outer bank of the migrating channel erodes sediment and deposition occurs on the opposite bank. This leads to channels that are closely coupled to their floodplains, with frequent overbank flow and deposition, backwater deposits, wetlands, abandoned channels, and other floodplain features. During major events, overbank flooding and deposition adds sediment, nutrients, and contaminants to the floodplain surface, and may significantly rework preexisting deposits and

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drainage patterns. Constructional landforms typical of urbanized watersheds, such as levees, tend to disconnect streams from their floodplains.

Changes in Geomorphology from Urbanization

Changes to channel morphology are among the most common and readily visible effects of urban development on natural stream systems (Booth and Henshaw, 2001). The actions of deforestation, channelization, and paving of the uplands can produce tremendous changes in the delivery of water and sediment into the channel network. In channel reaches that are alluvial, the responses are commonly rapid and often dramatic. Channels widen and deepen, and in some cases may incise many meters below the original level of their beds. Alternatively, channels may fill with sediment derived from farther upstream to produce a braided form where a single-thread channel previously existed.

The clearest single determinant of urban channel change is the alteration of the hydrologic response of an urban watershed, notably the increase in stream-flow discharges. Increases in runoff mobilize sediment both on the land surface and within the stream channel. Because transport capacity increases nonlinearly with flow velocity (Vogel et al., 2003), much greater transport will occur in higher flow events. However, the low frequency of these events may result in decreasing cumulative sediment transport during the highest flows, as described by standard magnitude and frequency analysis (Wolman and Miller, 1960), such that the maximum time-integrated sediment transport occurs at moderate flows (e.g., bankfull stage in streams in the eastern United States).

If the increase in sediment transport caused by the shift in the runoff regime is not matched by the sediment supply, channel bed entrenchment and bank erosion and collapse lead to a deeper, wider channel form. Increases in channel dimensions caused by increased discharges have been observed in numerous studies, including Hammer (1972), Hollis and Luckett (1976), Morisawa and LaFlure (1982), Neller (1988), Whitlow and Gregory (1989), Moscrip and Montgomery (1997), and Booth and Jackson (1997). MacRae (1997), reporting on other studies, found that channel cross-sectional areas began to enlarge after about 20 to 25 percent of the watershed was developed, commonly corresponding to about 5 percent impervious cover. When the watersheds were completely developed, the channel enlargements were about 5 to 7 times the original cross-sectional areas. Channel widening can occur for several decades before a new equilibrium is established between the new cross-section and the new discharges.

Construction results in a large—but normally temporary—increase in sediment load to aquatic systems (e.g., Wolman and Schick, 1967). Indeed, erosion and sediment transport rates can reach up to more than 200 Mg/ha/yr on construction sites, which is well in excess of typical rates from agricultural land (e.g., Wolman and Schick, 1967; Dunne and Leopold, 1978); rates from undisturbed and well-vegetated catchments are negligible (e.g., <<1 Mg/ha/yr). The increased sediment loads from construction exert an opposing tendency to channel erosion and probably explain much of the channel narrowing or shallowing that is sometimes reported (e.g., Leopold, 1973; Nanson and Young, 1981; Ebisemiju, 1989; Odemerho, 1992).

Additional sediment is commonly introduced into the channel network by the erosion of the streambank and bed itself. Indeed, this source can become the largest single fraction of the sediment load in an urbanizing watershed (Trimble, 1997). For example, Nelson and Booth (2002) reported on sediment sources in the Issaquah Creek watershed, an urbanizing, mixed-use

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watershed in the Pacific Northwest. Human activity in the watershed, particularly urban development, has caused an increase of nearly 50 percent in the annual sediment yield, now estimated to be 44 tons/km^2/yr^1. The main sources of sediment in the watershed are landslides (50 percent), channel-bank erosion (20 percent), and stormwater discharges (15 percent).

The higher flow volumes and peak discharge caused by urbanization also tend to preferentially remove fine-grained sediment, leaving a lag of coarser bed material (armoring) or removing alluvial material entirely and eroding into the geologic substrate (Figure 3-24). The geomorphic outcome of these changes is a mix of erosional enlargement of some stream reaches, significant sedimentation in others, and potential head-ward downcutting of tributaries as discharge levels from small catchments increase. The collective effects of these processes have been described by Walsh et al. (2005) as "Urban Stream Syndrome," which includes not only the visible alteration of the physical form of the channel but also the consequent deterioration of stream biogeochemical function and aquatic trophic structures.

Other changes also accompany these geomorphic changes. Episodic inundation of the floodplain during floods may be reduced in magnitude and frequency, depending on the increases in peak flow relative to the deepening and resultant increase in flow capacity of the channel. Where deeply entrenched, this channel morphology will lower the groundwater level adjacent to the channel. The effectiveness of riparian areas in filtering or removing solutes is thus reduced because subsurface water may reach the channel only by flowpaths now well below the organic-rich upper soil horizons. Removal of fine-grained stream-bottom sediment, or erosion down to bedrock, may substantially lower the exchange of stream water with the surrounding groundwater of the hyporheic zone.

FIGURE 3-24 Example of an urban stream that has eroded entirely through its alluvium to expose the underlying consolidated geologic stratum below (Thornton Creek, Seattle, Washington).

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In addition to these indirect effects on the physical form of the stream channel, urbanization also commonly modifies streams directly to improve drainage, applying channel straightening and lining to reduce friction, increase flow capacity, and stabilize channel position (Figure 3-25). The enlarged and often lined and straightened stream-channel cross section reduces the complexity of the bed and the contact between the stream and floodplain, and increases transport efficiency of sediment and solutes to receiving waterbodies. Enhanced sedimentation of receiving waterbodies, in turn, reduces water clarity, decreases depth, and buries the benthic environment.

FIGURE 3-25 Example of a channelized urban stream for maximized flood conveyance and geomorphic stability (Los Angeles River, California). SOURCE: Reprinted, with permission, from Water Resources Research. Copyright by the American Geophysical Union.

POLLUTANT LOADING IN STORMWATER

Hydrologic flowpaths influence the production of particulate and dissolved substances on the land surface during storms, as well as their delivery to the stream-channel network. Natural watersheds typically develop a sequence of ecosystem types along hydrologic flowpaths that utilize available limiting resources, thereby reducing their export farther downslope or downstream, such that in-stream concentrations of these nutrients are low. As a watershed shifts from having mostly natural pervious surfaces to having heavily disturbed soils, new impervious surfaces, and activities characteristic of urbanization, the runoff quality shifts from relatively lower to higher concentrations of pollutants. Anthropogenic activities that can increase runoff pollutant concentrations in urban watersheds include application of chemicals for fertilization and pest control; leaching and corrosion of pollutants from exposed materials; exhaust emissions,

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leaks from, and wear of vehicles; atmospheric deposition of pollutants; and inappropriate discharges of wastes.

Most lands in the United States that have been developed were originally grasslands, prairies, or forest. About 40 percent of today's developed land went through an agricultural phase (cropland or pastureland) before becoming urbanized, while more than half of today's developed land area has been a direct conversion of natural covers (USDA, 2000). Agricultural land can produce stormwater runoff with high pollutant concentrations via soil erosion, the introduction of chemicals (fertilizers, pesticides, and herbicides), animal operations that are major sources of bacteria in runoff, and forestry operations. Indeed, urban stormwater may actually have slightly lower pollutant concentrations than other nonpoint sources of pollution, especially for sediment and nutrients. The key difference is that urban watersheds produce a much larger annual volume of runoff waters, such that the mass of pollutants discharged is often greater following urbanization. Some of the complex land-use–pollutant loading relationships are evident in Box 3-7, which shows the measured annual mass loads of nitrogen and phosphorus in four small watersheds of different land use monitored as part of the Baltimore Long-Term Ecological Research program. Depending on the nutrient and the year, the agricultural and urban watersheds had a higher nutrient export rate than the forested subwatershed.

BOX 3-7
Comparison of Nitrogen and Phosphorus Export from Watersheds with Different Land Uses

Land use is a significant influence on nutrient export as controlled by impervious area, sanitary infrastructure, fertilizer application, and other determinants of input, retention, and stormwater transport. Tables 3-2A and 3-2B compare dissolved nitrate, total nitrogen, phosphate, and total phosphorus loads exported from forest catchments with catchments in different developed land uses studied by the Baltimore Ecosystem Study (Groffman et al., 2004). Loads were computed with the Fluxmaster system (Schwarz et al., 2006) from weekly samples taken at outlet gauges. In these sites in Baltimore County, the forested catchment, Pond Branch, has nitrogen loads one to two orders of magnitude lower than the developed catchments. Baisman Run, with one-third of the catchment in low-density, septic-served suburban land use, has nitrogen export exceeding Dead Run, an older, dense urban catchment. In this case, nutrient load does not follow the direct variation of impervious area because of the switch to septic systems and greater fertilizer use in lower density areas. However, Figure 3-26 shows that as impervious area increases, a much greater proportion of the total nitrogen load is discharged in less frequent, higher runoff events (Shields et al., 2008), reducing the potential to decrease loads by on-site SCMs. Total phosphorus loads were similarly as low (0.05–0.6 kg P/ha/yr) as nitrogen in the Pond Branch catchment (forest) over the 2000–2004 time period, and one to two orders of magnitude lower compared to agricultural and residential catchments.

It should be noted that specific areal loading rates, even in undeveloped catchments, can vary significantly depending on rates of atmospheric deposition, disturbance, and climate conditions. The hydrologic connectivity of nonpoint pollutant source areas to receiving waterbodies is also a critical control on loading in developed catchments (Nadeau and Rains, 2007) and is dependent on both properties of the pollutant as well as the catchment hydrology. For example, total nitrogen was high in both the agricultural and low-density suburban sites. Total phosphorus, on the other hand, was high in the Baltimore Ecosystem Study agricultural catchment, but close to the concentration of the forest site in the low-density suburban site serviced by septic systems. This is because septic systems tend to retain phosphorus, while septic wastewater nitrogen is typically nitrified in the unsaturated zone below a spreading field and efficiently transported in the groundwater to nearby streams.

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BOX 3-7 Continued

TABLE 3-2A Dissolved Nitrate and Total Nitrogen Export Rates from Forest and Developed Land-Use Catchments in the Baltimore Ecosystem Study

Catchment	Land Use	Nitrate (kg N/ha/yr)			Total N (kg N/ha/yr)		
		2000	2001	2002	2000	2001	2002
Pond Branch	Forest	0.11	0.08	0.04	.47	.37	0.17
McDonogh	Agriculture	17.6	12.9	4.3	20.5	14.5	4.5
Baisman Run	Mixed Forest and Suburban	7.2	3.8	1.5	8.2	4.2	1.7
Dead Run	Urban	3.0	2.9	2.9	5.6	5.3	4.2

TABLE 3-2B Dissolved Phosphate and Total Phosphorus Export Rates from Forest and Developed Land-Use Catchments in the Baltimore Ecosystem Study

Catchment	Land Use	Phosphate (kg P/ha/yr)			Total P (kg P/ha/yr)		
		2000	2001	2002	2000	2001	2002
Pond Branch	Forest	0.009	0.007	0.003	0.02	0.014	0.006
McDonogh	Agriculture	0.12	0.080	0.022	0.22	0.14	0.043
Baisman Run	Mixed Forest and Suburban	0.009	0.005	0.002	0.02	0.011	0.004
Dead Run	Urban	0.039	0.037	0.03	0.10	0.10	0.08

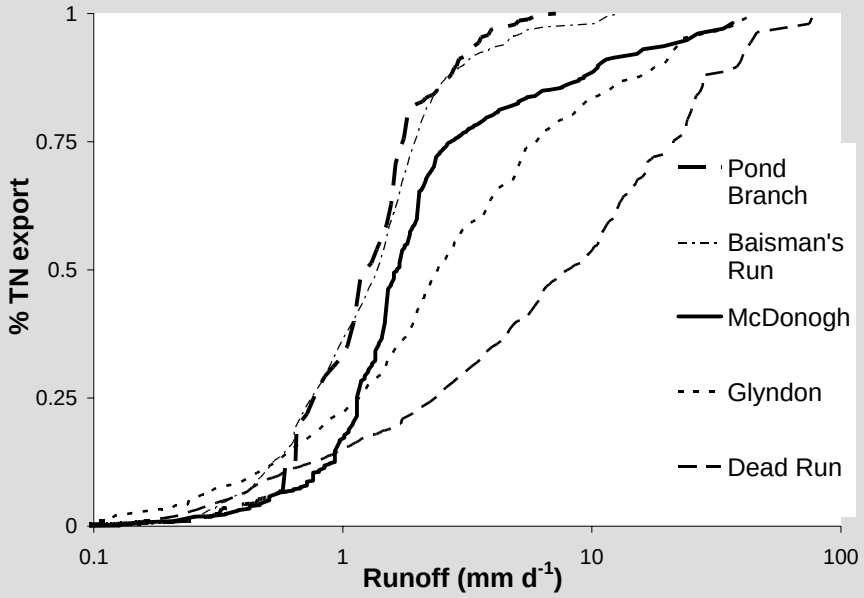

FIGURE 3-26 Cumulative transport of total nitrogen at increasing flow levels from catchments in Baltimore City and County including dominantly forest (Pond Branch), low-density development on septic systems and forest (Baisman Run), agricultural (McDonogh), medium-density suburban development on separate sewers (Glyndon), and higher-density residential, commercial, and highway land cover (Dead Run). SOURCE: Reprinted, with permission, from Shields et al. (2008). Copyright 2008 by the American Geophysical Union.

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Table 3-3 summarizes the comparative importance of urban land-use types in generating pollutants of concerns that can impact receiving waters (Burton and Pitt, 2002). This summary is highly qualitative and may vary depending on the site-specific conditions, regional climate, activities being conducted in each land use, and development characteristics. It should be noted that the rankings in Table 3-3 are relative to one another and classified on a per-unit-area basis. Furthermore, this table shows the parameters for each land-use category, such that the effects for a community at large would be dependent on the areas of each land use shown. Thus, although residential land use is shown to be a relatively smaller source of many pollutants, it is the largest fraction of land use in most communities, typically making it the largest stormwater source on a mass pollutant discharge basis. Similarly, freeway, industrial, and commercial areas can be very significant sources of many stormwater problems, and their discharge significance is usually much greater than their land area indicates. Construction sites are usually the overwhelming source of sediment in urban areas, even though they make up very small areas of most communities. A later table (Table 3-4) presents observed stormwater discharge concentrations for selected constituents for different land uses.

The following section describes stormwater characteristics associated with urbanized conditions. At any given time, parts of an urban area will be under construction, which is the source of large sediment losses, flow path disruptions, increased runoff quantities, and some chemical contamination. Depending on the time frame of development, increased stormwater pollutant discharges associated with construction activities may last for several years until land covers are stabilized. After construction has been completed, the characteristics of urban runoff are controlled largely by the increase in volume and the washoff of pollutants from impervious

TABLE 3-3 Relative Sources of Parameters of Concern for Different Land Uses in Urban Areas

Problem Parameter	Residential	Commercial	Industrial	Freeway	Construction
High flow rates (energy)	Low	High	Moderate	High	Moderate
Large runoff volumes	Low	High	Moderate	High	Moderate
Debris (floatables and gross solids)	High	High	Low	Moderate	High
Sediment	Low	Moderate	Low	Low	Very high
Inappropriate discharges (mostly sewage and cleaning wastes)	Moderate	High	Moderate	Low	Low
Microorganisms	High	Moderate	Moderate	Low	Low
Toxicants (heavy metals and organics)	Low	Moderate	High	High	Moderate
Nutrients (eutrophication)	Moderate	Moderate	Low	Low	Moderate
Organic debris (SOD and DO)	High	Low	Low	Low	Moderate
Heat (elevated water temperature)	Moderate	High	Moderate	High	Low

NOTE: SOD, sediment oxygen demand; DO, dissolved oxygen.
SOURCE: Summarized from Burton and Pitt (2002), Pitt et al. (2008), and CWP and Pitt (2008).

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surfaces. Stormwater in this phase is associated with increases in discharges of most pollutants, but with less sediment washoff than from construction and likely less sediment and nutrient discharges compared to any pre-urbanization agricultural operations (although increased channel erosion may increase the mass of sediment delivered in this phase; Pitt et al., 2007). A third significant urban land use is industrial activity. As described later, industrial site stormwater discharges are highly variable, but often greater than other land uses.

Construction Site Erosion Characteristics

Problems associated with construction site runoff have been known for many years. More than 25 years ago, Willett (1980) estimated that approximately 5 billion tons of sediment reached U.S. surface waters annually, of which 30 percent was generated by natural processes and 70 percent by human activities. Half of this 70 percent was attributed to eroding croplands. Although construction occurred on only about 0.007 percent of U.S. land in the 1970s, it accounted for approximately 10 percent of the sediment load to all U.S. surface waters and equaled the combined sediment contributions of forestry, mining, industrial, and commercial land uses (Willett, 1980).

Construction accounts for a much greater proportion of the sediment load in urban areas than it does in the nation as a whole. This is because construction sites have extremely high erosion rates and because urban construction sites are efficiently drained by stormwater drainage systems installed early during the construction activities. Construction site erosion losses vary greatly throughout the nation, depending on local rain, soil, topographic, and management conditions. As an example, the Birmingham, Alabama, area may have some of the highest erosion rates in the United States because of its combination of very high-energy rains, moderately to severely erosive soils, and steep slopes (Pitt et al., 2007). The typically high erosion rates mean that even a small construction project may have a significant detrimental effect on local waterbodies.

Extensive evaluations of urban construction site runoff problems have been conducted in Wisconsin for many years. Data from the highly urbanized Menomonee River watershed in southeastern Wisconsin indicate that construction sites have much greater potentials for generating sediment and phosphorus than do other land uses (Chesters et al., 1979). For example, construction sites can generate approximately 8 times more sediment and 18 times more phosphorus than industrial sites (the land use that contributes the second highest amount of these pollutants) and 25 times more sediment and phosphorus than row crops. In fact, construction sites contributed more sediment and phosphorus to the Menomonee River than any other land use, although in 1979, construction comprised only 3.3 percent of the watershed's total land area. During this early study, construction sites were found to contribute about 50 percent of the suspended sediment and total phosphorus loading at the river mouth (Novotny and Chesters, 1981).

Similar conclusions were reported by the Southeastern Wisconsin Regional Planning Commission (SEWRPC) in a 1978 modeling study of the relative pollutant contributions of 17 categories of point and nonpoint pollution sources to 14 watersheds in the southeast Wisconsin regional planning area (SEWRPC, 1978). This study revealed construction as the first or second largest contributor of sediment and phosphorus in 12 of the 14 watersheds. Although construction occupied only 2 percent of the region's total land area in 1978, it contributed

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approximately 36 percent of the sediment and 28 percent of the total phosphorus load to inland waters, making construction the region's second largest source of these two pollutants. The largest source of sediment was estimated to be cropland; livestock operations were estimated to be the largest source of phosphorus. By comparison, cropland comprised 72 percent of the region's land area and contributed about 45 percent of the sediment and only 11 percent of the phosphorus to regional watersheds. When looking at the Milwaukee River watershed as a whole, construction is a major sediment contributor, even though the amount of land under active construction is very low. Construction areas were estimated to contribute about 53 percent of the total sediment discharged by the Milwaukee River in 1985 (total sediment load of 12,500 lb/yr), while croplands contributed 25 percent, streambank erosion contributed 13 percent, and urban runoff contributed 8 percent.

Line and White (2007) recently investigated runoff characteristics from two similar drainage areas in the Piedmont region of North Carolina. One of the drainage areas was being developed as part of a large residential subdivision during the course of the study, while the other remained forested or in agricultural fields. Runoff volume was 68 percent greater for the developing compared with the undeveloped area, and baseflow as a percentage of overall discharge was approximately zero compared with 25 percent for the undeveloped area. Overall annual export of sediment was 95 percent greater for the developing area, while export of nitrogen and phosphorus forms was 66 to 88 percent greater for the developing area.

The biological stream impact of construction site runoff can be severe. For example, Hunt and Grow (2001) describe a field study conducted to determine the impact to a stream from a poorly controlled construction site, with impact being measured via fish electroshocking and using the Qualitative Habitat Evaluation Index. The 33-acre construction site consisted of severely eroded silt and clay loam subsoil and was located within the Turkey Creek drainage, Scioto County, Ohio. The number of fish species declined (from 26 to 19) and the number of fish found decreased (from 525 to 230) when comparing upstream unimpacted reaches to areas below the heavily eroding site. The Index of Biotic Integrity and the Modified Index of Well-Being, common fisheries indexes for stream quality, were reduced from 46 to 32 and 8.3 to 6.3, respectively. Upstream of the area of impact, Turkey Creek had the highest water quality designation available, but fell to the lowest water quality designation in the area of the construction activity. Water quality sampling conducted at upstream and downstream sites verified that the decline in fish diversity was not due to chemical affects alone.

Municipal Stormwater Characteristics

The suite of stormwater pollutants generated by municipal areas is expected to be much more diverse than construction sites because of the greater variety of land uses and pollutant source areas found within a typical city. Many studies have investigated stormwater quality, with the U.S. Environmental Protection Agency's (EPA's) NURP (EPA, 1983) being the best known and earliest effort to collect and summarize these data. Unfortunately, NURP was limited in that it did not represent all areas of the United States or all important land uses. More recently, the National Stormwater Quality Database (NSQD) (CWP and Pitt, 2008; Pitt et al., 2008 for version 3) has been compiling data from the EPA's NPDES stormwater permit program for larger Phase I municipal separate storm sewer system (MS4) communities. As a condition of their Phase I permits, municipalities were required to establish a monitoring program to

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characterize their local stormwater quality for their most important land uses discharging to the MS4. Although only a few samples from a few locations were required to be monitored each year in each community, the many years of sampling and large number of communities has produced a database containing runoff quality information for nearly 8,000 individual storm events over a wide range of urban land uses. The NSQD makes it possible to statistically compare runoff from different land uses for different areas of the country.

A number of land uses are represented in MS4 permits and also the database, including industrial stormwater discharges to an MS4. However, there is no separate compilation of quantitative mass emissions from specific industrial stormwater sources that may have been collected under industrial permit monitoring efforts. The observations in the NSQD were all obtained at outfall locations and do not include snowmelt or construction erosion sources. The most recent version of the NSQD contains stormwater data from about one-fourth of the total number of communities that participated in the Phase I NPDES stormwater permit monitoring activities. The database is located at http://unix.eng.ua.edu/~rpitt/Research/ms4/mainms4.shtml.

Table 3-4 is a summary of *some* of the stormwater data included in NSQD version 3, while Figure 3-27 shows selected plots of these data. The table describes the total number of observations, the percentage of observations above the detection limits, the median, and coefficients of variation for a few of the major constituents for residential, commercial, industrial, institutional, freeway, and open-space land-use categories, although relatively few data are available for institutional and open-space areas. It should be noted that even if there are significant differences in the median concentrations by the land uses, the range of the concentrations within single land uses can still be quite large. Furthermore, plots like Figure 3-27 do not capture the large variability in data points observed at an individual site.

There are many factors that can be considered when examining the quality of stormwater, including land use, geographical region, and season. The following is a narrative summary of the entire database and may not reflect information in Table 3-4 and Figure 3-29, which show only subsets of the data. First, statistical analyses of variance on the NSQD found significant differences among land-use categories for all of the conventional constituents, except for dissolved oxygen. (Turbidity, total solids, total coliforms, and total *E. coli* did not have enough samples in each group to evaluate land-use differences.) Freeway sites were found to be significant sources of several pollutants. For example, the highest TSS, COD, and oil and grease concentrations (but not necessarily the highest *median* concentrations) were reported for freeways. The median ammonia concentration in freeway stormwater is almost three times the median concentration observed in residential and open-space land uses, while freeways have the lowest orthophosphate and nitrite–nitrate concentrations—half of the concentration levels that were observed in industrial land uses.

In almost all cases the median metal concentrations at the industrial areas were about three times the median concentrations observed in open-space and residential areas. The highest lead and zinc concentrations (but not necessarily the highest *median* concentrations) were found in industrial land uses. Lower concentrations of TDS, five-day biological oxygen demand (BOD_5), and fecal coliforms were observed in industrial land-use areas. By contrast, the highest concentrations of dissolved and total phosphorus were associated with residential land uses. Fecal coliform concentrations are also relatively high for residential and mixed residential land uses. Open-space land-use areas show consistently low concentrations for the constituents examined. There was no significant difference noted for total nitrogen among any of the land uses monitored.

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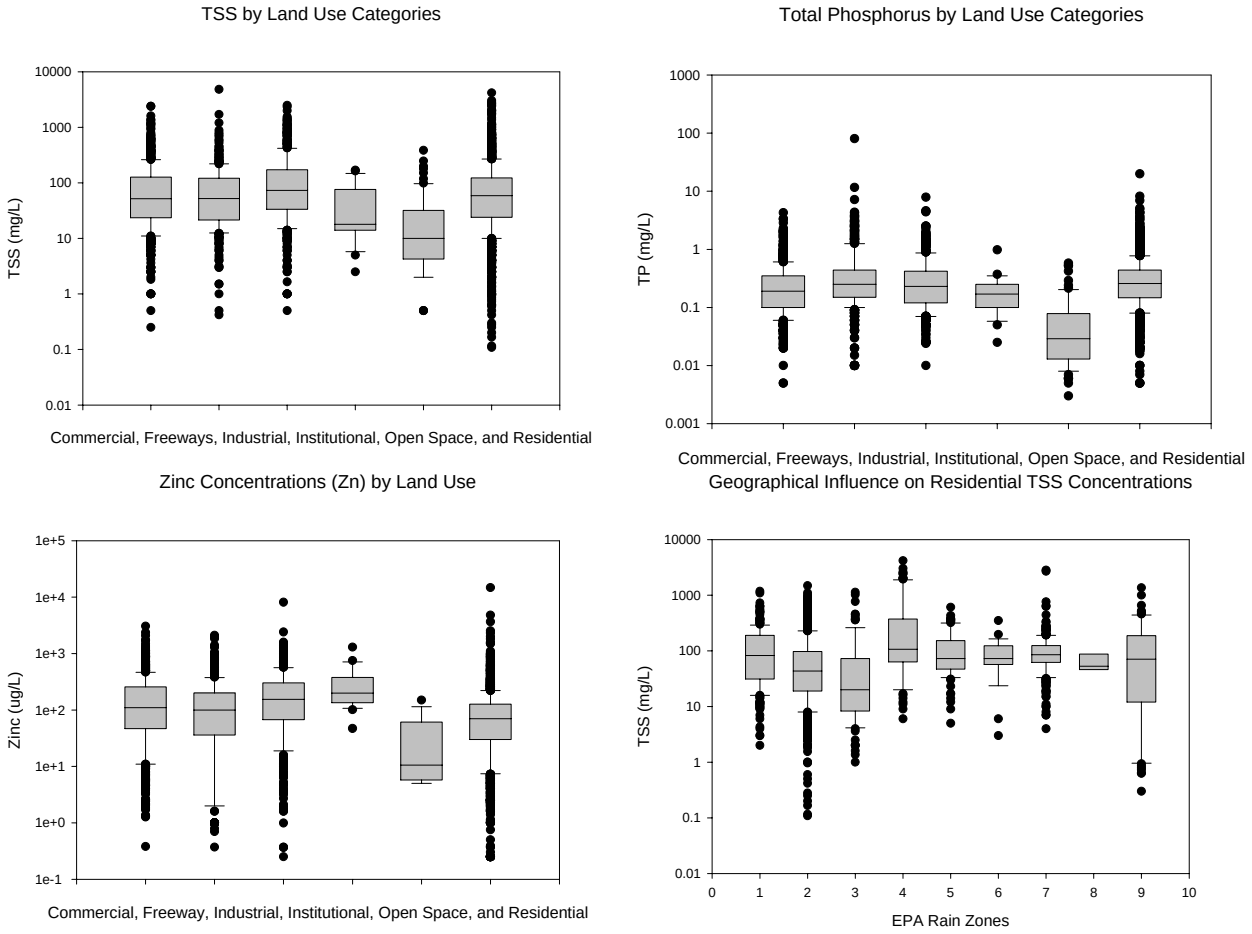

FIGURE 3-27 Grouped box and whisker plots of data from the NSQD. The median values are indicated with the horizontal line in the center of the box, while the ends of the box represent the 25th and 75th percentile values. The whickers extend to the 5th and 95th percentile values, and values outside of these extremes are indicated with separate dots. These groups were statistically analyzed and were found to have at least one group that is significantly different from the other groups. The ranges of the values in each group are large, but a very large number of data points is available for each group. The grouping of the data into these categories helps explain much of the total variability observed, and the large number of samples in each category allows suitable statistical tests to be made. Many detailed analyses are presented at the NSQD website (Maestre and Pitt, 2005).

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TABLE 3-4 Summary of Selected Stormwater Quality Data Included in NSQD, Version 3.0

	TSS (mg/L)	COD (mg/L)	Fecal Colif. (mpn/100 mL)	Nitrogen, Total Kjeldahl (mg/L)	Phosphorus, Total (mg/L)	Cu, Total (µg/L)	Pb, Total (µg/L)	Zn, Total (µg/L)
All Areas Combined (8,139)								
Coefficient of variation (COV)	2.2	1.1	5.0	1.2	2.8	2.1	2.0	3.3
Median	62.0	53.0	4300	1.3	0.2	15.0	14.0	90.0
Number of samples	6780	5070	2154	6156	7425	5165	4694	6184
% samples above detection	99	99	91	97	97	88	78	98
All Residential Areas Combined (2,586)								
COV	2.0	1.0	5.7	1.2	1.6	1.9	2.1	3.3
Median	59.0	50.0	4200	1.2	0.3	12.0	6.0	70.0
Number of samples	2167	1473	505	2026	2286	1640	1279	1912
% samples above detection	99	99	89	98	98	88	77	97
All Commercial Areas Combined (916)								
COV	1.7	1.0	3.0	0.9	1.2	1.4	1.7	1.4
Median	55.0	63.0	3000	1.3	0.2	17.9	15.0	110.0
Number of samples	843	640	270	726	920	753	605	839
% samples above detection	97	98	89	98	95	85	79	99
All Industrial Areas Combined (719)								
COV	1.7	1.3	6.1	1.1	1.4	2.1	2.0	1.7
Median	73.0	59.0	2850	1.4	0.2	19.0	20.0	156.2
Number of samples	594	474	317	560	605	536	550	596
% samples above detection	98	98	94	97	95	86	76	99
All Freeway Areas Combined (680)								
COV	2.6	1.0	2.7	1.2	5.2	2.2	1.1	1.4
Median	53.0	64.0	2000	1.7	0.3	17.8	49.0	100.0
Number of samples	360	439	67	430	585	340	355	587
% samples above detection	100	100	100	99	99	99	99	99
All Institutional Areas Combined (24)								
COV	1.1	1.0	0.4	0.6	0.9	0.6	1.0	0.9
Median	18.0	37.5	3400	1.1	0.2	21.5	8.6	198.0
Number of samples	23	22	3	22	23	21	21	22
% samples above detection	96	91	100	91	96	57	86	100
All Open-Space Areas Combined (79)								
COV	1.8	0.6	1.2	1.2	1.5	0.4	0.9	0.8
Median	10.5	21.3	2300	0.4	0.0	9.0	48.0	57.0
Number of samples	72	12	7	50	77	15	10	16
% samples above detection	97	83	100	96	97	47	20	50

NOTE: The complete database is located at: http://unix.eng.ua.edu/~rpitt/Research/ms4/mainms4.shtml. SOURCE: National Stormwater Quality Database.

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In terms of regional differences, significantly higher concentrations of TSS, BOD_5, COD, total phosphorus, total copper, and total zinc were observed in arid and semi-arid regions compared to more humid regions. In contrast, fecal coliforms and total dissolved solids were found to be higher in the upper Midwest. More detailed discussions of land use and regional differences in stormwater quality can be found in Maestre et al. (2004) and Maestre and Pitt (2005, 2006). In addition to the information presented above, numerous researchers have conducted source area monitoring to characterize sheet flows originating from urban surfaces (such as roofs, parking lots, streets, landscaped areas, storage areas, and loading docks). The reader is referred to Pitt et al. (2005a,b,c) for much of this information.

Industrial Stormwater Characteristics

The NSQD, described earlier, has shown that industrial-area stormwater has higher concentrations of most pollutants compared to other land uses, although the variability is high. MS4 monitoring activities are usually conducted at outfalls of drainage systems containing many individual industrial activities, so discharge characteristics for specific industrial types are rarely available. This discussion provides some additional information concerning industrial stormwater beyond that included in the previous discussion of municipal stormwater. In general, there is a profound lack of data on industrial stormwater compared to municipal stormwater, and a correspondingly greater uncertainty about industrial stormwater characteristics.

The first comprehensive monitoring of an industrial area that included stormwater, dry weather base flows, and snowmelt runoff was conducted in selected Humber River catchments in Ontario (Pitt and McLean, 1986). Table 3-5 shows the annual mass discharges from the monitored industrial area in North York, along with ratios of these annual discharges compared to discharges from a mixed commercial and residential area in Etobicoke. The mass discharges of heavy metals, total phosphorus, and COD from industrial stormwater are three to six times that of the mixed residential and commercial areas.

TABLE 3-5 Annual Storm Drainage Mass Discharges from Toronto-Area Industrial Land Use

Measured parameter	**units**	**annual mass discharges from industrial drainage area**	**stormwater annual discharge ratio (industrial compared to residential and commercial mixed area)**
Runoff volume	m^3/hr/yr	6,580	1.6
total solids	kg/ha/yr	6,190	2.8
total phosphorus	kg/ha/yr	4,320	4.5
TKN	g/ha/yr	16,500	1.2
COD	kg/ha/yr	662	3.3
Cu	g/ha/yr	416	4.0
Pb	g/ha/yr	595	4.2
Zn	g/ha/yr	1,700	5.8

SOURCE: Pitt and McLean (1986).

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Hotspots of contamination on industrial sites are a specific concern. Stormwater runoff from "hotspots" may contain loadings of hydrocarbons, trace metals, nutrients, pathogens and/or other toxicants that are greater than the loadings of "normal" runoff. Examples of these hotspots include airport de-icing facilities, auto recyclers/junkyards, commercial garden nurseries, parking lots, vehicle fueling and maintenance stations, bus or truck (fleet) storage areas, industrial rooftops, marinas, outdoor transfer facilities, public works storage areas, and vehicle and equipment washing/steam cleaning facilities (Bannerman et al., 1993; Pitt et al., 1995; Claytor and Schueler, 1996).

The elevated concentrations and mass discharges found in stormwater at industrial sites are associated with both the activities that occur and the materials used in industrial areas, as discussed in the sections that follow.

Effects of Roofing Materials on Stormwater Quality

The extensive rooftops of industrial areas can be a significant pollutant source area. A summary of the literature on roof-top runoff quality, including both roof surfaces and underlying materials used as subbases (such as treated wood), is presented in Table 3-6. Good (1993) found that dissolved metals' concentrations and toxicity remained high in roof runoff samples, especially from rusty galvanized metal roofs during both first flush and several hours after a rain has started, indicating that metal leaching continued throughout the events and for many years. During pilot-scale tests of roof panels exposed to rains over a two-year period, Clark et al. (2008) found that copper roof runoff concentrations for newly treated wood panels exceeded 5 mg/L (a very high value compared to median NSQD stormwater concentrations of about 10 to 40 µg/L for different land uses) for the first nine months of exposure. These results indicated that copper continued to be released from these wood products at levels high enough to exceed aquatic life criteria for long periods after installation, and were not simply due to excess surface coating washing off in the first few storms after installation.

Traditional unpainted or uncoated hot-dip galvanized steel roof surfaces can also produce very high zinc concentrations. For example, pilot-scale tests by Clark et al. (2008) indicated that zinc roof runoff concentrations were 5 to 30 mg/L throughout the first two years of monitoring of a traditional galvanized metal panel. These are very high values compared to median stormwater values reported in the NSQD of 60 to 300 µg/L for different land uses. Factory-painted aluminum–zinc alloy panels had runoff zinc levels less than 250 µg/L, which were closer to the reported NSQD median values. The authors concluded that traditional galvanized metal roofing contributed the greatest concentrations of many metals and nutrients. In addition, they found that pressure-treated and waterproofed wood contributed substantial copper loads. The potential for nutrient release exists in many of the materials tested (possibly as a result of phosphate washes and binders used in the material's preparation or due to natural degradation).

Other researchers have investigated the effects of industrial rooftop runoff on receiving waters and biota. Bailey et al. (1999) investigated the toxicity to juvenile rainbow trout of runoff from British Columbia sawmills and found that much of the toxicity may have been a result of divalent cations on the industrial site, especially zinc from galvanized roofs.

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TABLE 3-6 Roof Runoff Analysis—A Literature Summary

Roof Type	Location	Water Quality Parameter								Reference
		Cu (µg/L)	Zn (µg/L)	Pb (µg/L)	Cd (µg/L)	As (µg/L)	pH	NH_4^+ (mg/L)	NO_3^- (mg/L)	
Polyester Tile Flat gravel	Duebendorf, Switzerland	6817 1905 140	2076 360 36	510 172 22	3.1 2.1 0.2					Boller (1997)
Plywood w/ roof paper/tar Rusty galvanized metal Old metal w/Al paint Flat tar surface w/fibrous reflective Al paint New anodized Al	Washington	$166^T/128^D$ $20^T/2^D$ $11^T/7^D$ $25^T/14^D$ $16^T/7^D$	$877^T/909^D$ $12200^T/11900^D$ $1980^T/1610^D$ $297^T/257^D$ $101^T/82^D$	$11^T/<5^D$ $302^T/35^D$ $10^T/<5^D$ $10^T/5^D$ $15^T/<5^D$			4.3 5.9 4.8 4.1 5.9			Good (1993)
Zinc-galvanized Fe	Dunedin City, New Zealand	560 µg/g	5901 µg/g	670 µg/g						Brown & Peake (2006)
Fe-Zn sheets Concrete slate tiles Asbestos cement sheets Aluminum sheets	Ile-Ife, Nigeria						6.77 7.45 7.09 6.68	0.06 0.05 0.06 0.05	1.52 3.34 2.26 6.18	Adeniyi and Olabanji (2005)
Cu panels	Munich, Germany	200–11100					6.7–7.0			Athanasiadis et al. (2006)
Galvanized metals (primarily Galvalume®)	Seattle, WA	10–1400	420–14700	ND						Tobiason (2004)
CCA wood Untreated wood	Florida					1200–1800 2–3				Khan et al. (2006)

Note: D, dissolved; T, total; ND, not detected.

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Effects of Pavement and Pavement Maintenance on Stormwater Quality

Pavement surfaces can also have a strong influence on stormwater runoff quality. For example, concrete is often mixed with industrial waste sludges as a way of disposing of the wastes. However, this can lead to stormwater discharges high in toxic compounds, either due to the additives themselves or due to the mobilization of compounds via the additives. Salaita and Tate (1998) showed that high levels of aluminum, iron, calcium, magnesium, silicon, and sodium were seen in the cement-waste samples. A variety of sands, including waste sands, have been suggested as potential additives to cement and for use as fill in roadway construction. Wiebusch et al. (1998) tested brick sands and found that the higher the concentration of alkaline and alkaline earth metals in the samples, the more easily the heavy metals were released. Pitt et al. (1995) also found that concrete yard runoff had the highest toxicity (using Microtox screening methods) observed from many source areas, likely due to the elevated pH (about 11) from the lime dust washing off from the site.

The components of asphalt have been investigated by Rogge et al. (1997), who found that the majority of the elutable organic mass that could be identified consisted of *n*-alkanes (73 percent), carboxylic acids such as *n*-alkanoic acids (17 percent), and benzoic acids. PAHs and thiaarenes were 7.9 percent of the identifiable mass. In addition, heterocyclic aromatic hydrocarbons containing sulfur (S-PAH), such as dibenzothiophene, were identified at concentration levels similar to that of phenanthrene. S-PAHs are potentially mutagenic (similar to other PAHs), but due to their slightly increased polarity, they are more soluble in water and more prone to aquatic bioaccumulation.

In addition to the bitumens and asphalts, other compounds are added to paving (and asphaltic roofing) materials. Chemical modifiers are used both to increase the temperature range at which asphalts can be used and to prevent stripping of the asphalt from the binder. A variety of fillers may also be used in asphalt pavement mixtures. The long-term environmental effects of these chemicals in asphalts are unknown. Reclaimed asphalt pavements have also been proposed for use as fill materials for roadways. Brantley and Townsend (1999) performed a series of leaching tests and analyzed the leachate for a variety of organics and heavy metals. Only lead from asphalt pavements reclaimed from older roadways was found to be elevated in the leachate.

Stormwater quality from asphalt-paved surfaces seems to vary with time. Fish kills have been reported when rains occur shortly after asphalt has been installed in parking areas near ponds or streams (Anonymous, 2000; Perez-Rivas, 2000; Kline, 2002). It is expected that these effects are associated with losses of the more volatile and toxic hydrocarbons that are present on new surfaces. It is likely that the concentrations of these materials in runoff decrease as the pavement ages. Toxicity tests conducted on pavements several years old have not indicated any significant detrimental effects, except for those associated with activities conducted on the surface (such as maintenance and storage of heavy equipment; Pitt et al., 1995, 1999). However, pavement maintenance used to "renew" the asphalt surfaces has been shown to cause significant problems, which are summarized below.

A significant source of PAHs in the Austin, Texas, area (and likely elsewhere) has been identified as coal-tar sealants commonly used to "restore" asphalt parking lots and storage areas. Mahler et al. (2005) found that small particles of sealcoat that flake off due to abrasion by vehicle tires have PAH concentrations about 65 times higher than for particles washed off parking lots that are not seal coated. Unsealed parking lots receive PAHs from the same urban

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sources as do sealed parking lots (e.g., tire particles, leaking motor oil, vehicle exhaust, and atmospheric fallout), and yet the average yield of PAHs from the sealed parking lots was found to be 50 times greater than that from the control lots. The authors concluded that sealed parking lots could be the dominant source of PAHs in watersheds that have seal-coated surfaces, such as many industrial, commercial, and residential areas. Consequently, the City of Austin has restricted the use of parking lot coal-tar sealants, as have several Wisconsin communities.

Stored Materials Exposed to Rain

Although roofing and pavement materials make up a large fraction of the total surface covers and can have significant effects on stormwater quality, leaching of rain through stored materials may also be a significant pollutant source at industrial sites. Exposed metals in scrap yards can result in very high concentrations of heavy metals. For example, Table 3-7 summarizes data from three metals recycling facilities/scrap yards in Wisconsin and shows the large fraction of metals that are either dissolved in the runoff or associated with very fine particulate matter. For most of these metals, their greatest abundance is associated with the small particles (<20 μm in diameter), and relatively little is associated with the filterable fraction. These metals concentrations (especially zinc, copper, and lead) are also very high compared to that of most outfall industrial stormwater.

TABLE 3-7 Metal Concentration Ranges Observed in Scrapyard Runoff

Particle Size	**Iron (mg/L)**	**Aluminum (mg/L)**	**Zinc (mg/L)**
Total	20 – 810	15 – 70	1.6 – 8
< 63 μm diameter	22 – 767	15 – 58	1.5 – 7.6
< 38 μm diameter	21 – 705	15 – 58	1.4 – 7.4
< 20 μm diameter	15 – 534	12 – 50	1.1 – 7.2
< 0.45 μm diameter (filterable fraction)	0.1 – 38	0.1 – 5	0.1 – 6.7
	Copper (mg/L)	**Lead (mg/L)**	**Chromium (mg/L)**
Total	1.1 – 3.8	0.6 – 1.7	0.1 – 1.9
< 63 μm diameter	1.1 – 3.6	0.1 – 1.6	0.1 – 1.6
< 38 μm diameter	1.1 – 3.3	0.1 – 1.6	0.1 – 1.4
< 20 μm diameter	1.0 – 2.8	0.1 – 1.6	0.1 – 1.2
< 0.45 μm diameter (filterable fraction)	0.1 – 0.3	0.1 – 0.3	0.1 – 0.3

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OTHER SOURCES OF URBAN RUNOFF DISCHARGES

Wet weather stormwater discharges from separate storm sewer outfalls are not the only discharges entering receiving waters from these systems. Dry weather flows, snowmelt, and atmospheric deposition all contribute to the pollutant loading of urban areas to receiving waters, and for some compounds may be the largest contributor. Many structural SCMs, especially those that rely on sedimentation or filtration, have been designed to function primarily with stormwater and are not nearly as effective for dry weather discharges, snowmelt, or atmospheric deposition because these nontraditional sources vary considerably in key characteristics, such as the flow rate and volume to be treated, sediment concentrsations and particle size distribution, major competing ions, association of pollutants with particulates of different sizes, and temperature. Information on the treatability of stormwater vs. snowmelt and other nontraditional sources of urban runoff can be found in Pitt and McLean (1986), Pitt et al. (1995), Johnson et al. (2003), and Morquecho (2005).

Dry Weather Flows

At many stormwater outfalls, discharges occur during dry weather. These may be associated with discharges from leaking sanitary sewer and drinking water distribution systems, industrial wastewaters, irrigation return flows, or natural spring water entering the system. Possibly 25 percent of all separate stormwater outfalls have water flowing in them during dry weather, and as much as 10 percent are grossly contaminated with raw sewage, industrial wastewaters, and so forth (Pitt et al., 1993). These flow contributions can be significant on an annual mass basis, even though the flow rates are relatively small, because they have long duration. This is particularly true in arid areas, where dry weather discharges can occur daily. For example, despite the fact that rain is scarce from May to September in Southern California, an estimated 40 to 90 million liters of discharge flow per day into Santa Monica Bay through approximately 70 stormwater outlets that empty onto or across beaches (LAC DPW, 1985; SMBRP, 1994), such that the contribution of dry weather flow to the total volume of runoff into the bay is about 30 percent (NRC, 1984). Furthermore, in the nearby Ballona Creek watershed, dry weather discharges of trace metals were found to comprise from 8 to 42 percent of the total annual loading (McPherson et al., 2002). Stein and Tiefenthaler (2003) further found that the highest loadings of metals and bacteria in this watershed discharging during dry weather can be attributed to a few specific stormwater drains.

In many cases, stormwater managers tend to overlook the contribution of dry weather discharges, although the EPA's NPDES Stormwater Permit program requires municipalities to conduct stormwater outfall surveys to identify, and then correct, inappropriate discharges into separate storm sewer systems. The role of inappropriate discharges in the NPDES Stormwater Permit program, the developed and tested program to identify and quantify their discharges, and an extensive review of these programs throughout the United States can be found in the recently updated report prepared for the EPA (CWP and Pitt, 2004). The following photographs show various nontraditional sources of contaminants in urban runoff.

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Washing of vehicle engine and allowing runoff to enter storm drainage system. SOURCE: Robert Pitt.

Contamination of storm drainage with inappropriate disposal of oil. SOURCE: Center for Watershed Protection.

Dry weather flows from Toronto industrial area outfall. SOURCE: Pitt and McLean (1986).

Sewage from clogged system overflowing into storm drainage system. SOURCE: Robert Pitt.

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Failing sanitary sewer, causing upwelling of sewage through soil, and draining to gutter and then to storm drainage system.
SOURCE: Robert Pitt.

Dye tests to confirm improper sanitary sewage connection to storm drainage system SOURCE: Robert Pitt.

Snowmelt

In northern areas, snowmelt runoff can be a significant contributor to the annual discharges from urban areas through the storm drainage system. In locations having long and harsh winters, with little snowmelt until the spring, pollutants can accumulate and be trapped in the snowpack all winter until the major thaw when the contaminants are transported in short-duration events to the outfalls (Jokela, 1990). The sources of the contaminants accumulating in snowpack depend on the location, but they usually include emissions from nearby motor vehicles and heating equipment and industrial activity in the neighborhood. Dry deposition of sulfur dioxide from industrial and power plant smokestacks affects snow packs over a wider area and has frequently been studied because of its role in the acid deposition process (Cadle, 1991). Pollutants are also directly deposited on the snowpack. The sources of directly deposited pollutants include debris from deteriorated roadways, vehicles depositing petroleum products and metals, and roadway maintenance crews applying salt and anti-skid grit (Oberts, 1994). Urban snowmelt, like rain runoff, washes some material off streets, roofs, parking and industrial storage lots, and drainage gutters. However, snowmelt runoff usually has much less energy than striking rain and heavy flowing stormwater. Novotny et al. (1986) found that urban soil erosion is reduced or eliminated during winter snow-cover conditions. However, erosion of bare ground at construction sites in the spring due to snowmelt can still be very high.

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Snowmelt. SOURCE: Roger Bannerman.

Construction site in early spring after snowmelt showing extensive sediment transport. SOURCE: Roger Bannerman.

Sources of Contaminants in Snowmelt

Several mechanisms can bring about contamination of snow and snowmelt waters. Initially, air pollutants can be incorporated into snowflakes as they form and fall to the ground. After it falls to the ground and accumulates, the snow can become further contaminated by dry atmospheric deposition, deposition of nearby lost fugitive dust materials (usually blown onto snow packs near roads by passing vehicles), and wash off of particulates from the exposed ground surfaces as it melts and flows to the drainage system.

Snowflakes can remove particulates and gases from the air by in-cloud or below-cloud capture. In-cloud capture of pollutants can occur during snowflake formation as super-cooled cloud water condenses on particles and aerosols that act as cloud condensation nuclei. This is known as nucleation scavenging and is a major pathway for air pollution to be incorporated into snow. Particles and gases may also be scavenged as snowflakes fall to the ground. Gases can also be absorbed as snow falls. Snowflakes are more effective below-cloud scavengers than raindrops because they are bigger and fall slower. Barrie (1991) reports that large snowflakes

capture particles in the 0.2- to 0.4-μm-diameter range, not by impaction but by filtering the air that moves through the snow flakes as they fall to the ground.

Most of the contamination of snow in urban areas likely occurs after it lands on the ground. Table 3-8 shows the flow-weighted mean concentrations of pollutants found in undisturbed falling snow compared to snow found in urban snow cover (Bennett et al., 1981). Pitt and McLean (1986) also measured snowpack contamination as a function of distance from a heavily traveled road passing through a park. The contaminants in the snow were at much greater concentrations near the road (the major source of blown contamination on the snow) than farther away. (The pollutant levels in the fresh fallen snow are generally a small fraction of the levels in the snow collected from urban study areas.) Pierstorff and Bishop (1980) also analyzed freshly fallen snow and compared the quality to snow stored at a snow dump site. They concluded that "pollutant levels at the dump site are the result of environmental input occurring after the snow falls." Some pollutants in snowmelt have almost no atmospheric sources. For example, Oliver et al. (1974) found negligible amounts of chlorides in samples of snow from rooftops, indicating that the high chloride level found in the snowmelt runoff water comes almost entirely from surface sources (i.e., road salting). Similar roadside snowpack observations along city park roads by Pitt and McLean (1986) also indicated the strong association of road salt with snowpack chloride levels.

Runoff and Pollutant Loading from Snowmelt

Snowmelt events can exhibit a first flush, in which there are higher concentrations of contaminants at the beginning compared to the total event averaged concentration. The enrichment of the first portion of a snowmelt event by soluble pollutants may be due to snowpack density changes, where water percolation and melt/freeze events that occur in the snowpack cause soluble pollutants to be flushed from throughout the snowpack to concentrate at the bottom of the pack (Colbeck, 1981). This concentrated layer leaves the snowpack as a highly concentrated pulse, as snow melts from the bottom due to warmth from the ground (Oberts, 1994).

TABLE 3-8 Comparison of Flow-Weighted Pollutant Concentration Means of Snow Samples from Boulder, Colorado

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Note: The units are mg/L. SOURCE: Bennett et al. (1981). Permission pending.

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When it rains on snow, heavy pollutant loads can be produced because both soluble and particulate pollutants are melted from the snowpack simultaneously. Also, the large volume of melt plus rain can wash off pollutants that have accumulated on various surfaces such as roads, parking lots, roofs, and saturated soil surfaces. The intensity of runoff from a rain-on-snow event can be greater than a summer thunderstorm because the ground is saturated or frozen and the rapidly melting snowpack provides added runoff volume (Oberts, 1994).

Figure 3-28 compares the runoff volumes associated with snowmelts alone to those associated with snowmelts mixed with rain from monitoring at an industrial area in Toronto (Pitt and McLean, 1986). Rain with snowmelt contributes over 80 percent of the total cold-weather event runoff volume.

Whether pollutant loadings are higher or lower for snowmelt than for rainfall depends on the particular pollutant and its seasonal prevalence in the environment. For example, the high concentrations of dissolved solids found in snowmelt are usually caused by high chloride concentrations that stem from the amount of de-icing salt used. Figure 3-29 is a plot of the chloride concentrations in the influent to the Monroe Street detention pond in Madison, Wisconsin. Chloride levels are negligible in the non-winter months but increase dramatically when road salting begins in the fall, and remain high through the snow melting period, even extending another month or so after the snowpack in the area has melted. Bennett et al. (1981) found that suspended solids and COD loadings for snowmelt runoff were about one-half of those for rainfall. Nutrients were much lower for snowmelt, while the loadings for lead were about the same for both forms of precipitation. Oberts (1994) reports that much of the annual pollutant yields from event flows in Minneapolis is accounted for by end-of-winter major melts. End-of-winter melts yielded 8 to 20 percent of the total phosphorous and total lead annual load in Minnesota. Small midwinter melts accounted for less than 5 percent of the total loads. Box 3-8 shows mass pollutant discharges for a study site in Toronto and emphasizes the significance of snowmelt discharges on the total annual storm drainage discharges.

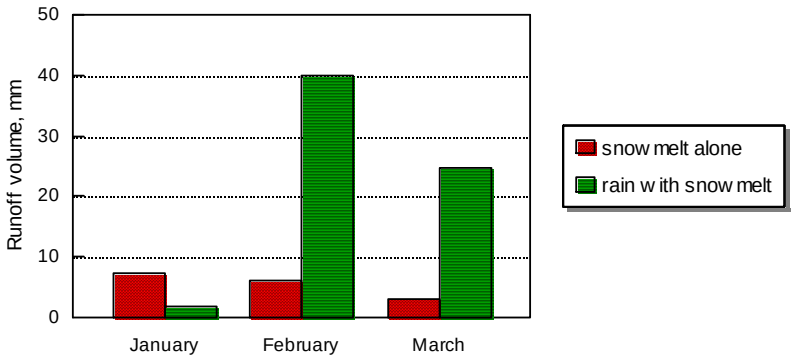

FIGURE 3-28 Runoff volumes for snowmelt events alone and when rain falls on melting snow packs (Toronto industrial area). SOURCE: Pitt and McLean (1986).

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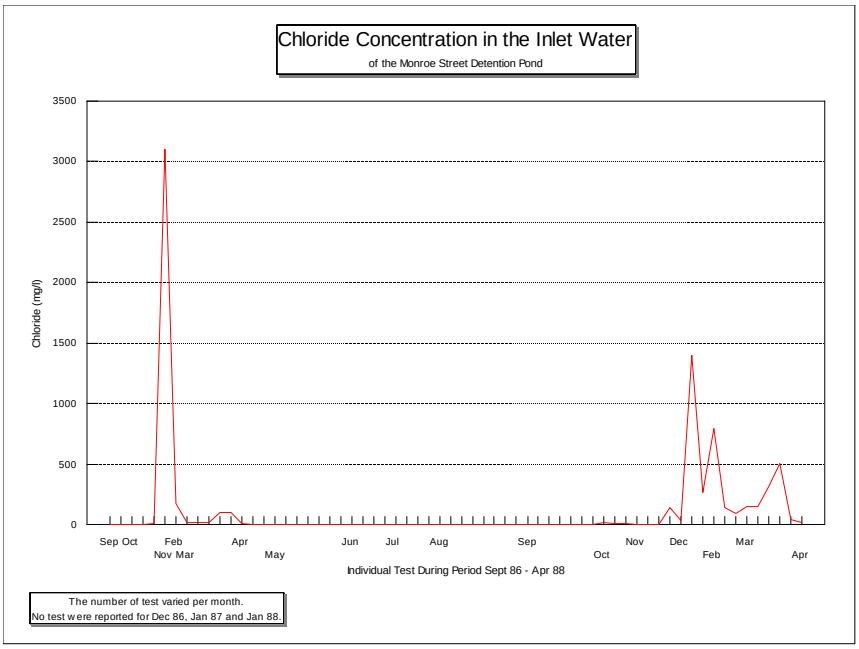

FIGURE 3-29 Monroe Street detention pond chloride concentration of influent (1986–1988). SOURCE: House et al. (1993).

Atmospheric Deposition

The atmosphere contains a diverse array of contaminants, including metals (e.g., copper, chromium, lead, mercury, zinc), nutrients (nitrogen, phosphorus), and organic compounds (e.g., PAHs, polychlorinated biphenyls, pesticides). These contaminants are introduced to the atmosphere by a variety of sources, including local point sources (e.g., power plant stacks) and mobile sources (e.g., motor vehicles), local fugitive emissions (e.g., street dust and wind-eroded materials), and transport from non-local areas. These emissions, composed of gases, small particles (aerosols), and larger particles, become entrained in the atmosphere and subject to a complex series of physical and chemical reactions (Schueler, 1983).

Atmospheric contaminants are deposited on land and water in two ways—termed wet deposition and dry deposition. Wet deposition (or wetfall) involves the sorption and condensation of pollutants to water drops and snowflakes followed by deposition with precipitation. This mechanism dominates the deposition of gases and aerosol particles. Dry deposition (or dryfall) is the direct transfer of contaminants to land or water by gravity (particles) or by diffusion (vapor and particles). Dry deposition occurs when atmospheric turbulence is not sufficient to counteract the tendency of particles to fall out at a rate governed, but not exclusively determined, by gravity (Schueler, 1983).

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BOX 3-8
The Contribution of Dry Weather Discharges and Snowmelt to Overall Runoff in Toronto, Ontario

An extensive analysis of all types of stormwater flow—for both dry and wet weather—was conducted in Toronto in the mid-1980s (Pitt and McLean, 1986). The Toronto Area Watershed Management Strategy study included comprehensive monitoring in a residential/commercial area and an industrial area for summer stormwater, warm season dry weather flows, snowmelt, and cold season dry weather flows. In addition to the outfall monitoring, detailed source area sheet flow monitoring was also conducted during rain and snowmelt events to determine the relative magnitude of pollutant sources. Particulate accumulation and wash-off tests were also conducted for a variety of streets in order to better determine their role in contaminant contributions.

Tables 3-9 and 3-10 summarize Toronto residential/commercial and industrial urban runoff median concentrations during both warm and cold weather, respectively. These tables show the relative volumes and concentrations of wet weather and dry weather flows coming from the different land uses. The bacteria densities during cold weather are substantially less than during warm weather, but are still relatively high; similar findings were noted during the NURP studies (EPA, 1983). However, chloride concentrations and dissolved solids are much higher during cold weather. Early spring stormwater events also contain high dissolved solids concentrations. Cold weather runoff accounted for more than half of the heavy metal discharges in the residential/commercial area, while warm weather discharges of zinc were much greater than the cold weather discharges for the industrial area. Warm weather flows were also the predominant sources of phosphorus for the industrial area.

One of the interesting observations is that, at these monitoring locations, warm weather stormwater runoff only contributed about 20 to 30 percent of the total annual flows being discharged from the separate stormwater outfalls. The magnitudes of the base flows were especially surprising, as these monitoring locations were research sites to investigate stormwater processes and were carefully investigated to ensure that they did not have significant inappropriate discharges before they were selected for the monitoring programs.

In comparing runoff from the industrial and residential catchments, Pitt and McLean (1986) observed that concentrations of most constituents in runoff from the industrial watershed were typically greater than the concentrations of the same constituents in the residential runoff. The only constituents with a unit-area yield that were lower in the industrial area were chlorides and total dissolved solids, which was attributed to the use of road de-icing salts in residential areas. Annual yields of several constituents (total solids, total dissolved solids, chlorides, ammonia nitrogen, and phenolics) were dominated by cold weather flows, irrespective of the land use.

A comparison of the Toronto sheet flow data from the different land-use areas indicated that the highest concentrations of lead and zinc were found in samples collected from paved areas and roads during both rain runoff and snowmelt (Pitt and McLean, 1986). Fecal coliform values were significantly higher on sidewalks and on, or near, roads during snowmelt sampling, likely because these areas are where dogs would be walked in winter conditions. In warm weather, dog walking would be less concentrated into these areas. The concentrations for total solids from grass or bare open areas were reduced dramatically during snowmelt compared to rain runoff, an indication of the reduced erosion and the poor delivery of particulate pollutants during snowmelt periods. Cold weather sheet flow median concentrations of particulate solids for the grass and open areas (80 mg/L) were much less than the TSS concentrations observed during warm weather runoff (250 mg/L) for these same areas. Snowmelt total solids concentrations also increased in areas located near roads due to the influence of road salting on dissolved solids concentrations. In the residential areas, streets were the most significant source of snowmelt solids, while yards and open areas were the major sources of nutrients. Parking and storage areas contributed the most snowmelt pollutants in the industrial area. An analysis of snow samples taken along a transect of a snowpack adjacent to an industrial road showed that the pollutant levels decreased as a function of distance from the roadway. At distances greater than 3 to 5 meters from the edge of the

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BOX 3-8 Continued

snowpack, the concentrations were relatively constant. Novotny et al. (1986) sampled along a transect of a snowpack by a freeway in Milwaukee. They also found that the concentration of constituents decreased as the distance from the road increased. Most of the measured constituents, including total solids and lead, were at or near background levels at 30 meters or more from the road.

TABLE 3-9 Median Pollutant Concentrations Observed at Toronto Outfalls during Warm Weather[1]

Measured Parameter	Baseflow		Stormwater	
	Residential	Industrial	Residential	Industrial
Stormwater volume (m^3/ha/season)	—	—	950	1500
Baseflow volume (m^3/ha/season)	1700	2100	—	—
Total residue	979	554	256	371
Total dissolved solids	973	454	230	208
Suspended solids	<5	43	22	117
Chlorides	281	78	34	17
Total phosphorus	0.09	0.73	0.28	0.75
Phosphates	<0.06	0.12	0.02	0.16
Total Kjeldahl nitrogen (organic N plus NH_3)	0.9	2.4	2.5	2.0
Ammonia nitrogen	<0.1	<0.1	<0.1	<0.1
Chemical oxygen demand	22	108	55	106
Fecal coliform bacteria (#/100 mL)	33,000	7,000	40,000	49,000
Fecal strep. bacteria (#/100 mL)	2,300	8,800	20,000	39,000
Pseudo. aeruginosa bacteria (#/100 mL)	2,900	2,380	2,700	11,000
Cadmium	<0.01	<0.01	<0.01	<0.01
Chromium	<0.06	0.42	<0.06	0.32
Copper	0.02	0.05	0.03	0.06
Lead	<0.04	<0.04	<0.06	0.08
Zinc	0.04	0.18	0.06	0.19
Phenolics (μg/L)	<1.5	2.0	1.2	5.1
α-BHC (ng/L)	17	<1	1	3.5
γ-BHC (lindane) (ng/L)	5	<2	<1	<1
Chlordane (ng/L)	4	<2	<2	<2
Dieldrin (ng/L)	4	<5	<2	<2
Pentachlorophenol (ng/L)	280	50	70	705

[1]Values are in mg/L unless otherwise indicated. Warm weather samples were obtained during the late spring, summer, and early fall months when the air temperatures were above freezing and no snow was present.

continues next page

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BOX 3-8 Continued

TABLE 3-10 Median Pollutant Concentrations Observed at Toronto Outfalls during Cold Weather[1]

Measured Parameter	Base flow		Snow melt	
	Residential	Industrial	Residential	Industrial
Stormwater volume (m^3/ha/season)	—	—	1800	830
Base flow volume (m^3/ha/season)	1100	660	—	—
Total residue	2230	1080	1580	1340
Total dissolved solids	2210	1020	1530	1240
Suspended solids	21	50	30	95
Chlorides	1080	470	660	620
Total phosphorus	0.18	0.34	0.23	0.50
Phosphates	<0.05	<0.02	<0.06	0.14
Total Kjeldahl nitrogen (organic N plus NH_3)	1.4	2.0	1.7	2.5
Ammonia nitrogen	<0.1	<0.1	0.2	0.4
Chemical oxygen demand	48	68	40	94
Fecal coliform bacteria (#/100 mL)	9800	400	2320	300
Fecal strep bacteria (#/100 mL)	1400	2400	1900	2500
Pseudomonas aeruginosa bacteria (#/100 mL)	85	55	20	30
Cadmium	<0.01	<0.01	<0.01	0.01
Chromium	<0.01	0.24	<0.01	0.35
Copper	0.02	0.04	0.04	0.07
Lead	<0.06	<0.04	0.09	0.08
Zinc	0.07	0.15	0.12	0.31
Phenolics (mg/L)	2.0	7.3	2.5	15
α-BHC (ng/L)	NA	3	4	5
γ-BHC (lindane) (ng/L)	NA	NA	2	1
Chlordane (ng/L)	NA	NA	11	2
Dieldrin (ng/L)	NA	NA	2	NA
Pentachlorophenol (ng/L)	NA	NA	NA	40

[1]Values are in mg/L unless otherwise indicated. Cold weather samples were obtained during the winter months when the air temperatures were commonly below freezing. Snowmelt samples were obtained during snowmelt episodes and when rain fell on snow.
NA, not analyzed

As atmospheric contaminants deposit, they can exert an influence on stormwater in several ways. Contaminants deposited by wetfall are directly conveyed to stormwater while those in dryfall can be washed off the land surface. For both processes, the atmospheric load of contaminants is strongly influenced by characteristics such as the amount of impervious surface, the magnitude and proximity of emission sources, wind speed and direction, and precipitation magnitude and frequency (Schueler, 1983). Deposition rates can depend on the type of contaminant and can be site-specific. The relationships between atmospheric deposition and stormwater quality are, however, not well understood and difficult to determine. Following are a few illustrative examples.

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Southern California

Several studies have addressed atmospheric deposition in Southern California (e.g., Lu et al., 2003; Harris and Davidson, 2005; Stolzenbach et al., 2007). Stolzenbach et al. and Lu et al. conclude the following *for this region:*

- the major source of contaminants to the atmosphere in this region is associated with resuspended dust, primarily from roads,
- contaminants in resuspended dust may reflect historical as well as current sources and distant as well as local sources,
- atmospheric loadings to the receiving water are primarily the result of chronic daily dry deposition of large particles greater than 10 µm in size on the watershed rather than directly on a waterbody,
- significant spatial variability occurs in trace metal mass loadings and deposition fluxes, particularly along transportation corridors along the coast and the mountain slopes of the airshed,
- significant diurnal and seasonal variations occur in the deposition of trace metals, and
- atmospheric deposition of metals is a significant component of contaminant loading to waterbodies in the region relative to other point and nonpoint sources.

Harris and Davidson (2005) have reported that traditional sources of lead to the south coast air basin of California accounted for less than 15 percent of the lead exiting the basin each year. They resolve this difference by considering that lead particles deposited during the years of leaded gasoline use are resuspended as airborne lead at this time, some decades after their original deposition. This result indicates that lead levels in the soil will remain elevated for decades and that resuspension of this lead will remain a major source of atmospheric lead well into the future.

Sabin et al. (2005) assessed the contribution of trace metals (chromium, copper, lead, nickel, and zinc) from atmospheric deposition to stormwater runoff in a small impervious urban catchment in the Los Angeles area. Dry deposition contributed 90 percent or more of the total deposition inside the catchment, indicating the dominance of dry deposition in semi-arid regions such as Los Angeles. Deposition potentially accounted for from 57 to 90 percent of the total trace metals in stormwater in the study area, demonstrating that atmospheric deposition can be an important source of trace metals in stormwater near urban centers.

San Francisco

Dissolved copper is toxic to phytoplankton, the base of the aquatic food chain. Copper and other metals are released in small quantities when drivers depress their brakes. The Brake Pad Partnership (http://www.suscon.org/brakepad/index/asp) has conducted studies to determine how much copper is released as wear debris, and how it travels through the air and streets to surface waters. A comprehensive and complex model of copper loads to and of transport and reactions in San Francisco Bay was developed (Yee and Franz, 2005). Objectives were to provide daily loadings of flow, TSS, and copper to the bay and to estimate the relative contribution of brake pad wear debris to copper in the bay. The modeling results (Rosselot, 2006a) indicated that an estimated 47,000 kg of copper was released to the atmosphere in the Bay Area in 2003. Of this

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amount, 17,000 kg Cu/yr was dry-deposited in subwatersheds; 3,200 kg Cu/yr was wet-deposited in subwatersheds; 1,200 kg Cu/yr was dry-deposited directly to bay waters; and 1,300 kg Cu/yr was wet-deposited directly to bay waters. The remaining 24,000 kg Cu/yr remained airborne until it left the Bay Area. The contribution of copper from brake pads to the bay is estimated to range from 10 to 35 percent of the total copper input, with the best estimate being 23 percent (Rosselot, 2006a,b).

Washington, D.C., Metropolitan Area

Schueler (1983) investigated the atmospheric deposition of several contaminants in Washington, D.C., and its surrounding areas in the early 1980s. The contaminants assessed included trace metals (cadmium, copper, iron, lead, nickel, and zinc), nutrients (nitrogen and phosphorus), solids, and organics as measured collectively by BOD and COD. Dryfall solids loading increased progressively from rural to urban sites. A similar trend was observed for total phosphorus, total nitrogen, and trace metal dry deposition rates. Wet deposition rates exhibited few consistent regional patterns.

The relative importance of wet and dry deposition varied considerably with each contaminant and each site. For example, most of the nitrogen was supplied by wet deposition while most of the phosphorus was delivered via dry deposition. If a contaminant is deposited primarily by wet deposition, it is likely that a major fraction of it will be rapidly entrained in urban runoff.

Atmospheric sources were estimated to contribute from 70 to 95 percent of the total nitrogen load to urban runoff and 20 to 35 percent of the total phosphorus load. Overall, atmospheric deposition appeared to be a moderate source of pollutants in urban runoff. However, with the exception of nitrogen, atmospheric deposition was not the major source.

Average annual atmospheric deposition rates suggested a general trend toward greater deposition rates from rural to suburban to urban sites. This pattern was most pronounced for dry deposition. Wet deposition was the most important deposition mechanism for total nitrogen, nitrate, organic nitrogen, COD, copper, and zinc. Dry deposition was most important for most soil-related constituents, such as total solids, iron, lead, total phosphorus, and orthophosphate.

Measurements of rainfall pH showed median values between 4.0 and 4.1 at all stations and during all seasons. Increased mobilization of trace metals from urban surfaces caused by acid rain was noted at several monitoring sites.

***

Relationships between atmospheric deposition rates and the quality of urban stormwater are complex and cannot be generalized regionally or temporally. Site-specific measurements or reliable estimates of (1) contaminant sources, (2) atmospheric particle size and contaminant concentrations, (3) deposition rates and mechanisms, (4) land surface characteristics, (5) local and regional hydrology and meteorology, and (6) contaminant concentrations in stormwater are needed to assess management decisions to improve stormwater quality. Transportation is a major source of metals (lead in gasoline, zinc in tires, copper in brake pads). The results of the modeling of copper in San Francisco and its watershed demonstrate the feasibility of modeling

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the impact of a source, in this case copper input by atmospheric deposition, on water quality in a receiving waterbody.

BIOLOGICAL RESPONSES TO URBANIZATION

As discussed in Chapter 1, the biological integrity of aquatic ecosystems is influenced by five major categories of environmental stressors: (1) chemical, (2) hydrologic, (3) physical (e.g., habitat), (4) biological (e.g., disease, alien species), and (5) energy-related factors (e.g., nutrient dynamics). Recent studies on biological assemblages in urban or urbanizing waters have begun to examine how stormwater stressors limit biological potential along various urban gradients (Horner et al., 2003; Carter and Fend, 2005; Meador et al., 2005; Barbour et al., 2008; Purcell et al., in press). Advances in biological monitoring and assessment over the past two decades have enabled much of this research. Today, many states and tribes use biological data to directly measure their aquatic life beneficial uses and have developed numeric biocriteria that are institutionalized in their water quality standards. Most of these approaches compare biology and stressors to suites of reference sites (Hughes, 1995; Stoddard et al., 2006), which can vary from near-pristine areas to agricultural landscapes. While this section focuses on streams because of the wealth of data, similar work is being performed on other waterbody types such as wetlands (Mack and Micacchion, 2007) and estuaries, both of which are susceptible to stormwater pollutants such as metals because of their depositional nature (Morrisey et al., 2000).

Aquatic life beneficial uses are based on achieving aquatic *potential* given feasible restorative actions. Because such potential may vary substantially across a region depending on land use and other factors, some states have adopted tiered aquatic life uses (see Box 2-1). The potential of many urban streams is likely to be something less than "biological integrity" (the ultimate goal of the CWA) or even "fishable–swimmable" goals, which are the interim goals of the CWA. Indeed, there is a near-universal, negative association between biological assemblages in streams and increasing urbanization, to the extent that it has been termed the "Urban Stream Syndrome" (Walsh et al., 2005). Recent investigations that have quantified the responses of macroinvertebrates and other biological assemblages along multiple measures of urban/stormwater stressors have discussed how best to set aquatic life goals for urban streams (Booth and Jackson, 1997; Bernhardt and Palmer, 2007). One of the most important contributions to this debate has been the development of the Biological Condition Gradient (BCG) concept by EPA. The BCG is an attempt to anchor and standardize interpretations of biological conditions and to unify biological monitoring results across the United States in order to advance the use of tiered aquatic life beneficial uses. This section summarizes the characteristic biological responses to urban gradients, within the framework of the BCG, and it reviews evidence of biological responses within the aforementioned five major categories of environmental stressors.

Biological Condition Gradient

The BCG framework is an ecological model of how structural and functional components of biological assemblages change along gradients of increasing stressors of many kinds (Davies and Jackson, 2006). Ecological systems have some common general attributes related to their

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structure and function that form the basis for how biological organisms respond to stressors in the environment. Over the past 20 years, development of biological indicators nationwide has taken advantage of these repeatable biological responses to stress; however, state benchmarks often have varied substantially, even between adjacent states. To gain consistency, the EPA convened a national workgroup of EPA Regions, States, and Tribes to develop the BCG—a standardized, nationally applicable model that defines important attributes of biological assemblages and describes how these attributes change along a gradient of increasing stress from pristine environments to severely impaired conditions (Figure 3-30; Davies and Jackson, 2006). The goals of this work were to improve national consistency in the rating and application of biological assessment tools for all types of waterbodies and to provide a baseline for the development of tiered aquatic life uses.

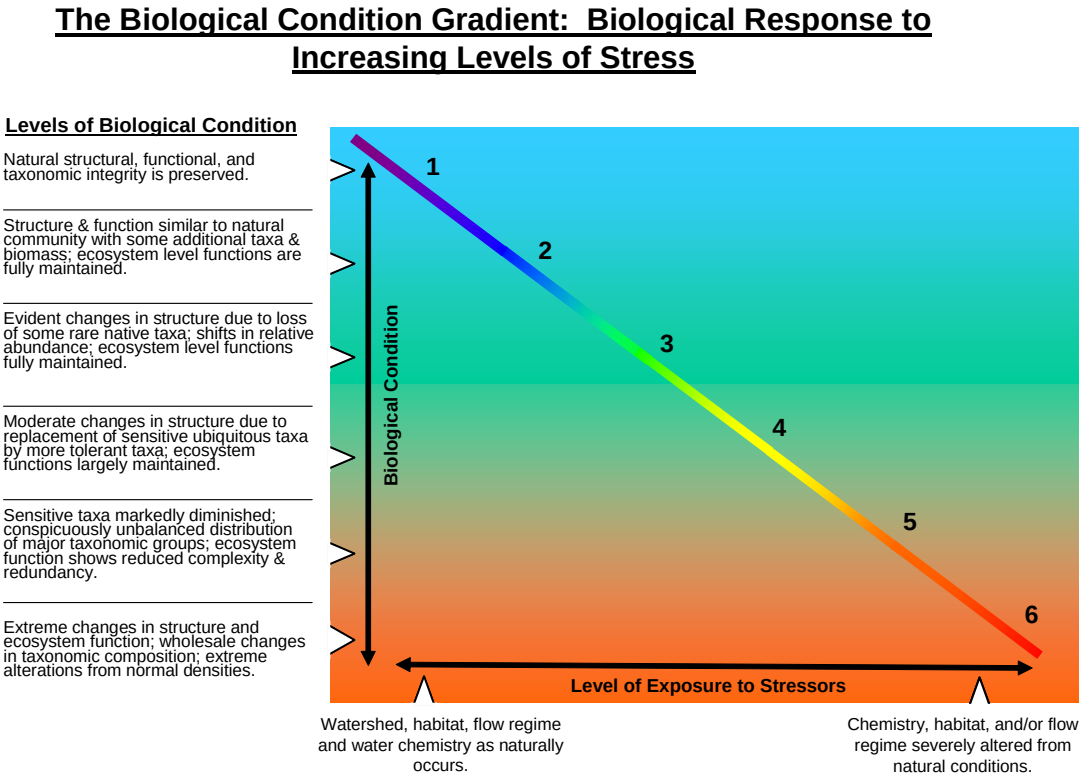

FIGURE 3-30 The Biological Condition Gradient (BCG) and summaries of biological condition along tiers of this gradient. SOURCE: Modified from Davies and Jackson (2006) by EPA.

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To date, the BCG has been applied to assemblages including aquatic macroinvertebrates, fish, Unionid mussels, and algae in streams, but it could be applied to any organism group in any type of waterbody. The BCG is derived by applying a suite of ten ecological attributes that allows biological condition to be interpreted independently of assessment method (Table 3-11; Davies and Jackson, 2006). The first five attributes focus on taxa sensitivity, an important component of tools such as multimetric indices (e.g., the Index of Biotic Integrity [IBI], the Invertebrate Community Index [ICI]; see Box 2-3) used in the United States and Europe. Many indicator taxa have been widely studied, and, for groups such as fish, historical data often exist. Most states have established lists of tolerant and intolerant species as part of their use of biological indices (Simon and Lyons, 1995). The relatively large literature on species population and distribution changes in response to stressors and landscape condition offers insight into the mechanisms for population shifts, some of which are summarized in this section.

The first two attributes of the BCG relate to those streams that are closest to natural or pristine, with most taxa "as naturally occur." Attribute 1 and 2 taxa are the most sensitive species that typically disappear with even minor stress. Table 3-12 lists some example attribute 1 taxa for four different regions of the United States. Attribute 3 reflects more ubiquitous, but still sensitive, species that can provide information as human influence on the landscape becomes more obvious, but is not yet severe. Attributes 5 and 6 are taxa that increase in abundance and distribution with increasing stress. The organism condition attribute (7) includes the presence of anomalies (e.g., tumors, lesions, eroded fins, etc.) or the presence of large or long-lived individuals in a population. Most natural streams typically have few or incidental rates of "anomalies" associated with disease and stress. Natural waterbodies typically also have the entire range of life stages present, as would be expected. However, as stress is increased, larger individuals may disappear or emigrate, or reproductive failure may occur. Ecosystem function (attribute 8) is very difficult to measure directly (Davies and Jackson, 2006). However, certain functions can be inferred from structural measures common to various multimetric indices, examples of which are listed in Table 3-13. The last two attributes (9 and 10) may be of particular importance with regard to stormwater and urban impacts. Cumulative impacts are a characteristic of urbanization, and biological organisms typically integrate the effects of many small insults to the landscape. Additionally, most natural systems often have strong "connectance," such that aquatic life often has stages that rely on migrating across multiple types or sizes of waterbodies. Urbanized streams can decrease connectance by creating migration blocks, including vertical barriers at road crossings and small dams (Warren and Pardew, 1998).

TABLE 3-11 Ecological attributes that comprise the basis for the BCG

1. Historically documented, sensitive, long-lived or regionally endemic taxa
2. Sensitive-rare taxa
3. Sensitive-ubiquitous taxa
4. Taxa of intermediate tolerance
5. Tolerant taxa
6. Non-native or introduced taxa
7. Organism condition
8. Ecosystem functions
9. Spatial and temporal extent of detrimental effects
10. Ecosystem connectance

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TABLE 3-12 Example of Taxa that *Might Serve* as Attribute 1: "Historically Documented, Sensitive, Long-Lived, Regionally Endemic Taxa for Streams in Four Regions of the United States"

State and taxon	Taxa representative of Attribute I
Maine	
Mollusks	brook floater (*Alasmodonta varicosa*), triangle floater (*Alasmodonta undulata*), yellow lampmussel (*Lampsilis cariosa*),
Fishes	brook stickleback (*Culaea inconstans*), swamp darter (*Etheostoma fusiforme*
Washington	
Fishes	steelhead (*Oncorhynchus mykiss*)
Amphibians	spotted frog (*Rana pretiosa*)
Arizona	
Mollusks	spring snails (*Pyrgulopsis* spp.)
Fishes	Gila trout, (*Oncorhynchus gilae*), Apache trout (*Oncorhynchus apache*), cutthroat trout (endemic strains) (*Oncorhynchus clarki*),
Amphibians	Chihuahua leopard frog (*Rana chiricahuensis*)
Kansas	
Mollusks†	hickorynut (*Obovaria olivaria*), black sandshell (*Ligumia recta*), ponderous campeloma (*Campeloma crassulum*)
Fishes	Arkansas River shiner (*Notropis girardi*), Topeka shiner (*Notropis topeka*), Arkansas darter (*Etheostoma cragini*), Neosho madtom (*Noturus placidus*), flathead chub (*Platygobio gracilisa*)
Other invertebrates	ringed crayfish (*Orconectes neglectus neglectus*), Plains sand-burrowing mayfly (*Homoeoneuria ammophila*)
Amphibians	Plains spadefoot toad (*Spea bombifrons*), Great Plains toad (*Bufo cognatus*), Great Plains narrowmouth toad (*Gastrophryne olivaceae*), Plains leopard frog (*Rana blairi*)

† Although not truly endemic to the central plains, these regionally extirpated mollusks were widely distributed in eastern Kansas prior to the onset of intensive agriculture.

SOURCE: Table 7 from Davies and Jackson (2006). Reprinted, with permission, from Davies and Jackson (2006). Copyright 2006 by Ecological Society of America.

TABLE 3-13 Function Ecological Attributes or Process Rates and Their Structural Indicators

Biotic level and function or process	Structural indicator
Individual level	
Fecundity	Maximum individual size, number of eggs
Growth and metabolism	Length/mass (condition)
Morbidity	Percentage anomalies
Population level	
Growth and fecundity	Density
Mortality	Size- or age-class distribution
Production	Biomass, standing crop, catch per unit effort
Sustainability	Size- or age-class distribution
Migration, reproduction	Presence or absence, density
Community or assemblage level	
Production/respiration ratio, autotrophy vs. heterotrophy	Trophic guilds, indicator species
Primary production	Biomass, ash-free dry mass
Ecosystem level	
Connectivity	Degree of aquatic and riparian fragmentation longitudinally, vertically, and horizontally; presence or absence of diadromous and potadromous species

SOURCE: Table 4 from Davies and Jackson (2006). Reprinted, with permission, from Davies and Jackson (2006). Copyright 2006 by Ecological Society of America.

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Construction of a BCG creates a conceptual framework for developing stressor–response gradients for particular urban areas. The initial work done to develop the BCG derived a series of six tiers to describe a gradient of biological condition that is anchored in pristine conditions ("as naturally occurs") and that extends to severely degraded conditions (see Figure 3-30). Exercises done by the national work group to derive such a gradient for macroinvertebrates in wadeable streams showed strong consistency in assigning tiers to datasets using the descriptions of taxa for each attribute along these gradients (Davies and Jackson, 2006). Substantial data already exist to populate many of the attributes of the BCG and to provide mechanistic underpinning for the expected directions of change.

The BCG is not a replacement for assessment tools such as the IBI or multivariate predictive models (e.g., RIVPACS approach), but rather a conceptual overlay for characterizing the anchor point-of-reference conditions and a consistent way to communicate biological condition along gradients of stress. As such, it has strong application to understanding stormwater impacts and to communicating where a goal is located along the gradient of biological condition. While most urban goals may be distant from "pristine" or "natural," the BCG process can dispel misconceptions that alternate urban goals are "dead streams" or unsafe in some manner.

Factors Limiting Aquatic Assemblages in Urban Waters

A slew of recent investigations have quantified the responses of macroinvertebrates and other biological assemblages to multiple measures of urbanization and to stormwater in particular. One important conclusion of some of this work is that declines in the highest biological condition start with low levels of anthropogenic change (e.g., 5 to 25 percent impervious surface); higher levels of urbanization severely alter aquatic conditions (Horner et al., 2003). This has important consequences for protecting sites with the highest biological integrity, as they may be among the most vulnerable. The non-threshold nature of this aquatic response and the typical wedge-shaped response to multiple stressors by aquatic assemblages are discussed in Box 3-9.

The sections that follow review the evidence underlying biological responses to each of the major categories of stressors: chemical, hydrologic, physical habitat, biological, and energy-related factors. As will be evident in some of the examples, the stressors themselves can interact (e.g., flow can influence habitat, habitat can influence energy processing, etc.), which increases the complexity of understanding how stormwater affects aquatic ecosystems.

Biological Responses to Toxic Pollutants

The chemical constituents of natural streams vary widely with climatic region, stream size, soil types, and geological setting. Most small natural streams, outside of unique areas wth naturally occurring toxicants, have very low levels of chemicals considered to be toxicants and have relatively low levels of dissolved and particulate materials in general. This applies to chemicals in the water column and in sediments. Increasing amounts of impervious surface in the watershed typically increase the concentrations of many chemical parameters in runoff derived from urban surfaces (e.g., Porcella and Sorenson, 1980; Sprague et al., 2007).

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BOX 3-9
Non-threshold Nature of the Decline of Biological Assemblages Along Urban Stressor Gradients

Several recent surveys have demonstrated that biological assemblages begin to decline in condition with even low levels of urban disturbance as measured by various gradients of urbanization (e.g., May, 1996; Horner et al., 1997; May et al., 1997; Horner et al., 2003; Moore and Palmer, 2005; Barbour et al., 2008). This box summarizes the work of Horner et al. (2003) in small streams in three regions: Montgomery County, Maryland; Austin, Texas; and the Puget Sound area of Washington. Geographic Information System (GIS) analyses using information such as land use, total impervious area, and riparian land use were used to develop multi-metric Watershed Condition Indices (WCIs) for each region. These in turn were related to fish and macroinvertebrate indices, e.g., benthic IBIs, (B-IBI, all three regions), a fish IBI (F-IBI for Maryland) and an index that was the ratio of the sensitive coho salmon to the more tolerant cutthroat trout in collections for the Puget Sound lowland area.

In each of these areas, no or extremely low urban development, substantial forest cover, and minimal disturbance of riparian zones characterized sites with the highest biological scores, but these conditions did not guarantee high scores because other impacts could limit biology even with these "natural" characteristics. In all three regions, high urbanization and loss of natural cover always led to biological degradation (Figures 3-31 and 3-32). The results of this study were similar to other recent studies such as Barbour et al. (2008) that identify a "wedge-shaped" relationship or a "polygonal" relationship (Carter and Fend, 2005) between urban gradients and biological condition. These types of relationships have also been termed "factor-ceiling" relationships (Thomson et al., 1996). The outer surface of these wedges or polygons reflects where the urban gradients limit biological assemblages, such that points below this surface typically represent sites affected by other stressors (e.g., combined sewer overflows, discharges, etc.). In all of these studies it is easier to predict loss of biological conditions as the urban gradients (e.g., WCI) worsen than it is to ensure high biological integrity at low proportions of urban stress (because some other stressor may still limit aquatic condition).

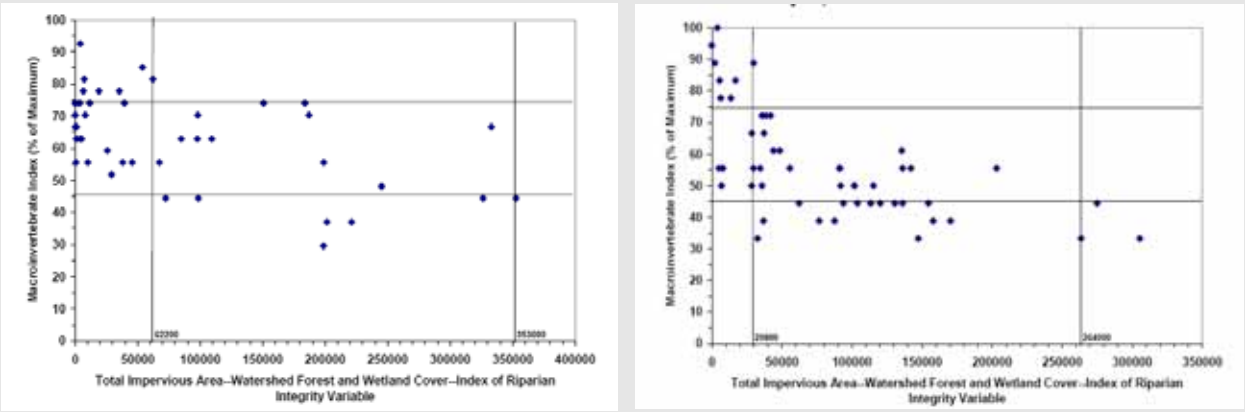

FIGURE 3-31 Plots of a measure of urbanization (TIA + Wetland & Forest Cover + IRI) versus B-IBIs for Austin, Texas (left), and Montgomery County, Maryland (right). SOURCE: Horner et al. (2003).

BOX 3-9 Continued

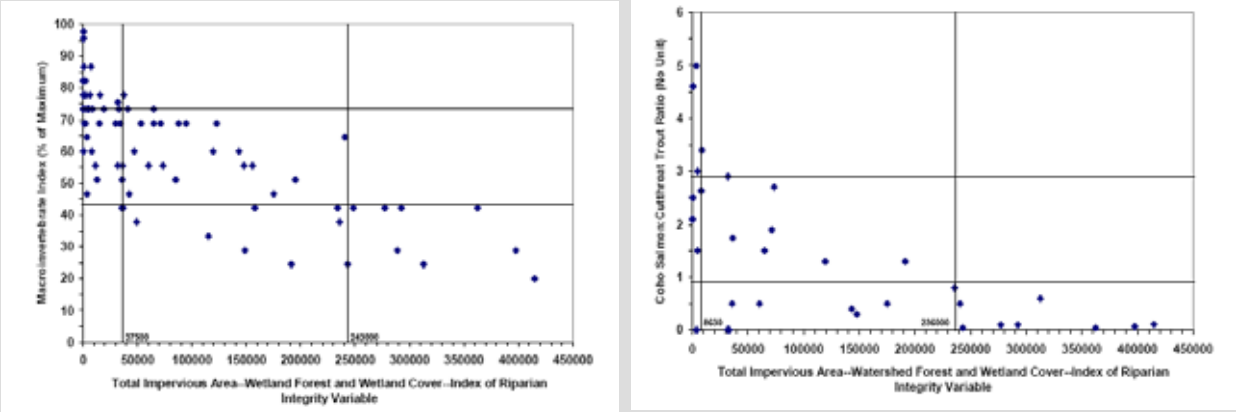

FIGURE 3-32 Plots of a measure of urbanization (TIA + Wetland & Forest Cover + IRI) versus B-IBIs for Puget Sound (left) and versus the ratio of coho salmon to cutthroat trout for Puget Sound (right). SOURCE: Horner et al. (2003).

Horner et al. (2003) also focused on whether structural SCMs could moderate the effects of urbanization on biological assemblages. They made detailed observations of two subbasins in the Puget Sound lowland area, one with a greater degree of stormwater management than the other (although neither had what would be considered comprehensive stormwater management with a focus on water quality issues). As shown in Figure 3-33, at the highest levels of urbanization (triangles), the subbasin with the more extensive use of structural SCMs did have better biological conditions. There was less evidence of biological benefit in the watershed that used SCMs but it had only moderate urbanization and more natural land cover (squares and diamonds). There were no circumstances where high biological condition was observed along with the use of SCMs because high biological condition only occurred where little human alteration was present, and thus SCMs were not used.

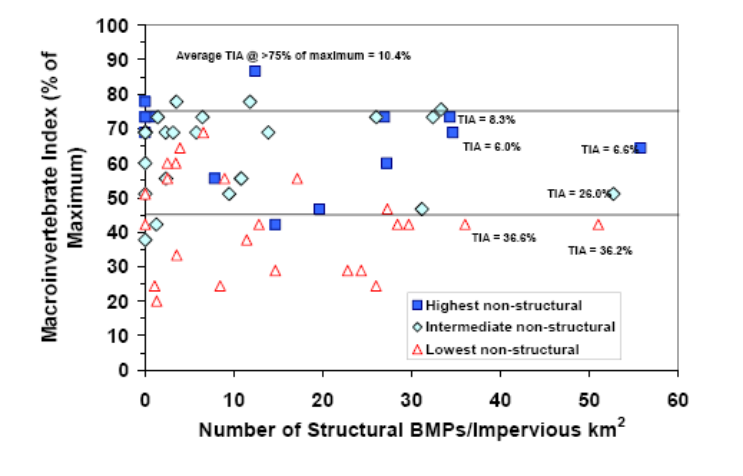

FIGURE 3-33 Macroinvertebrate community index versus structural SCM density with the highest, intermediate, and lowest one-third of natural watershed and riparian cover. The upper and lower horizontal lines represent indices considered to define relatively high and low levels of biological integrity, respectively. SOURCE: Horner et al. (2003).

Stormwater concentrations of these pollutants can be variable and sometimes extreme or "toxic" depending on the timing of flows (e.g., first flush), although concentrations at base flows may not routinely exceed water quality benchmarks (Sprague et al., 2007). Historical deposition of toxics in sediments can also be responsible for extremely high pollutant concentrations within waterbodies, even though the stormwater discharges may no longer be active. These situations have been termed "legacy pollution" and are most commonly associated with urban centers that have a history of industrial production.

Natural constituents such as dissolved materials (e.g., chlorides), particulate material (e.g., fine sediments), nutrients (e.g., phosphorus and nitrogen compounds), as well as a myriad of man-made parameters such as heavy metals and organic chemicals (e.g., hydrocarbons, pesticides and herbicides) have been documented to be increased and at times pervasive in stormwater (Heany and Huber, 1984; Paul and Meyer, 2001; Roy et al., 2003; Gilliom et al., 2006) although specific patterns of concentrations can vary with region and ecological setting (Sprague et al., 2007). Water chemistry impacts can also arise from a complex array of permitted discharges, storm sewer discharges, and combined sewer overflows that are treated to certain limits but at times fail to remove all constituents from flows, especially when associated with storm events (Paul and Meyer, 2001).

Streams in urban settings can have increases in toxicant levels compared to background concentrations. In many instances these cases have been associated with loss of aquatic species and impairment of aquatic life goals (EPA, 2002a), which are usually explained in terms of typical lethal responses. The complexity of urban systems with regard to pathways, magnitude, duration, and timing of toxicity as well as possible synergistic or antagonistic effects of mixtures of pollutants argues for a broad approach to characterizing effects including not only toxicity testing, but also novel approaches and direct monitoring of biological assemblages (Burton et al., 1999). What is problematic from a traditional management perspective is that aquatic communities may decline before exceedances of water quality criteria are evident (May et al., 1997; Horner et al., 2003).

The first three BCG attributes focus on populations of species of high to very high sensitivity, most of which are uncommon or absent in waters with any substantial level of urbanization. Multi-metric indices such as IBI, which reflect loss of these species, decline at least linearly with increasing urbanization (e.g., Miltner et al., 2004; Meador et al., 2005; Walters et al., 2005). Although toxicity to compounds varies with species, many species of federal and state endangered and threatened aquatic species are more sensitive than "commonly" used test species (Dwyer et al., 2005), such that the loss of aquatic species when toxicant levels exceed criteria are readily explained.

The mechanisms of species population declines in response to chemical contaminants are likely complex and not just limited to direct lethality of the pollutant. Indeed, initial chemical changes may have no "toxic" effects, but rather could change competitive and trophic dynamics by changing primary production and energy dynamics in streams. For example, exposures to aromatic and chlorinated organic compounds from sediments derived from urban areas have been found to increase the susceptibility of salmonids to the bacterial pathogen *Vibrio anguillarum* (Arkoosh et al., 2001). Recent work has found that salmonids show substantial behavioral changes from olfactory degradation related to copper at concentrations as low as 2 μg/L, well below copper water quality criteria and above levels measured in most stormwater-affected streams (Hecht et al., 2007; Sandahl et al., 2007). Salmonid and other fish depend extensively on olfactory cues for feeding, emigration, responding to prey and predators, social

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and spawning interactions, and other behaviors, such that loss or diminution of such cues may have population-level effects on these species (Sandahl et al., 2007). Copper has been shown to cause olfactory effects on other species (Beyers et al., 2001) and to impair the sensory ability of the fish lateral line (Hernandez et al., 2006), which is nearly ubiquitous in fishes and important for most freshwater species in feeding, schooling, spawning, and other behaviors.

Whole effluent toxicity testing or sediment toxicity testing may misclassify the effects of runoff and effluents in urban settings (Burton et al., 1999). Short-term toxicity tests of stormwater often result in no identified toxicity. However, longer studies (e.g., 30 days) have shown increasing toxicity with time (Masterson and Bannerman, 1994; Ramcheck and Crunkilton, 1995). This suggests that the mechanism of toxicity could be through an ingestion pathway, for example, rather than gill uptake. Metals are often in high concentrations where fine sediments accumulate, and their legacy can extend past the time period of active discharge. Metal concentrations in urban stream sediments have been associated with high rates of fish and invertebrate anomalies such as tumors, lesions, and deformities (Burton, 1992; Ingersoll et al., 1997; Smith et al., 2003).

Biological Responses to Non-Toxicant Chemicals

Non-toxic chemical compounds that occur in stormwater such as nutrients, dissolved oxygen (DO), pH, and dissolved solids as well as physical factors such as temperature can have impacts on aquatic life. The effects of some of these compounds (e.g., DO, pH) have been well documented from other impacts (e.g., wastewater, mining), such that nearly all states have developed water quality criteria for these parameters. For example, nutrient enrichment in stormwater runoff has been associated with declines of biological condition in streams (Miltner and Rankin, 1998). Chloride, sulfate, and other dissolved ions that are often elevated in urban areas can have effects on osmoregulation of aquatic organisms and have been associated with loss of species sensitive to dissolved materials such as mayflies (Kennedy et al., 2004). The concentrations of these compounds can vary regionally (Sprague et al., 2007) and with the degree of urbanization.

Water quality criteria for temperature were spurred by the need for thermal permits for industrial and power plant cooling water discharges. There is a very large literature on the importance of water temperature to aquatic organisms; preference, avoidance, and lethal temperature ranges have been derived for many aquatic species (e.g., Brungs and Jones, 1977; Coutant, 1977; Eaton et al., 1995). In addition, temperature is one of the key classification strata for aquatic life, in that streams are routinely classified as cold water, cool water, or warm water based on the geographic and natural settings of waters. The removal of catchment and riparian vegetation and the general increase in surface runoff from impervious, man-made, and heat-capturing surfaces has been associated with increasing water temperatures in urban waterbodies (Wang and Kanehl, 2003; Nelson and Palmer, 2007). A number of researchers have created models to predict in-stream temperatures based on urban characteristics (Krause et al., 2004; Herb et al., 2008).

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Hydrologic Influences on Aquatic Life

The importance of "natural" flow regimes on aquatic life has been well documented (Poff et al., 1997; Richter et al., 1997a, 2003). As watersheds urbanize, flow regimes change from little runoff to over 40 to 90 percent of the rainfall becoming surface runoff (Roesner and Bledsoe, 2003). Flow regimes in urban streams typically are very "flashy," with higher and more frequent peak events, compared to undisturbed systems (Poff et al., 1997; Baker et al., 2004) and well as reduced base flows and more frequent desiccation (Bernhardt and Palmer, 2007). Richter et al. (1996) proposed a series of indicators that could be used to measure hydrologic disturbance, many of which have been used in the recent studies identifying the hydrologic effects of stormwater on aquatic biota (Barbour et al., 2008). Pomeroy et al. (2008) did an extensive review of which flow characteristics appear to have the greatest influence on biological metrics and biological integrity. No single measure of flow was found to be significant in all studies; however, important attributes included flow variability and flashiness, flood frequency, flow volume, flow variability, flow timing, and flow duration.

There are a number of mechanisms that may be responsible for the influence of flow characteristics on aquatic assemblages. Aquatic species vary dramatically in their swimming performance and behaviors, and species are generally adapted to undisturbed flow regimes in an area. Many low- to moderate-gradient small streams in the United States, for example, have strong connections with their flood-prone areas and often possess habitat features that insulate poor swimming species from episodic natural high flows. Undercut banks, rootwads, oxbows, and backwater habitats all can act as refugia from high flows. Some aquatic species are more or less mobile within the sediments, like certain macroinvertebrates (meiofauna or hyporheos) and fish species such as sculpins and madtoms. Secondary impacts from hydrologic changes such as bank erosion and aggradation of fines can render substrates embedded and prohibit organisms, particularly the meiofauna, from moving vertically within the bottom substrates (Schmid-Araya, 2000). Substrate fining has been documented to occur with increasing urbanization, especially in the early stages of development, which can embed spawning habitats and eliminate or reduce spawning success of fish such as salmonids and minnows (Waters, 1995).

Flood flows can cause mortality in the absence of urbanization. For example, flood flows in streams under natural conditions have been documented as a cause of substantial mortality in young or larval fish such as smallmouth bass (Funk and Fleener, 1974; Lorantas and Kristine, 2004). Increased flashiness from urbanization is likely to exacerbate this effect. Thus, increases in the frequency of peak flows during spring will increase the probability of spawning failure, such that sensitive species may eventually be locally extirpated. In urban areas, culverts and other flow obstructions can create conditions that may preclude re-colonization of upstream reaches because weak-swimming fishes cannot move past flow constrictions or leap past vertical drops caused by artificial structures.

Hydrologic simplification and stream straightening that occur in urban streams, often as a result of increased peak flows or as a local management response, typically remove habitat used as temporary refuges from high flows, such as backwater areas, undercut banks, and rootwads. There is a large literature relating populations of fish and macroinvertebrates to various habitat features of streams, rivers, and wetlands. The first two attributes of the BCG identify taxa that are historically documented, sensitive, long-lived, or regionally endemic taxa or sensitive-rare taxa. Many of these taxa are endangered because of large-scale changes in flow-influenced habitats; that is, threats of extinction often center on habitat degradation that influence spawning,

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feeding, or other aspects of a species life history (Rieman et al., 1993). In contrast, many of the fish and macroinvertebrate taxa that compose regional lists of tolerant taxa are tolerant to habitat changes related to flow disturbance as well as chemical parameters. Understanding the life history attributes of certain species and how they may change with multiple stressors (Power, 1997) is an important tool for understanding complex responses of aquatic ecosystems to urban stressors.

Geomorphic and Habitat Influences on Aquatic Life

In natural waters, geomorphic factors and climate, modified by vegetation and land use, constrain the types of physical habitat features likely to occur in streams (Webster and D'Angelo, 1997). For example, very-low-gradient streams may have few riffles and be dominated by woody debris and bank cover, whereas higher gradient waters may have more habitat types formed by rapidly flowing waters (riffles, runs). Aquatic life in streams is influenced directly by the habitat features that are present, such as substrate types, in-stream structures, bank structure, and flow types (e.g., deep-fast vs. shallow-slow).

As discussed previously, human alteration of landscapes, encroachment on riparian areas, and direct channel modifications (e.g., channelization) that acompany urbanization have often resulted in unstable channels, with negative consequences for aquatic habitat. As urbanization has increased, channel density has declined because streams have been piped, dewatered, and straightened (Meyer and Wallace, 2001; Paul and Meyer, 2001). Changes in the magnitude, relative proportions, and timing of sediment and water delivery have resulted in loss of aquatic life and habitat via a wide range of mechanisms, including changes in channel bed materials, increased suspended sediment loads, loss of riparian habitat due to bank erosion, and changes in the variability of flow and sediment transport characteristics relative to aquatic life cycles (Roesner and Bledsoe, 2003). There are still significant gaps in knowledge about how stormwater stressors can affect stream habitat, especially as one moves from the reach scale to the watershed scale. Understanding the stage and trajectory of channel evolution is critical to understanding channel recovery and expected habitat conditions or in choosing effective restoration options (Simon et al., 2007).

Across much of the United States, stream habitats have been altered to the imperilment of aquatic species (Williams et al., 1989; Richter et al., 1997b; Strayer et al., 2004). A study of rapidly urbanizing streams in central Ohio identified the loss of highly and moderately sensitive species as a key factor the decline in the IBI in these streams (Miltner et al., 2004). These streams had historical fish collections when they were primarily influenced by agricultural land use; sampling after the onset of suburban development documented the loss of many of these species attributable to land-use changes and habitat degradation along these urban streams. Along the BCGs that have been developed for streams, most of the species in attributes 1–3 are specialists requiring very specific habitats for spawning, feeding, and refuge. Habitat alteration, either direct or indirect, creates harsh environments that tend to favor tolerant taxa, which would otherwise be in low abundance. Often these tolerant species are characterized by high reproductive potential, generalist feeding behaviors, tolerance to chemical stressors such as low DO, and pioneering strategies that allow rapid recolonization following acute stressful events.

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Altered Energy Pathways in Urban Streams

The pathways of energy flow in streams are an important determinant of aquatic species distributions. In most natural temperate streams, headwaters transform and export energy from stream side vegetation and adjacent land uses into aquatic biomass. The types, amount, and timing of delivery of water, organic material, and debris have important consequences for conditions downstream (Dolloff and Webster, 2000). The energy-transforming aspect of stream ecosystems is difficult to capture directly, so most measures are surrogates, such as the trophic characteristics of assemblages and chemical and physical characteristics consistent with natural energy processes.

An increasingly urban landscape can have a complex array of effects on energy dynamics in streams (Allan, 2004). Loss of riparian areas and changes in riparian vegetation can reduce the supply and quality of coarse organic matter that forms the base of aquatic food webs in most small streams. The reduction in the amount of organic matter with riparian loss is obvious; however, changing species of vegetation (e.g., invasion or planting of exotic species) can affect the quality of organic matter and influence higher trophic levels because, for example, exotic species may have different nutrient values (e.g., C/N ratios, trace chemicals) or process nutrients at a different rate (Royer et al., 1999). Furthermore, native invertebrate taxa may not be adapted to utilize the exotic material (Miller and Boulton, 2005). For example, changes in leaf species in a stream may alter the macroinvertebrate community by favoring species that feed on fast-decaying versus slow-decaying leaves (Smock and MacGregor, 1988; Cummins et al., 1989; Gregory et al., 1991).

Other recent work is examining ways that changes in geomorphology with increasing urbanization can influence trophic structure in streams (Doyle, 2006). Groffman et al. (2005) examined nitrogen processing in stream geomorphic structures such as bars, riffles, and debris dams in suburban and forested areas. Although suburban areas had high rates of production in organic-rich debris dams and gravel bars, higher storm flow effects in urban streams may make these features less stable and able to be maintained (Groffman et al., 2005). Changes in habitat and riparian vegetation may greatly alter trophic patterns of energy transport. For example, local nutrient enrichments combined with reduced riparian vegetation can result in nuisance algal growths in waterbodies that are evidence of simpler energy pathways. Corresponding effects are further water chemistry changes from algal decomposition (e.g.., low DO) or very high algal activity (e.g., high pH) (Ehlinger et al., 2004).

The complexity of energy flow through simple ecosystems is illustrated in Figure 3-34, a "simplified" food web of a headwater stream published by Meyer (1994). The forms in which nutrients are delivered to streams may be more important than actual concentrations as well as the availability of carbon sources essential for nutrient transformation. The nutrient components that form the base of the food web in Figure 3-34 are the FPOM and CPOM boxes. In many natural streams, woody and leafy debris are the most common form of nutrient input, and changes to urban landscapes often change this to dissolved and finer forms. Urbanization can also reduce the retention of organic debris of streams (Groffman et al., 2005) and the timing of nutrient delivery. Timing can be of crucial importance since species spawning and growth periods may be specifically timed to take advantage of available nutrients.

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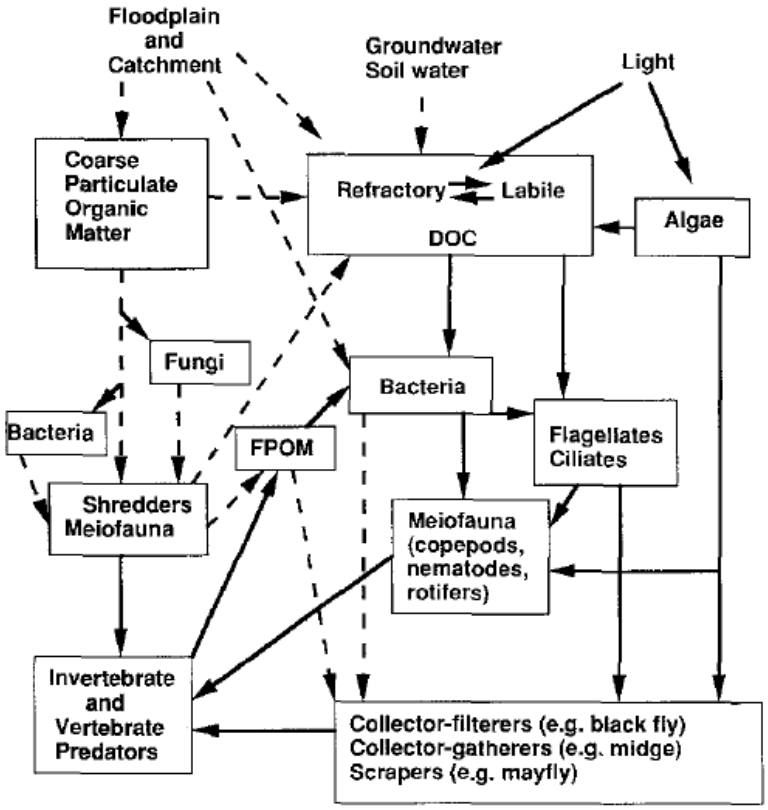

FIGURE 3-34 Simplified diagram of a lotic food web showing sources and major pathways of organic carbon. Dotted lines indicate flows that are a part of the microbial loop in flowing water but not in planktonic systems. SOURCE: Reprinted, with permission, from Meyer (1994). Copyright 1994 by Springer.

As important as energy and nutrient dynamics are to stream function, many of the stream characteristics that determine effective energy flow are not typically considered when characterizing stormwater impacts. The best chance for considering these variables and maximizing ecosystem function is through integrated, biologically based monitoring programs that include urban areas (Barbour et al., 2008) and stressor identification procedures (EPA, 2000) to isolate likely causes of impact and to inform the choices of SCMs.

Biological Interactions in Urban Streams

Streams in urbanized environments often are characterized by fewer native and more alien species than natural streams (DeVivo, 1996; Meador et al., 2005). The influence of exotic species is not always predictable and may be most severe in lentic environments (e.g., wetlands, estuaries) and in riparian zones where various exotic aquatic plants can greatly alter natural systems in both structure and function (Hood and Naiman, 2000). Riley et al. (2005) found that the presence of alien aquatic amphibians was positively related to degree of urbanization, as was the absence of certain native amphibian species. In a review of possible reasons for this observation, he suggested that altered flow regimes were responsible. In the arid California streams they studied, flow became more constant with urbanization (i.e., natural streams were generally ephemeral), which allowed invasion by exotic species that can prey on, compete with,

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or hybridize with native species (Riley et al., 2005). The alteration of stream habitat that accompanies urbanization can also lead to predation by domestic cats and dogs or collection by humans, especially where species (e.g., California newts) are large and conspicuous (Riley et al., 2005).

The effects of specific exotic species on aquatic systems has been observed to vary geographically, although recent work has found correlations between total invasion rate and the number of high-impact exotic species (Ricciardi and Kipp, 2008). This suggests that overall efforts to reduce the importation or spread of all alien species should be helpful.

The Role of Biological Monitoring

The preceding sections illustrate the importance of biological data to understanding the complexities associated with urban and stormwater impacts to waterbodies. Although categories of urban stressors have been discussed individually, these stressors routinely, if not universally, co-occur in urban waterbodies. Their cumulative impacts are best measured with biological tools because the biota integrate the influence of all of these stressors.

Many programmatic aspects of the CWA arose as a response to rather obvious impacts of chemical pollutants that were occurring in surface waters during this time. The initial focus of water quality standards was on developing chemical criteria that could serve as engineering endpoints for waste treatment systems (e.g., NPDES permits). Rather general aquatic life goals for streams and rivers that were suitable for the initial focus of the CWA are now considered insufficient to deal with the complex suite of stressors limiting aquatic systems. To that end, refined aquatic life goals and improved biological monitoring are essential for effective water quality management, including stormwater issues (NRC, 2001). Practical biological and physical monitoring tools have even been developed for very small headwater streams (Ohio EPA, 2002; Fritz et al., 2006), which are particularly affected by stormwater because of their prevalence (greater than 95 percent of channels), their relatively high surface-to-volume ratio, their role in nutrient and material processing, and their vulnerability to direct modification such as channelization and piping (Meyer and Wallace, 2001).

Surrogate indicators of stormwater impacts to aquatic life (such as TSS concentrations) have been widely used because direct biological measures were poorly developed and these surrogates were assumed to be important to pollutant delivery to urban streams. However, biological assessment has rapidly advanced in many states and can be readily applied or if needed modified to be sensitive to stormwater stressors (Barbour et al., 2008). As Karr and Chu (1999) warned, the management of complex systems requires measures that integrate multiple factors. Stormwater permitting is no different, and care must be taken to ensure that permitting and regulatory actions retain ecological relevance. Surrogate measures have an essential role in the assessment of individual SCMs; however, this needs to be kept in context with the entire suite of stressors likely to be important to the aquatic life goals in streams.

Stormwater management programs should not necessarily bear the burden of biological monitoring; rather, well-conceived biological monitoring should be the prevue of state and local government agencies (as discussed more extensively in Chapter 6). Refined aquatic life goals developed for all waters, including urban waters, measured with appropriate biological measures, should be the final endpoint for management. The collection of biological data needs to be closely integrated across multiple disciplines in order to be effective. Pomeroy et al. (2008)

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describe a multidisciplinary approach to study the effects of stormwater in urban settings, and Scholz and Booth (2001) also propose a monitoring approach for urban watersheds. Such efforts are not necessarily easy, and many institutions find pitfalls when trying to integrate scientific information across disciplines (Benda et al., 2002).

EPA water programs, such as the Total Maximum Daily Load (TMDL) program, have been criticized for having too narrow a focus on a limited number of traditional pollutants to the exclusion of important stressors such as hydrology, habitat alteration, and invasive taxa (Karr and Yoder, 2004)—all serious problems associated with stormwater and urbanization. The science has advanced significantly over the past decade so that biological assessment should be an essential tool for identifying stormwater impacts and informing the choice of SCMs in a region or watershed. Although biological responses to stressors in the ambient environment are by their nature correlative exercises, ecological epidemiology principles or "stressor identification" methods can identify likely causative agents of impairment with relatively high certainty in many instances (Suter, 1993, 2006; EPA, 2000). Coupled with other ambient and source monitoring information, biological information can form the basis for an effective stormwater program. As an example, Box 3-10 introduces the Impervious Cover Model (ICM), which was developed using correlative information on the association between impervious cover and biological metrics. The crux of the ICM is that stormwater management is tailored along a readily measureable gradient (impervious cover) that integrates multiple individual stressor categories that would otherwise be overlooked in the traditional pollutant-based approach to stormwater management. Even the form of the ICM (as conceptualized in Figure 3-37) matches that outlined for the BCG (Figure 3-30). Use of the ICM to improve the MS4 stormwater program is discussed in Chapter 6.

BOX 3-10
The Impervious Cover Model: An Emerging Framework for Urban Stormwater Management

The Impervious Cover Model (ICM) is a management tool that is useful for diagnosing the severity of future stream problems in a subwatershed. The ICM defines four categories of urban streams based on how much impervious cover exists in their subwatershed: *high-quality streams*, *impacted streams, non-supporting streams,* and *urban drainage*. The ICM is then used to develop specific quantitative or narrative predictions for stream indicators within each stream category (see Figure 3-35). These predictions define the severity of current stream impacts and the prospects for their future restoration. Predictions are made for five kinds of urban stream impacts: changes in stream hydrology, alteration of the stream corridor, stream habitat degradation, declining water quality, and loss of aquatic diversity.

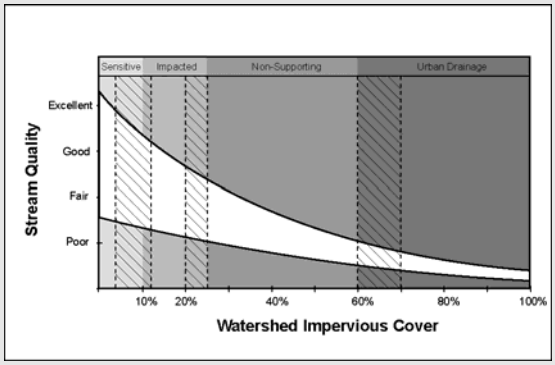

FIGURE 3-35 Changes in Stream Quality with Percent Impervious Cover in the Contributing Watershed. SOURCE: Chesapeake Stormwater Network (2008). Reprinted, with permission, from Schueler (2008). Copyright 2008 by T. Schueler.

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BOX 3-10 Continued

The general predictions of the ICM are as follows. Stream segments with less than 10 percent impervious cover (IC) in their contributing drainage area continue to function as **Sensitive Streams**, and are generally able to retain their hydrologic function and support good-to-excellent aquatic diversity. Stream segments that have 10 to 25 percent IC in their contributing drainage area behave as **Impacted Streams** and show clear signs of declining stream health. Most indicators of stream health will fall in the fair range, although some segments may range from fair to good as riparian cover improves. The decline in stream quality is greatest toward the higher end of the IC range. Stream segments that range between 25 and 60 percent subwatershed impervious cover are classified as **Non-Supporting Streams** (i.e., no longer supporting their designated uses in terms of hydrology, channel stability habitat, water quality, or biological diversity). These stream segments become so degraded that any future stream restoration or riparian cover improvements are insufficient to fully recover stream function and diversity (i.e., the streams are so dominated by subwatershed IC that they cannot attain predevelopment conditions). Stream segments whose subwatersheds exceed 60 percent IC are physically altered so that they merely function as a conduit for flood waters. These streams are classified as **Urban Drainage** and consistently have poor water quality, highly unstable channels, and very poor habitat and biodiversity scores. In many cases, these urban stream segments are eliminated altogether by earthworks and/or storm-drain enclosure. Table 3-14 shows in greater detail how stream corridor indicators respond to greater subwatershed impervious cover.

TABLE 3-14 General ICM Predictions Based on Urban Subwatershed Classification (CWP, 2004):

Prediction	Impacted (IC 11 to 25%) [8]	Non-supporting (IC 26 to 60%)	Urban Drainage (IC > 60%)
Runoff as a Fraction of Annual Rainfall [1]	10 to 20%	25 to 60%	60 to 90%
Frequency of Bankfull Flow per Year [2]	1.5 to 3 per year	3 to 7 per year	7 to 10 per year
Fraction of Original Stream Network Remaining	60 to 90%	25 to 60%	10 to 30%
Fraction of Riparian Forest Buffer Intact	50 to 70%	30 to 60%	Less than 30%
Crossings per Stream Mile	1 to 2	2 to 10	None left
Ultimate Channel Enlargement Ration [3]	1.5 to 2.5 larger	2.5 to 6 times larger	6 to 12 times larger
Typical Stream Habitat Score	Fair, but variable	Consistently poor	Poor, often absent
Increased Stream Warming [4]	2 to 4 °F	4 to 8 °F	8+ °F
Annual Nutrient Load [5]	1 to 2 times higher	2 to 4 times higher	4 to 6 times higher
Wet Weather Violations of Bacteria Standards	Frequent	Continuous	Ubiquitous
Fish Advisories	Rare	Potential risk of accumulation	Should be presumed
Aquatic Insect Diversity [6]	Fair to good	Fair	Very poor
Fish Diversity [7]	Fair to good	Poor	Very poor

[1] Based on annual storm runoff coefficient; ranges from 2 to 5% for undeveloped streams.
[2] Predevelopment bankfull flood frequency is about 0.5 per year, or about one bankfull flood every two years.
[3] Ultimate stream-channel cross-section compared to typical predevelopment channel cross section.
[4] Typical increase in mean summer stream temperature in degrees Fahrenheit, compared with shaded rural stream.
[5] Annual unit-area stormwater phosphorus and/or nitrogen load produced from a rural subwatershed.
[6] As measured by benthic index of biotic integrity. Scores for rural streams range from good to very good.
[7] As measured by fish index of biotic integrity. Scores for rural streams range from good to very good.
[8] IC is not the strongest indicator of stream health below 10% IC, so the sensitive streams category is omitted from this table.
SOURCE: Adapted from CWP (2004).

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BOX 3-10 Continued

Scientific Support for the ICM

The ICM predicts that hydrological, habitat, water quality, and biotic indicators of stream health first begin to decline sharply at around 10 percent total IC in smaller catchments (Schueler, 1994). The ICM has since been extensively tested in ecoregions around the United States and elsewhere, with more than 200 different studies confirming the basic model for single stream indicators or groups of stream indicators (CWP, 2003; Schueler, 2004). Several recent research studies have reinforced the ICM as it is applied to first- to third-order streams (Coles et al., 2004; Horner et al., 2004; Deacon et al., 2005; Fitzpatrick et al., 2005; King et al., 2005; McBride and Booth, 2005; Cianfrina et al., 2006; Urban et al., 2006; Schueler et al., 2008).

Researchers have focused their efforts to define the specific thresholds where urban stream degradation first begins. There is robust debate as to whether there is a sharp initial threshold or merely a continuum of degradation as IC increases, although the latter is more favored. There is much less debate, however, about the dominant role of IC in defining the hydrologic, habitat, water quality, and biodiversity expectations for streams with higher levels of IC (15 to 60 percent).

Caveats to the ICM

The ICM is a powerful predictor of urban stream quality when used appropriately. The first caveat is that subwatershed IC is defined as total impervious area (TIA) and not effective impervious area (EIA). Second, the ICM should be restricted to first- to third-order alluvial streams with moderate gradient and no major point sources of pollutant discharge. The ICM is most useful in projecting the behavior of numerous stream health indicators, and it is not intended to be accurate for every individual stream indicator. In addition, management practices in the contributing catchment or subwatershed must not be poor (e.g., no deforestation, acid mine drainage, intensive row crops, etc.); just because a subwatershed has less than 10 percent IC does not automatically mean that it will have good or excellent stream quality if past catchment management practices were poor.

ICM predictions are general and may not apply to every stream within the proposed classifications. Urban streams are notoriously variable, and factors such as gradient, stream order, stream type, age of subwatershed development, and past land use can and will make some streams depart from these predictions. Indeed, these “outlier” streams are extremely interesting from the standpoint of restoration. In general, subwatershed IC causes a continuous but variable decline in most stream corridor indicators. Consequently, the severity of individual indicator impacts tends to be greater at the upper end of the IC range for each stream category.

Effects of Catchment Treatment on the ICM

Most studies that investigated the ICM were done in communities with some degree of catchment treatment (e.g., stormwater management or stream buffers). Detecting the effect of catchment treatment on the ICM involves a very complex and difficult paired watershed design. Very few catchments meet the criteria for either full treatment or the lack of it, no two catchments are ever really identical, and individual catchments exhibit great variability from year to year. Not surprisingly, the first generation of research studies has produced ambiguous results. For example, seven research studies showed that ponds and wetlands are unable to prevent the degradation of aquatic life in downstream channels associated with higher levels of IC (Galli, 1990; Jones et al., 1996; Horner and May, 1999; Maxted, 1999; MNCPPC, 2000; Horner et al., 2001; Stribling et al., 2001). The primary reasons cited are stream warming (amplified by ponds), changes in organic matter processing, the increased runoff volumes delivered to downstream channels, and habitat degradation caused by channel enlargement.

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BOX 3-10 Continued

Riparian forest cover is defined as canopy cover within 100 meters of the stream, and is measured as the percentage of the upstream network in this condition. Numerous researchers have evaluated the relative impact of riparian forest cover and IC on stream geomorphology, aquatic insects, fish assemblages, and various indices of biotic integrity. As a group, the studies suggest that indicator values for urban streams improve when riparian forest cover is retained over at least 50 to 75 percent of the length of the upstream network (Booth et al., 2002; Morley and Karr, 2002; Wang et al., 2003; Allan, 2004; Sweeney et al., 2004; Moore and Palmer, 2005; Cianfrina et al., 2006; Urban et al., 2006).

Application of the ICM to other Receiving Waters

Recent research has focused on the potential value of the ICM in predicting the future quality of receiving waters such as tidal coves, lakes, wetlands and small estuaries. The primary work on small estuaries by Holland et al. (2004) [references cited in CWP (2003), Lerberg et al. (2000)] indicates that adverse changes in physical, sediment, and water quality variables can be detected at 10 to 20 percent subwatershed IC, with a clear biological response observed in the range of 20 to 30 percent IC. The primary physical changes involve greater salinity fluctuations, greater sedimentation, and greater pollutant contamination of sediments. The biological response includes declines in diversity of benthic macroinvertebrates, shrimp, and finfish.

More recent work by King et al. (2005) reported a biological response for coastal plain streams at around 21 to 32 percent urban development (which is usually about twice as high as IC). The thresholds for important water quality indicators such as bacterial exceedances in shellfish beds and beaches appears to begin at about 10 percent subwatershed IC, with chronic violations observed at 20 percent IC (Mallin et al., 2001). Algal blooms and anoxia resulting from nutrient enrichment by stormwater runoff also are routinely noted at 10 to 20 percent subwatershed IC (Mallin et al., 2004).

The primary conclusion to be drawn from the existing science is that the ICM does apply to tidal coves and streams, but that the impervious levels associated with particular biological responses appear to be higher (20 to 30 percent IC for significant declines) than for freshwater streams, presumably due to their greater tidal mixing and inputs from near-shore ecosystems. The ICM may also apply to lakes (CWP, 2003) and freshwater wetlands (Wright et al., 2007) under carefully defined conditions. The initial conclusion is that the application of the ICM shows promise under special conditions, but more controlled research is needed to determine if IC (or other watershed metrics) is useful in forecasting receiving water quality conditions.

Utility of the ICM in Urban Stream Classification and Watershed Management

The ICM is best used as an urban stream classification tool to set reasonable expectations for the range of likely stream quality indicators (e.g., physical, hydrologic, water quality, habitat, and biological diversity) over broad ranges of subwatershed IC. In particular, it helps define general thresholds where water quality standards or biological narrative conditions cannot be consistently met during wet weather conditions (see Table 6-2). These predictions help stormwater managers and regulators to devise appropriate and geographically explicit stormwater management and subwatershed restoration strategies for their catchments as part of MS4 permit compliance. More specifically, assuming that local monitoring data are available to confirm the general predictions of the ICM, it enables managers to manage stormwater within the context of current and future watershed conditions.

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Human Health Impacts

Despite the unequivocal evidence of ecosystem consequences resulting from urban stormwater, a formal risk analysis of the human health effects associated with stormwater runoff is not yet possible. This is because (1) many of the most important waterborne pathogens have not been quantified in stormwater, (2) enumeration methods reported in the current literature are disparate and do not account for particle-bound pathogens, and (3) sampling times during storms have not been standardized nor are known to have occurred during periods of human exposure. Individual studies have investigated the runoff impacts on public health in freshwater (Calderon et al., 1991) and marine waters (Haile et al., 1999; Dwight et al,. 2004; Colford et al., 2007). Although these studies provide ample evidence that stormwater runoff can serve as a vector of pathogens with potential health implications (for example, Ahn et al., 2005, found that fecal indicator bacteria concentrations could exceed California ocean bathing water standards by up to 500 percent in surf zones receiving stormwater runoff), it is difficult to draw conclusive inferences about the specific human health impacts from microbial contamination of stormwater. Calderon et al. (1991) concluded that the currently recommended bacterial indicators are ineffective for predicting potential health effects associated with water contaminated by nonpoint sources of fecal pollution. Furthermore, in a study conducted in Mission Bay, California, which analyzed bacterial indicators using traditional and non-traditional methods (chromogenic substrate and quantitative polymerase chain reaction), as well as a novel bacterial indicator and viruses, traditional fecal indicators were not associated with identified human health risks such as diarrhea and skin rash (Colford et al., 2007).

The Santa Monica Bay study (Haile et al., 1999) indicated that the risks of several health outcomes were higher for people who swam at storm-drain locations compared to those who swam farther from the drain. However, the list of health outcomes that were more statistically significant (fever, chills, ear discharge, cough and phlegm, and significant respiratory) did not include highly credible gastrointestinal illness, which is curious because the vast majority of epidemiological studies worldwide suggests a causal dose-related relationship between gastrointestinal symptoms and recreational water quality measured by bacterial indicator counts (Pruss, 1998). Dwight et al. (2004) found that surfers in an urban environment reported more symptoms than their rural counterparts; however, water quality was not specifically evaluated in that study.

To better assess the relationship between swimming in waters contaminated by stormwater, which have not been influenced by human sewage, and the risk of related illness, the California Water Boards and the City of Dana Point have initiated an epidemiological study. This study will be conducted at Doheny Beach, Orange County, California, which is a beach known to have high fecal indicator bacteria concentrations with no known human source. The project will examine several new techniques for measuring traditional fecal indicator bacteria, new species of bacteria, and viruses to determine whether they yield a better relationship to human health outcomes than the indicators presently used in California. The study is expected to be completed in 2010. In addition, the State of California is researching new methods for rapid detection of beach bacterial indicators and ways to bring these methods into regular use by the environmental monitoring and public health communities to better protect human health.

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CONCLUSIONS AND RECOMMENDATIONS

The present state of the science of stormwater reflects both the strengths and weaknesses of historic, monodisciplinary investigations. Each of the component disciplines—hydrology, geomorphology, aquatic chemistry, ecology, land use, and population dynamics—have well-tested theoretical foundations and useful predictive models. In particular, there are many correlative studies showing how parameters co-vary in important but complex and poorly understood ways (e.g., changes in fish community associated with watershed road density or the percentage of IC). Nonetheless, efforts to create mechanistic links between population growth, land-use change, hydrologic alteration, geomorphic adjustments, chemical contamination in stormwater, disrupted energy flows, and biotic interactions, to changes in ecological communities are still in development. Despite this assessment, there are a number of overarching truths that remain poorly integrated into stormwater management decision making, although they have been robustly characterized and have a strong scientific basis. These are expanded upon below.

There is a direct relationship between land cover and the biological condition of downstream receiving waters. The possibility for the highest levels of aquatic biological condition exists only with very light urban transformation of the landscape. Even then, alterations to biological communities have been documented at such low levels of imperviousness, typically associated with roads and the clearing of native vegetation, that there has been no real "urban development" at all. Conversely, the lowest levels of biological condition are inevitable with extensive urban transformation of the landscape, commonly seen after conversion of about one-third to one-half of a contributing watershed into impervious area. Although not every degraded waterbody is a product of intense urban development, all highly urban watersheds produce severely degraded receiving waters. Because of the close and, to date, inexorable linkage between land cover and the health of downstream waters, stormwater management is an unavoidable offshoot of watershed-based land-use planning (or, more commonly, its absence).

The protection of aquatic life in urban streams requires an approach that incorporates all stressors. Urban Stream Syndrome reflects a multitude of effects caused by altered hydrology in urban streams, altered habitat, and polluted runoff. Focusing on only one of these factors is not an effective management strategy. For example, even without noticeably elevated pollutant concentrations in receiving waters, alterations in their hydrologic regimes are associated with impaired biological condition. Achieving the articulated goals for stormwater management under the CWA will require a balanced approach that incorporates hydrology, water quality, and habitat considerations.

The full distribution and sequence of flows (i.e., the flow regime) should be taken into consideration when assessing the impacts of stormwater on streams. Permanently increased stormwater volume is only one aspect of an urban-altered storm hydrograph. It contributes to high in-stream velocities, which in turn increase streambank erosion and accompanying sediment pollution of surface water. Other hydrologic changes, however, include changes in the sequence and frequency of high flows, the rate of rise and fall of the hydrograph, and the season of the year in which high flows can occur. These all can affect both the physical

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and biological conditions of streams, lakes, and wetlands. Thus, effective hydrologic mitigation for urban development cannot just aim to reduce post-development peak flows to predevelopment peak flows.

A single design storm cannot adequately capture the variability of rain and how that translates into runoff or pollutant loadings, and thus is not suitable for addressing the multiple objectives of stormwater management. Of particular importance to the types of problems associated with urbanization is the size of rain events. The largest and most infrequent rains cause near-bank-full conditions and may be most responsible for habitat destruction; these are the traditional "design storms" used to design safe drainage systems. However, moderate-sized rains are more likely to be associated with most of the annual mass discharges of stormwater pollutants, and these can be very important to the eutrophication of lakes and nearshore waters. Water quality standards for bacterial indicators and total recoverable heavy metals are exceeded for almost *every* rain in urban areas. Therefore, the whole distribution of storm size needs to be evaluated for most urban receiving waters because many of these problems coexist.

Roads and parking lots can be the most significant type of land cover with respect to stormwater. They constitute as much as 70 percent of total impervious cover in ultra-urban landscapes, and as much as 80 percent of the directly connected impervious cover. Roads tend to capture and export more stormwater pollutants than other land covers in these highly impervious areas because of their close proximity to the variety of pollutants associated with automobiles. This is especially true in areas of the country having mostly small rainfall events (as in the Pacific Northwest). As rainfall amounts become larger, pervious areas in most residential land uses become more significant sources of runoff, sediment, nutrients, and landscaping chemicals. In all cases, directly connected impervious surfaces (roads, parking lots, and roofs that are directly connected to the drainage system) produce the first runoff observed at a storm-drain inlet and outfall because their travel times are the quickest.

Generally, the quality of stormwater from urbanized areas is well characterized, with the common pollutants being sediment, metals, bacteria, nutrients, pesticides, trash, and polycyclic aromatic hydrocarbons. These results come from many thousands of storm events from across the nation, systematically compiled and widely accessible; they form a robust data set of utility to theoreticians and practitioners alike. These data make it possible to accurately estimate pollutant concentrations, which have been shown to vary by land cover and by region across the country. However, characterization data are relatively sparse for individual industrial operations, which makes these sources less amenable to generalized approaches based on reliable assumptions of pollutant types and loads. In addition, industrial operations vary greatly from site to site, such that it may be necessary to separate them into different categories in order to better understand industrial stormwater quality.

Nontraditional sources of stormwater pollution must be taken into consideration when assessing the overall impact of urbanization on receiving waterbodies. These nontraditional sources include atmospheric deposition, snowmelt, and dry weather discharges, which can constitute a significant portion of annual pollutant loadings from storm systems in urban areas (such as metals in Los Angeles). For example, atmospheric deposition of metals is a

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very significant component of contaminant loading to waterbodies in the Los Angeles region relative to other point and nonpoint sources. Similarly, much of the sediment found in receiving waters following watershed urbanization can come from streambank erosion as opposed to being contributed by polluted stormwater.

Biological monitoring of waterbodies is critical to better understanding the cumulative impacts of urbanization on stream condition. Over 25 years ago, individual states developed the concept of regional reference sites and developed multi-metric indices to identify and characterize degraded aquatic assemblages in urban streams. Biological assessments respond to the range of non-chemical stressors identified as being important in urban waterways including habitat degradation, hydrological alterations, and sediment and siltation impacts, as well as to the influence of nutrients and other chemical stressors where chemical criteria do not exist or where their effects are difficult to measure directly (e.g., episodic stressors). The increase in biological monitoring has also helped to frame issues related to exotic species, which are locally of critical importance but completely unrecognized by traditional physical monitoring programs.

Epidemiological studies on the human health risks of swimming in freshwater and marine waters contaminated by urban stormwater discharges in temperate and warm climates are needed. Unlike with aquatic organisms, there is little information on the health risks of urban stormwater to humans. Standardized watershed assessment methods to identify the sources of human pathogens and indicator organisms in receiving waters need to be developed, especially for those waters with a contact-recreation use designation that have had multiple exceedances of pathogen or indicator criteria in a relatively short period of time. Given their difficulty and expense, epidemiological studies should be undertaken only after careful characterization of water quality and stormwater flows in the study area.

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Chapter 4
Monitoring and Modeling

As part of its statement of task, the committee was asked to consider several aspects of stormwater monitoring, including how useful the activity is, what should be monitored and when and where, and how benchmarks should be established. As noted in Chapter 2, the stormwater monitoring requirements under the U.S. Environmental Protection Agency (EPA) stormwater program are variable and generally sparse, which has led to considerable skepticism about their usefulness. This chapter first considers the value of the data collected over the years by municipalities and makes suggestions for improvement. It then does the same for industrial stormwater monitoring, which has lagged behind the municipal separate storm sewer system (MS4) program both in requirements and implementation.

It should be noted upfront that this chapter does not discuss the fine details of MS4 and industrial monitoring that pertain to regulatory compliance—questions such as should the average end of pipe concentrations meet water quality standards, how many exceedances should be allowed per year, or should effluent concentrations be compared to acute or chronic criteria. Individual benchmarks and effluent limits for specific chemicals emanating from specific industries are not provided. The current state of MS4 and industrial stormwater monitoring and the paucity of high quality data are such that it is premature and in many cases impossible to make such determinations. Rather, the chapter suggests both *how* to monitor an individual industry and *how* to determine benchmarks and effluent limits for industrial categories. It suggests how monitoring requirements should be tailored to accommodate the risk level of an individual industrial discharger. Finally, it makes numerous technical suggestions for improving the monitoring of MS4s, building on the data already submitted and analyzed as part of the National Stormwater Quality Database. Policy recommendations about the monitoring of both industries and MS4s are found in Chapter 6.

This chapter's emphasis on monitoring of stormwater should not be interpreted as a disinterest in other types of monitoring, such as biomonitoring of receiving waters, precipitation measurements, or determination of land cover. Indeed, these latter activities are extremely important (they are introduced in the preceding chapter) and they underpin the new permitting program proposed in Chapter 6 (especially biological monitoring). Stormwater management would benefit most substantially from a well-balanced monitoring program that encompasses chemical, biological, and physical parameters from outfalls to receiving waters. Currently, however, decisions about stormwater management are usually made with incomplete information; for example, there are continued recommendations by many that street cleaning will solve a municipality's problems, even when the municipality does not have any information on the sources of the material being removed.

A second charge to the committee was to define the elements of a "protocol" to link pollutants in stormwater discharges to ambient water quality criteria. As described in Chapter 3, many processes connect sources of pollution to an effect observed in a downstream receiving water. More and more, these processes can be represented in watershed models, which are the key to linking stormwater sources to effects observed in receiving waters. The latter half of the chapter explores the current capability of models to make such links, including simple models, statistical and conceptual models, and more involved mechanistic models. At the present time,

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associating a single discharger with degraded in-stream conditions is generally not possible because of the state of both modeling and monitoring of stormwater.

MONITORING OF MS4s

EPA's regulations for stormwater monitoring of MS4s is very limited, in that only the application requirements are stated [see 40 CFR § 122.26(d)]. The regulations require the MS4 program to identify five to ten stormwater discharge outfalls and to collect representative stormwater data for conventional and priority toxic pollutants from three representative storm events using both grab and composite sampling methods. Each sampled storm event must have a rainfall of at least 0.1 inch, must be preceded by at least 72 hours of a dry period, and the rain event must be within 50 percent of the average or median of the per storm volume and duration for the region. While the measurement of flow is not specifically required, an MS4 must make estimates of the event mean concentrations (EMCs) for pollutants discharged from all outfalls to surface waters, and in order to determine EMCs, flow needs to be measured or calculated.

Other than these requirements, the exact type of MS4 monitoring that is to be conducted during the permit term is left to the discretion of the permitting authority. EPA has not issued any guidance on what would be considered an adequate MS4 monitoring program for permitting authorities to evaluate compliance. Some guidance for MS4 monitoring based on desired management questions has been developed locally (for example, see the SCCWRP Technical Report No. 419, SMC 2004, Model Monitoring Program for MS4s in Southern California).

In the absence of national guidance from EPA, the MS4 monitoring programs for Phase I MS4s vary widely in structure and objectives, and Phase II MS4 programs largely do not perform any monitoring at all. The types of monitoring typically contained in Phase I MS4 permits include the (1) wet weather outfall screening and monitoring to characterize stormwater flows, (2) dry weather outfall screening and monitoring under illicit discharge detection and elimination programs, (3) biological monitoring to determine storm water impacts, (4) ambient water quality monitoring to characterize water quality conditions, and (5) stormwater control measure (SCM) effectiveness monitoring.

The Nationwide Stormwater Quality Database

Stormwater monitoring data collected by a portion of Phase I MS4s has been evaluated for years by the University of Alabama and the Center for Watershed Protection and compiled in a database called the Nationwide Stormwater Quality Database (NSQD). These data were collected in order to describe the characteristics of stormwater on a national level, to provide guidance for future sampling needs, and to enhance local stormwater management activities in areas with limited data. The MS4 monitoring data collected over the past ten years from more than 200 municipalities throughout the country have great potential in characterizing the quality of stormwater runoff and comparing it against historical benchmarks. Version 3 of the NSQD is available online at: http://unix.eng.ua.edu/~rpitt/Research/ms4/mainms4.shtml. It contains data from more than 8,500 events and 100 municipalities throughout the country. About 5,800 events are associated with homogeneous land uses, while the remainder are for mixed land uses.

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The general approach to data collection was to contact EPA regional offices to obtain state contacts for the MS4 data, then the individual municipalities with Phase I permits were targeted for data collection. Selected outfall data from the International BMP Database were also included in NSQD version 3, eliminating any source area and any treated stormwater samples. Some of the older National Urban Runoff Program (NURP) (EPA, 1983) data were also included in the NSQD, along with some data from specialized U.S. Geological Survey (USGS) stormwater monitoring activities in order to better represent nationwide conditions and additional land uses. Because there were multiple sources of information, quality assurance and quality control reviews were very important to verify the correctness of data added to the database, and to ensure that no duplicate entries were added.

The NSQD includes sampling location information such as city, state, land use, drainage area, and EPA Rain Zone, as well as date, season, and rain depth. The constituents commonly measured for in stormwater include total suspended solids (TSS), 5-day biological oxygen demand (BOD_5), chemical oxygen demand (COD), total phosphorus (TP), total Kjeldahl nitrogen (TKN), nitrite plus nitrate (NO_2+NO_3), total copper (Cu), total lead (Pb), and total zinc (Zn). Less information is available for many other constituents (including filterable heavy metals and bacteria). Figure 4-1 is a map showing the EPA Rain Zones in the United States, along with the locations of the communities contributing to the NSQD, version 3. Table 4-1 shows the number of samples for each land use and for each Rain Zone. This table does not show the number of mixed land-use site samples. Rain Zones 8 and 9 have very few samples, and institutional and open-space areas are poorly represented. However, residential, commercial, industrial, and freeway data are plentiful, except for the few Rain Zones noted above.

Land use has an important impact on the quality of stormwater. For example, the concentrations of heavy metals are higher for industrial land-use areas due to manufacturing processes and other activities that generate these materials. Fecal coliform concentrations are relatively high for residential and mixed residential land uses, and nitrate concentrations are higher for the freeway land use. Open-space land-use areas show consistently low concentrations for the constituents examined. Seasons could also be a factor in the variation of nutrient concentrations in stormwater due to seasonal uses of fertilizers and leaf drop occurring during the fall season. Most studies also report lower bacteria concentrations in the winter than in the summer. Lead concentrations in stormwater have also significantly decreased since the elimination of lead in gasoline (see Figure 2-6). Most of the statistical tests used are multivariate statistical evaluations that compare different constituent concentrations with land use and geographical location. More detailed discussions of the earlier NSQD results are found in various references, including Maestre et al. (2004, 2005) and Pitt et al. (2003, 2004).

TABLE 4-1 Number of Samples per Land Use and EPA Rain Zone

Single land use	1	2	3	4	5	6	7	8	9	Total
Commercial	234	484	131	66	42	37	64	0	22	1080
Freeways	0	241	14	0	262	189	28	0	0	734
Industrial	100	327	90	51	83	74	146	0	22	893
Institutional	9	46	0	0	0	0	0	0	0	55
Open Space	68	37	0	18	0	2	0	0	0	125
Residential	294	1470	290	122	105	32	532	7	81	2933
Total	705	2605	525	257	492	334	770	7	125	5820

Note: there are no mixed-use sites in this table. SOURCE: National Stormwater Quality Database.

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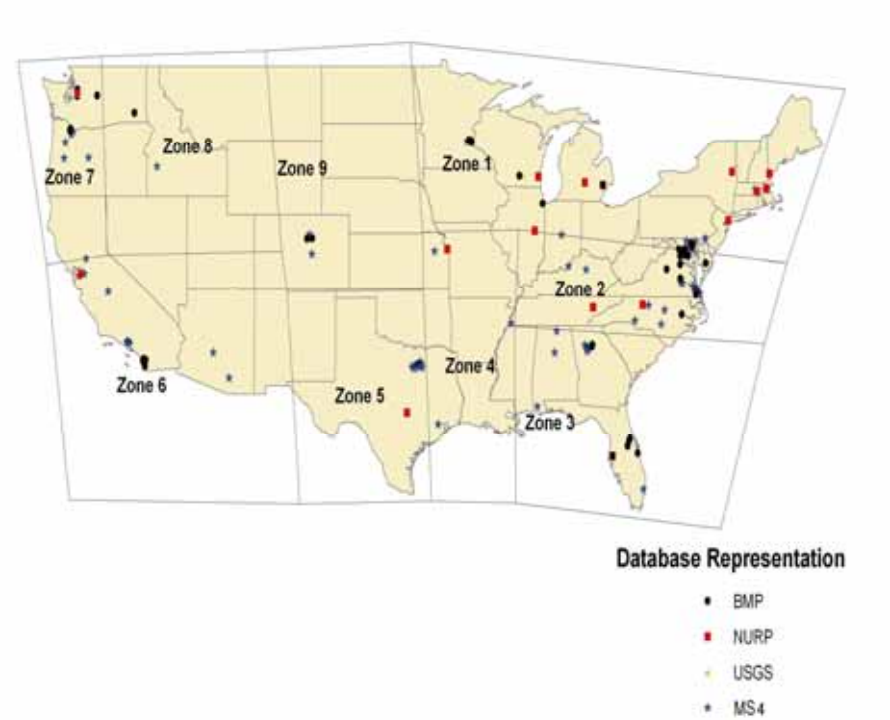

FIGURE 4-1 Sampling Locations for Data Contained in the National Stormwater Quality Database, version 3.

How the NSQD can be used to Calculate Representative EMC Values

EMC values were initially used during the NURP to describe typical concentrations of pollutants in stormwater for different monitoring locations and land uses. An EMC is intended to represent the average concentration for a single monitored event, usually based on flow-weighted composite sampling. It can also be calculated from discrete samples taken during an event if flow data are also available. Many individual subsamples should be taken throughout most of the event to calculate the EMC for that event. Being an overall average value, an EMC does not represent possible extremes that may occur during an event.

The NSQD includes individual EMC values from about 8,500 separate events. Stormwater managers typically want a representative single value for a land use for their area. As such, they typically evaluate a series of individual storm EMC values for conditions similar to those representing their site of concern. With the NSQD in a spreadsheet form, it is relatively simple to extract suitable events representing the desired conditions. However, the individual EMC values will likely have a large variability. Maestre and Pitt (2006) reviewed the NSQD data to better explain the variability according to different site and sampling conditions (land use, geographical location, season, rain depth, amount of impervious area, sampling methods, antecedent dry period, etc.). The most common significant factor was land use, with some geographical and fewer seasonal effects observed. As with the original NURP data, EMCs in the NSQD are usually expressed using medians and coefficients of variation to reflect uncertainty, assuming lognormal distributions of the EMC values. Figure 4-2 shows several lognormal probability plots for a few constituents from the NSQD. Probability plots shown as straight lines indicate that the concentrations can be represented by lognormal distributions (see Box 4-1).

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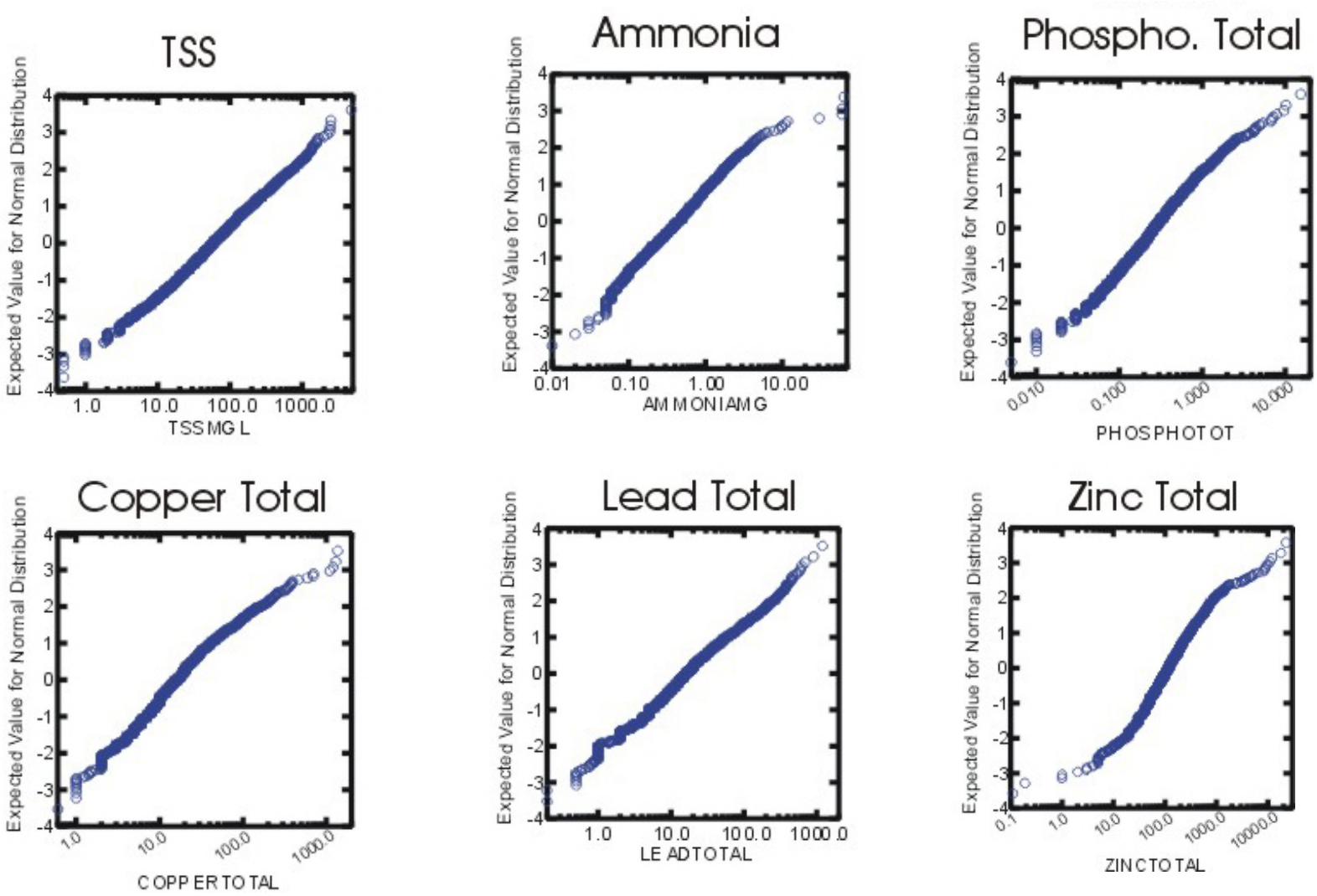

FIGURE 4-2 Lognormal probability plots of stormwater quality data for selected constituents (pooled data from NSQD version 1.1).

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BOX 4-1
Probability Distributions of Stormwater Data

The coefficient of variation (COV) values for many constituents in the NSQD range from unusually low values of about 0.1 (for pH) to highs between 1 and 2. One objective of a data analysis procedure is to categorize the data into separate stratifications, each having small variations in the observed concentrations. The only stratification usually applied is for land use. However, further analyses indicated many differences by geographical area and some differences by season. When separated into appropriate stratifications, the COV values are reduced, ranging between about 0.5 to 1.0. With a reasonable confidence of 95 percent (α= 0.05) and power of 80 percent (β= 0.20), and a suitable allowable error goal of 25 percent, the number of samples needed to characterize these conditions would therefore range from about 25 to 50 (Burton and Pitt, 2002). In a continuing monitoring program (such as the Phase I stormwater National Pollutant Discharge Elimination System [NPDES] permit monitoring effort) characterization data will improve over time as more samples are obtained, even with only a few samples collected each year from each site.

Stormwater managers have generally accepted the assumption of lognormality of stormwater constituent concentrations between the 5th and 95th percentiles. Based on this assumption, it is common to use the log-transformed EMC values to evaluate differences between land-use categories and other characteristics. Statistical inference methods, such as estimation and tests of hypothesis, and analysis of variance, require statistical information about the distribution of the EMC values to evaluate these differences. The use of the log-transformed data usually includes the location and scale parameter, but a lower-bound parameter is usually neglected.

Maestre et al. (2005) conducted statistical tests using NSQD data to evaluate the lognormality assumptions of selected common constituents. It was found in almost all cases that the log-transformed data followed a straight line between the 5th and 95th percentile, as illustrated in Figure 4-3 for total dissolved solids (TDS) in residential areas.

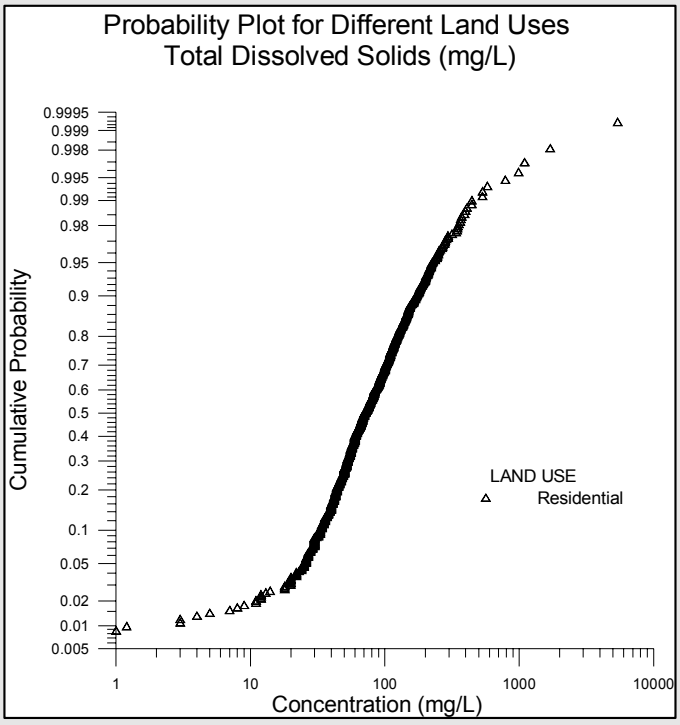

FIGURE 4-3 Probability plot of total dissolved solids in residential land uses (NSQD version 1.1 data).

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BOX 4-1 Continued

For many statistical tests focusing on the central tendency (such as for determining the concentrations that are to be used for mass balance calculations), this may be a suitable fit. As an example, the model WinSLAMM (Pitt, 1986; Pitt and Voorhees, 1995) uses a Monte Carlo component to describe the likely variability of stormwater source flow pollutant concentrations using either lognormal or normal probability distributions for each constituent. However, if the most extreme values are of importance, such as when dealing with the influence of many non-detectable values on the predicted concentrations, or determining the frequency of observations exceeding a numerical standard, a better description of the extreme values may be important.

The NSQD contains many factors for each sampled event that likely affect the observed concentrations. These include such factors as seasons, geographical zones, and rain intensities. These factors may affect the shape of the probability distribution. The only way to evaluate the required number of samples in each category is by using the power of the test, where power is the probability that the test statistic will lead to a rejection of the null hypothesis (Gibbons and Chakraborti, 2003).

In the NSQD, most of the data were from residential land uses. The Kolmogorov-Smirnov test was used to indicate if the cumulative empirical probability distribution of the residential stormwater constituents can be adequately represented with a lognormal distribution. The number of collected samples was sufficient to detect if the empirical distribution was located inside an interval of width 0.1 above and below the estimated cumulative probability distribution. If the interval was reduced to 0.05, the power varies between 40 and 65 percent. Another factor that must be considered is the importance of relatively small errors in the selected distribution and the problems of false-negative determinations. It may not be practical to collect as many data observations as needed when the distributions are close. Therefore, it is important to understand what types of further statistical and analysis problems may be caused by having fewer samples than optimal. For example, Figure 4-4 (total phosphorus in residential areas) shows that most of the data fall along the straight line (indicating a lognormal fit), with fewer than 10 observations (out of 933) in the tails being outside of the obvious path of the line, or a false-negative rate of about 0.01 (1 percent).

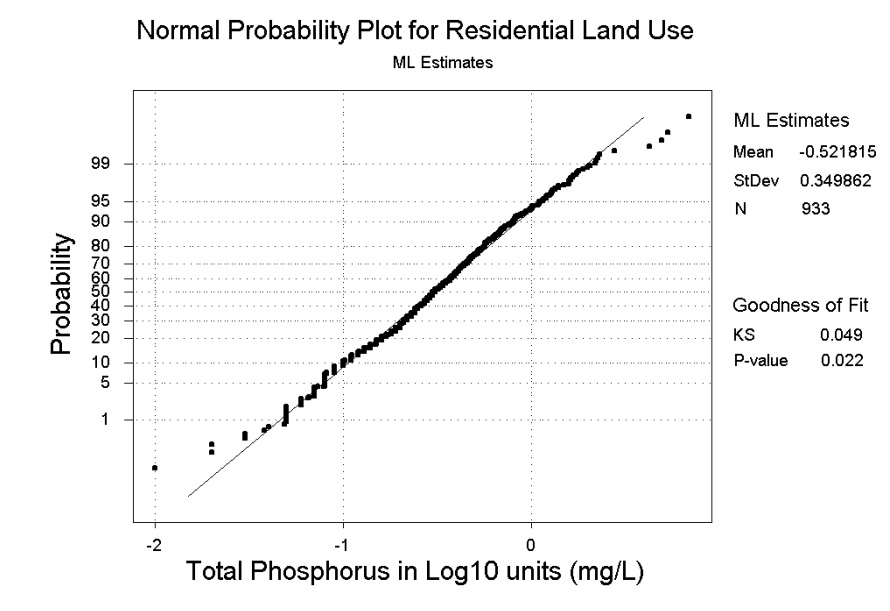

FIGURE 4-4 Normality test for total phosphorus in residential land uses using the NSQD.

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BOX 4-1 Continued

Further analyses to compare the constituent concentration distributions to other common probability distributions (normal, lognormal, gamma, and exponential) were also conducted for all land uses by Maestre et al. (2004). Most of the stormwater constituents can be assumed to follow a lognormal distribution with little error. The use of a third parameter in the estimated lognormal distribution may be needed, depending on the number of samples. When the number of samples is large per category (approximately more than 400 samples) the maximum likelihood and the two-parameter lognormal distribution better fit the empirical distribution. For large sample sizes, the L-moments method usually unacceptably truncates the distribution in the lower tail. However, when the sample size is more moderate per category (approximately between 100 and 400 samples), the three-parameter lognormal method, estimated by L-moments, better fits the empirical distribution. When the sample size is small (less than 100 samples, as is common for most stormwater programs), the use of the third parameter does not improve the fit with the empirical distribution and the common two-parameter lognormal distribution produces a better fit than the other two methods. The use of the lognormal distribution also has an advantage over the other distribution types because it can be easily transformed to a normal distribution and the data can then be correctly examined using a wide variety of statistical tests.

Fitting a known distribution is important as it helps indicate the proper statistical tests that may be conducted. Using the *median* EMC value in load calculations, without considering the data variability, will result in smaller mass loads compared to actual monitored conditions. This is due to the medians underrepresenting the larger concentrations that are expected to occur. The use of *average* EMC values will represent the larger values better, although they will still not represent the variability likely to exist. If all of the variability cannot be further explained adequately (such as being affected by rain depth), which would be highly unlikely, then a set of random calculations (such as that obtained using Monte Carlo procedures) reflecting the described probability distribution of the constituents would be the best method to use when calculating loads.

Municipal Monitoring Issues

As described in Chapter 2, typical MS4 monitoring requirements involve sampling during several events per year at the most common land uses in the area. Obviously, a few samples will not result in very useful data due to the variability of stormwater characteristics. However, during the period of a five-year permit with three samples per year, about 15 events would be sampled for each land use. While still insufficient for many analyses, this number of data points likely allows the confidence limits to be reasonably calculated for the average conditions. When many sites of the same land use are monitored for a region, substantial data may be collected during a permit cycle. This was the premise of the NSQD where MS4 data were collected for many locations throughout the country. These data were evaluated and various findings made. The following comments are partially based on these analyses, along with additional data sources.

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Sampling Technique and Compositing

There are a variety of methods for collecting and compositing stormwater samples that can result in different values for the EMC. The first distinction is the mode of sample collection, either as grab samples or automatic sampling. Obviously, grab sampling is limited by the speed and accuracy of the individuals doing the sampling, and it is personnel intensive. It is for this reason that about 80 percent of the NSQD samples are collected using automatic samplers. Manual sampling has been observed to result in slightly lower TSS concentrations compared to automatic sampling procedures. This may occur, for example, if the manual sampling team arrives after the start of runoff and therefore misses an elevated first flush (if it exists for the site), resulting in reduced EMCs.

A second important concept is how and whether the samples are combined following collection. With *time-based discrete sampling*, **s**amplers (people or machines) are programmed to take an aliquot after a set period of time (usually in the range of every 15 minutes) and each aliquot is put into a separate bottle (usually 1 liter). Each bottle is processed separately, so this method can have high laboratory costs. This is the only method, however, that will characterize the changes in pollutant concentrations during the event. *Time-based composite sampling* refers to samplers being programmed to take an aliquot after a set period of time (as short as every 3 minutes), but then the aliquots are combined into one container prior to analysis (compositing). All parts of the event receive equal weight with this method, but the large number of aliquots can produce a reasonably accurate composite concentration. Finally, *flow-weighted composite sampling* refers to samplers being programmed to collect an aliquot (usually 1 liter) for a set volume of discharge. Thus, more samples are collected during the peak of the hydrograph than toward the trailing edge of the hydrograph. All of the aliquots are composited into one container, so the concentration for the event is weighted by flow.

Most communities calculate their EMC values using flow-weighted composite sample analyses for more accurate mass discharge estimates compared to time-based compositing. This is especially important for areas with a first flush of very short duration, because time-composited samples may overly emphasize these higher flows. An automatic sampler with flow-weighted samples, in conjunction with a bed-load sampler, is likely the most accurate sampling method, but only if the sampler can obtain a representative sample at the location (such as sampling at a cascading location, or using an automated depth-integrated sampler) (Clark et al., 2008).

Time- and flow-weighted composite options have been evaluated in residential, commercial, and industrial land uses in EPA Rain Zone 2 and in industrial land uses in EPA Rain Zone 3 for the NSQD data. No significant differences were observed for BOD_5 concentrations using either of the compositing schemes for any of the four categories. TSS and total lead median concentrations in EPA Rain Zone 2 were two to five times higher in concentration when time-based compositing was used instead of flow-based compositing. Nutrients in EPA Rain Zone 2 collected in residential, commercial, and industrial areas showed no significant differences using either compositing method. The only exceptions were for ammonia in residential and commercial land-use areas and total phosphorus in residential areas where time-based composite samples had higher concentrations. Metals were higher when time-based compositing was used in residential and commercial land-use areas. No differences were observed in industrial land-use areas, except for lead. Again, in most cases, mass discharges are of the most importance in order to show compliance with TMDL requirements. Flow-weighted

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sampling is the most accurate method to obtain these values (assuming sufficient numbers of subsamples are obtained). However, if receiving water effects are associated with short-duration high concentrations, then discrete samples need to be collected and analyzed, with no compositing of the samples during the event. Of course, this is vastly more costly and fewer events are usually monitored if discrete sampling is conducted.

Numbers of Data Observations Needed

The biggest issue associated with most monitoring programs is the number of data points needed. In many cases, insufficient data are collected to address the objectives of the monitoring program with a reasonable amount of confidence and power. Burton and Pitt (2002) present much guidance in determining the amount of data that should be collected. A basic equation that can be used to estimate the number of samples to characterize a set of conditions is as follows:

$$n = [COV(Z_{1-\alpha} + Z_{1-\beta})/(error)]^2$$

where:

n = number of samples needed.

α = false-positive rate ($1-\alpha$ is the degree of confidence; a value of α of 0.05 is usually considered statistically significant, corresponding to a $1-\alpha$ degree of confidence of 0.95, or 95%).

β = false-negative rate ($1-\beta$ is the power; if used, a value of β of 0.2 is common, but it is frequently and improperly ignored, corresponding to a β of 0.5).

$Z_{1-\alpha}$ = Z score (associated with area under a normal curve) corresponding to $1-\alpha$; if α is 0.05 (95% degree of confidence), then the corresponding $Z_{1-\alpha}$ score is 1.645 (from standard statistical tables).

$Z_{1-\beta}$ = Z score corresponding to $1-\beta$ value; if β is 0.2 (power of 80%), then the corresponding $Z_{1-\beta}$ score is 0.85 (from standard statistical tables); however, if power is ignored and β is 0.5, then the corresponding $Z_{1-\beta}$ score is 0.

error = allowable error, as a fraction of the true value of the mean.

COV = coefficient of variation (sometimes noted as CV), the standard deviation divided by the mean (dataset assumed to be normally distributed).

Figures 4-5 and 4-6 can be used to estimate the sampling effort, based on the expected variability of the constituent being monitored, the allowable error in the calculated mean value, and the associated confidence and power. Figure 4-5 can be used for a single sampling point that is being monitored for basic characterization information, while Figure 4-6 is used for paired sampling when two locations are being compared. Confidence and power are needed to control the likelihood of false negatives and false positives. The sample needs increase dramatically as the difference between datasets becomes small when comparing two conditions with a paired

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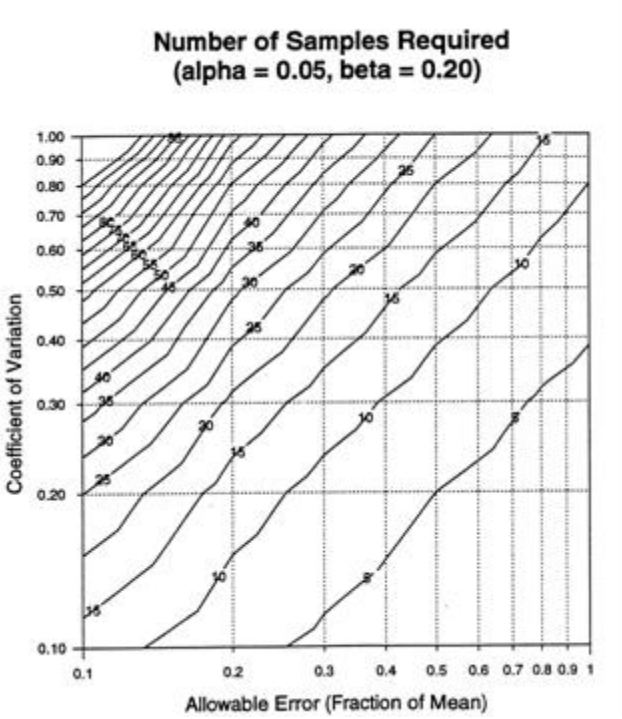

FIGURE 4-5 Number of samples to characterize median (power of 80% and confidence of 95%). SOURCE: Reprinted, with permission from, Burton and Pitt (2002). Copyright 2002 by CRC Press.

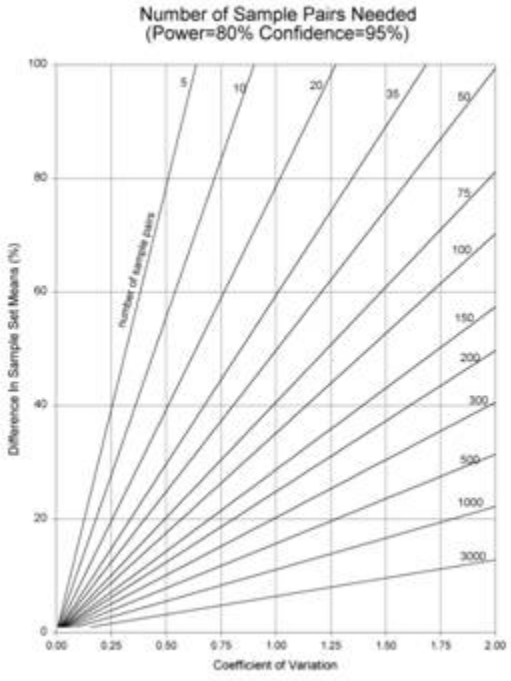

FIGURE 4-6 Number of paired samples needed to distinguish between two sets of observations (power 80% and confidence of 95%). SOURCE: Reprinted, with permission from, Burton and Pitt (2002). Copyright 2002 by CRC Press.

analysis, as shown in Figure 4-6 (above and below an outfall, influent vs. effluent, etc.). Typically, being able to detect a difference of at least about 25 percent (requiring about 50 sample pairs with typical sample variabilities) is a reasonable objective for most stormwater projects. This is especially important when monitoring programs attempt to distinguish test and control conditions associated with SCMs. It is easy to confirm significant differences between influent and effluent conditions at wet detention ponds, as they have relatively high removal rates. Less effective controls are much more difficult to verify, as the sampling program requirements become very expensive.

First-Flush Effects

First flush refers to an assumed elevated load of pollutants discharged in the beginning of a runoff event. The first-flush effect has been observed more often in small catchments than in large catchments (Thompson et al., 1995, cited by WEF and ASCE, 1998). Indeed, in large catchments (>162 ha, 400 acres), the highest concentrations are usually observed at the times of flow peak (Brown et al., 1995; Soeur et al., 1995). Adams and Papa (2000) and Deletic (1998) both concluded that the presence of a first flush depends on numerous site and rainfall characteristics.

Figure 4-7 is a plot of monitoring data from the Villanova first-flush study (Batroney, 2008) showing the flows, rainfall, TSS concentration, TDS concentration, and TDS and TSS event mean concentrations for the inflow to an infiltration trench. Because of the first-flush

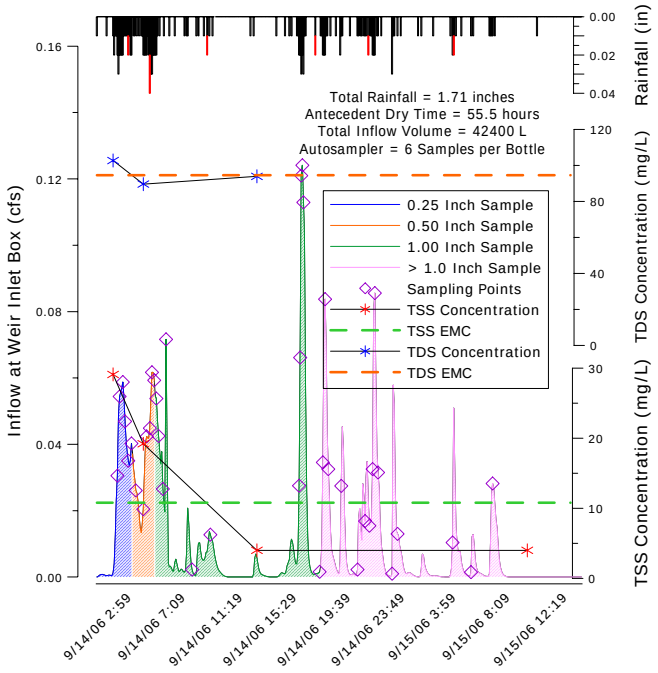

FIGURE 4-7 Villanova first-flush study showing pollutant concentration as a function of inflow rainfall volume. This study collected runoff leaving the top floor of a parking garage. Samples were taken of the runoff in one-quarter-inch increments, up to an inch of rain, and then every inch thereafter. The plot of TSS concentration versus rainfall increment shows a strong first flush for this storm, while the TDS concentration does not. SOURCE: Reprinted, with permission, Batroney (2008). Copyright 2008 by T. Thomas Batroney.

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effect, a grab sample early in the storm would have over-predicted the TSS event mean concentration of the site, and a later sample would have under-predicted this same value, although for TDS the results would have been similar.

Figure 4-8 shows data for a short-duration, high-intensity rain in Tuscaloosa, Alabama, that had rain intensities as great a 6 inches per hour for a 10-minute period. The drainage area was a 0.4-ha paved parking lot with some landscaping along the edges. The turbidity plot shows a strong first flush for this event, and the particle size distributions indicate larger particles at the beginning of the event, then becoming smaller as the event progresses, and then larger near the end. Most of the other pollutants analyzed had similar first-flush patterns like the turbidity, with the notable exception of bacteria. Both *E. coli* and enterococci concentrations started off moderately low, but then increased substantially near the end of the rain. Several rains have been monitored at this site so far, and most show a similar pattern with decreasing turbidity and increasing bacteria as the rain continues.

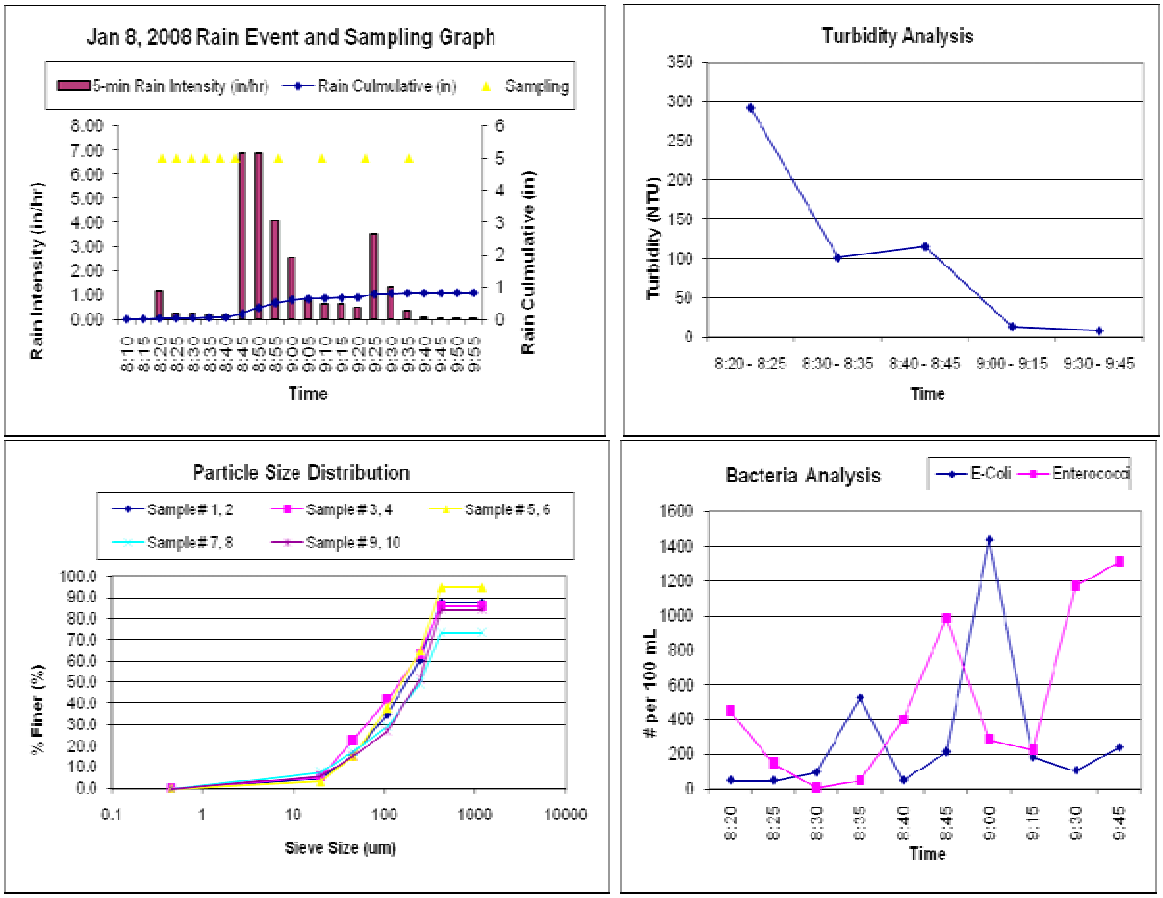

FIGURE 4-8 Pollutant variations during rain period (0.4-ha drainage area, mostly paved parking with small fringe turf area, Tuscaloosa, Alabama). SOURCE: Robert Pitt.

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Sample collection conducted for some of the NPDES MS4 Phase I permits required both a grab and a composite sample for each event. A grab sample was to be taken during the first 30 minutes of discharge to capture the first flush, and a flow-weighted composite sample was to be taken for the entire time of discharge (every 15 to 20 minutes for at least three hours or until the event ended). Maestre et al. (2004) examined about 400 paired sets of 30-minute and 3-hour samples from the NSQD, as shown in Table 4-2. Generally, a statistically significant first flush is associated with a median concentration ratio of about 1.4 or greater (the exceptions are where the number of samples in a specific category is much smaller). The largest ratios observed were about 2.5, indicating that for these conditions the first 30-minute flush sample concentrations are about 2.5 times greater than the composite sample concentrations. More of the larger ratios are found for the commercial and institutional land-use categories, where larger paved areas are likely to be found. The smallest ratios are associated with the residential, industrial, and open-space land uses—locations where there may be larger areas of unpaved surfaces.

TABLE 4-2 Significant First Flush Ratios (First Flush to Composite Median Concentration)

Parameter	Commercial				Industrial				Institutional			
	n	sc	R	ratio	n	sc	R	ratio	n	sc	R	ratio
Turbidity, NTU	11	11	=	1.32			X				X	
COD, mg/L	91	91	≠	2.29	84	84	≠	1.43	18	18	≠	2.73
TSS, mg/L	90	90	≠	1.85	83	83	=	0.97	18	18	≠	2.12
Fecal coliform, col/100mL	12	12	=	0.87			X				X	
TKN, mg/L	93	86	≠	1.71	77	76	≠	1.35			X	
Phosphorus total, mg/L	89	77	≠	1.44	84	71	=	1.42	17	17	=	1.24
Copper, total, µg/L	92	82	≠	1.62	84	76	≠	1.24	18	7	=	0.94
Lead, total, µg/L	89	83	≠	1.65	84	71	≠	1.41	18	13	≠	2.28
Zinc, total, µg/L	90	90	≠	1.93	83	83	≠	1.54	18	18	≠	2.48

Parameter	Open Space				Residential				All Combined			
	n	sc	R	ratio	n	sc	R	ratio	n	sc	R	ratio
Turbidity, NTU			X		12	12	=	1.24	26	26	=	1.26
COD, mg/L	28	28	=	0.67	140	140	≠	1.63	363	363	≠	1.71
TSS, mg/L	32	32	=	0.95	144	144	≠	1.84	372	372	≠	1.60
Fecal coliform, col/100mL			X		10	9	=	0.98	22	21	=	1.21
TKN, mg/L	32	14	=	1.28	131	123	≠	1.65	335	301	≠	1.60
Phosphorus, total, mg/L	32	20	=	1.05	140	128	≠	1.46	363	313	≠	1.45
Copper, total, µg/L	30	22	=	0.78	144	108	≠	1.33	368	295	≠	1.33
Lead, total, µg/L	31	16	=	0.90	140	93	≠	1.48	364	278	≠	1.50
Zinc, total, µg/L	21	21	=	1.25	136	136	≠	1.58	350	350	≠	1.59

Note: n, number of total possible events; sc, number of selected events with detected values; R, result; X, not enough data; =, not enough evidence to conclude that median values are different; ≠, median values are different. “Ratio” is the ratio of the first flush to the full-period sample concentrations.
SOURCE: NSQD, as reported by Maestre et al. (2004).

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The data in Table 4-2 were from North Carolina (76.2 percent), Alabama (3.1 percent), Kentucky (13.9 percent), and Kansas (6.7 percent) because most other states' stormwater permits did not require this sampling strategy. The NSQD investigation of first-flush conditions for these data locations indicated that a first-flush effect was not present for all the land-use categories and certainly not for all constituents. Commercial and residential areas were more likely to show this phenomenon, especially if the peak rainfall occurred near the beginning of the event. It is expected that this effect will more likely occur in a watershed with a high level of imperviousness, but even so, the data indicated first flushes for less than 50 percent of the samples for the most impervious areas. This reduced frequency of observed first flushes in areas most likely to have first flushes is probably associated with the varying rain conditions during the different events, including composite samples that did not represent the complete runoff duration.

Groups of constituents showed different behaviors for different land uses. All the heavy metals evaluated showed higher concentrations at the beginning of the event in the commercial land-use category. Similarly, all the nutrients showed higher initial concentrations in residential land-use areas, except for total nitrogen and orthophosphorus. This phenomenon was not found in the bacterial analyses. None of the land uses showed a higher population of bacteria at the beginning of the event.

The general conclusion from these data is that, in areas having low and generally even-intensity rains, first-flush observations are more common, especially in small and mostly paved areas. As an area increases in size, multiple routing pathways tend to blend the water, and runoff from the more distant locations reaches the outfall later in the event. SCMs located at outfalls in areas having low levels of impervious cover should be selected and sized to treat the complete event, if possible. Preferential treatment of first flushes may only be justified for small impervious areas, but even then, care needs to be taken to prevent undersizing and missing substantial fractions of the event.

Seasonal first flushes refer to larger portions of the annual runoff and pollutant discharges occurring during a short rain season. Seasonal first flushes may be observed in more arid locations where seasonal rainfalls are predominant. As an example, central and southern California can have dry conditions for extended periods, with the initial rains of the season occurring in the late fall. These rains can be quite large and, since they occur after prolonged dry periods, may carry substantial portions of the annual stormwater pollutant load. This is especially pronounced if later winter rains are more mild in intensity and frequent. For these areas, certain types of seasonally applied SCMs may be effective. As an example, extensive street, channel, and inlet cleaning in the late summer and early fall could be used to remove large quantities of debris and leaves from the streets before the first heavy rains occur. Other seasonal maintenance operations benefiting stormwater quality should also be scheduled before these initial rains.

Rain Depth Effects

An issue related to first flushes pertains to the effects of rain depth on stormwater quality. The NSQD contains much rainfall data along with runoff data for most areas of the country. Figure 4-9 contains scatter plots showing concentrations plotted against rain depth for some NSQD data. Although many might assume a correlation between concentrations and rain depth,

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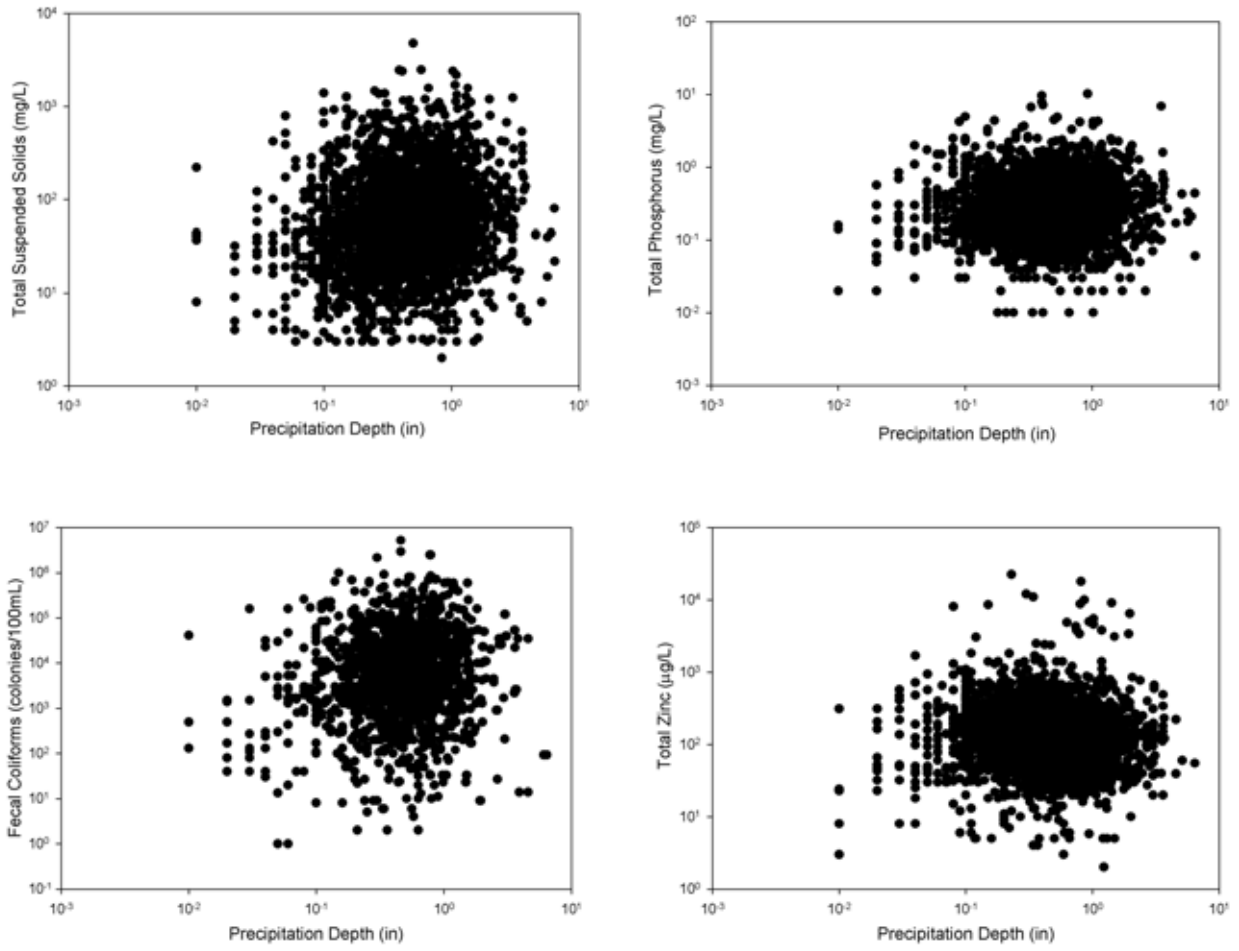

FIGURE 4-9 Examples of scatter plots by precipitation depth. SOURCE: NSQD.

in fact there are no obvious trends of concentration associated with rain depth. Rainfall energy determines erosion and wash-off of particulates, but sufficient runoff volume is needed to carry the particulate pollutants to the outfalls. Different travel times from different locations in the drainage areas results in these materials arriving at different times, plus periods of high rainfall intensity (that increase pollutant wash-off and movement) occur randomly throughout the storm. The resulting outfall stormwater concentration patterns for a large area having various surfaces is therefore complex and rain depth is just one of the factors involved.

Reported Monitoring Problems

A number of monitoring problems were described in the local Phase I community MS4 annual monitoring reports that were summarized as part of assembling the NSQD. About 58 percent of the communities described monitoring problems. Problems were mostly associated

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with obtaining reliable data for the targeted events. These problems increased costs because equipment failures had to be corrected and sampling excursions had to be rescheduled. One of the basic sampling requirements was to collect three samples every year for each of the land-use stations. These samples were to be collected at least one month apart during storm events having at least 0.1-inch rains, and with at least 72 hours from the previous 0.1-inch storm event. It was also required (when feasible) that the variance in the duration of the event and the total rainfall not exceed the median rainfall for the area. About 47 percent of the communities reported problems meeting these requirements. In many areas of the country, it was difficult to have three storm events per year with these characteristics. Furthermore, the complete range of site conditions needs to be represented in the data-collection effort; focusing only on a narrow range of conditions limits the representativeness of the data.

The second most frequent problem, reported by 26 percent of the communities, concerned backwater tidal influences during sampling, or that the outfall became submerged during the event. In other cases, it was observed that there was flow under the pipe (flowing outside of the pipe, in the backfill material, likely groundwater), or sometimes there was no flow at all. These circumstances all caused contamination of the collected samples, which had to be discarded, and prevented accurate flow monitoring. Greater care is obviously needed when locating sampling locations to eliminate these problems.

About 12 percent of the communities described errors related to malfunctions of the sampling equipment. When reported, the equipment failures were due to incompatibility between the software and the equipment, clogging of the rain gauges, and obstruction in the sampling or bubbler lines. Memory losses in the equipment recording data were also periodically reported. Other reported problems were associated with lighting, false starts of the automatic sampler before the runoff started, and operator error due to misinterpretation of the equipment configuration manual.

The reported problems suggest that the following changes should be made. First, the rain gauges need to be placed close to the monitored watersheds. Large watersheds cannot be represented with a single rain gauge at the monitoring station. In all cases, a standard rain gauge needs to supplement a tipping bucket rain gauge, and at least three rain gauges should be used in the research watersheds. Second, flow-monitoring instrumentation also needs to be used at all water quality monitoring stations. The lack of flow data greatly hinders the value of the chemical data. Third, monitoring needs to cover the complete storm duration. Automatic samplers need to be properly programmed and maintained to handle very short to very long events. It is unlikely that manual samplers were able to initiate sampling near the beginning of the events, unless they were deployed in anticipation of an event later in the day. A more cost-effective and reliable option would be to have semi-permanent monitoring stations at the various locations with sampling equipment installed in anticipation of a monitored event. Most monitoring agencies operated three to five land-use stations at one time. This number of samplers, and flow equipment, could have been deployed in anticipation of an acceptable event and would not need to be continuously installed in the field at all sampling locations.

Non-Detected Analyses

Left-censored data involve observations that are reported as below the limits of detection, whereas right-censored data involve above-range observations. Unfortunately, many important

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stormwater measurements (such as for filtered heavy metals) have large fractions of undetected values. These incomplete data greatly hinder many statistical tests. To estimate the problems associated with censored values, it is important to identify the probability distributions of the data in the dataset and the level of censoring. As discussed previously, most of the constituents in the NSQD follow a lognormal distribution. When the frequencies of the censored observations were lower than 5 percent, the means, standard deviations, and COVs were almost identical to the values obtained when the censored observations were replaced by half of the detection limit. As the percentage of nondetected values increases, replacing the censored observation by half of the detection limit instead of estimating them using Cohen's maximum likelihood method produced lower means and larger standard deviations. Replacing the censored observations by half of the detection limit is not recommended for levels of censoring larger than 15 percent. Because the Cohen method uses the detected observations to estimate the nondetected values, it is not very accurate, and therefore not recommended, when the percentage of censored observations is larger than 40 percent (Burton and Pitt, 2002). In this case, summaries should only be presented for the detected observations, with clear notations stating the level of nondetected observations.

The best method to eliminate problems associated with left-censored data is to use an appropriate analytical method. By keeping the nondetectable level below 5 percent, there are many fewer statistical analysis problems and the value of the datasets can be fully realized. Table 4-3 summarizes the recommended minimum detection limits for various stormwater constituents to obtain manageable nondetection frequencies (< 5 percent), based on the NSQD data observations. Some of the open-space stormwater measurements (lead, and oil and grease, for example) would likely have greater than 5 percent nondetections, even with the detection limits shown. The detection limits for filtered heavy metals should also be substantially less than shown on this table.

TABLE 4-3 Suggested Analytical Detection Limits for Stormwater Monitoring Programs to Obtain Less Than 5 Percent Nondetections

Parameter	Residential, Commercial, Industrial, Freeway	Open Space
Conductivity	20 μS/cm	20 μS/cm
Hardness	10 mg/L	10 mg/L
Oil and grease	0.5 mg/L	0.5 mg/L
TDS	10 mg/L	10 mg/L
TSS	5 mg/L	1 mg/L
BOD_5	2 mg/L	1 mg/L
COD	10 mg/L	5 mg/L
Ammonia	0.05 mg/L	0.01 mg/L
$NO_2 + NO_3$	0.1 mg/L	0.05 mg/L
TKN	0.2 mg/L	0.2 mg/L
Dissolved P	0.02 mg/L	0.01 mg/L
Total P	0.05 mg/L	0.02 mg/L
Total Cu	2 μg/L	2 μg/L
Total Pb	3 μg/L (residential 1 μg/L)	1 μg/L
Total Ni	2 μg/L	1 μg/L
Total Zn	20 μg/L (residential 10 μg/L)	5 μg/L

SOURCE: Maestre and Pitt (2005).

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Seasonal Effects

Another factor that some believe may affect stormwater quality is the season when the sample was obtained. If the few samples collected for a single site were all collected in the same season, the results may not be representative of the whole year. The NPDES sampling protocols were designed to minimize this effect by requiring the three samples per year to be separated by at least one month. The few samples still could be collected within a single season, but not within the same week. Seasonal variations for residential fecal coliform data are shown in Figure 4-10 for NSQD data for all residential areas. These data were the only significant differences in concentration by season for any constituent measured. The bacteria levels are lowest during the winter season and highest during the summer and fall (a similar conclusion was obtained during the NURP data evaluations).

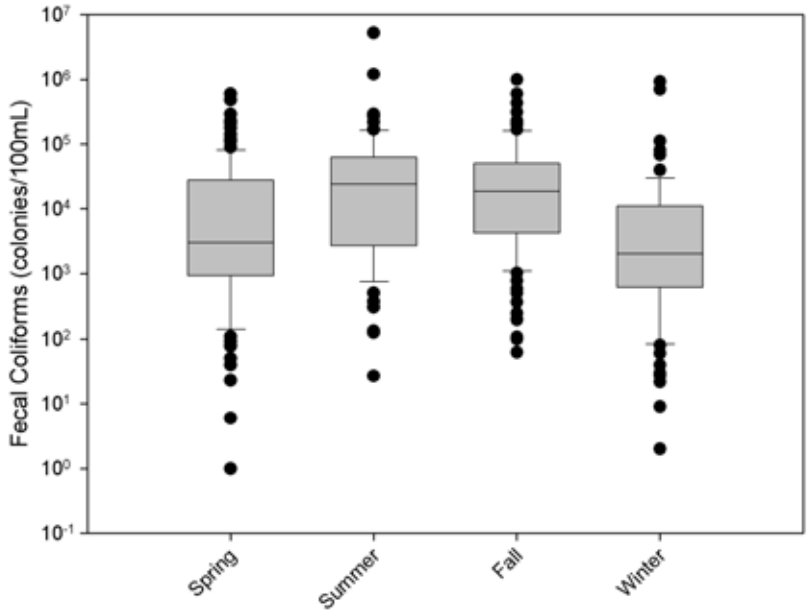

FIGURE 4-10 Fecal coliform concentrations in stormwater by season. SOURCE: NSQD.

Recommendations for MS4 Monitoring Activities

The NSQD is an important tool for the analysis of stormwater discharges at outfalls. About a fourth of the total existing information from the NPDES Phase I program is included in the database. Most of the statistical analyses in this research were performed for residential, commercial, and industrial land uses in EPA Rain Zone 2 (the area of emphasis according to the terms of the EPA-funded research). Many more data are available from other stormwater permit holders that are not included in this database. Acquiring these additional data for inclusion in the NSQD is a recommended and cost-effective activity and should be accomplished as additional data are also being obtained from ongoing monitoring projects.

The use of automatic samplers, coupled with bed-load samplers, is preferred over manual sampling procedures. In addition, flow monitoring and on-site rainfall monitoring need to be

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included as part of all stormwater characterization monitoring. The additional information associated with flow and rainfall data will greatly enhance the usefulness of the much more expensive water quality monitoring. Flow monitoring must also be correctly conducted, with adequate verification and correct base-flow subtraction methods applied. A related issue frequently mentioned by the monitoring agencies is the lack of on-site precipitation information for many of the sites. Using regional rainfall data from locations distant from the monitoring location is likely to be a major source of error when rainfall factors are being investigated.

Many of the stormwater permits only required monitoring during the first three hours of the rain event. This may have influenced the EMCs if the rain event continued much beyond this time. Flow-weighted composite monitoring should continue for the complete rain duration. Monitoring only three events per year from each monitoring location requires many years before statistically adequate numbers of observations are obtained. In addition, it is much more difficult to ensure that such a small fraction of the total number of annual events is representative. Also, there is minimal value in obtaining continued data from an area after sufficient information is obtained. It is recommended that a more concentrated monitoring program be conducted for a two- or three-year period, with a total of about 30 events monitored for each site, covering a wide range of rain conditions. Periodic checks can be made in future years, such as repeating concentrated monitoring every 10 years or so (and for only 15 events during the follow-up surveys).

Finally, better watershed area descriptions, especially accurate drainage-area delineations, are needed for all monitored sites. While the data contained in the NSQD are extremely useful, future monitoring information obtained as part of the stormwater permit program would be greatly enhanced with these additional considerations.

MONITORING OF INDUSTRIES INCLUDING CONSTRUCTION

The various industrial stormwater monitoring requirements of the EPA Stormwater Program have come under considerable scrutiny since the program's inception. Input to the committee at its first meeting conveyed the strong sense that monitoring as it is being done is nearly useless, is burdensome, and produces data that are not being used. The requirements consist of the following. All industrial sectors covered under the Multi-Sector General Permit (MSGP) must conduct visual monitoring four times a year. This visual monitoring is performed by collecting a grab sample within the first hour of stormwater discharge and observing its characteristics qualitatively (except for construction activities—see below). A subset of MSGP industries are required to perform analytical monitoring for benchmark pollutant parameters (see Table 2-5) four times in year 2 of permit coverage and again in year 4 if benchmarks are exceeded in year 2. A benchmark sample is collected as a grab sample within the first hour of stormwater discharge after a rainfall event of 0.1 inch or greater and with an interceding dry period of at least 72 hours. An even smaller subset of MSGP industries that are subject to numerical effluent guidelines under 40 C.F.R. must, in addition, collect grab samples of their stormwater discharge after every discharge event and analyze it for specific pollutant parameters as specified in the effluent guidelines (see Table 2-6). There is no monitoring requirement for stormwater discharges from construction activity in the Construction General Permit. There is only an elective requirement that the construction site be visually inspected within 24 hours after the end of a storm event that is 0.5 inch or greater, if inspections are not performed weekly.

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EPA selected the benchmark analytical parameters for industry subsectors to monitor using data submitted by industrial groups in 1993 as part of their group applications. The industrial groups were required to sample a minimum of 10 percent of facilities within an industry group for pH, TSS, BOD_5, oil and grease, COD, TKN, nitrate plus nitrite nitrogen, and total phosphorous. Each sampling facility within a group collected a minimum of one grab sample within the first 30 minutes of discharge and one flow-weighted composite sample. Other nonconventional pollutants such as fecal coliform bacteria, iron, and cobalt were analyzed only if the industry group expected it to be present. Similarly, toxic pollutants such as lead, copper, and zinc were not sampled but rather self-identified only if expected to be present in the stormwater discharge. As a result of the self-directed nature of these exercises, the data submitted with the group applications were often incomplete, inconsistent, and not representative of the potential risk posed by the stormwater discharge to human health and aquatic life. EPA has not conducted or funded independent investigations and has relied solely on the data submitted by industry groups to determine which pollutant parameters are appropriate for the analytical monitoring of an industry subsector. Thus, there are glaring deficiencies; for example, the only benchmark parameter for asphalt paving and roofing materials is TSS, even though current science shows that the most harmful pollutants in stormwater discharges from the asphalt manufacturing industry are polycyclic aromatic hydrocarbons (compare Table 2-5 with Mahler et al., 2005).

Aside from the suitability of benchmark parameters is the fact the too few samples are collected to sufficiently characterize the variability of pollutant concentrations associated with industrial facilities within a sector. This is discussed in detail in Box 4-2, which describes one of the few efforts to collect and analyze data from the benchmark monitoring of industries done in Southern California. EPA has not requested a nationwide effort to compile these data, as was done for the MS4 program, although this could potentially lead to average effluent concentrations by industrial sector that could be used for a variety of purposes, including more considerate regulations. Finally, the compliance monitoring that is presently being conducted under the MSGP is of limited usefulness because it is being done to comply with effluent guidelines that have not been updated to reflect the best available technology relevant to pollutants of most concern. All of these factors have led to an industrial stormwater monitoring program that is not very useful for the purposes of reducing stormwater pollution from industries or informing operators on which harmful pollutants to expect from their sites.

Industrial-Area Monitoring Issues

Monitoring at industrial sites has some unique issues that must be overcome. The most important aspect for any monitoring program is understanding and specifying the objectives of the monitoring program and developing and following a detained experimental design to allow these objectives to be met. The following discussion is organized around the reasons why monitoring at industrial sites may be conducted.

Regional Monitoring of Many Facilities

An important monitoring objective would be regional monitoring to calibrate and verify stormwater quality models, to randomly verify compliance at facilities not normally requiring

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BOX 4-2
The Plight of Industrial Stormwater Data

Unlike the data collected by municipalities and stored in the NSQD, the benchmark monitoring data collected by permitted industries are not compiled or analyzed on a national basis. However, there has been at least one attempt to compile these data on a more local basis. California required that industrial facilities submit their benchmark monitoring data over a nine-year period, and it was subsequently analyzed by Michael Stenstrom and colleagues at UCLA (Stenstrom and Lee, 2005; Lee et al., 2007). The collected data were for such parameters as pH, turbidity, specific conductance, oil and grease (or total organic carbon), and several metals. There are more than 6,000 industries covered under the California general permit, each of which was to have collected two grab samples per year for a limited number of parameters. Whether these data were collected each year and for each industry was highly variable.

The analysis of the data from Los Angeles and Ventura counties revealed that stormwater monitoring data are not similar to the types of data that the environmental engineering field is used to collecting, in particular wastewater data. Indeed, as shown in Figure 4-11, stormwater data are many orders of magnitude more variable than drinking water and wastewater data. The coefficients of variation for municipal and industrial stormwater were almost two orders of magnitude higher than for drinking water and wastewater, with the industrial stormwater data being particularly variable. This variability comes from various sources, including intrinsic variability given the episodic nature of storm events, analytical methods that are more variable when applied to stormwater, and sampling technique problems and error.

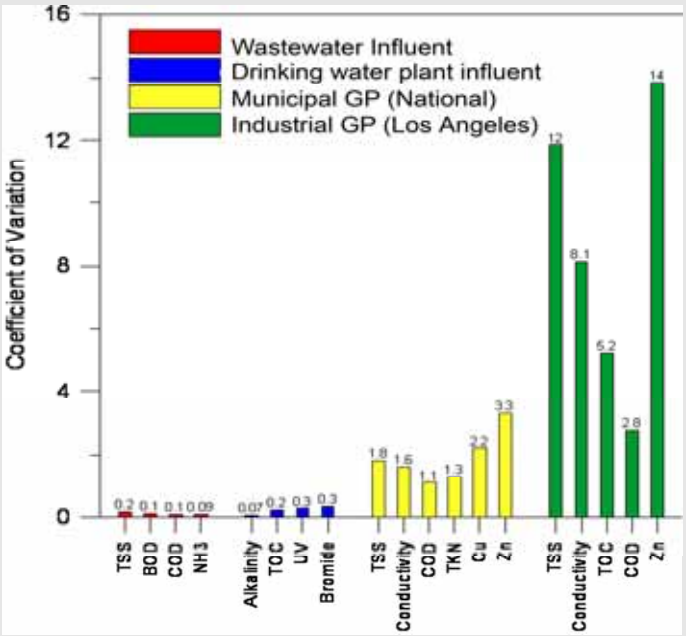

FIGURE 4-11 A comparison of data from four sources: wastewater influent, drinking water plant effluent, municipal stormwater, and industrial stormwater. SOURCE: Reprinted, with permission from Stenstrom (2007). Copyright 2007 by Michael K. Stenstrom.

This enormous variability means that it is extremely difficult to make meaningful statements. For example, it was impossible, using different analyses, to correlate certain chemical pollutants with certain industries. Furthermore, although the data revealed that there are exceedances of benchmark values for certain parameters (Al, Cu, Fe, Pb, and Zn in particular), the data are not of sufficient quantity or quality to identify problem polluters. Finally, there were also large numbers of outliers (that is, samples whose concentrations were well above the 75th percentile range).

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BOX 4-2 Continued

Because of these large coefficients of variation, greater numbers of samples are needed to be able to say there is a significant difference between samples. As shown in Figure 4-12 using COD and a 50 percent difference in means as an example, one would need six data points to tell the difference between two wastewater influents, 80 data points if one had municipal stormwater data, and around 1,000 data points for industrial stormwater. These numbers obviously eclipse what is required under all states' MSGPs.

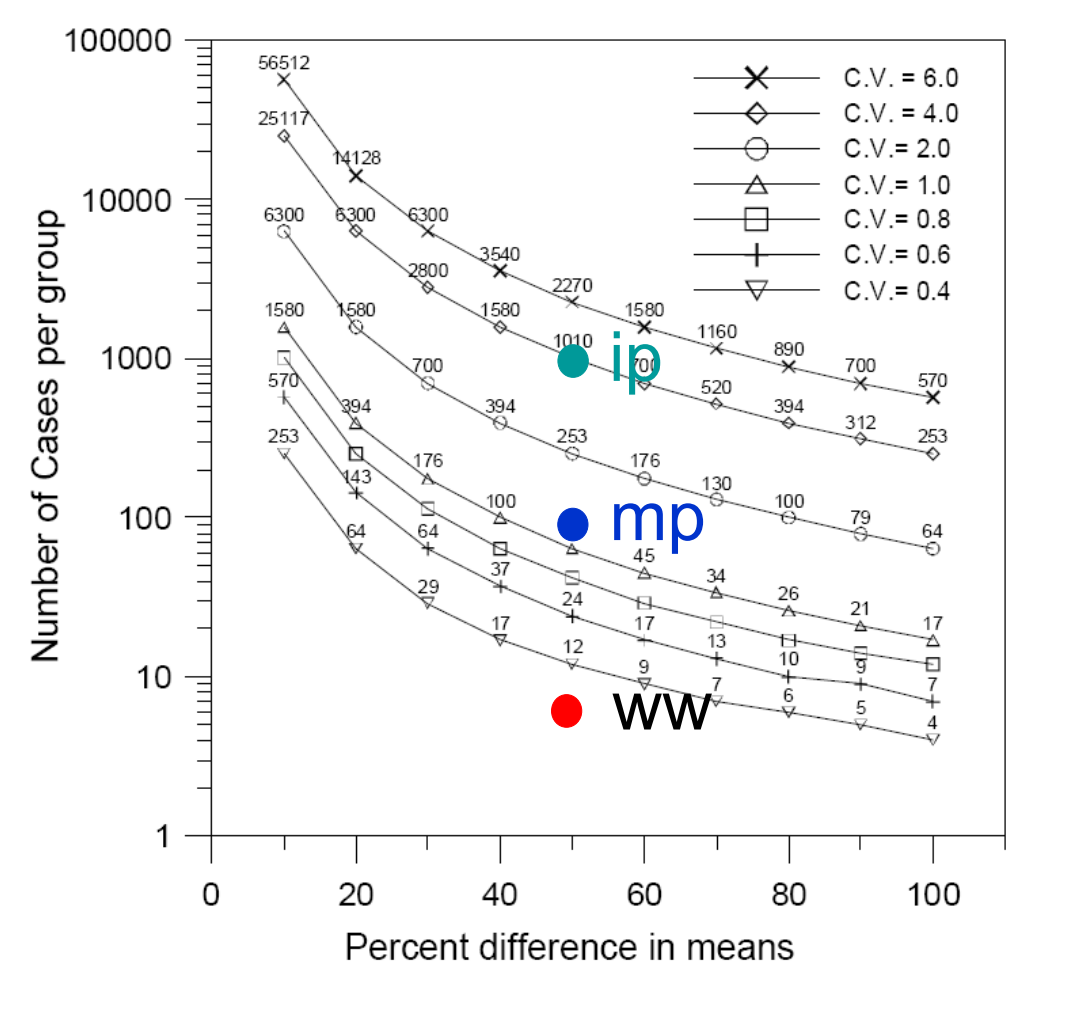

FIGURE 4-12 Number of cases needed to detect a certain percentage difference in the means, using COD as an example. SOURCE: Reprinted, with permission from Stenstrom (2007). Copyright 2007 by Michael K. Stenstrom.

For drinking water treatment, monitoring is done to ensure the quality of the product, while for wastewater, there is a permit that requires the plant to meet a specific quality of water. Unlike these other areas of water resources, there are few incentives that might compel an industry to increase its frequency of stormwater monitoring. As a result, industries are less invested in the process and rarely have the expertise needed to carry out self-monitoring.

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BOX 4-2 Continued

Permitted industries are not required to sample flow. However, Stenstrom and colleagues used Los Angeles rainfall data (see Figure 4-13) as a surrogate for flow and demonstrated that there is a seasonal first-flush phenomenon occurring in early fall. That is, samples taken after a prolonged dry spell will have higher pollutant concentrations. There are always high concentrations of contaminants during the first rainfall because contaminants have had time to accumulate since the previous rainfall. This is important because EPA asks the industrial permittees to collect data from the first rainfall, such that they may end up overestimating the mass emissions for the year. Furthermore, it shows that numeric limits for grab samples would be risky because the measured data are highly affected by the timing of the storm.

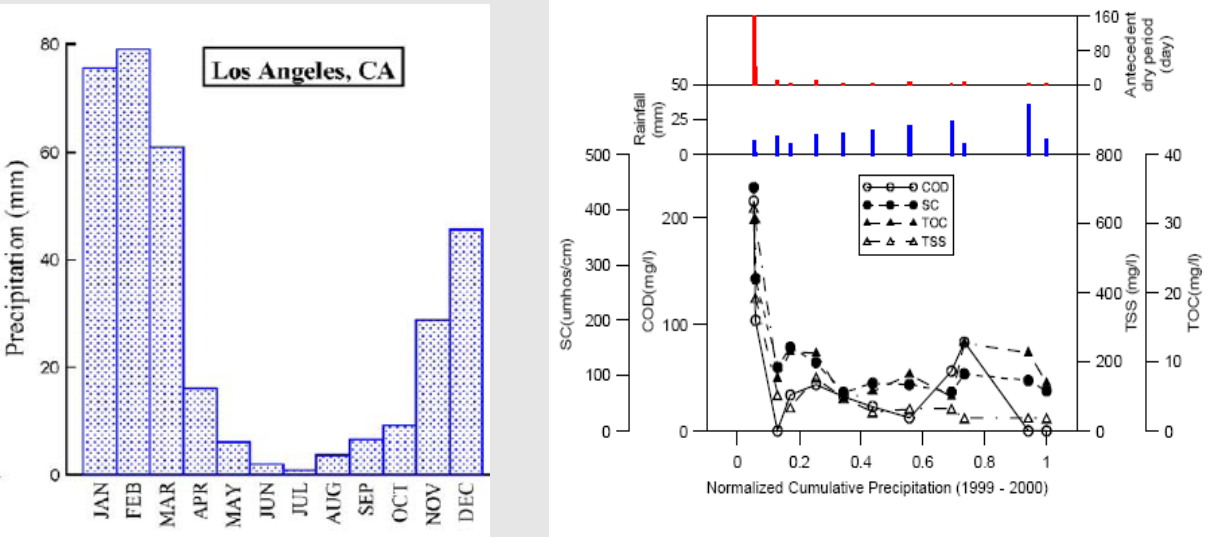

FIGURE 4-13 Annual precipitation in Los Angeles (left) and seasonal first flushes of various contaminants (right). SOURCE: SOURCE: Reprinted, with permission from Stenstrom (2007). Copyright 2007 by Michael K. Stenstrom.

The controversy about numeric limits for industrial stormwater dischargers has existed for more than ten years in California. A recent expert panel concluded that in some cases, numeric limits are appropriate (for construction, but not for municipalities). Stenstrom's recommendations are that industrial monitoring should be either ended or upgraded (for competent industries). If upgraded, it should include more types of monitored parameters, a sampling method with a lower coefficient of variation, real-time monitoring as opposed to grab samples, more quality assurance/quality control, and web-based reporting. A fee-based program with a subset of randomly selected industries may be better than requiring every industry to sample. Stenstrom and Lee (2005) suggest who might do this monitoring if the industry does not have the necessary trained personnel. There is concern that the California water boards are too understaffed to administer such programs and respond to high emitters.

SOURCES: Stenstrom and Lee (2005), Lee et al. (2007), Stenstrom (2007).

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monitoring, and to establish benchmarks for compliance. As shown in Box 4-2, haphazard monitoring throughout an area would require a very large effort, and would still likely result in large errors in the expected data. It is recommended that a regional stormwater authority coordinate regional monitoring as part of the MS4 monitoring requirements, possibly even at the state level covering several Phase I municipalities. A coordinated effort would be most cost-effective with the results compiled for a specific objective. The general steps in this effort would include the following.

(1) Compiling available regional stormwater quality data and comparing the available data to the needs (such as calibration of a regional model; verifying compliance of facilities not requiring monitoring; and establishing regional benchmarks). This may include expanding the NSQD for the region to include all of the collected data, plus examination of data collected as part of other specialized monitoring activities. These objectives will result in different data needs, so it is critical that the uses of the data are identified before sampling plans are established.

(2) Identifying monitoring opportunities as part of other on-going activities that can be expanded to also meet data gaps for these specific objectives. It is important to understand the time frame for the monitoring and ensure that it will meet the needs. As an example, current NPDES stormwater monitoring only requires a few events to be sampled per year at a facility. It may take many years before sufficient data are obtained unless the monitoring effort is accelerated.

(3) Preparing an experimental design that identifies the magnitude of the needed data, considering the allowable errors in the results, and carrying out the sampling program. Different types of data may have varying data quality objectives, depending on their use. It may be possible to truncate some of the monitoring when a sufficient understanding is obtained.

A regionally calibrated and verified model can be used to review development plans and proposed SCMs for new facilities. When suitably integrated with receiving-water modeling tools, a stormwater model can also be used to develop discharge objectives and numeric discharge limits that are expected to meet regulatory requirements. Eventually, it may be possible to couple watershed stormwater models with regional receiving water assessments and beneficial use studies. Haphazard monitoring of a few events each year will be very difficult to correlate with regional receiving water objectives, while a calibrated and verified watershed model, along with receiving water assessments, will result in a much more useful tool and understanding of the local problems.

Regional monitoring can also be targeted to categories of industries that were previously determined to be of low priority. This monitoring activity would randomly target a specific number of these facilities for monitoring to verify the assumption that they are of low priority and are still carrying out the minimum management practices. This activity would also quantify the discharges from these facilities and the performance of the minimum controls. If the discharges are excessive when compared to the initial assumptions, or the management practices being used are not adequate, then corrective actions would be instigated. A single category of specific industries could be selected for any one year, and a team from the regional stormwater management authority could randomly select and monitor a subset of these facilities. An efficient experimental design would need to be developed based on expected conditions, but it is expected that from 10 to 15 such facilities would be monitored for at least a year in a large metropolitan area that has a Phase I stormwater permit, or even state-wide.

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Regional monitoring is also necessary to more accurately establish benchmarks for numeric permits. Geographical location, along with land use, is normally an important factor affecting stormwater quality. Receiving water impacts and desired beneficial uses also vary greatly for different locations. It is therefore obvious that compliance benchmarks also be established that consider these regional differences. This could be a single statewide effort if the state agency has the permit authority and if the state has minimal receiving water and stormwater variations. However, in most cases, significant variations occur throughout the state and separate monitoring activities would be needed for each region. In the simplest case, probability distributions of stormwater discharge quality can be developed for different discharge categories and the benchmarks would be associated with a specific probability value. In some cases, an overall distribution may be appropriate, and only the sites having concentrations greater than the benchmark value would need to have additional treatment. In all cases, a basic level of stormwater management should be expected for all sites, but the benchmark values would identify sites where additional controls are necessary. The random monitoring of sites not requiring extensive monitoring could be used to identify and adjust the basic levels of control needed for all categories of stormwater dischargers.

Identification of Critical Source Areas Associated with Specific Industrial Operations

The objective of this monitoring activity would be to identify and characterize critical source areas for specific industries of concern. If critical source areas can be identified, targeted control or treatment can be much more effective than relying only on outfall monitoring. Many of the treatment strategies for industrial sites involve pollution prevention, ranging from covering material or product storage areas to coating galvanized metal. Other treatment strategies involve the use of highly effective treatment devices targeting a small area, such as filters used to treat zinc in roof runoff or lamella plate separators for pretreatment of storage yard runoff before wet pond treatment. Knowledge of the characteristics of the runoff from the different areas at a facility is needed in order to select and design the appropriate treatment methods.

Box 4-3 is a case study of one such group monitoring effort—for a segment of the telecommunications industry targeting a specific maintenance practice. Instead of having each telecommunication company throughout the country conduct a detailed monitoring program for individual stormwater permits associated with maintenance efforts, many of the companies joined together under an industrial trade group to coordinate the monitoring and to apply for a group permit. This was a significant effort that was conducted over several years and involved the participation of many regional facilities throughout the nation. This coordinated effort spread the cost over these different participants, and also allowed significant amounts of data to be collected, control practices to be evaluated, and the development of screening methods that allow emergency maintenance operations of the telecommunication system to proceed in a timely manner. The experimental design of this monitoring program allowed an efficient examination of factors affecting stormwater discharges from these operations. This enabled the efficient implementation of effective control programs that targeted specific site and operational characteristics. Although the total cost for this monitoring program was high, it was much less costly than if each individual company had conducted their own monitoring. In addition, this group effort resulted in much more useful information for the industry as a whole.

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BOX 4-3
Monitoring to Support a General Stormwater Group Permit Application for the Telecommunications Industry

This monitoring program was conducted to support a group permit application for the telecommunications industry, specifically to cover maintenance operations associated with pumping water out of communications manholes that is then discharged into the storm drainage system. Under federal and state environmental statues, the generator (owner or operator) is responsible for determining if the discharged water needs treatment. The work performed under this project covered characterization, prevention, and treatment methods of water found in manholes.

The objective of this project was to develop a test method to quickly evaluate water in manholes and then to recommend on-site treatment and preventative methods. To meet the telecommunication industry needs, the evaluating tests of water found in manholes need to be simple, quick, inexpensive, field applicable, and accurate indicators of contaminated conditions. The on-site treatment methods must be cost-effective and quickly reduce the concentrations of the contaminant of concern to acceptable levels before the water from manholes is discharged, to result in a safe environment for workers.

A sampling effort was conducted by Pitt et al. (1998) to characterize the quality of the water and sediment found in manholes. More than 700 water samples and 300 sediment samples were analyzed over a three-year period, representing major land-use, age, season, and geographical factors from throughout the United States. The samples were analyzed for a wide range of common and toxic constituents. The statistical procedures identified specific relationships between these main factor categories and other manhole characteristics. Part of the project was to evaluate many field analytical methods. Finally, research was also conducted to examine possible water treatment methods for water being pumped from telecommunication manholes.

Summary of Sampling Effort and Strategy

The objective of the monitoring program was to characterize telecommunication manhole water and sediment. Important variables affecting the quality of these materials were also determined. A stratified random sampling design was followed, with the data organized in a full 2^4 factorial design, with repeated sampling of the same manholes for each season. The goal for the minimum number of samples per strata was ten. This sampling effort enabled the determination of errors associated with the results, which was expected to be less than 25 percent. In addition, this level of effort enabled comparison tests to be made outside of the factorial design. Table 4-4 lists the constituents that were evaluated for each of the sample types.

The immense amount of data collected during this project and the adherence to the original experimental design enabled a comprehensive statistical evaluation of the data. Several steps in data analysis were performed, including:

- exploratory data analyses (mainly probability plots and grouped box plots),
- simple correlation analyses (mainly Pearson correlation matrices and associated scatter plots),
- complex correlation analyses (mainly cluster and principal component analyses, plus Kurskal-Wallis comparison tests), and
- model building (based on complete 2^4 factorial analyses of the most important factors).

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BOX 4-3 Continued

The toxicity screening tests (using the Azur Microtox® method) conducted on both unfiltered and filtered water samples from telecommunication manholes indicated a wide range of toxicity, with no obvious trends for season, land use, or age. About 60 percent of the samples were not considered toxic (less than an I25 light reduction of 20 percent, the light reduction associated with phosphorescent bacteria after a 25-minute exposure to undiluted samples), about 20 percent were considered moderately toxic, while about 10 percent were considered toxic (light reductions of greater than 40 percent), and 10 percent were considered highly toxic (light reductions of greater than 60 percent). Surprisingly, samples from residential areas generally had greater toxicities than samples from commercial and industrial areas. Samples from newer areas were also more toxic than those from older areas. Further statistical tests of the data indicated that the high toxicity levels were likely associated with periodic high concentrations of salt (in areas using de-icing salt), heavy metals (especially filterable zinc, with high values found in most areas), and pesticides (associated with newer residential areas).

TABLE 4-4 Constituents Examined in Water and Sediment from Telecommunication Manholes

Constituent	Unfiltered Water	Filtered Water	Sediment
Solids, volatile solids, COD, Cu, Pb, and Zn	X	X	X
Turbidity, color, and toxicity (Microtox screening method)	X	X	
pH, conductivity, hardness, phosphate, nitrate, ammonia, boron, fluoride, potassium, and detergents	X		
Odor, color, and texture			X
E. coli, enterococci, particle size, and chromium	Selected		
Metal scan (ICP)			Selected
PAHs, phenols (GC/MSD), and pesticides	X	Selected	Selected

SOURCE: Pitt et al., (1998).

Concentrations of copper, lead, and zinc were evaluated in almost all of the water samples, and some filtered samples were also analyzed for chromium. From 470 to 548 samples (75 to 100 percent of all unfiltered samples analyzed) had detectable concentrations of these metals. Filterable lead concentrations in the water were as high as 160 μg/L, while total lead concentrations were as high as 810 μg/L. Zinc values in filtered and unfiltered samples were as high as about 3,500 μg/L. Some of the copper concentrations were also high in both filtered and unfiltered samples (as high as 1,400 μg/L). Chromium concentrations as high as 45 μg/L were also detected.

About 300 sediment samples were analyzed and reviewed for heavy metals. An ICP/MS was used to obtain a broad range of metals with good detection limits. The following list shows the median observed concentrations for some of the constituents found in the sediments (expressed as milligrams of the constituent per kilogram of dry sediment):

Aluminum	14,000 mg/kg
COD	85,000 mg/kg
Chromium	<10 mg/kg
Copper	100 mg/kg
Lead	200 mg/kg
Strontium	35 mg/kg
Zinc	1,330 mg/kg

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BOX 4-3 Continued

Geographical area had the largest effect on the data observations, while land use, season, and age influenced many fewer parameters. The most obvious relationship was found for high dissolved solids and conductivity associated with winter samples from snowmelt areas. The high winter concentrations slowly decreased with time, with the lowest concentrations noted in the fall. Another important observation was the common association between zinc and toxicity. Residential-area samples generally had larger zinc concentrations than the samples from commercial and industrial areas. Samples from the newest areas also had higher zinc concentrations compared to samples from older areas. No overall patterns were observed for zinc concentrations in sediment samples obtained from manholes. Other constituents (especially nutrients and pesticides) were also found to have higher concentrations in water collected from manholes in newer residential areas. Very few organic toxicants were found in the water samples, but sediment sample organic toxicant concentrations appeared to be well correlated to sediment texture and color. About 10 to 25 percent of the sediment samples had relatively large concentrations of organics. Bacteria analyses indicated some relatively high bacteria counts in a small percentage of the samples. Bacteria were found in lower amounts during sampling periods that were extremely hot or extremely cold. Pacific Northwest samples also had the lowest bacteria counts.

The data were used to develop and test predictive equations based on site conditions. These models were shown to be valid for most of the data, but the highest concentrations were not well predicted. Therefore, special comparisons of many site conditions were made for the manholes having water with the highest concentrations of critical constituents for comparison to the other locations. It was interesting to note that about half of the problem manholes were repeated samples from the same sites (after complete pumping), but at different seasons, indicating continuous problems and not discrete incidents. In addition, the problem manholes were found for all areas of the country and for most rain conditions. Water clarity and color, along with sediment texture, were found to be significant factors associated with the high concentrations of other constituents, while land use was also noted as a significant factor. These factors can be used to help identify problem manholes, but the rates of false positives and false negatives were found to be high. Therefore, these screening criteria can be used to identify more likely problematic manholes, but other methods (such as confirmation chemical analyses) are also needed to identify those that could not be identified using these simpler methods.

The field analytical test methods worked reasonably well, but had much higher detection limits than advertised, limiting their usefulness. Due to the complexity and time needs for many of these on-site analyses, it is usually more effective to analyze samples at a central facility. For scheduled maintenance operations, a crew could arrive at the site before the maintenance time to collect samples and have them analyzed before the maintenance crew arrives. For emergency repairs, it is possible to pump the collected water into a tank truck for later analyses, treatment, and disposal.

The treatment scenario developed and tested is relatively rapid and cheap and can be used for all operations, irrespective of screening analyses. Chemical addition (using ferric chloride) to the standing water in the manhole was found to reduce problematic levels of almost all constituents to low levels. Slow pumping from the water surface over about a 15- to 30-minute period, with the discharged water then treated in 20-μm cartridge filters, allows the manhole to be entered and the repairs made relatively rapidly, with the water safely discharged. The remaining several inches of water in the bottom of the manhole, along with the sediment, can be removed at a later time for proper disposal.

SOURCE: Pitt et al. (1998).

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Outfall Monitoring at a Single Industrial Facility for Permit Compliance and to Demonstrate Effectiveness of Control Practices

Sampling at an individual facility results in outfall data that can be compared to pre-control conditions and numeric standards. There are many guidance documents and reports available describing how to monitor stormwater at an outfall. Two comprehensive sources that describe stormwater monitoring procedures include the handbook written by Burton and Pitt (2002) and a recent guidance report prepared by Shaver et al. (2007). There are a number of basic components that need to be included for an outfall characterization monitoring effort, many which have been described in this report. These include the following:

- rainfall monitoring in the drainage area (rate and depth, at least at two locations).
- flow monitoring at the outfall (calibrated with known flow or using dye dilution methods).
- flow-weighted composite sampler, with sampler modified to accommodate a wide range of rain events.
- recommended use of water quality sonde to obtain high-resolution and continuous measurements of such parameters as turbidity, conductivity, pH, oxidation reduction potential, dissolved oxygen (DO), and temperature.
- preparation of adequate experimental design that quantifies the needed sampling effort to meet the data quality objectives (adequate numbers of samples in all rain categories and seasons).
- selection of constituents that meet monitoring objectives. In addition, the analytical methods must be appropriately selected to minimize "nondetected" values.
- monitoring station maintenance must also be conducted appropriately to ensure reliable sample collection. Sampling plan must also consider sample retrieval, sample preparation and processing, and delivery to the analytical laboratory to meet quality control requirements.

Burton and Pitt (2002) describe these monitoring components in detail, along with many other monitoring elements of potential interest (e.g., receiving water biological, physical, and chemical monitoring, including sediment and habitat studies), and include many case studies addressing these components, along with basic statistical analyses and interpretation of the collected data. Box 4-4 provides a detailed example of industrial stormwater monitoring at individual sites in Wisconsin.

In general, monitoring of industries should be tailored to their stormwater pollution potential, considering receiving water uses and problems. There are a number of site survey methods that have been developed to rank industry by risk that mostly rely on visual inspections and information readily available from regional agencies. The Center for Watershed Protection developed a hot-spot investigation procedure that is included in the Urban Subwatershed Restoration Manual No. 11 (Wright et al., 2005). This site survey reconnaissance method ranks each site according to its likely stormwater pollutant discharge potential. A detailed field sheet is used when surveying each site to assist with the visual inspections. Cross and Duke (2008) developed a methodology, described in greater detail in Chapter 6, to visually assess industrial facilities based on the level of activities exposed to stormwater. They devised four categories—Category A, no activities exposed to stormwater; Category B, low intensity; Category C, medium intensity; and Category D, high intensity—and tested this scheme by examining many southern Florida industrial facilities. About 25 percent of the facilities surveyed that were officially included in the stormwater permit program had no stormwater exposure (Category A), but very

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few had submitted the necessary application to qualify for an exception under the "no exposure" rule. Slightly more than half of the of the surveyed facilities were included in the "no exposure" and "low exposure" categories, obviously deserving less attention compared to the higher impact categories.

BOX 4-4
Wisconsin's Monitoring of Industrial Stormwater

The State of Wisconsin also uses a site assessment method to rank industrial operations into three tiers, mostly based on their standard industrial codes. This system groups facilities by industry and how likely they are to contaminate stormwater. The general permits differ in monitoring requirements, inspection frequency, plan development requirements, and the annual permit fee. The Tier 1 general permit covers the facilities that are considered "heavy" industries, such as paper manufacturing, chemical manufacturing, petroleum refining, ship building/repair, and bulk storage of coal, minerals, and ores. The monitoring required of these facilities is presented in this box. The Tier 2 general permit covers facilities that are considered "light" industries and includes such sites as furniture manufacturing, printing, warehousing, and textiles. Facilities with no discharge of contaminated stormwater are in the Tier 3 category and include sites that have no outdoor storage of materials or waste products.

In accordance with the Wisconsin MSGP, Tier 1 industries are required to perform an annual chemical stormwater sampling at each outfall for those residual pollutants listed in the industry's stormwater pollution prevention plan. The one runoff event selected for sampling must occur between March and November and the rainfall depth must be at least 0.1 inch. At least 72 hours must separate the sampled event and the previous rainfall of 0.1 inch. The concentration of the pollutant must represent a composite of at least three grab samples collected in the first 30 minutes of the runoff event. There is concern about the value of collecting so few samples from just one storm each year.

To evaluate how well this sampling protocol characterizes pollutant concentrations in industrial runoff, the Wisconsin Department of Natural Resources partnered with the USGS to collect stormwater samples from three Tier 2 industrial sites (Roa-Espinosa and Bannerman, 1994). Seven runoff events were monitored at each site, and the samples were collected using five different sampling methods, including (1) flow-weighted composites, (2) time-based discrete samples, (3) time-based composites, (4) a composite of discrete samples from first 30 minutes, and (5) time-based composite sheet flow samples. The first three methods have been described previously. For the composite of discrete samples from the first 30 minutes, the sampler is programmed to take an aliquot after a set period of time (usually every 5 minutes) and the aliquots are combined into one container. The sampler stops collecting samples after 30 minutes. For many sites the samples are collected manually, so there is a high probability the sample does not represent the first 30 minutes of the event. For the time-based composite sheet flow samples, a sheet flow sampler is programmed to take an aliquot of sheet flow after a set period of time (usually about every 5 to 15 minutes). All the aliquots are deposited in one bottle beneath the surface of the ground. All of the parts of the hydrograph receive equal weight in the final concentration, but the larger number of aliquots makes for a reasonably accurate composite concentration. This method is unique in that it can be placed near the source of concern. Automatic samplers were used for the first four methods, while sheet flow samplers designed by the USGS were used for the fifth method (Bannerman et al., 1993). Samples were collected during the entire event. All the automatic samplers had to be installed at a location with concentrated flow, such as an outfall pipe, while the sheet flow samplers could be installed in the pavement near a potential source, such as a material storage area.

The time-based discrete, time-based composite, first-30-minute composite, and sheet flow samples were analyzed for COD, total recoverable copper, total recoverable lead, total recoverable zinc, TSS, total solids, and hardness. In addition to these constituents, the flow-weighted composite samples were analyzed for antimony, arsenic, beryllium, chromium, ammonia-N, nitrate plus nitrite, TKN, and TP. All the analysis was done at the State Laboratory of Hygiene in Madison, Wisconsin, and the data are stored in the USGS's QWDATA database.

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BOX 4-4 Continued

The number of samples collected during a runoff event varied greatly among the five types of sampling. By design, the median number of samples collected for the first 30 minutes was three. Limits on the funds available for laboratory cost limited the time-based discrete sampling to about six per storm. Since they are not restricted by laboratory cost, the composites can be based on more sub-samples during a storm. Thus, the median numbers of sub-samples collected for the flow-weighted composite and time-based composite were 13 and 24, respectively. The time-based composite sheet flow sample could not document the number of samples it collected, but it was set to collect a sample every few minutes.

To judge the accuracy of the sampling methods, one method had to be selected as the most representative of the concentration and load affecting the receiving water. Because a relatively large number of samples are collected and the timing of the sampling is weighted by volume, the flow-weighted composite concentrations were used as the best representation of the quality of the industrial runoff. Concentrations in water samples collected by the time-based composite method compared very well to those collected by the flow-weighted composite method, especially if the time-based composite resulted in 20 sub-samples or more. This was not true for the discrete sampling method, because many fewer sub-samples were used to represent changes across the hydrograph. The time-based composite sheet flow sampler produced concentrations slightly higher than the time-based composite samplers collecting water in the concentrated flow. Concentrations from the sheet flow sampler are probably not diluted by other source areas such as the roof.

Concentrations of total recoverable zinc and TSS collected in the first 30 minutes of the event were usually two to three times higher than the flow-weighted composite samples. For many of the events, the highest concentration of these constituents occurred in the first 10 minutes of the event. Although the concentrations might be higher in the first part of the event, the earlier parts of the event might only represent one third or less of the total runoff volume. Thus, using the concentrations from the first 30 minutes of the event could greatly overestimate the constituent load from the site.

Along with accuracy, the selection of an appropriate sampling method must consider cost and the criteria for installing the sampling equipment. To measure flow, the site must have a location where the flow is concentrated, such as a pipe or well-defined channel, and the runoff is just coming from the site. Out of 474 sites evaluated for this project, only 14 met the criteria for an accurate flow measurement. A few more sites might be suitable for using an automatic sampler without flow measurements, but the number of sites would still be limited. Sheet flow samplers can be used on most sites, since they are simply installed in the pavement near the source of concern.

For each sampling method, approximate costs were determined including equipment, installation of equipment, and the analysis of one sample (Table 4-5). Collecting the samples and processing the data should also be included, but they were not because this cost is highly variable. Flow-weighted composite and time-based discrete sampling had the highest cost. Flow measurements made the composite sampling more expensive, while the laboratory cost of analyzing six discrete samples increased the cost of the time-based discrete method. It should be noted that hand grab samples could be used to collect the discrete samples in the first 30 minutes at lower cost, although this depends strongly on the skill of the person collecting the sample. The sheet flow sampler could be the most cost effective approach to sampling an industrial site.

TABLE 4-5 Cost of Using Different Sampling Methods in 1993 Dollars

Method	*Estimated Cost for equipment, installation, and analysis of one sample*
Flow-weighted composite	$16,052
Time-based discrete	$22,682
Time-based composite	$5,920
First-30-minutes (automatic sampler)	$6,000
First-30-minutes (grab sample)	$1,800[1]
Time-based composite sheet flow sampler	$2,889

[1]Cost of laboratory analysis only. SOURCE: Reprinted, with permission, Roa-Espinosa and Bannerman (1994). Copyright 1994 by the American Society of Civil Engineers.

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BOX 4-4 Continued

A determination must be made of how many runoff events should be sampled in order to accurately characterize a site's water quality. As shown in Table 4-6, representing a site with the results from one storm can be very misleading. Concentrations in Table 4-6 were collected by the flow-weighted composite method. The geometric means of EMCs from five or more events were very different than the lowest or highest concentration observed for the set of storms. The chances of observing an extreme value by sampling just one event is increased by selecting a sampling method designed to collect a limited number of sub-samples, such as the first-30-minutes method. Too few storms were monitored in this project to properly evaluate the variability in the EMCs, but sufficient changes occur between the zinc and TSS geometric means in Table 4-6 to suggest that a compliance monitoring schedule should include a minimum of five events be sampled each year.

To overcome the high COV observed for municipal stormwater data collected in Wisconsin, EMCs should be determined for about 40 events (Selbig and Bannerman, 2007; Horwatich et al., 2008). The 40 event mean concentrations would probably represent the long-range distribution of rainfall depths, and there would be sufficient data available to perform some trend analysis, such as evaluating the benefits of an SCM implemented at an industrial site. Monitoring 40 events each year, however, would be too costly for an annual compliance monitoring schedule for each industrial site.

TABLE 4-6 Effects of Including a Different Number of Events in the Geometric Mean Calculation for Zinc and TSS[a]

Number of Events	Total Recoverable Zinc	Total Suspended Solids
	AC Rochester	
1 (Lowest Concentration)	57	8
1 (Highest Concentration)	150	84
3	76	24
5	91	36
	PPG Industries	
1 (Lowest Concentration)	140	32
1 (Highest Concentration)	330	49
3	153	57
6	186	53
	Warman International	
1 (Lowest Concentration)	68	17
1 (Highest Concentration)	140	56
3	67	15
5	81	26
7	74	19

[a]Samples were collected using the flow-weighted composite method. SOURCE: Reprinted, with permission, Roa-Espinosa and Bannerman (1994). Copyright 1994 by the American Society of Civil Engineers.

Results from this project indicate that the stormwater monitoring required at industrial sites cannot adequately characterize the quality of runoff from an industrial site. Only collecting samples from the first 30 minutes of a storm is probably an overestimate of the concentration, and a load calculated from this concentration would exaggerate the impact of the site on the receiving waters. Time- and flow-based composite sampling would be much better methods for monitoring a site if there are locations to operate an automatic sampler. For sites without such a location, the time-based composite sheet flow sampler offers the best results at the least cost. Given all the variability in concentrations between runoff events, the annual monitoring schedule for any site should include sampling multiple storms.

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Recommendations for Industrial Stormwater Monitoring

Suitable industrial monitoring programs can be implemented for different categories of industrial activities. The following is one such suggestion, based on the likely risks associated with stormwater discharges from each type of facility.

No Exposure to Industrial Activities and Other Low-Risk Industrial Operations

For sites having limited stormwater exposure to industrial operations, such as no outdoor storage of materials or waste products, basic monitoring would not normally be conducted. However, roof runoff (especially if galvanized metals are used) and large parking areas need to be addressed under basic stormwater regulations dealing with these common sources of contaminants and the large amounts of runoff that may be produced. Simple SCM guidance manuals can be used to select and size any needed controls for these sites, based on the areas of concern at the facility. For these facilities, simple visual inspections with no monitoring requirements may be appropriate to ensure compliance with the basic stormwater regulations. A regionally calibrated stormwater quality model can be used to evaluate these basic stormwater conditions and to calculate the expected benefits of control measures. Periodic random monitoring of sites in this category should be conducted to verify the small magnitude of discharges from these sites and the performance of SCMs.

Medium-Risk Industrial Operations

For "medium-intensity" industry facilities, site inspections and modeling should be supplemented with suitable outfall monitoring to ensure compliance. As noted in Box 4-2, there can be a tremendous amount of variability in industrial runoff characteristics. However, the dataset described in that example was a compilation of data from many different types of facilities, with no separation by industrial type. Even different facilities in a single industrial group may have highly variable runoff characteristics. However, a single facility has much less variability, and reasonable monitoring strategies can be developed for compliance purposes. As noted in Box 4-4, about 40 samples were expected to be needed for each site in that example. With typical permit periods of five years, this would require that less than ten samples per year (more than the three samples per year currently obtained at many locations) be collected in order to determine the EMC for the site for comparison to allowable discharge conditions. Obviously, the actual number of samples needed is dependent on the variability of the runoff characteristics and the allowable error, as described elsewhere. After about 10 to 15 storms have been monitored for a site, it would be possible to better estimate the total number of samples actually needed based on the data quality objectives. If the monitoring during the permit period indicated excessive stormwater discharges, then the SCMs are obviously not adequate and would need improvement. The permit for the next five-year period could then be modified to reflect the need for more stringent controls, and suitable fines accessed if the facility was not in compliance. It is recommended that absolute compliance not be expected in the industrial permits, but that appropriate benchmarks be established that allow a small fraction of the monitored events to

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exceed the goals. This is similar to discharge permit requirements for combined sewers, and for air quality regulations, where a certain number of excessive periods are allowed per year.

High-Risk Industrial Facilities

For "high-risk" industrial sites of the most critical nature, especially if noncompliance may cause significant human and environmental health problems, visual inspections and site modeling should be used in conjunction with monitoring of each event during the permit period. Because of the potential danger associated with noncompliance, the most stringent and robust controls would be required, and frequent monitoring would be needed to ensure compliance. If noncompliance was noted, immediate action would be needed to improve the discharge conditions. This is similar to industrial and municipal NPDES monitoring requirements for point sources.

MODELING TO LINKING SOURCES OF POLLUTION TO EFFECTS IN RECEIVING WATERS

Stormwater permitting is designed to regulate dischargers, develop information, and reduce the level of stormwater pollutants and impact on receiving waterbodies. An important assumption is that the level of understanding of the stormwater system, through a combination of monitoring and modeling, is sufficient to associate stormwater discharges with receiving waterbody impacts. Impairment of waterbodies can occur for a variety of physical, chemical, and biological reasons, often with a complex combination of causes. The ambient water quality of a receiving waterbody, which may result in a determination of impairment, is itself a function of the total mass loading of pollutant; dilution with stream discharge or standing waterbody volume; the capacity of the aquatic ecosystem to assimilate, transform, or disperse the pollutant; and transport out of the waterbody. In addition to the chemical and physical attributes of the water, impairment may also be characterized by degraded biologic structure or geomorphic form of the waterbody (e.g., channel incision in urban areas). Interactions between multiple pollutant loadings, long turnover and residence times, saturation effects, and cascading feedbacks with biological communities complicate the apparent response of waterbodies to pollutant discharge. This is particularly important when considering cumulative watershed effects, in which interactions between stressors and long-term alteration of watershed conditions may contribute to threshold responses of a waterbody to continued loading or alteration. Under these conditions, simple "loading-response" relations are often elusive and require consideration of historical and local watershed conditions.

As an example, pollutant loading at high stream flow or into strong tidally flushed systems may be advected downstream or into the coastal ocean without building up significant concentrations, while pollutant loading at low flow may not be effectively transported and dispersed and may build up to harmful concentrations. In the former case the pollutant may be rapidly transported out of the local waterbody, but may impact a more distant, downstream system. In addition, certain pollutants, such as inorganic nitrogen, may be discharged into surface waters and subsequently transformed and removed from the water column into vegetation or outgassed (e.g., volatilized or denitrified) into the atmosphere under certain

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ecosystem conditions. Sediment and other pollutants may be stored for long time periods in alluvial or lacustrine deposits, and then remobilized long after the initial loading into a stream reach or standing waterbody in response to extreme climate events, land-use change, reservoir management, or even reductions in the pollutant concentrations in the water column. Consequently, long lags may exist between the actual discharge of the sediment (and any pollutants adsorbed or otherwise stored within the deposits) and their contribution to waterbody impairment. Therefore, understanding the fate of pollutants, particularly nonconservative forms, may require consideration of the full ecosystem cycling and transport of the material over long time periods.

Impairment of waterbodies can be assessed on the basis of biological indicators, as discussed in Chapter 2. As organisms and communities respond to multiple stressors, it is not always clear what the direct or indirect effects of any specific pollutant discharge is, or how that may be exacerbated by correlated or interacting activity in the watershed. The association of specific types of impairment with surrounding land use implicitly accounts for these interactions but does not provide a mechanistic understanding of the linkage sufficient to specify effective remedial activity. However, much progress has been made in determining toxic effects of certain contaminants on different aquatic species assemblages (see, e.g., Shaver et al., 2007) and on quantifying impacts of land use on flow duration curves, EMCs, and loading rates for a number of pollutants (Maestre and Pitt, 2005). For the latter effort, it has been shown that there is large variability within land-use categories, both as a function of specific SCMs and of innate differences due to historical legacies, climate, and hydrogeology.

A protocol linking pollutants in stormwater discharges to ambient water quality criteria should be based on conservation of mass, in which the major inputs, outputs, transformations, and stores of the pollutant can be quantified. Indeed, these are the components of hydrologic and watershed models used to simulate the fate and transport of stormwater and its pollutants. SCMs that improve ambient water quality criteria are designed to act on one or more of these mass balance terms. A number of these measures act to reduce the magnitude of a stormwater source (e.g., porous pavement), while others are designed to absorb or dissipate a pollutant within a hydrologic flowpath downstream from a source (e.g., rain garden, detention pond, stream restoration). The latter requires some consideration of the flowpath from the source to the receiving waterbody. Therefore, determining the major sources, sinks, and transformations of the pollutant should be the first step in this procedure. For a number of pollutants there may be very few potential sources, while for others there may be multiple significant sources. The spatial diversity of these sources and sinks may also range from uniform distribution to “hot spot” patterns that are difficult to detect and quantify. Many stormwater models work effectively with sources, but are not structured to follow the transport or transformation of pollutants from source to waterbody along hydrologic flowpaths.

Figure 4-14 shows the drainage area of Jordan Lake, an important regional drinking water source in the Triangle area of North Carolina. Catchment areas are shaded to relate the percentage of industrial and commercial land cover, according to the National Land Cover Database (NLCD). Figure 4-15 shows a small tributary within the Jordan Lake watershed in Chapel Hill (outlined in Figure 4-14) with a high-resolution image of all impervious surfaces overlain on the topographically defined surface flowpath network. Each of the distributed sources of stormwater is routed through a flowpath consisting of other pervious and impervious segments, within which additions, abstractions, and transformations of water and pollutants occur depending on weather, hydrologic, and ecosystem conditions. The cumulative delivery

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and impact of all stormwater sources include the transformations occurring along the flowpaths, which could include specific SCMs such as detention or infiltration facilities or simply infiltration or transformations in riparian areas or low-order streams. The riparian area may be bypassed depending on stormwater concentration or piping, and it may have various levels of effectiveness on reducing pollutants depending on geomorphic, ecosystem, and hydrologic conditions. The ability of a stormwater model to capture these types of effects is a key property influencing its ability to associate a stormwater source with a waterbody outcome.

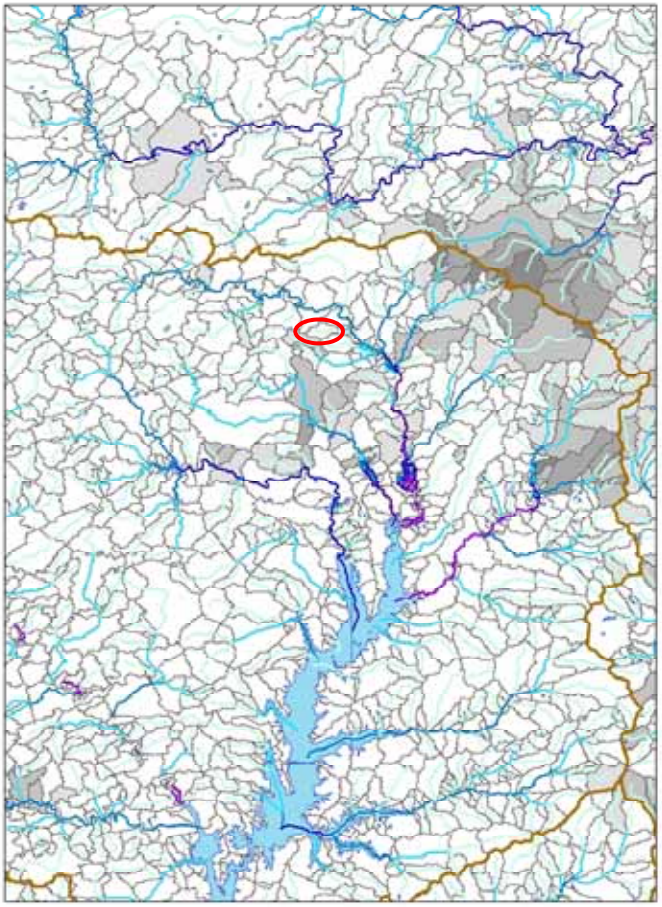

FIGURE 4-14 The drainage area to Jordan Lake, a major drinking water reservoir in the Triangle area of North Carolina, is under nutrient-sensitive rules, requiring reductions in total nitrogen and phosphorus. Drainage flowlines and catchment areas are from NHDplus, and are shaded according to their percentage of industrial and commercial land cover from the NLCD. The area outlined in red is a small urban catchment, detailed in Figure 4-15, and comprised of a wooded central region, surrounded by residential and institutional land use.

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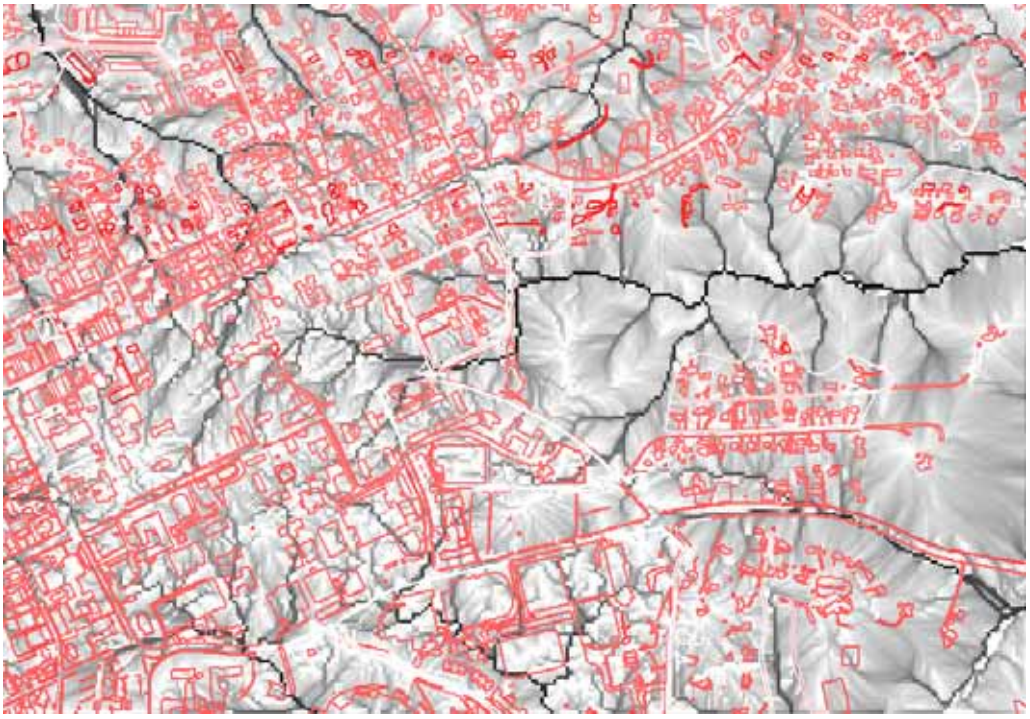

FIGURE 4-15 A small urban catchment in the Lake Jordan watershed of North Carolina with distributed sources of impervious surface (buildings and roads) stormwater arranged within the full surface drainage flowpath system. Stormwater from each source is routed down surface and subsurface flowpaths to the nearest tributary and out the drainage network, with additions and abstractions of water and pollutants along each flowpath segment.

This section discusses the fundamentals of stormwater modeling and the capabilities of commonly used models. Much of this information is captured in a summary table at the end of the section (Table 4-7). The models included are the following:

- The Rational Method, or $Q = C*I*A$, where Q is the peak discharge for small urban catchments, A is the catchment area, I is the rainfall intensity, and C is a rainfall-runoff coefficient.
- The Simple Method, which classifies stormwater generation and impact regimes by the percent impervious cover
- TR-20 and TR-55
- The Generalized Watershed Loading Function (GWLF)
- Program for Predicting Polluting Particle Passage through Pits, Puddles, and Ponds (P8)
- Model for Urban Stormwater Improvement Conceptualization (MUSIC)
- Stormwater Management Model (SWMM)
- Source Loading and Management Model (WinSLAMM)
- Soil and Water Assessment Tool (SWAT)
- Hydrologic Simulation Program–Fortran (HSPF)
- Western Washington Hydrologic Model
- Chesapeake Bay Watershed Model (CBWM)

Detailed descriptions of some of these models and their unique applications are given in Appendix D.

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Fundamentals of Stormwater Models

Stormwater models are designed to evaluate the impacts of a stormwater discharge on a receiving waterbody. In order to do this, the model must have the capability of describing the nature of the source term (volumes, constituents), transport and transformation to the receiving waterbody, and physical, chemical, and biological interaction with the receiving water body and ecosystem. No model can mechanistically reproduce all of these interactions because of current limitations in available data, incomplete understanding of all processes, and large uncertainties in model and data components. Computer resources, while rapidly advancing, still limit the complexity of certain applications, especially as spatial data become increasingly available and it is tempting to model at ever-increasing resolution and comprehensiveness. Therefore, models must make a set of simplifying assumptions, emphasizing more reliable and available data, while attempting to retain critical processes, feedbacks, and interactions. Models are typically developed for a variety of applications, ranging from hydraulic design for small urban catchments to urban and rural pollutant loading at a range of watershed scales.

An evaluation of the current state of stormwater modeling should say much about our ability to link pollutant sources with effects in receiving waters. Both stormwater models and models supporting the evaluation of SCM design and effectiveness are based on simulating a mass budget of water and specific pollutants. The detail of mass flux, transformation, and storage terms vary depending on the scale and purpose of the application, level of knowledge regarding the primary processes, and available data. In many cases, mechanisms of transformation may be either poorly understood or may be dependent on detailed interactions. As an example, nitrogen-cycle transformations are sensitive to very short temporal and spatial conditions, termed “hot spots” and “hot moments” relative to hydrologic flowpaths and moisture conditions (McClain et al., 2003).

Stormwater runoff production and routing are common components of these models. All models include an approach to estimate the production of stormwater runoff from one or more zones in the watershed, although runoff routing from the location(s) of runoff production to a point or waterbody is not always included explicitly. Major divisions between approaches are found in the representation of the watershed “geography” in terms of patterns and heterogeneity, and in runoff production and routing. Some stormwater models do not consider the effects of routing from a runoff source to a local waterbody directly, but may attempt to reproduce net impacts at larger scales through the use of unit hydrograph theory to estimate peak flows, and delivery ratios or stormwater control efficiency factors to estimate export to a waterbody.

There are a number of different approaches and paradigms used in stormwater models that include varying degrees of watershed physical, biological, and chemical process detail, as well as spatial and temporal resolution and the representation of uncertainty in model estimates. A number of researchers have written about the nature of watershed models (e.g., Beven, 2001; Pitt and Vorhees, 2002). At present, many hydrologic and stormwater models have become so complex, with multiple choices for different components, that standard descriptions apply only to specific components of the models. The following discussion is generalized; most models fit the descriptions only to certain degrees or only under specific conditions in which they are operated.

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Lumped Versus Distributed Approaches

Central to the design of watershed models is the concept of a "control volume," which is a unit within which material and energy contents and balances are defined, with boundaries across which material and energy transport occurs. Control volumes can range from multiple subsurface layers and vegetation canopy layers bounded in three dimensions to a full watershed. Lumped models ignore or average spatial heterogeneity and patterns of watershed conditions, representing all control volumes, and the stores, sources, and sinks of water and pollutants in a vertically linked set of conceptual components, such as surface interception, unsaturated and saturated subsurface zones, and a single stream or river reach. For example, SWAT or HSPF are conceptually lumped at the scale of subwatersheds (e.g., the level of geography in Figure 4-14) and do not show any spatial patterns at higher resolutions (e.g., Figure 4-15) than these units. While multiple land-use/soil combinations may be represented, these models do not represent the connectivity of the land segments (e.g., which land segments drain into which land segments) and assume all unique land segment types drain directly to a stream.

Distributed models include some scheme to represent spatial heterogeneity of the watershed environment pertinent to stormwater generation, including land cover, soils, topography, meteorological inputs, and stream reach properties distributed through a set of linked control volumes. Control volumes representing land elements, including vertically linked surface and subsurface stores, are connected by a representation of water and pollutant lateral routing through a network of flowpaths that may be predefined or set by the dynamics of surface, soil, and saturated zone water storage. The land elements may be grid cells in a regular lattice, or irregular elements (e.g., triangles) with the pattern adapted to variations in land surface characteristics or hydraulic gradients.

A number of models are intermediate between lumped and distributed, with approaches such as lumping at the subwatershed scale, incorporating statistical distributions of land element types within subwatersheds but without explicit pattern representation, or lumping some variables and processes (such as groundwater storage and flux), while including distributed representation of topography and land cover. Thus, within the model SLAMM (Pitt and Vorhees, 2002), the catchment is described in sufficient detail to summarize the breakdown of different drainage sequences. As an example, roof area will be broken down to the proportion that drains to pervious areas and to directly connected impervious areas. An important distinction is that there is no routing of the output of one land element into another, such that there is no drainage sequence that may significantly modify the stormwater runoff from its source to the stream. Implicitly, all land elements drain directly into a stream, although a loss rate or delivery ratio can be specified.

The choice of a more lumped or distributed model is often dependent on available data and overall complexity of the model. Simpler, lumped models may be preferred in the absence of sufficient data to effectively parameterize a distributed approach, or for simplicity and computational speed. However, fully lumped models may be limited in their ability to represent spatial dependency, such as the development and dynamics of riparian zones, or the effects of SCM patterns and placement. As there is typically an irreducible level of spatial heterogeneity in land surface characteristics down to very small levels below the resolution of individual flow elements, we note that all models lump at some scale (Beven, 2000).

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Mechanistic Versus Conceptual Process Representation

Mechanistic, or process-based, approaches attempt to reproduce key stormwater transport and transformation processes with more physically, chemically, or biologically based detail, while conceptual models represent fluxes between stores and transformations with aggregate, simplified mathematical forms. No operational models are built purely from first principles, so the distinction between mechanistic and conceptual process basis is one of degree.

The level of sampling necessary to support detailed mechanistic models, as well as remaining uncertainty in physicochemical processes active in heterogeneous environments typically limits the application of first-principle methods. The development or application of more mechanistic approaches is currently limited by available measurements, which require both time and resources to adequately carry out. Unfortunately, modeling and monitoring have often been mutually exclusive in terms of budgets, although it is necessary for both to be carefully planned and integrated. A new generation of sensors and a more rigorous and formal sampling protocol for existing methods will be necessary to advance beyond the current practice.

At present, most operational hydrologic and transport models are based on a strong set of simplifying assumptions regarding active processes and/or the spatial variation of sources, sinks, and stores in the watershed. Runoff production can be computed by a range of more mechanistic to more conceptual or empirical methods. More mechanistic methods include estimation of infiltration capacities based on soil hydraulic properties and moisture conditions, excess runoff production, and hydraulic routing over land surfaces into and through a stream-channel network. More conceptual approaches use a National Resources Conservation Service (NRCS) curve number approach (see Box 4-5) and unit hydrograph methods to estimate runoff volume and time of concentration. Pollutant concentrations or loads are often estimated on the basis of look-up tables using land use or land cover. Land use- or land cover-specific EMC or unit area loading for pollutants can be developed directly from monitoring data or from local, regional, or national databases. The NSQD statistically summarizes the results of a large number of stormwater monitoring projects (as discussed previously in this chapter). The effects of SCM performance (typically percent removal) can be estimated from similar databases (e.g., www.bmpdatabase.org). A set of models, such as SWAT, incorporate fairly detailed descriptions of nutrient cycling as an alternative to using EMC, requiring more detailed inputs of soil, crop, and management information. Unfortunately, the detailed biogeochemistry of this and similar models is typically not matched by the hydrology, which remains lumped at individual Hydrologic Response Unit (HRU) levels using NRCS curve number methods, although options exist to incorporate more mechanistic infiltration excess runoff.

Deterministic Versus Stochastic Methods

Deterministic models are fully determined by their equation sets, initial and boundary conditions, and forcing meteorology. There are no components that include random variation. In a stochastic model, at least one parameter or variable is drawn from a probability distribution function such that the same model set-up (initial and boundary conditions, meteorology, parameter sets) will have randomly varying results. The advantage of the latter approach is the ability to generate statistical variability of outcomes, reflecting uncertainty in parameters,

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processes, or any other component. In fact, any deterministic model can be operated in a stochastic manner by sampling parameter values from specified probability distributions.

It is recognized that information on the probability distribution of input parameters may be scarce. For situations with limited information on parameter values, one option is to assume a uniform distribution that brackets a range of values of the parameter reported in the literature. This would at least be a start in considering the impacts of the variability of model inputs on outputs. A thorough discussion on methods for incorporating uncertainty analysis into model evaluation is provided in Chapter 14 of Ramaswami et al. (2005). It should be noted that the ability to generate probability distribution information on stormwater outcomes requires a potentially large number of model runs, which may be difficult for detailed mechanistic and distributed models that have large computational loads.

Continuous Versus Event-Based Approaches

Another division between modeling approaches is the time domain of the simulation. Event-based models limit simulation time domains to a storm event, covering the time of rainfall and runoff generation and routing. Initial conditions need to be estimated on the basis of antecedent moisture or precipitation conditions. For catchments in which runoff is dominated by impervious surfaces, this is a reasonable approach. In landscapes dominated by variable source area runoff dynamics in which runoff is generated from areas that actively expand and contract on the basis of soil moisture conditions, a fuller accounting of the soil moisture budget is required. Furthermore, event-based modeling is inappropriate for water quality purposes because it will not reproduce the full distribution of receiving water problems. Continuous models include simulation of a full time domain composed of storm and inter-storm periods, thus tracking soil moisture budgets up to and including storm events.

Outfall Models

After beneficial use impairments are recognized, cause-and-effect relationships need to be established and restorative discharge goals need to be developed. Models are commonly used to calculate the expected discharges for different outfalls affecting the receiving water in a community. All of the models shown in Table 4-7 can calculate outfall discharge quantities, although some may only give expected average annual discharge. Models calculate these discharges using a variety of processes, but all use an urban hydrology component to determine the runoff quantity and various methods to calculate the quality of the runoff. The runoff quantity is multiplied by the pollutant concentration in the outfall to obtain the mass discharges of the different pollutants. The outfall mass discharge from the various outfalls in the area can then be compared to identify the most significant outfalls that should be targeted for control.

The most common hydrology “engines” in simple stormwater models are the NRCS curve number method or a simple volumetric runoff coefficient—R_v, the ratio of runoff to rainfall—for either single rainfall events or the total annual rainfall depth. Runoff quality in the simple models is usually calculated based on published EMCs for similar land uses in the same geographical area. More complex models may use build-up and wash-off of pollutants from impervious surfaces in a time series or they may derive pollutant concentrations from more

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detailed biogeochemical cycling mechanisms, including atmospheric deposition and other inputs (e.g., fertilizer). Some models use a combination of these processes depending on the area considered, and others offer choices to the model user. Again, these processes all need local calibration and verification to reduce the likely uncertainty associated with the resultant calculated discharge conditions.

Source Area

When the outfalls are ranked according to their discharges of the pollutants of importance, further detailed modeling can be conducted to identify sources of the significant pollutants within the outfall drainage area. Lumped parameter models cannot be used, as the model parameters vary within the drainage area according to the different source areas. Distributed area models can be used to calculate contributions from different source areas within the watershed area. This information can then be used to rank the land uses and source area contributions. In-stream responses can be calculated if the land-area models are linked to appropriate receiving-water models.

Need for Coupling Models

As urban areas become increasingly extensive and heterogeneous, including a gradient of dense urban to forest and agricultural areas, linkage and coupling of models to develop feedback and interactions (e.g., impacts of urban runoff hydraulics with stream scour and sedimentation, mixed with agricultural nutrient and sediment production on receiving waterbodies) is a critical area that requires more development. In general, stormwater models were designed to track and predict discharges from sources by surface water flowpaths into receiving waterbodies, such that infiltration was considered to be a loss (or retention) of water and its constituents. To fully evaluate catchment-scale impacts of urbanization on receiving waterbodies, the infiltration term needs to be considered a source term for the groundwater, and a groundwater component or model needs to be coupled to complete the surface–subsurface hydrologic interactions and loadings to the waterbody.

Finally, each of the models may or may not incorporate explicit consideration of SCM performance based on design, implementation and location within the catchment. As discussed in the next chapter, SCM models can range from simple efficiency factors (0–1 multipliers on source discharge) to more detailed treatment of physical, chemical, and biological transport and transformations.

Linking to Receiving-Water Models

Specific problems for urban receiving waters need to be identified through comprehensive field monitoring and modeling. Monitoring can identify current problems and may identify the stressors of importance (see Burton and Pitt [2002] for tools to evaluate receiving water impairments). However, monitoring cannot predict conditions that do not yet exist and for other periods of time that are not represented at the time of monitoring. Modeling is therefore needed to gain a more comprehensive understanding of the problem. In small-scale

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totally urbanized systems, less complex receiving-water models are needed. However, as the watershed becomes more complex and larger with multiple land uses, the receiving-water models also need to become more complex. Complex receiving-water models need to include transport and transformations of the pollutants of concern, for example. Examples of models shown on the comparison table that include receiving-water processes are MUSIC and HSPF. Other models (such as WinSLAMM) provide direct data links to external receiving-water models. Calibration and verification of important receiving-water processes that are to be implemented in a model can be very expensive and time consuming, and still result in substantial uncertainty.

Model Calibration and Verification

Calibration is the process where model parameters are adjusted to minimize the difference between model output and field measurements, with an aim of keeping model parameters within a range of values reported in the literature. Model *verification*, similar to model validation, is used to mean comparison between calibrated model results using part of a data set as input and results from application of the calibrated model using a second (independent) part of the data set as input. Oreskes et al. (1994) present the viewpoint that no model can really be verified; at best, verification should be taken to mean that a model is consistent with a physical system under a given set of comparison data. This is not synonymous with saying that the model can reliably represent the real system under any set of conditions. In general, the water quantity aspects of stormwater modeling are easier to calibrate and verify than the water quality aspects, in part because there are more water quantity data available and because chemical transformations are more complex to simulate. A thorough discussion of the broad topic of model evaluation is provided by several excellent texts on this subject, including Schnoor (1996) and Ramaswami et al. (2005).

Models in Practice Today

Table 4-7 presents a set of models used for stormwater evaluation that range in complexity from first-generation stormwater models making use of simple empirical land cover/runoff and loading relations to more detailed and information-demanding models. The columns in Table 4-7 provide an abbreviated description of some of the attributes of these models—common usage, typical application scales, the degree of model complexity, some data requirements (for the hydrologic component), whether the model addresses groundwater, and whether the model has the ability to simulate SCMs. Models capable of simulating a water quality component require EMC data, with some models also having a simple build-up/wash-off approach to water quality simulation (e.g., SWMM, WinSLAMM, and MUSIC) and others simulating more complex geochemistry (e.g., SWAT and HSPF). The set of columns in Table 4-7 is not meant to be exhaustive in describing the models, which is why websites are provided for comprehensive model descriptions and data requirements.

In addition to the models listed in Table 4-7, a representative set of emerging research models that are not specifically designed for stormwater, but may offer some advantages for specific uses, are also described below. In general, it is important that models that integrate

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hydrologic, hydraulic, meteorologic, water quality, and biologic processes maintain balance in their treatment of process details. Both model design and data collection should proceed in concert and should be geared toward evaluating and diagnosing the consistency of model or coupled model predictions and the uncertainty attached to each component and the integrated modeling system. The models should be used in a manner that produces both best estimates of stormwater discharge impacts on receiving waterbodies, as well as the level of uncertainty in the predictions.

The Rational Method is a highly simplified model widely used to estimate peak flows for in sizing storm sewer pipes and other low level drainage pathways. The method assumes a constant rainfall rate (intensity), such that the runoff rate will increase until the time at which all of the drainage area contributes to flow at its outlet (termed the *time of concentration*). The product of the drainage area and rainfall intensity is considered to be the input flow rate to the drainage area under consideration; the ratio of the input flow rate to an outflow discharge rate is termed the runoff coefficient. Runoff coefficients for a variety of land surface types and slopes have been compiled in standard tables (see e.g., Chow et al., 1988). The outflow is determined by multiplying inflow (rainfall intensity times drainage area) by the runoff coefficient for the land-surface type. As pointed out by Chow et al. (1988), this method is often criticized owing to its simplified approach, so its use is limited to stormwater inlet and piping designs.

The Simple Method estimates stormwater pollutant loads for urban areas, and it is most valuable for assessing and comparing the relative stormwater pollutant load changes of different land use and stormwater management scenarios. It requires a modest amount of information, including the subwatershed drainage area and impervious cover, stormwater pollutant concentrations (as defined by the EMC), and annual precipitation. The subwatershed can be broken up into specific land uses, such that annual pollutant loads are calculated for each type of land use. Stormwater pollutant concentrations are usually estimated from local or regional data, or from national data sources. The Simple Method estimates pollutant loads for chemical constituents as a product of annual runoff volume and pollutant concentration, as $L = 0.226\ R\ x\ C\ x\ A$, where L = annual load (lbs), R = annual runoff (inches), C = pollutant concentration (mg/l), and A = area (acres).

Of slightly increased complexity are those models initially developed decades ago by the Soil Conservation Service, now the NRCS of the U.S. Department of Agriculture (USDA). NRCS Technical Releases (TR) 20 and 55 are widely used in many municipalities, despite the availability of more rigorous, updated stormwater models. Box 4-5 provides an overview of the NRCS TR-55 assumptions and approaches.

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BOX 4-5
NRCS Technical Release 55

NRCS methods to estimate runoff volumes and flows have been popular since the early 1950s (Rallison, 1980). Fundamentally they can be broken into the separation of runoff from the rainfall volume (Curve Number Method), the pattern of runoff over time (dimensionless unit hydrograph), and their application within computer simulation models. In the late 1970s these components were packaged together in a desktop hydrology method known as Technical Release 55 (TR-55). TR-55 became the primary model used by the majority of stormwater designers, and there is considerable confusion over the terms used to describe what aspects of the NRCS methods are in use.

The NRCS Curve Number Method was first derived in the 1950s for prediction of runoff from ungauged agricultural areas. It relates two summation ratios, that of runoff to rainfall and that of moisture retained to maximum potential retention. Two statistically based relations were developed to drive the ratio, the first of which is based on a "curve number" which depicts the soil type, land cover, and initial moisture content. The second or initial abstraction is defined as the volume of losses that occur prior to the initiation of runoff, and is also related to the curve number. Data were used to derive curve numbers for each soil type and cover as shown in Figure 4-17 (Rallison, 1980).

The Curve Number method is a very practical method that gives "average" runoff results from a watershed and is used in many models (WIN TR-55, TR-20, SWMM, GWLF, HEC-HMS, etc.). Caution has to be exercised when using it for smaller urbanizing storm events. For example, past practice was to average curve numbers for developments for pavement and grass based on percent imperviousness. While this works well for large storms, for smaller storms it gives erroneous answers through violation of the initial abstraction relationship. Current state manuals (MDE, 2000; PaDEP, 2006) do not allow paved- and unpaved-area curve numbers to be averaged. When applied to continuous simulation models (such as in SWMM or GWLF), it requires an additional method to recover the capacity to remove runoff because the soil capacity to infiltrate water is restored over time.

The NRCS Dimensionless Unit Hydrogaph has also evolved over many years and simply creates a temporal pattern from the runoff generated from the curve number method. This transformation is based upon the time of concentration, defined as the length of time the water takes to travel from the top to the bottom of the watershed. The dimensionless curve ensures that conservation of mass is maintained. The main purpose of this method is to estimate how long it takes the runoff generated by the curve number to run off the land and produce discharge at the watershed outlet.

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BOX 4-5 Continued

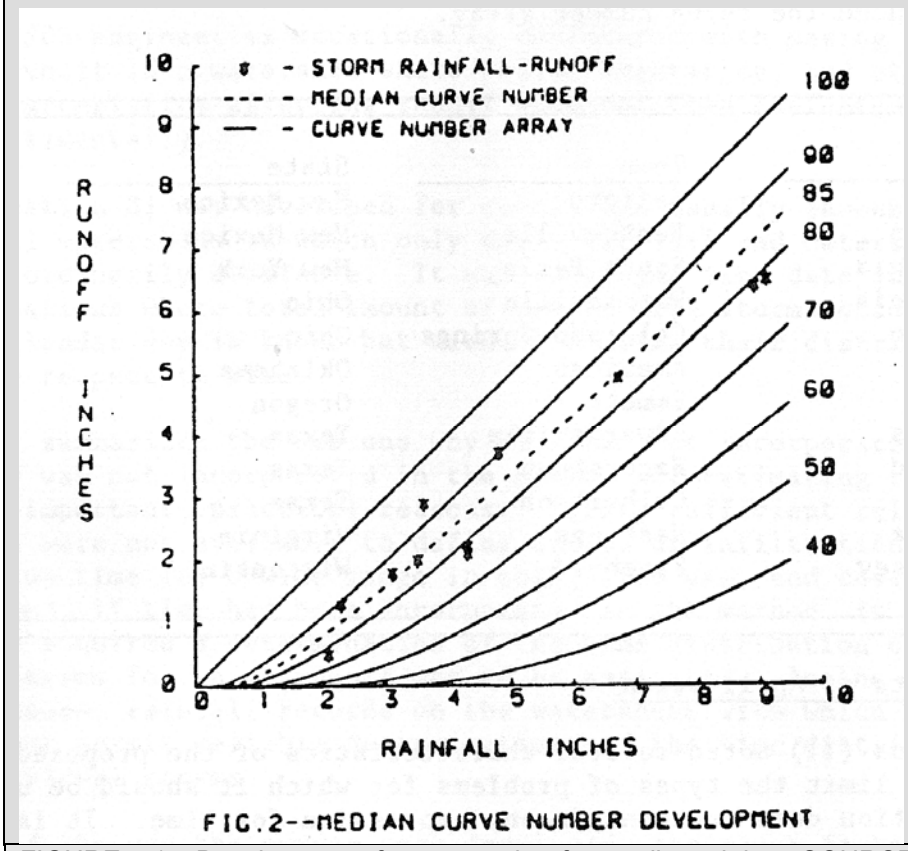

FIGURE 4-17 Development of curve number from collected data. SOURCE: Reprinted, with permission, from Rallison (1980). Copyright 1980 by the American Society of Civil Engineers.

The NRCS curve number and dimensionless unit hydrograph were first incorporated in the Soil Conservation Service (SCS) TR-20 hydrologic computer model developed in the 1960s. As most stormwater professionals did not have access to mainframes, SCS put together TR-55, which created a hand or calculator method to apply the curve number and dimensionless unit hydrograph. In order to create this hand method, many runs were generated using TR-20 to develop patterns for different times of concentration. The difficulty with using the original TR-55 in the modern era is that the simplifications to the hydrograph development do not allow the benefits of SCMs to be easily accounted for.

The use of the term TR-55 has been equated with the curve number method; this has created confusion, especially when it is included in municipal code. Further clouding the issue, there are two types of TR-55 computer models available. One is based on the original, outdated, simplified hand method, and the other (Win TR-55) returns to the more appropriate application of the curve number and dimensionless hydrograph methods. In either case, the focus of these models is on single event hydrology and cannot easily incorporate or demonstrate the benefits of the wide range of structural and nonstructural SCMs. Note that the curve number and dimensionless unit hydrograph methods are incorporated in many continuous flow models, including SWMM and GWLF, as the basis of runoff generation and runoff timing.

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A number of watershed models that are used for stormwater assessment are lumped, conceptual forms, with varying levels of process simplification and spatial patterns aggregated at the subwatershed level, with aspatial statistical distribution of land types as described above. The GWLF model (Haith and Shoemaker, 1987) is an example of this type of approach, using simple land use-based EMC with NRCS curve number estimates of runoff within a watershed context. GWLF is a continuous model with simplified upper- and lower-zone subsurface water stores, and a simple linear aquifer to deliver groundwater flow. EMCs are assigned or calibrated for subsurface and surface flow delivery, while sediment erosion and delivery are computed with the use of the Universal Soil Loss Equation and delivery coefficients. The methods are easily linked to a Geographical Information System (GIS), which provides land-use composition at the subwatershed level and develops estimates of runoff and loading that are typically used to estimate annual loading. AVGWLF links GWLF with ArcView and is used as a planning- or screening-level tool. A recent example of AVGWLF for nutrient loading linked to a simple stream network nutrient decay model for the development of a TMDL for a North Carolina water supply area is given in Box 4-6.

P8 (Program for Predicting Polluting Particle Passage through Pits, Puddles, and Ponds) is a curve number-based model for predicting the generation and transport of stormwater runoff pollutants in urban watersheds, originally developed to help design and evaluate nutrient control in wet detention ponds (Palmstrom and Walker, 1990; http://wwwalker.net/p8/). Continuous water-balance and mass-balance calculations are performed and consist of the following elements: watersheds, devices, particle classes, and water quality components. Continuous simulations use hourly rainfall and daily air temperature time series. The model was initially calibrated to predict runoff quality typical of that measured under NURP (EPA, 1983). SCMs in P8 include detention ponds (wet, dry, extended), infiltration basins, swales, and buffer strips. Groundwater and baseflows are also included in the model using linear reservoir processes.

MUSIC is a part of the Catchment Modelling Toolkit (www.toolkit.net.au) developed by the Cooperative Research Center for Catchment Hydrology in Australia (Wong et al., 2001). The model concentrates on the quality and quantity of urban stormwater, including detailed accounting of multiple SCMs acting within a treatment train and life-cycle costing. It employs a simplified rainfall–runoff model (Chiew and McMahon, 1997) based on impervious area and two moisture stores (shallow and deep). TSS, total nitrogen, and total phosphorus are based on EMCs, sampled from lognormal distributions. The model does not contain detailed hydraulics required for routing or sizing of SCMs, and it is designed as a planning tool.

EPA's SWMM has the capability of simulating water quantity and quality for a single storm event or for continuous runoff. The model is commonly used to design and evaluate storm, sanitary, and combined sewer systems. SWMM accounts for hydrologic processes that produce runoff from urban areas, including time-varying rainfall, evaporation, snow accumulation and melting, depression storage, infiltration into soil, percolation to groundwater, interflow between groundwater and the drainage system, and nonlinear reservoir routing of overland flow. Spatial variability is modeled by dividing a study area into a collection of smaller, homogeneous subcatchment areas, each containing its own fraction of pervious and impervious sub-areas. Overland flow can be routed between sub-areas, between subcatchments, or between entry points of a drainage system. SWMM can also be used to estimate the production of pollutant loads associated with runoff for a number of user-defined water quality constituents. Transport processes include dry-weather pollutant buildup over different land uses, pollutant wash-off from specific land uses, direct contribution of rainfall deposition, and the

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BOX 4-6
The B. Everett Jordan Lake GWLF Watershed Model Development

Jordan Lake is a regionally important water supply reservoir at the base of the 1,686-square-mile Haw watershed in North Carolina (see Figure 4-18). It is considered a nutrient-sensitive waterbody. Officials are now in the process of implementing watershed goals to reduce nitrogen and phosphorus, with the reduction goals differentiated by geographic location within the basin. In support of the development of these rules as part of a TMDL effort, the North Carolina Division of Water Quality commissioned a water quality modeling study (Tetra Tech, 2003). The modeling effort was needed to support the evaluation of nutrient reduction strategies in different parts of the watershed relative to Jordan Lake, which requires both a model of nutrient loading, as well as river transport and transformation. Given data and resource restrictions, a more detailed model was not considered feasible. As GWLF does not support nutrient transformations in the stream network, the model was used in conjunction with a method to decay nutrient source loading by river transport distance to the lake. A spreadsheet model was designed to take as input GWLF estimates of seasonal loads for 14-digit hydrologic unit code (HUC) subbasins of the Haw, and to reduce the loads by river miles between the subwatershed and Jordan Lake. The GWLF loading model was calibrated to observations in small subwatersheds within the Haw using HRUs developed from soil and NLCD land classes, updated with additional information from county GIS parcel databases and the 2000 Census. This information was used to estimate subwatershed impervious surface cover, fertilizer inputs, runoff curve numbers, soil water capacity, and vegetation cover to adjust evapotranspiration rates. Wastewater disposal (sewer or septic) was estimated on the basis of urban service boundaries. GWLF was used to provide loading estimates, using limited information on soil and groundwater nutrient concentrations, and calibrated delivery ratios. In-stream loss was based on a first-order exponential decay function of river travel time to Jordan Lake, with the decay coefficient generated by estimates of residence time in the river network, and upstream/downstream nutrient loads following non-linear regression methods used in SPARROW (Alexander et al., 2000). Further adjustments based on impoundment trapping of sediment and associated nutrient loads were carried out for larger reservoirs in the Haw. The results provided estimates of both loading and transport efficiency to Jordan Lake, with estimates of relative effectiveness of sectoral loading reductions in different parts of the watershed.

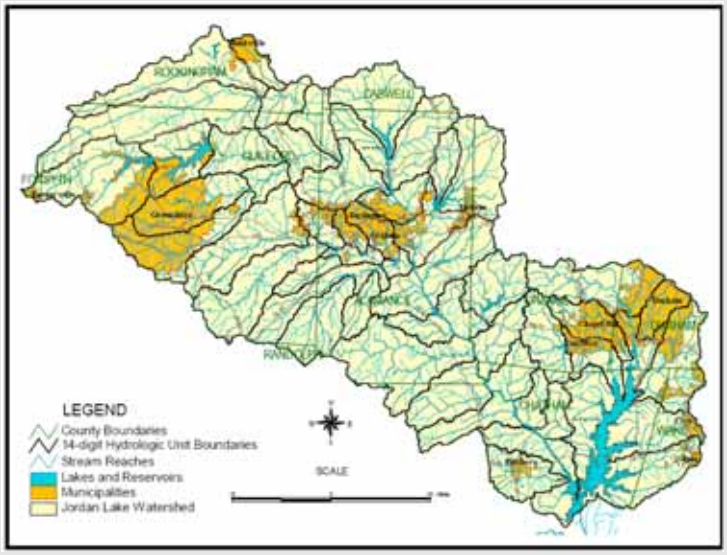

FIGURE 4-18 14 digit HUCs draining to Jordan Lake in the Haw River watershed of North Carolina. SOURCE: NHD+.

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action of such SCMs as street cleaning, source control, and treatment in storage units, among others. Further details are provided in Appendix D.

Watershed models such as SWAT (Arnold et al., 1998) or HSPF (Bicknell et al., 1997, 2005) have components based on similar land-use runoff and loading factors, but also incorporate options to utilize detailed descriptions of interception, infiltration, runoff, routing, and biogeochemical transformations. Both models are based on hydrologic models that were developed prior to the availability of detailed digital spatial information on watershed form and use conceptual control volumes that are not spatially linked. HRUs are based on land use, soils, and vegetation (and crop) type, among other characteristics, and are considered uniformly distributed through a subbasin. Within each HRU, simplified representations of soil upper and lower zones, or unsaturated and saturated components, are vertically integrated with a conceptual groundwater storage-release component. There is no land surface routing and all runoff from a land element is considered to reach the river reach, with some delivery ratio if appropriate for sediment and other constituents. Like GWLF, the models are typically not designed to estimate loadings from individual dischargers, but are used to help guide and develop TMDL for watersheds. SWAT and HSPF are integrated within the EPA BASINS system (http://www.epa.gov/waterscience/basins) with GIS tools designed to use available spatial data to set up and parameterize simulations for watersheds within the United States. Examples of combining one of these models, typically designed for larger-scale applications (such as the area shown in Figure 4-14) with more site-specific models such as SLAMM or SWMM, are given in Box 4-7.

BOX 4-7
Using SWAT and WinSLAMM to Predict Phosphorus Loads in the Rock River Basin, Wisconsin

Wisconsin Administrative Code NR 217 states that wastewater treatment facilities in Wisconsin must achieve an effluent concentration of 1 mg/L for phosphorus. Alternative limits are allowed if it can be demonstrated that achieving the 1 mg/L limit will not "result in an environmentally significant improvement in water quality" (NR 217.04(2)(b)1). In response to NR 217, a group of municipal wastewater treatment facilities formed the Rock River Partnership (RRP) to assess water quality management issues (Kirsch, 2000). The RRP and the Wisconsin Department of Natural Resources funded a study to seek water quality solutions across all media, and not just pursue additional reductions from point sources. A significant portion of the study required a modeling effort to determine the magnitude of various nutrient sources and determine potential reductions through the implementation of global SCMs.

The Rock River Basin covers approximately 9,530 square kilometers and lies within the glaciated portion of south central and eastern Wisconsin (Figure 4-19). The Rock River and its numerous tributaries thread their way through this landscape that spreads over 10 counties inhabited by more than 750,000 residents. There are 40 permitted municipalities in the watershed, representing 4 percent of the land area, and they are served by 57 sewage treatment plants. Urban centers include Madison, Janesville, and Beloit as well as smaller cities such as Waupun, Watertown, Oconomowoc, Jefferson, and Beaver Dam. Although the basin is experiencing rapid growth, it is still largely rural in character with agriculture using nearly 75 percent of the land area. Crops range from continuous corn and corn–soybean rotations in the south to a mix of dairy, feeder operations, and cash cropping in the north. The basin enjoys a healthy economy with a good balance of agricultural, industrial, and service businesses.

The focus of the modeling was to construct an intermediate-level macroscale model to better quantify phosphorus loads from point and nonpoint sources throughout the basin. The three goals of the modeling effort were to (1) estimate the average annual phosphorus load, (2) estimate the relative

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BOX 4-7 Continued

contribution of phosphorus loads from both nonpoint (urban and agricultural) and point sources, and (3) estimate changes in average annual phosphorus loads from the application of global SCMs and point source controls.

SWAT was selected for the agricultural analysis and WinSLAMM was selected to develop phosphorus loads for the urban areas. WinSLAMM was selected to make estimates of stormwater loads, because it is already calibrated in Wisconsin for stormwater volumes and pollutant concentrations. Outputs of phosphorus loads from WinSLAMM were used as input to SWAT. One output of SWAT was a total nonpoint phosphorus load based on agricultural loads calculated in SWAT and stormwater loads estimated by WinSLAMM.

SWAT was calibrated with data from 23 USGS gauging stations in the Rock River Basin. Hydrology was balanced first on a yearly basis looking at average annual totals, then monthly to verify snowfall and snowmelt routines, and then daily. Daily calibration was conducted to check crop growth, evapotranspiration, and daily peak flows. Crop yields predicted by SWAT were calibrated to those published in the USDA Agricultural Statistics.

Under current land-use and management conditions, the model predicted an average annual load of approximately 1,680,000 pounds of total phosphorus for the basin with 41 percent from point sources and 59 percent from nonpoint sources. Less than 10 percent of the annual phosphorus load is generated by the urban areas in the watershed. Evaluation of various SCM scenarios shows that with implementation of NR 217 (applicable point source effluent at 1 mg/L) and improvement in tillage practices and nutrient management practices, total phosphorus can be reduced across the basin by approximately 40 percent. It is important to note that the nonpoint management practices that were analyzed were limited to two options: modifications in tillage practices, and adoption of recommended nutrient application rates. No other management practices (i.e., urban controls, riparian buffer strips, etc.) were simulated. Urban controls were not included because the urban areas contributed a relatively small percentage of the total phosphorus load. Thus, loadings depicted by SWAT under these management scenarios do not necessarily represent the lowest attainable loads. Results suggest that a combination of point and nonpoint controls will be required to attain significant phosphorus reductions.

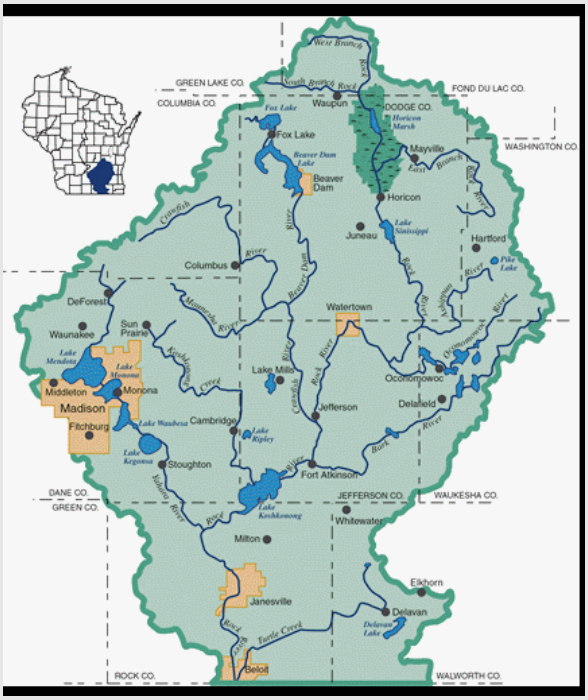

FIGURE 4-19 Rock River Basin, Wisconsin. SOURCE: Reprinted, with permission, from Kirsch (2000). Copyright 2000 by American Society for Biological and Agricultural Engineers.

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The CBWM is a detailed watershed model that is extended from HSPF as a base, but includes additional components to incorporate stormwater controls at the land segment level. HSPF is operated for a number of subbasins, and each subbasin model includes different land segments based on land cover and soil units as aspatial, lumped distribution functions, but also includes representation of SCMs and (large) stream routing. Model implementation at the scale of the full Chesapeake Bay watershed requires fairly coarse-grained land partitioning. A threshold of 100 cfs mean annual flow is used to represent streams and rivers, and the one-to-one mapping of land segment to river reach produces large, heterogeneous land segments as the basic runoff-producing zones. SCMs are implemented either at the field or runoff production unit as distinct land segment types in terms of management or land cover, or as "edge-of-field" reductions of runoff or pollutant loads. The latter are assigned as static efficiency factors irrespective of flow conditions or season, with all SCMs within a land segment integrated into a single weighted efficiency value.

SLAMM is designed for complex, urban catchments and is used as a planning tool to assess both stormwater and pollutant runoff production and the capability of specific stormwater control strategies to reduce stormwater discharges from urban sources. It is specifically designed to capture the most significant distributed and sequential drainage effects of variable source areas in urban catchments (Pitt and Vorhees, 2002) and is based on detailed descriptions of the catchment composition, including both type and relative position (drainage sequence) of land elements. The model is dependent on high-resolution classification or description of the catchment that has become increasingly available in urban areas over the past two decades, and comprehensive field assessment of runoff and pollutant loading from different urban land elements. SLAMM uses continuous simulation for some aspects, such as the build up of street pollutant loads between storms, while using event-based simulation for runoff. The description of build-up and wash-off is a critical component in urban stormwater models applied to areas with substantial impervious surfaces and is a good example of the need to match detailed and rigorous field sampling in order to adequately describe and represent dominant processes. Details of measurement and model representation for build-up and wash-off of contaminants are given in Box 4-8.

Potential New Applications of Coupled Distributed Models

The advent of high-resolution digital topographic and land-cover data over the past two decades has fueled a significant shift in runoff modeling towards "spatially explicit" simulations that distinguish and connect runoff producing elements in a detailed flow routing network. While models developed prior to the availability of high-resolution data or based on older paradigms developed in the absence of this information required spatial and conceptual lumping of control volumes, more recently developed distributed models may contain control volumes linked in multiple vertical layers (soil and aquifer elements) and laterally from a drainage divide to the stream, including stream-channel and riparian segments. A set of models has been developed and applied to stormwater generation using this paradigm that can be applied at the scale of residential neighborhoods, resolving land cover and topography at the parcel level. These models also vary in terms of their emphasis, with some models better representing coupled surface water–groundwater interactions, water, carbon and nutrient cycling, or land–atmosphere interactions. Boyer et al. (2006) have recently reviewed a set of hydrologic and ecosystem

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BOX 4-8
Build-up and Wash-off of Contaminants from Impervious Surfaces

The accumulation and wash-off of street particulates have been studied for many years (Sartor and Boyd, 1972; Pitt, 1979, 1985, 1987) and are important considerations in many stormwater models, such as SWMM, HSPF, and SLAMM, that require information pertaining to the movement of pollutants over land surfaces. Accumulation rates are usually obtained through trial and error during calibration, with little, if any, actual direct measurements. Furthermore, those direct measurements that have been made are often misapplied in modeling applications, resulting in unreasonable model predictions.

Historically, streets have been considered the most important directly connected impervious surface. Therefore, much early research was directed toward measuring the processes on these surfaces. Although it was eventually realized that other surfaces can also be significant pollutant sources (see Pitt et al., 2005b,c, for reviews), additional research to study accumulation and wash-off for these other areas has not been conducted, such that the following discussion is focused on street dirt accumulation and wash-off.

Accumulation of Particulates on Street Surfaces

The permanent storage component of street surface particulates is a function of street texture and condition and is the quantity of street dust and dirt that cannot be removed naturally by rain or wind, or by street cleaning equipment. It is literally trapped in the texture of the street. The street dirt loading at any time is this initial permanent loading plus the accumulation amount corresponding to the exposure period, minus the resuspended material removal by wind and traffic-induced turbulence.

One of the first research studies to attempt to measure street dirt accumulation was conducted by Sartor and Boyd (1972). Field investigations were conducted between 1969 and 1971 in several cities throughout the United States and in residential, commercial, and industrial land-use areas. Figure 4-20 is a plot of the 26 test area measurements collected from different cities, but separated by the three land uses. The data are the accumulated solids loading plotted against the number of days since the street had been cleaned by the municipal street cleaning operation or a “significant” rain. There is a large amount of variability. The street cleaning and this rain were both assumed to remove all of the street dirt; hence, the curves were all forced through zero loading at zero days.

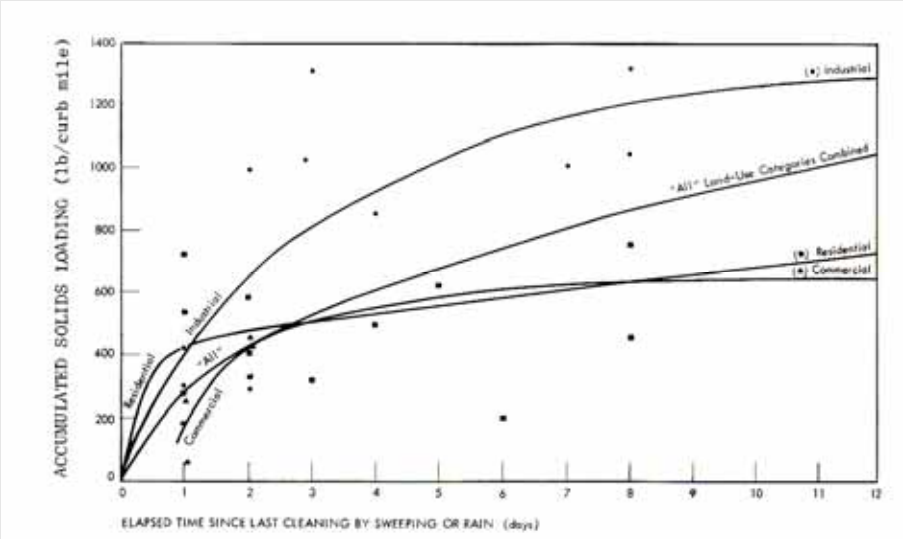

FIGURE 4-20 Accumulation curves developed during early street cleaning research. SOURCE: Sartor and Boyd (1972).

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BOX 4-8 Continued

A more thorough study was conducted in San Jose, California by Pitt (1979), during which the measured street dirt loading for a smooth street was also found to be a function of time. As shown in Figure 4-21, both accumulation rates and increases in particle size of the street dirt increase as time between street cleaning lengthens. However, it is also evident that there is a substantial residual loading on the streets immediately after the street cleaning, which differs substantially from the assumption of Sartor and Boyd that rains reduce street dirt to zero.

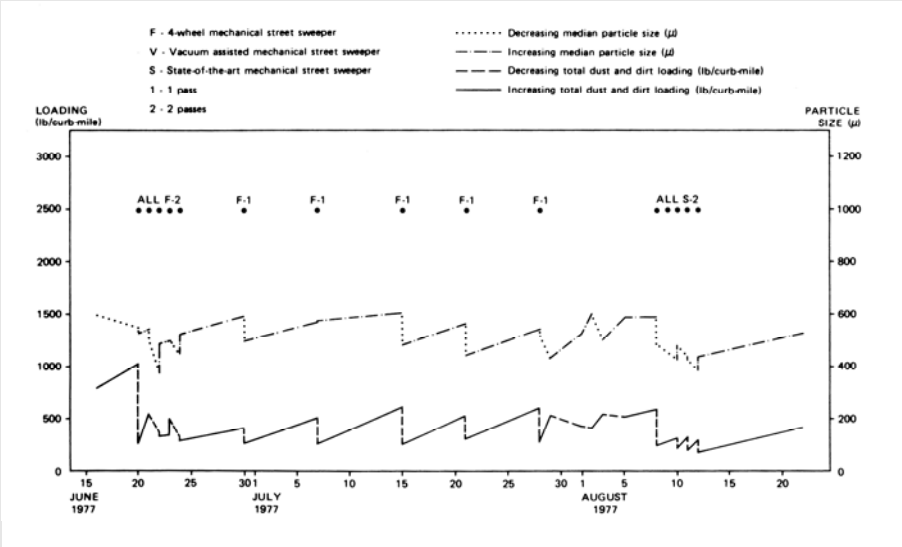

FIGURE 4-21 Street dirt accumulation and particle size changes on good asphalt streets in San Jose, California. SOURCE: Pitt (1979).

The San Jose study also investigated the role of different street textures, which resulted in very different street dirt loadings. Although the accumulation and deposition rates are quite similar, the initial loading values (the permanent storage values) are very different, with greater amounts of street dirt trapped by the coarser (oil and screens) pavement. Street cleaning and rains are not able to remove this residual material. The early, uncorrected Sartor and Boyd accumulation rates that ignored the initial loading values were almost ten times the corrected values that had reasonable “initial loads.”

Finally, it was found that, at very long accumulation periods relative to the rain frequency, the wind losses (fugitive dust) may approximate the deposition rate, resulting in very little increases in loading. In Bellevue, Washington, with inter-event rain periods averaging about three days, steady loadings were observed after about one week (Pitt, 1985). However, in Castro Valley, California, the rain inter-event periods were much longer (ranging from about 20 to 100 days), and steady loadings were never observed (Pitt and Shawley, 1982).

Taking many studies into account (Sartor and Boyd 1972—corrected; Pitt, 1979, 1983, 1985; Pitt and Shawley, 1982; Pitt and Sutherland, 1982; Pitt and McLean, 1986), the most important factors affecting the initial loading and maximum loading values have been found to be street texture and street condition, and not land use. When data from many locations are studied, it is apparent that smooth streets have substantially less loadings at any accumulation period compared to rough streets for the same land use. Very long accumulation periods relative to the rain frequency result in high street dirt loadings. However, during these conditions the wind losses of street dirt (as fugitive dust) may approximate the deposition rate, resulting in relatively constant street dirt loadings.

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BOX 4-8 Continued

Wash-off of Street Surface Pollutants

Wash-off of particulates from impervious surfaces is dependent on the available supply of particulates on the surface that can be removed by rains, the rain energy available to loosen the material, and the capacity of the runoff to transport the loosened material. Observations of particulate wash-off during controlled tests have resulted in empirical wash-off models. The earliest controlled street dirt wash-off experiments were conducted by Sartor and Boyd (1972) to estimate the percentage of the available particulates on the streets that would wash off during rains of different magnitudes. Sartor and Boyd fitted their data to an exponential curve, as shown in Figure 4-22 (accumulative wash-off curves for several particle sizes). The empirical equation that they developed, $N = N_o e^{-kR}$, is only sensitive to the total rain depth up to the time of interest and the initial street dirt loading.

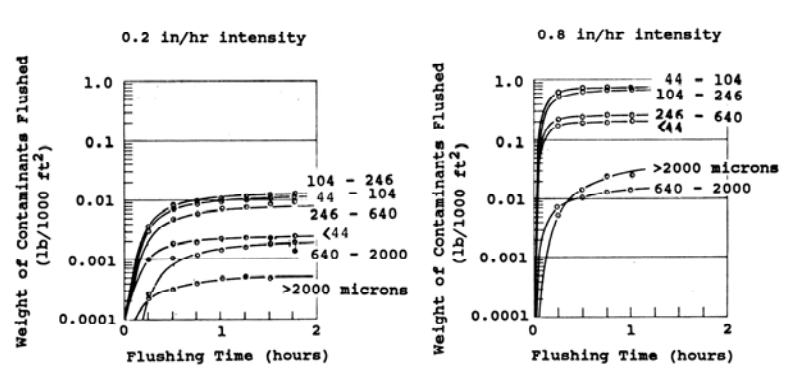

FIGURE 4-22 Street dirt wash-off during high-intensity rain tests. SOURCE: Sartor and Boyd (1972).

There are several problems with this approach. First, these figures did not show the total street dirt loading that was present before the wash-off tests. Most modelers have assumed that the asymptotic maximum shown was the total "before-rain" street dirt loading; that is, the N_o factor has been assumed to be the total initial street loading, when in fact it is only the portion of the total street load available for wash-off (the maximum asymptotic wash-off load observed during the wash-off tests). The actual total street dirt loadings were several times greater than the maximum wash-off amounts observed. STORM and SWMM now use an availability factor (*A*) for particulate residue as a calibration procedure in order to reduce the wash-off quantity for different rain intensities (Novotny and Chesters, 1981). Second, the proportionality constant, *k*, was found by Sartor and Boyd to be slightly dependent on street texture and condition, but was independent of rain intensity and particle size. The value of this constant is usually taken as 0.18/mm, assuming that 90 percent of the particulates will be washed from a paved surface in one hour during a 13 mm/h rain. However, Alley (1981) fitted this model to watershed outfall runoff data and found that the constant varied for different storms and pollutants for a single study area. Novotny examined "before" and "after" rain-event street particulate loading data using the Milwaukee NURP stormwater data (Bannerman et al., 1983) and found almost a three-fold difference between the proportionality constant value for fine (<45 □m) and medium-sized particles (100 to 250 □m). Jewell et al. (1980) also found large variations in outfall "fitted" values for different rains compared to the typical default value. They stressed the need to have local calibration data before using the exponential wash-off equation, as the default values can be very misleading. The exponential wash-off equation for impervious areas is justified, but wash-off coefficients for each pollutant would improve its accuracy. The current SWMM5 version discourages the use of accumulation and wash-off functions due to lack of data, and the misinterpretation of available data.

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BOX 4-8 Continued

It turns out that particle dislodgement and transport characteristics at impervious areas can be directly measured using relatively simple wash-off tests. The Bellevue, Washington, urban runoff project (Pitt, 1985) included about 50 pairs of street dirt loading observations close to the beginnings and ends of rains to determine the differences in loadings that may have been caused by the rains. The observations were affected by rains falling directly on the streets, along with flows and particulates originating from non-street areas. When all the data were considered together, the net loading difference was about 10 to 13 g/curb-m removed, which amounted to a street dirt load reduction of about 15 percent. Large reductions in street dirt loadings for the small particles were observed during these Bellevue rains. Most of the weight of solid material in the runoff was concentrated in fine particle sizes (<63 μm). Very few wash-off particles greater than 1,000 μm were found; in fact, street dirt loadings increased for the largest sizes, presumably due to settled erosion materials. Urban runoff outfall particle size analyses in Bellevue (Pitt, 1985) resulted in a median particle size of about 50 μm; similar results were obtained in the Milwaukee NURP study (Bannerman et al., 1983). The results make sense because the rain energy needed to remove larger particles is much greater than for small particles.

In order to clarify street dirt wash-off, Pitt (1987) conducted numerous controlled wash-off tests on city streets in Toronto. The experimental factors examined included rain intensity, street texture, and street dirt loading. The differences between available and total street dirt loads were also related to the experimental factors. The runoff flow quantities were also carefully monitored to determine the magnitude of initial and total rain water losses on impervious surfaces. The test setup was designed and tested to best represent actual rainfall conditions, such as rain intensities (3 mm/h) and peak rain intensities (12 mm/h). The kinetic energies of the "rains" during these tests were therefore comparable to actual rains under investigation. Figure 4-23 shows the asymptotic wash-off values observed in the tests, along with the measured total street dirt loadings. The maximum asymptotic values are the "available" street dirt loadings (N_o). As can be seen, the measured total loadings are several times larger than these "available" loading values. For example, the asymptotic available total solids value for the high-intensity rain–dirty street–smooth street test was about 3 g/m^2 while the total load on the street for this test was about 14 g/ m^2, or about five times the available load. The differences between available and total loadings for the other tests were even greater, with the total loads typically about ten times greater than the available loads. The total loading and available loading values for dissolved solids were quite close, indicating almost complete wash-off of the very small particles.

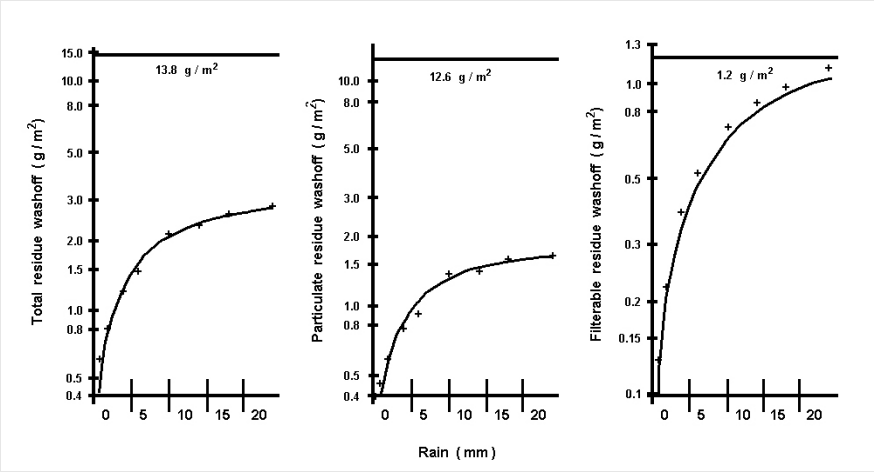

FIGURE 4-23 Wash-off plots for high rain intensity, dirty street, and smooth street test, showing the total street dirt loading. SOURCE: Pitt (1987).

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BOX 4-8 Continued

The availability factor (the ratio of the available loading, N_0, to the total loading) depended on the rain intensity and the street roughness, such that wash-off was more efficient for the higher rain energy and smoother pavement tests. The worst case was for a low rain intensity and rough street, where only about 4.5 percent of the street dirt would be washed from the pavement. In contrast, the high rain intensities on the smooth streets were more than four times more efficient in removing street dirt (20 percent removal).

A final important consideration in calculating wash-off of street dirt during rains is the carrying capacity of the flowing water to transport sediment. If the calculated wash-off is greater than the carrying capacity (such as would occur for relatively heavy street dirt loads and low to moderate rain intensities), then the carrying capacity is limiting. For high rain intensities, the carrying capacity is likely sufficient to transport most or all of the wash-off material. Figure 4-24 shows the maximum wash-off amounts (g/m^2) for the different tests conducted on smooth streets plotted against the rain intensity (mm/h) used for the tests (data from Sartor and Boyd, 1972, and Pitt, 1987). Wash-off limitations for rough streets would be more restrictive.

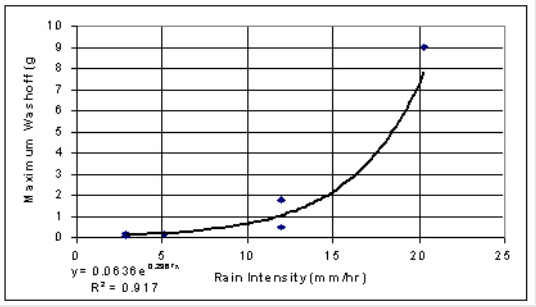

FIGURE 4-24 Maximum wash-off capacity for smooth streets (based on measurements of Sartor and Boyd, 1972; Pitt, 1987). If the predicted wash-off, using the previous "standard" wash-off equations, is smaller than the values shown in this figure, then those values can be used directly. However, if the predicted wash-off is greater than the values shown in this figure, then the values in the figure should be used.

Accumulation and Wash-off Summary

This discussion summarized street particulate wash-off observations obtained during special wash-off tests, along with associated street dirt accumulation measurements. The objectives of these tests were to identify the significant rain and street factors affecting particulate wash-off and to develop appropriate wash-off models. The controlled wash-off experiments identified important relationships between "available" and "total" particulate loadings and the significant effects of the test variables on the wash-off model parameters. Past modeling efforts have typically ignored or misused this relationship to inaccurately predict the importance of street particulate wash-off. The available loadings were almost completely washed off streets during rains of about 25 mm (as previously assumed). However, the fraction of the total loading that was available was at most only 20 percent of the total loading, and averaged only 10 percent, with resultant actual wash-offs of only about 9 percent of the total loadings.

In many model applications, total initial loading values (as usually measured during field studies) are used in conjunction with model parameters as the available loadings, resulting in predicted wash-off values that are many times larger than observed. This has the effect of incorrectly assuming greater pollutant contributions originating from streets and less from other areas during rains. This in turn results in inaccurate estimates of the effectiveness of different source area urban runoff controls. Although streets can be important sources of runoff and stormwater pollutants, their significance varies greatly depending on the land use and rainfall pattern. They are much more important sources in areas having relatively mild rains (e.g., the Pacific Northwest), where contaminants from other potential sources are not effectively transported to the storm drainage system.

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models in terms of their ability to simulate sources, transport, and transformation of nitrogen within terrestrial and aquatic ecosystems. Data and information requirements are typically high, and the level of process specificity may outstrip the available information necessary to parameterize the integrated models. However, an emphasis is placed on providing mechanistic linkage and feedbacks between important surface, subsurface, atmospheric, and ecosystem components. Examples of these models include the Distributed Hydrology Soil Vegetation model (DHSVM, Wigmosta et al., 1994); the Regional Hydro-Ecologic Simulation System (RHESSys, Band et al., 1993; Tague and Band, 2004); ParFlow-Common Land Model (CLM, Maxwell and Miller, 2007); the Penn State Integrated Hydrologic Model (PIHM, Qu and Duffy, 2007); the Soil Moisture Distribution and Routing (SMDR) model (Easton et al., 2007); and that of Xiao et al. (2007).

One advantage of integrating surface and subsurface flow systems within any of these model structures is the ability to incorporate different SCMs by specifying characteristics of specific locations within the flow element networks linked to the subsurface drainage. Examples can include alteration of surface detention storage and release curves to simulate detention ponds, or soil depth, texture, vegetation, and drainage release for rainfall gardens. The advantage of this approach is the tight coupling of these SCM features with the connected surface and subsurface drainage systems, allowing the direct incorporation of the SCM as sink or source terms within the flowpath network. Burgess et al. (1998) effectively demonstrated that suburban lawns can become the major source of stormwater in seasonally wet conditions (Seattle), while Cuo et al. (2008) have explored the modification of DHSVM to include detention SCMs. Xiao et al. (2007) explicitly integrated and evaluated parcel scale SCM design and efficiency into their model. Wang et al. (2008) integrated a canopy interception model with a semi-distributed subsurface moisture scheme (TOPMODEL) to evaluate the effectiveness of urban tree canopy interception on stormwater production, utilizing a detailed spatial dataset of urban tree cover. Band et al. (2001) and Law (2003) coupled a water-, carbon-, and nitrogen-cycling model to a distributed water routing system modified from DHSVM to simulate nitrogen cycling and export in a high-spatial-resolution representation of forested and suburban catchments. While these models have the potential to directly link stormwater generation with specific dischargers, the challenge of scaling to larger watersheds remains. SMDR (Easton et al., 2007) has recently been used to integrate rural and urban stormwater production, including dissolved phosphorus source and transport in New York State.

Alternatives to mass budget-based models include fully statistical approaches such as simple regressions based on watershed land use and population (e.g., Boyer et al., 2002); nonlinear regression using detailed watershed spatial data and observed loads to estimate retention parameters and loading of nutrients, sediment, and other pollutants (e.g., Smith et al., 1997; Brakebill and Preston, 1999; Schwarz et al., 2006); and Bayesian chain models (e.g., Reckhow and Chapra, 1999; Borsuk et al., 2001). These models have the advantage of being data-based, and therefore capable of assimilating observations as they become available to update water quality probabilities, but also lack a process basis that might support management intervention. A major debate exists within the literature as to the relative advantages of detailed process-based models that may not have inadequate information for parameterization, and the more empirical, data-based approaches.

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TABLE 4-7 Example Mathematical Models That Have Been or Can Be Used in Stormwater Modeling

Model	Common Use	Typical Scale	Complexity	Data Requirements	Ground-water	SCM	Reference
Rational Method	Urban hydraulic design—peak flow	Small	Simple	Land cover, rainfall intensity, T_c	None	None	Standard hydrology text
Simple Method	Urban annual runoff, loads	Small to medium	Simple	Impervious surface cover, land use, annual rainfall	None	None	http://www.stormwatercenter.net/monitoring%20and%20assessment/simple%20meth/simple.htm
TR-20 TR-55	Rural/urban runoff production for simple stormwater models, hydraulic design	Small to medium	Simple to medium	Land use, soil texture, T_c	None	Pond sizing for hydraulic benefits and others through CN modification	http://www.wsi.nrcs.usda.gov/products/W2Q/H&H/Tools_Models
GWLF	Rural/urban runoff, pollutant loading	Medium to watershed	Simple to medium	Land use, soil texture, precipitation time series	Simple linear reservoir	Runoff reduction with CN modification	Haith and Shoemaker (1987) http://www.avgwlf.psu.edu/overview.htm
P8	Urban runoff, pollutant loading	Small to large	Simple to medium	Land use, soil texture, precipitation time series, SCM type and sizing	Simple linear reservoir	Runoff reduction with CN modification, ponds (evaluation and sizing), infiltration, street cleaning	Palmstrom and Walker (1990) http://www.wwwalker.net/p8/
MUSIC	Urban runoff, pollutant loading, hydraulic design, simple receiving water	Small to large	Medium to complex	Land use, soil texture, precipitation/PET? time series, drainage system details, SCM type and sizing	Simple linear reservoir	Comprehensive evaluation of SCM systems	Wong (2000) (proprietary) http://www.toolkit.net.au/cgi-bin/WebObjects/toolkit.woa/wa/productDetails?productID=1000000

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Model	Common Use	Typical Scale	Complexity	Data Requirements	Ground-water	SCM	Reference
SWMM	Urban runoff, pollutant loading, hydraulic design	Small to large	Medium to complex	Land use, soil texture, meteorological time series, drainage system details, SCM type and sizing	Simple linear reservoir?	Infiltration practices, ponds, street cleaning	http://www.epa.gov/ednnrmrl/models/swmm
PCSWMM	Same as above	Same as above	Same as above	Same as above	Same as above	Enhanced SCM compared to SWMM	(proprietary) http://www.computationalhydraulics.com/Software/PCSWMM.NET
WinSLAMM	Urban runoff, pollutant loads	Small to large	Intermediate	Land cover, land use, development characteristics, soil texture, compaction, rainfall event time series, monthly PET, monthly water evaporation, SCM type and sizing	Mounding under infiltration controls	Comprehensive evaluation of SCM systems	(proprietary) http://www.winslamm.com/prod01.htm
SWAT	Rural runoff, loading	Medium to watershed	Intermediate	Land cover/land use, soil texture, precipitation, temperature, humidity, solar radiation time or PET series	Simple subbasin reservoir	Impoundments, agricultural conservation practices, nutrient management, buffers	http://www.epa.gov/waterscience/BASINS/bsnsdocs.html#swat
HSPF	Comprehensive watershed evaluation, receiving water dynamics	Medium to watershed	Complex	Land cover/land use, soil texture, precipitation, temperature, humidity, solar radiation or PET time series	Subbasin reservoir	Infiltration, ponds	Bicknell et al. (2005) http://www.epa.gov/ceampubl/swater/hspf/index.htm http://www.epa.gov/waterscience/BASINS/bsnsdocs.html#hspf

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Model	Common Use	Typical Scale	Complexity	Data Requirements	Ground-water	SCM	Reference
WWHM	HSPF engine with regional modifications,	Puget Sound	Complex	Same as above	Same as above	Enhanced infiltration, ponds (from HSPF)	http://www.ecy.wa.gov/programs/wg/stormwater/wwhm_training/index.html.
CBWM	HSPF engine with regional modifications, integration specific spatial data processing	Chesapeake Bay Watershed	Complex	Same as above	Same as above	Enhanced infiltration, ponds (from HSPF)	http://www.chesapeakebay.net/phase5.htm

Note: CN, curve number

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Limitations in Extending Stormwater Models to Biological Impacts

The mass budget approach may be successful in developing the physical and chemical characteristics of the receiving waterbody in terms of the flow (or stage) duration curve, the distribution of concentrations over time, and the integrated pollutant storage and flux (load) terms. However, the biological status of the waterbody requires a link between the physical and chemical conditions, primary productivity, and trophic system interactions. Progressing from aquatic ecosystem productivity to trophic systems includes increasingly complex ecological processes such as competition, herbivory, predation, and migration. To date, mechanistic linkage between flow path hydraulics, biogeochemistry, and the ecological structure of the aquatic environment has not been developed. Instead, habitat suitability for different communities is identified through empirical sampling and analysis, with the implicit assumption that, as relative habitat suitability changes, transitions will occur between species or assemblages. These methods may work well at the base of the trophic system (algae, phytoplankton) and for specific conditions such as DO limitations on fish communities, but the impacts of low to moderate concentrations of pollutants on aquatic ecosystems may still be poorly understood. A critical assumption in these and similar models (e.g., ecological community change resulting from physical changes to the watershed or climate) is the substitution of space for time. More detailed understanding of the mechanisms leading to a shift in ecological communities and interactions with the physical environment is necessary to develop models of transient change, stability of the shifts, and feedback to the biophysical environment.

Given these limitations, it should be noted that statistical databases on species tolerance to a range of aquatic conditions have been compiled that will allow the development of habitat suitability mapping as a mechanism for (1) targeting ecosystem restoration, (2) determining vulnerable sites (for use in application of the Endangered Species Act), and (3) assessing aquatic ecosystem impairment and “best use” relative to reference sites.

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Stormwater models have been developed to meet a range of objectives, including small-scale hydraulic design (e.g., siting and sizing a detention pond), estimation of potential contributions of stormwater pollutants from different land covers and locations using empirically generated EMC, and large watershed hydrology and gross pollutant loading. The ability to associate a given discharger with a particular waterbody impairment is limited by the scale and complexity of watersheds (i.e., there maybe multiple discharge interactions); by the ability of a model to accurately reproduce the distribution function of discharge events and their cumulative impacts (as opposed to focusing only on design storms of specific return periods); and by the availability of monitoring data of sufficient number and design to characterize basic processes (e.g., build-up/wash-off), to parameterize the models, and to validate model predictions.

In smaller urban catchments with few dominant dischargers and significant impervious area, current modeling capabilities may be sufficient to associate the cumulative impact of discharge to waterbody impairment. However, many impaired waterbodies have larger, more heterogeneous stormwater sources, with impacts that are complex functions of current and past conditions. The level of sampling that would be necessary to support linked model calibration and verification using current measurement technologies is both time-consuming and expensive.

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In order to develop a more consistent capability to support stormwater permitting needs, there should be increased investment in improving model paradigms, especially the practice and methods of model linkage as described above, and in stormwater monitoring. The latter may require investment in a new generation of sensors that can sample at temporal resolutions that can adjust to characterize low flow and the dynamics of storm flow, but are sufficiently inexpensive and autonomous to be deployed in multiple locations from distributed sources to receiving waterbodies of interest. Finally, as urban areas extend to encompass progressively lower-density development, the interactions of surface water and groundwater become more critical to the cumulative impact of stormwater on impaired waterbodies.

EPA needs to ensure continuous support and development of their water quality models and spatial data infrastructure. Beyond this, a set of distributed watershed models has been developed that can resolve the location and position of parcels within hydrologic flow fields; these are being modified for use as urban stormwater models. These models avoid the pitfalls of lumping, but they require much greater volumes of spatial data, provided by current remote sensing technology (e.g., lidar, airborne digital optical and infrared sensors) as well as the emerging set of in-stream sensor systems. While these methods are not yet operational or widespread, they should be further investigated and tested for their capabilities to support stormwater management.

CONCLUSIONS AND RECOMMENDATIONS

This chapter addresses what might be the two weakest areas of the stormwater program—monitoring and modeling of stormwater. The MS4 and particularly the industrial stormwater monitoring programs suffer from (1) a paucity of data, (2) inconsistent sampling techniques, (3) a lack of analyses of available data and guidance on how permittees should be using the data to improve stormwater management decisions, and (4) requirements that are difficult to relate to the compliance of individual dischargers. The current state of stormwater modeling is similarly limited. Stormwater modeling has not evolved enough to consistently say whether a particular discharger can be linked to a specific waterbody impairment, although there are many correlative studies showing how parameters co-vary in important but complex and poorly understood ways (see Chapter 3). Some quantitative predictions can be made, particularly those that are based on well-supported causal relationships of a variable that responds to changes in a relatively simple driver (e.g., modeling how a runoff hydrograph or pollutant loading change in response to increased impervious land cover). However, in almost all cases, the uncertainty in the modeling and the data, the scale of the problems, and the presence of multiple stressors in a watershed make it difficult to assign to any given source a specific contribution to water quality impairment. More detailed conclusions and recommendations about monitoring and modeling are given below.

Because of a ten-year effort to collect and analyze monitoring data from MS4s nationwide, the quality of stormwater from urbanized areas is well characterized. These results come from many thousands of storm events, systematically compiled and widely accessible; they form a robust dataset of utility to theoreticians and practitioners alike. These data make it possible to accurately estimate the EMC of many pollutants. Additional data are available from other stormwater permit holders that were not originally included in the database

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and from ongoing projects, and these should be acquired to augment the database and improve its value in stormwater management decision-making.

Industry should monitor the quality of stormwater discharges from certain critical industrial sectors in a more sophisticated manner, so that permitting authorities can better establish benchmarks and technology-based effluent guidelines. Many of the benchmark monitoring requirements and effluent guidelines for certain industrial subsectors are based on inaccurate and old information. Furthermore, there has been no nationwide compilation and analysis of industrial benchmark data, as has occurred for MS4 monitoring data, to better understand typical stormwater concentrations of pollutants from various industries. The absence of accurate benchmarks and effluent guidelines for critical industrial sectors discharging stormwater may explain the lack of enforcement by permitting authorities, as compared to the vigorous enforcement within the wastewater discharge program.

Industrial monitoring should be targeted to those sites having the greatest risk associated with their stormwater discharges. Many industrial sites have no or limited exposure to runoff and should not be required to undertake extensive monitoring. Visual inspections should be made, and basic controls should be implemented at these areas. Medium-risk industrial sites should conduct monitoring so that a sufficient number of storms are measured over the life of the permit for comparison to regional benchmarks. Again, visual inspections and basic controls are needed for these sites, along with specialized controls to minimize discharges of the critical pollutants. Stormwater from high-risk industrial sites needs to be continuously monitored, similar to current point source monitoring practices. The use of a regionally calibrated stormwater model and random monitoring of the lower-risk areas will likely require additional monitoring.

Continuous, flow-weighted sampling methods should replace the traditional collection of stormwater data using grab samples. Data obtained from too few grab samples are highly variable, particularly for industrial monitoring programs, and subject to greater uncertainly because of experimenter error and poor data-collection practices. In order to use stormwater data for decision making in a scientifically defensible fashion, grab sampling should be abandoned as a credible stormwater sampling approach for virtually all applications. It should be replaced by more accurate and frequent continuous sampling methods that are flow weighted. Flow-weighted composite monitoring should continue for the duration of the rain event. Emerging sensor systems that provide high temporal resolution and real-time estimates for specific pollutants should be further investigated, with the aim of providing lower costs and more extensive monitoring systems to sample both streamflow and constituent loads.

Flow monitoring and on-site rainfall monitoring need to be included as part of stormwater characterization monitoring. The additional information associated with flow and rainfall data greatly enhance the usefulness of the much more expensive water quality monitoring. Flow monitoring should also be correctly conducted, with adequate verification and correct base-flow subtraction methods applied. Using regional rainfall data from locations distant from the monitoring location is likely to be a major source of error when rainfall factors are being investigated. The measurement, quality assurance, and maintenance of long-term precipitation records are both vital and nontrivial to stormwater management.

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Whether a first flush of contaminants occurs at the start of a rainfall event depends on the intensity of rainfall, the land use, and the specific pollutant. First flushes are more common for smaller sites with greater imperviousness and thus tend to be associated with more intense land uses such as commercial areas. Even though a site may have a first flush of a constituent of concern, it is still important that any SCM be designed to treat as much of the runoff from the site as possible. In many situations, elevated discharges may occur later in an event associated with delayed periods of peak rainfall intensity.

Stormwater runoff in arid and semi-arid climates demonstrates a seasonal first-flush effect (i.e., the dirtiest storms are the first storms of the season). In these cases, it is important that SCMs are able to adequately handle these flows. As an example, early spring rains mixed with snowmelt may occur during periods when wet detention ponds are still frozen, hindering their performance. The first fall rains in the southwestern regions of the United States may occur after extended periods of dry weather. Some SCMs, such as street cleaning targeting leaf removal, may be more effective before these rains than at other times of the year.

Watershed models are useful tools for predicting downstream impacts from urbanization and designing mitigation to reduce those impacts, but they are incomplete in scope and typically do not offer definitive causal links between polluted discharges and downstream degradation. Every model simulates only a subset of the multiple interconnections between physical, chemical, and biological processes found in any watershed, and they all use a grossly simplified representation of the true spatial and temporal variability of a watershed. To speak of a "comprehensive watershed model" is thus an oxymoron, because the science of stormwater is not sufficiently far advanced to determine causality between all sources, resulting stressors, and their physical, chemical, and biological responses. Thus, it is not yet possible to create a protocol that mechanistically links stormwater dischargers to the quality of receiving waters. The utility of models with more modest goals, however, can still be high—as long as the questions being addressed by the model are in fact relevant and important to the functioning of the watershed to which that model is being applied, and sufficient data are available to calibrate the model for the processes included therein.

EPA needs to ensure that the modeling and monitoring capabilities of the nation are continued and enhanced to avoid losing momentum in understanding and eliminating stormwater pollutant discharges. There is a need to extend, develop, and support current modeling capabilities, emphasizing (1) the impacts of flow energy, sediment transport, contaminated sediment, and acute and chronic toxicity on biological systems in receiving waterbodies; (2) more mechanistic representation (physical, chemical, biological) of SCMs; and (3) coupling between a set of functionally specific models to promote the linkage of source, transport and transformation, and receiving water impacts of stormwater discharges. Stormwater models have typically not incorporated interactions with groundwater and have treated infiltration and recharge of groundwater as a loss term with minimal consideration of groundwater contamination or transport to receiving waterbodies. Emerging distributed modeling paradigms that simulate interactions of surface and subsurface flowpaths provide promising tools that should be further developed and tested for applications in stormwater analysis.

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Chapter 5
Stormwater Management Approaches

A fundamental component of the U.S. Environmental Protection Agency's (EPA) Stormwater Program, for municipalities as well as industries and construction, is the creation of stormwater pollution prevention plans. These plans invariably document the stormwater control measures that will be used to prevent the permittee's stormwater discharges from degrading local waterbodies. Thus, a consideration of these measures—their effectiveness in meeting different goals, their cost, and how they are coordinated with one another—is central to any evaluation of the Stormwater Program. This report uses the term stormwater control measure (SCM) instead of the term best management practice (BMP) because the latter is poorly defined and not specific to the field of stormwater.

The committee's statement of task asks for an evaluation of the relationship between different levels of stormwater pollution prevention plan implementation and in-stream water quality. As discussed in the last two chapters, the state of the science has yet to reveal the mechanistic links that would allow for a full assessment of that relationship. However, enough is known to design systems of SCMs, on a site scale or local watershed scale, to lessen many of the effects of urbanization. Also, for many regulated entities the current approach to stormwater management consists of choosing one or more SCMs from a preapproved list. Both of these facts argue for the more comprehensive discussion of SCMs found in this chapter, including information on their characteristics, applicability, goals, effectiveness, and cost. In addition, a multitude of case studies illustrate the use of SCMs in specific settings and demonstrate that a particular SCM can have a measurable positive effect on water quality or a biological metric. The discussion of SCMs is organized along the gradient from the rooftop to the stream. Thus, pollutant and runoff prevention are discussed first, followed by runoff reduction and finally pollutant reduction.

HISTORICAL PERSPECTIVE ON STORMWATER CONTROL MEASURES

Over the centuries, SCMs have met different needs for cities around the world. Cities in the Mesopotamian Empire during the second millennium BC had practices for flood control, to convey waste, and to store rain water for household and irrigation uses (Manor, 1966) (see Figure 5-1). Today, SCMs are considered a vital part of managing flooding and drainage problems in a city. What is relatively new is an emphasis on using the practices to remove pollutants from stormwater and selecting practices capable of providing groundwater recharge. These recent expectations for SCMs are not readily accepted and require an increased commitment to the proper design and maintenance of the practices.

With the help of a method for estimating peak flows (the Rational Method, see Chapter 4), the modern urban drainage system came into being soon after World War II. This generally consisted of a system of catch basins and pipes to prevent flooding and drainage problems by efficiently delivering runoff water to the nearest waterbody. However, it was soon realized that delivering the water too quickly caused severe downstream flooding and bank erosion in the receiving water. To prevent bank erosion and provide more space for flood waters, some stream channels were enlarged and lined with concrete (see Figure 5-2). But while hardening and

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FIGURE 5-1 Cistern tank, Kamiros, Rhodes (ancient Greece, 7th century BC). SOURCE: Robert Pitt.

FIGURE 5-2 Concrete channel in Lincoln Creek, Milwaukee, Wisconsin. SOURCE: Roger Bannerman.

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enlarging natural channels is a cost-effective solution to erosion and flooding, the modified channel increases downstream peak flows and it does not provide habitat to support a healthy aquatic ecosystem.

Some way was needed to control the quantity of water reaching the end of pipes during a runoff event, and on-site detention (Figure 5-3) became the standard for accomplishing this. Ordinances started appearing in the early 1970s, requiring developers to reduce the peaks of different size storms, such as the 10-year, 24-hour storm. The ordinances were usually intended to prevent future problems with peak flows by requiring the installation of flow control structures, such as detention basins, in new developments. Detention basins can control peak flows directly below the point of discharge and at the property boundary. However, when designed on a site-by-site basis without taking other basins into account, they can lead to downstream flooding problems because volume is not reduced (McCuen, 1979; Ferguson, 1991; Traver and Chadderton, 1992; EPA, 2005d). In addition, out of concerns for clogging, openings in the outlet structure of most basins are generally too large to hold back flows from smaller, more frequent storms. Furthermore, low-flow channels have been constructed or the basins have been graded to move the runoff through the structure without delay to prevent wet areas and to make it easier to mow and maintain the detention basin.

Because of the limitations of on-site detention, infiltration of urban runoff to control its volume has become a recent goal of stormwater management. Without stormwater infiltration, municipalities in wetter regions of the country can expect drops in local groundwater levels, declining stream base flows (Wang et al., 2003a), and flows diminished or stopped altogether from springs feeding wetlands and lakes (Leopold, 1968; Ferguson, 1994).

The need to provide volume control marked the beginning of low-impact development (LID) and conservation design (Arendt, 1996; Prince George's County, 2000), which were founded on the seminal work of landscape architect Ian McHarg and associates decades earlier (McHarg and Sutton, 1975; McHarg and Steiner, 1998). The goal of LID is to allow for development of a site while maintaining as much of its natural hydrology as possible, such as infiltration, frequency and volume of discharges, and groundwater recharge. This is accomplished with infiltration practices, functional grading, open channels, disconnection of

FIGURE 5-3 On-site detention. SOURCE: Tom Schueler.

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impervious areas, and the use of fewer impervious surfaces. Much of the LID focus is to manage the stormwater as close as possible to its source—that is, on each individual lot rather than conveying the runoff to a larger regional SCM. Individual practices include rain gardens (see Figure 5-4), disconnected roof drains, porous pavement, narrower streets, and grass swales. In some cases, LID site plans still have to include a method for passing the larger storms safely, such as a regional infiltration or detention basin or by increasing the capacity of grass swales.

Infiltration has been practiced in a few scattered locations for a long time. For example, on Long Island, New York, infiltration basins were built starting in 1930 to reduce the need for a storm sewer system and to recharge the aquifer, which was the only source of drinking water (Ferguson, 1998). The Cities of Fresno, California, and El Paso, Texas, which faced rapidly dropping groundwater tables, began comprehensive infiltration efforts in the 1960s and 1970s. In the 1980s Maryland took the lead on the east coast by creating an ambitious statewide infiltration program. The number of states embracing elements of LID, especially infiltration, has increased during the 1990s and into the new century and includes California, Florida, Minnesota, New Jersey, Vermont, Washington, and Wisconsin.

FIGURE 5-4 Rain Garden in Madison, Wisconsin. SOURCE: Roger Bannerman.

Evidence gathered in the 1970s and 1980s suggested that pollutants be added to the list of things needing control in stormwater (EPA, 1983). Damages caused by elevated flows, such as stream habitat destruction and floods, were relatively easy to document with something as simple as photographs. Documentation of elevated concentrations of conventional pollutants and potentially toxic pollutants, however, required intensive collection of water quality samples during runoff events. Samples collected from storm sewer pipes and urban streams in the Menomonee River watershed in the late 1970s clearly showed the concentrations of many pollutants, such as heavy metals and sediment, were elevated in urban runoff (Bannerman et al., 1979). Levels of heavy metals were especially high in industrial-site runoff, and construction-site erosion was calculated to be a large source of sediment in the watershed. This study was followed by the National Urban Runoff Program, which added more evidence about the high levels of some pollutants found in urban runoff (Athayde et al., 1983; Bannerman et al., 1983).

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With new development rapidly adding to the environmental impacts of existing urban areas, the need to develop good stormwater management programs is more urgent than ever. For a variety of reasons, the greatest potential for stormwater management to reduce the footprint of urbanization is in the suburbs. These areas are experiencing the fastest rates of growth, they are more amenable to stormwater management because buildings and infrastructure are not yet in place, and costs for stormwater management can be borne by the developer rather than by taxpayers. Indeed, most structural SCMs are applied to new development rather than existing urban areas. Many of the most innovative stormwater programs around the country are found in the suburbs of large cities such as Seattle, Austin, and Washington, D.C. When stormwater management in ultra-urban areas is required, it entails the retrofitting of detention basins and other flow control structures or the introduction of innovative below-ground structures characterized by greater technical constraints and higher costs, most of which are charged to local taxpayers.

Current-day SCMs represent a radical departure from past practices, which focused on dealing with extreme flood events via large detention basins designed to reduce peak flows at the downstream property line. As defined in this chapter, SCMs now include practices intended to meet broad watershed goals of protecting the biology and geomorphology of receiving waters in addition to flood peak protection. The term encompasses such diverse actions as using more conventional practices like basins and wetland to installing stream buffers, reducing impervious surfaces, and educating the public.

REVIEW OF STORMWATER CONTROL MEASURES

Stormwater control measures refer to what is defined by EPA (1999) as "a technique, measure, or structural control that is used for a given set of conditions to manage the quantity and improve the quality of stormwater runoff in the most cost-effective manner." SCMs are designed to mitigate the changes to both the quantity and quality of stormwater runoff that are caused by urbanization. Some SCMs are engineered or constructed facilities, such as a stormwater wetland or infiltration basin, that reduce pollutant loading and modify volumes and flow. Other SCMs are preventative, including such activities as education and better site design to limit the generation of stormwater runoff or pollutants.

Stormwater Management Goals

It is impossible to discuss SCMs without first considering the goals that they are expected to meet. A broadly stated goal for stormwater management is to reduce pollutant loads to waterbodies and maintain, as much as possible, the natural hydrology of a watershed. On a practical level, these goals must be made specific to the region of concern and embedded in the strategy for that region. Depending on the designated uses of the receiving waters, climate, geomorphology, and historical development, a given area may be more or less sensitive to both pollutants and hydrologic modifications. For example, goals for groundwater recharge might be higher in an area with sandy soils as compared to one with mostly clayey soils; watersheds in the coastal zone may not require hydrologic controls. Ideally, the goals of stormwater management should be linked to the water quality standards for a given state's receiving waters. However,

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because of the substantial knowledge gap about the effect of a particular stormwater discharge on a particular receiving water (see Chapter 3 conclusions), surrogate goals are often used by state stormwater programs in lieu of water quality standards. Examples include credit systems, mandating the use of specific SCMs, or achieving stormwater volume reduction. Credit systems might be used for practices that are known to be productive but are difficult to quantify, such as planting trees. Specific SCMs might be assumed to remove a percent of pollutants, for example 85 percent removal of total suspended solids (TSS) within a stormwater wetland. Reducing the volume of runoff from impervious surfaces (e.g., using an infiltration device) might be assumed to capture the first flush of pollutants during a storm event. Before discussing specific state goals, it is worth understanding the broader context in which goals are set.

Trade-offs Between Stormwater Control Goals and Costs

The potentially substantial costs of implementing SCMs raise a number of fundamental social choices concerning land-use decisions, designated uses, and priority setting for urban waters. To illustrate some of these choices, consider a hypothetical urban watershed with three possible land-cover scenarios: 25, 50, and 75 percent impervious surface. A number of different beneficial uses could be selected for the streams in this watershed. At a minimum, the goal may be to establish low-level standards to protect public health and safety. To achieve this, sufficient and appropriate SCMs might be applied to protect residents from flooding and achieve water quality conditions consistent with secondary human contact. Alternatively, the designated use could be to achieve the physical, chemical, and/or biological conditions sufficient to provide exceptional aquatic habitat (e.g., a high-quality recreational fishery). The physical, biological, and chemical conditions supportive of this use might be similar to a reference stream located in a much less disturbed watershed. Achieving this particular designated use would require substantially greater resources and effort than achieving a secondary human contact use. Intermediate designated uses could also be imagined, including improving ambient water quality conditions that would make the water safe for full-body emersion (primary human contact) or habitat conditions for more tolerant aquatic species.

Figure 5-5 sketches what the marginal (incremental) SCM costs (opportunity costs) might be to achieve different designated uses given different amounts of impervious surface in the watershed. The horizontal axis orders potential designated uses in terms of least difficult to most difficult to achieve. The three conceptual curves represent the SCM costs under three different impervious surface scenarios. The relative positions of the cost curves indicate that achieving any specific designated use will be more costly in situations with a higher percentage of the watershed in impervious cover. All cost curves are upward sloping, reflecting the fact that incremental improvements in designated uses will be increasingly costly to achieve. The cost curves are purely conceptual, but nonetheless might reasonably reflect the relative costs and direction of change associated with achieving specific designated uses in different watershed conditions.

The locations of the cost curves suggest that in certain circumstances not all designated uses can be achieved or can be achieved only at an extremely high cost. For example, the attainment of exceptional aquatic uses may be unachievable in areas with 50 percent impervious surface even with maximum application of SCMs. In this illustration, the cost of achieving even secondary human contact use is high for areas with 75 percent impervious surfaces. In such

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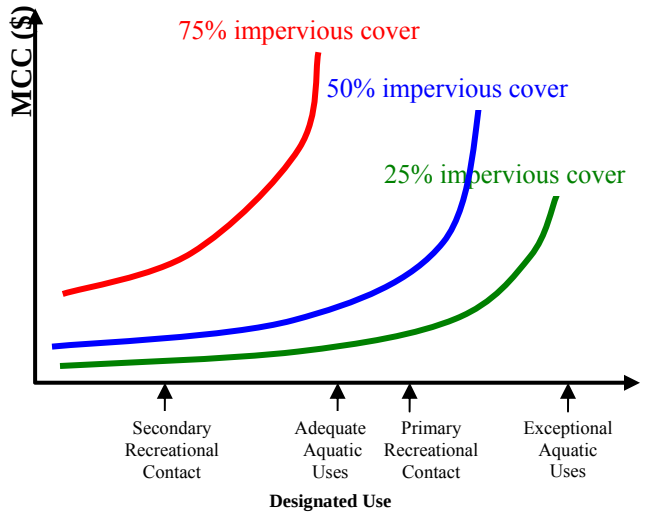

FIGURE 5-5 Cost of achieving designated uses in a hypothetical urban watershed. MCC is the marginal control cost, which represents the incremental costs to achieve successive expansion of designated uses through SCMs. The curves are constructed on the assumption that the lowest cost combination of SCMs would be implemented at each point on the curve.

highly urbanized settings, achievement of only adequate levels of aquatic uses could be exceedingly high and strain the limits of what is technically achievable. Finally, the existing and likely expected future land-use conditions have significant implications for what is achievable and at what cost. Clearly land-use decisions have an impact on the cost and whether a use can be achieved, and thus they need to be included in the decision process. The trade-off between costs and achieving specific designated uses can change substantially given different development patterns.

The purpose of Figure 5-5 is not to identify the precise location of the cost curves or to identify thresholds for achieving specific designated uses. Rather, these concepts are used to illustrate some fundamental trade-offs that confront public and private investment and regulatory decisions concerning stormwater management. The general relationships shown in Figure 5-5 suggest the need for establishing priorities for investments in stormwater management and controls, and connecting land usage and watershed goals. Setting overly ambitious or costly goals for urban streams may result in the perverse consequence of causing more waters to fail to meet designated uses. For example, consider efforts to secure ambitious designated uses in highly developed areas or in an area slated for future high-density development. Regulatory requirements and investments to limit stormwater quantity and quality through open-space requirements, areas set aside for infiltration and water detention, and strict application of maximum extent practicable controls have the effect of both increasing development costs and diminishing land available for residential and commercial properties. Policies designed to achieve exceedingly costly or infeasible designated uses in urban or urbanizing areas could have the net consequence of shifting development (and associated impervious surface) out into neighboring areas and watersheds. The end result might be minimal improvements in "within-watershed" ambient conditions but a decrease in designated uses (more impairments) elsewhere.

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In such a case, it might be sound water quality policy to accept higher levels of impervious surface in targeted locations, more stormwater-related impacts, and less ambitious designated uses in urban watersheds in order to preserve and protect designated uses in other watersheds.

Setting unrealistic or unachievable water quality objectives in urban areas can also pose political risks for stormwater management. The cost and difficulty of achieving ambitious water quality standards for urban stream goals may be understood by program managers but pursued nonetheless in efforts to demonstrate public commitment to achieving high-quality urban waters. Yet, promising what cannot be realistically achieved may act to undermine public support for urban stormwater programs. Increasing costs without significant observable improvements in ambient water conditions or achievement of water quality standards could ultimately reduce public commitment to the program. Thus, there are risks of "setting the bar" too high, or not coordinating land use and designated stream uses.

The cost of setting the bar too low can also be significant. Stormwater requirements that result in ineffective stormwater management will not achieve or maintain the desired water uses and can result in impairments. Loss of property, degraded waters, and failed infrastructure are tangible costs to the public (Johnston et al., 2006). Streambank rehabilitation costs can be severe, and loss of confidence in the ability to meet stormwater goals can result.

The above should not be construed as an argument for or against devoting resources to SCMs; rather, such decisions should be made with an open and transparent acknowledgment and understanding of the costs and consequences involved in those decisions.

Common State Stormwater Goals

Most states do not and have never had an overriding water quality objective in their stormwater program, but rather have used engineering criteria for SCM performance to guide stormwater management. These criteria can be loosely categorized as

- Erosion and sedimentation control,
- Recharge/base flow,
- Water quality,
- Channel protection, and
- Flooding events.

The SCMs used to address these goals work by minimizing or eliminating increases in stormwater runoff volume, peak flows, and/or the pollutant load carried by stormwater.

The criteria chosen by any given state usually integrate state, federal, and regional laws and regulations. Areas of differing climates may emphasize one goal over another, and the levels of control may vary drastically. Contrast a desert region where rainwater harvesting is extremely important versus a coastal region subject to hurricanes. Some areas like Seattle have frequent smaller volume rainfalls—the direct opposite of Austin, Texas—such that small volume controls would be much more effective in Seattle than Austin. Regional geology (karst) or the presence of Brownfields may affect the chosen criteria as well.

The committee's survey of State Stormwater Programs (Appendix C) reflects a wide variation in program goals as reflected in the criteria found in their SCM manuals. Some states have no specific criteria because they do not produce SCM manuals, while others have manuals that address every category of criteria from flooding events to groundwater recharge. Some states rely upon EPA or other states' or transportation agencies' manuals. In general, soil and

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erosion control criteria are the most common and often exist in the absence of any other state criteria. This wide variation reflects the difficulties that states face in keeping up with rapidly changing information about SCM design and performance.

The criteria are ordered below (after the section on erosion and sediment control) according to the size of the storm they address, from smallest to most extreme. The criteria can be expressed in a variety of ways, from a simple requirement to control a certain volume of rainfall or runoff (expressed as a depth) to the size of a design storm to more esoteric requirements, such as limiting the time that flow can be above a certain threshold. The volumes of rainfall or runoff are based on statistics of a region's daily rainfall, and they approximate one another as the percentage of impervious cover increases. Design storms for larger events that address channel protection and flooding are usually based on extreme event statistics and tend to represent a temporal pattern of rainfall over a set period, usually a day. Finally, it should be noted that the categories are not mutually exclusive; for example, recharge of groundwater may enhance water quality via pollutant removal during the infiltration process.

Erosion and Sedimentation Control. This criterion refers to the prevention of erosion and sedimentation of sites during construction and is focused at the site level. Criteria usually include a barrier plan to prevent sedimentation from leaving the site (e.g., silt fences), practices to minimize the potential erosion (phased construction), and facilities to capture and remove sediment from the runoff (detention). Because these measures are considered temporary, smaller extreme events are designated as the design storm than what typically would be used if flood control were the goal.

Recharge/Base Flow. This criterion is focused on sustaining the preconstruction hydrology of a site as it relates to base flow and recharge of groundwater supplies. It may also include consideration of water usage of the property owners and return through septic tanks and tile fields. The criterion, expressed as a volume requirement, is usually to capture around 0.5 to 1.0 inch of runoff from impervious surfaces depending on the climate and soil type of the region. (For this range of rainfall, very little runoff occurs from grass or forested areas, which is why runoff from impervious surfaces is used as the criterion.)

Water Quality. Criteria for water quality are the most widespread, and are usually crafted as specific percent removal for pollutants in stormwater discharge. Generally, a water quality criterion is based on a set volume of stormwater being treated by the SCM. The size of the storm can run from the first inch of rainfall off impervious surfaces to the runoff from the one-year, 24-hour extreme storm event. It should be noted that the term "water quality" covers a wide range of groundwater and surface water pollutants, including water temperature and emerging contaminants.

Many of the water quality criteria are surrogates for more meaningful parameters that are difficult to quantify or cannot be quantified, or they reflect situations where the science is not developed enough to set more explicit goals. For example, the Wisconsin state requirement of an 80 percent reduction in TSS in stormwater discharge does not apply to receiving waters themselves. However, it presumes that there will be some water quality benefits in receiving waters; that is, phosphorus and fecal coliform might be captured by the TSS requirement. Similarly water quality criteria may be expressed as credits for good practices, such as using LID, street sweeping, or stream buffers.

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Channel Protection. This criterion refers to protecting channels from accelerated erosion during storm events due to the increased runoff. It is tied to either the presumed "channel-forming event"—what geomorphologists once believed was the storm size that created the channel due to erosion and deposition—or to the minimum flow that accomplishes any degree of sediment transport. It is generally defined as somewhere between the one- and five-year, 24-hour storm event or a discharge level typically exceeded once to several times per year. Some states require a reduction in runoff volume for these events to match preconstruction levels. Others may require that the average annual duration of flows that are large enough to erode the streambank be held the same on an annual basis under pre- and postdevelopment conditions.

It is not uncommon to find states where a channel protection goal will be written poorly, such that it does not actually prevent channel widening. For example, MacRae (1997) presented a review of the common "zero runoff increase" discharge criterion, which is commonly met by using ponds designed to detain the two-year, 24-hour storm. MacRae showed that stream bed and bank erosion occur during much lower events, namely mid-depth flows that generally occur more often than once a year, not just during bank-full conditions (approximated by the two-year event). This finding is entirely consistent with the well-established geomorphological literature (e.g., Pickup and Warner, 1976; Andrews, 1984; Carling, 1988; Sidle, 1988). During monitoring near Toronto, MacRae found that the duration of the geomorphically significant predevelopment mid-bankfull flows increased by more than four-fold after 34 percent of the basin had been urbanized. The channel had responded by increasing in cross-sectional area by as much as three times in some areas, and was still expanding.

Flooding Events. This criterion addresses public safety and the protection of property and is applicable to storm events that exceed the channel capacity. The 10- through the 100-year storm is generally used as the standard. Volume-reduction SCMs can aid or meet this criterion depending on the density of development, but usually assistance is needed in the form of detention SCMs. In some areas, it may be necessary to reduce the peak flow to below preconstruction levels in order to avoid the combined effects of increased volume, altered timing, and a changed hydrograph. It should be noted that some states do not consider the larger storms (100-year) to be a stormwater issue and have separate flood control requirements.

Each state develops a framework of goals, and the corresponding SCMs used to meet them, which will depend on the scale and focus of the stormwater management strategy. A few states have opted to express stormwater goals within the context of watershed plans for regions of the state. However, the setting of goals on a watershed basis is time-consuming and requires study of the watersheds in question. The more common approach has been to set generic or minimal controls for a region that are not based on a watershed plan. This has been done in Maryland, Wisconsin (see Box 5-1), and Pennsylvania (see Box 5-2). This strategy has the advantage of more rapid implementation of some SCMs because watershed management plans are not required. In order to be applicable to all watersheds in the state, the goals must target common pollutants or flow modification factors where the processes are well known. It must also be possible for these goals to be stated in National Pollutant Discharge Elimination System (NPDES) permits. Many states have selected TSS reduction, volume reduction, and peak flow control as generic goals. A generic goal is not usually based on potentially toxic pollutants, such as heavy metals, due to the complexity of their interaction in the environment, the dependence on

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BOX 5-1
Wisconsin Statewide Goal of TSS Reduction for Stormwater Management

To measure the success of stormwater management, Wisconsin has statewide goals for sediment and flow (Wisconsin DNR, 2002). A lot is known about the impacts of sediment on receiving waters, and any reduction is thought to be beneficial. Flow can be a good indicator of other factors; for example, reducing peak flows will prevent bank erosion.

Developing areas in Wisconsin are required to reduce the annual TSS load by 80 percent compared to no controls (Wisconsin DNR, 2002). Two flow-rated requirements for developing areas are in the administrative rules. One is that the site must maintain the peak flow for the two-year, 24-hour rainfall event. Second, the annual infiltration volume for postdevelopment must be within 90 percent of the predevelopment volumes for residential land uses; the number for non-residential is 60 percent. Both of these flow control goals are thought to also have water quality benefits.

The goal for existing urban areas is an annual reduction in TSS loads. Municipalities must reduce their annual TSS loads by 20 percent, compared to no controls, by 2008. This number is increased to 40 percent by 2013. All of these goals were partially selected to be reasonable based on cost and technical feasibility.

BOX 5-2
Volume-Based Stormwater Goals in Pennsylvania

Pennsylvania has developed a stormwater *Best Management Practices* manual to support the Commonwealth's Storm Water Management Act. This manual and an accompanying sample ordinance advocates two methods for stormwater control based on volume, termed Control Guidance (CG) 1 and 2. The first (CG-1) requires that the runoff volume be maintained at the two-year, 24-hour storm level (which corresponds to approximately 3.5 inches of rainfall in this region) through infiltration, evapotranspiration, or reuse. This criterion addresses recharge/base flow, water quality, and channel protection, as well as helping to meet flooding requirements.

The second method (CG-2) requires capture and removal of the first inch of runoff from paved areas, with infiltration strongly recommended to address recharge and water quality issues. Additionally, to meet channel protection criteria, the second inch is required to be held for 24 hours, which should reduce the channel-forming flows. (This is an unusual criterion in that it is expressed as what an SCM can accomplish, not as the flow that the channel can handle.) Peak flows for larger events are required to be at preconstruction levels or less if the need is established by a watershed plan. These criteria are the starting point for watershed or regional plans, to reduce the effort of plan development. Some credits are available for tree planting, and other nonstructural practices are advocated for dissolved solids mitigation. See http://www.dep.state.pa.us/dep/deputate/watermgt/wc/subjects/stormwatermanagement/default.htm.

the existing baseline conditions, and the need for more understanding on what are acceptable levels. The difficulty with the generic approach is that specific watershed issues are not addressed, and the beneficial uses of waters are not guaranteed.

One potential drawback of a strategy based on a generic goal coupled to the permit process is that the implementation of the goal is usually on a site-by-site basis, especially for developing areas. Generic goals may be appropriate for certain ubiquitous watershed processes and are clearly better than having no goals at all. However, they do not incorporate the effects of differences in past development and any unique watershed characteristics; they should be considered just a good starting point for setting watershed-based goals.

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Role of SCMs in Achieving Stormwater Management Goals

One important fundamental change in SCM design philosophy has come about because of the recent understanding of the roles of smaller storms and of impervious surfaces. This is demonstrated by Box 3-4, which shows that for the Milwaukee area more than 50 percent of the rainfall by volume occurs in storms that have a depth of less then 0.75 inch. If extreme events are the only design criteria for SCMs, the vast majority of the annual rainfall will go untreated or uncontrolled, as it is smaller than the minimum extreme event. This relationship is not the same in all regions. For example, in Austin, Texas, the total yearly rainfall is smaller than in Milwaukee, but a large part of the volume occurs during larger storm events, with long dry periods in between.

The upshot is that the design strategy for stormwater management, including drainage systems and SCMs, should take a region's rainfall and associated runoff conditions into account. For example, an SCM chosen to capture the majority of the suspended solids, recharge the baseflow, reduce streambank erosion, and reduce downstream flooding in Pennsylvania or Seattle (which have moderate and regular rainfall) would likely not be as effective in Texas, where storms are infrequent and larger. In some areas, a reduction in runoff volume may not be sufficient to control streambank erosion and flooding, such that a second SCM like an extended detention stormwater wetland may be needed to meet management goals.

Finally, as discussed in greater detail in a subsequent section, SCMs are most effective from the perspective of both efficiency and cost when stormwater management is incorporated in the early planning stages of a community. Retrofitting existing development with SCMs is much more technically difficult and costly because the space may not be available, other infrastructure is already installed, or utilities may interfere. Furthermore, if the property is on private land or dedicated as an easement to a homeowners association, there may be regulatory limitations to what can be done. Because of these barriers, retrofitting existing urban areas often depends on engineered or manufactured SCMs, which are more expensive in both construction and operation.

Stormwater Control Measures

SCMs reduce or mitigate the generation of stormwater runoff and associated pollutants. These practices include both "structural" or engineered devices as well as more "nonstructural measures" such as land-use planning, site design, land conservation, education, and stewardship practices. Structural practices may be defined as any facility constructed to mitigate the adverse impacts of stormwater and urban runoff pollution. Nonstructural practices, which tend to be longer-term and lower-maintenance solutions, can greatly reduce the need for or increase the effectiveness of structural SCMs. For example, product substitution and land-use planning may be key to the successful implementation of an infiltration SCM. Preserving wooded areas and reducing street widths can allow the size of detention basins in the area to be reduced.

Table 5-1 presents the expansive list of SCMs that are described in this chapter. For most of the SCMs, each listed item represents a class of related practices, with individual methods discussed in greater detail later in the chapter. There are nearly 20 different broad categories of SCMs that can be applied, often in combination, to treat the quality and quantity of stormwater runoff. A primary difference among the SCMs relates to which stage of the development cycle

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they are applied, where in the watershed they are installed, and who is responsible for implementing them.

The development cycle extends from broad planning and zoning to site design, construction, occupancy, retrofitting, and redevelopment. As can be seen, SCMs are applied throughout the entire cycle. The scale at which the SCM is applied also varies considerably. While many SCMs are installed at individual sites as part of development or redevelopment applications, many are also applied at the scale of the stream corridor or the watershed or to existing municipal stormwater infrastructure. The final column in Table 5-1 suggests who would implement the SCM. In general, the responsibility for implementing SCMs primarily resides with developers and local stormwater agencies, but planning agencies, landowners, existing industry, regulatory agencies, and municipal separate storm sewer system (MS4) permittees can also be responsible for implementing many key SCMs.

In Table 5-1, the SCMs are ordered in such a way as to mimic natural systems as rain travels from the roof to the stream through combined application of a series of practices throughout the entire development site. This order is upheld throughout the chapter, with the implication that no SCM should be chosen without first considering those that precede it on the list.

Given that there are 20 different SCM groups and a much larger number of individual design variations or practices within each group, it is difficult to authoritatively define the specific performance or effectiveness of SCMs. In addition, our understanding of their performance is rapidly changing to reflect new research, testing, field experience, and maintenance history. The translation of these new data into design and implementation guidance is accelerating as well. What is possible is to describe their basic hydrologic and water quality objectives and make a general comparative assessment of what is known about their design, performance, and maintenance as of mid-2008. This broad technology assessment is provided in Table 5-2, which reflects the committee's collective understanding about the SCMs from three broad perspectives:

- Is widely accepted design or implementation guidance available for the SCM and has it been widely disseminated to the user community?
- Have enough research studies been published to accurately characterize the expected hydrologic or pollutant removal performance of the SCM in most regions of the country?
- Is there enough experience with the SCM to adequately define the type and scope of maintenance needed to ensure its longevity over several decades?

Affirmative answers to these three questions are needed to be able to reliably quantify or model the ability of the SCM, which is an important element in defining whether the SCM can be linked to improvements in receiving water quality. As will be discussed in subsequent sections of this chapter, there are many SCMs for which there is only a limited understanding, particularly those that are nonstructural in nature.

The columns in Table 5-2 summarize several important factors about each SCM, including the ability of the SCM to meet hydrologic control objectives and water quality objectives, the availability of design guidance, the availability of performance studies, and whether there are maintenance protocols. The hydrologic control objectives range from complete prevention of stormwater flow to reduction in runoff volume and reduction in peak flows. The column on water quality objectives describes whether the SCM can prevent the generation of, or remove, contaminants of concern in stormwater.

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TABLE 5-1 Summary of Stormwater Control Measures—When, Where, and Who

Stormwater Control Measure	When	Where	Who
Product Substitution	Continuous	National, state, regional	Regulatory agencies
Watershed and Land-Use Planning	Planning stage	Watershed	Local planning agencies
Conservation of Natural Areas	Site and watershed planning stage	Site, watershed	Developer, local planning agency
Impervious Cover Minimization	Site planning stage	Site	Developer, local review authority
Earthwork Minimization	Grading plan	Site	Developer, local review authority
Erosion and Sediment Control	Construction	Site	Developer, local review authority
Reforestation and Soil Conservation	Site planning and construction	Site	Developer, local review authority
Pollution Prevention SCMs for Stormwater Hotspots	Post-construction or retrofit	Site	Operators and local and state permitting agencies
Runoff Volume Reduction—Rainwater harvesting	Post-construction or retrofit	Rooftop	Developer, local planning agency and review authority
Runoff Volume Reduction—Vegetated	Post-construction or retrofit	Site	Developer, local planning agency and review authority
Runoff Volume Reduction—Subsurface	Post-construction or retrofit	Site	Developer, local planning agency and review authority
Peak Reduction and Runoff Treatment	Post-construction or retrofit	Site	Developer, local planning agency and review authority
Runoff Treatment	Post-construction or retrofit	Site	Developer, local planning agency and review authority
Aquatic Buffers and Managed Floodplains	Planning, construction and post-construction	Stream corridor	Developer, local planning agency and review authority, landowners
Stream Rehabilitation	Postdevelopment	Stream corridor	Local planning agency and review authority
Municipal Housekeeping	Postdevelopment	Streets and stormwater infrastructure	MS4 Permittee
Illicit Discharge Detection and Elimination	Postdevelopment	Stormwater infrastructure	MS4 Permittee
Stormwater Education	Postdevelopment	Stormwater infrastructure	MS4 Permittee
Residential Stewardship	Postdevelopment	Stormwater infrastructure	MS4 Permittee

Note: Nonstructural SCMs are in italics.

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The availability of design guidance tends to be greatest for the structural practices. Some but not all nonstructural practices are of recent origin, and communities lack available design guidance to include them as an integral element of local stormwater solutions. Where design guidance is available, it may not yet have been disseminated to the full population of Phase II MS4 communities.

The column on the availability of performance data is divided into those SCMs where enough studies have been done to adequately define performance, those SCMs where limited work has been done and the results are variable, and those SCMs where only a handful of studies are available. A large and growing number of performance studies are available that report the efficiencies of structural SCMs in reducing flows and pollutant loading (Strecker et al., 2004; ASCE, 2007; Schueler et al., 2007; Selbig and Bannerman, 2008). Many of these are compiled in the Center for Watershed Protection's National Pollutant Removal Performance Database for Stormwater Treatment Practices (http://www.cwp.org/Resource_Library/Center_Docs/SW/bmpwriteup_092007_v3.pdf), in the International Stormwater BMP Database (http://www.bmpdatabase.org/Docs/Performance%20Summary%20June%202008.pdf), and by the Water Environment Research Foundation (WERF, 2008). In cases where there is incomplete understanding of their performance, often information can be gleaned from other fields including agronomy, forestry, petroleum exploration, and sanitary engineering. Current research suggests that it is not a question if whether structural SCMs "work" but more of a question of to what degree and with what longevity (Heasom et al., 2006; Davis et al., 2008; Emerson and Traver, 2008). There is considerably less known about the performance of nonstructural practices for stormwater treatment, partly because their application has been uneven around the country and it remains fairly low in comparison to structural stormwater practices.

Finally, defined maintenance protocols for SCMs can be nonexistent, emerging, or fully available. SCMs differ widely in the extent to which they can be considered permanent solutions. For those SCMs that work on the individual site scale on private property, such as rain gardens, local stormwater managers may be reluctant to adopt such practices due to concerns about their ability to enforce private landowners to conduct maintenance over time. Similarly, those SCMs that involve local government decisions (such as education, residential stewardship practices, zoning, or street sweeping) may be less attractive because governments are likely to change over time.

The following sections contain more detailed information about the individual SCMs listed in Tables 5-1 and 5-2, including the operating unit processes, the pollutants treated, the typical performance for both runoff and pollutant reduction, the strengths and weaknesses, maintenance and inspection requirements, and the largest sources of variability and uncertainty.

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TABLE 5-2 Current Understanding of Stormwater Control Measure Capabilities

SCM	Hydrologic Control Objectives	Water Quality Objectives	Available Design Guidance	Performance Studies Available	Defined Maintenance Protocols
Product Substitution	NA	Prevention	NA	Limited	NA
Watershed and Land-Use Planning	All objectives	Prevention	Available	Limited	Yes
Conservation of Natural Areas	Prevention	Prevention	Available	None	Yes
Impervious Cover Minimization	Prevention and reduction	Prevention	Available	Limited	No
Earthwork Minimization	Prevention	Prevention	Emerging	Limited	Yes
Erosion and Sediment Control	Prevention and reduction	Prevention and removal	Available	Limited	Yes
Reforestation and Soil Conservation	Prevention and reduction	Prevention and removal	Emerging	None	No
Pollution Prevention SCMs for Hotspots	NA	Prevention	Emerging	Very few	No
Runoff Volume Reduction—Rainwater harvesting	Reduction	NA	Emerging	Limited	Yes
Runoff Volume Reduction—Vegetated (Green Roofs, Bioretention Bioinfiltration, Bioswales)	Reduction and some peak attenuation	Removal	Available	Limited	Emerging
Runoff Volume Reduction—Subsurface (Infiltration Trenches, Pervious Pavements)	Reduction and some peak attenuation	Removal	Available	Limited	Yes
Peak Reduction and Runoff Treatment (Stormwater Wetlands, Dry/Wet Ponds)	Peak attenuation	Removal	Available	Adequate	Yes
Runoff Treatment (Sand Filters, Manufactured Devices)	None	Removal	Emerging	Adequate—sand filters Limited—manufactured devices	Yes
Aquatic Buffers and Managed Floodplains	NA	Prevention and removal	Available	Very few	Emerging
Stream Rehabilitation	NA	Prevention and removal	Emerging	Limited	Unknown
Municipal Housekeeping (Street Sweeping/Storm-Drain Cleanouts)	NA	Removal	Emerging	Limited	Emerging
Illicit Discharge Detection/Elimination	NA	Prevention and removal	Available	Very few	No
Stormwater Education	Prevention	Prevention	Available	Very few	Emerging
Residential Stewardship	Prevention	Prevention	Emerging	Very few	No

Note: Nonstructural SCMs are in italics.

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Key:		
Hydrologic Objective	Water Quality Objective	Available Design Guidance?
Prevention: Prevents generation of runoff **Reduction:** Reduces volume of runoff **Treatment:** Delays runoff delivery only **Peak Attenuation**: Reduction of peak flows through detention	**Prevention**: Prevents generation, accumulation, or wash-off of pollutants and/or reduces runoff volume **Removal:** Reduces pollutant concentrations in runoff by physical, chemical, or biological means	**Available:** Basic design or implementation guidance is available in most areas of the country are readily available **Emerging:** Design guidance is still under development, is missing in many parts of the country, or requires more performance data
Performance Data Available?	Defined Maintenance Protocol?	Notes:
Very Few: Handful of studies, not enough data to generalize about SCM performance **Limited:** Numerous studies have been done, but results are variable or inconsistent **Adequate**: Enough studies have been done to adequately define performance	**No:** Extremely limited understanding of procedures to maintain SCM in the future **Emerging:** Still learning about how to maintain the SCM **Yes**: Solid understanding of maintenance for future SCM needs	**NA:** Not applicable for the SCM

Product Substitution

Product substitution refers to the classic pollution prevention approach of reducing the emissions of pollutants available for future wash-off into stormwater runoff. The most notable example is the introduction of unleaded gasoline, which resulted in an order-of-magnitude reduction of lead levels in stormwater runoff in a decade (Pitt et al., 2004a,b). Similar reductions are expected with the phase-out of methyl tert-butyl ether (MTBE) additives in gasoline. Other examples of product substitution are the ban on coal-tar sealants during parking lot renovation that has reduced PAH runoff (Van Metre et al., 2006), phosphorus-free fertilizers that have measurably reduced phosphorus runoff to Minnesota lakes (Barten and Johnson, 2007), the painting of galvanized metal surfaces, and alternative rooftop surfaces (Clark et al., 2005). Given the importance of coal power plant emissions in the atmospheric deposition of nitrogen and mercury, it is possible that future emissions reductions for such plants may result in lower stormwater runoff concentrations for these two pollutants.

The level of control afforded by product substitution is quite high if major reductions in emissions or deposition can be achieved. The difficulty is that these reductions require action in another environmental regulatory arena, such as air quality, hazardous waste, or pesticide regulations, which may not see stormwater quality as a core part of their mission.

Watershed and Land-Use Planning

Communities can address stormwater problems by making land-use decisions that change the location or quantity of impervious cover created by new development. This can be accomplished through zoning, watershed plans, comprehensive land-use plans, or Smart Growth incentives.

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The unit process that is managed is the amount of impervious cover, which is strongly related to various residential and commercial zoning categories (Cappiella and Brown, 2000). Numerous techniques exist to forecast future watershed impervious cover and its probable impact on the quality of aquatic resources (see the discussion of the Impervious Cover Model in Chapter 3; CWP, 1998a; MD DNR, 2005). Using these techniques and simple or complex simulation models, planners can estimate stormwater flows and pollutant loads through the watershed planning process and alter the location or intensity of development to reduce them.

The level of control that can be achieved by watershed and land-use planning is theoretically high, but relatively few communities have aggressively exercised it. The most common application of downzoning has been applied to watersheds that drain to drinking water reservoirs (Kitchell, 2002). The strength of this practice is that it has the potential to directly address the underlying causes of the stormwater problem rather than just treating its numerous symptoms. The weakness is that local decisions on zoning and Smart Growth are reversible and often driven by other community concerns such as economic development, adequate infrastructure, and transportation. In addition, powerful consumer and market forces often have promoted low-density sprawl development. Communities that use watershed-based zoning often require a compelling local environmental goal, since state and federal regulatory authorities have traditionally been extremely reluctant to interfere with the local land-use and zoning powers.

Conservation of Natural Areas

Natural-area conservation protects natural features and environmental resources that help maintain the predevelopment hydrology of a site by reducing runoff, promoting infiltration, and preventing soil erosion. Natural areas are protected by a permanent conservation easement prescribing allowable uses and activities on the parcel and preventing future development. Examples include any areas of undisturbed vegetation preserved at the development site, including forests, wetlands, native grasslands, floodplains and riparian areas, zero-order stream channels, spring and seeps, ridge tops or steep slopes, and stream, wetland, or shoreline buffers. In general, conservation should maximize contiguous area and avoid habitat fragmentation.

While natural areas are conserved at many development sites, most of these requirements are prompted by other local, state, and federal habitat protections, and are not explicitly designed or intended to provide runoff reduction and stormwater treatment. To date, there are virtually no data to quantify the runoff reduction and/or pollutant removal capability of specific types of natural area conservation, or the ability to explicitly link them to site design.

Impervious Cover Reduction

A variety of practices, some of which fall under the broader term “better site design,” can be used to minimize the creation of new impervious cover and disconnect or make more permeable the hard surfaces that are needed (Nichols et al., 1997; Richman, 1997; CWP, 1998a). A list of some common impervious cover reduction practices for both residential and commercial areas is provided below.

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Elements of Better Site Design: Single-Family Residential

- Maximum residential street width
- Maximum street right-of-way width
- Swales and other stormwater practices can be located within the right-of-way
- Maximum cul-de-sac radius with a bioretention island in the center
- Alternative turnaround options such as hammerheads are acceptable if they reduce impervious cover
- Narrow sidewalks on one side of the street (or move pedestrian pathways away from the street entirely)
- Disconnect rooftops from the storm-drain systems
- Minimize driveway length and width and utilize permeable surfaces
- Allow for cluster or open-space designs that reduce lot size or setbacks in exchange for conservation of natural areas
- Permeable pavement in parking areas, driveways, sidewalks, walkways, and patios

Elements of Better Site Design: Multi-Family Residential and Commercial

- Design buildings and parking to have multiple levels
- Store rooftop runoff in green roofs, foundation planters, bioretention areas, or cisterns
- Reduce parking lot size by reducing parking demand ratios and stall dimensions
- Use landscaping areas, tree pits, and planters for stormwater treatment
- Use permeable pavement over parking areas, plazas, and courtyards

CWP (1998a) recommends minimum or maximum geometric dimensions for subdivisions, individual lots, streets, sidewalks, cul-de-sacs, and parking lots that minimize the generation of needless impervious cover, based on a national roundtable of fire safety, planning, transportation and zoning experts. Specific changes in local development codes can be made using these criteria, but it is often important to engage as many municipal agencies that are involved in development as possible in order to gain consensus on code changes.

At the present time, there is little research available to define the runoff reduction benefits of these practices. However, modeling studies consistently show a 10 to 45 percent reduction in runoff compared to conventional development (CWP, 1998b,c, 2002). Several monitoring studies have documented a major reduction in stormwater runoff from development sites that employ various forms of impervious cover reduction and LID in the United States and Australia (Coombes et al., 2000; Philips et al., 2003; Cheng et al., 2005) compared to those that do not.

Unfortunately, better site design has been slowly adopted by local planners, developers, designers, and public works officials. For example, although the project pictured in Figure 5-6 has been very successful in terms of controlling stormwater, the better-site-design principles used have not been widely adopted in the Seattle area. Existing local development codes may discourage or even prohibit the application of environmental site design practices, and many engineers and plan reviewers are hesitant to embrace them. Impervious cover reduction must be incorporated at the earliest stage of site layout and design to be effective, but outdated development codes in many communities can greatly restrict the scope of impervious cover reduction (see Chapter 2). Finally, the performance and longevity of impervious cover reduction are dependent on the infiltration capability of local soils, the intensity of development, and the future management actions of landowners.

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FIGURE 5-6 110th Street, Seattle, part of the Natural Drainage Systems Project. This location exhibits several elements of impervious cover reduction. In particular, vegetated swales were installed and curbs and gutters removed. There are sidewalks on only one side of the street, and they are separated from the road by the swales. The residences' rooftops have been disconnected from the storm-drain systems and are redirected into the swales. SOURCE: Seattle Public Utilities.

Earthwork Minimization

This source control measure seeks to limit the degree of clearing and grading on a development site in order to prevent soil compaction, conserve soils, prevent erosion from steep slopes, and protect zero-order streams. This is accomplished by (1) identifying key soils, drainage features, and slopes to protect and then (2) establishing a limit of disturbance where construction equipment is excluded. This element is an important, but often under-utilized component of local erosion and sediment control plans.

Numerous researchers have documented the impact of mass grading, clearing, and the passage of construction equipment on the compaction of soils, as measured by increase in bulk density, declines in soil permeability, and increases in the runoff coefficient (Lichter and Lindsey, 1994; Legg et al., 1996; Schueler, 2001a,b; Gregory et al., 2006). Another goal of earthwork minimization is to protect zero-order streams, which are channels with defined banks that emanate from a hollow or ravine with convergent contour lines (Gomi et al., 2002). They represent the uppermost definable channels that possess temporary or intermittent flow. Functioning zero-order channels provide major watershed functions, including groundwater recharge and discharge (Schollen et al., 2006; Winter, 2007), important nutrient storage and transformation functions (Bernot and Dodds, 2005; Groffman et al., 2005), storage and retention

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of eroded hill-slope sediments (Meyers, 2003), and delivery of leaf inputs and large woody debris. Compared to high-order network streams, zero-order streams are disproportionately disturbed by mass grading, enclosure, or channelization (Gomi et al., 2002; Meyer, 2003).

The practice of earthwork minimization is not widely applied across the country. This is partly due to the limited performance data available to quantify its benefits, and the absence of local or national design guidance or performance benchmarks for the practice.

Erosion and Sediment Control

Erosion and sediment control predates much of the NPDES stormwater permitting program. It consists of the temporary installation and operation of a series of structural and nonstructural practices throughout the entire construction process to minimize soil erosion and prevent off-site delivery of sediment. Because construction is expected to last for a finite and short period of time, the design standards are usually smaller and thus riskier (25-year versus the 100-year storm). By phasing construction, thereby limiting the exposure of bare earth at any one time, the risk to the environment is reduced significantly.

The basic practices include clearing limits, dikes, berms, temporary buffers, protection of drainage-ways, soil stabilization through hydroseeding or mulching, perimeter controls, and various types of sediment traps and basins. All plans have some component that requires filtration of runoff crossing construction areas to prevent sediment from leaving the site. This usually requires a sediment collection system including, but not limited to, conventional settling ponds and advanced sediment collection devices such as polymer-assisted sedimentation and advanced sand filtration. Silt fences are commonly specified to filter distributed flows, and they require maintenance and replacement after storms as shown in Figure 5-7. Filter systems are added to inlets until the streets are paved and the surrounding area has a cover of vegetation (Figure 5-8). Sedimentation basins (Figure 5-9) are constructed to filter out sediments through rock filters, or are equipped with floating skimmers or chemical treatment to settle out pollutants. Other common erosion and sediment control measures include temporary seeding and rock or rigged entrances to construction sites to remove dirt from vehicle tires (see Figure 5-10).

FIGURE 5-7 A functioning silt fence (left) and an improperly maintained silt fence (right).
SOURCES: EPA NPDES Menu of BMPs and Robert Traver.

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FIGURE 5-8 Sediment filter left in place after construction. SOURCE: Robert Traver.

FIGURE 5-9 Sediment basin. SOURCE: EPA NPDES Menu of BMPs.

FIGURE 5-10 Rumble strips to remove dirt from vehicle tires. SOURCE: Laura Ehlers.

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Control of the runoff's erosive potential is a critical element. Most erosion and sediment control manuals provide design guidance on the capacity and ability of swales to handle runoff without eroding, on the design of flow paths to transport runoff at non-erosive velocities, and on the dissipation of energy at pipe outlets. Examples include rock energy dissipaters, level spreaders (see Figure 5-11), and other devices.

Box 5-3 provides a comprehensive list of recommended construction SCMs. The reader is directed to reviews by Brown and Caraco (1997) and Shaver et al. (2007) for more information. Although erosion and sediment control practices are temporary, they require constant operation and maintenance during the complicated sequence of construction and after major storm events. It is exceptionally important to ensure that practices are frequently inspected and repaired and that sediments are cleaned out. Erosion and sediment control are widely applied in many communities, and most states have some level of design guidance or standards and specifications. Nonetheless, few communities have quantified the effectiveness of a series of construction SCMs applied to an individual site, nor have they clearly defined performance benchmarks for individual practices or their collective effect at the site. In general, there has been little monitoring in the past few decades to characterize the performance of construction SCMs, although a few notable studies have been recently published (e.g., Line and White, 2007). Box 5-4 describes the effectiveness of filter fences and filter fences plus grass buffers to reduce sediment loadings from construction activities and the resulting biological impacts.

FIGURE 5-11 Level spreader. SOURCE: Robert Traver.

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BOX 5-3
Recommended Construction Stormwater Control Measures

1. As the top priority, emphasize construction management SCMs as follows:
- Maintain existing vegetation cover, if it exists, as long as possible.
- Perform ground-disturbing work in the season with smaller risk of erosion, and work off disturbed ground in the higher risk season.
- Limit ground disturbance to the amount that can be effectively controlled in the event of rain.
- Use natural depressions and planning excavation to drain runoff internally and isolate areas of potential sediment and other pollutant generation from draining off the site, so long as safe in large storms.
- Schedule and coordinate rough grading, finish grading, and erosion control application to be completed in the shortest possible time overall and with the shortest possible lag between these work activities.

2. Stabilize with cover appropriate to site conditions, season, and future work plans. For example:
- Rapidly stabilize disturbed areas that could drain off the site, and that will not be worked again, with permanent vegetation supplemented with highly effective temporary erosion controls until achievement of at least 90 percent vegetative soil cover.
- Rapidly stabilize disturbed areas that could drain off the site, and that will not be worked again for more than three days, with highly effective temporary erosion controls.
- If at least 0.1 inch of rain is predicted with a probability of 40 percent or more, before rain falls stabilize or isolate disturbed areas that could drain off the site, and that are being actively worked or will be within three days, with measures that will prevent or minimize transport of sediment off the property.

3. As backup for cases where all of the above measures are used to the maximum extent possible but sediments still could be released from the site, consider the need for sediment collection systems including, but not limited to, conventional settling ponds and advanced sediment collection devices such as polymer-assisted sedimentation and advanced sand filtration.

4. Specify emergency stabilization and/or runoff collection (e.g., using temporary depressions) procedures for areas of active work when rain is forecast.

5. If runoff can enter storm drains, use a perimeter control strategy as backup where some soil exposure will still occur, even with the best possible erosion control (above measures) or when there is discharge to a sensitive waterbody.

6. Specify flow control SCMs to prevent or minimize to the extent possible:
- Flow of relatively clean off-site water over bare soil or potentially contaminated areas;
- Flow of relatively clean intercepted groundwater over bare soil or potentially contaminated areas;
- High velocities of flow over relatively steep and/or long slopes, in excess of what erosion control coverings can withstand; and
- Erosion of channels by concentrated flows, by using channel lining, velocity control, or both.

7. Specify stabilization of construction entrance and exit areas, provision of a nearby tire and chassis wash for dirty vehicles leaving the site with a wash water sediment trap, and a sweeping plan.

8. Specify construction road stabilization.

9. Specify wind erosion control.

10. Prevent contact between rainfall or runoff and potentially polluting construction materials, processes, wastes, and vehicle and equipment fluids by such measures as enclosures, covers, and containments, as well as berming to direct runoff.

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BOX 5-4
Receiving Water Impacts Associated with Construction Site Discharges

The following is a summary of a recent research project that investigated in-stream biological conditions downstream of construction sites having varying levels of erosion controls (none, the use of filter fences, and filter fences plus grass buffers) for comparison. The project title is *Studies to Evaluate the Effectiveness of Current BMPs in Controlling Stormwater Discharges from Small Construction Sites* and was conducted for the Alabama Water Resources Research Institute, Project 2001AL4121B, by Drs. Robert Angus, Ken Marion, and Melinda Lalor of the University of Alabama at Birmingham. The initial phase of the project, described below, was completed in 2002. While this case study is felt to be representative of many sites across the United States, there are other examples of where silt fences have been observed to be more effective (e.g., Barrett et al., 1998).

Methods

This study was conducted in the upper Cahaba River watershed in north central Alabama, near Birmingham. The study areas had the following characteristics. (1) Topography and soil types representative of the upland physiographic regions in the Southeast (i.e., southern Appalachian and foothill areas); thus, findings from this study should be relevant to a large portion of the Southeast. (2) The rainfall amounts and intensities in this region are representative of many areas of the Southeast and (3) the expanding suburbs of the Birmingham metropolitan area are rapidly encroaching upon the upper Cahaba River and its tributaries. Stormwater runoff samples were manually collected from sheet flows above silt fences, and from points below the fence within the vegetated buffer. Water was sampled during "intense" (≥1 inch/hour) rain events. The runoff samples were analyzed for turbidity, particle size distribution (using a Coulter Counter Multi-Sizer IIe), and total solids (dissolved solids plus suspended/non-filterable solids). Sampling was only carried out on sites with properly installed and well-maintained silt fences, located immediately upgrade from areas with good vegetative cover.

Six tributary or upper mainstream sites were studied to investigate the effects of sedimentation from construction sites on both habitat quality and the biological "health" of the aquatic ecosystem (using benthic macroinvertebrates and fish). EPA's Revision to Rapid Bioassessment Protocols for Use in Streams and Rivers was used to assess the habitat quality at the study sites. Each site was assessed in the spring to evaluate immediate effects of the sediment, and again during the following late summer or early fall to evaluate delayed effects.

Results

Effectiveness of Silt Fences. Silt fences were found to be better than no control measures at all, but not substantially. The mean counts of small particles (<5 μm) below the silt fences were about 50 percent less than that from areas with no erosion control measures, even though the fences appeared to be properly installed and in good order. However, the variabilities were large and the difference between the means was not statistically significant. For every variable measured, the mean values of samples taken below silt fences were significantly higher ($p < 0.001$) than samples collected from undisturbed vegetated control sites collected nearby and at the same time. These data therefore indicate that silt fences are only marginally effective at reducing soil particulates in runoff water.

Effectiveness of Filter Fences with Vegetated Buffers. Runoff samples were also collected immediately below filter fences, and below filter fences after flow over buffers having 5, 10, and 15 feet of dense (intact) vegetation. Mean total solids in samples collected below silt fences and a 15-foot-wide vegetated buffer zone were about 20 percent lower, on average, than those samples collected only below the silt fence. The installation of filter fences above an intact, good vegetated buffer removes sediment from construction site runoff more effectively than with the use of filter fences alone.

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BOX 5-4 Continued

Biological Metrics Sensitive to Sedimentation Effects (Fish). Analysis of the fish biota indicates that various metrics used to evaluate the biological integrity of the fish community also are affected by highly sedimented streams. As shown in Figure 5-12, the overall composition of the population, as quantified by the Index of Biotic Integrity (IBI) is lower; the proportion and biomass of darters, a disturbance-sensitive group, is lower; the proportion and biomass of sunfish is higher; the Shannon-Weiner diversity index is lower; and the number of disturbance-tolerant species is higher as mean sediment depth increases.

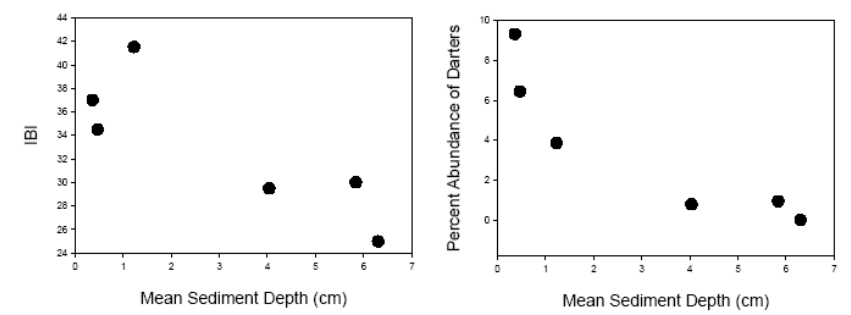

FIGURE 5-12 Association between two fish metrics and amount of stream sediment. NOTE: The IBI is based on numerous characteristics of the fish population. The percent relative abundance of darters is the percentage of darters to all the fish collected at a site. SOURCE: Alabama WRRI.

Benthic Macroinvertebrates. A number of stream benthic macroinvertebrate community characteristics were also found to be sensitive to sedimentation. Metrics based on these characteristics differ greatly between sediment-impacted and control sites (Figure 5-13). Some of the metrics that appear to reflect sediment-associated stresses include the Hilsenhoff Biotic Index (HBI), a variation of the EPT index (percent EPT minus Baetis), and the Sorensen Index of Similarity to a reference site. The HBI is a weighted mean tolerance value; high HBI values indicate sites dominated by disturbance-tolerant macroinvertebrate taxa. The EPT% index is the percent of the collection represented by organisms in the generally disturbance-sensitive orders *Ephemeroptera, Plecoptera,* and *Trichoptera*. Specimens of the genus *Baetis* were not included in the index as they are relatively disturbance-tolerant. The HBI and the EPT indices also show positive correlations to several other measures of disturbance, such as percent of the watershed altered by development.

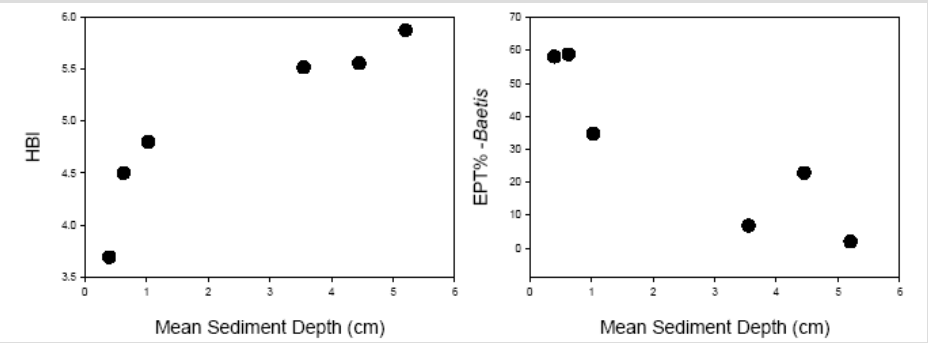

FIGURE 5-13 Associations between two macroinvertebrate metrics and the amount of stream sediment. SOURCE: Alabama WRRI.

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Reforestation and Soil Compost Amendments

This set of practices seeks to improve the quality of native vegetation and soils present at the site. Depending on the ecoregion, this may involve forest, prairie, or chapparal plantings, tilling, and amending compacted soils to improve their hydrologic properties.

The goal is to maintain as much predevelopment hydrologic function at a development site as possible by retaining canopy interception, duff/soil layer interception, evapotranspiration, and surface infiltration. The basic methods to implement this practice are described in Cappiella et al. (2006), Pitt et al. (2005), Chollak and Rosenfeld (1998), and Balusek (2003).

At this time, there are few monitoring data to assess the degree to which land reforestation or soil amendments can improve the quality of stormwater runoff at a particular development site, apart from the presumptive watershed research that has shown that forests with undisturbed soils have very low rates of surface runoff and extremely low levels of pollutants in runoff (Singer and Rust, 1975; Johnson et al., 2000; Chang, 2006). More data are needed on the hydrologic properties of urban forests and soils whose ecological functions are stressed or degraded by the urbanization process (Pouyat et al., 1995, 2007).

Pollution Prevention SCMs for Stormwater Hotspots

Certain classes of municipal and industrial operations are required to maintain a series of pollution prevention practices to prevent or minimize contact of pollutants with rainfall and runoff. Pollution prevention practices involve a wide range of operational practices at a site related to vehicle repairs, fueling, washing and storage, loading and unloading areas, outdoor storage of materials, spill prevention and response, building repair and maintenance, landscape and turf management, and other activities that can introduce pollutants into the stormwater system (CWP, 2005). Training of personnel at the affected area is needed to ensure that industrial and municipal managers and employees understand and implement the correct stormwater pollution prevention practices needed for their site or operation.

Examples of municipal operations that may need pollution prevention plans include public works yards, landfills, wastewater treatment plants, recycling and solid waste transfer stations, maintenance depots, school bus and fleet storage and maintenance areas, public golf courses, and ongoing highway maintenance operations. The major industrial categories that require stormwater pollution prevention plans were described in Table 2-3. Both industrial and municipal operations must develop a detailed stormwater pollution prevention plan, train employees, and submit reports to regulators. Compliance has been a significant issue with this program in the past, particularly for small businesses (Duke and Augustenberg, 2006; Cross and Duke, 2008) Recently filed investigations of stormwater hotspots indicate many of these operations are not fully implementing their stormwater pollution prevention plans, and a recent GAO report (2007) indicates that state inspections and enforcement actions are extremely rare.

The goal of pollution prevention is to prevent contact of rainfall or stormwater runoff with pollutants, and it is an important element of the post-construction stormwater plan. However, with the exception of a few industries such as auto salvage yards (Swamikannu, 1994), basic research is lacking on how much greater event mean concentrations are at municipal and industrial stormwater hotspots compared to other urban land uses. In addition, little is presently

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known about whether aggressive implementation of stormwater pollution prevention plans actually can reduce stormwater pollutant concentrations at hot spots.

Runoff Volume Reduction—Rainwater Harvesting

A primary goal of stormwater management is to reduce the volume of runoff from impervious surfaces. There are several classes of SCMs that can achieve this goal, including rainwater harvesting systems, vegetated SCMs that evapotranspirate part of the volume, and infiltration SCMs. For all of these measures, the amount of runoff volume to be captured depends on watershed goals, site conditions including climate, upstream nonstructural practices employed, and whether the chosen SCM is the sole management measure or part of a treatment train. Generally, runoff-volume-reduction SCMs are designed to handle at least the first flush from impervious surfaces (1 inch of rainfall). In Pennsylvania, control of the 24-hour, two-year storm volume (about 8 cm) is considered the standard necessary to protect stream-channel geomorphology, while base flow recharge and the first flush can be addressed by capturing a much smaller volume of rain (1–3 cm). Where both goals must be met, the designer is permitted to either oversize the volume reduction device to control the larger volume, or build a smaller device and use it in series with an extended detention basin to protect the stream geomorphology (PaDEP, 2006). Some designers have reported that in areas with medium to lower percentage impervious surfaces they are able to control up to the 100-year storm by enlarging runoff-volume-reduction SCMs and using the entire site. In retrofit situations, capture amounts as small as 1 cm are a distinct improvement. It should be noted that there are important, although indirect, water quality benefits of all runoff-volume-reduction SCMs—(1) the reduction in runoff will reduce streambank erosion downstream and the concomitant increases in sediment load, and (2) volume reductions lead to pollutant load reductions, even if pollutant concentrations in stormwater are not decreased.

Rainwater harvesting systems refer to use of captured runoff from roof tops in rain barrels, tanks, or cisterns (Figures 5-14 and 5-15). This SCM treats runoff as a resource and is one of the few SCMs that can provide a tangible economic benefit through the reduction of treated water usage. Rainwater harvesting systems have substantial potential as retrofits via the use of rain barrels or cisterns that can replace lawn or garden sprinkling systems. Use of this SCM to provide gray water within buildings (e.g., for toilet flushing) is considerably more complicated due to the need to construct new plumbing and obtain the necessary permits.

The greatest challenge with these systems is the need to use the stored water and avoid full tanks, since these cannot be responsive in the event of a storm. That is, these SCMs are effective only if the captured runoff can be regularly used for some grey water usage, like car washing, toilet flushing, or irrigation systems (golf courses, landscaping, nurseries). In some areas it might be possible to use the water for drinking, showering, or washing, but treatment to potable water quality would be required. Sizing of the required storage is dependent on the climate patterns, the amount of impervious cover, and the frequency of water use. Areas with frequent rainfall events require less storage as long as the water is used regularly, while areas with cold weather will not be able to utilize the systems for irrigation in the winter and thus require larger storage.

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FIGURE 5-14 Rainwater harvesting tanks at a Starbucks in Austin, Texas. SOURCE: Laura Ehlers.

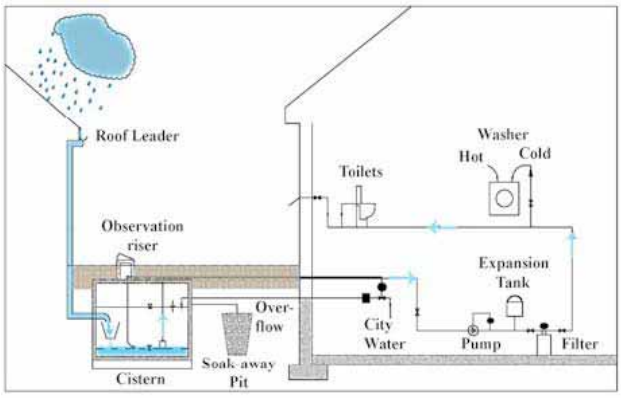

FIGURE 5-15 A Schematic of rainwater harvesting . SOURCE: PaDEP (2006).

One substantial advantage of these systems is their ability to reduce water costs for the user and the ability to share needs. An example of this interaction is the Pelican Hill development in Irvine, California, where excess runoff from the streets and houses is collected in enormous cisterns and used for watering of a nearby golf course. Furthermore, compared to other SCMs, the construction of rainwater harvesting facilities provide a long-term benefit with minimal maintenance cost, although they do require an upfront investment for piping and storage tanks.

Coombes et al. (2000) found that rainwater harvesting achieved a 60 to 90 percent reduction in runoff volume; in general, few studies have been conducted to determine the performance of these SCMs. It should be noted that rainwater harvesting systems do collect airborne deposition and acid rain.

Runoff Volume Reduction—Vegetated

A large and very promising class of SCMs includes those that use infiltration and evapotranspiration via vegetation to reduce the volume of runoff. These SCMs also directly address water quality of both surface water and groundwater by reducing streambank erosion, capturing suspended solids, and removing other pollutants from stormwater during filtration through the soil (although the extent to which pollutants are removed depends on the specific pollutant and the local soil chemistry). Depending on their design, these SCMs can also reduce peak flows and recharge groundwater (if they infiltrate). These SCMs can often be added as retrofits to developed areas by installing them into existing lawns, rights of way, or traffic islands. They can add beauty and property value.

Flow volume is addressed by this SCM group by first capturing runoff, creating a temporary holding area, and then removing the stored volume through infiltration and evapotranspiration. Examples include bioswales, bioretention, rain gardens, green roofs, and bioinfiltration. Swales refer to grassy areas on the side of the road that convey drainage. These were first designed to move runoff away from paved areas, but can now be designed to achieve a certain contact time with runoff so as to promote infiltration and pollutant removal (see Figure 5-

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16). Bioretention generally refers to a constructed sand filter with soil and vegetation growing on top to which stormwater runoff from impervious surfaces is directed (Figure 5-17). The original rain garden or bioretention facilities were constructed with a fabric at the bottom of the prepared soil to prevent infiltration and instead had a low-level outflow at the bottom. Green roofs (Figure 5-18) are very similar to bioretention SCMs. They tend to be populated with a light expanded shale-type soil and succulent plants chosen to survive wet and dry periods. Finally, bioinfiltration is similar to bioretention but is better engineered to achieve greater infiltration (Figure 5-19). All of these devices are usually at the upper end of a treatment train and designed for smaller storms, which minimizes their footprint and allows for incorporation within existing infrastructure (such as traffic control devices and median strips). This allows for distributed treatment of the smaller volumes and distributed volume reduction.

FIGURE 5-16 Vegetated swale.
SOURCE: PaDEP (2006).

FIGURE 5-17 Bioretention during a storm event at the University of Maryland.
SOURCE: Reprinted, with permission, from Davis et al. (2008). Copyright 2008 by the American Society of Civil Engineers.

FIGURE 5-18 City Hall in the center of Chicago's downtown was retrofitted with a green roof to reduce the heat island effect, remove airborne pollutants, and attenuate stormwater flows as a demonstration of innovative stormwater management in an ultra-urban setting. SOURCE: Conservation Design Forum.

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FIGURE 5-19 Retrofit bioinfiltration at Villanova University immediately following a storm event. SOURCE: Robert Traver.

These SCMs work by capturing water in a vegetated area, which then infiltrates into the soil below. They are primarily designed to use plant material and soil to evapotranspirate the runoff over several days. A shallow depth of ponding is required, since the inflows may exceed the possible infiltration ability of the native soil. This ponding is maintained above an engineered sandy soil mixture and is a surface-controlled process (Hillel, 1998). Early in the storm, the soil moisture potential creates a suction process that helps draw water into the SCM. This then changes to a steady rate that is "practically equal to the saturated hydraulic conductivity" of the subsurface (Hillel, 1998). The hydrologic design goal should be to maximize the volume of water that can be held in the soil, which necessitates consideration of the soil hydraulic conductivity (which varies with temperature), climate, depth to groundwater, and time to drain. Usually these devices are designed to empty between 24 and 72 hours after a storm event. In some cases (usually bioretention), these SCMs have an underdrain.

The choice of vegetation is an important part of the design of these SCMs. Many sites where infiltration is desirable have highly sandy soils, and the vegetation has to be able to endure both wet and dry periods. Long root growths are desired to promote infiltration (Barr Engineering Co., 2001), and plants that attract birds can reduce the insect population. Bioretention cells may be wet for longer periods than bioinfiltration sites, requiring different plants. Denser plantings or "thorns" may be needed to avoid the destruction caused by humans and animals taking shortcuts through the beds.

The pollutant removal mechanism operating for volume-reduction SCMs are different for each pollutant type, soil type, and volume-reduction mechanism. For bioretention and SCMs using infiltration, the sedimentation and filtration of suspended solids in the top layers of the soil are extremely efficient. Several studies have shown that the upper layers of the soil capture metals, particulate nutrients, and carbon (Pitt, 1996; Deschesne et al., 2005; Davis et al., 2008). The removal of dissolved nutrients from stormwater is not as straightforward. While ammonia is caught by the top organic layer, nitrate is mobile in the soil column. Some bioretention systems have been built to hold water in the soil for longer periods in order to create anaerobic conditions that would promote denitrification (Hunt and Lord, 2006a). Phosphorus removal is related to the amount of phosphorus in the original soil. Some studies have shown that bioretention cells built with agricultural soils increased the amount of phosphorus released. Chlorides pass through the system unchecked (Ermilio and Traver, 2006), while oils and greases are easily removed by the

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organic layer. Hunt et al. (2008) have reported in studies in North Carolina that the drying cycle appears to kill off bacteria. Temperature is not usually a concern as most storms do not overflow these devices. Green roofs collect airborne deposition and acid rain and may export nutrients when they overflow. However, this must be tempered by the fact that in larger storms, most natural lands would produce nutrients.

A group of new research studies from North America and Australia have demonstrated the value of many of these runoff-volume-reduction practices to replicate predevelopment hydrology at the site. The results from 11 recent studies are given in Table 5-3, which shows the runoff reduction capability of bioretention. As can be seen, the reduction in runoff volume achieved by these practices is impressive—ranging from 20 to 99 percent with a median reduction of about 75 percent. Box 5-5 discusses the excellent performance of the bioswales installed during Seattle's natural drainage systems project (see also Horner et al., 2003; Jefferies, 2004; Stagge, 2006). Bioinfiltration has been less studied, but one field study concluded that close to 30 percent of the storm volume was able to be removed by bioinfiltration (Sharkey, 2006). A very recent case study of bioinfiltration is provided in Box 5-6, which demonstrates that the capture of small storms through these SCMs is extremely effective in areas where the majority of the rainfall falls in smaller storms.

TABLE 5-3 Volumetric Runoff Reduction Achieved by Bioretention

Bioretention Design	Location	Runoff Reduction	Reference
Infiltration	CT	99%	Dietz and Clausen (2006)
	PA	86%	Ermilio and Traver (2006)
	FL	98%	Rushton (2002)
	AUS	73%	Lloyd et al. (2002)
Underdrain	ONT	40%	Van Seters et al. (2006)
	Model	30%	Perez-Perdini et al. (2005)
	NC	40 to 60%	Smith and Hunt (2007)
	NC	20 to 29%	Sharkey (2006)
	NC	52 to 56%	Hunt et al. (2008)
	NC	20 to 50%	Passeport et al. (2008)
	MD	52 to 65%	Davis et al. (2008)

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BOX 5-5
Bioswale Case Study
100th Street Cascade, Seattle, Washington

A recent example of the ability of SCMs to accomplish a variety of goals was illustrated for water quality swales in Seattle, Washington. As part of its Natural Drainage Systems Project, the City of Seattle retrofitted several blocks of an urban residential neighborhood with curbside vegetated swales. On NW 110th Street, the two-block-long system was developed as a cascade, due to the steep slope (6 percent). Twelve stepped, in-series biofilters were installed between properties and the road, each of which contains a storage area and an overflow weir. During rain events, the cells were designed to fill before emptying into the cell downstream. The soils in the bottom of each cell were over one foot thick and consisted of river rocks overlain by a swale mix. Native plants were chosen to vegetate the sides of the swale.

Extensive flow and water quality sampling occurred during 2003–2006 at the inflow and outflow of the biofilters as well as at references points elsewhere in the neighborhood that are not served by the new SCMs. Perhaps the most profound observation was that almost 50 percent of all rainfall flowing into the cascade was infiltrated, resulting in a corresponding reduction in runoff. Indeed, the cascade discharged measurable flow only during 49 of 235 storm events during the period. Depending on preceding conditions, the cascade was able to retain all of the flow for storms up to 1 inch in magnitude. In addition to the reduction in runoff affected by the swales, they also achieved significant peak flow reduction, as shown in Figure 5-20. Many peak flow rates were entirely dampened, even those where the inflow peak rate was as high as 0.7 cfs.

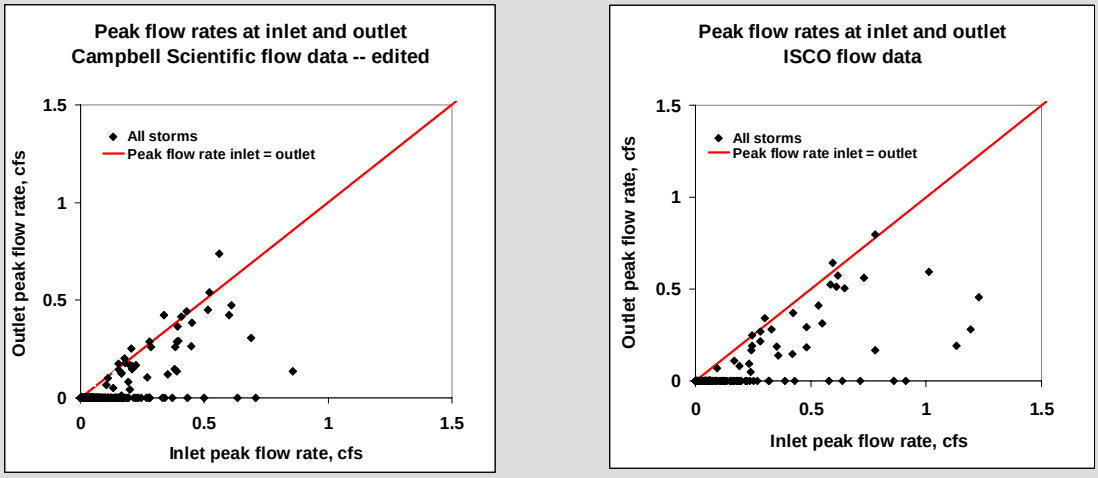

FIGURE 5-20 Peak flow rates at the inlet and outlet of the cascade, as measured by two different devices: Campbell Scientific (left) and ISCO (right). SOURCE: Horner and Chapman (2007).

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BOX 5-5 Continued

Water quality data were also extremely encouraging, as shown in Table 5-4. For total suspended solids, influent concentration of 94 mg/L decreased to 29 mg/L at the outlet of the cascade. Similar percent removals were observed for total copper, total phosphorus, total zinc, and total lead (see Table 5-4). Soluble phosphorus concentrations tended to increase from the inflow of the cascade to the outflow.

TABLE 5-4 Typical Outflow Quality from the 100th Street Cascade. Permission pending.

Pollutant	Range (mg/L)
Total Suspended Solids	10–40
Total Nitrogen	0.6–1.4
Total Phosphorus	0.09–0.23
Soluble Reactive Phosphorus	0.02–0.05
Total Copper	0.004–0.008
Dissolved Copper	0.002–0.005
Total Zinc	0.04–0.11
Dissolved Zinc	0.02–0.06
Total Lead	0.002–0.007
Dissolved Lead	<0.001
Motor Oil	0.11–0.33

SOURCE: Horner and Chapman (2007).

Taking both measured concentrations and volume reduction into account, the cascade reduced the mass loadings for the contaminants by 60 percent to greater than 90 percent. As shown in Table 5-5, pollutants associated with sediments were reduced to the greatest extent, while dissolved pollutants were less readily removed.

TABLE 5-5 Pollutant Mass Loading Reductions at 100th Street Cascade. Permission pending.

Pollutant	Percent Reduction (90% Confidence Interval)
Total Suspended Solids	84 (72–92)
Total Nitrogen	63 (53–74)
Total Phosphorus	63 (49–74)
Total Copper	83 (77–88)
Dissolved Copper	67 (50–78)
Total Zinc	76 (46–85)
Dissolved Zinc	55 (21–70)
Total Lead	90 (84–94)
Motor Oil	92 (86–97)

SOURCE: Horner and Chapman (2007).

This level of performance was compared to other parts of the neighborhood treated with conventional ditch and pipe systems. The concentrations of almost all pollutants at the outlet of the 100th Cascade was significantly lower than a corresponding outlet at 120th Street. Furthermore, the ability of this SCM to attenuate peak flows and reduce runoff was remarkable.

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BOX 5-6
SCM Evaluation Through Monitoring:
Villanova Bioinfiltration SCM

The Bioinfiltration Traffic Island located on the campus of Villanova University in Southeastern Pennsylvania is part of the Villanova Urban Stormwater Partnership (VUSP) BMP Demonstration Park (see Figure 5-21). Originally funded through the Pennsylvania Growing Greener Program, and now through the State's 319 nonpoint source monitoring program, the site has been monitored continuously since soon after it was constructed in 2001. This monitoring has lead to a wealth of information about the performance and monitoring needs of infiltration SCMs.

FIGURE 5-21 Villanova Bioinfiltration Traffic Island SCM. SOURCE : Reprinted, with permission, from VUSP. Copyright by Villanova Urban Stormwater Partnership.

The SCM is a retrofit of an existing curb-enclosed traffic island in the parking lot of a university dormitory complex. The original grass area was dug out to approximately six feet. The soil removed during the excavation was then mixed with sand onsite to create a 50 percent sand–soil mixture. This soil mixture was then placed back into the excavation to a depth of approximately four feet, leaving a surface depression that is an average of two feet deep. Care was taken during construction to prevent any compaction of either the soil mixture or the undisturbed soil below. Placement of the mixed soil is shown in Figure 5-22.

During construction two curb cuts were created to direct runoff into the SCM. Creation of one of the cuts entailed filling and paving over an existing stormwater inlet to redirect the runoff that previously entered the stormwater drainage system of the parking lot. Another existing inlet was used to collect and redirect runoff into the SCM. Plants were chosen based on their ability to thrive in both extreme wet and dry conditions; the species chosen are commonly found on sand dunes where similar wet/dry conditions may exist.

The contributing watershed is approximately 50,000 square feet and is 52 percent impervious surfaces. The design goal of the SCM was for it to temporarily store the first inch of runoff. The one-inch capture depth is based on an analysis of local historical rainfall data showing that capture of the first inch of each storm would account for approximately 96 percent of the annual rainfall. This capture depth would therefore also account for the majority of the annual pollutant load coming from the drainage area.

FIGURE 5-22 Placement of the mixed soil in the basin. Notice the construction equipment being kept away from the basin to avoid potential compaction of the sub-base. SOURCE : Reprinted, with permission, from VUSP. Copyright by Villanova Urban Stormwater Partnership.

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BOX 5-6 Continued

Continuous monitoring over multiple years has increased our understanding of how this type of structure operates and its benefits. For example, Heasom et al. (2006) was able to produce a continuous hydrologic flow model of the site based on season. Figure 5-23 shows the variability of the infiltration rate on a seasonal basis, and the relationship between infiltration and temperature (Emerson and Traver, 2008). This work has also shown no statistical change in performance over the five-year monitoring period.

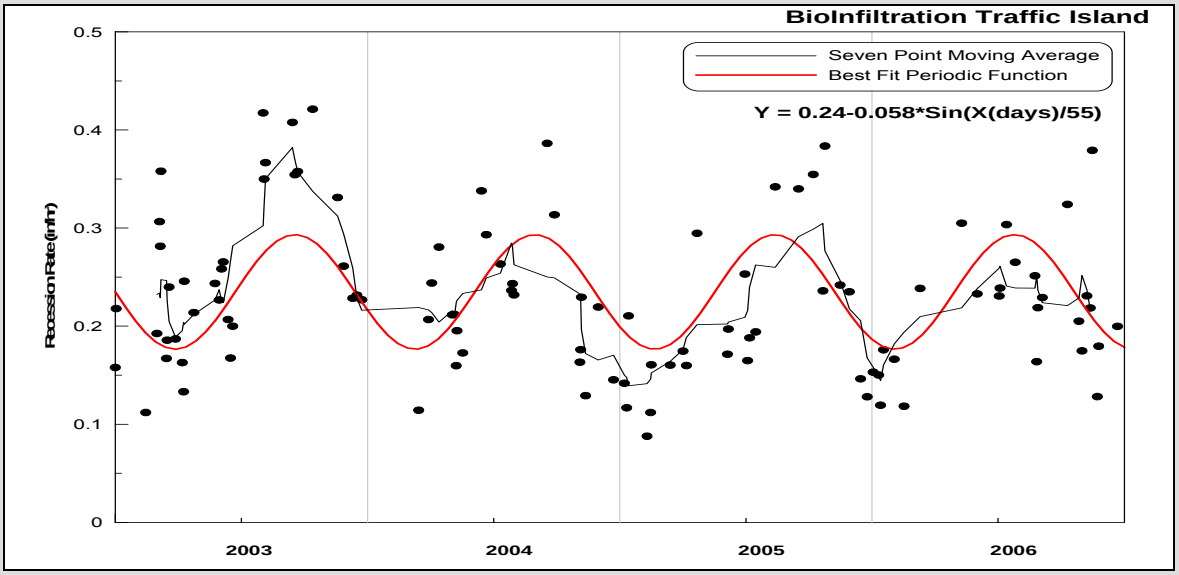

FIGURE 5-23 Seasonal Infiltration Rate. SOURCE: Reprinted, with permission, from Emerson and Traver (2008). Copyright 2008 by Journal of Irrigation and Drainage Engineering.

When examining the yearly performance of the site from a surface water standpoint, it is easily shown that on a regular basis approximately 50 to 60 percent of the runoff that reaches the site is removed from the surface waters, and 80 to 85 percent of the rainfall is infiltrated (Figure 5-24).

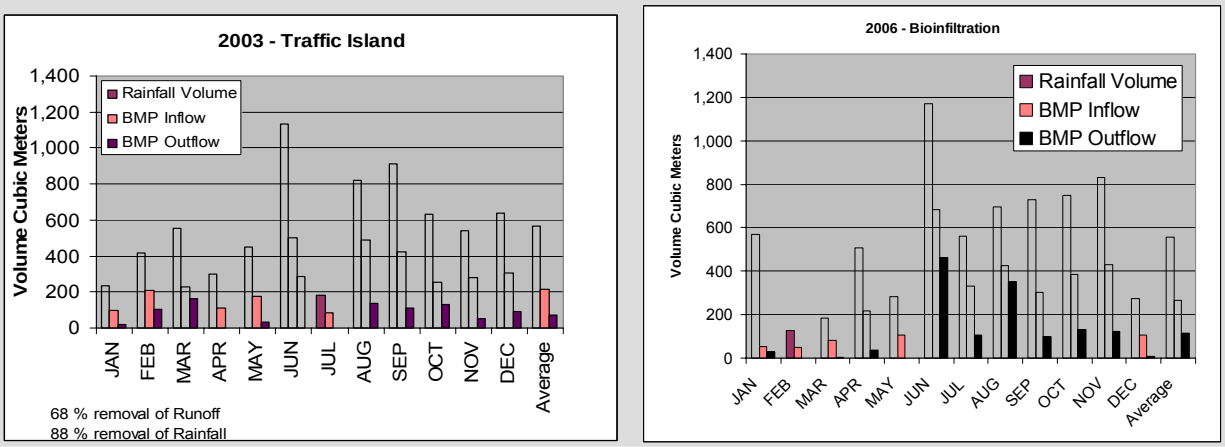

FIGURE 5-24 2003 Performance and 2006 Performance. SOURCE : Reprinted, with permission, from VUSP. Copyright by Villanova Urban Stormwater Partnership.

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The performance of the SCM during individual storm events was examined in 2005. Out of 77 rainfall events, overflow was recorded for only seven events. Generally overflow did not occur for rainfalls less than 1.95 inches except for one occasion. As the bowl volume is much less than this value, substantial infiltration must be occurring during the storm event. When one extreme 6-inch storm was recorded (Figure 5-25), it was surprising to note that infiltration occurred all during the storm event, as did some unexpected peak flow reduction. What is even more impressive is to examine the reduction in the duration of flows, which is directly related to downstream channel erosion (Figure 5-26). Clearly the bioinfiltration SCM exceeded its design goals.

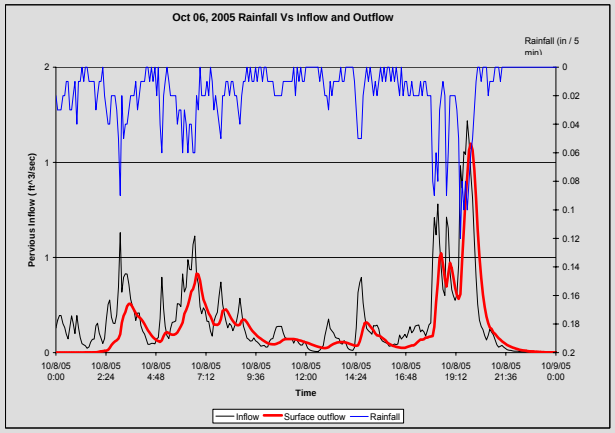

FIGURE 5-25 October 2005 extreme storm event. storm event. SOURCE : Reprinted, with permission, from VUSP. Copyright by Villanova Urban Stormwater Partnership.

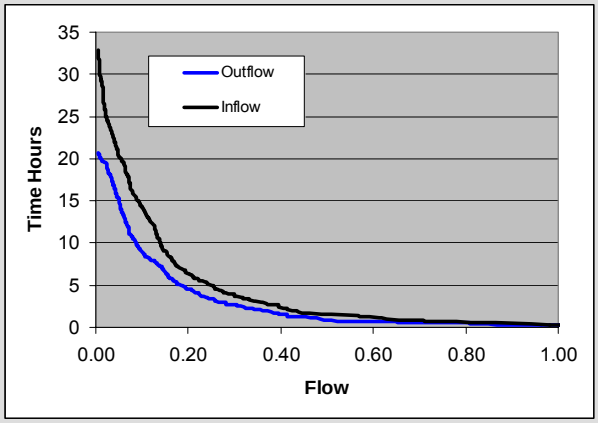

FIGURE 5-26 Flow duration curves, October 2005. SOURCE : Reprinted, with permission, from VUSP. Copyright by Villanova Urban Stormwater Partnership.

Research on this site is currently examining water quality benefits and groundwater interactions. When evaluating the pollutant removal of bioinfiltration, it is critical to consider flow volumes and pollutant levels together. For example, during many of the overflow events, there were higher nutrient levels leaving the SCM than entering due to the plants contained within the SCM. However, when the runoff volume reduction is considered, the total nitrogen and phosphorus removed from the influent is impressive (Davis et al., 2008). Water quality studies of the infiltrated water are still incomplete but generally show some conversion of nitrate to nitrite, and high chlorides from snow melt chemicals moving through the system. Nutrient levels are relatively low in the samples at the 8-foot depth.

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The strengths of vegetated runoff-volume-reduction SCMs include the flexibility to utilize the drainage system as part of the treatment train. For example, bioswales can replace drainage pipes, green roofs can be installed on buildings, and bioretention can replace parking borders (Figure 5-27), thereby reducing the footprint of the stormwater system. Also, through the use of swales and reducing pipes and inlets, costs can be offset. Vegetated systems are more tolerant of the TSS collected, and their growth cycle maintains pathways for infiltration and prevents clogging. Freeze–thaw cycles also contribute to pathway maintenance. The aesthetic appeal of vegetated SCMs is also a significant strength.

Weaknesses include the dependence of these SCMs on native soil infiltration and the need to understand groundwater levels and karst geology, particularly for those SCMs designed to infiltrate. For bioinfiltration and bioretention, most failures occur early on and are caused by sedimentation and construction errors that reduce infiltration capacity, such as stripping off the topsoil and compacting the subsurface. Once a good grass cover is established in the contributing area, the danger of sedimentation is reduced. Nonetheless, the need to prevent sediment from overwhelming these structures is critical. The longevity of these SCMs and their vulnerability to toxic spills are a concern (Emerson and Traver, 2008), as is their failure to reduce chlorides. Finally, in areas where the land use is a hot spot, or where the SCM could potentially contaminate the groundwater supply, bioretention, non-infiltrating bioswales, and green roofs may be more suitable than infiltration SCMs.

The role of infiltration SCMs in promoting groundwater recharge deserves additional consideration. Although this is a benefit of infiltration SCMs in regions where groundwater levels are dropping, it may be undesirable in a few limited scenarios. For example, in the arid southwest contributions to base flow from irrigation have turned some dry ephemeral stream systems into perennial streams that support the growth of dense vegetation, which may be less desirable habitat for certain riparian species (like the Arroyo toad in Southern California). Infiltration SCMs could contribute to changing the flow regime in cases such as these. In most urban areas, there is so much impervious cover that it would be difficult to "overinfiltrate." Nonetheless, the use of infiltration SCMs will change local subsurface hydrology, and the ramifications of this—good and bad—should be considered prior to their installation.

FIGURE 5-27 North Carolina Retrofit Bioretention SCMs. SOURCE: Traver.

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Maintenance of vegetated runoff-volume-reduction SCMs is relatively simple. A visit after a rainstorm to check for plant health, to check sediment buildup, and to see if the water is ponded can answer many questions. Maintenance includes trash pickup and seasonal removal of dead grasses and weeds. Sediment removal from pretreatment devices is required. Depending on the pollutant concentrations in the influent, the upper layer of organic matter may need to be removed infrequently to maintain infiltration and to prevent metal and nutrient buildup.

At the site level, the chief factors that lead to uncertainty are the infiltration performance of the soil, particular for the limiting subsoil layer, and how to predict the extent of pollutant removal. Traditional percolation tests are not effective to estimate the infiltration performance; rather, testing hydraulic conductivity is required. Furthermore, the infiltration rate varies depending on temperature and season (Emerson and Traver, 2008). Basing measurements on percent removal of pollutants is extremely misleading, since every site and storm generates different levels of pollutants. The extent of pollutant removal depends on land use, time between storms, seasons, and so forth. These factors should be part of the design philosophy for the site. Finally, it should also be pointed out that climate is a factor determining the effectiveness of some of these SCMs. For example, green roofs are more likely to succeed in areas having smaller, more frequent storms (like the Pacific Northwest) compared to areas subjected to less frequent, more intense storms (like Texas).

Runoff Volume Reduction—Subsurface

Infiltration is the primary runoff-volume-reduction mechanism for subsurface SCMs, such that much of the previous discussion is relevant here. Thus, like vegetated SCMs, these SCMs provide benefits for groundwater recharge, water quality, stream channel protection, peak flow reduction, capture of the suspended solids load, and filtration through the soil (Ferguson, 2002). Because these systems can be built in conjunction with paved surfaces (i.e., they are often buried under parking lots), the amount of water captured, and thus stream protection, may be higher than for vegetated systems. They also have lower land requirements than vegetated systems, which can be an enormous advantage when using these SCMs during retrofitting, as long as the soil is conducive to infiltration.

Similar to vegetated SCMs, this SCM group works primarily by first capturing runoff and then removing the stored volume through infiltration. The temporary holding area is made either of stone or using manufactured vaults. Examples include pervious pavement, infiltration trenches, and seepage pits (see Figures 5-28, 5-29, 5-30, 5-31, and 5-32). As with vegetated SCMs, a shallow depth of ponding is required, since the inflows may exceed the possible infiltration ability of the native soil. In this case, the ponding is maintained within a rock bed under a porous pavement or in an infiltration trench. These devices are usually designed to empty between 24 and 72 hours after the storm event.

The infiltration processes operating for these subsurface SCMs are similar to those for the vegetated devices previously discussed. Thus, much like for vegetated systems, the level of control achieved depends on the infiltration ability of the native soils, the percent of impervious surface area in the contributing watershed, land use contributing to the pollutant loadings, and climate. A large number of recent studies have found that permeable pavement can reduce runoff volume by anywhere from 50 percent (Rushton, 2002; Jefferies, 2004; Bean et al., 2007)

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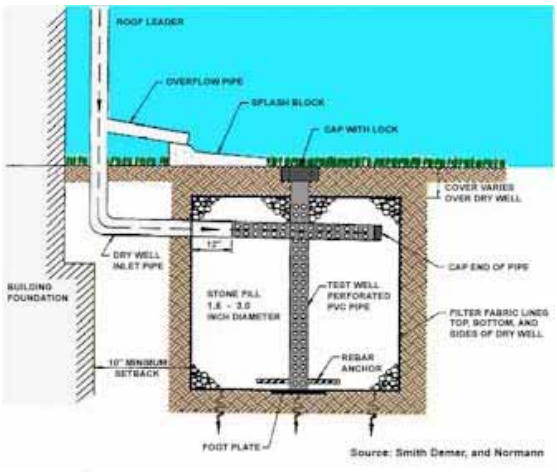

FIGURE 5-28 Schematic of a seepage pit. PaDEP.

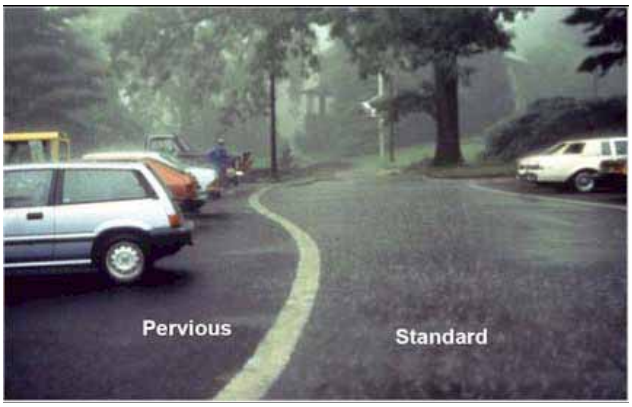

FIGURE 5-29 Porous asphalt. SOURCE: SOURCE: PaDEP.

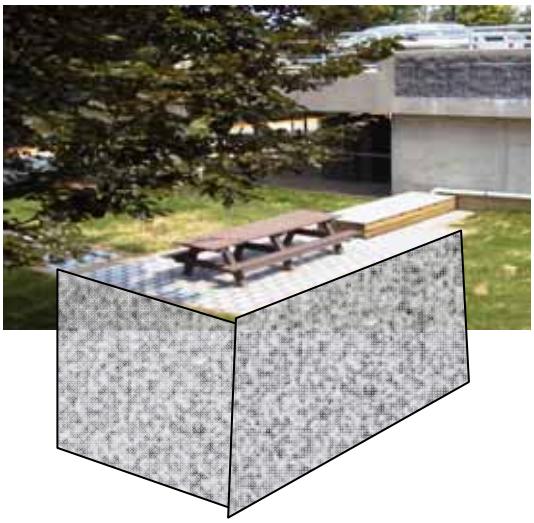

FIGURE 5-30 A retrofitted infiltration trench at Villanova University. SOURCE: Reprinted, with permission, from VUSP. Copyright by VUSP.

FIGURE 5-31 Pervious concrete at Villanova University. SOURCE: Reprinted, with permission from VUSP. Copyright by VUSP.

FIGURE 5-32 A small office building conversion at the edge of downtown Denver included the replacement of a portion of the site's parking with modular block porous pavement underlain by an 18-inch layer of crushed rock. Rainfall on the porous pavement and roof runoff for most storm events are contained in the reservoir created by the crushed rock. The pavement infiltrates runoff from most storm events for one-third of the impervious area on the half-acre site.

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to as much as 95 percent or greater (van Seters et al., 2006; Kwiatkowski et al., 2007). Box 5-7 describes the success of a recent retrofitting of asphalt with pervious pavement at Villanova University.

The strengths of subsurface runoff-volume-reduction SCMs are similar to those of their vegetated counterparts. Additional attributes include their ability to be installed under parking areas and to manage larger volumes of rainfall. These SCMs typically have few problems with safety or vector-borne diseases because of their subsurface location and storage capacity, and they can be very aesthetically pleasing. The potential of permeable pavement could be particularly far-reaching if one considers the amount of impervious surface in urban areas that is comprised of roads, driveways, and parking lots.

The weaknesses of these SCMs are also similar to those of vegetated systems, including their dependence on native soil infiltration and the need to understand groundwater levels and karst geology. Simply estimating the soil hydraulic conductivity can have an error rate of an order of magnitude. Specifically for subsurface systems that use geotextiles (not permeable pavement), there is a danger of TSS being compressed against the bottom of the geotextile, preventing infiltration. There are no freeze–thaw cycles or vegetated processes that can reopen pathways, so the control of TSS is even more critical to their life span. In most cases (permeable pavement is an exception), pretreatment is required, except for the cleanest of sources (like a slate roof). Typically, manufactured devices, sediment forebays, or grass strips are part of the design of subsurface SCMs to capture the larger sediment particles.

The maintenance of subsurface runoff-volume-reduction SCMs is relatively simple but critical. If inspection wells are installed, a visit after a rainstorm will check that the volume is captured, and later that it has infiltrated. Porous surfaces should undergo periodic vacuum street sweeping when a sediment source is present. Pretreatment devices require sediment removal. The difficulty with this class of SCMs is that, if a toxic spill occurs or maintenance is not proactive, there are no easy corrective measures other than replacement.

Low-Impact Development. LID refers primarily to the use of small, engineered, on-site stormwater practices to treat the quality and quantity of runoff at its source. It is discussed here because the SCMs that are thought of as LID—particularly vegetated swales, green roofs, permeable pavement, and rain gardens—are all runoff-volume-reduction SCMs. They are designed to capture the first portion of a rainfall event and to treat the runoff from a few hundred square meters of impervious cover.

As discussed earlier, several studies have measured the runoff volume reduction of individual LID practices. Fewer studies are available on whether multiple LID practices, when used together, have a cumulative benefit at the neighborhood or catchment scale. Four monitoring studies have clearly documented a major reduction in runoff from developments that employ LID and Better Site Design (see Box 5-8) compared to those that do not. In addition, six studies have documented the runoff reduction benefits of LID at the catchment or watershed scale using a modeling approach (Alexander and Heaney, 2002; Stephens et al., 2002; Holman-Dodds et al., 2003; Coombes, 2004; Hardy et al., 2004; Huber et al., 2006).

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BOX 5-7
Evaluation Through Monitoring: Villanova Pervious Concrete SCM

Villanova University's Stormwater Research and Demonstration Park is home to a pervious concrete infiltration site (Figure 5-33). The site, formerly a standard asphalt paved area, is located between two dormitories. The area was reconstructed in the summer of 2002 and outfitted with three infiltration beds overlain with pervious concrete. Usage of the site consists primarily of pedestrian traffic with some light automobile traffic. The pervious concrete site is designed to infiltrate small-volume storms (1 to 2 inches). Roof top runoff is directly piped to the rock bed under the concrete. For these smaller events, there is essentially no runoff from the site.

Figure 5-33 Villanova University pervious concrete retrofit site. SOURCE: Reprinted, with permission, from VUSP. Copyright by VUSP.

The pervious concrete is outlined with decorative pavers that divide the pervious concrete into three separate sections as seen in Figure 5-33. Underneath these three sections are individual storage beds. Since the site lies on a significant slope it was necessary to create earthen dams that isolate each storage area. At the top of each dam there is an overflow pipe which connects the storage area with the next one downstream. The final storage bed has an overflow that connects to the existing storm sewer. The beds are approximately 4 feet deep and are filled with stone, producing about 40 percent void space within the beds. A geotextile pervious liner was laid down to separate the storage beds from the undisturbed soil below (Figure 5-34). The primary idea was to avoid any upward migration of the in-situ soil, which could possibly reduce the capacity of the beds over time.

FIGURE 5-34 Infiltration bed under construction. Pervious concrete has functionality and workability similar to that of regular concrete. However, the pervious concrete mix lacks the sand and other fine particles found in regular concrete. This creates a significant amount of void space which allows water to flow relatively unobstructed through the concrete. This site was the first attempt at creating a pervious concrete SCM in the area, and there were construction and material problems. Since that time the industry has matured, and a second site on campus constructed in 2007 has not had any significant difficulties. SOURCE: Reprinted, with permission, from VUSP. Copyright by VUSP.

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Note the runoff from impervious concrete spilling over to the pervious concrete

Continuous monitoring of the site over a number of years has considerably increased our understanding of infiltration. Similar to the bioinfiltration site (Box 5-6), the infiltration rate of permeable concrete does vary as a function of temperature (Braga et al., 2007; Emerson and Traver, 2008), and the SCM volume reduction is impressive. As shown in Figure 5-35, over 95 percent of the yearly rainfall was infiltrated with minimal overflow. Besides hydrologic plots, water quality plots also show the benefits of permeable concrete (Kwiatkowski et al., 2007). Because over 95 percent of the runoff is infiltrated, well over 95 percent of the pollutant mass is also removed. Figure 5-36 shows the level of copper extracted from lysimeters buried under the rock bed and surrounding grass. The plot is arranged in quartiles, with readings in milligrams per liter. Lysimeter samples from under the surrounding grass and one foot and four feet under the infiltration bed all report almost no copper, compared to samples taken from the port in the rock bed and from the gutters draining the roof tops.

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BOX 5-7 Continued

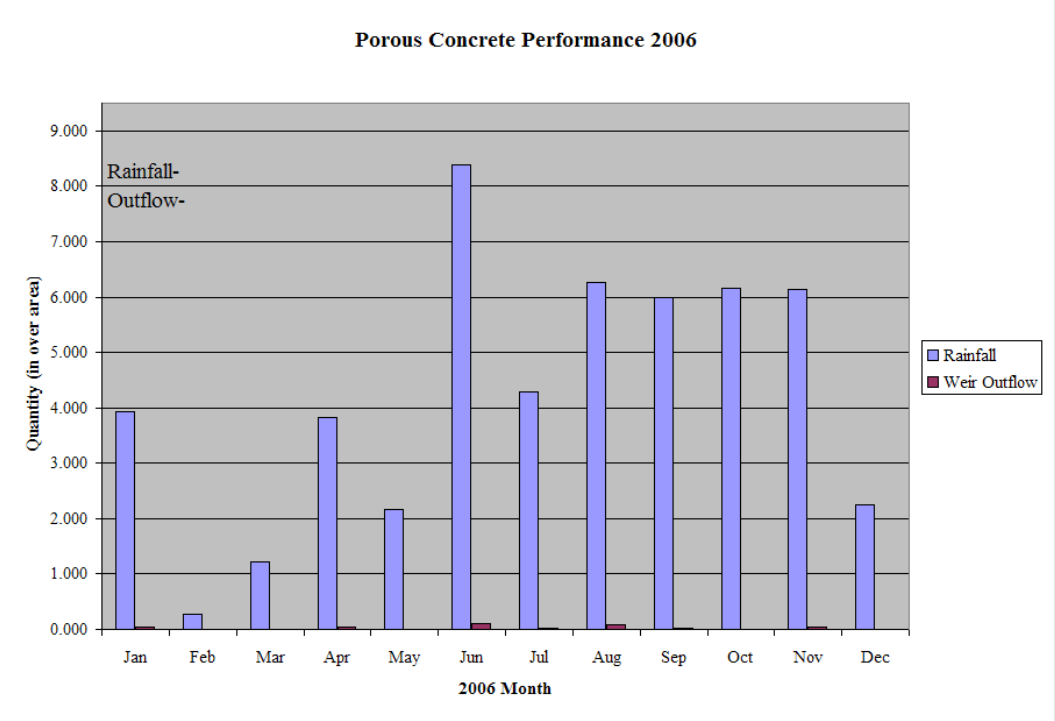

FIGURE 5-35 Rainfall and corresponding outflow from the weir of the SCM. SOURCE: Reprinted, with permission, from VUSP. Copyright by VUSP.

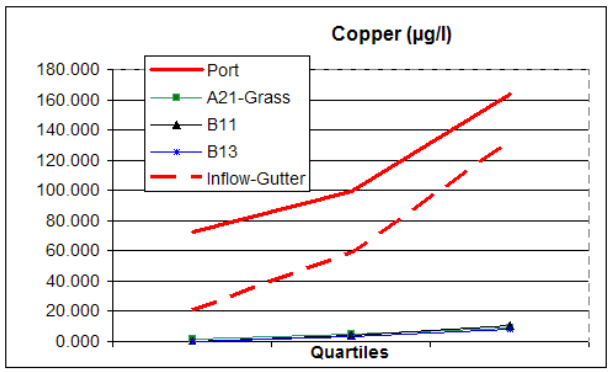

FIGURE 5-36 Copper measured at various locations. The three quartiles correspond to the 25th, 50th, and 75th percentile value of all data collected. A21 is a lysimeter location under the surrounding grass, while B11 and B13 refer to locations that are one foot and four feet under the infiltration bed, respectively. SOURCE: Reprinted, with permission, from VUSP. Copyright by VUSP.

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BOX 5-8
Jordan Cove—An LID Watershed Project

LID refers to the use of a system of small, on-site SCMs to counteract increases in flow and pollution following development and to control smaller runoff events. Although some studies are available that measure the runoff volume reduction of individual LID practices, fewer studies are available on whether multiple LID practices, when used together, have a cumulative benefit at the neighborhood or catchment scale. Of those listed in Table 5-6, Jordan Cove is the most extensively studied, as it was monitored for ten years as part of a paired watershed study that included a site with no SCMs and a site with traditional (detention) SCMs. The watersheds were monitored during calibration, construction, and post-construction periods. The project consisted of 12 lots, and the SCMs used were bioretention, porous pavements, no-mow areas, and education for the homeowners (Figure 5-37).

TABLE 5-6 Review of Recent LID Monitoring Research on a Catchment Scale

Location	Practices	Runoff Reduction
Jordan Cove, USA Dietz and Clausen (2008)	Permeable pavers, bioretention, grass swales, education	84%
Somerset Heights, USA Cheng et al. (2005)	Grass swale, bioretention, and rooftop disconnection	45%
Figtree Place, Australia Coombes et al. (2000)	Rain tanks, infiltration trenches, swales	100%

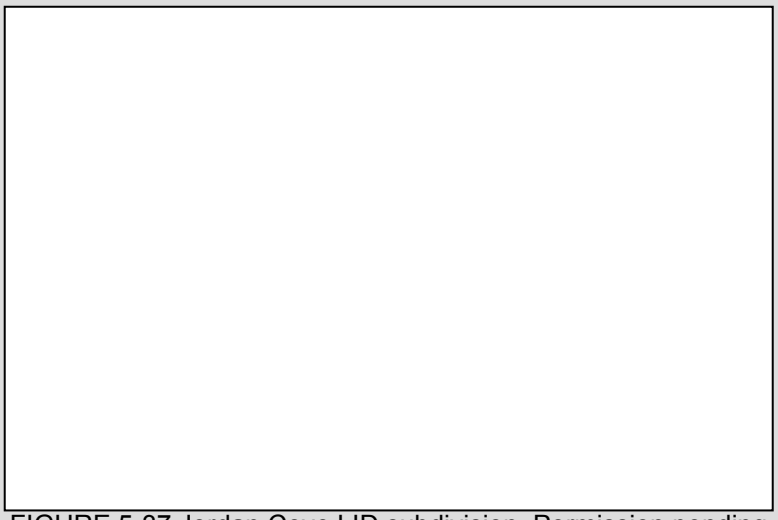

FIGURE 5-37 Jordan Cove LID subdivision. Permission pending

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BOX 5-8 Continued

Figure 5-38 (right panel) displays the hydrograph from a post-construction storm comparing the LID, traditional, and control watersheds. Note that the traditional watershed shows the delay and peak reduction from the detention basins, while the LID watershed has almost no runoff. The LID watershed was found to reduce runoff volume by 74 percent by increasing infiltration over preconstruction levels.

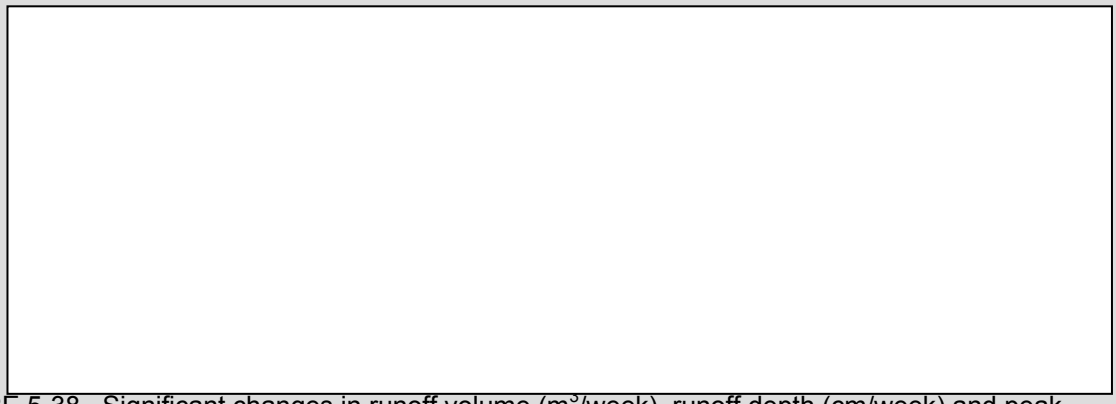

FIGURE 5-38. Significant changes in runoff volume (m^3/week), runoff depth (cm/week) and peak discharge (m^3/sec/week) after construction was completed (left panel). Hydrograph of all three subdivisions in the project, showing the larger volume and rate of runoff from the traditional and control subdivisions, as compared to the LID (right panel). Permission pending.

Comparisons of nutrient and metal concentrations and total export in the surface water shows the value of the LID approach as well as the significance of the reduction in runoff volume. Figure 5-39 shows the changes in pollutant concentration and mass export before and after construction for the traditional and LID subdivisions. Note that concentrations of TSS and nutrients are increased in the LID subdivision (left-hand panel); this is because swales and natural systems are used in place of piping as a "green" drainage system and because only larger storms leave the site. The right-hand panel shows how the large reduction in runoff achieved through infiltration can dramatically reduce the net export of pollutants from the LID watershed.

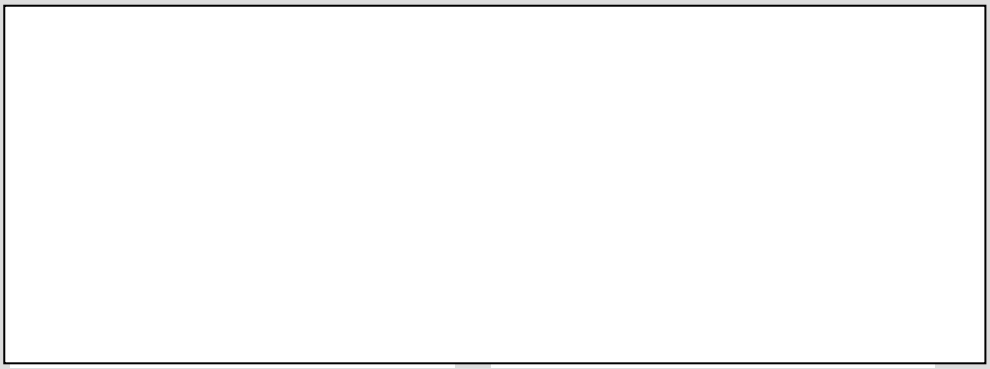

FIGURE 5-39 Significant changes in pollutant concentration, after construction was completed (left). Units are mg/L for NO_3-N, NH_3-N, TKN, TP, and BOD, and µg/L for Cu, Pb, and Zn. Significant changes in mass export (kg/ha/year) after construction was completed (right). Permission pending

SOURCE: Clausen (2007).

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Peak Flow Reduction and Runoff Treatment

After efforts are made to prevent the generation of pollutants and to reduce the volume of runoff that reaches stormwater systems, stormwater management focuses on the reduction of peak flows and associated treatment of polluted runoff. The main class of SCMs used to accomplish this is extended detention basins, versions of which have dominated stormwater management for decades. These include a wide variety of ponds and wetlands, including wet ponds (also known as retention basins), dry extended detention ponds (as known as detention basins), and constructed wetlands. By holding a volume of stormwater runoff for an extended period of time, extended detention SCMs can achieve both water quality improvement and reduced peak flows. Generally the goal is to hold the flows for 24 hours at a minimum to maximize the opportunity of settling, adsorption, and transformation of pollutants (based on past pollutant removal studies) (Rea and Traver, 2005). For smaller storm events (one- to two-year storms), this added holding time also greatly reduces the outflows from the SCM to a level that the stream channel can handle. Most wet ponds and stormwater wetlands can hold a "water quality" volume, such that the flows leaving in smaller storms have been held and "treated" for multiple days. Extended detention dry ponds greatly reduce the outflow peaks to achieve the required residence times.

Usually extended detention devices are lower in the treatment train of SCMs, if not at the end. This is both due to their function (they are designed for larger events) and because the required water sources and less permeable soils needed for these SCMs are more likely to be found at the lower areas of the site. Some opportunities exist to naturalize dry ponds or to retrofit wet ponds into stormwater wetlands but it depends on their site configuration and hydrology. Stormwater wetlands are shown in Figures 5-40 and 5-41. A wet pond and a dry extended detention basin are shown in Figures 5-42 and 5-43.

Simple ponds are little more than a hole in the ground, in which stormwater is piped in and out. Dry ponds are meant to be dry between storms, whereas wet ponds have a permanent pool throughout the year. Detention basins reduce peak flows by restricting the outflows and creating a storage area. Depending on the detention time, outflows can be reduced to levels that do not accelerate erosion, that protect the stream channel, and that reduce flooding.

FIGURE 5-40 Constructed wetland at
SOURCE: PaDEP (2006).

FIGURE 5-41 Retrofitted stormwater wetland.
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The flow normally enters the structure through a sediment forebay (Figure 5-44), which is included to capture incoming sediment, remove the larger particles through settling, and allow for easier maintenance. Then a meandering path or cell structure is built to "extend" and slow down the flows. The main basin is a large storage area (sometimes over the meandering flow paths). Finally, the runoff exits through an outflow control structure built to retard flow.

Wet ponds, stormwater wetlands, and (to a lesser extent) dry extended detention ponds provide treatment. The first step in treatment is the settling of larger particles in the sediment forebay. Next, for wet ponds a permanent pool of water is maintained so that, for smaller storms, the new flows push out a volume that has had a chance to interact with vegetation and be "treated." This volume is equivalent to an inch of rain over the impervious surfaces in the drainage area. Thus, what exits the SCM during smaller storm events is baseflow contributions and runoff that entered during previous events. For dry extended detention ponds, there is no permanent pool and the outlet is instead greatly restricted. For all of these devices, vegetation is considered crucial to pollutant removal. Indeed, wet ponds are designed with an aquatic bench around the edges to promote contact with plants. The vegetation aids in reduction of flow velocities, provides growth surfaces for microbes, takes up pollutants, and provides filtering (Braskerud, 2001).

FIGURE 5-42 Wet pond. SOURCE: PaDEP (2006).

FIGURE 5-43 Dry extended detention pond. SOURCE: PaDEP (2006).

FIGURE 5-44 Villanova University sediment forebay.
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The ability of detention structures to achieve a certain level of control is size related—that is, the more peak flow reduction or pollutant removal required, the more volume and surface area are needed in the basin. Because it is not simply the peak flows that are important, but also the duration of the flows that cause damage to the stream channels (McCuen, 1979; Loucks et al., 2005), some detention basins are currently sized and installed in series with runoff-volume-reduction SCMs.

The strength of extended detention devices is the opportunity to create habitats or picturesque settings during stormwater management. The weaknesses of these measures include large land requirements, chloride buildup, possible temperature effects, and the creation of habitat for undesirable species in urban areas. There is a perception that these devices promote mosquitoes, but that has not been found to be a problem when a healthy biological habitat is created (Greenway et al., 2003). Another drawback of this class of SCMs is that they often have limited treatment capacity, in that they can reduce pollutants in stormwater only to a certain level. These so-called irreducible effluent concentrations have been documented mainly for ponds and stormwater wetlands, as well as sand filters and grass channels (Schueler, 1998). Finally, it should be noted that either a larger watershed (10–25 acres; CWP, 2004) or a continuous water source is needed to sustain wet ponds and stormwater wetlands.

Maintenance requirements for extended detention basins and wetlands include the removal of built-up sediment from the sediment forebay, harvesting of grasses to remove accumulated nutrients, and repair of berms and structures after storm events. Inspection items relate to the maintenance of the berm and sediment forebay.

While the basic hydrologic function of extended detention devices is well known, their performance on a watershed basis is not. Because they do not significantly reduce runoff volume and are designed on a site-by-site basis using synthetic storm patterns, their exclusive use as a flood reduction strategy at the watershed scale is uncertain (McCuen, 1979; Traver and Chadderton, 1992). Much of this variability is reduced when they are coupled with volume reduction SCMs at the watershed level. Pollutant removal is effected by climate, short-circuiting, and by the schedule of sediment removal and plant harvesting. Extreme events can resuspend captured sediments, thus reintroducing them into the environment. Although there is debate, it seems likely that plants will need to be harvested to accomplish nutrient removal (Reed et al., 1998).

Runoff Treatment

As mentioned above, many SCMs associated with runoff volume reduction and extended detention provide a water quality benefit. There are also some SCMs that focus primarily on water quality with little peak flow or volume effect. Designed for smaller storms, these are usually based on filtration, hydrodynamic separation, or small-scale bioretention systems that drain to a subsequent receiving water or other device. Thus, often these SCMs are used in conjunction with other devices in a treatment train or as retrofits under parking lots. They can be very effective as pretreatment devices when used "higher up" in the watershed than infiltration structures. Finally, in some cases these SCMs are specifically designed to reduce peak flows in addition to providing water quality benefits by introducing elements that make them similar to detention basins; this is particularly the case for sand filters.

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The sand filter is relied on as a treatment technology in many regions, particular those where stream geomorphology is less of a concern and thus peak flow control and runoff volume reduction are not the primary goals. These devices can be effective at removing suspended sediments and can extend the longevity and performance of runoff-volume-reduction SCMs. They are also one of the few urban retrofits available, due to the ability to implement them within traditional culvert systems. Figures 5-45 and 5-46 show designs for the Austin sand filter and the Delaware sand filter.

Filters use sand, peat, or compost to remove particulates, similar to the processes used in drinking water plants. Sand filters primarily remove suspended solids and ammonia nitrogen. Biological material such as peat or compost provides adsorption of contaminants such as dissolved metals, hydrocarbons, and other organic chemicals. Hydrodynamic devices use rotational forces to separate the solids from the flow, allowing the solids to settle out of the flow stream. There is a recent class of bioretention-like manufactured devices that combine inlets with planters. In these systems, small volumes are directed to a soil planter area, with larger flows bypassing and continuing down the storm sewer system. In any event, for manufactured items the user needs to look to the manufacturer's published and reviewed data to understand how the device should be applied.

The level of control that can be achieved with these SCMs depends entirely on sizing of the device based on the incoming flow and pollutant loads. Each unit has a certified removal rate depending on inflow to the SCM. Also all units have a maximum volume or rate of flow they can treat, such that higher flows are bypassed with no treatment. Thus, the user has to determine what size unit is needed and the number to use based on the area's hydrologic cycle and what criteria are to be met.

With the exception of some types of sand filters, the strengths of water quality SCMs are that they can be placed within existing infrastructure or under parking lots, and thus do not take up land that may be used for other purposes. They make excellent choices for retrofit situations. For filters, there is a wealth of experience from the water treatment community on their operations. For all manufactured devices there are several testing protocols that have been set up to validate the performance of the manufactured devices (the sufficiency of which is discussed in Box 5-9). Weaknesses of these devices include their cost and maintenance requirements.

FIGURE 5-45 Austin sand filter. SOURCE: Robert Traver.

FIGURE 5-46 Delaware sand filter. SOURCE: Tom Schueler.

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BOX 5-9
Insufficient Testing of Proprietary Stormwater Control Measures

Manufacturers of proprietary SCMs offer a service that can save municipalities time and money. Time is saved by the ability of the manufactures to quickly select a model matching the needs of the site. A city can minimize the cost of buying the product by requiring the different manufacturers to submit bids for the site. All the benefits of the service will have no meaning, however, if the cities cannot trust the performance claims of the different products. Because the United States does not have, at this time, a national program to verify the performance of proprietary SCMs, interested municipalities face a high amount of uncertainty when they select a product. Money could be wasted on products that might have the lowest bid, but do not achieve the water quality goals of the city or state.

The EPA's Environmental Technology Verification (ETV) program was created to facilitate the deployment of innovative or improved environmental technologies through performance verification and dissemination of information. The Wet Weather Flow Technologies Pilot was established as part of the ETV program to verify commercially available technologies used in the abatement and control of urban stormwater runoff, combined sewer overflows, and sanitary sewer overflows. Ten proprietary SCMs were tested under the ETV program (see Figure 5-47), and the results of the monitoring are available on the National Sanitation Foundation International website. Unfortunately, the funding for the ETV program was discontinued before all the stormwater products could be tested. Without a national testing program some states have taken a more regional approach to verifying the performance of proprietary practices, while most states do not have any type of verification or approval program.

The Washington Department of Ecology has supported a testing protocol called Technology Assessment Protocol–Ecology that describes a process for evaluating and reporting on the performance and appropriate uses of emerging SCMs. California, Massachusetts, Maryland, New Jersey, Pennsylvania, and Virginia have sponsored a testing program called Technology Acceptance and Reciprocity Partnership (TARP), and a number of products are being tested in the field. The State of Wisconsin has prepared a draft technical standard (1006) describing methods for predicting the site-specific reduction efficiency of proprietary sedimentation devices. To meet the criteria in the standard the manufacturers can either use a model to predict the performance of the practice or complete a laboratory protocol designed to develop efficiency curves for each product. Although none of these state or federal verification efforts have produced enough information to sufficiently reduce the uncertainty in selection and sizing of proprietary SCMs, many proprietary practices are being installed around the country, because of the perceived advantage of the service being provided by the manufacturers and the sometimes overly optimistic performance claims.

All those involved in stormwater management, including the manufacturers, will have a much better chance of implementing a cost-effective stormwater program in their cities if the barriers to a national testing program for proprietary SCMs are eliminated. Two of the barriers to the ETV program were high cost and the transferability of the results. Also, the ETV testing did not produce results that could be used in developing efficiency curves for the product. A new national testing program could reduce the cost by using laboratory testing instead of field testing. Each manufacturer would only have to do one series of tests in the lab and the results would be applicable to the entire country. The laboratory protocol in the Wisconsin Technical Standard 1006 provides a good example of what should be included to evaluate each practice over a range of particle sizes and flows. These types of laboratory data could also be used to produce efficiency curves for each practice. It would be relatively easy for state and local agencies to review the benefits of each installation if the efficiency curves were incorporated into urban runoff models, such as WinSLAMM or P8.

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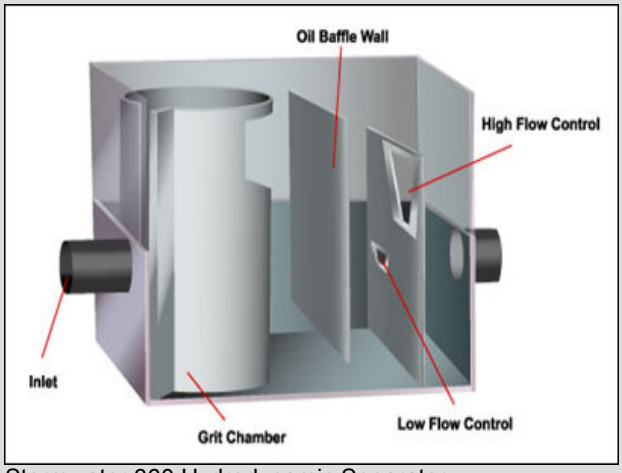
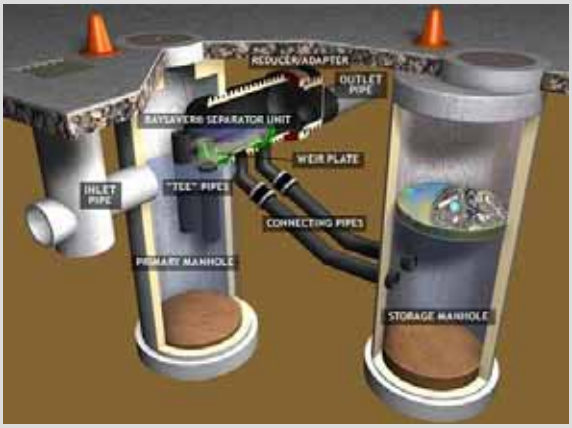
BOX 5-9 Continued

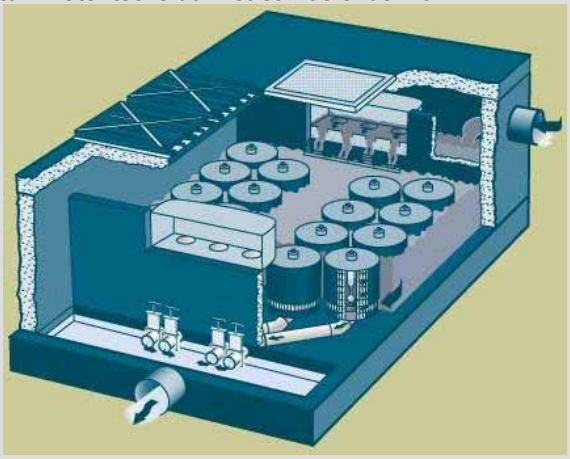


Stormwater 360 Hydrodynamic Separator. SOURCE: EPA (2005c)

Downstream Defender. SOURCE: Available online at http://epa.gov/Region1/assistance/ceitts/stormwater/techs/downstreamdefender.html



Bay Seperator: SOURCE: EPA (2005a).



Stormfilter. SOURCE: EPA (2005b).

FIGURE 5-47 Proprietary Manufactured Devices tested by the ETV Program.

Regular maintenance and inspection at a high level are required to remove captured pollutants, to replace mulch, or to rake and remove the surface layer to prevent clogging. In some cases specialized equipment (vacuum trucks) is required to remove built-up sediment. Although the underground placement of these devices has many benefits, it makes it easy to neglect their maintenance because there are no signs of reduced performance on the surface. Because these devices are manufactured, the unit construction cost is usually higher than for other SCMs. Finally, the numerous testing protocols are confusing and prevent more widespread applications.

The chief uncertainty with these SCMs is due to the lack of certification of some manufactured devices. There is also concern about which pollutants are removed by which class

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of device. For example, hydrodynamic devices and sand filters do not address dissolved nutrients, and in some cases convert suspended pollutants to their dissolved form. Both issues are related to the false perception that a single SCM must be found that will comprehensively treat stormwater. Such pressures often put vendors in a position of trying to certify that their devices can remove all pollutants. Most often, these devices can serve effectively as part of a treatment train, and should be valued for their incremental contributions to water quality treatment. For example, a filter that removes sediment upstream of a bioinfiltration SCM can greatly prolong the life of the infiltration device.

Aquatic Buffers and Managed Floodplains

Aquatic buffers, sometimes also known as stream buffers or riparian buffers, involve reserving a vegetated zone adjacent to streams, shorelines, or wetlands as part of development regulations or as an ordinance. In most regions of the country, the buffer is managed as forest, although in arid or semi-arid regions it may be managed as prairie, chapparal, or other cover. When properly designed, buffers can both reduce runoff volumes and provide water quality treatment to stormwater.

The performance of urban stream buffers cannot be predicted from studies of buffers installed to remove sediment and nutrients from agricultural areas (Lowrance and Sheridan, 2005). Agricultural buffers have been reported to have high sediment and nutrient removal because they intercept sheet flow or shallow groundwater flow in the riparian zone. By contrast, urban stream buffers often receive concentrated surface runoff or may even have a storm-drain pipe that short-circuits the buffer and directly discharges into the stream. Consequently, the pollutant removal capability of urban stream buffers is limited, unless they are specifically designed to distribute and treat stormwater runoff (NRC, 2000). This involves the use of level spreaders, grass filters, and berms to transform concentrated flows into sheet flow (Hathaway and Hunt, 2006). Such designed urban stream buffers have been applied widely in the Neuse River basin to reduce urban stormwater nutrient inputs to this nitrogen-sensitive waterbody.

The primary benefit of buffers is to help maintain aquatic biodiversity within the stream. Numerous researchers have evaluated the relative impact of riparian forest cover and impervious cover on stream geomorphology, aquatic insects, fish assemblages, and various indexes of biotic integrity. As a group, the studies suggest that indicator values for urban stream health increase when riparian forest cover is retained over at least 50 to 75 percent of the length of the upstream network (Goetz et al., 2003; Wang et al., 2003b; McBride and Booth, 2005; Moore and Palmer, 2005). The width of the buffer is also important for enhancing its stream protection benefits, and it ranges from 25 to 200 feet depending on stream order, protection objectives, and community ordinances. At the present time, there are no data to support an optimum width for water quality purposes. The beneficial impact of riparian forest cover is less detectable when watershed impervious cover exceeds 15 percent, at which point degradation by stormwater runoff overwhelms the benefits of the riparian forest (Roy et al., 2005, 2006; Walsh et al., 2007).

Maintenance, inspection, and compliance for buffers can be a problem. In most communities, urban stream buffers are simply a line on a map and are not managed in any significant way after construction is over. As such, urban stream buffers are prone to residential encroachment and clearing, and to colonization by invasive plants. Another important practice is to protect, preserve, or otherwise manage the ultimate 100-year floodplain so that vulnerable property and infrastructure are not damaged during extreme floods. Federal Emergency

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Management Agency (FEMA), state, and local requirements often restrict or control development on land within the floodway or floodplain. In larger streams, the floodway and aquatic buffer can be integrated together to achieve multiple social objectives.

Stream Rehabilitation

While not traditionally considered an SCM, certain stream rehabilitation practices or approaches can be effective at recreating stream physical habitat and ecosystem function lost during urbanization. When combined with effective SCMs in upland areas, stream rehabilitation practices can be an important component of a larger strategy to address stormwater. From the standpoint of mitigating stormwater impacts, four types of urban stream rehabilitation are common:

- Practices that stabilize streambanks and/or prevent channel incision/enlargement can reduce downstream delivery of sediments and attached nutrients (see Figure 5-48). Although the magnitude of sediment delivery from urban-induced stream-channel enlargement is well documented, there are very few published data to quantify the potential reduction in sediment or nutrients from subsequent channel stabilization.

- Streams can be hydrologically reconnected to their floodplains by building up the profile of incised urban streams using grade controls so that the channel and floodplain interact to a greater degree. Urban stream reaches that have been so rehabilitated have increased nutrient uptake and processing rates, and in particular increased denitrification rates, compared to degraded urban streams prior to treatment (Bukavecas, 2007; Kaushal et al., 2008). This suggests that urban stream rehabilitation may be one of many elements that can be considered to help decrease loads in nutrient-sensitive watersheds.

- Practices that enhance in-stream habitat for aquatic life can improve the expected level of stream biodiversity. However, Konrad (2003) notes that improvement of biological diversity of urban streams should still be considered an experiment, since it is not always clear what hydrologic, water quality, or habitat stressors are limiting. Larson et al. (2001) found that physical habitat improvements can result in no biological improvement at all. In addition, many of the biological processes in urban stream ecosystems remain poorly understood, such as carbon processing and nutrient uptake.

- Some stream rehabilitation practices can indirectly increase stream biodiversity (such as riparian reforestation, which could reduce stream temperatures, and the removal of barriers to fish migration).

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FIGURE 5-48 Three photographs illustrate stream rehabilitation in Denver. The top left picture is a creek that has eroded in its bed due to urbanization. The top right picture shows a portion of the stabilized creek immediately after construction. Check structures, which keep the creek from cutting its bed, are visible in the middle distance. The bottom image shows the creek just upstream of one of the check structures two years after stabilization. The thickets of willows established themselves naturally. The only revegetation performed was to seed the area for erosion control.

It should be noted that the majority of urban stream rehabilitation projects undertaken in the United States are designed for purposes other than mitigating the impacts of stormwater or enhancing stream biodiversity or ecosystem function (Bernhardt et al., 2005). Most stream rehabilitation projects have a much narrower design focus, and are intended to protect threatened infrastructure, naturalize the stream corridor, achieve a stable channel, or maintain local bank stability (Schueler and Brown, 2004). Improvements in either biological health or the quality of stormwater runoff have rarely been documented.

Unique design models and methods are required for urban streams, compared to their natural or rural counterparts, given the profound changes in hydrologic and sediment regime and stream–floodplain interaction that they experience (Konrad, 2003). While a great deal of design guidance on urban stream rehabilitation has been released in recent years (FISRWG, 2000; Doll and Jennings, 2003; Schueler and Brown, 2004), most of the available guidance has not yet been tailored to produce specific outcomes for stormwater mitigation, such as reduced sediment delivery, increased nutrient processing, or enhanced stream biodiversity. Indeed, several researchers have noted that many urban stream rehabilitation projects fail to achieve even their narrow design objectives, for a wide range of reasons (Bernhardt and Palmer, 2007; Sudduth et al., 2007). This is not surprising given that urban stream rehabilitation is relatively new and rarely addresses the full range of in-stream alteration generated by watershed-scale changes.

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This shortfall suggests that much more research and testing are needed to ensure urban stream habilitation can meet its promise as an emerging SCM.

Municipal Housekeeping (Street Sweeping and Storm-Drain Cleanouts)

Phase II NPDES stormwater permits specifically require municipal good housekeeping as one of the six minimum management measures for MS4s. Although EPA has not presented definitive guidance on what constitutes "good housekeeping", CWP (2008) outlines ten municipal operations where housekeeping actions can improve the quality of stormwater, including the following:

- municipal hotspot facility management,
- municipal construction project management,
- road maintenance,
- street sweeping,
- storm-drain maintenance,
- stormwater hotline response,
- landscape and park maintenance ,
- SCM maintenance, and
- employee training.

The overarching theme is that good housekeeping practices at municipal operations provide source treatment of pollutants before they enter the storm-drain system. The most frequently applied practices are street sweeping (Figure 5-49) and sediment cleanouts of sumps and storm-drain inlets. Most communities conduct both operations at some frequency for safety and aesthetic reasons, although not specifically for the sake of improving stormwater quality (Law et al., 2008).

Numerous performance monitoring studies have been conducted to evaluate the effect of street sweeping on the concentration of stormwater pollutants in downstream storm-drain pipes (see Pitt, 1979; Bender and Terstriep, 1994; Brinkman and Tobin, 2001; Zarrielo et al., 2002; Chang et al., 2005; USGS, 2005; Law et al., 2008). The basic finding is that regular street sweeping has a low or limited impact on stormwater quality, depending on street conditions, sweeping frequency, sweeper technology, operator training, and on-street parking. Sweeping will always have a limited removal capability because rainfall events frequently wash off pollutants before the sweeper passes through, and only some surfaces are accessible to the sweeper, thus excluding sidewalk, driveways, and landscaped areas. Frequent sweeping (i.e., weekly or monthly) has a moderate capability to remove sediment, trash and debris, coarse solids, and organic matter.

Fewer studies have been conducted on the pollutant removal capability of frequent sediment cleanout of storm-drain inlets, most in regions with arid climates (Lager et al., 1977; Mineart and Singh, 1994; Morgan et al., 2005). These studies have shown some moderate pollutant removal if cleanouts are done on a monthly or quarterly basis. Most communities, however, report that they clean out storm drains on an annual basis or in response to problems or drainage complaints (Law, 2006).

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FIGURE 5-49 Vacuum street sweeper at Villanova University. SOURCE: Robert Traver.

Frequent sweeping and cleanouts conducted on the dirtiest streets and storm drains appear to be the most effective way to include these operations in the stormwater treatment train. However, given the uncertainty associated with the expected pollutant removal for these practices, street sweeping and storm-drain cleanout cannot be relied on as the sole SCMs for an urban area.

Illicit Discharge Detection and Elimination

MS4 communities must develop a program to detect and eliminate illicit discharges to their storm-drain system as a stormwater NPDES permit condition. Illicit discharges can involve illegal cross-connections of sewage or washwater into the storm-drain system or various intermittent or transitory discharges due to spills, leaks, dumping, or other activities that introduce pollutants into the storm-drain system during dry weather. National guidance on the methods to find and fix illicit discharges was developed by Brown et al. (2004). Local illicit discharge detection and elimination (IDDE) programs represent an ongoing and perpetual effort to monitor the network of pipes and ditches to prevent pollution discharges.

The water quality significance of illicit discharges has been difficult to define since they occur episodically in different parts of a municipal storm drain system. Field experience in conducting outfall surveys does indicate that illicit discharges may be present at 2 to 5 percent of all outfalls at any given time. Given that pollutants are being introduced into the receiving water during dry weather, illicit discharges may have an amplified effect on water quality and biological diversity.

Many communities indicate that they employ a citizen hotline to report illicit discharges and other water quality problems (Brown et al., 2004), which sharply increases the number of illicit discharge problems observed.

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Stormwater Education

Like IDDE, stormwater education is one of the six minimum management measures that MS4 communities must address in their stormwater NPDES permits. Stormwater education involves municipal efforts to make sure individuals understand how their daily actions can positively or negatively influence water quality and work to change specific behaviors linked to specific pollutants of concern (Schueler, 2001c). Targeted behaviors include lawn fertilization, littering, car fluid recycling, car washing, pesticide use, septic system maintenance, and pet waste pickup. Communities may utilize a wide variety of messages to make the public aware of the behavior and more desirable alternatives through radio, television, newspaper ads, flyers, workshops, or door-to-door outreach. Several communities have performed before-and-after surveys to assess both the penetration rate for these campaigns and their ability to induce changes in actual behaviors. Significant changes in behaviors have been recorded (see Schueler, 2002), although few studies are available to link specific stormwater quality improvements to the educational campaigns (but see Turner, 2005; CASQA, 2007).

Residential Stewardship

This SCM involves municipal programs to enhance residential stewardship to improve stormwater quality. Residents can undertake a wide range of activities and practices that can reduce the volume or quality of runoff produced on their property or in their neighborhood as a whole. This may include installing rain barrels or rain gardens, planting trees, xeriscaping, downspout disconnection, storm-drain marking, household hazardous waste pickups, and yard waste composting (CWP, 2005). This expands on stormwater education in that a municipality provides a convenient delivery service to enable residents to engage in positive watershed behavior. The effectiveness of residential stewardship is enhanced when carrots are provided to encourage the desired behavior, such as subsidies, recognition, discounts, and technical assistance (CWP, 2005). Consequently, communities need to develop a targeted program to educate residents and help them engage in the desired behavior.

SCM Performance Monitoring and Modeling

Stormwater is characterized by widely fluctuating flows. In addition, inflow pollutant concentrations vary over the course of a storm and can be a function of time since the last storm, watershed, size and intensity of rainfall, season, amount of imperviousness, pollutant of interest, and so forth. This variability of the inflow to SCMs along with the very nature of SCMs makes performance monitoring a complex task. Most SCMs are built to manage stormwater, not to enable flow and water quality monitoring. Furthermore, they are incorporated into the collection system and spread throughout developments. Measurement of multiple inflows, outflows, evapotranspiration, and infiltration are simply not feasible for most sites. Many factors, such as temperature and climate, play a role in how well SCMs function. Infiltration rates can vary by an order of magnitude as a function of temperature (Braga et al., 2007; Emerson and Traver, 2008), such that a reading in late summer might be twice that of a winter reading. Determining performance can be further complicated because, e.g., at the start of a storm a detention basin

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could still be partially full from a previous storm, and removal rates for wetlands are a function of the growing season, not to mention snowmelt events.

Monitoring of SCMs is usually performed for one of two purposes: functionality or more intensive performance monitoring. Monitoring of functionality is primarily to establish that the SCM is functioning as designed. Performance monitoring is focused on determining what level of performance is achieved by the SCM.

Functionality Monitoring

Functionality monitoring, in a broad sense, involves checking to see whether the SCM is functioning and screening it for potential problems. Both the federal and several state industrial and construction stormwater general permits have standard requirements for visual inspections following a major storm event. Visual observations of an SCM by themselves do not provide information on runoff reduction or pollutant removal, but rather only that the device is functioning as designed. Adding some grab samples for laboratory analysis can act as a screening tool to determine if a more complex analysis is required.

The first step of functionality monitoring for any SCM is to examine the physical condition of the device (piping, pervious surfaces, outlet structure, etc.). Visual inspection of sediments, eroded berms, clogged outlets, and other problems are good indications of the SCM's functionality (see Figure 5-50). For infiltration devices, visiting after a storm event will show whether or not the device is functioning. A simple staff gauge (Figure 5-51) or a stilling well in pervious pavement can be used to measure the amount of water-level change over several days to estimate infiltration rates. Minnesota suggests the use of fire equipment or hydrants to fill infiltration sites with a set volume of water to measure the rate of infiltration. For sites that are designed to capture a set volume, for example a green roof, a visit could be coordinated with a rainfall event of the appropriate size to determine whether there is overflow during the event. If so, then clearly further investigation is required.

FIGURE 5-50 Rusted outlet structure. SOURCE: Reprinted, with permission, from Emerson. Copyright by Clay Emerson.

FIGURE 5-51 Staff gauge attached to ultrasonic sensor after a storm. SOURCE: VUSP.

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For extended detention and stormwater wetlands, the depth of water during an event is an indicator of how well the SCM is functioning. Usually high-water marks are easy to determine due to debris or mud marks on the banks or the structures. If the size of the storm event is known, the depths can be compared to what was expected for the structure. Other indicators of problems would include erosion downstream of the SCM, algal blooms, invasive species, poor water clarity, and odor.

For water quality and manufactured devices, visual inspections after a storm event can determine whether the SCM is functioning properly. Standing water over a sand or other media filter 48 hours after a storm is a sign of problems. Odor and lack of flow clarity could be a sign of filter breakthrough or other problems. For manufactured devices, literature about the device should specify inspection and maintenance procedures.

Monitoring of nonstructural SCMs is almost exclusively limited to visual observation due to the difficulty in applying numerical value to their benefits. Visual inspection can identify eroded stream buffers, additional paved areas, or denuded conservation areas (see Figure 5-52).

Performance Monitoring

Performance monitoring is an extremely intensive effort to determine the performance of an SCM over either an individual storm event or over a series of storms. It requires integration of flow and water quality data creating both a hydrograph and a polutograph for a storm event as shown in Figure 5-53. The creation of these graphs requires continuous monitoring of the hydrology of the site and multiple water quality samples of the SCM inflow and outflow, the vadose zone, and groundwater. Event mean concentrations can then be determined from these data. There should be clear criteria for the number and type of storms to be sampled and for the conditions preceding a storm. For example, for most SCMs it would be improper to sample a second storm event in series, as the inflow may be free of pollutants and the soil moisture filled, resulting in a poor or negative performance. (Extended detention basins are an exception because the outflow during a storm event may include inflows from previous events.) The size of the sampled storm is also important. If the water quality goal is focused on smaller events, the 100-year storm would not give a proper picture of the performance because the occurrence is so rare that it is not a water quality priority.

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FIGURE 5-52 Wooded conservation area stripped of trees. Note pile of sawdust. SOURCE: Robert Traver.

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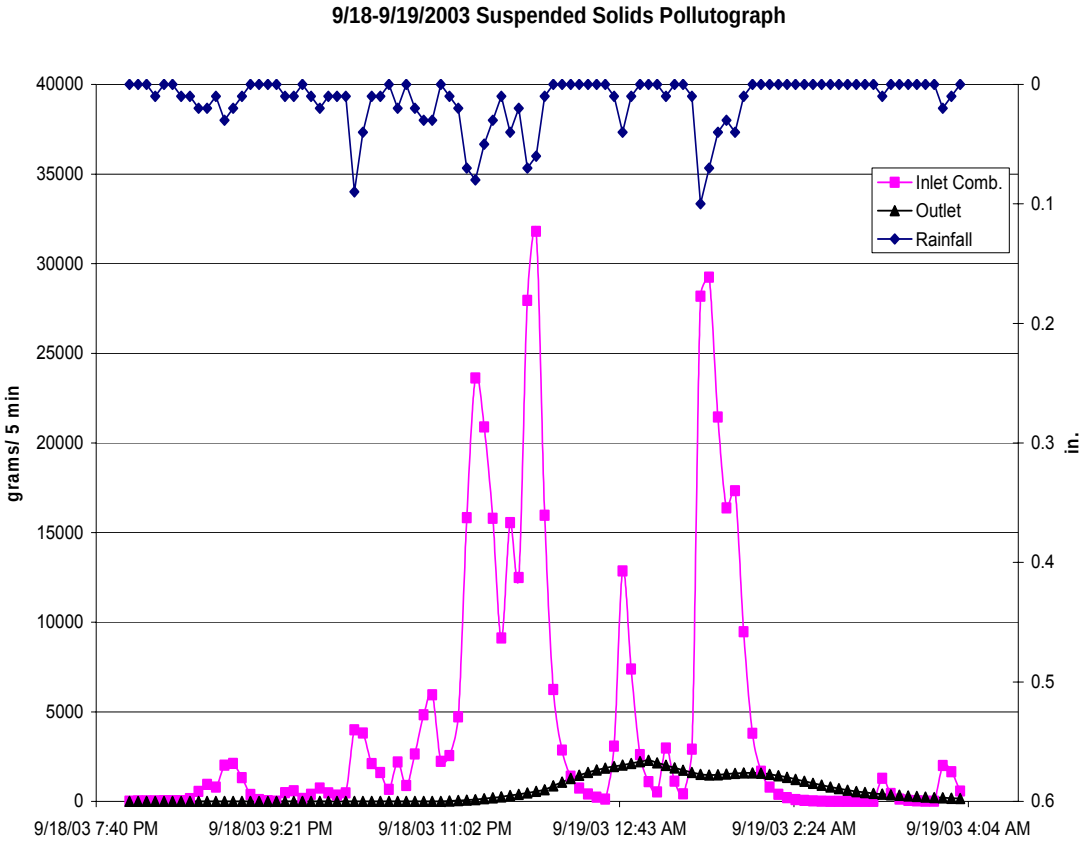

FIGURE 5-53 Example polutograph that displays inflow and outflow TSS during a storm event from the Villanova wetland stormwater SCM. SOURCE: Reprinted, with permission, Rea and Traver (2005). Copyright 2005 by the American Society of Civil Engineers.

For runoff-volume-reduction SCMs, performance monitoring can be extremely difficult because these systems are spread over the project site. The monitoring program must consider multiple-size storms because these SCMs are designed to remove perhaps the first inch of runoff. Therefore, for storms of less than an inch, there is no surface water release, so the treatment is 100 percent effective for surface discharges. During larger events, a bioretention SCM or green roof may export pollutants. When viewed over the entire spectrum of storms, these devices are an outstanding success; however, this may not be evident during a hurricane.

Through the use of manufactured weirs (Figure 5-54), it is possible to develop flow-depth criteria based on hydraulic principles for surface flows entering or leaving the SCM. Where this is not practical, various manufacturers have Doppler velocity sensors that, combined with geometry and depth, provide a reasonable continuous record of flow. Measurement of depth within a device can be accomplished through use of pressure transducers, bubblers, float gauges, and ultrasonic sensors. Other common measures would include rainfall and temperature. One advantage of these data recording systems is that they can be connected to water quality probes and automated samplers to provide a flow-weighted sample of the event for subsequent laboratory analysis. Field calibration and monitoring of these systems is required.

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FIGURE 5-54 Weir flow used to measure flow rate. Courtesy of Robert Traver.

Groundwater sampling for infiltration SCMs is a challenge. Although the rate of change in water depth can indicate volume moving into the soil mantle, it is difficult to establish whether this flow is evapotranspirated or ends up as baseflow or deep groundwater input. Sampling in the vadose zone can be established through the use of lysimeters that, through a vacuum, draw out water from the soil matrix. Soil moisture probes can give a rough estimation of the soil moisture content, and weighing lysimeters can establish evapotranspiration rates. Finally groundwater wells can be used to establish the effect of the SCM on the groundwater depth and quality during and after storm events.

Performance monitoring of extended detention SCMs is difficult because the inflows and outflows are variable and may extend over multiple days. Hydrologic monitoring can be accomplished using weirs (Figure 5-54), flow meters, and level detectors. The new generation of temperature, dissolved oxygen, and conductivity probes allows for automated monitoring. (It should be noted that in many cases the conductivity probes are observing chlorides, which are not generally removed by SCMs.) In many cases monitoring of the downstream stream-channel geomorphology and stream habitat may be more useful than performance monitoring when assessing the effect of the SCM.

The performance monitoring of treatment devices is straightforward and involves determining the pollutant mass inflows and outflows. Performance monitoring of manufactured SCMs has been established through several protocols. An example is TARP, used by multiple states (http://www.dep.state.pa.us/dep/deputate/pollprev/techservices/tarp/). This requires the manufacturer to test their units according to a set protocol of lab or field experiments to set performance criteria. Several TARP member and other states have published revised protocols for their use. These and other similar criteria are evolving and the subject of considerable effort by industry organizations that include the American Society of Civil Engineers.

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Finally, much needs to be done to determine the performance of nonstructural SCMs, for which little to no monitoring data are available (see Table 5-2). Currently most practitioners expand upon current hydrologic modeling techniques to simulate these techniques. For example, disconnection of impervious surfaces is often modeled by adding the runoff from the roof or parking area as distributed "rainfall" on the pervious area. Experiments and long-term monitoring are needed for these SCMs.

More information on SCM monitoring is available through the International Stormwater BMP Database (http://www.bmpdatabase.org).

Modeling of SCM performance

Modeling of SCMs is required to understand their individual performance and their effect on the overall watershed. The dispersed nature of their implementation, the wide variety of possible SCM types and goals, and the wide range of rainfall events they are designed for makes modeling of SCMs extremely challenging. For example, to model multiple SCMs on a single site may require simulation of many hydrologic and environmental processes for each SCM in series. Modeling these effects over large watersheds by simulating each SCM is not only impractical, but the noise in the modeling may make the simulation results suspect. Thus, it is critical to understand the model's purpose, limitations, and applicability.

As discussed in Chapter 4, one approach to simulating SCM performance is through mathematical representation of the unit processes. The large volumes of data needed for process-based models generally restrict their use to smaller-scale modeling. For flow this would start with the hydrograph entering the SCM and include infiltration, evapotranspiration, routing through the system, or whatever flow paths were applicable. The environmental processes that would need to be represented could include settling, adsorption, biological transformation, and soil physics. Currently there are no environmental process models that work across the range of SCMs. Rather, the state of art is to use general removal efficiencies from publications such as the International Stormwater BMP Database (http://www.bmpdatabase.org) and the Center for Watershed Protection's National Pollutant Removal Database (CWP, 2000b, 2007b). Unfortunately, this approach has many limitations. The percent removal used on a site and storm basis does not include storm intensity, period between the storms, land use, temperature, management practices, whether other SCMs are upstream, and so forth. It also should be noted that percent removals are a surface water statistic and do not address groundwater issues or include any biogeochemistry.

Mechanistic simulation of the hydrologic processes within an SCM is much advanced compared to environmental simulation, but from a modeling scale it is still evolving. Indeed, models such as the Prince George's County Decision Support System are greatly improved in that the hydrologic simulation of the SCM includes infiltration, but they still do not incorporate the more rigorous soil physics and groundwater interactions. Some models, such as the Stormwater Management Model (SWMM), have the capability to incorporate mechanistic descriptions of the hydrologic processes occurring inside an SCM.

At larger scales, simulation of SCMs is done primarily using lumped models that do not explicitly represent the unit processes but rather the overall effects. For example, the goal may be to model the removal of 2 cm of rainfall from every storm from bioinfiltration SCMs. Thus, all that would be needed is how many SCMs are present and their configuration and what their capabilities are within your watershed. What is critical for these models is to represent the

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interrelated processes correctly and to include seasonal effects. Again, the pollutant removal capability of the SCM is represented with removal efficiencies derived from publications.

Regardless of the scale of the model, or the extent to which it is mechanistic or not, nonstructural SCMs are a challenge. Limiting impervious surface or maintenance of forest cover have been modeled because they can be represented as the maintenance of certain land uses. However, aquatic buffers, disconnected impervious surfaces, stormwater education, municipal housekeeping, and most other nonstructural SCMs are problematic. Another challenge from a watershed perspective is determining what volume of pollutants comes from streambank erosion during elevated flows versus from nonpoint source pollution. Most hydrologic models do not include or represent in-stream processes.

In order to move forward with modeling of SCMs, it will be necessary to better understand the unit processes of the different SCMs, and how they differ for hydrology versus transformations. Research is needed to gather performance numbers for the nonstructural SCMs. Until such information is available, it will be virtually impossible to predict that an individual SCM can accomplish a certain level of treatment and thus prevent a nearby receiving water from violating its water quality standard.

DESIGNING SYSTEMS OF STORMWATER CONTROL MEASURES ON A WATERSHED SCALE

Most communities have traditionally relied on stormwater management approaches that result in the design and installation of SCMs on a site-by-site basis. This has created a large number of individual stormwater systems and SCMs that are widely distributed and have become a substantial part of the contemporary urban and suburban landscape. Typically, traditional stormwater infrastructure was designed on a subdivision basis to reduce peak storm flow rates to predevelopment levels for large flood events (> 10-year return period). The problem with the traditional approach is that (1) the majority of storms throughout the year are small and therefore pass through the detention facilities uncontrolled, (2) the criterion of reducing storm flow does not address the need for reducing total storm volume, and (3) the facilities are not designed to work as a system on a watershed scale. In many cases, the site-by-site approach has exacerbated downstream flooding and channel erosion problems as a watershed is gradually built out. For example, McCuen (1979) and Emerson et al. (2005) showed that an unplanned system of site-based SCMs can actually increase flooding on a watershed scale owing to the effect of many facilities discharging into a receiving waterbody in an uncoordinated fashion—causing the very flooding problem the individual basins were built to solve.

With the relatively recent recognition of unacceptable downstream impacts and the regulation of urban stormwater quality has come a rethinking of the design of traditional stormwater systems. It is becoming rapidly understood that stormwater management should occur on a watershed scale to prevent flow control problems from occurring or reducing the chances that they might become worse. In this context, the "watershed scale" refers to the small local watershed to which the individual site drains (i.e., a few square miles within a single municipality). Together, the developer, designer, plan reviewer, owners, and the municipality jointly install and operate a linked and shared system of distributed practices across multiple sites that achieve small watershed objectives. Many metropolitan areas around the country have institutions, such as the Southeast Wisconsin Regional Planning Commission and the Milwaukee

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Metropolitan Sewage District, that are doing stormwater master planning to reduce flooding, bank erosion, and water quality problems on a watershed scale.

Designing stormwater management on a watershed scale creates the opportunity to evaluate a system of SCMs and maximize overall effectiveness based on multiple criteria, such as the incremental costs to development beyond traditional stormwater infrastructure, the limitations imposed on land area required for site planning, the effectiveness at improving water quality or attenuating discharges, and aesthetics. Because the benefits that accrue with improved water quality are generally not realized by those entities required to implement SCMs, greater value must be created beyond the functional aspects of the facility if there is to be wide acceptance of SCMs as part of the urban landscape. Stormwater systems designed on a watershed basis are more likely to be seen as a multi-functional resource that can contribute to the overall quality of the urban environment. Potential even exists to make the stormwater system a primary component of the civic framework of the community—elements of the public realm that serve to enhance a community's quality of life like public spaces and parks. For example, in central Minneapolis, redevelopment of a 100-acre area called Heritage Park as a mixed-density residential neighborhood was organized around two parks linked by a parkway that served dual functions of recreation and stormwater management.

Key elements of the watershed approach to designing systems of SCMs are discussed in detail below. They include the following:

1. Forecasting the current and future development types.
2. Forecasting the scale of current and future development.
3. Choosing among on-site, distributed SCMs and larger, consolidated SCMs.
4. Defining stressors of concern.
5. Determining goals for the receiving water.
6. Noting the physical constraints.
7. Developing SCM guidance and performance criteria for the local watershed.
8. Establishing a trading system.
9. Ensuring the safe performance of the drainage network, streams, and floodplains.
10. Establishing community objectives for the publically owned elements of stormwater infrastructure.
11. Establishing a maintenance plan.

Forecasting the Current and Future Development Types

Forecasting the type of current and future development within the local watershed will guide or shape how individual practices and SCMs are generally assembled at each individual site. The development types that are generally thought of include Greenfield development (small and large scales), redevelopment within established communities and on Brownfield sites, and retrofitting of existing urban areas. These development types range roughly from lower density to higher density impervious cover. Box 5-10 explains how the type of development can dictate stormwater management, discussing two main categories—*Greenfield* development and *redevelopment* of existing areas. The former refers to development that changes pristine or agricultural land to urban or suburban land uses, frequently low-density residential housing. Redevelopment refers to changing from an existing urban land use to another, usually of higher

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BOX 5-10
Development Types and their Relationship to the Stormwater System

Development falls into two basic types. Greenfield development requires new infrastructure designed according to contemporary design standards for roads, utilities, and related infrastructure. Redevelopment refers to developed areas undergoing land-use change. In contrast to Greenfields, infrastructure in previously developed areas is often in poor condition, was not built to current design standards, and is inadequate for the new land uses proposed. The stormwater management scenarios common to these types of development are described below.

Greenfield Development

At the largest scale, Greenfield development refers to planned communities at the developing edge of metropolitan areas. Communities of this type often vary from several hundred acres to very large projects that encompassed tens of thousands of acres requiring buildout over decades. They often include the trunk or primary stormwater system as well as open stream and river corridors. The most progressive communities of this type incorporate a significant portion of the area to stormwater systems that exist as surface elements. Such stormwater system elements are typically at the subwatershed scale and provide for consolidated conveyance, detention, and water quality treatment. These elements of the infrastructure can be multi-functional in nature, providing for wildlife habitat, trail corridors, and open-space amenities.

Greenfield development can also occur on a small scale—neighborhoods or individual sites within newly developing areas that are served by the secondary public and tertiary stormwater systems. This smaller-scale, incremental expansion of existing urban patterns is a more typical way for cities to grow. A more limited range of SCMs and innovative stormwater management practices are available on smaller projects of this type, including LID practices.

Redevelopment of Existing Areas

Redevelopment within established communities is typically at the scale of individual sites and occasionally the scale of a small district. The area is usually served by private, on-site systems that convey larger storm events into preexisting stormwater systems that were developed decades ago, either in historic city centers or in “first ring,” post-World War II suburbs adjacent to historic city centers. Redevelopment in these areas is typically much denser than the original use. The resulting increase in impervious area, and typically the inadequacy of existing stormwater infrastructure serving the site often results in significant development costs for on-site detention and water quality treatment. Elaborate vaults or related structures, or land area that could be utilized for development, must often be committed to on-site stormwater management to comply with current stormwater regulations.

Brownfields are redevelopments of industrial and often contaminated property at the scale of an individual site, neighborhood, or district. Secondary public systems and private stormwater systems on individual sites typically serve these areas. In many cases, especially in outdated industrial areas, little or no stormwater infrastructure exists, or it is so inadequate as to require replacement. Water quality treatment on contaminated sites may also be necessary. For these reasons, stormwater management in such developments presents special challenges. As an example, the most common methods of remediation of contaminated sites involve capping of contaminated soils or treatment of contaminants in situ, especially where removal of contaminated soils from a site is cost prohibitive. Given that contaminants are still often in place on redeveloped Brownfield sites and must not be disturbed, certain SCMs such as infiltration of stormwater into site soils, or excavation for stormwater piping and other utilities, present special challenges.

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density, such as from single-family housing to multi-family housing. Finally, *retrofitting* as used in this report is not a development type but rather the upgrading of stormwater management within an existing land use to meet higher standards.

Table 5-7 shows which SCMs are best suited for Greenfield development (particularly low-density residential), redevelopment of urban areas, and intense industrial redevelopment. The last category is broken out because the suite of SCMs needed is substantially different than for urban redevelopment. Each type of development has a different footprint, impervious cover, open space, land cost, and existing stormwater infrastructure. Consequently, SCMs that are ideally suited for one type of development may be impractical or infeasible for another. One of the main points to be made is that there are more options during Greenfield development than during redevelopment because of existing infrastructure, limited land area, and higher costs in the latter case.

TABLE 5-7 Applicability of Stormwater Control Measures by Type of Development

Stormwater Control Measure	**Low-Density Greenfield Residential**	**Urban Redevelopment**	**Intense Industrial Redevelopment**
Product Substitution	○	●	●
Watershed and Land-Use Planning	■	■	○
Conservation of Natural Areas	■	♦	○
Impervious Cover Minimization	■	♦	♦
Earthwork Minimization	■	♦	♦
Erosion and Sediment Control	■	■	■
Reforestation and Soil Conservation	■	●	●
Pollution Prevention SCMs	♦	●	■
Runoff Volume Reduction—Rainwater Harvesting	■	■	●
Runoff Reduction—Vegetated	■	○	●
Runoff Reduction—Subsurface	■	○	♦
Peak Reduction and Runoff Treatment	■	♦	○
Runoff Treatment	●	●	■
Aquatic Buffers and Managed Floodplains	●	♦	○
Stream Rehabilitation	○	♦	♦
Municipal Housekeeping	○	○	NA
IDDE	○	○	○
Stormwater Education	●	●	●
Residential Stewardship	■	●	NA

NOTE: ■, always; ●, often; ○, sometimes; ♦, rarely; NA, not applicable.

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Forecasting the Scale of Current and Future Development

The choice of what SCMs to use depends on the area that needs to be serviced. It turns out that some SCMs work best over a few acres, whereas others require several dozen acres or more; some are highly effective only for the smallest sites, while others work best at the stream corridor or subwatershed level. Table 5-1 includes a column that is related the scale at which individual SCMs can be applied ("where" column). The SCMs mainly applied at the site scale include runoff volume reduction—rainwater harvesting, runoff treatment like filtering, and pollution prevention SCMs for hotspots. As one goes up in scale, SCMs like runoff volume reduction—vegetated and subsurface, earthwork minimization, and erosion and sediment control take on more of a role. At the largest scales, watershed and land-use planning, conservation of natural areas, reforestation and soil conservation, peak flow reduction, buffers and managed floodplains, stream rehabilitation, municipal housekeeping, IDDE, stormwater education, and residential stewardship play a more important role. Some SCMs are useful at all scales, such as product substitution and impervious cover minimization.

Choosing Among On-Site, Distributed SCMs and Larger, Consolidated SCMs

There are distinct advantages and disadvantages to consider when choosing to use a system of larger, consolidated SCMs versus smaller-scale, on-site SCMs that go beyond their ability to achieve water quality or urban stream health. Smaller, on-site facilities that serve to meet the requirements for residential, commercial, and office developments tend to be privately owned. Typically, flows are directed to porous landscape detention areas or similar SCMs, such that volume and pollutants in stormwater are removed at or near their source. Quite often, these SCMs are relegated to the perimeter project, incorporated into detention ponds, or, at best, developed as landscape infiltration and parking islands and buffers. On-site infiltration of frequent storm events can also reduce the erosive impacts of stormwater volumes on downstream receiving waters. Maintenance is performed by the individual landowner, which is both an advantage because the responsibility and costs for cleanup of pollutants generated by individual properties are equitably distributed, and a disadvantage because ongoing maintenance incurs a significant expense on the part of individual property owners and enforcement of properties not in compliance with required maintenance is difficult. On the negative side, individual SCMs often require additional land, which increases development costs and can encourage sprawl. Monitoring of thousands of SCMs in perpetuity in a typical city creates a significant ongoing public expense, and special training and staffing may be required to maintain SCM effectiveness (especially for subgrade or in-building vaults used in ultra-urban environments). Finally, given that as much as 30 percent of the urban landscape is comprised of public streets and rights-of-way, there are limited opportunities to treat runoff from streets through individual on-site private SCMs. (Notable exceptions are subsurface runoff-volume-reduction SCMs like permeable pavement that require no additional land and promote full development density within a given land parcel because they use the soil areas below roads and the development site for infiltration.)

In contrast, publicly owned, consolidated SCMs are usually constructed as part of larger Greenfield and infill development projects in areas where there is little or no existing infrastructure. This type of facility—usually an infiltration basin, detention basin, wet/dry pond, or stormwater wetland—tends to be significantly larger, serving multiple individual properties.

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Ownership is usually by the municipality, but may be a privately managed, quasi-public special district. There must be adequate land available to accommodate the facility and a means of up-front financing to construct the facility. An equitable means of allocating costs for ongoing maintenance must also be identified. However, the advantage of these facilities is that consolidation requires less overall land area, and treatment of public streets and rights-of-way can be addressed. Monitoring and maintenance are typically the responsibility of one organization, allowing for effective ongoing operations to maintain the original function of the facility. If that entity is public, this ensures that the facility will be maintained in perpetuity, allowing for the potential to permanently reduce stormwater volumes and for reduction in the size of downstream stormwater infrastructure. Because consolidated facilities are typically larger than on-site SCMs, mechanized maintenance equipment allows for greater efficiency and lower costs. Finally, consolidated SCMs have great potential for multifunctional uses because wildlife habitat, recreational, and open-space amenities can be integrated to their design. Box 5-11 describes sites of various scales where either consolidated or distributed SCMs were chosen.

Defining Stressors of Concern

The primary pollutants or stressors of concern (and the primary source areas or stormwater hotspots within the watershed likely to produce them) should be carefully defined for the watershed. Although this community decision is made only infrequently, it is critical to ensuring that SCMs are designed to prevent or reduce the maximum load of the pollutants of greatest concern. This choice may be guided by regional water quality priorities (such as nutrient reduction in the Chesapeake Bay or Neuse River watersheds) or may be an outgrowth of the total maximum daily load process where there is known water quality impairment or a listed pollutant. The choice of a pollutant of concern is paramount, since individual SCMs have been shown to have highly variable capabilities to prevent or reduce specific pollutants (see WERF, 2006; ASCE, 2007; CWP, 2007b). In some cases, the capability of SCMs to reduce a specific pollutant may be uncertain or unknown.

Determining Goals for the Receiving Waters

It is important to set biological and public health goals for the receiving water that are achievable given the ultimate impervious cover intended for the local watershed (see the Impervious Cover Model in Box 3-10). If the receiving water is too sensitive to meet these goals, one should consider adjustments to zoning and development codes to reduce the amount of impervious cover. The biological goals may involve a keystone species, such as salmon or trout, a desired state of biological integrity in a stream, or a maximum level of eutrophication in a lake. In other communities, stormwater goals may be driven by the need to protect a sole-source drinking water supply (e.g., New York watersheds) or to maintain water contact recreation at a beach, lake, or river. Once again, the watershed goals that are selected have a strong influence on the assembly of SCMs needed to meet them, since individual SCMs vary greatly in their ability to achieve different biological or public health outcomes.

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BOX 5-11
Examples of Communities Using Consolidated versus Distributed SCMs

Stapleton Airport New Community

This is a mixed-use, mixed-density New Urbanist community that has been under development for the past 15 years on the 4,500-acre former Stapleton Airport site in central Denver. As shown in Figures 5-55 and 5-56, the stormwater system emphasizes surface conveyance and treatment on individual sites, as well as in consolidated regional facilities.

FIGURE 5-55 The community plan, shown on the left, is organized around two day lighted creeks, formerly buried under airport runways, and a series of secondary conveyances which provide recreational open space within neighborhoods. The image on the right illustrates one of the multi-functional creek corridors. Consolidated stormwater treatment areas and surface conveyances define more traditional park recreation and play areas. Courtesy of Stapleton Redevelopment Foundation.

FIGURE 5-56 A consolidated treatment area adjacent to one of several neighborhoods that have been constructed as part of the project's build-out.

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Heritage Park Neighborhood Redevelopment

A failed public housing project adjacent to downtown Minneapolis, Minnesota, has been replaced by a mixed-density residential neighborhood. Over 1,200 rental, affordable, and market-rate single- and multi-family housing units have been provided in the 100-acre project area. The neighborhood is organized around two neighborhood parks and a parkway that serve dual functions as neighborhood recreation space and as surface stormwater conveyance and a consolidated treatment system (see Figure 5-57). Water quality treatment is being provided for a combined area of over 660 acres that includes the 100-acre project area and over 500 acres of adjacent neighborhoods. Existing stormwater pipes have been routed through treatment areas with treatment levels ranging from 50 to 85 percent TSS removal, depending on the available land area.

FIGURE 5-57 View of a sediment trap and porous landscape detention area in the central parkway spine of Heritage Park. The sediment trap in the center left of the photo was designed for ease of maintenance access by city crews with standard city maintenance equipment. Courtesy of SRF Consulting Group, Inc.

The High Point Neighborhood

This Seattle project is the largest example of the city's Natural Drainage Systems Project and it illustrates the incorporation of individual SCMs into street rights-of-way as well as a consolidated facility. The on-site, distributed SCMs in this 600-acre neighborhood are swales, permeable pavement, and disconnected downspouts. A large detention pond services the entire region that is much smaller than it would have been had the other SCMs not been built. Both types of SCMs are shown in Figure 5-58.

FIGURE 5-58 Natural drainage system methods have been applied to a 34-block, 1,600-unit mixed-income housing redevelopment project called High Point. Vegetated swales, porous concrete sidewalks, and frontyard rain gardens convey and treat stormwater on-site. On the right is the detention pond for the development.

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BOX 5-11 Continued

Pottsdammer Platz

This project, in the heart of Berlin, Germany, illustrates the potential for stormwater treatment in the densest urban environments by incorporating treatment into building systems and architectural pools that are the centerpiece of a series of urban plazas. As shown in Figure 5-59, on-site, individual SCMs are used to collect stormwater and use it for sanitary purposes.

FIGURE 5-59 Stormwater is collected and stored on-site in a series of vaults. Water is circulated through a series of biofiltration areas and used for toilets and other mechanical systems in the building complex. Large storms overflow into an adjacent canal. Permission pending.

Menomonee Valley Redevelopment, Wisconsin

The 140-acre redevelopment of abandoned railyards illustrates how a Brownfield site within an existing floodplain can be redeveloped using both on-site and consolidated treatment. As shown in Figure 5-60, consolidated treatment is incorporated into park areas which provide recreation for adjacent neighborhoods and serve as a centerpiece for a developing light industrial area that provides jobs to surrounding neighborhoods. Treatment on individual privately owned parcels is limited to the removal of larger sediments and debris only, making more land available for development. The volume of water that, by regulation, must be captured and treated on individual sites is conveyed through a conventional subsurface system for treatment in park areas.

FIGURE 5-60 Illustrations show consolidated treatment areas in proposed parks. The image on the left illustrates the fair weather condition, the center image the water quality capture volume, and the image on the right the 100-year storm event. Construction was completed in spring 2007.

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Noting the Physical Constraints

The specific physical constraints of the watershed terrain and the development pattern will influence the selection and assembly of SCMs. The application of SCMs must be customized in every watershed to reflect its unique terrain, such as karst, high water tables, low or high slopes, freeze–thaw depth, soil types, and underlying geology. Each SCM has different restrictions or constraints associated with these terrain factors. Consequently, the SCM prescription changes as one moves from one physiographic region to another (e.g., the flat coastal plain, the rolling Piedmont, the ridge and valley, and mountainous headwaters).

Developing SCM Guidance and Performance Criteria for the Local Watershed

Based on the foregoing factors, the community should establish specific sizing, selection, and design requirements for SCMs. These SCM performance criteria may be established in a local, regional, or state stormwater design manual, or by reference in a local watershed plan. The Minnesota Stormwater Steering Committee (MSSC, 2005) provides a good example of how SCM guidance can be customized to protect specific types of receiving waters (e.g., high-quality lakes, trout streams, drinking water reservoirs, and impaired waters). In general, the watershed- or receiving water-based criteria are more specific and detailed than would be found in a regional or statewide stormwater manual. For example, the local stormwater guidance criteria may be more prescriptive with respect to runoff reduction and SCM sizing requirements, outline a preferred sequence for SCMs, and indicate where SCMs should (or should not) be located in the watershed. Like the identification of stressors or pollutants of concerns, this step is rarely taken under current paradigms of stormwater management.

Establishing a Trading System

A stormwater trading or offset system is critical to situations when on-site SCMs are not feasible or desirable in the watershed. Communities may choose to establish some kind of stormwater trading or mitigation system in the event that full compliance is not possible due to physical constraints or because it is more cost effective or equitable to achieve pollutant reduction elsewhere in the local watershed. The most common example is providing an offset fee based on the cost to remove an equivalent amount of pollutants (such as phosphorus in the Maryland Critical Area—MD DNR, 2003). This kind of trading can provide for greater cost equity between low-cost Greenfield sites and higher-cost ultra-urban sites.

Ensuring the Safe and Effective Performance of the Drainage Network, Streams, and Floodplains

The urban water system is not solely designed to manage the quality of runoff. It also must be capable of safely handling flooding from extreme storms to protect life and property. Consequently, communities need to ensure that their stormwater infrastructure can prevent increased flooding caused by development (and possibly exacerbated future climate change). In

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addition, many SCMs must be designed to safely pass extreme storms when they do occur. This usually requires a watershed approach to stormwater management to ensure that quality and quantity control are integrated together, with an emphasis on the connection and effective use of conveyance channels, streams, riparian buffers, and floodplains.

Establishing Community Objectives for the Publicly Owned Elements of Stormwater Infrastructure

The stormwater infrastructure in a community normally occupies a considerable surface area of the landscape once all the SCMs, drainage easements, buffers, and floodplains are added together. Consequently, communities may require that individual SCM elements are designed to achieve multiple objectives, such as landscaping, parks, recreation, greenways, trails, habitat, sustainability, and other community amenities (as discussed extensively above). In other cases, communities may want to ensure that SCMs do not cause safety or vector problems and that they look attractive. The best way to maximize community benefits is to provide clear guidance in local SCM criteria at the site level and to ensure that local watershed plans provide an overall context for their implementation.

Establishing an Inspection and Maintenance Plan

The long-term performance of any SCM is fundamentally linked to the frequency of inspections and maintenance. As a result, NPDES stormwater permit conditions for industrial, construction, and municipal permittees specify that pollution prevention, construction, and post-construction SCMs be adequately maintained. MS4 communities are also required under NPDES stormwater permits to track, inspect, and ensure the maintenance of the collective system of SCMs and stormwater infrastructure within their jurisdiction. In larger communities, this can involve hundreds or even thousands of individual SCMs located on either public or private property. In these situations, communities need to devise a workable model that will be used to operate, inspect, and maintain the stormwater infrastructure across their local watershed. Communities have the lead responsibility in their MS4 permits to assure that SCMs are maintained properly to ensure their continued function and performance over time. They can elect to assign the responsibility to the public sector, the private sector (e.g., property owners and homeowners association), or a hybrid of the two, but under their MS4 permits they have ultimate responsibility to ensure that SCM maintenance actually occurs. This entails assigning legal and financial responsibilities to the owners of each SCM element in the watershed, as well as maintaining a tracking and enforcement system to ensure compliance.

Summary

Taking all of the elements above into consideration, the emerging goal of stormwater management is to mimic, as much as possible, the hydrological and water quality processes of natural systems as rain travels from the roof to the stream through combined application of a series of practices throughout the entire development site and extending to the stream corridor.

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The series of SCMs incrementally reduces the volume of stormwater on its way to the stream, thereby reducing the amount of conventional stormwater infrastructure required.

There is no single SCM prescription that can be applied to each kind of development; rather, a combination of interacting practices must be used for full and effective treatment. For a low-density residential Greenfield setting, a combination of SCMs that might be implemented is illustrated in Table 5-8. There are many successful examples of SCMs in this context and at different scales. By contrast, Tables 5-9 and 5-10 outline how the general "roof-to-stream" stormwater approach is adapted for intense industrial operations and urban redevelopment sites, respectively. As can be seen, these development situations require a differ combination of SCMs and practices to address the unique design challenges of dense urban environments. The tables are meant to be illustrative of certain situations; other scenarios, such as commercial development, would likely require additional tables.

TABLE 5-8 From the Roof to the Stream: SCMs in a Residential Greenfield

SCM	What it Is	What it Replaces	How it Works
Land-Use Planning	Early site assessment	Doing SWM design after site layout	Map and plan submitted at earliest stage of development review showing environmental, drainage, and soil features
Conservation of Natural Areas	Maximize forest canopy	Mass clearing	Preservation of priority forests and reforestation of turf areas to intercept rainfall
Earthwork Minimization	Conserve soils and contours	Mass grading and soil compaction	Construction practices to conserve soil structure and only disturb a small site footprint
Impervious Cover Minimization	Better site design	Large streets, lots and cul-de-sacs	Narrower streets, permeable driveways, clustering lots, and other actions to reduce site IC
Runoff Volume Reduction—Rainwater Harvesting	Utilize rooftop runoff	Direct connected roof leaders	A series of practices to capture, disconnect, store, infiltrate, or harvest rooftop runoff
Runoff Volume Reduction—Vegetated	Frontyard bioretention	Positive drainage from roof to road	Grading frontyard to treat roof, lawn, and driveway runoff using shallow bioretention
	Dry swales	Curb/gutter and storm drain pipes	Shallow, well-drained bioretention swales located in the street right-of-way
Peak Reduction and Runoff Treatment	Linear wetlands	Large detention ponds	Long, multi-cell, forested wetlands located in the stormwater conveyance system
Aquatic Buffers and Managed Floodplains	Stream buffer management	Unmanaged stream buffers	Active reforestation of buffers and restoration of degraded streams

Note: SCMs are applied in a series, although all of the above may not be needed at a given residential site. This "roof-to-stream" approach works best for low- to medium-density residential development.

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In summary, a watershed approach for organizing site-based stormwater decisions is generally superior to making site-based decisions in isolation. Communities that adopt the preceding watershed elements not only can maximize the performance of the entire system of SCMs to meet local watershed objectives, but also can maximize other urban functions, reduce total costs, and reduce future maintenance burdens.

TABLE 5-9 From the Roof to the Outfall: SCMs in an Industrial Context

SCM Category	What it Is	What it Replaces	How it Works
Pollution Prevention	Drainage mapping	No map	Analysis of the locations and connections of the stormwater and wastewater infrastructure from the site
	Hotspot site investigation	Visual inspection	Systematic assessment of runoff problems and pollution prevention opportunities at the site
	Rooftop management	Uncontrolled rooftop runoff	Use of alternative roof surfaces or coatings to reduce metal runoff, and disconnection of roof runoff for stormwater treatment
	Exterior maintenance practices	Routine plant maintenance	Special practices to reduce discharges during painting, powerwashing, cleaning, sealcoating and sandplasting
	Extending roofs for no exposure	Exposed hotspot operations	Extending covers over susceptible loading/unloading, fueling, outdoor storage, and waste management operations
	Vehicular pollution prevention	Uncontrolled vehicle operations	Pollution prevention practices applied to vehicle repair, washing, fueling, and parking operations
	Outdoor pollution prevention practices	Outdoor materials storage	Prevent rainwater from contact with potential pollutants by covering, secondary containment, or diversion from storm-drain system
	Waste management practices	Exposed dumpster or waste streams	Improved dumpster location, management, and treatment to prevent contact with rainwater or runoff
	Spill control plan and response	No plan	Develop and test response to spills to the storm-drain system, train employees, and have spill control kits available on-site
	Greenscaping	Routine landscape and turf maintenance	Reduce use of pesticides, fertilization, and irrigation in pervious areas, and conversion of turf to forest
	Employee stewardship	Lack of stormwater awareness	Regular ongoing training of employees on stormwater problems and pollution prevention practices
	Site housekeeping and stormwater maintenance	Dirty site and unmaintained infrastructure	Regular sweeping, storm-drain cleanouts, litter pickup, and maintenance of stormwater infrastructure
Runoff Treatment	Stormwater retrofitting	No stormwater treatment	Filtering retrofits to remove pollutants from most severe hotspot areas
IDDE	Outfall analysis	No monitoring	Monitoring of outfall quality to measure effectiveness

Note: While many SCMs are used at each individual industrial site, the exact combination depends on the specific configuration, operations, and footprint of each site.

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TABLE 5-10 From the Roof to the Street: SCMs in a Redevelopment Context

SCM Category	What it Is	What it Replaces	How it Works
Impervious Cover Minimization	Site design to prevent pollution	Conventional site design	Designing redevelopment footprint to restore natural area remnants, minimize needless impervious cover, and reduce hotspot potential
Runoff Volume Reduction—Rainwater Harvesting and Vegetated	Treatment on the roof	Traditional rooftops	Use of green rooftops to reduce runoff generated from roof surfaces
	Rooftop runoff treatment	Directly connected roof leaders	Use of rain tanks, cisterns, and rooftop disconnection to capture, store, and treat runoff
	Runoff treatment in landscaping	Traditional landscaping	Use of foundation planters and bioretention areas to treat runoff from parking lots and rooftops
Soil Conservation and Reforestation	Runoff reduction in pervious areas	Impervious or compacted soils	Reducing runoff from compacted soils through tilling and compost amendments, and in some cases, removal of unneeded impervious cover
	Increase urban tree canopy	Turf or landscaping	Providing adequate rooting volume to develop mature tree canopy to intercept rainfall
Runoff Reduction—Subsurface	Increase permeability of impervious cover	Hard asphalt or concrete	Use of permeable pavers, porous concrete, and similar products to decrease runoff generation from parking lots and other hard surfaces.
Runoff Reduction—Vegetated	Runoff treatment in the street	Sidewalks, curb and gutter, and storm drains	Use of expanded tree pits, dry swales and street bioretention cells to further treat runoff in the street or its right-of-way
Runoff Treatment	Underground treatment	Catch basins and storm-drain pipes	Use of underground sand filters and other practices to treat hotspot runoff quality at the site
Municipal Housekeeping	Street cleaning	Unswept streets	Targeted street cleaning on priority streets to remove trash and gross solids
Watershed Planning	Off-site stormwater treatment or mitigation	On-site waivers	Stormwater retrofits or restoration projects elsewhere in the watershed to compensate for stormwater requirements that cannot be met onsite

Note: SCMs are applied in a series, although all of the above may not be needed at a given redevelopment site.

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COST, FINANCE OPTIONS, AND INCENTIVES

Municipal Stormwater Financing

To be financially sustainable, stormwater programs must develop a stable long-term funding source. The activities common to most municipal stormwater programs (such as education, development design review, inspection, and enforcement) are funded through general tax revenues, most commonly property taxes and sales taxes (NAFSMA, 2006), which is problematic for several reasons. First, stormwater management financed through general tax receipts does not link or attempt to link financial obligation with services received. The absence of such links can reduce the ability of a municipality to adequately plan and meet basic stormwater management obligations. Second, when funded through general tax revenues, stormwater programs must compete with other municipal programs and funding obligations. Finally, in programs funded by general tax revenue, responsibilities for stormwater management tend to be distributed into the work responsibilities of existing and multiple departments (e.g., public works, planning, etc.). One recent survey conducted in the Charles River watershed in Massachusetts found that three-quarters of local stormwater management programs did not have staff dedicated exclusively for stormwater management (Charles River Watershed Association, 2007).

Increasingly, many municipalities are establishing stormwater utilities to manage stormwater (Kaspersen, 2000). Most stormwater utilities are created as a separate organizational entity with a dedicated, self-sustaining source of funding. The typical stormwater utility generates the large majority of revenue through user fees (Florida Stormwater Association, 2003; Black and Veatch, 2005; NAFSMA, 2006). User fees are established and set so as to have a close nexus to the cost of providing the service and, thus, are most commonly based on the amount of impervious surface, frequently measured in terms of equivalent residential unit. For example, an average single-family residence may create 3,000 square feet of impervious surface (roof and driveway area). A per-unit charge is then assigned to this "equivalent runoff unit." To simplify program administration, utilities typically assign a flat rate for residential properties (customer class average) (NAFSMA, 2006). Nonresidential properties are then charged individually based on the total amount of impervious surface (square feet or equivalent runoff units) of the parcel. Fees are sometimes also based on gross area (total area of a parcel) or some combination of gross area and a development intensity measure (Duncan, 2004; NAFSMA, 2006).

Municipalities have the legal authority to create stormwater utilities in most states (Lehner et al., 1999). In addition to creating the utility, a municipality will generally establish the utility rate structure in a separate ordinance. Separating the ordinances allows the municipality flexibility to change the rate structure without revising the ordinance governing the entire utility (Lehner et al., 1999). While municipalities generally have the authority to collect fees, some states have legal restrictions on the ability of local governments to levy taxes (Lehner et al., 1999; NAFSMA, 2006). The legal distinction between a tax and a fee is the most common legal challenge to a stormwater utility. For example, stormwater fees have been subject to litigation in at least 17 states (NAFSMA, 2006). To avoid legal challenges, care must be taken to meet a number of legal tests that distinguish a fee for a specific service and a general tax.

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Stormwater utilities typically bill monthly, and fees range widely. A recent survey of U.S. stormwater utilities reported that fees for residential households range from $1 to $14 per month, but a typical residential household rate is in the range of $3 to $6 (Black and Veatch, 2005). Despite the dedicated funding source, the majority of stormwater utilities responding to a recent survey (55 percent) indicated that current funding levels were either inadequate or just adequate to meet their most urgent needs (Black and Veatch, 2005).

Both municipal and state programs can finance administrative programming costs through stormwater permitting fees. Municipal stormwater programs can use separate fees to finance inspection activities. For instance, inspection fees can be charged to cover the costs of ensuring that SCMs are adequately planned, installed, or maintained (Debo and Reese, 2003). Stormwater management programs can also ensure adequate funding for installation and maintenance of SCMs by requiring responsible parties to post financial assurances. Performance bonds, letters of credit, and cash escrow are all examples of financial assurances that require up-front financial payments to ensure that longer-term actions or activities are successfully carried out. North Carolina's model stormwater ordinance recommends that the amount of a maintenance performance security (bond, cash escrow, etc.) be based on the present value of an annuity based on both inspection costs and operation and maintenance costs (Whisnant, 2007).

In addition to fees or taxes, exactions such as impact fees can also be used as a way to finance municipal stormwater infrastructure investments (Debo and Reese, 2003). An impact fee is a one-time charge levied on new development. The fee is based on the costs to finance the infrastructure needed to service the new development. The ability to levy impact fees varies between states. Municipalities that use impact fees are also required to show a close nexus between the size of the fee and the level of benefits provided by the fee; a failure to do so exposes local government to law suits (Keller, 2003). Compared to other funding sources, impact fees also exhibit greater variability in revenue flows because the amount of funds collected is dependent on development growth.

Bonds and grants can supplement the funding sources identified above. Bonds and loans tend to smooth payments over time for large up-front stormwater investments. For example, state and federal loan programs (state revolving funds) provide long-term, low-interest loans to local governments or capital investments (Keller, 2003). In addition, grant opportunities are sometimes available from state and federal sources to help pay for specific elements of local stormwater management programs.

Municipalities require funds to meet federal and state stormwater requirements. Understanding of the municipal costs incurred by implementing stormwater regulations under the Phase I and II stormwater rules, however, is incomplete (GAO, 2007). Of the six minimum measures of a municipal stormwater program (public education, public involvement, illicit discharge detection and elimination, construction site runoff control, post-construction stormwater management, and pollution prevention/good housekeeping—see Chapter 2), a recent study of six California municipalities found that pollution prevention activities (primarily street sweeping) accounted for over 60 percent of all municipal stormwater management costs in these communities (Currier et al., 2005). Annual per-household costs ranged from $18 to $46.

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Stormwater Cost Review

Conceptually, the costs of providing SCMs are all opportunity costs (EPA, 2000). Opportunity costs are the value of alternatives (next best) given up by society to achieve a particular outcome. In the case of stormwater control, opportunity costs include direct costs necessary to control and treat runoff such as capital and construction costs and the present value of annual operation and maintenance costs. Initial installation costs should also include the value of foregone opportunities on the land used for stormwater control, typically measured as land acquisition (land price).

Costs also include public and private resources incurred in the administration of the stormwater management program. Private-sector costs might include time and administrative costs associated with permitting programs. Public costs include agency monitoring and enforcement costs.

Opportunity costs also include other values that might be given up as a consequence of stormwater management. For example, the creation of a wet pond in a residential area might be opposed because of perceived safety, aesthetic, or nuisance concerns (undesirable insect or animal species). In this case, the diminished satisfaction of nearby property owners is an opportunity cost associated with the wet pond. On the other hand, if SCMs are considered a neighborhood amenity (e.g., a constructed wetland in a park setting), opportunity costs may decrease. In addition, costs of a given practice may be reduced by reducing costs elsewhere. For example, increasing on-site infiltration rates can reduce off-site storage costs by reducing the volume and slowing the release of runoff.

In general the cost of SCMs is incompletely understood and significant gaps exist in the literature. More systematic research has been conducted on the cost of conventional stormwater SCMs (wet ponds, detention basins, etc.), with less research applied to more recent, smaller-scale, on-site infiltration practices. Cost research is challenging given that stormwater treatment exhibits considerable site-specific variation resulting from different soil, topography, climatic conditions, local economic conditions, and regulatory requirements (Lambe et al., 2005).

The literature on stormwater costs tend to be oriented around construction costs of particular types of SCMs (Wiegand et al., 1986; SWRPC, 1991; Brown and Schueler, 1997; Heaney et al., 2002; Sample et al., 2003; Wossink and Hunt, 2003; Caltrans, 2004; Narayanan and Pitt, 2006; DeWoody, 2007). In many of these studies, construction cost functions are estimated statistically based on a sample of recently installed SCMs and the observed total construction costs. Observed costs are then related statistically to characteristics that influence cost such as practice size. Other studies estimate costs by identifying the individual components of a construction project (pipes, excavation, materials, labor, etc.), estimating unit costs of each component, and then summing all project components. These studies generally find that construction costs decrease on a per-unit basis as the overall size (expressed in volume or drainage area) of the SCM increases (Lambe et al., 2005). These within-practice economies of scale are found across certain SCMs including wet ponds, detention ponds, and constructed wetlands. Several empirical studies, however, failed to find evidence of economies of scale for bioretention practices (Brown and Schueler, 1997; Wossink and Hunt, 2003).

Increasing attention has been paid to small-scale practices, including efforts to increase infiltration and retain water through such means as green roofs, permeable pavements, rain barrels, and rain gardens (under the label of LID). The costs of these practices are less well studied compared to the other stormwater practices identified above. In general, per-unit

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construction and design costs exceed larger-scale SCMs (Low Impact Development Center, 2007). Higher construction costs, however, may be offset to various degrees by reducing the investments in stormwater conveyance and storage infrastructure (i.e., less storage volume is needed) (CWP, 1998a, 2000a; Low Impact Development Center, 2007). Others have suggested that per-unit costs to reduce runoff may be less for these small-scale distributed practices because of higher infiltration rates and retention rates (MacMullan and Reich, 2007).

Compared to construction costs, less is known about the operation and maintenance costs of SCMs (Wossink and Hunt, 2003; Lambe et al., 2005; MacMullan and Reich, 2007). Most stormwater practices are not maintenance free and can create financial and long-term management obligations for responsible parties (Hager, 2003). Cost-estimation programs and procedures have been developed to estimate operation and maintenance costs as well as construction costs (SWRPC, 1991; Lambe et al., 2005; Narayanan and Pitt, 2006), but examination of observed maintenance costs is less common. Based on estimates from Wossink and Hunt (2003), the total present value of maintenance costs over 20 years can range from 15 to 70 percent of total capital construction costs for wet ponds and constructed wetlands and appear generally consistent with percentages reported in EPA (1999). Operation and maintenance costs were also reported to be a substantial percentage of construction costs of infiltration pits and bioretention areas in Southern California (DeWoody, 2007). Others estimate that over the life of many SCMs, maintenance costs may equal construction costs (CWP, 2000a). In general, maintenance costs tend to decrease as a percentage of total SCM cost as the total size of the SCM increases (Wossink and Hunt, 2003).

Very few quantifiable estimates are available for public and private regulatory compliance costs. Compliance costs could include both initial permitting costs (labor and time delays) of gaining regulatory approval for a particular stormwater design to post-construction compliance costs (administration, inspection monitoring, and enforcement). Compliance monitoring is a particular concern if a stormwater management program relies on widespread use of small-scale distributed on-site practices (Hager, 2003). Unlike larger-scale or regional stormwater facilities that might be located on public lands or on private lands with an active stormwater management plan, a multitude of smaller SCMs would increase monitoring and inspection times by increasing the number of SCMs. Furthermore, municipal governments may be reluctant to undertake enforcement actions against citizens with SCMs located on private land.

Land costs tend to be site specific and exhibit a great deal of spatial variation. Some types of SCMs, such as constructed wetlands, are more land intensive than others. In highly urban areas, land costs may be the single biggest cost outlay of land-intensive SCMs (Wossink and Hunt, 2003).

In general, cost analyses generally find that the cost to treat a given acreage or volume of water is less for regional SCMs than for smaller-scale SCMs (Brown and Schueler, 1997; EPA, 1999; Wossink and Hunt, 2003). For example, considering maintenance, capital construction, and land costs, recent estimates for North Carolina indicate that annual costs for wet ponds and constructed wetlands range between $100 and $3,000 per treated acre (typically less than $1,000). Per-acre annual costs for bioretention and sand filters typically ranged between $300 and $3,500, and between $4,500 and 8,500, respectively. However, if SCMs face space constraints, bioretention areas can become more cost effective. Furthermore, other classes of small, on-site practices, such as grass swales and filter strips, can sometimes be implemented for relatively low cost.

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There are exceptions to the general conclusion that larger-scale stormwater practices tend to be less costly on a per-unit basis than more numerous and distributed on-site practices. For instance, in Sun Valley, California, a recent study indicates that installing small distributed practices (infiltration practices, porous pavement, rain gardens) was more cost effective than centralized approaches for a retrofit program (Cutter et al., 2008). In this particular setting, the difference tended to revolve around the high land costs in the urbanized setting. Small-scale practices can be placed on low-valued land or integrated into existing landscaping, reducing land costs. Centralized stormwater facilities require substantial purchases of high-priced urban properties. Similarly, small distributed practices (porous pavement, green roofs, rain gardens, and constructed wetlands) can also provide a more cost-effective approach to reducing combined sewer overflow (CSO) discharges in a highly urban setting than large structural CSO controls (storage tanks) (Montalto et al., 2007).

SCMs are now a part of most development processes and consequently will increase the cost of the development. Randolph et al. (2006) report on the cost of complying with stormwater and sediment and erosion control regulations for six developments in the Washington, D.C., metropolitan area. These costs include primarily stormwater facility construction and land costs. The findings from these case studies indicate that stormwater and erosion and sediment control comprised about 60 percent of all environmental-related compliance costs for the residential developments studied and added about $5,000 to the average price of a home. Nationwide, stormwater and erosion and sediment controls are estimated to add $1,500 to $9,000 to the cost of a new residential dwelling unit (Randolph et al., 2006).

As a means to control targeted chemical constituents, SCMs may be an expensive control option relative to other control alternatives. For example, nutrients from anthropocentric sources are an increasing water quality concern for many fresh and marine waters. Some states (e.g., Virginia, Maryland, and North Carolina) require stormwater programs to achieve specific nutrient (nitrogen or phosphorus) stormwater standards. The construction, maintenance, and land costs of reducing nitrogen discharge from residential developments using bioretention areas, wet ponds, constructed wetlands, or sand filters range from $60 to $2,500 per pound (Aultman, 2007). These control costs can be an order of magnitude higher than nitrogen control costs from point sources or agricultural nonpoint sources. The high per-pound removal costs are due in part to the relatively low mass load of nutrients carried in stormwater runoff. These estimates, however, assume that all costs are allocated exclusively to nitrogen removal. The high per-pound removal costs from the control of single pollutants highlight the importance of achieving ancillary and offsetting benefits associated with stormwater control (e.g., removal of other pollutants of concern, stream-channel protection from volume reduction, and enhancement of neighborhood amenities).

It should also be noted that installing SCMs in an existing built environment tends to be significantly more expensive than new construction. Construction costs for retrofitted extended detention ponds, wet ponds, and constructed wetlands were estimated to be two to seven times more costly than new SCMs (Schueler et al., 2007). Retrofit costs can be higher for a variety of reasons, including the need to upgrade existing infrastructure (culverts, drainage channels, etc.) to meet contemporary engineering and regulatory requirements. Retrofitting a single existing residential city block in Seattle with a new stormwater drainage system that included reduced street widths, biofiltration practices, and enhanced vegetation cost an estimated $850,000 (see Box 5-5; Seattle Public Utilities, 2007). Estimates suggested that the costs might have been even

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higher using more conventional stormwater piping/drainage systems (Chris May, personal communication, August 2007; EPA, 2007).

As discussed earlier in the chapter, stormwater runoff can be reduced and managed through better site design to reduce impervious cover. Low- to medium-density developments can reduce impervious cover through cluster development patterns that preserve open space and reduce lot sizes. Impervious surfaces and infiltration rates could be altered by any number of site-design characteristics such as reduction in street widths, reduction in the number of cul-de-sacs, and different setback requirements (CWP, 2000a). Finally, impervious surface per capita could be substantially reduced by increasing the population per dwelling unit.

Quantifying the cost of many of these design features is more challenging, and the literature is much less developed or conclusive than the literature on conventional SCM costs. Many design features described above (clustering, reduced setbacks, narrower streets, less curb and gutter) can significantly lower construction and infrastructure costs (CWP, 2001; EPA, 2007). Such features may reduce the capital cost of subdivision development by 10 to 33 percent (CWP, 2000a).

On the other hand, the evidence is unclear whether consumers are willing to pay for these design features. If consumers prefer features typically associated with conventional developments (large suburban lot, for example), then some aspects of alternative development designs/patterns could impose an opportunity cost on builders and buyers alike in the form of reduced housing value. For example, most statistical studies in the U.S. housing market find that consumers prefer homes with larger lots and are willing to pay premiums for homes located on cul-de-sacs, presumably for privacy and safety reasons (Dubin, 1998; Fina and Shabman, 1999; Song and Knapp, 2003). These effects, however, might be partly or completely offset by the higher value consumers might place on the proximity of open space to their homes (Palmquist, 1980; Cheshire and Sheppard, 1995; Qiu et al., 2006). Anecdotal evidence indicates that residents feel that Seattle's Street Edge Alternative program (the natural drainage system retrofit program that combines swales, bioretention and reduced impervious surfaces) increased their property values (City of Seattle, undated). Studies that have attempted to assess the net change in costs are limited, but some evidence suggests that the amenity values of lower-impact designs may match or outweigh the disamentities (Song and Knapp, 2003).

Incentives for Stormwater Management

The dominant policy approach to controlling effluent discharge under the Clean Water Act is through the application of technology-based effluent standards or the requirements to install particular technologies or practices. Some note that this general policy approach may not provide the regulated community with (1) incentives to invest in pollution prevention activities beyond what is required in the standard or with (2) sufficient opportunities or flexibility to lower overall compliance costs (Parikh et al., 2005).

A loosely grouped set of policies, called here "incentive-based,"[1] aim to create financial incentives to manage effluent or volume discharge. Such policies tend to be classified into two groups: price- and quantity-based mechanisms (Stavins, 2000; Parikh et al., 2005). Price-based mechanisms are created when government creates a charge (tax, fee, etc.) or subsidy (payment)

[1] These policies are sometimes called "market-based" policies, but that term will not be used here because many of the incentive-based policies discussed fail to contain features characteristic of a market system.

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on an outcome that government wants to either discourage or encourage. Ideally, the price would be placed on a target outcome (effluents discharged, volume of water released, etc.) and not on the means to achieve that outcome end (such as a tax or subsidy to adopt specific technologies or practices).[2] Quantity-based policies require government to establish some binding limit or cap on an outcome (e.g., mass load of effluent, volume of runoff, etc.) for an identified group of dischargers, but then allow the regulated parties to "trade" responsibilities for meeting that limit or cap. The opportunity to trade creates the financial incentive. The trading concept is discussed in greater detail in Chapter 6, while this section focuses on price-based incentives.

Some stormwater utilities offer reductions in stormwater fees to landowners who voluntarily undertake activities to reduce runoff from their parcels (Doll and Lindsey, 1999; Keller, 2003). The reduction in tax obligations, called credits, can be interpreted as a financial subsidy or payment for implementing on-site runoff controls. Credit payments are typically made based on the volume of water detained. For example, as part of Portland, Oregon's Clean River Rewards program, residents and commercial property owners can reduce their stormwater utility fee by as much as 35 percent by reducing stormwater runoff from existing developed properties (Portland Bureau of Environmental Services, 2008a). Residential and commercial property owners are given a number of ways to reduce runoff to receive this financial benefit. In addition, Portland has a downspout disconnection program that aims to reduce discharge into CSOs in targeted areas in the city. Property owners may be reimbursed up to $53 per eligible downspout (Portland Bureau of Environmental Services, 2008b).

Alternatively, stormwater utilities could (where allowed) also use fee revenue to provide private incentives for stormwater control through a competitive bidding process. Such a bidding process ("reverse auction") would request proposals for stormwater reduction projects and fund projects that reduce volume at the least cost. Proposed investments that can meet the program objectives at the lowest per unit cost would receive payments. Such a program creates private incentives to search for low-cost stormwater investments by creating a price for runoff volume reduction. The bidding program could also be used to identify cost-effective stormwater investments in areas targeted for enhanced levels of restoration. A bidding program has been proposed as a way to lower overall costs of a stormwater program in Southern California (Cutter et al., 2008). Revenue to fund such a competitive bid program could come from a variety of sources including stormwater utility fees or fees paid into an in lieu fee program.

Finally, impact fees on new developments can be structured in a way to create incentives to reduce stormwater runoff volumes. Charges based on runoff volume (or a surrogate measure like impervious surface) can provide an incentive for developers to reduce the volume of new runoff created.

[2] The literature on what level to set the price (tax or subsidy) is vast, complex, and controversial. Parikh et al. (2005) seem to wander into this debate (perhaps unwittingly) by making a distinction between taxes based on some optimality rule (marginal damage costs equal to marginal control costs) and those based on some other sort of decision rule. Without getting into the specifics of this debate here, this discussion will simply assert more generally that price-based incentive policies structure taxes and subsidies to induce desirable behavioral change (rather than simply to raise revenue).

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CHALLENGES TO IMPLEMENTATION OF WATERSHED-BASED MANAGEMENT AND STORMWATER CONTROL MEASURES

The implementation of SCMs has seen variable success. Environmental awareness, threats to potable water sources or to habitat for threatened and endangered species, problems with combined sewer overflows, and other environmental factors have caused cities such as Portland, Oregon; Seattle, Washington; Chicago, Illinois; and Austin, Texas to aggressively pursue widespread implementation of a broad range of SCMs. In contrast, other cities have been slow to implement recommended practices, for many reasons. This is particularly true for nonstructural SCMs, despite their popularity among planners and regulators for the past two decades. A host of real and perceived concerns about individual nonstructural SCMs are often raised regarding development costs, market acceptance, fire safety, emergency access, traffic and parking congestion, basement seepage, pedestrian safety, backyard flooding, nuisance conditions, maintenance, and winter snow removal operations. While most of these concerns are unfounded, they contribute to a culture of inertia when it comes to code change (CWP, 1998a, 2000a). As a result, some nonstructural SCMs are discouraged or even prohibited by local development codes. Very few communities make the consideration of nonstructural practices a required element of stormwater plan review, nor do they require that they be considered early in the site layout and design process when their effectiveness would be maximized. Finally, many engineers and planners feel they can fully comply with existing stormwater criteria without resorting to nonstructural SCMs.

Cost Issues

There are numerous cost issues that have proven to be significant barriers to the use of innovative SCMs. Special construction techniques required for the proper design and function of SCMs, specially formulated manufactured soils, expensive subsurface vaults, and increased land area requirements as a result of increased stormwater storage requirements can significantly increase site development costs. For smaller projects in highly urbanized areas where land costs are high, there can be a disproportionately large expense to comply with stormwater regulations, causing developers to seek, and often receive, exemption from requirements.

Sediment removal and related maintenance activities required to ensure the proper ongoing functioning of SCMs are activities that are not a part of normal building maintenance. Data on maintenance costs of SCMs on privately owned facilities are limited, and management companies responsible for commercial and office building maintenance have yet to provide SCM maintenance as part of their services.

Additional costs are incurred when development review periods by public agencies get extended because of an increased level of design review required to evaluate the compliance of SCMs with city ordinances. Additional review increases development costs and extends the design process. Even with specialized training for city staff to evaluate SCM submittals, deviation from the most basic type of SCM design seems to require extended review and documentation.

Cost concerns are partly responsible for the markedly slow implementation of the stormwater program. The federal deadlines for permit coverage have long passed; in fact more than 14 years have lapsed for medium and large municipalities. A good part of the delay can be

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explained by the resistance of states and local governments to the unknown cost burden. Cities contend that the permit requirements are unreasonable, expensive, and unrealistic to achieve. Many local government officials view some permit provisions such as LID or better site design as intrusion into the land-use authority of local governments.

As discussed in Chapter 2, the U.S. Congress provided no start-up or upgrade financial assistance, unlike what it did for municipally owned and operated wastewater treatment plants after the promulgation of the NPDES permit program under the Clean Water Act in 1972. Local governments have been reluctant to tax residents or create stormwater utilities. States like California and Michigan even have laws that require voter approval in order for local governments to assess new fees. Thus, to implement the NPDES stormwater program, states have had to largely rely on stormwater permit fees collected to support a skeletal to modest staff for program oversight. In Denver, and presumably in other cities, there is no reduction in stormwater fees when impervious area is reduced because of construction of on-site SCMs. This amounts to a disincentive to do the "right thing." Meanwhile, the overall federal budget for the NPDES program, including stormwater, has been declining.

Long-Term Maintenance of Stormwater Control Measures

One of the weakest parts of most stormwater management programs is the lack of information about, and funding to support, the long-term maintenance of SCMs. If SCMs are not inspected and maintained on a regular basis, the stormwater management program is likely to fail. This also negatively impacts the design process—if there is no inspection program oand no accountability for maintenance, the designer has no incentive to build better, more maintenance-friendly SCMs. Finally, without an accurate assessment of the maintenance needs of an SCM, land owners and other responsible parties cannot anticipate their total costs over the lifetime of the device.

Almost all SCMs require active long-term maintenance in order to continue to provide volume and water quality benefits (Hoyt and Brown, 2005; Hunt and Lord, 2006b). Furthermore, a typical municipality may contain hundreds or thousands of individual SCMs within its jurisdiction. Thus, the long-term obligations for maintenance are considerable. For example, the annual maintenance cost of 100 medium-sized wet ponds (one-half acre to 2 acres) is estimated to be a quarter of a million dollars (Hunt and Lord, 2006c). Currently, the majority of municipal stormwater programs do not have adequate plans or resources in place for the long-term maintenance of SCMs (GAO, 2007).

A number of issues confront the long-term maintenance of SCMs. First, legal and financial responsibility for maintenance must be assigned. Historically stormwater ownership and responsibility have been poorly defined and implemented (Reese and Presler, 2005). If a party is an industrial facility that is required to obtain a permit, then responsibility for maintaining SCMs rests with the permittee. Other instances are more ambiguous. For residential developments, the responsibility for long-term maintenance could be assigned to the developer (e.g., establishing long-term financial accounts for maintenance), individual landowners, homeowners associations, or the municipality itself. Some cities, like Austin and Seattle, assume responsibility for long-term maintenance of SCMs in residential areas. Concerns over assigning responsibility to individual residential landowners or homeowners associations include insufficient technical and financial resources to conduct consistent maintenance and a

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lack of inspection to require maintenance. A recent survey of municipal stormwater programs found that less than one-third perform regular maintenance on stormwater detention ponds or water quality SCMs in general residential areas (Reese and Presler, 2005). To ensure that adequate maintenance will occur, municipalities can require performance securities (performance bonds, escrow accounts, letter of credit, etc.) that ensure adequate funds are available for maintenance and repair in the event of failure to maintain the SCM by the responsible party.

An effective maintenance program also requires a system to inventory and track SCMs, inspection/monitoring, and enforcement against noncompliance. The large number of SCMs to track and manage creates management challenges. Municipal stormwater programs must administer their regulatory programs, perform inspection and enforcement activities, and maintain SCMs in public lands/rights-of-way and sometimes in residential areas. Municipal programs often do not have adequate staff to ensure that these maintenance responsibilities are adequately carried out. The lack of adequate staff for inspection and an inadequate system for prioritizing inspections have been repeatedly pointed out (Duke and Beswick, 1997; Duke, 2007; GAO, 2007).

Tracking and monitoring costs may also create disincentives for municipalities to adopt or encourage smaller-scale SCMs. For example, residential-scale rain gardens, porous driveways, rain barrels, and grass swales all have the potential to increase the cost and complexity of compliance monitoring because of the multitude of small infiltration devices that are located on private property as opposed to having fewer SCMs located in public rights-of-way or public lands. Small-scale distributed SCMs located on private property raise concerns of municipal willingness to inspect and enforce against noncompliance. Indeed, some municipalities have banned innovative SCMs like pervious pavement because the municipalities have no means to ensure their maintenance and continued operation.

Finally, there is concern that there is inadequate funding to maintain the growing number of SCMs on the landscape. The long-term funding obligation for maintenance has been difficult to assess (GAO, 2007), partly because many stormwater programs frequently do not have adequate accounting practices to define capital value and depreciation, maintenance, operation, or management programs (Reese and Presler, 2005). The problem is compounded because the long-term maintenance cost associated with various types of SCMs is not well understood. Additional research and information are needed on the costs of maintaining the performance of SCMs as experienced in the field (rather than ex ante estimates based on design plans). Research into long-term maintenance costs should include not only routine operation and maintenance costs but also costs for inspection and enforcement and remediation costs associated with SCM performance failures. Such research is critical to understanding the long-term cost obligation that is being assumed by municipal stormwater programs that are responsible for managing a growing number of SCMs.

At the present time, the maintenance schedule for many of the proprietary and non-proprietary SCMs is poorly defined. It will vary with the type of drainage area and the activities that are occurring within it and with the efficiency of the SCM. (For example, the city of Austin, Texas, has determined that the average lifespan of their sand filters ranges from 5 to 15 years, but can be as little as one year if there is construction in the drainage area.) In order to establish a maintenance schedule, an assessment protocol needs to be adopted by municipalities. The protocol, which is specific to the type of SCM, could consist of the following: each year municipalities would be required to collect data from a subset of their SCMs on public and private property, and then over a period of years these data could be used to determine

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maintenance schedules, predict performance based on age and sediment loading, and identify failed systems. A measurement of the depth of deposited sediment might be the only test needed for settling devices, such as hydrodynamic devices and wet detention ponds. Two levels of analysis could be performed for infiltration devices—one based on simple visual observations and the other using an instrument to check infiltration rates. These assessment methods for infiltration devices have been tested at the University of Minnesota (Gulliver and Anderson, 2007). Without an assessment protocol for SCMs, the chances for poor maintenance and outright failure are greatly increased, it is difficult if not impossible to determine the actual performance of an SCM, and there will be insufficient data to reduce the uncertainty in future SCM design.

Lack of Design Guidance on Important SCMs and Lack of Training

Progress in implementing SCMs is often handicapped by the lack of local or national design guidance on important SCMs, and by the lack of training among the many players in the land development community (planners, designers, plan reviewers, public works staff, regulators, and contractors) on how to properly implement them on the ground. For example, design guidance is lacking or just emerging for many of the non-traditional SCMs, such as conservation of natural areas, earthwork minimization, product substitution, reforestation, soil restoration, impervious cover reduction, municipal housekeeping, stormwater education, and residential stewardship. Some LID techniques are better covered, such as the standards for pervious concrete from the American Concrete Institute and the National Ready Mixed Concrete Association. Design guidance for traditional SCMs such as erosion and sediment control may exist but is often incomplete, outdated, or lacking key implementation details to ensure proper on-the-ground implementation. In other cases, design guidance is available, but has not been disseminated to the full population of Phase II MS4 communities. For example, in an unpublished survey of state manuals used to develop national post-construction stormwater guidance, Hirschman and Kosco (2008) found that less than 25 percent provided sizing criteria, detailed engineering design specifications, or maintenance criteria. Nationwide guidance on SCM design and implementation may not be advisable or applicable to all physiographic, climatic, and ecoregions of the country. Rather, EPA and the states should encourage the development of regional design guidance that can be readily adapted and adopted by municipal and industrial permittees. Improvement of SCM design guidance should incorporate more direct consideration of the parameters of concern, how they move across the landscape, and the issues in receiving waters—a strategy both espoused in this report (page 351) and in recent publications on this topic (Strecker et al., 2005, 2007).

The second key issue relates to how to train and possibly certify the hundreds of thousands of individuals that are responsible for land development and stormwater infrastructure at the local and state level. New stormwater methods and practices cannot be effectively implemented until local planners, engineers, and landscape architects fully understand them and are confident on how to apply them to real-world sites. Currently, stormwater design is not a major component of the already crowded curriculum of undergraduate or graduate planning engineering or landscape architecture programs. Most stormwater professionals acquire their skills on the job. Given the rapid development of new stormwater technologies, there is a critical need for implementation of regional or statewide training programs to ensure that stormwater

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professionals are equipped with the latest knowledge and skills. The training programs should ultimately lead to formal certification for stormwater designers, inspectors, and plan reviewers.

Different Standards in Different Jurisdictions That Are Within the Same Watershed

Governmental and watershed boundaries rarely coincide, with the result that most watersheds are made up of many municipal bodies regulating stormwater management. Unfortunately in most cases there is no overarching stormwater regulatory structure that is based upon a watershed analysis. This can result in many unfortunate conflicts, where approval of a stormwater facility does not affect the community issuing the permit. It is often said that the most effective stormwater management for an area high in the watershed is to speed the water downstream, thus saving the upstream community but severely damaging the downstream rivers. While this may be an exaggeration, the problems downstream are less of a concern to the upper watershed communities, and downstream communities may not be able to solve their water issues without help from the upstream communities.

Often neighboring communities' plans or the methods or data used do not coincide. For example, often out-of-date rainfall distributions, methods, or standards are required in the code that do not apply to the newer focus on smaller storms and volume reduction. If methods that include Modified Rational or TR-55 are used, it is difficult if not impossible to show the benefits in peak flow reduction gained through volume reduction devices. Also, some municipalities may require curb and piping and not allow swales, impending the implementation of a cost-effective design. Finally, it is difficult to observe a measureable impact of SCMs when they are guided by a patchwork of regulations. One community may require removal of the first inch of runoff, and another may require the reduction of the 25-year, post-construction peak to the 10-year pre-construction level.

Water Rights that Conflict with Stormwater Management

In the West, water is considered real property, governed by state law and regional water compacts. Landowners in urban areas rarely own surface water rights and are typically prohibited from "beneficial use" of that water, which affects how SCMs are chosen. For example, current practices in Colorado typically allow stormwater to be infiltrated within a short period of time on-site without violation of water laws. However, storage of and/or pumping this water for broader distribution is considered to be a beneficial use and is therefore prohibited. Moreover, as discussed in Chapter 2, SCMs that manage stormwater by driving the water underground with a bored, drilled, or driven shaft or a hole dug deeper than its widest surface dimension are typically considered to be "injection wells," requiring a federal permit and regular monitoring under the Safe Drinking Water Act.

Some states prohibit infiltration because of concerns over long-term groundwater pollution. In California, which does not have a uniform policy for groundwater management and groundwater rights, authority over groundwater quality management falls to several regional and local agencies. For example, the Upper Los Angeles River Area (ULARA) has a court-appointed Watermaster to manage the complex appropriation of its groundwater to user cities and agencies. The ULARA has clashed with the City of Los Angeles regarding rights to all of

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the water that normally recharges the Los Angeles River via runoff from precipitation. In 2000, the ULARA Watermaster expressed a concern with certain permit provisions of the Los Angeles County MS4 Permit for New Development/ Redevelopment that promoted infiltration, stating that the MS4 permit interfered with the adjudicated right of the City of Los Angeles to manage groundwater.

Urban Development and Sprawl

The continued expansion of urban areas is inevitable given population increases worldwide and the transition from agricultural to industrial economies. Given that urbanization of almost any magnitude—even less than 10 percent impervious area—has been demonstrated to have an impact on in-stream water quality, a central question to be addressed is how water quality can be maintained as cities grow, without having negative impacts on social and economic systems. Ideally, SCMs would perform their water quality function, contribute to the livability of cities, and enhance their economic and social potentials.

Low-density, auto-oriented urban development, commonly known as sprawl, has been the predominant pattern of development in the United States, and increasingly worldwide, since World War II. It has been widely criticized for its inefficient use of land, its high use of natural resources, and its high energy costs—all of which are associated with the required auto-oriented travel. Additionally, ongoing economic costs related to the provision of widely dispersed services and social impacts of a breakdown in community life have been identified (Brugemann, 1974). Sprawl and the impacts on in-stream water quality that result from urbanization have been an inevitable consequence of improved economic conditions. In the United States, sprawl constitutes the vast majority of development occurring today because a majority of the population is attracted to the benefits of a suburban lifestyle, government has subsidized roads and highways at the expense of public transit, and local zoning often limits development density.

There has been a great deal of innovation in city planning and design in the past decade that encourages greater density and a return to urban living. New types of zoning, New Urbanism, Smart Growth, and related innovations in urban planning and design have been developed in parallel with environmental regulations at local to national levels (see Chapter 2). They acknowledge the importance of protecting natural resources to maintain quality of life and have established water quality as an important consideration in city building.

It is not clear that current stormwater regulations can be effectively implemented over the broad range of development patterns that characterize contemporary cities or if they inadvertently favor one type of development over another. For example, on-site SMCs are often recommended as the preferred means of stormwater management, although they tend to encourage lower-density development patterns. And while they are easily implemented and regulated given the incremental, site-by-site development that is typical of most urban growth, monitoring and maintenance can be expensive and difficult for both the individual property owner and the regulating authority. In highly urbanized areas, they are often relegated to subsurface systems that are expensive and that, to be effective, require high levels of maintenance.

In newly developing areas, cluster development should be encouraged whenever possible, according to the Smart Growth principles of narrower streets, reduced setbacks, and related approaches to reduce the amount of impervious area required and land consumed. Furthermore,

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an interconnected series of on-site and consolidated SCMs can reduce subsurface stormwater piping requirements. Most planned communities have dedicated park and open-space areas that can constitute 25 percent or more of a development's total land area, making it feasible to easily accommodate consolidated SCMs (typically 8 to 10 percent of impervious area) within multi-functional open space and park lands. Cost efficiencies such as a 30 percent reduction in infrastructure costs (Duaney Plater-Zyberk & Company, 2006) can be realized through Smart Growth development techniques. Clustered housing surrounded by open space, laced with trails, has appreciated in value at a higher rate than conventionally designed subdivisions (Crompton, 2007).

In order to encourage infill or redevelopment over sprawl patterns of development, innovative zoning and other practices will be needed to prevent stormwater management from becoming onerous. For example, incentive zoning or performance zoning could be used to allow for greater densities on a site, freeing other portions of the site for SCMs. Innovations in governance and finance can also be used to incorporate consolidated SCMs into urban environments. For example, the City of Denver, in updating its Comprehensive Plan, designated certain underdeveloped corridors and districts in the city as "areas of change" where it hoped to encourage large-scale infill redevelopment. Given the scale of redevelopment, it would be feasible to establish special maintenance districts, allowing the development of consolidated SCMs that have multiple functions. To fund land purchase and facility design and construction, cash in lieu of payments could be made.

Safety and Aesthetic Concerns

Vector-borne diseases, especially West Nile virus, are a concern when SCMs such as extended detention basins, constructed wetlands, and rain barrels are proposed. Furthermore, other SCMs that are poorly designed, improperly constructed, or inadequately maintained may retain water and provide an ideal breeding ground for mosquitoes, increasing the potential for disease transmission to humans and wildlife. Kwan et al. (2005) found that water-retaining SCMs increase the availability of breeding habitats for disease vectors and provide opportunistic species an extended breeding season. State Health Departments generally recommend that SCMs be designed to drain fully in 72 hours, which is the minimum time required for a mosquito to complete its life cycle under optimum conditions. In SCMs where there is permanent standing water, such as stormwater wetlands, there is the possibility of introducing biota that might prey on mosquitoes. Municipalities may have to consider the added cost of vector control and public health when implementing stormwater quality management programs.

With larger consolidated and regional extended detention facilities, concerns about the safety of children who may be attracted to such SCMs and ensuing liability must be considered. These SCMs need to be fenced off or otherwise designed appropriately to reduce the risk of drowning.

One aspect of stormwater management that is infrequently considered is the aesthetic appeal, or lack thereof, of SCMs. The visual qualities of SCMs are important because they are a growing part of the urban landscape setting. Although it can be assumed that landscapes that are carefully tended are often preferred over other types of landscapes, it depends substantially on one's point of view. For example, an engineer may consider a particular SCM that is functioning as expected to be beautiful in the sense that its engineering function has been realized, even

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though there is sediment buildup, algae, or other products of a properly functioning SCM visible. Similarly, a biologist or ecologist evaluating an ecologically healthy SCM in an urban context might find it to be beautiful because of its biological or ecological diversity, whereas another individual who evaluates the same SCM finds it to be "weedy." SCMs can be viewed as a means of restoring a degraded landscape to a state that might have existed before urban development. The desire to "return to nature" is a seductive idea that suggests naturalistic SCMs that may have very little to do with an original landscape, given the dramatic changes in hydrology that are inevitable with urban streams. Each of these widely varied views of SCMs may be appropriate depending on the context and the viewer.

One goal of stormwater management should be to make SCMs desirable and attractive to a broader audience, thereby increasing their potential for long-term effectiveness. For example, the Portland convention center rain gardens demonstrate how native and non-native wetland plantings can be carefully composed as a landscape composition and also provide for stormwater treatment. If context and aesthetics of a chosen SCM are poorly matched, there is a high probability that the SCM will be eliminated or its function compromised because of modifications that make its landscape qualities more appropriate for its context.

CONCLUSIONS AND RECOMMENDATIONS

SCMs, when designed, constructed, and maintained correctly, have demonstrated the ability to reduce runoff volume and peak flows and to remove pollutants. However, in very few cases has the performance of SCMs been mechanistically linked to the guaranteed sustainment at the watershed level of receiving water quality, in-stream habitat, or stream geomorphology. Many studies demonstrate that degradation in rivers is directly related to impervious surfaces in the contributing watershed, and it is clear that SCMs, particularly combinations of SMCs, can reduce the runoff volume, erosive flows, and pollutant loadings coming from such surfaces. However, none of these measures perfectly mimic natural conditions, such that the accumulation of these SCMs in a watershed may not protect the most sensitive beneficial aquatic life uses in a state. Furthermore, the implementation of SCMs at the watershed scale has been too inconsistent and too recent to observe an actual cause-and-effect relationship between SCMs and receiving waters. The following specific conclusions and recommendations about stormwater control measures are made.

Individual controls on stormwater discharges are inadequate as the sole solution to stormwater in urban watersheds. SCM implementation needs to be designed as a system, integrating structural and nonstructural SCMs and incorporating watershed goals, site characteristics, development land use, construction erosion and sedimentation controls, aesthetics, monitoring, and maintenance. Stormwater cannot be adequately managed on a piecemeal basis due to the complexity of both the hydrologic and pollutant processes and their effect on habitat and stream quality. Past practices of designing detention basins on a site-by-site basis have been ineffective at protecting water quality in receiving waters and only partially effective in meeting flood control requirements.

Nonstructural SCMs such as product substitution, better site design, downspout disconnection, conservation of natural areas, and watershed and land-use planning can dramatically reduce the volume of runoff and pollutant load from a new development.

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Such SCMs should be considered first before structural practices. For example, lead concentrations in stormwater have been reduced by at least a factor of 4 after the removal of lead from gasoline. Not creating impervious surfaces or removing a contaminant from the runoff stream simplifies and reduces the reliance on structural SCMs.

SCMs that harvest, infiltrate, and evapotranspirate stormwater are critical to reducing the volume and pollutant loading of small storms. Urban municipal separate stormwater conveyance systems have been designed for flood control to protect life and property from extreme rainfall events, but they have generally failed to address the more frequent rain events (<2.5 cm) that are key to recharge and baseflow in most areas. These small storms may only generate runoff from paved areas and transport the "first flush" of contaminants. SCMs designed to remove this class of storms from surface runoff (runoff-volume-reduction SCMs—rainwater harvesting, vegetated, and subsurface) can also address larger watershed flooding issues.

Performance characteristics are starting to be established for most structural and some nonstructural SCMs, but additional research is needed on the relevant hydrologic and water quality processes within SCMs across different climates and soil conditions. Typical data such as long-term load reduction efficiencies and pollutant effluent concentrations can be found in the International Stormwater BMP Database. However, understanding the processes involved in each SCM is in its infancy, making modeling of these SCMs difficult. Seasonal differences, the time between storms, and other factors all affect pollutant loadings emanating from SCMs. Research is needed that moves away from the use of percent removal and toward better simulation of SCM performance. Hydrologic models of SCMs that incorporate soil physics (moisture, wetting fronts) and groundwater processes are only now becoming available. Research is particularly important for nonstructural SCMs, which in many cases are more effective, have longer life spans, and require less maintenance than structural SCMs. EPA should be a leader in SCM research, both directly by improving its internal modeling efforts and by funding state efforts to monitor and report back on the success of SCMs in the field.

Research is needed to determine the effectiveness of suites of SCMs at the watershed scale. In parallel with learning more about how to quantify the unit processes of both structural and nonstructural practices, research is needed to develop surrogates or guidelines for modeling SCMs in lumped watershed models. Design formulas and criteria for the most commonly used SCMs, such as wet ponds and grass swales, are based on extensive laboratory and/or field testing. There are limited data for other SCMs, such as bioretention and proprietary filters. Whereas it is important to continue to do rigorous evaluations of individual SCMs, there is also a role for more simple methods to gain an approximate idea about how SCMs are performing. The scale factor is a problem for watershed managers and modelers, and there is a need to provide guidance on how to simulate a watershed of SCMs, without modeling thousands of individual sites.

Improved guidance for the design and selection of SMCs is needed to improve their implementation. Progress in implementing SCMs is often handicapped by the lack of design guidance, particularly for many of the non-traditional SCMs. Existing design guidance is often

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incomplete, outdated, or lacking key details to ensure proper on-the-ground implementation. In other cases, SCM design guidance has not been disseminated to the full population of MS4 communities. Nationwide guidance on SCM design and implementation may not be advisable or applicable to all physiographic, climatic, and ecoregions of the country. Rather, EPA and the states should encourage the development of regional design guidance that can be readily adapted and adopted by municipal and industrial permittees. As our understanding of the relevant hydrologic, environmental, and biological processes increases, SCM design guidance should be improved to incorporate more direct consideration of the parameters of concern, how they move across the landscape, and the issues in receiving waters.

The retrofitting of urban areas presents both unique opportunities and challenges. Promoting growth in these areas is desirable because it takes pressure off the suburban fringes, thereby preventing sprawl, and it minimizes the creation of new impervious surfaces. However, it is more expensive than Greenfields development because of the existence of infrastructure and the limited availability of land. Both innovative zoning and development incentives, along with the selection of SCMs that work well in the urban setting, are needed to achieve fair and effective stormwater management in these areas. For example, incentive or performance zoning could be used to allow for greater densities on a site, freeing other portions of the site for SCMs. Publicly owned, consolidated SCMs should be strongly considered as there may be insufficient land to have small, on-site systems. The performance and maintenance of the former can be overseen more effectively by a local government entity. The types of SCMs that are used in consolidated facilities—particularly detention basins, wet/dry ponds, and stormwater wetlands—perform multiple functions, such as prevention of streambank erosion, flood control, and large-scale habitat provision.

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Chapter 6
Innovative Stormwater Management and Regulatory Permitting

There are numerous innovative regulatory strategies that could be used to improve EPA's stormwater program. This chapter first outlines a substantial departure from the status quo, namely, basing all stormwater and other wastewater discharge permits on watershed boundaries instead of political boundaries. Watershed-based permitting is not a new concept, but it has been attempted in only a few communities. Development of the new permitting paradigm is followed by more modest and easily implemented recommendations for improving the stormwater program, from a new plan for monitoring industrial sites to encouraging greater use of quantitative measures of the maximum extent practicable requirement. The recommendations in the latter half of the chapter do not preclude adoption of watershed-based permitting at some future date, and indeed they lay the groundwork in the near term for an eventual shift to watershed-based permitting.

WATERSHED PERMITTING FRAMEWORK FOR MANAGING STORMWATER

In its initial meeting in January 2007, the committee heard opinions that collectively pointed in a new direction for managing and regulating stormwater that would differ from the end-of-pipe approach traditionally applied by regulatory agencies under the National Pollutant Discharge Elimination System (NPDES) permits and be based instead on a watershed framework. Indeed, the U.S. Environmental Protection Agency (EPA) has already given substantial thought to watershed permitting and issued a Watershed-Based NPDES Permitting Policy Statement (EPA, 2003a) that defined watershed-based permitting as an approach that produces NPDES permits that are issued to point sources on a geographic or watershed basis. It went on to declare that, "The utility of this tool relies heavily on a detailed, integrated, and inclusive watershed planning process. Watershed planning includes monitoring and assessment activities that generate the data necessary for clear watershed goals to be established and permits to be designed to specifically address the goals."

In the statement, EPA listed a number of important benefits of watershed permitting:

- More environmentally effective results;
- Ability to emphasize measuring the effectiveness of targeted actions on improvements in water quality;
- Greater opportunities for trading and other market-based approaches;
- Reduced cost of improving the quality of the nation's waters;
- More effective implementation of watershed plans, including total maximum daily loads (TMDLs); and
- Other ancillary benefits beyond those that have been achieved under the Clean Water Act (e.g., integrating CWA and Safe Drinking Water Act [SDWA] programs).

Subsequent to the policy statement, EPA published two guidance documents that lay out a general process for a designated state that wishes to set up any type of permit or permits under

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CWA auspices on a watershed basis (EPA, 2003b, 2007a). It also outlined a number of case studies illustrating various kinds of permits that contain some watershed-based elements. Box 6-1 describes in greater detail the more recent report (EPA, 2007a) and its 11 "options" for watershed-based permitting. Unfortunately, the EPA guidance is lacking in its description of what constitutes watershed-based permitting, who would be covered under such a permit, and how it would replace the current program for municipalities and industries discharging stormwater under an individual or general NPDES permit. Few examples are given, some of which are not even watershed-based, with most of the examples involving grouping municipal wastewater treatment works under a single permit with no reference to stormwater. Most of the 11 options are removed from the fundamental concept of watershed-based permitting. Finally, the guidance fails to elaborate on the policy statement goal to make water quality standards watershed-based. The committee concluded that, although the EPA documents lay some groundwork for watershed-based permitting—especially the ideas of integrated municipal permits, water quality trading, and monitoring consortia—the sum total of EPA's analysis does not define a framework for moving toward true watershed-based permitting. The guidance attends to few of the details associated with such a program and it has made no attempt to envision how such a system could be extended to the states and the municipal and industrial stormwater permittees. This chapter attempts to overcome these shortcomings by presenting a more comprehensive description of watershed-based permitting for stormwater dischargers.

The approach proposed in this chapter fits within the general framework outlined by EPA but goes much further. First, it is intended to replace the present structure, instead of being an adjunct to it, and to be uniformly applied nationwide. The proposal adopts the goal orientation of the policy statement and then extends it to root watershed management and permitting in comprehensive objectives representing the ability of waters to actually support designated beneficial uses. The proposal builds primarily around the integrated municipal permit concept in the policy statement and technical guidance. Like EPA's outline, the committee emphasizes measuring the effectiveness of actions in bringing improvements, but goes on from there to recommend a set of monitoring activities designed to support active adaptive management to achieve objectives, as well as to assess compliance. Credit trading, indicator development, the rotating basin approach, and monitoring should be part of management and permitting programs within watersheds, and ideas are advanced to develop these and other elements.

In addition to building on the work of EPA, the proposed approach tackles many of the impediments to effective watershed management identified in the National Research Council (NRC) treatise on watershed management (NRC, 1999). That report noted that watershed approaches are easiest to implement at the local level; thus, the approach developed in this chapter is a bottom-up process in which programmatic responsibility lies mainly with municipalities. Because the natural boundaries of watersheds rarely coincide with political jurisdictions, watersheds as geographic areas are less useful for political, institutional, and funding purposes, such that initiatives and organizations directed at watershed management should be flexible. The proposed approach recognizes this reality and makes numerous suggestions for pilot testing, funding, and institutional arrangements that will facilitate success. Finally, NRC (1999) notes the need to "develop practical procedures for considering risk and uncertainty in real world decision-making in order to advance watershed management." The proposed revised monitoring system presented later in this chapter is designed to provide information in the face of ongoing uncertainty, i.e., adaptive management in a permitting context.

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BOX 6-1
EPA's Current Guidance on Watershed-Based Permitting

Rather than explicitly define watershed based permitting, the EPA's recent guidance (EPA, 2007a) groups a large number of activities as having elements of watershed-based permitting, and defines how each might be utilized by a community. They are

- NPDES permitting development on a watershed basis,
- Water quality trading,
- Wet weather integration,
- Indicator development for watershed-based stormwater management,
- TMDL development and implementation,
- Monitoring consortium,
- Permit synchronization,
- Statewide rotating basin planning,
- State-approved watershed management plan development,
- Section 319 planning, and
- Source water protection planning.

Taking these topics in order, the first option is generally similar to that in EPA (2003a,b), but with some more detail on possible permitting forms. "Coordinated individual permits" implies that individual permits would be made similar and set with respect to one another and to a holistic watershed goal. The nature of such permits is not fully described, and there are no examples given. An "integrated municipal permit," also presented in the earlier policy statement, would place the disparate individual NPDES permits in a municipality (e.g., wastewater plants, combined sewer overflows, municipal separate storm sewer systems [MS4s]) under one permit. However, such a permit is not necessarily watershed-based. Finally, the "multi-source permit" could go in numerous directions, none of which are described in detail. In one concept, all current individual permittees who discharge a common pollutant into a watershed would come under one new individual permit that regulates that pollutant, while keeping the existing individual permits intact for other purposes. The Neuse River Consortium is given as an example. Alternatively, a multi-source permit could cover all dischargers of a particular type now falling under one individual permit that regulates all of their pollutants (no examples are given). In yet another application, this permit could be a general permit, and it would be identical to the existing general permits, except that it would be organized along watershed boundaries. As above, it could be refined on the basis of pollutant or discharger type.

The other ten options are more distant from the fundamental concept of watershed-based permitting. The water quality trading description is minimal, though it does mention a new EPA document that gives guidance to permittees for trading. Wet weather integration, the third topic, can mean any number of things, from creating a single permit to cover all discharges of pollutants during wet weather in a municipality, as described above for "coordinated individual permits," to just having all the managers of the systems get together and strategize. Although a stated goal is to reduce the amount of water in the sewer system after a storm, this integration is not particularly well defined in the document, nor is it well differentiated from other activities that would normally occur under an MS4 permit.

Indicator development for watershed-based stormwater management refers to identifying indicators that are better than one or a few pollutants at characterizing the degree of impairment wrought by stormwater. Stormwater runoff volume is one indicator being developed by Vermont, and percent impervious surface is another. As discussed in Chapter 2, some states have long used biological indicators that integrate the effects of many pollutants as well as physical stresses such as elevated flow velocities. Indicators can be used as TMDL targets or as goals in NPDES permits. Identifying and adopting indicators is, essentially, a prerequisite to implementing some of the other options listed above.

Regarding the next topic on the list, the option of TMDL development is obvious, since the TMDL program is by definition watershed based. If it can be made the highest priority, and if stormwater is a

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BOX 6-1 Continued

contributor, then the implementation plan can be an excellent way to combat stormwater pollution on a watershed basis. Reducing the contribution of the pollutant from a stormwater source can involve water quality trading, better enforcement of existing permits, or creating new watershed-based permits. Hence, again, there is considerable overlap with the previously discussed options.

Developing a monitoring consortium is an option that works when sufficient data are not available to do much else. The concept mainly refers to monitoring of ambient waters. The activity is shared among partners (e.g., all wastewater plants in a region), with the goal of collecting and analyzing enough data to improve management decisions on a watershed basis, instead of for a single plant.

The following topic, permit synchronization, refers to having all permits within a watershed expire and be renewed simultaneously. This approach could be helpful for streamlining administrative, monitoring, and management tasks associated with maintaining the permits. Some states have operated in this way, whereas others have decided not to. It is one way to coordinate permits in cases where other types of watershed-based permitting would not work. Similarly, the statewide rotating basin approach, used by many states, relies on a five-year cycle. The state is divided into major watersheds, and each watershed is in a different stage of the cycle every year. It is a way to distribute the workload such that there is never a year when, for example, every watershed would require monitoring. Since it is a statewide program, how it relates to a watershed-based permitting situation is not at all clear.

With regard to the next topic, there has been a great deal of watershed planning around the nation and tremendous variety in form and comprehensiveness. Plans generally contain some information on the state of the watershed, goals for the watershed, and activities to meet those goals. Development of such plans in areas that do not have them could facilitate watershed-based permitting by providing much needed information about conditions, sources of pollutants, and methods to reduce pollution. According to EPA, a watershed plan may or may not indicate the need for watershed-based permitting.

The Section 319 Program refers to voluntary efforts to reduce pollution from nonpoint sources. The program in and of itself is not relevant to NPDES permits, since it deals strictly with activities that are not regulated. However, these activities could be traded with more traditional stormwater practices as part of a watershed-based effort to reduce overall pollution reaching waterbodies. Many watershed plans must consider guidance for the 319 program in order to get funding for their management activities.

If the watershed in question contains a drinking water source (either surface water or groundwater), then a good source water protection plan can have a significant impact on NPDES permitting in a watershed. Information collected during the assessment phase of source water protection could be used to help inform watershed-based permitting. Also, NPDES permits could be rewritten taking into account the proximity of discharges to source water intakes.

Following its coverage of the 11 options, EPA (2007a) gives a hypothetical example of picking six of the options to develop permitting for a watershed. It discusses how the options might be prioritized, but in a very qualitative manner, according to considerations such as availability of funding and personnel, stakeholder desires, environmental impacts, and sequencing of events. Chapter 1 of the report ends with a list of performance goals that might apply to the 11 options.

Chapter 2 further explains the multi-source watershed-based permit, discussing, for example, who would be covered by it, who would administer it, and how credit trading fits in. The chapter has a lot of practical, although quite intuitive, information about how to write such a permit. Much of the decision making is left to the permit writer. There are discussions of effluent limitations, monitoring requirements, reporting and record keeping, special conditions, and public notice. Chapter 3 follows by presenting case studies, although fewer than appeared in 2003 and not all truly watershed based.

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Watershed Management and Permitting Issues

There are many implications of redirecting the stormwater management and regulatory system from a site-by-site, SCM-by-SCM approach to an emphasis on attainment of beneficial uses throughout a watershed. Most fundamentally, the program's focus would shift to a primary concentration on broad goals in terms of, for example, achieving a targeted condition in a biological indicator associated with aquatic ecosystem beneficial uses or no net increase in elevated flow duration. Application of site-specific stormwater control measures (SCMs) would no longer constitute presumptive evidence of permit compliance, as is often the case in permits now, although it would still be an essential means to meeting goals. Achieving those goals, however, would form the compliance criteria.

In recognition of the demonstrated negative effects of watershed hydrologic modification on the attainment of beneficial uses, the proposal steps beyond the generally prevailing practice by embracing water quantity as a concern along with water quality. The inclusion of hydrology is consistent with the CWA on several grounds. First, elevated runoff peak flow rates and volumes increase erosive shear stress on stream beds and banks and directly contribute particulate pollutants to the flow (such as suspended and settleable solids, as well as nutrients and other contaminants bound to the soil material). Conversely, reduced dry-weather flows often occur in urban streams as a result of lost groundwater recharge and tend to concentrate pollutants and, hence, worsen their biological effects. Moreover, pollutant mass loading is the product of concentration and flow volume, and thus increased wet-weather surface runoff directly augments the cumulative burden on receiving waters. Finally, regulatory precedent for incorporating hydrology exists, as demonstrated by Vermont's stormwater program (LaFlamme, 2007).

At this time, stormwater management and regulation are divorced from the management and regulation of municipal and industrial wastewater. A true watershed-based approach would incorporate the full range of municipal and industrial sources, including (1) public streets and highways; (2) municipal stormwater drainage systems; (3) municipal separate and combined wastewater collection, conveyance, and treatment systems; (4) industrial stormwater and process wastewater discharges; (5) private residential and commercial property; and (6) construction sites. These many sources represent an array of uncoordinated permits under the current system and a strong challenge to developing a watershed-based approach. As pointed out in Chapter 2, multi-source considerations are an implicit facet of TMDL assessments, wherein states must consider both point and nonpoint sources. EPA (2003b) identified, among other possible permit types, an Integrated Municipal NPDES Permit, which would bundle all requirements for a municipality (e.g., stormwater, combined sewer overflows, biosolids, pretreatment) into a single permit. The Tualatin River watershed in Oregon has faced this challenge, at least in part, through an innovative watershed permit that combines both wastewater treatment and stormwater, brings in management of agricultural contributions to thermal pollution, and allows for pollutant trading among sources (see Box 6-2). It appears that the various participating parties did not use their energies in trying to allocate blame but instead determined the most effective and efficient ways of improving conditions. For example, the municipal permittees willingly offered incentives to agricultural landowners to plant riparian shade trees as an alternative to more expensive means of reducing stream temperatures under their direct control. Indeed, with agriculture not being regulated by the Clean Water Act, watershed permitting and initiatives of this type represent the best, and perhaps only, mechanism for ameliorating negative effects of agricultural runoff that, left unattended, would undo gains in managing urban runoff. The Neuse River case study, discussed later in this chapter, is another example of bringing

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agricultural contributions to aquatic degradation under control, along with urban sources, through a watershed-based approach.

BOX 6-2
Watershed-Based Permitting in Oregon

Clean Water Services is a wastewater and stormwater utility that covers a special service district of 12 cities and unincorporated areas in urban Washington County, Oregon. It was originally chartered in the 1970s as the Unified Sewerage Agency to consolidate the management of 26 "package" wastewater treatment facilities. Its responsibilities expanded to stormwater management in the early 1990s and it now serves nearly 500,000 customers. There are four wastewater treatment plants (WWTPs) in the district, with a dry weather capacity of 71 million gallons per day (MGD). During low-flow months, the discharge from these plants can account for 50 percent of the water in the Tualatin River. The district also own rights to one-quarter of the stored water in Hagg Lake. The land use in the watershed is about one-third urban, one-third agriculture, and one-third forest.

In 2001, the region was faced with TMDLs on the Tualatin River or its tributaries for total phosphorus, ammonia, temperature, bacteria, and dissolved oxygen. By 2002, the area was also dealing with four expired NPDES permits and one expired MS4 permit (all of which had been administratively extended), approval of a second TMDL, and an Endangered Species Act (ESA) listing. The region decided that it wanted to try to integrate all of these programs using a watershed-based regulatory framework. This would include a TMDL implementation mechanism, an ESA response plan, and integrated water resources management (meaning that water quantity, water quality, and habitat considerations would be made at the same time). Prior to integration, water quality was covered by the TMDL and NPDES programs, but these programs did not cover water quantity and habitat issues. The ESA listing addressed the habitat issues, but it was done totally independently of the TMDLs and NPDES permits.

Thus, the region applied for an integrated municipal NPDES permit that bundles all NPDES permit requirements for a municipality into a single permit, including publicly owned treatment works (POTWs), pretreatment, stormwater, sanitary sewer overflows, and biosolids. Initially, it encompassed the four WWTP permits, the one MS4 permit, and the industrial and construction stormwater permits. The hope was that this would streamline multiple permits and capture administrative and programmatic efficiencies; provide a mechanism for implementing more cost-effective technologies and management practices including water quality credit trading; integrate watershed management across federal statutes such as the CWA, SDWA, and ESA; and encourage early and meaningful collaboration and cooperation among key stakeholders.

This case study was successful because a single entity—Clean Water Services—was already in charge of what would have otherwise been a group of individual permittees. Furthermore, all the NPDES permits had expired and the TMDL had just been issued, providing a window of opportunity. The state regulatory agency was very willing, and EPA provided a $75,000 grant. Finally, there was a robust water quality database and modeling performed for the area because of the previous TMDL work. The watershed-based permit, the first in the nation, was issued February 26, 2004. Among its unique elements are an intergovernmental agreement companion document signed by the Oregon Department of Environmental Quality (DEQ), water quality credit trading, and consolidation of reporting requirements. The water quality trading is one of the most interesting elements, and several variations have been attempted. Biological oxygen demand (BOD) and NH_3 have been traded both intra-facility and inter-facility.

The temperature TMDL on the Tualatin River is a particularly interesting example of trading because it helped to bring agriculture into the process, where it would otherwise not have been involved. Along the length of the river, there are portions that exceed the temperature standard. A TMDL allocation was calculated that would lower temperatures by the same amount everywhere, such that there would be no point along the river that would be in exceedance. Options for reducing temperature include reducing the influent wastewater temperature (which is hard to do), reducing the total WWTP discharge to the

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BOX 6-2 Continued

Tualatin River (which is not practical), mechanically cooling or refrigerating WWTP discharge (which would require more energy), or trading the heat load via flow augmentation and increased shading (which is what was attempted).

Clean Water Services choose to utilize a market-based, watershed approach to meet the Tualatin temperature TMDL. It was market-based because it had financial incentives for certain groups to participate, it was cost-effective, and it provided ancillary ecosystem services. It was a watershed-based approach because it capitalized on the total assimilative capacity of the basin. What was done was to (1) provide cooling and in-stream flow augmentation by releasing water from Hagg Lake Reservoir, and (2) trade riparian stream surface shading improvement credits. They also reused WWTP effluent in lieu of irrigation withdrawals. For the riparian shading, they developed an "enhanced" CREP program to increase the financial incentives to rural landowners (with Clean Water Services paying the difference over existing federal and state programs). Clean Water Services also made incentive payments to the Soil and Water Conservation District to hire people to act as agents of Clean Water Services. Oregon DEQ's Shadalator model was used to quantify thermal credits for riparian planting projects, which required that information be collected at 100-foot increments along the stream on elevation, aspect, wetted width, Nordfjord-Sogn Detachment Zone, channel incision, and plant type and planting corridor width. To summarize, over the five-year term of the permit, Clean Water Services will release 30 cfs/d of stored water from Hagg Lake each July and August and shade roughly 35 miles of tributary riparian area (they have already planted 34 miles of riparian buffer). This plan involved an element of risk taking, since the actions of unregulated parties (such as farmers) have suddenly become the responsibility of Clean Water Services.

Significant disadvantages of the current system of separate permits for municipal, construction, and industrial activities are (1) the permits attack the problem on a piecemeal basis, (2) they are hard to coordinate because they expire at different times, (3) they are not designed to allow for long-term operation of SCMs, and (4) they do not cover all discharges. A solution to these problems would be to integrate all discharge permitting under municipal authority, as is proposed here. The lead permittee and co-permittees would bear ultimate responsibility for meeting watershed goals and would regulate all public and private discharges within their jurisdictions to attain them. Municipalities are the natural focus for this role because they are the center of land-use decisions throughout the nation.

Municipalities must be provided with substantially greater resources than they have now to take on this increased responsibility. Beyond funding, regulatory responsibilities must be realigned to some degree. The norm now is for states to administer industrial permits directly and generally attend to all aspects of permit management. However, states, more often than not, are unable because of resource limitations to give permittees much attention in the form of inspection and feedback to ensure compliance. At the same time, some states, explicitly or implicitly, expect municipal permittees to set up programs to meet water quality standards in the waters to which all land uses under their jurisdictions discharge.[1] It only makes sense in this

[1] For example, the second Draft Ventura County [California] Municipal Separate Storm Sewer System Permit states (under Findings D. Permit Coverage), "Provisions of this Order apply to the urbanized areas of the municipalities, areas undergoing urbanization and areas which the Regional Water Board Executive Officer determines are discharging storm water that causes or contributes to a violation of a water quality standard … ." The permit further states (under Part 2—Receiving Water Limitations), "1. Discharges from the MS4 that cause or contribute to a violation of water quality standards are prohibited. … 3. … This Order shall be implemented to achieve

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situation to have designated states (or EPA for the others) specify criteria for industrial and construction permits but revise regulations to empower and support municipal co-permittees in compliance-related activities. This paradigm is not unprecedented in environmental permitting, as under the Clean Air Act, states develop state implementation plans for implementation by local entities. For this new arrangement to work, states would have to be comfortable that municipalities could handle the responsibility and be able to exercise the added authority granted. The committee's opinion is that municipalities generally do have the capability, working together as co-permittees with a large-jurisdiction lead permittee and with guidance and support from states.

It bears noting at the outset that the proposed new program would not reduce the present system's reliance on general permits. Whereas a general permit now can be issued to a group of municipalities having differing circumstances, under the new system a permit could just as well be formulated in the same way for a group of varying watersheds. General industrial and construction permits would be just as prevalent too.

Toward Watershed-Based Permitting

Watershed-based permitting is taken in this report to mean regulated allowance of discharges of water and wastes borne by those discharges to waters of the United States, with due consideration of (1) the implications of those discharges for preservation or improvement of prevailing ecological conditions in the watershed's aquatic systems, (2) cooperation among political jurisdictions sharing a watershed, and (3) coordinated regulation and management of all discharges having the potential to modify the hydrology and water quality of the watershed's receiving waters.

Determining Watershed Scale for Permitting

A fundamental question that must be answered at the outset of any move to watershed permitting is, What is a watershed? Hydrologically, a watershed is the rain catchment area draining to a point of interest. Hence, the question comes down to, Where should the point of interest be located to define watersheds for permitting purposes? If placed close to the initial sources of surface runoff (e.g., on each first-order stream just above its confluence with another first-order stream), attention would be very specifically directed. However, there would be little flexibility to devise solutions for the greatest good. For example, trading of the commodities runoff quantity and quality would be very restricted. If on the other hand the point of interest is placed far downstream, thus defining a very large watershed, a welter of issues, and probably also of involved jurisdictions, would overly confuse the management and regulatory task.

The U.S. Geological Survey (USGS) delineates watersheds in the United States using a nationwide system based on surface hydrologic features. This system divides the country into 21 regions, 222 subregions, 352 accounting units, and 2,262 cataloging units. These hydrologic units are arranged within each other, from the smallest (cataloging units) to the largest (regions). USGS identifies each hydrologic unit by a unique hydrologic unit code (HUC) consisting of 2 to

compliance with receiving water limitations. If exceedence(s) of water quality objectives or water quality standards persist … the Permittee shall assure compliance with discharge prohibitions and receiving water limitations … ."

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16 digits based on the four levels of classification in the hydrologic unit system. Watersheds thus delineated are typically of the order a few square kilometers in area. This system is now being linked to the National Hydrography Dataset (NHD) and the National Land Cover Dataset to produce NHDPlus, an integrated suite of application-ready geospatial datasets.

The USGS system provides a starting point. Ultimately, though, what constitutes a watershed will best be answered with reference to specific biogeophysical conditions and problems and by personnel at relatively close hand (i.e., state or regional oversight agency staff). A general guideline might be the catchment area of a waterbody influenced by a set of similar subwatersheds. Similar subbasins would presumably be amenable to similar solutions and trading off reduced efforts in some places for compensating additional efforts elsewhere, as well as to analysis and monitoring on a representative basis, instead of exhaustively throughout. Often, a watershed defined in this way would flow into another watershed and influence it. Thus, there would have to be coordination among managers and regulators of interacting watersheds. It would be common for several watersheds ranging from relatively small to large in scale to be nested. Each would have its management team, and a committee drawn from those teams should be formed to coordinate goals and actions.

A prerequisite to moving toward watershed permitting, then, is for states or regions within states to delineate watersheds. California took this step early in the NPDES stormwater permitting process and offers a model in this respect, as well as in encompassing all jurisdictions coordinated by a lead permittee. First, the state organized its California EPA regional water boards on a watershed basis. Furthermore, since 1992 it has been common in California to establish one jurisdiction as the lead permittee (e.g., Los Angeles County in the Los Angeles region, Orange County in the Santa Ana Region, and San Diego County in the San Diego Region) and all of the politically separate cities as co-permittees. The lead permittee has typically been the jurisdiction most widely distributed geographically in the region and large enough to develop compliance mechanisms and coordinate their implementation among all participants. Box 6-3 describes the approach taken to delineating management units within the Chesapeake Bay watershed, which comprises parts of Pennsylvania, Maryland, Virginia, and the District of Columbia. The case study illustrates well the approach advocated here of focusing on the outcome in the receiving water and considering all aspects of land and water resources management that determine that outcome.

Steps Toward Watershed-Based Permitting

Once a watershed is defined, a further question arises regarding how much and what part of its territory to cover formally under permit conditions. Under the present system substantial development occurring outside Phase I or Phase II municipal jurisdictions is escaping coverage. Failing to control relatively high levels of development both outside a permitted jurisdiction and upstream of more lightly developed areas within a permitted area is particularly contrary to the watershed approach. Areas having a more urban than rural character are already essentially treated as urban in water supply and sewer planning, and the same should occur in the area of stormwater management. Accordingly, the permit should extend to any area in the watershed, even if outside Phase I or II jurisdictions, zoned or otherwise projected for development at an urban scale (e.g., more than one dwelling per acre). States do have authority under the CWA to designate any area for Phase II coverage based on projected growth or the presence of impact

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BOX 6-3
Watershed Delineation for the Chesapeake Bay

The "Tributary Strategy Team" approach of the Chesapeake Bay Watershed provides a specific example of a watershed-scale approach to implementation of water quality control measures. Some background on this longstanding program is first provided, before turning to how watersheds were delineated. In 1983, the states of Virginia, Maryland, and Pennsylvania; the District of Columbia; and EPA signed an agreement to form the Chesapeake Bay Program with a goal to restore and protect the bay, which was suffering from nutrient overenrichment, severely reduced submerged aquatic vegetation, and contamination by toxics. In 1987 the program established a target of a 40 percent reduction in the amount of nutrients entering the Bay by 2000. In 1992 the bay program partners agreed to continue the 40 percent reduction goal beyond 2000 by allocating nutrient reduction targets to the bay's tributaries. In Chesapeake 2000, the most recent version of the Chesapeake Bay agreement, the nutrient reduction goals were reaffirmed, and an additional goal of sediment reduction was established. New York, Delaware, and West Virginia, locations of the bay's headwaters, also became involved in nutrient and sediment reduction. Cap load allocations for nutrients (nitrogen and phosphorus) and sediment to be reached by 2010 were agreed upon by the states. The states began developing 36 voluntary watershed-based tributary strategies to meet the state cap load allocations covering the entire 64,000-square-mile Chesapeake Bay watershed.

Watershed-based tributary strategies are developed in cooperation with local watershed stakeholders. For rural areas, where stakeholders include farmers, nutrient strategies include promotion of management practices such as maintaining cover crops on recently harvested cropland to reduce soil erosion, reduction in nitrogen applications, conservation tillage, and establishment of riparian buffers. For urban-area stakeholders such as homeowners and municipalities, tributary strategies include practices such as enhanced nutrient removal at WWTPs, low-impact development (LID) practices, erosion and sediment control practices, and septic system upgrades.

The first cut at delineating the watershed, which was based on hydrography and topography, defined the eight major areas draining to the Chesapeake Bay: six major basins (Susquehanna, Potomac, York, James, Rappahannock, and Patuxent) plus smaller areas not draining to a major river on the Eastern and Western Shores of the bay in Maryland. These subdivisions are disparate with respect to size (the Susquehanna can engulf almost the entire other seven), but direct drainage to the bay was the criterion at this level.

The next cut was made at state borders. For example, the Susquehanna traverses three states and was subdivided at the New York–Pennsylvania and Pennsylvania–Maryland political boundaries. Further cuts were subsequently made within some states. The criteria for these cuts varied from state to state, but generally involved a combination of smaller political jurisdictions (e.g., county, township), subwatershed basin borders, and other local considerations, such as local interest and investment (e.g., watershed associations).

The resulting delineations are highly variable in size but apparently satisfactory to the local parties who decided on the areas. They represent individual "tributary strategy areas" but are also nested within the larger eight designations and involve interjurisdictional and interstate coordination where a subbasin is divided by a political boundary. Although the example of the Chesapeake Bay is at a very large scale, the principles of watershed delineation it illuminates apply at all scales.

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sources. They should be required to do so for nationwide uniformity and best protection of water resources.

It is essential to clarify that watershed-based permitting as formulated in this chapter differs sharply from what has been termed watershed (or basin) planning. According to EPA, watershed planning "identifies broad goals and objectives, describes environmental problems, outlines specific alternatives for restoration and protection, and documents where, how, and by whom these action alternatives will be evaluated, selected, and implemented" (http://www.epa.gov/watertrain/planning/planning7.htm). Drawing up such a plan is a time-consuming process, which has often become an end in itself, instead of a means to an end. Completing a full watershed plan, as usually construed, should not be a prerequisite to watershed-based permitting. Rather, the anticipated process would spring much more from comprehensive, advanced scientific and technical analysis of the water resources to be managed and their contributing catchment areas than from a planning framework.

Effective watershed-based permitting as outlined in this report is composed of

- Centralizing responsibility and authority for implementation with a municipal lead permittee working in partnership with other municipalities in the watershed as co-permittees;
- Adopting a minimum goal in every watershed to avoid any further loss or degradation of designated beneficial uses within the watershed's component waterbodies;
- Assessing waterbodies that are not providing designated beneficial uses in order to set goals aimed at recovering these uses;
- Defining careful, complete, and clear specific objectives to be achieved through management and permitting;
- Comprehensive impact source analysis as a foundation for targeting solutions;
- Determining the most effective ways to isolate, to the extent possible, receiving waterbodies from exposure to those impact sources;
- Developing and appropriately allocating funding sources to enable the lead permittee and partners to implement effectively;
- Developing a monitoring program composed of direct measures to assess compliance and progress toward achieving objectives and diagnosing reasons for the ability or failure to meet objectives, in support of active adaptive management; and
- Developing a market system of trading credits as a tool available to municipal co-permittees to achieve watershed objectives, even if solutions cannot be uniformly applied.

The system proposed herein is a significant departure from the road traveled in the 20 years since CWA amendments began to bring stormwater under direct regulation. This reorganization is necessary because of the failure of the present system to achieve widespread and relatively uniform compliance (see Chapter 2) and, ultimately, to protect the nation's water resources from degradation by municipal, industrial, and construction runoff. The workload associated with adopting this approach will be considerable and will take some time to complete. The structure of the new program should be fully in place within five years, which is considered to be a reasonable period to complete the work. It could be fully implemented throughout the nation within ten years. However, interim measures toward its fulfillment should occur sooner, within one to two years. Such measures should be applied to each land-use and impact-source

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category (i.e., existing residential and commercial development, existing industry, new development, redevelopment, construction sites). For example, measures such as an effective impervious area limit or a requirement to maintain predevelopment recharge to the subsurface zone could make early progress in managing new development, and lead toward the ultimate, objective-based management and permitting strategy for that category. Advanced source control performance standards would be appropriate interim measures for existing development.

One innovative approach to watershed-based management that can ease the burden of the proposed new system is the rotating basin approach. As described by EPA (2007a), this option entails delineating state watershed boundaries and grouping the watersheds into basin management units, usually by the state water pollution control agency. Next, states implement a watershed management process on a rotating schedule, which is usually composed of five activities: (1) data collection and monitoring, (2) assessment, (3) strategy development, (4) basin plan review, and (5) implementation. Over time, different waterbodies are intensively studied as part of the rotation. Data collected can be used to support a number of different reporting and planning requirements, including a finding of attainment of water quality standards, a determination of impairment, or possible delisting if the waterbody is found not to be impaired. Florida offers a good example of the rotating basin approach. The Florida Department of Environmental Protection has defined five levels of intensity, or phases, each taking about one year to complete, and it has divided the state into 30 areas based on HUCs. At any one time six areas are in each phase before rotating to a subsequent phase. This division of effort would help alleviate the burden of moving to a new system of watershed-based permitting by programming the work over a period of years. It could certainly be organized on a priority basis, in which the watersheds of greatest interest for whatever reason (e.g., having the highest resource values, being most subject to new impacts) would get attention first.

An Objective-Based Framework

The proposed framework for watershed-based management and regulation of stormwater relies on broad goals to retain and recover aquatic resource beneficial uses, backed by specific objectives (e.g., water quality criteria) that must be achieved if the goals are to be fulfilled. Meeting the objectives and overarching goals is intended to become the basis for determining permit compliance, instead of the current reliance on implementation of SCMs as presumptive evidence of compliance.

The broad goals of retaining and recovering beneficial uses are entirely consistent with the antidegradation clause of the CWA. Antidegradation means that the current level of water quality shall be maintained and protected, unless waters exceed levels necessary for maintaining their beneficial uses *and* the state finds that allowing lower water quality is necessary to accommodate important economic or social development. In accordance with the antidegradation clause, a major pillar of the proposed concept is the goal of preventing degradation from the existing state of biological health, whatever it may be, to a lower state. Thus, fully and nearly pristine watersheds are to remain so and, at a minimum, partially or highly impaired ones are to suffer no further impairment. Beyond this minimum, impaired waters should be assessed to determine if feasible actions can be taken to recover lost designated beneficial uses or at least improve degraded uses.

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As discussed in Chapter 2, beneficial uses relate to the social and ecological services offered, or intended to be offered, by waterbodies. For example, California has 20 categories of beneficial uses embracing water supply for various domestic, agricultural, and industrial purposes; provision of public recreation; and support of aquatic life and terrestrial wildlife (CalEPA, Central Coast Regional Water Board Basin Plan). That beneficial uses are usually assigned at the state level by waterbody classes or specific waterbodies would not change under the proposed permitting program revision. Most waters have several beneficial uses encompassing some water supply and ecological functions and, perhaps, some form of recreation. Unlike most current stormwater programs where attainment of beneficial uses is only implicit, these goals would become explicit in the altered system and officially promulgated by the authority operating the permit program (a designated state, in most cases, or EPA). The permitting authority would then partner with municipal permittees to determine the conditions that must be brought to bear to attain beneficial uses, set objectives or criteria to establish those conditions, and follow through with the tasks to accomplish objectives.

The proposed framework's reliance on achieving objectives that reflect the cumulative aquatic resource effects of contributing watershed conditions suggests the following related concepts:

- In whatever manner watershed boundaries are set, the full extent of the watershed from headwaters onward should be considered in defining objectives. This is important even where watershed scale and boundaries are based on local and/or regional hydrogeomorphic circumstances and their associated management and regulatory needs. Watersheds can and often will be defined and nested at different scales (e.g., streams tributary to a lake, a river flowing into an estuary or marine bay).

- The scale of objectives must be consistent with the scale and recognized beneficial uses of the watershed(s) in question; for example, sustaining salmonid fish spawning could be the basis for a stream objective, while retaining an oligotrophic state could be the essential objective for a lake to which the stream is tributary.

- Whenever beneficial uses pertain to living organisms (aquatic life or humans), representing the vast majority of all cases, objectives should be largely in biological terms. That is not to say that supplementary objectives cannot be stated otherwise (e.g., in terms of flow characteristics, chemical water quality constituents, or habitat attributes), but the ultimate direct thrust of the program should be toward the biota.

- Objectives must be carefully chosen to represent attributes of importance from a resource standpoint, limited in number for feasibility of tracking achievement, and defined in a way that achievement can be measured. For example, nitrogen is generally the nutrient limiting algal growth in saline systems and in excess it stimulates growth that can reduce dissolve oxygen, killing fish and other aerobic organisms. In this case the most productive objectives would probably target reduction of nitrogen concentration and mass flux and maintenance of dissolved oxygen. For waterbodies designated for contact recreation, fecal coliform indicators (although not directly pathogenic when waterborne) have proven to be an effective means of assessing condition and should continue to form the basis for objectives to protect contact recreation until research produces superior measures. If drinking water supply is a designated beneficial use of a

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lake, it will better serve that function in a lower than a higher state of eutrophication, which can be managed, according to a long limnological research record, by restricting water column chlorophyll *a* as an objective. Where the beneficial use is fish protection and propagation, biological criteria might include (1) maintenance of a specific population size of a resident fish species when that species' population can be assayed conveniently; (2) maintenance of a numerical index (e.g., benthic index of biotic integrity) when a fish species of ultimate interest cannot be assessed so conveniently but is known or reasonably hypothesized to be associated with the index; or (3) a related parameter, such as eelgrass beds, which are important fish nursery areas in estuarine waters, such that areal coverage by these beds would be an appropriate objective to track over time. An intermittent waterbody could have biological criteria related to, for example, fish migration or amphibian reproduction.

- The achievement of objectives, or lack thereof, is the basis for follow-up and prescription of remedies in an active adaptive management mode; that is, falling short of objectives would trigger a search for reasons throughout the watershed, followed by identification of actions necessary and sufficient to remedy the shortfall, assessment of their ability to reach objectives, and the cost of doing so. In the course of this assessment it may be concluded that the objective itself is faulty and should be restated, replaced, or discarded.

Basing the watershed framework principally on biological objectives grows out of the CWA's fundamental charge to protect the biological (as well as physical and chemical) integrity of the nation's waters. The tie between specific physical and chemical conditions and the sustenance of aquatic biological communities is not well established through an extensive, well-verified body of research. Moreover, living organisms consuming or living in water are subject to a vast multitude of simultaneous physical and chemical agents having the potential to harm them individually and interactively. There are no realistic prospects for research to determine the levels of these numerous agents that must be maintained to support beneficial uses. Therefore, their integrative effects must be determined using measures of biological populations or communities of interest.

By and large, state water quality standards as now promulgated would not serve the proposed objective-based system well. They are usually not phrased in biological terms or with respect to hydrologic variables now known to have instrumental negative effects on aquatic organisms, but instead mostly as concentrations of selected chemical elements or compounds. However, there is no prohibition of biological or hydrologic standards in the law. The recommended emphasis is consistent with and informed by the tiered aquatic life uses system applied by some states and illustrated for Ohio in Box 2-1. The use of such systems must expand greatly to support the recommended framework. An opportunity to do so exists through the triennial review already required for each state's water quality standards.

Certain special considerations affect the development and use of objectives as the device to carry forward watershed-based stormwater management and regulation. First, other elements of the CWA beyond the stormwater program and other laws may very well be involved in a watershed (see Chapter 2). Municipal and industrial wastewater discharges will often be contributors along with stormwater. Aquatic organisms may be listed as threatened or endangered under the federal ESA or state authority. Both objectives and the management and regulatory program designed to achieve objectives should reflect any such circumstances.

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Instituting the proposed permitting program will require converting the TMDL program to one more suitable for its purposes and structure. The TMDL program is watershed based and hence offers some precedent and experience applicable to the new system. However, for the most part, it has operated only on waters declared to be impaired for specific pollutants, and it relies on management of specific physical and chemical water quality variables. Furthermore, in its current mode it takes no account of potential future impact sources. The TMDL program should be replaced with one adapted to the objective-based framework proposed here. This new program should apply to all waters assigned objectives, "impaired" or not, and formulate limits in whatever terms are best to achieve objectives. Hence, although the program would expand in coverage area, the efficient tailoring of objectives directly to beneficial uses could compensate for the expansion by targeting fewer variables. Finally, the new program should look to the future as well as the present by encompassing the anticipated impacts of prospective landscape changes.

The nature of a program to replace TMDLs can be glimpsed from a few attempts to move in the anticipated direction even under the existing structure. For example, Connecticut collected data directly linking impervious cover to poor stream health in Eagleville Brook (Connecticut Department of Environmental Protection, 2007). The stream's TMDL was developed using watershed impervious cover as a surrogate parameter for a mix of pollutants conveyed by stormwater. The intention is to reduce effective imperviousness by disconnecting impervious areas, installing unspecified SCMs, minimizing additional disturbance, and enhancing in-stream and riparian habitat. Flow was used as a surrogate for stormwater pollution in the Potash Brook, Vermont TMDL (Vermont DEC, 2006). In this waterbody, the impairment was based on biological indices that were then related to a hydrologic condition believed to be necessary to achieve the Vermont criteria for aquatic life. The TMDL will be implemented via the use of runoff-volume-reduction SCMs throughout the watershed.

Impact Sources

The CWA provides for regulating, as specific land-use types, only designated industrial categories, with construction sites disturbing one acre or more considered to be one of those categories. Otherwise, it gives authority to regulate municipal jurisdictions operating separate storm sewer systems. Generally speaking, these jurisdictions encompass, in addition to the industrial categories, the full range of urban land-use types, such as single- and multiple-family residential, various kinds and scales of commercial activity, institutional, and parks and other open space. All of these land uses and the activities conducted on them are, to one degree or another, sources of the agents that physically and chemically modify aquatic systems to the detriment of their biological health. Hence, most of the impact sources to which these aquatic systems are subject are not directly regulated under CWA authority as are industrial sources, but instead are indirectly regulated through the municipal program. Also, as already discussed, the situation is further complicated by the presence of municipal and industrial wastewater sources along with landscape sources contributing flow and pollutants to receiving waters via stormwater discharges.

The watershed-based framework envisioned here relies on municipalities led by a principal permittee. Thus, a fundamental task that municipal permittees charged with operating under a watershed-based permit must do is to find industries and construction sites in the

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watershed that have not filed for permit coverage and bring them under regulation. Furthermore, municipal co-permittees, with leadership by a watershed lead permittee, must classify industries and construction sites within their borders according to risk and accordingly prioritize them for inspection and monitoring (methods for doing this are discussed later in the chapter). Municipal permittees must have better tools than they have had in the past to assess the various impact sources and formulate strategies to manage them that have a reasonably high probability of fulfilling objectives. The present state of practice and research findings offers some directions for choosing or more completely developing these tools. However, by no means are all the necessary elements available, and substantial new basic and applied research must be performed.

From the literature come several possibilities to improve source analysis in the complex urban environment. Some examples of apparent promise, drawn from Clark et al. (2006) include the following:

- Nirel and Revaclier (1999) used the ratio of dissolved rubidium (Rb) to strontium (Sr) to identify and quantify the impact of sewage effluents on river quality in Switzerland. Rubidium was present in larger quantities than strontium in feces and urine, making the ratio of these two elements an effective tracer that does not vary with river flow for a given water quality condition. Using the ratio alone produced the same conclusions regarding impact as measuring a host of physicochemical water quality variables. The researchers estimated that the Rb:Sr ratio must be lower than 0.007 if biological diversity is to be maintained, which could be the basis of an objective to manage river water quality. Although this case pertains to municipal wastewater and the technique works best in waters with a naturally low Rb:Sr ratio (e.g., calcareous regions), it success points out a potential avenue of research to simplify stormwater management on the basis of quantitative objectives related to biological integrity.

- Cosgrove (2002) described the approach used in New Jersey to characterize the relative contribution of point and nonpoint sources of pollutants in the Raritan River Basin. Twenty-one surface water sampling locations within the watershed were monitored four to five times per year from 1991 to 1997. These data were evaluated by comparing the median concentration at each sampling location with land-use statistics. Cumulative probability curves were also developed for each pollutant to demonstrate the probability that the concentration at a given location would be below a certain level (e.g., a stream standard). These probability curves were useful in determining the risk that a given location would violate a particular standard. The concentration data, coupled with continuous flow monitoring records, were utilized to determine the total load for each constituent. Regression analysis was used to develop a relationship between the total in-stream loads and flow. Such an analysis provided an indication of municipal or industrial discharge versus diffuse-source-dominated locations. Pollutant loads could then be converted to yield (load per unit area) to normalize the results for comparison from one station to another. The “screening level” methodology uses only existing data and, not requiring advanced modeling techniques, can be used to understand where to focus more rigorous modeling techniques.

- Maimone (2002) presented the overall approach that was used to screen and evaluate potential pollutant sources within the Schuylkill River watershed as part of the Schuylkill River Source Water Assessment Partnership. The partnership performed source water assessments of 42 public water supply intakes for the Pennsylvania Department of Environmental Protection.

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The watershed encompasses over 1,900 square miles with more than 3,000 potential point sources of contamination. In addition, runoff from diverse land uses such as urban and agriculture had to be characterized using the Stormwater Management Model. For all 42 surface water intakes, potential point sources were identified using existing databases. The list was first passed through a series of Geographic Information System-based "screening" sieves to limit the sources to only those considered to be high priority (including proximity and travel time from source to intake). Ten categories were identified that cover the range of the most important contaminants that might be found within the watershed, and a representative or surrogate chemical was identified whose properties were used to stand in for the category. Beyond the geographic screening, a more sophisticated screening was needed to limit the number of sites, using a decision support computer software program called EVAMIX. The greatest benefit of EVAMIX, compared to other software, is that it allows mixed criteria evaluation, qualitative and quantitative, to be considered concurrently. EVAMIX produced source rankings representing an organized and consistent use of both the objective data and the subjective priorities of decision makers.

- Hetling et al. (2003) investigated the effect of water quality management efforts on wastewater discharges to the Hudson River (from Troy, New York to the New York City Harbor) from 1900 to 2000. The paper demonstrated a methodology for estimating historic loadings where data are not available. Under these circumstances, estimated historic sewered and treated populations and per capita values were used to calculate wastewater flow and loadings for 5-day biochemical oxygen demand (BOD_5), total suspended solids (TSS), total nitrogen, and total phosphorus. The analysis showed that dispersed landscape sources have become the most significant contributors of the first two contaminants to the river, while municipal wastewater plants remain the largest sources of nutrients. The methodology presented in this paper could be used by co-permittees to estimate present-day sources of various types and contribute to moving toward a comprehensive permit incorporating multiple sources.

- Zeng and Rasmussen (2005) used multivariate statistics to characterize water quality in a lake and its tributaries. Tributary water was composed of three components. Factor analysis demonstrated that stormwater runoff was the predominant cause of elevation of a group of water quality variables in a factor including TSS, the measurement of which is a convenient surrogate for all variables in the factor. Similarly, municipal and industrial discharges could be characterized by total dissolved solids, and groundwater by alkalinity plus soluble reactive phosphorus. These sources can thus be distinguished through measurement of just four common water quality variables. Reducing the number of analytes reduces laboratory costs and allows resources to be freed up for other purposes. Cluster analyses performed on the data indicated that further savings could be realized by sampling just one among several stations in a cluster and sampling at just one point in time over a period of relatively stable water quality (e.g., a relatively dry period).

A key research need associated with applying the proposed framework is assessment of these and other mechanisms for sorting out the contributions of the variety of impact sources in the urban environment. Leading this effort would be a natural role for EPA.

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Impact Reduction Strategies

The philosophical basis for impact reduction under a modified permitting system centered on a lead municipal permittee and associated co-permittees is to avoid, as far as possible, exposing receiving waters to impact sources or to otherwise minimize that exposure. The concept embraces both water quantity and quality impact sources and specifically raises the former category to the same level of scrutiny as traditionally applied to water quality sources. Furthermore, the endpoints upon which success and compliance would be judged are directly related to achievement of beneficial uses. This approach to impact reduction, where the direct focus is on reducing the loss of aquatic ecosystem functioning supportive of beneficial uses, fundamentally contrasts with the currently prevailing system. What are primary concerns in the existing system (e.g., discharge concentrations of certain chemical and physical substances, technological strategies from a menu of practices) are still prospectively important, but only as a means toward realizing functional objectives, not as endpoints themselves. To be sure, attaining beneficial uses will require wise choices among tools to decrease discharges and contaminant emissions. However, the ultimate proof will always be in biological outcomes.

As made clear in Chapters 3 and 4, linkages among myriad stressing agents, impact receptors, and specific mitigating abilities of technological fixes are poorly understood and not easily understandable. The proposed new paradigm acknowledges that the linkages are not established among the voluminous elements in an exceptionally complex system ranging from impact sources, through environmental transport and fate mechanisms, to ecosystem health. However, it is intuitively and theoretically clear that minimizing the generation of impacts in the first place and slowing their progression into aquatic environments can break the chain of landscape alteration that leads to increased runoff and pollutant production, modifies aquatic habitat, and ultimately causes deterioration of the biological community. Landscapes can be managed in a preventive, integrated fashion that deals with the many undifferentiated agents of impact and avoids, or at least reduces, the damage. Although the application of these theories may not automatically and quickly stem biological losses, the powerful mechanism of adaptive management, if correctly applied, can be used to make course corrections toward meeting the defined objectives.

An earlier National Research Council (NRC) committee examined the scientific basis of EPA's TMDL program and recommended "adaptive implementation" (AI) to water quality standards (NRC, 2001a). That committee drew AI directly from the concept of adaptive management for decision making under uncertainty, introduced by Holling and Chambers (1973) and Holling (1978) and described it as an iterative process in which TMDL objectives and the implementation plans to meet those objectives are regularly reassessed during the ongoing implementation of controls. Shabman et al. (2007) and Freedman et al. (2008) subsequently extended and refined the applicability of AI for promoting water quality improvement both within and outside of the TMDL program. In that broader context, AI fits well with the framework put forward here. Indeed, the proposed revised monitoring system presented later in this chapter is designed to provide information to support adaptive management in a permitting context.

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The Stages of Urbanization and Their Effects on Strategy

In waterbodies that are not in attainment of designated uses, it is likely that the physical stresses and pollutants responsible for the loss of beneficial uses will have to be decreased, especially as human occupancy of watersheds increases. Reducing stresses, in turn, entails mitigative management actions at every life stage of urban development: (1) during construction when disturbing soils and introducing other contaminants associated with building; (2) after new developments on Greenfields are established and through all the years of their existence; (3) when any already developed property is redeveloped; and (4) through retrofitting static existing development. Most management heretofore has concentrated on the first two of those life stages.

The proposed approach recognizes three broad stages of urban development requiring different strategies: new development, redevelopment, and existing development. *New development* means building on land either never before covered with human structures or in prior agricultural or silvicultural use relatively lightly developed with structures and pavements (i.e., Greenfields development). *Redevelopment* refers to fully or partially rebuilding on a site already in urban land use; there are significant opportunities for bringing protective measures to these areas where none previously existed. The term *existing development* means built urban land not changing through redevelopment; retrofitting these areas will require that permittees operate creatively.

What is meant by redevelopment requires some elaboration. Regulations already in force typically provide some threshold above which stormwater management requirements are specified for the redeveloped site. For example, the third Draft Ventura County Municipal Separate Storm Sewer System Permit defines "significant redevelopment" as land-disturbing activity that results in the creation or addition or replacement of 5,000 square feet or more of impervious surface area on an already developed site. The permit goes on to state that where redevelopment results in an alteration to more than 50 percent of the impervious surfaces of a previously existing development, and the existing development was not subject to postdevelopment stormwater quality control requirements, the entire site becomes subject to application of the same controls required for new development. Where the alteration affects 50 percent or less of the impervious surfaces, only the modified portion is subject to these controls. All urban areas are redeveloped at some rate, generally slowly (e.g., roughly one or at most a few percent *per annum*) but still providing an opportunity to ameliorate aquatic resource problems over time. Extending stormwater requirements to redeveloping property also gradually "levels the playing field" with new developments subject to the requirements. As pointed out in Chapter 2, some jurisdictions offer exemptions from stormwater management requirements to stimulate desired economic activities or realize social benefits. Such exemptions should be considered very carefully with respect to firm criteria designed to weigh the relative socioeconomic and environmental benefits, to prevent abuses, to gauge just how instrumental the exemption is to gaining the socioeconomic benefits, and to compensate through a trading mechanism as necessary to achieve set aquatic resource objectives.

It is important to mention that not only residential and commercial properties are redeveloped, but also streets and highways are periodically rebuilt. Highways have been documented to have stormwater runoff higher than other urban land uses in the concentrations and mass loadings of solids, metals, and some forms of nutrients (Burton and Pitt, 2002; Pitt et al., 2004; Shaver et al., 2007). Redevelopment of transportation corridors must be taken as an opportunity to install SCMs effective in reducing these pollutants.

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Opportunities to apply SCMs are obviously greatest at the new development stage, somewhat less but still present in redevelopment, but most limited when land use is not changing (i.e., existing development). Still, it is extremely important to utilize all readily available opportunities and develop others in static urban areas, because compromised beneficial uses are a function of the development in place, not what has yet to occur. Often, possibly even most of the time, to meet watershed objectives it will be necessary to retrofit a substantial amount of the existing development with SCMs. To further progress in this overlooked but crucial area, the Center for Watershed Protection issued a practical Urban Stormwater Retrofit Practices manual (Schueler et al., 2007).

Practices for Impact Reduction

As described in Chapter 5, in the past 15 to 20 years stormwater management has passed through several stages. First, it was thought that the key to success was to match postdevelopment with predevelopment peak flow rates, while also reducing a few common pollutants (usually TSS) by a set percentage. Finding this to require large ponds but still not forestalling impacts, stormwater managers next deduced that runoff volumes and high discharge durations would also have to decrease. Almost simultaneously, although not necessarily in concert, the idea of LID arose to offer a way to achieve actual avoidance or at least minimization of discharge quantity and pollutant increases reaching far above predevelopment levels. For purposes of this discussion, the SCMs associated with LID along with others are named Aquatic Resources Conservation Design (ARCD). First, this term signifies that the principles and many of the methods apply not only to building on previously undeveloped sites, but also to redeveloping and retrofitting existing development. Second, incorporating aquatic resources conservation in the title is a direct reminder of the central reason for improving stormwater regulation and management. ARCD goes beyond LID to encompass many of the SCMs discussed in Chapter 5, in particular those that decrease surface runoff peak flow rates, volumes, and elevated flow durations caused by urbanization, and those that avoid or at least minimize the introduction of pollutants to any surface runoff produced. This concentration reduction, together with runoff volume decrease, cuts the cumulative mass loadings (mass per unit time) of pollutants entering receiving waters over time. The SCM categories from Table 5-1 that qualify as ARCD include

- Product Substitution,
- Watershed and Land-Use Planning,
- Conservation of Natural Areas,
- Impervious Cover Minimization,
- Earthwork Minimization,
- Reforestation and Soil Conservation,
- Runoff Volume Reduction—Rainwater Harvesting, Vegetated, and Subsurface,
- Aquatic Buffers and Managed Floodplains, and
- Illicit Discharge Detection and Elimination.

The menu of ARCD practices begins with conserving, as much as possible, existing trees, other vegetation, and soils, as well as natural drainage features (e.g., depressions, dispersed sheet

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flows, swales). Clustering development to affect less land is a fundamental practice advancing this goal. Conserving natural features would further entail performing construction in such a way that vegetation and soils are not needlessly disturbed and soils are not compacted by heavy equipment. Using less of polluting materials, isolating contaminating materials and activities from contacting rainfall or runoff, and reducing the introduction of irrigation and other non-stormwater flows into storm drain systems are essential. Many ARCD practices fall into the category of minimizing impervious areas through decreasing building footprints and restricting the widths of streets and other pavements to the minimums necessary. Water can be harvested from impervious surfaces, especially roofs, and put to use for irrigation and gray water system supply. Harvesting is feasible at the small scale using rain barrels and at larger scales using larger collection cisterns and piping systems. Relatively low traffic areas can be constructed with permeable surfaces such as porous asphalt, open-graded Portland cement concrete, coarse granular materials, concrete or plastic unit pavers, or plastic grid systems. Another important category of ARCD practices involves draining runoff from roofs and pavements onto pervious areas, where all or much can infiltrate or evaporate in many situations.

If these practices are used, but excess runoff still discharges from a site, ARCD offers an array of techniques to reduce the quantity through infiltration and evapotranspiration and improve the quality of any remaining runoff. These practices include (1) bioretention cells, which provide short-term ponded and soil storage until all or much of the water goes into the deeper soil or the atmosphere; (2) swales, in which water flows at some depth and velocity; (3) filter strips, broad surfaces receiving sheet flows; (4) infiltration trenches, where temporary storage is in below-ground gravel or rock media; and (5) vegetated ("green") roofs, which offer energy as well stormwater management benefits. Natural soils sometimes do not provide sufficient short-term storage and hydraulic conductivity for effective surface runoff reduction because of their composition but, unless they are very coarse sands or fine clays, can usually be amended with organic compost to serve well.

ARCD practices should be selected and applied as close to sources as possible to stem runoff and pollutant production near the point of potential generation. However, these practices must also work well together and, in many cases, must be supplemented with strategies operating farther downstream. For example, the City of Seattle, in its "natural drainage system" retrofit initiative, built serial bioretention cells flanking relatively flat streets that subsequently drain to "cascades" of vegetated stepped pools created by weirs, along more sloping streets. The upstream components are highly effective in attenuating most or even all runoff. Flowing at higher velocities, the cascades do not perform at such a high level, although under favorable conditions they can still infiltrate or evapotranspire the majority of the incoming runoff (Horner et al., 2001, 2002, 2004; Chapman, 2006; Horner and Chapman, 2007). Their role is to reduce runoff from sources not served by bioretention systems as well as capture pollutants through mechanisms mediated by the vegetation and soils. The success of Seattle's natural drainage systems demonstrates that well-designed SCMs can mimic natural landscapes hydrologically, and thereby avoid raising discharge quantities above predevelopment levels.

In some situations ARCD practices will not be feasible, at least not entirely, and the SCMs conventionally used now and in the recent past (e.g., retention/detention basins, biofiltration without soil enhancement, and sand filters) should be integrated into the overall system to realize the highest management potential.

The proposed watershed-based program emphasizing ARCD practices would convey significant benefits beyond greatly improved stormwater management. ARCD techniques

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overall would advance water conservation, and infiltrative practices would increase recharge of the groundwater resource. ARCD practices can be made attractive and thereby improve neighborhood aesthetics and property values. Retention of more natural vegetation would both save wildlife habitat and provide recreational opportunities. Municipalities could use the program in their general urban improvement initiatives, giving incentives to property owners to contribute to goals in that area while also complying with their stormwater permit.

Municipal Permittee Roles in Implementing Strategies

Municipal permittees sharing a watershed will have key roles in promoting ARCD under the proposed new system. First, the lead permittee and its partners would be called upon to perform detailed scientifically and technically based watershed analysis as the program's foundation. The City of San Diego (2007) offers a model by which permittees could operate with its Strategic Plan for Watershed Activity Implementation. The plan consists of

- Activity location prioritization—locations prioritized for action based on pollutant loading potential;
- Implementation strategy and activity prioritization—tiered approach identifying activities directed at meeting watershed goals over a five-year period;
- Potential watershed activities—general list of activities required and potentially required to meet goals as guidance for planning and budgeting;
- Watershed activity maps—specified locations for activities; and
- Framework for assessment monitoring—a plan for development of the monitoring and reporting program.

Municipal permittees would be required under general state regulations to make ARCD techniques top priorities for implementation in approving new developments and redevelopments, to be used unless they are formally and convincingly demonstrated to be infeasible. In that situation permit approval would still require full water quantity and quality management using conventional practices. Beyond regulation, municipalities would be called upon to give private property owners attractive incentives to select ARCD methods and support to implement them. Furthermore, they should supplement on-site ARCD installations with municipally created, more centralized facilities in subwatersheds.

Other municipal roles in the proposed program revolve around the prominence of soil infiltration as a mechanism in ARCD. Successful use of infiltration requires achieving soil hydraulic conductivity sufficient to drain the runoff collector quickly enough to provide capacity for subsequent storms and avoid nuisance conditions, while not so rapid that contaminants would reach groundwater. One important task for municipal co-permittees will be defining watershed soils and hydrogeological conditions to permit proper siting and design of infiltrative facilities. A great deal of soils information already exists in any community but must be assembled and interpreted to assist stormwater managers. U.S. Department of Agriculture soil surveys, while a start, are often insufficiently site-specific to characterize the subsurface accurately at a point on the landscape. More localized data available to municipalities come from years of recorded well logs, soil borings, and percolation test results. Municipalities should tap these records to define, to their best ability, soil types, hydraulic conductivities, and seasonal groundwater positions. Although abundant and valuable, these data are unlikely to be sufficient to define subsurface attributes across a watershed. Thus, municipalities should collect additional data (soil borings,

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soils analyses, and percolation tests) to obtain a good level of assurance of the prospects for infiltrative ARCD.

Part of the task for municipalities will be overcoming opposition to infiltration if it is unjustified. Some opponents discourage infiltration based on coarse soil survey data that may not apply at all at a locality, or they fail to take into account that the well-established ARCD practice of soil amendment, generally with organic compost, can improve the characteristics of somewhat marginal soils sufficiently to function well during infiltration. While such amendment cannot increase hydraulic conductivity sufficiently in restrictive clay soils, the technique has proven to effectuate substantial infiltration and attendant reduction in runoff volumes and peak flow rates in Seattle's natural drainage systems, discussed above. These systems lie on variable soils, including formations categorized by the Natural Resources Conservation Service (2007) as being in hydrologic group C. This group generally has somewhat restricted saturated hydraulic conductivity in the least transmissive layer between the surface and 50 centimeters (20 inches) of between 1.0 micrometers per second (0.14 inches per hour) and 10.0 micrometers per second (1.42 inches per hour). Furthermore, additional runoff reduction often occurs through evapotranspiration, which is enhanced by the vegetation in ARCD systems.

Another objection sometimes raised to infiltrating stormwater is its perceived potential to compromise groundwater quality. Whether or not that potential is very great depends upon a number of variables: rate of infiltration, ability of the soil type to extract and retain contaminants, distance of travel to groundwater, and any contaminated layers through which the water passes. It is unlikely that urban stormwater, with its prevailing pollutant concentrations, will threaten groundwater if it travels at a moderate rate, through soils of medium or fine textures without contaminant deposits, to groundwater at least several meters below the surface. To ensure that groundwater is not compromised when surface water is routed through infiltrative practices, municipalities must establish where appropriate conditions do and do not exist and spot infiltration opportunities accordingly. Records of past waste disposal, leaks, and spills must be consulted to clean up or stay away from contaminated zones. There are alternatives even if documented soils or groundwater limitations rule out infiltrative practices. Much can be accomplished to reduce the quantities of contaminated urban runoff discharged to receiving waters through impervious surface reduction, water harvesting, and green roofs.

One additional problem to infiltrating stormwater runoff exists in some relatively dry areas and must be countered by municipalities. Overirrigation of lawns and landscape plantings has already increased infiltration well over the predevelopment amount and raised groundwater tables, sometimes to problematic levels. This unnecessary use of irrigation not only wastes potable water, often scarce in such areas, but reduces capacity to infiltrate stormwater without further water table rise. Municipalities should set up effective programs to conserve water and simultaneously increase stormwater infiltration capacity.

A final element of an integrated management and permitting program under municipal control is use of capacity in the sanitary sewer and municipal wastewater treatment systems to treat some stormwater. This initiative must be pursued very carefully. For one reason, municipal treatment works have historically been overburdened with stormwater flows in combined sewers and have not yet broken free of that burden through sewer separation programs. A second reason for care is that municipal sewage treatment plants are generally designed to remove particulates and decompose organic wastes, and not to capture the array of pollutants in stormwater, many dissolved or associated with the finest and most difficult to capture particles. Toxic contaminants can damage microbes and upset biological treatment

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plants. Nonetheless, capacity exists in many WWTPs to treat stormwater. The delivery of pollutants the plant was not designed to handle can be managed by pretreatment requirements, applied to industrial stormwater dischargers particularly. Dry weather flows, consisting mostly of excess irrigation water runoff, can be diverted to treatment plants to prevent at least some of the nutrient and pesticide contamination that otherwise would flow to receiving waters. Additional capacity to treat stormwater can be gained by repairing defective municipal wastewater pipes that allow groundwater entry.

Special Considerations for Construction and Industrial Land Uses

All of the principles discussed above apply to industrial and construction sites as well: minimize the quantity of surface runoff and pollutants generated in the first place, or act to minimize what is exported off the site. Unfortunately, construction site stormwater now is managed all too often using sediment barriers (e.g., silt fences and gravel bags) and sedimentation ponds, none of which are very effective in preventing sediment transport. Much better procedures would involve improved construction site planning and management, backed up by effective erosion controls, preventing soil loss in the first place, which might be thought of as ARCD for the construction phase of development. Just as ARCD for the finished site would seek to avoid discharge volume and pollutant mass loading increase above predevelopment levels, the goal of improved construction would be to avoid or severely limit the release of eroded sediments and other pollutants from the construction site. Chapter 5 discusses construction-phase stormwater management in more detail.

Other industrial sites are faced with some additional challenges. First, industrial sites usually have less landscaping potentially available for land-based treatments. Their discharges are often more contaminated and carry greater risk to groundwater. On the other hand, industrial operations are amenable to a variety of source control options that can completely break the contact between pollutants and rainfall and runoff. Moving operations indoors or roofing outdoor material handling and processing areas can transform a high-risk situation to a no-risk one. It is recommended that industrial permits strongly emphasize source control (e.g., pollution prevention) as the first priority and the remaining ARCD measures as secondary options (as outlined in Table 5-9). Together these measures would attempt to avoid, or minimize to the extent possible, any discharge of stormwater that has contacted industrial sources.

It is likely that the remaining discharges that emanate from an industrial site will often require treatment and, if relatively highly contaminated, very efficient treatment to meet watershed objectives. Some industrial stormwater runoff carries pollutant concentrations that are orders of magnitude higher than now prevailing water quality standards. In these cases meeting watershed objectives may require providing active treatment, which refers to applying specifically engineered physicochemical mechanisms to reduce pollutant concentrations to reliably low levels (as opposed to the passive forms of treatment usually given stormwater, such as ponds, biofiltration, and sand filters). Examples now in the early stages of application to stormwater include chemical coagulation and precipitation, ion exchange, electrocoagulation, and filtration enhanced in various ways. These practices are undeniably more expensive than source controls and other ARCD options and traditional passive treatments. If they must be used at all, it is to the advantage of all parties that costs be lowered by decreasing contaminated waste stream throughput rates to the absolute minimum.

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Administrative and Funding Arrangements

A number of practical, logistical considerations pertain to converting to the permitting and regulatory system discussed above. These considerations include:

- What design and performance standards should be placed on the management systems?
- What administrative vehicles offer the best prospects for success?
- What funding arrangements are necessary to support the revised permitting and management system?

Design and Performance Standards

It has already been asserted under the discussion of objectives above that ultimate performance standards should be based on results in the aquatic systems under protection. The report further advocates promulgating these standards primarily in terms of biological health (for protection of human health, aquatic life, or both), supplemented by measures of conditions well known to influence biological health quite directly, such as hydrologic variables. It was further proposed that active adaptive management be applied in relation to the degree of achievement of water resource objectives. However, it would not be wise to standardize entirely on this level and leave all questions of the means to the end to individual permittees. Certain design-level standards would also be appropriate. An example is provided by the recently issued draft municipal permit for Ventura County, California. In that permit, application of low-impact methods to new development and redevelopment is specified to hold the effective impervious area to 5 percent of the total contributing catchment. While technical experts may disagree on the precise number, the point is that adopting such a standard gives a straightforward design requirement on an evidentiary basis. Results in the receiving waters would still be tracked and used in active adaptive management if necessary, but effective application of the design standard would provide some level of initial assurance that the aquatic health standards can be met.

Forging Institutional Partnerships

At the heart of the proposal for a new system of regulating discharges to the nation's waters is issuing permits to groups of municipalities in a watershed operating as co-permittees under a lead permittee. Furthermore, the proposal envisions these municipal permittees assuming responsibility for and implementing the permits for all public and private dischargers in their jurisdictions. These admittedly sweeping changes in the way waters have been managed almost everywhere in the nation raise serious issues of acquiescence to the new arrangements, compatibility, and devising a sufficient and stable funding base. This section draws from the small number of examples where arrangements like those proposed here have been attempted.

The Los Angeles County Municipal Storm Water Permit offers a case study in how to aggregate municipalities in a co-permittee system while still allowing prospective members latitude should they perceive their own interests to deviate, even considering the advantages of group action. The permit, first issued in 1990, presently covers five watersheds and 86 municipal permittees. During the process of reissuing the 1996 permit, the City of Long Beach

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challenged the provisions of the Los Angeles County MS4 permit. The city was given the option of applying for its own individual permit, which it did. Long Beach was issued its own individual MS4 permit in 1999 with provisions similar to the Los Angeles County MS4 permit. As another example, a small coastal municipality (Hermosa Beach) covered by the Los Angeles County Municipal Storm Water Permit investigated the possibility of withdrawing from the county permit in 2000 to be reclassified as a Phase II municipality. Just as with Long Beach, Hermosa Beach was given the option of applying for an individual permit as a Phase I MS4, but in the end Hermosa Beach elected to remain within the areawide permit. Although this report strongly encourages cooperative participation of municipalities as co-permittees, it does not mandate it. Rather, the flexibility illustrated above should be retained in the proposed new permitting program. What matters for compliance with the CWA is that a municipality manage discharges in a manner at least equivalent to other permittees in the watershed.

Stephenson and Shabman (2005) gave thought to the dilemma of entities who may not naturally work well together being asked to cooperatively solve a problem that all have had a share in creating. They argued that new organizational forms that consolidate multiple regulated entities under a single organizational umbrella could be used to coordinate and manage jointly the collective obligations of a group of regulated parties at lower costs to members. Private and public regulated entities alike could benefit from participation in these new organizations. Such cooperative organizations could offer participating parties financial incentives and decision-making flexibility through credit trading programs.

Two larger-scale compliance associations exist in the Neuse and Tar-Pamlico river basins in North Carolina (Stephenson and Shabman, 2005). In both programs the state was concerned about nutrient enrichment of estuary waters and imposed an aggregate cap on industrial and municipal wastewater dischargers equivalent to a 30 percent reduction in nitrogen loads. In both programs, the state granted individual point source dischargers a choice: (1) accept new requirements to control nitrogen through individual NPDES permits or (2) form and join a discharger association. The rigidities associated with individual NPDES permits provided enough incentive for most point source dischargers to opt for the second choice. Compliance associations were then created and issued permits.

The Neuse River rules cover nonpoint agricultural sources as well as point discharges. Counties are responsible for reducing nutrient loads, and farmers must either join county associations that apply different strategies or individually contribute to meeting objectives by setting aside 50- to 100-foot buffers along all streams.

North Carolina requires compliance associations to meet a single mass load cap. In the Tar-Pamlico case, the legal requirement to meet the cap was established by an enforceable contractual agreement signed by the association and the state. In the Neuse program, a single "group compliance permit" was issued to the association. Both legal mechanisms established financial penalties for the two associations if aggregate discharges of the group exceed the association cap. A key advantage of the association is similar to that of a formal effluent trading program—granting dischargers flexibility to decide how best to meet the aggregate load cap. To date, the associations have managed to keep nitrogen loads considerably below their respective caps. Compliance costs have also fallen below original projections. Further, there is some evidence that the association concept is producing incentives for strong cooperative behavior that did not exist prior to implementation.

The case studies presented here illustrate ways in which both public and private entities subject to regulation can exercise options for operating autonomously should they not wish to

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incorporate with a group, while still contributing to the achievement of watershed objectives. The case studies suggest that most dischargers conclude in the end that group membership offers considerable advantages.

Funding Considerations

The existing stormwater permit program is characterized, in most of the nation, by municipal Phase I and now Phase II permittees operating mostly alone. In contrast the new system envisions coalitions of permittees that share a watershed operating in concert, under the coordination and leadership of a principal permittee. The present structure tends to bring about duplication in effort and staff, whereas cooperation should stimulate efficiencies that could defray at least part or even much of the extra local costs associated with new responsibilities for municipal permittees.

As explored in the preceding section, municipalities may not necessarily wish to join in co-permittee arrangements; and mechanisms are proposed to allow them to operate individually, as long as watershed objectives are met. However, the state could encourage participation through financial inducements, for example, by estimating the resources needed to meet the requirements of each watershed permit and pointing out to permittees how shared resources can save each contributor money. The state should also set preferences and better terms for grants in the favor of municipalities who join together.

To the questions of administrative vehicles and funding arrangements, stormwater utilities are the preferred mechanism, and regulations should support creating stormwater utilities. It should be added that, with watershed-based permitting as proposed here, utilities should also be regionalized on a watershed basis. A utility draws funds from the entities served in direct relation to the cost of providing the services, here management of the quantity and quality of stormwater discharged to natural waterbodies. These funds must be dedicated to that purpose and that purpose only, and cannot be redirected to general agency coffers or for any unrelated use.

Not only are more funds from more reliable sources needed, but monies should be redirected in ways differing from their allocation under the current system. It was proposed earlier that a lead municipal permittee, working with other municipal co-permittees, be given responsibility for coordinating permitting and management of municipal, industrial, and construction stormwater permits, and even permits involving other sources, such as industrial process and municipal wastewaters. Those entities would hence be doing work now devolving to individual private developers and industrial plants and other public authorities. They would need to attract the revenue from those other bodies in proportion to the added work taken on. A utility structure would provide a well-tested means of carrying out this reallocation.

Stormwater utility fees are generally assessed according to a simple formula, such as a flat rate for all single-unit dwellings and in proportion to impervious area for commercial property. Some municipalities have investigated charging more directly according to the estimated quantity and quality of stormwater discharged into the public drainage system. Municipal permittees may choose to formulate such a system, but the development process itself is not a trivial task and, being based on general (and usually quite simple) hydrologic and water quality models, can generate considerable arguments from rate payers. Going through this process is probably not necessary or even advisable for most municipal permittees, who will

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have many new functions should the proposed system be adopted. Instead, they should concentrate on implementing a fee structure based on a simple formula like the one above and then capture additional revenues for special functions that they will take over from industrial and construction permittees.

As discussed previously, in the proposed program municipal co-permittees, with leadership by a watershed lead permittee, will be asked to classify industries and construction sites within their borders according to risk and accordingly prioritize them for inspection and monitoring. It is proposed in the section on Measures of Achievement, below, that inspection include reviewing and approving industrial and construction site stormwater pollution prevention plans (SWPPPs). While many municipalities now inspect construction sites for stormwater compliance and some inspect industries, this work will increase significantly in the new system, and SWPPP review and approval will be a completely new element. Moreover, municipalities would perform some industrial monitoring now conducted by the industries themselves and may monitor high-risk construction sites. These special functions would require different institutional arrangements and substantial new revenue that could not be fairly charged to all rate payers. There are several possible sources for these funds. One way would be to increase industrial and construction permit fees and direct large proportions to municipalities to support inspection and monitoring. The permitting authority (designated state or EPA) would still hold ultimate authority, and municipalities could refer industrial and construction permittees found during inspection to be out of compliance to the permitting authority for enforcement. Another means would be to form consortia of industries of similar type and assess fees directly applicable to inspection and monitoring. For example, scrapyards under the jurisdiction of the California EPA Los Angeles Regional Water Board formed a monitoring consortium under which sample collection by a qualified contractor rotates among the members, with funding by all. While the members operate this system, it could be adapted to operation by municipal co-permittees.

A second-level funding concern is, once revenues are generated, how should they be put to use? It is very important that funds largely be devoted directly to the tasks at hand regarding the achievement of objectives instead of into excessive administrative and bureaucratic structure. These tasks are scientific and technical and are highly oriented toward what is actually going on in the drainage systems and their receiving waters. Thus, the majority of funds should be directed to making scientific and technical judgments based on observations and monitoring results obtained in the field (see the discussion below).

Measures of Achievement

Critique of the Current Monitoring System

No area exemplifies the differences between the present and proposed new stormwater permitting and monitoring systems more than the measures used to gauge achievement. The current monitoring system is characterized by scattered and uncoordinated measurements of discharges from Phase I MS4s and some industries, and some visual observations of construction sites. The system proposed to take its place would emphasize monitoring of receiving water biological conditions as a data source for prescribing management adaptations to meet specified biological objectives. The discussion here first critiques the prevailing system to construct part

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of the rationale for changing it. It then proceeds to outline a recommended monitoring structure to replace it.

To expand very briefly on the point that the present system is scattered and uncoordinated, monitoring under all three stormwater permits is according to minimum requirements not founded in any particular objective or question. It therefore produces data that cannot be applied to any question that may be of importance to guide management programs, and it is entirely unrelated to the effects being produced in the receiving waters. Phase I municipal permit holders are generally required to monitor some storms at some discharges for no stated purposes but to report periodically to the permitting agency (Phase II municipalities have no monitoring requirements, although they may represent the major or even only impact sources in a given watershed). The usual model for industries across the nation is to collect a few discharge grab samples a year and send the results to the permitting authority, plus occasionally to make observations for obvious signs of pollution (e.g., oil sheen, odor). Construction site monitoring is less standardized and often involves no water quality monitoring at all. Again, no permittee under any of the three programs is obligated according to national standards to check the effects of its discharges on receiving waters. Since the individual effects of any discharger are often not distinguishable from any other, the scattershot system would usually not be able to discern responsibility for negative effects in the receiving water ecosystem.

Input to the committee conveyed the strong sense that monitoring as it is being done is nearly useless, burdensome, and producing data that are not being used. For example, the City of Philadelphia conducts substantial amounts of wet weather monitoring, which is very expensive, but it can barely monitor for TSS in many of its heavily impacted streams (Crockett, 2007). The resources to monitor for the more exotic pollutants do not exist. Smaller municipal permittees without the resources and sophistication of a big-city program have difficulty performing even the most basic monitoring. City water managers believe that the traditional stormwater program places too much emphasis on monitoring of individual chemicals rather than looking at ecological results (Crockett, 2007).

Industry representatives have also described several problems they see in industrial stormwater monitoring as it is performed now (Bromberg, 2007; Longsworth, 2007; Smith, 2007). One concerns the high degree of variability, from the methods used to what is actually measured (Stenstrom and Lee, 2005; Lee et al., 2007). Opponents have been quite critical of the benchmarks to which industrial monitoring data are compared, believing that the benchmarks have no basis in direct measurements associating stormwater with impacts. Some have suggested replacing monitoring with an annual stormwater documentation report to the permitting authority. It seems that industry personnel disrespect the current monitoring framework for some good reasons and feel it conveys a burden for little purpose. There was some implication that industry would be receptive to measures offering more meaningful information in place of poorly conceived monitoring requirements (Bromberg, 2007; Longsworth, 2007; Smith, 2007).

Proposed Revised Monitoring System

A structure in several tiers is proposed as a monitoring system to serve the watershed-based permitting and management framework.

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Progress Evaluation Tier. This tier would represent the ultimate basis for judgment on whether the objectives adopted for the watershed are being met. Because these objectives would mainly be expressed in terms related to direct support of beneficial uses, so too would monitoring in the Progress Evaluation Tier principally emphasize direct measurements of ecological health. The preferred model for this evaluation would be the paired watershed approach, which is based on the classic method of scientific experimentation and was developed for water resource management investigations by EPA (Clausen and Spooner, 1993). Ideally, conditions in the waterbody under evaluation would be compared to conditions in the same waterbody before imposition of a permit and management scheme (before versus after comparison), as well as to conditions in a similar waterbody not subject to human-induced changes (affected system versus reference system comparison). At least one of these comparisons must be made if both cannot. If the objectives involve improving conditions, and not just avoiding more degradation, the reference should represent that state to which the objective points.

This function has traditionally been the province of the permitting authority (i.e., the designated state or EPA). In the new program, the function is assigned to municipal permittees, guided by the lead permittee, to conduct or contract, but with a substantial contribution by the permitting authority in the form of material support and guidance. The primary vehicle envisioned to perform the progress assessment is a well-qualified monitoring consortium serving the watershed, and perhaps other watersheds in the vicinity. Case studies below present examples of successful joint ventures in monitoring that can serve as models. The proposal is based on the belief that monitoring should be more manageable and effective at the watershed compared to the state level and, furthermore, that utilizing a consortium approach should make it feasible for a coalition of municipal co-permittee partners to commission monitoring.

Findings of objective shortfall would trigger development of active adaptive management strategies. Generally, an assessment should be conducted to determine what additional measures should be put in place in regulating new development and redevelopment, as well as increasing coverage of existing developments with retrofits.

Diagnostic Tier. The second tier would be designed to provide the municipal permittees with the necessary information to formulate active adaptive management strategies, and they would be responsible for this second tier as well as the first. The Diagnostic Tier would be composed of assessment of information from the Compliance Reporting Tier, plus some specific field monitoring to determine the main reasons for ability or failure to meet objectives. Some highly directed monitoring of receiving water conditions could determine the need to improve management of water quantity, water quality, or both. A tool like the Vermont flow-duration curves is an example of a potentially useful device for diagnostic purposes. To allow the use of such a tool, it is important that continuous flow recorders be installed on key streams in the watershed. The techniques described in the Impact Sources section above, once they are further developed, would also be useful in Diagnostic Tier monitoring.

An important dimension of this tier would be prioritized inspection and monitoring of potentially high-risk industrial and construction sites. In addition, data submitted by the industrial and construction permittees according to the Compliance Reporting Tier would assist in targeting dischargers to bring about the necessary improvements in water quantity and/or quality management.

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Compliance Reporting Tier. It is proposed that the first step in compliance reporting be submission of SWPPPs by all construction and industrial permittees (plus municipal corporation yards as an industrial-like activity) to the jurisdictional municipal permittee for review and approval. It is further proposed that the industrial permittees and municipal corporation yards be relieved of sample collection, *if* they develop SWPPPs making maximum possible use of ARCD practices, supplemented by active treatment as necessary, and the municipal permittee approves the SWPPP. Construction sites would be given a similar sampling dispensation if they develop an approved SWPPP along the lines of Box 5-3.

Otherwise, the permittees would be required to perform scientifically valid sampling and analysis and report results to the watershed co-permittees. This more comprehensive and meaningful monitoring would increase the burden already felt by permittees and create a strong incentive to apply excellent SCMs. This burden could be relieved to a degree through participation with other similar dischargers in the watershed in a monitoring coalition. As an example, in North Carolina coalitions of wastewater dischargers are working with the state Division of Water Quality (DWQ) to create and manage coalition-led watershed monitoring programs that operate in conjunction with DWQ's ambient chemistry and biological programs (Atkins et al., 2007). Lee et al. (2007), after an assessment of industrial stormwater and other monitoring data, concluded that selecting a subset of permittees from each monitored category would yield better results at lower overall cost compared to monitoring at every location. This strategy would permit the use of more advanced sampling techniques, such as flow-weighted composite samplers instead of grab sampling, to estimate representative loads from each category with improved accuracy and reduced variability.

All permittees would still make observations of the SCMs and discharges and keep records. The final proposed step in compliance reporting is an annual report covering observations, SCM operation and maintenance, SWPPP modifications, and monitoring results (if any), to be sworn as to correctness, notarized, and submitted to the lead municipal permittee. The Massachusetts Environmental Results Program (April and Greiner, 2000) offers a possible model for compliance reporting and verification. This program uses annual self-certification to shift the compliance assurance burden onto facilities. Senior-level company officials certify annually that they are, and will continue to be, in compliance with all applicable air, water, and hazardous waste management performance standards. The state regulatory agency reviews the certifications, conducts both random and targeted inspections, and performs enforcement when necessary.

Research Tier. The final tier would be outside the permit system and exist to develop broad mechanistic understanding of stormwater impacts and SCM functioning important to assist permittees in reaching their objectives. EPA and state agencies designated to operate the permit system would have charge of this tier. These agencies would develop projects and contract with universities and other qualified research organizations on a competitive basis to carry out the research.

Instructive Case Studies for the Proposed Revised Monitoring System

Many municipalities, even large ones, would be challenged and burdened by taking on comprehensive watershed monitoring. The Southern California Coastal Water Research Project

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Authority (SCCWRP, http://www.sccwrp.org) offers an excellent model of how co-permittees in a watershed or an even broader area could organize to diffuse these challenges and burdens. SCCWRP is a joint-powers agency, one that is formed when several government bodies have a common mission that can be better addressed by pooling resources and knowledge. In SCCWRP's case, the common mission is to gather the necessary scientific information so that member agencies can effectively and cost-efficiently protect the Southern California marine environment. Key goals adopted by SCCWRP are defining the mechanisms by which aquatic biota are potentially affected by anthropogenic inputs and fostering communication among scientists and managers. Comprised of a multidisciplinary staff, SCCWRP encompasses units specializing in analytical chemistry, benthic ecology, fish biology, watershed conditions, toxicology, and emerging research.

SCCWRP's current mission stems from the results of a 1990 NRC review of marine environmental monitoring programs in the Southern California Bight (NRC, 1990). It was determined that although $17 million was being spent annually on marine monitoring, it was not possible to provide an integrated assessment of the status of the Southern California coastal marine environment. Most monitoring was associated with NPDES permit requirements and directed toward addressing questions about site-specific discharge sources. As a result, most monitoring in the bight was restricted to an area covering less than 5 percent of the bight's overall watershed, making it difficult to draw conclusions about the system as a whole. The limited spatial extent of monitoring was also found to limit the quality of local-scale assessments, since the boundaries of most monitoring programs did not match the spatial and temporal boundaries of the important physical and biological processes in the bight.

NRC (1990) further found that there was a lack of coordination among existing programs, with substantial differences in the parameters measured among programs, preventing integration of data. Even when the same parameters were examined, they were often measured with different methodologies or with different (or unknown) levels of quality assurance. Moreover, the NRC found that even when the same parameters were measured in the same way, substantial differences in data storage systems among monitoring programs limited access to the data for more comprehensive assessment. To avoid repetition of these shortcomings, the SCCWRP example should be given very thorough consideration as a template for the Progress Evaluation, Diagnostic, and Research Tiers in the proposed revised monitoring program.

The San Gabriel River Regional Monitoring Program (SGRRMP, http://www.lasgrwc.org/SGRRMP.html) is a watershed-scale counterpart to the larger-scale regional monitoring efforts in Southern California. The SGRRMP incorporates local and site-specific issues within a broader watershed-scale perspective. The program exists to improve overall monitoring cost effectiveness, reduce redundancies within and between existing monitoring programs, target monitoring efforts to contaminants of concern, and adjust monitoring locations and sampling frequencies to better respond to management priorities in the San Gabriel River watershed. Five core questions provide the structure for the regional program:

- What is the environmental health of streams in the overall watershed?
- Are the conditions at areas of unique importance getting better or worse?
- Are receiving waters near discharges meeting water quality objectives?
- Are local fish safe to eat?
- Is body-contact recreation safe?

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The workgroup convened to establish the program recommended monitoring designs to answer the core questions effectively and efficiently. The resulting program is a multilevel monitoring framework that combines probabilistic and targeted sampling for water quality, toxicity, and bioassessment and habitat condition.

The City of Austin, Texas, has more than 20 years of stormwater monitoring experience and offers additional guidance on designing and implementing watershed monitoring programs (City of Austin, 2006). Austin performs detailed periodic synoptic sampling in the watersheds it manages to track trends in stormwater quantity and quality. The city uses the results to evaluate the impacts of land development on stormwater quantity and pollution, establishing statistical relationships between measures of these conditions and the amount of impervious cover. Trend assessment over time leads to recommended changes to the City of Austin Environmental Criteria Manual as needed.

Creating Flexibility and Incentives Within a Watershed Approach

A watershed-based permitting approach to stormwater management focuses attention on watershed objectives and endpoints. To be able to achieve these goals, observable performance measures beyond the success of an individual SCM need to be identified that are consistent and necessary to meet designated uses. These might include watershed-level numeric limits on the amount of a particular pollutant allowed to enter a waterbody (e.g., pounds of phosphorus) or various measures of allowable volume of discharge. A watershed focus shifts attention away from specific SCM performance and site-specific technological requirements to achieving a larger watershed goal. As a consequence, there is considerable management flexibility in deciding how these goals will be achieved. Indeed, this flexibility was cited by the NRC (1999) as a prerequisite to successful watershed management.

One way of exercising this flexibility is to create an "incentive-based" or "market-based" approach to choose how watershed goals are met. It is recognized throughout the environmental management field that entities subject to regulation do not necessarily have equal opportunities and qualifications to comply sufficiently to sustain resources. To compensate for this, the market-based approach allows individual discretion to select how effluent (or runoff volume) will be controlled (choice of technology, processes, or practices) and where they will be controlled (on site or off site). That is, any discharger legitimately unable to meet discharge quantity and quality allocations would be able to finance offsets elsewhere to achieve the watershed goals. An important element and challenge is to couple this decision-making flexibility with personal (typically financial) incentives so that people willingly make choices supportive of the watershed objectives. Broadly stated, the idea is to create financial reasons and decision-making opportunities to lower compliance costs and create or implement new effluent/volume control options (Shabman and Stephenson, 2007).

Because incentive-based policies require a shift in emphasis from technologies and practices to outcomes (e.g., volume or quantity of effluents), the municipal manager would not be responsible for deciding what SCM will be implemented in specific areas or hand picking specific practices to promote. Rather the stormwater program manager's responsibilities shift to establishing watershed goals, developing metrics to measure outcomes and performance, and performing necessary inspection and enforcement activities.

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Effluent trading, sometimes called "water-quality trading," is one type of incentive-based policy. In an ideal form, effluent trading requires government to establish a binding aggregate limit or cap on an outcome (e.g., mass load of effluent, volume of runoff) for an identified group of dischargers. The cap or aggregate allowable discharge is set to support and achieve a socially determined environmental goal. Because it is fixed, the cap provides the public assurances that environmental objectives will be achieved in the face of a growing and changing economy. The total allowable discharge is then divided into discrete and transferable units, called allowances, and either distributed or auctioned to existing dischargers. All dischargers must own sufficient allowances to cover their discharges. For instance, any new or expanding source must first purchase allowances (and hence effluent or volume reductions) from another source before legally discharging. The requirement to hold allowances on the condition to discharge and the positive allowance price creates financial incentives for pollution prevention. Dischargers holding allowances rather than reducing discharge face forgone revenues that could have been achieved from the sale of allowances. Conversely, expanding dischargers have incentives to invest in pollution prevention in order to avoid the cost of purchasing additional allowances.

In the context of the revised permit system advocated here, achievement of objectives (generally of a biological nature) will require some combination of strategies such as no net increases in hydrologic parameters (e.g., peak flow rates, durations, volumes), water pollutants, forest cover loss, and effective impervious area. If one entity is unable to contribute adequately to meeting its share of compliance, then it must obtain the necessary credit by buying it from another similar entity that is able to contribute more than its designated share. Ideally, all sources of a waterbody's problems, not only stormwater, would come under the trading system.

Implementing the market system requires development of a resource-based currency, a nontrivial exercise but one for which models are available in other fields, especially air emissions. For example, emission trading has been a critical element of the nation's strategy to limit sulfur dioxide and nitrogen oxide emissions (Ellerman et al., 2000). Carbon trading is a cornerstone policy in the European Union effort to limit greenhouse gas emissions. The EPA promotes the use of trading to help achieve the goals of the CWA and has issued several policy statements and recently published guidance on how trading programs can be grafted within existing NPDES permitting programs (EPA, 2003a, 2007b).

However, compared to the air program, experience and success with trading in the water program have been limited (Shabman et al., 2002). Furthermore, programs labeled trading have been implemented in a multitude of ways in the nation's water quality program (Woodward et al., 2002; Stephenson et al., 2005; Shabman and Stephenson, 2007). In many instances, trading programs are case-specific and isolated "trades" that do not fundamentally change the choice and incentives facing dischargers in a conventional permitting system. The extent to which trading policies can be effectively employed on a watershed scale is limited not only by the physical differences between air and water mediums, but also by the unique legal structure of the CWA (Stephenson et al., 1999). For example, the CWA is oriented around imposing technology-based performance requirements on specific subset of discharge sources. Individual NPDES permits require sources to achieve these agency-identified levels of performance and may specify how performance is achieved. The statute also places limits and disincentives on the degree to which permit agencies can deviate from these limits (e.g., "antibacksliding").

Thus, the focus of the NPDES permitting system has been on individual source control and technologies, unlike the air program, which has a stronger statutory orientation around achieving broader air quality goals (ambient air quality standards). The orientation of the

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NPDES program limits the flexibility and incentives for regulated parties that might make market-oriented trading possible. It turns out that some of the more successful applications of trading in the water program have occurred because of permitting innovations that effectively avoid some of these rigidities (see discussion of North Carolina point source control program on the Neuse River, above).

Trading programs of various types have been proposed or suggested for stormwater (Thurston et al., 2003; Parikh et al., 2006). Although conceptual models of a comprehensive trading program based on the total volume of allowable water to be discharged have been proposed, no working examples have yet to be implemented. More limited versions of trading programs, however, have been developed. These programs provide compliance flexibility for new sources of stormwater runoff. In some locations, new developments face a requirement to provide a specific level of volume or effluent control from the parcel to be developed. The regulated entity is typically obligated to meet this requirement with the applications of on-site SCMs. Trading programs create opportunities for regulated entities to meet their regulatory requirement off site (off the parcel to be developed), called here an offset. In some trading programs, the off-site controls can be accomplished by the creation of an in lieu fee program. Such programs typically occur for dischargers that are not required to hold or obtain individual NPDES permits.

In lieu fee programs offer some opportunity for regulated parties to make a financial payment (fee) to a local government entity in lieu of implementing on-site controls. The fees are collected and used to implement stormwater controls in other areas of the watershed. Controlling runoff at a regional level rather than through the construction of many small on-site controls may be more cost-effective given the economies of scale associated with some SCMs (see Chapter 5 pages 362–363). The option for off-site controls also allows the stormwater program to direct investments in stormwater control to specifically targeted areas of the watershed.

Examples of in lieu fee programs include Santa Monica, California, the Neuse River Basin in North Carolina, and Williamsburg, Virginia. Santa Monica's program requires new and redevelopment projects to treat a specific volume of runoff. The program first requires the regulated entity to take all feasible steps to meet the requirement through the implementation of on-site infiltration practices. If the regulated party can demonstrate why it is economically and physically infeasible to install any type of infiltration or treatment SCM, the regulated party can pay a fee based on the volume of water that needs to be controlled (the total mitigation volume is the volume that would have been attenuated via an SCM). The fee set by Santa Monica is $18/gallon of total required mitigation volume. The $18 reflects the cost of constructing an SCM and maintaining it over 40 years (DeWoody, 2007). Presumably these fees are used to construct infiltration measures elsewhere.

The Neuse River Program requires all new land development to meet a nitrogen export standard of 3.6 pounds per acre per year (North Carolina Division of Water Quality, 1999). The water quality goal for the Neuse basin is to reduce mass nitrogen loads by 30 percent in order to improve water quality in the estuary. The export standard was set to achieve a 30 percent reduction from the average nitrogen load from lands prior to development. Developers have the option to meet this export standard either through the application of on-site SCMs or by paying a fee into a state-administered Riparian Buffer Restoration Fund (see 15A North Carolina Administrative Code 02B .0240), which would be used to reduce nitrogen loads elsewhere in the

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basin. Developer discretion, however, is not unlimited. Under no circumstances may developers discharge more than an estimated 6.0 pounds per acre per year from a residential site.

The Williamsburg program has an in lieu fee program for total phosphorus loads created by new development (Frie et al., 1996; Stephenson et al., 1998). For every new development, the increase in total phosphorus load from stormwater runoff from impervious surfaces is estimated. Developers have the choice to meet the phosphorus load reduction requirement through the application of on-site controls or by paying a fee to the city. The fee is set at $5,000/lb of phosphorus, with the fees earmarked to the construction of regional stormwater facilities or for the preservation of open space within the city. The presence of a fee option could also provide incentives for developers to implement source reduction practices.

The above programs differ in some important ways. For example, the Santa Monica program requires regulated entities to undergo a "sequencing" process that places regulatory preference on on-site controls before being able to use the fee option. The Williamsburg program allows regulated entities the option to select between constructing on-site controls and paying the fee without a regulatory preference for on-site controls. Sequencing rules tend to limit control options and thus the cost-effectiveness of these types of programs.

In lieu fee programs are distinguished from other offset programs in that it is the responsibility of the local government (or more generally, any designated fee service provider such as a nongovernmental organization) to provide the off-site SCMs. In lieu fee programs, common in the U.S. wetlands program, face a number of implementation and design challenges (Shabman and Scodari, 2004). For example, enforcement sometimes becomes a concern because the local stormwater management agency responsible for constructing and maintaining the SCMs is also responsible for monitoring and enforcement. These dual responsibilities create potential conflicts of interest; if an off-site mitigation project fails, there maybe no apparent overseeing agency to enforce corrective actions. The lack of transparency in accounting to determine whether the offset projects provide enough compensation is also sometimes a challenge. Finally, the ability to fully offset the volume of effluent discharge from a new development is contingent on collecting enough revenue from the fee to pay for the construction and maintenance of offsite SCMs. The delay between impacts and compensation and lack of full public cost accounting complicate the challenges of setting an appropriate fee.

Ensuring that in lieu fee programs provide the necessary mitigation could be accomplished in a number of ways. For example, an oversight agency may be designated to establish tracking and reporting requirements and monitor in lieu fee program performance. Or, the potential conflicts of interest inherent in the lieu fee program design could be avoided by separating the provision of the off-site mitigation service from the monitoring and enforcement. It is possible to imagine that the private sector, rather than an in lieu fee administrator, could provide off-site stormwater reduction services to those subject to the stormwater control requirements. In this case, the private sector would provide stormwater detention/retention services above and beyond what is required by law. These private service providers would receive stormwater runoff credits for these investments ("above baseline") that could be sold to developers who might wish to meet their control obligations in ways other than on-site controls. In essence, the role of searching, designing, and constructing offsite SCMs would be transferred to the private-sector stormwater credit providers. The local stormwater managers, however, would retain full authority to monitor, verify, and enforce to ensure that these offsets are successfully implemented.

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The flexibility provided by in lieu fee and trading programs requires that pollutant loads or runoff volume created at one site be reduced at another site. Thus, a design issue confronting these types of programs is the consideration of the spatial extent in which offsetting activities can occur. The extent of the spatial range of offsetting activities in turn will depend partly on the nature and type of service being offset. For example, in the Neuse example nitrogen is a regional, basinwide concern with minimal localized effects. In such cases, the offsetting activities might be allowed basinwide (after adjusting for nitrogen attenuation through the basin). In other situations where localized concerns maybe a greater concern (say from localized flooding), the flexibility offered by such programs may be more limited. However, such spatial flexibility might also be a way to implement and achieve watershed planning objectives. For example, development may be encouraged in high-impact areas, and offsetting fees could be used to protect and enhance water quality objectives in other areas.

This last point deserves further explanation. Although this chapter advocates that biological conditions in waterbodies should be maintained or improved, there are many urban areas where local waterbodies cannot achieve the same designated uses as less developed areas. If a goal-setting entity chose to do so, beneficial uses for waters in these areas could be set at levels that acknowledge this highly altered condition, such that these streams would not be expected to achieve the same biological condition as streams outside the urban core (see Chapter 5 pages 8–10). This might be done to encourage development in high impact areas; San Jose, CA, provides an example (see Chapter 2). In that city's stormwater program, in urban areas where on-site control is either technically impossible (due to soil or space constraints) or prohibitively costly, the developers can meet the post-construction treatment standard by providing volume control either through participation in a regional stormwater project or by providing equivalent projects off site (e.g., stream restoration).

It is also possible to design a stormwater offset program that allows the different functions of stormwater management to be separated to achieve watershed objectives. For example, management of peak flow serves mostly to prevent localized flooding while more stringent volume control maybe required to protect stream channels and aquatic life. Control of peak flow might be required on site or within a narrow geographic region. In areas targeted for development, however, the volume control needed for channel protection might be transferred off site and into areas where watershed planning has identified the need for higher levels of stream channel protection or enhancement (more stringent water quality standards). A similar watershed approach based on functional assessment was recommended for wetland compensation (NRC, 2001b).

Regulatory and Legal Implications of Proposed Watershed-Based Permitting Framework for Managing Stormwater

EPA, the states, and municipal permittees would all have tasks to perform to transform the framework set forth in this report to a fully developed and functioning program. These efforts would be rewarded with a program that is rooted in science, transparent in its aims, fairer for all than the current program, and better for the aquatic environment. This section of the report outlines the tasks necessary to carry the proposal forward to full development.

EPA should seek significant congressional funding to support the states and municipalities in undertaking this new program, in the nature of the support distributed to

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upgrade municipal WWTPs after the 1972 passage of the Federal Water Pollution Control Act. Beyond financial support, EPA's tasks emphasize broad policy formulation, regulatory modifications and adaptations necessary to initiate the new program, and guidance to the states and permittees. The principal adaptation needed in the regulatory arena involves converting the current TMDL program to a form suitable for the new system. Guidance would be needed in a number of crucial areas, and it is EPA's natural role to develop it.

States (or EPA for states without delegated authority) would have broad responsibilities to translate policies and federal regulations into their own regulatory and management systems. A key task in this regard would be to recast water quality standards into objectives most directly supporting sustenance and improvement of beneficial uses. States already have considerable background for performing this task through their present definitions of beneficial uses, the Section 303(d) process for assessing waterbody compliance with water quality standards, and the triennial review of those standards. However, the added prominence of biological aspects of beneficial uses and associated objectives will require additional analysis. Other prominent state tasks will involve defining the watersheds subject to permits, forming bodies of co-permittees associated with the watersheds, and appointing the lead permittee. Many other state tasks entail cooperative work with the permittees to support and assist them in funding and conducting their activities.

Many aspects of the municipal permittees' roles in implementing strategies were explored above in a section titled accordingly. That section especially focused on activities to advance the use of ARCD methods. More broadly, the permittees will be coordinators of all permits pertaining to the watershed's aquatic resources, collectively pointed toward meeting objectives that the permittees adopt under state oversight. Other categories of tasks assigned to the municipalities under the proposed system include monitoring, in the contexts of both inspections and sampling performed through a consortium, and enforcement actions and program adaptations to promote progress toward achieving objectives. Box 6-4 provides a listing of anticipated tasks for the municipal permittees as well as the states and EPA.

A Pilot Program as a Stepping Stone

The shift of responsibility for stormwater regulation to municipalities under the watershed-based approach may lead to some surprises in implementation and enforcement. Primarily because of this, EPA is well advised to institute a pilot program that provides some experience in municipality-based stormwater regulation before instituting a nationwide program. This pilot program will also allow EPA to work through more predictable impediments to this watershed-based approach. The most obvious impediment arises from the inevitable limits of an urban municipality's responsibility within a larger watershed: substantial growth and accompanying stormwater loading may occur on the outside periphery of a municipality's designated boundaries. If an urban authority lacks legal authority over this future growth, and if this growth contributes significantly to water quality degradation, then a considerable share of the urban stormwater problem could remain poorly addressed. A pilot program should help identify the extent of this jurisdictional slippage and help identify ways to overcome it. Second, it is possible that some municipalities will balk at the added responsibility involved with the watershed-based approach, even with adequate funding. Unless the objective performance standards are rigid, the monitoring requirements substantial, and the rewards for compliance

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BOX 6-4
Government Agencies Roles during the Operation of a Watershed-Based Permitting System

EPA

1. Petition Congress for significant funding support for states and municipal permittees, and develop a program of fairly distributing funds based on environmental and financial needs at the watershed level.
2. Initiate regulatory modifications and clarifications necessary to establish the system.
3. Set policies for watershed permitting based on this report's recommendations.
4. Adapt TMDL program for use in the new program.
5. Produce guidance to assist the states and municipal permittees in the areas of:
   a. Developing a rotating basin approach;
   b. Developing an integrated municipal NPDES permit incorporating the full range of sources;
   c. Developing stormwater utilities and other funding mechanisms;
   d. Using impact source analysis (e.g., using reasonable potential analysis and new research results, industrial and construction site risk assessment);
   e. Using ARCD techniques for new development, redevelopment, and retrofitting;
   f. Developing monitoring consortia;
   g. Developing a credit trading system;
   h. Developing an active adaptive management program

Designated States (or EPA otherwise)

1. Define watersheds for which permits will be issued and set up a rotating basin approach to govern watershed analysis in support of subsequent steps.
2. Formulate and formally adopt goals relative to avoiding any further loss or degradation of designated beneficial uses in each watershed's component waterbodies and recovering lost beneficial uses.
3. Use the results of the existing Section 303(d) process and supplementary work to assess the extent of designated beneficial use achievement in each watershed and set goals for protection and recovery.
4. Match municipal permittees to watersheds and designate a lead permittee for each watershed.
5. Estimate resource needs to fulfill permit requirements in each watershed.
6. Develop a grant program, drawing on EPA and state funds, to support municipal permittees, with incentives for joining co-permittee associations.
7. Identify areas outside the jurisdictions of permitted municipalities that should be brought into the program because of projected development or the existence of problem sources that would compromise the protection and recovery of beneficial uses.
8. Use the triennial review process to modify water quality standards to the objective basis, emphasizing biological outcomes recommended in this report.
9. Revise the TMDL program in accord with the needs of the new program.
10. Set requirements for credit trading systems.
11. Set up an integrated municipal NPDES permit incorporating the full range of sources.
12. Work with municipal permittees to establish specific objectives as the basis for progress assessment.
13. Work with municipalities to develop adaptive management programs responding to progress assessment results.
14. Write municipal permits incorporating the above elements.
15. Write industrial and construction general or individual permits incorporating the recommendations in this report.
16. Allocate a substantial portion of industrial and construction permit fees to municipal permittees to oversee those sectors.
17. Set requirements for municipalities and private properties to opt out of the defined program without compromising the achievement of objectives.

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BOX 6-4 Continued

18. Provide consultation, support, and guidance (adapted from EPA materials or originally produced) to municipal permittees in the areas of:
    a. Developing stormwater utilities and other funding mechanisms;
    b. Using impact source analysis (e.g., industrial and construction site risk assessment);
    c. Using ARCD techniques for new development, redevelopment, and retrofitting;
    d. Developing monitoring consortia;
    e. Developing a credit trading system
19. Perform enforcement actions on non-complying dischargers referred by municipal permittees.
20. Assess performance of municipal permittees and specify corrections, rewards, and penalties accordingly.

Municipal Co-permittees (led by Lead Permittee)

1. Adopt specific objectives as the basis for program progress assessment.
2. Convert ordinances and regulations as needed to implement the modified program.
3. Supplement and reorganize staffing to emphasize progress and compliance assessment as the principal functions of the program.
4. Perform or contract detailed scientifically and technically based watershed analysis as a foundation for permit compliance.
5. Assemble existing data on soils and hydrogeologic properties and supplement with additional data collection as necessary to assess infiltration prospects across the municipality.
6. Create incentives for private property owners to maximize the use of ARCD methods in new development and redevelopment.
7. Build subwatershed-scale, publicly owned ARCD works to supplement on-site management measures and as retrofits.
8. Develop capacity for stormwater management in municipal WWTPs by reducing groundwater inflows to sanitary sewer lines.
9. In areas experiencing excessive infiltration and groundwater table rise resulting from non-stormwater flows, develop capacity for stormwater management through infiltration by formulating water conservation programs.
10. Identify industries and construction sites that are required to apply for permits but have not done so and compel their filing.
11. Establish or enhance existing programs to inspect and oversee industries and construction sites; report non-complying dischargers to the state for enforcement actions.
12. Set up or join a monitoring consortium structured to implement the progress evaluation and diagnostic tiers of the proposed monitoring program.
13. Annually report monitoring results to the permitting authority; submit a comprehensive progress assessment triennially.

compelling for municipalities that meet the standards, it is quite possible that noncompliance or bare minimal compliance will be the norm. A pilot program provides a less politically charged atmosphere to experiment with the benefits of watershed-based regulation at the local level and to generate local government support for the approach. Finally, because the watershed-based approach necessitates legislative amendments to the CWA, instituting a pilot program in the interim—both to improve the design of a watershed-based program as well as to generate enthusiasm for it—seems a sensible course.

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The pilot program should target those local governments that are most eager to redress water quality degradation in their watersheds, but feel stymied by what they perceive as inadequate legal authority and flexibility to make the necessary improvements. Willing municipalities or regional governments would thus opt-in to the program. The pilot program entices these more progressive municipalities to participate by allowing them to serve as the lead authority and providing them with much greater flexibility to determine how to meet their performance-based water quality goals with fewer legal constraints.

Under the pilot program, a municipal government or similar legal authority would apply to EPA or a delegated state to be designated as the lead agency for that portion of the watershed within its legal jurisdiction. In the application itself the municipality would establish—using modeling and ambient data—how it plans at a general level to maintain or exceed its water quality goals (objective performance standards). These goals must be at or above the state water quality goals, or if they are different (i.e., use biological criteria when the state adopts chemical criteria), the municipality must demonstrate how its performance standards will attain the equivalent of the state water quality goals at the downstream edge of the municipality's border. The municipality would also be required to provide assurance of sufficient infrastructure and funding to allow it to develop a water quality plan, implement that plan, issue permits, and enforce the requirements within its boundaries. Finally, municipal plans, once finalized, would need to meet minimum federal procedural requirements. For example, the plans must be transparent and provide opportunities for public comment; they must be enforceable; and they must establish monitoring programs that will track whether they in fact meet the objective performance standards. If a municipality fails to meet any of its performance standards by the requisite deadline, the state and EPA would have the option of revoking the municipality's program, and reinstituting federal requirements. Ideally, federal guidance would also be available to municipalities to provide direction on how they might institute a watershed-based plan within their boundaries, while still reserving considerable flexibility to allow them to develop creative and progressive stormwater solutions. For example, municipalities would be encouraged to form stormwater utilities that are financed from point and even nonpoint sources that assist them in establishing rigorous permitting and enforcement of their water quality plan.

Municipalities that voluntarily take on this role as lead authority will be rewarded with few legal constraints on how they meet their performance-based objectives. NPDES permits for major sources will still be required and must meet federal minima (technology-based controls) to avoid possible hot spots surrounding large dischargers, and states would remain listed as the lead permittee for these permits, but the lead municipality or other regional government would be able to propose new, more stringent limits that are presumptively favored in revised NPDES permits. Stormwater permits would also be mandatory, but their substantive requirements would be left wholly within the discretion of the lead municipality. Finally, states and municipalities would *not* be required to comply with all of the federal regulations governing TMDLs (they would make a basic load calculation for pollutants contributing to degraded conditions, 33 U.S.C. § 1313(d), but would not be required to do more). Instead, the watershed-based program would be considered the functional equivalent of TMDLs for at least the municipality's portion of the watershed since the program ensures that water quality objectives are met. Municipalities could even be allowed to set interim goals over a period of a decade or more so that TMDLs need not be achieved in a single permit cycle.

Other than federal minimum standards for major NPDES sources, municipalities would have primary if not exclusive authority to decide what types of sources (including nonpoint)

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require permits, whether certain land uses might be taxed for stormwater management fees, and whether and how to create trading programs among the contributors to water quality impairments within their watershed. Municipalities would also have legal authority to petition EPA to restrict upstream sources that contribute significantly to water quality degradation in ways that make it difficult for them to reach their goals. Upstream governments or sources could also be subject to more rigorous federal or state TMDLs and could be vulnerable to tort and related claims from downstream municipalities.

This added flexibility and authority for municipalities to control water quality problems within their legal jurisdiction—coupled with objective performance standards—should lead to more creative approaches to stormwater management that create significant benefits to the municipality (i.e., more green-space buffers along waterways for recreation) and stronger planning and taxation of new developments that otherwise might be uncontrolled. Municipal green space, parks, and a variety of other public goods that both reduce stormwater and enhance the public enjoyment of the surface waters could result from allowing a municipality the freedom to determine how best to regulate sources within its local boundaries. For example, rather than automatically allowing federally approved SCMs that have little aesthetic or recreational qualities, alternative approaches to SCMs that retain their effectiveness but provide other qualities (particularly qualities that draw the public outdoors for recreation or relaxation) are more likely to be encouraged or even required by a municipality that serves as lead over implementation of its water quality program.

Although a national watershed-based approach to stormwater regulation is likely to require legislative amendments, the pilot program may not necessitate additional legislative authorization. It is possible that through regulation, EPA may be able to develop "in lieu of" or "functional equivalent" requirements that allow a rigorous watershed plan to substitute for the bare federal requirements governing stormwater regulation, general permits, and TMDL planning laid out in the CWA. This type of intricate legal analysis, however, is beyond the scope of this document.

Final Thoughts

The watershed-based stormwater permitting program outlined above is ultimately essential if the nation is to be successful in arresting aquatic resource depletion stemming from sources dispersed across the landscape. EPA is called upon to adopt the framework now and set in motion a process to move it toward implementation over the next five to, at most, ten years. This chapter deals with some but not the entire realm of political, legal, regulatory, and logistical issues raised by converting to a fundamentally different system of management and permitting. Ideas are contributed regarding piloting and transitioning toward the new program, altering institutional arrangements to accommodate it, and incentives for effective participation. For watershed-based permitting to take hold, specific actions will have to be undertaken by EPA, state permitting authorities, and municipal permittees during the adoption and transition process.

The proposed program could be implemented by EPA in a number of ways, ranging from making it mandatory without any exception in all states and jurisdictions to leaving it entirely voluntary. The committee recommends neither extreme and believes the best course would be: (1) pilot test and refine the program as described in the report section titled "A Pilot Program as a Stepping Stone;" (2) make the refined program the default to be followed by all designated states

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(and EPA in others) and all municipal, industrial, and construction permittees, unless a state permitting authority convincingly demonstrates to EPA's satisfaction than an alternative approach will accomplish the program's overall goal of retaining and recovering aquatic resource beneficial uses; (3) develop very significant incentives for states and permittees to participate; and (4) require objective demonstration by any state opting for an alternative that it is broadly achieving the goal to at least the same extent as states within the program, with appropriate sanctions for noncompliance.

ENHANCEMENT OF EXISTING PERMITTING BASIS

The current federal stormwater regulatory framework has been in place since 1990, and the point source NPDES program under which it is being implemented has existed since 1972. The U.S. Congress deliberately acted in 1987 to amend the federal CWA with the goal of addressing stormwater pollution because it had been identified as a leading cause of surface water impairments, and regulations were inadequate to address it effectively. The total rethinking of the current framework of regulating stormwater pollution described above may require changes in statute and take a long time to implement. Thus, in addition to the longer-term approach that integrates a watershed-wide planning and permitting strategy into the program, several near-term solutions are also offered, with the objective of improving the current regulatory implementation and which at most might require changes in regulation.

Problems Complying with Both Municipal and General Industrial Permits

The NPDES permitting authority issues (1) separate individual permits or general permits to impose discharge requirements on small, medium, and large MS4s; (2) general permits that require construction activity operators who discharge stormwater to waters of the United States, including those who discharge via MS4s, to implement SCMs; and (3) general permits for operators of stormwater discharges associated with industrial activity who discharge to waters of the United States, including those who discharge via MS4s, to implement SCMs. The MS4 operators in turn are also required under the terms of their MS4 permits to require industries and construction site operators who discharge stormwater via the MS4 to implement controls to reduce pollutants in stormwater discharges to the maximum extent practicable, including those covered under the permitting authority's NPDES general permits. This dual-coverage scheme appears intended to recognize the separation of governmental authorities. Unfortunately, in practice it is duplicative, inefficient, and ineffective in controlling stormwater pollution that enters the MS4 from diffuse and dispersed sources. Particularly in the area of monitoring of water quality, the dual approach seems to have resulted in a lack of prioritization of high-risk industrial sources and the purposeless collection of industrial stormwater monitoring data or the poor use of it to strategically reduce the discharge of stormwater pollutants to the MS4.

The preference of EPA to use general NPDES permits to alleviate the administrative burden associated with permitting more than a 100,000 point sources discharging stormwater is understandable. It would have been prudent to have some form of prioritization to select some subset of the whole as high-risk or have a strategy for identifying a subset for individual NPDES permits to better achieve the objective of ensuring compliance with water quality standards on the basis of potential risk. As discussed in Chapter 2, there are no federal guidelines for

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prioritization (determining what industries are high-risk for stormwater discharges), and the state permitting authorities have largely not prioritized because of the overwhelming burden of administering a very expansive stormwater permitting program.

In the existing permitting scheme, the MS4 operator cannot be faulted for having a reasonable expectation that the permitting authority's general NPDES permits that regulate industrial activities and construction that discharge to the MS4 would require, at a minimum, a sufficient level of identification and implementation of SCMs to facilitate the MS4 operator's compliance with the MS4 permit. However, such controls are not identified by the NPDES permitting authority and rather are left to the choice of the industrial facility and construction site operators. Furthermore, the NPDES permitting authority imposes weak to no discharge sampling requirements on industrial facility and construction activity operators, which greatly impairs the MS4's ability to determine and control the worst regulated stormwater discharges to the MS4. Similarly, the NPDES permitting authority's general permit for construction activity encourages construction facility operators to consider post-construction stormwater controls, but it does not require them, even though the MS4 permit's programmatic measures mandate new development planning and post-construction controls as essential elements of the MS4 program. The lack of integration among stormwater permits and the absence of objective measures of compliance that are quantifiable is a glaring shortcoming in current stormwater permits and renders them difficult to enforce for water quality protection.

The California EPA State Water Board asked an expert panel to evaluate the extent of implementation success of the stormwater program in California and the feasibility of numeric effluent limits in stormwater permits. In its report (CA SWB, 2006), the panel concluded that the flexible approach of allowing a permittee to self-select SCMs for the purpose of controlling stormwater pollution was largely ineffective. The reasons stated were: (1) the SCMs were selected without proper consideration of design, performance, hydraulics, and function; (2) the MS4 permittees were not accountable for the performance of the SCMs; (3) the industrial and construction permittees were not responsible for the performance of the SCMs; and (4) the SCMs were seldom maintained properly except for aesthetic purposes. In other words, the flexibility provided by self-determination, self-evaluation, and self-reporting did not assure that SCMs were being implemented to effectively reduce stormwater pollutants to the MEP. Rather, the flexibility resulted in a lack of coordination of purpose and accountability between the MS4 permittees who owned or operate the MS4 and the industry and construction permittees who discharge to the MS4. Although typically enforcement by the permitting authority would have restored the integrity of the stormwater program, that remedy is likely to be ineffective here because the choice of SCMs is left too much to discretion and there are no quantifiable performance or design criteria for water quality purposes.

Integration and Dissemination of Authority

This section offers a near-term alternative solution to the problem cited above that utilizes the existing framework of the NPDES stormwater program. The strategy builds on the authority of MS4s over industry and construction sites to implement an integrated permitting scheme to reduce stormwater pollution into the waters of the United States. Unlike the first section of this chapter, it does not take a watershed approach to protecting water quality, even though the municipal stormwater programs may be more cost-effective if implemented on a

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watershed scale. It also addresses a significant shortcoming of the current scheme, that is, failure to recognize the enormous staff resources that it would take at the federal and state level for successful implementation in the absence of the leadership of local governments. Further, federal and state NPDES permitting authorities do not presently have, and can never reasonably expect to have, sufficient personnel under the principles of democratic governance, such as in the United States, to inspect and enforce stormwater regulations on more than 100,000 discrete point source facilities discharging stormwater. A better structure would be one where the NPDES permitting authority empowers the MS4 permittees, who are local governments working for the public good, to act as the first tier of entities exercising control on stormwater discharges to the MS4 to protect water quality—an approach here called "integration."

The central concept of integration is to give the MS4s controlling jurisdiction and responsibility over discharges from construction and industry to the MS4 in addition to their responsibility to implement the programmatic minimum measures identified in regulation. This approach would be similar to the current NPDES permitting scheme for publicly owned WWTPs, where a WWTP operator controls the quality of wastewater inputs (industrial waste streams) to make sure that the total output will not exceed water quality standards (see Box 6-5 on the National Pretreatment Program). The WWTP operators establish additional criteria such as local limits, require discharge monitoring of industrial wastes, and conduct inspections to make sure industrial discharges implement adequate wastewater treatment technologies, so that treated effluent from the wastewater treatment can comply with water quality standards to protect receiving waters. The same could be done for stormwater, except here the WWTP is replaced by the MS4, and the other inputs in this case are all industrial and construction discharges of stormwater into the MS4. The criteria by which the outputs of the industries are judged could be either water quality- or technology-based criteria. This arrangement puts the burden on the MS4 to identify high-risk industries because the MS4 is now responsible for the overall output (which could be, for example, the concentration of pollutants in stormwater monitored during events). If put in this position, municipalities will make intelligent choices and adopt effective strategies to identify which industries and sources to focus upon. Each of these issues is discussed in greater detail below.

Determination of High-Risk Dischargers

At present, the federal stormwater regulations do not specifically identify which sources would be considered high risk given the common pollutants in MS4 stormwater discharges. With the exception of the category of municipal landfills and hazardous waste treatment, storage, and disposal facilities, it does not even state that the other nine categories of industry singled out in the regulations for permitting under the multi-sector industrial stormwater general permit (MSGP) are really high risk. The devolution of this responsibility to the municipality is sensible because the municipality, as the land-use authority, already conducts development review and issues industrial conditional-use permits. The permitting authority would still be responsible for inspecting high-risk state, federal, and other facilities over which the MS4 permittee has no jurisdiction. In addition, the permitting authority would inspect municipal facilities such as airports, ports, landfills, and waste storage facilities to avoid the situation of self-inspection. Methods for ranking industries according to risk are discussed in a subsequent section.

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BOX 6-5
National Pretreatment Program

EPA's NPDES Permitting Program requires that all point source discharges to waters of the United States (i.e., "direct discharges") must be permitted. To address "indirect discharges" from industries to Publicly Owned Treatment Works (POTWs), EPA, through CWA authorities, established the National Pretreatment Program as a component of the NPDES Permitting Program. The National Pretreatment Program requires industrial and commercial dischargers to treat or control pollutants in their wastewater prior to discharge to POTWs.

In 1986, more than one-third of all toxic pollutants entered the nation's waters from POTWs through industrial discharges to public sewers. Certain industrial discharges, such as slug loads, can interfere with the operation of POTWs, leading to the discharge of untreated or inadequately treated wastewater into rivers, lakes, etc. Some pollutants are not compatible with biological wastewater treatment at POTWs and may pass through the treatment plant untreated. This "pass through" of pollutants impacts the surrounding environment, occasionally causing fish kills or other detrimental alterations of the receiving waters. Even when POTWs have the capability to remove toxic pollutants from wastewater, these toxics can end up in the POTW's sewage sludge, which in many places is land-applied to food crops, parks, or golf courses as fertilizer or soil conditioner.

The National Pretreatment Program is unique in that the general pretreatment regulations require all large POTWs (i.e., those designed to treat flows of more than 5 MGD) and smaller POTWs with significant industrial discharges to establish local pretreatment programs. These local programs must enforce all national pretreatment standards (effluent limitations) and requirements, in addition to any more stringent local requirements necessary to protect site-specific conditions at the POTW. More than 1,500 POTWs have developed and are implementing local pretreatment programs designed to control discharges from approximately 30,000 significant industrial users.

EPA has supported the pretreatment program through development of more than 30 manuals that provide guidance to EPA, states, POTWs, and industry on various pretreatment program requirements and policy determinations. Through this guidance, the pretreatment program has maintained national consistency in interpretation of the regulations.

The general pretreatment regulations establish responsibilities of federal, state, and local government, industry, and the public to implement pretreatment standards to control pollutants that pass through or interfere with POTW treatment processes or that may contaminate sewage sludge. The general pretreatment regulations apply to all non-domestic sources that introduce pollutants into a POTW. These sources of "indirect discharge" are more commonly referred to as industrial users (IUs). Since IUs can be as simple as an unmanned coin-operated car wash to as complex as an automobile manufacturing plant or a synthetic organic chemical producer, EPA developed four criteria that define a significant industrial user (SIU). Many of the general pretreatment regulations apply to SIUs as opposed to IUs, based on the fact that control of SIUs should provide adequate protection of the POTW.

Unlike other environmental programs that rely on federal or state governments to implement and enforce specific requirements, the Pretreatment Program places the majority of the responsibility on local municipalities**.** Specifically, Section 403.8(a) of the general pretreatment regulations states that any POTW (or combination of treatment plants operated by the same authority) with a total design flow greater than 5 million MGD and smaller POTWs with SIUs must establish a local pretreatment program. As of early 1998, 1,578 POTWs were required to have local programs. Although this represents only about 15 percent of the total treatment plants nationwide, these POTWs account for more than 80 percent (i.e., approximately 30 billion gallons a day) of the national wastewater flow.

Consistent with Section 403.8(f), POTW pretreatment programs must contain the six minimum elements described below (EPA, 1999):

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BOX 6-5 Continued

1. Legal Authority

The POTW must operate pursuant to legal authority enforceable in federal, state, or local courts, which authorizes or enables the POTW to apply and enforce any pretreatment regulations developed pursuant to the CWA. At a minimum, the legal authority must enable the POTW to:

i. deny or condition discharges to the POTW,
ii. require compliance with pretreatment standards and requirements,
iii. control IU discharges through permits, orders, or similar means,
iv. require IU compliance schedules when necessary to meet applicable pretreatment standards and/or requirements and the submission of reports to demonstrate compliance,
v. inspect and monitor IUs,
vi. obtain remedies for IU noncompliance, and
vii. comply with confidentiality requirements.

2. Procedures

The POTW must develop and implement procedures to ensure compliance with pretreatment requirements, including:

i. identify and locate IUs subject to the pretreatment program,
ii. identify the character and volume of pollutants contributed by such users,
iii. notify users of applicable pretreatment standards and requirements,
iv. receive and analyze reports from IUs,
v. sample and analyze IU discharges and evaluate the need for IU slug control plans,
vi. investigate instances of noncompliance, and
vii. comply with public participation requirements.

3. Funding

The POTW must have sufficient resources and qualified personnel to carry out the authorities and procedures specified in its approved pretreatment programs.

4. Local Limits

The POTW must develop local limits or document why those limits are not necessary.

5. Enforcement Response Plan (ERP)

The POTW must develop and implement an ERP that contains detailed procedures indicating how the POTW will investigate and respond to instances of IU noncompliance.

6. List of SIUs

The POTW must prepare, update, and submit to the approval authority a list of all significant industrial users (SIUs).

In addition to the six specific elements, pretreatment program submissions must include:

- A statement from the city solicitor (or the like) declaring the POTW has adequate authority to carry out program requirements;
- Copies of statutes, ordinances, regulations, agreements, or other authorities the POTW relies upon to administer the pretreatment program, including a statement reflecting the endorsement or approval of the bodies responsible for supervising and/or funding the program;
- A brief description and organizational chart of the organization administering the program; and
- A description of funding levels and manpower available to implement the program.

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BOX 6-5 Continued

The objectives of the National Pretreatment Program are achieved by applying and enforcing three types of discharge standards: (1) prohibited discharge standards, (2) categorical standards, and (3) local limits.

Prohibited Discharge Standards

All IUs, whether or not subject to any other national, state, or local pretreatment requirements, are subject to the general and specific prohibitions identified in 40 C.F.R. §§403.5(a) and (b), respectively. General prohibitions forbid the discharge of any pollutant(s) to a POTW that cause pass-through or interference. These prohibited discharge standards are intended to provide general protection for POTWs. Examples of these include prohibitions on discharges of pollutants that can create fire or explosion hazards, cause corrosive structural damage, obstruct flow within the POTW, and interfere with the POTW's biological treatment activity. However, their lack of specific pollutant limitations creates the need for additional controls, namely categorical pretreatment standards and local limits.

Categorical Standards

Categorical pretreatment standards (i.e., categorical standards) are national, uniform, technology-based standards that apply to discharges to POTWs from specific industrial categories (i.e., indirect dischargers) and limit the discharge of specific pollutants. Categorical pretreatment standards for both existing and new sources are promulgated by EPA pursuant to Section 307(b) and (c) of the CWA. Limitations developed for indirect discharges are designed to prevent the discharge of pollutants that could pass through, interfere with, or otherwise be incompatible with POTW operations. The categorical pretreatment standards can be concentration based or mass based. For example, the pretreatment standard for the electrical and electronic component manufacturing industry (40 C.F.R. Part 469, Subparts A-D) are concentration-based daily maximum and monthly average limits that vary by subpart and pollutant parameter.

Local Limits

Prohibited discharge standards are designed to protect against pass-through and interference generally. Categorical pretreatment standards, on the other hand, are designed to ensure that IUs implement technology-based controls to limit the discharge of pollutants. Local limits, however, address the specific needs and concerns of a POTW and its receiving waters**.** Federal regulations at 40 CFR §§403.8(f)(4) and 122.21(j)(4) require control authorities to evaluate the need for local limits and, if necessary, implement and enforce specific limits as part of pretreatment program activities. Local limits are developed for pollutants (e.g., metals, cyanide, BOD_5, TSS, oil and grease, organics) that may cause interference, pass-through, sludge contamination, and/or worker health and safety problems if discharged in excess of the receiving POTW treatment plant's capabilities and/or receiving water quality standards.

It is likely that some of the designated high-risk facilities would be better regulated by individual stormwater NPDES permits. In particular, good candidates for individual NPDES permits include international ports, airports, and multiphase construction land developments, which are similar (in the potential risk they pose to water quality) to traditional major wastewater facilities such as petroleum refineries and large POTWs.

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SCM Design Parameters, Numerical SCM Performance Criteria, and Monitoring

For the integration approach to work, the permitting authority and the MS4 permittee must better delineate SCM design parameters, numerical performance criteria, and default SCMs based on best available technology or water quality standards for the discharge of industrial and construction stormwater. Both the ASCE International Storm Water Database (which is now called the WERF International Storm Water Database because it is maintained by the Water Environment Research Foundation) and the National Stormwater Quality Database (NSQD), which were developed with EPA funding, are comprehensive datasets that can be used to develop numeric technology-based effluent criteria or limits for industrial and construction stormwater discharges. The MS4 can then determine the compliance of industry and construction activity with its requirements by using either some numeric criteria or a suite of SCMs that have been presumptively determined as capable of achieving the performance criteria. The EPA MSGP includes a general list of sector-specific SCMs, but these presently have no performance criteria associated with them. It is important that the EPA continue to support both the WERF and the NSQD databases as the repositories of SCM performance and MS4 monitoring data, so that MS4s can use them to establish local limits and update the performance criteria periodically to fully effectuate the iterative approach to ensuring that MS4 discharges eventually will meet water quality standards.

The proposed integration scheme will also facilitate the MS4 permittee's implementation of a purpose-oriented stormwater monitoring program directed toward identifying problematic industrial or construction stormwater discharges or high-risk industrial facility sectors. The current benchmark monitoring conducted by MSGP facilities would be eliminated. Instead, MSGP facilities would have the option of performing scientifically valid stormwater discharge sampling to demonstrate their compliance with performance criteria or to participate in an MS4-led monitoring program by paying in lieu fees to support the cost of the purpose-oriented MS4 monitoring program. The net effect of this alternative is to pool the resources to come up with an optimal sampling strategy to replace what is now a stormwater monitoring strategy that is haphazard and not useful.

MS4 Responsibilities

Under integration, the MS4 permittee would be primarily responsible for the quality of stormwater discharges that exit the MS4 to the waters of the United States. The MS4 permittee would not be responsible for stormwater discharges from federal and state facilities or for facilities that have been issued an individual NPDES permit for stormwater discharges. The MS4 permittee would be responsible for implementing the six minimum program measures, assisting in the oversight and inspection of facilities covered under the MSGP and the construction general permit (CGP), and implementing a strategic water quality monitoring program to identify and control pollutant discharges from high-risk sites. The permitting authority would share any fees collected under the MSGP and CGP with the MS4, and facilities covered by them would have the option to opt-out of self-monitoring and contribute equivalent funds to an MS4-led monitoring program. Similarly, the permitting authority would be expected to support research and special studies that address issues of regional or national significance through partnerships with the MS4 permittees.

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Some MS4s may balk at taking on more responsibility for the control of stormwater pollution, as required for integration to succeed. However, there are already several case examples that exist. The State of Oregon requires facilities that discharge industrial stormwater to file a Notice of Intent (NOI) for coverage under the MSGP with both the state and the local MS4 (Campbell, 2007). The state has an agreement with the local MS4s for the inspection of the facilities covered under the MSGP and the sharing of NOI fees. The State of Tennessee has a statewide pilot program to partner with local MS4s for the inspection of construction sites that are covered under the CGP.

Analogy to the WWTP Pretreatment Program

It is certainly true that the MS4s are a more challenging point source to regulate for the discharge of pollutants than WWTPs. WWTPs have fewer outfalls discharging to waters of the United States than MS4s, and inputs into them are through discrete rather than diffuse sources as in the case of MS4s. It is thus expected to be more difficult to identify problem stormwater sources and to hold them accountable for discharges in excess of standards. This problem is not insurmountable, however. Watershed and land-use hydrologic models can be developed and refined by strategic sampling of pollutant sources for use by MS4 permittees and regulatory agencies. If EPA and state permitting authorities establish measurable outcomes as expected endpoints of progress, MS4 permittees will make intelligent choices about which measures to implement in order to meet these endpoints. In large part, the lack of progress nationally towards controlling pollutants in stormwater discharges from the MS4s has been due to the absence of national SCM design standards, MS4 discharge performance criteria, and stormwater effluent guidelines. Presently, the MS4 permittees as owners and operators of the MS4 affirmatively approve connections to the conveyance system for rainfall runoff. Historically the issuance of the MS4 connection permit has been based on the sizing of the pipes for the conveyance of flood waters. There are few barriers to including water quality considerations in reauthorizing these connections and adding new ones.

Note that EPA did initially consider using the WWTP pretreatment approach for stormwater discharges by requiring MS4 permittees to be primarily responsible for discharges of stormwater associated with industrial activity through the MS4 (53 Fed. Reg. 49428; December 7, 1988). However, EPA deviated from this approach in issuing its Final Storm Water Rule (55 Fed. Reg. 48006; November 16, 1990). In the absence of regulations that specifically confer authority on MS4 permittees to establish local limits for stormwater discharges to the MS4 from industry and businesses, the EPA should promulgate specific SCMs and performance guidelines with rigorous requirements for self-monitoring and compliance in order to support the integrated framework for controlling stormwater pollution from MS4s.

Potential Legal Barriers

A revised stormwater program that requires MS4s to play a more significant role in enforcement and oversight and that provides greater specificity in permit requirements is not only contemplated, but arguably demanded by Congress in the CWA. Specifically, Congress directs that MS4 permits be conditioned on the requirement that the MS4s “shall require controls

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to reduce the discharge of pollutants to the maximum extent practicable" 42 U.S.C. § 1342(p)(3)(B)(iii). EPA has already conditioned Phase I MS4 permits on the requirement that the municipality establish that it has the legal authority to inspect discharges into the system and take regulatory and enforcement action against excessive or violating sources [40 C.F.R. § 122.26(d)(2)(i)]. Nevertheless, to ensure that MS4s play an even more active role, EPA should include several additional requirements in its implementing regulations. In addition to promulgating more detailed and specific SCM requirements as discussed above, EPA should also require that the Phase I MS4s establish that they possess sufficient funding and staff to effectuate their responsibilities [see, e.g., 40 C.F.R. § 403.8(f)(2) and (3) requiring this showing for the POTW program]. Like the POTW program, states should also be authorized as MS4 permittees when the local governments are unable or unwilling to carry out their mandatory stormwater permit responsibilities [see, e.g., 40 C.F.R. § 403.10(e) providing this authority for the POTW program].

Industrial Program

The industrial stormwater permit program presently incorporates a menu of SCMs that are to be selected by the facility operator, a rudimentary monitoring program that includes visual observations, some water quality sampling for selected parameters for certain types of industries subject to numerical effluent limitations (see Table 2-6) or a set of pollutant-level benchmarks that are to be used as a measure to appropriately revise the SWPPP (see Table 2-5), and annual reporting. Neither SCM performance criteria nor the characteristics of a design storm for water quality purposes have been established. Given the broad discretion that facility operators enjoy as a result, it has been difficult to gauge compliance with the MSGP and initiate enforcement for non-compliance even though industrial stormwater discharges are required to meet effluent limitations (technology- or water quality-based) that reflect water quality standards (Duke and Beswick, 1997; Duke and Augustenborg, 2006; Wagner, 2006). Several ideas to address some of the shortcomings in the implementation of the permitting program for industrial stormwater discharges are offered as *additions* to the concept of MS4 regulatory integration discussed previously. They would substantively improve the current industrial stormwater permitting program even if the integration recommendations were not acted upon.

Criteria for a Water Quality Design Storm and Subsequent SCM Selection

To improve the quality of stormwater discharges from industry, provide for better accountability, and advance the objectives of the CWA, it is important first to identify the criteria for a water quality design storm as opposed to one for flood control design, where the objective is to protect human life and real property. It is important that the permitting authority designate the basis for the determination of the water quality design storm, and explicitly state that it would form the criteria for evaluation of compliance with technology-based standards or water quality-based standards. This is essential because the engineering design decisions that determine how much stormwater is to be treated to remove toxic pollutants that pose a risk to human health or aquatic life is more a policy matter than a scientific one (Schiff et al., 2007). While modeling exercises using continuous simulation methods in theory could be performed for every project or

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subwatershed or region to support planning decisions on how much stormwater needs to be treated for optimum water quality benefits, such a detailed analysis will be too cumbersome and cost-prohibitive for routine planning and implementation purposes. Thus it is recommended that the EPA establish guidelines for the selection of water quality design storms for controlling pollution from MS4 and industrial stormwater discharges. This would not be a new practice for EPA because the agency has previously established design storms for certain industrial sectors when promulgating effluent guidelines (Table 2-6). Conceivably, unlike the technology limiting design storms that are set on rainfall recurrence intervals, the design storm to protect surface water quality and beneficial uses could be different for different eco-regions of the United States.

The water quality design storm, which may be expressed as total rainfall depth, runoff volume, or rainfall intensity, incorporates the concept that extreme rainfall events are rare, and that a few times each year the runoff volume or flow rate from a storm will exceed the design volume or rate capacity of an SCM. Therefore, for the purpose of best available technology and cost-effectiveness, industrial facility operators should not be held accountable for pollutant removal from storms beyond the size for which an SCM is designed.

For MS4 operators, the concept of designing MS4s for both flood control conveyance (capital flood design) and for water quality protection (water quality design) involves a fundamental shift. Whereas flood control engineers design conveyance systems with return frequencies of two years (streets), ten years (detention basins), 50 years, and 100 years (channels), the water quality design storm event is for a return frequency of six months to a year. The water quality design implicitly focuses on treating the first flush of runoff, which contains the highest load and concentration of pollutants and which occurs in the first half to one inch of runoff. In contrast, flood control designs are built to convey tens of inches of runoff.

In addition to issuing the guidelines to support the setting of stormwater criteria for water quality design, it is important that the EPA establish SCM performance criteria based on best technologies and identify the “presumptive technologies” that have been demonstrated to achieve the performance criteria. The water quality design storm and the best available technologies with their associated criteria can then form a basis for technology-based effluent limitations to be included in industrial stormwater permits. If the facility operator elects the identified presumptive technology, then compliance monitoring requirements can be scaled down to a minimum to ensure that the treatment systems are being properly maintained. On the other hand, if the operator elects to go with a suite of alternative SCMs, then the monitoring requirements sufficient to demonstrate that the suite of alternative SCMs are in fact achieving the effluent quality of the selected technology can be prescribed. In such a scheme, visual monitoring will serve to ensure that the treatment systems are being properly maintained, and compliance can be reported using the same procedures as required presently for the industrial wastewater permits.

How to Identify a High-Risk Industry

Both the watershed-based permitting approach described previously in this chapter and the integration approach call for municipal permittees, as part of their responsibilities, to identify high-risk industrial stormwater dischargers. This involves identifying the potential sources of concern, evaluating the extent of their potential impacts, and then prioritizing them for attention—a classic risk assessment. Municipalities would generally not be able to give equal and full attention to all sources, nor should they. Unfortunately, what constitutes high risk or any

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level of risk for industries covered by NPDES stormwater permits has not been defined by EPA, although the states have developed various interpretations (see Appendix C).

Two methodologies for identifying industrial and commercial facilities that are considered high-risk for discharging pollutants in stormwater are presented below. Box 6-6 describes the "intensity of industrial activity" method devised for the City of Jacksonville (Duke, 2007). This method uses telephone queries and a point scale system to visually score each facility based on the intensity of the industrial activities exposed to stormwater, and groups the results into categories A, B, C, or D in increasing order of intensity (Cross and Duke, 2008). The categories are designed to distinguish high-risk facilities from low-risk facilities, and not to make fine distinctions among facilities with similar characteristics. This typology is sufficient to distinguish facilities with little or no potential for discharging pollutants associated with stormwater from facilities that might discharge those pollutants. More than half of the facilities that were subject to Florida's MSGP were determined to be low-risk (Cross and Duke, 2008).

Box 6-7 outlines an empirical methodology used by the County of Los Angeles to rank the risk of industrial facilities for stormwater pollution on the basis of pollution potential P. The pollution potential P was computed as a product of the number of on-site sources, percent imperviousness, pollutant toxicity, degree of exposure, and the number of facilities (Los Angeles County, 2001). Based on this ranking scheme, five top high-risk industries were selected: (1) automobile dismantlers, (2) automobile repair, (3) metal fabrication, (4) motor freight, and (5) automobile dealers. Stormwater discharges from six facilities in each category were characterized over a two-year period, and the effectiveness of SCMs was assessed at a subset of them. However, the monitoring was minimal, and so much of the prioritization was based on best professional judgment about pollutant discharges.

Industrial Stormwater Discharge Monitoring

Monitoring data from Phase I MS4s have been compiled in the NSQD for several years, making possible a number of important findings about the quality of municipal stormwater (see Chapter 3). Although industry that occurs within MS4s is technically included in the NSQD, the data are lumped together and not sector specific. There is no comparable, reliable source of data specifically on industrial discharges, even though EPA requires benchmark monitoring for MSGP industrial permittees. The intent was that industrial facility operators would use benchmark exceedances as action levels to improve SCMs, but this self-directed approach has been largely a failure. Many industrial facilities reported repeated exceedances of benchmark values without action, and others have failed to report any monitoring data at all. In addition, the representativeness of single grab samples taken to characterize the discharge and less-than-rigorous sample collection and quality assurance procedures have resulted in monitoring data that are not very useful. One of the only analyses of benchmark monitoring data ever done evaluated California's program between 1992 and 2001 (see Box 4-2; Stenstrom and Lee, 2005; Lee et al., 2007). The study showed no relationship between facility type and stormwater discharge quality. The cited reasons for the poor relationship included variability in sampling parameters, sampling time, and sampling strategy—that is, poor data.

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BOX 6-6
Risk Assessment for Industrial Dischargers of Stormwater

The City of Jacksonville has had very good success in determining what industries pose the highest stormwater risks by starting with businesses having the Standard Industrial Classification (SIC) codes designated for permit coverage but using multiple lists of potential sources and cross checking them to target inspections and other interventions where they will have the best effect. Other clues to sources of interest include other environmental permits (e.g., wastewater NPDES permits, permits for discharge to sanitary sewer), tax records, records of fire code inspections, building permit filings, planning agency proceedings, contacts with business associations, marketing information put out by companies, Resource Conservation and Recovery Act hazardous waste reports, and telephone and field surveys.

Duke (2007) proposed a 0- to 8-point scoring scheme (shown below) to rate the intensity of industrial activities exposed to stormwater. The system is based on the relative amount of exposure to precipitation and runoff by industrial materials, processes, wastes, and vehicles. Once municipalities gather the data and then classify their industries accordingly, they would have a very useful tool to program inspections and monitoring emphasizing the industries most risking their success in achieving established objectives. A similar system could and should be developed for construction sites.

0 points
- Small bulk waste, e.g., covered dumpster: area <100 m^2
- Hazardous waste: containers not exposed to precipitation

1 point
- Outdoor vehicle use: 1-2 vehicles, outdoors occasionally/never, not used in precipitation
- Vehicle washing outdoors, 1-2 vehicles, rarely or occasionally done

2 points
- Outdoor vehicles, e.g., forklifts: 1-2, outdoors occasionally/never, used in precipitation
- Outdoor vehicles, e.g., forklifts: 1-2, outdoors every day, not used in precipitation
- Outdoor vehicles, e.g., forklifts: 3-4, outdoors occasionally/never, not used in precipitation
- Vehicle maintenance or re-fueling, 1-2 vehicles, rarely or occasionally done, outside
- Vehicle washing outdoors, 1-2 vehicles, regularly done
- Vehicles washing outdoors, 3 vehicles, rarely or occasionally done

4 points
- Storage of materials or products: area < 100m^2 and/or < five 55-gallon drums
- Fixed outdoor equipment: 1-2 small or large item(s)
- Outdoor vehicles, e.g., forklifts: 1-2, outdoors every day, used in precipitation
- Outdoor vehicles, e.g., forklifts: 3-4, outdoors occasionally/never, used in precipitation
- Outdoor vehicles, e.g., forklifts: 3-4, outdoors every day, not used in precipitation
- Uncovered shipping/receiving area: 1-2 docks
- Vehicle maintenance or re-fueling outdoors, 1-2 vehicles, regularly done
- Vehicle maintenance or re-fueling outdoors, vehicles, rarely or occasionally done
- Plant yard, rail lines, access roads: 1,000 ft^2
- Small process equipment, e.g., compressors, generators: exposed to precipitation

6 points
- Outdoor vehicles, e.g., forklifts: 3-4, outdoors every day, used in precipitation
- Outdoor vehicles, e.g., forklifts: > 5 or heavy, outdoors occasionally, used in precipitation
- Outdoor vehicles, e.g., forklifts: > 5 or heavy, outdoors every day, not used in precipitation
- Vehicle maintenance or re-fueling outdoors, 3 vehicles, regularly done
- Plant yard, rail lines, access roads: 1,000 ft^2

8 points
- Storage of materials or products: area 100^2 and/or five 55-gallon drums
- Boneyard of scrap, disused equipment, similar
- Hazardous waste: containers exposed to precipitation
- Fixed outdoor equipment: small or 2 large items
- Outdoor vehicles, e.g., forklifts: > 5 or heavy, outdoors every day, used in precipitation
- Uncovered shipping/receiving area: 3 docks
- Plant yard, rail lines, access roads: 5,000 ft^2
- Manufacturing activities, e.g., cutting, painting, coating materials: exposed to precipitation

SOURCE: Duke (2007).

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BOX 6-7
Los Angeles County Critical Facilities Monitoring Data

One of the few sources of data on industrial stormwater discharges comes from the County of Los Angeles. A stepwise process was used to identify the highest-risk industrial/commercial facilities, which were then monitored to measure the quality of their stormwater discharges and to evaluate the effectiveness of SCMs. The initial list of candidate facilities was identified from their relative numbers and the extent of their outdoor activities. This list was then refined using an empirical equation for pollutant potential P:

$$P = Q \times R \times T \times E \times N$$

where

Loading (*Q*) is the number of sources at a site and the likelihood of release;
Imperviousness (*R*) of a site is the percent of paved area;
Pollutant toxicity (*T*) denotes the number of toxic pollutants and the inherent toxicity of the mix;
An exposure factor (*E*) signifies if activities are exposed to rainfall; and
The Number (*N*) represents the total number of sites in the county.

Each variable was assigned a qualitative number from 1 to 10, with 10 representing the worst condition.

Based on this equation, five top "critical source" industries were determined: (1) automobile dismantlers; (2) automobile repair; (3) metal fabrication; (4) motor freight; and (5) automobile dealers. Six facilities from each of these categories were monitored during five storms a year for two years. The stormwater discharge samples were analyzed for general conventional pollutants, heavy metals, bacteria, and semi-volatile organic compounds. Half of the facilities were then fitted with SCMs, which were monitored to evaluate their effectiveness.

The highest median values were observed for total zinc (approx. 450 □g/L), dissolved zinc (approx. 360 □g/L), total copper (approx. 240 □g/L), and dissolved copper (approx. 110 □g/L) in stormwater discharges from fabricated metal sites. However, levels for total and dissolved zinc did not appear to be significantly different among the industry types. SCMs in the form of good housekeeping and spill containment measures were installed at half of the sites. For total and dissolved zinc, the median concentration lowered or stayed nearly the same with the implementation of SCMs at the auto dismantling, auto repair, and fabricated metals industries (i.e., in none of the circumstances was the difference significant). For total and dissolved copper, however, where the fabricated metal industry had displayed the highest median concentrations, levels were significantly reduced with the implementation of SCMs. The auto dismantling and auto repair businesses showed no significant differences in copper after the implementation of SCMs.

SOURCE: Los Angeles County (2001).

In the past, it has been proposed to EPA that it fund a project that would systematically collect the benchmark monitoring data across the nation, as has been done for MS4s, but these suggestions have been rejected. To get better data from specific industrial sectors, it is recommended that a small subset of industrial users and sectors be selected for composite sampling in a program directed by the MS4. Alternatively, making a trained team responsible for monitoring of small-business industrial dischargers would reduce, if not eliminate, current problems with quality assurance.

Monitoring of industrial stormwater discharges could be streamlined by considering the adoption of a Reasonable Potential Analysis (RPA), which is already part of the existing practice

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in developing limits for NPDES wastewater permits (EPA, 1991). The RPA is a procedure that uses statistical distribution assumptions in association with a limited number of wastewater discharge quality measurements to determine the likelihood that a receiving water quality standard would be violated, which assists the permitting authority in determining what permit limitations should be set to protect receiving water quality. The effluent data from any treatment system may be described using standard descriptive statistics such as the mean concentration and the coefficient of variation. Using a statistical distribution such as the lognormal, an entire distribution of values can be projected from limited data; limits on pollutant concentrations in discharge can then be set at a specified probability of occurrence so that the receiving water is protected. An RPA for stormwater pollutants may be particularly relevant in developing performance criteria for SCMs for facilities discharging stormwater within the integrated framework of MS4 permitting. Also, MS4 permittees could use the method to reduce the number of pollutants that high-risk industries would be required to monitor in order to demonstrate to the municipality that they are not the source of pollutants in MS4 discharges that are impairing surface waters.

Construction Program

The recommendations for stormwater discharges associated with construction activity are very similar to those offered for stormwater discharges associated with industrial activity. The integration with the MS4 program is less of a challenge because municipalities have always had primacy on land development planning and construction activity. Most municipalities have had requirements for soil erosion and sediment control plans on construction sites that precede the federal stormwater regulations. EPA regulations already allow permitting authorities to approve Phase I and Phase II MS4 permittee oversight of CGP construction sites under the qualifying local program provision (40 C.F.R. 122.44(s)) (Grumbles, 2006). The weakness in the implementation of this provision currently is the absence of rigorous SCM performance criteria guidelines for MS4s permittees to meet in order to be deemed as qualifying.

The construction stormwater general permit program requires the development and implementation of an SWPPP. The SWPPP, which must be prepared before construction begins, focuses on two major requirements: (1) describing the site adequately and identifying the sources of pollution to stormwater discharges associated with construction activity on site and (2) identifying and implementing appropriate measures to reduce pollutants in stormwater discharges to ensure compliance with the terms and conditions of this permit. The SWPPP must describe the sequence of major stormwater control activities and the kinds of SCMs that will be in place, and it must identify interim and permanent stabilization practices, including a schedule of their implementation. There is an expectation that the construction site operator will use good site planning, preserve mature vegetation, and properly stage major earth-disturbing activities to avoid sediment loss and prevent erosion. Post-construction stormwater controls need to be considered, but are not required. Construction site operators are required to visually inspect the construction site weekly and perform a walk through before predicted storm events. No annual reports are required, but records must be kept for a period of three years after permit coverage has been terminated. There are no SCM performance criteria, other than a suggestion that most SCMs should be able to achieve 80 percent TSS removal. As with industry, it is difficult to gauge compliance with the CGP except when inadequate SCMs result in a massive discharge of sediment from a construction site.

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The pollutant parameters that are of concern in stormwater discharges from construction activity are TSS, settleable solids, turbidity, and nutrients from erosion; pH from concrete and stucco; and a wide range of metallic and organic pollutants from construction materials, processes, wastes, and vehicles and other motorized equipment. The permitting authority, in addition to guidelines for the water quality design storm, must establish SCM performance criteria for stormwater discharges associated with construction activity. The construction site operator should be given the option of implementing SCMs that are the presumptive technology, or equivalent SCMs that can achieve the performance criteria. For example, the recommended SCMs in Box 5-3 could serve as the presumptive construction SCMs on a typical construction site that is less than 50 acres in size. If the operator elects to go with a suite of alternative SCMs, then adequate monitoring must be performed to demonstrate that the alternative SCMs are in fact achieving the performance criteria. In addition, the CGP presently does not mandate or require that post-construction SCMs be integrated with the MS4 permittee requirements under its New Development/Redevelopment Program requirements. The proper planning for and implementation of SCMs that will help mitigate stormwater pollution from planned future use of the site will be critical to protecting water quality. Thus the post-construction requirements of the CGP should be strengthened and better integrated with the new development/redevelopment requirements of the MS4 permits.

Municipal Program

Several key enhancements to the MS4 permitting program are needed to ensure that resources are targeted to achieve the greatest on-the-ground implementation of SCMs to make incremental progress in meeting water quality standards. Six specific issues are discussed below; their implementation will require greater collaboration and flexibility among regulators and permitted parties. These recommendations are suggested for communities that are not ready for the integrated watershed approach proposed in the prior section, and represent a bridge toward building internal capacity to implement them.

Numeric Expression of "Maximum Extent Practicable"

The ambiguity of the term "maximum extent practicable" (MEP) has been a major impediment to achieving meaningful water quality results in the MS4 program. The EPA should develop numerical expressions of MEP in the next round of permit renewals that can be measured and tracked. A national numeric benchmark should be avoided; states should focus on regional benchmarks that are tied to their water quality problems. Four examples of methods to define MEP in a numeric manner are provided below: the first three are applied at a regional or state level, whereas the last (impervious cover-based TMDLs) offers more flexibility to be applied at individual sites.

Establish Municipal Action Levels. This approach relies on the use of a national database of stormwater runoff quality to establish reasonable expectations for outfall monitoring in highly developed watersheds. The NSQD (Pitt et al., 2004) allows users to statistically establish action levels based on regional or national event mean concentrations developed for

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pollutants of concern. The action level would be set to define unacceptable levels of stormwater quality (e.g., two standard deviations from the median statistic, for simplicity). Municipalities would then routinely monitor runoff quality from major outfalls. Where an MS4 outfall to surface waters consistently exceeds the action level, municipalities would need to demonstrate that they have been implementing the stormwater program measures to reduce the discharge of pollutants to the maximum extent practicable. The MS4 permittees can demonstrate the rigor of their efforts by documenting the level of implementation through measures of program effectiveness, failure of which will lead to an inference of noncompliance and potential enforcement by the permitting authority.

Site-Based Runoff and/or Pollutant Load Limits. This approach is primarily used for watersheds that are experiencing rapid development; it establishes numeric targets or performance standards for pollutant or runoff reduction that must be met on individual development sites. The numeric targets may involve specific pollutant load limits or runoff reduction volumes. For example, Virginia DCR (2007) and Hirschman et al. (2008) established a statewide computational method to ensure that SCMs are sized, designed, and sequenced to comply with specific nutrient-based load and runoff reduction limits. The nutrient load limits of 0.28 lb/acre/yr for total phosphorus and 2.68 lb/acre/yr for total nitrogen were computed using the Chesapeake Bay Model for Virginia tributaries to the bay. The design process also requires the computation of runoff reduction volumes achieved to promote the use of nonstructural SCMs. The basic concept is that new development on non-urban land must not exceed the average annual nutrient load and runoff volume for non-urban land using effective SCMs in the watershed. This blended site-based runoff and load limit approach has been advocated by the Office of Inspector General (2007) and Schueler (2008a) and is under active consideration by several other Chesapeake Bay states.

Wenger et al. (2008) reports on a no-net-hydrologic-increase strategy to protect endangered fish species in the northern Georgia Piedmont that sets specific on-site runoff reduction requirements for a range of land uses and design storm events. A similar approach has been incorporated into the recently enacted Energy Independence and Security Act of 2007 that contains provisions that require that the "sponsor of any development or redevelopment project involving a Federal facility with a footprint that exceeds 5,000 square feet shall use site planning, design, construction, and maintenance strategies for the property to maintain or restore, to the maximum extent technically feasible, the predevelopment hydrology of the property with regard to the temperature, rate, volume, and duration of flow."

The challenge of defining MEP as a runoff reduction or pollutant load limit is that considerable scientific and engineering analysis is needed to establish the performance standards, evaluate SCM capability to meet them, and devise a workable computational approach that links them together at both the site and watershed levels. In addition, care must be taken to define an appropriate baseline to represent predevelopment conditions that does not unduly penalize redevelopment projects or make it impossible to comply with limits at new development sites after maximum effort to apply multiple SCMs is made.

Turbidity Limits for Construction Sites. Numeric enforcement criteria can be used to define what constitutes an egregious water quality violation at construction sites and provide a technical criterion to measure the effectiveness of erosion and sediment control practices.

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Currently, most states and localities do not specify either numeric enforcement criteria or a monitoring requirement within their CGP (see the survey data contained in Appendix C).

A maximum turbidity limit would establish definitive criteria as to what constitutes a direct sediment control violation and trigger an assessment for remediation and prevention actions. For example, local erosion and sediment control ordinances could establish a numeric turbidity limit of 75 Nephelometric Turbidity Units (NTU) as an instantaneous maximum for rainfall events less than an inch (or a 25 NTU monthly average) and would prohibit visible sediment in water discharged from upland construction sites. While the exact turbidity limit would need to be derived on a regional basis to reflect geology, soils, and receiving water sensitivity, research conducted in the Puget Sound of Washington indicates that turbidity limits in the 25 to 75 NTU can be consistently achieved at most highway construction sites using current erosion and sediment control technology that is properly maintained (Horner et al., 1990). If turbidity limits are exceeded, a detailed assessment of site conditions and follow-up remediation actions would be required. If turbidity limits continue to be exceeded, penalties and enforcement actions would be imposed. Enforcement of turbidity limits could be performed either by state, local, or third party erosion and sediment control inspectors, or—under appropriate protocols, training, and documentation—by citizens or watershed groups.

Impervious Cover Limits and IC-based TMDLs. MS4s that discharge into TMDL watersheds also require more quantitative expression of how MEP will be defined to reduce pollutant loads to meet water quality standards. Maine, Vermont, and Connecticut have recently issued TMDLs that are based on impervious cover rather than individual pollutants of concern (Bellucci, 2007). In such a TMDL, impervious cover is used as a surrogate for increased runoff and pollutant loads as a way to simplify the urban TMDL implementation process. Impervious cover-based TMDLs have been issued for small subwatersheds that have biological stream impairments associated with stormwater runoff but no specific pollutant listed as causing the impairment (in most cases, these subwatersheds are classified as impacted according to the Impervious Cover Model [ICM]—see Box 3-10). A specific subwatershed threshold is set for effective impervious cover, which means impervious cover reductions are required through removal of impervious cover, greater stormwater treatment for new development, offsets through stormwater retrofits, or other means.

Traditional pollutant-based TMDLs would continue to be appropriate for "non-supporting" and "urban drainage" subwatersheds, although they could be modified to focus compliance monitoring on priority urban source areas or subwatersheds that produce the greatest pollutant loads. Although EPA (2002) indicates that this analysis does not extend to demonstrating that changes will occur in receiving waters, it does outline a rigorous process for evaluating pollutant discharges and SCM performance. More recent EPA guidance (2007c) recommends that MS4s conduct a four-step analysis, which is distilled to its essence below:

Step 1: Estimate loads for pollutant of concern for the watershed.
Step 2: Provide a specific list of SCMs that will be applied in the listed watershed.
Step 3: Estimate the pollutant removal capability of the individual SCMs applied.
Step 4: Compute aggregate watershed pollutant reduction achieved by the MS4.

Although this is not a particularly new interpretation of addressing stormwater loads in watersheds listed as impaired and/or having written TMDLs, it is exceptionally uncommon for

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individual MS4s to document the link between their stormwater discharges and water quality standard exceedances, as modified by the system of SCMs that they used to reduce these pollutants. As of 2007, EPA could only document 17 TMDLs that addressed stormwater discharges using this sequential analysis. EPA and states need to provide more specific guidance for MS4s to comply with TMDLs in their permit applications and annual reports.

Focus MS4 Permit Implementation at the Subwatershed Level

Chapter 5 noted the importance of the watershed context for making better local stormwater decisions. This context can be formally incorporated into local MS4 permits by focusing implementation on a subwatershed basis, using the ICM, as described in Box 3-10 and outlined in Table 6-1. When urban streams are classified by the ICM, this basic subwatershed planning process can be used to establish realistic water quality and biodiversity goals for individual classes of subwatersheds, as shown in Table 6-2. As can be seen, goals for water and habitat quality become less stringent as impervious cover increases within the subwatershed. This subwatershed approach provides stormwater managers with more specific, measurable, and attainable implementation strategies than the one-size-fits-all approach that is still enshrined in current wet-weather management regulations.

TABLE 6-1 Components of Subwatershed-Based Stormwater Management

1. Define interim water quality and stormwater goals (i.e., pollutants of concern, biodiversity targets) and the primary stormwater source areas and hotspots that cause them.
2. Delineate subwatersheds within community boundaries.
3. Measure current and future impervious cover within individual subwatersheds.
4. Establish the initial subwatershed management classification using the ICM.
5. Undertake field monitoring to confirm or modify individual subwatershed classifications.
6. Develop specific stormwater strategies within each subwatershed classification that will guide or shape how individual practices and SCMs are generally assembled at each individual site.
7. Undertakes restoration investigations to verify restoration potential in priority subwatersheds.
8. Agree on the specific implementation measures that will be completed within the permit cycle. Evaluate the extent to which each of the six minimum management practices can be applied in each subwatershed to meet municipal objectives.
9. Agree on the maintenance model that will be used to operate or maintain the stormwater infrastructure, assign legal and financial responsibilities to the owners of each element of the system, and develop a tracking and enforcement system to ensure compliance.
10. Define the trading or offset system that will be used to achieve objectives elsewhere in the local watershed objectives in the event that full compliance cannot be achieved due to physical constraints (e.g., indexed fee-in-lieu to finance municipal retrofits).
11. Establish sentinel monitoring stations in subwatersheds to measure progress towards goals.
12. Revise subwatershed management plans in the subsequent NPDES permitting cycle based on monitoring data.

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TABLE 6-2 Expectations for Different Urban Subwatershed Classes

Lightly Impacted Subwatersheds (1 to 5% IC)	• Consistently attain scores for specific indicators for hydrology, biodiversity, and geomorphology that are comparable to streams whose entire subwatersheds are fully protected in a natural state (e.g., national parks). Should provide for healthy reproduction of trout, salmon, or other keystone fish species.
Moderately Impacted Subwatersheds (6 to 10% IC)	• Consistently attain scores for specific stream indicators that are comparable to the highest 10 percent of streams in a population of rural watersheds in order to maintain or restore ecological structure, function, and diversity of the streams. The "good to excellent" indicator scores for this category of subwatersheds will be the benchmark against which the relative quality of more developed subwatersheds will be measured.
Heavily Impacted Subwatersheds (11 to 25% IC)	• Consistently attain good stream quality indicator scores to ensure enough stream function to adequately protect downstream receiving waters from degradation. • Function is defined in terms of flood storage, in-stream nutrient processing, biological corridors, stable stream channels, and other factors.
Non-Supporting Subwatersheds (26 to 60% IC)	• Consistently attain "fair to good" stream quality indicator scores. • Meet bacteria standards during dry weather and trash limits during wet weather. • Maintain existing stream corridor to allow for safe passage of fish and floodwaters.
Urban Drainage Subwatersheds (61 to 100% IC)	• Maintain "good" water quality conditions in downstream receiving waters. • Consistently attain "fair" water quality scores during wet weather and "good" water scores during dry weather. • Provide clean "plumbing" in upland land uses such that discharges of sewage and toxics do not occur.

Note: the objectives presume some portion of the subwatershed has already been developed, thereby limiting attainment of objectives. If a subwatershed is not yet developed, managers should shift expectations up one category (e.g., urban drainage should behave like non-supporting). Also, the specific ranges of IC that define each management category should always be derived from local or regional monitoring data. Note that the ranges in IC shown to define a subwatershed management category are illustrative and will vary regionally.

Some examples of how to customize stormwater strategies for different subwatersheds are described in Table 6-3. This approach enables MS4s to utilize the full range of watershed planning, engineering, economic, and regulatory tools that can manage the intensity, location, and impact of impervious cover on receiving waters. In addition, the application of multiple tools in a given subwatershed class helps provide the maximum level of protection or restoration for an individual subwatershed when impervious cover is forecast to increase due to future growth and development. The conceptual management approach shown in Table 6-3 is meant to show how urban stream classification can be used to guide stormwater decisions on a subwatershed basis. The first column of the table lists some key stormwater management issues that lend themselves to a subwatershed approach and are explained in greater detail below.

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TABLE 6-3 Examples of Customizing Stormwater Strategies on a Subwatershed Basis

Stormwater Management Issue	Lightly Impacted Subwatershed (1 to 5% IC)	Moderately Impacted Subwatershed (6 to 10% IC)	Impacted (IC 11 to 25%)	Non-Supporting (IC 26 to 60%)	Urban Drainage (61% + IC)
Linkage with Local Land-Use Planning and Zoning	Utilize extensive land conservation and acquisition to preserve natural land cover	Implement site-based or watershed-based IC caps and maximize conservation of natural areas	Reduce the IC created for each zoning category by changing local codes and ordinances	Encourage redevelopment, development intensification and mass transit to decrease per-capita IC utilization in the urban landscape. Develop watershed restoration plans to maintain or enhance existing aquatic resources.	
Site-based Stormwater Reduction and Treatment Limits	Allow no net increase in runoff volume, velocity and duration up to the five-year design storm	Treat runoff from two-year design storm, using SCMs to achieve 100% runoff reduction		Treat runoff from the one-year design storm, using SCMs to achieve at least 75% runoff reduction	
Site-Based IC Fees	None	Establish Excess IC fee for projects that exceed IC for zoning category		Allow IC mitigation fee	
Subwatershed Trading	Receiving Area for Conservation Easements	Receiving Area for Restoration Projects and/or Retrofit		Receiving or Sending Area for Retrofit	Sending Area for Restoration Projects
Stormwater Monitoring Approach	Measure in-stream metrics of biotic integrity		Track subwatershed IC and measure SCM performance	Check outfalls and measure SCM performance	Check stormwater quality against municipal actions levels at outfalls
TMDL Approach	Protect using antidegradation provisions of the CWA	Use IC-based TMDLs that use flow or IC as a surrogate for traditional pollutants		Use pollutant TMDLs to identify problem subwatersheds	Use pollutant TMDLs to identify priority source areas
Dry Weather Water Quality	Perform in-stream grab sampling of water quality at sentinel stations	Check for failing septic systems	Screen outfalls for illicit discharges	Perform dry weather sampling in streams and outfall screening	Perform dry weather sampling in receiving waters
Addressing Existing Development	Protect or conserve natural areas, enhance riparian cover, assess road crossings, and ensure farm, forest, and pasture best practices are used		Perform stream repairs, riparian reforestation, and residential stewardship	Perform storage retrofits and stream repairs	Use pollution source controls and municipal housekeeping

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Linkage with Local Land-Use Planning and Zoning. Given the critical relation between land use and the generation of stormwater, communities should ensure that their planning tools (e.g., comprehensive plans, zoning, and watershed planning) are appropriately aligned with the intended management classification for each subwatershed. For example, it is reasonable to encourage redevelopment, infill, and other forms of development intensification within non-supporting or urban drainage subwatersheds, whereas down-zoning, site-based IC caps, and other density-limiting planning measures are best applied to sensitive subwatersheds.

Stormwater Treatment and Runoff Reduction MEP. Subwatershed classification allows managers to define achievable numerical benchmarks to define treatment in terms of the maximum extent practicable. Thus, a greater level of treatment is required for less-developed subwatersheds and a reduced level of treatment is applied for more intensely developed subwatersheds. This is most frequently expressed in terms of a rainfall depth associated with a given design storm. Designers are required to treat and/or reduce runoff for all storm events up to the designated storm event. This flexibility recognizes the greater difficulty and cost involved in providing the same level of treatment in an intensely developed subwatershed, as well as the fact that less treatment is needed to maintain stream condition in a highly urban subwatershed.

The other key element of defining MEP is to specify how much of the treatment volume must be achieved through runoff reduction. The runoff reduction volume has emerged as the primary performance benchmark to maintain predevelopment runoff conditions at a site after it is developed. In its simplest terms, this means achieving the same predevelopment runoff coefficient for each storm up to a defined storm event through a combination of canopy interception, soil infiltration, evaporation, rainfall harvesting, engineered infiltration, extended filtration, or evapotranspiration (Schueler, 2008b). Once again, the physical feasibility and need to provide treatment through runoff reduction becomes progressively harder as subwatershed impervious cover increases.

Site-Based IC Fees. Several economic strategies can be used to promote equity and efficiency when it comes to managing stormwater in different kinds of subwatersheds. In lower-density subwatersheds, an excess impervious cover fee can be charged to individual sites that exceed a maximum threshold for impervious cover for their zoning category. Similarly, an impervious cover mitigation fee can be levied at individual development sites in more intensely developed subwatersheds when on-site compliance is not possible or it is more cost-effective to provide an equivalent amount of treatment elsewhere in the watershed. The type of fee and the frequency that is used is expected to be closely related to the subwatershed classification.

Subwatershed Trading. The degree of impervious cover in a subwatershed also has a strong influence on the feasibility, cost, and appropriateness of restoration projects. Consequently, any revenues collected from various site IC fees can be traded among subwatersheds to arrive at the least-cost, effective solutions. In general, the most intensely developed subwatersheds are sending areas and the more lightly developed subwatersheds are used as receiving areas for such projects.

Stormwater Monitoring Approach. Subwatershed classification can also be used to define the type and objectives for stormwater monitoring to track compliance over time. For example, in sensitive subwatersheds, it may be advisable to routinely measure in-stream metrics

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of biological integrity to ensure stream quality is being maintained or enhanced. As impervious cover increases, stormwater managers may want to shift toward tracking of subwatershed impervious cover and actual performance monitoring of select SCMs to establish their effectiveness (e.g., impacted subwatersheds). At even higher levels of impervious cover, streams are transformed into urban drainage, and monitoring becomes more focused on identifying individual stormwater outfalls with the worst quality during storm conditions.

TMDL Approach. Subwatershed classification may also serve as a useful tool to decide how to apply TMDLs to impaired waters, or how to ensure that healthy waters are not degraded by future land development. For example, most lightly developed subwatersheds will seldom be subject to a TMDL, or if so, urban stormwater is often only a minor component in the final waste load allocation. Antidegradation provisions of the CWA are often the best means to protect the quality of these healthy waters before they are degraded by future land development. By contrast, impaired watersheds appear to be the best candidates to apply impervious cover-based TMDLs, as described earlier in this section. As subwatershed impervious cover increases, more traditional pollutant-based TMDLs are warranted, with a focus on problem subwatersheds for non-supporting streams and priority source areas for urban drainage.

Dry Weather Water Quality. The type, severity, and sources of illicit discharges often differ among different subwatershed classifications, which can have a strong influence on the kind of dry weather detective work needed to isolate them. For example, in lightly developed subwatersheds, failing septic systems are often the most illicit discharges, which prompts assessments at the lot or ditch level. The storm-drain network and potential discharge source areas becomes progressively more complex as subwatershed impervious cover increases. Consequently, illicit-discharge assessments shift toward outfall screening, catchment analysis, and individual source analysis.

Addressing Existing Development. The need for, type of, and feasibility for restoration efforts shift as subwatershed impervious cover increases. In general, lightly developed watersheds have the greatest land area available for retrofits and restoration projects in the stream corridor. Consequently, unique restoration strategies are developed for different subwatershed classifications (Schueler, 2004).

Require More Quantitative Evaluation of MS4 Programs

The next round of permit renewals should contain explicit conditions to define and measure outcomes from the six minimum management measures that constitute a Phase II MS4 program. Measurable program evaluation is critical to develop, implement, and adapt effective local stormwater programs, and has been consistently requested in permits and application guidance. To date, however, only a small fraction of MS4 communities have provided measurable outcomes with regard to aggregate pollutant reduction achieved by their municipal stormwater programs.

CASQA (2007) defines a six-level pyramid to assess program effectiveness, beginning with documenting activities, raising awareness, changing behaviors, reducing loads from

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sources, improving runoff quality, and ultimately leading to protection of receiving water quality (see Figure 6-1).

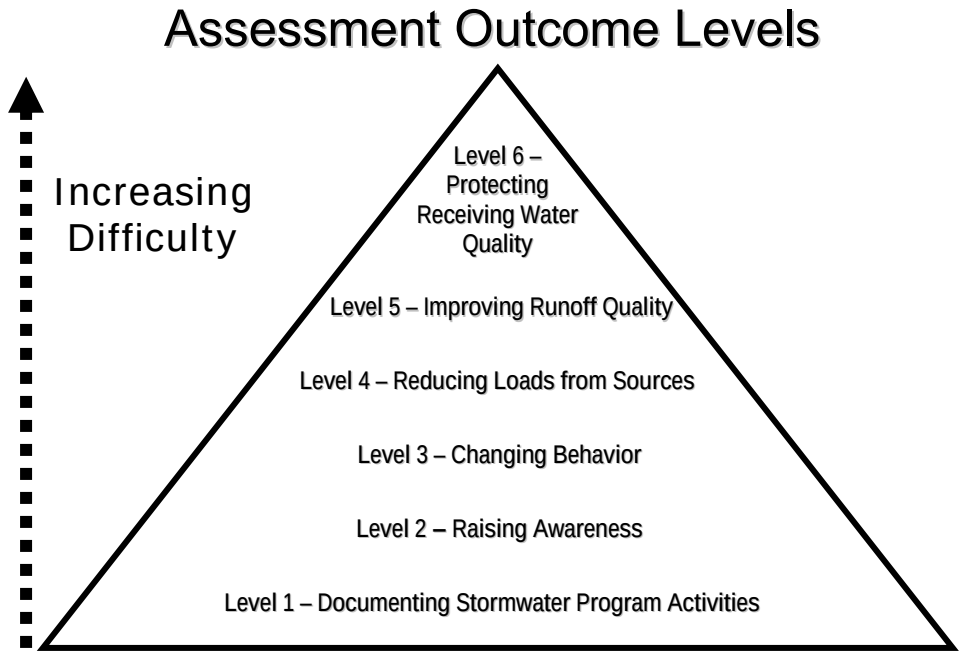

FIGURE 6-1 Pyramid of Assessment Outcome Levels for an MS4. SOURCE: CASQA (2007).

At the current time, most MS4s are struggling simply to organize or document their program activities (i.e., the first level), and few have moved up the pyramid to provide a quantitative link between program activities and water quality improvements. The framework and methods to evaluate program effectiveness for each of the six minimum management measures has been outlined by CASQA (2007). Regulators are encouraged to work with permitted municipalities to define increasingly more specific quantitative measures of program performance in each succeeding permit cycle.

Shift Monitoring Requirements to Measure the Performance of Stormwater Control Measures

The lack of monitoring requirements in the Phase II stormwater program makes it virtually impossible to measure or track actual pollutant load or runoff volume reductions achieved. While the existing Phase I outfall monitoring requirements have improved our understanding of urban stormwater runoff quality, they are also insufficient to link program effort to receiving water quality. It is recommended that both Phase I and II MS4s shift to a more collaborative monitoring effort to link management efforts to receiving water quality, as described below:

- If a review of past Phase 1 MS4s stormwater outfall monitoring indicates no violations of the Municipal Action Limits, then their current outfall monitoring efforts can be replaced by pooled annual financial contributions to a regional stormwater monitoring

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collaborative or authority to conduct basic research on the performance and longevity of range of SCMs employed in the community.

- If some subwatersheds exceed Municipal Action Levels, outfall monitoring should be continued at these locations, as well as additional source area sampling in the problem subwatershed to define the sources of the stormwater pollutant of concern.

- Phase II MS4s should be encouraged to make incremental financial contributions to a state or regional stormwater monitoring research collaborative to conduct basic research on SCM performance and longevity. Although the committee knows of no examples where this has been accomplished, this pooling of financial resources by multiple MS4s should produce more useful scientific data to support municipal programs than could be produced by individual MS4s alone. Phase II communities that do not participate in the research collaborative would be required to perform their own outfall and/or SCM performance monitoring, at the discretion of the state or federal permitting authority.

- All MS4s should be required to indicate in their annual reports and permit renewal applications how they incorporated research findings into their existing stormwater programs, ordinances, and design manuals.

CONCLUSIONS AND RECOMMENDATIONS

The watershed-based permitting program outlined in the first part of this chapter is ultimately essential if the nation is to be successful in arresting aquatic resource depletion stemming from sources dispersed across the landscape. Smaller-scale changes to the EPA stormwater program are also possible. These include integration of industrial and construction permittees into municipal permits ("integration"), as well as a number of individual changes to the current industrial, construction, and municipal programs.

Improvements to the stormwater permitting program can be made in a tiered manner. Thus, individual recommendations specific to advancing one part of the municipal, industrial, or construction stormwater programs could be implemented immediately and with limited additional funds. "Integration" will need additional funding to provide incentives and to establish partnerships between municipal permittees and their associated industries. Finally, the watershed-based permitting approach will likely take up to ten years to implement. The following conclusions and recommendations about these options are made:

The greatest improvement to the EPA's Stormwater Program would be to convert the current piecemeal system into a watershed-based permitting system. The proposed system would encompass coordinated regulation and management of all discharges (wastewater, stormwater, and other diffuse sources), existing and anticipated from future growth, having the potential to modify the hydrology and water quality of the watershed's receiving waters.

The committee proposes centralizing responsibility and authority for implementation of watershed-based permits with a municipal lead permittee working in partnership with other municipalities in the watershed as co-permittees, with enhanced authority and funding commensurate with increased responsibility. Permitting authorities would adopt a minimum

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goal in every watershed to avoid any further loss or degradation of designated beneficial uses in the watershed's component waterbodies and additional goals in some cases aimed at recovering lost beneficial uses. The framework envisions the permitting authorities and municipal co-permittees working cooperatively to define careful, complete, and clear specific objectives aimed at meeting goals.

Permittees, with support from the permitting authority, would then move to comprehensive scientific and technically based watershed analysis as a foundation for targeting solutions. The most effective solutions are expected to lie in isolating, to the extent possible, receiving waterbodies from exposure to those impact sources. In particular, low-impact design methods, termed Aquatic Resources Conservation Design in this report, should be employed to the full extent feasible and backed by conventional SCMs when necessary. This report also outlines a monitoring program structured to assess progress toward meeting objectives and the overlying goals, diagnosing reasons for any lack of progress, and determining compliance by dischargers. The new concept further includes market-based trading of credits among dischargers to achieve overall compliance in the most efficient manner and adaptive management to program additional actions if monitoring demonstrates failure to achieve objectives.

Integration of the three permitting types, such that construction and industrial sites come under the jurisdiction of their associated municipalities, would greatly improve many deficient aspects of the stormwater program. Federal and state NPDES permitting authorities do not presently have, and can never reasonably expect to have, sufficient personnel to inspect and enforce stormwater regulations on more than 100,000 discrete point source facilities discharging stormwater. A better structure would be one where the NPDES permitting authority empowers the MS4 permittees to act as the first tier of entities exercising control on stormwater discharges to the MS4 to protect water quality. The National Pretreatment Program, EPA's successful treatment program for municipal and industrial wastewater sources, could serve as a model for integration.

Short of adopting watershed-based permitting or integration, a variety of other smaller-scale changes to the EPA stormwater program could be made now, as outlined below.

EPA should issue guidance for MS4, MSGP, and CGP permittees on what constitutes a design storm for water quality purposes. Precipitation events occur across a spectrum from small, more frequent storms to larger and more extreme storms, with the latter being a more typical focus of guidance manuals to date. Permittees need guidance from regional EPA offices on what water quality considerations to design SCMs for beyond issues such as safety of human life and property. In creating the guidance there should be a good faith effort to integrate water quality requirements with existing stormwater quantity requirements.

EPA should issue guidance for MS4 permittees on methods to identify high-risk industrial facilities for program prioritization such as inspections. Two visual methods for establishing rankings that have been field tested are provided in the chapter. Some of these high-risk industrial facilities and construction sites may be better covered by individual NPDES stormwater permits rather than the MSGP or the CGP, and if so would fall directly under the permitting authority and not be part of MS4 integration.

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EPA should support the compilation and collection of quality *industrial* stormwater effluent data and SCM effluent quality data in a national database. This database can then serve as a source for the agency to develop technology-based effluent guidelines for stormwater discharges from industrial sectors and high-risk facilities.

EPA should develop numerical expressions to represent the MS4 standard of Maximum Extent Practicable. This could involve establishing municipal action levels based on expected outfall pollutant concentrations from the National Stormwater Quality Database, developing site-based runoff and pollutant load limits, and setting turbidity limits for construction sites. Such numerical expressions would create improved accountability, bring about consistency, and result in implementation actions that will lead to measurable reductions in stormwater pollutants in MS4 discharges.

Communities should use an urban stream classification system, such as a regionally adapted version of the Impervious Cover Model, to establish realistic water quality and biodiversity goals for individual classes of subwatersheds. The goals for water and habitat quality should become less stringent as impervious cover increases within the subwatershed. This should not become an excuse to work less diligently to improve the most degraded waterways—only to recognize that equivalent, or even greater, efforts to improve water quality conditions will achieve progressively less ambitious results in more highly urbanized watersheds. This approach would provide stormwater managers with more specific, measurable, and attainable implementation strategies than the one-size-fits-all approach that is promoted in current wet weather management regulations.

Better monitoring of MS4s to determine outcomes is needed. Only a small fraction of MS4 communities have provided measurable outcomes with regard to aggregate flow and pollutant reduction achieved by their municipal stormwater programs. A framework and methods to evaluate program effectiveness for each of the six minimum management measures have been outlined by CASQA (2007) and should be adopted. In addition, the lack of monitoring requirements in the Phase II stormwater program makes it virtually impossible to measure or track actual pollutant load or runoff volume reductions achieved. It is recommended that both Phase I and II MS4s shift to a more collaborative monitoring paradigm to link management efforts to receiving water quality.

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Watershed-based permitting will require additional resources and regulatory program support. Such an approach shifts more attention to ambient outcomes as well as expanded permitting coverage. Additional resources for program implementation could come from shifting existing programmatic resources. For example, some state permitting resources may be shifted away from existing point source programs toward stormwater permitting. Strategic planning and prioritization could shift the distribution of federal and state grant and loan programs to encourage and support more watershed-based stormwater permitting programs. However, securing new levels of public funds will likely be required. All levels of government must recognize that additional resources may be required from citizens and businesses (in the form of taxes, fees, etc.) in order to operate a more comprehensive and effective stormwater permitting program.

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Appendixes

Appendix A
Acronyms

BAC	best attainable conditions
BAT	best available technology
BCG	Biological Condition Gradient
BCT	best control technology
BOD	biological oxygen demand
CAFO	concentrated animal feeding operation
CBWM	Chesapeake Bay Watershed Model
CCI	Census of Construction Industries
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CGP	Construction General Permit
CN	Curve Number
COD	chemical oxygen demand
COV	coefficient of variability
CWA	Clean Water Act
DHSVM	Distributed Hydrology, Soil, and Vegetation Model
EIA	effective impervious area
EMC	event mean concentration
ERP	Enforcement Response Plan
ETV	Environmental Technology Verification Program
EWH	exceptional warmwater habitat
FEMA	Federal Emergency Management Agency
FHWA	Federal Highway Administration
FIFRA	Federal Insecticide, Fungicide, and Rodenticide Act
GIS	Geographic Information System
GWLF	General Watershed Loading Function
HRU	Hydrologic Response Unit
HSPF	Hydrologic Simulation Program–Fortran
HUC	hydrologic unit code
ICM	Impervious Cover Model
KCRTS	King County Runoff Time Series
LDC	least disturbed conditions
LEED	Leadership in Energy and Environmental Design
LID	low-impact development
MDC	minimally disturbed conditions
MEP	maximum extent practicable
MGD	million gallons per day
MSGP	multi-sector industrial stormwater general permit
MTBE	methyl tert-butyl ether
NCSI	Normalized Channel Stabilization Index
NOI	Notice of Intent
NPDES	National Pollutant Discharge Elimination System
NRDC	Natural Resources Defense Council

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NRI	National Resource Inventory
NSQD	National Stormwater Quality Database
NTU	Nephelometric Turbidity Unit
NURP	National Urban Runoff Program
PAH	polycyclic aromatic hydrocarbons
PCB	polychlorinated biphenyl
POTW	publicly owned treatment works
PUD	planned unit development
RCRA	Resource Conservation and Recovery Act
RPA	Reasonable Potential Analysis
SBUH	Santa Barbara Unit Hydrograph
SCCWRP	Southern California Coastal Water Research Project Authority
SCM	stormwater control measure
SIC	Standard Industrial Classification
SLAMM	Source Loading and Management Model
SMDR	Soil Moisture Distributed and Routing
SWAT	Soil and Water Assessment Tool
SWMM	Stormwater Management Model
SWPPP	stormwater pollution prevention plan
TALU	tiered aquatic life use
TARP	Technology Acceptance and Reciprocity Partnership
TIA	total impervious area
TKN	total Kjedahl nitrogen
TMDL	total maximum daily load
TND	traditional neighborhood development
TOD	transit-oriented development
TSCA	Toxic Substances Control Act
TSS	total suspended solids
UAA	Use Attainability Analysis
UDC	unified development code
ULARA	Upper Los Angeles River Area
USLE	Universal Soil Loss Equation
WERF	Water Environment Research Foundation
WQA	Water Quality Act
WQS	water quality standard
WWH	warmwater habitat
WWHM	Western Washington Hydrologic Model
WWTP	wastewater treatment plant

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Appendix B
Glossary

Antidegradation: Policies which ensure protection of water quality from a particular waterbody where the water quality exceeds levels necessary to protect fish and wildlife propagation and recreation on and in the water. This also includes special protection of waters designated as outstanding natural resource waters. Antidegradation plans are adopted by each state to minimize adverse effects on water.

Best Management Practice (BMP): Physical, structural, and/or managerial practices that, when used singly or in combination, reduce the downstream quality and quantity impacts of stormwater. The term is synonymous with Stormwater Control Measure (SCM).

Biofiltration: The simultaneous process of filtration, infiltration, adsorption, and biological uptake of pollutants in stormwater that takes place when runoff flows over and through vegetated areas.

Bioinfiltration: A particular SCM that is like bioretention but has more infiltration, and thus would be categorized as an infiltration process.

Bioretention: A stormwater management practice that utilizes shallow storage, landscaping, and soils to control and treat urban stormwater runoff by collecting it in shallow depressions before filtering through a fabricated planting soil media. This SCM is often categorized under "filtration" although it has additional functions.

Buffer: The zone contiguous with a sensitive area that is required for the continued maintenance, function, and structural stability of the sensitive area. The critical functions of a riparian buffer (those associated with an aquatic system) include shading, input of organic debris and coarse sediments, uptake of nutrients, stabilization of banks, interception of fine sediments, overflow during high-water events, protection from disturbance by humans and domestic animals, maintenance of wildlife habitat, and room for variation of aquatic system boundaries over time due to hydrologic or climatic effects. The critical functions of terrestrial buffers include protection of slope stability, attenuation of surface water flows from stormwater runoff and precipitation, and erosion control.

> **Stream buffers** are zones of variable width that are located along both sides of a stream and are designed to provide a protective natural area along a stream corridor.

Combined Sewer Overflow (CSO): A discharge of untreated wastewater from a combined sewer system at a point prior to the headworks of a publicly owned treatment works. CSOs generally occur during wet weather (rainfall or snowmelt). During periods of wet weather, these systems become overloaded, bypass treatment works, and discharge directly to receiving waters.

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Combined Sewer System: A wastewater collection system that conveys sanitary wastewaters (domestic, commercial, and industrial wastewaters) and stormwater through a single pipe to a publicly owned treatment works for treatment prior to discharge to surface waters.

Constructed Wetland: A wetland that is created on a site that previously was not a wetland. This wetland is designed specifically to remove pollutants from stormwater runoff.

Created Wetland: A wetland that is created on a site that previously was not a wetland. This wetland is created to replace wetlands that were unavoidably destroyed during design and construction of a project. This wetland cannot be used for treatment of stormwater runoff.

Detention: The temporary storage of stormwater runoff in an SCM with the goals of controlling peak discharge rates and providing gravity settling of pollutants.

Detention Facility/Structure: An above- or below-ground facility, such as a pond or tank, that temporarily stores stormwater runoff and subsequently releases it at a slower rate than it is collected by the drainage facility system. There is little or no infiltration of stored stormwater, and the facility is designed to not create a permanent pool of water.

Drainage: Refers to the collection, conveyance, containment, and/or discharge of surface and stormwater runoff.

Drainage Area: That area contributing runoff to a single point measured in a horizontal plane, which is enclosed by a ridge line.

Drainage Basin: A geographic and hydrologic subunit of a watershed.

Dry Pond: A facility that provides stormwater quantity control by containing excess runoff in a detention basin, then releasing the runoff at allowable levels. Synonymous with detention basin, it is intended to be dry between storms.

Effluent Limitation: Any restriction imposed by the EPA director on quantities, discharge rates, and concentrations of pollutants that are discharged from point sources into waters of the United States, the waters of the contiguous zone, or the ocean.

Effluent Limitation Guidelines: A regulation published by the EPA Administrator under Section 304(b) of the Clean Water Act that establishes national technology-based effluent requirements for a specific industrial category.

Exfiltration: The downward movement of water through the soil; the downward flow of runoff from the bottom of an infiltration SCM into the soil.

Extended Detention: A stormwater design feature that provides for the gradual release of a volume of water in order to increase settling of pollutants and protect downstream channels from frequent storm events. When combined with a pond, the settling time is increased by 24 hours.

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Filter Strip: A strip of permanent vegetation above ponds, diversions, and other structures to retard the flow of runoff, causing deposition of transported material and thereby reducing sedimentation. As an SCM, it refers to riparian buffers, which run adjacent to waterbodies and intercept overland flow and shallow subsurface flow (both of which are usually sheet flow rather than a distinct influent pipe). The term is borrowed from the agricultural world.

Flood Frequency: The frequency with which the flood of interest may be expected to occur at a site in any average interval of years. Frequency analysis defines the n-year flood as being the flood that will, over a long period, be equaled or exceeded on the average once every n years.

Frequency of Storm (Design Storm Frequency): The anticipated period in years that will elapse, based on average probability of storms in the design region, before a storm of a given intensity and/or total volume will recur; thus, a 10-year storm can be expected to occur on the average once every 10 years. Sewers designed to handle flows which occur under such storm conditions would be expected to be surcharged by any storms of greater amount or intensity.

General Permit: A single permit issued to a large number of dischargers of pollutants in stormwater. General permits are issued by the permitting authority, and interested parties then submit a Notice of Intent (NOI) to be covered. The permit must identify the area of coverage, the sources covered, and the process for obtaining coverage. Once the permit is issued, a permittee may submit an NOI and receive coverage within a very short time frame.

Grab Sample: A sample which is taken from a stream on a one-time basis without consideration of the flow rate of the stream and without consideration of time.

Hotspot: An area where land use or activities generate highly contaminated runoff, with concentrations of pollutants in excess of those typically found in stormwater.

Hydrograph: A graph of runoff rate, inflow rate, or discharge rate, past a specific point as a function of time.

Hydroperiod: A seasonal occurrence of flooding and/or soil saturation; it encompasses depth, frequency, duration, and seasonal pattern of inundation.

Hyetograph: A graph of measured precipitation depth (or intensity) at a precipitation gauge as a function of time.

Impervious Surface or Impervious Cover: A hard surface area which either prevents or retards the entry of water into the soil. Common impervious surfaces include roof tops, walkways, patios, driveways, parking lots or storage areas, concrete or asphalt paving, gravel roads, packed earthen materials, and oiled surfaces.

Infiltration: The downward movement of water from the surface to the subsoil.

Infiltration Facility: A drainage facility designed to use the hydrologic process of runoff soaking into the ground, commonly referred to as percolation, to dispose of stormwater.

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Infiltration Pond: A facility that provides stormwater quantity control by containing excess runoff in a detention facility, then percolating that runoff into the surrounding soil.

Level Spreader: A temporary SCM used to spread stormwater runoff uniformly over the ground surface as sheet flow. The purpose of level spreaders is to prevent concentrated, erosive flows from occurring. Levels spreaders will commonly be used at the upstream end of wider biofilters to ensure sheet flow into the biofilter.

Municipal Separate Storm Sewer System: A conveyance or system of conveyances (including roads with drainage systems, municipal streets, catch basins, curbs, gutters, ditches, man-made channels, or storm drains) owned by a state, city, town, or other public body that is designed or used for collecting or conveying stormwater, which is not a combined sewer and which is not part of a publicly owned treatment works.

National Pollutant Discharge Elimination System: A provision of the Clean Water Act that prohibits the discharge of pollutants into waters of the United States unless a special permit is issued by EPA, a state, or, where delegated, a tribal government on an Indian reservation. The permit applies to point sources of pollutants to ensure that their pollutant discharges do not exceed specified effluent standards. The effluent standards in most permits are based on the best available pollution technology or the equivalent.

Nonpoint Source: Diffuse pollution source, but with a regulatory connotation; a source without a single point of origin or not introduced into a receiving stream from a specific outlet. The pollutants are generally carried off the land by stormwater. Some common nonpoint sources are agriculture, forestry, mining, dams, channels, land disposal, and saltwater intrusion.

Nonstructural SCM: Stormwater control measure that uses natural measures to reduce pollution levels, does not require extensive construction efforts, and/or promotes pollutant reduction by eliminating the pollutant source.

Peak Discharge Rate: The maximum instantaneous rate of flow during a storm, usually in reference to a specific design storm event.

Point Source: Any discernible, confined, and discrete conveyance, including but not limited to any pipe, ditch, channel, tunnel, conduit, well, discrete fixture, container, rolling stock, concentrated animal feeding operation, landfill leachate collection system, vessel, or other floating craft from which pollutants are or may be discharged.

Pollutant: A contaminant in a concentration or amount that adversely alters the physical, chemical, or biological properties of the natural environment. Dredged soil, solid waste, incinerator residue, filter backwash, sewage, garbage, sewage sludge, munitions, chemical wastes, biological materials, radioactive materials (except those regulated under the Atomic Energy Act of 1954, as amended), heat, wrecked or discarded equipment, rock, sand, cellar dirt and industrial, municipal, and agricultural waste discharged into water (EPA, 2008).

Polutograph: A graph of pollutant loading rate (mass per unit time) as a function of time.

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Predevelopment Conditions: Those conditions that existed at a site just prior to the development in question, which are not necessarily pristine conditions.

Pretreatment: The removal of material such as gross solids, grot, grease, and scum from flows prior to physical, biological, and chemical treatment processes to improve treatability. The reduction of the amount of pollutants, the elimination of pollutants, or the alteration of the nature of pollutant properties in wastewater prior to or in lieu of discharging or otherwise introducing such pollutants into a publicly owned treatment works [40 C.F.R. § 403.3(q)]. Pretreatment may include screening, grit removal, stormwater, and oil separators. With respect to stormwater, it refers to techniques employed in stormwater SCMs to help trap coarse materials and other pollutants before they enter the SCM.

Recharge: The flow of groundwater from the infiltration of stormwater runoff.

Recharge Volume: The portion of the water quality volume used to maintain groundwater recharge rates at development sites.

Retention: The process of collecting and holding stormwater runoff with no surface outflow. Also, the amount of precipitation on a drainage area that does not escape as runoff. It is the difference between total precipitation and total runoff.

Retention/Detention Facility: A type of drainage facility designed either to hold water for a considerable length of time and then release it by evaporation, plant transpiration, and/or infiltration into the ground, or to hold stormwater runoff for a short period of time and then release it to the stormwater management system.

Runoff: The term is often used in two senses. For a given precipitation event, direct *storm runoff* refers to the rainfall (minus losses) that is shed by the landscape to a receiving waterbody. In an area of 100 percent imperviousness, the runoff equals the rainfall. Over greater time and space scales, *surface water runoff* refers to streamflow passing through the outlet of a watershed, including base flow from groundwater that has entered the stream channel.

Soil Stabilization: The use of measures such as rock lining, vegetation, or other engineering structure to prevent the movement of soil when loads are applied to the soil.

Source Control: A type of SCM that is intended to prevent pollutants from entering stormwater. A few examples of source control are erosion control practices, maintenance of stormwater facilities, constructing roofs over storage and working areas, and directing wash water and similar discharges to the sanitary sewer or a dead end sump.

Stormwater: That portion of precipitation that does not naturally percolate into the ground or evaporate, but flows via overland flow, interflow, channels, or pipes into a defined surface water channel or a constructed infiltration facility. According to 40 C.F.R. § 122.26(b)(13), this includes stormwater runoff, snow melt runoff, and surface runoff and drainage.

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Stormwater Control Measure (SCM): Physical, structural, and/or managerial measures that, when used singly or in combination, reduce the downstream quality and quantity impacts of stormwater. Also, a permit condition used in place of or in conjunction with effluent limitations to prevent or control the discharge of pollutants. This may include a schedule of activities, prohibition of practices, maintenance procedures, or other management practices. SCMs may include, but are not limited to, treatment requirements; operating procedures; practices to control plant site runoff, spillage, leaks, sludge, or waste disposal; or drainage from raw material storage.

Stormwater Drainage System: Constructed and natural features which function together as a system to collect, convey, channel, hold, inhibit, retain, detain, infiltrate, divert, treat, or filter stormwater.

Stormwater Facility: A constructed component of a stormwater drainage system, designed or constructed to perform a particular function or multiple functions. Stormwater facilities include, but are not limited to, pipes, swales, ditches, culverts, street gutters, detention basins, retention basins, constructed wetlands, infiltration devices, catch basins, oil/water separators, sediment basins, and modular pavement.

Structural SCMs: Devices which are constructed to provide temporary storage and treatment of stormwater runoff.

Swale: A shallow drainage conveyance with relatively gentle side slopes, generally with flow depths of less than one foot.

> **Biofilter (**same as a **Biofiltration Swale):** A sloped, vegetated channel or ditch that provides both conveyance and water quality treatment to stormwater runoff. It does not provide stormwater quantity control but can convey runoff to SCMs designed for that purpose.
>
> **Dry Swale**: An open drainage channel explicitly designed to detain and promote the filtration of stormwater runoff through an underlying fabricated soil media. It has an underdrain.
>
> **Wet Swale:** An open drainage channel or depression, explicitly designed to retain water or intercept groundwater for water quality treatment.

Technology-Based Effluent Limit: A permit limit for a pollutant that is based on the capability of a treatment method to reduce the pollutant to a certain concentration.

Time of Concentration: The time period necessary for surface runoff to reach the outlet of a subbasin from the hydraulically most remote point in the tributary drainage area.

Total Maximum Daily Load (TMDL): The amount, or load, of a specific pollutant that a waterbody can assimilate and still meet the water quality standard for its designated use. For impaired waters the TMDL reduces the overall load by allocating the load among current

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pollutant loads (from point and nonpoint sources), background or natural loads, a margin of safety, and sometimes an allocation for future growth.

Volumetric Runoff Coefficient (R_v): The value that is applied to a given rainfall volume to yield a corresponding runoff volume based on the percent impervious cover in a drainage basin.

Water Quality-Based Effluent Limit (WQBEL): A value determined by selecting the most stringent of the effluent limits calculated using all applicable water quality criteria (e.g., aquatic life, human health, and wildlife) for a specific point source to a specific receiving water for a given pollutant.

Water Quality SCM: An SCM specifically designed for pollutant removal.

Water Quantity SCM: An SCM specifically designed to reduce the peak rate of stormwater runoff.

Water Quality Volume (W_{qv}): The volume needed to capture and treat 90 percent of the average annual stormwater runoff volume equal to 1 inch times the volumetric runoff coefficient (R_v) times the site area.

Wetlands: Those areas that are inundated or saturated by surface water or groundwater at a frequency and duration sufficient to support, and that under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soil conditions. Wetlands generally include swamps, marshes, bogs, and similar areas. This includes wetlands created, restored, or enhanced as part of a mitigation procedure. This does not include constructed wetlands or the following surface waters of the state intentionally constructed from sites that are not wetlands: irrigation and drainage ditches, grass-lined swales, canals, agricultural detention facilities, farm ponds, and landscape amenities.

Wet Pond: A facility that treats stormwater for water quality by utilizing a permanent pool of water to remove conventional pollutants from runoff through sedimentation, biological uptake, and plant filtration. Synonymous with a retention basin.

SOURCES: Most of the definitions are from EPA (2003), "BMP Design Considerations," 600/R-03/103, or EPA (2008), "Handbook for Developing Watershed Plans to Restore and Protect Our Waters," EPA 841-B-08-002.

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Appendix C
Summary of Responses from State Stormwater Coordinators

On February 21, 2007, on behalf of the committee, Jenny Molloy of EPA's Office of Wastewater Management sent the following questions to a group of state stormwater program managers and received six responses (found in Tables C-1 and C-2).

1. For industrial and/or construction: do you have information on non-filers, i.e., folks who should have submitted NOIs, but did not? If so, how old are these data, and how do they compare to overall numbers of those with permit coverage? How did you find and/or estimate the number of non-filers?

2. Also for industrial and/or construction: do you have information on compliance rates? Yes, this is a really broad question, but something along the lines of: based on inspections (or monitoring data, or whatever metric you use), have you made any determinations on numbers of facilities out of compliance, or alternatively, in compliance? If so, define what you mean by compliance (paper violations, SWPPP/BMP inadequacies, water quality standards violations, etc.).

TABLE C-1 Nonfilers

State	Information on Industrial Non-Filers	Estimate Percent Non-Filers as of Total	Basis of Estimate	Period of Estimate	Comment
CA	Yes	50 percent of heavy industry statewide 69 percent of industry within City of Los Angeles	Study—CA Water Board, 1999; Duke and Shaver, 1999. Study—Swamikannu et al., 2001	1995–1998 1998–2000	
MN	No				Study in progress
OH	No				Plan outreach to business
OR	No				Do not compile data
VT	Yes	88–90 percent of industry	Mass mailing	2006	No response from 2,400 of 3,000 mailings
WI	No				

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TABLE C-2 Compliance

State	Information on Compliance Rates	Estimate of Covered Facilities Non-Compliant	Basis of Estimate	Period of Estimate	Comment
CA	Yes (Construction)	40 percent deficient in paperwork; 30 percent with inadequate E&S controls	MS4 construction audit in Los Angeles and Ventura counties, and large CGP construction sites	2002, 2004, and 2005	Prioritized large CGP sites for inspection
	Yes (Industrial)	60 percent poor house-keeping practices; 40 percent incomplete SWPPPs	Transportation sector, plastics manufacturing inspections in Los Angeles County	2005 and 2007	
NH	No				Inspect in response to complaints
OH	No				Inspect construction sites as a priority
OR	No				Do not compile data
VT	No				Plan to inspect for compliance
WV	Yes (Industrial)	66 percent failed to submit report	Monitoring report submittal tracking	2007	Mailed deficiency notices
WI	Yes (Construction)	38 percent with minor and 43 percent with major violations	A subsample of 1 percent of CGP sites	2007	Perform inspections annually; no central database tracking

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In September 2007, the NRC Committee on Reducing Stormwater Discharge Contributions to Water Pollution sent the following survey to 50 state stormwater program managers. Responses were received from 18 states, including at least one from every EPA region. The blank survey is shown below, and Tables C-3 through C-9 contain the states' responses.

The NRC committee members will greatly appreciate receiving the following information from State Stormwater Coordinators. Please complete both sides of this form and return to Xavier Swamikannu, CalEPA, Los Angeles Regional Water Board, xswamikannu@waterboards.ca.gov or Fax: (213) 576-6625.

State:
Name of information provider:

Please summarize your State's Stormwater Permit Program

	Municipal Permit	Industrial General Permit	Construction General Permit
What are the monitoring requirements?			
How is compliance demonstrated (monitoring or other activity)?			
To whom is the SWPPP submitted?			
Can an MS4 perform an inspection of an industry within its boundary?			
What industries are considered "high-risk"?			
Do BMP manuals exist for implementation guidance?			
No. of dedicated staff or FTEs			

Does your State Storm Water BMP Manual contain the following, and what are they?

WQ sizing criteria	
Recharge criteria	
Channel protection criteria	
Overbank flood criteria	
Extreme flows	
Acceptable BMP list	
Detailed engineering specs for BMPs	
Soil and erosion control requirements (unless this is left to the local government)	

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TABLE C-3 Monitoring Requirements

State	Municipal	Industrial	Construction
Alabama	Monitoring requirements are specific to the Phase I MS4. MS4 Phase II permit does not require monitoring.	Monitoring is specific to the General Permit type and associated discharge. Alabama has 18 NPDES Industrial Stormwater General Permits. http://www.adem.state.al.us/genpermits.htm	Monitoring is required under specific conditions, but in general compliance with the permit does not require monitoring. ADEM Admin. Code Chapter 335-6-12 is attached.
California	Monitoring requirements are specific to the Phase 1 MS4 permits. MS4 Phase II permit monitoring is discretionary.	2 wet weather sampling events per year – 4 basic parameters and other pollutants known to be on site. Quarterly visual monitoring.	Visual monitoring before, during, and after rain events. Analytical monitoring for discharges to sediment-impaired waterbodies.
Connecticut	Sample six outfalls once a year. Twelve chemical parameters.	Sample all outfalls once a year. Ten chemical parameters plus aquatic toxicity.	None, yet. Soon to modify permit to sample for turbidity.
Georgia	Dry weather outfall screening.	Standard monitoring from the EPA MSGP. Additional monitoring for the pollutant of concern for industries that may be causing or contributing to stream impairment.	Monitoring is required for a qualifying rain event (0.5 inch) once after clearing and grubbing, and once after mass grading.
Hawaii	Visual and water chemistry sampling.	Visual and water chemistry sampling.	Visual
Maine	None	No benchmark monitoring, only effluent limitations. Additional monitoring upon request based on discharges, complaints, audits, or inspections	None
Minnesota	The Phase I MS4 permits for Minneapolis and St. Paul require monitoring. MS4 Phase II permit does not require monitoring.	The current state MSGP does not have monitoring requirements. The proposed next term draft permit would require at least 4 stormwater monitoring events per year.	The current state CGP does not require monitoring. The proposed next term draft permit is not expected to include monitoring.
Nebraska	Stormwater monitoring required on different use sites. BMP monitoring.	None. Monitoring can be required by the director through permit.	None. Monitoring can be required by the director through permit.
Nevada	Required for storm events that produce runoff.	None	None
New York	Ad hoc	Similar to monitoring in the EPA MSGP.	None. Self-inspection.

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State	Municipal	Industrial	Construction
Ohio	Phase I MS4 permits require some chemical and biological monitoring. Phase II MS4 permit does not require mandatory monitoring, although recommended as part of IDDE program.	Similar to monitoring in the EPA MSGP, except annually. No priority chemical monitoring required.	For the state CGP, no chemical monitoring. For special watershed CGPs associated with TMDLs, TSS monitoring required.
Oklahoma	Phase 1 MS4s permits require dry weather monitoring, floatables monitoring, and watershed characterization monitoring, including biological assessments.	Quarterly visual monitoring and annual analytical monitoring.	None
Oregon	Monitoring requirements are specific to the Phase I MS4. The Phase II MS4 permit does not require monitoring, though some permittees do monitor on their own accord. The average frequency is 2-4 times a year.	Industrial facilities required to sample their stormwater discharge 4 times per year. Also required to conduct visual monitoring of their discharge on a monthly basis when discharge is present. Mining sites in addition are subject to the same requirements as in the state CGP since sediment is the main pollutant of concern.	None. However, permittees discharging stormwater to waters listed specifically for turbidity/sedimentation on the most recent 303(d) list or that have a TMDL for turbidity/sedimentation have the option of either monitoring for turbidity or implementing additional BMPs.
Vermont	None other than the development of an IDDE program and follow-up until elimination occurs	Benchmark monitoring for individual sectors, quarterly for the first year. Visual inspection 4 times per year. Effluent limitations (if applicable) once per year.	None at present. Turbidity monitoring for moderate-risk projects included in draft CGP.
Virginia	Monitoring requirements are specific to the Phase I MS4 permit. The Phase II MS4 permit does not require monitoring.	Benchmark and effluent limitation (the same as EPA's 2000 MSGP), except we only require one sample per year for benchmark samples.	None
Washington	Monitoring requirements are specific to the Phase I MS4, *Outfall conveyance system monitoring*. Selected outfalls for representative land uses are monitored intensively for a wide range of chemical constituents including toxicity. *BMP effectiveness*	Industry required to sample for turbidity, pH, zinc, and petroleum oil and grease. If exceeds zinc benchmark, then also need to monitor for total copper, total lead, and hardness. There are additional monitoring requirements for different	All state CGP sites are required to do weekly monitoring for turbidity and pH. If benchmark exceeded, specific actions/responses are triggered. For sites which discharge to waters impaired by phosphorous, turbidity, fine sediments, or

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State	Municipal	Industrial	Construction
	monitoring. Selected stormwater BMPs are monitored to determine performance and how effective the designs are. The Phase II MS4 permit does not require monitoring, except as required under the IDDE program or for a TMDL.	industry categories. For discharges to impaired 303(d) waters monitor required for the pollutants for which the waterbody is impaired.	high pH, monitoring required for these parameters additionally.
West Virginia	NA	Benchmark monitoring. Sector specific.	None
Wyoming	None	Benchmark monitoring for timber, metal mining, concrete and gypsum, junkyards and recycling. Effluent limitation monitoring for coal piles, concrete manufacture, and asphalt emulsion.	None

NOTE: NA, not answered.

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TABLE C-4 How is Compliance Demonstrated?

State	Municipal	Industrial	Construction
Alabama	MS4 Phase I – monitoring and BMPs MS4 Phase II – BMPs	Monitoring reporting and BMP implementation	Inspections. Monitoring; SWPPP implementation during inspection; aerial reconnaissance
California	Annual and monitoring reporting. MS4 audits and inspections.	Annual and monitoring reporting. Inspections.	Annual certifications. Inspections
Connecticut	Annual and monitoring reporting.	Annual and monitoring reporting. Inspections.	Inspections. SWPPP review and implementation for large projects.
Georgia	Annual and monitoring reporting.	Annual and monitoring reporting.	Reporting.
Hawaii	Annual and Monitoring reporting. Inspections.	Annual and monitoring reporting. Inspections.	Inspections. Reporting.
Maine	Annual reporting and municipal audits.	Inspections and audits, at least two per 5-year permit term.	NA
Minnesota		Annual reporting and inspections.	
Nebraska	MS4 audits and annual reporting.	Inspections and SWPPP implementation.	Inspections and SWPPP implementation—complaint only.
Nevada	Annual reporting, MS4 audits, inspections.	Annual reporting, inspections	Inspections.
New York	Annual reporting and MS4 audits.	Annual and monitoring reporting. Inspections.	Inspections and SWPPP implementation.
Ohio	Annual reporting.	SWPPP implementation.	SWPPP implementation.
Oklahoma	Annual reporting. MS4 audits and compliance schedules.	Annual and monitoring reporting. Inspections.	SWPPP implementation and inspections based on complaints received.
Oregon	Annual and monitoring reporting.	Annual and monitoring reporting. Action Plan approval.	Inspections and SWPPP implementation.
Vermont	Annual reporting and MS4 audits.	Monitoring reporting.	Inspections, recordkeeping.
Virginia	Registration statement BMP implementation.	Monitoring reporting and inspections.	Inspections. SWPPP and E&S plan implementation.
Washington	Implementation of prescriptive stormwater management program.	Monitoring reporting and inspections.	Inspections and monitoring reporting.
West Virginia	NA	SWPPP implementation and monitoring reporting.	Inspections. SWPPP implementation.
Wyoming	Periodic MS4 audits.	Inspections, monitoring reporting.	Inspections.

NOTE: NA, not answered.

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TABLE C-5 To Whom Is the SWPPP Submitted?

State	Municipal	Industrial	Construction
Alabama	MS4 Phase I – Storm Water Management Program (SWMP) sent to state. Should be available for review at the time of inspection. (SWPPP information should also be provided to the department.) MS4 Phase 2 – SWMP submitted with the Notice of Intent (NOI).	No submittal to state. The SWPPP must be kept on site and made available for review at the time of inspection.	No submittal to state. The SWPPP must be kept on site and made available for review at the time of inspection. SWPPP required to be submitted under certain circumstance during registration and re-registration.
California	MS4 Phase 1 – SWMP incorporated as prescriptive requirements in the permit. MS4 Phase 2 – SWMP submitted to state with NOI	No submittal to state. The SWPPP must be kept on site and made available for review at the time of inspection.	No submittal to state. The SWPPP must be kept on site and made available for review at the time of inspection.
Connecticut	NA	The SWPPP is submitted to the state only if requested.	The SWPPP is submitted to the state only if requested.
Georgia	The SWMP is submitted to the state.	The SWPPP is submitted to the state only if requested. Otherwise it is kept on-site.	The E&S Control Plan equivalent to the SWPPP is submitted to the Local Issuing Authority. It is also submitted to the state if the project disturbs more than 50 ac, or if there is no LIA.
Hawaii	NA	The SWMP is submitted to the state.	The SWMP is submitted to the state.
Maine	NA	The SWPPP is submitted to the state only if requested.	The E&S Control Plan equivalent to the SWPPP is submitted to the state for review.
Minnesota	Phase 1 MS4 - The SWMP is submitted to the state for review and public notice.	The SWPPP is not required to be submitted to the state.	The SWPPP must be must be submitted to the state for review for projects disturbing 50 acres or more, and has a discharge point within 2,000 feet of an impaired or special water listed in the state CGP. A SWPPP must also be submitted for projects proposing to use alternative method(s) for the permanent stormwater management system.

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State	Municipal	Industrial	Construction
Nebraska	NA	The SWPPP is submitted to the state only if requested.	The SWPPP is submitted to the MS4 permittee and to the state when requested.
Nevada	NA	No submittal to state. The SWPPP must be kept on site.	No submittal to state. The SWPPP must be kept on site.
New York	NA	Some SWPPPs submitted to state (very few).	About 1/6 SWPPPs submitted to state.
Ohio	NA	The SWPPP is submitted to the MS4 permittee and to the state when requested.	The SWPPP is submitted to the state.
Oregon	NA	The SWPPP is submitted to the state on first application and when renewing coverage under the state MSGP.	The SWPPP is submitted to the state on first application and when renewing coverage under the state CGP. Projects that are greater than 5 acres are subject to public notice and comment.
Vermont	NA	A copy of the SWPPP is submitted to the state, and the original kept on site.	The E&S Control Plan is submitted to the state. Low-risk projects have a standard assigned E&S Control Plan – "Low Risk Handbook".
Virginia	NA	No submittal to the state. The SWPPP must be kept on-site.	No submittal to the state. The SWPPP must be kept on-site.
Washington	NA	The SWPPP is submitted to the state upon first application only. Otherwise, the SWPPP must be kept on site and must be made available to the state, the MS4 permittee, or the public upon request.	The SWPPP is not submitted to the state. The SWPPP must be kept on site and must be made available to the state, the MS4 permittee or the public upon request.
West Virginia	NA	The SWPPP is submitted to the state upon first application only.	The SWPPP is submitted to the state.
Wyoming	NA	The SWPPP is submitted to the state for facilities >50 ac. Class 1 waters not eligible for coverage under the state MSGP.	The SWPPP is submitted to the state for projects >100 ac or on Class 1 waters.

NOTE: NA, not applicable.

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TABLE C-6 Can an MS4 Inspect Industries Within Its Boundary?

Alabama	Yes, if adequate legal authority exists.
California	Yes. Local agencies inspection to ensure compliance with local stormwater or municipal ordinance.
Connecticut	Yes. Nothing specific. State MSGP requires industries to comply with the stormwater management program of the MS4 in which they are located.
Georgia	Yes
Hawaii	Yes
Maine	Yes
Minnesota	Yes. Capability to do this varies with the MS4.
Nebraska	Yes. Phase 1 MS4s only.
Nevada	Yes
New York	Yes. MS4s can inspect for illicit discharge detection and elimination. Industries can be inspected under local authority, but local inspections are infrequently conducted.
Ohio	Yes. Phase I MS4s can check for MSGP coverage and that a SWPPP exists in conjunction with pretreatment inspections.
Oklahoma	Yes
Oregon	Yes, under various authorities. Pretreatment, industrial stormwater, construction stormwater, etc.
Vermont	Yes. The MS4 can request an inspection but can be denied access.
Virginia	No. No state statute for private property access to inspect for stormwater management. Some do use Fire Marshall's authority through the fire code.
Washington	Yes
West Virginia	NA
Wyoming	Yes. If the MS4 has authority.

NOTE: NA, not answered.

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TABLE C-7 What Industries Are Considered High Risk?

Alabama	Metal foundries.
California	None specified in the state MSGP. Some MS4 permits may specify high-risk industries. Construction activity discharging to sediment-impaired waterbodies are identified as high risk in the state CGP.
Connecticut	None specified in the state MSGP.
Georgia	None specified in the state MSGP. Facilities that may be causing or contributing to stream impairment are high risk.
Hawaii	None specified in the state MSGP
Maine	Auto salvage, scrap metal recycling, boatyards and marinas, concrete and asphalt, batch plants, vehicle maintenance facilities.
Minnesota	None specified in the state MSGP. Heavy industries are considered higher risk.
Nebraska	Ethanol, scrap metal recycling.
Nevada	Waste oil recyclers, auto salvage, aggregate mines, cement plants.
New York	Auto salvage, scrap recycling.
Ohio	None specified in the state MSGP. Individual stormwater permits required for some airports, landfills, sand and gravel operations, and bulk terminals.
Oklahoma	None specified in the state MSGP.
Oregon	None specified in the state MSGP.
Vermont	None specified in the state MSGP. Gravel pits, salvage yards, scrap recycling facilities are considered high risk.
Virginia	None specified in the state MSGP.
Washington	MS4 permit identifies a list of industries and land uses that the permittee must inspect (See Permit appendix 8).
West Virginia	None specified in the state MSGP. Mills and auto salvage yards are considered high risk.
Wyoming	None specified in the state MSGP. Case by case based on proximity to high class waters and industry type.

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TABLE C-8 Do State BMP Manuals Exist for Implementation Guidance?

State	Municipal	Industrial	Construction
Alabama	No. Use EPA materials.	No. Use EPA Materials.	Yes. State E&S Manual. http://swcc.state.al.us/erosion_handbook.htm
California	Yes. CASQA and Caltrans manuals. Not officially adopted.	Yes. CASQA and Caltrans manuals. Not officially adopted	Yes. CASQA and Caltrans manuals. Not officially adopted.
Connecticut	No	No. An SWPPP guidance document is available online.	Yes. E&S Guidelines (2002) and CT Stormwater Quality Manual (2004).
Hawaii	No. Use EPA materials.	No. Use EPA materials.	No. Use EPA materials.
Georgia	Yes. Georgia Stormwater Management Manual.	No. Use EPA materials.	Yes. Manual for Erosion and Sediment Control in Georgia.
Maine	Yes	Yes	Yes
Minnesota	Yes. The Minnesota Stormwater Manual at: http://www.pca.state.mn.us/water/stormwater/stormwater-manual.html Stormwater BMPs – Protecting Water Quality in Urban Areas at: http://www.pca.state.mn.us/water/pubs/sw-bmpmanual.html	No. Plan to develop one.	Yes. Fact sheets and guidance at: http://www.pca.state.mn.us/water/stormwater/stormwater-ms4.html#bmp
Nebraska	No	No	No
Nevada	Yes	Yes	Yes
New York	Yes	Yes. A few state materials.	Yes
Ohio	No. Use EPA materials.	No. Use EPA materials.	Yes. http://www.dnr.state.oh.us/water/rainwater/default/tabid/9186/Default.aspx
Oklahoma	No. Use EPA materials.	No. Use EPA materials.	No. Use EPA materials.
Oregon	No	No. Have BMP technical assistance guidance documents.	Yes. Use of Oregon BMP manual is optional.
Vermont	Yes	No	Yes. Standards for designers, a field guide for contractors (2006), and the Low Risk Handbook.
Virginia	Yes. E&S control and stormwater handbooks.	No	Yes. E&S control and stormwater handbooks.

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State	Municipal	Industrial	Construction
Washington	Yes. Stormwater Management Manual for Western Washington (2005) and Stormwater Management Manual for Eastern Washington (2004)	Yes. http://www.ecy.wa.gov/programs/wq/stormwater/manual.html	Yes. http://www.ecy.wa.gov/programs/wq/stormwater/eastern_manual/index.html
West Virginia	No	No	Yes
Wyoming	No	No. Refer to manuals from other states.	No. Refer to manuals from other states.

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TABLE C-9 Full-Time Staff Dedicated to the Stormwater Program

State	Municipal	Industrial	Construction	Total Statewide
Alabama	1.5	7	25–30	33.5–38.5
California				89
Connecticut				5
Georgia	4.5	2.5	46	53
Hawaii	0.5	1	2	3.5
Maine	0.7	2.5	NA	
Minnesota		4.3	14	36
Nebraska				3
Nevada	1	1.5	3	5.5
New York	7	1	11	19
Ohio				18
Oklahoma				7
Oregon	1	4–5 (shared with construction)	4–5 (shared with industrial)	5–6
Vermont	0.5	2	5	7.5
Virginia	3	8 (shared with other programs)	10	13
Washington	10	17	16	43
West Virginia	NA	1	5	
Wyoming				4

NOTE: NA, not answered.

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Appendix D
Select Stormwater Model Descriptions and Application

DESCRIPTION OF THE SOIL AND WATER ASSESSMENT TOOL

The Soil and Water Assessment Tool (SWAT) model (Arnold et al., 1998; Arnold and Fohrer, 2005; Gassman et al., 2007) is a tool for assessing water resource and nonpoint source pollution problems for a wide range of scales and environmental conditions across the globe (SWAT, 2008). SWAT is being used in the United States to support total maximum daily load (TMDL) analysis, to research the effectiveness of conservation practices within the U.S. Department of Agriculture Conservation Effects Assessment Program initiative (Mausbach and Dedrick, 2004; CEAP, 2007), to perform "macro-scale assessments" for large regions such as the upper Mississippi River basin (Arnold et al., 1999; Jha et al., 2006), and for a wide range of other water use and water quality applications. It is primarily used in agricultural watersheds, but an agricultural model must be used with an urban runoff model, such as WinSLAMM, when a watershed has both urban and agricultural nonpoint sources.

SWAT has been found to be sound and suitable for long-term continuous simulations in agricultural watersheds (Borah and Bera, 2004). Although the model is primarily used for evaluating agricultural runoff problems, it is very useful for evaluating sources of pollutants and the benefits of management practices in watersheds containing both agricultural and urban areas, especially for TMDL analysis. Output from urban management models, such as WinSLAMM, can be input to SWAT for a mass balance analysis of pollutant sources and an evaluation of the most cost-effective approach to achieving pollutant reduction goals.

SWAT is a basin-scale, continuous-time model that operates on a daily time step and is designed to predict the impact of management (point and nonpoint) on water, sediment, and agricultural chemical yields in ungauged watersheds. The model is a physically based model developed to simulate landscape processes with a high level of spatial detail in large watersheds. A watershed is divided into multiple subwatersheds, which are then further subdivided into hydrologic response units (HRUs) that consist of homogeneous land-use, management, and soil characteristics. A watershed can also be divided into only subwatersheds that are characterized by dominant land uses, soil type, and management.

Processes simulated in the model are driven by the water balances in the watershed. The water balance is separated into a land phase and a routing phase of the hydrologic cycle. Loads of water, sediment, nutrients, and pesticides are controlled by the land phase. The routing phase determines the movement of water, sediments, nutrients, and pesticides through the channel network to the outlet of the watershed. The overall hydrologic balance is calculated for each HRU. This combination of upland and channel processes is an important strength of SWAT.

Input information required to run the model include climatic data, soil properties, topography, vegetation, and land management practices in the watershed. Since most of the inputs are physically based or readily available, the watersheds can be modeled without collecting any monitoring data. It is important to note that SWAT is not a "parametric model" with a formal optimization procedure to fit any data (Santhi et al., 2005). Instead, a few important variables that are not well defined physically—such as runoff curve number, or the

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Universal Soil Loss Equation's cover and management factor—may be adjusted to provide a better fit.

A key strength of SWAT is a flexible framework that allows the simulation of a wide variety of conservation practices and other best management practices, such as fertilizer and manure application rates and timing, cover crops, filter strips, conservation tillage, irrigation management, flood prevention structures, grassed waterways, and wetlands. The majority of conservation practices can be simulated in SWAT with straightforward parameter changes.

THE SOURCE LOADING AND MANAGEMENT MODEL

WinSLAMM, the Source Loading and Management Model, was developed starting in the mid-1970s as part of early EPA street cleaning and receiving water projects in San Jose (Pitt, 1979) and Coyote Creek, California (Pitt and Bozeman, 1982). The primary purpose of the model is to identify sources of urban stormwater pollutants and to evaluate the efficiency of stormwater control measures. During the mid-1980s, the model was expanded to include more management options beyond street cleaning. The Nationwide Urban Runoff Program projects (EPA, 1983) provided a large dataset for model, especially for Alameda County, California (Pitt and Shawley, 1982); Bellevue, Washington (Pitt and Bissonnette, 1994); and Milwaukee, Wisconsin (Bannerman et al., 1983). Research funded by the Ontario Ministry of the Environment, Ottawa (Pitt, 1987), and the Toronto Area Watershed Management Strategy study in the Humber River (Pitt and McLean, 1986) also provided much information on bacteria sources in urban areas. During the mid-1980s, the model started to be used by the Wisconsin Department of Natural Resources (DNR) in their Priority Watershed Program (Pitt, 1986). The first Windows version of the model was developed in 1995 and the current version is 9.3. The model is continuously being updated based on user needs and new research (recent and current support from the Stormwater Management Authority of Jefferson County, Alabama; the Tennessee Valley Authority, Economic Development group; WI DNR; the USGS; and Imbrium). The next version currently being developed will include drag-and-drop watershed elements and more complete routing options.

Over the years, WinSLAMM has been extensively revised and expanded and now includes a wide range of capabilities. The following lists several important model features:

- The model can evaluate a long series of rain events; usually one to five years of typical rains are used, but several decades of rains can be evaluated.
- The model is based on actual field data. Street dirt accumulation and wash-off equations and direct runoff from paved surfaces during all rains are used, for example, based on many thousands of actual measurements.
- The effects of compacted urban soils are also considered.
- Uncertainties of many modeling parameters are represented by built-in Monte Carlo components.
- Costs of control practices can be directly calculated and considered in model runs.
- Runoff flow-duration probability distributions and associated receiving water biological conditions are calculated based on site conditions and the control measures being used.
- The model can be interfaced with several other models for more detailed drainage system and receiving water evaluations.

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Prior descriptions of WinSLAMM have been presented during the Engineering Foundation and in the Urban Water Modeling Conference series, and in other publications (e.g., Pitt, 1986, 1997, 1999; Pitt and Voorhees, 2002). The model website (http://www.winslamm.com/) also contains further model descriptions and references. The applications of WinSLAMM include the following:

- Permit compliance—municipal pollutant loadings and discharge reductions
- Evaluate alternative stormwater controls
    - City-wide
    - Watershed
    - Site development
- Identify critical drainage areas:
    - ID critical land uses
    - ID critical source areas
    - Assist with cost-sharing
    - Identify the most cost-effective stormwater control and development scenarios.

WinSLAMM is an urban stormwater model (it does not directly address agricultural areas, etc.). It is designed to be effective for multiple scales (individual lots to whole communities) and to calculate annual or seasonal pollutant loads. It evaluates individual or multiple stormwater control scenarios (source area, land use, drainage, outfalls), as shown in the following table:

	Hydro-dynamic Devices	Wet Detention Ponds	Street Cleaning	Biofil-tration	Porous Pave-ment	Rain Barrels/ Tanks	Beneficial Uses of Stormwater	Grass Swales	Catch-basin Cleaning	Drainage Disconnec tions
Roof	X	X		X		X	X			X
Paved Parking/Storage	X	X		X	X	X	X			X
Unpaved Parking/Storage	X	X		X		X	X			X
Playgrounds	X	X		X	X	X	X			X
Driveways		X		X	X	X	X			X
Sidewalks/Walks		X		X	X	X	X			X
Streets/Alleys			X	X		X	X			
Undeveloped Areas	X	X		X		X	X			
Small Landscaped Areas	X	X		X		X	X			
Other Pervious Areas	X	X		X		X	X			
Other Impervious Areas	X	X		X	X	X	X			X
Freeway Lanes/Shoulders	X	X					X			
Large Landscaped Areas	X	X					X			
Land Uses (multiple source areas)				X		X	X	X		
Drainage System	X			X	X	X	X	X	X	
Outfall	X	X		X		X	X			

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The effectiveness of stormwater control measures (SCMs) are calculated based on the actual sizing and other attributes of the devices, the source area or outfall location characteristics, and the calculated runoff characteristics. The model does a complete mass balance and routing of water volume and particulate mass, considering the combined effects of all controls. Hydraulic and particle size routing occurs individually for each device, although serial effects of multiple devices are being expanded for these parameters in the newer model versions. The effects of the sedimentation controls are calculated using modified Puls hydraulic routing with surface overflow rate particulate routing. The performance of wet ponds has been verified by extensive monitoring of several ponds (http://unix.eng.ua.edu/~rpitt/SLAMMDETPOND/WinDetpond/WinDETPOND%20user%20guide%20and%20documentation.pdf). The infiltration and biofiltration devices use a combination of hydraulic routing with infiltration and evaporation losses, plus any pumped withdrawals. Evapotranspiration losses are being added to the devices in the next model update. Underdrain filtering is based on extensive tests of media filtration. Grass swale performance is calculated based on extensive laboratory and outdoor testing of particulate trapping of shallow flowing water and infiltration losses (Johnson et al., 2003; Kirby et al., 2005; Nara et al., 2006). Porous pavement performance is calculated based on infiltration losses and clogging effects. Street cleaning and catch-basin benefits are based on extensive EPA research, and newer updated research that has examined modern equipment. Hydrodynamic devices are based on the basic sedimentation processes but have been verified by tests conducted by the USGS and the DNR, plus continued tests at the University of Alabama. The following figure shows some example screen shots used to enter information for some of the controls.

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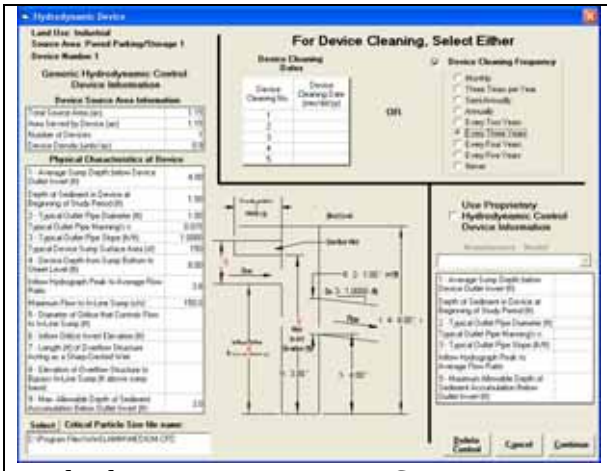
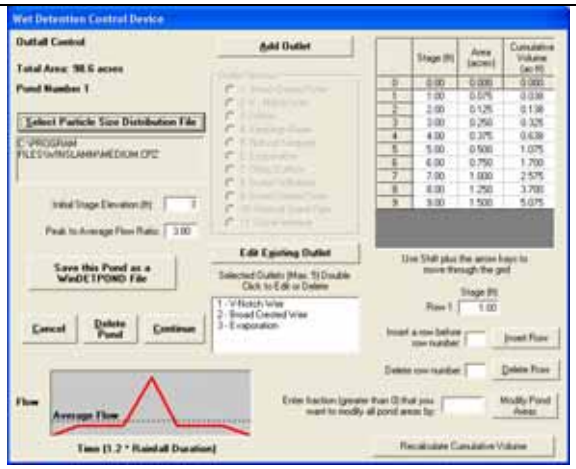
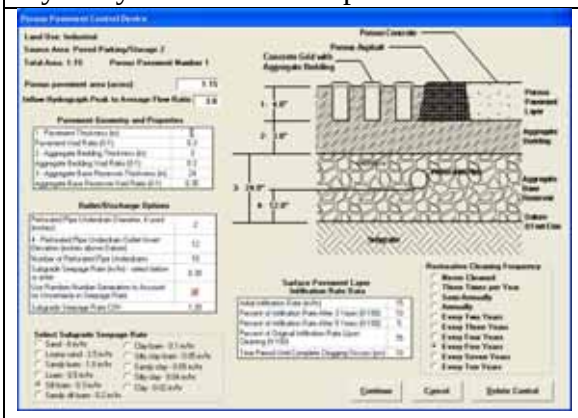


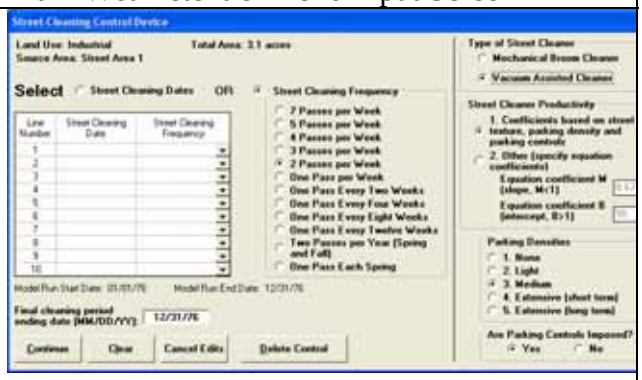
Hydrodynamic Device Input Screen



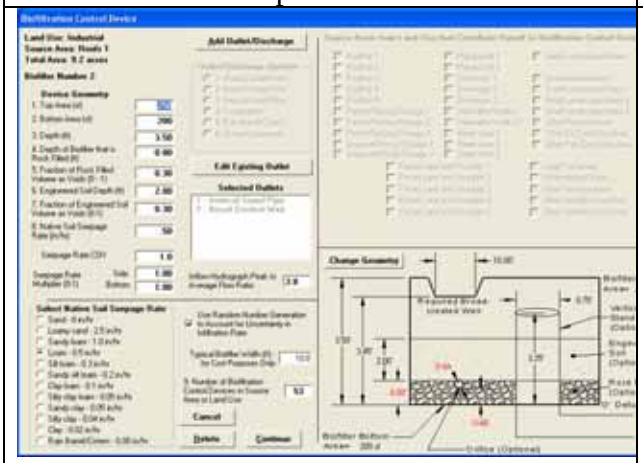
Main Wet Detention Pond Input Screen



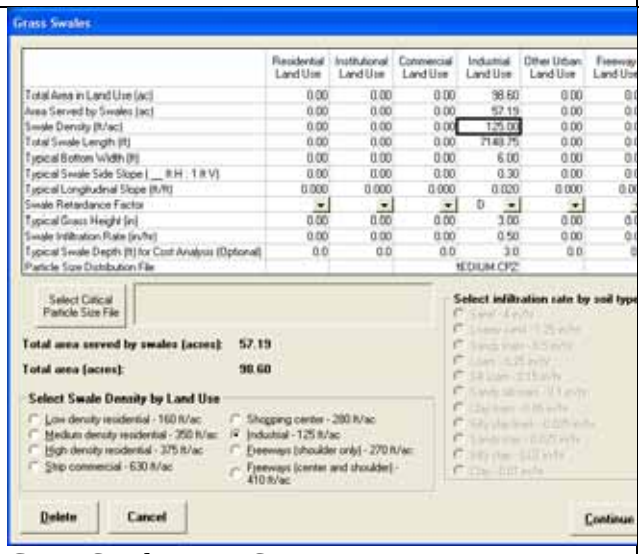
Porous Pavement Input Screen



Street Cleaning Input Screen



Biofilter Input Screen



Grass Swale Input Screen

Example control practice input screens for WinSLAMM.

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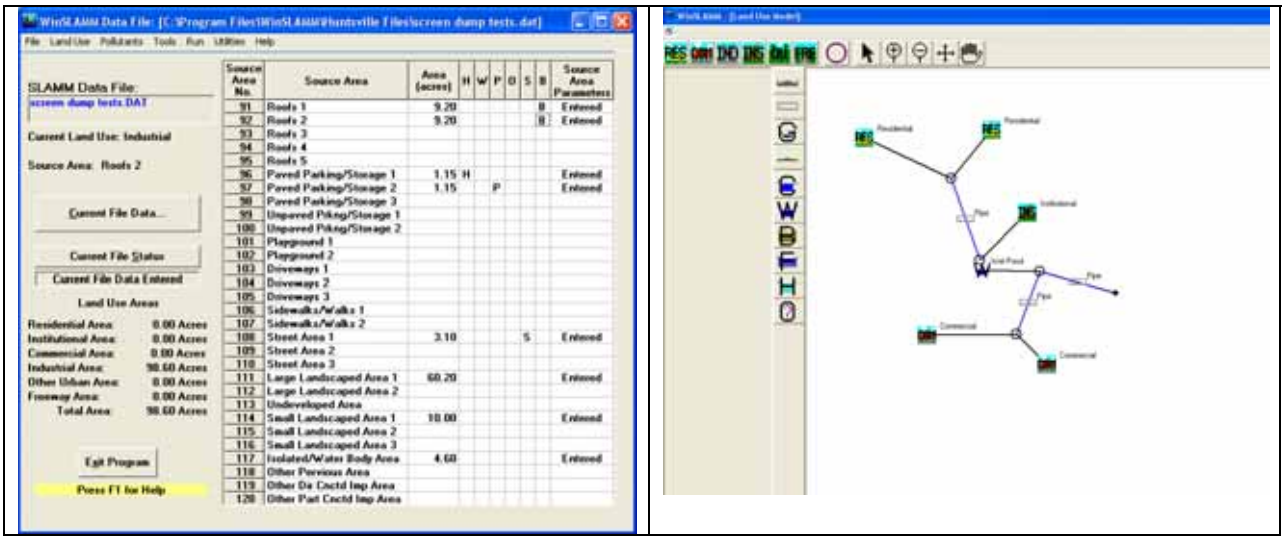
Each land use is described by characterizing elements for each source area within the land use, including source area and land-use controls. Outfall and drainage system controls are described using the dropdown menus. A new drag-and-drop interface is currently being developed that will allow greater efficiency and flexibility in placement of controls and multiple land-use source areas. The following figure shows these screens.



Current source area WinSLAMM screen and new drag-and-drop routing screen being developed.

The calculated outputs from WinSLAMM are organized in several tiers. For most of the output options, a summary table is presented. The data in the summary table includes the following information:

- Runoff volume (ft^3, percent reduction; and R_v, runoff coefficient), particulate solids (lbs and mg/L), for
    - source area total without controls,
    - total before drainage system,
    - total after drainage system, and
    - total after outfall controls.
- Total control practice costs:
    - capital costs,
    - land cost,
    - annual maintenance cost,
    - present value of all costs, and
    - annualized value of all costs.
- Receiving water impacts due to stormwater runoff:
    - calculated R_v with and without controls,
    - approximate biological condition of receiving water (good, fair, or poor), and
    - flow duration curves (probabilities of flow rates for current model run and without controls).

Most of this information is included on the first output page, while the flow duration curves are included on an optional second page, as shown in the following figure.

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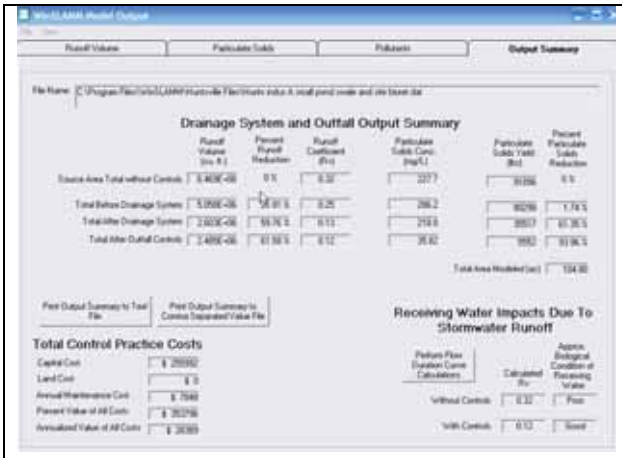
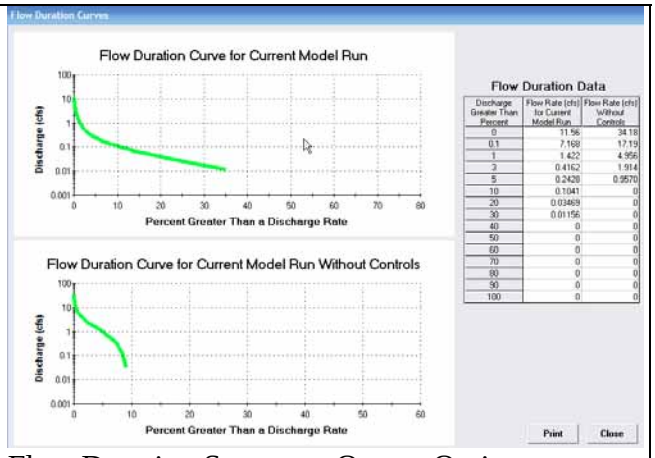


Summary Table with Detailed Output Tabs

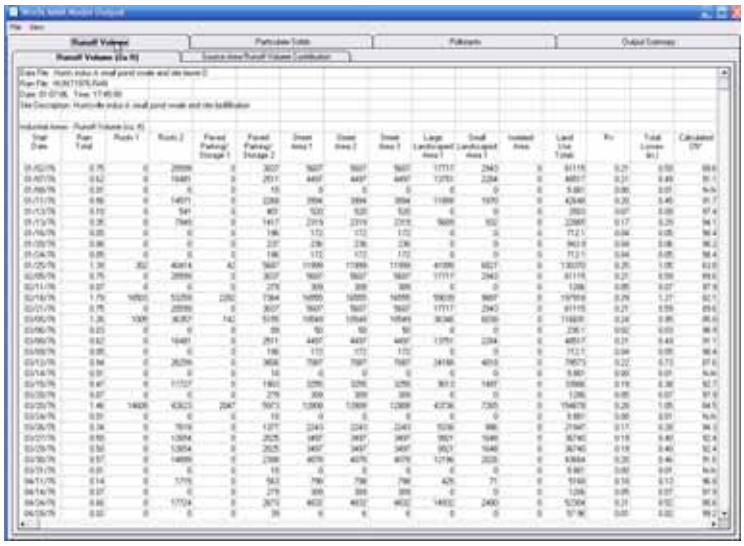


Flow Duration Summary Output Option

The tabs along the top of the summary table enable additional information to be displayed for runoff volume, particulate solids, and pollutants, such as the following:

- Runoff volume (ft^3), source area contributions, particulate solids (lbs and mg/L), and pollutants (lbs and mg/L)
    - by source area for each rain event,
    - land-use total,
    - summary for all rains,
    - total for land use and for each event,
    - outfall summary, before and after drainage system and before and after outfall controls,
    - R_v (runoff volume only),
    - total losses (runoff volume only), and
    - calculated curve number (runoff volume only).

An example of the detailed data for runoff volume is shown in the following figure.



Runoff volume detailed WinSLAMM output.

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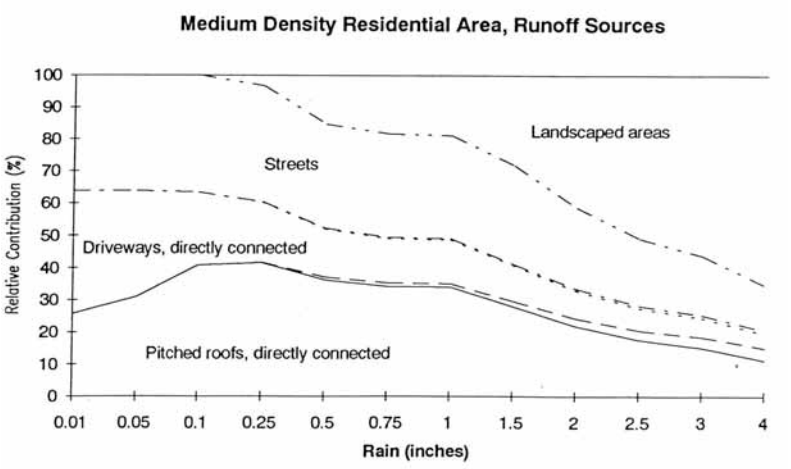
Another group of output options are "one-line-per-event" datasets saved in a csv file format that can be opened in a spreadsheet for further data manipulation. These files can also be examined by selecting the "utilities/view file/use notepad or use Windows view," pull-down menu option from the main WinSLAMM page. The data presented in these files include "One-Line per Event Runoff Details," with data for each event and statistical summaries for all events (number of events, total, equivalent annual total, minimum, maximum, average of all events, median, standard deviation, and coefficient of variation):

- rain duration (hours),
- rain inter-event period (days),
- runoff duration (hours),
- rain depth (inches),
- runoff volume (ft^3),
- R_v,
- average flow (cfs),
- peak flow (cfs), and
- suspended solids (lbs and mg/L).

One of the main features of WinSLAMM is to identify the sources of pollutants for different rain conditions for a specific development. The following example plot shows how runoff volume originates from different sources in a medium-density residential area for different categories of rains. This type of plot is very useful when determining the most likely effective locations for stormwater controls, or for changes in development characteristics.



A powerful feature of WinSLAMM is the batch processor that enables many control options to be quickly compared for an area. The following plot of the cost-performance data for one study site shows the unit costs associated with preventing particulate solids from being discharged from an area:

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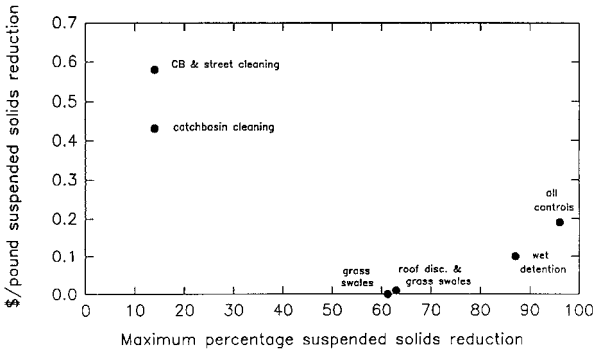

THE STORMWATER MANAGEMENT MODEL, VERSION 5

The Stormwater Management Model (SWMM) can be used to evaluate a number of urban water hydrology and hydraulic problems. It is commonly used to design and evaluate separate storm drainage and sanitary systems and to evaluate combined sewers. Its detailed hydraulic capabilities have made it the most popular tool for evaluating CSO problems and controls. SWMM also includes various water quality options and it is currently being expanded to include a variety of low-impact development options.

The U.S. EPA National Risk Management Laboratory and CDM, Inc., completely recoded the SWMM software recently, with the release of SWMM5. The original version of this software was developed between 1969 and 1971, with Metcalf and Eddy (M&E) of Palo Alto, California, as the main contractor to develop the different modules in the program. M&E subcontracted some of the modules to Water Resources Engineers of Walnut Creek, California (WRE) and the University of Florida (UoF). WRE (now part of CDM) developed the original RUNOFF, RECEIV, and GRAPH models. M&E developed the RUNOFF quality and STORAGe/Treatment routines. UoF developed the TRANSPORT module. In 1973, WRE developed the TRANS model that later in 1977 was modified to EXTRAN (Larry Roesner). Also in 1977, William James developed the minicomputer version known as FASTSWMM and SWESWMM. In 1984, Computational Hydraulics Institute (CHI), the company formed by William James, developed the first user-friendly microcomputer version known as PCSWMM. In 1988, version 4 of SWMM was released by EPA and included some of the enhancements developed by PCSWMM. Since that time, UoF (Wayne Huber and Jim Heaney), the University of Guelph (where William James taught), and Oregon State University (Wayne Huber) have been improving version 4, with the release of version 4.4gu in 1999 (James et al., 2002).

SWMM5 was developed for many reasons: the previous versions were developed in DOS-based FORTRAN over more than a 30-year period with different levels of documentation. The development of the Windows environment and object-oriented programming techniques improved programming capabilities and graphical user interfaces. One advantage of the new model is that only a single file is needed, and not multiple modules, for a single simulation. A single file can now be created that contains RUNOFF, TRANSPORT, and/or EXTRANS at the same time. SWMM5 uses the same environment that EPANET uses, assigning the values to the objects used during the simulation. Other reasons for the new SWMM version are its ability to eventually develop routines for modeling SCMs, to improve the routing procedures of water

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quality in the model, and to create the possibility to simulate real-time control by manipulating control structures (EPA, 2002).

The following summary of SWMM5's capabilities and applications is from the EPA's SWMM5 website, where one can download the model and documentation (http://www.epa.gov/ednnrmrl/models/swmm/index.htm).

"The EPA Storm Water Management Model (SWMM) is a dynamic rainfall-runoff simulation model used for single event or long-term (continuous) simulation of runoff quantity and quality from primarily urban areas. The runoff component of SWMM operates on a collection of subcatchment areas that receive precipitation and generate runoff and pollutant loads. The routing portion of SWMM transports this runoff through a system of pipes, channels, storage/treatment devices, pumps, and regulators. SWMM tracks the quantity and quality of runoff generated within each subcatchment, and the flow rate, flow depth, and quality of water in each pipe and channel during a simulation period comprised of multiple time steps.

Capabilities

SWMM accounts for various hydrologic processes that produce runoff from urban areas. These include:

- time-varying rainfall
- evaporation of standing surface water
- snow accumulation and melting
- rainfall interception from depression storage
- infiltration of rainfall into unsaturated soil layers
- percolation of infiltrated water into groundwater layers
- interflow between groundwater and the drainage system
- nonlinear reservoir routing of overland flow.

Spatial variability in all of these processes is achieved by dividing a study area into a collection of smaller, homogeneous subcatchment areas, each containing its own fraction of pervious and impervious sub-areas. Overland flow can be routed between sub-areas, between subcatchments, or between entry points of a drainage system.

SWMM also contains a flexible set of hydraulic modeling capabilities used to route runoff and external inflows through the drainage system network of pipes, channels, storage/treatment units and diversion structures. These include the ability to:

- handle drainage networks of unlimited size
- use a wide variety of standard closed and open conduit shapes as well as natural channels
- model special elements such as storage/treatment units, flow dividers, pumps, weirs, and orifices
- apply external flows and water quality inputs from surface runoff, groundwater interflow, rainfall-dependent infiltration/inflow, dry weather sanitary flow, and user-defined inflows
- utilize either kinematic wave or full dynamic wave flow routing methods
- model various flow regimes, such as backwater, surcharging, reverse flow, and surface ponding
- apply user-defined dynamic control rules to simulate the operation of pumps, orifice openings, and weir crest levels

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In addition to modeling the generation and transport of runoff flows, SWMM can also estimate the production of pollutant loads associated with this runoff. The following processes can be modeled for any number of user-defined water quality constituents:

- dry-weather pollutant buildup over different land uses
- pollutant wash-off from specific land uses during storm events
- direct contribution of rainfall deposition
- reduction in dry-weather buildup due to street cleaning
- reduction in wash-off load due to stormwater controls
- entry of dry weather sanitary flows and user-specified external inflows at any point in the drainage system
- routing of water quality constituents through the drainage system
- reduction in constituent concentration through treatment in storage units or by natural processes in pipes and channels

Applications

Since its inception, SWMM has been used in thousands of sewer and stormwater studies throughout the world. Typical applications include:

- design and sizing of drainage system components for flood control
- sizing of detention facilities and their appurtenances for flood control and water quality protection
- flood plain mapping of natural channel systems (SWMM 5 is a FEMA-approved model for NFPI studies)
- designing control strategies for minimizing combined sewer overflows
- evaluating the impact of inflow and infiltration on sanitary sewer overflows
- generating non-point source pollutant loadings for waste load allocation studies
- evaluating the effectiveness of stormwater controls for reducing wet weather pollutant loadings."

SWMM has been used as an engine by many other model developers in several countries. These other products usually add both front-end data collection and GIS support and post-processing tools. In many cases, the integration of these additional tools is seamless. One of the more popular extensions has been a series of programs developed by Dr. Bill James at the University of Guelph and Computational Hydraulics International, Guelph, Ontario (http://www.computationalhydraulics.com/). The following is a brief description of PCSWMM.NET, their newest version that integrates SWMM5, as an illustration of the expanded capabilities that these SWMM program extensions can offer. This model is a GIS-based, graphical decision support system for EPA SWMM5 urban drainage modeling (sanitary, storm, and/or combined systems). It implements additional tools for streamlining sewer collection system model development, optimization and analysis. PCSWMM.NET allows both engineers and GIS professionals to work on the same data as it offers direct support for ESRI ArcGIS geodatabases, ArcView shape files, and ArcInfo E00 files, along with several open standard and proprietary GIS and CAD formats. The GIS engine is completely scalable, allowing a wide range of site conditions to be evaluated.

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Other added attributes of PCSWMM.NET include advanced quality assurance and quality control features that include attribute validation, orphan detection, and pipe slope screening tools. As an example, disconnected entities (link, node, and subcatchment), missing data, and potential data errors such as negative pipe slopes are identified and reported. Calculator tools are also included for identifying and estimating missing data. For example, it is possible to manually control the calculation of subcatchment areas or conduit attributes from map units, or to turn on the autolength feature and have these spatial attributes automatically synchronized. The subcatchment widths can also be directly calculated from user-defined overland flow path lengths. A dry weather flow (DWF) analyzer tool allows for automatic creation of hourly, daily, and/or monthly patterns for sanitary sewer DWF model inputs. Subcatchment-specific hyetographs can be computed from rain-gauge calibrated radar-rainfall data through an area weighting process (DE-9IM model) relating a radar-rainfall overlay (polar coordinate, grid, etc.) to the model's subcatchment polygons. This process supports any length of radar-rainfall time series and any number of radar cells or subcatchments. Native support is provided for Vieux and Associates (rain-gauge calibrated radar-rainfall data providers) data.

A major feature of many of the third-party SWMM packages is additional support for importing data. PCSWMM.NET, for example, supports extended interfaces with GIS/CAD, database, spreadsheet, and delimited text files. The Import Data Wizard supports importing to multiple SWMM5 layers from multiple data sources simultaneously and provides data filtering and attribute matching control. An interesting feature of PCSWMM.NET is the ability to automatically transfer the site data directly into Google Earth for three-dimensional visualizations of the model layouts and the results. Other extended output features include the ability to create scatter plots for any two computed model time series (conduit depth vs. velocity, storage depth vs. discharge, subcatchment rainfall vs. runoff, etc.). Positive or negative strong, weak, or no correlation is reported. Trend lines or best-fit curves can also be plotted on the scatter plots.

There is much third-party support for SWMM5. James et al. (2005) is the latest edition of the SWMM user guide, containing much supplemental material, including tutorials. Many beginning model users are intimidated by SWMM; however, it is quite possible to use the new versions quickly for a variety of common problems. As an example, Pitt has a comprehensive "hello world" user guide available at http://unix.eng.ua.edu/~rpitt/Class/Water%20Resources%20Engineering/WREMainPage.htm that is used in undergraduate water resources classes. This guide covers both storm drainage and sanitary collection system designs. The example is for a small area, but the guide is also applicable for larger and more complex situations. The following are a few selected screen shots from this guide showing some of the basic features of SWMM.

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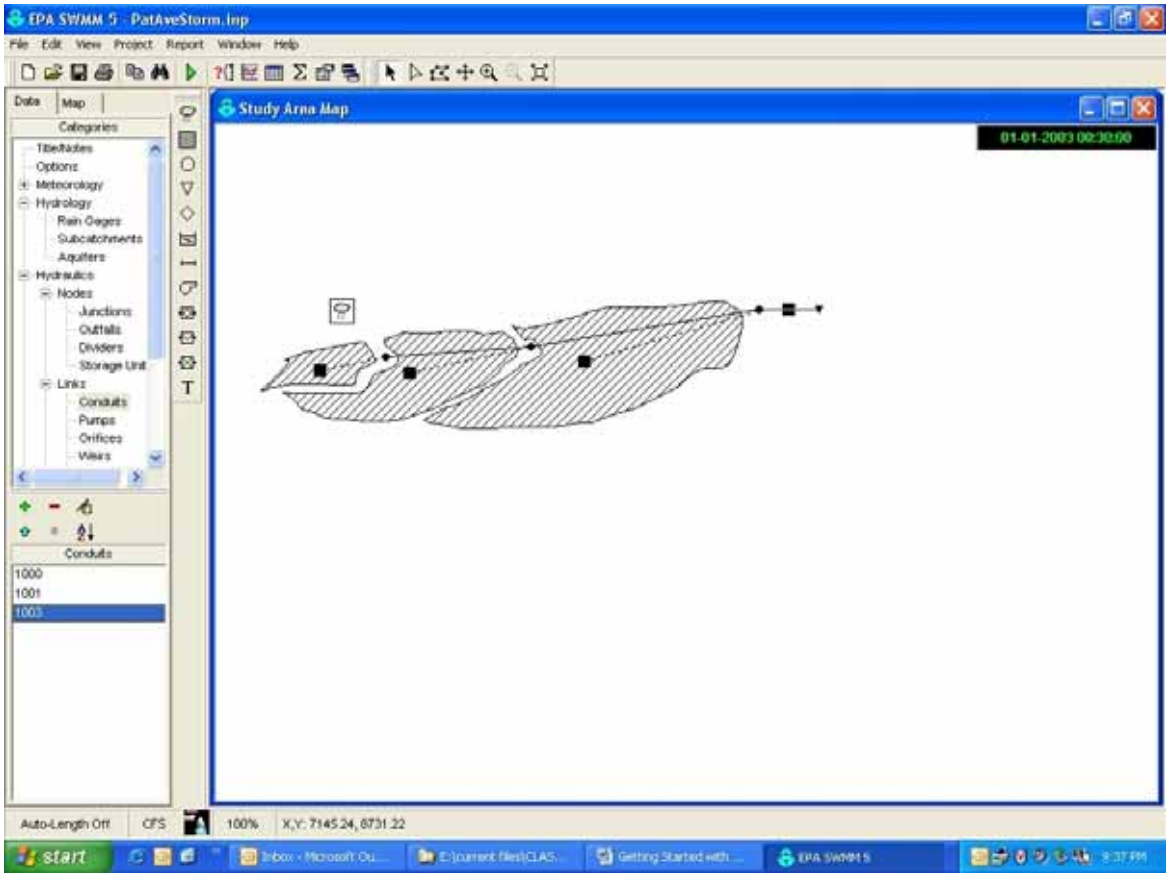
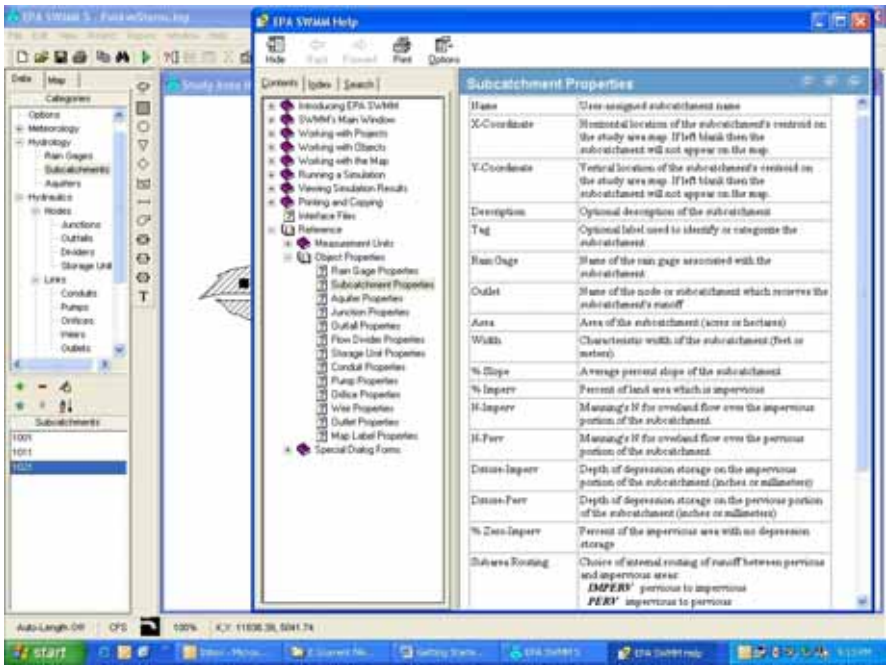


Example storm drainage system layout for SWMM5 evaluation.



Extensive Help files are available that explains each parameter and input need.

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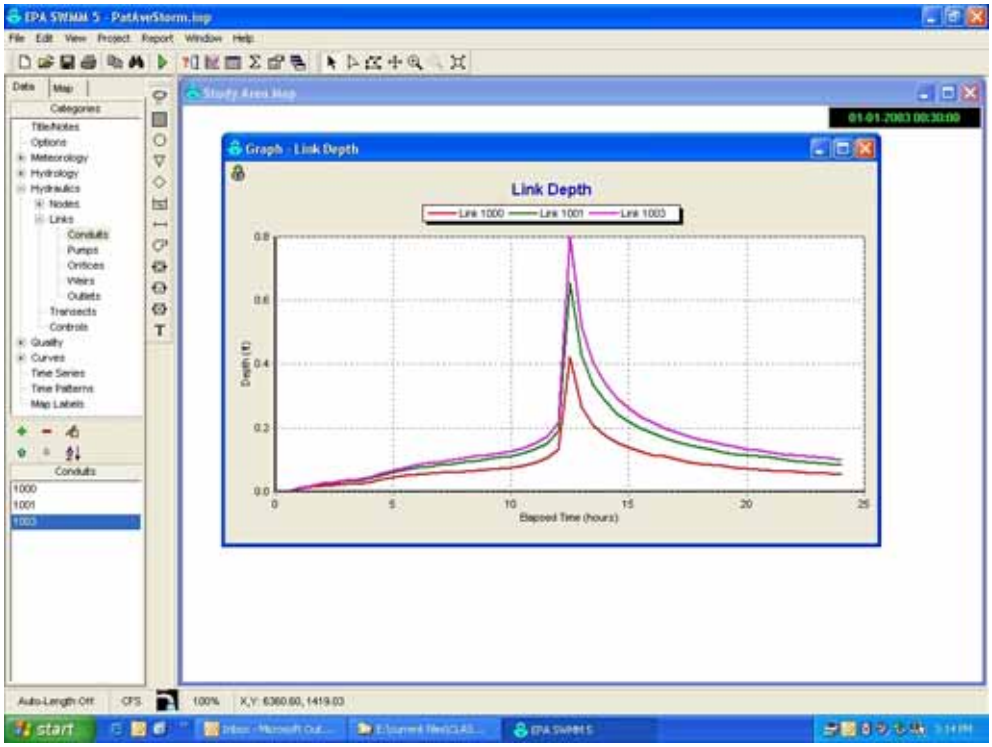
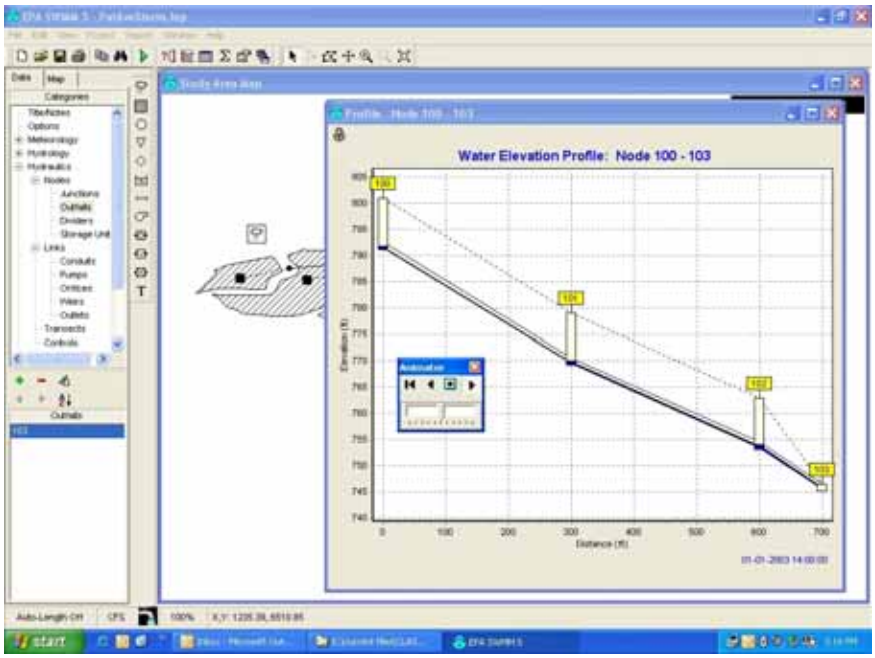


Calculated water depth for a storm-drain system.



Water surface profiles can also be calculated in SWMM5 to examine backwater problems.

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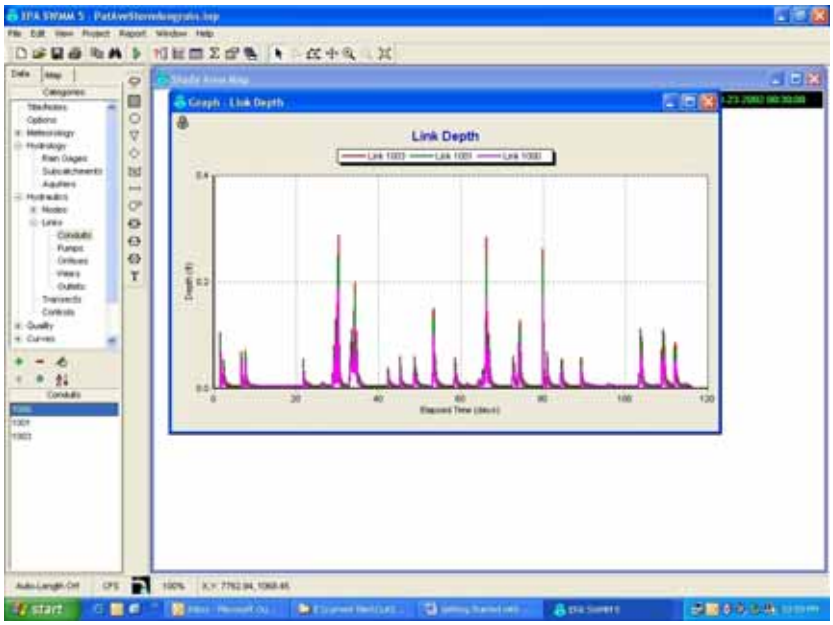
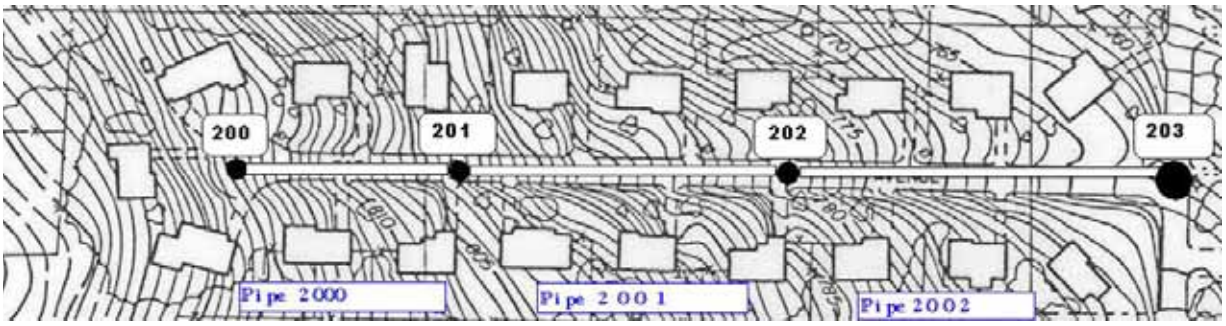


Four-month rain history simulation using SWMM5.



Road and pipe layout for sanitary sewer design for same area.

Continuous simulations for water depths on sanitary sewer with SWMM5.

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WESTERN WASHINGTON HSPF APPLICATION

A Brief History of Western Washington Stormwater Hydrology Modeling

Municipal stormwater management programs in western Washington go back more than 30 years. They grew out of flood prevention and control programs and from there expanded to encompass concern with stream-channel and habitat damage by elevated storm flows and, later, water quality degradation by stormwater runoff. Early hydrologic modeling supporting retention/detention pond design to attempt control of elevated flows utilized a derivative of the Rational Method. By the late 1980s hydrologists had begun using HSPF for continuous flow modeling, but most modeling by other professionals was based on a Santa Barbara Unit Hydrograph (SBUH) approach rooted in the U.S. Soil Conservation Service (USCS; now Natural Resources Conservation Service, NRCS) TR-55 storm event–based model (USCS, 1986). The latter model was the basis for most analyses prescribed by the first comprehensive stormwater management manual issued in the region, King County's Surface Water Design Manual (King County Surface Water Management Division, 1990).

Shortly after the manual's appearance some of the more experienced hydrologic analysts in the area began developing various dissatisfactions with the prevailing, highly simplified modeling methodology, focusing ultimately on its inability to produce pond designs that actually control peak discharge rates in a predictable manner. At the same time it became apparent that, although HSPF offered promise to improve analysis and design substantially, several factors limited its broader use. First, its relative complexity restricted effective use to the specialists. HSPF's application was further limited by its extensive input data requirements and orientation to drainage catchments more on the order of square kilometers or larger than on development site-scale sizes.

In 1992 King County and the University of Washington began work to develop a "runoff files" system to remove HSPF's limitations and gain its benefits much more broadly (Jackson et al., 2001). The runoff files concept dates back to Lumb and James (1976), who developed it for flood analysis in DeKalb County, Georgia. Runoff files comprise a set of time-series data files of unit-area land surface runoff presimulated with HSPF for a range of land-cover conditions and soil types. To expedite analysis and design, the runoff files depend on a reduced hydrologic record that is statistically representative of the available extended record. Estimation of design flows and facilities design is accomplished by accessing and manipulating the runoff file data by means of supporting software.

The work culminated in the development of the King County Runoff Time Series (KCRTS) software package. The Washington Department of Ecology (WDOE, 2005) later extended the runoff file coverage to all of western Washington and produced accompanying software—the Western Washington Hydrologic Model (WWHM). The next section briefly describes the initial runoff files development process, as an illustration of the effort necessary to establish a runoff files–based system. Subsequent sections discuss the characteristics, data requirements, capabilities, limitations, and applications of WWHM.

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Runoff Files Development for KCRTS

Approach

To determine reliable flows and design stormwater management facilities, continuous hydrologic models must simulate long time series of flows, on the order of 40 years or more. To relieve the burden on the user imposed by these extensive data needs, an important feature of the runoff files method is selection of a shorter sample of hydrologic data that are statistically representative of the full record. As a prerequisite to developing KCRTS, the University of Washington compiled precipitation and flow records from a number of locations in King County and examined them to identify seven years that had flow statistics representative of the most critical conditions for stormwater facility design. An eighth year represents the hypothetical 100-year discharge event, simulated by scaling up runoff from a large January 1990 storm.

Steps in Development

Eight steps were involved in developing the runoff files and KCRTS (Jackson et al., 2001, a reference with more detail on each step): (1) selection of HSPF parameters for a range of land-cover conditions and soil types, (2) quality assurance and correction of rainfall data, (3) selection of a short climate record that accurately substitutes for the long record, (4) generation of runoff files using HSPF, (5) determining plot positions for peak annual flows so that the short record could be used for flow recurrence estimation, (6) creation of 100-year flood hydrographs, (7) model verification against long-term HSPF simulations, and (8) training the engineering community to use the new system.

The first step was covered by preceding USGS work developing generalized model parameters from HSPF calibrations against flow data from 21 gauged streams in King and neighboring Snohomish County. These parameters were used with HSPF to generate hydrologic responses as time series of unit area land surface runoff for eight soil and land-cover types and two long-term hourly rainfall stations. King County soils are almost entirely derived from continental glaciation 12,000 years ago and consist of either low-porosity till or high-porosity outwash. These two soil types were paired with forest, pasture, and grass (lawn) to make up six soil and cover types. To these types were added two others, impervious and wetlands. One precipitation station represented the lowlands of western King County, and the other the foothills and valleys to the east. More stations were initially evaluated but discarded because of short records, data gaps, errors, and recording too coarse for the modeling purposes (e.g., in tenth-inch instead of hundredth-inch increments).

In the third step, the longest, most complete rainfall record, from Seattle-Tacoma International Airport, was searched for any combination of seven water years that together would produce flow duration statistics for the selected soil and cover types that match the statistics from a simulation of the full record (step 5). The search yielded seven years from 1951 to 1987 that met this criterion. These years also proved to be acceptable for the eastern rain station.

Generation of the 100-year frequency simulation (step 6) was complicated by the fact that a given storm generally does not produce maximum flows from all soil and land-cover types. However, the January 1990 storm, falling on already very wet ground, had characteristics that

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did produce highly elevated flows from all of the types of interest. For till soils and impervious land, 100-year peak flow rates were estimated by fitting a Log Pearson Type III distribution to peak annual flows generated with the available 42-year record. This technique did not work well for outwash soils and wetlands, because of the relatively large soil storage in the former case and the flow attenuating effects of wetlands. In these cases semi-logarithmic graphing fit a flow frequency curve to peak flows. Scale factors were chosen to produce a weighted-average factor that increases the January 1990 peak flows from a mixture of soil and cover types to statistically determined 100-year rates.

For verification (step 7), extensive tests of KCRTS-designed detention facilities were conducted by routing long-term HSPF-generated flow series from the full record through the units to determine if discrepancies in flow statistics from the short record caused faulty designs. Almost all designs using KCRTS met or came close to meeting their performance standards when tested with HSPF. Notwithstanding a small number of deviations at the relatively frequent recurrence end of the storm spectrum, producing both larger and smaller facilities than designed by HSPF, it was concluded that KCRTS-designed detention devices are expected to meet performance standards much better than units designed with single-event methodologies. Two watershed-scale (1,404 and 4,706 ha) tests demonstrated the utility of KCRTS as a basis for designing networks of detention facilities to maintain predevelopment stream hydrology (see KCRTS Case Study).

KCRTS Case Study

KCRTS was applied to compare the model's ability to specify runoff detention facilities meeting runoff control standards to results using the SBUH method instead. The Soosette Creek watershed (1,404 ha) in King County provided the test case. This stream was already impacted biologically and expected to experience additional development to a full buildout condition. Predevelopment simulations were based on land cover obtained from 1985 aerial photographs. Pasture predominated in undeveloped areas at that time. The postdevelopment case assumed that all developable land would be built in high-density residential land use (10 to 15 dwellings per hectare), with assumed 25 percent impervious cover and 75 percent lawns. The supposition was that 91 percent of this development would drain to detention facilities, and the remainder would consist of small projects not subject to King County drainage review. It was further assumed that 20 percent of the forest cover and all wetlands existing in 1985 would remain undisturbed.

Performance standards applied to gauge results were as follows: (1) ability to match pre- and postdevelopment peak flow rates between the 2- and 10-year discharges, and (2) ability to match pre- and postdevelopment flow durations between 50 percent of the 2-year and the 50-year flow. More specifically, the Normalized Channel Stability Index (NCSI) was taken as a basis for judgment:

$$NCSI = (2\text{-year}_{postdevelopment} - 2\text{-year}_{predevelopment})/(10\text{-year}_{predevelopment} - 2\text{-year}_{predevelopment})$$

Previous observations of channel morphology, habitat characteristics and fish usage indicated that channels with an index greater than 1 are unstable and unable to support anadromous salmonid fish, whereas those with an index near zero have excellent habitat and

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healthy fish populations, unless some other negative factor (e.g., blockage to fish passage, poor water quality) is present (Jackson et al., 2001).

KCRTS-designed detention systems were estimated to maintain the two-year peak flow rates at different stream stations with very little change, whereas those facilities designed according to SBUH would allow increases of 15 to 20 percent. In the latter case two-year flow durations were forecast to rise by up to 80 percent, while those based on KCRTS would hold durations with almost no increases. The KCRTS facilities were also estimated to keep NCSI values at already degraded levels of 1.2–2.1, while the SBUH devices would permit further deterioration to 1.7–2.7.

The Western Washington Hydrologic Model

Characteristics

WWHM is an outgrowth of KCRTS, extending the runoff-files approach from King County to all of western Washington. Accordingly, it utilizes model parameters and rainfall data from a wider area. The same eight soil and land-cover types underlying KCRTS are also used in WWHM, with parameter selections appropriate to the different locations in the region. Western Washington rainfall regimes are represented by 17 gauging stations at elevations below 457 m (1,500 ft), where almost all development occurs. For better representation of local conditions in the large area served by the model, it includes multipliers to adjust rainfall geographically. Pan evaporation coefficients similarly adjust evapotranspiration from place to place.

Capabilities

WWHM computes the pre- and postdevelopment 2- through 100-year flow frequency values from a detention facility discharge point. It then compares the pre- and postdevelopment flow durations to check if the device would meet WDOE's flow control requirements, which are duration-based according to the following criterion: if postdevelopment flow duration values exceed any of the predevelopment durations occurring between 50 percent of predevelopment two-year up to the predevelopment 50-year surface runoff peak flow rates, then the requirement is not met.

Limitations

Being based on HSPF, WWHM shares the limitations inherent in that continuous model (e.g., not being capable of modeling backwater or tailwater situations). WWHM is a site-scale model and has been programmed specifically to design individual stormwater management practices. While the model can route runoff through multiple stormwater control devices in series, it cannot route through a natural lake or wetland. Routing effects become more important with increase in catchment area. For this reason it is recommended that WWHM not be used for drainage areas larger than 130 ha (320 acres).

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Appendix E
Biographical Information for the Committee on Reducing Stormwater Discharge Contributions to Water Pollution

Claire Welty, *Chair*, is the Director of the Center for Urban Environmental Research and Education and Professor of Civil and Environmental Engineering at University of Maryland, Baltimore County (UMBC). Dr. Welty's work has primarily focused on transport processes in aquifers; her current research interest is in watershed-scale urban hydrology, particularly in urban groundwater. Prior to her appointment at UMBC, Dr. Welty was a faculty member at Drexel University for 15 years, where she taught hydrology and also served as Associate Director of the School of Environmental Science, Engineering, and Policy. Dr. Welty is the chair of the National Research Council's (NRC's) Water Science and Technology Board and has previously served on three NRC study committees. She is the Chair-Elect of the Consortium of Universities for the Advancement of Hydrologic Science Inc. Dr. Welty received a B.A. in environmental sciences from the University of Virginia, an M.S. in environmental engineering from the George Washington University, and a Ph.D. in civil and environmental engineering from the Massachusetts Institute of Technology.

Roger T. Bannerman has been an environmental specialist for the Wisconsin Department of Natural Resources for over 30 years. For most of that time he has directed research projects investigating urban runoff. Topics addressed by his studies over the years include the quality of urban streams, identification of problem pollutants in stormwater, toxicity of stormwater pollutants, effectiveness of different stormwater control practices, sources of stormwater pollutants, selection of cost-effective control practices, and benefits of low-impact development. He has applied these results to management plans developed for most urban areas in Wisconsin. This includes the calibration of the urban runoff model called the Source Loading and Management Model. The results of his research projects have been used to develop Wisconsin's new administrative rules that regulate stormwater management. Mr. Bannerman received his B.S. in chemistry from Humboldt State College and an M.S. from the University of Wisconsin in water chemistry.

Derek B. Booth has joint positions as Senior Geologist at Stillwater Sciences, Inc., and Adjunct Professor at the University of Washington where he is senior editor of the international journal *Quaternary Research* and holds faculty appointments in Civil Engineering and Earth & Space Sciences. Prior to this, he was director of the Center for Urban Water Resources Management (and its successor, the Center for Water and Watershed Studies) at the university. He maintains active research into the causes of stream-channel degradation, the effectiveness of stormwater mitigation strategies, and the physical effects of urban development on aquatic systems, with over a dozen publications and a wide range of national and international invited presentations on the topic. Dr. Booth received a B.A. in literature from Hampshire College, a B.A. in geology from the University of California at Berkeley, an M.S. in geology from Stanford University, and a Ph.D. in geological sciences from the University of Washington.

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Richard R. Horner is a professor in the Department of Civil and Environment Engineering at the University of Washington, with adjunct appointments in Landscape Architecture and in the College of Forest Resources' Center for Urban Horticulture. He received his Ph.D. from the University of Washington's Department of Civil and Environmental Engineering and previous engineering degrees from the University of Pennsylvania. Dr. Horner splits his time between university research and private practice. In both cases his work concerns how human occupancy of and activities on the landscape affect natural waters, and how negative effects can be reduced. He has been involved in two extended research projects concerning the ecological response of freshwater resources to urban conditions and the urbanization process. The first studied the effect of human activities on freshwater wetlands of the Puget Sound lowlands and led to a comprehensive set of management guidelines to reduce negative effects. A ten-year study involved the analogous investigation of human effects on Puget Sounds' salmon spawning and rearing streams. In addition, he has broad experience in all aspects of stormwater management, having helped design many stormwater programs in Washington, California, and British Columbia. He previously served on the NRC's Committee on the Comparative Costs of Rock Salt and Calcium Magnesium Acetate for Highway Deicing.

Charles R. O'Melia (NAE) is the Abel Wolman Professor of Environmental Engineering and Chair of the Geography and Environmental Engineering Department at the Johns Hopkins University, where he has served on the faculty for over 25 years. Dr. O'Melia's research areas include aquatic chemistry, environmental colloid chemistry, water and wastewater treatment, modeling of natural surface and subsurface waters, and the behavior of colloidal particles. He has served on the advisory board and review committees for the environmental engineering departments of multiple universities. He has served in a range of advising roles to professional societies including the American Water Works Association and Research Foundation, the Water Pollution Control Federation, the American Chemical Society, and the International Water Supply Association. He has served on several NRC committees, including chairing the Steering Committee, Symposium on Science and Regulation, and the Committee on Watershed Management for New York City. He was also a member of the NRC Water Science and Technology Board and the Board on Environmental Studies and Toxicology. Dr. O'Melia earned a Ph.D. in Sanitary Engineering from the University of Michigan. In 1989, Dr. O'Melia was elected to the National Academy of Engineering for significant contributions to the theories of coagulation, flocculation, and filtration leading to improved water-treatment practices throughout the world.

Robert E. Pitt is the Cudworth Professor of Urban Water Systems in the Department of Civil, Construction, and Environmental Engineering at the University of Alabama (UA). He is also Director of the UA interdisciplinary Environmental Institute. Dr. Pitt's research concerns the effects, sources, and control of urban runoff, which has resulted in numerous development management plans, stormwater ordinances, and design manuals. Dr. Pitt has also developed and tested procedures to recognize and reduce inappropriate discharges of wastewaters to separate storm drainages. He has investigated the sources and control of stormwater toxicants and examined stormwater effects on groundwater. He has also carried out a number of receiving water impact studies associated with stormwater. These studies have included a variety of field monitoring activities, including water and sediment quality, fish and benthos taxonomic composition, and laboratory toxicity tests. His current research includes developing a

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nationwide database of national stormwater permit information and conducting comprehensive evaluations of these data. Dr. Pitt received a B.S. in engineering science from Humboldt State University, an M.S. in civil engineering from San Jose State University, and a Ph.D. in civil and environmental engineering from the University of Wisconsin.

Edward T. Rankin is a Senior Research Associate in the Center for Applied Bioassessment and Biocriteria within the Midwest Biodiversity Institute (MBI) and an Environmental Management Associate with Ohio University in Athens, Ohio. Prior to 2002, he was an aquatic ecologist with Ohio EPA for almost 18 years. MBI is a 125-member organization devoted to advancing the natural sciences, applied ecology and field biology in 12 midwestern states. Mr. Rankin's research centers around the effects of stormwater and other urban stressors on aquatic life, development and application of stream habitat assessment methodologies, development and application of biological criteria and biological-based chemical criteria for aquatic life, and improving the accuracy of total maximum daily loads for nutrients and sediment. He is particularly interested in the application of research to management of aquatic life issues and has extensive experience with the development of tiered aquatic life uses and use attainability analyses in streams. He is currently participating in two studies funded by the Water Environment Research Foundation on urban stressors. Mr. Rankin received his B.S. in biology from St. Bonaventure University and his M.S. in zoology from The Ohio State University.

Thomas R. Schueler founded the Center for Watershed Protection in 1992 as a nonprofit organization dedicated to protecting our nation's streams, lakes and wetlands through improved land management. In 2007, he launched the Chesapeake Stormwater Network, whose mission is to improve on-the-ground implementation of more sustainable stormwater management and environmental site design practices in each of 1,300 communities and seven states in the Chesapeake Bay Watershed. He has conducted extensive research on the pollutant removal performance, cost, and longevity of stormwater control measures, and he has developed guidance for both Phase I and Phase II communities to meet minimum management measures to comply with municipal stormwater permits, including development of a national stormwater monitoring database and national guidance on illicit discharge detection and elimination. Mr. Schueler has written several widely referenced manuals that describe how to apply the tools of watershed protection and restoration, and he is working on a wide range of research projects and watershed applications across the United States. Prior to founding the Center, he worked for ten years at the Metropolitan Washington Council of Governments, where he led the Anacostia Watershed Restoration Team, one of first efforts to comprehensively restore an urban watershed. He received his B.S. in environmental science from the George Washington University.

Kurt Stephenson is an associate professor of Environmental and Natural Resource Economics in the Department of Agricultural and Applied Economics at the Virginia Polytechnic Institute and State University. His professional objective is to better integrate economic perspectives and analysis into decision making related to water resource issues. Particular emphasis is placed on the application of economic analysis to interdisciplinary research of policy issues. The design and implementation of market-based policies to secure environmental objectives is a primary area of study within this context. He is currently involved in determining effective strategies for reducing nutrient loads in the Opequon Watershed in Virginia and West Virginia, including evaluating the cost effectiveness and feasibility of using urban nonpoint source controls (including

stormwater management) as an offset to growth in point source loads. He is a member of the Virginia Department of Environmental Quality's Nutrient Trading Technical Advisory Committee and the Academic Advisory Committee. Dr. Stephenson received his B.S. in economics from Radford University, his M.S. in agricultural economics from Virginia Tech, and his Ph.D. in economics from the University of Nebraska.

Xavier Swamikannu is Chief of the Stormwater Permitting Program for the Los Angeles Regional Water Board and the California EPA, where he has worked for nearly 20 years. He has extensive experience with the implementation of municipal and industrial stormwater programs in Southern California, including the evaluation of pollutant discharges, determining the effectiveness of stormwater control measures in treating stormwater runoff, developing performance criteria and better understanding of their costs. He has participated on EPA's General Permits and Total Maximum Daily Load Work Groups and he has served on many state and regional technical advisory committees concerned with stormwater regulations. He was recognized by the California Water Boards in 2007 for his national leadership in the stormwater program, and by the California State Senate for his service on the technical advisory committee of the Santa Monica Bay Restoration Commission. Dr. Swamikannu received his B.S. in natural and chemical sciences from St. Joseph's College in Bangalore, India, his M.S. in environmental sciences from Texas Christian University, and his Ph.D. in environmental science and engineering from the University of California, Los Angeles.

Robert G. Traver is a professor of Civil and Environmental Engineering at Villanova University and the Director of the Villanova Urban Stormwater Partnership. He conducts research on topics that include modeling of stream hydraulics, urban hydrology, water quality, and measures to mitigate stormwater effects of urbanization. Most recently he has created a Stormwater Best Management Practice Demonstration and Research Park on the Villanova Campus. Dr. Traver is also involved with the implementation of stormwater policy. He has participated in a team study to review the effects of Pennsylvania's water regulation from a watershed sustainability viewpoint, acted as a reviewer for Pennsylvania's 1995 Best Management Practice Handbook, and has served as Chair for the 1998, 1999, 2001, 2003, and 2005 Pennsylvania Stormwater Management Symposiums held at Villanova. More recently he was selected to serve on the American Society of Civil Engineers' External Review Panel of the Corps investigation of Hurricane Katrina. Dr. Traver is a retired LTC in the Army Reserves and a veteran of Operation Desert Storm. He received his B.S. in civil engineering from the Virginia Military Institute, his M.S. in civil engineering from Villanova, and his Ph.D. in civil engineering from Pennsylvania State University.

Wendy E. Wagner is the Joe A. Worsham Centennial Professor at the University of Texas School of Law. Before joining the UT faculty, she was a professor at Case Western Reserve University School of Law and a visiting professor at Columbia Law School and the Vanderbilt School of Law. Wagner's research focuses on the interface between science and environmental law, and her articles have appeared in numerous journals, including the Columbia, Cornell, Duke, Georgetown, Illinois, Texas, Wisconsin, and Yale Law Reviews. She has published on the practical problems with EPA's current approach to stormwater regulation. She has also written several articles on the challenges of regulating media like stormwater, on restoring polluted waters with public values, on the legal aspects of the regulatory use of environmental

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modeling, and on technology-based standards. Ms. Wagner received a master's degree in environmental studies from the Yale School of Forestry and Environmental Studies and a law degree from Yale Law School. She clerked for the Honorable Judge Albert Engel, Chief Judge of the U.S. Court of Appeals for the 6th Circuit.

William E. Wenk is founder and president of Wenk Associates, Inc., a Denver-based landscape architectural firm. He is also an Adjunct Associate Professor of Landscape Architecture at the University of Colorado in Denver. For over 20 years, he has been influential in the restoration and redevelopment of urban river and stream corridors, the transformation of derelict urban land, and the design of public parks and open spaces. Mr. Wenk was the Principal Urban Designer for the Menomonee River Valley Redevelopment, an award-winning "green infrastructure" redevelopment in Milwaukee that integrated a network of parks and open spaces through stormwater infrastructure, regional and local trails, and a restored river corridor into a proposed 130-acre mixed-use and light industrial development. Other projects of his include the Prairie Trail Community Master Plan in Ankeny, Iowa (a surface stormwater system designed to provide flood control and water quality for a new 1000-acre mixed-use community), and the Stapleton Airport Parks and Open Space Redevelopment (a surface stormwater drainage design for the 4,500-acre redevelopment), as well as the Stapleton Water Quality Guidelines book to guide planners and developers on how to integrate stormwater best management practices into redevelopment. Mr. Wenk received a B.S.L.A. and M.L.A. from Michigan State University and the University of Oregon, respectively.

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Santa Cruz Sentinel (http://www.santacruzsentinel.com)

Measure E looks like a win

By Genevieve Bookwalter - Sentinel staff writer

Wednesday, November 5, 2008

SANTA CRUZ - City voters overwhelmingly supported a property tax hike to play for cleaner water on Tuesday.

Measure E, which would raise annual property taxes to help Santa Cruz meet state requirements to clean up storm water runoff, was winning with more than 75 percent of the vote early Wednesday morning, with all precincts reporting, according to the county clerk's office. It needed two-thirds approval to pass.

"Santa Cruz voters tonight put their wallets where their hearts are. We are proud of the work done by volunteers, donors and supporters who care deeply about our community and our beaches, river and ocean," said Dan Haifley, co-chair of the Yes on E campaign.

City Councilman Mike Rotkin summed it up in two words: "I'm thrilled."

The measure will raise property taxes $28 per year for residential parcels and $94 per year on other developed plots, thus collecting about $700,000 in new city revenue. That money should pay to clean up water that runs into local waterways and the Pacific Ocean after storms, carrying oil, trash and other pollutants with it.

The money raised by Measure E can only be spent on storm water cleanup projects, and does not have a sunset clause.

While Santa Cruz voters typically can be counted on to put their money where their environmental values are, city leaders were nervous that the nation's flailing economy would prompt residents to keep their pocketbooks closed. They also feared that the many students who turned out to vote for Democrat president-elect Barack Obama would not continue to vote on the local issues down-ticket.

If the measure was not approved, the money would have come out of the city's $78.4 million general fund. That could have hamstrung the city, which already faces a $5 million deficit this year.

Instead, the Measure E dollars would complement the $760,000 that the city already spends each year to clean up storm water, much of which is raised through an existing Storm Water Enterprise Utility Fee.

Of the additional $700,000, about $300,000 would be spent on more storm drains and catch basin cleaning; $100,000 to upgrade existing storm drains; and $150,000 for education and outreach to help keep pollutants from washing or being dumped into the sea, among other expenses. The city and state are working on a plan and time line for meeting the goals.

Contact G. Bookwalter at 706-3286 or gbookwalter@santacruzsentinel.com.

URL: http://www.santacruzsentinel.com/general-news/20081105/measure-e-looks-like-a-win/1

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California Regional Water Quality Control Board
Santa Ana Region

Linda S. Adams
Secretary for
Environmental Protection

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Arnold Schwarzenegger
Governor

November 10, 2008

TO: The Attached Mailing list

RENEWAL OF WASTE DISCHARGE REQUIREMENTS FOR THE COUNTY OF ORANGE, ORANGE COUNTY FLOOD CONTROL DISTRICT AND THE INCORPORATED CITIES OF ORANGE COUNTY, TENTATIVE ORDER NO. R8-2008-0030, NPDES NO. CAS618030, AREAWIDE URBAN STORM WATER RUNOFF

Tentative Order No. R8-2008-0030, NPDES No. CAS 618030, has been posted on the Regional Board website and can be downloaded from:
http://www.waterboards.ca.gov/santaana/water_issues/programs/stormwater/oc_permit.shtml

This order renews waste discharge requirements for the discharge of urban storm water from areas of Orange County within the Santa Ana Region. This permit will be introduced at a public workshop during the November 21, 2008 Board meeting.

While the primary purpose of the November 21st workshop will be to present the proposed order to the Board, time will be made available for public comments. For the accuracy of the record, all comments should also be submitted in writing. All comments **received prior to December 30, 2008** will be considered during formulation of the next draft of this tentative order. We will respond to all comments either in writing or during subsequent workshops and/or public hearings. This item will be scheduled for a public hearing at a later date, and all interested parties will be notified.

A copy of the agenda for the November 21, 2008 Board meeting can be downloaded at:
http://www.waterboards.ca.gov/santaana/board_info/agendas/2008_agendas.shtml

To be notified of future draft releases, workshops and public hearings, please sign on to our E-mail notification list (select "Storm Water – Orange County Municipal") at:
http://www.waterboards.ca.gov/resources/email_subscriptions/reg8_subscribe.shtml

If you have any questions, please call me at (951) 782-3238, Mark Smythe at (951) 782-4998, or Marc Brown at (951) 321-4584.

Sincerely,

Michael J. Adackapara
Division Chief

State of California
California Regional Water Quality Control Board
Santa Ana Region

ORDER NO. R8-2008-0030
NPDES No. CAS618030

Waste Discharge Requirements
for
the County of Orange, Orange County Resources and Development Management Department
and
The Incorporated Cities of Orange County Within the Santa Ana Region
Areawide Urban Storm Water Runoff
Orange County

FINDINGS

The California Regional Water Quality Control Board, Santa Ana Region (hereinafter Regional Board) finds that:

A. REGULATORY BASIS

1. The 1987 amendments to the Clean Water Act (CWA) added Section 402(p) (USC §1342(p)) establishing a framework for regulating municipal and industrial (including construction) storm water discharges under the National Pollutant Discharge Elimination System (NPDES) permit. Section 402(p) of the CWA requires NPDES permits for storm water discharges from municipal separate storm sewer systems[1] (storm drains or MS4s) as well as other designated storm water discharges that are considered significant contributors of pollutants to waters of the United States (waters of the US). On November 16, 1990, the United States Environmental Protection Agency (hereinafter EPA) amended its NPDES permit regulations to include permit application requirements for storm water discharges. These regulations are codified in Code of Federal Regulations, Title 40, Parts 122, 123 and 124 (40 CFR Parts 122, 123 & 124).

2. This order is based on Section 402(p) of the CWA; 40 CFR Parts 122, 123, and 124; Porter-Cologne Water Quality Control Act (Division 7 of the California Water Code or CWC, commencing with Section 13000); all applicable provisions of statewide Water Quality Control Plans and Policies adopted by the State Water Resources Control Board (State Board); the Water Quality Control Plan for the Santa Ana River Basin (Basin Plan); the California Toxics Rule (CTR); and the California Toxics Rule Implementation Plan. A revised Basin Plan was adopted by the Regional Board and became effective on January 24, 1995. The Basin Plan contains water quality objectives and beneficial uses for water bodies in the Santa Ana Region. Under the CWA, the beneficial uses and the water quality objectives to protect those beneficial uses are collectively referred to as water quality standards.

[1] A municipal separate storm sewer **system** (MS4) is any conveyance or a system of conveyances designed to collect and/or transport storm water, such as, storm drains, manmade channels, ditches, roads w/drainage systems, catch basins, curbs, gutters, etc., which is not part of a Publicly Owned Treatment Works (i.e., not a combined sewer).

The Basin Plan also incorporates by reference all State Board water quality control plans and policies, including the 1990 Water Quality Control Plan for Ocean Waters of California (Ocean Plan).

3. The requirements contained in this order are necessary to protect water quality standards of the receiving waters and to implement the plans and policies described in the above finding. These plans and policies contain numeric and narrative water quality standards for the water bodies in this Region. In accordance with Section 402(p)(2)(B)(iii) of CWA and its implementing regulations, this order requires the permittees to develop and implement programs and policies necessary to reduce the discharge of pollutants in urban storm water runoff to waters of the US to the maximum extent practicable (MEP)[2]. The legislative history and the preamble to the federal storm water regulations (40 CFR Parts 122, 123 and 124) indicate that the Congress and the EPA were aware of the difficulties in regulating urban storm water runoff solely through traditional end-of-pipe treatment. Consistent with the CWA, it is the Regional Board's intent that this order require the implementation of best management practices (BMPs)[3] to reduce to the maximum extent practicable, the discharge of pollutants in urban storm water from the MS4s in order to support attainment of water quality standards. This order, therefore, includes Receiving Water Limitations[4] based upon water quality objectives, and requires implementation of control measures to protect the beneficial uses. It also prohibits the creation of nuisance and requires the reduction of water quality impairment in receiving waters with an ultimate goal of achieving water quality objectives of the receiving waters.

4. This order is consistent with recent court decisions and precedential orders adopted by the State Board related to municipal storm water NPDES permits. These precedential State Board orders include: Orders No. 99-05, WQ 2001-15 and WQO 2002-0014.

5. This order does not constitute an unfunded mandate subject to subvention under Article XIII.B, Section (6) of the California Constitution for several reasons, including the following:

[2] MEP is not defined in the CWA; it refers to management practices, control techniques, and system, design and engineering methods, and such other provisions as the Administrator or the State determines appropriate for the control of pollutants taking into account considerations of synergistic, additive, and competing factors, including, but not limited to, gravity of the problem, technical feasibility, fiscal feasibility, public health risks, societal concerns, and social benefits.

[3] Best Management Practices (BMPs) are programs and policies, including structural controls where appropriate, that are implemented to control the discharge of pollutants.

[4] Receiving Water Limitations are requirements included in the orders issued by the Regional Board to assure that the regulated discharge does not violate water quality standards established in the Basin Plan at the point of discharge to waters of the US or the State.

a) This order implements federally mandated requirements under Clean Water Act Section 402(p)(3)(B). (33 USC § 1342(p)(3)(B)).

b) The permittees' obligation under this order are similar to, and in many respects less stringent than, the obligations of non-governmental dischargers who are issued NPDES permits for storm water discharges.

c) The permittees have the authority to levy service charges, fees, or assessments to pay for compliance with this order[5].

d) The permittees requested permit coverage in lieu of compliance with the complete prohibition against the discharge of pollutants contained in federal Clean Water Act Section 301, subdivision (a). (33 USC § 1311(a)).

B. REGULATED ENTITIES (PERMITTEES OR DISCHARGERS)

6. On July 22, 2006, the Orange County Resources and Development Management Department (RDMD), Orange County Flood Control District (OCFCD) and the incorporated cities of Anaheim, Brea, Buena Park, Costa Mesa, Cypress, Fountain Valley, Fullerton, Garden Grove, Huntington Beach, Irvine, Laguna Hills, Laguna Woods, La Habra, La Palma, Lake Forest, Los Alamitos, Newport Beach, Orange, Placentia, Santa Ana, Seal Beach, Stanton, Tustin, Villa Park, Westminster, and Yorba Linda (hereinafter collectively referred to as permittees or dischargers), submitted NPDES Application No. CAS618030 and a Report of Waste Discharge for reissuance of their areawide urban storm water permit. In order to more effectively carry out the requirements of this order, the permittees have agreed that RDMD will continue as principal permittee and the OCFCD and the incorporated cities will continue as co-permittees. Certain portions of the cities of Laguna Hills, Laguna Woods and Lake Forest are within the San Diego Regional Board's jurisdiction. As such, these cities are also regulated under urban storm water permit issued by the San Diego Regional Board.

7. The permittees fall into one of the following categories: (1) a medium or large municipality that services a population of greater than 100,000 or 250,000 respectively; or, (2) a small municipality that is interrelated to a medium or large municipality. Under Section 402(p) of the Clean Water Act, these dischargers (permittees) are required to obtain coverage under an NPDES permit for storm water runoff from their jurisdictions.

C. REGULATED DISCHARGES

8. This order is intended to regulate the discharge of pollutants in urban storm water runoff from anthropogenic (generated from human activities) sources and/or activities within the jurisdiction and control of the permittees and is not intended to address background or naturally occurring pollutants or flows.

[5] For example, the City of Santa Cruz voted to raise property taxes to fund the storm water program at the November 4, 2008 election (see: http://www.santacruzsentinel.com/localnews/ci_10904561)

9. The permittees own and operate storm drains, including flood control facilities. Some of the natural channels, streambeds and other drainage facilities that are generally considered as waters of the US have been converted to flood control facilities. The permittees have established legal authority to control discharges into these systems that they own, operate and/or regulate. As owners and/or operators of the MS4 systems, the permittees are responsible for discharges into their systems that they do not prohibit or control (except where they lack jurisdiction; see A.10 below). The discharge of pollutants into the MS4s may cause or contribute to, or threaten to cause or contribute to, a condition of pollution in receiving waters. Federal regulations, 40 CFR 122.26(d)(2)(i), require the permittees to control the discharge of pollutants into the MS4s to the maximum extent practicable.

10. The permittees may lack legal jurisdiction over urban runoff into their systems from some state and federal facilities, utilities and special districts, Native American tribal lands, waste water management agencies and other point and non-point source discharges otherwise permitted by the Regional Board. The Regional Board recognizes that the permittees should not be held responsible for such facilities and/or discharges. Similarly, certain activities that generate pollutants present in urban runoff may be beyond the ability of the permittees to eliminate. Examples of these include operation of internal combustion engines, atmospheric deposition, brake pad wear, tire wear and leaching of naturally occurring minerals from local geography.

11. This order regulates storm water runoff and certain types of de-minimus discharges specifically authorized under Section III of this order (collectively referred to as urban runoff) from areas under the jurisdiction of the permittees. For purposes of this order, urban runoff includes storm water and authorized non-storm water (see Section III) discharges from residential, commercial, industrial and construction areas within the permitted area and excludes discharges from feedlots, dairies, and farms. Urban runoff consists of surface runoff generated from various land uses in all the hydrologic drainage areas that discharge into waters of the US. The quality of these discharges varies considerably and is affected by land use activities, basin hydrology and geology, season, the frequency and duration of storm events, and the presence of illicit discharge[6] practices and illegal[7] connections.

12. The permittees have the authority to approve plans for residential, commercial, and industrial developments. If not properly controlled and managed, urbanization could result in the discharge of pollutants in urban runoff[8]. "America's Clean Water-The

[6] Illicit discharge means any disposal, either intentionally or unintentionally, of material or waste that can pollute urban runoff or create a nuisance.

[7] Illegal connections are those which are not properly authorized or permitted by the municipality or the owner/operator of the conveyance system.

[8] U.S. EPA. 1983. Results of the Nationwide Urban Runoff Program, Vol. 1, Final report. NTIS PB84-185552

States' Nonpoint Source Assessment, 1985" and the Biennial National Water Quality Inventory Reports to Congress cite urban runoff as a major source of beneficial use impairment. Urban area runoff may contain[9] elevated levels of pathogens (e.g., bacteria, protozoa, viruses), sediment, trash, fertilizers (nutrients, compounds of nitrogen and phosphorus), pesticides (e.g., DDT, Chlordane, Diazinon, Chlorpyrifos), heavy metals (e.g., cadmium, chromium, copper, lead, zinc), and petroleum products (e.g., oil, grease, petroleum hydrocarbons, polycyclic aromatic hydrocarbons). Urban runoff can carry these pollutants to rivers, streams, lakes, bays and the ocean (receiving waters[10]). In addition, increased flows due to urbanization may increase erosion of stream banks and channels and cause stream channel alterations and impact aquatic resources. This order regulates the discharge of pollutants to waters of the US, to protect beneficial uses of the receiving waters.

13. Urban activities also generate non-storm water discharges such as air conditioning condensate, irrigation runoff, individual residential car washing, etc., generally referred to as de minimus type of discharges. If properly managed, these types of discharges may not contain significant amount of pollutants. Some of these de minimus types of discharges are currently being regulated under separate orders issued by the Regional Board, and some of the specific types of de minimus discharges are authorized under this order (see Section III of this order). Orders No. R8-2003-0061 (NPDES No CAG998001), R8-2004-0021 (NPDES No. CAG998002) and R8-2007-0041 (NPDES No. CAG918002) issued by the Regional Board regulate de-minimus types of discharges.

D. HISTORY OF ORANGE COUNTY MUNICIPAL STORM WATER PERMIT

14. Prior to EPA's promulgation of the storm water permit regulations, the three counties (Orange, Riverside, and San Bernardino) and the incorporated cities within the jurisdiction of the Santa Ana Regional Board requested areawide NPDES permits for urban runoff. On July 13, 1990, the Regional Board adopted Order No. 90-71 for urban storm water runoff from urban areas in Orange County within the Santa Ana Region (first term Permit). Orders No. 96-31 (second term Permit) and R8-2002-0010 (third term Permit), issued by the Regional Board on March 8, 1996 and January 18, 2002, respectively, renewed the Orange County MS4 permit.

15. Order No. R8-2002-0010 expired on January 19, 2007. On July 22, 2006, the permittees submitted a Report of Waste Discharge for renewal of the Permit. On February 20, 2007, Order No. 2002-0010, NPDES No. CAS618030, was administratively extended in accordance with Title 23, Division 3, Chapter 9, §2235.4 of the California Code of Regulations.

[9] Makepeace, D.K., D.W. Smith, and S.J. Stanley. 1995. Urban stormwater quality: summary of contaminant data. Critical Reviews in Environmental Science and Technology 25(2):93-139.

[10] Receiving waters are waters of the U.S. (and their tributaries) which are identified in the Basin Plan as having certain beneficial uses (see Finding 19, below, for a list of these waters).

E. PERMIT RENEWAL APPLICATION AND RELATED DOCUMENTS

16. The Report of Waste Discharge (the permit renewal application) included the following major documents/information:

    a) A summary of status of current Storm Water Management Program;

    b) A Proposed Plan of Storm Water Quality Management Activities for 2007-20012, as outlined in the Draft 2007 Drainage Area Management Plan (DAMP). The 2007 DAMP includes all the activities the permittees propose to undertake during the next permit term, goals and objectives of such activities, and an evaluation of the need for additional source control and/or structural and non-structural BMPs and proposed pilot studies;

    c) The permittees have developed Local Implementation Plans (LIPs); established a formal training program; and developed a program effectiveness assessment strategy and Watershed Action Plans;

    d) A Performance Commitment that includes new and existing program elements and compliance schedules necessary to implement controls to reduce pollutants to the maximum extent practicable;

    e) A summary of procedures implemented to detect illegal discharges and illicit connection practices;

    f) A summary of enforcement procedures and actions taken to require storm water discharges to comply with the approved Storm Water Management Program;

    g) A summary of public agency activities, results of monitoring program, and program effectiveness assessment; and,

    h) A fiscal analysis.

17. The documents referenced in Finding E.16, above, are hereby incorporated as enforceable elements of this order.

F. PERMITTED AREA

18. The permitted area is shown on Attachment A. It includes the northern portions of Orange County, including the 26 incorporated cities listed under Finding 6, above. The permittees serve a population of approximately 3.1 million, occupying an area of approximately 786 square miles (including unincorporated areas and the limits of 34 cities, 26 of which are within the jurisdiction of this Regional Board; three of the cities, Laguna Hills, Laguna Woods and Lake Forest, are within both the San Diego and Santa Ana Regional Boards' jurisdictions). The permittees have jurisdiction over and/or maintenance responsibility for storm water conveyance systems within Orange County. The County's systems include an estimated 400 miles of storm drains. A major portion of the urbanized areas of Orange County drains into waterbodies within this Regional Board's jurisdiction. In certain cases, where a natural streambed is modified to convey storm water flows, the conveyance system becomes both a storm drain and a receiving water. The major storm drain systems

and drainage areas in Orange County, which are within this Region, are shown on Attachment B. A portion of the Orange County drainage area is within the jurisdiction of the San Diego Regional Board and is regulated under an order issued by that Board.

G. RECEIVING WATERS AND BENEFICIAL USES

19. Storm water runoff from the MS4s in Orange County enter, or are tributary to, various water bodies of the Region. The permitted area can be subdivided into five tributary watersheds: the San Gabriel River drainage area, the Huntington Harbour and Bolsa Bay drainage area, the Santa Ana River drainage area, the Newport Bay drainage area, and the Irvine and Newport Coast Areas of Special Biological Significance (see Attachment B). These watersheds are tributary to the Pacific Ocean. The surface water bodies in Orange County that could be impacted by urban runoff include:

Inland Surface Streams

Santa Ana River, Reaches 1 and 2

Aliso Creek (tributary to Santa Ana River)

Carbon Canyon Creek (tributary to Santa Ana River)

Santiago Creek, Reaches 1, 2, 3, and 4 (tributary to the Santa Ana River)

Silverado Creek (tributary to Santiago Creek)

Black Star Creek (tributary to Santiago Creek)

Ladd Creek (tributary to Santiago Creek)

San Diego Creek, Reaches 1 and 2 (tributary to Newport Bay)

San Joaquin Freshwater Marsh (tributary to San Diego Creek)

Other tributaries to San Diego Creek: Bonita Creek, Serrano Creek, Peters Canyon Wash, Hicks Canyon Wash, Bee Canyon Wash, Borrego Canyon Wash, Agua Chinon Wash, Laguna Canyon Wash, Rattlesnake Canyon Wash, and Sand Canyon Wash

Santa Ana Delhi Channel (tributary to Newport Bay)

Big Canyon Wash (tributary to Newport Bay)

Buck Gully

Los Trancos Creek

Coyote Creek (tributary to San Gabriel River)

Other tributaries to the above listed rivers, creeks and channels

Bays, Estuaries, and Tidal Prisms

Anaheim Bay and Seal Beach National Wildlife Refuge

Sunset Bay

Bolsa Bay and Bolsa Chica Ecological Reserve

Upper and Lower Newport Bay

Tidal Prism of Santa Ana River (to within 1000 feet of Victoria Street) and Newport Slough, Santa Ana Salt Marsh

Tidal Prism of San Gabriel River (River Mouth to Marina Drive)

Tidal Prisms of Flood Control Channels Discharging to Coastal or Bay Waters (e.g. Huntington Harbour)

Ocean Water

Nearshore Zone

San Gabriel River to Poppy Street in Corona Del Mar

Poppy Street to Southeast Regional Boundary

Offshore Zone

Waters between Nearshore Zone and limit of State Waters

Lakes and Reservoirs

Anaheim Lake

Irvine Lake (Santiago Reservoir)

Laguna, Lambert, Peters Canyon, Rattlesnake, Sand Canyon and Siphon Reservoirs

20. The beneficial uses of these water bodies include: municipal and domestic supply, agricultural supply, industrial service and process supply, groundwater recharge, navigation, hydropower generation, water contact recreation, non-contact water recreation, commercial and sport fishing, warm freshwater and limited warm freshwater habitats, cold freshwater habitat, preservation of biological habitats of special significance, wildlife habitat, preservation of rare, threatened or endangered species, marine habitat, shellfish harvesting, spawning, reproduction and development of aquatic habitats, and estuarine habitat. The ultimate goal of this storm water management program is to achieve water quality objectives in the receiving waters, thereby protecting their beneficial uses.

21. Federal regulations, 40 CFR 131.10(a), prohibits the states from designating a water body for waste transport or waste assimilation. This order prohibits the construction of treatment BMPs within waters of the US. However, if the discharges are sufficiently treated to protect the beneficial uses of the receiving waters, further polishing of the discharge within waters of the US may be considered on a case-by-case basis. Federal authorization under Section 404 and Water Quality Standards Certification under Section 401 of the Clean Water Act may be required for waste treatment or conveyance within waters of the US. Pursuant to Water Code Section 13260, Waste Discharge Requirements may be required for such facilities within waters of the State. Under certain conditions, stream flows may be diverted for

treatment (see Section III for conditions on return flows from facilities that extract, treat and return flows from the waters of the US).

H. INTERRELATED WATERSHEDS AND STORM WATER PERMITS

22. The Santa Ana River Basin is the major watershed within the jurisdiction of the Regional Board. The lower Santa Ana River Basin (downstream from Prado Basin) includes the Orange County drainage areas, and the Upper Santa Ana River Basin includes the San Bernardino County and the Riverside County drainage areas. Generally, the San Bernardino County drainage areas drain to the Riverside County drainage areas, and Riverside County drainage areas discharge to Orange County.

23. Within the Region, runoff from the San Bernardino County areas is generally conveyed to the Riverside County areas through the Santa Ana River or other drainage channels tributary to the Santa Ana River. These flows are then discharged to Reach 2 of the Santa Ana River through Prado Basin (Reach 3 of the Santa Ana River). During dry weather conditions, most of the flow in Reach 2 is recharged in Orange County. During wet weather, some of the flow is discharged to the Pacific Ocean through Reach 1 of the Santa Ana River.

24. The three county areas within this Region are regulated under three areawide permits for urban storm water runoff. These areawide NPDES permits are:

    Orange County, NPDES No. CAS618030;

    Riverside County, NPDES No. CAS618033; and,

    San Bernardino County, NPDES No. CAS618036.

    For an effective watershed management program, cooperation and coordination among the regulators, the municipal permittees, the public, and other entities are essential.

25. Studies conducted by the USEPA, the states, flood control districts and other entities indicate the following major sources for urban storm water pollution nationwide:

    Industrial sites where appropriate pollution control and BMPs are not implemented;

    Construction sites where erosion and siltation controls and other BMPs are not implemented; and,

    Urban runoff where the drainage area is not properly managed.

26. A number of permits have been adopted to address pollution from the sources identified in Finding 25, above. The State Board issued three statewide general NPDES permits: one for storm water runoff from industrial activities (NPDES No. CAS000001, General Industrial Activities Storm Water Permit), a second permit for storm water runoff from construction activities (NPDES No. CAS000002, General Construction Activity Storm Water Permit) and a third permit for Storm Water Runoff Associated with Small Linear Underground/Overhead Construction Projects

(CAS000005). Industrial activities (as identified in 40 CFR 122.26(b)(14)) and construction sites of one acre or more, are required to obtain coverage under these statewide general permits. The permittees have developed project conditions of approval requiring coverage under the State's General Permits for new developments to be implemented at the time of grading or building permit issuance for construction sites on one acre or more and at the time of local permit issuance for industrial facilities.

27. The State Board also adopted NPDES No. CAS000003 for storm water runoff from facilities (including freeways and highways) owned and/or operated by California Department of Transportation (Caltrans) and NPDES No. CAS000004, for Storm Water Discharges from Small Municipal Separate Storm Sewer Systems. The Regional Board adopted Order No. R8-2007-0001, NPDES No. CAG018001, for concentrated animal feeding operations, including dairies. The Regional Board also issues individual storm water permits for certain industrial facilities within the Region. Currently there are two facilities located within Orange County. Additionally, for a number of facilities that discharge process wastewater and storm water, storm water discharge requirements are included with the facilities' NPDES permit for process wastewater.

28. In most cases, the industries and construction sites covered under the Statewide General Industrial and Construction Permits discharge into storm drains and/or flood control facilities owned and operated by the permittees. These industries and construction sites are also regulated under local laws and regulations. Federal regulations, 40 CFR Part 122.26(d)(2)(iv)(C), also require the permittees to develop and implement programs to control the discharge of pollutants from these sites. A coordinated effort between the permittees and Regional Board staff is critical to avoid duplicative and overlapping efforts when overseeing the compliance of dischargers covered under the Statewide General Permits. As part of this coordination, the permittees have been notifying Regional Board staff when they observe conditions that pose a threat or potential threat to water quality, or when an industrial facility or construction activity has failed to obtain required coverage under the appropriate general storm water permit.

29. The Regional Board and the permittees recognize the importance of integrated watershed management initiatives and regional planning and coordination in the development and implementation of programs and policies related to water quality protection. A number of such efforts are underway in which the permittees are active participants. The Regional Board recognizes that a watershed management program should integrate all related programs, including the storm water program and TMDL processes. Consistent with this approach, some of the municipal storm water monitoring programs have already been integrated into a regional monitoring program. The Regional Board also recognizes that, in certain cases, diversion of funds targeted for certain monitoring programs to regional monitoring programs may be necessary. The Executive Officer is authorized to approve, after proper public notification and consideration of all comments received, the integrated watershed

management initiatives and regional planning and coordination programs and regional monitoring programs. The permittees are required to submit all documents, where appropriate, in an electronic format. All such documents will be posted at the Regional Board's website and all interested parties will be notified. In addition, the website will include the administrative and civil procedures for appealing any decision made by the Executive Officer. Some urban runoff issues, such as monitoring, public education and training can be more effectively addressed on a regional or statewide basis, thereby increasing program consistency and efficiency. This order encourages continued participation in such programs and policies.

30. The permittees are required to conduct inspections (40 CFR Part 122.26(d)(2)(iv)(C)(2)) of construction sites, industrial facilities and commercial establishments. To avoid duplicative efforts, the permittees need not inspect facilities that have been inspected by Regional Board staff, if the inspection was conducted during the specified time period. It is anticipated that many of the inspections required under this order can and will be carried out by inspectors currently conducting other types of inspections for the permittees (i.e., grading, building, code enforcement, etc.), during their normal duties. It is critical that these inspectors be properly trained in storm water pollution prevention and related issues.

I. POTENTIAL POLLUTANTS IN STORM WATER RUNOFF/IMPACTS ON BENEFICIAL USES

31. The permittees have conducted urban runoff and receiving water monitoring as required under the first, second and third term permits. The third term permit required monitoring using a wider array of methods to assess impacts caused by pollutants in urban runoff. In addition to monitoring the water column under wet and dry weather conditions, the permittees were required to monitor: water column toxicity, mass emission rates, estuary/wetlands including sediment and benthic monitoring, bacteriological/pathogen concentrations and bioassessment analysis. These monitoring programs indicate exceedances of Basin Plan, CTR and/or AB 411 objectives for a number of constituents. The Report of Waste Discharge identifies copper and zinc, trash and debris, pesticide toxicity and pathogens as the major pollutants of concern. Monitoring data indicate that storm water and dry weather urban runoff continue to have pollutants at levels that could cause or contribute to exceedances of water quality objectives in the receiving waters. The permittees are proposing to conduct special studies to address these pollutants of concern during the fourth term permit.

32. The annual reports submitted by the permittees indicate that urban runoff is still causing or contributing to water quality standards violations. Some of the samples collected during both dry and wet weather exceeded the water quality standards. However, the exceedances during wet weather were more widespread compared to dry weather runoff. The monitoring reports indicate that there is some reduction in the mass loading rates for some of the metals, such as copper and zinc.

33. The results from the monitoring programs did not establish a clear correlation between pollutants in dry or wet weather runoff and impacts on beneficial uses in the receiving waters. However, exceedances of water quality objectives, including exceedances of AB411 standards, were reported for a number of monitoring locations by the permittees. Shoreline monitoring data indicate that AB411 exceedances are higher during the summer months (AB411 season) compared to the winter months. For the interior channels, AB411 exceedances were higher than shoreline, but were not significantly different for summer and winter months[11]. The index of biotic integrity rating is generally poor for most urban streams. The monitoring data also indicated sporadic exceedances of water quality objectives for dissolved oxygen, pH, turbidity, ammonia-nitrogen, surfactants, and some of the metals[12].

34. During the summers of 1999 and 2000, a number of locations along the Orange County coast exhibited elevated bacterial levels. Since then a number of studies have been conducted that indicate that urban runoff, especially dry weather runoff, is a major contributing factor to the Orange County coastal bacterial contamination problems. To address this bacterial problem, the permittees currently divert dry weather low flows from some of these areas to the sanitary sewer. With the diversion of dry weather flows to the sanitary sewer, there have been significant improvement in the beach water quality. A number of studies have been conducted to determine the source of this microbial contamination and to develop permanent remedial measures. These studies have not conclusively determined the sources or solutions to this problem.

35. Monitoring results have indicated the presence of elevated concentrations of pesticides in storm water runoff from urban areas. The permittees have developed and implemented a model plan entitled, “Management Guidelines for Use of Fertilizers and Pesticides”. The Report of Waste Discharge indicates that through implementation of this program, the municipalities have reduced the use of fertilizers and pesticides. The permittees are required to review this plan to make any needed changes. TMDLs are being developed for some of the pesticides for the Newport Bay watershed. This order may be reopened to include any TMDL requirements.

36. Pollutants in urban runoff can impact the beneficial uses of the receiving waters and can cause or threaten to cause a condition of pollution or nuisance. Pathogens, such as bacteria, viruses, protozoa, (from sanitary sewer overflows, septic system leaks, spills and leaks from portable toilets, pets, wildlife and human activities) can impact water contact recreation, non-contact water recreation and shellfish harvesting. Microbial contamination of the beaches from urban runoff and other sources has resulted in a number of health advisories issued by the Orange County Health Officer. Oil and grease (from automobiles, industrial sites, etc.) can coat

[11] Unified Annual Progress Report, 2005-2006, Page C-11-31

[12] Unified Annual Progress Report, 2005-2006, Attachment C-11-VII

birds and aquatic organisms, adversely affecting respiration and/or thermoregulation. Other petroleum hydrocarbon components can cause toxicity to aquatic organisms and can impact human health. Suspended and settleable solids (from sediment, trash, and industrial activities) can be deleterious to benthic organisms and may cause anaerobic conditions. Sediments and other suspended particulates (from construction sites, erosion due to hydromodification, etc.) can cause turbidity, clog fish gills and interfere with respiration in aquatic fauna. These pollutants can also screen out light, hindering photosynthesis and normal aquatic plant growth and development. Toxic substances (from pesticides, herbicides, petroleum products, metals) can cause acute and/or chronic toxicity, and can bioaccumulate in organisms to levels that may be harmful to human health. Nutrients (from fertilizers, confined animal feeding operations, wildlife, pets and birds) can cause excessive algal blooms. These blooms can lead to problems with taste, odor, color and increased turbidity, and can depress the dissolved oxygen content, leading to fish kills. Trash and debris, in particular plastics, have long been recognized as both aesthetic nuisances and as threats to freshwater and marine environments. Plastic debris, in the form of broken-down packaging and pre-production plastic pellets or 'nurdles', harms hundreds of wildlife species through ingestion, entanglement and entrapment. These plastic nurdles have the capability of absorbing pollutants, such as PCBs, and when ingested by wildlife, expose those animals to pollutant concentrations that are orders of magnitude higher than the surrounding water. Water Code Section 13367 requires the State Board and the regional boards to implement a program to control discharges of preproduction plastic from point and nonpoint sources. In collaboration with the permittees, Regional Board staff is currently trying to address this problem through the State's General Storm Water Permit for Industrial Activities and local controls.

37. Pollutants in urban runoff could adversely impact human health and the environment. Human illnesses have been linked to recreational activities in coastal waters especially near storm drain outlets[13]. Bioaccumulation of pollutants, present in urban runoff, can occur in fish and other aquatic organisms. These organisms may be consumed by birds and humans. Pollutants in urban runoff can also cause mortality, impair growth and reproduction anomalies in aquatic organisms.

38. It is important to control litter in order to eliminate trash and other materials in storm water runoff. In addition to the municipal ordinances prohibiting litter, the permittees participate or organize a number of other programs such as "Coastal Cleanup Day", "Pride Days", "Volunteer Collection Day", etc. The permittees also organize solid waste collection programs, household hazardous waste collections, and recycling programs to reduce litter and illegal discharges. Additionally, the permittees have installed debris booms at a number of locations to capture trash and debris preventing it from depositing on beaches.

[13] The Santa Monica Bay Restoration Project, Epidemiology Study, 1996

39. The pollutants from urbanized areas are also a significant threat to environmentally sensitive areas, such as waterbodies designated as supporting a RARE beneficial use (supporting rare, threatened or endangered species), areas of special biological significance (ASBSs) and Clean Water Act Section 303(d) listed impaired waterbodies. The State Board is developing Special Protections for Storm Water and Non-point Source Discharges to ASBSs. Where applicable, the permittees are expected to comply with these Special Protection requirements for the ASBSs.

J. CWA SECTION 303(d) LISTED WATERBODIES AND TMDLS

40. Water quality assessments conducted by Regional Board staff have identified a number of water quality standards impairments due, in part, to urban runoff. Section 305(b) of the CWA requires each of the regional boards to routinely monitor and assess the quality of waters of the region. If this assessment indicates that beneficial uses and/or water quality objectives are not being met, then that waterbody must be listed under Section 303(d) of the CWA as an impaired waterbody. The 2006 State water quality assessment listed a number of water bodies within the Region under Section 303(d) as impaired waterbodies. For many of these impaired waterbodies, one of the listed causes of impairment is urban runoff. In the Orange County area, these include:

    San Diego Creek, Reach 1 (listed for toxaphene, selenium, fecal coliform, nutrients, pesticides, sediment/siltation);

    San Diego Creek, Reach 2 (listed for metals, nutrients, sediment/siltation, unknown toxicity);

    Upper Newport Bay Ecological Reserve (listed for sediment toxicity, metals, copper, chlordane, PCBs, DDT, nutrients, pathogens, pesticides, sediment/siltation);

    Lower Newport Bay (listed for chlordane, copper, DDT, sediment toxicity, PCBs, nutrients, pathogens, pesticides);

    Anaheim Bay (listed for nickel, dieldrin, sediment toxicity, PCBs);

    Huntington Harbour (listed for copper, lead, nickel, chlordane, pathogens, PCBs, sediment toxicity);

    Santiago Creek, Reach 4 (listed for salinity, TDS, chlorides);

    Seal Beach (listed for enteroccocus, PCBs);

    Silverado Creek (listed for pathogens, salinity, TDS, chlorides);

    Rhine Channel (listed for copper, lead, mercury, zinc, sediment toxicity, PCBs);

    Peters Canyon Channel (listed for DDT, toxaphene);

    Los Trancos Creek (Crystal Cove Creek) (listed for total and fecal coliform);

Huntington Beach State Park (listed for enteroccocus, indicator bacteria, PCBs);

Bolsa Chica State Beach (listed for copper and nickel);

Buck Gully Creek (listed for total and fecal coliform); and

Balboa Beach (listed for dieldrin, DDT, PCBs).

41. Federal regulations require that a total maximum daily load (TMDL) be established for each 303(d) listed waterbody for each of the pollutants causing impairment. The TMDL is the total amount of the pollutant that can be discharged while water quality standards in the receiving water are attained, i.e., water quality objectives are met and the beneficial uses are protected. A TMDL is the sum of the individual wasteload allocations (WLA) for point source inputs, load allocations (LA) for non-point source inputs and natural background, plus a margin of safety. TMDLs are one of the bases for limitations established in waste discharge requirements.

42. For 303(d) listed waterbodies without a TMDL, the permittees are required to provide special protections through development and implementation of Watershed Action Plans or other focused control measures that would address the pollutant of concern. If a TMDL has been developed and an implementation plan is yet to be developed, the permittees are required to develop constituent specific source control measures, conduct additional monitoring and/or cooperate with the development of an implementation plan.

43. TMDLs have been established by the Regional Board for sediment, fecal coliform, diazinon, chlorpyrifos and nutrients for the San Diego Creek/Newport Bay watershed. Organochlorine compounds TMDLs were adopted by the Regional Board on September 7, 2007. In addition, toxics TMDLs were promulgated by USEPA on June 14, 2002, including TMDLs for metals and selenium, and a TMDL specific to the Rhine Channel located in Lower Newport Bay.

44. TMDLs for diazinon and chlorpyrifos in San Diego Creek, and for chlorpyrifos in Upper Newport Bay, were adopted by the Regional Board on April 4, 2003, and subsequently approved by the State Board, State Office of Administrative Law, and EPA. The diazinon and chlorpyrifos TMDLs require all MS4 permittees in the Newport Bay Watershed to develop and implement monitoring programs for diazinon and chlorpyrifos. The TMDLs also impose limits on the discharge of these compounds. This order incorporates these requirements.

45. The fecal coliform TMDL specifies WLAs for urban runoff to protect water contact recreation and shellfish harvesting beneficial uses. The implementation plan for the fecal coliform TMDL requires that monitoring and certain investigations be conducted, including a source identification and characterization investigation of urban runoff. An updated TMDL report is to be prepared based on the data and information collected, and the TMDL is to be adjusted, as necessary, based on

the updated TMDL report. This order may be reopened to incorporate additional requirements based on findings in the source identification and characterization plan that is expected to be completed in 2009. This order may be reopened to incorporate additional or revised requirements based on the updated TMDL report and/or approved changes to the TMDL.

46. As indicated above, nutrient (nitrogen and phosphorus) TMDLs have been established by the Regional Board for the San Diego Creek/Newport Bay watershed. The current and future (year 2012) targets for the nutrient TMDLs are already being met. However, Board staff is currently reevaluating the nutrient TMDLs in light of evidence that there remains impairment of these waters due to eutrophication. The EPA promulgated TMDLs for selenium but, an implementation plan is yet to be developed. The Regional Board adopted Orders No. R8-2004-021 and R8-2007-0041 as interim control measures to address nitrogen and selenium in groundwater-related discharges to the San Diego Creek/Newport Bay watershed. In response to Order No. R8-2004-0021, stakeholders established a Nitrogen Selenium Management Program (NSMP) Working Group. The Working Group is implementing an approved workplan that is expected to identify comprehensive management plans for both selenium and nitrogen in groundwater in the San Diego Creek/Newport Bay watershed. Board staff is currently developing selenium TMDLs that will update and revise those established by EPA and that will include an implementation plan. The implementation plan will rely heavily on the findings and recommendations made by the NSMP Working Group. It is expected that the implementation plan will include the opportunity for an adaptive, collaborative approach by stakeholders in the watershed to address selenium and nitrogen in comprehensive and efficient fashion. This approach may be implemented through a cooperative agreement or, alternatively, through waste discharge requirements or a conditional waiver of waste discharge requirements.

47. In support of the nutrient TMDLs implementation plan, a regional monitoring program (RMP) was developed to monitor nutrients in San Diego Creek and Newport Bay. This order requires the permittees listed under the RMP to continue their participation in the RMP program.

48. On September 7, 2007, the Regional Board adopted TMDLs for organochlorine compounds (OCs) that specify WLAs for urban runoff for DDT and toxaphene in San Diego Creek, and DDT, chlordane, and PCBs in Upper and Lower Newport Bay. The OCs TMDLs also specify informational TMDLs with informational urban runoff WLAs for chlordane and PCBs in San Diego Creek. The OCs TMDLs require approval from the State Board, the State Office of Administrative Law, and EPA. The implementation plan for the OCs TMDLs includes monitoring and, where necessary, enhanced implementation of best management practices (BMPs) to reduce erosion and sediment transport as organochlorine compounds tend to adhere to fine sediment. In addition, the OCs TMDL implementation plan provides an opportunity for dischargers to participate in the development and implementation

of a comprehensive Work Plan that would address the OCs and other sources of toxicity in the San Diego Creek and Newport Bay watersheds. Once a Work Plan is developed, it is required to be approved by the Regional Board at a public hearing. Participation by the permittees in this process will obviate the need for individual actions on the tasks in Table NB-OCs-13[14] by members of the Working Group. The County of Orange and Newport Bay watershed MS4 permittees have initiated efforts to develop a Work Plan. MS4 permittees not electing to participate in the Work Plan approach will be required to implement the tasks shown in Table NB-OCs-13, as appropriate.

49. The State Board awarded a grant to the South Coast Resource Conservation and Development Council in partnership with the University of California Cooperative Extension to investigate and demonstrate strategies to reduce pesticide runoff from urban areas. A pesticide management plan for the Newport Bay watershed has been developed under this program[15].

50. If the TMDL implementation plans include compliance schedules beyond the permit term, monitoring and other requirements are being included in this order to monitor progress towards achieving future compliance.

51. Certain portions of the San Gabriel River watershed are under the Los Angeles Regional Board's jurisdiction. Urban runoff from cities and county areas within the northwestern portions of Orange County discharge into the San Gabriel River and/or its tributaries. On July 13, 2006, the Los Angeles Regional Board adopted TMDLs for metals in the San Gabriel River watershed. However, because of the state's inability to meet the March 2007 deadline for an approved TMDL prescribed in a consent decree (Heal the Bay Inc., et al. v. Browner C98-4825 SBA), on March 26, 2007, the EPA promulgated TMDLs for metals and selenium for the San Gabriel River. The upper portions of Coyote Creek flow through Orange County to join the San Gabriel River above the tidal prism. Other unnamed tributaries located in northwestern Orange County also discharge into the San Gabriel River estuary. The EPA promulgated TMDLs include wet weather wasteload allocations for Coyote Creek for copper, lead and zinc and dry weather wasteload allocations for copper for Coyote Creek. The permittees are expected to implement programs and policies consistent with the metals and selenium TMDLs for the San Gabriel River watershed. This includes constituent-specific source control programs or other equally effective programs to control the discharge of copper, lead and zinc into Coyote Creek and other tributaries in Orange County that discharge into the San Gabriel River.

52. This order requires permittees to comply with established TMDL wasteload allocations specified for urban runoff and/or storm water by implementing the necessary BMPs. Continuation of water quality/biota monitoring and analysis of

[14] Attachment 2 to Resolution No. R8-2007-0024

[15] Darren L. Haver and John N. Kabashima, June 30, 2008, Pesticide Runoff Management Plan, Newport Bay Watershed

the data are essential to better understand the impacts of storm water discharges on the water quality of the receiving waters, impairment caused by urban runoff and for assessing the effectiveness of control measures.

53. Permittees will be required to comply with established TMDLs and other water quality standards or discharge requirements that may be imposed by the EPA or the State prior to the expiration of this order. This order may be reopened to address established or revised TMDLs and/or other requirements developed and adopted by the Regional Board, EPA or the State Board.

K. DRAINAGE AREA MANAGEMENT PLAN (DAMP)

54. Urban development increases population density and pollutant sources[16] such as construction activities, industrial facilities, auto emissions, wastes related to automobile maintenance activities, sanitary wastes, pesticides, pet wastes, household hazardous wastes and trash[17]. If appropriate BMPs are not implemented, retail gasoline outlets and automobile service stations could be significant sources of pollutants in urban runoff including petroleum hydrocarbons, oil and grease, metals and solvents[18].

55. The local agencies (the permittees) are the owners and operators of the storm water conveyance systems and have established appropriate legal authority to control discharge of pollutants to the MS4s. The permittees have adopted grading and erosion control ordinances, guidelines and best management practices (BMPs) for municipal, commercial, and industrial activities. The permittees must exercise a combination of these programs, policies, and legal authority to ensure that pollutant loads resulting from urbanization are properly controlled and managed.

56. One of the major tools that the permittees use for urban runoff pollution prevention is the development and implementation of an appropriate DAMP, including best management practices (BMPs). The ultimate goal of the urban storm water management program is to support attainment of water quality objectives for the receiving waters and to protect beneficial uses through the implementation of the DAMP. The permittees developed and submitted a revised draft 2007 DAMP.

57. The DAMP is a dynamic document and the permittees have implemented, or are in the process of implementing, various elements of the DAMP. This order requires the permittees to continue to implement the BMPs listed in the revised DAMP;

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[16] U.S. EPA (1992). *Environmental Impacts of Storm Water Discharges: A National Profile.* EPA 841-R-92-001. Office of Water. Washington, DC.

[17] National Management Measures to Control Nonpoint Source Pollution from Urban Areas. USEPA Publication No. EPA 841-B-05-004, November 2005.

[18] Retail Gasoline Outlet and Commercial Parking Lot Storm Water Runoff Study, Western States Petroleum Association and American Petroleum Institute (1994) at p 13. The study concludes that pollutant concentrations in storm water discharges from properly managed RGOs are similar to concentrations from commercial parking lots and diffuse urban runoff.

update or modify the DAMP, when appropriate, consistent with the MEP and other applicable standards; and to effectively prohibit illegal and illicit discharges to the storm drain system.

58. The Orange County DAMP defined: (1) a management structure for the permittees' compliance effort; (2) a formal agreement to underpin cooperation; and (3) a detailed municipal effort to develop, implement, and evaluate various BMPs or control programs in the areas of public agency activities, public information, new development and construction, public works construction, industrial discharger identification, and illicit discharger/connection identification and elimination.

59. In order to meet DAMP requirements and characterize and manage pollutant sources on a local level, the permittees developed LIPs. Each jurisdiction has developed its own LIP and is implementing the LIP to properly manage, reduce and mitigate potential and actual pollution sources within the boundaries of each permittee's jurisdiction.

L. NEW DEVELOPMENT/SIGNIFICANT REDEVELOPMENT – WQMP/LIP/LID

60. A major portion of Orange County is urbanized with residential, commercial and industrial developments. Urban development increases impervious surfaces and storm water runoff volume and velocity and decreases vegetated, pervious surface areas available for infiltration and evapotranspiration of storm water. Increase in runoff volume and velocity can cause scour, erosion (sheet, rill and/or gully), aggradation (raising of a streambed from sediment deposition) and can change fluvial geomorphology, hydrology and aquatic ecosystems. This order includes requirements to address increases in imperviousness and changes in water quality and quantity, including hydrologic conditions of concern.

61. Recent studies have indicated that low impact development[19] (LID) is one of the most effective ways to minimize any adverse impacts on storm water runoff quality and quantity resulting from urban developments. Southern California Coastal Water Research Project (SCCWRP) under the auspices of Storm Water Monitoring Coalition and in collaboration with the California Storm Water Quality Association (CASQA) and the State Board is developing a Low Impact Development Manual for Southern California. This guidance document will be incorporated into the CASQA BMP Handbooks. The permittees are encouraged to utilize the guidance manual as a resource to implement LID techniques.

62. The USEPA has determined that by limiting the effective impervious area of a development site to 5% or less, downstream impacts could be minimized (also see

[19] Low impact development is an approach to land development (or re-development) that works with nature to manage storm water as close to its source as possible by using structural and non-structural best management practices to reduce environmental impacts.

the SCCWRP study[20]). A limited study conducted by Dr. Richard Horner[21] concluded that a 3% EIA standard for development is feasible in Ventura County. These principles are incorporated into requirements for new developments and redevelopment projects.

63. On October 5, 2000, the State Board adopted Order No. WQ-2000-11, which is a precedential order. Order No. WQ-2000-11 required that urban runoff generated by 85th percentile storm events from specific types of development categories should be infiltrated, filtered or treated. The essential elements of this precedential order were incorporated into the Region 8 Orange County third term permit. In accordance with the requirements specified in the third term permit, the permittees developed a model Water Quality Management Plan (WQMP) by amending their Drainage Area Management Plan (DAMP). The model WQMP provides a framework to incorporate watershed protection principles into the permittees planning, construction and post-construction phases of defined new and redevelopment projects. The WQMP includes site design, source control and treatment control elements to reduce the discharge of pollutants in urban runoff. On September 26, 2003, the Regional Board approved the model WQMP. The permittees have incorporated provisions of the WQMP into their LIPs. The permittees are requiring new developments and significant redevelopments to develop and implement appropriate WQMPs. This order requires continued implementation of structural and non-structural BMPs for new developments and significant redevelopments as per the approved model WQMP. However, with the implementation of LID techniques, some of the structural treatment control BMPs may not be necessary. The WQMP for the project is required to include a discussion on how LID principles are incorporated into the project.

64. The Region 8 Orange County third term permit required the permittees to review their planning (CEQA, General Plan, etc.) and approval processes to determine the need to revise those processes to address appropriate storm water protection principles. The model WQMP provides a framework for addressing these issues. However, Regional Board staff's audit of the permittees MS4 program indicated that all the permittees had not fully implemented the program. This order requires the permittees to reevaluate and to revise the current program implementation processes. Pollution prevention techniques, appropriate planning processes and early identification of potential storm water impacts and mitigation measures can significantly reduce storm water pollution problems. The permittees shall consider these impacts and appropriate mitigation measures during the planning and approval processes.

[20] Studies conducted by Southern California Coastal Water Research Project (SCCWRP) and others indicate that environmental impacts from developments could be minimized by limiting the effective impervious area to 5% or less.

[21] Dr. Richard Horner, Investigation of the Feasibility and Benefits of Low-Impact Site Design Practices ("LID") for Ventura County, Development (undated)

65. The intent of the WQMP, SWPPP and other programs and policies incorporated into this order is to minimize the impact from the project on water quality and the environment. However, compliance with this order and the DAMP does not necessarily constitute mitigation that is sufficiently specific to satisfy the requirements of CEQA with regards to projects.

66. The treatment control BMPs include vortex systems, catch basin inserts, detention basins, retention basins, regional treatment systems, constructed wetlands, various types of storm water filters, etc.. If not properly designed and managed, these systems could be sources of groundwater pollution and could become a nuisance and/or cause the spreading of surface water pollution. The requirements specified in this order include identification of responsible agencies for maintaining the systems and for providing funding for operation and maintenance.

67. If not properly designed and maintained, the BMPs identified in Finding 65 could create a nuisance and/or habitat for vectors[22] (e.g., mosquitoes and rodents). Third term permit required the permittees to closely collaborate with the Orange County Vector Control District during the development and implementation of such treatment systems. The permittees should continue these collaborative efforts with the Vector Control District to ensure that treatment control systems do not become a nuisance or a potential source of pollutants.

M. NON-STORM WATER/DE-MINIMUS DISCHARGES

68. The MS4s generally contain non-storm water flows such as irrigation runoff, runoff from non-commercial car washes, runoff from miscellaneous washing and cleaning operations, and other nuisance flows generally referred to as de-minimus discharges. Federal regulations, 40 CFR Part 122.26(d)(2)(i)(B), prohibit the discharge of non-storm water containing pollutants into the MS4s and to waters of the U.S. unless they are regulated under a separate NPDES permit, or are exempt, as indicated in Discharge Prohibitions, Section III.3 of this order. The Regional Board adopted a number of NPDES permits[23] to address de-minimus type of pollutant discharges. However, the permittees need not get coverage under the de-minimus permits for the types of discharges listed under Section III.3, except for discharges to the San Diego Creek/Newport Beach watershed, as long as they are in compliance with the conditions specified under Section III of this order.

69. Many areas of the San Diego Creek/Newport Bay watershed have high nitrate and/or selenium levels in the soils and/or groundwater. Dewatering operations, construction activities and agricultural and other operations could mobilize these pollutants and carry them into San Diego Creek and Newport Bay. The Regional Board has adopted a General Permit, Order No. R8-2007-0041, to regulate

[22] Managing Mosquitoes in Stormwater Treatment Devices, Marco E. Metzger, University of California Davis, Division of Agriculture and Natural Resources, Publication 8125.

[23] E.g., R8-2003-0061,as amended by R8-2004-0021.

dewatering wastes into the San Diego Creek/Newport Bay watershed. In addition, stakeholders in the watershed are in the process of developing a comprehensive nitrogen/selenium management plan to address the nitrogen/selenium issues.

N. PERMIT REQUIREMENTS AND NUMERIC EFFLUENT LIMITS

70. The first term permit required the permittees to: (1) develop and implement the DAMP and a storm water and receiving water monitoring plan; (2) eliminate illegal[24]and illicit discharges[25] to the MS4s; and (3) enact the necessary legal authority to effectively prohibit such discharges. The overall goal of these requirements was to reduce pollutant loadings to surface waters from urban runoff to the MEP. The second term permit required continued implementation of the DAMP and the monitoring plan, and required the permittees to focus on those areas that threaten beneficial uses. The third term permit required the permittees to inspect construction sites and industrial and commercial facilities. The permittees were also required to develop and implement a WQMP to address runoff from new development and significant redevelopment projects. The principal permittee, in co-operation with the co-permittees, developed administrative strategies and implementation procedures for each program element. Each permittee incorporated these tools into its LIP. The permittees are required to continue to implement each of these program elements and to aggressively pursue implementation of LID techniques during the fourth term permit. As required under the third term permit, the principal permittee, in collaboration with the co-permittees, evaluated the effectiveness of the overall program during the permit term. The permittees, in consultation with Regional Board staff, evaluated each program element and proposed new and improved program commitments in their 2006 Report of Waste Discharge. Regional Board staff audited each of the permittee programs during the third term permit and determined that some of the permittees had significant violations with respect to implementation of certain program elements. Enforcement actions were taken to bring these permittees into compliance. The permittees were required to address problems identified during the audit. Some of the permittees were to amend their LIPs to address deficiencies noted during the audit.

71. The Report of Waste Discharge proposes to enhance implementation of various program elements through the development of performance indicators and auditable systems, and by focusing on addressing problems on a watershed-specific basis. To improve program management efficiencies, the permittees are

[24] Illegal discharge means any discharge (or seepage) to the municipal separate storm sewer that is not composed entirely of storm water except for the authorized discharges listed in Section III of this permit. Illegal discharges include the improper disposal of wastes into the storm sewer system.

[25] Illicit Discharge means any discharge to the storm drain system that is prohibited under local, state, or federal statutes, ordinances, codes, or regulations. The term illicit discharge includes all non storm-water discharges except discharges pursuant to an NPDES permit, discharges that are identified in Section III, Discharge Limitations/Prohibitions, of this order, and discharges authorized by the Regional Board Executive Officer.

proposing to define expertise and competencies for program managers and inspectors, and to develop and implement an effective training program for them. The principal permittee in collaboration with the co-permittees is required to develop guidelines for defining the expertise and competencies for various positions and training programs and schedules for training for these positions. The permittees are required to document procedures used to determine the defined competencies for each storm water position (this may be accomplished through a test at the end of the training program or through an on-the-job testing procedure).

72. This order includes numeric effluent limits for those constituents for which the Regional Board has already established TMDLs. Consistent with the federal storm water laws and regulations, the order does not include numeric effluent limits for other potential pollutants. Federal Clean Water Act requires the permittees to have appropriate controls to reduce the discharge of pollutants to the maximum extent practicable, including management practices, control techniques and systems, design and engineering methods, and such other provisions as the Administrator or the State determines appropriate for the control of such pollutants (33 USC 1342(p)(3)(B)). MEP is a dynamic performance standard and it evolves as our knowledge of urban runoff control measures increases.

73. On June 17, 1999, the State Board adopted Water Quality Order No. 99-05. This is a precedential order that incorporates the receiving water limitations language recommended by the USEPA. Consistent with the State Board's order, this order requires the permittees to comply with the applicable water quality standards, which is to be achieved through an iterative approach requiring the implementation of increasingly more effective BMPs. This approach is consistent with most of the municipal storm water permits issued in California that specify certain minimum control measures and incorporate an iterative process that requires increasingly more effective control measures if the water quality objectives are not met.

O. MUNICIPAL FACILITIES AND ACTIVITIES

74. The permittees own and operate MS4s and appurtenances, build and maintain roads and other transportation facilities, sanitary waste collection and conveyance systems, recreational facilities such as parks, hiking trails, etc., and other infrastructures of the urban environment. This order requires the permittees to consider water quality impacts during the planning stages of these projects, during construction and post-construction use, and during operation and maintenance of these facilities. This order includes requirements for the control of trash and debris, for street sweeping, and for drainage facilities maintenance. The permittees have already installed eleven trash and debris booms in flood control channels and harbors to recover floatable material. The permittees have promoted a number of public awareness and volunteer cleanup programs. The Orange County Integrated Waste Management Board administers the household hazardous waste collection program. Most of the permittees, in collaboration with the Orange County Health Care Agency, implement the oil recycling program.

75. The permittees own and/or operate facilities where industrial or related activities take place that may have an impact on storm water quality. Some of the permittees also enter into contracts with outside parties to carry out municipal related activities that may also have an impact on storm water quality. The permittees have developed and are implementing a Model Municipal Activities Program that established a framework for conducting a systematic program of evaluation and BMP implementation for fixed facilities, field operations and drainage facilities. Non-storm water discharges from these facilities and/or activities could also affect water quality. This order prohibits non-storm water discharges from public facilities, unless the discharges are exempt under Section III, Discharge Limitations of this order, or are permitted by the Regional Board under an individual NPDES permit or the de-minimus permits.

76. Successful implementation of the provisions and limitations in this order will require the cooperation of public agency organizations within Orange County having programs/activities that have an impact on storm water quality. A list of these organizations is included in Attachment C. As such, these organizations should actively participate in implementing the Orange County NPDES Storm Water Program. The Regional Board has the discretion and authority to require certain non-cooperating entities to participate in this areawide permit or obtain individual storm water discharge permits, pursuant to 40 CFR 122.26(a). The permittees have developed a Storm Water Implementation Agreement among the County, the cities and the Orange County Flood Control District. The Implementation Agreement establishes the responsibilities of each party, a funding mechanism for the shared costs, and recognizes the Technical Advisory Committee (TAC).

77. The permittees have developed and implemented programs and policies to address fixed facilities, fertilizer and pesticide use, employee training, storm drain inspection and maintenance activities, and other related planning, inspection and maintenance programs. This order requires the permittees to continue these programs and propose any needed changes to these programs.

78. Some of the permittees own and operate sewage collection systems. Sanitary sewer overflows (SSOs) have been a significant source of water quality impairments and beach closures in Orange County. On May 2, 2006, the State Board adopted Water Quality Order No. 2006-0003 to provide a consistent statewide regulatory approach to address SSOs. In addition, the principal permittee, in collaboration with the Orange County Sanitation District and a number of the co-permittees, has developed the Countywide Area Spill Control Program to address SSOs in certain areas of Orange County. These two programs are expected to address issues related to SSOs.

P. PUBLIC EDUCATION/PARTICIPATION

79. Urban runoff contains pollutants from privately owned and operated facilities, such as residences, businesses, private and/or public institutions, and commercial establishments. Therefore, a successful storm water management plan should

include the participation and cooperation of the public, businesses, the permittees and the regulators. The DAMP has a strong emphasis on public education. Public education includes education of the public at large, commercial establishments, industrial facilities and developers. It also includes proper training for municipal planning, inspection and maintenance activities. The permittees have developed inter-departmental training programs and have made commitments to conduct a certain number of these training programs during the term of this permit.

80. Public education is an important part of storm water pollution prevention. The permittees have employed a variety of means to educate the public, business and commercial establishments, industrial facilities and construction sites, and in 1999 developed a long term public education strategy. In 2002, the permittees created a public and business outreach strategy and developed the "Orange County Stormwater Public Education Program Recommendations." This strategy was updated in 2004 and established a long-term cost-effective approach to educate the public and targeted businesses about the effects of storm water pollution and encourages their participation in protecting water quality. In accordance with this strategy the permittees conducted a public awareness survey and translated relevant public education materials into Spanish and Vietnamese. The permittees employed a variety of media, including newspapers, radio, television, movie theaters, advertisements on public transportation vehicles, schools and printed brochures to provide information regarding storm water pollution and the public's role in controlling it. In addition to the multi-media approach, the permittees have started to work with business establishments such as Home Depot and PetsMart, utilities such as Waste Management and Southern California Edison, organizations such as Chamber of Commerce and Welcome Express, and a number of other organizations and establishments. The permittees also established a countywide 24-hour, bilingual, hotline for reporting illegal or illicit activities that could impact water quality. The permittees are required to continue their efforts in public education programs.

81. The storm water regulations require public participation in the development and implementation of the storm water management program. As such, the permittees are required to solicit and consider all comments received from the public and submit copies of the comments to the Executive Officer of the Regional Board with the annual reports due on November 15 of each year. It is expected that the permittees would include comments received on any significant revisions to the Monitoring Plan, LIPs and WQMPs. In response to public comments, the permittees may modify reports, plans, or schedules prior to submittal to the Executive Officer.

Q. MONITORING AND REPORTING PROGRAM AND EFFECTIVENESS ASSESSMENT

82. In order to characterize storm water discharges, to identify problem areas, to determine the impact of urban runoff on receiving waters, and to determine the effectiveness of the various BMPs, an effective monitoring program is critical. The

principal permittee administers the monitoring program for the permittees. During the previous permit term, the permittees completed the 99-04 Monitoring Plan. This plan included storm water monitoring, receiving water monitoring, dry weather monitoring and sediment monitoring in previously identified critical aquatic resources areas, as well as, mass emissions monitoring of both wet and dry season flows. On July 1, 2003, the permittees submitted the Third Term Monitoring Plan. This plan was approved by the Executive Officer on July 15, 2005. Monitoring under this plan was expanded to cover monitoring requirements for the development and implementation of TMDLs for impaired waters in Orange County. The Monitoring Plan approved in 2005, included mass emissions monitoring, estuary/wetlands monitoring, bacteriological/pathogen monitoring, bioassessment monitoring, illicit discharge reconnaissance monitoring, and land use correlations. Three different approaches were used for these monitoring programs: core monitoring, regional monitoring, and special studies. The permittees are required to review the monitoring program on an annual basis to determine the need for any revisions. The monitoring program may have to be revised to meet TMDL and ASBS monitoring requirements and/or to make the program consistent with any statewide or regional monitoring guidance developed either by the State Board or the Stormwater Monitoring Coalition.

R. ILLEGAL DISCHARGES, ILLICIT CONNECTIONS AND LEGAL AUTHORITY

83. Illegal discharges to the storm drains can contribute to storm water and surface water contamination. A reconnaissance survey of the municipal storm drain systems (open channels and underground storm drains) was completed by the permittees during the third term permit, the permittees significantly enhanced the programmatic framework for detecting and quickly controlling discharges into the MS4s. The permittees have initiated a dry weather monitoring program that is based on statistically derived benchmarks to detect illegal discharges and illicit connections. The program also facilitates public reporting of illegal and illicit discharges by providing 24-hour access to a toll free hotline. The program has a number of mechanisms in place to identify and eliminate illicit discharges to the MS4s, including: construction, commercial and industrial facility inspections, drainage facility inspections, water quality monitoring programs, and public education including a 24-hour hotline. The permittees developed a ten module training program for training municipal staff to identify and eliminate illegal discharges to the MS4s and to take appropriate enforcement actions.

84. In order to insure countywide consistency and to provide a legal underpinning to the entire Orange County storm water program, a model water quality ordinance was completed on August 15, 1994 and has been adopted by all the permittees. A countywide Enforcement Consistency Guide was established by the permittees in 1995. These documents establish legal authority for enforcing storm water ordinances and countywide uniformity in the enforcement actions. The permittees have the authority to control pollutants into the MS4s, to prohibit illegal connections and illicit discharges, to control spills, to require compliance with local water quality

ordinances and to carry out inspections of the storm drain systems within their jurisdictions.

85. During the third term permit, the principal permittees in collaboration with the Orange County Sanitation District developed and implemented a coordinated sewage spill prevention and response demonstration project. This program is being evaluated for implementation throughout the Orange County Sanitation District's service area .

86. There may be discharges that are not within the permittees jurisdiction. The permittees may petition the Regional Board to issue a separate NPDES permit to any discharger of non-storm water into storm drain systems that they own or operate.

S. COMPLIANCE WITH CZARA, CEQA AND THE ANTI-DEGRADATION POLICY

87. The Coastal Zone Act Reauthorization Amendments of 1990 (CZARA), Section 6217(g), requires coastal states with approved coastal zone management programs to address non-point source pollution impacting or threatening coastal water quality. CZARA addresses five sources of non-point pollution: agriculture, silviculture, urban, marinas, and hydromodification. This order addresses the management measures required for the urban category, with the exception of septic systems. Compliance with requirements specified in this order relieves the permittees for developing a non-point source plan, for the urban category, under CZARA. The Regional Board addresses septic systems through the administration other programs.

88. In accordance with California Water Code Section 13389, the issuance of waste discharge requirements for this discharge is exempt from those provisions of the California Environmental Quality Act contained in Chapter 3 (commencing with Section 21100), Division 13 of the Public Resources Code.

89. The permitted discharge is consistent with the anti-degradation provisions of 40 CFR 131.12 and the State Board Resolution 68-16. This order requires implementation of programs (i.e., BMPs) to reduce the level of pollutants in the storm water discharges. The combination of programs and policies required to be implemented under this order for new and existing developments are designed to improve urban storm water quality.

T. PUBLIC COMMENTS AND PUBLIC HEARING

90. The Regional Board has notified the permittees and interested parties of its intent to issue waste discharge requirements for this discharge and has provided them with an opportunity to submit their written views and recommendations.

91. The Regional Board, in a public hearing, heard and considered all comments pertaining to the discharge and to the tentative requirements.

PERMIT REQUIREMENTS:

IT IS HEREBY ORDERED that the permittees, in order to meet the provisions contained in Division 7 of the California Water Code and regulations adopted thereunder, and the provisions of the Clean Water Act, as amended, and regulations and guidelines adopted thereunder, shall comply with the following:

I. RESPONSIBILITIES OF PRINCIPAL PERMITTEE

A. The principal permittee shall be responsible for the overall program management and shall:

1. Conduct chemical and biological water quality monitoring, as required by this order and any additional monitoring as directed by the Executive Officer.
2. Conduct inspections and maintain the storm drain systems within its jurisdiction.
3. Review and revise, if necessary, policies/ordinances necessary to establish legal authority as required by the Federal Storm Water Regulations.
4. Respond and/or arrange for responding to emergency situations, such as accidental spills, leaks, illicit discharges and illegal connections, etc., to prevent or reduce the discharge of pollutants to storm drain systems and waters of the US within its jurisdiction.
5. Take appropriate enforcement actions for illicit discharges to the MS4 systems owned or controlled by the principal permittee.
6. Prepare and submit to the Executive Officer of the Regional Board unified reports, plans, and programs as required by this order, including the annual report.

B. The activities of the principal permittee shall include, but not be limited to, the following:

1. Coordinate and conduct Management Committee meetings on an as needed basis. The principal permittee will take the lead role in initiating and developing areawide programs and activities necessary to comply with this order.
2. Coordinate permit activities and participate in any subcommittees formed as necessary to coordinate compliance activities with this order.
3. Provide technical and administrative support and inform the co-permittees of the progress of other pertinent municipal programs, pilot projects, research studies, etc.
4. Coordinate the implementation of areawide storm water quality management activities such as public education, pollution prevention, household hazardous waste collection, etc.
5. Develop and implement mechanisms, performance standards, etc., to promote uniform and consistent implementation of BMPs among the permittees.
6. Pursue enforcement actions as necessary within its jurisdiction to ensure compliance with storm water management programs, ordinances and

implementation plans, including physical elimination of undocumented connections and illicit discharges.

7. In conjunction with the other permittees, implement the BMPs listed in the DAMP, and take such other actions as may be necessary to meet the MEP standard.
8. Monitor the implementation of the plans and programs required by this order and determine their effectiveness in protecting beneficial uses.
9. Coordinate all the activities with the Regional Board, including the submittal of all reports, plans, and programs, as required under this order.
10. Obtain public input for any proposed management and implementation plans, such as Monitoring Plans, Local Implementation Plans and significant changes to Water Quality Management Plans.
11. Cooperate in watershed management programs and regional and/or statewide monitoring programs.
12. In collaboration with the co-permittees, develop guidelines for defining expertise and competencies of storm water program managers and inspectors and develop and submit for approval a training program for various positions in accordance with these guidelines.

II. RESPONSIBILITIES OF THE CO-PERMITTEES

A. The co-permittees shall be responsible for the management of storm drain systems within their jurisdictions and shall:

1. Implement management programs, monitoring programs, implementation plans and all BMPs outlined in the DAMP/LIP within each respective jurisdiction, and take any other actions as may be necessary to meet the MEP standard.
2. Coordinate among their internal departments and agencies, as appropriate, to facilitate the implementation of this order and the DAMP/LIP.
3. Establish and maintain adequate legal authority, as required by the Federal Storm Water Regulations.
4. Conduct storm drain system inspections and maintenance in accordance with the criteria developed by the principal permittee.
5. Take appropriate enforcement actions for illicit discharges to the MS4 systems owned or controlled by the co-permittee.

B. The co-permittees' activities shall include, but not be limited to, the following:

1. Participate in the Management Committee comprised of the principal permittee and one representative of each co-permittee. The principal permittee will take the lead role in initiating and developing areawide programs and activities necessary to comply with this order. The Committee will meet on a regular basis (at least six times per year). Each permittee shall designate one official representative to the

Management Committee and attend at least 75% of the meetings each calendar year.

2. Review, approve, implement, and comment on all plans, strategies, management programs, and monitoring programs, as developed by the principal permittee or any permittee subcommittee to comply with this order.
3. Pursue enforcement actions as necessary to ensure compliance with the storm water management programs, ordinances and implementation plans, including physical elimination of undocumented connections and illicit discharges to drainage systems owned or controlled by the co-permittees.
4. Conduct and coordinate with the principal permittee any surveys and characterizations needed to identify pollutant sources and drainage areas.
5. Submit storm drain system maps, including any periodic revisions, with each annual report.
6. Respond to emergency situations, such as accidental spills, leaks, illicit discharges, illegal connections, etc., to prevent or reduce the discharge of pollutants to storm drain systems and waters of the US.
7. Prepare and submit all required reports to the principal permittee in a timely manner.

III. DISCHARGE LIMITATIONS/PROHIBITIONS

1. In accordance with the requirements of 40 CFR 122.26(d)(2)(i)(B) and 40 CFR 122.26(d)(2)(i)(F), the permittees shall prohibit illicit/illegal discharges (non-storm water) from entering into the municipal separate storm sewer systems unless such discharges are either authorized by a NPDES permit, or not prohibited in accordance with Section III.3, below.
2. The discharge of storm water from the MS4s to waters of the US containing pollutants that have not been reduced to the maximum extent practicable is prohibited.
3. The permittees shall effectively prohibit the discharge of non-storm water into the MS4s, unless such discharges are authorized by a separate NPDES permit or as otherwise specified in this provision. For purposes of this order, a discharge may include storm water or other types of discharges identified below.
    i. The discharges identified below need not be prohibited by the permittees if they have been determined not to be substantial contributors of pollutants to the MS4s and the receiving waters. The DAMP shall include public education and outreach activities directed at reducing these discharges even if they are not substantial contributors of pollutants to the MS4s.
        a) Discharges composed entirely of storm water;
        b) Air conditioning condensate;

c) Irrigation water from agricultural sources;

d) Passive foundation drains;

e) Passive footing drains;

f) Water from crawl space pumps;

g) Non-commercial vehicle washing;

h) Diverted stream flows;

i) Rising ground waters and natural springs;

j) Ground water infiltration as defined in 40 CFR 35.2005 (20) and uncontaminated pumped groundwater;

k) Flows from riparian habitats and wetlands;

l) Emergency fire fighting flows (i.e., flows necessary for the protection of life and property) do not require BMPs and need not be prohibited. However, where possible, when not interfering with health and safety issues, BMPs should be implemented (also see Section XIX, Provision 5);

m) Waters not otherwise containing wastes as defined in California Water Code Section 13050 (d); and

n) Other types of discharges identified and recommended by the permittees and approved by the Regional Board.

ii. The permittees shall prohibit the following categories of non-storm water discharges unless the stated conditions are met:

a) Discharges from potable water sources, including water line flushing, superchlorinated water line flushing, fire hydrant system flushing, and pipeline hydrostatic test water: Planned discharges shall be dechlorinated to a concentration of 0.1 ppm[26] or less, pH adjusted if necessary, and volumetrically and velocity controlled to prevent resuspension of sediments.

b) Discharges from lawn watering and other irrigation runoff from non-agricultural operations: These discharges shall be minimized through public education and water conservation efforts, as prescribed under Section XI, Residential Program.

c) Dechlorinated swimming pool discharges: Dechlorinated to a concentration of 0.1 ppm[27] or less, pH adjusted and reoxygenated if necessary, and volumetrically and velocity controlled to prevent resuspension of sediments. Swimming pool cleaning wastewater and filter backwash shall not be discharged to the MS4s.

[26] Total residual chlorine = 0.1 mg/l or parts per million (ppm) or less; compliance determination shall be at a point before the discharge mixes with any receiving water.

[27] See footnote 25.

d) Discharges from facilities that extract, treat and discharge water diverted from waters of the US: These discharges shall meet the following conditions: (1) The discharges to waters of the US must not contain pollutants added by the treatment process or pollutants in greater concentration than the influent; (2) The discharge must not cause or contribute to a condition of erosion; (3) The extraction and treatment must be in compliance with Section 404 of the Clean Water Act; and (4) Conduct monitoring in accordance with Monitoring and Reporting Program attached to this order.

The Regional Board may add categories of non-storm water discharges that are not significant sources of pollutants or remove categories of non-storm water discharges listed above based upon a finding that the discharges are a significant source of pollutants.

4. Non-storm water discharges from public agency activities into waters of the US are prohibited unless the non-storm water discharges are permitted by an NPDES permit or are included in Section III.3.
5. The permittees shall reduce the discharge of pollutants, including trash and debris, from the storm water conveyance systems to the maximum extent practicable (also see Section VII).
6. Discharges from the MS4s shall be in compliance with the applicable discharge prohibitions contained in Chapter 5 of the Basin Plan.
7. Discharges from the MS4s of storm water or non-storm water, as defined in Section III.3, shall not cause or contribute to a condition of nuisance, as that term is defined in Section 13050 of the Water Code.
8. All discharges to Areas of Special Biological Significance shall be consistent with the Special Protections/Exceptions granted by the State Board, or waste discharges shall be prohibited in accordance with the Ocean Plan.

IV. RECEIVING WATER LIMITATIONS

1. Discharges from the MS4s shall not cause or contribute to exceedances of receiving water quality standards (designated beneficial uses and water quality objectives) for surface waters or groundwaters.
2. The DAMP and its components shall be designed to achieve compliance with receiving water limitations. It is expected that compliance with receiving water limitations will be achieved through an iterative process and the application of increasingly more effective BMPs. The permittees shall comply with Sections III.2 and IV.1 of this order through timely implementation of control measures and other actions to reduce pollutants in urban runoff in accordance with the DAMP and other requirements of this order, including any modifications thereto.
3. If exceedance of water quality standards persist, notwithstanding implementation of the DAMP and other requirements of this order, the permittees shall assure

compliance with Sections III.2 and IV.1 of this order by complying with the following procedure:

a) Upon a determination by either the permittees or the Executive Officer that the discharges from the MS4 systems are causing or contributing to an exceedance of an applicable water quality standard, the permittees shall promptly notify and thereafter submit a report to the Executive Officer that describes BMPs that are currently being implemented and additional BMPs that will be implemented to prevent or reduce any pollutants that are causing or contributing to the exceedance of water quality standards. The report may be incorporated in the annual update to the DAMP, unless the Executive Officer directs an earlier submittal. The report shall include an implementation schedule. The Executive Officer may require modifications to the report;

b) Submit any modifications to the report required by the Executive Officer within 30 days of notification;

c) Within 30 days following approval by the Executive Officer of the report described above, the permittees shall revise the DAMP and monitoring program to incorporate the approved modified BMPs that have been and will be implemented, the implementation schedule, and any additional monitoring required; and,

d) Implement the revised DAMP and monitoring program in accordance with the approved schedule.

So long as the permittees have complied with the procedures set forth above and are implementing the revised DAMP, the permittees do not have to repeat the same procedure for continuing or recurring exceedances of the same receiving water limitations unless the Executive Officer determines it is necessary to develop additional BMPs.

4. Nothing in Section IV.3 must prevent the Regional Board from enforcing any provision of this order while the permittee prepares and implements the above programs.

V. IMPLEMENTATION AGREEMENT

1. Within 6 months of adoption of this order, the existing Implementation Agreement shall be reviewed and revised, if necessary, to include any cities that were not signatories to this agreement. A copy of the signature page and any revisions to the Agreement shall be included in the annual report.
2. Within 6 months of adoption of this order and annually thereafter, the permittees shall evaluate the storm water management structure and the Implementation Agreement and determine the need for any revisions. The corresponding annual report shall include the findings of this review and a schedule for any needed revisions.

VI. LEGAL AUTHORITY/ENFORCEMENT

1. The permittees shall maintain adequate legal authority to control the discharge of pollutants to the MS4s from urban runoff and enforce those authorities. This may be accomplished through ordinance, statute, permit, contract or similar means. Such legal authority must address all illegal connections and illicit discharges into the MS4s, including those from all industrial and construction sites. The permittees may use the Enforcement Consistency Guide or develop its own enforcement program and shall incorporate the enforcement program into their Local Implementation Plan.

2. The permittees shall carry out inspections, surveillance, and monitoring necessary to determine compliance with their ordinances and permits. The permittees' ordinance must include adequate legal authority to enter, inspect and gather evidence (pictures, videos, samples, documents, etc.) from industrial, construction and commercial establishments. The permittees shall progressively and decisively take enforcement actions against any violators of their Water Quality Ordinance. These enforcement actions must, at a minimum, meet the guidelines and procedures listed in the Enforcement Consistency Guide.

3. Permittees' ordinances or other local regulatory mechanisms shall include sanctions and follow up inspection milestones to ensure compliance. Sanctions shall include, but are not limited to: monetary penalties, non-monetary penalties, bonding requirements, and/or permit denials/revocations/stays for non-compliance. Follow up inspection milestones shall be consistent with applicable sections of this order. Permittees' ordinances shall have a provision for civil or criminal penalties for violations of their water quality ordinances. These penalties shall be issued in a decisive manner within a predetermined timeframe, from the time of the violation's occurrence and/or respective follow up inspection.

4. Within one year of the adoption of this order, each permittee shall submit a statement, signed by legal counsel, that the permittee has obtained all necessary legal authority in accordance with 40 CFR 122.26(d)(2)(i)(A-F) and to comply with this order through adoption of ordinances and/or municipal code modifications.

5. If necessary, the permittees shall revise their LIPs to include citations of appropriate local ordinances, identification of departmental jurisdictions in the implementation and enforcement of these ordinances, and key personnel. The LIP shall include procedures and timeframes for progressive enforcement actions.

6. The permittees shall continue to provide notification to Regional Board staff regarding storm water related information gathered during site inspections of industrial and construction sites regulated by the Statewide General Storm Water Permits and at sites that should be regulated under those Statewide General Permits. The notification shall be provided on a quarterly basis and shall include any observed violations, or threat of potential violations of the General Permits (e.g.,

problematic housekeeping issues) prior history of violations, any enforcement actions taken by the permittee, and any other relevant information. (Also see notification requirements under Sections VIII, IX, and X of this Order.)

7. The permittees shall annually review their water quality ordinances and provide findings within the annual report each year on the effectiveness of these ordinances and associated enforcement programs, in prohibiting the following types of discharges to the MS4s (the permittees may propose appropriate control measures in lieu of prohibiting these discharges, where the permittees are responsible for ensuring that dischargers adequately maintain those control measures):
   a) Sewage (also prohibited under the Statewide SSO order[28]);
   b) Wash water resulting from the hosing or cleaning of gas stations, auto repair garages, and other types of automobile service stations;
   c) Discharges resulting from the cleaning, repair, or maintenance of any type of equipment, machinery, or facility, including motor vehicles, concrete mixing equipment, portable toilet servicing, etc.;
   d) Wash water from mobile auto detailing and washing, steam and pressure cleaning, carpet/upholstery cleaning, pool cleaning and other such mobile commercial and industrial activities;
   e) Water from cleaning of municipal, industrial, and commercial sites, including parking lots, streets, sidewalks, driveways, patios, plazas, work yards and outdoor eating or drinking areas, etc.;
   f) Runoff from material storage areas or uncovered receptacles that contain chemicals, fuels, grease, oil, or other hazardous materials[29];
   g) Discharges of runoff from the washing of toxic materials[30] from paved or unpaved areas;
   h) Discharges of pool or fountain water containing chlorine, biocides, or other chemicals; pool filter backwash containing debris and chlorine;
   i) Pet waste, yard waste, litter, debris, sediment, etc.; and,
   j) Restaurant or food processing facility wastes such as grease, floor mat and trash bin wash water, food waste, etc.
8. The permittees are encouraged to enter into interagency agreements with owners of other MS4 systems, such as Caltrans, school and college districts, universities,

[28] State Board WQO No. 2006-0003.
[29] Hazardous material is defined as any substance that poses a threat to human health or the environment due to its toxicity, corrosiveness, ignitability, explosive nature or chemical reactivity. These also include materials named by EPA to be reported if a designed quantity of the material is spilled into the waters of the United States or emitted into the environment.

[30] Toxic material is a chemical or a mixture that may present an unreasonable risk of injury to health or the environment.

Department of Defense, Native American Tribes, etc., to control the contribution of pollutants from one portion of the MS4s to another portion. The Regional Board will continue to notify the owner/operator of the MS4 systems and the local municipality if the Board issues a permit for discharges into the MS4 systems.

VII. ILLICIT DISCHARGES/ILLEGAL CONNECTIONS; LITTER, DEBRIS AND TRASH CONTROL

1. The permittees shall continue to prohibit all illegal connections to the MS4s through their ordinances, inspections, monitoring programs, and enforcement actions. The permittees shall conduct inspections for illegal connections and illicit discharges during routine maintenance of all MS4 facilities. If routine inspections or dry weather screening and/or monitoring indicate any illegal connections, they shall be investigated and eliminated or permitted within 120 days of discovery and identification.
2. The permittees shall control, to the maximum extent practicable, the discharge of spills, leaks, or dumping of any materials other than storm water and authorized non-storm water per Section III, above, into the MS4s. All reports of spills, leaks, and/or illegal dumping shall be promptly investigated and reported as specified under Section XVII.
3. Within six months of adoption of this order, the permittees shall evaluate the current Illicit Discharges/Illegal Connections Training Program. If necessary, the program shall be revised to meet the expected expertise and competencies of the municipal inspectors.
4. The permittees shall continue to implement appropriate control measures to reduce and/or to eliminate the discharge of trash and debris to waters of the US. These control measures shall be reported in the annual report.
5. By July 1st of each year the permittees shall review their litter/trash control ordinances to determine the need for any revision. The permittees shall characterize trash, determine its main source(s) and develop and implement appropriate BMPs to control trash in urban runoff. The findings of this review shall be included in each annual report.
6. The permittees shall determine the need for any additional debris control measures. The findings shall be included in each annual report.
7. The permittees who are regulated under State Board's Water Quality Order No. 2006-0003 shall continue to comply with that order to control sanitary system overflows. The principal permittee shall continue to evaluate the applicability of the "Countywide Area Spill Control Program (CASC)" to all areas within the Santa Ana Regional Board's jurisdiction to control and mitigate sanitary sewer overflows. This evaluation shall be included in the first annual report due after adoption of this order. Within 12 months of adoption of this order, the principal permittee in collaboration with the Orange County Sanitation District, Irvine Ranch Water District and the co-permittees shall implement essential elements of the CASC or other equally

effective programs (such as the Statewide SSO order) to control and mitigate sanitary sewer overflows in Orange County areas that are within the Region.

VIII. MUNICIPAL INSPECTIONS OF CONSTRUCTION SITES

1. Each permittee shall ensure that all construction activities within its jurisdiction are consistent with the Model Construction Program developed by the permittees.
2. Each permittee shall continue to maintain and update (at least on a quarterly basis) an inventory of all construction sites within its jurisdiction for which building or grading permits have been issued and where activities at the site include: soil movement; uncovered storage of materials or wastes, such as dirt, sand or fertilizer; or exterior mixing of cementaceous products, such as concrete, mortar or stucco. All construction sites shall be included regardless of whether the construction site is subject to the General Construction Permit or other individual NPDES permit. This inventory shall be maintained in the 2002 Spreadsheet developed by the permittees or a similar computer-based database system and shall include relevant information on site ownership, General Construction Permit WDID number (if any), size, location (latitude/longitude (in decimals) or NAD83/WGS84[31] compatible formatting as identified by GIS for a spot within the site perimeter), inspection data, etc.
3. The permittees shall continue to prioritize construction sites within their jurisdictions as a high, medium or low threat to water quality. Evaluation of construction sites shall be based on factors, which shall include, but not be limited to: soil erosion potential, project size, site slope, proximity to and sensitivity of receiving waters and any other relevant factors. At a minimum, high priority construction sites shall include: sites 20 acres and larger; sites over 1 acre that are tributary to Clean Water Act Section 303(d) waters listed for sediment or turbidity impairments; and sites that are tributary to and within 500 feet of an area defined by the Ocean Plan as an Area of Special Biological Significance (ASBS). At a minimum, medium priority construction sites shall include sites between 5 to 20 acres of disturbed soil.
4. Each permittee shall conduct construction site inspections for compliance with its ordinances (grading, Water Quality Management Plans, etc.), local permits (construction, grading, etc.), the Model Construction Program and the Construction Runoff Guidance Manual, both developed by the permittees. The permittees must develop a checklist for conducting construction site inspections. Inspections of construction sites shall include, but not be limited to:
   a) Verification of coverage under the General Construction Permit (Notice of Intent or Waste Discharge Identification Number, WDID Number) during the initial inspection;
   b) A documented review of the Erosion and Sediment Control Plan (ESCP) to ensure that the BMPs to be implemented on-site are consistent with the

[31] NAD83/WGS84=North American Datum of 1983 and World Geodetic System of 1984 are systems to define three-dimensional coordinates of a single physical point.

appropriate phase of construction (Preliminary Stage, Mass Grading Stage, Streets and Utilities Stage, etc.);

c) Visual observation for non-storm water discharges and potential pollutant sources;

d) Determination of compliance with local ordinances, permits, Water Quality Management Plans, Construction Runoff Guidance Manual and other relevant requirements including the implementation and maintenance of BMPs required under local requirements; and,

e) An assessment of the effectiveness of BMPs implemented at the site and the need for any additional BMPs.

5. At a minimum, the inspection frequency shall include the following:

   a) During the dry season (i.e., May 1 through September 30 of each year), all construction sites shall be inspected at a frequency sufficient to ensure that sediment and other pollutants are properly controlled and that unauthorized, non-storm water discharges are prevented.

   b) During the wet season (i.e., October 1 through April 30 of each year), all high priority sites are to be inspected, in their entirety, once a month. All medium priority sites are to be inspected at least twice during the wet season. All low priority sites are to be inspected at least once during the wet season. When BMPs or BMP maintenance is deemed inadequate or out of compliance, an inspection frequency of once every week will be maintained until BMPs and BMP maintenance are brought into compliance.

6. To establish a consistent enforcement program for non-compliant construction sites, the permittees shall enforce their ordinances and permits at all construction sites in a fair, firm and consistent manner. If necessary, the permittees shall revise their LIPs within 12 months of adoption of this order to include a mechanism to notify and to establish a clear and coordinated enforcement linkage for further enforcement action with Regional Board staff. Sanctions for non-compliance must include: a written enforcement order at the time of inspection and other appropriate actions, such as Administrative Compliance Orders, Cease and Desist Orders, Stop Work Orders, Misdemeanor/Infractions, monetary penalties, bonding requirements and/or permit denial or administrative termination.

7. All violations shall be notified as per Section XVII.

8. Each permittee shall respond to complaints received from third parties in a timely manner to ensure that the construction sites are not a source of pollutants in the MS4s and the receiving waters.

9. All construction site inspectors shall be trained in accordance with Section XVI.

IX. MUNICIPAL INSPECTIONS OF INDUSTRIAL FACILTIES

1. Each permittee shall continue to maintain an inventory of industrial facilities within its jurisdiction. All sites that have the potential to discharge pollutants to the MS4 should be included in this inventory regardless of whether the facility is subject to business permits, licensing, the State's General Industrial Permit or other individual NPDES permit. This database must be updated on an annual basis. This inventory must be maintained in a computer-based database system and must include relevant information on ownership, SIC code(s), General Industrial Permit WDID # (if any), size, location, etc. Inclusion of a Geographical Information System (GIS) is required, with latitutde/longitude (in decimals) or NAD83/WGS84[32] compatible formatting.
2. To establish priorities for inspection requirements under this order, the permittees shall continue to prioritize industrial facilities within their jurisdiction as a high, medium or low threat to water quality. Continuous evaluation of these facilities should be based on such factors as type of industrial activities (SIC codes), materials or wastes used or stored outside, pollutant discharge potential, facility size, proximity and sensitivity of receiving waters and any other relevant factors. At a minimum, a high priority shall be assigned to: facilities subject to section 313 of Title III of the Superfund Amendments and Reauthorization Act of 1986 (SARA); facilities requiring coverage under the General Industrial Permit; facilities with a high potential for, or history of, unauthorized, non-storm water discharges; and facilities that are tributary to, and within 500 feet of, an area defined by the Ocean Plan as an Area of Special Biological Significance.
3. Each permittee shall conduct industrial facility inspections for compliance with its ordinances, permits and this order. Inspections shall include a review of material and waste handling and storage practices, written documentation of pollutant control BMP implementation and maintenance procedures and digital photographic documentation for any water quality violations, as well as, evidence of past or present unauthorized, non-storm water discharges and enforcement actions issued at the time of inspection. All high priority facilities identified in Section IX.2 shall be inspected at least once a year and a report on these inspections shall be submitted in the annual report for each year.
4. All medium priority sites are to be inspected at least once every two years; and all low priority sites are to be inspected at least once per permit cycle. In the event that inappropriate material or waste handling or storage practices are observed, or there is evidence of past or present unauthorized, non-storm water discharges, an enforcement order shall be issued and a re-inspection frequency schedule adequate to bring the site into compliance, must be maintained (at a minimum, once a month). Once compliance is achieved, a minimum inspection frequency of once every six months will be maintained for the next calendar year.

[32] See Footnote 31

5. Each permittee shall continually identify any industrial facilities within their jurisdiction and shall add them to the database, as identified in Section IX.1. Additionally, each facility shall be listed with its respective prioritization in accordance with the specifications identified in Section IX.2, within 15 days from the initial date of discovery of the facility.
6. Information including, at a minimum, inspection dates, inspectors present, the photographic and written results of the inspection and any enforcement actions taken must be maintained in the database identified in Section IX.1 or must be linked to that database. A copy of this database must be provided to the Regional Board with each annual report.
7. Each permittee shall enforce its ordinances and permits at all industrial facilities in accordance with the Enforcement Consistency Guide to maintain compliance with this order. At a minimum, each facility shall be required to implement source control and pollution prevention measures consistent with the BMP Fact Sheets developed by the permittees. Sanctions for non-compliance shall be adequate to bring the site into compliance and must include: an oral or written warning for minor violations at the time of inspection, a written enforcement order for violations that pose a threat to water quality that should include consideration of monetary penalties, bonding requirements and/or permit denial or revocation depending on the severity of the violation and in accordance with the Enforcement Consistency Guide.
8. Regional Board shall be notified of all violations in accordance with Section XVII.
9. Industrial site inspectors shall be trained as stipulated in Section XVI.
10. The permittees need not inspect facilities already inspected by Regional Board staff, if the inspection was conducted within the specified time period.

X. MUNICIPAL INSPECTIONS OF COMMERCIAL FACILITIES

1. Each permittee shall continue to maintain and update quarterly an inventory of the types of commercial facilities/businesses listed below within its jurisdiction. As required under the third term permit, this inventory must be maintained in a computer-based database system (Commercial Database) and must include relevant information on ownership, size, location, etc. For fixed facilities, inclusion of a Geographical Information System (GIS), with latitude/longitude (in decimals) or NAD83/WGS84[33] compatible formatting is required. For water quality planning purposes, the permittees should consider using a parcel-level GIS that contains an inventory of the types of facilities/discharges listed below.

   Commercial facilities may include, but may not be limited to[34]:

   a) Transport, storage or transfer of pre-production plastic pellets.

[33] See Footnote 31.

[34] Mobile cleaning services are addressed in X.8, below.

b) Automobile mechanical repair, maintenance, fueling or cleaning;
c) Airplane repair, maintenance, fueling or cleaning;
d) Marinas and boat repair, maintenance, fueling or cleaning;
e) Equipment repair, maintenance, fueling or cleaning;
f) Automobile impound and storage facilities;
g) Pest control service facilities;
h) Eating or drinking establishments, including food markets and restaurants;
i) Automobile and other vehicle body repair or painting;
j) Cement mixing, concrete cutting, masonry facilities;
k) Building materials retail and storage facilities;
l) Portable sanitary service facilities;
m) Painting and coating;
n) Animal facilities such as petting zoos and boarding and training facilities;
o) Nurseries and greenhouses;
p) Landscape and hardscape installation;
q) Pool, lake and fountain cleaning;
r) Golf courses;
s) Other commercial sites/sources that the permittee determines may contribute a significant pollutant load to the MS4; and,
t) Any commercial sites or sources that are tributary to and within 500 feet of an area defined by the Ocean Plan as an Area of Special Biological Significance.

2. Each permittee shall conduct inspections of its commercial facilities as indicated below. To establish priorities for inspection, the permittees shall continue to prioritize commercial facilities/businesses within their jurisdiction as a high, medium or low threat to water quality based on such factors as the type, magnitude and location of the commercial activity, potential for discharge of pollutants to the MS4, any history of unauthorized, non-storm water discharges, proximity and sensitivity of receiving waters, material used and wastes generated at the site. The following minimum criteria must be met: 10% of commercial sites (not including restaurants/food markets) must be ranked 'high' and these represent the greatest threat to water quality[35]; 40% of commercial sites (not including restaurants/food markets) must be ranked 'medium'; and, the remainder may be ranked 'low'.

3. Each permittee shall conduct commercial facility inspections, at frequencies as determined by the threat to water quality prioritization, for compliance with its ordinances, permits and this order. All high priority sites shall be inspected at least once a year; all medium priority sites shall be inspected at least every two years; and all low priority sites shall be inspected at least once per permit cycle. At a minimum, each facility shall be required to implement source control and pollution prevention measures consistent with the BMP Fact Sheets developed by the permittees. Inspections should include a review of control measures implemented, their effectiveness and maintenance; written and photographic documentation of

[35] Where there are less than 100 commercial sites within a municipality, at least 10 sites must be ranked 'High'.

materials and waste handling and storage practices; evidence of past or present unauthorized, non-storm water discharges; and an assessment of management/employees awareness of storm water pollution prevention measures.

4. In the event that inappropriate material or waste handling or storage practices are observed, or there is evidence of past or present unauthorized, non-storm water discharges, a written enforcement order shall be issued, at the time of inspection, to bring the site into compliance.
5. Information, including inspection dates, inspectors present, the written and photographic documentation results of the inspection and any enforcement actions including mitigative compliance orders must be maintained in the Commercial Database or must be linked to that database. A copy of this database must be provided to the Regional Board with each annual report.
6. Each permittee shall enforce its ordinances and permits at commercial facilities. Sanctions for non-compliance must include: enforcement orders issued at the time of inspections, monetary penalties, bonding requirements and/or permit denial or revocation. Sanctions shall be consistent with methods and protocols established in the Enforcement Consistency Guide.
7. All violations shall be notified as specified in Section XVII.
8. Within 12 months of adoption of this order, the principal permittee shall notify all mobile businesses operating within the County concerning the minimum source control and pollution prevention measures that they must develop and implement. For purposes of this order, mobile businesses include: mobile auto washing/detailing; equipment washing/cleaning; carpet, drape, furniture cleaning; and mobile high pressure or steam cleaning. The mobile businesses shall be required to implement appropriate control measures within 3 months of being notified by the permittees. Within 12 months of adoption of this order, the principal permittee shall develop an enforcement strategy to address mobile businesses. Each permittee shall also distribute the BMP Fact Sheets for the mobile businesses that has been developed by the permittees. At a minimum, the mobile business Fact Sheets/training program should include: laws and regulations dealing with urban runoff and discharges to storm drains; appropriate BMPs and proper procedure for disposing of wastes generated from each mobile business.
9. The principal permittee shall continue to maintain a restaurant inspection program, or coordinate and collaborate with the Orange County Health Care Agency's restaurant inspection program. The restaurant inspection program shall, at a minimum, address:

    a) Oil and grease disposal to verify that these wastes are not poured onto a parking lot, street or adjacent catch basin;

    b) Trash bin areas to verify that these areas are clean, the bin lids are closed, the bins are not filled with liquid and the bins have not been washed out;

c) Parking lot, alley, sidewalk and street areas to verify that floor mats, filters and garbage containers are not washed in those areas and that no washwater is poured in those areas;

d) Parking lot areas to verify that they are cleaned by sweeping, not by hosing down and that the facility operator uses dry methods for spill cleanup; and,

e) Inspection of existing devices designed to separate grease from wastewater (e.g., grease traps or interceptors) to ensure adequate capacity and proper maintenance is currently performed under the Fats, Oils and Grease (FOG) program (the FOG inspections conducted under the Statewide SSO order (Water Quality Order No. 2006-0003) could be substituted for this inspection).

All violations of the Water Quality Ordinance should be enforced by the permittees and all violations of the Health and Safety Code should be enforced by the Health Care Agency.

10. All commercial site inspectors shall be trained as specified in Section XVI.

11. The permittees need not inspect facilities already inspected by Regional Board staff if the inspection was conducted within the specified time period.

XI. RESIDENTIAL PROGRAM

1. Each permittee shall develop and implement a residential program to reduce the discharge of pollutants from residential facilities to the MS4s to the maximum extent practicable so as to prevent discharges from the MS4s from causing or contributing to a violation of water quality standards in the receiving waters.

2. The permittees should identify residential areas and activities that are potential sources of pollutants and develop Fact Sheets/BMPs. At a minimum, this should include: residential auto washing and maintenance activities; use and disposal of pesticides, herbicides, fertilizers and household cleaners; and collection and disposal of pet wastes. The permittees shall require residents to implement pollution prevention measures. The permittees should work with sub-watershed groups (e.g., the Serrano Creek Conservancy) to disseminate latest research information, such as the UC Master Gardeners Program[36] and USDA's Backyard Conservation Program[37].

3. The permittees, collectively or individually, shall facilitate the proper collection and management of used oil, toxic and hazardous materials, and other

[36] The UC Master Gardener volunteer program provides gardening and horticulture information to the residents of Orange County through trained volunteers who disseminate University research based scientific information.

[37] Backyard Conservation, Bringing Conservation from the Countryside to Your Backyard, USDA Natural Resources Conservation Service, National Association of Conservation Districts, Wildlife Habitat Council and National Audubon Society.

household wastes. Such facilitation should include educational activities, public information activities, and establishment of curbside or special collection sites managed by the permittees or private entities, such as solid waste haulers.

4. The permittees shall develop and implement control measures for common interest areas and areas managed by homeowner associations or management companies. The permittees should evaluate the applicability of programs such as the Landscape Performance Certification Program[38] to encourage efficient water use and to minimize runoff[39].

5. The permittees shall enforce their Water Quality Ordinance for all residential areas and activities. The permittees should encourage new developments to use weather-based evapotranspiration (ET) irrigation controllers[40].
6. Each permittee shall include an evaluation of its Residential Program in the annual report starting with the first annual report after adoption of this order.

XII. NEW DEVELOPMENT (INCLUDING SIGNIFICANT RE-DEVELOPMENT)

A. GENERAL REQUIREMENTS:

1. The permittees shall continue to maintain a computerized database to ensure (prior to issuance of any local permits or other approvals) that all construction sites that are required to obtain coverage under the State's General Construction Permit have filed with the State Board a Notice of Intent for coverage under the General Permit.
2. Within 6 months of adoption of this order, the principal permittee, in collaboration with the co-permittees, shall develop a guidance document for the preparation of conceptual or preliminary WQMPs to more effectively ensure that water quality protection, including LID principles, is considered in the earliest phases of a project. The appropriate revisions to the DAMP to incorporate this guidance shall be submitted with the first annual report after adoption of this permit. Within 12 months of adoption of this order, each permittee shall revise its LIP to be consistent with the guidance. The permittees are encouraged to require submission of a conceptual WQMP as early in the planning process as possible.
3. Each permittee shall minimize the short and long-term impacts on receiving water quality from new developments and significant re-developments, as

[38] For example, see the Metropolitan Water District of Orange County's Evaluation of the Landscape Performance Certification Program, January 2004.

[39] The Residential Runoff Reduction Study, Municipal Water District of Orange County, Irvine Ranch Water District and Metropolitan Water District of Southern California, July 2004.

[40] Westpark Study, Municipal Water District of Orange County, Irvine Ranch Water District and Metropolitan Water District of Southern California, 2001.

required in Section XII.B.2., below, by requiring the submittal of a WQMP, emphasizing implementation of LID principles and addressing hydrologic conditions of concern, prior to issuance of any grading or building permits and/or prior to recordation of any subdivision maps.

4. In the first annual report following adoption of this permit, the permittees shall include a summary of their review of the watershed protection principles and policies in their General Plan and related documents (such as Development Standards, Zoning Codes, Conditions of Approval, Development Project Guidance, Local Coastal Plan, etc.) to ensure that these principles and policies, including LID principles, are properly considered and are incorporated into these documents. These principles and policies should include, but not be limited to, LID principles discussed in Section XII. C and hydrologic conditions of concern discussed in Section XII. D. Within 6 months of adoption of this order, the principal permittee shall facilitate the formation of a technical advisory committee (TAC) consisting of the Community Development/Planning Department directors of the co-permittees to effectively incorporate watershed protection principles (including LID) and policies during the early stages of a project. The TAC shall meet at least on an annual basis to develop common development standards, zoning codes, conditions of approval and other principles and policies necessary for water quality protection. Each annual report shall include a brief summary of the TAC meetings including its recommendations.

5. Each permittee shall provide the Regional Board with the draft amendment or revision when a pertinent General Plan element or the General Plan is noticed for comment in accordance with Govt. Code § 65350 et seq.

6. The permittees shall continue to review their planning procedures and CEQA document preparation processes on an annual basis, to ensure that urban runoff-related issues are properly considered and addressed. If necessary, these processes shall be revised to consider and mitigate impacts to storm water quality. Should findings of the review result in changes to the above processes, the permittee shall include these changes in the LIP and submit a revised copy of the LIP to the Regional Board with the next annual report. The permittees shall ensure that the following potential impacts are considered during CEQA reviews:

   a) Potential impact of project construction on storm water runoff;

   b) Potential impact of project's post-construction activity on storm water runoff;

   c) Potential for discharge of storm water pollutants from areas of material storage, vehicle or equipment fueling, vehicle or equipment maintenance (including washing), waste handling, hazardous materials handling or storage, delivery areas. loading docks or other outdoor work areas;

   d) Potential for discharge of storm water to affect the beneficial uses of the receiving waters;

e) Potential for significant changes in the flow velocity or volume of storm water runoff to cause environmental harm; and,

f) Potential for significant increases in erosion of the project site or surrounding areas.

g) Potential decreases in quality and quantity of recharge to groundwater.

h) Potential impact of pollutants in storm water runoff from the project site on any 303(d) listed waterbodies.

7. The permittees shall modify the project approval process, consistent with the guidance for conceptual or preliminary WQMP, to ensure that proper conditions of approval, design specifications and tracking mechanisms are included.

8. The permittees shall train their employees involved with the preparation and/or review of CEQA documents as specified in Section XVI.

B. WATER QUALITY MANAGEMENT PLAN (WQMP) FOR URBAN RUNOFF (FOR NEW DEVELOPMENT/SIGNIFICANT REDEVELOPMENT):

1. The permittees shall annually review the existing structural treatment control and other BMPs for New Developments and submit any changes for review and approval by the Executive Officer. Within 12 months of adoption of this order, the principal permittee shall revise the appropriate tables in the Water Quality Management Plan with the latest information on BMPs and provide additional clarification regarding their effectiveness and applicability.

2. Each permittee shall ensure that an appropriate WQMP is prepared for the following categories of new development/significant redevelopment projects (priority development projects). The WQMP shall be developed in accordance with the approved Model WQMP and shall incorporate LID principles in the WQMP.

a) All significant redevelopment projects, where significant redevelopment is defined as priority development projects, which include the addition or replacement of 5,000 square feet or more of impervious surface on a developed site. Redevelopment does not include routine maintenance activities that are conducted to maintain original line and grade, hydraulic capacity, original purpose of the facility, or emergency redevelopment activity required to protect public health and safety. Where redevelopment results in an increase of less than fifty percent of the impervious surfaces of a previously existing developed site, and the existing development was not subject to WQMP requirements, the numeric sizing criteria discussed below applies only to the addition or replacement, and not to the entire developed site. Where redevelopment results in an increase of more than fifty percent of the impervious surfaces of a previously existing developed site, the numeric sizing criteria applies to the entire development.

b) Subdivisions creating 10 lots or units and more, and subdivisions creating less than 10 lots or units, where the combined impervious surface area of the lots or units is equal to or greater than 10,000 square feet. This includes single family residences, multi-family residences, condominiums, apartments, etc.

c) Commercial and industrial developments, which are not subdivisions, of 10,000 square feet or more. This includes non-residential developments.

d) Automotive repair shops (with SIC codes 5013, 5014, 5541, 7532-7534, 7536-7539).

e) Restaurants where the land area of development is 5,000 square feet or more.

f) All hillside developments on 5,000 square feet or more, which are located on areas with known erosive soil conditions or where the natural slope is twenty-five percent or more.

g) Developments of 2,500 square feet of impervious surface or more, adjacent to (within 200 feet) or discharging directly[41] into environmentally sensitive areas, such as areas designated in the Ocean Plan as Areas of Special Biological Significance or waterbodies listed on the CWA Section 303(d) list of impaired waters.

h) Parking lots of 5,000 square feet or more of impervious surface exposed to storm water. Parking lot is defined as a land area or facility for the temporary storage of motor vehicles.

i) Streets, roads, highways and freeways of 5,000 square feet of paved surface[42]. The WQMP should address the project area. This category includes any paved surface used for the transportation of automobiles, trucks, motorcycles and other vehicles and excludes any routine road maintenance activities where the footprint is not changed.

j) Retail gasoline outlets of 5,000 or more square feet with a projected average daily traffic of 100 or more vehicles per day.

k) Emergency and public safety projects in any of the above-listed categories may be excluded if the delay caused due the requirement for a WQMP compromises public safety, public health and/or environmental protection.

[41] Discharging directly means a drainage or conveyance which carries flows entirely from the subject development and not commingled with any other flows

[42] If a feasibility study indicates that it is not feasible to implement standard WQMP requirements due to unique constraints imposed on the project, alternatives acceptable to the Executive Officer must be implemented.

3. WQMPs shall include BMPs for source control, pollution prevention, site design and structural treatment control BMPs (also see Section C, below). For all structural treatment controls, WQMPs shall identify the responsible party for maintenance of the treatment system, and a funding source or sources for its operation and maintenance. WQMPs shall reflect consideration of the following goals, which may be addressed through on-site-and/or watershed-based BMPs:

   a) The effective impervious area[43] (EIA) shall be limited to 5% or less of the total project site. Also see Section C, below.

   b) The project shall not cause a hydrologic condition of concern (see Section D, below).

   c) Through an integrated watershed approach that integrates source control, pollution prevention, site design and structural treatment controls (if needed), the post-development runoff water quality and quantity shall mimic pre-development water quality and quantity.

   d) The discharge of any listed pollutant[44] to an impaired waterbody on the 303(d) list shall not cause or contribute to an exceedance of receiving water quality objectives.

4. At a minimum, structural BMPs shall be designed and built in accordance with the approved model WQMP and must be sized to comply with one of the following numeric sizing criteria:

   A. Volume

   Volume–based BMPs shall be designed to infiltrate, filter, or treat either:

   1) The volume of runoff produced from a 24-hour, 85th percentile storm event, as determined from the County of Orange's 85th Percentile Precipitation Isopluvial Map[45]; or,

   2) The volume of annual runoff produced by the 85th percentile, 24-hour rainfall event, determined as the maximized capture storm water volume for the area, from the formula recommended in Urban Runoff Quality Management, WEF Manual of Practice No. 23/ASCE Manual of Practice No. 87 (1998); or,

[43] Effective impervious areas are those areas which are not connected to a pervious feature (such as a landscaped area, pervious concrete or asphalt surfaces with a sub-base of infiltration materials) and from where storm water runoff is conveyed to a storm water conveyance system or directly to waters of the US.

[44] For a waterbody listed under Section 303(d) of the Clean Water Act, the pollutant that is causing the impairment is the "listed pollutant".

[45] The isopluvial map is available from: http://www.ocwatersheds.com/StormWater/PDFs/2003 DAMP Section 7 New Development Significant Redevelopment.pdf.

3) The volume of annual runoff based on unit basin storage volume, to achieve 80% or more volume treatment by the method recommended in California Stormwater Best Management Practices Handbook – Industrial/Commercial; or,

4) The volume of runoff, as determined from the local historical rainfall record, that achieves approximately the same reduction in pollutant loads and flows as achieved by mitigation of the 85th percentile, 24-hour runoff event;

OR

B. Flow

Flow-based BMPs shall be designed to infiltrate, filter, or treat either:

1) The maximum flow rate of runoff produced from a rainfall intensity of 0.2 inch of rainfall per hour, for each hour of a storm event; or,

2) The maximum flow rate of runoff produced by the 85th percentile hourly rainfall intensity, as determined from the local historical rainfall record, multiplied by a factor of two; or,

3) The maximum flow rate of runoff, as determined from the local historical rainfall record, which achieves approximately the same reduction in pollutant loads and flows as achieved by mitigation of the 85th percentile hourly rainfall intensity multiplied by a factor of two.

5. To protect ground water resources any structural infiltration BMPs shall meet the following minimum requirements:

a) Use of structural infiltration treatment BMPs shall not cause or contribute to an exceedance of groundwater water quality objectives.

b) Source control and pollution prevention control BMPs shall be implemented in conjunction with structural infiltration BMPs to protect groundwater quality. The need for sedimentation or filtration should be evaluated prior to infiltration.

c) Structural infiltration treatment BMPs shall not cause a nuisance or pollution, as defined in Water Code Section 13050 .

d) The vertical distance from the bottom of the infiltration system to the seasonal high groundwater must be at least 10 feet. Where the groundwater basins do not support beneficial uses, this vertical distance criteria may be reduced, provided groundwater quality is maintained.

e) The infiltration systems must be located at least 100 feet horizontally from any water supply wells.

f) Infiltration systems must not be used for areas of industrial or light industrial activity; areas subject to high vehicular traffic (25,000 or more daily traffic)

automotive repair shops; car washes; fleet storage areas; nurseries; or any other high threat to water quality land uses or activities[46].

6. Within 12 months from the date of adoption of this order, the principal permittee shall develop recommendations for streamlining regulatory agency approval of regional treatment control BMPs. The recommendations should include information needed to be submitted to the Regional Board for consideration of regional treatment control BMPs. At a minimum, it should include: BMP location; type and effectiveness in removing pollutants of concern; projects tributary to the regional treatment system; engineering design details; funding sources for construction, operation and maintenance; and parties responsible for monitoring effectiveness, operation and maintenance.

7. The permittees shall require non-priority development projects to document, via a WQMP or similar mechanism, site design, source control and any other BMPS which may or may not include treatment control BMPs.

C. LOW IMPACT DEVELOPMENT TO CONTROL POLLUTANTS IN URBAN RUNOFF FROM NEW DEVELOPMENT/SIGNIFICANT REDEVELOPMENT:

1. The permittees shall incorporate LID site design principles that reduce runoff to the maximum extent practicable during each phase of priority development projects. The permittees shall require that each priority development project include site design BMPs during development of the preliminary and final WQMPs. Site design BMP considerations shall include, but not be limited to:

   a) Limit disturbance of natural water bodies and drainage systems; conserve natural areas; minimize paving, impervious areas and compaction of highly permeable soils; protect slopes and channels; and minimize impacts from storm water and urban runoff on the biological integrity of natural drainage systems and water bodies;

   b) Minimize changes in hydrology and pollutant loading; require incorporation of controls, including structural and non-structural BMPs, to mitigate the projected increases in pollutant loads and flows; ensure that post-development runoff durations and volumes from a site have no significant adverse impact on downstream erosion and stream habitat; minimize the quantity of storm water directed to impermeable surfaces and the MS4s; minimize directly connected impervious areas; design impervious areas to drain to pervious areas; consider construction of parking lots, walkways, etc., with permeable concrete and porous asphalt; minimize pipes, culverts and engineered systems for storm water conveyance; and maximize the percentage of permeable surfaces distributed throughout the site's landscape to allow more percolation of storm water into the ground;

[46] This restriction applies only to sites that are known to have soil and groundwater water contamination. Recent studies by the Los Angeles and San Gabriel Watershed Council of Storm Water Recharge has shown that there is no statistically significant degradation of groundwater quality from the infiltration of storm water-borne constituents.

c) Preserve wetlands, riparian corridors, natural waterbodies, natural drainage systems and vegetated buffer zones and establish reasonable limits on the clearing of vegetation from the project site;

d) Use of water quality wetlands, bioretention areas, biofiltration swales, watershed-scale retrofits, etc., where such measures are likely to be effective and technically and economically feasible;

e) Provide for appropriate permanent measures to reduce storm water pollutant loads in storm water from the development site;

f) Establish development guidelines for areas particularly susceptible to erosion and sediment loss;

g) Implement effective education programs to educate property owners to use pollution prevention measures and to maintain on-site hydrologically functional landscape controls; and

h) Integrate Watershed Action Plans and TMDL Implementation Plans into the sites conceptual WQMP.

2. The permittees shall require the following source control BMPs for each priority development project, unless formally substantiated as unwarranted in a written submittal to the permittee:

   a) Minimize contaminated runoff, including irrigation runoff, from entering the MS4s;

   b) Provide appropriate secondary containment and/or proper covers or lids for materials storage, trash bins, and outdoor processing and work areas;

   c) Minimize storm water contact with pollutant sources;

   d) Provide community car wash and equipment wash areas that discharge to sanitary sewers;

   e) Minimize trash and debris in storm water runoff through regular street sweeping and through litter control ordinances; and

   f) Minimize the alteration of natural flow regime as discussed under Section XII.D.

3. Through implementation of appropriate site design, source control, pollution prevention and other LID principles, the EIA for the project site shall be limited to 5% or less. This EIA goal should be accomplished by implementing LID measures at the project site as close as possible to the source of storm water runoff. The goal of LID is to mimic pre-development site hydrology through technically and economically feasible source control and site design techniques. LID combines hydrologically functional site design with pollution prevention methods to compensate for land development impact on hydrology and water quality. Even though the LID principles are universally applicable, there could be constraining factors such as: soil conditions including soil compaction, saturation

(e.g., hydric soils) and permeability, groundwater levels, soil contaminants (Brown field developments), space restrictions (in-fill projects, redevelopment projects, high density development, transit-oriented developments), etc. In such cases, the LID principles could be integrated into other programs such as: Smart Growth[47], New Urbanism[48] or regional or sub-watershed management approaches. The permittees shall require that each priority development project include site design BMPs during development of the preliminary and final WQMPs. The pollutants in post-development runoff shall be reduced using controls that utilize best management practices, as described in the California Stormwater Quality Handbooks, Caltrans Storm Water Quality Handbook or other reliable sources. If site conditions do not permit achieving the goal of 5% EIA close to the source of excess storm water generation[49], the alternatives discussed below and the credits and in-lieu programs discussed under Section E, below, may be considered:

a) Implement LID principles at the project site. This is the preferred approach. For example, in a single family residential development: connect roof drains to a landscaped area, divert driveway runoff to a vegetated strip and minimize any excess runoff generated from the development. The pervious areas to which the runoff from the impervious areas are connected should have the capacity to percolate at least the excess runoff[50] from a two-year storm event.

b) Implement as many LID principles as possible at the project site close to the point of storm water generation and achieve the 5% EIA for the entire project through designated infiltration/treatment areas elsewhere within the project site. For example, at a condominium development: connect the roof drains to landscaped areas, construct common parking areas with pervious asphalt with a sub-base of rocks or other materials to facilitate percolation of storm water, direct road runoff to curbless, vegetated sidewalks. The pervious areas which receive runoff from connected impervious areas should have the capacity to percolate at least the excess runoff[51] from a two-year storm event.

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[47] Smart Growth refers to the use of creative strategies to develop ways that preserve natural lands and critical environmental areas, protect water and air quality, and reuse already-developed land.

[48] New Urbanism is somewhat similar to Smart Growth and is based on principles of planning and architecture that work together to create human-scale, walkable communities that preserve natural resources.

[49] Excess storm water runoff = volume of post-development runoff minus pre-development runoff for a 2-year 24-hour storm event. This is mostly the runoff from impervious areas and excess runoff due to changes in site conditions, such as soil compaction, eliminating vegetative cover, etc..

[50] See Footnote 38

[51] See Footnote 38.

c) Implement LID on a sub-regional basis. For example, at a 100 unit high density housing unit with a small strip mall and a school: connect all roof drains to vegetated areas (if there are any vegetated areas, otherwise storm water storage and reuse may be considered or else divert to the local storm water conveyance system, to be conveyed to the local treatment system), construct a storm water infiltration gallery below the school playground to infiltrate the excess runoff from the pervious areas of the entire development. The pervious areas to which the runoff from the impervious areas are connected should have the capacity to percolate at least the excess runoff[52] from a two-year storm event. (Also see discussion on hydrologic conditions of concern, below.)

d) Implement LID on a regional basis. For example, several developments could propose a regional system to address storm water runoff from all the participating developments. The pervious areas to which the runoff from the impervious areas are connected should have the capacity to percolate at least the excess runoff[53] from a two-year storm event from the entire tributary area. (Also see discussion on hydrologic conditions of concern, below.)

4. The permittees may allow a project proponent to substitute treatment control BMPs for LID measures if the following conditions are met:

   a) The project proposes to implement applicable site design and source control BMPs;

   b) The EIA for the project site is limited to 5% or less;

   c) The post-development site hydrology (including runoff volume and time of concentration[54],) is not significantly different from pre-development hydrology (a difference of 5% or less is considered insignificant);

   d) The project proponent has included an analysis that indicates that post-development runoff water quality is equal to or better than pre-development runoff water quality; and

   e) The permittee(s) establishes a mechanism to verify that the LID measures are designed, constructed and operated in accordance with acceptable engineering practices or in accordance with the LID Guidance Manual for Southern California developed by the Southern California Coastal Water Research Project (currently being developed).

[52] See Footnote 38.

[53] See Footnote 38.

[54] Time of concentration is defined as the time after the beginning of rainfall when all portions of the drainage basin are contributing simultaneously to flow at the outlet.

D. HYDROLOGIC CONDITIONS OF CONCERN (HYDROMODIFICATION[55])

1. Each priority development project shall be required to ascertain the impact of the development on the site's hydrologic regime and include the findings in the WQMP, including the following for a two-year frequency storm event:

   a) Increases in runoff volume;

   b) Decreases in infiltration;

   c) Changes in time of concentration;

   d) Potential for increases in post development downstream erosion; and,

   e) Potential for adverse downstream impacts on physical structure, aquatic and riparian habitat.

2. The project does not have a hydrologic condition of concern if any one of the following conditions is met:

   a) The volumes and the time of concentration of storm water runoff for the post-development condition do not significantly exceed those of the pre-development condition for a two-year frequency storm event (a difference of 5% or less is considered insignificant). This may be achieved through site design and source control BMPs.

   b) All downstream conveyance channels that will receive runoff from the project are engineered, hardened and regularly maintained to ensure design flow capacity, and no sensitive stream habitat areas will be affected.

   c) The total effective impervious cover on a site is increased by less than 5% in new development projects. In considering the effective impervious cover, the impervious areas that are directly connected to a storm water conveyance system should be included, and those areas that are connected to pervious areas with a capacity to percolate at least the runoff from a two-year storm event, need not be considered. The permittees may request for a variance from these criteria, based on studies conducted by the Storm Water Monitoring Coalition, Southern California Coastal Water Research Project, or other regional studies. Requests for consideration of any variances should be submitted to the Executive Officer.

3. If a hydrologic condition of concern exists, then the WQMP shall include an evaluation of whether the project will adversely impact downstream erosion, sedimentation or stream habitat. This evaluation should include a hydrograph with pre- and post-development time of concentration for a 2-year frequency storm event. If the evaluation determines adverse impacts are likely to occur, the project proponent shall implement additional site design controls, on-site management controls, structural treatment controls and/or in-stream controls to mitigate the impacts. The project proponent should first consider site design

[55] Hydromodification is the alteration of natural flow characteristics.

controls and on-site controls prior to proposing in-stream controls; in-stream controls must not adversely impact beneficial uses or result in sustained degradation of water quality of the receiving waters.

4. The project proponent may also address hydrologic conditions of concern by mimicking the pre-development hydrograph with the post-development hydrograph, for a two year return frequency storm. Generally, the hydrologic conditions of concern are not significant, if the post-development hydrograph is no more than 10% greater than pre-development hydrograph. In cases where excess volume cannot be infiltrated or captured and reused, discharge from the site must be limited to a flow rate no greater than 110% of the pre-development 2-year peak flow.

E. ALTERNATIVES AND IN-LIEU PROGRAMS

1. If a particular BMP is not technically feasible, other BMPs should be implemented to achieve the same level of compliance, or if the cost of BMP implementation greatly outweighs the pollution control benefits, the permittees may grant a waiver of the BMPs. All waivers, along with waiver justification documentation, must be submitted to the Regional Board in writing within 30 days. If it is determined by the Regional Board that waivers are being inappropriately granted, this order may be reopened to modify these waiver conditions. The permittees may collectively or individually propose to establish an urban runoff fund to be used for urban water quality improvement projects within the same watershed that is funded by contributions from developers granted waivers. The contributions should be at least equivalent to the cost savings for waived projects. If a waiver is granted and an urban runoff fund is established, the annual report for the year should include the following information with respect to the urban runoff fund:

   a) Total amount deposited into the funds and the party responsible for managing the urban runoff fund;

   b) Projects funded or proposed to be funded with monies from the urban runoff fund;

   c) Party or parties responsible for design, construction, operation and maintenance of urban runoff funded projects; and

   d) Current status and a schedule for project completion.

2. The obligation to install structural treatment control BMPs at a new development is met if, for a common plan of development, BMPs are constructed with the requisite capacity to serve the entire common project, even if certain phases of the common project may not have BMP capacity located on that phase in accordance with the requirements specified above. The goal of the WQMP is to develop and implement practicable programs and policies to minimize the effects of urbanization on site hydrology, urban runoff flow rates, velocities and pollutant loads. This goal may be achieved through watershed-based structural

treatment controls, in combination with site-specific BMPs. All treatment control BMPs should be located as close as possible to the pollutant sources, should not be located within waters of the US, and pollutant removal should be accomplished prior to discharge to waters of the US. Regional treatment control BMPs shall be operational prior to occupation of any of the priority project sites tributary to the regional treatment BMP.

3. The permittees may establish a water quality credit system for alternatives to evapotranspiration, infiltration, LID and hydromodification requirements specified above. A summary of any waivers of LID, hydromodification, and infiltration requirements should be included in the annual report for each year. Any credit system that the permittees establish should be submitted to the Executive Officer for review and approval. The following types of projects may be considered for the credit system:

   a) Redevelopment projects that reduce the overall impervious footprint

   b) Brownfield redevelopment

   c) High density developments (>7 units per acre)

   d) Mixed use and transit-oriented development (within ½ mile of transit)

   e) Dedication of undeveloped portions of the project to parks, preservation areas and other pervious uses

   f) Regional treatment systems with a capacity to treat flows from all upstream developments

   g) Contribution to an urban runoff fund (see 1, above)

   h) Offsite mitigation or dedications within the same watershed

   i) City Center area

   j) Historic Districts and Historic Preservation areas

   k) Live-work developments

   l) In-fill projects

F. APPROVAL OF WQMPs

1. The permittees shall utilize a mechanism for review and approval of WQMPs, including a checklist that incorporates the minimum requirements from the model WQMP.
2. The permittees shall maintain a database to track all structural treatment control BMPs, including the location of BMPs, parties responsible for construction, operation and maintenance (also see I.3, below).
3. The permittees shall train those involved with WQMP reviews in accordance with Section XVI, Training Requirements.

G. FIELD VERIFICATION OF BMPS

1. The permittees shall establish and implement a mechanism (a checklist or other tools) to verify that treatment control BMPs are designed and constructed in accordance with the approved WQMP.
2. Prior to occupancy of each priority development project, the permittees shall field verify that the site design, source control and treatment control BMPs have been implemented in accordance with the approved WQMP.
3. Prior to occupancy, the permittees shall verify through visual observation, that the BMPs are operating and functional.

H. CHANGE OF OWNERSHIP AND RECORDATION

1. The permittees shall establish a mechanism not only to track treatment control BMPs, but also to ensure that appropriate easements and ownerships are properly recorded in public records at the County and/or the city and the information is conveyed to all appropriate parties when there is a change in project or site ownership.

I. OPERATION AND MAINTENANCE OF POST-CONSTRUCTION BMPS

1. The permittees shall ensure that all structural treatment control BMPs are designed and implemented with control measures necessary to effectively minimize the creation of nuisance or pollution associated with vectors, such as mosquitoes, rodents, flies, etc. The permittees should consult the Orange County Vector Control District to ensure that structural treatment control systems are designed to minimize the potential for vector breeding.
2. The permittees shall specify conditions of approval that require proper maintenance and operation of all structural treatment control BMPs installed in new developments. The parties responsible for the long-term maintenance and operation of the structural treatment control BMPs for the life of the project and a funding mechanism for operation and maintenance, shall be identified prior to approval of the WQMP.
3. The permittees shall develop a database with information regarding each structural treatment control BMP. At a minimum, it should include: type of BMP, watershed where it is located, date of construction, party responsible for maintenance, source of funding for operation and maintenance, maintenance verification, and any problems identified during inspections including any vector or nuisance problems. If vector or nuisance problems are identified, the site should be referred to the Orange County Vector Control District. The permittees should work with the Vector Control District to remedy the problems associated with vectors.
4. The annual report shall include a list of all structural treatment control BMPs approved, constructed and/or operating within each permittee's jurisdiction.
5. Within 12 months of adoption of this order and annually thereafter, all public agency structural treatment control BMPs, and at least 50% of priority

development project structural treatment control BMPs, shall be inspected prior to the rainy season. All structural treatment control BMPs shall be inspected within a two year period. The permittees shall ensure that the BMPs are operating and are maintained properly and all control measures are working effectively to remove pollutants in runoff from the site. All inspections shall be documented and kept as permittee record.

J. PRE-APPROVED PROJECTS

1. The above provisions for LID and hydrologic conditions of concern are not applicable to projects that have an approved Water Quality Management Plan as of the date of adoption of this order.

XIII. PUBLIC EDUCATION AND OUTREACH

1. The permittees shall continue to implement the public education efforts already underway and shall implement the most effective elements of the comprehensive public and business education strategy contained in the Report of Waste Discharge/DAMP. By July 1, 2012, the permittees shall complete a public awareness survey to determine the effectiveness of the current public and business education strategy and any need for changes to the current multimedia public education efforts. The findings of the survey and any proposed changes to the current program shall be included in the annual report for 2011-2012.
2. The permittees shall sponsor or staff a storm water table or booth at community, regional, and/or countywide events to distribute public education materials to the public. Each permittee shall participate in at least one event per year.
3. The permittees shall continue to participate in the Public Education Committee to review and update existing guidance for the implementation of the public education program. The Public Education Committee shall meet at least twice per year. The Public Education Committee shall continue to make recommendations for any changes to the public and business education program including: how to make the multimedia efforts more effective; a reevaluation of audiences and key messages for targeted behaviors; and opportunities for participation in regional and statewide public education efforts. The goal of the public and business education program shall be to target 100% of the residents, including businesses, commercial and industrial establishments. Through use of local print, radio and television, the permittees must ensure that the public and business education program makes a minimum of 10 million impressions per year and that those impressions measurably increase the knowledge and measurably change the behavior of the targeted groups.

4. The permittees shall continue their outreach and other public education activities. Each permittee should try to reach the following sectors: manufacturing facilities; mobile service industry; commercial, distribution and retail sales industry; residential/commercial landscape construction and services industry; residential and commercial construction industry; and residential and community activities. Individual workshops (or regional workshops) for each of the aforementioned elements shall be administered by each permittee (or on a countywide basis) by July 1, 2010 and on an annual basis thereafter. Commercial and industrial facility inspectors shall distribute developed educational information (Fact Sheets) to these facilities during inspections. Further, for restaurant, automotive service centers and gasoline service station corporate chains, new information or that which has been previously developed shall be provided to corporate environmental managers during outreach visits that should take place twice during the permit term. The outcomes from all outreach requirements contained herein shall be reported in the applicable annual reports.

5. The permittees shall further develop and maintain public education materials to encourage the public to report illegal dumping and unauthorized, non-storm water discharges from residential, industrial, construction and commercial sites into public streets, storm drains and to surface waterbodies and their tributaries; clogged storm drains; faded or missing catch basin stencils and general storm water and BMP information. Hotline and web site information shall be included in the public and business education program and shall be listed in the governmental pages of all regional phone books and on the permittees' website.

6. Within 12 months from the date of adoption of this order, the permittees shall further develop and maintain BMP guidance for the control of those potentially polluting activities identified during the previous permit cycle, which are not otherwise regulated by any agency, including guidelines for the household use of fertilizers, pesticides, herbicides and other chemicals, and guidance for mobile vehicle maintenance, carpet cleaners, commercial landscape maintenance, and pavement cutting. These guidance documents shall be distributed to the public, trade associations, etc., through participation in community events, trade association meetings and/or by mail.

7. The principal permittee, in collaboration with the co-permittees, shall develop and implement a mechanism for public participation in the updating and implementation of the Drainage Area Management Plans, monitoring plans, Water Quality Management Plan guidance and Fact Sheets for various activities. The public shall be informed of the availability of these documents through public notices in local newspapers, County and/or city websites, local libraries/city halls and/or courthouses.

XIV. MUNICIPAL FACILITIES/ACTIVITIES

1. The permittees shall continue to implement the Model Municipal Activities Program developed by the permittees for fixed facilities, field operations and drainage facilities to ensure that public agency facilities and activities do not cause or contribute to a pollution or nuisance in receiving waters. By July 1 of each year, the permittees shall review all their activities and facilities to determine the need for any revisions to the facility inventories, prioritization, and maintenance programs. The annual report shall

include the findings of this review and a schedule for any needed revisions. All revisions should consider a pollution prevention strategy to ensure that the public agency facilities and/or activities that are currently not required to obtain coverage under the State's general storm water permits reduce the discharge of pollutants into waters of the US to the maximum extent practicable.

2. The permittees shall continue to implement BMPs as per the Fact Sheets developed by the permittees for fixed facilities, field programs and drainage facilities for public agency and contract field operations and maintenance staff. A reporting of these activities shall be included in each annual report.

3. The permittees shall conduct inspections of municipal facilities at least on an annual basis and record the findings in the inspection forms developed by the permittees. At a minimum the following municipal areas should be inspected:

   a) Parking facilities;

   b) Flood management and storm water conveyance systems;

   c) Areas or facilities discharging directly to lagoons, the ocean, or environmentally sensitive areas such as 303(d) listed waterbodies and Areas of Special Biological Significance; and

   d) Municipal landfills, solid waste transfer facilities, land application sites, corporate yards, sewage collection and treatment facilities, parks and recreation facilities including golf courses, and airfields.

4. All applicable public agency staff shall be trained as specified under Section XVI.

5. In collaboration with the University of California Cooperative Extension and consistent with the Model Integrated Pest Management, Pesticide and Fertilizer Management Guidelines, the permittees shall:

   a) Conduct annual integrated pest management self-audits;

   b) Implement the Model Integrated Pest Management, Pesticide and Fertilizer Guidelines;

   c) Provide proper training to municipal and contract staff involved in the above activities;

   d) Within six months of adoption of this order, revise the LIP to include an integrated pest management program.

6. The permittees shall evaluate the need for any revisions to the Integrated Pest Management, Pesticide and Fertilizer Management Guidelines and determine the need for developing pesticide use indicators.

7. Within six months of adoption of this order, the principal permittee shall evaluate the effectiveness of debris booms and determine if additional debris booms are needed to address floatables in inland streams. This evaluation should also include an evaluation

of other control measures such as more effective street sweeping program, litter control measures, and drain inlet screens and /or other inlet controls.

8. Within twelve months of adoption of this order, the principal permittee shall develop an intragency agreement with the County Integrated Waste Management Department to ensure that household solid and hazardous waste collection, transfer and disposal practices do not cause or contribute to a water quality problem.

9. The permittees shall ensure that their flood management processes and projects do not contribute pollutants to receiving waters to the MEP.

10. Each permittee shall examine opportunities to retrofit existing storm water conveyance systems and parks and other recreational areas with water quality protection measures, where feasible. The 2005 RBF Retrofit Study may be used by the principal permittee for a system-wide evaluation in lieu of each permittee conducting its own evaluation. Within 12 months of adoption of this order, the principal permittee shall submit a proposal for additional retrofit studies that incorporates opportunities for addressing any applicable TMDL implementation plans.

11. The permittees shall continue to implement the established model maintenance procedure for drainage facilities (catch basins, storm drains inlets, open channels, etc.). Each permittee shall clean and maintain at least 80% of its drainage facilities on an annual basis, with 100% of the facilities included in a two-year period, using the model maintenance procedures developed by the permittees. Each permittee shall keep a record of its inspections, maintenance and cleaning activities, and overall quantity of waste removed. This record shall be included in the annual report.

12. The permittees shall determine whether a more aggressive maintenance frequency is necessary for the cleaning of drainage facilities, including catch basins, based on the data generated by the historic and ongoing inspections of these facilities. This program shall be based on a list of drainage facilities and prioritized on such factors as: proximity to receiving waters, receiving water beneficial uses and impairments of beneficial uses, historical pollutant types and loads from past inspections/cleanings and the presence of downstream regional facilities that would remove the types of pollutants found in the drainage facility. Using this list, the permittees shall revise clean out schedules and frequency and provide justification for any proposed clean out frequency that is less than once a year. This information shall be included in the annual report.

13. Within six months of adoption of this order, the permittees shall evaluate the applicability of the Model Municipal Activities Program to municipal maintenance contracts, contracts for field maintenance operations, and leases. The findings from the evaluation shall be included in the next annual report.

14. Each permittee shall implement control measures necessary to minimize infiltration of seepage from sanitary sewers to the storm drain systems through routine preventive maintenance of the storm drain system. The permittees who are also owners and/or operators of sewage collection systems shall also implement a routine maintenance

program for the sewage collection systems in accordance with the State Board's Water Quality Order No. 2006-0003. Each permittee shall cooperate and coordinate with the sewage collection/treatment agencies (Orange County Sanitation District and/or Irvine Ranch Water District) to swiftly respond to and contain any sewage spills.

XV. MUNICIPAL CONSTRUCTION PROJECTS/ACTIVITIES

1. This order authorizes the discharge of storm water runoff from construction projects that may result in land disturbance of one (1) acre or more (or less than one acre, if it is part of a larger common plan of development or sale which is one acre or more) that are under ownership and/or direct responsibility of any of the permittees. All permittee construction activities shall be in accordance with DAMP Sections 7 and 8.
2. All construction activities shall be in compliance with the latest version of State's General Permit for Storm Water Discharges Associated with Construction Activities except that an NOI need not be filed with the State Board.
3. Prior to commencement of construction activities, the permittees shall notify the Executive Officer of the Regional Board concerning the proposed construction project. Upon completion of the construction project, the Executive Officer shall be notified of the completion of the project.
4. The permittees shall develop and implement a storm water pollution prevention plan (SWPPP) and a monitoring program that is specific for the construction project greater than one acre, prior to the commencement of any of the construction activities, except for routine maintenance activities. The SWPPP shall be kept at the construction site and released to the public and/or Regional Board staff upon request.
5. The SWPPP (and any other plans and programs required under the General Permit) and the monitoring program for the construction projects shall be consistent with the requirements of the latest version of the State's General Construction Permit.
6. The permittees shall give advance notice to the Executive Officer of the Regional Board concerning any planned changes in the construction activity, which may result in non-compliance with the latest version of the State's General Construction Permit.

XIV. TRAINING PROGRAM FOR STORM WATER MANAGERS, PLANNERS, INSPECTORS AND MUNICIPAL CONTRACTORS

1. Within 12 months from the date of adoption of this order, the principal permittee, in coordination with the co-permittees, shall develop a training program including a training schedule, curriculum content, and defined expertise and competencies for storm water managers, inspectors, maintenance crew, those involved in the review and approval of WQMPs, public works employees, community planners and for those preparing and/or reviewing CEQA documentation and for municipal contractors.
2. The curriculum content should include: federal, state and local water quality laws and regulations as they apply to construction and grading activities, industrial and commercial activities; the potential effects of construction, industrial and commercial activities and urbanization on water quality; implementation and maintenance of erosion

control and pollution prevention measures and sediment control BMPs; the proper use and maintenance of erosion and sediment controls; the enforcement protocols and methods established in the Drainage Area Management Plan, Local Implementation Plan, the Construction Runoff Guidance Manual, Enforcement Consistency Guide and Illicit Discharge/Illegal Connection Training Program.

3. The training modules for each category of trainees (managers, inspectors, planners, contractors, public works crew, etc.) should define the required competencies, outline the curriculum, a testing procedure at the end of the training program and proof of completion of training (Certificate of Completion).
4. At least on an annual basis, the principal permittee shall provide and document training to applicable public agency staff on Fixed Facility Model Maintenance Procedure, Field Program Model Training and Drainage Facility Model Maintenance Training. The field program training should include Model Integrated Pest Management, Pesticide and Fertilizer Guidelines. Each permittee shall attend at least three of these training sessions during the term of this permit. The training sessions may be conducted in classrooms or using videos, DVDs, or other multimedia with appropriate documentation and a final test to verify that the material has been properly reviewed and understood.
5. The principal permittee shall conduct and document public employee training for model environmental review, and on how to conduct public/business education for preparation of environmental documents.
6. The principal permittee shall provide BMP and training information to municipal contractors to assist the contractors in training their staff. In instances where applicable municipal operations are performed by contract staff, the permittees shall require evidence that contract staff have received a level of training equivalent to that listed above.
7. The principal permittee shall notify designated Regional Board staff via e-mail at least 30 days prior to conducting any of these training sessions.
8. Each permittee shall have adequately trained all its staff involved with storm water related projects within 60 days from being assigned these duties and on an annual basis thereafter, prior to the rainy season.
9. Each permittee shall maintain a written record of all training provided to its storm water and related program staff.

XVII. NOTIFICATION REQUIREMENTS

1. Within 24 hours of discovery, each permittee shall provide oral or e-mail notification to Regional Board staff of non-compliant sites within its jurisdiction that are determined to pose imminent threat to human health or the environment (e.g., sewage spills that could impact water contact recreation, an oil spill that could impact wildlife, a hazardous substance spill where residents are evacuated, etc.). Following oral or email notification, a written report must be submitted to the Regional Board office within 5 business days, detailing the nature of the non-compliance, any corrective action taken by the site owner, other relevant information (e.g., past history of non-compliance,

environmental damage resulting from the non-compliance, site owner responsiveness) and the type of enforcement that will be carried out by the permittee. Further, incidences of non-compliance shall be recorded along with the information noted in the written report and the final outcome/enforcement for the incident in the databases for construction, industrial and commercial inspections.

2. At a minimum, all sewage spills above 1,000 gallons and all reportable quantities of hazardous waste spills as per 40CFR 117 and 302 shall be reported within 24 hours. All spill incidents shall be also included in the annual report. The permittees may propose a reporting program, including reportable incidents and quantities, jointly with other agencies, such as the County Health Care Agency, for approval by the Executive Officer.

XVIII. WATERSHED ACTION PLANS AND TMDL IMPLEMENTATION

A. IMPAIRED WATERBODIES WITH NO TMDLS

1. The principal permittee, in collaboration with the co-permittees, shall develop Watershed Action Plans for areas where such a Plan has not been developed. Currently existing Watershed Action Plans and those under development shall be updated as new TMDLs are approved by the Regional Board.
2. Each Watershed Action Plan shall identify impaired waters [CWA § 303(d) listed], pollutants causing impairment, monitoring programs for these pollutants, control measures, including any BMPs that the permittees are currently implementing, and any BMPs the permittees are proposing to implement. All construction sites that are adjacent to (within 200 feet) or discharging directly to a waterbody listed for sediments or turbidity shall be treated as high priority sites. In selecting control measures, the listed pollutants shall be treated as primary pollutants of concern and these pollutants shall be addressed through source control, site design, pollution prevention and structural treatment control BMPs.

B. WATERBODIES WITH TECHNICAL TMDLS (NO IMPLEMENTATION PLANS)

1. Implementation plans are being developed for the following TMDLs:
   a) Metals (San Diego Creek and Newport Bay)
   b) Metals (Rhine Channel)
   c) Organochlorine compounds (San Diego Creek and Newport Bay, also see Paragraphs 4 & 5, below)
   d) Selenium (San Diego Creek and Newport Bay)
   e) Copper, lead and zinc (Coyote Creek, TMDL developed by the EPA and the Los Angeles Regional Water Quality Control Board for wet weather)
   f) Copper (Coyote Creek, TMDL developed by the EPA and the Los Angeles Regional Water Quality Control Board for dry weather)

As required under a consent decree, the EPA promulgated TMDLs for toxic pollutants in San Diego Creek and Newport Bay that included TMDLs for selenium, metals, organochlorine compounds and organophosphate pesticides. As noted in the Findings, the Regional Board adopted TMDLs for the organochlorine compounds in September 2007, and TMDLs are under implementation for diazinon and chlorpyrifos. Regional Board staff, in collaboration with the stakeholders, is developing TMDLs for metals and selenium that will include implementation plans and monitoring programs. The permittees within the San Diego Creek watershed shall continue to participate in the development and implementation of these TMDLs.

2. For the organochlorine compounds TMDLs, the Regional Board has adopted an implementation plan. That plan requires approvals from the State Board, the Office of Administrative Law and the EPA. The organochlorine compounds are carried by fine sediment into the water column. Since the use of organochlorine pesticides has been banned, the levels of these compounds have been steadily decreasing in the watershed. The implementation plan requires monitoring to verify the decreasing trend and strict controls on sediment discharges. The stakeholders in the San Diego Creek/Newport Bay watershed have an established Regional Monitoring Program (RMP), and in early 2008, initiated a Toxicity Reduction and Investigation Program (TRIP) consistent with the implementation plan for the organochlorine compounds TMDLs. The permittees shall evaluate the monitoring results with the following targets and determine the need for any additional control measures to achieve the targets. Monitoring shall be conducted at representative locations within San Diego Creek and Newport Bay. The permittees may use current monitoring locations:

Tables 1A/B - Water Column Targets for Protection of Aquatic Life, Wildlife & Human Health[56]

A - San Diego Creek and Tributaries

	Total DDT	Toxaphene
Acute Criterion	1.1 µg/l	0.73 µg/l
Chronic Criterion	0.001 µg/l	0.0002 µg/l
Human Health Criterion	0.00059 µg/l	0.00075 µg/l

B - Upper and Lower Newport Bay

	Total DDT	Chlordane	Total PCBs
Acute Criterion	0.13 µg/l	0.09 µg/l	

[56] From Resolution No. R8-2007-0024, Table NB-OCs-4

Chronic Criterion	0.001 µg/l	0.0004 µg/l	0.03 µg/l
Human Health Criterion	0.00059 µg/l	0.00059 µg/l	0.00017 µg/l

Table 2 - Water Column Targets from the Informational TMDLs for Chlordane and PCBs[57]

Sand Diego Creek and Tributaries

	Chlordane	Total PCBs
Acute Criterion	2.4 µg/l	
Chronic Criterion	0.0043 µg/l	0.014 µg/l
Human Health Criterion	0.00059 µg/l	0.00017 µg/l

3. In conjunction with watershed stakeholders, Regional Board staff is in the process of developing recommendations for revisions to the nutrient TMDLs and to the EPA TMDLs for selenium, and is formulating a selenium TMDL implementation plan. Selenium is a naturally occurring element in the soil and is partitioned into groundwater. Selenium-laden shallow and rising groundwater enters the storm water conveyance systems and flows into San Diego Creek and its tributaries. Groundwater inputs are the major source of selenium in San Diego Creek and Newport Bay. Currently, there are no economically and technically feasible treatment techniques to remove selenium from the water column. The stakeholders have initiated pilot studies to determine the most efficient methods for treatment and removal of selenium. Through the Nitrogen and Selenium Management Program, the watershed stakeholders are developing comprehensive nitrogen and selenium management plans, which are expected to form the basis, at least in part, for a revised nutrient TMDL implementation plan and the selenium implementation plan. A collaborative watershed approach to implement the nitrogen and selenium TMDLs for San Diego Creek and Newport Bay is expected. As long as the stakeholders are participating in and implementing the collaborative approach, if approved, they will not be in violation of this order with respect to the nitrogen and selenium TMDLs for San Diego Creek and Newport Bay. In the event that any of the stakeholders does not participate, or if the collaborative approach is not approved or fails to achieve the TMDLs, the Regional Board will exercise its

[57] From Resolution No. R8-2007-0024, Table NB-OCs-5

option to issue individual waste discharge requirements or waivers of waste discharge requirements.

4. The permittees with discharges tributary to Coyote Creek or the San Gabriel River shall develop and implement constituent-specific source control BMPs for copper, lead and zinc until a TMDL implementation plan is developed. The source control plan shall include a monitoring program and shall be completed within 12 months from the date of adoption of this order. The source control plan shall be designed to meet the following wasteload allocations:

Table 3 – Municipal Storm Water Wasteload Allocations
Coyote Creek

	Copper	Lead	Zinc
Dry Weather	0.941 kg/day		
Wet Weather	9.41 kg/day	36.9 kg/day	55.0 kg/day

5. Within 12 months of adoption of this order, the principal permittee, in collaboration with the co-permittees with discharges to the San Gabriel River/Coyote Creek and/or their tributaries, shall develop a monitoring program to monitor dry weather (for copper) and wet weather (for copper, lead and zinc) flows in Coyote Creek. The monitoring results shall be evaluated against the following numeric targets:

Table 4 – Numeric Targets - Coyote Creek
(total recoverable metals)

	Copper	Lead	Zinc
Dry Weather[58]	3.7 µg/l		
Wet Weather	27 µg/l	106 µg/l	158 µg/l

Dry Weather limit for copper is based on CTR saltwater criterion in San Gabriel River estuary

[58] Based on saltwater CTR criterion.

C. WATERBODIES WITH TMDL COMPLIANCE SCHEDULES BEYOND THE PERMIT TERM

1. The Regional Board adopted a TMDL implementation plan for fecal coliform bacteria in Newport Bay that included a compliance date for water contact recreation standards no later than December 30, 2013 (within the permit term), and with shellfish standards no later than December 30, 2019. The allocations are shown in the tables below.

Table 5a – Fecal Coliform TMDL and Loads for Newport Bay
To be achieved no later than December 30, 2013

Total Maximum Daily Load for Fecal Coliform	As soon as possible, but no later than December 30, 2013	5-Sample/30-days Geometric Mean less than 200 organisms/100 mL, and not more than 10% of the samples exceed 400 organisms/100 mL for any 30- day period.
Total Maximum Daily Load for Fecal Coliform		5-Sample/30-days Geometric Mean less than 200 organisms/100 mL, and not more than 10% of the samples exceed 400 organisms/100 mL for any 30-day period.
Load Allocations for Fecal Coliform in Agricultural Runoff, including stormwater, Discharges		5-Sample/30-days Geometric Mean less than 200 organisms/ 100 mL, and not more than 10% of the samples exceed 400 organisms/100 mL for any 30-day period.
Load Allocations for Fecal Coliform from Natural Sources in all Discharges	In effect	5-Sample/30-days Geometric Mean less than 200 organisms/100 mL, and not more than 10% of the samples exceed 400 organisms/100 mL for any 30-day period.
Allocations for Vessel Waste		0 MPN/100 mL - No discharge.

Table 5b – Fecal Coliform TMDL and Loads for Newport Bay
Before December 30, 2019

Total Maximum Daily Load for Fecal Coliform		Monthly Median less than 14 MPN/100 mL, and not more than 10% of the samples exceed 43 MPN/100 mL.
Total Maximum Daily Load for Fecal Coliform		Monthly Median less than 14 MPN/100 mL, and not more than 10% of the samples exceed 43 MPN/100 mL.

Load Allocations for Fecal Coliform in Agricultural Runoff, including stormwater, Discharges	As soon as possible, but no later than December 30, 2019	Monthly Median less than 14 MPN/100 mL, and not more than 10% of the samples exceed 43 MPN/100 mL.
Load Allocations for Fecal Coliform from Natural Sources in all Discharges		Monthly Median less than 14 MPN/100 mL, and not more than 10% of the samples exceed 43 MPN/100 mL.
Allocations for Vessel Waste	In effect	0 MPN/100 mL - No discharge.

Compliance determination for fecal coliform shall be based on monitoring conducted at representative sampling locations within San Diego Creek and Newport Bay. (The permittees may use the current sampling locations for compliance determination.)

2. The fecal coliform TMDL implementation plan includes a number of studies that are expected to inform possible revision of the TMDL, including the wasteload allocations for urban runoff and the implementation plan. The permittees shall revise the DAMP to include implementation measures and schedules for further studies related to the TMDL for fecal coliform in Newport Bay, as set forth in the January 2000, March 2000 and April 2000 Newport Bay Fecal Coliform TMDL Technical Reports submitted by the permittees. The permittees within this watershed shall complete a source identification and characterization plan for urban runoff by December 31, 2009 and continue their participation in the studies and monitoring programs as specified in the implementation plan. Recommendations for an updated TMDL report and revisions to the fecal coliform TMDL shall be provided within six months of completion of the Source Identification and Characterization Investigation and Report submittal, as specified in the implementation plan.
3. The fecal coliform TMDL includes waste load allocations for storm water in urban runoff and load allocations in agricultural runoff. The University of California Cooperative Extension and Orange County Coastkeeper are working with the agricultural operators in the area to reduce runoff from their operations.

D. WATERBODIES WITH TMDL COMPLIANCE SCHEDULES WITHIN THE PERMIT TERM

1. The Regional Board/EPA developed TMDLs for diazinon and chlorpyrifos in San Diego Creek and for chlorpyrifos in Newport Bay. The following allocations are

included in the TMDLs (Tables 6a and 6b are extracted from the Implementation Plan[59]).

Table 6a

Diazinon and Chlorpyrifos Allocations for San Diego Creek

Category	Diazinon (ng/l)		Chlorpyrifos (ng/l)	
	Actue	Chronic	Acute	Chronic
Wasteload Allocation	72	45	18	12.6
Load Allocation	72	45	18	12.6
MOS	8	5	2	1.4
TMDL	**80**	**50**	**20**	**14**

MOS=Margin of safety; Chronic means 4-consecutive day average

Table 6b

Chlorpyrifos Allocations for Upper Newport Bay

Category	Acute (ng/l)	Chronic (ng/)
Wasteload allocation	18	8.1
Load Allocation	18	8.1
MOS	2	0.9
TMDL	**20**	**9**

MOS=Margin of safety; Chronic means 4-consecutive day average

The Regional Board adopted an implementation plan for these TMDLs. In accordance with the implementation plan, the Regional Monitoring Program was modified to include analysis for organophosphate pesticides and toxicity. The Regional Board also performed simulation studies to predict contaminant concentrations in the Bay. Based on the results of these studies, the Regional Board will reevaluate the TMDLs every three years. The permittees shall continue to participate in any additional monitoring that is needed to confirm that the permittees are in compliance with the allocations.

Compliance determination for diazinon and chlorpyrifos for San Diego Creek shall be based on monitoring conducted at representative monitoring locations within San Diego Creek (the permittees may use current monitoring locations for this purpose).

[59] Attachment to Resolution No. R8-2003-0039

Compliance determination for chlorpyrifos for Upper Newport Bay shall be based on monitoring conducted at representative monitoring locations within Upper Newport Bay (the permittees may use current monitoring locations for this purpose).

2. The waste load allocations established in the nutrient TMDLs adopted by the Regional Board in 1998 for Newport Bay included 5, 10 and 15 year allocations. The overall allocations for 2012 have been met.

Table 7 - Seasonal Load Allocations of Total Nitrogen for the Newport Bay Watershed (Urban Runoff)[60]

Nutrient TMDL	1990-1997 Loading	2002 Summer Allocation (Apr-Sept)[61]	2007 Summer Allocation (Apr-Sept)[62]	2012 Winter Allocation (Oct-Mar)[63]
Newport Bay Watershed	lbs/year TN[64,65]	lbs/season TN	lbs/season TN	lbs/season TN
Wasteload Allocation				
Urban runoff	277,131[66]	20,785	16,628	55,442
		5 year target	10 year target	15 year target

[60] From Attachment to Resolution No. 98-9 as amended by Resolution No. 98-100, Table 5-9b.

[61] Compliance to be achieved no later than this date. The Regional Board may require earlier compliance with these targets when it is feasible and reasonable.

[62] See footnote 54.

[63] Total nitrogen winter loading limit applies between October 1 and March 31 when the mean daily flow rate at San Diego Creek at Campus Drive is below 50 cubic feet per second (cfs), and when the mean daily flow rate in San Diego Creek at Campus Drive is above 50 cubic feet per second (cfs), but not as the result of precipitation. Compliance to be achieved no later than this date. The Regional Board may require earlier compliance with these targets when it is feasible and reasonable. Assumes 67 non-storm days.

[64] TIN = (NO3+NH3).

[65] TN = (TIN + Organic N).

[66] Estimated annual average (summer and winter loading).

Table 8 - Annual Total Nitrogen Load Allocations For San Diego Creek, Reach 2 During Non-Storm Conditions.[67]

	2012 Allocation lbs/day TN[68]
TMDL	14 lbs/day (TN)
Waste Load Allocation (Urban runoff)	5.5 lbs/day (TN)

3. The permittees shall verify, through monitoring or other mechanisms, that they have met the following load allocations for phosphorous for urban runoff (recent monitoring data indicate that these target load allocations have been already met).

Table 9 - Annual Total Phosphorous Load Allocations For The Newport Bay Watershed

	2002 Allocation lbs/year TP[1]	2007 Allocation lbs/year TP[61]
TMDL	86,912	62,080
Urban areas	4,102	2,960

Compliance determination for nutrients in San Diego Creek and Newport Bay shall be based on monitoring conducted at representative monitoring locations within San Diego Creek and Newport Bay.

4. The permittees shall meet the following target load allocations for sediment in urban runoff by implementing the BMPs contained in Sections 7 and 8 of the DAMP and the "March 1999 Technical Report on the Implementation of the TMDL for Sediment in the Newport Bay Watershed, the October 1999 Preliminary Sediment Load Allocation Analysis for San Diego Creek and Newport Bay, and the February 2000 Sediment Yield and Transport Investigation for San Diego Creek and Newport Bay".

   a) The load allocations for sediment discharges to Newport Bay from urban areas shall not exceed 2,500 tons per year, implemented as a 10-year running annual average.

[67] Total nitrogen loading limit applies when the mean daily flow rate at San Diego Creek at Culver Drive is below 25 cubic feet per second (cfs), and when the mean daily flow rate in San Diego Creek at Culver Drive is above 25 cubic feet per second (cfs), but not as the result of precipitation.

[68] Compliance to be achieved no later than this date. The Regional Board may require earlier compliance with these targets when it is feasible and reasonable.

b) The load allocations for sediment discharges to San Diego Creek and its tributaries from urban areas shall not exceed 2,500 tons per year, implemented as a 10-year running annual average.

Compliance determination for sediment in San Diego Creek and Newport Bay shall be based on monitoring conducted at the end-of-pipe from representative MS4 systems, starting from year 2000 and based on a 10-year running average.

5. This order may be reopened to include additional requirements based on new or revised TMDLs.

E. COMPLIANCE DETERMINATION WITH TMDLs AND BMP IMPLEMENTATION

1. Except for sediment TMDLs in San Diego Creek and Newport Bay, compliance determination is based on monitoring within the receiving waters. For sediment TMDLs, compliance determination is based on end-of-pipe monitoring.

2. Based on the TMDLs, numeric effluent limits are specified for most constituents. If the monitoring results indicate a violation of the numeric effluent limits, the permittees shall reevaluate the current control measures and propose additional BMPs/control measures. This reevaluation and proposal for revisions to the current BMPs/control measures (revised plan) shall be submitted to the Executive Officer within 12 months of determining that a violation has occurred. Upon approval, the permittees shall immediately start implementation of the revised plan.

XIX. PROGRAM MANAGEMENT/DAMP REVIEW

1. By July 1 of each year, the permittees shall evaluate the DAMP to determine whether any revisions are necessary in order to reduce pollutants in MS4 discharges to the maximum extent practicable. In addition, the first annual review after adoption of this order shall include the following:

   a) Review of the formal training needs of municipal employees

   b) Review of coordinating meeting/training for the designated NPDES inspectors.

2. The annual report shall include the findings of this review and a schedule for any needed revisions or a copy of the amended DAMP with the proposed changes.

3. Upon the effective date of this Order, the permittees shall start implementing the 2007 DAMP. If modifications to the 2007 DAMP are determined to be necessary, the permittees shall prepare and submit DAMP modifications to the Regional Board Executive Officer, for consideration by the Regional Board at a public hearing. Such modifications may include regional and watershed-specific requirements and/or waste load allocations developed and approved pursuant to the TMDL process.

4. The Management Committee shall meet at least six times a year to discuss issues related to permit implementation and regional and statewide issues. Each

permittee's designated representative or a designated alternate should attend at least 75% of these meetings.

XX. FISCAL ANALYSIS

1. Each permittee shall secure the resources necessary to meet all requirements of this order.
2. The permittees shall prepare and submit a unified fiscal accountability analysis to the Executive Officer of the Regional Board. The fiscal analysis shall be submitted with the annual report shall, at a minimum, include the following:
   a) Each permittee's expenditures for the previous fiscal year,
   b) Each permittee's budget for the current fiscal year,
   c) A description of the source of funds, and
   d) Each permittee's estimated budget for the next fiscal year.

XXI. PROVISIONS

1. All reports submitted by the permittees as per the requirements in this order for the approval of the Executive Officer shall be publicly noticed and made available on the Regional Board's website, or through other means, for public review and comments. The Executive Officer shall consider all comments received prior to approval of the reports. Any unresolved significant issues shall be scheduled for a public hearing at a Regional Board meeting prior to approval by the Executive Officer.
2. Permittees shall demonstrate compliance with all the requirements in this order and specifically with Section III.2 Discharge Limitations and Section IV. Receiving Water Limitations, through timely implementation of their DAMP and any modifications, revisions, or amendments developed pursuant to this order approved by the Executive Officer or determined by the permittee to be necessary to meet the requirements of this order.
3. The permittees shall, at a minimum, implement all elements of the DAMP. Where the dates in the DAMP are different than those of this order, the dates in this order shall prevail. Any proposed revisions to the DAMP shall be submitted with the annual report to the Executive Officer of the Regional Board for review and approval. All approved revisions to the DAMP shall be implemented as per the time schedules approved by the Executive Officer. In addition to those specific controls and actions required by (1) the terms of this order and (2) the DAMP, each permittee shall implement additional controls, if any are necessary, to reduce the discharge of pollutants in storm water to the maximum extent practicable, as required by this order.
4. The permittees shall comply with Monitoring and Reporting Program NO. R8-2008-0030, and any revisions thereto, which is hereby made a part of this order. The Executive Officer is authorized to revise the Monitoring and Reporting Program to

allow the permittees to participate in regional, statewide, national or other monitoring programs in lieu of or in addition to Monitoring and Reporting Program No. R8-2008-0030.

5. Within six months of adoption of this order, the permittees, in coordination with the Orange County Fire Chiefs Association, shall develop a list of appropriate BMPs to be implemented to reduce pollutants from training activities, fire hydrant/sprinkler testing or flushing, non-emergency fire fighting and any BMPs feasible for emergency fire fighting flows.
6. Upon approval by the Executive Officer of the Regional Board, all plans, reports and subsequent amendments required by this order shall be implemented and shall become an enforceable part of this order. Prior to approval by the Executive Officer, these plans, reports and amendments shall not be considered as an enforceable part of this order.
7. The permittees shall report to the Executive Officer of the Regional Board:
   a) Any enforcement actions and discharges of storm or non-storm water, known to the permittees, which may have an impact on human health or the environment,
   b) Any suspected or reported activities on federal, state, or other entity's land or facilities, where the permittees do not have any jurisdiction, and where the suspected or reported activities may be contributing pollutants to waters of the US.

   (Also see reporting requirements in Monitoring and Reporting Program No. R8-2008-0030)
8. The permit application package and special NPDES program requirements contained in 40 CFR 122.21 (a), (b), (d)(2), (f), (p); 122.41 (a), (b), (c), (d), (e), (f), (g), (h), (i), (j), (k), (l); and 122.42 (c) are incorporated into this order by reference.

XXII. PERMIT MODIFICATION

1. In accordance with 40 CFR 122.41(f), this order may be modified, revoked or reissued prior to its expiration date for the following reasons:
   a) To address significant changes in conditions identified in the technical reports required by the Regional Board which were unknown at the time of the issuance of this order;
   b) To incorporate applicable requirements of statewide water quality control plans adopted by the State Water Resources Control Board or any amendments to the Basin Plan approved by the Regional Board, the State Board and, if necessary, by the Office of Administrative Law;
   c) To comply with any applicable requirements, guidelines, or regulations issued or approved under the Clean Water Act, if the requirements, guidelines, or regulations contain different conditions or additional requirements than those included in this order; or,

d) To incorporate any requirements imposed upon the permittees through the TMDL process.

2. The filing of a request by the permittees for modification, revocation and re-issuance, or termination or a notification of planned changes or anticipated noncompliance does not stay any conditions of this order.

XXIII. PERMIT EXPIRATION AND RENEWAL

1. This order expires on XXXXXXXX and the permittees must file a Report of Waste Discharge (permit application) no later than 180 days in advance of such expiration date as application for issuance of new waste discharge requirements (40 CFR 122.41(b)). The Report of Waste Discharge shall, at a minimum, include the following:

   a) Any revisions to the Drainage Area Management Plan including, but not limited to, all the activities the permittees propose to undertake during the next permit term, goals and objectives of such activities, an evaluation of the need for additional source control and/or structural BMPs, any proposed pilot studies, etc.;

   b) Changes in land use and/or population including land use map updates;

   c) Any significant changes to the storm drain systems, outfalls, detention or retention basins or dams and other controls including map updates of the storm drain systems; and,

   d) Any new or revised program elements and compliance schedule(s) necessary to comply with Section IV of this order.

2. All permit applications (Report of Waste Discharge), annual reports and other information submitted under this order shall be signed by either a principal executive officer or a ranking elected official (40 CFR 122.22(a)(3)) or a duly authorized representative as per 40 CFR 122.22(b).

3. This order shall serve as a National Pollutant Discharge Elimination System (NPDES) Permit pursuant to Section 402(p) of the Clean Water Act, or amendments thereto, and shall become effective ten days after the date of its adoption, provided the Regional Administrator of the EPA has no objections. If the Regional Administrator objects to its issuance, the permit shall not become effective until such objection is withdrawn.

4. Order No. R8-2002-0010 is hereby rescinded.

I, Gerard Thibeault, Executive Officer, do hereby certify that the foregoing is a full, true, and correct copy of an order adopted by the California Regional Water Quality Control Board, Santa Ana Region, on XXXXXXXXXX.

_____

Gerard J. Thibeault
Executive Officer

To be provided at a later date.

Order No. R8-2008-0030 (NPDES No. CAS618030) – cont'd
The County of Orange, OCFCD, and Incorporated Cities
Area wide Urban Storm Water Runoff

Attachment "B"

To be provided at a later date.

Order No. R8-2008-0030
Attachment "C"
LIST OF OTHER ENTITIES WITH THE POTENTIAL TO DISCHARGE POLLUTANTS TO THE ORANGE COUNTY STORM WATER SYSTEM

California Department of Transportation (Caltrans), District 12
Southern Pacific Railroad
Atchison, Topeka & Santa Fe Railway Company
Seal Beach Naval Weapons Station
Seal Beach Naval Reserve Center, Los Alamitos
National Forest Service

Universities and Colleges

University of California, Irvine
California State University, Fullerton
Chapman College
Coastline College
Cypress College
Fullerton College
Irvine Valley College
Golden West College
Orange Coast College
Rancho Santiago College

School Districts

Anaheim Elementary School District
Anaheim Union High School District
Brea-Olinda Unified School District
Buena Park Joint Union High School District
Centralia Elementary School District
Cypress Elementary School District
Fountain Valley Union High School District
Fullerton Joint Union High School District
Garden Grove Unified School District
Huntington Beach Elementary School District
Huntington Beach Union High School District
Irvine Unified Union High School District
La Habra Joint Union High School District
Los Alamitos Unified School District
Lowell Joint Union High School District
Magnolia Elementary School District
Newport-Mesa Unified School District

Ocean View Union High School District

Orange Unified School District
Placentia Unified School District
Santa Ana Unified School District
Savanna Union High School District
Tustin Unified School District
Westminster Union High School District
Yorba Linda Joint Union High School District

Hospitals

Anaheim General Hospital
Brea Community Hospital
Chapman General Hospital
Children's Hospital of Orange County, Orange
Coastal Communities Hospital, Santa Ana
Fairview Hospital
FHP Hospital, Fountain Valley
Fountain Valley Regional Hospital and Medical Center
Hoag Hospital, Newport Beach
Kaiser Foundation Hospital, Anaheim
Orange County Community Hospital, Buena Park
Pacifica Community Hospital, Huntington Beach
Placentia Linda Community Hospital
Santa Ana Hospital and Medical Center
St. Joseph's Hospital, Orange
U.C. Irvine Medical Center
Vencor Hospital of Orange County, Westminster
Whittier Hospital and Medical Center, Buena Park

Water/Wastewater Agencies

Santa Ana Watershed Project Authority
Irvine Ranch Water District
Los Aliso Water District
El Toro Water District
San Bernardino County Flood Control District
Riverside County Flood Control & Water Conservation District
L.A. County Department of Public Works
County Sanitation Districts of Orange County
Orange County Water District
Metropolitan Water District

State of California
California Regional Water Quality Control Board
Santa Ana Region

Monitoring and Reporting Program No. R8-2008-0030
NPDES No. CAS618030

for
the County of Orange, Orange County Flood Control District,
and
Incorporated Cities of Orange County Within the Santa Ana Region
Areawide Urban Storm Water Runoff

I. GENERAL

1. Revisions of the monitoring and reporting program are appropriate to ensure that the permittees are in compliance with requirements and provisions contained in this order. Revisions may be made under the direction of the Executive Officer at any time during the term, and may include a reduction or increase in the number of parameters to be monitored, the frequency of monitoring, or the number and size of samples collected.
2. The Executive Officer is authorized to allow the permittees to participate in statewide, national, or other monitoring programs in lieu of or in addition to this monitoring program.
3. All sample collection, handling, storage, and analysis shall be in accordance with 40 CFR Part 136 or other methods approved by the Executive Officer.
4. The permittees are authorized to complement their monitoring data with other monitoring sources, provided the monitoring conditions and sources are similar to those in the Santa Ana Watershed.
5. Any proposals for revisions to the 2003 Monitoring Plan shall be accompanied by a Quality Assurance Project Plan.

II. OBJECTIVES

The Orange County monitoring program was initiated in the mid 1970s with the goal of protecting key environmental resources. Successive iterations of the Orange County MS4 permit required the permittees to develop and implement comprehensive monitoring programs. During the first part of the third term permit, the permittees continued to implement the 1999 Water Quality Monitoring program. In August 2005, the Executive Officer approved the 2003 Monitoring Program that was developed in accordance with the requirements specified in the third term permit. The 2003 Monitoring Program was based on "The Model Monitoring Program for Municipal Separate Strom Sewer Systems in Southern California" developed by the Southern California Monitoring Coalition. The permittees also participate in the Regional Monitoring Program for San Diego Creek Nutrient TMDL, Southern California Bight Regional Monitoring Program, Southern California Stormwater Monitoring/Research Cooperative Program and other regional monitoring programs. The overall goal of these monitoring programs is to develop and

support an effective watershed and key environmental resources management program. The following are the major objectives:

1. To develop and support an effective municipal urban runoff pollutant source control program.
2. To define water quality status, trends, and pollutants of concern associated with urban runoff and their impact on the beneficial uses of the receiving waters.
3. To characterize pollutants associated with urban runoff and to assess the influence of urban land uses on water quality and the beneficial uses of receiving waters.
4. To identify significant water quality problems related to urban runoff.
5. To identify other sources of pollutants in urban runoff to the maximum extent possible (e.g., atmospheric deposition, contaminated sediments, other non-point sources, etc.)
6. To identify and prohibit illicit discharges.
7. To identify those waters, which without additional action to control pollution from urban storm water discharges, cannot reasonably be expected to attain or maintain applicable water quality standards required to sustain the beneficial uses in the Basin Plan (TMDL monitoring).
8. To determine unit loading rates from different urban land use categories.
9. To determine reference loads and concentrations from unimpacted areas of Orange County including sediment loads from open spaces at the foothills.
10. To determine runoff concentrations and loads as close as possible to the source (e.g., golf courses, restaurants, etc.)
11. To evaluate the effectiveness of existing urban runoff water quality management programs, including an estimate of pollutant reductions achieved by the structural and nonstructural BMPs implemented by the permittees. This should also include a determination of concentrations and unit loads that are achievable upon BMP implementation.
12. To evaluate costs and benefits of proposed municipal storm water quality control programs to the stakeholders, including the public.

The Regional Board recognizes that program modifications may be necessary to attain these objectives and authorizes the Executive Officer to evaluate and to determine adequate progress toward meeting each objective and the need for any modifications to the monitoring and reporting program.

III. MONITORING PROGRAM REQUIREMENTS

1. The permittees shall continue to implement the 2003 Monitoring Program. The permittees shall review the 2003 Monitoring Program on an annual basis and

determine the need for any modifications to the program. Each of the following elements of the program shall be evaluated:

a) Mass Emissions Monitoring. Currently the principal permittee monitors 11 mass emissions stations to estimate the total mass emissions from the MS4; assess trends in mass emissions over time; and to determine if the MS4 is contributing to exceedances of water quality objectives or beneficial uses, by comparing results to the California Toxics Rule (CTR), Basin Plan, Ocean Plan and/or other relevant standards. Samples are collected from the first storm event and two more storm events during the rainy season. A minimum of three dry-weather samples are also collected. Samples from the first rain event each year are analyzed for the entire suite of priority pollutants. All samples are analyzed for metals, pH, TSS, TOC, pesticides/herbicides, and constituents which are known to have contributed to impairment of local receiving waters. An additional 4 mass emissions stations are utilized only for nutrient analysis for TMDL requirements. Dry weather samples are also analyzed for oil and grease. Sediments associated with mass emissions are analyzed for constituents of concern.

b) Estuary/Wetlands Monitoring: Currently the permittees monitor 20 sites in Upper Newport estuary, Talbert Marsh, and Bolsa Chica wetlands areas to determine the effects of storm water and non-storm water runoff associated with increased urbanization on these systems. These monitoring locations include representative areas surrounding channel outfalls and areas away from channel outfalls to enable the determination of storm water and non-storm water effects on sediment chemistry, toxicity, benthic communities, nutrient status, and spatial extent of sediment fate within the estuarine environment.

c) Water Column Toxicity Monitoring: The current monitoring program analyses for toxicity to freshwater and marine species on mass emissions samples to determine the impacts of storm water and non-storm water runoff on toxicity of receiving waters.

d) Sediment : The permittees monitor sediment toxicity at seven stations in Newport Bay and seven stations along Huntington Harbour/Talbert Marsh areas.

e) Bacteriological/Pathogen Monitoring: The permittees currently monitor 9 representative areas along the Orange County coastline and six inland water bodies/channels, for total coliform, fecal coliform, and enterococcus in order to determine the impacts of storm water and non-storm water runoff on loss of beneficial uses to receiving waters.

f) Bioassessment: The permittees currently monitor 12 stations in cooperation with the Southern California Coastal Water Research Project (SCCWRP) in efforts to evaluate the biological index approach for Southern California and to

design a research project for developing an Index of Biological Integrity (IBI) for the region.

g) Reconnaissance: The permittees are currently conducting dry and wet weather reconnaissance surveys to identify and prohibit illicit discharges.

h) Land Use Correlations: The permittees continue to gather additional data for determining the effects of land use on the quality of receiving waters and the impact of development on sediment loading within receiving waters.

2. TMDL/303(d) Listed Waterbody Monitoring: The Permittees shall continue to participate in the Regional Monitoring Programs for the San Diego Creek Nutrient TMDL and the Toxics TMDL.

3. In addition, strategies must be revised/developed to evaluate the impacts of storm water or non-storm water runoff on all impairments within the Newport Bay watershed and other 303(d) listed waterbodies. Since the 303(d) listing is dynamic, with new waterbodies and new impairments being identified over time, the permittees shall revise their monitoring plan to incorporate new information as it becomes available.

IV. PROGRAM EFFECTIVENESS ASSESSMENT AND REPORTING

1. All progress reports and proposed strategies and plans required by this order shall be signed by the principal permittee, and copies shall be submitted to the Executive Officer of the Regional Board under penalty of perjury.

2. The permittees shall submit an ANNUAL PROGRESS REPORT to the Executive Officer of the Regional Board and to the Regional Administrator of the U.S. EPA, Region 9, no later than November 15th, of each year. This progress report may be submitted in a mutually agreeable electronic format. At a minimum, annual progress report shall include the following:

a) A review of the status of program implementation and compliance (or non-compliance) with the schedules contained in this order;

b) An assessment of the effectiveness of control measures established under the illicit discharge elimination program and the Drainage Area Management Plan. The effectiveness may be measured in terms of how successful the program has been in eliminating illicit/illegal discharges and reducing pollutant loads in storm water discharges;

c) As assessment of control measures and their effectiveness in addressing pollutants causing or contributing to an exceedance of water quality objectives in receiving waters that are on the 303(d) list of impaired waters.

d) The annual report shall include an overall program assessment . The permittees may use the "Municipal Stormwater Program Effectiveness Assessment Guidance" developed by the California Stormwater Quality Association in May 2007 as guidance for assessing program activities at the various outcome levels. The assessment should include each program element required under this order, the expected outcome and the measures used to assess the outcome. The permittees may propose any other methodology for program assessment using measurable targeted outcomes.

e) Each permittee shall develop and implement a plan and schedule to address program modifications and improvements identified during the program assessment.

f) A summary and analysis of monitoring results from the previous year and any changes to the monitoring program for the following year;

g) A unified fiscal accountability analysis, as described in Section XX., Provision, 2, of this order;

h) A draft workplan which describes the proposed implementation of the DAMP for next fiscal year. The workplan shall include clearly defined tasks, responsibilities, and schedules for implementation of the storm water program and each permittee actions for the next fiscal year;

i) Major changes in any previously submitted plans/policies; and

j) An assessment of the permittees compliance status with the Receiving Water Limitations, Section IV of the Order, including any proposed modifications to the DAMP if the Receiving Water Limitations are not fully achieved.

3. The permittees shall be responsible for the submittal to the principal permittee of all required information/materials needed to comply with this order in a timely manner. All such submittals shall be signed by a duly authorized representative of the permittee under penalty of perjury.

4. The data transmittals to the Regional Board shall be in the form developed by the Stormwater Monitoring Coalition (SMC) and approved by the State Water Resources Control Board in the document entitled "Standardized Data Exchange Formats." This document was developed in order to provide a standard format for all data transfer so that data can universally be shared and evaluated from various programs.

V. REPORTING SCHEDULE

All reports required by this order shall be submitted to the Executive Officer of the Regional Board in accordance with the following schedule:

ITEM	COMPLETION DATE	REPORT DUE DATE
Review planning procedures and CEQA document preparation processes	Annually	Annual Report
Public Education Committee Meetings	Twice/year	Annual Report
Review DAMP	Annually	Annual Report
Review/revise public education materials including the web site	Annually	Annual Report
Update inventory of construction sites and prioritize for inspections	Quarterly	Annual Report
Inspect municipal facilities	Annually	Annual Report
Maintain drainage facilities	80% annually/100% in every two years	Annual Report
Review/revise Implementation Agreement	Annually	Annual Report
Review/revise Illegal Discharge/Illicit Connection Training Program	Annually	Annual Report
Evaluate the need for additional debris control measures	Annually	Annual Report
Complete Public Awareness Survey	Annually	Annual Report
Review Monitoring Program	Annually	Annual Report
Update industrial site database, including prioritization for inspection	Quarterly	Annual Report
Update the commercial site database, including prioritization for inspection	Quarterly	Annual Report
Develop a mobile business enforcement strategy	Within 12 months of adoption	Annual Report
Residential Program Evaluation	Annually	Annual Report

Develop a guidance document for preparing conceptual WQMP	Within six months of adoption	Annual Report
Review planning documents to ensure water quality protection	Annually	Annual Report
Report of Waste Discharge	180 days before permit expires	Six months prior to expiration
Annual Report/Fiscal Analysis	November 15th of each year	Nov 15
Provide training to public agency staff and to contract field operations staff	Annually	Nov 15
Re-evaluate monitoring program priorities based on previous year's data	Annually	Nov 15
Evaluate the DAMP	Annually	Nov 15
Permittee Committee meetings to discuss permit implementation and regional and state-wide issues	Held at least 6 times each year	Nov 15

Ordered by_____
Gerard J. Thibeault
Executive Officer

PRONTOWASH

Michael,

Attached are my comments to the Region 8 NPDES Permit. I have shared this with over 20 of the current CoPermittees and none of them responded with any concern. Several have validated the comments are reasonable and even necessary.

Below is a summary of the attached comments:

1. Shift the focus from water containment to contamination capture

1. It is the contaminants that are the issue
2. By having the standard be that no water can leave the property, you leave contaminants that will be picked up and taken into the MS4 in the next rain

2. Set standards at Best Available Technology

1. Best Available Technology is reasonable and is being utilized

3. Require Mobile Car Wash and Detail operators to obtain Inspection and Education in Business License Process

1. Inspection to verify compliance of process
2. Opportunity to educate Industry

When is the Region 8 meeting to receive public comments and review the Permit? I request notification of the meeting.

I look forward to working with you and the Board to reasonably utilize Best Available Technology to achieve these evolving standards.

Jim Fitzpatrick
ProntoWash

949.257.8448

California Regional Water Quality Control Board
Santa Ana Region

Linda S. Adams
Secretary for Environmental Protection

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Arnold Schwarzenegger
Governor

A G E N D A A N N O U N C E M E N T

REGIONAL BOARD MEETING
Friday, November 21, 2008
9:30 A.M.
City of Loma Linda
25541 Barton Road
Loma Linda, CA

NOTICE

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Supporting documents for agenda items are now posted on our website at least 7 days prior to the scheduled meeting. To view or download the documentation, go to www.waterboards.ca.gov/santaana/ and select the "Public Notices" page.

1. **Introductions**

2. **Public Forum —** Any person may address the Board at the commencement of the meeting on any matter within the Regional Board's jurisdiction and not related to an item that is to be considered separately. The Regional Board Chair requests that each person addressing the Regional Board observe a three–minute time limit.

3. **State Water Resources Control Board Liaison Report** – This item is for discussion only. No public testimony will be allowed, and the Regional Board will take no formal action.

4. **Approval of the Minutes of the Regular Board Meeting of September 5, 2008.**
{Felipa Carrillo 951/782-3285 fcarrillo@waterboards.ca.gov}

5. **Consideration of Consent Calendar Items.** Items marked with an asterisk (*) are expected to be routine and non-controversial. The Regional Board will be asked to approve these items at one time without discussion. If any interested party, Board Member or staff requests that an item be removed from the consent calendar, it will be taken up in the order shown.

*6. **Appeal of Staff's Denial of an Exemption from the 30 Percent Maximum Slope Requirement for the Subsurface Disposal Systems** - Cary and Lisa Anderson, 11990 Dawson Canyon Road, Corona, Riverside County - APN 283-130-027.
(Jun Martirez 951/782-3258 jmartirez@waterboards.ca.gov)

*7. **Rescissions** - Orders for the following facilities are proposed to be rescinded because the facility discharge has ceased, the facility discharges are regulated under a general permit, or because the project is completed and WDRs are no longer required.
{Jun Martirez 951/782-3258 jmartirez@waterboards.ca.gov} Order No. R8-2008-0097

Order No.	Facility and Location	Reason for Rescission
R8-2003-0056	Serrano Water District, Howiler Filtration Plant, Villa Park	Facility discharges are now regulated under a general permit, Order No. R8-2003-0061
R8-2006-0017	U.S. Navy, MCAS Tustin	Facility discharges are now sewered
R8-2002-0079	National Guard Bureau, Joint Forces Training Base, Los Alamitos	Facility discharges have ceased
R8-2005-0087	Pinnacle Communities, Quincy Channel Hydromodification, Moreno Valley	Project has been completed and WDR no longer required
R8-2004-0046	Canyon Lake POA, Sediment Dewatering Project, Canyon Lake	The project has been completed

*8. **Amendment of Waste Discharge Requirements for the City of Redlands, California Street Landfill** - Amending the existing Waste Discharge Requirements for California Street Landfill to allow the discharge of treated wood waste, and other designated waste as approved by the Executive Officer.
{Dixie B. Lass 951/782-3295 dlass@waterboards.ca.gov} Order No. R8-2008-0094

9. **Administrative Civil Liability Complaint, Carson Hall, Jr., Riverside County** - The Board will consider the adoption of an order regarding the administrative civil liability assessment proposed in Administrative Civil Liability Complaint No. R8-2008-0082. (Rescheduled from July 18, 2008 meeting)
{Stephen D. Mayville 951/782-4992 smayville@waterboards.ca.gov} Order No. R8-2008-0074

10. **Workshop on Clean Water Act Section 305(b) Integrated Report/Clean Water Act Section 303(d) List of Impaired Waterbodies** – Regional Board staff will present the proposed Integrated Report including proposed revisions to the 303(d) list of impaired waterbodies. The Board will consider adoption of the proposed Integrated Report and proposed 303(d) list, revised as appropriate in response to comments, at a subsequent public hearing (information item; no action will be taken).
{Hope A. Smythe 951/782-4493 hsmythe@waterboards.ca.gov}

11. **Public Workshop, Renewal of Waste Discharge Requirements, Orange County Resources and Development Management Department, the County of Orange and Incorporated Cities of Orange County, Areawide Urban Storm Water Runoff Management Program (NPDES No. CA8618030) -** This public workshop is to review and solicit comments on the proposed draft permit. No action on the draft permit will be taken at this time. This item, revised as appropriate in response to comments, will be considered for adoption at a future Board meeting (information item).
{Mark E. Smythe 951/782-4998 msmythe@waterboards.ca.gov} Order No. R8-2008-0030

12. **Regional Board Member and Executive Officer Communications** - Board Members and the Executive Officer may discuss meetings, communications, correspondence, or other items of general interest relating to matters within the Regional Board's jurisdiction. There will be no voting or formal action taken.

13. **Appointment of a Committee to Nominate Regional Board Officers for 2009-** The Board will appoint a nominating committee consisting of 2 or 3 Board members to provide recommendations for Regional Board officers for 2009 (action item).
{Gerard J. Thibeault 951/782-3284 gthibeault@waterboards.ca.gov}

14. **Proposed Board Meeting Dates for 2009** - The Board will consider adoption of a calendar of meeting dates and locations for 2009 (action item).
{Gerard J. Thibeault 951/782-3284 gthibeault@waterboards.ca.gov}

15. **List of New Enrollees under the General Permits** - Staff will provide a list of all new permitees recently enrolled under the Region's general permits (information item).
{Jun Martirez 951/782-3258 jmartirez@waterboards.ca.gov}

16. **Hazardous Waste Incident Report** - Board staff will provide a list of hazardous waste incidents within the Region to the Board (information item).
{Kenneth R. Williams 951/782-4496 kwilliams@waterboards.ca.gov}

17. **Underground Storage Tanks Corrective Action Plans** - Board staff will provide a list of sites where Corrective Action plans have been submitted for sites within the Region as required by the California Underground Storage Tank Regulations, Title 23, Article 11, Section 2728 (information item).
{Kenneth R. Williams 951/782-4496 kwilliams@waterboards.ca.gov}

18. **Underground Storage Tanks Site Closure Report** - Board staff will provide a list of site closures that have occurred within the Region as required by the California Underground Storage Tank Regulations, Title 23, Article 11, Section 2728(d) (Information item).
{Kenneth R. Williams 951/782-4496 kwilliams@waterboards.ca.gov}

Closed Session - At any time during the regular session, the Regional Board may adjourn to a closed session to:

a. consider evidence received in an adjudicatory hearing and deliberate on a decision to be reached based on that evidence (Gov. Code Section 11126(c)(3));
b. consider the appointment, employment, evaluation of performance, or dismissal of a public employee or to hear complaints or charges brought against a public employee (Gov. Code Section 11126(a)(1));
c. discuss significant exposure to litigation (Gov. Code Section 11126(e)(2)(B)(i));
d. discuss whether to initiate litigation (Gov. Code Section 11126(e)(2)(C)(i)); and
e. discuss pending litigation in the following matters (Gov. Code, § 11126, subd.(e)):
   (1) Stringfellow Hazardous Waste Site;
   (2) US EPA, Santa Ana Region v. Orange County Sanitation District (U.S. Dist. Ct., CD Cal.);
   (3) Goodrich Corporation v. California State Water Resources Control Board et al. (Los Angeles Sup. Ct. Case No. BS 110389, [consolidated with BS 110390 and BS 110391].);
   (4) In re Petitions of Kwikset Locks, Inc. (SWRCB/OCC File Nos. A-1732, 1732(a), 1732(b), 1732(c), and 1732(d));
   (5) In re Petition of Natural Resources Defense Council, Inc. (SWRCB/OCC File No. A-1883); and

   In re Own Motion Review of Rialto-Area Perchlorate Contamination (SWRCB/OCC File No. A-1824).

Adjournment to the regular meeting of [pending] 2009, at 9:00 a.m., [location TBD]

NOTICES

Any person who has a disability and requires reasonable accommodation to participate in this Regional Board Meeting should contact Felipa Carrillo at fcarrillo@waterboards.ca.gov, or at 951/782-3285, no later than ten (10) days prior to the meeting.

Any person interested in obtaining information and/or providing input regarding pending applications for Water Quality Standards Certification under Section 401 of the Federal Clean Water Act may do so by contacting Mark G. Adelson at 951/782-3234.

California Regional Water Quality Control Board
Santa Ana Region

Linda S. Adams
Secretary for Environmental Protection

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Arnold Schwarzenegger
Governor

ADDENDUM TO AGENDA ANNOUNCEMENT

REGIONAL BOARD MEETING
Friday, November 21, 2008
(Prepared 11-19-08)

NOTICE

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Supporting documents for agenda items are now posted on our website at least 7 days prior to the scheduled meeting. To view or download the documentation, go to www.waterboards.ca.gov/santaana/ and select the item of interest.

The following item has been added to the agenda.

8b. **Emergency Resolution Regarding the Use of Class I Biosolid and Green Waste Compost for Erosion Control Applications Within the Areas Burned During the November 2008 Fires in Orange, Riverside and San Bernardino Counties Within the Santa Ana Region –** In response to Governor Schwarzenegger's recent Declarations of Emergency for the Orange, Riverside, and San Bernardino Counties for the Freeway Complex Fires in these areas, the Regional Board will consider a resolution clarifying the use of Class I Biosolid and Green Waste Compost within areas damaged by the fires. {Gerard J. Thibeault 951/782-3284 gthibeault@waterboards.ca.gov}

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Santa Ana Region

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ADDENDUM TO AGENDA ANNOUNCEMENT

REGIONAL BOARD MEETING
Friday, November 21, 2008

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The following item has been added to the agenda.

8a. **Maximum Benefit Update** – The Chino Basin Watermaster and Inland Empire Utilities District will report back to the Board concerning the status of these agencies meeting the Maximum Benefit commitments for the Chino Groundwater Management Zones. Information Item.
{Gerard J. Thibeault 951/782-3284 jthibeault@waterboards.ca.gov}

California Regional Water Quality Control Board
Santa Ana Region
3737 Main Street, Suite 500
Riverside, CA 92501-3348

FACT SHEET

November 21, 2008

ITEM: **11**

SUBJECT: **Waste Discharge Requirements for the County of Orange, Orange County Resources and Development Management Department, and the Incorporated Cities of Orange County within the Santa Ana Region, Urban Storm Water Runoff Management Program, Orange County, Order No. R8-2008-0030 (NPDES No. CAS 618030)**

I. INTRODUCTION

The 1972 Clean Water Act (CWA) established the National Pollutant Discharge Elimination System (NPDES) permit program to regulate the discharge of pollutants from point sources to waters of the United States (U.S.). Since then, considerable strides have been made in reducing conventional forms of pollution, such as from sewage treatment plants and industrial facilities, through the implementation of the NPDES program and other federal, state and local programs. The adverse effects of some of the persistent toxic pollutants (e.g., DDT, PCB and TBT) were addressed through manufacturing and use restrictions and through cleanup of contaminated sites. On the other hand, pollution from land runoff (including atmospheric deposition, urban, suburban and agricultural) was largely unabated until the 1987 CWA amendments. As a result, diffuse sources, including urban storm water runoff, now contribute a larger portion of many kinds of pollutants than the more thoroughly regulated sewage treatment plants and industrial facilities. The National Urban Runoff Program (NURP) final report to the Congress (U.S. EPA, 1983) concluded that the goals of the CWA could not be achieved without addressing urban runoff discharges. The 1987 CWA amendments established a framework for regulating urban storm water runoff. Pursuant to these amendments, the Santa Ana Regional Water Quality Control Board (Regional Board) began regulating municipal storm water runoff in 1990.

The attached pages contain information concerning an application for renewal of Waste Discharge Requirements and a NPDES permit, which prescribe waste discharge requirements for urban storm water runoff from the cities and unincorporated areas in Orange County within the jurisdiction of the Santa Ana Regional Board. On July 21, 2006, the County of Orange and the Orange County Flood Control District (OCFCD), in cooperation with the cities of Anaheim, Brea, Buena Park, Costa Mesa, Cypress, Fountain Valley, Fullerton, Garden Grove, Huntington Beach, Irvine, Laguna Hills, Laguna Woods, La Habra, La Palma, Lake Forest, Los Alamitos, Newport Beach, Orange, Placentia, Santa Ana, Seal Beach, Stanton, Tustin, Villa Park, Westminster, and Yorba Linda (hereinafter collectively referred to as permittees or dischargers), submitted NPDES Application No. CAS 618030 (Report of Waste Discharge) for reissuance of their areawide storm water NPDES permit. The permit application was submitted in accordance with the requirements of the previous NPDES permit (Order No. R8-2002-0010, NPDES No. CAS618030), which expired on January 19, 2007. Additionally, the permit application follows guidance provided by staff of the State Water Resources Control Board (State

Board), the Regional Water Quality Control Boards (Regional Boards), and the United States Environmental Protection Agency (U.S. EPA).

On February 20, 2007, Order No. R8-2002-0010, NPDES No. CAS618030, was administratively extended in accordance with 40 CFR Part 122.6 and Title 23, Division 3, Chapter 9, §2235.4 of the California Code of Regulations.

Order No. R8-2008-0030 regulates discharges of urban storm water from the lower Santa Ana watershed to waters of the U.S., which ultimately drain into the Pacific Ocean.

II. REGULATORY BACKGROUND/CLEAN WATER ACT REQUIREMENTS

Urban runoff includes dry weather flows and storm water runoff from urbanized areas through a storm water conveyance system. As water flows over streets, parking lots, construction sites, and industrial, commercial, residential and municipal areas, it can intercept pollutants from these areas and transport them to waters of the U.S. If appropriate pollution control measures are not implemented, urban runoff may contain pathogens (bacteria, protozoa, viruses), sediment, trash, fertilizers (nutrients, mostly nitrogen and phosphorus compounds), oxygen-demanding substances (decaying matter), pesticides (DDT, Chlordane, Diazinon, Chlorpyrifos), heavy metals (cadmium, chromium, copper, lead, zinc) and petroleum products (oil & grease, PAHs, petroleum hydrocarbons). If not properly managed and controlled, urbanization can change the stream hydrology and increase pollutant loading to receiving waters. As a watershed undergoes urbanization, pervious surface area decreases, runoff volume and velocity increase, riparian and wetland habitat decrease, the frequency and severity of flooding increase and pollutant loading increases. Most of these impacts are due to human activities that occur during and/or after urbanization. The pollutants and hydrologic changes can cause declines in aquatic resources, toxicity to marine organisms, and impact human health and the environment.

However, properly planned high-density development, with sufficient open space and low impact developments, can reduce urban sprawl and problems associated with sprawl. Urban in-fill development can be an element of smart growth, creating the opportunity to maintain relatively natural open space elsewhere in the area. The goal of low impact development is to mimic post-construction runoff quality and quantity to pre-construction runoff quality and quantity.

The U.S. EPA recognizes urban runoff as the number one source of estuarine pollution in coastal communities[1]. Studies[2] conducted in the Southern California area and other studies have reported a definite link between storm water runoff from urban areas and pollution in nearshore zones. A number of Orange County beaches were closed during 1999 and 2000 due to microbial contamination. One of the studies conducted to

[1] US EPA, 1999, 40CFR Parts 9, 122, 123, 124, National Pollutant Discharge Elimination System – Regulations for Revision of the Water Pollution Control Program Addressing Storm Water Discharges; Final Rule, 64FR 68727.

[2] Bay, S., Jones, B. H. and Schiff, K, 1999, Study of the Impact of Stormwater Discharge on Santa Monica Bay. Sea Grant Program, University of Southern California; and Haile, R.W., et. al., 1996, An Epidemiological Study of Possible Adverse Health Effects of Swimming in Santa Monica Bay.

determine the source of this microbial contamination indicated that urban runoff may be one of the sources of this contamination. If not properly controlled, urban runoff could be a significant source of pollutants in waters of the U.S. Table 1 includes a list of pollutants, their sources, and some of the adverse environmental consequences mostly resulting from urbanization.

Table 1. Pollutants/Impacts of Urbanization on Waters of the US (Marine Pollution) [3]

Pollutants	Sources	Effects and Trends
Toxins (e.g., biocides, PCBs, trace metals, heavy metals)	Industrial and municipal wastewaters; runoff from farms, forests, urban areas, and landfills; erosion of contaminated soils and sediments; vessels; atmospheric deposition	Poison and cause disease and reproductive failure; fat-soluble toxins may bioaccumulate, particularly in birds and mammals, and pose human health risks. Inputs into US waters have declined, but remaining inputs and contaminated sediments in urban and industrial areas pose threats to living resources.
Pesticides (e.g., DDT, diazinon, chlorpyrifos)	Urban runoff, agricultural runoff, commercial, industrial, residential, and farm use	Legacy pesticides (DDT, Chlordane, Dieldrin, etc.) use has been banned; still persists in the environment; some of the other pesticide uses are curtailed or restricted.
Biostimulants (organic wastes, plant nutrients)	Sewage and industrial wastes; runoff from farms and urban areas; nitrogen from combustion of fossil fuels	Organic wastes overload bottom habitats and deplete oxygen; nutrient inputs stimulate algal blooms (some harmful), which reduce water clarity, cause loss of seagrass and coral reef, and alter food chains supporting fisheries. While organic waste loadings have decreased, nutrient loadings have increased.
Petroleum products (oil, grease, petroleum hydrocarbons, PAHs)	Urban runoff and atmospheric deposition from land activities; shipping and tanker operations; accidental spills; coastal and offshore oil and gas production activities; natural seepage; PAHs from internal combustion engines	Petroleum hydrocarbons can affect bottom organisms and larvae; spills affect birds, mammals and nearshore marine life. While oil pollution from ships, accidental spills, and production activities has decreased, diffuse inputs from land-based activities have not.
Radioactive isotopes	Atmospheric fallout, industrial and military activities	Few known effects on marine life; bioaccumulation may pose human health risks where contamination is heavy.

[3] Adapted from "Marine Pollution in the United States" prepared for the Pew Oceans Commission, 2001.

Sediment	Erosion from farming, construction activities, forestry, mining, development; river diversions; coastal dredging and mining	Reduce water clarity and change bottom habitats; carry toxins and nutrients; clog fish gills and interfere with respiration in aquatic fauna. Sediment delivery by many rivers has decreased, but sedimentation poses problems in some areas; erosion from coastal development and sea-level rise is a future concern.
Plastics and other debris	Ships, fishing nets, containers, trash, urban runoff	Entangles marine life or is ingested; degrades beaches, wetlands and nearshore habitats. Floatables (from trash) are an aesthetic nuisance and can be a substrate for algae and insect vectors.
Thermal	Cooling water from power plants and industry, urban runoff from impervious	Kills some temperature-sensitive species; displaces others. Generally, less a risk to marine life than thought 20 years ago.
Noise	Vessel propulsion, sonar, seismic prospecting, low-frequency sound used in defense and research	May disturb marine mammals and other organisms that use sound for communication.
Pathogens (bacteria, protozoa, viruses)	Sewage, urban runoff, livestock, wildlife, discharges from boats and cruise ships	Pose health risks to swimmers and consumers of seafood. Sanitation has improved, but standards have been raised.
Alien species	Ships and ballast water, fishery stocking, aquarists	Displace native species, introduce new diseases; growing worldwide problem.

The Clean Water Act (CWA) prohibits the discharge of any pollutant to navigable waters from a point source unless an NPDES permit authorizes the discharge. Efforts to improve water quality under the NPDES program traditionally and primarily focused on reducing pollutants in discharges of industrial process wastewater and municipal sewage. The 1987 amendments to the CWA required municipal separate storm sewer systems (MS4s) and industrial facilities, including construction sites, to obtain NPDES permits for storm water runoff from their facilities. On November 16, 1990, the United States Environmental Protection Agency (EPA) promulgated the final Phase I storm water regulations. The storm water regulations are contained in 40 CFR Parts 122, 123 and 124.

The areawide NPDES permit for Orange County areas within the Santa Ana Regional Board's jurisdiction is being considered for renewal in accordance with Section 402 (p) of the CWA and all requirements applicable to an NPDES permit issued under the issuing authority's discretionary authority. The requirements included in this order are consistent with the CWA, the federal regulations governing urban storm water discharges, the Water Quality Control Plan for the Santa Ana River Basin (Basin Plan), the California Water Code, and the State Board's Plans and Policies, including the Ocean Plan.

The Basin Plan is the basis for the Regional Board's regulatory programs. The Plan was developed and is periodically reviewed and updated in accordance with relevant federal and state law and regulations, including the Clean Water Act and the California Water Code. As required, the Basin Plan designates the beneficial uses of the waters of the region and specifies water quality objectives intended to protect those uses. (Beneficial uses and water quality objectives, together with an antidegradation policy, comprise federal "water quality standards"). The Basin Plan also specifies an implementation plan, which includes certain discharge prohibitions. In general, the Basin Plan makes no distinctions between wet and dry weather conditions in designating beneficial uses and setting water quality objectives, i.e., the beneficial uses, and correspondingly, the water quality objectives are assumed to apply year-round. (Note: In some cases, beneficial uses for certain surface waters are designated as "I", or intermittent, in recognition of the fact that surface flows (and beneficial uses) may be present only during wet weather.) Most beneficial uses and water quality objectives were established in the 1971, 1975 and 1983 Basin Plans.

Water Code Section 13241 requires that certain factors be considered, at a minimum, when water quality objectives are established. These include economics and the need for developing housing in the Region. (The latter factor was added to the Water Code in 1987).

During the third term permit (R8-2002-0010) development process, the permittees raised an issue regarding compliance with Section 13241 of the California Water Code with respect to water quality objectives for wet weather conditions, specifically the cost of achieving compliance during wet weather conditions and the need for developing housing within the Region and its impact on urban storm water runoff. In response to this request, Regional Board staff in collaboration with the permittees in the region has organized a Storm Water Quality Standards Task Force (SWQSTF). The SWQSTF is closely monitoring actual and potential beneficial uses of surface waters within the region. Based on the findings, it is likely that the SWQSTF would recommend changes to the current beneficial use designations and water quality objectives specified in the Basin Plan. This order may be reopened to incorporate any changes to the water quality standards. In the meantime, the provisions of this order will result in reasonable further progress towards the attainment of the existing water quality objectives, in accordance with the discretion in the permitting authority recognized by the United States Court of Appeals for the Ninth Circuit in Defenders of Wildlife v Browner, 191 F.3d 1159, 1164 (9th Cir. 1999).

III. BENEFICIAL USES

Storm water flows that are discharged to municipal storm drain systems in Orange County are tributary to various water bodies (inland surface streams, bays and tidal prisms, ocean waters, and lakes and reservoirs) of the state. The beneficial uses of these water bodies include municipal and domestic supply, agricultural supply, industrial service and process supply, groundwater recharge, navigation, hydropower generation, water contact recreation, non-contact water recreation, commercial and sportfishing, warm freshwater habitat, cold freshwater habitat, preservation of biological habitats of special significance, wildlife habitat, preservation of rare, threatened or endangered

species, marine habitat, shellfish harvesting, spawning, reproduction and development of aquatic habitats and estuarine habitat. The ultimate goal of this storm water management program is to protect the water quality standards of the receiving waters.

IV. PERMITTED AREA

The permitted area is delineated by the Los Angeles County-Orange County boundary line on the northwest, the San Bernardino-Orange County boundary line on the north and northeast, the Riverside County-Orange County boundary line on the east, the Santa Ana Regional Board-San Diego Regional Board boundary line on the southeast, and the Pacific Ocean on the southwest (see Attachment A of the order). The permittees serve a population of approximately 3.006[4] million, occupying an area of approximately 789 square miles (including unincorporated areas and the limits of 34 cities, 26 of which are within the Santa Ana Regional Board's jurisdiction). The permittees have jurisdiction over, and/or maintenance responsibility for, storm water conveyance systems within Orange County. The County's systems include an estimated 400 miles of storm drain systems. A major portion of the urbanized areas of Orange County drains into water bodies within this Regional Board's jurisdiction. Storm water discharges from urbanized areas consist mainly of surface runoff from residential, commercial, and industrial developments. In addition, there are storm water discharges from agricultural land uses, including farming and animal operations. However, the CWA specifically excludes agricultural discharges from regulation under this program. Other areas of the County not addressed or which are excluded by the storm water regulations and areas not under the jurisdiction of the permittees are excluded from the area requested for coverage under this permit. These excluded areas and activities include:

- Federal lands and state properties, including, but not limited to, military bases, national forests, hospitals, schools, colleges, universities, and highways;
- Native American tribal lands; and
- Utilities and special district properties.

Discharges from the permitted area drain into the Pacific Ocean. The watersheds regulated under this order generally referred to as the San Diego Creek/Newport Bay watershed and the Lower Santa Ana River Basin.

V. WATERSHED MANAGEMENT/LOWER SANTA ANA RIVER BASIN

To manage the water resources of the region efficiently, it is critical to have a holistic approach. The entire storm drain system in Orange County is not controlled by a single entity; the County of Orange, the OCFCD, several cities, Caltrans, U.S. Army Corps of Engineers and a number of other entities own, operate and/or manage the storm drain systems. In addition to the cities, the County and the OCFCD, there are a number of other significant contributors of storm water runoff to these storm drain systems. These include: large institutions such as the State University facilities, schools, hospitals, etc.; federal facilities such as Department of Defense facilities; State agencies such as Caltrans; water

[4] SCAG County Population Forecasts for 2005 (this is for the entire County) (http://www.eltoroairport.org/issues/population.html)

and wastewater management agencies such as Orange County Water District, Metropolitan Water District etc.; the National Forest Service; state parks; and entertainment centers such as Disneyland. The quality and quantity of storm water runoff into and out of Orange County also depends upon runoff from San Bernardino and Riverside County areas that are tributary to Orange County. Some of the runoff from Orange County enters the San Gabriel River or systems controlled by other entities, such as the Los Angeles County Flood Control District, which are under the Los Angeles Regional Board's jurisdiction.

Some of these facilities, such as California Department of Transportation facilities and Disneyland, are already under individual permits for storm water runoff. The Los Angeles and San Diego Regional Boards have also issued areawide storm water permits for areas within their jurisdiction.

Cooperation and coordination among all the stakeholders are essential for efficient and economical management of the watershed. It is also critical to manage nonpoint sources at a level consistent with the management of urban storm water runoff in a watershed in order to prevent or remedy water quality impairment. Regional Board staff will facilitate coordination of monitoring and management programs among the various stakeholders, where necessary.

An integrated watershed management approach is consistent with the Strategic Plan (2008-2012[5]) for the State and Regional Boards. A watershed wide approach is also necessary for implementation of the load and waste load allocations developed under the TMDL process (see Section B, below). The MS4 permittees and all the affected entities should be encouraged to participate in regional or watershed solutions instead of project-specific and fragmented solutions.

The pollutants in urban runoff originate from a multitude of sources and effective control of these pollutants requires a cooperative effort of all the stakeholders and many regulatory agencies. Every stage of urbanization should be considered in developing appropriate urban runoff pollution control methodologies. The program's success depends upon consideration of pollution control techniques during planning, construction and post-construction operations. At each stage, appropriate pollution prevention measures, proper site design considerations, source control measures and, if necessary, treatment techniques should be considered.

1. SUB-WATERSHEDS AND MAJOR CHALLENGES

   The Lower Santa Ana River Watershed can be subdivided into five tributary watersheds:

   a. *The San Gabriel River Drainage Area:* Carbon Canyon Creek and Coyote Creek drain into the San Gabriel River. Only a portion of the San Gabriel River is within the Santa Ana Regional Board's jurisdiction. The River empties into the Pacific Ocean at the boundary between two Regional Boards (Regions 4 and 8). Region 4 regulates most of the discharges to the San Gabriel River.

[5] State Water Resources Control Board, Strategic Plan Update, 2008-2012, September 2, 2008

The Los Angeles Regional Board (Region 4) listed the San Gabriel River as an impaired waterbody on the CWA Section 303(d) list of impaired waters. It is listed for ammonia, toxicity, algae, eutrophication, pH, odors, low dissolved oxygen, trash, lead, arsenic, copper, silver, mercury (tissue), coliform, DDT, PCBs, chlordane, and abnormal fish histology. A trash TMDL for the East Fork of the River was adopted by the Regional Board (Region 4) and approved by the US EPA. On July 13, 2006, the Los Angeles Regional Board adopted TMDLs for metals in the San Gabriel River watershed. However, because of the state's inability to meet the March 2007 deadline for an approved TMDL prescribed in a consent decree (Heal the Bay Inc., et al. v. Browner C98-4825 SBA), on March 26, 2007, the EPA promulgated TMDLs for metals and selenium for the San Gabriel River. The upper portions of Coyote Creek flow through Orange County to join the San Gabriel River above the tidal prism. Other unnamed tributaries located in northwestern Orange County also discharge into the San Gabriel River estuary. The EPA promulgated TMDLs include wet weather wasteload allocations for Coyote Creek for copper, lead and zinc and dry weather wasteload allocations for copper for Coyote Creek. The permittees are expected to implement programs and policies consistent with the metals and selenium TMDLs for the San Gabriel River watershed. This includes constituent-specific source control programs or other equally effective programs to control the discharge of copper, lead and zinc into Coyote Creek and other tributaries in Orange County that discharge into the San Gabriel River.

b. *The Huntington Harbour and Bolsa Bay Drainage Area:* This includes Anaheim Bay, Huntington Harbour, Bolsa Bay, and Bolsa Chica Ecological Reserve. A number of flood control channels discharge into this area, including Anaheim-Barber, East Garden Grove-Wintersberg, and Bolsa Chica Channel. The area historically had a number of oil production facilities and an oil-well drilling mud disposal area. There are still some production wells in the area. Certain areas of the Bolsa Chica wetlands have been impacted by the oil production and related activities in the area. The drilling mud disposal area has been cleaned up, and through a collaborative effort of a number of state, federal, and local agencies and other entities the Bolsa Chica wetlands have been restored.

   Anaheim Bay and Huntington Harbour are listed as impaired waterbodies (see Table 2), and TMDLs will be developed to address the pollutants causing the impairment.

c. *The Santa Ana River Drainage Area:* This includes Santa Ana River Reaches 1 and 2, Santiago Creek Reaches 1, 2, 3 and 4, Silverado Creek, Black Star Creek, Talbert Channel, Talbert Marsh and Greenville-Banning Channel. The major problem for the area is microbial contamination of the coastal zone. The initial studies conducted by the Orange County Sanitation District determined that their facilities were probably not the cause of the microbial problems in the nearshore zone. Subsequently, the Executive Officer issued a directive to the County of Orange and the cities of Santa Ana, Costa Mesa, Fountain Valley and Huntington Beach (urban storm water dischargers to this tributary area) under Section 13267 of the Water Code. This directive required the dischargers to provide a plan to identify, characterize and control sources that contributed to the microbial problems in the Huntington Beach area. Several studies were conducted to trace the source(s) of the microbial contamination. These studies could not conclusively determine the sources of microbial contamination in the Huntington Beach area.

However, urban runoff was identified as one of the sources. The permittees have diverted most of the dry-weather flows to the sanitary sewer system and significant improvements have been noted in the beach water quality.

d. *The Newport Bay Drainage Area:* Tributaries include Bonita Creek, Serrano Creek, Peters Canyon Wash, Hicks Canyon Wash, Bee Canyon Wash, Borrego Canyon Wash, Agua Chinon Wash, Laguna Canyon Wash, Rattlesnake Canyon Wash, Sand Canyon Wash, San Diego Creek Reaches 1 and 2, and San Joaquin Freshwater Marsh.

The Newport Bay watershed has a number of impaired waterbodies listed under Section 303(d) of the CWA (see Section 2, below for details). The impairments are mostly due to nutrients, sediment, pesticides, pathogens and metals. To date, TMDLs have been developed for nutrients, sediment, and fecal coliform bacteria and certain pesticides (diazinon and chlorpyrifos). These TMDLs are being implemented. The current and future (year 2012) targets for the nutrient TMDLs are already being met. However, Board staff is currently reevaluating the nutrient TMDLs in light of evidence that there remains impairment of these waters due to eutrophication. In addition, toxics TMDLs were promulgated by USEPA on June 14, 2002, including TMDLs for metals and selenium, and a TMDL specific to the Rhine Channel located in Lower Newport Bay. The Regional Board is in the process of developing TMDL implementation plans for these TMDLs.

The Irvine Ranch Water District (IRWD), which provides sewage collection and treatment services for most areas in the Newport Bay Drainage area, has been also accepting dry weather flows from some of the storm sewer systems. The IRWD constructed a number of water quality treatment wetlands for treating urban storm water runoff. These treatment wetlands are strategically located to capture and treat flows from different portions of the watershed. The IRWD also sponsored legislation that authorizes the District to collect storm water fees for maintenance of these treatment wetlands. These treatment wetlands are designed to remove sediment and nutrients from urban runoff but may be less efficient in removing pathogens and toxics (metals, pesticides, etc.). It is anticipated that a combination of site design, low impact development, source control and other best management practices and these treatment wetlands will help to control the discharge of pollutants in urban runoff.

e. *Irvine Coast and Newport Coast Areas of Special Biological Significance (ASBSs)* The Ocean Plan has 35 designated areas of special biological significance throughout the State; two of these ASBSs are within the Santa Ana Region, Irvine Coast Areas of Special Biological Significance, Newport Coast Areas of Special Biological Significance. The ASBSs require protection of species and/or biological communities to the extent that alteration of natural water quality is undesirable. The Crystal Cove area, which is within the Irvine Coast ASBS, is currently experiencing increased urban runoff from new developments in the area. The Ocean Plan contains a prohibition on discharges of wastes to ASBS. The State Board has developed conditions for special protection of ASBSs[6]. All waste discharges to the

[6] Special Protections for Selected Storm Water and Nonpoint Source Discharges into Areas of Special Biological Significance, March 3, 2008 (http://www.waterboards.ca.gov/water_issues/programs/ocean/docs/asbs/draft_special_protections.pdf)

ASBS are governed by the prohibition in the Ocean Plan and are subject to the special protections prescribed by the State Board.

2. CWA SECTION 303(d) LIST AND TMDLs:

The 2006 water quality assessment conducted by the Regional Board identified a number of waterbodies within the Region as impaired waterbodies, under Section 303(d) of the CWA. These are waterbodies where the designated beneficial uses are not met and/or the water quality objectives are being violated. These waterbodies were placed on the CWA Section 303(d) list of impaired waters[7]. The impaired waterbodies in Orange County within the Santa Ana Regional Board's jurisdiction are listed in Table 2.

Federal regulations require that a total maximum daily load (TMDL) be established for each 303(d) listed waterbody for each of the pollutants causing impairment. The TMDL is the total amount of the problem pollutant that can be discharged while water quality standards in the receiving water are attained, i.e., water quality objectives are met and the beneficial uses are protected. It is the sum of the individual wasteload allocations (WLA) for point source inputs, load allocations (LA) for non-point source inputs and natural background, with a margin of safety. The TMDLs are the basis for limitations established in waste discharge requirements. TMDLs have been developed for sediment and nutrients for San Diego Creek and Newport Bay and for fecal coliform bacteria in Newport Bay. The stakeholders in this watershed are collaborating in the development and implementation of the TMDLs. The Regional Board's Executive Officer has issued requirements for the submittal and implementation by the responsible parties of plans and schedules to address the TMDL requirements.

Table 2. Clean Water Act Section 303(d) Listed Waterbodies[8]

Water Body	Hydro Unit	Pollutant Stressor	Source	Priority	Size Affected	Unit	TMDL End Date
Anaheim Bay	80111000	Nickel[9]	Source Unknown	Medium	402	Acres	2019
		Dieldrin[10]	Source Unknown	Medium	402	Acres	2019
		PCBs[11]	Source Unknown	Medium	402	Acres	2019
		Sediment Toxicity	Source Unknown	Medium	402	Acres	2019

[7] 2006 CWA Section 303(d) list of water quality limited segments (http://www.waterboards.ca.gov/coloradoriver/water_issues/programs/tmdl/docs/303d/usepa_final_r8_2006_303dlist.pdf

[8] Extracted from 2006 CWA Section 303(d) list of water quality limited segments

[9] EPA listing

[10] EPA listing

[11] EPA listing

Balboa Beach	80114000	Pesticides (DDT, dieldrin)	Source Unknown	Medium	1.8	Miles	2019
		PCBs	Source Unknown	Medium	1.8	Miles	2019
Bolsa Chica State Beach	80111000	Metals (copper[12] and nickel[13])	Source Unknown	Medium	2.6	Miles	2019
Buck Gully Creek	80111000	Pathogens (fecal coliform, total coliform)	Source Unknown	Medium	0.3	Miles	2019
Huntington Beach State Park	80111000	Pathogens (Enterococcus and indicator bacteria)	Source Unknown	Medium	5.8	Miles	2019
		PCBs	Source Unknown	Medium	5.8	Miles	2019
Huntington Harbour	80111000	Metals (copper[14], lead, nickel[15])	Source Unknown	Medium	221	Acres	2019
		Pathogens	Urban Runoff/ Storm Sewers	Medium	221	Acres	2019
		Chlordane	Source Unknown	Medium	221	Acres	2019
		PCBs[10]	Source Unknown	Medium	221	Acres	2019
		Sediment Toxicity	Source Unknown	Medium	221	Acres	2019
Los Trancos Creek (Crystal Cove Creek)	80111000	Pathogens (fecal coliform, total coliform)	Source Unknown	Medium	0.19	Miles	2019
Newport Bay, Lower	80111000	Chlordane	Source Unknown	Medium	767	Acres	2019
		DDT	Source Unknown	Medium	767	Acres	2019
		Copper	Source Unknown	High	767	Acres	2007
		PCBs	Source Unknown	Medium	767	Acres	2019
		Sediment Toxicity	Source Unknown	Medium	767	Acres	2019

[12] EPA listing
[13] EPA listing
[14] EPA listing
[15] EPA listing

Newport Bay, Upper Ecological Reserve	80111000	Copper	Source Unknown	High	653	Acres	2007
		Chlordane	Source Unknown	Medium	653	Acres	2019
		Metals	Urban Runoff/ Storm Sewers	Medium	653	Acres	2019
		DDT	Source Unknown	Medium	653	Acres	2019
		PCBs	Source Unknown	Medium	653	Acres	2019
		Sediment Toxicity	Source Unknown	Medium	653	Acres	2019
Peters Canyon Channel	80111000	Pesticides (DDT, Toxaphene)	Source Unknown	Medium	3	Miles	2019
Rhine Channel	80114000	Metals (copper, lead, mercury, zinc)	Source Unknown	Medium	20	Acres	2019
		PCBs	Source Unknown	Medium	20	Acres	2019
		Sediment Toxicity	Source Unknown	Medium	20	Acres	2019
San Diego Creek, Reach 1	80111000	Selenium	Source Unknown	High	7.8	Miles	2009
		Fecal Coliform	Urban Runoff/Storm Sewers Other Urban Runoff	Medium	7.8	Miles	2019
		Toxaphene	Source Unknown	Medium	7.8	Miles	2019
San Diego Creek Reach 2	80111000	Metals	Urban Runoff/Storm Sewers	High	6.3	Miles	2009
Santiago Creek R4	80112000	Salinity/ TDS/ Chlorides	Source Unknown	Low	9.8	Miles	2019
Seal Beach	80111000	Enterococcus	Source Unknown	Low	0.53	Miles	2019
		PCBs	Source Unknown	Low	0.53	Miles	2019

Silverado Creek	80112000	Pathogens	Unknown Nonpoint Source	Low	11	Miles	2019
		Salinity/ TDS/ Chlorides	Unknown Nonpoint Source	Low	11	Miles	2019

The proposed order includes numeric effluent limits based on the wasteload/load allocations developed and approved by the Regional Board, State Board, Office of Administrative Law and the EPA.

VI. FIRST, SECOND AND THIRD TERM PERMITS: STORM WATER POLLUTION CONTROL PROGRAMS/POLICIES

Prior to EPA's promulgation of the final storm water regulations, the counties of Orange, Riverside and San Bernardino applied for areawide NPDES permits for storm water runoff. On July 13, 1990, the Regional Board issued Order No. 90-71 to the permittees (first term permit). On March 8, 1996, the Board adopted Order No. 96-31 (second term permit). On January 18, 2002, the Board adopted Order No. R8-2002-0010 (third term permit). These permits included the following requirements as outlined in the storm water regulations:

1. Prohibited non-storm water discharges to the MS4s, with certain exceptions.
2. Required the municipalities to develop and implement a drainage area management plan (DAMP) to reduce pollutants in urban storm water runoff to the maximum extent practicable (MEP[16]).
3. Required the discharges from the MS4s to meet water quality standards in receiving waters.
4. Required the municipalities to identify and eliminate illicit discharges and illegal connections to the MS4s.
5. Required the municipalities to establish and maintain legal authority to enforce storm water regulations.
6. Required monitoring of dry weather flows, storm flows, and receiving water quality, and required program assessment.
7. Required the permittees to identify and inspect construction sites and industrial and commercial facilities.
8. Required the permittees to develop and implement a Water Quality Management Plan to address post-development runoff.

The following programs and policies have been implemented or are being implemented by the permittees. During the first term permit, the permittees developed a Drainage Area Management Plan (1993 DAMP) which was approved by the Executive Officer of the Regional Board on April 29, 1994. The 1993 DAMP included a number of best management practices (BMPs) and a very extensive public education program. The 1993

[16] Maximum Extent Practicable (MEP) means to the maximum extent feasible, taking into account equitable considerations of synergistic, additive, and competing factors, including but not limited to, gravity of the problem, technical feasibility, fiscal feasibility, public health risks, societal concerns, and social benefits.

DAMP was updated a number of times and a draft 2007 version of the DAMP was submitted with the permit renewal application. The monitoring program for the first term permit included 89 monitoring stations within streams and flood control channels and 21 stations within the bays, estuaries and the ocean. The findings and conclusions from these monitoring stations and monitoring programs of other municipal permittees (Riverside and San Bernardino Counties and others) were used to identify problem areas and to re-evaluate the monitoring program and the effectiveness of the BMPs. The direction of these program elements were depended upon the results of the ongoing studies and a holistic approach to watershed management.

Other elements of the storm water management program included identification and elimination of illicit discharges and illegal connections and establishment of adequate legal authority to control pollutants in storm water discharges. The permittees have completed a survey of their storm drain systems to identify illicit discharges/illegal connections and have adopted appropriate ordinances to establish legal authority. Some of the more specific achievements during the previous term permits are as follows:

1. *Interagency Agreements and Coordination*: Established a program management structure through an Interagency Implementation Agreement. Participated in regional monitoring programs and focused special studies/research programs. Worked with the County Sanitation Districts, Health Care Agency, Integrated Waste Management Agency, and the Water Districts to provide a consistent urban storm water pollution control message to the public. Worked with Caltrans, other transportation agencies, the Storm Water Quality Task-Force, and others to further study and understand urban runoff problems and control measures. Supported regional studies to improve storm water management programs and monitoring programs through the Southern California Coastal Water Research Project.
2. *Ordinances, Plans and Policies:* Adopted a Model Water Quality Ordinance and Enforcement Consistency Guide; prepared a Water Pollution Enforcement Implementation Plan, Public Agency Activity BMP guideline, a Public Pesticide and Fertilizer Use Guideline, Criteria for MS4 Inspections, and a Water Quality Monitoring Plan, Model Water Quality Management Plan; and established a Technical Advisory Committee for overall program development and implementation.
3. *Program Review*: A number of existing programs were reviewed to determine their effectiveness in combating urban pollution and to recommend alternatives and or improvements, including litter control measures, street sweeping frequencies and methods, public agency activities and facilities, illegal and illicit connections to the MS4 systems, and existing monitoring programs.
4. *Public Education:* A number of steps were taken to educate the public, businesses, industries, and commercial establishments regarding their role in urban runoff pollution controls. The appropriate industrial dischargers were notified of the storm water regulatory requirements. For a number of unregulated activities, BMP guidances (Fact Sheets) were developed (mobile detailing, automotive service centers, restaurants, pool maintenance). Finally, a countywide hotline was established for reporting any suspected water quality problems.
5. *Public Agency Training:* Training was provided to public agency employees on how to implement New Development Guidelines and Public Works BMPs, how to conduct

investigations of reported water quality problems and how to conduct inspections of industrial facilities, construction sites and public work projects. The municipal planners were trained to recognize water quality related problems in proposed developments.

6. *Related Activities:* Flood control channels were stabilized, sediment basins were constructed, and debris booms were installed; illegal connections were eliminated and illicit connections to the MS4s were documented , eradicated or permitted.

VII. PRIOR TERM PERMITS - WATER QUALITY IMPROVEMENTS

An accurate and quantifiable measurement of the impact of the above stated storm water management programs is difficult for a variety of reasons, such as the variability in chemical water quality data, the incremental nature of BMP implementation, lack of baseline monitoring data, and the existence of some of the programs and policies prior to initiation of formal storm water management programs. There are generally two accepted methodologies for assessing water quality improvements: (1) conventional monitoring such as chemical-specific water quality monitoring; and (2) non-conventional monitoring such as monitoring of the amount of household hazardous waste collected and disposed off at appropriate disposal sites, amount of used oil collected, debris removed by the debris boom, etc.

The water quality monitoring data collected during prior permit terms did not indicate any discernible trends or significant changes. However, the most recent monitoring data indicate that there are reductions in the mass loading rates for some of the metals like copper and zinc and improvements in beach water quality after diversion of dry weather flows to the sanitary sewers. The non-conventional monitoring data also indicate that other programs and policies have been very effective in keeping a significant quantity of wastes from being discharged into waters of the US.

During the second and third term permits, there was an increased focus on watershed management initiatives and coordination among the municipal permittees in Orange, Riverside and San Bernardino Counties. These efforts resulted in a number of regional monitoring programs and other coordinated program and policy developments.

It is anticipated that with continued implementation of the revised DAMP and other requirements specified in this order, including low impact developments, the goals and objectives of the storm water regulations will be met, including protection of water quality standards for all receiving waters.

VIII. FUTURE DIRECTION/2007 DRAFT DAMP

The NPDES permit renewal application included a revised draft of the DAMP (2007 DAMP) that includes programs and policies the permittees are proposing to implement during the fourth term permit. The 2007 draft DAMP is the principal guidance document for urban storm water management programs in Orange County and includes the following major components:

1. Continues to provide a framework for the program management activities and plan development.
2. Continues to provide the legal authority to control discharges to the MS4s.
3. Improves current BMPs to achieve further reduction in pollutant loading to the MS4s.
4. Continues to include programs and policies for public education processes and to seek public support for urban storm water pollution prevention BMPs.
5. Increases requirements for controls on new developments and significant redevelopments.
6. Continues to ensure that construction sites implement appropriate pollution control measures during construction and effective post-construction water quality management plan (WQMP) implementation.
7. Continues to ensure that industrial, construction and commercial sites are adequately identified, categorized and inspected for compliance with storm water regulations.
8. Continues to include programs and policies to eliminate illicit discharges and illegal connections to the MS4s.
9. Includes continued monitoring of urban runoff.
10. Includes provisions for any special focus studies and/or control measures.

A combination of these programs and policies and the requirements specified in this order should ensure control of pollutants in storm water runoff from facilities owned and/or controlled by the permittees.

IX. PERMIT REQUIREMENTS

The legislative history of storm water statutes (1987 CWA Amendments), US EPA regulations (40CFR Parts 122, 123, and 124), and clarifications issued by the State Water Resources Control Board (State Board Orders No. WQ 91-03 and WQ 92-04) indicate that a non-traditional NPDES permitting strategy was anticipated for regulating urban storm water runoff. Due to the economic and technical infeasibility of full-scale end-of-pipe treatments and the complexity of urban storm water runoff quality and quantity, MS4 permits generally include narrative requirements for the implementation of BMPs in place of numeric effluent limits.

The requirements included in this order are meant to specify those management practices, control techniques and system design and engineering methods that will result in maximum extent practicable protection of the beneficial uses of the receiving waters. The State Board (Orders No. WQ 98-01 and WQ 99-05) concluded that MS4s must meet the technology-based maximum extent practicable (MEP) standard and water quality standards (water quality objectives and beneficial uses). The US Court of Appeals for the Ninth Circuit subsequently held that strict compliance with water quality standards in MS4 permits is at the discretion of the permitting authority. Any requirements included in the order that are more stringent than the federal storm water regulations are in accordance with the CWA Section 402(p)(3)(iii), and the California Water Code Section 13377 and are consistent with the Regional Board's interpretation of the requisite MEP standard.

The Report of Waste Discharge (ROWD) included a discussion of the current status of Orange County's urban storm water management program and the proposed programs and policies for the next five years (fourth term permit). The proposed order incorporates these documents and the performance commitments made in the ROWD.

This order recognizes the significant progress made by the permittees during the first, second and third term permits in implementing the storm water regulations. The permit also recognizes regional and innovative solutions to such a complex problem. For these reasons, the order is somewhat less prescriptive when compared to some of the MS4 NPDES permits for urban runoff issued by other Regional Boards. However, it incorporates an integrated watershed approach in solving urban runoff related water quality and quantity issues. The proposed permit also includes numeric effluent limits based on wasteload/load allocations and an emphasis on implementation of low impact development principles. With these requirements, it should achieve the same or better water quality benefits because of the programs and policies already being implemented or proposed for implementation, including regional and watershed wide solutions.

The major requirements include: (1) Discharge prohibitions; (2) Receiving water limitations; (3) Prohibition on illicit discharges and illegal connections; (4) Public and business education; (5) Adequate legal authority; (6) Programs and policies for municipal facilities and activities; (7) Inspection Activities by the municipalities; (8) A program to address runoff from residential areas; (9) New development/re-development requirements including a requirement to fully implement low impact development principles and to minimize any hydrologic conditions of concern; (10) Waste load allocations for nutrients, sediment, and fecal coliform bacteria; metals, and pesticides, including numeric effluent limits; and (11) Monitoring and reporting requirements.

These programs and policies are intended to improve urban storm water quality and protect the beneficial uses of receiving waters of the region.

1. DISCHARGE PROHIBITIONS

   In accordance with CWA Section 402(p)(3)(B)(ii), this order prohibits the discharge of non-storm water to the MS4s, with a few exceptions. The specified exceptions are consistent with 40 CFR 122.26(d)(2)(iv)(B)(1). If the permittees or the Executive Officer determines that any of the exempted non-storm water discharges contain pollutants, a separate NPDES permit or coverage under the Regional Board's De Minimis permit will be required.

2. RECEIVING WATER LIMITATIONS

   Receiving water limitations are included to ensure that discharges from MS4 systems do not cause or contribute to violations of applicable water quality standards in receiving waters. The compliance strategy for receiving water limitations is consistent with the US EPA and State Board guidance and recognizes the complexity of storm water management.

   This order requires the permittees to meet water quality standards in receiving waters in accordance with US EPA requirements as specified in State Board Order No. WQ 99-05. If water quality standards are not met by implementation of current BMPs, the permittees are required to re-evaluate the programs and policies and to propose

additional BMPs. Compliance determination will be based on this iterative BMP implementation/compliance evaluation process.

3. ILLICIT DISCHARGES AND ILLEGAL CONNECTIONS TO MS4s

   The permittees have completed their survey of the MS4 systems and eliminated or permitted all identified illegal connections. The permittees have also established a program to address illicit discharges and a mechanism to respond to spills and leaks and other incidents of discharges to the MS4s. The permittees are required to continue these programs to ensure that the discharges from MS4s do not become a source of pollutants in receiving waters.

4. PUBLIC AND BUSINESS EDUCATION OUTREACH PROGRAM

   Public outreach is an important element of the overall urban pollution prevention program. The permittees have committed to implement a strategic and comprehensive public education program to maintain the integrity of the receiving waters and their ability to sustain beneficial uses. The principal permittee has taken the lead role in the outreach program and has targeted various groups including businesses, industry, development, utilities, environmental groups, institutions, homeowners, school children, and the general public. The proposed order includes additional requirements to address runoff from residential developments. The permittees have developed a number of educational materials, established a storm water pollution prevention hotline, started an advertising and educational campaign and distribute public education materials at a number of public events. The permittees are required to continue these efforts and to expand public participation and education programs.

5. LEGAL AUTHORITY

   During the first two permit cycles, each permittee adopted a number of ordinances, municipal codes, and other regulations to establish legal authority to control discharges to the MS4s and to enforce these regulations as specified in 40 CFR 122.26(d)(2)(I)(B, C, E, and F). The permittees are required to enforce these ordinances and to take enforcement actions against violators (40 CFR 122.26(d)(2)(iv)(A-D)). The enforcement activities undertaken by a majority of the permittees have consisted primarily of Notices of Violation, which act to educate the public on the environmental consequences of illicit discharges. Several coastline municipalities have regularly issued Citations. In the case of the County, additional action has sometimes included recovery of investigation and clean-up costs from a responsible party. In the event of egregious or repeated violations, the option exists for a referral to the County District Attorney for possible prosecution. In order to eliminate unauthorized, non-storm water discharges, reduce the amount of pollutants commingling with storm water runoff and thereby protect water quality, an additional level of enforcement is required between Notices of Violation and District Attorney referrals. The third term permit required the permittees to establish the authority and resources to administer either civil or criminal fines and/or penalties for violations of their local water quality ordinances (and the Federal Clean Water Act). The permittees now have this authority for civil and/or criminal penalties.

6. PUBLIC FACILITIES AND ACTIVITIES

Education of municipal planning, inspection, and maintenance staff is critical to ensure that municipal facilities and activities do not cause or contribute to an exceedance of receiving water quality standards. The second and third term permits required the permittees to prepare an Environmental Performance Report to address public agency facilities and activities that are not regulated under the State's General Industrial Activities Storm Water Permit. It also required the permittees to report on an annual basis the actions taken to eliminate the discharge of pollutants from public agency activities and facilities. The permittees are required to inspect and maintain drainage facilities free of waste materials to control pollutants in storm water runoff flowing through these systems. The proposed order requires the permittees to continue to re-evaluate their facilities and activities on an annual basis to see if additional BMPs are needed to ensure water quality protection.

7. MUNICIPAL INSPECTION PROGRAM

The third term permit included requirements for inspection of construction, industrial, and commercial facilities within the permittees' jurisdiction in order to control the loading of pollutants entering the MS4s from these sites. The permittees were required to inventory construction, industrial and commercial facilities; prioritize those facilities with respect to their potential for discharge of pollutants in runoff and their proximity to sensitive receiving waters; and perform regular inspections to insure compliance with local ordinances. While initial observations of non-compliance may result in 'educational' type enforcement, repeated non-compliance should result in more severe forms of enforcement, such as, monetary penalties, stop work orders or permit revocation.

8. NEW DEVELOPMENT

During the third term permit, the permittees developed and revised existing new development guidelines. The permittees were required to implement these guidelines, with program implementation of post construction Water Quality Management Plan criteria standards. Additionally, this order requires the permittees to work towards the goal of restoring and preserving the natural hydrologic cycles in approving urban developments. To accomplish this goal, the permittees are required to implement low impact development principles through appropriate site design and source control BMPs. The proposed order includes a 5% limitation on effective impervious area[17] for new developments. It also recognizes that certain soil and groundwater conditions might preclude a particular site from achieving the 5% effective impervious area goal and includes alternatives and in-lieu programs.

9. SANITARY SEWER OVERFLOWS, SEPTIC SYSTEM FAILURES AND PORTABLE TOILET DISCHARGES

The third term permit required the permittees to investigate adverse impacts on urban runoff quality from leaking septic systems and portable toilets. The information provided by the permittees indicates that leaking or failing septic systems are not a

[17] Effective impervious areas are those areas which are not connected to a pervious feature (such as a landscaped area, pervious concrete or asphalt surfaces with a sub-base of infiltration materials) and from where storm water runoff is conveyed to a storm water conveyance system or directly to waters of the US.

significant problem in Orange County as most areas of the County are sewered. A number of beach closures in Orange County have been due to spills, overflows, and leaks from the sanitary sewer lines. To address these concerns, waste discharge requirements (SSO order) for local sanitary sewer agencies were adopted by the Regional Board. Subsequently, the State Board adopted an SSO order, Water Quality Order No. 2006-0003, to address this problem on a statewide basis. The Regional Board SSO order has since been rescinded. The permittees are required to comply with the statewide SSO order.

10. 303(d) LISTED WATERBODIES AND TMDL IMPLEMENTATION

The proposed order includes special provisions for the protection of impaired waterbodies. The 303(d) listed watebodies fall under the following four categories:

a. 303(d) listed with no TMDLs: The permittees are required to develop and implement pollutant-specific Watershed Action Plans to control the discharge of the pollutant causing the impairment.

b. 303(d) listed with a technical TMDL (no implementation plan): If the TMDL specifies a wasteload/load allocation for urban runoff or storm water, the proposed order includes the appropriate load allocation or a numeric effluent limit derived from it.

c. 303(d) listed with a TMDL implementation plan that has a compliance date beyond the permit term: The permittees are required to implement control measures to reduce the pollutant causing the impairment and monitor the progress towards achieving the target numeric effluent limit.

d. 303(d) listed with a TMDL implementation plan that requires meeting the target goals within the permit term: Numeric effluent limits based on the allocations are included in the proposed order.

11. MONITORING REQUIREMENTS

During the first term permit and part of the second term permit, the permittees conducted extensive monitoring of the storm water flows, receiving water quality and sediment quality. These early programs focused on identifying pollutants, estimating pollutant loads, tracking compliance with water quality objectives, and identifying sources of pollutants. The Orange County monitoring program, like other monitoring programs nationwide, has established that there is a high degree of uncertainty in the quality of storm water runoff and that there are significant variations in the quality of urban runoff spatially and temporally. However, most of the monitoring programs to date have indicated that there a number of pollutants in urban storm water runoff. Only in a few cases has a definite link between pollutants in urban runoff and beneficial use impairment been established.

In 1999, the permittees re-evaluated their monitoring program and proposed a revised monitoring program. The goals of the 1999 Water Quality Monitoring Program were:

- To determine the role of urban runoff in beneficial use impairment;
- To collect technical information to develop an effective urban storm water management plan; and

- To determine the effectiveness of a number of BMPs, also as an aid to the overall urban storm water management plan.

To accomplish these goals, the monitoring program focused on three areas:

- Areas where constituent concentrations are substantially above system-wide averages. These areas were referred to as "warm spots" and the designation is based on monitoring data from prior years.
- Areas of Critical Aquatic Resources (sites with important aquatic resources).
- Sub-watersheds where certain BMPs have been installed to study their effectiveness.

The third term permit required the permittees to re-evaluate their Water Quality Monitoring Program and submit a revised plan for approval including the following elements: mass emissions, estuary/wetlands, water column toxicity, bacteriological/pathogen, bioassessment, reconnaissance, land use correlation, and TMDL/303(d) listed waters monitoring. Based on these requirements, the results from prior monitoring efforts, and based on guidance provided in "The Model Monitoring Program for Southern California"[18] , a revised monitoring program was submitted in 2003 (2003 Monitoring Program). In 2005, the Executive Officer approved the 2003 Monitoring Program. The proposed order requires the permittees to review the 2003 Monitoring Program to determine the need for any revisions.

The permittees also participate in a number of other regional monitoring programs such as those conducted by the Southern California Coastal Water Research Project and the California Regional Marine Monitoring Program and monitoring programs in response to TMDLs. The permittees are encouraged to continue their participation in regional and watershed-wide monitoring programs.

X. WATER QUALITY BENEFITS/COST ANALYSIS/FISCAL ANALYSIS

There are direct and indirect benefits from clean beaches, clean water, and a clean environment. It is difficult to assign a dollar value to the benefits the public derives from fishable and swimmable waters. In 1972, at the start of the NPDES program, only 1/3 of the US waters were swimmable and fishable. In 2008, more than 2/3 of the US waters meet these criteria. Clean beaches and other water recreational facilities also attract tourists. According to the Orange County 2006 Community Indicators Project, it is estimated that on average, an out-of-county visitor spent an average of $107.00 per day in 2004. Huntington Beach's 8.5-mile shoreline attracts 10 million visitors a year[19]. During the summer of 1999 and 2000 when the beaches were closed to water contact recreation, the beach communities reported multi-million-dollar losses in tourist revenues.

The true magnitude of the urban runoff problem is still elusive and any reliable cost estimate for cleaning up urban runoff would be premature. For urban storm water runoff, end-of-pipe treatments are cost prohibitive and are not generally considered as a

[18] Model Monitoring Technical Committee, 2004

[19] Los Angeles Times, May 9, 2001

technologically and economically feasible option. Over the last decade, the permittees have attempted to define the problem and implement best management practices. The costs incurred by the permittees in implementing these programs and policies can be divided into three broad categories (the costs indicated below are for the entire Orange County storm water program):

1. Shared costs: These are costs that fund activities performed mostly by the principal permittee under the Implementation Agreement. These activities include overall storm water program coordination; intergovernmental agreements; representation at the California Storm Water Quality Association, Regional Board/State Board meetings and other public forums; preparation and submittal of compliance reports and other reports required under the NPDES permits and Water Code Section 13267, budget and other program documentation; coordination of consultant studies, co-permittee meetings; training seminars, water quality monitoring, and Countywide pubic education and outreach. Shared costs have increased from $0.81M at the inception of the Orange County storm water program to $4.8M in 2006-2007.
2. Individual Costs for DAMP Implementation: These are costs incurred by each permittee for implementing the BMPs (drainage facility inspections for illegal connections, drain inlet/catchbasin stenciling, public education, inspections of construction, industrial and commercial facilities, etc.) included in the DAMP. A number of programs and policies for non-point and storm water pollution controls existed prior to the urban storm water runoff NPDES program. However, the DAMP that was developed and implemented in response to the urban storm water runoff NPDES program required additional programs and policies for pollution control. These costs are attributable to DAMP implementation. In 2006/07, the Permittees determined their total Individual Costs to be $82.2M.

In addition to these expenditures, volunteer efforts (such as the annual “Beach Cleanup Day”, “Inner Coastal Watershed Cleanup Day”, etc.) also contributed to the urban runoff pollution control efforts.

The permittees identified the following funding sources (2006/07):

FUNDING SOURCE	*PERCENTAGE*
General Funds	11.8%
Gas Taxes	1.3%
Grants	30%
Sanitation Fees	31.3%
Time & Materials Ordinance & Permit Fees	0.6%
Special District Funds	24.3%
Other Sources	0.2%

XI. ANTIDEGRADATION ANALYSIS

The Regional Board has considered whether a complete antidegradation analysis, pursuant to 40 CFR 131.12 and State Board Resolution No. 68-16, is required for these storm water discharges. The Regional Board finds that the pollutant loading rates to the receiving waters will be reduced with the implementation of the requirements in this order.

As a result, the quality of storm water discharges and receiving waters will be improved. Since this order will not result in a lowering of water quality, a complete antidegradation analysis is not necessary, consistent with the federal and state antidegradation requirements.

XII. PUBLIC WORKSHOP

The Regional Board recognizes the significance of Orange County's Storm Water/Urban Runoff Management Program and will conduct, participate, and/or assist with any workshop during the term of this order to promote and discuss the progress of the storm water management program. The details of the workshops will be posted on the Regional Board's website, published in local newspapers and/or mailed to interested parties. Persons wishing to be included in the mailing list for any of the items related to this order may register their e-mail address and/or mailing address with the Regional Board office at the address given below.

XIII. PUBLIC HEARING

A public hearing to consider adoption of this order will be scheduled during the early part of 2009.

XIV. INFORMATION AND COPYING

Persons wishing further information may write to the address given below or call Marc Brown at (951) 321-4584 or email at: mbrown@waterboards.ca.gov. Copies of the application, proposed waste discharge requirements, and other related documents (other than those which the Executive Officer maintains as confidential) are available at the Regional Board office for inspection and copying by appointment scheduled between the hours of 8:30 a.m. and 4:00 p.m., Monday through Friday (excluding holidays).

XV. REGISTER OF INTERESTED PERSONS

Any person interested in a particular application or group of applications may leave his/her e-mail and/or mailing address and phone number as part of the file for an application. Copies of tentative waste discharge requirements will be mailed to all interested parties.

Mailing address:

Marc Brown

Regional Water Quality Control Board

3737 Main Street, Suite 500

Riverside, CA 92501-3348

Email registration:

http://www.waterboards.ca.gov/resources/email_subscriptions/reg8_subscribe.shtml

In addition to the permittees, comments were solicited from the following agencies and/or persons:

U. S. Environmental Protection Agency – John Kemmerer/Eugene Bromley (W-5-1)
US Army District, Los Angeles, Corps of Engineers - Permits Section
NOAA, National Marine Fisheries Service
US Fish and Wildlife Service - Carlsbad
State Water Resources Control Board – David Rice, Office of the Chief Counsel
State Water Resources Control Board – Bruce Fujimoto, Division of Water Quality
State Department of Water Resources - Glendale
California Regional Water Quality Control Board, North Coast Region (1)
California Regional Water Quality Control Board, San Francisco Bay Region (2)
California Regional Water Quality Control Board, Central Coast Region (3)
California Regional Water Quality Control Board, Los Angeles Region (4)
California Regional Water Quality Control Board, Central Valley Region (5S)
California Regional Water Quality Control Board, Central Valley Region (5R)
California Regional Water Quality Control Board, Central Valley Region (5F)
California Regional Water Quality Control Board, Lahontan Region (6SLT)
California Regional Water Quality Control Board, Lahontan Region (6V)
California Regional Water Quality Control Board, Colorado River Basin Region (7)
California Regional Water Quality Control Board, San Diego Region (9)
State Department of Fish and Game - Long Beach
State Department of Health Services - Santa Ana
State Department of Parks and Recreation
Orange County Health Care Agency
South Coast Air Quality Management District, Diamond Bar
Caltrans, District 12, Santa Ana
Southern Pacific Railroad
Atchison, Topeka & Santa Fe Railway Company
Seal Beach Naval Weapons Station
Seal Beach Naval Reserve Center, Los Alamitos
National Forest Service
URS/Greiner - Bob Collacott
The Irvine Company - Sat Tamaribuchi
Building Industry Association –Mark Grey
Latham & Watkins – Paul Singarella
Best, Best, and Krieger
Southern California Association of Governments, Los Angeles

<u>Universities and Colleges</u> (Chancellor)
University of California, Irvine
California State University, Fullerton
Chapman College
Coastline College
Cypress College
Fullerton College
Irvine Valley College

Golden West College
Orange Coast College
Rancho Santiago College

School Districts (Superintendent)
Anaheim Elementary School District
Anaheim Union High School District
Brea-Olinda Unified School District
Buena Park Joint Union High School District
Centralia Elementary School District
Cypress Elementary School District
Fountain Valley Union High School District
Fullerton Elementary School District
Fullerton Joint Union High School District
Garden Grove Unified School District
Huntington Beach Elementary School District
Huntington Beach Union High School District
Irvine Unified Union High School District
La Habra Joint Union High School District
Los Alamitos Unified School District
Lowell Joint Union High School District
Magnolia Elementary School District
Newport-Mesa Unified School District
Ocean View Union High School District
Orange Unified School District
Placentia Unified School District
Santa Ana Unified School District
Savanna Union High School District
Tustin Unified School District
Westminster Union High School District
Yorba Linda Joint Union High School District

Hospitals (Administrator)
Anaheim General Hospital
Brea Community Hospital
Chapman General Hospital, Orange
Children's Hospital of Orange County. Orange
Coastal Communities Hospital, Santa Ana
Fairview Hospital
FHP Hospital, Fountain Valley
Fountain Valley Regional Hospital and Medical Center
Hoag Hospital, Newport Beach
Kaiser Foundation Hospital, Anaheim
Orange County Community Hospital, Buena Park
Pacifica Community Hospital, Huntington Beach
Placentia Linda Community Hospital
Santa Ana Hospital and Medical Center
St. Joseph's Hospital, Orange
U.C. Irvine Medical Center

Vencor Hospital of Orange County, Westminster
Whittier Hospital and Medical Center, Buena Park

Environmental Organizations
Lawyers for Clean Water – Daniel Cooper
Orange County Coastkeeper – Garry Brown
Defend the Bay – Bob Caustin
Sierra Club, Orange County Chapter
Sierra Club, Los Angeles Chapter
Natural Resources Defense Council (NRDC) – David Beckman/Michelle Mehta
Cousteau Society
Amigos De Bolsa Chica
Audobon Sea & Sage Chapter
Huntington Beach Wetlands Conservancy
Surfrider Foundation

Newspapers
Orange County Register – Pat Brennan
Los Angeles Times
Press Enterprise
Daily Pilot

Major Water/Wastewater Agencies
Santa Ana Watershed Project Authority – Celeste Cantu
Irvine Ranch Water District – General Manager
Los Alisos Water District - General Manager
El Toro Water District - General Manager
San Bernardino County Flood Control District – Matt Yeager
Riverside County Flood Control & Water Conservation District – Jason Uhley
L.A. County Department of Public Works
Orange County Sanitation Districts – Robert Ghirelli
Orange County Water District
Metropolitan Water District

Orange County MS4 Permit Urban Storm Water Runoff Management Program

Order No. R8-2008-0030 (NPDES No. CAS618030)

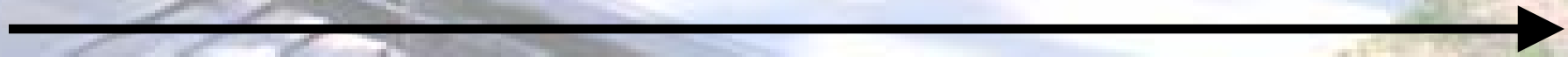
Public Workshop
November 21, 2008

Mark Smythe
Senior Environmental Scientist
Coastal Storm Water Unit
Santa Ana RWQCB

History of Storm Water

- National Pollutant Discharge Elimination System (NPDES) was established in 1972 through the Federal Clean Water Act to control point source pollution.
- In 1987, Federal regulations required industries and large municipalities to obtain NPDES permits for their storm water runoff.
- The three Region 8 MS4 permits were adopted in 1990 and the two Statewide storm water permits were adopted in 1992.

Shift of Regulatory Focus



Point Sources

sewage treatment plants, major industrial dischargers

Non-Traditional Point Sources

Construction site runoff, industrial runoff, municipal activities

Service activities, commercial act., residential act., new development & redevelopment planning

Storm Water Permits

- Statewide General Construction
- Statewide General Industrial
- Caltrans

<u>Other storm water discharges regulated through:</u>

- MS4 - Municipal Separate Storm Sewer System
  - Municipal activities
  - Industrial and construction activities
  - Commercial and service activities
  - Residential activities

Municipal Permit Overview

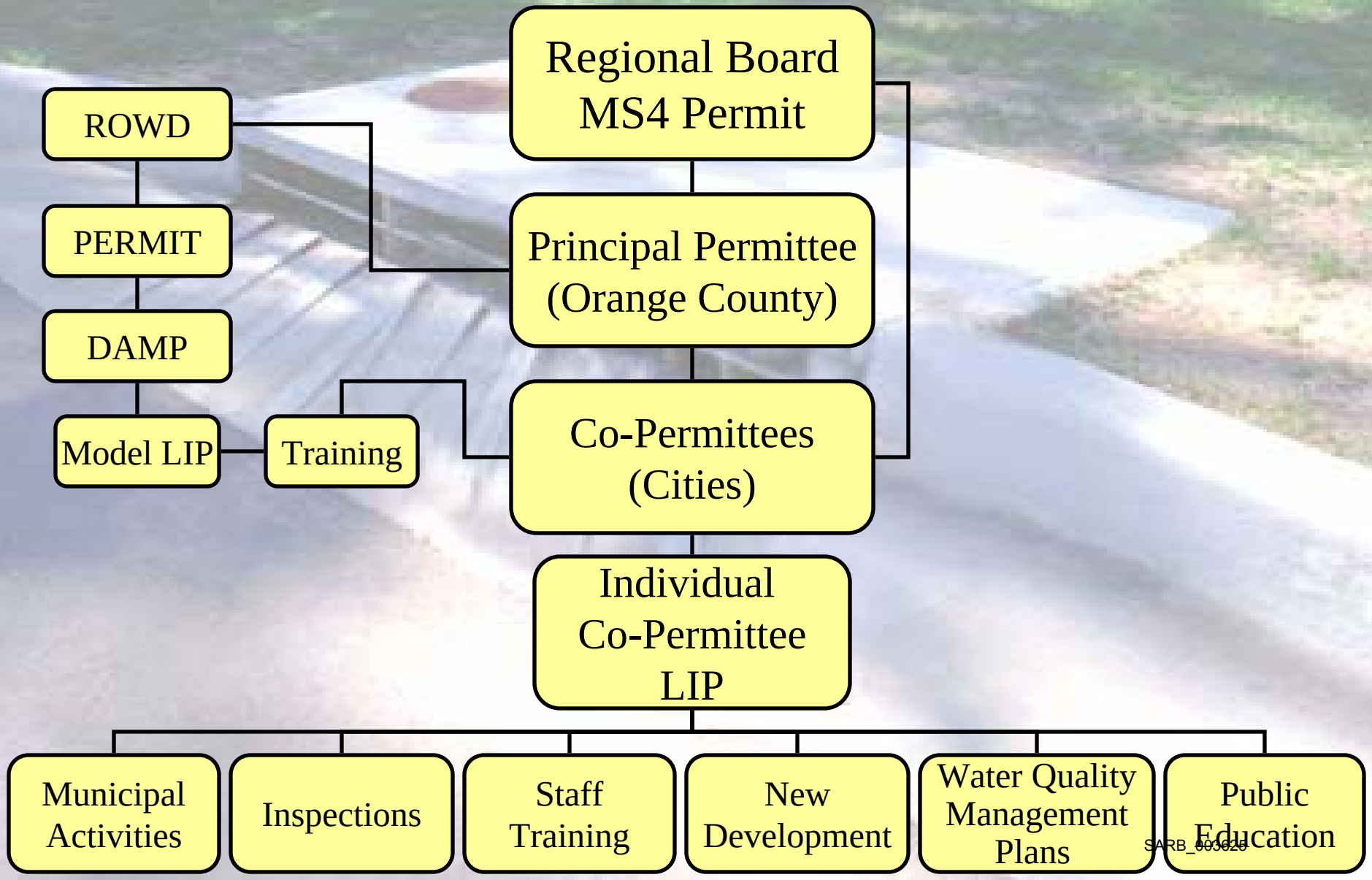
- MS4 permits have not historically had numeric effluent limits, but TMDLs change that.
- For the most part, permittees must reduce pollutant loads in discharges from their MS4 to the **"Maximum Extent Practicable (MEP)."**
- Where MEP takes into account such issues as: the gravity of the problem, technical & economic feasibility, public health risks and societal benefits and concerns.

Maximum Extent Practicable

The permittees meet that MEP standard through an iterative process.

- If water quality standards (wqs) aren't being met,
- Implement Best Management Practices (BMPs)
- Monitor
- If there are still wqs exceedences,
- Implement improved BMPs
- Monitor

Permit Process



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Program From 1990-1996 OC MS4 Permit

- Public education
- Enforcement of Water Quality Ordinances
  - Prohibition of illegal connections to MS4
  - Prohibition of illicit discharges (dumping)
  - Prohibition of most non-storm water discharges.
- BMP implementation for municipal activities
- Requiring Water Quality Management Plans for new development.

2002 Permit Emphasis

- Municipal inspection program
  - Construction and Industrial Sites
  - Commercial and Restaurants
- More structural post construction BMPs for new development and re-development
- First time Total Maximum Daily Loads (TMDLs) were implemented

Total Maximum Daily Load (TMDL) Implementation

- TMDLs are developed when a water body fails to support it's designated Beneficial Uses
- Load Allocations for urban runoff are enforced through the MS4 Permits
- The 2002 permit included load allocations for nutrients and sediment in the San Diego Creek and Newport Bay watersheds and fecal coliform for the Newport Bay watersheds
- To date, the load allocation targets have been met.

Changes with the Draft 2008 Permit

- Increased Permitee Accountability
  - Results from Municipal Program Audits
- Municipal Inspection Programs
- New Development/Re-development Requirements
- Additional TMDL Requirements

Proposed Increase in Permittee Accountability

- Water Quality Management Plan Review
- Water Quality Ordinance Enforcement
- Local Implementation Plan

Proposed Changes to the Inspection Program

Construction

- Emphasis on abandoned/idle sites.
- Lower size thresholds for medium and high prioritization.
- Conformance with the Statewide Construction Storm Water permit when it's adopted by the State Board.

Commercial

- Mobile cleaning services enforcement strategy

Residential Program

- New Program

Proposed Residential Inspection Program

- Permittees are to identify, track, enforce & evaluate residential sources
- Common interest area control measures
- Household Hazardous Waste Program
- Annual Report reporting criteria

New Development and Significant Re-development

This draft permit emphasizes the use of Low Impact Development (LID) as a way of mitigating development's effect on flows and pollutant loading.

Low Impact Development (LID)

- The goal of LID is to mimic pre-development site hydrology through technically and economically feasible source control and site design.
- 5% Effective Impervious Area (EIA)
  - permeable paving, infiltration, rain barrels, bioswales, rain gardens, etc.
- Drawbacks
  - Shallow groundwater, clayey soils, subsidence & **space**
- Alternatives
  - Included in Permit should site conditions be infeasible

New TMDL Requirements

Impaired Waters Status

- 303(d) listed, but no TMDL.
- Technical TMDL, but no implementation plan
  - Region 4 metals TMDL for San Gabriel River.
- TMDL/implementation plan adopted, but compliance dates are beyond the permit term.
- TMDL/implementation plan adopted, compliance dates within permit term.

Current TMDLs

- Diazinon in San Diego Creek
- Chlorpyrifos in San Diego Creek and Upper Newport Bay
- Nutrients in San Diego Ck and Newport Bay
- Sediment in San Diego Ck and Newport Bay
- Fecal Coliform in Newport Bay

Conclusions & Proposed Permit Direction

- The Proposed Permit is building on the current 2002 Permit
- Increased Accountability of Co-Permittees
- Several Program Adjustments
  - Residential Pollution Control Oversight
  - TMDL
  - WQMP Review

Informal Comments

Prior to public release, informal comments were solicited from:

- Orange County and Co-Permittees
- Orange County CoastKeeper
- BIA
- NRDC
- U.S. EPA

Anticipated Timeline

December 30, 2008	**Deadline for written comments on the 1st draft permit.**
January 26, 2009	**Release of 2nd draft permit.**
March 2009	**2nd workshop at regular Board Mtg.**
April 2009	**Release of final draft**
May 2009	**Deadline for written comments prior to Public Hearing**
May/June 2009	**Public Hearing on proposed permit**

State of California
California Regional Water Quality Control Board
Santa Ana Region

Minutes of November 21, 2008 Board Meeting
25541 Barton Road
Loma Linda, CA 92354

1. Chair Beswick called the meeting to order at 9:30 a.m.

Board Members Present	Board Members Absent
Carole Beswick, Chair	
Seymour Van Gundy, Vice-Chair	
Fred Ameri	
Mary Cramer	
William Ruh	
Steven PonTell	

Staff Members Present

Gerard J. Thibeault, Executive Officer
Kurt V. Berchtold, Assistant Executive Officer
Joanne Schneider, Environmental Program Manager
David Rice, Regional Board Counsel
Frances McChesney, Sr. Staff Counsel
Michael J. Adackapara, Supervising Water Resource Control Engineer
Robert L. Holub, Supervising Water Resource Control Engineer
Stephen Mayville, Chief of Enforcement
Mark E. Smythe, Chief of Storm Water (Coastal Waters)
Hope Smythe, Chief of Basin Planning (Inland Waters)
Mary Bartholomew, Environmental Scientist
Marc K. Brown, Environmental Scientist
Keith L. Elliott, Water Resources Control Engineer
Cindy Li, Engineering Geologist
Terri Reeder, Engineering Geologist
Maria Macario, Water Resources Control Engineer
Kevin Heinemann, Staff Information Systems Analyst
Daniel Mefford, Staff Information Systems Analyst
Felipa Carrillo, Executive Assistant

Public Attendance

Mary Anne Skorpanich, County of Orange	Matt Yeager, San Bernardino Co SW Program
Jennifer Weiland, County of Orange	Latoya Cyrus, Charles Abbott Assoc.
Christy Norris, County of Orange	Jeremy Jackson, City of Moreno Valley
Kent Wegelin, City of Moreno Valley	James Forturn, County of Orange
Michael Yang, City of Irvine	David Crohn, UC Riverside
Mike Loving, City of Irvine	Dan Cruz, PBS & J for OC Great Park
Devin Slaven, City of Lake Forest	Mark Grey, BIA/SL-CICWQ
Shanda Beltran, Allen Matkins	Zeki Kaylrhn, AKM Consulting engineers
Allen Matkins	Larry McKenney, RBF Consulting
Mary Lynn Coffee, Nossaman	Jason Pereira, Calif. Watershed Engineering

Don Lee, Tetra Tech
Jeff Endicott, AEI-CASC Consulting
Albert Martinez, RCFC & WCD
Gene Estrada, City of Orange
Ken Jeske, Ontario, CDA, CBWM
Mike Shetler, County of Riverside
Jason Uhley, RCFC & WCO
Bob Collacott, URS Corp.
Aladdin Masry, ABC Environmental
Janice King, URS
Mark Baker, CONTECH
Vaikko Allen, CONTECH
Claudia Padres, Riverside Co Flood Control
Richard Boon, County of Orange
Blake Anderson, Newport Bay Naturalists & Friends
Mark Grey, BIA/CICWQ
John Kemmerer, US EPA R9
Joe Zoba, Yucaipa VWD
Marsha Westropp, OCWD
Sandy Caldwell, City of Riverside
Jessica Chin, City of Riverside
Alex Waite, City of Tustin
Patrick Bauer, City of Costa Mesa

2. Public Forum

Joe Zoba from Yucaipa Valley Water District described the District's approach to meeting maximum benefit commitments, including improvements to the District's wastewater treatment plant. He said that the District has a brine line that will be connected by 2012. New developments in the District's service area for which septic system use is proposed are required to install dry sewers so that connections to the sewer system can be made in the future. The goal is to reduce the pollution created by septic systems.

Aladdin Masry expressed his concern for the dairy farmers and the environment. He said that by building a prototype farm to recycle waste, dairy farmers can save money. He added that new modern technology is also available to protect the environment and the dairy farmers, and that many States are already using this new technology.

3. State Water Resources Control Board (SWRCB) Liaison Report

Tam Doduc, Chair of the SWRCB, reported on the state-wide draft septic system regulations, the upcoming public hearings and the deadline to submit public comment. Chair Doduc also reported on progress on the recycled water policy.

Tam Doduc encouraged all Board Members to attend the next WQCC workshop scheduled in the spring.

4. Approval of Minutes

Action: It was moved by Member Ruh, seconded by Member Van Gundy, and unanimously approved that the Minutes of September 5, 2008 Board Meeting be approved as presented.

Agenda Update: It was noted that Items No. 6 and No. 10 had been postponed, Items 8A and 8B had been added, and Item 9 had errata.

5. Consideration of Consent Calendar Items

*7. Rescissions – Order No. R8-2008-0097

*8. Amendment of Waste Discharge Requirements for the City of Redlands, California Street Landfill – Order No. R8-2008-0094

Action: It was moved by Member Ruh, seconded by Member Van Gundy, and unanimously approved that the Board adopt Order Nos. R8-2008-0097 and R8-2008-0094 as presented.

8A. Maximum Benefit Update

Mr. Thibeault mentioned that at our last Board Meeting, Board staff and Chino Basin Water Master (CBWM) representatives gave presentations concerning compliance with the maximum benefit requirements for the Chino Basin. He said that the outstanding issue related to the Chino Desalter Authority and Western Municipal Water District (WMWD) had been resolved. The City of Chino Hills has agreed to approve WMWD to join the Chino Desalter Authority. By doing so, the proposal by the CBWM and IEUA will bring them back into compliance. This will keep the process moving, and get the hydraulic control facilities in place faster.

Ken Jeske, City of Ontario, said they are moving forward and are working closely with staff on timelines to complete the hydraulic control projects. He said with today's economy the transfer from prior uses and agriculture to urban uses is not occurring as fast as expected. He said hydraulic control was about managing salt, cleaning up pollution, and protecting down-stream users. He asked the Board for their continued cooperation.

8B. Emergency Resolution Regarding the Use of Class A Biosolids and Green Waste Compost for Erosion Control Applications Within the Areas Burned During the November 2008 Fires in Orange, Riverside and San Bernardino Counties Within the Santa Ana Region – Resolution No. R8-2008-0100

This resolution was prepared in response to the Governor's declaration of emergency.

Mr. Thibeault noted that a comment letter was received from the Integrated Waste Management Board, supporting this emergency resolution. He said the resolution is intended to facilitate rapid implementation of erosion control projects. He told the Board that if changes to the resolution become necessary, the resolution would be brought back to the Board at a future Board meeting. Staff recommended the adoption of this resolution.

Action: It was moved by Member PonTell, seconded by Member Ruh, and unanimously approved that the Board adopt Resolution No. R8-2008-0100.

9. Administrative Civil Liability Complaint, Carson Hall, Jr., Riverside County - Order No. R8-2008-0074

Information concerning this item is contained in a verbatim transcript of the proceedings.

The Board conducted a hearing to receive relevant evidence and testimony regarding Administrative Civil Liability Complaint No. R8-2008-0082 issued to Carson Hall, Jr. The hearing was conducted with a separation of functions. Gerard Thibeault, David Rice and Frances McChesney served as advisory staff to the Board. The parties in the proceeding were the Board Prosecution Staff (David Boyers, Kurt Berchtold, Michael Adackapara, Steve Mayville, and Mary Bartholomew) and Mr. Hall.

Testimony was presented by Ms. Bartholomew and Mr. Hall. Mr. Hall requested that an additional document (a financial statement) be admitted into evidence. The Board decided to admit the document into evidence.

Board Prosecution Staff recommended that the Board adopt Order No. R8-2008-0074 with errata, affirming administrative civil liability in the amount of $20,000. Mr. Rice recommended

that the order be revised under Factor B to reflect Mr. Hall's assertion of financial hardship and submittal of a document to support his claim.

Action: It was moved by Member Ameri, seconded by Member Ruh, and approved (with Member PonTell opposed) that the Board adopt Order No. R8-2008-0074 with errata and incorporating the revision recommended by Mr. Rice, affirming the administrative civil liability of $20,000.

10. Workshop on Clean Water Act Section 305(b) Integrated Report/Clean Water Act Section 303(d) List of Impaired Water bodies
This item was postponed.

11. Public Workshop, Renewal of Waste Discharge Requirements, Orange County Resources and Development Management Department, the County of Orange and Incorporated Cities of Orange County, Areawide Urban Storm Water Runoff Management Program (NPDES No. CA8618030) – Order No. R8-2008-0030

Mark Smythe, Chief of the Coastal Storm Water Section, presented a brief history of the implementation of stormwater regulation via MS4 NPDES permits, which cover Orange, Riverside and San Bernardino Counties. He said the initial focus of NPDES regulation was on sewage treatment plants. He said later the focus shifted toward things like construction site runoff, municipal runoff and industrial site runoff. The focus continued to evolve into new development and redevelopment planning issues, service activities, commercial activities, and public education.

He explained how the Statewide General Construction stormwater permit, the Statewide General Industrial permit and the MS4 permits have been unique compared to all other water quality permits, and how "maximum extent practicable" is implemented through the stormwater permits.

There are major changes that have taken place since the MS4 permit for Orange County was adopted in 2002. TMDLs have been adopted that need to be addressed in the permit. The draft permit also includes new programs that are intended to reduce the amount of pollutants in stormwater inputs to surface waters.

He ended by saying that the draft MS4 permit for Orange County was recently distributed for comment, and that there would be additional workshops and opportunities for comment before a revised draft is presented to the Board for consideration of adoption in May or June of 2009.

Speakers:
Mary Ann Skorpanich, County of Orange
Richard Boon, County of Orange
John Kemmerer, USEPA
Mike Loving, City of Irvine
Michael Yang, City of Irvine
Jason Uhley, RCFC & WCO
Matt Yeager, San Bernardino Co SW Program
Larry McKenney, RBF Consulting
Gene Estrada, City of Orange
Mark Grey, BIA/CICWQ
Vaikko Allen, Contech
Blake Anderson, Newport Bay Naturalists & Friends

12. Regional Board Member and Executive Officer Communications

Chair Beswick announced that Board Members were invited to attend a State of the Santa Ana River Watershed event on 1-29-09 at the Convention Center

13. Appointment of a Committee to Nominate Regional Board Officers for 2009

Board Members Ruh and PonTell were appointed as the committee to Nominate Regional Board Officers for 2009.

14. Proposed Board Meeting Dates for 2009

Board Members discussed a couple of conflicts in the dates proposed for 2009. Modifications were made, and any future conflicts should be addressed to the EO.

15. List of New Enrollees under the General Permits
Information item.

16. Hazardous Waste Incident Report
Information item.

17. Underground Storage Tanks Corrective Action Plans
Information item.

18. Underground Storage Tanks Site Closure Report
Information item.

19. Closed Session

There was no closed session.

20. Adjournment

The meeting was adjourned at 1:30 p.m. to the regular Board meeting of January 23, 2009 at 9:30 a.m., in the City Council Chambers, 25541 Barton Road, Loma Linda, CA.

Respectfully submitted:

GERARD J. THIBEAULT
Executive Officer

/fc

California Regional Water Quality Control Board
Santa Ana Region

Linda S. Adams
Secretary for
Environmental Protection

3737 Main Street, Suite 500, Riverside, California 92501-3348
Phone (951) 782-4130 • FAX (951) 781-6288
www.waterboards.ca.gov/santaana

Arnold Schwarzenegger
Governor

December 22, 2008

TO: The Attached Mailing list

RENEWAL OF WASTE DISCHARGE REQUIREMENTS FOR THE COUNTY OF ORANGE, ORANGE COUNTY FLOOD CONTROL DISTRICT AND THE INCORPORATED CITIES OF ORANGE COUNTY, TENTATIVE ORDER NO. R8-2008-0030, NPDES NO. CAS618030, AREAWIDE URBAN STORM WATER RUNOFF

The above-referenced tentative order was posted on our website and mailed to interested parties on November 10, 2008. A public workshop regarding this item was conducted at the November 21, 2008 Board meeting. In the November 10, 2008 transmittal letter and at the workshop, we had indicated that written comments were due by December 30, 2008. This is to notify you that the comments due date has been extended to January 30, 2009.

The tentative order and related information may be downloaded from:

http://www.waterboards.ca.gov/santaana/water_issues/programs/stormwater/oc_permit.shtml

To be notified of future draft releases, workshops and public hearings, please sign on to our E-mail notification list (select "Storm Water – Orange County Municipal") at: http://www.waterboards.ca.gov/resources/email_subscriptions/reg8_subscribe.shtml

If you have any questions, please call me at (951) 782-3238, Mark Smythe at (951) 782-4998, or Marc Brown at (951) 321-4584.

Sincerely,

Michael J. Adackapara
Division Chief

Critique of Certain Elements of "Low Impact Development Metrics in Stormwater Permitting"

By Richard Horner

GENERAL CONCLUSION

While the authors drew certain negative (and not always well-founded, as explained below) conclusions about a maximum 3-5 percent effective impervious area ("EIA") site design criterion, the results of the report's analysis overall contribute to the growing consensus that implementing LID according to a numeric metric is technically feasible in both new development and redevelopment contexts. The results thus buttress my findings in analyses performed earlier for San Diego and Ventura Counties and for the San Francisco Bay Area (Horner 2006; 2007a, b) and support the feasibility of meeting a 5% EIA standard in southern California. However, the report's suggestion that a "delta volume" standard be adopted would depart from standard and well-accepted practice in the United States, resulting in significantly greater volumes of stormwater with concomitant, significant increases in the mass volume of a range of pollutants in stormwater.

CRITIQUE OF WATER QUALITY TREATMENT DESIGN BASIS

The authors of Low Impact Development Metrics in Stormwater Permitting ("the report") propose and employ in their case studies a quantity they term "excess stormwater runoff," which forms the basis for their sizing and designing of low impact development ("LID") facilities to treat stormwater runoff. In footnote 21 on page 31, the authors have defined "excess stormwater runoff" as the volume of post-development runoff minus pre-development runoff for the 85th percentile storm event (or for an equivalent water quality design event). However, using the differential volume ("delta volume") between pre- and post-development conditions breaks the long-standing national and state precedent of using the full volume of stormwater discharged from the developed site as the basis for stormwater best management practices ("BMPs") that store runoff for longer than a few minutes.

The virtually universal adoption (see examples below) of the full water quality volume instead of the delta volume occurred for good reasons. The total runoff volume from the 85th percentile event—the prevailing design standard in southern California—was determined through objective analysis to represent the point above which substantially diminishing returns in water quality improvement would accompany considerable size enlargement and, therefore, cost (Guo and Urbonas 1996). The analysis identified the *full* volume generated by the 85th percentile event—not some lesser quantity like the delta volume—as the appropriate threshold at which the decrease in benefits accelerates.

The use of a differential hydrologic measure that compares pre- and post-development states is common in the management of storm runoff quantity (i.e., hydromodification). The pre- vs. post-development measure is appropriate in that situation because successfully matching pre-

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and post-development hydrologic characteristics causes no modification in the hydrologic status of the receiving water and, hence, no negative physical effects. When managing water quality, in contrast, any untreated volume (in the delta volume scenario, this would be the amount that originally flowed from the undeveloped land) would deliver to the receiving water the many pollutants characteristic of urban runoff. There, these pollutants would create negative physical, chemical, and biological effects. On the other hand, if the appropriate water quality volume is used (i.e., no less than the full volume of the 85th percentile event), the LID-based stormwater management BMPs should deliver no pollutants to the receiving water, since the retention and reuse or infiltration of that volume is practicable and achievable, as I have demonstrated separately by analyzing a range of development scenarios in southern California.

The loss in treatment capacity from using the delta volume measure, and hence the loss in water quality protection, would vary depending on climatology and the characteristics of the undeveloped parcel and the developed site (type of pervious and impervious land cover, soil, slope, etc.). In the Walnut Village and 60 California case studies presented in the report, the difference ranged from 15 to 20 percent and could be higher in different scenarios. This difference is not small, considering that the National Stormwater Quality Database (Pitt, Maestre, and Morquecho 2004) shows that pollutants like solids, metals, nutrients, and bacteria are typically present in urban runoff at concentrations two to five times as high as in storm flow from undeveloped land. Discharging the pre-development volume, contaminated by urban pollutants without any water quality treatment, would subject human users and aquatic life to substantial runoff quantities with pollutant mass loadings and potentially acutely toxic pollutant concentrations. These loadings and concentrations would be increased by factors of approximately two to five, compared to the pre-development state, thus compromising the beneficial uses of the water body that existed before development. It is essential for resource protection that the full post-development volume be retained onsite through infiltration, evapotranspiration, and/or harvesting for reuse.

As pointed out above, adopting a volumetric basis for stormwater treatment design and then subjecting that full volume to onsite retention or treatment has been the rule in the United States. Jurisdictions take differing approaches to defining that volume, but, once it is set, they utilize the entire quantity as the basis for BMP design. Common approaches include the storm percentile method: a storm event of selected frequency and duration is chosen, which correlates to a certain depth of precipitation spread over a watershed area. In addition to southern California, Georgia provides an example of the first approach (http://www.georgiastormwater.com/vol2/1-3.pdf at 1.3-1):

> Treat the runoff from 85% of the storms that occur in an average year. For Georgia, this equates to providing water quality treatment for the runoff resulting from a rainfall depth of 1.2 inches.

The state of Washington employs a second approach, actually in relation to a storm percentile analysis (http://www.ecy.wa.gov/pubs/0510029.pdf at 2-28):

> Water Quality Design Storm Volume: The volume of runoff predicted from a 24-hour storm with a 6-month return frequency (a.k.a., 6-month, 24-hour storm). Wetpool

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> facilities are sized based upon the volume of runoff predicted through use of the Natural Resource Conservation Service curve number equations in Chapter 2 of Volume III, for the 6-month, 24-hour storm. Alternatively, the 91st percentile, 24-hour runoff volume indicated by an approved continuous runoff model may be used.

Numerous jurisdictions, such as Maine, use the precipitation depth approach (http://www.maine.gov/dep/blwq/docstand/stormwater/stormwaterbmps/vol3/chapter2.pdf at 2-12):

> Stormwater management facilities must be designed to treat the first 1 inch of runoff ...

Maryland (http://www.mde.state.md.us/assets/document/chapter2.pdf at 2.1):

> P= rainfall depth in inches and is equal to 1.0" in the Eastern Rainfall Zone and 0.9" in the Western Rainfall Zone ...

Pennsylvania (http://www.depweb.state.pa.us/watershedmgmt/cwp/view.asp?a=1437&q=529063&watershedmgmtNav=| at 3.3.4):

- Stormwater facilities shall be sized to capture at least the first two inches (2") of runoff from all contributing impervious surfaces.
- At least the first one inch (1.0") of runoff from new impervious surfaces shall be permanently removed from the runoff flow – i.e., it shall not be released into the surface Waters of this Commonwealth. Removal options include reuse, evaporation, transpiration, and infiltration.

and North Carolina (http://h2o.enr.state.nc.us/su/documents/BMPManual_WholeDocument_CoverRevisedDec2007.pdf at 2-2):

> Non-coastal counties: Control and treat the first 1.0" of rain. (Note: a more complex basis applies to coastal counties.)

In none of these cases does the stormwater treatment design basis involve a delta volume computation such as advocated by the authors of the report.

CRITIQUE OF CASE STUDIES

Even though the report forthrightly demonstrates technical feasibility, it nonetheless takes a somewhat negative stance by overemphasizing difficulties and high costs, both of which are poorly justified. The report, moreover, is devoid of estimates of the benefits that accrue from reducing the discharge of pollutants to receiving waters, recharging groundwater through infiltration, conserving water through harvesting and reuse, and decreasing hydromodification of

receiving waters. I made such estimates in my previous reports, and these benefits are very significant. For example, I concluded that (Horner 2007a):

> Draining impervious surfaces onto the loam soils typical of Ventura County, in connection with limiting directly connected impervious area to three percent of the site total area, should eliminate storm runoff from some development types and greatly reduce it from more highly impervious types. Adding roof runoff elimination to the LID approach (by harvesting or directing it to downspout infiltration trenches) should eliminate runoff from all but mostly impervious developments. Even in the development scenario involving the highest relative proportion of impervious surface, losses of rainfall capture for beneficial uses could be reduced from more than 85 to less than 40 percent, and pollutant mass loadings would fall by 83-95 percent from the untreated scenario when draining to pervious areas was supplemented with water harvesting.

Failure to include a discussion of such important benefits inappropriately biases the report against feasible LID numeric performance standards such as an EIA limitation. There is a somewhat grudging admission that LID based on an EIA limitation can be implemented, but this is countered with assertions that doing so will take some extra work and cost too much. Both of these negative claims should not be given much weight for the reasons stated below. Furthermore, neglecting the aforementioned very real and important benefits of robust LID implementation omits the counterbalancing consideration that the aquatic environment will be better protected with an improved site design paradigm.

Additionally, the report fails to take into account two aspects of LID that are at least relatively cost-neutral or, in many configurations, even cost-saving. First, landscaping is a normal part of developed and redeveloped sites and can serve stormwater management purposes, as well as aesthetic purposes, with little or no extra cost. Second, most LID practices primarily utilize soft infrastructure instead of more expensive hard infrastructure like extensive piping and concrete. While the cost analyses presented in the report were poorly detailed in the first place, as discussed in greater depth below, it appears that these financially mitigating factors were not even considered.

Walnut Village

The report's presentation of the multi-family residential Walnut Village redevelopment project reflects the general criticisms noted above. It demonstrates the technical feasibility of implementing LID practices according to an EIA limitation (in fact, the authors achieved an EIA of zero), stating, "this result ... illustrates that LID benefits can be achieved by both extensive implementation (i.e., routing of runoff to vegetated systems) and more intensive design of active landscaping (i.e., greater retention depth) where opportunities exist."

Nevertheless, the authors put a negative spin—unjustified, in my opinion—on this success. In one negative passage the report declares, "the 14-17 inches of retention required to capture the delta 2-year volume is much less feasible, as it would require a combination of fairly deep amended soils and significant surface storage." I contend that providing 14-17 inches of storage in surface ponding and soil pores is entirely feasible. For instance, 18 inches of amended soils

with 33 percent porosity would provide 6 inches of storage, which could be supplemented by 8-11 inches of above-grounded temporarily ponded volume, a thoroughly feasible design. Elsewhere, the report characterizes decreasing EIA from 18 to 0 percent as "difficult," although this decrease merely involves converting non-essential hardscape to landscaping. The reader is left to wonder why any developer would choose to buy and install *non-essential* asphalt or concrete (almost certainly more expensive than LID landscaping) rather than constructing vegetated BMPs that would be an asset in more ways than one. In my opinion, it is more "difficult" from fiscal and marketing perspectives to justify the use of pavement for no reason. In any case, whatever impression one has of this issue, from a technical, objective perspective, the report does not contain a reasonably complete and even-handed assessment of costs, significantly undercutting its claims of infeasibility. Likewise, subjective and undefined assertions regarding the "difficulty" of meeting even relatively high volumes (such as the two-year storm) are presented without supporting analysis or justification which, once again, limits the utility of the report.

Further, with regard to landscaping, the final sentence in the case study states, "landscape plans typically include features that restrict usage of landscaping for runoff control (e.g., tree choice can limit inundation depths and duration), therefore, it is unreasonable to assume that all landscaping may be available." There is no reason why landscaping plans should be incompatible with vegetative LID practices, however. Bioretention cells and similar LID features routinely include trees, which serve several important hydrologic roles (rainfall interception, advancing infiltration by opening conveyance pathways through soil, water storage in tissues, and transpiration). It is no challenge for landscape designers to select trees that are not limited by moisture conditions in such BMPs.

The Walnut Village site has hydrologic group B soils, to which the authors assigned an infiltration rate of 0.2 inch/hour, assuming that the soils would be "compacted". They thereby ignore a fundamental LID practice: guarding against the removal and compaction of soils outside the active building area during construction (Hinman 2005). While infiltration rates vary depending on the specific soil type within a hydrologic soil group, B soils overall have rates much above the authors' assumption; i.e., 0.5-1 inch/hour (http://www.vcstormwater.org/documents/workproducts/landuseguidelines/appC.pdf). The National Resource Conservation Service (2007) observes that, "Soils that are deeper than 100 centimeters [40 inches] to a water impermeable layer or water table are in Group B if the saturated hydraulic conductivity of all soil layers within 100 centimeters [40 inches] of the surface exceeds 4.0 micrometers per second (0.57 inches per hour) but is less than 10.0 micrometers per second (1.42 inches per hour)." It would be irresponsible building practice anywhere, and certainly in a development that is implementing LID practices, to permit such indiscriminant soil disturbance that across the landscape the infiltration rate is decreased to as little as 15 percent of its natural magnitude.

The infiltration rate assumption has consequences for the analysis and the authors' interpretation of their results. While the report shows that adequate volume attenuation could be accomplished to meet the case study's stated objectives, with the 0.2 inch/hour infiltration rate, active landscaping drain times could exceed the recommended 72-hour maximum and approach 83 hours. If the infiltration rate were just slightly higher at 0.3 inch/hour, though, drawdown would

occur 50 percent faster and easily lower the drain time beneath the maximum. Avoiding the drastic diminution in hydraulic conductivity that the authors have assumed is eminently achievable on the site's B soils and would produce an even more optimistic picture than the already successful Walnut Village hypothetical design.

The authors observe that imposing a fixed EIA standard alone promotes the routing of runoff to vegetated systems but does not boost the companion strategy of pursuing more intensive design of active landscaping. In so doing, the authors provide a valuable service in pointing out that a design basis must accompany the EIA limitation for real effectiveness. An example of such a comprehensive standard is:

> Limit effective impervious area to 3 percent. Impervious surfaces can qualify as "ineffective" only when the entire volume of runoff (based on the design storm) from those areas is captured onsite through infiltration, evapotranspiration, and/or harvesting for beneficial use. In the rare circumstance in which onsite compliance is infeasible according to established criteria, the permittee or developer shall identify opportunities for off-site mitigation in the same sub-watershed that will achieve the overall goal of reducing effective impervious area to no more than the 3 percent design standard.

60 California

Like the Walnut Village case study, the authors' presentation of the 60 California multi-use commercial/retail redevelopment project also tends in an overall manner to support my own analyses and conclusions regarding the practicability of meeting the 5% EIA standard. This case study, too, demonstrates the technical feasibility of meeting a maximum 5 percent EIA standard, in this case by employing a green roof and water harvesting on a highly constrained site. Once again, though, the authors put forth some negative interpretations that are, in my opinion, unjustified.

One such claim is that green roofs and cisterns are generally beyond the level of BMP implementation in common practice in the United States nowadays. In fact, both practices are no longer at all unusual. Without attempting any comprehensive literature review of applications, I would note that Chicago has numerous green roofs in place, most prominently on its city hall (http://www.artic.edu/webspaces/greeninitiatives/greenroofs/main_map.htm). In Seattle, green roofs top a growing number of public and private buildings (http://www.seattle.gov/DPD/GreenBuilding/OurProgram/Resources/TechnicalBriefs/DPDS_009485.asp#case). Seattle's city hall also harvests rain for graywater supply and irrigation, as does the county administration building and a neighborhood environmental education center (http://www.harvesth2o.com/seattle.shtml). The Texas Water Development Board (2005) prepared an excellent, practical manual on water harvesting at all scales, complete with examples in place and design calculations. The manual covers the entire state of Texas, whose western areas have rainfall conditions very much like southern California's. Hence, little adaptation is needed to use the manual's recommendations here.

The report also claims that the suitability of green roofs for southern California is not well understood and that, "during the rainiest times of the year in southern California, the potential

evapotranspiration is the lowest, meaning that the ability to regenerate storage capacity between storms is low." It is true that the potential is lowest during the wettest season, but, given the frequent sun and relative warmth during dry intervals in the southern California winter, the regenerative ability is still not "low." Berghage et al. (2007) performed green roof research at Pennsylvania State University (PSU). They found that over 50 percent of annual stormwater volume was retained and not discharged, even with as little as 20 mm (under 1 inch) of storage capacity, and the site reduced peak discharge rates to no more than the pre-development level for the 2-, 25-, and 100-year frequency events. PSU is located in Centre County, PA, where precipitation is not highly seasonal but tends to be slightly greater in the summer, compared to other months. Pan evaporation rates there range from 3.3 to 4.2 inches/month during June-September (http://www.pa.nrcs.usda.gov/technical/Engineering/PaRainEvapRunoff.pdf). The November-February Los Angeles pan evaporation range is 3.5 to 4.0 inches (http://www.calclim.dri.edu/ccda/comparative/avgpan.html). Therefore, Los Angeles has as much evaporation potential in the months when it most needs that potential as locations with successful green roofs elsewhere. Similar research should be performed in California, but enough encouraging evidence exists to begin establishing full-scale projects, which can be monitored to confirm performance and refine design guidance for the region.

A final negative point made by the report is that green roofs and water harvesting may conflict with existing building and health codes. Codes should not be regarded as an unbending constraint on moving to new, more environmentally beneficial technologies. As experience in the growing number of applications of both practices shows, building safety and health are not being compromised. If constraints do exist in a jurisdiction's codes, they should be examined to assess their justification and revised if no overriding reasons exist to maintain them. Indeed, it is my understanding that municipal separate storm sewer permits often if not always require that local codes be amended to support implementation of programs and approaches to reduce stormwater pollution.

Redevelopment of Kmart Site

The Kmart site redevelopment case study was based on the use of vegetated filter strips and infiltration trenches. Its primary purpose was to estimate costs for these practices by apparently taking a challenging site with relatively poor soils. As an initial manner, the decision to evaluate only one site to reach a conclusion about costs of LID practices is suspect. This is particularly the case when, as here, the report's conclusions tend to contradict mainstream evaluations of the cost of implementing LID. Such studies, including an analysis of several projects by the U.S. Environmental Protection Agency, report significant cost savings compared to traditional water quality approaches across the vast majority of building sites.

More specifically, there are several flaws in the foundation of this case study. The authors developed estimates of runoff volume in pre-development and post-development conditions by using the Natural Resources Conservation Service's Curve Number Method, which is well-known to overestimate the pre-development hydrologic characteristics and thus set the wrong targets for post-construction designs. The site has hydrologic group C soils. The authors performed calculations assuming an infiltration rate of 0.5 inch/hour, higher than the rate used for B soils in the Walnut Village case study (an unexplained discrepancy). There appears to

have been no consideration of organically amending soils to increase water storage and improve infiltration. Soil amendment for these purposes is a very common LID practice, especially in group C soils. The authors appear to have given some thought to other LID practices (tree boxes, bioretention, pervious pavement, green roofs, and water harvesting) but rejected all of them for unexplained reasons. Failure to use a broader pallet of alternatives and soil amendment indicates that the case study may not have been based on the most technically effective and/or cost-effective choices.

This case study fails to convincingly meet its objective of demonstrating what the LID designs would cost, in large part because the authors give no detail whatsoever regarding how the cost figures were derived. The per-acre and percentage-of-redevelopment costs are simply not credible unless their derivation can be traced and confirmed. The cost analysis also suffers from the general criticisms stated above regarding costs: it implicitly assigns all landscaping costs to the filter strips, although these areas would be landscaped anyway at roughly the same cost; the analysis further fails to recognize that stormwater runoff must be conveyed and managed in some way, and those obligations carry costs, which are probably higher if performed conventionally through the use of large quantities of piping and concrete. With these shortcomings in analysis, it is assuredly not justified to say, as the case study conclusions do, that, "[i]t is clear from the Kmart case study cost estimates that the proposed draft permit requirements would significantly increase the drainage costs of urban redevelopment projects." And although more difficult to monetize, environmental benefits—and their economic value to society—are entirely neglected in this case study, as in the others.

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SARB_003654

CITY OF FULLERTON

Engineering Department

January 20, 2009

Gerard Thibeault
Executive Officer
California Regional Water Quality Control Board, Santa Ana Region
3737 Main Street, Suite 500
Riverside, CA 92501-3348

Subject: Comment Letter – Draft Order No. R8-2008-0030 NPDES No. CAS618030

Dear Mr. Thibault:

The City of Fullerton is in receipt of the November 10, 2008, *Waste Discharge Requirements for the County of Orange, Orange County Resources and Development Management Department and the Incorporated Cities of Orange County Within the Santa Ana Region Areawide Urban Storm Water Runoff Orange County* (Draft Order No. R8-2008-0030). The City of Fullerton, as a Co-Permittee, welcomes the opportunity to provide comments on the Regional Water Quality Control Board's (RWQCB) Draft Order as prepared and distributed by Regional Board staff.

The Orange County Stormwater Program (the "Orange County Program" or "Program") has been in existence under a National Pollutant Discharge Elimination System (NPDES) permit since 1990. This permit was re-issued in 1996 and 2002. In 2006, the Co-Permittees submitted a Report of Waste Discharge (ROWD) in anticipation of permit renewal in 2007. The basis of this document was a comprehensive program assessment undertaken using a multiple lines of evidence approach, including audit findings, facilitated workshops, and the California Stormwater Quality Association (CASQA) Program Effectiveness Guidance. The ROWD identified many positive program outcomes and, where the assessments indicated the need for improvement, proposed changes and added program development commitments to the Drainage Area Management Plan (DAMP).

In the ROWD and proposed 2007 DAMP, the City of Fullerton committed to enhancing program implementation, developing BMPs for identified Countywide water quality constituents of concern, and establishing a watershed-based approach to water quality planning and protection to complement the Countywide management effort. While the draft Tentative Order is clearly responsive to the recommendations made in the ROWD, the City is concerned regarding proposed new requirements intended to increase the City's accountability, extend the City's regulatory reach, incorporate additional TMDLs, and create a new basis for the land development requirements of the Order. This concern is now being significantly amplified by the worsening condition of the economy.

GENERAL COMMENTS

I. Increasing Administrative Burden

At the inception of the Program the County of Orange, as Principal Permittee, and the 26 Co-Permittees developed a DAMP to serve as the principal policy and programmatic guidance document for the Program. Since 1993, the DAMP has been modified through an adaptive

management process to reflect the needs of the Co-Permittees, ensure Co-Permittee accountability, and deliver positive water quality and environmental outcomes. The DAMP now provides definitive guidance to the City of Fullerton and each Co-Permittee in the development of each jurisdiction's respective Local Implementation Plan (LIP), which specifically describes how the Program will be implemented on a city/jurisdiction basis. Concurrently, the annual progress report has been developed into a rigorous systematic assessment of program effectiveness that is conducted at jurisdictional, watershed, and countywide levels of resolution, using CASQA program effectiveness assessment guidance, and with identified headline measures of programmatic performance. The Draft Tentative Order requires additional reporting to the Regional Board staff. The City believes that adjusting the existing reporting processes, rather than creating additional reporting requirements, is the most effective approach to increasing transparency and accountability. Such an approach also offers the additional potential benefit of identifying opportunities to reduce rather than increase the administrative burden of the Program for both the RWQCB and for the Co-Permittees.

II. Extending the Regulatory Reach of Local Jurisdictions

In the most recent Annual Report the City noted that 498 industrial and commercial facilities in the City of Fullerton were subject to inspection for compliance with the water quality ordinance. Nonetheless, the Draft Tentative Order includes new requirements that significantly increase the universe of commercial facilities subject to inspection, mandates the annual inspection of treatment controls in completed land development and re-development projects, and more prescriptively turns the attention of the City toward residences and mobile businesses. The overarching concerns here are the significant resource implication for the City and the absence of technical justifications.

The Co-Permittees, in the detailed program assessment that preceded the ROWD, did not discern a rationale for a more inclusive inspection of commercial enterprise, nor is one presented in the Findings of the Tentative Order. With land development projects, the installation and subsequent maintenance of treatment controls certainly needs to be verified. However, self certification is already a verification mechanism being used by Co-Permittees and it and other third party verification mechanisms should not be precluded by the Order in exclusive favor of Co-Permittee inspection. The current opportunity to strategically re-consider the use of inspection resources should be used to target and focus these activities rather than simply expand their scope. Furthermore, given the current state of the economy, the City, like all municipalities, is facing shrinking budgets and the Regional Board should give great weight to the best use of limited resources in achieving water quality objectives.

The prescribed creation of a residential program also needs to be carefully considered. The effectiveness of Project Pollution Prevention, the public education and outreach initiative of the Program, has been validated by public opinion surveys that show incremental, but also statistically significant, increases in public awareness of stormwater issues and positive changes in protective behaviors. The new residential program requirements therefore appear duplicative of the current public education and outreach obligations that have already produced, and continue to yield, positive measurable outcomes. However, there is also a separate concern that prescribed efforts to "require residents to implement pollution prevention measures" (XI. 2) will be counter-productive and quickly erode general public support for the Program. The justification for this additional program when current requirements have produced positive outcomes needs to be provided to the Co-Permittees in the Draft Tentative Order.

The last area of prescribed new regulatory oversight is mobile businesses. The Co-Permittees have already produced educational materials for these businesses, cooperatively developed wash water disposal options with Orange County's sewer agencies, and coordinated on enforcement. The further required regulation of these businesses is a potentially resource intensive undertaking that currently appears to lack a strong technical rationale.

III. Creating a New Basis for the Land Development Requirements of the Order.

The Model Water Quality Management Plan prepared for the Third Term Permit explicitly recognizes the channel stability implications of watershed urbanization and provides for this potential impact to be addressed as a hydrologic condition of concern. The commitment made in the ROWD was to adjust the Model WQMP based on work being undertaken on this issue by the Southern California Coastal Water Research Project which is still pending. Since that time, an Effective Impervious Area of 5% or less has appeared as a performance standard for land development in the Draft Ventura Permit and in the Draft Tentative Order. This new requirement for land development is inappropriately establishing a watershed assessment metric as a site specific performance standard. It is also establishing an unreliable surrogate for flow reduction (see case study discussion in Attachment B of County of Orange Comment Letter, January, 2009) as the basis for conformance with the stormwater mandate. The City believes that although this standard may be appropriate in regions where there is the potential of large new developments, the Santa Ana region, specifically the City of Fullerton, is an urbanized area that has little new development, but rather significant in-fill or redevelopment projects. These areas are subject to various development standards that encourage high-density development and a 5% or less effective impervious area may not be feasible or appropriate in certain situations. The City believes there is no compelling technical justification that can be made for this requirement and would instead look to the original ROWD commitment regarding land development as the starting point for considering any adjustment to the existing land development element of the Program. The City also suggests that many of the various other approaches that provide proven results in reducing flow be considered as part of this Draft Tentative Order.

IV. Using Available Programmatic Performance and Environmental Quality Data

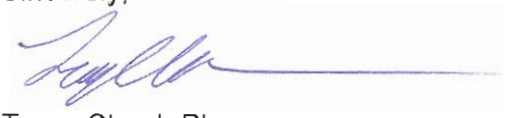
In advance of preparing the ROWD the Co-Permittees undertook a detailed program assessment drawing upon prior annual report findings, a comprehensive environmental quality database, audit findings, facilitated workshops, and the California Stormwater Quality Association (CASQA) Program Effectiveness Guidance. This assessment provided a strong technical basis for the further improvements to the Program recommended in the ROWD and which have been subsequently validated in later annual progress reports. These informational resources and, in particular, the environmental quality database, have been compiled at great expense and provide unique and site specific information on the state of Orange County's surface waters and the performance of the Orange County Stormwater Program. To the extent that the Draft Tentative Order prescribes requirements supplemental to the ROWD recommendations, they need to be explicitly supported by a strong technical justification that is developed from the information that has been compiled over the last 18 years by the Co-Permittees. New requirements also need to be consistent with the federal stormwater regulations and within the scope of the Clean Water Act. The Draft Tentative Order has attempted to step outside the scope of the authority provided by the Clean Water Act by including the regulation of non-point sources. The City believes that these sections of the Draft Tentative Order should be revised to be in compliance with the appropriate federal laws.

In addition to these comments, the City supports the County of Orange, Public Works – Environmental Resources comment letter (January, 2009). The County's letter provides comments that are relevant to all Co-Permittees and some similar concerns, directly affecting the City of Fullerton, are addressed in this comment letter.

We appreciate the effort that you and the Regional Board staff have devoted to the development of the fourth term permit for the Orange County Stormwater Program. We look forward to meeting with you and the staff to quickly resolve the City's concerns regarding the Draft Tentative Order to ensure that it meets our mutual goals.

Thank you for your attention to our comments. Please direct any questions to Trung Chanh Phan 714-738-5333.

Sincerely,



Trung Chanh Phan
Stormwater/Wasterwater Compliance Specialist

cc: COF NPDES Program Leads, OC - RB

File: OC Co-Permittee Program

California Regional Water Quality Control Board
Santa Ana Region

Linda S. Adams
Secretary for
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Arnold Schwarzenegger
Governor

January 22, 2009

TO: The Attached Mailing list

RENEWAL OF WASTE DISCHARGE REQUIREMENTS FOR THE COUNTY OF ORANGE, ORANGE COUNTY FLOOD CONTROL DISTRICT AND THE INCORPORATED CITIES OF ORANGE COUNTY, TENTATIVE ORDER NO. R8-2008-0030, NPDES NO. CAS618030, AREAWIDE URBAN STORM WATER RUNOFF

The above-referenced tentative order was posted on our website and mailed to interested parties on November 10, 2008. A public workshop regarding this item was conducted at the November 21, 2008 Board meeting. In the November 10, 2008 transmittal letter and at the workshop, we had indicated that written comments were due by December 30, 2008. A subsequent announcement, on December 22, 2008 had extended the deadline for comments to January 30, 2009. This is to notify you that the comments due date has been further extended to a final deadline of February 13, 2009.

The tentative order and related information may be downloaded from:

http://www.waterboards.ca.gov/santaana/water_issues/programs/stormwater/oc_permit.shtml

To be notified of future draft releases, workshops and public hearings, please sign on to our E-mail notification list (select "Storm Water – Orange County Municipal") at: http://www.waterboards.ca.gov/resources/email_subscriptions/reg8_subscribe.shtml

If you have any questions, please call me at (951) 782-3238, Mark Smythe at (951) 782-4998, or Marc Brown at (951) 321-4584.

Sincerely,

Michael J. Adackapara
Division Chief

City of Westminster

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(714) 898-3311

CRWQCB - REGION 8
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MARGIE L. RICE
MAYOR

TRI TA
MAYOR PRO TEM

FRANK G. FRY
COUNCIL MEMBER

ANDY QUACH
COUNCIL MEMBER

TRUONG DIEP
COUNCIL MEMBER

RAMON SILVER
CITY MANAGER

January 26, 2009

FEB 13 2009

California Regional Water Quality Control Board, Santa Ana Region
Attn: Gerard Thibeault, Executive Officer
3737 Main Street, Suite 500
Riverside, CA. 92501

Re. Tentative Order No. R8-2008-0030 NPDES No. CAS 618030

Dear Mr. Thibault:

City of Westminster welcomes the chance to provide comments to the Regional Water Quality Control Board's Tentative Order No. R8-2008-0030, dated November 10, 2008.

In general, the City is mostly concerned with the increase in administrative burden. The draft permit is imposing many new requirements upon the permitees when we are in a time of economic hardship. At a time where there is a budget restriction and hiring freeze, it is difficult for permitees to meet some of the new demands listed in the draft permit that requires more frequent inspections or report submissions.

The City of Westminster is in support of the comments prepared by the County of Orange in regards to the subject matter. In addition, we have the following specific concerns in regards to the draft permit:

Section III.3 – The proposed language implies that permitted categories of discharges are assumed to be in violation until permitees have determined them to be in compliance, while the current permit assumed the discharges to be in compliance until permitees have determined them to be in violation. City believes that the tone of the current permit should be kept.

Section X.2 – Ranking for commercial sites should be risk based instead of a mandatory curve based (10% high 40% med.)

Section X.3 – For commercial inspection, photographic documentations should only be required in cases of violations similar to that of the industrial inspection (section IX.3).

Section IX.6 & X.5 – Please clarify if the Board is asking for the submittal of only an inventory list with the annual report or the actual electronic database with all inspection data and pictures.

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Section XII.B.3 – Please provide a better definition or examples of Effective Impervious Area.

We appreciate the opportunity to bring our comments and concerns to the Regional Board for consideration. If you have any questions, please call me at (714) 898-3311, ext. 446.

Sincerely,

Daniel Hsieh,
Associate Civil Engineer

SARB_003661

City of Brea

CRWQCB - REGION 8
MS
FEB 03 2009

January 30, 2009

Gerard Thibeault
Executive Officer
California Regional Water Quality Control Board, Santa Ana Region
3737 Main Street, Suite 500
Riverside, CA 92501-3348

Subject: Comment Letter – Draft Order No. R8-2008-0030 NPDES No. CAS618030

Dear Mr. Thibeault:

We appreciate the opportunity to provide comments on the Santa Ana Regional Board's Draft Order No. R8-2008-0030, as distributed in November 2008. The draft Tentative Order is indeed reflective of the recommendations made in the Report of Waste Discharge (ROWD), submitted by the principal Permittee and Co-permittees of North Orange County. However, there are several concerns that the City of Brea would like to emphasize with the new requirements proposed by the draft Tentative Order, in particular, where costs to implement such requirements would be prohibitive to meet substantial compliance with the draft Tentative Order. In addition to our concurrence with the comment letter submitted by the County of Orange, the City of Brea would like to submit these additional comments for your consideration.

Comment #1: Increased administrative burden from reporting requirements.
The City of Brea echoes the County's comments regarding the increasing administrative burden on Co-permittees with the new requirements in the draft Tentative Order. Like other Co-permittees over the years, fiscal expenditure on the City's Storm Water NPDES program has steadily increased 33%. Coupled with the current economic climate, the lack of development fees to supplement City budgets along with state-wide budget cuts and hiring freezes, the increase in administrative requirements proposed by the draft Tentative Order may place a prohibitive strain on cities to meet compliance objectives or compromise the goal of improving water quality.

The information submittals required in Section IX.6 and X.5, in particular, may prove to be a resource-intensive endeavor. During the past fiscal year, the City invested money and resources in the development of an electronic database to track and record information for the New Development Program, Existing Development Program, Construction Program, ID/IC Program, and the Municipal Program. To incorporate and maintain the functions outlined in the draft Tentative Order to those databases may prove to be resource-intensive. Furthermore, to require Co-permittees provide their databases to the Regional Board may prove to be logistically difficult, as each Co-permittee may be relying upon different software

City Council John Beauman Mayor | Ron Garcia Mayor Pro Tem | Roy Moore Councilmember | Don Schweitzer Councilmember | Marty Simonoff Councilmember

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programs (or proprietary software), which may or may not be compatible to Regional Board systems. To convert such systems for compatibility may require significant costs to the Permittee.

Comment #2: Unwarranted addition of commercial facility categories for the commercial inspection program.

In Section X.1 of the draft Tentative Order, 11 new categories of commercial facilities are subject to municipal inspections. No justification is provided by the Findings of the Tentative Order that support these 11 commercial categories as posing a significant water quality threat to the MS4, thereby warranting their listing. The City currently has 316 commercial facilities in its inventory, with 3 dedicated Authorized Inspectors to perform industrial/commercial inspections in addition to their primary field services duties. To add 11 new categories of facilities to inspect, without any justification demonstrating them as significant non-point source polluters, will place a significant and unwarranted strain on City resources for an unknown water quality benefit, if any.

As with other Co-permittees, the City regularly trains its staff/Authorized Inspectors on municipal inspections of commercial facilities per the requirements of the current term MS4 Permit. Authorized Inspectors are, therefore, equipped with the skills to adequately identify problematic commercial facilities during their daily field activities. When such facilities are inspected and determined as a water quality threat, they are added to the commercial inventory. Facilities are routinely added to the commercial program, as well as the industrial program, in such a manner. For these reasons, arbitrarily adding 11 new facility categories to the commercial program are, in our opinion, unnecessary and fiscally burdensome. Until such categories are determined to pose significant water quality threats, they should not be included in the draft Tentative Order.

Comment #3: Applying minimum percentages for high, medium, and low priority commercial facilities trivializes the prioritization process.

The new requirement to have 10% of commercial sites ranked "high", 40% ranked "medium", and the rest of the commercial inventory ranked low, as stated in X.2 of the draft tentative order is unfounded. The Findings do not provide any basis for these minimum criteria. By doing so, it trivializes the process of ranking commercial facilities, which should be based solely on their water quality threat. If a facility is ranked "low" based on the listed factors evaluated, it should be deemed as such. Furthermore, setting this minimum percentage penalizes Co-permittees with a low population of commercial facilities with "high" pollution potential by imposing unwarranted inspections. This would further strain that city's resources. This requirement should be removed from the Tentative Order.

Comment #4: The Residential Program proposed in Section XI is redundant and conflicts with the Public Education/Outreach approach established in the current MS4 permit term.

The City agrees with the sentiments expressed in the County's comments regarding the proposed Residential Program in the draft Tentative Order. The obligation to require residents to implement BMPs to mitigate polluted storm water runoff discharges is contrary to the Public Education and Outreach program which strives to engender environmental stewardship and to affect the public through behavior change. The City supports a Residential Program component to the draft Tentative Order, but recommends the program be driven or measured through behavior change and awareness, and not through requirements for BMP implementation.

Comment #5: LID requirements for 5% Effective Impervious Area are not justified in the Proposed Permit and may discourage infill and redevelopment opportunities.

The City supports the principal Permittee's comments on the 5% EIA requirements in the draft Permit. In addition, the City would like to reiterate that the 5% EIA requirements inappropriately takes a watershed assessment tool and applies it to site-specific projects. Justification for this application is not provided and does not ensure the protection of water quality but significantly encroaches upon the municipality's land use discretion authority. The City recognizes this requirement may be appropriate for new master planned communities but is not as appropriate for a city such as Brea where it is largely built out. For the City of Brea, there is a significantly higher potential for higher density in-fill or redevelopment projects that can be developed in a much more sustainable way that reduces the carbon footprint of the site. Encouraging sustainable redevelopment within the City is an important objective of the City and is consistent with other land use regulations such as AB 375. EIA requirements on high-density developments may not be feasible or appropriate in certain situations and may discourage redevelopment projects.

Respectfully Submitted,

John Beauman
Mayor

cc: Brea City Council
Tim O'Donnell, City Manager
Charles View, Development Services Director

CITY OF COSTA MESA

P.O. BOX 1200 • 77 FAIR DRIVE • CALIFORNIA 92628-1200

FROM THE DEPARTMENT OF PUBLIC SERVICES/ENGINEERING DIVISION

CRWQCB - REGION 8
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January 30, 2009

Gerard Thibeault
Executive Officer
California Regional Water Quality Control Board, Santa Ana Region
3737 Main Street, Suite 500
Riverside, California 92501-3348

SUBJECT: **Draft Order No. R8-2008-0030 NPDES No. CAS618030 Comment Letter**

Dear Mr. Thibeault:

The City of Costa Mesa appreciates the opportunity to provide comments on the Regional Water Quality Control Board's (RWQCB) Draft Order as prepared and distributed by Regional Board staff. The City is looking forward to working with your staff, the principal permittee (County of Orange), fellow co-permittees, and other stakeholders, to develop a program that will insure continued improvements to surface water quality. Now, more than ever in these challenging economic times, the City appreciates and recognizes the benefits of collaborating with other agencies to continue protecting our surface waters.

The Orange County Stormwater Program has been in existence under a National Pollutant Discharge Elimination System (NPDES) permit since 1990. Since then, the City of Costa Mesa has been a copermittee along with 33 other cities in the County of Orange. This permit was re-issued in 1996 and 2002. In 2006, the City of Costa Mesa contributed to and supported the County's submittal of a Report of Waste Discharge (ROWD) in anticipation of permit renewal in 2007. The ROWD identified many positive program outcomes and added program development commitments to the Drainage Area Management Plan (DAMP) and subsequently into the City's Local Implementation Plan (LIP).

The City recognizes the acknowledgement by the Regional Board of the iterative management approach to comply with receiving water limitations. There have been discussions of implementing Municipal Action Limits (MALs) in other permits in the Southern California area. The City continues to support compliance with water quality objectives through the iterative approach. While the draft Tentative Order is clearly responsive to the recommendations made in the ROWD, the City is concerned with the proposed new requirements intended to increase the City's accountability, extend the regulatory reach of its

jurisdiction, incorporate additional Total Maximum Daily Loads (TMDLs), and create a new basis for the land development requirements of the Order. This concern is now intensified due to the current economic conditions.

The City looks forward to continuing its partnership with the County as principal permittee. We feel this continues to be the most economically feasible and effective method of implementing and complying with the Order, while achieving the most benefit to surface waters of the United States.

The following are the City's main concerns with the draft Tentative Order:

I. Increasing Administrative Burden

At the inception of the Program, the City supported development of a Drainage Area Management Plan (DAMP) to serve as the principal policy and programmatic guidance document for the program. Since 1993, the DAMP has been modified through an adaptive management process to ensure the City's accountability, and delivery of positive water quality and environmental outcomes. The DAMP now provides definitive guidance in the development of our City specific Local Implementation Plan (LIP) which specifically describes how the Program will be implemented at a local level. Additionally, the annual progress report spells out California Stormwater Quality Association (CASQA) program effectiveness assessment guidance which includes program performance metrics. The Draft Tentative Order requires additional reporting to the Regional Board staff. The City believes that modifying the existing reporting processes, rather than creating additional reporting requirements, is the most effective approach to increasing transparency and accountability. Such an approach also offers the additional benefit of identifying opportunities to reduce rather than increase the administrative burden of the Program for both the RWQCB and the City.

II. Expanded Regulatory Reach

In the most recent Annual Report prepared by the City, over 1000 industrial and commercial facilities were identified which are subject to inspection for compliance with local water quality ordinances. Nonetheless, the Draft Tentative Order proposed new requirements including eleven (11) new priority categories, which significantly increase the coverage of commercial facilities subject to inspection. These changes would essentially double the City's inventory to 2,000-2,200 inspections throughout the permit term. Additionally, it mandates the annual inspection of treatment controls in completed land development and re-development projects, and more prescriptively turns the attention of our efforts toward residences and mobile businesses. The concern here is the significant increase in resources needed from the City and the absence of technical justifications for this increase.

With land development projects, the installation and subsequent maintenance of treatment controls certainly need to be verified. However, self certification, along with other third party verification mechanisms should be included as an option in addition to program staff performing the inspections and verifications. Given the current state of the economy and shrinking budgets, the Regional Board should give great weight to the best use of limited resources in achieving water quality objectives.

The prescribed creation of a residential program also needs to be carefully considered. The effectiveness of "*Project Pollution Prevention*", the public education and outreach initiative of the program, has been validated by public opinion surveys that show incremental, but also statistically significant, increases in public awareness of stormwater issues and positive changes in protective behaviors. The new residential program requirements appear duplicative of the current public education and outreach obligations that have already produced, and continue to yield, positive measureable outcomes. However, there is also a separate concern that prescribed efforts to "require residents to implement pollution prevention measures" (XI. 2) will be counter-productive and quickly erode general public support for the program. Justification for this additional program when current requirements have produced positive outcomes need to be provided.

The last area of prescribed new regulatory oversight is mobile businesses. The City, through the public education and outreach committee, has already produced educational materials for these businesses, and cooperatively developed wash water disposal options with our local sewering agencies, with which we have coordinated our enforcement efforts. Through the City's business license process, we are able to identify mobile businesses and supply them with these educational materials. Requiring further regulation of these businesses is a potentially resource-intensive undertaking.

III. Creating a New Basis for the Land Development Requirements of the Order.

The Model Water Quality Management Plan prepared for the Third Term Permit explicitly recognizes the channel stability implications of watershed urbanization and provides for this potential impact to be addressed as a hydrologic condition of concern. Since that time, an Effective Impervious Area of 5% or less has appeared as a performance standard for land development in the Draft Ventura Permit and in the Draft Tentative Order. This new requirement for land development is inappropriately establishing a watershed assessment metric as a site specific performance standard. The City believes that although this standard may be appropriate in regions where there is the potential of large new developments, the City of Costa Mesa is an urbanized area that has little new development, but rather significant in-fill and redevelopment projects. These areas are subject to various development standards that encourage high-density

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development and a 5% or less effective impervious area may not be feasible or appropriate in certain situations. Additionally, soil conditions within the City may not allow for percolation which continues to be a method of choice in the Low Impact Development (LID) models suggested. These factors, in addition to a flat topography, limited space for detention/retention of stormwater and aging infrastructure system continue to provide significant challenges with land development projects in Costa Mesa. The City suggests that many of the various other approaches that provide proven results in reducing flow be considered as part of this Draft Tentative Order.

The City appreciates your and the Regional Board staff efforts devoted to the development of the fourth term permit for the Orange County Stormwater Program, and looks forward to meeting with you and your staff to resolve the City's concerns regarding the Draft Tentative Order to insure that it meets our mutual goals.

Thank you for your attention to our comments. Please direct any questions to Patrick Bauer at (714) 754-5633 or myself, at (714) 754-5335.

Sincerely,

Ernesto Muñoz, P.E.
City Engineer

c: Allan L. Roeder, City Manager
Peter Naghavi, Director, Public Services Department
Don Lamm, Director, Development Services Department
Patrick Bauer, Associate Engineer

CITY OF LAGUNA HILLS

CRWQCB - REGION 8
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January 30, 2009

By Email and U.S. Mail

Gerard Thibeault
Executive Officer
California Regional Water Quality Control Board, Santa Ana Region
3737 Main Street, Suite 500
Riverside, CA 92501-3348

Subject: COMMENTS FOR TENTATIVE ORDER NO. R8-2008-0030; NPDES NO. CAS618030

Dear Mr. Thibeault:

The City of Laguna Hills has reviewed the subject order dated November 10, 2008, Waste Discharge Requirements for Discharges of Urban Runoff from the Municipal Separate Storm Sewer Systems (MS4s) Draining the Watersheds of the County of Orange, the Incorporated Cities of Orange County, and the Orange County Flood Control District within the San Diego Region (Tentative Order No. R8-2008-0030) (NPDES No. CAS618030). The City of Laguna Hills as Co-Permittee, welcomes the opportunity to provide comments on the Tentative Order. The City supports the comment letter prepared by the County of Orange (Principal Permittee) and would also like to address specific technical comments that may affect the City locally.

Overall, the Tentative Order establishes general standards of care to be met for water quality as a result of urban runoff. Hence, the permit includes specific regulations affecting City operations including development planning, construction and municipal activities, watershed urban runoff management, etc. These regulations increase the City's responsibilities, extend the regulatory reach and incorporate additional TMDLs.

The City of Laguna Hills believes that some of the specific regulations in the Tentative Order may adversely affect our ability to effectively deliver the water quality improvements that the Board and the City are seeking to obtain. Consequently, the City of Laguna Hills, working through the Principal Permittee, would like to work closely with the Regional Water Board staff to revise the Tentative Order to ensure that the most effective strategies are implemented to ensure improved water quality.

Throughout the Tentative Order, certain actions are strictly mandated to be taken by the Permittees. These directives limit the City's discretion and the flexibility in effectively

addressing water quality issues in our community. Some of the directives and provisions of concern are as follows:

- Section VI.6, page 34 requires the permittees to provide notification to the Regional Board regarding storm water related information gathered during site inspections of industrial and construction sites regulated by the Statewide General Storm Water Permits. Furthermore, the permittees are directed to provide quarterly notifications to the Regional Board regarding violations and observations. The Cities do not administer or enforce these permits. The only reporting that can be provided to the Regional Board is with regards to conformance with local codes and ordinances on an as needed basis. This section should be modified.

- Section X.1, page 40 requires the permittees to maintain and quarterly update an inventory of commercial facilities within its jurisdiction. This requirement does not seem necessary, and would be a waste of resources. The City currently updates its database annually for inspection and reporting purposes. This section should be modified to allow the permittees to update their commercial inventory annually and submit it with the annual NPDES report.

- Section X.2, page 41 allocates arbitrary percentages for high, medium, and low priority commercial sites. The permittees should be given the flexibility as to designating its facilities without being restricted by the Regional Board. This requirement should be deleted.

- Section X.8, page 42 requires the Principal Permittee to notify all mobile businesses operating within the County concerning pollution prevention measures they must implement. Subsequently within 3 months of being notified by the permittees, the mobile businesses shall be required to implement the appropriate control measures. This requirement cannot be enforced due to the nature of mobile businesses and the limited resources of the permittees. This section should be modified in order to allow permittees to develop a mobile business pilot program in which outreach and enforcement strategies are created to address mobile businesses.

- Section XI.2, page 43 requires the permittees to have residents implement pollution prevention measures. This requirement is vague as "Pollution Prevention Measures" are not specifically defined. Moreover, the City has an effective public education program in which residents are educated with mailers, encouraged to participate in cleanup programs, and implement BMP's as residential sites are remodeled. Residents are responsive and compliant towards NPDES issues. Requiring residents to implement pollution prevention measures is counter productive. Current strategies are yielding positive results and hence this section should be modified.

- Section XII.A.2., page 44 requires the Principal Permittee and the co-permittees to develop a guidance document for the preparation of WQMPs within 6 months of adoption of the Tentative Order. Subsequently the co-permittees will be required to update their LIP's within 6 months. This requirement needs to be developed through a stakeholder driven process and will require additional time to be implemented. The City recommends this requirement be changed to 24 months.

- Section XII.B.3.a, page 48 requires the effective impervious area (EIA) be limited to 5% or less of the total project site. This requirement for land development is inappropriately establishing a watershed assessment metric as a site specific performance standard and is a land-use control restriction. This requirement may not be suitable for many locations in Laguna Hills due to soil types, and there is no technical justification that can be made for this requirement. In order to establish an appropriate standard for land development in this region, a stakeholder driven process that incorporates input from those engaged in design and implementation of LID based practices needs to occur. The timeframe for such a task should be 24 months from the adoption of this Order to establish an appropriate effective impervious area standard for new development.

- Section XII.H.1, page 57 requires the permittees to ensure that all public records including treatment control information is conveyed to the appropriate parties when there is a change in site ownership. This condition should be removed as it is unnecessarily placing a responsibility on the permittees. Legally recorded information is automatically transferred to the new owners in the case of an owner change, and the City should not be responsible in keeping track of this. This requirement should be deleted.

- Section XIII.4, page 59 requires the permittees to conduct individual or regional workshops for various commercial businesses on an annual basis. The City believes it is very difficult to have the business community attend these sorts of workshops during their business hours. The City suggests that it is more beneficial to educate while inspecting and with mailers, which the City currently does per the permit requirements. These activities have yielded positive results. This requirement should be deleted.

The Tentative Order will place undue financial burden and prescriptive technical requirements on the City's Stormwater Program, without necessarily achieving the desired water quality improvements. The City believes that a revised Order addressing the City and County comments would assist the City in carrying out a more effective and successful Stormwater Program.

Sincerely,

Kenneth H. Rosenfield

Kenneth H. Rosenfield, P.E.
Director of Public Services

CITY of CYPRESS

5275 Orange Avenue, Cypress, California 90630

Phone 714-229-6700 www.ci.cypress.ca.us

February 6, 2009

CRWQCB - REGION 8

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Mr. Gerard J. Thibeault
Executive Director
California Regional Water Quality Control Board
Santa Ana Region
3737 Main Street, Suite 500
Riverside, CA 92501-3348

Subject: Comments from the City Relative to the Tentative Order No. R8-2008-0030 (Draft 4th Term NPDES/Stormwater Permit)

Dear Mr. Thibeault:

Thank you for the opportunity to comment on the draft permit. The City fully supports the intent of the stormwater pollution prevention program, and its objectives to minimize pollutants from entering our rivers, streams, and beaches. We also understand the daunting task of drafting a permit that must address regulatory mandates, and the complex and challenging issue of water quality protection.

The City is pleased with the draft permit's increased attention on public education. However, the draft permit also prescribes new areas of program responsibility which present significant concern, and which are identified in our detailed comments. The City's four primary concerns with the draft permit relate to the practical implementation issues with the draft permit for local agencies, the rapid timetable for implementation during the current economic climate, inconsistencies with different provisions within the draft permit, and potential legal Issues.

The first three will be discussed in detail within Attachment A. For the fourth issue, which is the legality of some provisions, it is our understanding that the County of Orange will submit comments to the Regional Board relative to the draft permit. We agree in principle with many of their concerns including, but not limited to, those that encourage plan development through a stakeholder approach, clarification of Permit provisions, and updated fact sheets that support the findings. We are in full concurrence with their legal comments submitted by the County of Orange including the following assertions that the permit attempts to prescribe conditions that go beyond that required by Federal law, improperly intrudes upon City's land use authority in violation of the Tenth Amendment, and imposes a prescriptive standard as compliance, improperly attempts to regulate non-point sources in violation of the Clean Water Act, and lastly, imposes inspection requirements on the City that would violate the Fourth Amendment.

Doug Bailey, Mayor

Prakash Narain, M.D., Mayor Pro Tem **Phil Luebben**, Council Member

Leroy Mills, Council Member **Todd W. Seymore**, Council Member

Furthermore, the City of Cypress recently attended the meeting of January 29, 2009, with the County of Orange and the Regional Board staff to discuss concerns with the various non-land development concerns raised by the County and co-permittees. The City agrees with many of the recommendations that were raised by the group, and have included references to these suggestions in the detailed comments.

Also, we understand that the sections of the draft Permit relative to New Development/Redevelopment including the Low Impact Development (LID) provisions are currently under review by the stakeholder group. The comments in this letter regarding this area are limited. The City of Cypress will elaborate further when it submits its comments on the final development provisions once a consensus has been reached by all parties involved.

We share your goal of improving water quality. The current permit configuration may potentially cause cities to fail. Additionally, this strained economic climate is the worst time for cities to implement new requirements that contain financial impacts.

The City of Cypress looks forward to the continued and collaborative refinement of the proposed Permit. We appreciate the effort currently being taken by the stakeholder group and Board Staff as they address the development sections of the draft Permit, and look forward to a resolution that will satisfy all parties involved. We hope you take our suggestions as a dialogue to improve the permit. Therefore, if you are amenable, we would like to schedule a separate meeting to discuss our concerns with Mark Smythe of your staff in the spirit of cooperation. If you have any questions regarding this letter, please contact me directly at (714) 229-6740.

Sincerely,

Douglas A. Dancs
Director of Public Works/City Engineer

Attachments: Attachment "A" City of Cypress Comments

cc: John B. Bahorski, City Manager
Mark Smythe, Senior Environmental Scientist, SARWQCB
Mary Anne Skorpanich, County of Orange

Attachment "A"

Comments from the City of Cypress Relative to the Draft 4th Term Permit

Section III, Discharge Limitations/Prohibitions –

With regard to the following section:

"3. The permittees shall effectively prohibit the discharge of non-storm water into the MS4s, unless such discharges are authorized by a separate NPDES permit or as otherwise specified in this provision. For purposes of this order, a discharge may include storm water or other types of discharges identified below.

ii. The permittees shall prohibit the following categories of non-storm water discharges unless the stated conditions are met:

a) Discharges from potable water sources, including water line flushing, superchlorinated water line flushing, fire hydrant system flushing, and pipeline hydrostatic test water: Planned discharges shall be dechlorinated to a concentration of 0.1 ppm, 26 or less, pH adjusted if necessary, and volumetrically and velocity controlled to prevent resuspension of sediments."

The Orange County Stormwater program has developed BMP Fact Sheets *FP-6 - Water and Sewer Utility Operation and Maintenance*, *FP-7 Fire Department Activities* and *IC-23 Fire Sprinkler Testing/Maintenance.* In the absence of any Finding that existing control efforts are inadequate, specific requirements for the discharges identified in Section 3.ii.a) should reference these Fact Sheets.

From our January 29th meeting with Board Staff, it is our understanding that cities served by private water purveyors will not be subject to the County Permit requirements for discharges from potable water sources since private water companies are subject to coverage under their own NPDES permit. Cypress is served by Golden State Water Company for its water.

b) Discharges from lawn watering and other irrigation runoff from non-agricultural operations: These discharges shall be minimized through public education and water conservation efforts, as prescribed under Section XI, Residential Program.

This requirement states that cities must prohibit the discharge, while at the same time states, cities should minimize the discharge with public education. We agree that public education regarding this effort is the preferred strategy. Co-permittees are already doing this by means of target advertising such as irrigation runoff advertisements that are published in local newspapers.

c) Dechlorinated swimming pool discharges: Dechlorinated to a concentration of 0.1 ppm 27 or less, pH adjusted and reoxygenated if necessary, and volumetrically and velocity controlled to prevent resuspension of sediments. Swimming pool cleaning wastewater and filter backwash shall not be discharged to the MS4s.

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Placing numeric limits for pool discharges affirms what the City is already doing by distributing the County's "Tips for Pool Maintenance" brochure. The City wants to be certain the intent is not to make the City test each discharge or have the City require residents to obtain permits for such.

Section VI, Legal Authority/Enforcement –

"2. The permittees shall carry out inspections, surveillance, and monitoring necessary to determine compliance with their ordinances and permits. The permittees' ordinance must include adequate legal authority to enter, inspect and gather evidence (pictures, videos, samples, documents, etc.) from industrial, construction and commercial establishments. The permittees shall progressively and decisively take enforcement actions against any violators of their Water Quality Ordinance. These enforcement actions must, at a minimum, meet the guidelines and procedures listed in the Enforcement Consistency Guide."

The Fourth Amendment is clear in its policy of protecting the security and privacy rights of individuals against unpermitted or unwarranted governmental invasions. The permittees' ordinance cannot allow unpermitted entry into private property for the purpose of inspection or collection of evidence to ensure compliance with the permittees' water quality ordinance. Section VI needs to explicitly recognize the limitations imposed by the constitutions of California and the United States to enter premises to inspect etc.

"3. Permittees' ordinances or other local regulatory mechanisms shall include sanctions and follow up inspection milestones to ensure compliance. Sanctions shall include, but are not limited to: monetary penalties, non-monetary penalties, bonding requirements, and/or permit denials/revocations/stays for non-compliance. Follow up inspection milestones shall be consistent with applicable sections of this order. Permittees' ordinances shall have a provision for civil or criminal penalties for violations of their water quality ordinances. These penalties shall be issued in a decisive manner within a predetermined timeframe, from the time of the violation's occurrence and/or respective follow up inspection. Within one year of the adoption of this order, each permittee shall submit a statement, signed by legal counsel, that the permittee has obtained all necessary legal authority in accordance with 40 CFR 122.26(d)(2)(i)(A-F) and to comply with this order through adoption of ordinances and/or municipal code modifications."

The City of Cypress believes that the Model Water Quality Ordinance, Investigation Guidance Manual and our own enforcement procedure, or an agency's self-developed program, would satisfy this requirement.

"6. The permittees shall continue to provide notification to Regional Board staff regarding storm water related information gathered during site inspections of industrial and construction sites regulated by the Statewide General Storm Water Permits and at sites that should be regulated under those Statewide General Permits. The notification shall be provided on a quarterly basis and shall include any observed violations, or threat of potential violations of the General Permits (e.g., problematic housekeeping issues) prior history of violations, any enforcement actions taken by the permittee, and any other relevant information. (Also see notification requirements under Sections VIII, IX, and X of this Order.")

As you may know, we have provided the Board staff a wealth of information on a monthly basis to show our compliance with the permit, and to inform Board Staff on what is occurring within our City including areas where there are statewide general permits. The Third Term Permit allows the agencies the flexibility to report issues as they occur or at other intervals. It should be up to the agency to provide this information, and not set a prescribed quarterly time period. In addition, the City agrees with the recommendation made by the County of Orange at the January 29th meeting regarding compliance with the Statewide General Permits. Compliance with the intent of the Permit can be achieved by agencies using their own local ordinances and water quality codes rather than with a global approach. A clear distinction between local and state responsibilities must be defined.

"8. The permittees are encouraged to enter into interagency agreements with owners of other MS4 systems, such as Caltrans, school and college districts, universities, Department of Defense, Native American Tribes, etc., to control the contribution of pollutants from one portion of the MS4s to another portion. The Regional Board will continue to notify the owner/operator of the MS4 systems and the local municipality if the Board issues a permit for discharges into the MS4 systems."

Local government agencies historically have never had any authority over activities performed by state and federal agencies. For example, with AB 939 requirements for solid waste diversion, it proved challenging to partner with school districts and community colleges since they are not under our regulatory jurisdiction to implement solid waste source reduction initiatives. Moreover, Phase II stormwater permittees are primarily a Regional Board responsibility. The language of the current permit (p.8 Finding 25) should be retained in this instance as the sole reference to these entities.

Section VIII, Municipal Inspections of Construction Sites –

"2. Each permittee shall continue to maintain and update (at least on a quarterly basis) an inventory of all construction sites within its jurisdiction for which building or grading permits have been issued and where activities at the site include: soil movement; uncovered storage of materials or wastes, such as dirt, sand or fertilizer; or exterior mixing of cementaceous products, such as concrete, mortar or stucco. All construction sites shall be included regardless of whether the construction site is subject to the General Construction Permit or other individual NPDES permit. This inventory shall be maintained in the 2002 Spreadsheet developed by the permittees or a similar computer-based database system and shall include relevant information on site ownership, General Construction Permit WDID number (if any), size, location (latitude/longitude (in decimals) or NAD83/WGS8431 compatible formatting as identified by GIS for a spot within the site perimeter), inspection data, etc."

This GIS information is an additional data collection process that will require additional staff time to update and monitor to ensure its accuracy while at the same time, it is not known what benefit this information provides. Furthermore, how will public works-type construction, such as pipelines, be treated since they cannot accurately be identified with a single point? Also, how are projects that cover multiple locations such as a sanitation district, a manhole replacement project, or an above ground multi cabinet installation by a telephone company to be identified? This GIS data collection requirement should be left to the discretion of the Permittee after consideration of the practicality and utility to its stormwater management efforts.

Alternatively, we would suggest the following language or similar equivalent:

"Construction within the public right of way is excluded from this GIS requirement."

Section IX, Municipal Inspections of Industrial Facilities –

1. "Each permittee shall continue to maintain an inventory of industrial facilities within its jurisdiction. All sites that have the potential to discharge pollutants to the MS4 should be included in this inventory regardless of whether the facility is subject to business permits, licensing, the State's General Industrial Permit or other individual NPDES permit. This database must be updated on an annual basis. This inventory must be maintained in a computer-based database system and must include relevant information on ownership, SIC code(s), General Industrial Permit WDID # (if any), size, location, etc. Inclusion of a Geographical Information System (GIS) is required, with latitude/longitude (in decimals) or NAD83/WGS8432 compatible formatting."

As mentioned previously, this GIS information is an additional data collection process that will require additional staff time to update and monitor to ensure its accuracy. It is not known what benefit this information provides. There may be little use of this information to cities that do not have GIS. This GIS data collection requirement should be left to the discretion of the Permittee after consideration of the practicality and utility to its stormwater management efforts. The same statement also holds true for the commercial facilities inspection requirement.

Section X, Municipal Inspections of Commercial Facilities –

"2. Each permittee shall conduct inspections of its commercial facilities as indicated below. To establish priorities for inspection, the permittees shall continue to prioritize commercial facilities/businesses within their jurisdiction as a high, medium or low threat to water quality based on such factors as the type, magnitude and location of the commercial activity, potential for discharge of pollutants to the MS4, any history of unauthorized, non-storm water discharges, proximity and sensitivity of receiving waters, material used and wastes generated at the site. The following minimum criteria must be met: 10% of commercial sites (not including restaurants/food markets) must be ranked 'high' and these represent the greatest threat to water quality; 40% of commercial sites (not including restaurants/food markets) must be ranked 'medium'; and, the remainder may be ranked 'low'."

This section presents a number of fundamental concerns. For example, facilities that do not meet the minimum requirements for inspection will be subject to inspections on an entirely arbitrary basis in order to comply with the Permit. Please consider how would a Permittee refute petitions filed by commercial facilities who believe that they have been unfairly re-prioritized? This was discussed at the January 29th meeting. Also consider if agencies tried to recoup their efforts through fees, how would it justify the arbitrary nature of this effort for a business selected for a higher inspection threshold?

The City understands the position of the Regional Board that a target goal should be established for commercial facilities prioritization. However, consideration should be given to reducing the number of mandatory inspections. By permitting the revision of the DAMP, we could achieve a technically robust risk-based approach to inspection and still meet the intent of the Permit.

"8. Within 12 months of adoption of this order, the PRINCIPAL PERMITEE shall notify all mobile businesses operating within the County concerning the minimum source control and pollution prevention measures that they must develop and implement. For purposes of this order, mobile businesses include: mobile auto washing/detailing; equipment washing/cleaning; carpet, drape, furniture cleaning; and mobile high pressure or steam cleaning. The mobile businesses shall be required to implement appropriate control measures within 3 months of being notified by the permittees. Within 12 months of adoption of this order, the PRINCIPAL PERMITEE shall develop an enforcement strategy to address mobile businesses. Each permittee shall also distribute the BMP Fact Sheets for the mobile businesses that have been developed by the permittees. At a minimum, the mobile business Fact Sheets/training program should include: laws and regulations dealing with urban runoff and discharges to storm drains; appropriate BMPs and proper procedure for disposing of wastes generated from each mobile business."

Although we understand the relevance of this section, we believe that this requirement is difficult to implement considering the nature of mobile businesses, and the additional resources that will be required to monitor their activities. Many of these businesses fail to obtain business licenses to operate in jurisdictions, which makes it even more difficult to monitor. The cities are already performing enforcement of mobile businesses through existing public education programs. If the mobile business operators are observed working in the City, they will be approached and apprised of their responsibilities. At this time, the pertinent information such as business location, telephone number, and operator name can be obtained and entered into a database and later provided to the Regional Board. However, launching a regional canvassing program could be very time consuming and costly for agencies.

As was discussed at the January 29th meeting, the City supports the idea of implementing a pilot program to address the issue of mobile businesses. The comments made at the meeting supported the argument that this is an issue that crosses many jurisdictional boundaries as mobile businesses are located throughout Southern California. An effort must be made to avoid the development of a program that will require significant resources to implement and result in diminished returns. We also agree with the County of Orange that this requirement should be the responsibility of the Principal Permittee.

Section XI Residential Program –

"2. The permittees should identify residential areas and activities that are potential sources of pollutants and develop Fact Sheets/BMPs. At a minimum, this should include: residential auto washing and maintenance activities; use and disposal of pesticides, herbicides, fertilizers and household cleaners; and collection and disposal of pet wastes. The permittees shall require residents to implement pollution prevention measures. The permittees should work with sub-watershed groups (e.g., the Serrano Creek Conservancy) to disseminate latest research information, such as the UC Master Gardeners Program and USDA's Backyard Conservation Program."

The prevention of illegal discharges in residential neighborhoods can be achieved through public education. Residents have become more aware of protecting water quality, especially through the City's current public education program, which includes the quarterly City newsletter, City website, local cable television public service announcements, as well as, Powerpoint slide presentations aired on the local cable television channel. The

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proposed revisions reflect a move to a more punitive approach for violations committed by residents, and may be viewed as unwarranted government intrusion by local residents. We agree with the comment made at the January 29th meeting that permittees should "encourage" as oppose to "require" compliance by residents. This falls in line with the approach that has been utilized by co-permittees to gain cooperation from residents and continued public support for the NPDES program. Furthermore, the separate requirements in Section XIII to conduct public education and outreach make the requirements in *Section XI Residential Program* redundant and therefore unecessary.

"3 .The permittees, collectively or individually, shall facilitate the proper collection and management of used oil, toxic and hazardous materials, and other household wastes. Such facilitation should include educational activities, public information activities, and establishment of curbside or special collection sites managed by the permittees or private entities, such as solid waste haulers.

Consideration should be given to the potential threat of these materials being released into the storm drain system as they are waiting to be collected. If this is not a concern, then it appears to contradict the requirement of commercial establishments to store hazardous wastes within secondary containment devices.

The City is concerned with funding for conducting the collection events. Events held by agencies are known to cost several thousand dollars to conduct, not including all of the hazardous waste reporting that must be completed when these events are held. The current County of Orange Household Hazardous Waste Collection Program has been working well since its implementation and agencies continue to do a good job making residents aware of this service. Therefore, there does not seem the need to prescribe new programs. It is suggested to change the language from a "shall" requirement to an "are encouraged" requirement since the next statement says "should" facilitate.

"4. The permittees shall develop and implement control measures for common interest areas and areas managed by homeowner associations or management companies. The permittees should evaluate the applicability of programs such as the Landscape Performance Certification Program to encourage efficient water use and to minimize runoff."

The imposition of control measures for common interest areas and areas managed by homeowners will be difficult to implement, especially for projects that were constructed under conditions of approval without water quality conditions. We concur with the comments that were made at the January 29th meeting that the permittees should be encouraged to develop and implement the control measures or consider implementing pilot programs where the effectiveness of these control measures can be evaluated.

Section XII New Development (Including Significant Redevelopment)

These are only preliminary comments until such time the stakeholder group concludes their discussion.

"XII A 8. The permittees shall train their employees involved with the preparation and/or review of CEQA documents as specified in Section XVI."

We understand the importance of training of employees to keep them apprised of the requirements of the NPDES program so that all of the actions are implemented in accordance with the Permit. Please also refer to our comments made on Section XII.F.3. If training is required, then we are in support of a training program that will extend over a two year period or give co-permittees an opportunity to develop and conduct their own employee training programs.

"XII B 2 i) Streets, roads, highways and freeways of 5,000 square feet of paved surface. The WQMP should address the project area. This category includes any paved surface used for the transportation of automobiles, trucks, motorcycles and other vehicles and excludes any routine road maintenance activities where the footprint is not changed."

The City does not understand whether these criteria will make projects, such as street reconstruction projects, subject to treatment requirements. This is important to know being that the entire street system can be considered a conveyance system for all stormwater runoff. It would seem ineffective to have the street detain a two year storm for its own area when it is receiving all the surrounding water from the adjacent properties to convey it to a pipe system. We would recommend excluding streets from this requirement.

In addition, clarification is needed as to whether a project would be considered a priority project if it includes the disturbance of 5,000 square feet but the project area is not contiguous. For example, if there is a city-wide sidewalk replacement program that entails an area greater than 5,000 square feet of damaged sidewalk at various locations within the City, would this make the project subject to a WQMP and require the incorporation of structural treatment measures? Again, this type of project should have exclusionary language within the permit.

Furthermore, the footnote for above states:

"42. If a feasibility study indicates that it is not feasible to implement standard WQMP requirements due to unique constraints imposed on the project, alternatives acceptable to the Executive Officer must be implemented."

There are many routine projects that a City undertakes to improve its infrastructure, such as sidewalk and street reconstruction. To require a "feasibility" study for these types of projects, (and submit an alternative analysis to the Executive Officer) appears both burdensome and cost prohibitive, without yielding any appreciable difference in storm water quality. Please clarify the reasoning behind this proposal, as this may not be your intent.

"XII F 2. The permittees shall maintain a database to track all structural treatment control BMPs, including the location of BMPs, parties or operation and maintenance"

The City requests clarification as to the type of data tracking that is expected from co-permittees when it relates to structural treatment control BMPs. Will this tracking only include those treatments that are constructed during the period of the 4th Term Permit or will it be retroactive and, if so, from what date or time period? We suggest the following language be added "*starting with the implementation of the 4th term permit.*"

"XII.F.3. The principal permittee, in collaboration with the co-permittees, shall define expertise and competencies needed for permittee staff for the review and approval of WQMPs. The permittees shall develop a training program and a schedule to train permittee staff for this task. By July 1, 2009, and annually thereafter, all permittee staff that review WQMP shall be trained. The training information for each permittee staff shall be included in the annual report."

As discussed in the January 29th meeting, a certificate program may cause issue with various employee groups. Please realize there are many state mandated training requirements that are required of city personnel for other efforts. This cumulatively removes them from their regular job duties. However, as stated previously, the City would be in support of a training program that extends over a two year period or provides the option of the City to develop and conduct its own training program for employees.

"XII.I.2. The permittees shall specify conditions of approval that require proper maintenance and operation of all structural treatment control BMPs installed in new developments. The parties responsible for the long-term maintenance and operation of the structural treatment control BMPs for the life of the project and a funding mechanism for operation and maintenance shall be identified prior to approval of the WQMP."

With regard to this section, one viable option to ensure ongoing maintenance of BMPs is through the issuance of a maintenance bond as assumed by the occupant of the building. However, the City is concerned with this approach, as it will place an additional financial burden on the building occupant and, eventually, negatively impact businesses in the long run.

In summary, the City is concerned with the implementation of the proposed development process contained in the draft permit. We look forward to the consensus that will be reached as a result of the ongoing discussions by the stakeholder group who is reviewing the draft development process. If a compromise is not reached prior to the end of the comment period, it is recommended that this matter continue to be evaluated by the stakeholder representatives until a consensus can be reached. We believe that there are other approaches that provide proven results, and minimal impacts on development, that have not been explored, and should be considered for the permit.

Section XIII Public Education and Outreach –

"4. The permittees shall continue their outreach and other public education activities. Each permittee should try to reach the following sectors: manufacturing facilities; mobile service industry; commercial, distribution and retail sales industry; residential/commercial landscape construction and services industry; residential and commercial construction industry; and residential and community activities. Individual workshops (or regional workshops) for each of the aforementioned elements shall be administered by each permittee (or on a countywide basis) by July 1, 2010 and on an annual basis thereafter. Commercial and industrial facility inspectors shall distribute developed educational information (Fact Sheets) to these facilities during inspections. Further, for restaurant, automotive service centers and gasoline service station corporate chains, new information or that which has been previously developed shall be provided to corporate environmental managers during outreach visits that should take place twice during the permit term. The outcomes from all outreach requirements contained herein shall be reported in the applicable annual reports."

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The City has noticed a discrepancy with this paragraph where it initially states the "co-permittee shall continue" and then is followed with the word "should" in the subsequent sentence. Additionally, there may be alternative methods to deliver the message to corporations than speaking with the environmental managers at their facilities. As a result of its inspections, the City has gained better cooperation from facilities when we go directly to top management as they will ensure that the information gets delivered to the appropriate employees and disseminated to the balance of the employees accordingly. The target recipient for education and outreach efforts needs to be determined by each Permittee and not prescribed in the Permit.

"7. The PRINCIPAL PERMITEE, in collaboration with the co-permittees, shall develop and implement a mechanism for public participation in the updating and implementation of the Drainage Area Management Plans, monitoring plans, Water Quality Management Plan guidance and Fact Sheets for various activities. The public shall be informed of the availability of these documents through public notices in local newspapers, County and/or city websites, local libraries/city halls and/or courthouses."

The City is concerned with this section as it appears to dictate the means and methods that should be used by cities to gain public participation in the review and approval process of water quality related documentation.

Section XIV Municipal Facilities/Activities –

"7. Within six months of adoption of this order, the principal permittee shall evaluate the effectiveness of debris booms and determine if additional debris booms are needed to address floatables in inland streams. This evaluation should also include an evaluation of other control measures such as more effective street sweeping program, litter control measures, and drain inlet screens and /or other inlet controls."

Debris booms have already been studied by the City of Seal Beach under a grant funded by the Coastal Conservancy. It is our understanding that the City of Seal Beach received correspondence during their debris boom project from the City of Long Beach Fire Chief regarding concerns by first responders regarding the possibility that both rescuers and victims could be trapped in the booms. This may lessen the need for further study on high volume waterways due to public safety concerns regarding booms.

"9. The permittees shall ensure that their flood management processes and projects do not contribute pollutants to receiving waters to the MEP."

This statement could be very broadly interpreted. The City does not understand how this will be enforced without some more specific language.

"14. Each permittee shall implement control measures necessary to minimize infiltration of seepage from sanitary sewers to the storm drain systems through routine preventive maintenance of the storm drain system. The permittees who are also owners and/or operators of sewage collection systems shall also implement a routine maintenance program for the sewage collection systems in accordance with the State Board's Water Quality Order No. 2006-0003. Each permittee shall cooperate and coordinate with the sewage collection/treatment agencies (Orange County Sanitation District and/or Irvine Ranch Water District) to swiftly respond to and contain any sewage spills."

This is currently being performed by agencies under the Statewide WDR. It is not understood why this is being reiterated in the permit. It is recommended that this section be removed from the permit.

Section XVII Notification Requirements –

"2. At a minimum, all sewage spills above 1,000 gallons and all reportable quantities of hazardous waste spills as per 40CFR 117 and 302 shall be reported within 24 hours. All spill incidents shall be also included in the annual report. The permittees may propose a reporting program, including reportable incidents and quantities, jointly with other agencies, such as the County Health Care Agency, for approval by the Executive Officer."

For implementation, it would seem to be more effective to have one point of contact within the Regional Board in these situations. Reporting to multiple agencies appears as a duplication of effort and could result in confusion. To prevent this, the City suggests that there be one point of notification when it involves sewage spills.

Section XVIII – Watershed Action Plans and TMDL Implementation –

"4. The permittees with discharges tributary to Coyote Creek or the San Gabriel River shall develop and implement constituent-specific source control BMPs for copper, lead and zinc until a TMDL implementation plan is developed. The source control plan shall include a monitoring program and shall be completed within 12 months from the date of adoption of this order."

With regard to the imposition of TMDL requirements upon Coyote Creek, the City recommends that TMDL requirements be deleted. We believe that imposing TMDL requirements upon a tributary that has had TMDLs imposed by another Regional Board (Los Angeles) exceeds the boundaries of the Santa Ana Regional Board's jurisdiction. Requiring permittees to implement constituent-specific source control BMPs is unfounded until a correlation can be made as to the point of origin of the pollutants. Furthermore, it is our understanding that a TMDL cannot be imposed upon this section of the Coyote Creek without the supporting studies, and public notification process taking place. To base this solely on waste load allocation findings produced by another Regional Board conflicts with the entire TMDL implementation process as established by the Clean Water Act and the United States Environmental Protection Agency. Public input is a key component to the development of TMDLs. The proposed permit does not afford this opportunity. Basically, TMDLs should not be imposed by the Santa Ana Regional Board until a determination can be made that pollutants originating from the Santa Ana Region impair the upper reach of Coyote Creek. Without a TMDL implementation plan, this designation cannot be applied to the section of the watershed.

Section XX Fiscal Analysis –

"1. Each permittee shall secure the resources necessary to meet all requirements of this order."

The Board suggests in the findings section of the permit to raise taxes via a Proposition 218 vote. However, any such initiative most likely will be defeated by voters, especially in these hard economic times. If the City goes out for a vote, then loses, it effectively becomes a

mandate not to address water quality. The City is concerned with the financial impact that all of the requirements will have on City operations, now and in the future. It is extremely important in this economy to make certain that the cost/benefit be evaluated of what is being required, and its benefits to water quality.

"2. The permittees shall prepare and submit a unified fiscal accountability analysis to the Executive Officer of the Regional Board."

City requests clarification on the definition of "a unified fiscal accountability analysis", and why "accountability" was added to the definition.

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CITY OF ORANGE

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February 10, 2009

Gerard J. Thibeault
Executive Officer
California Regional Water Quality Control Board Santa Ana Region
3737 Main St. Suite 500
Riverside, CA 92501- 3348

Subject: Renewal of Waste Discharge Requirements for the County of Orange, Orange County Flood Control District and Incorporated Cities of Orange County, Tentative Draft Order R8–2008-0030, NPDES No. CAS618030, Areawide Urban Storm Water Runoff

Dear Mr. Thibeault:

As a permittee of the Orange County Areawide Urban Storm Water Runoff permit, the City of Orange would like to take the opportunity to comment on the proposed municipal storm water draft permit. The City appreciates the efforts undertaken by regional board staff to maintain programs that work and to modify or revise those program elements that need adjusting.

We are pleased that certain permit provisions of the existing permit have been maintained such as the iterative process to address program exceedances, continued coverage of public agency construction projects under the municipal permit, exemption of approved projects from the new LID requirements and other provisions.

This letter addresses some of the draft permit's provisions that are of concern to the City, which we believe can be resolved by working cooperatively with regional board staff. We also support the County of Orange's comments as the principal permittee whose letter addresses some of the larger policy issues.

One area that the City is particularly concerned about is the New Development/Significant Redevelopment section that adds significant new requirements for the approval of new projects. We recognize that there are ongoing discussions on this subject by a number of interested parties that include the principal permittee; however, our comments are based on the existing language in the proposed permit.

The draft permit contains new LID requirements that include limiting priority projects to 5% Effective Impervious Area. Redevelopment projects and new street widening projects that utilize existing impervious surface to expand will find compliance with the 5%EIA provision extremely difficult if not impossible to meet. The 5% EIA provision will be problematic and result in prohibitive costs for such projects.

We appreciate the alternative In-Lieu programs included in the draft permit but are not certain how this program will work. Consideration should be given to omitting the LID and 5% EIA requirements for these type of projects.

In addition, the Commercial Inspection section adds eleven new categories of facilities for inspection while arbitrarily mandating a certain percentage of facilities to be designated as High and Medium priorities. We estimate that these mandatory inspection requirements will add 50 more annual, 250 biennial and 900 more commercial inspections during the permit term. Compliance with this requirement will require additional new City resources and expenditures during a time of uncertain economic conditions.

There are also many other comments regarding the proposed permit's requirements that are more fully discussed in the attachment to this letter. We note that there are many increased administrative requirements for inspections in some of the existing and new programs that may be unwarranted and provide little benefit in the improvement of water quality. We also suggest that consideration be given to extending the time for implementing some of the new programs, in particular the new LID requirements until the concept is fully understood.

Sincerely,

Joe DeFrancesco
Interim Public Works Director

Attachment: Comments on Draft Municipal Storm Water Permit

cc: John Sibley, City Manager
Alice Angus, Director, Community Development
Chris Crompton, Manager, Environmental Resources County of Orange

ATTACHMENT

Comments on Draft Municipal Storm Water Permit

Following are comments on the draft Orange County Municipal Storm Water permit. Comments are arranged in the order in which the provisions are found in the permit. Along with an analysis of the provisions, recommendations are provided that contain suggested revisions (in bold) or clarification to permit language.

PERMIT PROVISIONS

Section VII – Illicit Discharge/Illegal Connection; Litter, Debris and Trash Control

Paragraph 5 requires permittees to characterize trash and determine its sources. Is the intent to require each permittee to carry out this requirement? It makes more sense to conduct a countywide study instead of having each municipality repeat the study since trash sources do not vary significantly among municipalities.

Recommendation:

Revise paragraph to require the principal permittee instead of the permittees to conduct one countywide trash study over the 5-year permit to characterize trash sources.

Section VIII – Municipal Inspection of Construction Sites

Paragraph 2 contains conflicting language regarding the sites to be included in the construction inventory. The first part of the paragraph requires those sites that have the potential to impact water quality to be inventoried but later in the paragraph it states that all sites should be included in the inventory. Sites included in the City's annual report include only those sites with grading or sites that pose a threat to water quality. Encroachment permits and building permits such as plumbing or other indoor permits are not included in the inventory.

Recommendation:

Clarify which sites are to be included in the construction category.

Section IX- Municipal Inspections of Industrial Facilities

This section designates the prioritization of industrial facilities and requires certain facilities such as facilities covered under the state's general industrial permit and other categories to be automatically designated as high. High priority sites are inspected

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annually and because of their mandatory designation, there is no provision for reprioritizing these facilities based on the ranking criteria in the DAMP after inspections have been conducted.

Past experience has shown that once a facility has been inspected at least once, there is increased awareness of water quality impacts and facilities will implement BMPs to minimize storm water and nonstorm water discharges. These actions allow the facility to be re-evaluated in accordance with the procedure in the DAMP and redesignated if appropriate. Without allowing for facility redesignation of high priority sites, City resources will be unnecessarily spent on facility inspections that are not warranted. These resources could be better utilized elsewhere to meet other permit requirements.

Attached are the cover sheets of 4 facilities that because of their SIC code and the requirement to be covered under the State's General Industrial Permit are automatically designated High priority. As the latest inspection cover sheets show, their ranking under the DAMP factors would lower the facility's priority designation to Low (less than 15 pts.). However, because of their mandatory High ranking, the facilities must be inspected annually.

Recommendations:

Paragraph 2 & 3. Allow redesignation of mandatory high priority facilities based on the suite of factors in the DAMP used to rank a facility.

Section X – Municipal Inspection of Commercial Facilities

This section contains the requirements for inspection of commercial facilities. In this section eleven new commercial categories are added along with mandatory priority designations. This section requires10% of all commercial sites to be designated high priority, 40% medium and the remaining sites Low. This requirement is arbitrary and without justification. This provision requires the City to conduct over 50 inspections annually, 250 every two years and 900 during the permit term (50 annually, 200 biennially and 250 once) without any likely measureable improvement in water quality. This effort will require additional City staffing during uncertain economic times.

The DAMP already contains a procedure to assess the priority of commercial sites based on activity type, size, proximity to ASBS water bodies, pollutant potential and nonstorm water discharges. This process should be allowed to continue for prioritization of all commercial sites since it provides a formal procedure for prioritizing and setting inspection frequencies based on the threat to water quality. It also provides for reprioritizing of sites after inspection based on implementation of BMPs and other

factors as noted above. Arbitrarily mandating priority designation and inspection frequencies achieves no purpose other than to unnecessarily expend City resources without a direct benefit to the improvement of water quality.

Recommendations:

Paragraph 1. Provide justification for the additional commercial categories or delete requirement.

Paragraph 2. Allow sites to be prioritized based on the procedure in the DAMP.

Section XII - New Development

This section contains many new requirements that will have a significant impact on how new development/significant redevelopment projects will be approved and the process for approving these projects. More specific information is provided under each of the section headings.

Section A - General Requirements

Successive municipal draft permits have required that new development requirements of the permit be incorporated into permittees' General Plan. Paragraph 4 seems to continue with the same requirements. General Plans are typically revised every 5-10 years. It is an intensive and exhausting process that expends a lot of city resources. Revising other documents such as city policies or the zoning code can achieve the same purpose of incorporating permit requirements into the project review process.

Recommendation:

Revise paragraph 4 to state that other documents besides the General Plan may be revised to incorporate LID principles and policies.

Section B – Water Quality Management Plan (WQMP) for Urban Runoff (For New Development/Significant Redevelopment)

This section identifies the categories of projects that are to be designated as priority projects. The section contains two new categories while lowering the thresholds of other existing categories. This is a concern because no information or justification for these changes is provided.

Paragraph 2.a states that redevelopment projects that add or replace 5000 sq. ft. of existing impervious surface are designated priority projects and subject to the site design and treatment BMP requirements. The wording in the paragraph should clarify that replacement means where the existing pavement or impermeable surface is removed, replaced and soil exposed. There are many cases in which parking lots or other facilities have their surface grinded down and replaced or overlayed but the soil is not exposed. Under the existing text in the paragraph, these types of projects would be considered priority projects.

The paragraph should also allow discretion in defining what redevelopment projects fall into this category. The City has encountered cases in existing development where improvements were to be made but the nature of the facility was not changed. Such a case was the removal of a vertical tank foundation that exceeded the 5000 sq. threshold with the intent repave the area without any additional uses. Under the exiting permit, these types of projects have been required to provide treatment BMPs for these small areas simply because they removed and replaced 5000 square feet of impervious surface. It makes little sense from a practical point to have this requirement when no other land use improvements are undertaken. The draft permit might cover these cases under the "original purpose of facility" with a slight modification as recommended below.

Recommendations

1. Revise the last part of the first sentence in paragraph 2 as follows: "--, which include the addition or replacement of 5, 000 square feet or more of impervious surface **where the underlying soil is exposed** on a developed site."

2. Revise the last part of the second sentence as follows "---hydraulic capacity, **improvements that do not change the** original purpose of the facility, or emergency ---"

Paragraph 2.b. The subdivision priority category has been revised to include subdivisions with less than 10 units with combined impermeable surfaces of 10,000 sq. ft. The word "subdivision" itself needs to be defined. A strict interpretation relates to the use of a parcel or tract map. Is the intent to cover particular types of projects such as apartments where there could be 10 units or less in a single lot or does it refer to projects with property lines?

The subdivision category change could also require single family residences where two lots are combined into one or two separate lots with combined 10,000 sq. ft. or more of impervious surface to comply with all priority project requirements including LID and

treatment BMPs. No justification has been provided to conclude that single family homes or two lots are significant contributors to water quality problems.

Requiring single family home owners to comply with the requirements of a priority project will add unnecessary costs and expenses and maintenance of treatment BMPs, which is problematic because individual homeowners are not capable of maintaining BMPs.

It is not good policy making to adopt regulations do not have a chance of succeeding. Individual single family homes are not a big threat in comparison to industrial and commercial sites, which are more heavily regulated.

Recommendation:

Revise paragraph 2.b to maintain the previous provision that includes subdivision of 10 units or more as priority projects and delete the requirement that designates less than 10 units as priority projects.

Paragraph 2.c has lowered the threshold of commercial and industrial facilities to 10,000 sq. ft. Again, this change has been made without any justification. In this category, the 10,000 sq. ft. threshold is interpreted to apply to the size of the building and not the total improvements onsite.

Recommendation:

Revise paragraph 2.c to clearly state that the square footage applies to the building area.

Paragraph 2.e appears to use a different threshold for designating priority projects. Most categories use building area (2.c) for designation of priority projects but this category uses total area of development.

Recommendation:

Provide justification for use of land area and not building size or revise paragraph.

Paragraph 2.f. has lowered the threshold from 10,000 sq. ft. to 5,000 sq. ft. for hillside homes. There does not appear to be a justification for this change and clarification needs to be provided on whether the square footage threshold applies to the lot size, total impervious surface onsite or building area. Justification also needs to be provided

on why the hillside home is different from a regular single family development on a site that is less than 25% (definition of hillside). The pollutants generated are essentially the same except you may have higher velocities. What are the pollutants of concern and how are they different from a regular single family home which is not a priority project?

Recommendation:

Provide justification on the lowering of the square footage threshold and the pollutant of concern.

Paragraph 2.i adds streets, roads and highways with 5,000 sq. ft. of paved area as a priority category. Although footnote 42 recognizes that these type of projects may not meet standard WQMP requirements and allows for alternatives, most projects will not be able to meet the LID 5% EIA requirements due to site constraints and economic feasibility.

Recommendation:

Delete this category in its entirety. Most projects will require alternatives.

Paragraph 5.f does not does not allow infiltration to be used in industrial areas or where light industrial activity occurs. The text can be interpreted to exclude the use of infiltration in nonindustrial projects simply because they are located in an industrial zone.

Recommendation:

Revise paragraph 5.f to clarify that infiltration is allowed in an industrial zone where the facility is not involved with industrial activities or processes such as storage areas or residential and commercial projects.

Section C – Low Impact Development to Control Pollutants In Urban Runoff From New Development/Significant Redevelopment

This section of the permit contains significant new requirements that will be difficult to implement and for all practical purposes impossible to meet for redevelopment and roadway and street projects as noted in B.2.i above. There also seems to be conflicting information or requirements between various paragraphs.

The biggest concern is paragraph C.3 where there is a requirement to limit the project Effective Impervious Areas to 5%. The premise behind this requirement is that impervious surface has a significant role in the degradation of habitat and increases pollutant loads in natural streams and that through the implementation of LID measures the existing hydrological cycle can be maintained to avoid downstream impacts.

While there is little dispute that urban development and associated impervious surface may cause downstream impacts, most studies supporting this conclusion are carried out in undeveloped watersheds where the impact of development on natural streams can be measured. We are not aware of studies carried out in developed watersheds, which is the case in much of northern Orange County where the watersheds have been developed and the streams and channels engineered with concrete and rip rapped for flood control purposes. Applying the 5% impervious cover concept in these watersheds is impractical and not justified since physical degradation of these channels is unlikely.

The City of Orange is mostly built out and about 95% of all approved priority projects involve redevelopment projects. This type of project generally maintains or reduces the hydrologic runoff characteristics of the existing site due to increased landscaping requirements and the use of other pervious surfaces, which is the intent of the LID 5% EIA requirement. These projects will not increase the impacts downstream and are most likely to reduce them. If the intent of the 5% EIA requirement is to mimic predevelopment conditions, projects where the existing hydrological cycle can be maintained as required in Section D should not be subject to the 5% EIA requirement. Otherwise requiring these projects to meet the 5% EIA threshold will be cost prohibitive and will not be achieved in roadway and street projects where the expansion area for these projects is already impervious (sidewalks) and additional acquisition of right-of-way is cost prohibitive.

As another example, consider the case of a strip mall development where a 5000 sq. ft. building will be demolished and rebuilt or expanded by 5000 sq. ft. The proposed regulations will require a change in the drainage pattern of the site and the addition of pervious surfaces. The added costs to regrade, repave, add new pervious surfaces and potentially add or modify the onsite storm drain system would make the project infeasible. Cases such as this are quite frequent in the city and project applicants have made it clear that any improvements required other than the treatment of runoff from the building or proposed applicant improvements that would require significant more work such as regrading of the site would make the project infeasible. In these cases the water quality requirements are viewed as unrealistic and cost prohibitive.

In the cases above, the proposed regulations will deter redevelopment. In the end the City loses an opportunity to redevelop and improve older sections and the environment loses an opportunity for improvement of water quality.

In addition, there is also conflicting information in C.4.b related to the substitution of treatment control BMPs for LID measures. It is stated that treatment BMPs can be substituted for LID measures but there is a requirement to first meet the 5% EIA threshold, which negates what substitution of treatment BMPs for LID. If you meet the 5% EIA requirements you have most likely already met the LID requirement.

There also seems to be a distinction on the meaning of infill and redevelopment projects. For purposes of complying with the water quality requirements of the permit, infill and redevelopment are viewed as the same.

Recommendations:

Paragraph C.3.

1. Limit the 5% Effective Impervious Area (EIA) to undeveloped watersheds only and are not applicable to redevelopment projects or streets and roadways.
2. Footnote 50, 51, 52, and 53 in 3.a- 3.d should reference footnote 49.

Paragraph C.4 – Clarify that treatment measures alone can be used in place of LID measures by revising the paragraph as follows:

1. Delete the 5% EIA requirement as it is conflicting to what the paragraph is trying to achieve.
2. The proof for showing that the post development runoff water quality is equal or better to the existing runoff (item d) is through implementation of treatment BMPs contained in the DAMP.
3. Delete (e) since there is reference to LID measures, which are being substituted for by treatment BMPs.

Section D - Hydrologic Conditions of Concern (Hydromodification)

This section contains the requirements for determining when there are conditions of concern. Again, this section contains conflicting information in relation to LID and hydrological requirements.

Paragraph 2.c. The paragraph states that impervious areas connected to pervious areas that can infiltrate a 2-year storm do not need to be considered in the effective impervious calculation. It is not clear why the pervious areas must be capable of

infiltrating a 2-year storm. Footnote 43 clearly defines effective impervious areas as those areas that run over pervious surfaces: it does not require infiltration of a 2-year storm. Requiring infiltration equal to a 2-year storm event for all impervious surfaces connected to pervious will not be met and will exceed the project treatment requirements for BMPs specified in Section XII B.4.

As an example of what it means, consider a small area where the site has a 10 minute time of concentration. In the Orange County Hydrology Manual this time corresponds to an intensity of 1.5"/hr.: well above the water quality treatment requirement specified in paragraph B.4. Most projects are unlikely to meet this requirement and all projects where effective impervious areas are calculated in accordance with this paragraph will unnecessarily end up with conditions of concern. The infiltration requirement should apply only to the excess runoff produced from the 2-year storm as stated in footnote 49.

Recommendation:

Revise second sentence in paragraph as follows: "In considering the effective impervious cover, the impervious areas that are directly connected to a storm water conveyance system should be included, and those areas that are connected to pervious areas with a capacity to percolate at least the **excess** runoff from a 2-year storm event, need not be considered."

Paragraph 4. The paragraph states that "hydrologic conditions or concern are not significant, if the post-development hydrograph is no more than 10% greater than the pre-development hydrograph." The characteristics of what needs to be considered in the hydrograph comparison needs to be defined. Besides peak discharges and volume are there other factors? The paragraph also states that where the excess volume from the 2-year storm event cannot be infiltrated, capturing is acceptable as long as the discharge flow rate does not exceed 110% of the predevelopment condition. Detention basins which capture and detain runoff until the peak has passed would quality as meeting this requirement.

Recommendation:

Clarify which characteristics of hydrograph need to be compared and the use of detention basins to capture and release runoff.

Section E – Alternatives and In-Lieu Programs

This section contains programs that may be used in place of LID, which require further clarification.

Paragraph 3 identifies several types of projects that qualify for a water quality credit system that may be established as alternatives to evapotranspiration, infiltration, LID and the Hydromodification. The credit program is welcomed as a way to offset other projects but it is not clear if this would be a one to one offset or how the program would work. For instance, if an In-fill project (redevelopment private or public) is undertaken, would it offset the requirement for another project on an acre for acre basis. In-fill projects or any other projects listed will themselves have difficulty meeting some of the New Development/Significant Redevelopment LID 5% EIA requirements in the permit. Since these are desirable projects, are they required to meet all requirements in the permit?

Recommendation:

1. Clarify how a water quality credit system might work and if the listed project categories need to comply with all New Development/Significant Redevelopment requirements.

Section F - Approval of WQMPs

Paragraph 1 requires the use of a checklist to ensure that the WQMP incorporates the minimum requirements of the Model WQMP.

Recommendation:

Revise paragraph to state that checklists need not be used if the WQMP template incorporates the requirements of the Model WQMP.

Section J - Preapproved Projects

Paragraph 1 allows approved Water Quality Management Projects to be exempted from the new LID requirements, which include the 5% EIA criteria as well as the hydrologic conditions of concern if the project's final WQMP has been approved.
In previous permits, projects have been exempted from meeting the new permit requirements if they had received entitlement approvals such as tentative or parcel

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maps. This provision was intended to assure continuity of projects that received City approvals for land development and did not conflict with approvals given by cities. This is an important provision that allows projects to continue without delay and the need to restart the entitlement process, and possibly redesign the project, to meet new permit requirements.

City approvals included in project review process besides Tentative or Parcel maps include Site Plan or Conditional Use Permits as well as Preliminary WQMP approval. In the Preliminary WQMP approval, the City ensures that all applicable site design and treatment BMPs are incorporated into the WQMP. The Preliminary becomes the Final WQMP with minor text changes unless the project has undergone significant changes during the approval process that affect the approved BMPs. The Preliminary WQMP is where the majority of effort is expended to ensure the project complies with the Model WQMP and new development requirements. This review cycle generally lasts several months and is the basis for City approval of the project WQMP.

Without including Site Plan, Preliminary WQMP or other discretionary city approvals in the provision to exempt previously approved projects, many projects will be forced to restart the entire approval process.

Recommendation:

Exempt projects that have received Tentative or Parcel Map or other discretionary city approvals such as Site Plan, Conditional Use Permits, Preliminary or Final WQMP approval from the new development/significant redevelopment requirements.

Section XIV – Municipal Facilities/Activities

Paragraph 3.b requires permittees to inspect flood control and storm water conveyances systems on an annual basis. While flood control channels are inspected annually, storm drains are not. In previous permits, large storm drains were inspected to identify illegal connections. This requirement was removed after it was determined that illegal connections were not a concern. The paragraph should be revised to clarify that storm water conveyance systems do not mean storm drains.

Recommendation:

Delete storm water conveyance systems and revise to "Open Flood Control Channels."

Paragraph 3.d requires permittees to inspect their sewage collection system on an annual basis. Cities that own collection systems in California are subject to WDR Order 2006-0003. That order requires municipalities to develop a maintenance plan and schedule. It does not require annual inspection. The City has a five-year maintenance cycle where some collection lines are inspected annually and others can take up to five years. The sewer inspection provision should be consistent with the state WDR requirements.

Recommendation:

Delete reference to sewage collection and reference state WDR permit as noted in paragraph 14.

Paragraph 5.d. requires that the LIP be revised within six months of permit adoption to incorporate an Integrated Pest Management Program (IPM). Incorporation of a complete IPM will be completed after the UC Cooperative Extension completes the Model Integrated Pest Management Program. It is not known when this document will be completed and the City has not had a chance to review any drafts. Six months may not be sufficient and the timeline should be to allow for six months after the completion of the Model IPM by the UC Cooperative Extension. The City currently follows the Model Integrated Pest Management, Pesticides and Fertilizer Guidelines of section 5.5 of the DAMP as noted in 5.b.

Recommendation:

Revise paragraph to allow for six months to revise LIP after the Model IPM has been completed by the UC Cooperative Extension.

Section XVI - Training

ROWD

Training commitments submitted in the Report of Waste Discharge (ROWD) were meant to ensure that individuals were properly trained. These training commitments can be accomplished through revision of existing training modules developed by the principal permittee (County of Orange) for the various program elements. Cities can in turn modify these modules or develop their own to provide the necessary training.

Certifications

The City fully supports having trained individuals to carry out the requirements of the permit. However, the proposed Training section contains provisions that go well beyond

having appropriate training by requiring testing and certifications such Certificates of Completion to document training. This creates an additional and unnecessary expense to the permittees.

Public agencies by law approve class specifications and training requirements. By requiring certifications the permit infringes on the rights of cities to set employee training requirements. In addition, changes to class specifications required by proposed certifications must be negotiated appropriate bargaining units and approved by the city council. The permit should simply require individuals to be properly trained and leave it to the permittees to provide the necessary training and ensure competency in carrying out work assignments.

Other Provisions

Paragraphs 1 and 3 require public works employees and maintenance crews to have expertise and competence in carrying out their assignments. This requirement is over-reaching. Not all public works employees conduct work that affects water quality. There are many that have office jobs and do not need to be trained beyond providing them with information about water quality through newsletters, brochures and internal storm water presentations.

Maintenance crews are trained on minimizing water discharges and nonstorm water discharges through internal presentations and the Model Maintenance Procedure fact sheets and are made aware of federal (CWA) and state (Water Code) water quality requirements. This training should suffice for these employees without the need to show expertise and competence in water quality. Some employees may have difficulty taking tests and this should not be a requirement to determine whether they can perform their jobs. Supervisors are capable of providing the guidance needed.

The section also requires the principal permittee to provide training on an annual basis for specific individuals involved in implementing the requirements of the permit and for permittees to attend a minimum of three sessions during the term of the permit. The City believes attending two training sessions is sufficient.

In addition, requiring annual training for the sake of permit compliance seems unnecessary unless there is a change in laws, permit requirements or other factors. Repeating the same material year after year serves little purpose other than to use up time and valuable resources.

Recommendations:

Paragraph1. Clarify that public works employees refers to those individuals that actually carry out the requirements of the permit and that maintenance crews need to be trained only on water quality requirements and Model Maintenance procedures.

Paragraph 3. As noted above, requiring testing and proof of completion such as certificates infringes on the rights of cities to set class specification requirements. Revise the paragraph as follows: "The training modules for each category of trainees (managers, inspectors, planners, contractors, public works crews, etc.) should define the required competencies.

Paragraph 4. Delete the requirement to attend 3 training sessions and to determine competency and testing.

1. Revise third sentence as follows: " Each permittee shall attend at least **two** of these training sessions during the term of this permit."

2. Delete testing requirement.

Paragraph 6. Consistent with the comments above requiring testing and competency, revise the last sentence as follows: "---, the permittees shall require evidence that contract staff have received an adequate level of training."

Paragraph 8. 60 days may not be sufficient to be trained and implement the requirements of the permit. The training time depends on the assignment to be carried out and involves more than simply viewing training modules. There may be field inspections and written documents to be reviewed (DAMP, LIP, codes, etc.). Understanding these documents will require more than 60 days. Program managers may require a year or more, other staff less.

Recommendation:

Allow a minimum of 120 days for inspectors and up to 1 yr. for program managers. A varying scale of 6 months to a year can be used for plan checkers and environmental reviewers.

Industrial Inspection Cover Sheets

INDUSTRIAL - COMMERCIAL FACILITY INSPECTION

CITY OF ORANGE
National Pollution Discharge Elimination System (NPDES)

Public Works Department
637 W. Struck Ave., Orange CA 92867
(714) 532-6480

Date: 8/11/08 Time: 9:30 am Inspector(s): R. Esparza

☐ Initial Inspection ☒ Routine Inspection ☐ Follow-up Inspection ☐ Response to Complaint

I. GENERAL INFORMATION

Facility Name: Furniture Traditions **Site Address:** 1450 W. Collins
Contact Name: Francisco Mesinas **Contact Phone:** 538-2088
SIC Code: 5712 **SIC Code Description:** Furniture Stores
Primary Business Activity: Wood Furniture Manufacturing
Facility Type: ☒ Industrial ☐ Commercial **Priority Status:** ☒ High ☐ Medium ☐ Low
Is the facility covered under a storm water permit? ☐ Individual NPDES ☒ General NPDES WDID# 015484
Does the facility have a Storm Water Pollution Prevention Plan (SWPPP) Onsite? ☒ Yes, dated: 10/02 ☐ No ☐ N/A
City of Orange Business License Number: 5368

II. ACTIVITIES / BEST MANAGEMENT PRACTICES (BMP) ASSESSMENT

General Facility Description:
2 Large Industrial buildings with indoor work processing areas. One building used for storage and one for wood furniture manufacturing

Nearby conveyances and/or visible off-site discharge points:
5 drains are located on the property, all lead to O.C. flood channel

Outdoor walk through (note activities and any BMPs in use):
Dust vacuum used to clean whole facility. Areas along the west fence are done every other day as well as areas with the most sawdust
Trucks are serviced by outside company every 3 months.
Lumber stored under cover with curtains to prevent exposure to storm water.

Indoor walk through (note activities and any BMPs in use):
Sawdust is swept by hand regularly
Good housekeeping,
Operations have slowed to 4 days a week (Fridays off)

III. PRIORITIZATION VERIFICATION 7 - LOW BUT Keep High

Industrial/Commercial

Type of Activity – Percent of activities outdoors and uncovered: ☒ <25% ☐ 25-50% ☐ 50-75% ☐ >75%

Discharge Potential – Overall implementation of BMPs: ☒ Fully Implemented ☐ Partially Implemented ☐ None or Unknown

Non-stormwater Discharges:
☒ None observed / no evidence of / no sources noted
☒ Sources observed, but BMPs in place
☐ Sources observed, no BMPs in place, but no discharge
☐ Observed discharges / evidence of discharges / no BMPs

Facility size – Approximate size of impervious area: ☐ <5,000 sq. ft. ☒ 5,000-100,000 sq. ft. ☐ >100,000 sq. ft.

Material used – Amount of raw material kept indoors or properly covered outdoors: ☒ All ☐ Most ☐ Some ☐ Few / none

Waste Generated: ☐ N/A ☒ Not generated or disposed of properly ☐ Generated and not disposed properly

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INDUSTRIAL - COMMERCIAL FACILITY INSPECTION

CITY OF ORANGE
National Pollution Discharge Elimination System (NPDES)

...lic Works Department
637 W. Struck Ave., Orange CA 92867
(714) 532-6480

Date: 8/26/08 Time: 10:00 am Inspector(s): T. DUNN

☐ Initial Inspection ☒ Routine Inspection ☐ Follow-up Inspection ☐ Response to Complaint

I. GENERAL INFORMATION

Facility Name: USF REDDAWAY **Site Address:** 2200 N BATAVIA ST
Contact Name: BOB BOHI **Contact Phone:** 637-9745
SIC Code: 4212 **SIC Code Description:** LOCAL TRUCKING W/O STORAGE
Primary Business Activity: TRUCKING / MATERIAL TRANSPORTATION
Facility Type: ☒ Industrial ☐ Commercial **Priority Status:** ☒ High ☐ Medium ☐ Low
Is the facility covered under a storm water permit? ☐ Individual NPDES ☐ General NPDES WDID#_____
Does the facility have a Storm Water Pollution Prevention Plan (SWPPP) Onsite? ☐ Yes, dated: _____ ☐ No ☐ N/A
City of Orange Business License Number: 124908

II. ACTIVITIES / BEST MANAGEMENT PRACTICES (BMP) ASSESSMENT

General Facility Description:
OFFICES/SHOP BLDGS, LOADING DOCK & OPEN YARD FOR VEHICLES

Nearby conveyances and/or visible off-site discharge points:
PROP SLOPES SOUTHEAST TO MAIN ENTRY DRIVE

Outdoor walk through (note activities and any BMPs in use):
CONTAINMENT SHED @ FUEL AREA (NEW/USED FLUIDS)
ABSORBENT AVAILABLE
TRASH CONTAINERS W/ LIDS
VEHICLE MAINT/CLEANING ELSEWHERE OR MAINT ON-SITE BY OTHERS

Indoor walk through (note activities and any BMPs in use):
MECH. SHOP CLOSED — MOST MAINT OFF-SITE
WEEKLY SAFETY MTGS / SAFETY COMMITTEE — MONTHLY

III. PRIORITIZATION VERIFICATION

TOTAL (10) LOW HI-PRI PER RWQCB

Industrial/Commercial

Type of Activity – Percent of activities outdoors and uncovered: ☐ <25% ☒ 25-50% ☐ 50-75% ☐ >75%

Discharge Potential – Overall implementation of BMPs: ☒ Fully Implemented ☐ Partially Implemented ☐ None or Unknown

Non-stormwater Discharges:
☐ None observed / no evidence of / no sources noted
☒ Sources observed, but BMPs in place
☐ Sources observed, no BMPs in place, but no discharge
☐ Observed discharges / evidence of discharges / no BMPs

Facility size – Approximate size of impervious area: ☐ <5,000 sq. ft. ☐ 5,000-100,000 sq. ft. ☒ >100,000 sq. ft.

Material used – Amount of raw material kept indoors or properly covered outdoors: ☒ All ☐ Most ☐ Some ☐ Few / none

Waste Generated: ☐ N/A ☒ Not generated or disposed of properly ☐ Generated and not disposed properly

INDUSTRIAL - COMMERCIAL FACILITY INSPECTION

CITY OF ORANGE
National Pollution Discharge Elimination System (NPDES)

Public Works Department
637 W. Struck Ave., Orange CA 92867
(714) 532-6480

Date: 8/27/08 Time: 9:30am Inspector(s): R. Esparza

☐ Initial Inspection ☒ Routine Inspection ☐ Follow-up Inspection ☐ Response to Complaint

I. GENERAL INFORMATION

Facility Name: ABF Freight **Site Address:** 1601 N. Batavia
Contact Name: Jerry Wright **Contact Phone:** 974-2485
SIC Code: 4213 **SIC Code Description:** Trucking
Primary Business Activity: Trucking & Freight Transportation
Facility Type: ☒ Industrial ☐ Commercial **Priority Status:** ☒ High ☐ Medium ☐ Low
Is the facility covered under a storm water permit? ☐ Individual NPDES ☒ General NPDES WDID# Waiting for WDID
Does the facility have a Storm Water Pollution Prevention Plan (SWPPP) Onsite? ☒ Yes, dated: Old SWPPP For Former Co. ☐ No ☐ N/A
City of Orange Business License Number: 110767

II. ACTIVITIES / BEST MANAGEMENT PRACTICES (BMP) ASSESSMENT

General Facility Description:
Large building with covered loading docks for Freight Trucks.

Nearby conveyances and/or visible off-site discharge points:
Curbed concrete swales on the north and south sides of the property divert stormwater to Batavia.

Outdoor walk through (note activities and any BMPs in use):
Sweeping of outdoor areas is done weekly by landscaping company.
Outside areas are checked daily for problems. Forklifts are serviced onsite by outside company. Trucks are serviced at facility in Pico Rivera
Vehicle & Trailer storage – Areas are clean

Indoor walk through (note activities and any BMPs in use):
Spill Kits clearly labled and available
Biannual Spill response training for employees
Loading and unloading of vehicles
Extremely clean loading dock

III. PRIORITIZATION VERIFICATION

7 LOW BUT KEEP HIGH

Industrial/Commercial

Type of Activity – Percent of activities outdoors and uncovered: ☒ <25% ☐ 25-50% ☐ 50-75% ☐ >75%

Discharge Potential – Overall implementation of BMPs: ☒ Fully Implemented ☐ Partially Implemented ☐ None or Unknown

Non-stormwater Discharges:
☒ None observed / no evidence of / no sources noted
☐ Sources observed, but BMPs in place
☐ Sources observed, no BMPs in place, but no discharge
☐ Observed discharges / evidence of discharges / no BMPs

Facility size – Approximate size of impervious area: ☐ <5,000 sq. ft. ☐ 5,000-100,000 sq. ft. ☒ >100,000 sq. ft.

Material used – Amount of raw material kept indoors or properly covered outdoors: ☒ All ☐ Most ☐ Some ☐ Few / none

Waste Generated: ☐ N/A ☒ Not generated or disposed of properly ☐ Generated and not disposed properly

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INDUSTRIAL - COMMERCIAL FACILITY INSPECTION

CITY OF ORANGE
National Pollution Discharge Elimination System (NPDES)

Public Works Department
637 W. Struck Ave., Orange CA 92867
(714) 532-6480

Date: 9/9/08 Time: 9:00 am Inspector(s): T. DUNN

☐ Initial Inspection ☒ Routine Inspection ☐ Follow-up Inspection ☐ Response to Complaint

I. GENERAL INFORMATION

Facility Name: UNIVERSAL CYL. EXCHANGE **Site Address:** 692 N CYPRESS ST # B
Contact Name: BRIAN OGIER **Contact Phone:** 714 774-1036
SIC Code: 3593 **SIC Code Description:** FLUID POWER CYLINDERS & ACTUATORS
Primary Business Activity: PROPANE CYLINDER PROCESSING
Facility Type: ☒ Industrial ☐ Commercial **Priority Status:** ☒ High ☐ Medium ☐ Low
Is the facility covered under a storm water permit? ☐ Individual NPDES ☐ General NPDES WDID# _____
Does the facility have a Storm Water Pollution Prevention Plan (SWPPP) Onsite? ☐ Yes, dated: _____ ☐ No ☐ N/A
City of Orange Business License Number: 105087

II. ACTIVITIES / BEST MANAGEMENT PRACTICES (BMP) ASSESSMENT

General Facility Description:
(2) UNIT BLDG OF OFFICES, SHOP OPEN YARD ON WEST SIDE

Nearby conveyances and/or visible off-site discharge points:
YARD SLOPES NORTH TO SWALE LEADING EAST TO STREET
NORTHWEST AREA PONDS, THEN EVAPORATES

Outdoor walk through (note activities and any BMPs in use):
YARD IS CLEAN - SWEPT DAILY - ALL IS PAVED
NORTH SIDE SWALE CLEANED REGULARLY
STORAGE IN YARD KEPT OFF GROUND
MATERIAL RECYCLING BY OTHERS
CLEANING OF CYLINDERS IN DRUMS / WATER CONTAINED

Indoor walk through (note activities and any BMPs in use):
SHOP AREA APPEARS CLEAN - SWEPT REGULARLY
WEEKLY MTG W/ STAFF

III. PRIORITIZATION VERIFICATION

TOTAL (8) LOWER TO MED-PRI

Industrial/Commercial

Type of Activity – Percent of activities outdoors and uncovered: ☐ <25% ☐ 25-50% ☒ 50-75% ☐ >75%

Discharge Potential – Overall implementation of BMPs: ☒ Fully Implemented ☐ Partially Implemented ☐ None or Unknown

Non-stormwater Discharges:
☐ None observed / no evidence of / no sources noted
☒ Sources observed, but BMPs in place
☐ Sources observed, no BMPs in place, but no discharge
☐ Observed discharges / evidence of discharges / no BMPs

Facility size – Approximate size of impervious area: ☐ <5,000 sq. ft. ☒ 5,000-100,000 sq. ft. ☐ >100,000 sq. ft.

Material used – Amount of raw material kept indoors or properly covered outdoors: ☐ All ☒ Most ☐ Some ☐ Few / none

Waste Generated: ☐ N/A ☒ Not generated or disposed of properly ☐ Generated and not disposed properly

SARB 003705

CITY OF YORBA LINDA

4845 Casa Loma Avenue P.O. Box 87014 Yorba Linda, CA 92885 – 8714
(714) 961-7138 Fax: (714) 993-9148

CRWQCB - REGION 8
MES

FEB 13 2009

February 11, 2009

Gerard Thibeault
Executive Officer
California Regional Water Quality Control Board, Santa Ana Region
3737 Main Street, Suite 500
Riverside, CA 92501-3348

Subject: Comment Letter – Draft Order No. R8-2008-0030 NPDES No. CAS618030

Dear Mr. Thibeault:

We appreciate the opportunity to provide comments on the Santa Ana Regional Board's Draft Order No. R8-2008-0030, as distributed in November 2008. The draft Tentative Order is indeed reflective of the recommendations made in the Report of Waste Discharge (ROWD), submitted by the Principal Permittee and Copermittees of North Orange County. However, there are several concerns that the City of Yorba Linda would like to emphasize with the new requirements proposed by the draft Tentative Order, in particular, where costs to implement such requirements would be prohibitive to meet substantial compliance with the draft Tentative Order. In addition to our concurrence with comment letter submitted by the County of Orange, the City of Yorba Linda would like to submit these additional comments for your consideration.

Comment #1: Increased administrative burden from reporting requirements.
The City of Yorba Linda echoes the County's comments regarding the increasing administrative burden on Copermittees with the new requirements in the draft Tentative Order. Like other Copermittees over the years, fiscal expenditure on the City's Storm Water NPDES program has steadily increased. Over a 4 year period, it has increased approximately 13.5 percent. Coupled with the current economic climate, the lack of development fees to supplement City budgets along with state-wide budget cuts and hiring freezes, the increase in administrative requirements proposed by the draft Tentative Order may place a prohibitive strain on Cities to meet compliance objectives or compromise the goal of improving water quality.

The information submittals required in Section IX.6 and X.5, in particular, may prove to be a resource intensive endeavor. During the past fiscal year, the City invested money and resources in the development of an electronic database to track and record information for the New Development Program, Existing Development Program, Construction Program, ID/IC Program, and the Municipal Program. To incorporate and maintain the functions outlined in the draft Tentative Order to those databases may prove to be resource intensive. Furthermore, to require Copermittees provide their databases to the Regional Board may prove to be logistically difficult, as each Copermittee may be relying upon different software programs (or proprietary software), which may or may not be compatible to Regional Board systems. To convert such systems for compatibility may require significant costs to the permittee.

Comment #2: Unwarranted addition of commercial facility categories for the commercial inspection program.

In Section X.1 of the draft Tentative Order, 11 new categories of commercial facilities are subject to municipal inspections. No justification is provided by the Findings of the Tentative Order that support these 11 commercial categories as posing a significant water quality threat to the MS4, thereby warranting their listing. The City currently has 228 commercial facilities in its inventory, with 2 dedicated Authorized Inspectors to perform industrial/commercial inspections in addition to their primary code enforcement duties. To add 11 new categories of facilities to inspect, without any justification demonstrating them as significant non-point source polluters, will place a significant and unwarranted strain on City resources for an unknown water quality benefit, if any.

The City recognizes the importance of commercial inspections to the Storm Water Program. The program, since its inception, has been an excellent tool for public outreach and education. As with other Copermittees, the City regularly trains its staff/Authorized Inspectors on municipal inspections of commercial facilities per the requirements of the current term MS4 Permit. Authorized inspectors are, therefore, equipped with the skills to adequately identify problematic commercial facilities during their daily field activities. When such facilities are inspected and determined as a water quality threat, they are added to the commercial inventory. Facilities are routinely added to the commercial program, as well as the industrial program, in such a manner. Moreover, the City also targets its industrial/commercial districts for a more focused effort of monitoring and inspection, rather than relying solely on commercial classification of businesses. Based on the City's experience, a large number of commercial and industrial facilities are misclassified as facilities subject to the Existing Development inspection program on their business license applications and are discovered as not subject to the program upon inspection. For these reasons, arbitrarily adding 11 new facility categories to the commercial program are, in our opinion, unnecessary and fiscally burdensome. Until such categories are determined to pose significant water quality threats, they should not be included in the draft Tentative Order.

Comment #3: Applying minimum percentages for high, medium, and low priority commercial facilities trivializes the prioritization process.

The new requirement to have 10% of commercial sites ranked "high", 40% ranked "medium", and the rest of the commercial inventory ranked low, as stated in X.2 of the draft tentative order is unfounded. The Findings do not provide any basis for these minimum criteria. By doing so, it trivializes the process of ranking commercial facilities, which should be based solely on their water quality threat. If a facility is ranked "low" based on the listed factors evaluated, it should be deemed as such. Furthermore, setting this minimum percentage penalizes Copermittees with a low population of commercial facilities with "high" pollution potential by imposing unwarranted inspections. This would further strain that City's resources. This requirement should be removed from the Tentative Order. Instead, the City of Yorba Linda suggests that the draft Tentative Order provide criteria for the proposed ranking of facilities.

Comment #4: The Residential Program proposed in Section XI is redundant and conflicts with the Public Education/Outreach approach established in the current MS4 permit term.

The City agrees with the sentiments expressed in the County's comments regarding the proposed Residential Program in the draft Tentative Order. The obligation to require residents to implement BMPs to mitigate polluted storm water runoff discharges is contrary to the Public Education and Outreach program, which strives to engender environmental stewardship and to affect the public through behavior change. The City supports a Residential Program component to the draft Tentative Order, but recommends the program be driven or measured through behavior change and awareness, and not through requirements for BMP implementation.

Comment #5: LID requirements for 5% Effective Impervious Area are not justified in the Proposed Permit and may discourage infill and redevelopment opportunities.

The City supports the Principal Permittee's comments on the 5% EIA requirements in the draft Permit. In addition, the City would like to reiterate that the 5% EIA requirements inappropriately takes a watershed assessment tool and applies it to site-specific projects. Justification for this application is not provided and does not ensure the protection of water quality but significantly encroaches upon the municipality's land use discretion authority. The City recognizes this requirement may be appropriate for new master planned communities but is not as appropriate for a City such as Yorba Linda where it is largely built out. For the City of Yorba Linda, there is a significantly higher potential for higher density in-fill or redevelopment projects that can be developed in a much more sustainable way that reduces the carbon footprint of the site. Encouraging sustainable redevelopment within the City is an important objective of the City and is consistent with other land use regulations such as AB 375. EIA requirements on high-density developments may not be feasible or appropriate in certain situations and may discourage redevelopment projects.

However, the City of Yorba Linda has been encouraged by the efforts of the Principle Permittee staff, the Santa Ana Regional Board Staff, and local NGOs to sit down and develop an alternative approach. The watershed approach currently being developed by all parties appears to address the concerns that the City had. The City is encouraged that the parties will continue to develop an alternative plan after this first draft comment deadline.

Consistent with the working group noted above, the City of Yorba Linda strongly supports technically equivalent performance standards other than the EIA percentage (3-5%) for implementing LID BMPs. The City also wants to make note that the proposed changes to land development would require a period of time for the Permittees to develop technical resources and capacity to implement them. At a minimum, there should be at least a 12-month period after permit adoption before any new obligations take effect.

Sincerely,

Steven K. Harris
Community Development Director

Cc: William R. Kelly, Interim City Manager
Howard Weldon, Sr. Community Preservation Officer / NPDES Coordinator

CITY OF LAKE FOREST

February 12, 2009

Mayor
Mayor Pro Tem
Peter Herzog
Council Members
Richard Dixon
Kathryn McCallough
Marcia Rudolph
City Manager
Robert Chamberlain

Via US Mail and Fax

Mr. Gerard Thibeault
Executive Officer
California Regional Water Quality Control Board, Santa Ana Region
9174 Sky Park Court, Suite 100
San Diego, CA 92123

Subject: Comments on First Draft Order No. R8-2008-0030, Waste Discharge Requirements for the County of Orange, Orange County Resources and Development Management Department and The Incorporated Cities of Orange County Within the Santa Ana Region Areawide Urban Stormwater Runoff Orange County

Dear Mr. Thibeault:

The City of Lake Forest ("City") respectfully submits this letter to the Santa Ana Regional Water Quality Control Board ("SARWQCB") to convey the City's formal written comments on Tentative Order No. R8-2008-0030/NPDES Permit No. CAS618030 ("Draft Permit"). The City commends the SARWQCB staff on its preparation of the Draft Permit. The Draft Permit is well written, contains significant environmental protections, and represents a very positive starting point for the collaborative development of a mutually beneficial Large MS4 Permit.

The City is additionally aware that the County of Orange ("County") is submitting a similar comment letter regarding specific conditions contained in the Permit. The City would like to express its full support for the County's comments and intends the comments contained in this letter to supplement those submitted by the County and the other Permittees. Accordingly, please consider the County's comments to be incorporated in the City's letter by this reference. The City's comments follow.

COMMENTS

Consistency with the San Diego Region Large MS4 Permit

The City, along with several other Copermittees are subject to the jurisdiction of both the Santa Ana Regional Water Quality Control Board and the San Diego Regional Water Quality Control Board. Both jurisdictions issue comprehensive Large MS4 Permits that require the City to implement extensive compliance programs. Differences in the substantive requirements of both Regions' Large MS4 Permits have significant impacts on City operations. Major, program level differences force the City to implement what amounts to two different compliance programs within City limits. This results in an

DRUG USE IS LIFE ABUSE

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unnecessary resource and administrative burden which, in turn, causes valuable resources to be diverted away from program implementation..

Additionally, differences in the timeline for adoption of both Permits impact the City's program implementation in planning, organization, and reporting. For example, it will be necessary for the City submit a revised Local Implementation Plan (the comprehensive principal guidance document at the Copermittee level) following the adoption of an MS4 Permit. Once the San Diego Region's Large MS4 Permit is adopted, it will be necessary for the City to redouble efforts to revise and submit an updated Local Implementation Plan (LIP). This, is a substantial task since preparation of the LIP will require consideration of the City's program in comprehensive terms and includes: program management, planning, organization, establishment or confirmation of legal authorities, municipal activities programs, public education, new development/significant redevelopment, construction, industrial and commercial existing development, residential programs, homeowners associations, illegal discharges and illicit connections, and water quality monitoring. The City will be required to do this twice to comply with both permit regimens. If the permits are issued at similar times and include similar reporting guidelines, the burden associated with this and other similar reporting requirements will be reduced.

A recent report by the Little Hoover Commission, an independent state oversight agency, discussed this issue in depth. The Commission recommended numerous measures to ensure consistency among the Regional Water Quality Control Boards. In order to further this goal of consistency, both Regional Boards should work together to limit the substantive differences in their respective Large MS4 Permits, and issue their permits along similar timelines.

Effective Impervious Area Objectives

Draft Permit Section XII.C.3. requires the Effective Impervious Area (EIA) for priority development projects be limited to 5% or less. Section XII.C.3. further requires this to be achieved through the use of Low Impact Development ("LID") measures at the project site, as close as possible to the source of runoff. Although the Draft Permit does allow for in lieu programs and other LID alternatives, these alternatives all require LID measures – effectively requiring infiltration BMPs – at the project site, and most still require 5% EIA. The City has the following concerns with the Draft Permit's heavy reliance on LID and a 5% EIA standard:

1. The requirement for 5% EIA and encouragement of infiltration does not allow considerations of the overall site water balance and could lead to unnatural levels of groundwater infiltration. Excessive infiltration could cause a range of problems, including habitat changes in downstream water bodies that were formerly dry most of the year and/or issues with naturally occurring pollutants being mobilized (e.g., selenium).

2. Requiring the use of LID BMPs on each project site means an increase in infiltration BMPs at each site. In the aggregate, and particularly with infill redevelopment, this can promote sprawl by increasing the size of individual project sites.

3. Not all sites will need to implement the 5% EIA to prevent impacts to downstream water bodies. In some cases a combination of treatment control BMPs and LID BMPs will effectively mitigated stormwater impacts without reaching the 5% EIA threshold.

4. The EIA metric does not necessarily protect stream dynamics and susceptibility to hydromodification. To protect stream channel geomorphology and habitat, permit standards should reflect channel conditions and rely on channel-related metrics.

5. The EIA standard may lead to poor LID implementation. Compliance with 5% EIA can be manipulated and not result in the goal of mimicking pre-development hydrology.

Because neither the EIA standard nor the benefits of LID provide an all encompassing solution to stormwater, the Draft Permit should not rely on either to the extent that it currently does. Both should be used as one measure among several to achieve runoff reductions for new development/significant redevelopment.[1] The City therefore requests that the Draft Permit be revised to remove or significantly revise the 5% EIA requirement.

Incorporation of San Diego Creek/Newport Bay Selenium TMDL

Draft Permit section XVIII.B.3. incorporates the San Diego Creek/Newport Bay Selenium TMDL into the Draft Permit. Selenium discharges from the MS4 occur from groundwater seepage or "rising groundwater" that enters the MS4 before making its way to surface waters. Selenium is naturally occurring in the San Diego Creek Watershed and beyond the ability of the Permittees to control. Its discharge should not be regulated in an NPDES permit, and to the extent that it is part of a TMDL, it should be recognized as a naturally occurring, background load allocation.

Municipal Inspections of Commercial Facilities

Draft Permit Section X.2. sets minimum criteria for commercial facility prioritization including the requirement that 10% of a Permittee's inventory be ranked high priority, 40% be ranked medium priority, and the balance ranked low priority. Draft Permit

[1] For further discussion of this issue, please refer to *Low Impact Development Metrics in Stormwater Permits* (Jan. 2009) produced by Geosyntec Consultants and Larry Walker Associates for the Ventura County Stormwater Quality Management Program and the Orange County Stormwater Program (submitted under separate cover by the County of Orange).

Section X.3 then sets aggressive inspection requirements based upon the prioritization. Requiring a specific percentage of commercial facilities to be given a set priority does not take into account the actual priority of commercial sites within a Permittee's jurisdiction. For some Permittees, more than 10% of the commercial sites within their jurisdiction should be classified high priority. For others, less than 10% would be appropriate. For that reason, the City requests that the mandatory percentage requirements for facility ranking be removed or revised to represent a suggested goal.

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We appreciate your attention to our comments. As stated above, the City views these comments as part of the ongoing, open dialogue between the Permittees and the SARWQCB to help develop an effective Large MS4 Permit for North Orange County. The City is committed to the goal of water quality improvement and wants to work with the SARWQCB in developing the most prudent and cost effective way to reach that goal. We look forward to receiving your response to the above comments and concerns. If you should have any questions, please contact Devin Slaven, Water Quality Specialist, at (949) 461-3436.

Sincerely,
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cc: Robert C. Dunek, City Manager
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CITY OF LAKE FOREST

SAN DIEGO REGIONAL WATER QUALITY CONTROL BOARD
2009 FEB 18 P 2:45

February 12, 2009

Mayor
Mark Tettemer
Mayor Pro Tem
Peter Herzog
Council Members
Richard Dixon
Kathryn McCullough
Marcia Rudolph
City Manager
Robert C. Dunek

Via US Mail and Fax

Mr. Gerard Thibeault
Executive Officer
California Regional Water Quality Control Board, Santa Ana Region
9174 Sky Park Court, Suite 100
San Diego, CA 92123

Subject: Comments on First Draft Order No. R8-2008-0030, Waste Discharge Requirements for the County of Orange, Orange County Resources and Development Management Department and The Incorporated Cities of Orange County Within the Santa Ana Region Areawide Urban Stormwater Runoff Orange County

CRWQCB - REGION 8
FEB 26 2009

Dear Mr. Thibeault:

The City of Lake Forest ("City") respectfully submits this letter to the Santa Ana Regional Water Quality Control Board ("SARWQCB") to convey the City's formal written comments on Tentative Order No. R8-2008-0030/NPDES Permit No. CAS618030 ("Draft Permit"). The City commends the SARWQCB staff on its preparation of the Draft Permit. The Draft Permit is well written, contains significant environmental protections, and represents a very positive starting point for the collaborative development of a mutually beneficial Large MS4 Permit.

The City is additionally aware that the County of Orange ("County") is submitting a similar comment letter regarding specific conditions contained in the Permit. The City would like to express its full support for the County's comments and intends the comments contained in this letter to supplement those submitted by the County and the other Permittees. Accordingly, please consider the County's comments to be incorporated in the City's letter by this reference. The City's comments follow.

COMMENTS

Consistency with the San Diego Region Large MS4 Permit

The City, along with several other Copermittees are subject to the jurisdiction of both the Santa Ana Regional Water Quality Control Board and the San Diego Regional Water Quality Control Board. Both jurisdictions issue comprehensive Large MS4 Permits that require the City to implement extensive compliance programs. Differences in the substantive requirements of both Regions' Large MS4 Permits have significant impacts on City operations. Major, program level differences force the City to implement what amounts to two different compliance programs within City limits. This results in an

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unnecessary resource and administrative burden which, in turn, causes valuable resources to be diverted away from program implementation..

Additionally, differences in the timeline for adoption of both Permits impact the City's program implementation in planning, organization, and reporting. For example, it will be necessary for the City submit a revised Local Implementation Plan (the comprehensive principal guidance document at the Copermittee level) following the adoption of an MS4 Permit. Once the San Diego Region's Large MS4 Permit is adopted, it will be necessary for the City to redouble efforts to revise and submit an updated Local Implementation Plan (LIP). This, is a substantial task since preparation of the LIP will require consideration of the City's program in comprehensive terms and includes: program management, planning, organization, establishment or confirmation of legal authorities, municipal activities programs, public education, new development/significant redevelopment, construction, industrial and commercial existing development, residential programs, homeowners associations, illegal discharges and illicit connections, and water quality monitoring. The City will be required to do this twice to comply with both permit regimens. If the permits are issued at similar times and include similar reporting guidelines, the burden associated with this and other similar reporting requirements will be reduced.

A recent report by the Little Hoover Commission, an independent state oversight agency, discussed this issue in depth. The Commission recommended numerous measures to ensure consistency among the Regional Water Quality Control Boards. In order to further this goal of consistency, both Regional Boards should work together to limit the substantive differences in their respective Large MS4 Permits, and issue their permits along similar timelines.

Effective Impervious Area Objectives

Draft Permit Section XII.C.3. requires the Effective Impervious Area (EIA) for priority development projects be limited to 5% or less. Section XII.C.3. further requires this to be achieved through the use of Low Impact Development ("LID") measures at the project site, as close as possible to the source of runoff. Although the Draft Permit does allow for in lieu programs and other LID alternatives, these alternatives all require LID measures – effectively requiring infiltration BMPs – at the project site, and most still require 5% EIA. The City has the following concerns with the Draft Permit's heavy reliance on LID and a 5% EIA standard:

1. The requirement for 5% EIA and encouragement of infiltration does not allow considerations of the overall site water balance and could lead to unnatural levels of groundwater infiltration. Excessive infiltration could cause a range of problems, including habitat changes in downstream water bodies that were formerly dry most of the year and/or issues with naturally occurring pollutants being mobilized (e.g., selenium).

2. Requiring the use of LID BMPs on each project site means an increase in infiltration BMPs at each site. In the aggregate, and particularly with infill redevelopment, this can promote sprawl by increasing the size of individual project sites.

3. Not all sites will need to implement the 5% EIA to prevent impacts to downstream water bodies. In some cases a combination of treatment control BMPs and LID BMPs will effectively mitigated stormwater impacts without reaching the 5% EIA threshold.

4. The EIA metric does not necessarily reflect stream dynamics and susceptibility to hydromodification. To protect stream channel geomorphology and habitat, permit standards should reflect channel conditions and rely on channel-related metrics.

5. The EIA standard may lead to poor LID implementation. Compliance with 5% EIA can be manipulated and not result in the goal of mimicking pre-development hydrology.

Because neither the EIA standard nor the benefits of LID provide an all encompassing solution to stormwater, the Draft Permit should not rely on either to the extent that it currently does. Both should be used as one measure among several to achieve runoff reductions for new development/significant redevelopment.[1] The City therefore requests that the Draft Permit be revised to remove or significantly revise the 5% EIA requirement.

Incorporation of San Diego Creek/Newport Bay Selenium TMDL

Draft Permit section XVIII.B.3. incorporates the San Diego Creek/Newport Bay Selenium TMDL into the Draft Permit. Selenium discharges from the MS4 occur from groundwater seepage or "rising groundwater" that enters the MS4 before making its way to surface waters. Selenium is naturally occurring in the San Diego Creek Watershed, and beyond the ability of the Permittees to control. Its discharge should not be regulated in an NPDES permit, and to the extent that it is part of a TMDL, it should be recognized as a naturally occurring, background load allocation.

Municipal Inspections of Commercial Facilities

Draft Permit Section X.2. sets minimum criteria for commercial facility prioritization including the requirement that 10% of a Permittee's inventory be ranked high priority, 40% be ranked medium priority, and the balance ranked low priority. Draft Permit

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FOR

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Director of Public Works/City Engineer

cc: Robert C. Dunek, City Manager
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Devin E. Slaven, REA, Water Quality Specialist
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SAN BERNARDINO COUNTY STORMWATER PROGRAM

A Consortium of Local Agencies

825 East Third Street
San Bernardino, CA 92415-0835
(909) 387-8112 / FAX 387-8130

Member Agencies

City of Big Bear Lake

City of Chino

City of Chino Hills

City of Colton

City of Fontana

City of Grand Terrace

City of Highland

City of Loma Linda

City of Montclair

City of Ontario

City of Rancho Cucamonga

City of Redlands

City of Rialto

City of San Bernardino

City of Upland

City of Yucaipa

County of San Bernardino

San Bernardino County Flood Control District

February 12, 2009

10(NPD)-2.02

Mr. Gerard J. Thibeault, Executive Officer
California Regional Water Quality Control Board, Santa Ana Region
3737 Main 20 W. 4th Street, Suite 500
Riverside, CA 92501-3348

RE: Orange County MS4 Draft Permit Comments

Dear Mr. Thibeault:

Thank you for the opportunity to provide comments on the draft MS4 NPDES Permit for the County of Orange within the Santa Ana River Watershed (draft Permit). The San Bernardino County Municipal Stormwater Program is providing these preliminary comments in the event that the Regional Board may incorporate some of the various elements of Orange County's draft Permit into the forthcoming renewed MS4 Permit for San Bernardino County.

Regional/Programmatic Concerns

Renewed Permits Should Build Upon Existing Permits and Programs

It had been our understanding that the renewed permit would use our Report of Waste Discharge (ROWD) and Regional Board recommendations from the MS4 program evaluations as a starting point to develop the new San Bernardino County MS4 Permit. However, since submitting our ROWD in October 2006, we have had numerous opportunities to interact with Regional Board staff and stakeholders in our Permit area, and to discuss the terms of the draft Permit. In recent months, we have become concerned about the direction of ongoing discussions and negotiations to develop and revise permit requirements and language for Orange County's draft Permit. While we share many of the same concerns as the Orange County stakeholders, there are substantial differences in our respective watershed areas that affect MS4 program implementation. These differences include the presence of ocean beaches in Orange County, with their economic and social benefits and susceptibility to stormwater impacts; differences in property values and the related tax base; the disparate potential for urban growth; and differing receiving water types and uses. In addition, the Santa Ana River watershed is hydrologically divided by Prado Dam so that downstream (reaches 1 and 2) and upstream (reached 3, 4, 5, and 6) areas require different management approaches. Since the completion of the Seven Oaks Dam, the flow and sediment regime of Reaches 4 and 5 (and to a lesser extent Reach 3) of the Santa Ana River are now significantly controlled by the presence and operation of the dam. The purpose of this comment is not to fully describe these differences, but to reinforce our belief that these differences must be considered when developing the San Bernardino County MS4 Permit.

Recycled Paper

We also understand that the draft Ventura County MS4 Permit has been vigorously discussed among stakeholders in recent months, and that the revised draft is being evaluated by the Natural Resources Defense Council and the USEPA. It appears that there is a strong desire from these groups to have more specificity and consistency among all the California MS4 Permits, and that there is an expectation that requirements adopted in the Ventura MS4 Permit should also be included in the Orange County MS4 Permit and that these requirements will ultimately be inserted into the San Bernardino County and Riverside County MS4 permits in their turn. We are concerned that decisions made with regard to Orange County's permit may establish fixed precedents for our MS4 permit without due consideration of unique local conditions.

Current and Expected Economic Constraints

The San Bernardino County Permittees share the economic concerns of the Orange County Permittees, as presented at the Regional Board meeting of November 21, 2008. Local governments are losing revenue and instituting severe budget reduction actions, such as furloughs and layoffs. We are uncertain of the duration and magnitude of the ongoing economic downturn, but it appears certain that significant staffing and expenditure constraints will continue for another year or more. While we understand that there are regulatory and statutory requirements to ensure compliance with the federal Clean Water Act, we suggest the Regional Board consider phased permit implementation, or prioritize the required programs for implementation based on available resources or economic indicators. The prospect of significant increases in program implementation costs that would be required to comply with the draft Permit contrasts sharply with the current California State budget limitations and the State's recent directive to suspend funding under water quality and conservation-based grant programs.

Specific Comments

Findings in the Draft Permit

Finding 3. We support a definition of maximum extent practicable (MEP) that includes consideration of a variety of factors, including technical and fiscal feasibility (see Footnote 2). We do not agree with the position espoused by others commenting on Orange County's draft Permit that MEP is an iterative process that imposes a continuing obligation *until water quality standards are achieved*. Such an interpretation effectively nullifies the meaning of the phrase "maximum extent practicable." It is possible for MS4 Permittees to be in full compliance with the federal Clean Water Act (CWA) and their MS4 Permits, even if water quality standards are not being attained, provided pollutants are reduced to the maximum extent practicable.

Finding 5. Despite this statement that the permit does not constitute an "unfunded mandate," there are some elements of the draft permit that are more stringent than the CWA and, therefore, constitute an unfunded mandate. This is especially true where the State of California elects to impose more restrictive water quality standards than are required by federal law. For example, federal law does not require the E. coli objective to provide a level of risk protection equal to 8 illnesses per 1000 swimmers. EPA has stated that this is a state risk management decision and it will accept higher E. coli objectives (up to 10 illnesses per 1000 swimmers). Similarly, federal law does not require more restrictive E. coli objectives to be applied to limited contact recreation, such as wading and fishing. That, too, is a state risk management decision. Therefore, the incremental cost of complying with more stringent water quality objectives than required by the CWA is an unfunded mandate.

Finding 8. We strongly support this finding that the permit is not intended to address background or naturally occurring pollutants or flows. This finding seems to conflict with some of the discharges listed in the draft Permit (Section III.3.i), including "irrigation from agricultural sources," and "rising groundwaters and natural springs." Agricultural flows are not regulated under the NPDES program and natural springs are, of course, naturally occurring.

Finding 10. We strongly support this finding. However, we suggest that Finding 10 actually contains two separate, but essential concepts: first, that permittees lack legal jurisdiction over a variety of entities that may generate pollutants; and second, that there are pollutant-generating activities that are beyond the ability of the permittees to eliminate. Therefore, we request that Finding 10 be stated as two distinct findings. This is important because, whereas jurisdictional issues may be overcome in some cases through administrative or legal means, control of some pollutant sources involves solving technical problems.

Finding 21. We support this finding. However, we suggest further clarification of the definition of pollutant "polishing" to protect our unfettered ability to rely on natural treatment systems to improve stormwater quality. As written, the finding also contains an apparent conflict between 40 CFR 131.10(a) (prohibits designating a waterbody for waste transport) and the stated "federal authorization under Sections 404 and 401 of the CWA (in that the 404 Permit/401 Certification may be required for waste treatment or conveyance). We suggest that there should also be a finding allowing transport of waste, where appropriate, to implement regional treatment strategies.

Finding 42. This finding requires Watershed Action Plans for 303(d) listed waters without an approved TMDL. This requirement is contrary to the assurances given by Regional Board staff that merely "listing" a segment did not impose any new obligations on Permittees. It is inappropriate to require remediation or mitigation without first adopting a formal TMDL.

Finding 61. We suggest further clarification of the role of the LID Manual. For example, the manual should define the standard of compliance. This manual will be reviewed by a wide array of stakeholders, including Regional Board staff, Permittees, and developers, and will undergo public review. Using a manual as the standard will allow periodic revisions of LID technical criteria without revising permits.

Finding 62. We disagree with the inference that the 5% EIA metric is as well proven and protective as suggested. For example, the SCCWRP study does not state that 5% EIA will prevent downstream impacts. The draft Orange County Permit has not documented a scientific basis to support the use of a 5% EIA limit, especially on a project-by-project approach. Scientific literature provides watershed- or subwatershed-scale evaluations that show a correlation between watershed imperviousness (whether expressed as EIA or total impervious area) and adverse impacts to stream ecology (most notably: Booth & Jackson 1997. Urbanization of aquatic systems: degradation thresholds, stormwater detention, and the limits of mitigation. Journal of the American Water Resources Association. 33(5):1077-1090). However, it does not necessarily follow that site-by-site implementation of an EIA limit will have the expected benefits, particularly in fully or partially urbanized watershed areas. It is probable that a substantial implementation burden will be placed on individual projects with little resultant ecological benefit.

Finding 72. We disagree with the decision to impose "Numeric Effluent Limits." While it is true that completed TMDLs often contain numeric targets, load allocations, and waste load allocations, Regional Board staff have repeatedly stated in response to public comments that these numeric values were not effluent limits, and would not be used as such in MS4 permits. If the Regional Board now wishes to adopt

a different interpretation of these requirements, it must first revisit the TMDLs and provide a new opportunity for public review and comment.

Finding 73. We disagree with the conclusion of this finding regarding the iterative process described in WQO 99-05. WQO 99-05 explicitly modifies WQO 98-01 regarding the "receiving water limitations" language to be included in future municipal stormwater permits in California based on objections to the language that was specified in WQO 98-01. Briefly, the resulting language specified by WQO 99-05 describes the procedure that is required following a determination that discharges are causing or contributing to an exceedance of water quality standards. This procedure, described in WQO 99-05 and included in the draft OC Permit in Section IV.3.a – d, describes what is referred to as the "iterative approach" in Finding 73. However, the steps describing the iterative approach are followed by the statement:

> *"So long as the permittees have complied with the procedures set forth above and are implementing the revised DAMP,* ***the permittees do not have to repeat the same procedure for continuing or recurring exceedances of the same receiving water limitations*** *unless the Executive Officer determines it is necessary to develop additional BMPs.(bold emphasis added)"*

Therefore, WQO-99-05 actually limits the number of required iterations, rather than requiring "increasingly more effective" control measures. The Executive Officer has ultimate control over the implementation of control measures—it is not an automatic continuing "do-loop" as suggested in Finding 73.

Comments on Permit Provisions

Section I.B.12: Responsibilities of the Principal Permittee. This requires developing an entire training program. These competencies are in large part already well-established by the California Stormwater Quality Association (CASQA), the California Department of Transportation, the Center for Watershed Protection, and the International Erosion Control Association, among others. We suggest this requirement be revised to allow materials and training programs developed and provided by CASQA or other reputable sources to suffice. It would be appropriate for the Principal Permittee to coordinate the training effort.

Section III.6: We strongly support this statement that MEP (as described above regarding Finding 3) is the compliance standard.

Section IV: This section is consistent with MEP and WQO 99-05 and does not modify the iterative process as suggested in Finding 73.

Sections VIII, IX, and X: These inspection requirements have new specific actions, such as an electronic database, to check if sites have filed an NOI, photos that need to be in the inspection database, or linked to it, and requirements for on-site enforcement actions. We suggest that the permittees be allowed to prioritize and take enforcement actions based on their own criteria.

Section XI: The requirement for a residential program (beyond education and outreach) will be problematic for the Permittees. It will add substantial cost; it seems likely to have little water quality benefit. Residential pollutant sources, such as pesticides, should be regulated by other state agencies (such as the Department of Pesticide Regulation) that have greater authority to require labels and restrict public use.

The requirement for a Water Quality Ordinance for residential activities is likely to be difficult to enforce, and it is not clear how it will effectively address pollutants.

The use of irrigation controllers should be consistent with the proposed landscape ordinance requirements from Assembly Bill 1881. It may be appropriate to refer to the AB 1881 requirements here.

Section XII contains numerous new and enhanced requirements compared to the 2002 Orange County MS4 and San Bernardino County MS4 Permits. The most problematic of these are summarized below:

The requirement for the Principal Permittee to "facilitate the formation of" a Technical Advisory Committee of Community Development Planning Directors appears to actually require the development of such a TAC. We understand that the Orange County Stormwater Program already convenes committee meetings that include Planning Directors. Although the San Bernardino County Flood Control District would be willing to facilitate formation of such a TAC among their Co-Permittees, it may be beyond their authority to require participation by any particular Co-Permittee Planning Directors.

Section XII.2.i: WQMP and LID requirements for street/road projects 5,000 square feet or larger will be difficult to implement due to constraints on road right-of-way and cost. We suggest the option for alternatives proposed in Footnote 42 be expanded, clarified, and brought into the body text of the Permit. Typical WQMP requirements will not be appropriate or feasible for these projects. Road projects conducted within local government rights-of-way are typically constrained by very limited widths, and the need to mesh with existing drainage pathways and property boundaries. Therefore, the design and construction of these projects allow very little opportunity to incorporate site design or other WQMP features. We suggest that WQMP requirements for these projects be streamlined to address these constraints during the Permit approval process rather than requiring a feasibility study for each project as described in Footnote 42.

XII.B.6: Regional Treatment Control BMPs: we suggest this requirement be revised to require the creation of a regional task force to develop the regulatory approval recommendations to improve the implementation prospects for Regional Treatment. This issue is equally problematic throughout our region, if not the entire state, and warrants a broader effort.

XII.C.3: As stated, it is unclear whether the 5% EIA metric for LID is a goal or a strict metric. We suggest that the 5% EIA requirement is superfluous if LID techniques are already required, and should be removed as a compliance metric from the draft Permit. Also, the paragraphs under Section XII.C.3.a – d appear to offer alternate ways to implement LID. However, the entirety of Section XII.C is not clear on what is actually required for LID versus what is an alternative, and how compliance would be determined. We suggest that a more clear approach be presented in this section that shows a decision process for determining how to select the implementation options for a specific project.

XII.D.2.a: We suggest that the terminology be made as clear as possible. For example, it is not clear to state that the time of concentration should not "significantly exceed" those of pre-development conditions. The intent is that times of concentration be maintained.

XII.D.2.b: It would be practical to place reasonable limits to how far downstream this exclusion should apply. For example, controlled release points, such as dams or basins, should serve as an evaluation endpoint for HCOCs. For Reaches 4 and 5 of the Santa Ana River, the flow and sediment transport

regimes, as well as the sediment supply to the river, are now greatly impacted by the presence of the Seven Oaks Dam. We suggest that the dam and its operation exert more influence upon the geomorphic characteristics and habitat quality of those river reaches than could be prevented or mitigated by development projects in the contributing watershed area. In addition, we are very concerned that there is a growing trend to consider rainwater itself as a "pollutant." There is no evidence in the record to suggest that increased flow is intrinsically harmful, especially when it is contained in improved flood control channels. The permit should be written to impose more restrictive requirements only where harmful effects occur. If the Regional Board believes "excessive" flows may impair beneficial uses, then it should adopt a water quality objective limiting such flows before imposing more stringent numeric effluent limits, such as the proposed 5% EIA requirement. In addition, we believe any new flow restrictions would constitute a state unfunded mandate, as such limits are not required, and may not even be authorized, by the CWA.

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XII.D.2.c: As stated in comments on Finding 62 above, the 5% EIA metric has not been demonstrated to be necessary, or effective, in protecting against actual downstream impacts. Please clarify whether variances are also to be approved by the Executive Officer.

XII.D.3 and D.4: It is unclear what is expected in the evaluation of potential downstream impacts from the project. Scientific findings suggest that control of the 2-year peak flow is not likely to be protective (see MacRae 1996. Experience from morphological research on Canadian streams: is control of the two-year frequency event the best basis for stream channel protection? In Roesner, L., ed., Effects of watershed development and management on aquatic ecosystems. Snowbird, Utah. ASCE; pp. 144-162.).

XII.E: We support the alternative approaches. Development of in-lieu or credit-trading programs might be more effectively accomplished through a regional stakeholder effort within the Santa Ana Watershed.

If you have questions regarding these comments please contact Matt Yeager at (909) 387-8112.

Sincerely,

VANA R. OLSON, P.E., Flood Control Engineer
San Bernardino County Flood Control District

VRO/NPV/MAY/nh:CRWQCB – Santa Ana_Orange County MS4 Draft Permit Comments

cc: San Bernardino County Stormwater NPDES Coordinators
Julie Rynerson-Rock, Director, San Bernardino County Land Use Services Department
Chris Crompton, County of Orange
Jason Uhley, Riverside County Flood Control and Water Conservation District
ARI Reading File

City of Anaheim
DEPARTMENT OF PUBLIC WORKS

February 13, 2009

Gerard J. Thiebeault
Executive Officer
Santa Ana Regional Water Quality Control Board
3737 Main Street, Suite 500
Riverside, CA 92501

BY U.S. POST AND ELECTRONIC MAIL

Subject: **SARWQCB Order No. R8-2008-0030, NPDES No. CAS618030 Waste Discharge Requirements for the County of Orange and the Incorporated Cities of Orange County Within the Santa Ana Region**

Dear Mr. Thiebeault:

Thank you for this opportunity to comment on the November 10, 2008 draft MS4 NPDES Permit (the "Permit") for the County of Orange. The City of Anaheim recognizes that the Regional Boards across the State take different approaches to implementing waste discharge requirements and we appreciate the deliberative manner in which you and the Board are working with the cities, counties and other stakeholder interests to deliver meaningful Permits improve water quality and to comply with the law.

The City has reviewed the comment letter provided by the County of Orange, dated February 13, 2009, and supports their comments and agrees with the basis for their findings. Additionally, the City requests the following changes to the permit:

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TEL (714) 765-5176
FAX (714) 765-5225
www.anaheim.net

1. The Economic Impacts of the New Permit Provisions are Substantial

The draft Permit states that "Each permittee shall secure the resources necessary to meet all requirements of this order." This provision has an increased significance as this 4th term permit comes at a time when State, County and City resources are dwindling at an alarming pace. All co-permittees are being forced to make difficult cutbacks. Critical public services, including emergency services (Police and Fire) are being carefully reviewed. Hiring freezes are in place at the City and employees at some agencies are losing their jobs. While these conditions may persist for years, regardless of the duration of the current economic downturn, all public funds should be spent responsibly in good times and bad. Therefore, while the City supports the goal of clean water, it is also very important to ensure that resources are focused on the most important and meaningful activities. The current draft of the permit – as detailed below – focuses substantial new resources on programs that may result in no measurable water quality improvements in the short or long term.

A. The Permit Should Be Reviewed for Economic Impacts and Should Focus on Direct Water Quality Benefits

The proposed Permit includes many new requirements which will obligate substantial resources in order to achieve compliance. These new costs County-wide, are estimated to be on the order of several millions of dollars, which in these times, equates to the potential loss of dozens of employment positions. The City is concerned that many of the new mandated activities are administrative and provide no measurable benefit to receiving waters.

With the publication of the CASQA Municipal Stormwater Program Effectiveness Assessment Guidance Manual (May 2007), there exists a well-recognized and reputable document to guide program implementation and Permit development. This document advocates elevating efforts (public resources) toward the highest "Outcome Level." The lowest Outcome Level is "Documenting Activities," while the highest is "Protecting Receiving Water Quality."

Many of the new administrative provisions of this proposed permit seem to support the lowest outcome level. Considering alternatives which would achieve higher level outcomes, the City requests that the Board take the following steps:

- Review the permit obligations in the context of the CASQA Municipal Stormwater Program Effectiveness Assessment Guidance Manual, and,
- Analyze alternatives to the current Permit requirements to identify activities which might achieve similar or even more substantial positive impacts at less cost.

B. Certain Permit Obligations Impose Undue Financial and Administrative Burdens

Specifically, the following Permit obligations seem to impose undue financial and administrative burdens on cities, without providing a measurable benefit to water quality:

- Administrative Paperwork Obligations. The proposed Permit includes extensive new paperwork obligations that significantly increase reporting obligations, not only the annual report, but at other times of the year. (e.g., quarterly reports on enforcement). Consistent with the need to focus on higher Outcome Levels, our limited public resources are seemingly better focused on tasks such as BMP installation and maintenance which may have a measurable impact on water quality. The City requests that the Board review the necessity of the increased reporting requirements, which, *de facto*, replaces other activities that provide a greater impact to environmental health.

- Commercial Inspections. The new mandatory ranking, inspection and reporting procedures for commercial facilities will require approximately 1,600 new inspections with the City of Anaheim alone. It is important to realize the burden on the City imposed by this Permit element is not simply the inspection. Each inspection requires pre-inspection coordination and post-inspection follow-up, database tracking and reporting and is effectively a "policing" system. Accordingly, the cost associated with this single permit provision is estimated to cost the taxpayers $200,000 to $400,000 annually. Moreover, City data shows that, given the breadth of the inspection scope, the majority of this effort will be focus on facilities that are unlikely to adversely affect water quality and are, in large part, conforming to existing water quality regulations. Therefore, the City believes that this requirement, even though it focuses on mid-range

unlikely to adversely affect water quality and are, in large part, conforming to existing water quality regulations. Therefore, the City believes that this requirement, even though it focuses on mid-range Outcome Levels, has very limited potential for actual water quality benefit. The City requests a cost-effective alternate approach of refocusing public education efforts toward the commercial businesses identified as targets in this Permit section.

- Tracking and Inspection of All Structural Treatment Controls. The requirement for the Cities to individually track and inspect every public and private treatment control BMP every other year is a cost that is substantial and unpredictable. Obtaining legal authority to enter private land to perform these inspections, doing the inspection, tracking and following up with each inspection creates an entire policing regime. The City recognizes and agrees that sizeable treatment controls do merit inspection. However, requiring inspection and tracking of every filter strip or landscape detention area (of which there are tens of thousands County-wide) does not seem to be a sound use of public funds. This is particularly true considering that Water Quality Management Plans require private property owners perform regular inspection and maintenance of these facilities. The costs of this element of the Program become staggering when one recognizes that the expanded WQMP mandate increases the number of structural controls necessary on individual sites.

Notwithstanding the mandates of the Porter Cologne Act, a consistent methodology to measure the economic impacts of water quality regulations on taxpayer resources and the public has yet to be developed. It is the City's hope that staff will share the economic analysis it has done (or will be doing) regarding the obligations in this Permit so that we can all ensure the obligations can be reasonably without an unjustified economic burden on our citizens.

2. The Effective Impervious Area Limitations Are Unreasonable Limitations on the Use of Land

The five percent Effective Impervious Area (EIA) limitations for new and significant redevelopment projects is problematic for several reasons. Putting aside the scientific discussion as to whether this specific stormwater attenuation

plan development and potentially precludes the development of important public and private projects for several reasons:

- Many infill and redevelopment projects simply do not have the geographic luxury of capturing the required volumes of water on site in swales or detention basins.
- The City of Anaheim has areas where extensive "infiltration" is neither advisable nor possible due to geologic conditions (e.g. landslide and slope instability issues onsite or adjacent to development, solid rock formations or clay lenses underlying development).
- It acts as a disincentive to maximize the use land in urbanized areas and transportations centers which is the goal of SB 375.
- The cost of retaining stormwater on site acts as substantial surcharge on public projects, including life safety, community and affordable housing projects that currently struggle to meet funding requirements.
- The requirement substantially devalues both private and publicly owned land where space for development is needed.

Specifically, this requirement would put an end to many redevelopment/ affordable housing projects and would effectively prohibit the City from complying with the intent of the Regional Housing Needs Assessment and SB 375. For example, in 2004, the Anaheim Redevelopment Agency entered into an Agreement with a private developer to develop and operate a 7-acre mixed-use, urban infill project with 465 rental units, ground floor retail space, and a regional museum complex. This project created new housing and employment in an urban area that reduced/eliminated the need for additional vehicle trips. However, if this project were subject to the development constraints in the Proposed Order it would not be feasible due to the significant costs associated with onsite retention for a site with no setbacks or landscape. Further, trying to gain a discretionary "waiver" from the Regional Water Quality Control Board for these types of projects is not a practical solution to planning and economic development for Anaheim.

The City recognizes the need to consider hydromodification and Low Impact Development objectives, but believes this important goal should be tackled regionally, in addition to considering an onsite approach. The Permit confuses

its encouragement of regional solutions with its prohibition of treatment controls in the Waters of the U.S.

Finally, the requirement for Public Works projects as small as 5,000 sf to comply with new development requirements (including incorporating treatment controls) is unnecessarily burdensome. The cutoff perhaps was meant to be 1 acre (and is much more reasonable), in keeping with the trigger for required coverage under the General Construction Permit, therefore the City recommends that this is the cutoff, rather than 5,000 sf.

3. The Annual Characterization of Trash Is Unnecessary

The requirement to "characterize trash, determine its main source(s) and develop and implement appropriate BMPS to control trash in urban runoff" is a vague obligation and potentially costly task. The requirement to perform this exercise annually is unnecessarily burdensome and the changes year over will likely be minimal. Changes observed will more likely reflect daily changes rather than showing actual trends. The City of Anaheim has over 1,200 curb-miles of roadways that are swept on a weekly basis. It collects over 100 tons of trash and debris per week. "Characterizing" this trash to determine its "main source" is an endeavor that would require the hiring of specialized consultants and would have little, if any benefits to water quality. The City recommends a more practical solution to achieve the same goal of requiring a one-time characterization of trash by the County to obtain data for various types of land uses.

4. There Is No Legal Authority to Search and Seize Items from Private Property in the Absence of Legal Justification

Permit section VI, Paragraph 2 states: *"The permittees' ordinance must include adequate legal authority to enter, inspect and gather evidence (pictures, videos, samples, documents, etc.) from industrial, construction and commercial establishments."*

The City requests clarification of this item. If the intent of the provision is to require Cities to create legal authority to search private property, and seize items therein in the absence of landowner consent or a Court Order, this cannot likely be achieved without offending a number of State laws and Constitutional protections. Additionally, in many cases, the State, rather than the City, has

therein in the absence of landowner consent or a Court Order, this cannot likely be achieved without offending a number of State laws and Constitutional protections. Additionally, in many cases, the State, rather than the City, has authority to inspect/search private property through the General Industrial Permit and other similar mechanisms.

5. Requiring Residents to Implement Best Management Practices is Problematic

The mandate to force residents, who typically do not fall within the regulatory purview of the Clean Water Act, to implement best management practices at their homes is a difficult and costly Permit provision. This provision could result in the City taking an individual to court for – for example – not using a "bio-degradable soap" when washing their car (even though this is not a "prohibited discharge"). This would likely erode public support for the NPDES program and could create a "backlash" of opposition to the NPDES program as a whole. The City requests a suitable alternative to this requirement such as refocusing the public education component of the Permit to target homeowners rather than mandate enforcement.

6. Coordination between the State and Permittees on Regulatory Activities Would Benefit All Involved

Currently, the State database indicates that currently there are 126 State-issued General Industrial Stormwater Permits within the City of Anaheim. These permits require the creation of a unique Stormwater Pollution Prevention Plan (SWPPP) involving high level controls – including stormwater sampling – by the permitted industries. Since this is a State Permit, the City neither regulates, reviews nor implements the SWPPP. The same holds true for the General Construction Permit. Similarly, the State oversees activities (Development, Construction and to a lesser degree Operations) at School sites, and Caltrans (a State Agency) operates under a separate individual permit, as do a select few large private businesses. While findings 26 – 30 of the current Draft Permit identify these facts it does not go far enough to identify the coordination and oversight of these permits by the State to prevent overlap and avoid redundancy of effort.

adoption. The Cities provide extensive volumes of information to the RWQCB, however, virtually no information is sent in the other direction. Therefore the City is requesting that all NPDES Permits, Inspection Reports (Industrial, Construction and others), Notices of Violation, and other related correspondence be copied to the County and Cities that might be affected. This would help prevent redundant inspections (a waste of city and business time and creates a feel of double jeopardy for businesses) and would foster better cooperation between the Permittees and the RWQCB

The state of our collective economic affairs is a prominent reminder of the need to focus public dollars on maximizing public benefit. The City remains strongly committed to ensuring water quality is a top priority in Anaheim and appreciates your guidance in making this a realistic and achievable goal.

Very truly yours,

Natalie Meeks,
Director of Public Works

City of Huntington Beach

2000 Main Street ♦ PO Box 190 ♦ CA 92648

Travis K. Hopkins, PE
Director

Department of Public Works
(714) 536-5431

FEB 17 2009

CRWQCB - REGION 8

CRWQCB - REGION 8
MES
MKB

FEB 17 2009

February 13, 2009

Via email and U.S. Mail

California Regional Water Quality Control Board, Santa Ana Region
3737 Main Street, Suite 500
Riverside, CA 92501-3348
Attn: Marc Brown

Subject: Comment Letter - Tentative Order No. R8-2008-0030 NPDES No. CAS618030

Dear Mr. Brown:

The City of Huntington Beach has reviewed the *Renewal of Waste Discharge Requirements for the County of Orange, Orange County Flood Control District and the Incorporated Cities of Orange County, Tentative Order No. R8-2008-0030, NPDES No. CAS618030, Areawide Urban Storm Water Runoff* and is in concurrence with the Orange County Public Works letter.

The City is offering the following comments for your consideration in addition to the Orange County's letter:

- **Page 40, Section X Municipal Inspections of Commercial Facilities**

  The Tentative Order adds a new requirement for commercial facilities that priorities be established for inspection as a high, medium and low threat to water quality. Also, a minimum criterion must be met: 10% of commercial sites (not including restaurants/food markets) must be ranked "high"; 40% of commercial sites (not including restaurants/food markets) must be ranked "medium; and the remainder may be ranked "low". The high priorities are to be inspected at least once a year, all medium priorities are to be inspected at least every two years and all low priority sites are to be inspected at least once per permit cycle.

  The City does not have the resources for the increase in the amount of inspections required annually which increases from approximately 70 commercial facilities to over 600 commercial facilities; this is an increase of over 800% for commercial inspections.

The City is in concurrence with the letter from Chris Crompton, Orange County Public Works letter in regards to the language modification as follows:

Each permittee shall conduct inspections of its commercial facilities as indicated below. To establish priorities for inspection, the permittees shall continue to prioritize commercial facilities/businesses within their jurisdiction as a high, medium or low threat to water quality based on such factors as the type, magnitude and location of the commercial activity, potential for discharge of pollutants to the MS4, any history of unauthorized, non-storm water discharges, proximity and sensitivity of receiving waters, material used and wastes generated at the site. Within 6 months of the adoption of this Order, the Permittees shall review their existing prioritization system, criteria, and results based on the inspections, and determine if any modifications are necessary. The modifications shall be completed within 6 months of the determination and reported on in the annual report.

- ☐ **Page 81, Attachment "C"** delete the following:
  - Fountain Valley Union High School District
  - Huntington Beach Elementary School District
  - Ocean View Union High School District
- ☐ **Page 81, Attachment "C"** add the following:
  - Fountain Valley School District
  - Huntington Beach City School District
  - Ocean View School District
- ☐ **Page 82, Attachment "C"**, add Huntington Beach Hospital

The City would like to thank you for your consideration of the above comments and if you have any questions, please contact me at 714-375-8494.

Sincerely,

Terri Elliott, PE
Principal Civil Engineer

TE:cs

Public Works Department www.ci.irvine.ca.us

City of Irvine, One Civic Center Plaza, P.O. Box 19575, Irvine, California 92623-9575 (949) 724-6000

February 13, 2009

Gerard J. Thibeault, Executive Officer
California Regional Water Quality Control Board
Santa Ana Region
3737 Main Street, Suite 500
Riverside, CA 92501-3348

Subject: First Draft of Order No. R8-2008-0030 (NPDES No. CAS618030), Orange County Areawide Stormwater NPDES (National Pollutant Discharge Elimination System) Permit

Dear Mr. Thibeault:

The City of Irvine would like to express our appreciation for the opportunity to comment on draft Tentative Order No. R8-2008-0030 (NPDES No. CAS618030). We have especially appreciated the opportunity to meet with you, your staff, and other stakeholders to discuss the low impact development (LID) and hydromodification portions of the draft order. We are looking forward to working with your staff, the principal permittee, our co-permittees, and other stakeholders, to develop a program that will ensure continued improvements to surface water quality while providing a way forward for well planned future development and redevelopment. As a result of our recent meetings on new development and significant redevelopment, we understand the fourth term MS4 permit may be amended at some point in the future. However, the comments provided in this letter and attached comment table (Attachment 1) and set forth in Attachment 2, which summarizes our understanding of the conceptual discussions of the new development and redevelopment LID and hydromodification control requirements, are based on the November 10, 2008 First Draft of Order No. R8-2008-0030 ("draft tentative order").

We have analyzed the draft tentative order to determine if: 1) it is technically feasible for the City and others to comply; and 2) sufficient resources are available for compliance. We believe it will be difficult for many of the permittees to continue growing the stormwater program considering the current economic crisis. It is essential, therefore, that a permit is adopted which will result in continuing water quality improvements while recognizing current economic constraints.

Attachment 1 to this letter, the comment table, contains detailed comments on the entire draft tentative order. Attachment 2 focuses on the City's comments and analysis of LID and hydromodification control concepts. Attachment 2 comments have been substantially improved by the stakeholder meetings held during the public comment period, and the expert information, including white papers, reports prepared for the Ventura region, redlined draft tentative order language, conceptual comments, a watershed planning

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framework, and other reports and information submitted in those meetings by a variety of stakeholders and experts, including Dr. Richard Horner, Dr. Eric Strecker, Geosyntec Consultants, Orange County Coast Keeper, Latham & Watkins and the National Resources Defense Council.

By necessity, the City prepared the comments in this letter and in Attachments 1 and 2 to this letter concurrently with the preparation of comments on the draft tentative order by the County of Orange, the principal permittee. This week we had the opportunity to review the County's comment letter dated February 13, 2009, and Attachments A, B, and C to that letter. The City adopts and supports those comments submitted by the principal permittee. Because the City and County needed to prepare comments concurrently, the City's comments in this letter and its attachments may overlap to some extent with those submitted by the County. Other comments submitted today by the City address issues and concerns that the County comments do not address, or address the same on similar issues and concerns, but provide a slightly different or more detailed perspective on those issues. To the extent that the City's comments in this letter and its attachments overlap with and address exactly the same issues, the City, of course, would be pleased to review responses prepared to County comments in the event that such an approach assists the Regional Board staff in streamlining the process of preparing responses to comments.

We encourage the Regional Board to consider the comments in this letter and attachments which we believe will result in a permit that will continue to improve water quality while meeting the needs of the co-permittees, residents, and other stakeholders in Orange County.

If you have any questions or need additional information, please contact Mike Loving, Water Quality Administrator, at (949) 724-6315.

Sincerely,

Manuel Gomez
Director of Public Works

Attachments:
1. Comment table
2. Low impact development & hydromodification comments

cc: Mark Carroll, P.E., City Engineer
Marcia Beckett, Fiscal & Environmental Programs Administrator
Mike Loving, Water Quality Administrator
Eric Tolles, Deputy Director of Community Development
Joe Kirkpatrick, Deputy Building Official
Michael Yang, Water Quality Engineer
Angie Burgh, Management Analyst
Glen Worthington, Great Park Manager of Planning
Chris Crompton, County of Orange

CITY OF IRVINE FIRST DRAFT COMMENTS
ORDER NO. R8-2008-0030

Comment No.	Section No.	Page No.	Permit Language	Comments	Recommendations
1	A.5.c	3	The permittees have the authority to levy service charges, fees, or assessments to pay for compliance with this order.	This finding should recognize that assessments to pay for compliance with the Order when adopted are subject to approval by voters, which may or may not be granted. In that regard, referencing the City of Santa Cruz in the footnote is a poor example of the ability of cities to raise taxes to fund storm water programs. Of all the cities in California, only a handful, including San Clemente, may be able to convince voters to allow taxes to be raised to fund a stormwater program. In light of the rapidly expanding crisis in the economy, this is even less likely than it was on November 4.	Remove A.5.c entirely or reference a more realistic example of raising funds to comply with this order. Cities have had limited success getting approval from voters for new or increased fees for storm water programs, including the City of Encinitas in March 2006 which could not pass a $5/month fee increase (61% of votes against the measure).
2	C.8	3	This order is intended to regulate the discharge of pollutants in urban storm water runoff from anthropogenic (generated from human activities) sources and/or activities within the jurisdiction and control of the permittees and is not intended to address background or naturally occurring pollutants or flows.	Finding 8 is indicates an appropriate focus of the draft tentative order, which is consistent with the Clean Water Act. Unfortunately, Section XVIII is not consistent with Finding 8. Selenium in rising groundwater is an example of a naturally occurring pollutant this order does address in Section XVIII. Selenium in rising groundwater entering channels via seeps should be addressed under the TMDL and NSMP program, rather than via requirements in this permit.	Revise the requirements of Section XVIII as necessary for consistency with Finding 8.
3	C.10	4	The permittees may lack legal jurisdiction over urban runoff into their systems from some state and federal facilities, utilities and special districts, Native American tribal lands, waste water management agencies and other point and non-point source discharges otherwise permitted by the Regional Board. The Regional Board recognizes that the permittees should not be held responsible for such facilities and/or discharges. Similarly, certain activities that generate pollutants present in urban runoff may be beyond the ability of the	Finding 10 appropriately recognizes legal limitations of co-permittees in operating MS4s. Unfortunately, certain requirements of Section XVIII appear to be inconsistent with Finding 10 to the extent, for example, that they require co-permittees to address, for example, nonpoint source selenium in rising groundwater. Similarly, requirements of Section III.3 mandating that co-permittees prohibit introduction into channels of rising groundwater and natural springs, and uncontrolled runoff from agricultural areas are inconsistent with practical	Eliminate inconsistencies between draft tentative order findings and requirements. Encourage state institutions such as UCI to join the NSMP and other applicable watershed efforts.

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			permittees to eliminate. Examples of these include operation of internal combustion engines, atmospheric deposition, brake pad wear, tire wear and leaching of naturally occurring minerals from local geography.	and regulatory limitations on the co-permittees' ability to control the introduction of flows into the MS4s. Section XVIII of the draft Order also contains provisions that exceed the legal and practical authority of the co-permittees to control. For example, Section XVIII requirements hold co-permittees responsible for pollutants such as copper in the receiving waters even if it's beyond their ability to eliminate those pollutants. Also, in certain circumstances, the Regional Board has authority to require parties to participate in the control of pollutants entering MS4s that the copermittees do not possess. For example, the agencies in the NSMP Working Group will be responsible for creating and implementing a plan for reducing levels of naturally occurring selenium naturally seeping into channels and receiving waters. However, some large state institutions, such as UCI, have not participated in NSMP and do not appear to have a responsibility to share in the costs associated with removing selenium seeping into receiving waters. Finding 10 seems to indicate that the NSMP stakeholders should not be responsible for encouraging or requiring facilities such as UCI, which occupies more than two square miles in the Newport Bay Watershed, to bear their proportionate share for controlling the seepage.	
4	E.16.b	6	A Proposed Plan of Storm Water Quality Management Activities for 2007-20012, as outlined in the Draft 2007 Drainage Area Management Plan (DAMP). The 2007 DAMP includes all the activities the permittees propose to undertake during the next MS4 permit term, goals and objectives of such activities, an evaluation of the need for additional	The co-permittees have not seen the entire Draft 2007 DAMP, only the 2006 Report of Waste Discharge (ROWD). It's impossible, therefore, for the co-permittees to provide constructive comments on anything in the draft order referencing the Draft 2007 DAMP other than the ROWD.	Ensure the co-permittees have had an opportunity to review and approve the entire Draft 2007 DAMP prior to adoption or clarify that the 2007 DAMP is intended to mean the 2006 Report of Waste Discharge (ROWD).

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			source control and/or structural and non-structural BMPs and proposed pilot studies;		
5	F.18	6	…The permittees have jurisdiction over and/or maintenance responsibility for storm water conveyance systems within Orange County. The County's systems include an estimated 400 miles of storm drains…	This indicates there are an estimated 400 miles of storm water conveyance systems in Orange County under the Regional Board's jurisdiction. This is the same number of miles in the current permit. The number should have increased somewhat in the last six years.	Update the number of miles of storm water conveyance systems in Orange County under the Regional Board's jurisdiction, if necessary.
6	G.21	8	Federal regulations, 40 CFR 131.10(a), prohibits the states from designating a water body for waste transport or waste assimilation. This order prohibits the construction of treatment BMPs within waters of the US. However, if the discharges are sufficiently treated to protect the beneficial uses of the receiving waters, further polishing of the discharge within waters of the US may be considered on a case-by-case basis…	The current language of the draft Order is overly broad, and appears to prohibit measures such as trash booms and Natural Treatment System facilities that are installed in retrofitted channels and basins, which are considered treatment control BMPs. References to the water quality benefits provided by NTS Facilities, retrofitting of flood control channels and basins, and installation of trash booms in receiving waters contained elsewhere in the draft order are inconsistent with the broad prohibition set forth in this finding.	Please eliminate or narrow the overly broad prohibition against natural and structural treatment BMPs.
7	H.30	11	To avoid duplicative efforts, the permittees need not inspect facilities that have been inspected by Regional Board staff, if the inspection was conducted during the specified time period. It is anticipated that many of the inspections required under this order can and will be carried out by inspectors currently conducting other types of inspections for the permittees (i.e., grading, building, code enforcement, etc.), during their normal duties.	While we agree with the Regional Board's conclusion that co-permittees should not be required to inspect facilities already inspected by Regional Board staff to minimize inefficient expenditures, the underlined wording implies that additional duties added to current inspections do not lead to additional workload or activities by City staff, requiring additional City resources to implement. This is not true since documentation of the inspection and follow-up on the findings result in additional work hours and as a result funding.	Remove underlined language since it is incorrect.
8	I.38	13	…The permittees also organize solid waste collection programs, household hazardous waste collections, and recycling programs to reduce litter and illegal discharges. Additionally, the permittees have installed debris booms at a number of locations to capture trash and debris preventing it	(see comment for Item G.21 above)	Please clarify

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			from depositing on beaches.		
9	J.43	15	TMDLs have been established by the Regional Board for sediment, fecal coliform, diazinon, chlorpyrifos and nutrients for the San Diego Creek/Newport Bay watershed…	It was our understanding that, henceforth, the San Diego Creek/Newport Bay watershed, will simply be referred to as the Newport Bay Watershed.	Please clarify
10	K.55	18	The permittees have adopted grading and erosion control ordinances, guidelines and best management practices (BMPs) for municipal, commercial, and industrial activities.	The co-permittees have not adopted BMPs but instead the DAMP and LIP contain adopted guidelines for implementation of minimum BMPs. The distinction is important, since the points of consensus reached by stakeholders with respect to the new development and redevelopment provisions if adopted by the Regional Board would result in new, more stringent requirements governing specification of minimum BMPs for this MS4 permit term. Therefore, we suggest revising the draft tentative order language as suggested.	Revise to read *The permittees have adopted grading and erosion control ordinances and guidelines for the implementation of minimum best management practices (BMPs) for municipal, commercial, and industrial activities.*
11	K.56	18	…The ultimate goal of the urban storm water management program is to support the attainment of water quality objectives for the receiving waters and to protect beneficial uses through the implementation of the DAMP. The permittees developed and submitted a revised draft 2007 DAMP.	The co-permittees have not seen the Draft 2007 DAMP, only the 2006 Report of Waste Discharge (ROWD). Therefore, it's impossible for the co-permittees provide constructive comments on anything in the draft order referencing the Draft 2007 DAMP.	Ensure the co-permittees have had an opportunity to review and approve the Draft 2007 DAMP prior to adoption, or that reference is made to the 2006 ROWD
12	L.	19	NEW DEVELOPMENT/SIGNIFICANT REDEVEOPMENT – WQMP/LIP/LID	Throughout the draft order, there should be a distinction between *model* WQMP and *project* WQMP	Please differentiate between *project* WQMP and *model* WQMP
13	L.61	19	…Southern California Coastal Water Research Project (SCCWRP) under the auspices of Storm Water Monitoring Coalition and in collaboration with the California Storm Water Quality Association (CASQA) and the State Board is developing a Low Impact Development Manual for Southern California…	It's our understanding that SCCWRP is not developing the Low Impact Development Manual for Southern California.	Please clarify

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14	L.62	19-20	The USEPA has determined that by limiting the effective impervious area of a development site to 5% or less, downstream impacts could be minimized (also see the SCCWRP study). A limited study conducted by Dr. Richard Horner concluded that a 3% EIA standard for development is feasible in Ventura County. These principles are incorporated into requirements for new developments and redevelopment projects.	USEPA has not determined that prescriptively limiting EIA to 5% or less is the best way to minimize receiving water impacts in all watersheds and for all physical conditions, and in several other regions has concurred in the adoption of different performance standards for low impact development and hydrological control. Further, while Dr. Horner reached the conclusion stated in studying Ventura County, the white papers prepared by Geosyntec for this process, and the white paper submitted to the Los Angeles Regional Board addressing case studies in Ventura County entitled January 2009 LID Metrics in Stormwater Planning, which were submitted during the stakeholder meetings convened by the Regional Board on the new development and significant redevelopment provisions of the draft tentative order indicate that a 3% EIA standard may be inappropriate for incorporation into the Permit. As noted in the County's comments on this draft tentative order dated February 13, 2009, (the "County Comments"), Dr. Horner and Dr. Eric Strecker from Geosyntec have reached consensus regarding the effectiveness of substituting design volume standards for low impact development controls in place of the EIA standards referenced in this finding. We concur with the consensus reached by the experts as outlined in the County comments We further concur with the principal permittee that, in order to resolve current uncertainty and ensure that the technically valid and environmentally appropriate low impact development and hydromodification control objectives for the land	Revise this finding to recognize, at a minimum, the other studies,white papers, and information submitted to the Regional Board as a part of the recent stakeholder process, which analyze the issues created by EIA and percolation /infiltration related performance standards, and show alternative and equally protective metrics are available to govern implementation of LID and hydromodification control measures on development and redevelopment projects. The New Development and Significant Redevelopment provisions of the draft tentative order should also be revised to: • Substitute the 85th percentile design volume treatment performance standard for LID implementation as agreed upon by stakeholders in place of currently proposed EIA or percolation related performance standards; and • Identify more specifically the range of appropriate circumstances in which development projects should be exempt from LID implementation, hydromodification control, and/or infiltration or percolation performance standards due to technically or environmentally undesirable conditions (*e.g.* project sites with very shallow or highly contaminated groundwater); and • Allow co-permittees to develop the most suitable long-term, subwatershed and watershed approach to LID implementation and hydromodification control by incrementally adding to ongoing watershed plans and the DAMP specific components

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				development program are established, there needs to be an opportunity to develop an appropriate approach for Orange County through a stakeholder driven process that incorporates information regarding physically appropriate areas within the Newport Bay watershed to accomplish recharge, percolation and infiltration, identifies surface water channels that are potentially susceptible to hydromodification impacts, and incorporates other information and input from those engaged in design and implementation of LID based practices to determine the best subwatershed and watershed based approaches to treatment and hydrologic controls. In addition to resolving areas of technical uncertainty, such a process would also provide an opportunity to integrate stormwater management into efforts to better conserve water supply, and to comply with other mandates, including TMDLs. Please see Attachment 2 for additional comments.	to address LID implementation and hydromodification control. These watershed planning components should derive appropriate LID and hydromodification control performance standards based on, among other appropriate considerations, (i) physical characteristics of this watershed (*i.e.,* mapping of areas appropriate for infiltration and channels susceptible to hydromodification); and (ii) stakeholder input. • The Order should specify a defined timeline and goal(s) for the stakeholder process to develop LID implementation and hydromodification control standards, as well as specific and sufficient timelines for action by co-permittees to incorporate the performance standards developed via the process into ongoing watershed planning, the DAMP and the LIPs. During the time that the process is ongoing, the 85th percentile design volume standard would serve LID implementation, achieving increased treatment and greater runoff volume reductions than currently required to provide enhanced protection to surface waters of the region.
15	L.66	21	The treatment control BMPs include vortex systems, catch basin inserts, detention basins, regional treatment systems, constructed wetlands, various types of storm water filters, etc. If not properly designed and maintained, these systems could be sources of groundwater pollution and could become a nuisance and/or cause the spreading of surface water...	LID BMPs are generally considered by experts to provide enhanced water quality treatment for runoff, and therefore the City of Irvine supports more stringent requirements in the Draft Permit, the DAMP and LIPs to increase the use of those technologies. However, LID infiltration BMPs, if implemented in areas with inappropriate physical conditions, including shallow groundwater,	Revise findings to indicate technical and environmental constraints on LID infiltration BMPs to address the fact that LID BMPs, like conventional BMPs, if not properly designed and maintained, could be sources of nuisance, groundwater waste and pollution, or surface water pollution.

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				improper soils, unstable geotechnical areas, or areas of groundwater contamination, or if not properly designed and maintained could be sources of undesirable increases in groundwater exfiltration, geotechnical failures, and/or groundwater pollution (from pesticides, for example) and could become a nuisance and/or cause groundwater waste, increased surface flow inundation, or the introduction of pollutants into groundwater and/or into surface waters.	These findings will, in turn, support a more clearly delineated list of circumstances where implementation of conventional BMPs will be more appropriate, and where exceptions to implementation of LID BMPs should be approved by co-permittees.
16	L.67	21	If not properly designed and maintained, the BMPs identified in Finding 65 could create a nuisance and/or habitat for vectors…	LID infiltration BMPs, If not properly designed and maintained, could create a nuisance and/or habitat for vectors.	Revise findings to add LID infiltration BMPs to the list of BMPs that, If not properly designed and maintained, could create a nuisance and/or habitat for vectors. Such a finding will help assure DAMP attention to proper maintenance of LID BMPs to control vectors.
17	M.68	21	The MS4s generally contain non-storm water flows such as irrigation runoff, runoff from non-commercial car washes, runoff from miscellaneous washing and cleaning operations, and other nuisance flows generally referred to as de-minimus discharges. Federal regulations , 40 CFR Part 122.26(d)(2)(i)(B), prohibit the discharge on non-storm water containing pollutants into the MS4s and to waters or the U.S. unless they are regulated under a separate NPDES permit, or are exempt, as indicated in Discharge Prohibitions, Section III.3 of this order. The Regional Board adopted a number of NPDES permits to address de-minimus type of pollutant discharges. However, the permittees need not get coverage under the de-minimus permits for the types of discharges listed under Section III.3 except for discharges to the San Diego Creek/Newport Beach watershed, as long as they are in compliance with the conditions specified under Section III of this order.	Finding 68 states that the permittees need not get coverage under the de-minimus permits for the types of discharges listed under Section III.3, except for discharges to the San Diego Creek/Newport Beach watershed. This can be interpreted to mean that all de-minimus discharges are prohibited for San Diego Creek/Newport Beach watershed without the de-minimus permit.	The language should be clarified to state that for the types of discharges listed under Section III.3, only those discharges addressed by the de-minimus permit in the San Diego Creek/Newport Beach watershed, including, for example, groundwater discharges and discharges associated with water line testing and flushing, require compliance with the de-minimus permit. The City further supports the County comments noting that the structure and requirements of Section III.3 should be revised to comport with federal regulations, which permit de-minimus discharges unless a finding is made that those discharges are a significant source of pollutants, and which specify a slightly different list of discharges to MS4s that should be considered de-minimus than that currently specified in the Draft Permit.

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18	M.69	21-22	Many areas of San Diego Creek/Newport Bay watershed have high nitrate and/or selenium levels in the soils and/or groundwater. Dewatering operations, construction activities and agricultural and other operations could mobilize these pollutants and carry them into the San Diego Creek and Newport Bay…	LID infiltration BMPs can also potentially mobilize nitrogen and selenium in the groundwater and carry them into the San Diego Creek and Newport Bay.	The findings, either here or perhaps in Finding 65 discussed above, should recognize that LID infiltration BMPs can potentially mobilize nitrogen and selenium in the groundwater and carry them into the San Diego Creek and Newport Bay. Such a finding supports the City's view that the draft tentative order should contain an exception to use of LID BMPs and application of infiltration standards in those circumstances where their use and application might result in mobilization of groundwater pollutants, including Nitrogen and Selenium.
19	N.71	22-23	The principal permittee in collaboration with the co-permittees is required to develop guidelines for defining the expertise and competencies for various positions and training programs and schedules for training for these positions. The permittees are required to document procedures used to determine the defined competencies for each storm water position (this may be accomplished through a test at the end of the training program or through an on-the-job testing procedure).	We agree all City staff involved in the stormwater program must be trained and have the tools necessary to perform their specific tasks. We do not agree, however, that formal testing and certifications are the only way to validate competency, and we need flexibility in the methods used to assess competency of personnel to comport with labor and employment regulations and contract requirements. Further, we concur with the County comments that, based on core competencies mutually developed by the co-permittees, the best, and most cost-effective training for our particular city can best be provided not by the principal permittee or one of their consultants, but instead by the City's experienced program management staff.	Revise this finding and add an option to enable individual co-permittees to provide in-house training using curriculum developed by the principal permittee in collaboration with the co-permittees.
20	O.74	23	…This order includes requirements for the control of trash and debris, for street sweeping, and for drainage facilities maintenance. The permittees have already installed eleven trash and debris booms in flood control channels…	(see comment for Item G.21 above)	Please clarify
21	O.76	24	Successful implementation of provisions and limitations in this order will require the cooperation of public agency organizations within Orange	The City of Irvine supports active cooperation among public agencies and stakeholders as the most effective means of addressing water quality	Encourage state institutions and other major dischargers in the watershed, such as UCI, to join the NSMP and other applicable watershed

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			County having programs/activities that have an impact on storm water quality. A list of these organizations is included in Attachment C. As such, these organizations should actively participate in implementing the Orange County NPDES Storm Water. The Regional Board has the discretion and authority to require the discretion and authority to require certain non-cooperating entities to obtain coverage under a Phase II MS$ permit, or obtain an individual storm water discharge permits, pursuant to 40 CFR 122.26(a), or to agree to participate in this areawide permit.	issues and achieving improvement in the watershed, and agrees that all public agencies should actively participate. However, we suggest that more needs to be done to secure the participation of some of the larger public agencies within the watershed. UCI, for example, has not actively participated in the Newport Bay Watershed working groups even though they occupy more than two square miles in the watershed.	efforts.
22	R.83	26	Illegal discharges to the storm drains can contribute to storm water and surface water contamination. A reconnaissance survey of the municipal storm drain systems (open channels and underground storm drains) was completed by the permittees during the third term permit, the permittees significantly enhanced the programmatic framework for detecting and quickly controlling discharges into the MS4s. The permittees have initiated a dry weather monitoring program that is based on statistically derived benchmarks to detect illegal discharges and illicit connections. The program also facilitates public reporting of illegal and illicit discharges by providing 24-hour access to a toll free hotline…	What terms should be used: illegal discharges or illicit discharges; illegal connections or illicit connections? The terms should not be used interchangeably.	Determine correct/consistent terminology and use throughout the permit.
23	B.2	28	Review, approve, implement, and comment on all plans, strategies, management programs, and monitoring programs, as developed by the principal permittee or any permittee subcommittee to comply with this order.	The co-permittees have not yet had an opportunity to review and approve programs developed by the principal permittee. The draft 2007 DAMP (to the extent that is a document that was not included in the Draft ROWD), RBF's 2005 Retrofit Study and the Core Competencies training program are examples.	Ensure the co-permittees have had an opportunity to review and approve programs developed by the principal permittee prior to their adoption.
24	I.B.12	29	In collaboration with the co-permittees, develop guidelines for defining expertise and competencies	The competency of staff and the outcome of any evaluation of competency are confidential and	The permittees may commit to training and education of employees with a defined program

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			of storm water program managers and inspectors and develop and submit for approval a training program for various positions in accordance with these guidelines.	subject to other limitations and regulations. The requirement cannot be satisfied without exposure to liability and other violations.	in place, but cannot commit to providing any competency evaluation or reporting on the results of confidential documents that are part of an employees' performance.
25	III.3.i.l	30	However, where possible, when not interfering with health and safety issues, BMPs should be implemented (also see Section XIX, Provision 5)	As currently set forth in DAMP provisions collaboratively developed by the co-permittees and fire fighting agencies, BMPs should only be required during controlled fire exercises and/or training. BMPs should not be required, even as "where possible" for emergency situations. Note: Provision 5 is in Section XXI, but this would be irrelevant since we request it be deleted entirely.	Delete second sentence in III.3.i.l
26	III.3.i.l	30	However, where possible, when not interfering with health and safety issues, BMPs should be implemented (also see Section XIX, Provision 5) Emergency fire fighting flows (i.e., flows necessary for the protection of life and property) do not require BMPs and need not be prohibited. However, where possible, when not interfering with health and safety issues, BMPs should be considered (also see Section XIX, Provision 5);	Section III.3 would require potable water discharge (i.e., fire hydrant flushing) to be captured, sampled and analyzed for chlorine and pH before it can be released. The release must be also volumetrically and velocity controlled. These requirements should be conformed to the requirements of the de-minimus permit governing these discharges, and a cross-reference to that permit rather than a statement of control requirements can avoid the unintentional creation of conflicting applicable discharge requirements for these flows.	Conform III.3.i.l to existing de-minimus permit requirements by cross-referencing that permit.
27	III.3.i.c	31	Irrigation water from agricultural sources	Agricultural sources are non-point sources, are not regulated or subject to NPDES permits under the federal Clean Water Act, and are not currently the subject of Waste Discharge Requirements or a Conditional Waiver of WDRs. Part III of the draft tentative order requires the co-permittees to prohibit illicit/illegal discharges (non-storm water) from entering into the MS4 unless they are authorized by another NPDES permit, waste discharge requirements, or are not prohibited in accordance with Section III.3 of the	We request the Water Board to amend this provision to conform to the Clean Water Act regulations, and include the discharges that are enumerated in 40 C.F.R. 122.26(d)(2)9iv)(B)(1) which specifically include "irrigation water" but not "irrigation water from agricultural sources." The category "irrigation water from agricultural sources" needs to be deleted from the tentative order and, instead, should be addressed through other Regional Board regulatory mechanisms.

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				draft tentative order. As noted in the County comments, Section III.3.i should enumerate the specific discharges that are permitted unless they are substantial contributors of pollutants to the MS4 and the receiving waters. The Regional Board has included the discharge of "irrigation water from agricultural sources" in Section III.3.i. As noted in the County comments, we object to the provision as worded, since it reverses the presumption as set forth in the federal regulations and would require findings that certain de-minimus discharges are NOT significant sources of pollution prior to their discharge, rather than permitting de-minimus discharges unless a finding is made that they ARE significant sources of pollution. Also as noted in the County comments, we are concerned about the inclusion of agricultural runoff as a de-minimus discharge in this section of the draft tentative order, primarily because: • Federal regulations do not specify agricultural irrigation runoff as a de-minimus discharge to MS4 systems; and • In the absence of regulation of these discharges by the Regional Board, the City does not have information from the Regional Board regarding the quality of agricultural runoff flows, or the degree to which agricultural runoff may or may not be a significant source of pollution.	
28	VI.1	34	Such legal authority must address all illegal connections and illicit discharges into the MS4s, including those from all industrial and construction sites.	The legal authority document (ordinance, etc.) give authority to the City to develop a program to control illicit discharges and illegal connections. However, the legal authority document does not set forth the	Revise the language of this requirement to indicate the role of the DAMP and LIPs in setting forth the program to address IC/IDs. Such legal authority must include the prohibition

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				specific components of the program, which need to be flexible and subject to ongoing update and revision. Therefore, it would be inappropriate for the legal authority document to fully "address" illegal connections or illicit discharges. Instead, the program for the identification or elimination of IC/IDs should be "addressed" through implementation of the program (LIP and/or DAMP). The legal authority can only provide the framework to prohibit and sanction IC/IDs. Legal authority should not be confused with procedures and methods to accomplish compliance.	of all illegal connections and illicit discharges into the MS4s, including those from all industrial and construction sites. The DAMP and LIPs should contain the program for control and preclusion of those discharges.
29	VI.1	34	Permittees' ordinances or other local regulatory mechanisms shall include sanctions and follow up inspection milestones to ensure compliance. Sanctions shall include but are not limited to: monetary penalties, non-monetary penalties, bonding requirements, and/or permit denials/revocations/stays for non-compliance. Follow up inspection milestones shall be consistent with applicable sections of this order. co-permittees' current ordinances shall have a provision for civil or criminal penalties for violations of their water quality ordinances.	The legal authority document (ordinance, etc.) is not the appropriate place for follow-up inspection milestones, because the ordinances that constitute legal authority documents are not flexible, and cannot be updated, revised or amended as needed to adaptively manage the City's water quality programs. Instead, the legal authority documents need to provide the framework and legal authority for the City to develop, implement, and revise as necessary its water quality programs. Any procedural milestones (inspections, etc.) should be retained as part of the implementation of the program (LIP and/or DAMP) or set forth in the Enforcement Consistency Guide, which can be implemented more adaptively than a water quality ordinance. Legal authority should not be confused with procedures and methods to accomplish compliance.	Please revise these requirements to make it clear that co-permittees' ordinances or other local regulatory mechanisms shall provide authority for sanctions, including monetary penalties, non-monetary penalties, bonding requirements, and/or permit denials/revocations/stays for non-compliance. Legal authority documents and co-permittees' current ordinances shall have a provision for civil or criminal penalties for violations of their water quality ordinances. But eliminate provisions that would require co-permittees to incorporate into their legal authority documents provisions governing inspections, milestones, inspection frequencies and other water quality program elements, which should appear in the DAMP, LIPs, and Enforcement Guidance documents.
30	VI.2	34	The permittees shall carry out inspections, surveillance, and monitoring necessary to determine compliance with their ordinances and permits. The permittees' ordinance must include adequate legal authority to enter, inspect and gather evidence (pictures, videos, samples,	The City agrees with the County comments that the draft tentative order could be interpreted to impose entry and inspection requirements on the co-permittees that would violate the Fourth Amendment.	We request that Part VI.2 be amended to state: "The permittees shall carry out inspections, surveillance, and monitoring necessary to determine compliance with their ordinances and permits. The permittees' ordinance must include

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			documents, etc.) from industrial, construction and commercial establishments. The permittees shall progressively and decisively take enforcement actions against any violators of their Water Quality Ordinance. These enforcement actions must, at a minimum, meet the guidelines and procedures listed in the Enforcement Consistency Guide.	The underlined statement could particularly be interpreted to require the co-permittees to adopt inspection procedures and enforcement authority that would violate the Fourth Amendment's prohibition on illegal searches and seizures. The Fourth Amendment to the U.S. Constitution states, "The right of the people to be secure in the persons, houses, papers, and effects, against unreasonable searches and seizures, shall not be violated; and no Warrants shall issue but upon probable cause, supported by Oath or affirmation, and particularly describing the place to be searched, and the persons or things to be seized."	adequate legal authority, to the extent permitted by California and Federal Law and subject to the limitations on municipal action under the constitutions of California and the United States, to enter, inspect and gather evidence (pictures, videos, samples, documents, etc.) from industrial, construction and commercial establishments…"
31	VI.6	34	The permittees shall continue to provide notification to Regional Board staff regarding storm water related information gathered during site inspections of industrial and construction sites regulated by the Statewide General Storm Water Permits and at sites that should be regulated under those Statewide General Permits. The notification shall be provided on a quarterly basis…	Section VI.6 requires quarterly reporting of any industrial and construction sites that have water quality violations. The quarterly reporting is unnecessary and burdensome, and we suggest that the current MS4 permit provisions governing reporting of inspection information, combined with requirements to notify the Regional Board of all events of non-compliance, are sufficient to inform the Regional Board of the water quality performance for industrial and construction sites. Currently, any notice of non-compliance issued to the construction site is already being faxed to the Regional Board. Also, any industrial sites that are or should be covered by Statewide General Storm Water Permit are referred to the Regional Board as soon as a finding of non-compliance is made. These notification procedures, combined with the current annual reporting of all inspections performed for both compliant and non-compliant sites appear to provide sufficient information to the Regional Board.	Eliminate new quarterly reporting requirements in favor of retaining notices and referral for non-compliance currently provided to the Regional Board together with annual reporting in the Program Effectiveness Assessment (PEA).

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				The City cannot identify any information that would improve the Regional Board's ability to address non-compliance that would be gained by the new, more stringent reporting requirement. The new more stringet reporting requirement would, however, result in substantial additional costs at a time when local government coffers are least able to absorb those costs.	
32	VII.1	36	The permittees shall continue to prohibit all illicit connections to the MS4s through their ordinances, inspections, monitoring programs, and enforcement actions	ICs can only be prohibited by the ordinance, and ordinances should not address inspections, monitoring programs or other activities designed to implement the ordinance. As noted before, legal authority (ordinances and permits) already prohibit ICs and it is the through program implementation activities (inspection, monitoring, etc.) that IC's are identified and eliminated.	We recommend revising the findings and requirements to eliminate the confusion between legal authority documents and the documents that set fort program parameters for implementing that legal authority. We suggest a revision to indicate that the co-permittees shall continue to pursue the identification and elimination of all illicit connections to the MS4s prohibited by local ordinances through their inspection programs, monitoring programs, and other enforcement activities.
33	VIII.2	37	Each permittee shall continue to maintain and update (at least on a quarterly basis) an inventory of all construction sites within its jurisdiction for which building or grading permits have been issued…	Section VIII.2 requires construction site inventory to be updated on a quarterly basis. The quarterly update will be burdensome and unnecessary as it will just be created to satisfy a draft tentative order requirement, but won't meaningfully contribute to the database used to guide inspections, since construction project timelines are not short enough to result in meaningful additions to the inventory within a period of three months.	The construction inventory should be updated twice yearly, including once in September in preparation for the rainy season, and rainy season inspections. The construction inventory should only be submitted to the Regional Board on an annual basis in preparation for the program effectiveness assessment report.
34	VIII.4	37	Each permittee shall conduct construction site inspections for compliance with its ordinances (grading, Water Quality Management Plans, etc.), local permits (construction, grading, etc.), the Model Construction Program and the Construction Runoff Guidance Manual, both developed by the permittees.	The ordinances do not include a reference to project WQMPs, which are required for the development projects under the DAMP and/or LIPs. Project WQMPs are post-construction documents.	Remove the examples in the parenthesis. Revise draft tentative order language to reference that each co-permittee shall conduct construction site inspections for compliance with its ordinances, local permits, the Model Construction Program and the Construction Runoff Guidance Manual, both developed by

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					the permittees.
35	IX.3	39	Each permittee shall conduct industrial facility inspections for compliance with its ordinances, permits and this order. Inspections shall include a review of material and waste handling and storage practices, written documentation of pollutant control BMP implementation and maintenance procedures and digital photographic documentation for any water quality violations, as well as, evidence of past or present unauthorized, non-storm water discharges and enforcement actions issued at the time of inspection. All high priority facilities identified in Section IX.2 shall be inspected at least once a year and a report on these inspections shall be submitted in the annual report for each year.	Section IX.3 states that inspections shall include a review of written documentation of pollutant control BMP implementation and maintenance procedures. This written documentation in the form of storm water pollution prevention plan (SWPPP) is only required for facilities with industrial storm water permits. The burden of SWPPP review for compliance with the State General Industrial Permit or individual industrial NPDES permits should remain with the Regional Board staff. The City's inspections should continue to assure no ICs/IDs and compliance of facilities with City water quality ordinances and requirements	Please clarify the intent of the industrial facility document inspections consistent the City's comments.
36	X.1	40	Each permittee shall continue to maintain and quarterly update an inventory of the types of commercial facilities/businesses listed below within its jurisdiction...	Section X.1 requires quarterly updates on the inventory of commercial facilities as compared to annual updates for industrial facilities, which generally pose a greater threat to water quality. The costs and expenses of quarterly updates to the inventory will not provide significant water quality benefits, given the period of time required to actually complete inspections for each group of commercial facilities to be assessed.	The inventory of commercial facilities should be updated on an annual basis, consistent with requirements for industrial facilities which generally pose a higher threat to water quality.
37	X.1	40-41	1. Each permittee shall continue to maintain and quarterly update an inventory of the types of commercial facilities/businesses listed below within its jurisdiction. As required under the third term permit, this inventory must be maintained in a computer-based database system (Commercial Database) and must include relevant information on ownership, size, location, etc. For fixed facilities, inclusion of a Geographical Information System (GIS), with latitude/longitude (in decimals) or NAD83/WGS84 compatible formatting is required. For water quality planning purposes, the	Section X.1 requires 11 new, additional categories to be added to the commercial facilities inventory. It does not make sense to increase the commercial facility inspection burden so significantly in the time of budget constraint, and there are no indications in the ROWD or other reports that commercial facilities are currently such significant sources of pollutants that regulation of these facilities must be so severely strengthened. Further, many of the new commercial facility categories appear to overlap with industrial facility categories, creating confusion regarding the inspection program that	We concur with the County comments that the new categories of commercial facilities should be deleted from the draft tentative order until such a time that these types of facilities have been determined to contribute a significant pollutant load to the MS4.

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			permittees should consider using a parcel-level GIS that contains an inventory of the types of facilities/discharges listed below. Commercial facilities may include, but not be limited to: a. Transport, storage or transfer of pre-production plastic pellets. b. Automobile mechanical repair, maintenance, fueling or cleaning; c. Airplane repair, maintenance, fueling or cleaning; d. Marinas and boat repair, maintenance, fueling or cleaning; e. Equipment repair, maintenance, fueling or cleaning; f. Automobile impound and storage facilities; g. Pest control service facilities; h. Eating or drinking establishments, including food markets and restaurants; i. Automobile and other vehicle body repair or painting; j. Cement mixing, concrete cutting, masonry facilities; Building materials retail and storage facilities; k. Portable sanitary service facilities; l. Painting and coating; m. Animal facilities such as petting zoos and boarding and training facilities; n. Nurseries and greenhouses; o. Landscape and hardscape installation; p. Pool, lake and fountain cleaning; q. Golf courses; r. Other commercial sites/sources that the permittee determines may contribute a	should apply.	

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			significant pollutant load to the MS4; and, s. Any commercial sites or sources that are tributary to and within 500 feet of an area defined by the Ocean Plan as an Area of Special Biological Significance.		
38	X.2 & X.3	41	2. Each permittee shall conduct inspections of its commercial facilities as indicated below… 3. Each permittee shall conduct inspections of its commercial facilities as indicated below. To establish priorities…	Sections X.2 and X.3 require the inspection of all commercial facilities during the permit term, and arbitrarily mandate that at least 10% of commercial sites must be prioritized as high and inspected once a year; 40% of commercial sites must be prioritized as medium and inspected once every two years; and the remaining 50% of commercial sites must be prioritized as low and inspected once every permit cycle. This prioritization scheme and related inspection frequency requirements are not based on technical data or on the potential or demonstrated risk posed by commercial facilities to water quality. At the same time, the prioritization scheme and inspection frequency requirements result in a substantial increase in the number of required commercial inspections to well over 2,000, accompanied by a significant increase in costs for the City at a time of budget challenges. The DAMP currently contains risk-based factors and criteria that each co-permittee, including the City, is required apply to identify the high, medium and low risk commercial facilities within its jurisdiction that must be inspected, and to determine the frequency of those inspections. If the Regional Board believes that the criteria in the DAMP are not sufficient to identify adequately those high risk commercial facilities posing risk to water quality as substantial sources of pollutants,	The draft tentative order should be revised to mandate that the co-permittees reassess and revise as necessary the DAMP and LIP provisions governing commercial facility inspections to assure that the criteria governing prioritization of risk and frequency of inspection are sufficient to adequately identify those high risk commercial facilities posing risk to water quality as substantial sources of pollutants. Until DAMP and LIP provisions governing commercial facility inspections are revised to adequately address prioritization of risks, the City of Irvine recommends conducting inspections at 10% of commercial facilities as high priority sites. In light of the substantial staff time and other costs associated with inspections, we also recommend that Regional Board staff consider decreasing the frequency of high priority site inspections from once a year to once during the permit term as mandated in the current permit. In addition, the City of Irvine recommends dropping inspection requirements for medium and low priority sites as these facilities would not pose a threat to the environment.

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				the current risk based criteria should be re-assessed and revised to function properly for their intended purpose, However, the current risk-based inspection paradigm should not be eliminated in its entirety in favor of an arbitrary prioritization and frequency of inspection scheme that will substantially increase commercial inspection costs without any identified needs or goals for improvement in water quality controls for substantial commercial pollutant sources.	
39	X.3 & X.5	41 & 42	3. Each permittee shall conduct commercial facility inspections, at frequencies as determined... 5. Information including, inspection dates, inspectors present, the written and photographic documentation results of the inspection…	Sections X.3 and X.5 contain a photographic documentation requirement for all aspects of commercial facility inspection. As with industrial facility inspections, the photographic documentation should be only required when there is a water quality violation, and in a manner consistent with the procedures and constitutional protections specified in City ordinances, and state and federal laws. Since industrial facilities generally pose a greater risk to water quality, having more aggressive program for commercial facilities than for industrial facilities does not make any sense.	See preceding recommendations for Sections V.I.2, and X.1, 2. and 3
40	XI.2	43	The permittees should identify residential areas and activities that are potential sources of pollutants and develop Fact Sheets/BMPs. At a minimum, this should include: residential auto washing and maintenance activities; use and disposal of pesticides, herbicides, fertilizers and household cleaners; and collection and disposal of pet wastes. The permittees shall require residents to implement pollution prevention…	Many aspects of the proposed residential program are already covered under the public education program. As the ROWD reports, the public education program has demonstrated significant improvement in public awareness and water quality practices among residents. . The draft tentative order as proposed fails to recognize the achievements of the public education program, and instead would mandate that municipalities enact and enforce new ordinances and regulations to force residents to implement specific minimum BMPs. Those types of municipal ordinances and regulations would be extremely unpopular, and	Given the investment made in, and success of that education program, the costs of the approach currently set forth in the draft tentative order, and the infeasibility of enforcing compliance with a mandatory set of minimum BMPs applicable to each resident within a municipality, we recommend that the draft tentative order be revised to retain the residential program as an element of the public education and outreach program, We also recommend a continuance of the Public Education Sub-Committee's outreach

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				therefore counterproductive, wasting much of the public education investment and achievements in residential education and practices achieved to date. Enforcing compliance by residents with mandatory BMPs would also be and cost-prohibitive. Under the current MS4 Permit, the co-permittees already implement and adaptively adjust a successful county-wide educational program that has improved water quality practices by residents. The Public Education Sub-Committee has developed a uniform look to the public education program and each city is using the materials that have been developed to promote the program in their respective cities.	strategy for educating residents on a county-wide level by having all the cities contribute their proportionate share to promote stormwater pollution prevention. Revise the key provision set forth in the draft tentative order as follows: The permittees shall ~~require~~ encourage residents to implement pollution prevention *measures via the public education and outreach program, as it is updated by the permittees Public Education Subcommittee during this permit term.*
41	XI.4	44	The permittees shall develop and implement control measures for common interest areas and areas managed by homeowner associations or management companies.	The City of Irvine supports cooperative development by the co-permittees of public education program elements designed to educate and provide information to homeowners associations, commercial property associations, and property managers. The City is currently implementing education and outreach strategies and providing materials to these groups to encourage and educate them in the implementation of better water quality control practices. In addition, the City is implementing a pilot program with certain common interest area property managers to help them both realize economic and water quality benefits that can be attained from adoption of more sensitive irrigation and landscaping practices. However, common interest areas are owned by private associations, and the City has no right to enter those areas or to mandate retrofit of those	Please revise the first sentence of the draft tentative order provision to state: "The permittees shall develop ~~and implement a~~ *public education and outreach component to encourage owners and managers to implement source control BMPs and similar* control measures for common interest areas and areas managed by homeowners associations, *commercial property associations*, or *landscape or property* management companies."

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				areas except in accordance with the requirements, procedures and other protections set forth in the City's water quality ordinances, and in State and Federal laws. The draft tentative order as currently written mandates that co-permittees must develop and implement new BMPs for common interest areas, including, we presume, structural treatment control BMPs as well as source control BMPs. The co-permittees have no authority to implement new BMPs on association properties, particularly to the extent that they would require physical alteration to private property, and the provision as drafted requires co-permittees to violate private property protection and anti-trespass laws, as well as the fourth amendment of the U.S. Constitution.	
42	XII	44	NEW DEVELOPMENT (INCLUDING SIGNIFICANT RE-DEVELOPMENT)	We agree with the County comments that there is a vital need to develop a contextual approach to the revised land development provisions of the draft tentative order. Instead of seeking to establish the final, long-term countywide LID implementation and hydromodification control performance standard for new development and redevelopment upon permit adoption, these new long term performance standards need to be developed in a stakeholder driven process with the benefit of watershed and subwatershed specific information regarding physical and water quality characteristics of surface waters in the watershed, and the goal of producing a substantially revised DAMP, LIP and Model Water Quality Management Plan (WQMP) within a reasonable time frame. In the interim, based on the consensus developed among stakeholders regarding the 85th percentile design volume treatment standard as an LID performance	See Attachment 2 and recommendations for Sections L. 61, 62, 66, and 67 above.

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				standard, the City supports adoption of that standard as an LID implementation and hydromodification control performance standard for developments where achieving that standard is technically and environmentally feasible and desirable. The City further suggests that the that the 85th percentile design volume treatment standard would substitute for the EIA, percolation, and infiltration related performance standards currently referenced in the draft tentative order as LID implementation and hydromodification control performance standards.	
43	XII.A.2	44	Within 6 months of adoption of this order, the principal permittee, in collaboration with the co-permittees, shall develop guidance for the preparation of conceptual or preliminary WQMPs to more effectively ensure that water quality protection, including LID principals, is considered in the earliest phases of a project. The appropriate revisions to the DAMP to incorporate this guidance shall be submitted with the first annual report after adoption of this permit. Within 12 months of adoption of this order, each permittee shall revise its LIP to be consistent with the guidance. The permittees are encouraged to require submission of a conceptual WQMP as early in the planning process as possible.	This section requires that the co-permittees, within 6 months of adoption of the order, develop a model WQMP guidance document to more effectively ensure that water quality protection, including LID principles, are considered in the earliest phases of a project. The schedule for developing this guidance is overly aggressive and does not allow the time to collect appropriate information regarding watershed characteristics and stakeholder participation necessary to develop an effective guidance document. It further fails to take into account the time required for processing and adoption by local governments of revised DAMP and LIP provisions, which should precede or occur concurrently with adoption of a new model WQMP.	The Tentative Order should be modified to allow a reasonable time frame for obtaining needed information and the development of the model WQMP guidance through a stakeholder driven process, as well as sufficient time for local governmental actions necessary to process and adopt revisions to the DAMP and LIPs (there are approximately 1,4000 pages in the City's LIP). The Tentative Order should therefore be modified to allow a reasonable time frame for the Permittees to revise the DAMP as may be necessary, and for each Permittee to revise its LIP and adopt model WQMP guidance. See also Attachment 2 and recommendations for Sections L. 61, 62, 66, and 67 above.
44	XII.A.2	44	Within 6 months of adoption of this order, the principal permittee, in collaboration with the co-permittees, shall develop guidance for the preparation of conceptual or preliminary WQMPs to more effectively ensure that water quality protection, including LID principals, is considered in the earliest	Redundant with first sentence in the same section which reads: "… shall develop guidance for the preparation of conceptual or preliminary WQMPs to more effectively ensure that water quality protection, <u>including LID principals</u>, is considered in the earliest phases of a project.".	Remove last sentence in the section.

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			phases of a project…		
45	XII.A.4	45	In the first annual report following adoption of this permit, the permittees shall include a summary of their review of the watershed protection principles and policies in their General Plan and related documents (such as Development Standards, Zoning Codes, Conditions of Approval, Development Project Guidance, Local Coastal Plan, etc.) to ensure that these principles and policies, including LID principles, are properly considered and are incorporated into these documents…	Section XII A.4 requires the City to update the General Plan and other implementing ordinances, City code provisions, conditions of approval and related guidance to incorporate watershed protection principles and policies, including LID principles, in these regulatory documents. While the City appreciates the need for and is committed to protection of water quality, this requirement as written appears to impermissibly intrude on the City's land use authority in violation of the US. and California constitutions, as further discussed in the County comments. Instead, this provision should be limited to requiring submission in the annual report of a summary of the legal and policy authority established by the City to enable it to comply with the requirements of the MS4 Permit when adopted. In addition, this provision as currently drafted appears to mandate a separate process to be conducted at an earlier time than that process used to adopt revisions and updates to the DAMP, LIPs and model WQMPs to address requirements of the new MS4 Permit, including new LID and hydromodification control requirements. This lack of coordination and failure to integrate update processes will create amendment cycles, and additional costs and staff burden on the City. Alternatively, our General Plan and implementing ordinances could be updated as determined to be appropriate by the City to implement the requirements of the new MS4 Permit, and at the same time that the DAMP, LIP and Model WQMP are adopted to comply with Section XII.A.,2 and XII E.3A.	Revise the draft tentative order provisions to limit the requirement imposed on local agencies with land use authority to review of the General Plan and implementing ordinances, and reporting to the Regional Board regarding the adequacy of its legal authority to comply with the provisions of the new MS4 permit. Revise the draft tentative order provisions to provide for a single, integrated and concurrent process to update the DAMP, LIPs, model WQMP, and to revise any other elements of the General Plan and implementing ordinances as determined necessary by the City to assure adequate legal authority to implement the requirements of the new MS4 Permit,

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46	XII.B.2	46	Each permittee shall ensure that an appropriate WQMP is prepared for the following categories of new development/significant redevelopment projects (priority development projects). The WQMP shall be developed in accordance with the approved model WQMP and shall incorporate LID principles in the WQMP.	Items f and g would potentially require treatment control BMPs for single family homes. Preparing a WQMP for each single family home would be very burdensome on new individual homeowners, and conducting treatment control BMP inspections at individual homes would be too burdensome on the City.	Do not require WQMPs or treatment control BMPs for single family residences.
47	XII.B.2.c)	47	Commercial and industrial developments, which are not subdivisions, of 10,000 square feet or more. This includes non-residential developments.	Section XII.B.2.(c) lowers the threshold criterion for commercial and industrial developments to comply with WQMP requirements from 100,000 square feet to 10,000 square feet.	The fact sheet should explain the basis for lowering the threshold criterion, the evidence indicating industrial discharges are significant sources of water quality pollution, and an evaluation of the cost to implement the new requirement after the anticipated water quality benefit from implementation is identified and explained.
48	XII.B.2.i)	47	Streets, roads, highways and freeways of 5,000 square feet of paved surface. The WQMP should address the project area. This category includes any paved surface used for the transportation of automobiles, trucks, motorcycles and other vehicles and excludes any routine road maintenance activities where the footprint is not changed.	This new requirement does not set a cost-effective or practical minimum threshold for requiring a project WQMP and retrofit of roadways to include new treatment BMPs and hydromodification controls. This minimum threshold will be even more impractical if the Regional Board adopts the consensus approach and mandates implementation of LID BMPs for the full 85th percentile treatment design volume. . Most road projects currently do not, and should not require a project WQMP and BMP retrofit because road projects that are as small as 5,000 square feet of impervious surface do not and cannot properly involve any changes to the drainage facilities serving the roadway system. A road project is part of an interconnected roadway system served by a single storm drainage system; therefore, it's does not make sense to have a project WQMP for, and to require storm drain retrofit for one small section of roadway and storm drain facility, while 99% of the remaining road sections and the remaining storm drain system	Please provide the basis for identifying even very small road projects as substantial sources of polluted runoff in the Fact Sheet. Please reconsider this new requirement mandating WQMPs and BMP retrofits for street, road, highway and freeway projects that are so small that meaningful retrofit is not feasible and will not provide significant water quality benefit, given the small area of impervious surface addressed. Please provide exemptions for small street, road, highway and freeway projects maintenance and expansion projects eliminating the requirement that they must prepare a project WQMP and retrofit both the discrete section of an otherwise interconnected street segment and storm drain segment to incorporate BMPs, except where feasible and practical.

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				remains unchanged. . I is not feasible to construct treatment control BMPs with most small road projects, and implementing 5% EIA or even LID BMPs for the 85th percentile design treatment volume is impossible. The basis for this change is unclear.	
49	XII.B.3.a	48	The effective impervious area (EIA) shall be limited to 5% or less, of the total project site. Also see Section C, below.	As noted above, Dr. Horner and Geosyntec experts have agreed in the stakeholder process that this EIA performance standard for LID implementation and hydromod control is technically meaningful absent a volume capture standard. We concur with the agreement reached in the stakeholder meetings and described in the County comments that the EIA standard should be replaced by the 85th percentile design treatment volume standards. Also, as discussed above, development projects should be exempt from satisfying any LID implementation standard, hydromodification control standard or infiltration/percolation related standard when it is not physically or technically feasible to accomplish that standard, or is otherwise not environmentally desirable. In many circumstances, it will be technically infeasible to meet particular LID implementation and hydromodification control performance standard, including most road projects, many of the dense infill and transit oriented development projects that regional planning organizations and local governments now must attempt to incorporate into their land use plans pursuant to recently adopted SB 375.	See Attachment 2 and recommendations for Sections L. 61, 62.66. and 67 above
50	XII.B.3.c	48	The effective impervious area (EIA) shall be limited to 5% or less, of the total project site. Also see Section C, below.	See preceding comment.	See preceding recommendation.
51	XII.B.5.a	49	Use of structural infiltration treatment BMPs shall	If the use of structural infiltration BMPs is feasible in	We recommend a revision of the draft tentative

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			not cause or contribute to an exceedance of groundwater water quality objectives.	the Newport Bay Watershed from a technical standpoint, it's very possible they will contribute to an exceedance of groundwater water quality objectives in addition to increasing the likelihood of contributing mobilization of groundwater pollutants, including brownfields pollutants, Nitrogen and Selenium geotechnical instability or failures, and groundwater waste	order to explicitly preclude the use of LID BMPs, and to exempt development projects from LID implementation and hydromodification control performance standards or any other infiltration or percolation standards or requirements when those projects are located in areas with shallow groundwater, significant groundwater pollution, inappropriate soils or geotechnical conditions, and/or areas of rising groundwater, where implementation of those types of BMPs and meeting those performance standards has the potential to result in groundwater waste, surface water or land inundation, geotechnical failure, migration of groundwater pollutants, or mobilization or conveyance of pollutants in the groundwater to the MS4 and/or receiving waters. Potential for these adverse environmental consequences is prevalent in the City of Irvine, for example in areas tributary to Peters Canyon Wash, and in or near brownfield redevelopment areas, including the former El Toro and Tustin military bases.
52	XII.C	50	LOW IMPACT DEVELOPMENT TO CONTROL POLLUTANTS IN URBAN RUNOFF FROM NEW DEVELOPMENT/SIGNIFICANT REDEVELOPMENT	We agree with the County comments noting that the draft tentative order improperly intrudes upon the co-permittees' land use authority in violation of the Tenth Amendment of the U.S. Constitution and imposes a prescriptive standard as to compliance with the draft tentative order, and concur in the approach outlined by the County and discussed in further detail above, and in Attachment 2 enclosed with these comments. The City concurs in the approach outlined by the County to use the alternative 85th percentile design volume performance standard as discussed in further detail above, and in Attachment 2 enclosed with these comments. That design volume standard is	See Attachment 2 and recommendations for Sections L. 61, 62.66. and 67 above

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				understandable by planners, engineers and developers, is adequate to meet treatment goals of the water quality experts participating in the stakeholder meetings, and is therefore appropriate as a default standard until more watershed specific information is developed by and at the discretion of the co-permittees to prepare long term LID implementation and hydromod control standards specifically applicable within and appropriate for protection of this watershed.	
53	XII.C	50	LOW IMPACT DEVELOPMENT TO CONTROL POLLUTANTS IN URBAN RUNOFF FROM NEW DEVELOPMENT/SIGNIFICANT REDEVELOPMENT	Section XII.C requires implementation of low impact development (LID) techniques for new development and significant redevelopment projects. It will be technically infeasible and/or environmentally undesirable to implement LID techniques for a significant number of redevelopment projects in the City of Irvine. As a part of the LID program, effective impervious area (EIA) is required to be less than 5%. This is based on a misapplication of watershed based technical studies, and varies substantially depending on watershed characteristics. The City appreciates the stakeholder meetings that the Regional Board has held during the public comment period to flush out the technical aspects of EIA and alternative performance standards. The City concurs in the approach outlined by the County to use the alternative 85th percentile design volume performance standard as discussed in further detail above, and in Attachment 2 enclosed with these comments..	The LID and hydromodification control requirements should be limited to new development projects only where LID is technically and economically feasible, and a sufficient list of exceptions should be developed to address and identify those situations where compliance with those requirements will be technically infeasible or environmentally undesirable. See Attachment 2 and recommendations for Sections L. 61, 62.66. and 67 above
54	XII.C.1	50-51	a. The permittees shall incorporate LID site design principles that reduce runoff to the maximum extent practicable during each phase of priority development projects. The permittees shall	This section identifies a list of site design BMPs that should be taken under consideration during each phase of priority development projects. The list provided, however, is a confusing mix of goals, tasks, and work products which does not provide a	Separate the provisions to distinguish between recommended site design BMPs, and other goals for the new development and redevelopment program. Work products that are required for compliance with the MS4

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			require that each priority development project include site design BMPs during development of the preliminary and final WQMPs…	clear basis for compliance.	Permit should be specified in a separate section of the draft tentative order.
55	XII.C.2	51	The permittees shall require the following source control BMPs for each priority development project, unless…	It is not clear why the major discussion of LID also includes prescribed source control BMPs.	For the purposes of clarity, Section XII.C.2 should be deleted from this section of the draft tentative order and proposed as separate section.
56	XII.C.4	53	a) The permittees may allow a project proponent to substitute treatment control BMPs for LID measures if the following conditions are met…	Section XII.C.4 states that treatment control BMPs can be used in lieu of LID measures as long as various conditions are met. One of the conditions is for EIA to be 5% or less. How does one achieve EIA of 5% or less without implementing LID? What value does an exemption from the performance standard have if it's only available for projects that meet the performance standard?	Delete this section, as it provides a useless EIA performance standard and fails to provide a meaningful exemption.
57	XII.D	54	HYDROLOGIC CONDITIONS OF CONCERN (HYDROMODIFICATION)	Section XII.D requires 5% or less hydrologic impact from new development and significant redevelopment projects. It is not clear how this standard would be measured, or the relationship of this standard to the many other hydrological standards set forth in section XII.D. Which standard is the default performance standard for hydrological control? Is it technically feasible and environmentally desirable to meet whichever standard is the default performance standard in the majority of new development and redevelopment circumstances, particularly where infiltration, percolation or meaningful runoff volume reductions cannot be achieved on site. Does the standard allow for dense infill development, transit oriented development and similar projects now mandated by SB 375? Is it anticipated that the default hydromodification control standard can be replaced by an appropriate watershed specific standard developed on the basis of watershed specific physical and environmental characteristics and	Please revise and clarify this provision of the draft tentative order to provide the information discussed in the comment.

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				information with stakeholder input?	
58	XII.E.2	55-56	The obligation to install structural treatment control BMPs at a new development is met if, for a common plan of development, BMPs are constructed with the requisite capacity to serve the entire common project, even if certain phases of the common project may not have BMP capacity located on that …	There is no mention of obtaining a consistency determination from the Executive Officer in this section. Will that detail be contained in the revised DAMP as it is in the current DAMP? Is it the intent to allow co-permittees to evaluate and approve BMPs designed to serve a common project area? Because use of BMPs that serve a common project area best accommodates implementation of site design BMPs, the City of Irvine supports streamlined and simple approval procedures, and endorses co-permittee approval of these types of BMPs.	Please clarify the intent with respect to approval of common project BMPs.
59	XII.G.3	57	Prior to occupancy, the permittees shall verify through visual observation, that the BMPs are operational and functional	It will be impossible to determine visually during City inspections to assure implementation of WQMPs that BMPs are operational and functional unless it's raining because permittees cannot run non-storm water through a drainage system.	Revise the draft tentative order language to state that "Prior to occupancy, the permittees shall verify through visual observation, that the BMPs have been installed in accordance with the approved plans and project WQMP."
60	XII.H	57	CHANGE OF OWNERSHIP AND RECORDATION	Section XII.H requires permittees to establish a mechanism to ensure that appropriate easements and ownerships for long term maintenance and operation of BMPs are properly recorded in public records at the County and/or the City. The City already has a program in place to track the transfer of long-term maintenance and operation responsibilities from a developer to an appropriate operator upon completion of development. However, ownership and real property interest documents are recorded at the County Recorder's Office, not in individual cities. It will be difficult if not impossible for the City to track recording of easements and ownerships with changes in project or site ownership, and is not necessary to assure that an entity is responsible for operation and maintenance of BMPs. The recordation requirement should be left to the discretion of the	Delete reference of recording any documents at a city and explicitly allow other methods of tracking ownership and responsibility such as the Notice of Transfer of Responsibility, which was developed by the City to track transfer of operational and maintenance responsibility for BMPs and is a document filed in city records, but not recorded.

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				permittees.	
61	XIII.J.1	58	The above provisions for LID and hydrologic conditions of concern are not applicable to projects the have an approved Water Quality Management Plan as of the date of adoption of this order.	Under the DAMP and LIPs, project WQMPs are prepared at both (i) the conceptual level, as a planning and design document that assure consideration and inclusion of appropriate site design BMPs (many of which are the LID BMPs currently favored by water quality experts for treatment control); and (ii) the project level, to implement the concept project WQMP planning document. The current draft tentative order provision is likely to cause confusion with respect to grandfathering in that it relies on the project WQMP as the appropriate trigger fro grandfathering, without specifying which WQMP is intended. The current MS4 Permit ties grandfathering directly to land use approvals that must be obtained by development projects, and we recommend a similar approach for be incorporated into the draft tentative order to provide greater ease and certainty in identifying those projects that are grandfathered and those that are not	Please revise the draft tentative order provision to specify land use approvals that will determine development projects that are grandfathered and those that are not, as the current MS4 Permit does.
62	XIII.3	58	…Through use of local print, radio and television, the permittees must ensure that the public and business education program makes a minimum of 10 million impressions per year and that those impressions measurably increase the knowledge and measurably change the behavior of the targeted groups.	There must be a clear definition for an impression. Currently an impression can consist of anything from passing a pollution prevention street banner in a car to an extended face-to-face interaction with a member of the public. We believe a much better indicator of a program's likely effectiveness is the description of the permittee's public education efforts contained in the PEA.	Consider a more effective way of evaluating the effectiveness of a public education program rather than relying on impressions. If impressions must be used, develop a standardized method of determining what qualifies as an impression.
63	XIV.7	59	Within six months of adoption of this order, the principal permittee shall evaluate the effectiveness of debris booms and determine if additional debris booms are needed to address floatables in inland streams…	(see comment for Item G.21 above)	Please clarify the Regional Board's position on the use of devices such as debris booms in waters of the U.S.
64	XIV.10	61	Each permittee shall examine opportunities to retrofit existing storm water conveyance systems and parks	The 2005 RBF Retrofit study has not, to our knowledge, been adopted or approved by the	The 2005 RBF Retrofit Study should not be mandated as the basis for co-permittee retrofit

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			and other recreational areas with water quality protection measures, where feasible. The 2005 RBF Retrofit Study may be used by the principal permittee for a system-wide evaluation in lieu of each permittee conducting its own evaluation. Within 12 months of adoption of this order, the principal permittee shall submit a proposal for additional retrofit studies that incorporates opportunities for addressing any applicable TMDL implementation plans.	principle permittee, and is still in draft form and most of the co-permittees have not had an opportunity to review the draft.	programs until the co-permittees have had an opportunity to review, comment, and approve the final draft, as required in the current MS4 permit for any program developed by the principal permittee.
65	XV. & XIV.	62	XV. MUNICIPAL CONSTRUCTION PROJECTS/ACTIVITIES XIV. TRAINING PROGRAM FOR STORM WATER MANAGERS, PLANNERS, INSPECTORS AND MUNICIPAL CONTRACTORS	These sections are out of sequence. Section XV is shown before Section XIV.	Put sections in the proper numerical sequence.
66	XIV.2	62-63	The curriculum content should include: federal, state and local water quality laws and regulations as they apply to construction and grading activities, industrial and commercial activities; the potential effects of construction, industrial and commercial activities and urbanization on water quality; implementation and maintenance of erosion control and pollution prevention measures and sediment control BMPs; the proper use and maintenance of erosion and sediment controls; the enforcement protocols and methods established in the Drainage Area Management Plan, Local Implementation Plan, the Construction Runoff Guidance Manual, Enforcement Consistency Guide and Illicit Discharge/Illegal Connection Training Program.	We suggest that better water quality training programs will be achieved if co-permittees are allowed to tailor their programs to address the particular responsibility of the different employee groups performing water quality related tasks. Does the current draft tentative permit require that all staff involved in a co-permittee's stormwater program need to be aware of all the curriculum content described in this section? We agree that program managers should be familiar with the entire regulatory framework; we believe, however, others involved in more discrete tasks required to implement the stormwater program may only need to be aware of the regulations and procedures that affect their particular range of responsibilities. For this reason, we suggest more flexibility in tailoring content to appropriately address the areas of responsibility assigned to various trainees.	Please revise the draft tentative order to allow greater flexibility in structuring and tailoring curriculum content to best train co-permittee personnel and develop core competencies appropriate for the employee's area of responsibility.
67	XIV.3	63	The training modules for each category of trainees (managers, inspectors, planners, contractors, public works crew, etc.) should define the required	We believe proof of attending mandatory training, practical application workshops, and similar mechanisms should be a suitable alternative to a	Delete the reference to a testing requirements, certifications, and Certificates of Completion to allow co-permittees the flexibility to assure

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			competencies; outline the curriculum, a training procedure at the end of the training program and proof of completion of training (Certificate of Completion).	Certificate of Completion. These alternatives do not raise employment and labor issues, but still assure adequate participation in training programs.	participation of personnel in adequate training, while avoiding employment and labor issues.
	XIV.4	63	At least on an annual basis, the principal permittee shall provide and document training to applicable public agency staff on Fixed Facility Model Maintenance Procedure, Field Program Model Training and Drainage Facility Model Maintenance Training. The field program training should include Model Integrated Pest Management, Pesticide and Fertilizer Guidelines. Each permittee shall attend at least three of these training sessions during the term of this permit. The training sessions may be conducted in classrooms or using videos, DVDs, or other multimedia with appropriate documentation and a final test to verify that the material has been properly reviewed and understood.	This section states explicitly that the principal permittee shall provide training. We concur with the County comments that it is unnecessary and inefficient for the principal permittee or its consultant to provide training in cities, such as Irvine, with experienced program managers, particularly given the collaborative development by core permittees of a single set of core competency requirements. We do agree, however, that cities with a demonstrated or perceived deficiency may well benefit from training provided by the principal permittee. The principal permittee supports the provision of in-house training by individual cities, and this approach can be much more cost effectively implemented for those cities with in-house stormwater managers	Please revise the draft tentative order to clarify that individual cities have the option of providing in-house training rather than participating in training administered by the principal permittee or a consultant retained by the principal permittee.
68	XIV.5	63	The principal permittee shall conduct and document public employee training for model environmental review, and on how to conduct public/business education for preparation of environmental documents.	(see XIV.4 comment above)	(see XIV.4 comment above)
69	XIV.6	63	The principal permittee shall provide BMP and training information to municipal contractors to assist the contractors in training their staff. In instances where applicable municipal operations are performed by contract staff, the permittees shall require evidence that contract staff have received a level of training equivalent that listed above.	(see XIV.4 comment above)	(see XIV.4 comment above)
70	XIV.7	63	The principal permittee shall notify designated Regional Board staff via e-mail at least 30 days prior to conducting any of these training sessions.	Individual co-permittees should be required to notify designated Regional Board staff via e-mail at least 30 days prior to conducting any of their training sessions	Please revise the notice and reporting requirements related to training sessions to allow for an annual summary of training

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				if in-house training is provided in lieu of training provided by the principal permittee. It appears this notification would also apply to training new hires within 60 days of employment which would mean the co-permittees or principal permittee may possibly be required to notify the Regional Board more or less continuously. We suggest that a summary of training provided and attended by co-permittee storm water personnel in the annual report is sufficient to evaluation whether adequate training is occurring, and does not create reporting procedures that are burdensome to the co-permittees or the Regional Board.	provided and the level of co-permittee participation.
71	XIV.8	63	Each permittee shall have adequately trained all its staff involved with storm water related projects within 60 days for being assigned these duties and on an annual basis thereafter, prior to the rainy season.	Who will be designated to provide this training? It's not practical for the principal permittee to provide training to all categories of stormwater personnel every two months. If required, the principal permittee or their consult(s) would be conducting training continuously for the duration of the permit term. Therefore, it would only be practical for the co-permittees to provide the training to new hires. If the co-permittees end up with the responsibility to train new hires, it stands to reason they should also be responsible for training existing staff.	Add an option to enable individual co-permittees to provide in-house training for new hires using curriculum developed by the principal permittee in collaboration with the co-permittees.
72	XVIII.B.3.	66	…A collaborative watershed approach to implement the nitrogen and selenium TMDLs for San Diego Creek and Newport Bay is expected. As long as the stakeholders are participating in and implementing the collaborative approach, if approved, they will not be in violation of this order with respect to the nitrogen and selenium TMDLs for San Diego Creek and Newport Bay. In the event that any of the stakeholders does not participate, or if the collaborative approach is not approved or fails to achieve the TMDLs, the Regional Board will exercise its option to issue individual waste…	The draft tentative order appears to improperly regulate rising groundwater in channels, which is properly characterized as a non-point source under of the Clean Water Act. As discussed in the draft Selenium TMDL, the source of selenium in the MS4 and receiving waters is primarily rising groundwater and natural seeps into surface water channels, and should not be subject to the NPDES permit.	Please revise the draft tentative order to be consistent with the draft TMDL, and to eliminate the implication that MS4 operators are responsible for introduction of selenium into surface waters that results from natural groundwater intrusion.

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			discharge requirements or waivers of waste discharge requirements.		
73	XIX.3	73	Upon the effective date of this Order, the permittees shall start implementing the 2007 DAMP. If modifications to the 2007 DAMP are determined to be necessary, the permittees shall prepare and submit DAMP modifications to the Regional Board Executive Officer…	The co-permittees have not seen or approved the 2007 DAMP as required by the current and draft order. It will, therefore, be impossible to start implementing the 2007 DAMP upon the effective date of this order.	Ensure the co-permittees have had an opportunity to review and approve the entire Draft 2007 DAMP prior to adoption or clarify that the 2007 DAMP is intended to mean the 2006 Report of Waste Discharge (ROWD). Define a timeline for the revision and final adoption of revisions to the DAMP (2009?) and LIPs to address all final new MS4 Permit requirements, that will take into account not only a reasonable time for co-permittees and stakeholders to develop the new provisions, but also sufficient time to properly process and provide for the adoption of revisions to the DAMP and LIPs by local governments.
74	XIX.4	73-74	The Management Committee shall meet at least six times a year to discuss issues related to permit …	Has the Permittee Committee's name been changed to the Management Committee?	Please clarify
75	XXI.5	75	Within six months of adoption of this order, the permittees, in coordination with the Orange County Fire Chiefs Association, shall develop a list of appropriate BMPs to be implemented to reduce pollutants from training activities, fire hydrant/sprinkler testing or flushing, non-emergency fire fighting and any BMPs feasible for emergency fire fighting flows.	BMPs should not be required for emergency fire fighting under any circumstances.	Delete BMP requirement for emergency fire fighting.

ATTACHMENT 1

ATTACHMENT 2

Low Impact Development (LID) and Hydromodification Control

The City supports the comments submitted by the principle permittee, the County of Orange, in its February 13, 2009 comment letter, and attachments A, B, and C to that comment letter (the "County Comments"), all of which address the November 10, 2008 First Draft of Order R8-2008-0030 ("draft tentative order"). These comments supplement the County Comments addressing LID and hydromodification control provisions and concepts currently set forth in the draft tentative order, including, without limitation, Findings 60 through 63, and Section XII of the draft tentative order.

As noted in the County Comments, the City of Irvine believes there is a vital need to develop a contextual approach to the revised LID and hydromodification control provisions of the draft tentative order. Instead of seeking to establish a Countywide performance standard for LID implementation and hydromodification control upon Permit adoption, these new requirements need to be developed in a stakeholder driven process with the goal of producing a substantially revised Model Water Quality Management Plan (Model WQMP) within 12-24 months.

The preparation of the revised Model WQMP would incorporate the development and analysis of information, mapping and data as necessary to integrate and address treatment SUSMP, LID and hydromodification requirements informed by consideration, on a watershed-by-watershed basis, of the opportunities and constraints presented by the existing physical characteristics of each watershed, including the existing urbanized landscape, water balance characteristics, the ecological condition of individual stream systems, groundwater conditions, including existing contamination and groundwater elevations, topography and other key characteristics relevant to establishing appropriate LID implementation and hydromodification control strategies and performance standards. The City believes that a critical portion of the data, information, and mapping that must be developed during the preparation of a Model WQMP that establishes appropriate LID implementation and hydromodification control standards for the Newport Bay Watershed is comprised of that information, data and mapping discussed in the Geosyntec White Papers 1, 2 and 3 submitted to the Regional Board during the stakeholder meetings held during this first public comment period on the draft tentative order expiring February 13, 2009 (the Comment Period).

As noted by the County Comments, the City of Irvine is concerned about draft tentative order provisions mandating performance standards for LID implementation and control hydromodification without first collecting, developing and analyzing the data, information and mapping outlined above and in White Papers 1, 2, and 3. As discussed in our stakeholder meetings and those White Papers, the January 2009 report entitled Low Impact Development Metrics in Stormwater Permitting, and based on a review of other approaches taken to LID implementation and hydromodification control outlined in the County Comments, the City of Irvine has

concluded that one-size-fits all performance standards mandating specific percentages of Effective Impervious Area (EIA) and/or absolute and inflexible minimum volumes that must be percolated or infiltrated on a project-by-project, site-by site basis, or even sub-watershed or watershed basis, without consideration for existing physical conditions that may characterize each site, project, sub-watershed or watershed is not appropriate and may be counterproductive for a number of reasons, including the following:

- Specific performance metrics for Low Impact Development (LID) are the subject of contention among experts.
- As discussed in the stakeholder meetings, and as Dr. Richard Horner has concurred, EIA is not a meaningful metric to govern project development unless combined with appropriate volume design standards;
- Without information regarding particular physical characteristics of the new development and redevelopment project sites to be regulated (information that is proposed for development by the co-permittees as part of the Model WQMP revision), including information regarding water balance (including anticipated an appropriate evapotranspiration rates), groundwater quality, groundwater elevation, soils characteristics, geotechnical constraints, susceptibility of receiving waters to hydromodification and destabilization, potential for advantages infiltration to groundwater and in-ground water storage, and the potential for mobilization of groundwater containing high levels of Selenium and Nitrogen, or other anthropogenic contaminants found at or near brownfields redevelopment sites (such as El Toro and Tustin closed military bases), a performance standard based on a specific volume of water that should be percolated or infiltrated cannot be determined in a manner that assures the standard is technically feasible and properly protective of the environment; and
- Absolute standards do not allow for implementation of other environmental policy goals in land use planning, including densification of existing development, implementation of infill and brownfields reuse projects, and encouraging mixed use, live-work, and transit oriented development.

As a result, the City of Irvine recommends that in order to properly and protectively ensure feasibility of compliance as well as water quality benefits associated with LID implementation and hydromodification control performance standards and metrics, the permittees must develop an integrated and contextual approach focused on enhanced treatment as well as volume reduction through an information driven stakeholder process incorporating input from LID designers, academia engaged in LID research, municipal stormwater and plan check staff, and environmental groups. In this way, requirements can be determined that more effectively emphasize LID treatment benefits, set physically and environmentally appropriate and protective levels of runoff volume reduction, and assure LID and hydromodification control implementation, while at the same time assuring technical feasibility, water quality protection and environmental desirability. With these goals in mind, the City of Irvine

supports the County's request that Section XII.C.3. be rewritten to provide for the development of a contextual approach for the renewal of the Orange County MS4 permit.

The City of Irvine also requests, based on the expert technical information and consensus points 1-3 reached in stakeholder meetings and outlined in the County's Comments that the Regional Board reconsider the metric that is most appropriate for use in setting LID implementation and hydromodification control performance standards. The City suggests that Section XII.C.3. should be re-written to expressly provide for development of performance standards based on a design volume metric, rather than an EIA or absolute volume infiltration and percolation metric.

As established in our stakeholder meetings, an EIA standard without a design volume metric is meaningless, but the experts agree as noted in the points of consensus that a design volume metric can be effective without an EIA standard. Therefore a design volume metric is preferable. In addition, designers, planners, engineers and developers, as well as water quality control experts all understand the meaning and technical implications of a design volume metric and related performance standard. As established in our stakeholder meetings, water quality experts do not all understand and agree upon the meaning and technical implications of an EIA performance metric.

With respect to volume infiltration or percolation standards, a design volume capture (rather than infiltration or percolation) metric was also established in the stakeholder meetings and associated information presented to be a more appropriate metric than a metric based on minimum volumes of runoff to be infiltrated or percolated. The stakeholder discussion, reports and white papers and other information considered in the stakeholder meetings together established that a technically feasible and an environmentally protective infiltration or percolation volume metric cannot be reasonably established on a regional or sub-regional basis, much less on a site-specific or project specific basis, in the absence of specific information regarding existing physical characteristics (including the information outlined regarding physical characteristics outlined above) found in a particular watershed, sub-watershed, or area.

For these reasons, the City of Irvine requests that Section XII.C.3. be rewritten to provide for the development through the Model WQMP revision process of LID and hydromodification control performance standards that are based on metrics related to design volume capture rather than either EIA or set infiltration or percolation volumes.

In addition to using a contextual approach to develop LID implementation and hydromodification control performance standards and metrics, the City of Irvine believes it is critical that the draft tentative order contain provisions expressly recognizing those situations and circumstances in which achievement of generally applicable performance standards and metrics would be inappropriate from a

technical feasibility, environmental protection, water quality protection or environmental policy perspective. For example, the City of Irvine recommends that Section XII.B.2 (defining priority development and redevelopment projects), Section XII.C.3., Section XII.C.4, Section XII.D., and Section XII.E. be revised to establish exceptions to LID implementation and hydromodification control performance standards for new development and redevelopment projects as necessary to take into account that it is likely inappropriate to apply those performance standards due to technical infeasibility and the potential for adverse impacts on water quality and environmental protection in the following types of circumstances:

- Known pollutants of concern exist in underlying groundwater;
- Saturated soils or shallow groundwater levels (less than 10 feet bgs) exist;
- Natural soils conditions are not conducive to infiltration and cannot be effectively amended, or geotechnical stability issues are created by infiltration, percolation, or the introduction of substantial volumes of runoff into the ground at shallow and/or intermediate depths;
- Potential for mobilization of groundwater pollutants, or increased exfiltration of groundwater flows or pollutants to surface waters exist;
- Proposed discharges either directly or via a storm drain enter into an engineered, stabilized, regularly maintained, or otherwise stabilized channels, or discharge into a sump area, area under tidal influence, or other receiving water that is not susceptible to hydromodification impacts, such that hydromodification control would not result in improved stabilization or receiving water quality; and
- Redevelopment projects are proposed that will reduce existing impervious surface in an urbanized watershed, and provide for increased density, or use of a particular development site consistent with transit oriented development, mixed use or live-work infill, brownfields reuse, and similar environmentally protective land use planning goals and paradigms encouraged and mandated by recently enacted environmental protection legislation and policies, including AB 32 and SB 375.

In providing for these exceptions to LID implementation and hydromodification control performance standards, we would further request that the Regional Board consider revisions to the draft tentative order provisions listed above that take into account the following critical concept:

- No in lieu programs or credit programs currently exist. They could only be developed after preparation of the revised Model WQMP. Therefore, any requirement that projects must provide offsite mitigation or contributions to regional or sub-regional programs that would be applicable in the upcoming permit term seems a bit unrealistic. In any event, if technical or environmental constraints make compliance with LID implementation or hydromodification control performance standards technically or environmentally infeasible or inappropriate, offsite mitigation and in lieu requirements cannot be imposed

on such projects until and unless the information is developed and available to allow projects to effectively participate in offsite, sub-regional or regional mitigation programs.

To the extent that the Regional Board has determined that an interim or default performance standard is necessary for LID implementation and hydromodification control, the City of Irvine supports the approach to an interim hydromodification control standard discussed in the County Comments. Currently, co-permittees have been able to adequately protect susceptible receiving water bodies from hydromodification control using current provisions of the DAMP related to identification, analysis and control measures for hydrologic conditions of concern. With respect to an interim or default LID implementation standard, the City would supplement the County Comments by suggesting that consideration of all of the above comments related to performance standards, metrics, and exceptions discussed above are critically important to both a long-term, contextually developed LID implementation standard as well as an interim or default LID implementation standard. Accordingly, the information provided in White Paper #4, and the January 2009 report entitled Low Impact Development Metrics in Stormwater Planning should guide development of any “default” or “interim” LID implementation and hydromodification control standards included by the Regional Board in the draft tentative order.

With respect to timing, the County Comments note that the development of appropriate LID and hydromodification control performance standards and metrics and incorporation of those standards into a Model WQMP is anticipated to require 24 months. However, the development of a revised Model WQMP is just one step in the process of effectively promulgating new performance standards and metrics. Consequently, the City of Irvine recommends revisions to the draft tentative order provisions as necessary to recognize that additional time will be necessary for co-permittees to further incorporate the revisions of the Model WQMP into the DAMP, LIPs, and local General Plans and implementing ordinances, regulations, guidelines and policies. Therefore, the draft tentative order should provide for a sufficient period of time after the 24 months required to develop a revised Model WQMP to incorporate those standards into other guidance and implementing documents. Similarly, additional time will be required after development of the revised Model WQMP to develop and implement in lieu or offsite mitigation programs, and the draft tentative order should be revised to allow for those programs to be implemented prior to requiring new development or significant redevelopment to provide any offsite mitigation.

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February 13, 2009

Gerard Thibeault
Executive Officer
California Regional Water Quality Control Board – Santa Ana Region
3737 Main Street, Suite 500
Riverside, CA 92501

Re: Tentative Order No. R8-2008-0030 – NPDES No. CAS618030

Dear Mr. Thibeault:

The NAIOP SoCal Chapter is submitting this correspondence to the Santa Ana Regional Water Quality Control Board (SARWQCB) to provide our formal comments on Tentative Order No. R8-2008-0030. By way of introduction, NAIOP is the nation's leading trade association for developers, owners, investors, and other professionals in industrial, office and mixed-use commercial real estate. NAIOP provides educational programs, research on trends and innovations, and strong legislative representation. The SoCal Chapter of NAIOP serves more than 1,200 members. It is the second largest chapter in the United States and is the leading commercial real estate trade association in Southern California.

NAIOP SoCal and its members have for many years been promoting efforts to design, construct and maintain buildings, infrastructure and their accompanying grounds in a manner that promotes the environment. In fact, the industrial and office development industry has voluntarily made great strides in using proven environmental strategies. These efforts have provided us with a vast experience in what can truly work in light of the realities that we all face. Clearly, for any program to be successful it needs to be focused on addressing the various realities of this region, and should provide for voluntary incentives that are cost effective.

One overarching reality and challenge we all face is as you note on page 10 of the tentative order. "A major portion of Orange County *is* urbanized with residential, commercial and industrial developments."(emphasis added) In fact, Orange County's population per square mile is the sixth densest in the entire United States. There is very little developable land remaining, and what open land remains is, essentially, already entitled. That means any future development to meet the projected population and business increases that are coming will be redevelopment/infill projects, not in pervious open spaces. Additionally, the State of California is creating more mandates and programs, such as SB 375, which further drive development into already developed/impervious areas. Thus, any NPDES permit for this region must reflect these realities.

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COMMENTS

1. The draft permit places a heavy reliance on the concept of achieving an Effective Impervious Area (EIA) of only 5% or less on a project by project basis. Furthermore,

this extremely minimal EIA standard is supposed to be achieved through Low Impact Development (LID) measures. Essentially, these requirements effectively mean infiltration Best Management Practices (BMPs) will be necessary at the project site. There are numerous areas in the County where infiltration is not advisable or even feasible. Sites are all different based upon soil conditions, land use densities, geotechnical issues, and locations of contaminated plumes. The proposed permit effectively would require infiltration at sites and such increased infiltration can even cause increases in the discharge of other pollutants such as selenium. The heavy reliance on the 5% EIA and infiltration does not take into consideration the overall site water balance, and could create unnatural levels of groundwater infiltration which also is dangerous to the natural habitat. As mentioned many State programs and laws, like SB 375, are designed to drive infill development to supposedly alleviate sprawl. The 5% EIA and infiltration requirements in the permit actually are inconsistent with that effort as they require larger, more spread-out, less dense project sites.

Based on the above and other reasons, it does not seem the draft permit should so heavily rely on the EIA and infiltration. NAIOP certainly believes the 5% EIA requirement needs to be deleted or significantly revised.

2. In the discussion of LID requirements and Water Quality Management Plans, there are references to "pre-development site hydrology" which is not defined. Based upon discussions in other parts of the draft permit, it does appear this term references the hydrology as it currently exists on the site, but may in fact reference site conditions prior to any human habitation. Clearly, there already is some existing runoff that is not in any way caused by the new or redevelopment project in already developed areas. As noted, the vast majority of projects are going to be on previously developed land, not greenfields. Thus, any requirements placed on new developments must only look at what may be created by the new project, not the already existing runoff. There should be no requirement or goal that would force site design to go back in time and reflect pre-anthropogenic conditions. Otherwise, you would be punishing developers for avoiding open impervious space, and this would also be inconsistent with SB 375 and the statewide efforts to increase density development in order to reduce greenhouse gas emissions.

3. The NAIOP members have many years of experience designing and implementing effective LID design features. In our review of the draft permit, it appears the LID concepts are unnecessarily limited, essentially focused on infiltration. It has been our experience that there are other techniques in designing effective stormwater management systems. NAIOP believes providing as many tools as possible is the best way to achieve the overall objective of stormwater management of pollution and runoff. Providing the development community with the widest range of options allows for the selection of a LID program that best achieves stormwater management given the unique features of each area. Thus, LID BMPs such as evapotranspiration, landscaping and vegetative solutions, harvesting and reuse should be allowed for in addition to infiltration. Furthermore, it appears the permit is biased against the use of watershed-based or regional type solutions. For example, the permit's discussion of LID requirements emphasizes location controls as close to pollutant sources as possible, which appears to conflict with other parts of the permit that appear to encourage or at least allow for the implementation of regional controls. Such a dichotomy should be resolved in favor of allowing the most

flexibility possible in achieving the permit's goals across the jurisdiction regulated by the permit. This would be in keeping with California Code section 13360 which prohibits the agency from dictating the manner of permit compliance.

4. It does appear there are numerous situations where the draft permit creates requirements that exceed mandatory federal requirements. There is no explanation or rational provided for doing so. The draft permit should not create requirements that exceed the federal standards, but if it chooses to do so, all requirements of the Porter-Cologne Water Quality Control Act must be fulfilled, including consideration of factors under sections 13000, 13241 and 13263, which to date does not appear to have been fully considered in this permit process.

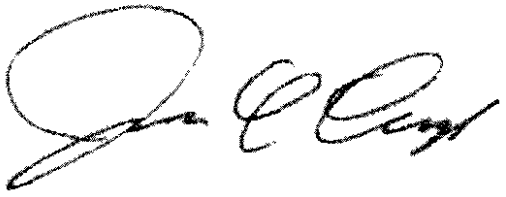
5. The entire issue surrounding hydromodification, infiltration and addressing water quality is very complex. The draft permit seems to want to approach it with a focus on a project by project basis. Yet, this would seem to be too narrow a focus, as it seems the true focus should be how to address the watersheds. Each watershed has unique receiving water issues, land uses, topography and soils, groundwater conditions, stream stability and habitat issues and other considerations. Stormwater management approaches that are tailored to a watershed, or on a sub-watershed basis, would seem to more likely lead to effectively and efficiently achieving the desired watershed goals. Watershed Mater Plans can be developed such that water resource goals can be integrated to address water quality, hydromodification, water supply and habitat issues. The recent National Academy of Science report on stormwater actually recommends permitting that is based upon watersheds, and prioritizing goals and implementation efforts on a watershed basis. In this region, there have been significant watershed planning efforts already conducted that can be used for watershed planning efforts.

Thus, NAIOP recommends that watershed master plan goals and prioritization of areas needs to be developed so a more targeted allocation of resources and results can be accomplished. The watershed should be the basic planning unit, and the issues and measures will vary depending on the actual conditions in each watershed. This approach would more likely result in the maximum beneficial result. The permit should be revised to reflect a watershed planning basis and to remove provisions that are overly-project specific, such as those related to WQMPs and LID, allowing such programs to be developed as necessary by the permittees as part of watershed planning efforts.

6. The permit purports to provide alternatives to the 5% EIA requirements and to other particular BMP requirements, however, the "alternatives" provided are not true alternatives. First of all, the allowance for treatment BMPs as alternatives to LID requirements would still require maintaining a 5% EIA. Thus, there is no real alternative provided. If 5% EIA is not possible to achieve and treatment is posed as an alternative, then it would make no logical sense to still require 5% EIA. This will be especially true for the infill and redevelopment projects in the region. Secondly, the section on waivers and alternatives to BMPS is not really providing an alternative. There are no established in-lieu fees program or credit systems and likely will no be for quite some time after permit issuance. Thus, projects wishing to proceed would be stopped indefinitely through implementation of the permit until such time as waiver programs are established, if ever. Therefore, although the permit attempts to provide for alternatives to the draconian EIA and LID requirements, there is no real alternative established.

NAIOP certainly appreciates the efforts so far of the SARWQCB in developing the draft permit. We feel it would be beneficial to all for the SARWQCB to work with the development community to finalize the work on the draft permit. NAIOP firmly believes such a cooperative approach would lead to the best and most effective plan for addressing the stormwater management of this region. Again, we appreciate this opportunity to comment on the draft permit, and look forward to working with you in completing this effort.

Sincerely,



James V. Camp
Chair, Legislative Action Committee

NRDC
THE EARTH'S BEST DEFENSE

NATURAL RESOURCES DEFENSE COUNCIL

February 13, 2009

Via U.S. Mail and electronic mail

Ms. Carole H. Beswick and Members of the Board
Santa Ana Regional Water Quality Control Board
3737 Main Street, Suite 500
Riverside, CA 92501-3348

Re: Draft NPDES Stormwater Permit for the County of Orange, Tentative Order No. R8-2008-0030

Dear Chair Beswick and Members of the Board:

We write on behalf of the Natural Resources Defense Council ("NRDC") and Orange County Coastkeeper ("Coastkeeper"). NRDC is a national environmental advocacy organization with over 120,000 members in California and has been involved in MS4 permit matters across the state, with a focus on the implementation of low-impact development ("LID") practices. Coastkeeper is a grassroots environmental organization with 17,000 members in the region, a decade's worth of successful projects that have improved water quality, and a record of collaboration in developing solutions to the impacts of water pollution. As a general matter, we strongly support LID because it is the most effective means of addressing the water quality and quantity problems associated with urban runoff. LID practices seek to replicate pre-development hydrology through the deployment of measures that infiltrate or capture water onsite, thereby significantly reducing the amount of water and water-borne pollutants that drain from developed areas. Since urban runoff is the single greatest contributor to water pollution in California, widespread implementation of LID is vital to the health of our state's renowned ecosystems.

We believe that LID techniques are required by the Clean Water Act's "maximum extent practicable" ("MEP") standard for pollution reduction because of their practicability, low cost, and superior performance relative to conventional BMPs. Additionally, LID practices generate significant ancillary benefits—such as cost savings, reduced need for imported water, and improved aesthetics—for developers, building owners, and city residents. For all of these reasons, we support the Santa Ana Regional Water Quality Control Board's inclusion of LID practices in the Draft MS4 Permit ("Permit") for the County of Orange, Orange County Flood Control District, and the Incorporated Cities of Orange County within the Santa Ana Region (Order No. R8-2008-0030; NPDES No. CAS618030).

NRDC has investigated the practicability of including specific, numeric metrics to guide LID implementation in MS4 permits in California. Working with national

storm water expert, Dr. Richard Horner, we have verified the feasibility of using the type of clear and transparent metrics that are appropriate for permits—and supported by EPA Region IX—to guide LID implementation. We have also quantified the range of pollution and water supply benefits that would accompany the use of these metrics in permits. The results of this California-focused technical work show that LID is a robust, pollution-reducing, water-supply enhancer. It is extremely cost-effective, as well, according to recent EPA evaluations.[1]

We have divided our comments into three sections that discuss:

(1) The necessity for LID implementation through a numeric performance standard that is transparent and enforceable and represents the level of compliance required to meet the MEP standard;

(2) Areas in which the Permit needs revision to clarify its requirements; and

(3) Recent expert analyses of the feasibility of implementing LID features through the type of numeric performance standard established in the Permit.

I. LID Implementation and Numeric Performance Standards

There is an emergent consensus nationwide that LID practices are the most effective stormwater management techniques, besides providing many other benefits, such as reducing the need for imported water, increasing property values, mitigating the urban heat island effect, and creating aesthetically pleasing landscapes. In California, the Ocean Protection Council, for instance, strongly endorsed LID last year by "resolv[ing] to promote the policy that new developments and redevelopments should be designed consistent with LID principles" because "LID is a practicable and superior approach … to minimize and mitigate increases in runoff and runoff pollutants and the resulting impacts on downstream uses, coastal resources and communities."[2] EPA has also called upon Regional Boards across California to prioritize the implementation of LID, even "recommend[ing] that the [South Orange County draft] permit be revised to put more emphasis on LID [and to] require[] that LID be woven into the design of specified new development and redevelopment projects."[3] In other MS4 permit contexts, EPA has also specifically endorsed the use of metrics, particularly the EIA approach in the Permit.

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[1] Environmental Protection Agency, *Reducing Stormwater Costs Through Low Impact Development (LID) Strategies and Practices* (Dec. 2007) (hereinafter "EPA LID Study").

[2] California Ocean Protection Council, *Resolution of the California Ocean Protection Council Regarding Low Impact Development* (May 15, 2008). We have enclosed a CD that includes all of the documents referenced in our letter, as well as additional information regarding the benefits and implementation of LID.

[3] Environmental Protection Agency, Comments re Draft MS4 Permit for Southern Orange County (email from Eugene Bromley) (Jan. 24, 2008) (hereinafter "EPA South OC Comments").

It is becoming clear that without requiring the implementation of LID practices designed to satisfy feasible and clear metrics, stormwater permits cannot meet the Clean Water Act's "maximum extent practicable" ("MEP") standard for pollution reduction. Critically, the prioritization of LID practices is insufficient by itself to meet the MEP standard and must be paired with a measurable requirement for the implementation of LID. Since its inception, the MS4 permitting program has been seriously hampered by a pervasive absence of numeric performance standards for the implementation of best management practices ("BMPs") such as LID. For this reason, in December 2007, the State Water Resources Control Board commissioned a report which found that "[t]he important concept across all of [the] approaches [described in the report] is that the regulations established a performance requirement to limit the volume of stormwater discharges."[4] The report also noted that "[m]unicipal permits have the standard of Maximum Extent Practicable (MEP) which lends itself more naturally to specifying and enforcing a level of compliance for low impact development."[5] EPA has highlighted similar but more specific concerns, remarking that subjective and imprecise language (such as requiring "a portion" of a site to address LID) is "vague" and that EPA recommends "more precise requirements."[6]

Various jurisdictions nationwide have begun adopting numeric performance standards for stormwater management, frequently pairing these with requirements to implement LID practices:

- **Pennsylvania:** Capture at least the first two inches of rainfall from all impervious surfaces and retain onsite (through reuse, evaporation, transpiration, and/or infiltration) at least the first one inch of runoff;[7]

- **Anacostia, Washington, D.C.:** Retain onsite the first one inch of rainfall and provide water quality treatment for rainfall up to the two-year storm volume;[8]

- **West Virginia:** Retain onsite the first one inch of rainfall from a 24-hour storm preceded by 48 hours of no measurable precipitation;[9]

- **Georgia:** Treat the runoff from 85% of the storms that occur in an average year (*i.e.*, provide treatment for the runoff that results from a rainfall depth of 1.2 inches);[10]

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[4] State Water Resources Control Board, *A Review of Low Impact Development Policies: Removing Institutional Barriers to Adoption* at 23 (Dec. 2007) (emphasis added) (hereinafter "SWRCB LID Report").
[5] *Id.* at 4.
[6] EPA South OC Comments.
[7] Pennsylvania Stormwater Best Management Practices Manual, Chapter 3 at 7 (Dec. 30, 2006).
[8] *See* SWRCB LID Report at 20-21.
[9] State of West Virginia, NPDES Permit No. WV0116025 at 13-14.

- **Central Coast, California (RWQCB, Phase II):** Limit effective impervious area ("EIA") at development projects to no more than 5% of total project area (interim criteria); establish an EIA limitation between 3% and 10% in local stormwater management plans (permanent criteria);[11]

- **All Federal Buildings over 5,000 square feet** (under EPA's draft guidance for implementation of the Energy Independence and Security Act of 2007): Manage onsite (*i.e.*, prevent the offsite discharge of) the 95th percentile storm through infiltration, harvesting, and/or evapotranspiration.

For these reasons, it is imperative that the Orange County Permit require new development and redevelopment projects to implement LID practices designed in accordance with a clear performance requirement. As detailed below, we support the Permit's use of an EIA limitation as this overall performance measure, teamed with a requirement to fulfill this obligation through appropriately sized LID features. These are critical elements of the Permit as a whole and assure that it is consistent with MEP and related requirements, as well as the mainstream of stormwater control across the country. However, as discussed below, some elements of the New Development section need revision. We also support the Permit's emphasis on LID and specifically agree with the findings on pages 19-20 of the Permit, which underscore the superiority of LID practices and the usefulness of establishing an EIA limitation.

II. Suggested Revisions to the Permit's New Development Requirements

A. EIA Should Be Defined to Require Full Onsite Retention of the Design Storm, and the Volumetric Requirement to Implement the EIA Limitation Should Be Defined as the Entirety of the Design Storm Volume.

As the overarching numeric performance standard for BMP implementation, the Permit imposes a mandatory 5% EIA limitation, based on the difference between the pre-development and post-development runoff ("delta volume") for the two-year design storm. Field-based studies have demonstrated that at 3 to 5% impervious area, watersheds begin to experience deleterious impacts from development, as noted in the attached reports by national stormwater expert Dr. Richard Horner.[12] For this reason, in other permitting contexts, we have

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[10] Georgia Stormwater Management Manual, Unified Stormwater Sizing Criteria at 1.3-1.
[11] Central Coast Regional Water Quality Control Board, Letter from Roger Briggs re Notification to Traditional, Small MS4s on Process for Enrolling under the State's General NPDES Permit for Storm Water Discharges (Feb. 15, 2008) (hereinafter "Central Coast Phase II Letter").
[12] Richard Horner, *Investigation of the Feasibility and Benefits of Low-Impact Site Design Practices ("LID") for Ventura County*; Richard Horner, *Investigation of the Feasibility and Benefits of Low-Impact Site Design Practices ("LID") for the San Diego Region*; Richard Horner, *Investigation of the Feasibility and Benefits of Low-Impact Site Design Practices ("LID") for the San Francisco Bay Area*; Richard Horner, *Supplementary Investigation of the*

recommended the establishment of a 3% EIA requirement for new development and redevelopment projects, and we recommend the same for Orange County. Dr. Horner's studies have shown the attainment of this standard onsite to be feasible in southern California.

The critical factor in determining whether an EIA limitation will be effective at reducing stormwater pollution is how the Permit defines the concept of "disconnecting" impervious surfaces such that they are rendered "ineffective" and thus do not count toward the 5% EIA requirement. This involves two different elements: (1) the volume of water that must be accommodated through stormwater BMPs and (2) the processes through which impervious surfaces can be considered "disconnected" from the storm sewer system.

On the first issue, in the Permit, as mentioned above, the volume of water for which developers must design stormwater BMPs to meet the EIA limitation is the delta volume for the two-year design storm. (Permit at p.52, fn.49.) For several reasons—most notably, the potential for calculations of pre-development volume that inflate the quantity of runoff which exists under natural conditions—NRDC does not support the use of the "delta volume" calculation and instead supports the use of the entire design storm as the volumetric requirement. (Our reasons are detailed in the attached critique by Dr. Horner,[13] which analyzes the study by Geosyntec et al., discussed below.) Thus, we suggest that the volumetric requirement for meeting the EIA limitation be revised to the full volume of the two-year design storm and that, for the sake of clarity, this crucial volumetric requirement be moved out of the footnote section and into the main text of the Permit.[14]

On the second issue, the Permit requires that BMPs have the capacity to "percolate" the design volume in order for impervious surfaces to be considered "disconnected" and effectively pervious. (Permit at p.52-53.) "Percolate," however, is not defined in the permit, and its meaning is not readily apparent. For this reason, we recommend revising the Permit such that BMPs are required to have the capacity to "infiltrate, harvest for reuse, or evapotranspire" the design storm volume. This onsite retention requirement will eliminate any ambiguity and allow for greater flexibility, as well as clarity, in meeting the EIA limitation. This change will also bring the Permit into line with other stormwater regulations around the country, which require onsite retention and thereby eliminate the potential for <u>any</u> polluted runoff from the design storm since there is no discharge.[15]

Feasibility and Benefits of Low-Impact Site Design Practices ("LID") for the San Francisco Bay Area.

[13] Richard Horner, *Critique of Certain Elements of "Low Impact Development Metrics in Stormwater Permitting"* (Feb. 2009).

[14] We also recommend that footnote 43 on page 48 include a cross-reference to the relevant full definition of EIA later in the Permit so that footnote 43 is not misinterpreted as the controlling definition of EIA.

[15] *See, e.g.*, requirements listed in section I, above, for Anacostia, the Energy Independence and Security Act of 2007, Pennsylvania, and West Virginia.

We would not support a definition of EIA that allows for onsite treatment and discharge to the storm sewer system, as this does not guarantee that pollutants will be removed from Orange County's receiving waters. Indeed, as further discussed below, the value of retention and reuse or infiltration is substantial, when measured both in terms of the ability to meet water quality standards and when measured in terms of other water resources imperatives, such as addressing drought and long-term reduction in water supply. Our analyses, presented as part of our submittal with this letter, document the extraordinary ability of LID to "create" new water supply, but this feature is operative only when water is retained and not discharged to surface waters.[16]

B. The Permit's Waiver Provision Must Require Offsite Compliance for Any Project that Cannot Meet the EIA Limitation Onsite and Must Set a Floor that All Developments Are Required to Meet.

The Permit, as currently written, would allow unfettered waivers for projects that can make an amorphous demonstration of disproportionate costs relative to the water quality benefits achieved. (Permit at p.55.) This loophole threatens to undermine the value of the EIA limitation and the entire New Development section. NRDC can support including flexibility in the permit's LID provisions to address true instances of technical infeasibility (and we detail below an appropriate scheme based on approaches taken in other jurisdictions). But the existing provision is overbroad, not supported by the facts, and is rife with the potential for abuse.

First, at a general level, this waiver provision is irreconcilable with the general findings of EPA and others that LID in most circumstances is *less* costly—often considerably so—than alternative building or stormwater management approaches. The provision, therefore, appears to be arbitrary and fundamentally counter-factual.

More specifically, the provision has a number of other fatal flaws as drafted. First, the LID requirements in the permit are based on addressing a *practicable* design storm, as discussed further in Dr. Horner's analysis, and this storm is well within the range of sizing requirements in place across the nation. Hence, the basic permit requirement already addresses and answers the question loosely posed by the waiver provision: the benefits and feasibility of the LID requirements are well-established generally and in reference to water quality improvements specifically. LID implemented across a watershed is far more capable of ensuring the attainment of water quality standards than traditional BMPs, and since ensuring compliance with standards is a fundamental requirement of the permit, LID is similarly a necessary element in new development and redevelopment.

Second, even if a waiver provision in general were appropriate, this one is not: the Permit does not define how these costs and benefits would be weighed against each other, and

[16] *See, e.g.*, Letter from David Beckman and Noah Garrison, NRDC, to Mary Nichols, Chair, California Air Resources Board, re AB 32 Draft Scoping Plan and Appendices (Aug. 11, 2008).

while the installation of BMPs can be easily priced, the human and ecosystem benefits of reduced water pollution are much more difficult to monetize and likely to receive short shrift in any such comparison. Even using a cost-benefit approach where (as is the case in much of the Permit area) waters are impaired may have the effect of allowing new sources of pollution to contribute to existing impairments, which is not allowable legally.

Third, the waiver provision includes no limiting factors, such as a requirement that projects implement all feasible LID (or even conventional) BMPs. Fourth, the Permit does not mandate offsite mitigation for any stormwater volume that a project is unable to retain onsite. This is the most appropriate "waiver" provision, allowing offsite compliance when onsite compliance is truly technically infeasible.

To close the waiver provision's loopholes, we would recommend first that the cost-benefit calculation be changed to a requirement that project applicants demonstrate the technical infeasibility of complying with the EIA limitation. The Permit should then define technical infeasibility, which could include circumstances such as severe space constraints, underground pollutant plumes, and non-infiltrative soils. Additionally, the Permit should specify that the project applicant must implement all technically feasible BMPs to the maximum extent practicable—if infiltration is infeasible, then harvesting and evapotranspiration should be maximized. The Permit should also set a floor for compliance with the EIA limitation onsite (*i.e.*, X% of the design volume must be infiltrated, harvested, or evapotranspired at the project site) so that project applicants do not utilize the alternative compliance option for the entirety of the design volume. This is a typical requirement of similar regulations in other parts of the country and ensures better results because of the limitations of offsite mitigation.[17] Any onsite discharge up to the design storm volume should be treated for water quality purposes.

The project applicant should then be required to perform offsite mitigation for the difference in volume between what is achieved onsite and the otherwise applicable EIA requirement. This could be accomplished by rewriting the waiver provision such that it *requires* permittees to establish an "urban runoff fund" (or project applicants to construct their own offsite projects) within the same hydrologic unit. For the sake of water quality and overall programmatic equivalence, the monetary contributions required should be based not on the avoided cost for developers, but rather on the volume of stormwater that is not retained on a given site. This system should also be paired with an obligation to mitigate stormwater volume offsite at a higher ratio than 1:1, such as 1:1.5, given the generally weaker performance of offsite mitigation projects. Several jurisdictions, including West Virginia and Washington, D.C. (Anacostia), have instituted such ratios.

Finally, we note that the Permit imposes no time limitation on the expenditure of funds for offsite mitigation. We recommend that offsite mitigation projects, whether public or private, should be constructed within three years of final discretionary approval (of the original

[17] *See, e.g.*, the requirements for West Virginia and Pennsylvania.

project) by the permittee. Additionally, the Permit should require project applicants to provide the necessary funds within one month to the permittee (for public mitigation projects) or to an escrow account (for private mitigation projects).

C. The Permit Must Impose Limits on "Water Quality Credit Systems" to Ensure that Equivalent Results Are Achieved on a Watershed Basis.

The Permit allows permittees to establish a "water quality credit system" that would waive LID, hydromodification, and infiltration requirements. (Permit at p.56.) While we agree that certain projects generate environmental benefits by the very nature of their circumstances, we also believe that waivers from otherwise applicable criteria should not be granted unless they are necessary and some nexus with water quality can be demonstrated. The fundamental requirements of the Clean Water Act include attainment of water quality standards. Without further specification, the approach taken in the permit effectively (and unlawfully) would delegate to those responsible for meeting the standards the ability to waive attainment through unilateral reductions in basic technological treatment requirements. This is unwarranted, poor policy, and in all eventualities, inconsistent with the text of the Act. For this reason, we suggest that the Permit impose certain restrictions on the water quality credit system.

First, the Permit should require that the permittees justify—scientifically and quantitatively—the stormwater volume and pollutant load reductions that accrue from a particular type of development granted "credit" under the system. These reductions should correlate with the amount of credit available for the project in question. Second, the Permit should set a maximum allowable credit amount for which a single project would be eligible. Other jurisdictions with such credit systems cap the allowable credit at half of the volumetric requirement or less, for instance, whereas the Permit currently includes no cap at all.[18] Without these changes, the water quality credit system could undermine the EIA numeric performance standard altogether by allowing projects blanket waivers without any specific demonstration of technical infeasibility or equivalent stormwater volume and pollutant load reduction—this would not meet the MEP standard. Moreover, it would not reduce pollution so as to reduce water quality impairment and, particularly in circumstances such as those in Orange County where many projects discharge to impaired waters, it is flatly inconsistent with the basic legal requirements that apply to protection and restoration of waters listed as impaired pursuant to 33 U.S.C. Section 1313(d) (including TMDL waste load allocations and requirements that pertain to additional sources of pollution discharged to waters listed as impaired).

D. Additional Concerns and Comments.

Below, we have listed some additional concerns and comments regarding specific provisions within the New Development section of the Permit.

[18] *See, e.g.*, the requirements for West Virginia.

- **Prioritization of LID:** In the LID section of the Permit, the language does not clearly state a hierarchy of stormwater management BMPs. (Permit at p.52.) It merely states that onsite implementation of LID principles is the "preferred approach." Because proprietary BMPs and conventional stormwater management techniques have proven less effective than LID, this section of the Permit should clearly establish a hierarchy such that project applicants must prove the technical infeasibility of implementing LID BMPs before they resort to proprietary or conventional technologies.

- **Treatment Control BMPs:** The Permit allows project applicants to substitute "treatment control BMPs" for LID measures if certain conditions are met. (Permit at p.53.) These conditions include limiting EIA to 5% or less. However, this is antithetical to the Permit's inchoate conception of EIA as onsite retention with no discharge, as we support. By definition, treatment control BMPs that discharge treated stormwater cannot render impervious areas "ineffective" for the purposes of meeting the 5% EIA limitation. For this reason, we recommend that any projects exercising this compliance option be required to retain the volume of their discharge (multiplied by our suggested 1:1.5 offsite mitigation ratio) elsewhere in the hydrologic unit.

- **Hydrologic Conditions of Concern:** We do not support the Permit's waiver of hydromodification criteria for any project that discharges to engineered, hardened, and regularly maintained conveyance channels. (Permit at p.54.) The Clean Water Act is a restorative statute with a restorative purpose—by not subjecting a whole group of projects to hydromodification criteria, the Permit will heavily burden future restoration efforts. With stream daylighting and habitat restoration a reality nowadays, the Permit should not condemn all hardened conveyances to their present, unnatural state. Instead, it should effectuate the goal of the Clean Water Act and begin to restore natural conditions to even those streams that are most burdened by human engineering. It is also noteworthy that one outcome of hydrological controls is reduced flooding. With projections that the impacts of climate change in California will include more intense storms, it would be unwise in the extreme to allow a waiver of hydromodification requirements.

- **Applicability:** We support the applicability section's establishment of a 5,000 square foot threshold for most projects (Permit at p.46-47), but the language in XII.B.2(a) for significant redevelopment projects needs to specify in the third and fourth sentences that the relevant question is how much impervious surface was added or replaced (not increased), consistent with the first sentence.

- **Depth to Groundwater:** The Permit states that infiltration BMPs must be at least 10 vertical feet above seasonal high groundwater. (Permit at 49.) However, recent studies and state and national standards demonstrate that five feet (or even less) is a

safe threshold, and the Permit's infiltration infeasibility criteria should be changed accordingly.[19]

III. Case Studies and the Feasibility of LID Implementation

We have submitted, as attachments to this letter, several reports by Dr. Horner. These reports take into account local rainfall patterns and building typologies and demonstrate that a 3-5% EIA limitation can be feasibly implemented by various types of development projects in southern California. Dr. Horner's reports show that considerable reductions in pollutant loadings occur through the implementation of an EIA limitation with LID techniques. They also highlight that onsite retention of stormwater can result in significant water savings, as well, through infiltration and harvesting for in-building uses or landscape irrigation. Such water savings are an important ancillary benefit of LID implementation and can decrease our reliance on expensive, increasingly unreliable sources of imported water. These water savings also result in considerable greenhouse gas emission reductions because water importation machinery is the single largest user of electricity in California.[20] For these various reasons, as mentioned above, we strongly support the Permit's establishment of an EIA limitation that requires the implementation of LID practices because they are the most effective means of improving water quality while also generating other benefits.

Recently, another study (entitled "Low Impact Development Metrics in Stormwater Permitting," hereinafter "the report") of three specific existing or proposed development sites was completed by Geosyntec Consultants and Larry Walker Associates for the Counties of Orange and Ventura.[21] Despite several flaws in assumptions and methodology, as documented in the attached critique by Dr. Horner, the study in many regards bolsters the argument that implementing LID through a numerical performance standard, such as proposed in the Permit, is feasible. Regarding the 60 California project, for instance, the study remarks that "it was not exceedingly difficult to achieve less than 5% EIA." (Geosyntec et al. at p.55.) However, various supposed problems identified by the report deserve attention in this context because we feel that the EIA concept and LID practices have been mischaracterized and that the report unjustifiably condemns, or at least puts an inappropriately negative spin on, worthwhile aspects of the Orange County Draft Permit.

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[19] The Los Angeles Regional Water Quality Control Board, for instance, typically allows 5 feet of separation between onsite system leachfields and groundwater. *See, e.g.*, Draft Waste Discharge Requirements for the Malibu Lumber Facility (requiring a 5-foot separation from groundwater). The AB 885 draft regulations (California's septic tank law) would allow dispersal systems of all conventional OWTS to have only 3 feet of separation. *See* 27 CCR § 30014 (draft).

[20] *See, e.g.*, NRDC, *Energy Down the Drain* at v (Aug. 2004).

[21] Geosyntec Consultants et al., *Low Impact Development Metrics in Stormwater Permitting* (Jan. 2009).

A. The Report Relies on a Flawed Definition of EIA to Draw its Negative Conclusions about the EIA Concept Overall.

The authors base their definition of EIA on the flawed language of the current Ventura draft permit. (Geosyntec et al. at p.3.) NRDC and Heal the Bay have repeatedly commented on the lack of hydraulic sizing criteria that should apply to the EIA limitation in that permit, and we agree with the authors of the report that this loophole allows for manipulation of the EIA concept. (Geosyntec et al. at p.5.) However, by basing their analysis of EIA limitations, writ large, on a single flawed definition of the concept, the authors have compromised the applicability and usefulness of their study. They are, therefore, unable to address the true benefits of an EIA standard from a water quality perspective, benefits recognized by a wide range of agencies and experts, including Dr. Horner (in his California studies), Tetra-Tech (in a study for the Ocean Protection Council),[22] EPA (in its own comments on the South Orange County Permit and in other permit proceedings around the state),[23] and the Central Coast Regional Water Quality Control Board (which adopted a default 5% EIA standard for Phase I and Phase II communities).[24] In this sense, it is not an overstatement to suggest that by adopting something of a "straw man" and then knocking it over, the report does not credibly refute the effectiveness or practicability of EIA properly implemented. The Orange County Draft Permit does not contain the same loophole as the Ventura draft permit, and although we recommend certain changes to the Permit's definition of EIA, it can easily be insulated from the type of abuse envisioned by the authors of the report.

B. The Permit Does Incentivize Infill, Redevelopment, and Smart Growth.

The authors mistakenly claim that the Permit creates significant disincentives for infill, redevelopment, and smart growth. (Geosyntec et al. at p.5.) In truth, the permit accommodates these development typologies by enabling developers to comply with the Permit's EIA limitation through four different options at varying scales and by allowing the permittees to establish both alternative compliance measures (*i.e.*, in-lieu fees for offsite mitigation) and a water quality credit system that would lessen the requirements for the exact sites about which the authors are worried. (Permit at pp.51-53, 55-56.) The Permit has gone further than several other states in encouraging infill, redevelopment, and smart growth, and we stand behind the Regional Board's efforts to accommodate these concerns in a manner that is consistent with water quality protection.

The environmental community's willingness to accept permit requirements that can be satisfied in part offsite should not be taken for granted, as it constitutes an attempt to address other stakeholders' stated concerns and, in any case, fully addresses any reasonable concern about infill and redevelopment. We are willing to accept offsite mitigation notwithstanding the

[22] Oceans Protection Council of California, *State and Local Policies Encouraging or Requiring Low Impact Development in California* at 27 (Jan. 2008).
[23] EPA South OC Comments.
[24] Central Coast Phase II Letter.

lack of a clear need for this flexibility when the matter is analyzed objectively. For example, some of the most aggressive LID requirements have been imposed in ultra-urban environments, like Philadelphia, PA, and Anacostia, Washington, D.C., demonstrating that the supposed conflict between LID and infill and redevelopment appears to be largely rhetorical. Moreover, as noted in Dr. Horner's critique of the report (and further below), even those sites chosen to represent the most challenging circumstances for LID implementation can feasibly (and in some cases easily) implement LID as envisioned by the Permit. And of course, the record also contains Dr. Horner's analysis of the feasibility of LID implementation across a range of building typologies, showing that LID can be accommodated in virtually any building situation with robust numeric metrics.

C. With Our Recommended Revisions, the Permit Will Not Lead to Unnatural Levels of Infiltration.

The report states that the Permit's infiltration requirements could destabilize the water balance in certain locations. (Geosyntec et al. at p.5.) This might be true in some situations if the Permit required infiltration of the entire design volume; very large numbers of sites were affected; and the water balance in the affected area were otherwise undisturbed compared to natural conditions. However, none of these three factors is present and, in particular, those who would contend that the LID provisions regulating new development and redevelopment could significantly affect water balance have failed to recognize that, in most of urbanized Orange County, the natural rate of infiltration has been dramatically reduced by a century of development focused on impervious surface. While we believe that this issue is yet another poorly justified criticism of LID, we note that the permit in any case does not require infiltration, per se, but rather any of three techniques that retain water. To make this even clearer, we have recommended the inclusion of language to clarify that three techniques are allowed: infiltration, harvesting, and evapotranspiration. If infiltration is ill-advised and thus infeasible, then project applicants will simply use the other allowable techniques for retaining water onsite.

Moreover, the Technical Advisory Committee (mentioned on page 46 of the Permit) should develop criteria—for potential insertion into the DAMPs and/or guidance manuals—to determine when infiltration would be counter-productive. These criteria will guide developers in deciding whether to utilize infiltration, harvesting, or evapotranspiration, or some combination of the three, to meet the EIA limitation. Additionally, developers have the option under the Permit of paying in-lieu fees when it is infeasible to attain the Permit's otherwise applicable requirements, including the infiltration requirement. Thus, there is no reason to assume that the level of infiltration encouraged by the Permit will lead to hydrologic imbalances, and there is every reason to assume that this potential problem will be easily avoided.

D. The EIA Limitation in the Permit Is Not Intended to Function As a Hydromodification Standard, Nor Should It.

The authors of the report posit that the EIA metric does not reflect the current understanding of stream hydrology and geomorphology. (Geosyntec et al. at p.6.) It does not reflect these issues because it is not intended to, and any interpretation of the EIA limitation that transmutes it into a hydromodification standard is misguided. Limiting the effective impervious area of a site is a means of addressing water quality—not water quantity—concerns. The purpose of retaining water onsite and infiltrating, harvesting, or evapotranspiring it is to prevent all pollutant loads contained within the design storm volume from entering aquatic ecosystems. While such retention may aid projects in meeting hydromodification criteria, and does have the salutary effect of making new water supplies available, the EIA metric stands as a water quality-focused, technology-based performance standard required by the Clean Water Act. This is why the Permit also contains a section that establishes requirements for "hydrologic conditions of concern." (Permit at p.54.) Any arguments about hydromodification should properly be addressed to this section. It also bears mention that even the report's recommended performance standard suffers from the same exact "problem" as the EIA limitation, and the authors thus included a separate hydromodification control standard in their recommendation. The Permit is structured in exactly the same fashion.

E. The Report's Case Studies Fail to Demonstrate that It Is Technically or Economically Infeasible to Implement a 5% EIA Standard.

The authors purport to prove through three case studies that the EIA concept is both difficult to implement and less protective of water quality than a volumetric reduction requirement. (Geosyntec et al. at p.16.) The principle failure of this analysis is, again, that the authors used a flawed definition of EIA (with no sizing requirement) as the basis for their analysis. They effectively seek to compare the function of two techniques, one of which they define nonsensically and one of which they define reasonably. This yields skewed analyses that, accordingly, run the risk of appearing to be results-oriented to support a predetermined perspective on the Permit. Moreover, the authors' assertion that a volumetric reduction approach would be "more constructive than a % EIA standard" highlights the degree to which the inadequate language of the Ventura draft permit has biased various entities' understanding of how an EIA limitation should operate. Ultimately, EIA limitations should be volumetric reduction approaches, as the authors of the report advocate. When EIA is properly defined as a requirement for onsite retention of a certain percentage of the design storm volume, it is literally a volumetric reduction requirement, and thus all of the report's negative conclusions about EIA have no real bearing on the worth of a properly designed EIA standard. Indeed, if it is a volumetric reduction approach that the authors favor, they should support a properly designed EIA standard. With this in mind, we offer the following thoughts on the specific case studies.

1. Walnut Village

As noted by Dr. Horner in the attached letter, this case study suffers from several analytical flaws. Without repeating those flaws here, we will simply draw attention to the fact that the authors found it almost feasible (and had they used appropriate infiltration rates, it would have been entirely feasible) to meet even the most stringent of the standards they analyzed, characterizing options as merely "less feasible" and "more feasible" based on problematic assumptions described by Dr. Horner. (Geosyntec et al. at pp.8-11.) This most stringent standard—delta volume for the two-year design storm—is by definition only 5% different from the EIA standard in the Permit because the Permit bases its definition of EIA on the delta volume for the two-year design storm. Thus, the authors' third proposed standard—although nowhere described as EIA—is just 5% away from the EIA metric in the Permit. This case study, therefore, demonstrates in general terms the practicability of the Permit's approach even on a very challenging building site and even when technically unsupported limitations are assumed that make accomplishing Permit requirements more difficult than necessary.

2. 60 California

The same flaws apply to this case study analysis; however, here, the authors openly admit that the site could feasibly achieve any of the three standards they used. (Geosyntec et al. at pp.13-14.) Their sole bases for questioning the utility of apparently any LID requirement are that green roofs and cisterns are relatively new concepts and that green roofs (anecdotally) might not be climate-appropriate, hardly reasons for dismissing them out-of-hand.

The 60 California case study can in fact assist us in partially understanding the cost implications of the various performance standards analyzed by the report, although the authors themselves have performed no such economic analysis. The authors concluded that for the largest storm event analyzed (the two-year design storm, which is nearly four times the volume of the 85th percentile storm), a combination of green roof and cistern would meet the standard. This green roof would require 4,300 square feet of space (Geosyntec et al. at p.13) and need to retain at least two inches of water. Assuming that this would require an intensive green roof, which can typically hold 80-150 pounds per square foot and accommodate soil depths up to 24 inches, the roof itself would cost (at the high end) approximately $25 per square foot, or almost $108,000.[25] The accompanying cistern that would need to hold an additional 4,170 gallons would likely cost less than $10,000, plus any plumbing necessary to carry stormwater from the roof to the cistern.[26] In all, the total cost of stormwater infrastructure would likely be less than

[25] *See, e.g.*, Great Lakes Water Institute, Green Roof Installation, at http://www.glwi.uwm.edu/research/genomics/ecoli/greenroof/roofinstall.php; Steven Peck and Monica Kuhn, *Design Guidelines for Green Roofs*, available at http://egov.cityofchicago.org/webportal/COCWebPortal/COC_ATTACH/design_guidelines_for_green_roofs.pdf.

[26] *See, e.g.*, Low Impact Development Center, Rain Barrels and Cisterns, at http://www.lid-stormwater.net/raincist_cost.htm.

$125,000. Of course, this does not take into account the costs of avoided conventional stormwater infrastructure, which would reduce the added cost of the LID infrastructure by some unknown but potentially substantial amount. Indeed, EPA found that at 11 out of 12 case study sites, LID infrastructure actually cost less than conventional stormwater management practices.[27]

The total development cost for this project was around $4 million. Hence, even if conventional stormwater infrastructure cost nothing and the green roof fell in the upper range of expected costs, the ~$125,000 stormwater compliance price-tag would be only 3% of total project cost. And this is supposedly one of the most constrained sites the authors could find where compliance would be the most technically and financially difficult. Hence, the best interpretation of the authors' analysis is that the upper limit of the cost to comply with the LID requirement—even assuming the most unfavorable conditions and without any credit for offsetting infrastructure cost savings that are clearly present—is only 3%. This is well within the accepted cost for compliance with existing MS4 requirements, such as the SUSMP provisions; the State Water Resources Control Board (in the *Bellflower* decision) already has determined in precedential orders that such provisions are reasonable and appropriate.

3. Kmart

The Kmart case study analysis is the most flawed of all from a methodological standpoint. Regardless of the LID techniques proposed, the report misconstrues the requirements of the Permit such that the conclusions vis-à-vis percentage of total project cost are entirely indefensible.

As a threshold matter, the authors misunderstood that an interior remodel that does not replace or add impervious surface would not trigger the Permit's requirements. Thus, the basis for their low-end estimate of redevelopment cost is a number far below any true redevelopment cost that would be associated with actually adding or replacing roof or other impervious surfaces. The applicability section of the Permit on page 46 specifies that redevelopments must comply with the Permit *only* when they result in the addition or replacement of impervious surface. An interior "remodel" would not add or replace impervious surface; only a demolition and reconstruction would do so. Consequently, the $50 per square foot low-end estimate should be revised to a more reasonable reconstruction—not remodel—cost figure, so as to allow an accurate calculation of the relative cost of the LID features compared to total construction cost.

Typical commercial construction costs range from $160 per square foot to $350 or more per square foot.[28] The authors' high-end estimate of $250 per square foot is, hence, an average cost figure for redevelopment. Using this more appropriate range, the total project cost (for the

[27] EPA LID Study at 12.
[28] *See, e.g.*, Saylor Publications, Inc., Square Foot Building Costs, at http://www.saylor.com/lacosts.

130,000 square foot building) is $21 million to $46 million. Just with this initial change in cost estimates, the "% of total redevelopment cost" figures given in the study changes from 4-22% to 3-6% for the "high volume interpretation" and from 1-3% to 0.5-1% for the "low volume interpretation."

Digging further into the report's assumptions, the authors once again misconstrued the applicability section of the permit. If the building alone were being redeveloped and the parking lot were left in its existing condition, the project would not obligated to comply across the entire site because it would result in an alteration of less than 50% of the impervious surface, thus requiring that only the altered portion comply with the permit. As the building footprint is slightly less than 25% of the site (approximately three out of 12.4 acres), the stormwater infrastructure costs would thus drop to about $300,000 or $50,000, depending on the high vs. low volume interpretation; the "% of total redevelopment cost" figures given in the study, consequently, would drop to 0.7-1.5% or 0.1-0.2%, respectively.

If the project altered more than three acres of the parking lot, as well as the entire building footprint, then the entire site would be required to comply with the Permit. However, in this situation, to find a meaningful value for the percentage of total redevelopment cost, one would have to calculate the costs of the stormwater infrastructure and landscaping that would otherwise be required by law or desired by the developer (for instance, the developer would surely include landscaping in the parking lot for aesthetic reasons, regardless of its stormwater functionality), and those costs would have to be deducted from the 3-6% or 0.5-1% of total redevelopment cost figures calculated above. It is thus impossible to draw any real conclusions from the study because of the lack of complete cost data. Without such data, even using correct redevelopment cost assumptions, the study actually tells us nothing that we want to know in terms of the marginal costs of complying with the permit vs. complying with requirements that would exist anyway in the absence of the permit.

IV. Conclusion

We commend the Regional Board staff's efforts to prioritize LID stormwater management practices and to establish an EIA limitation as the performance standard for BMP implementation in the Permit. Studies have demonstrated that attainment of this standard is feasible, and even so, the Permit contains sufficient alternative compliance criteria that (once properly revised) should allow equivalent results while granting developers more flexibility. Nonetheless, we believe that the effectiveness of the Permit's provisions could be compromised by various defects, especially the overbroad waiver language, the delta volume sizing criterion, and the Permit's failure to specify clearly that onsite retention (and not simply capture and discharge) is required. We have recommended various ways to remedy these and other problems, and we strongly urge the Regional Board to adopt these revisions.

We look forward to working further with Regional Board staff on the Permit and encourage you to contact us with any questions regarding our suggestions or the documents we have provided.

Sincerely,

David Beckman
Bart Lounsbury
Natural Resources Defense Council

Garry Brown

Orange County Coastkeeper

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Benefits of LID

	Author/Agency/Organization	Title	Date of Publication	Uniform Resource Locator (URL)
1	Anacostia River Business Coalition Update	Rain Gardens: Beautifying your Business and Helping the Anacostia	2003	http://www.potomacriver.org/arbc/newsletters/newsletterspring03.pdf
2	Blankenship, K.	It's a Hard Road Ahead for Meeting New Sprawl Goal: States Will Try to Control Growth of Impervious	2004	http://www.bayjournal.com/article.cfm?article=66
3	Center for Watershed Protection	Stormwater Management 101: Past, Present, and Future	04/06	http://www.rockvillemd.gov/government/commissions/ec/documents/Stormwater_101_CWP.pdf
4	Center for Watershed Protection	Redevelopment Roundtable Consensus Agreement	10/01	http://www.cwp.org/smartsites.pdf
5	Center for Watershed Protection (Stormwater Manager's Resource Center)	Model Post-Construction Stormwater Runoff Control Ordinance		http://www.stormwatercenter.net/Model%20Ordinances/Post%20Construction%20Stormwater%20Management/Final%20Model%20Stormwater%20Control.htm
6	Conservation Research Institute	Changing Cost Perceptions: An Analysis of Conservation Development	02/05	http://www.nipc.org/environment/sustainable/conservationdesign/cost_analysis/Cost%20Analysis%20Report.pdf
7	Guillette, A.	Low Impact Development Technologies	5/18/06	http://www.wbdg.org/design/lidtech.php
8	Guillette, A.	Achieving Sustainable Site Design Through Low Impact Development Practices	5/18/06	http://www.wbdg.org/design/lidsitedesign.php
9	Jones, D.	Low Impact Development	11/98	http://www.ncsu.edu/wrri/conference/2006ac/pdf/Jones_LID-1.pdf
10	Local Government Commission	The Ahwahnee Principles for Resource Efficient Land Use	2005	http://www.lgc.org/ahwahnee/h2o_principles_print.html
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12	Mallin, M.	Wading in Waste	06/06	http://www.sciam.com/article.cfm?chanID=sa006&colID=1&articleID=0003B364-B58B-146C-B2F983414B7F0000
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16	NEMO	Low Impact Development (LID): A sensible approach to land development and stormwater management		http://www.coastal.ca.gov/nps/lid-factsheet.pdf
17	Puget Sound Action Team	Low Impact Development Local Regulation Assistance Project 2005	2005	http://www.psat.wa.gov/Programs/LID/assistance/LID_assistance.htm
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19	The Low Impact Development Center, Inc.	Low Impact Development for Big Box Retailers	11/05	http://lowimpactdevelopment.org/bigbox/lid%20articles/bigbox_final_doc.pdf
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Spring 2003

ANACOSTIA RIVER BUSINESS COALITION UPDATE

C/O ICPRB
6110 Executive Boulevard, Suite 300
Rockville, MD 20852

Rain Gardens: Beautifying your Business and Helping the Anacostia

Interested in simple, inexpensive ways to reduce your business' impact on the environment? Would you like to receive credit and publicity for your pollution prevention activities? Read on! If you like what you read, contact Steve Saari at (301) 984-1908x103 or **ssaari@icprb.org** for more information, or to set up a free and confidential evaluation of your business' property.

Rain . . . it's nature's way of nourishing our world and replenishing our water sources. However, many of our daily activities, from changing a car's oil to fertilizing lawns, can turn this precious resource into an environmental problem. The flow of water created by a rainstorm - storm water runoff - can be polluted by oil, chemicals, pesticides, and sediments built up on our lawns, driveways, streets, and parking lots. Rain washes these pollutants into storm drains and ultimately into local streams and rivers.

Why is Storm Water a Problem?

The Environmental Protection Agency (EPA) has determined that up to 70% of the pollution in our surface waters comes from storm water. We tend to think that most of this is caused by large industrial facilities, but this is not the case. Many studies have found that more than 50% of that pollution comes from small businesses, individuals and homeowners, due to lawn care, household chemicals and automobile usage.

What is a Rain Garden?

A rain garden is an attractive native plant garden with a special purpose: to reduce and filter the storm water entering our streams.
It is constructed as a place to direct storm water from roofs, driveways and parking lots, allowing water to be held in the plants, mulch and soil.

Rain Gardens aren't just for houses! In fact, the use of rain gardens for storm water management originated at commercial and industrial sites where space is limited, and the installation and maintenance of conventional environmental practices, such as oil and water separators and stormwater ponds, is expensive.

A Rain Garden Collecting Runoff from a Parking Lot in Prince George's County

Why a Rain Garden?

Rain Gardens use the concept of bioretention: a water quality practice in which plants and soils remove pollutants from storm water naturally.

Rain Gardens are created in a low-lying area, with specific layers of soil, sand, and organic mulch. These layers naturally filter the rain as it runs into the Rain Garden. During the next few days after a storm, the soil absorbs and stores the rainwater and nourishes the Garden's grasses, trees, and flowers.

The traditional system of curbs, gutters, and storm drains carries storm water runoff directly to local streams and rivers without any bioretention filtering process. Instead, Rain Gardens filter and reuse the water, reducing storm water pollution, while providing attractive landscaping.

In addition to their water quality benefits, Rain Gardens:

- ✓ Promote your business' environmental stewardship and community pride
- ✓ Provide habitat for wildlife and native plants
- ✓ Moderate air temperatures through evaporation
- ✓ Increase real estate values by creating an aesthetically pleasing landscape

Upcoming Events

Earth Day Tree Plantings at DC Schools - Volunteers are needed to help school children plant trees. Plantings will occur at various sites in the District between April 22nd and April 25th. For more information, contact Habieba Isreal at 202-535-2964.

Earth Day Anacostia River Cleanup - Volunteers are needed to help clean up sites in D.C. and P.G. County. The cleanup will take place the morning of April 26th. For more information, contact James Willie at 202-479-6710.

Frequently Asked Questions:

Q: - Don't rain gardens attract a lot of mosquitoes?

A: - No. For reproduction, mosquitoes require a number of days in standing water. Water rarely stands long enough for mosquito reproduction in a well-designed rain garden.

Q: - Can I create a rain garden that doesn't look too wild or messy?

A: - Yes! A wide variety of plants can be used in creating a rain garden so you can create one that suites your tastes.

Q: - What happens to water-tolerant plants when we have a dry spell?

A: - Native plants can withstand a range of weather conditions. Native plants that do well in poorly drained soil will be fine during dry weather.

Q: - How large must a rain garden be to be worthwhile?

A: - Any water that seeps into the ground instead of running into a storm sewer helps water quality. A rain garden of any size has a positive impact, however, to completely absorb rain water from a site the system should be sized between 5% and 10% of the impervious area draining to it.

Q: - How difficult are rain gardens to maintain?
A: - Rain gardens are like any other garden. They require more care initially to establish the plants, but then only monthly inspections are needed to repair eroding areas, prune and repair vegetation and remove trash and debris.

ALLIANCE FOR THE CHESAPEAKE BAY
BAY JOURNAL

It's a hard road ahead for meeting new sprawl goal

States will try to control growth of impervious

By Karl Blankenship

The Chesapeake drainage, it appears, is suffering from a hardening of the watershed.

The sign of the malady is a rapidly increasing amount of impervious surfaces—solid areas such as roads and rooftops which prevent rain from soaking into the ground and instead quickly shunt it, along with any accumulated pollutants, into nearby streams.

According to new figures from the Bay Program, the amount of impervious surfaces in the watershed increased by nearly 250,000 acres between 1990 and 2000, an area more than five times the size of the District of Columbia.

The Bay Program has adopted impervious surfaces as its new measurement of "harmful sprawl," which the states pledged to slow by 30 percent when signing the Chesapeake 2000 agreement four years ago.

Until now, though, no one has agreed exactly what harmful sprawl was, or how much of it was in the watershed.

After abandoning several techniques, officials agreed to use the amount of rooftops, pavement and other solid surfaces—as measured through satellite images —as a proxy to measure the rate of sprawl.

The recently compiled figures show that impervious surfaces increased from 611,017 acres in 1990 to 860,004 acres in 2000, an increase of 248,987 acres, or more than 40 percent.

See Also:

- Debate rages over new rules for TMDLs
- Most streams, many wetlands could lose protection
- Suits seek cleanup plans for waterways

Put another way, that's like blanketing an area more than twice the size of Shenandoah National Park with blacktop and shingles.

Impervious surfaces cover 2.1 percent of the watershed, compared with 1.5 percent nationwide. But the watershed's hard surfaces tend to be concentrated near the Bay, while outer portions of the watershed are still dominated by farms and forests.

Nonetheless, the data show that the headwater states, which are not bound to the sprawl goal, had the most rapid rates of development. Imperviousness increased by 61.7 percent in New York's portion of the watershed, by 137.4 percent in West Virginia, and by 170 percent in Delaware.

Among the Bay jurisdictions that are signatories to the Chesapeake 2000 agreement, the data show development occurring more rapidly in Virginia (44.7 percent increase in imperviousness) and Pennsylvania (43.7 percent increase) than in Maryland (29.8 percent increase). Imperviousness increased by only 4 percent in the heavily developed District of Columbia.

What's true in the Bay watershed is true nationwide. A recent mapping exercise by the National Oceanic and Atmospheric Administration found that in 2000, hard surfaces covered 43,480 square miles in the lower 48

states, an area equivalent to the state of Ohio.

In fact, the study published in the journal Eos that showed impervious surfaces nationwide cover 5,500 more square miles than do all wetlands in the United States.

The research team that conducted the study noted that more than 10,000 miles of new roads and 1 million single family homes are expected nationwide in the next decade. "Given these trends, [impervious surface area] is likely to become a more prominent environmental and growth management issue in the coming years," the research team said.

When the Chesapeake 2000 agreement was signed, the Bay Program was initially praised for taking the nation's first regional approach to combating sprawl. But setting—much less achieving—the harmful sprawl goal has been a challenge for the Bay Program.

The original agreement called for reducing the rate of harmful sprawl 30 percent by 2012 from a baseline rate measured between 1992 and 1997. Those dates were selected because they coincided with the five-year release dates for the U.S. Department of Agriculture's National Resources Inventory.

But some objected to the use of NRI data, saying that its sampling design was not adequate for describing the rate of development within sub-areas of the Bay watershed and questioned the accuracy of the NRI-derived rates of development.

Further, officials from the states could not agree on what constituted harmful—as opposed to non-harmful—sprawl. Some argued, for instance, that well-planned new developments with modern stormwater drainage that minimizes runoff should not be considered harmful, but officials finally determined tracking such developments would be impossible.

After more debate, state officials agreed to define harmful sprawl as the conversion of farmland and forest to developed lands. But no method existed to reliably measure such conversions.

Finally, they settled on the measurement of impervious cover and agreed to use figures derived from Landsat satellite images taken in 1990 and 2000 as a baseline for measuring the rate of increase.

Exactly when the goal must be achieved remains unresolved, said Carin Bisland, associate director for ecosystem management with the EPA's Bay Program Office. The original Chesapeake 2000 agreement called for reaching the goal by 2012, which coincided with the release of NRI data.

The Bay Program is considering the purchase of satellite data, which is primarily used to develop computer models of watershed land uses, every five years. That means the impervious surface goal would need to be measured with 2005 or 2010 images, she said, but no decision has been made.

"What is more important than the passive measurement of impervious cover is the more active ability to use this data in combination with other indicators as a screening tool to locate areas that are the most vulnerable to development pressures," Bisland said. "With this type of screening tool, we can more actively focus our resources to assist with planning in the areas that are most at risk."

If development were to continue at the rate of the past decade through 2010, the watershed would have 1.1 million acres of impervious surfaces, said Peter Claggett of the U.S. Geological Survey, who analyzed impervious surface data. Reducing the 1990–2000 rate by 30 percent, he said, would result in a 75,000-acre reduction in the amount of impervious surface projected for 2010.

Claggett cautioned that making exact comparisons between years can be difficult because the quality of 2000 satellite images is generally better than the quality of the 1990 images, making it more likely that more impervious surfaces would be identified.
Nonetheless, he said, just looking at impervious surfaces undercounts the full extent of development. The analysis probably underestimates the amount of impervious surfaces in rural areas.

"It's also going to miss places where the tree cover hides impervious surfaces under the canopy," Claggett said.

Those low-density areas may have less of an impact on water quality than high density development, but cause other problems, such as fragmentation of habitat for birds and wildlife. "If you're looking at sprawl, those areas are important," Claggett said.

Development, and impervious surfaces in particular, are considered a major water quality threat because—unless areas are using state-of-the-art runoff controls—they tend to rapidly shunt rainwater into streams.

That rain picks up large amounts of nutrients and toxic pollutants—everything from animal wastes to oil and grease from carts to contaminants falling from air pollution—as it runs off the land.

The sudden surge of water in urban waterways after storms dramatically alters stream hydrology, increasing erosion rates within the channel and smothering aquatic life. By contrast, most of the rainwater soaks into the ground if it hits forest or farm land.

As a result, surveys consistently show that stream habitats in developed areas are in a poorer condition than in any other land use.

In small watersheds, studies by the Maryland Department of Natural Resources Biological Stream Survey have shown that some sensitive species are affected by even low amounts of impervious cover.

For instance, the survey never found brook trout in any stream whose watershed had more than 2 percent impervious cover. In fact, the study found brook trout were rare in any watershed with more than 0.5 percent impervious cover. For reference, 0.5 percent would be equivalent to a two-lane road going through a square mile of land. A recent study in Montgomery County, MD, shows that overall stream health becomes degraded at impervious levels around 6 percent.

Studies by the nonprofit Center for Watershed Protection conclude it is "extremely difficult to maintain predevelopment stream quality when watershed development exceeds 10–15 percent impervious cover." That translates into about one house per every one to two acres, when roofs, roads and driveways are all factored in.

While impacts of impervious surfaces can be reduced through new low-impact development techniques, which emphasize stormwater controls and promote infiltration into the ground rather than runoff into streams, such techniques are not widely used in most areas.

Karl is the Editor of the Bay Journal.

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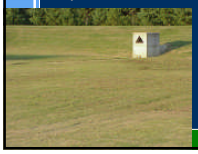
Stormwater Management 101: Past, Present, and Future

Presented by:
Sally Hoyt

Center for Watershed Protection

Presented at:
Stormwater Management Environmental Summit
Rockville Commission on the Environment

April 11, 2006



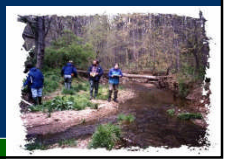
Presentation Overview

- Why do stormwater management?
  - Streams
  - Regulations
- Stormwater management "Market Outlook"
- What to do with this information
  - As community leaders
  - As property owners

About the Center for Watershed Protection

- Non-profit 501(c)3, non-advocacy organization
- Work with local watershed groups, local, state, and federal governments
- Provide tools communities need to protect streams, lakes, and rivers
- Stormwater Institutes

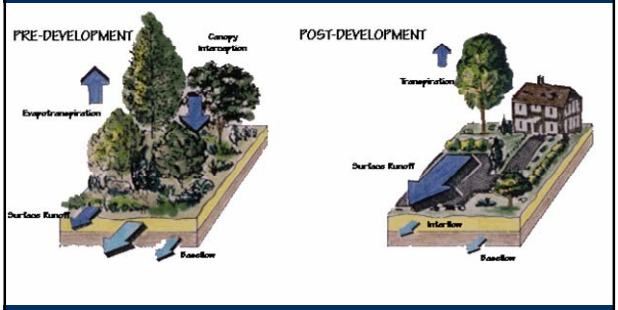
Center for Watershed Protection



Terminology

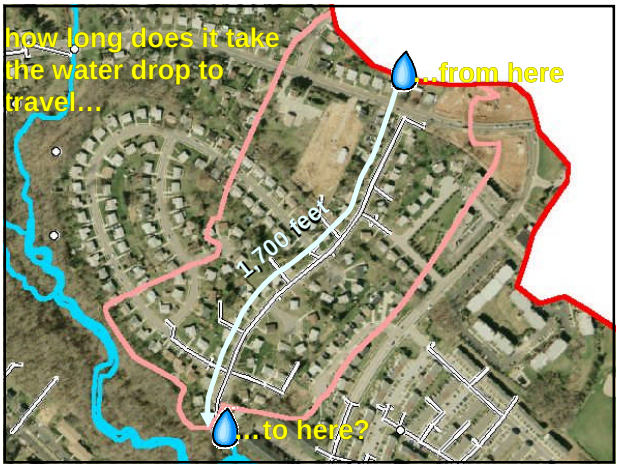
- Stormwater – runoff from rainstorms
- Stormwater Management – *physical measures* to mitigate the impacts of urbanization on water quality, aquatic life, infrastructure

Impacts of Urbanization



Pathway of Runoff to Streams

Rainwater runs off of impervious surfaces → Enters the storm drain system → Directed to streams



How long does it take???

Before Development

About 3,600 seconds, or 60 minutes

After Development

About 600 seconds, or 10 minutes

Runoff Volume for the 1" Storm,

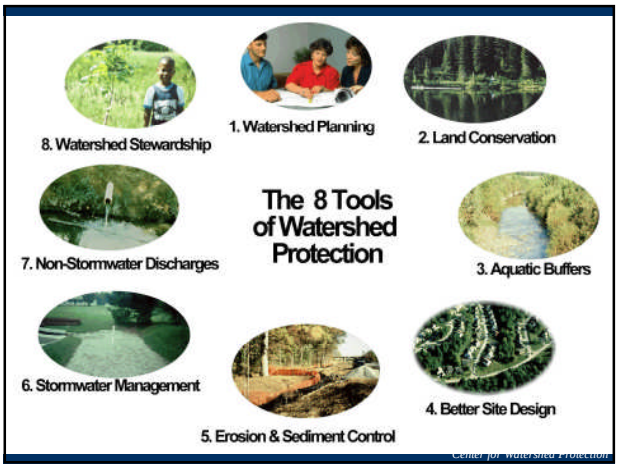
(rainfall depth, P) (runoff coefficient, Rv) (drainage area, DA)

Before Development, = (1") (0.05) (38 acres), or
6,900 cubic feet of runoff (≈ 51,600 gallons)

After Development, = (1") (0.32) (38 acres), or
44,140 cubic feet of runoff (≈ 330,200 gallons)

Water Quality Impacts

- Nutrients (N, P)
- Fine sediments (TSS)
- Stream temperature
- Bacteria
- Pesticides
- Chlorides
- Metals and hydrocarbons
- Trash and debris



A Brief History of Stormwater in the Chesapeake Bay

1960's – Pave it and Pipe it
1970's – Dry Ponds and Sediment Basins
1983 - Maryland's Stormwater Management Regulations adopted
Early 1980's – Wet ponds
1985 - Infiltration (briefly)
1988 - Regional Ponds Reign (briefly)
1990 - Phase I Stormwater permits under Clean Water Act
1992 - Stormwater Wetlands

A Brief History of Stormwater in the Chesapeake Bay

1993 – Urban Streams are Degrading
1995 – Filtering Systems and Bioretention
1998 - Better Site Design and LID
2000 - Maryland Manual – new regulations and design guidance
2002 - Phase II Stormwater Permits

Clean Water Act & Stormwater Management

- Clean Water Act "NPDES Phase I and Phase II" permit programs
  - Municipal Separated Storm Sewer Systems (MS4s)
  - Industrial
  - Construction

NPDES MS4 Permit Program- What it Means

Who is Covered?

PHASE I

- Communities that have separated storm drain system with a population more than 100,000.

PHASE II

- Communities with pop. of more than 50K and a density greater than 1,000 people/sq mi. States assess whether communities from 10K to 50K should be covered, based on certain criteria.

NPDES MS4 Permit Program- What it Means

What is Required?

PHASE I
- Stormwater quality monitoring
- Mapping storm drain network
- Outfall screening
- Removal of illicit discharges
- Source identification
- Structural and source control measures to reduce pollutants
- ESC program
- Demonstrate legal authority
- Fiscal analysis

PHASE II
- Public education/outreach
- Public participation/ involvement
- Illicit discharge detection
- Construction site runoff control
- Post-construction runoff control
- Pollution prevention

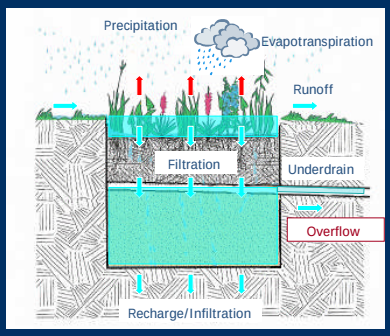
6 Minimum Measures for Phase II Communities

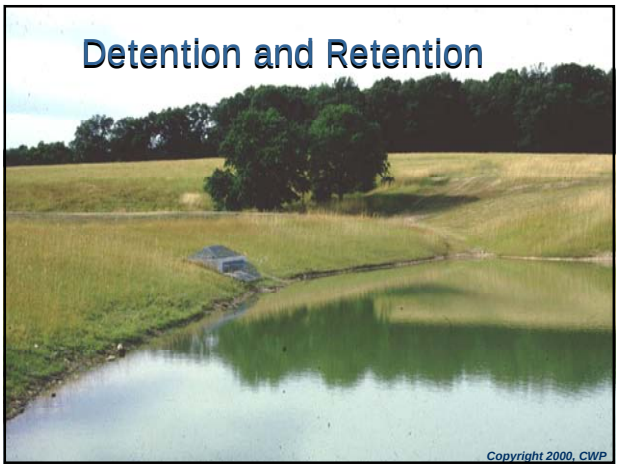
- Public education/outreach
- Public participation/ involvement
- Illicit discharge detection
- Construction site runoff control
- **Post-construction runoff control**
- Pollution prevention

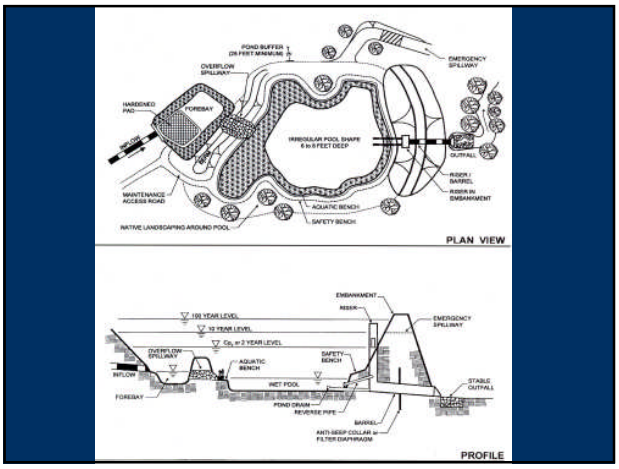
2000 Maryland Stormwater Design Manual

- Water Quality
- Channel Protection
- Overbank Flood Protection
- Groundwater Recharge
- Runoff Reduction (Better Site Design / Low Impact Development Practices)
- Credits

Infiltration and Filtration







The Schueler Stormwater Market Outlook

Is your stormwater portfolio under-performing?

Review the history of 8 investment products by BMP, Inc.*

* A wholly owned subsidiary of R.U. Wet Inc.
Remember past performance does not always guarantee future results.
The Center is in no way responsible for your stormwater losses.

1. Municipal Detention Bonds

dry detention ponds, pipes, inlets and curbs and gutters

Very traditional
Straightforward engineering
Low performing, but safe
Still widely accepted by most local and state governments.

Recommendation: Sell

2. Wet Bonds

Steady performance for mature technology
Major holding in most communities
Brand somewhat tarnished recently
Strong competition from emerging STP technologies

Recommendation: Hold

3. Infiltration Stocks

- Hi risk, hi reward
- Preferred stock in the 1980's
- Sharp downturn in 1990's due to widespread product failures
- Better designs and testing in recent years
- Poised for a resurgence?

Recommendation: Buy

Provide groundwater recharge

Infiltration

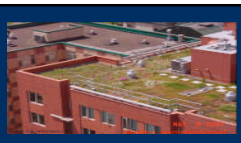
Source: Martin Covington, P.E.

4. Stormwater Wetland Trusts

- Market favorite in the 1990s
- Strong performer, but weak sales
- Competition from foreign plants
- Potential liability with West Nile Virus has harmed brand

Recommendation: Hold

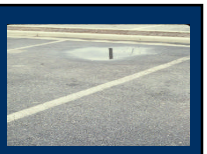
5. Green Roof Stocks



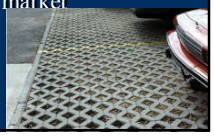
- New product to USA, although it has been sold in Europe for years
- Targeted toward exclusive clientele of high end green owners
- Some analysts consider it over-hyped, while others claim it will be the next Starbucks
- Despite a lot of research, not much product sold yet

Recommendation: Buy?

6. Porous Pavement, Inc.



- First issued in 1980's, was wonderkid of the industry
- Spectacular sell-off in early 1990s due to product failure and poor branding
- Alternative materials and new designs continue to emerge, but lack adequate testing
- Still a small player in the parking lot market



Recommendation: Buy

Typical Appli

Photos: Bill Hunt/NCSU

7. Stormwater Biotech Sector

- Launched in 1990s, fasting growing BMP stock
- Currently the darling of the industry
- "Bio" has enormous brand appeal for most customers
- Recent performance data has not met market expectations
- Possibly a little oversold?

Recommendation: Buy

8. Stormwater Microcaps

Proprietary devices, hydrodynamic structures, stormwater in a can)

- Hundreds of them out there
- Targeted toward consumers that want convenience
- Extravagant claims about performance are seldom achieved
- Hard to pick the few microcaps that will succeed, expect that most will fail

Recommendation: Sell

Tips on Managing Your Municipal STP Portfolio

- Read prospectus before investing
- Review your current STP portfolio every few years
- Diversify your portfolio, but root out non-performers
- Invest for the long run, as you need reliable performance over many decades
- Choose the STP stocks that will meet your future lifestyle needs

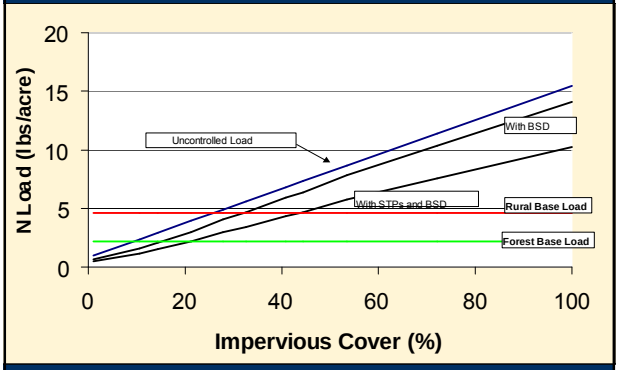
New Paradigms are Needed

- Maintenance –financing and enforcement
- Retrofits

Maintenance

A lot of problems waiting to happen

The Best We Can Do



New Paradigms are Needed

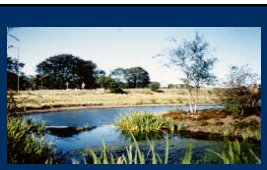
- Better SWM –
  - Improved performance standards
  - Training the designers, regulators, contractors
  - Research
  - Protect receiving waters

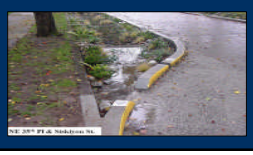
New Paradigms are Needed

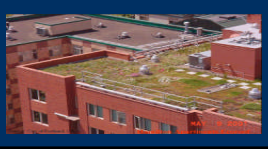
- Incorporating stormwater – wetlands and forests
- Better Site Design

We still get A lot more Subdivisions Like This

Than This







What you can do

Promote new paradigms

- Maintain community association-owned stormwater management practices
- Keep local government SWM programs on track for
  - Funding
  - Inspection and Enforcement
  - Improved standards for new and redevelopment
- Participate in public review of development

What you can do

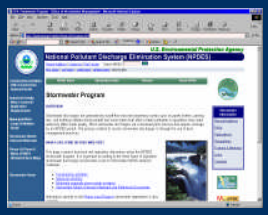
- Prevent Pollution at Home
  - Test your soil, limit fertilizers and pesticides
  - Pick up pet waste
  - Wash cars at commercial car wash or on lawn, not in street.
  - Take household hazardous waste to collection sites
  - Compost yard waste or participate in City pickup. Don't put yard waste in gutters or streams.

What you can do

- Runoff Reduction at home
  - Minimize turf area
  - Replace lawns with native vegetation
  - Direct roof top runoff to vegetated areas
  - Use a rain barrel for watering landscaping

Resources

- www.stormwatercenter.net
- http://cfpub.epa.gov/npdes/
- http://www.bae.ncsu.edu/programs/extension/



Redevelopment Roundtable

Consensus Agreement

Smart Site Practices for Redevelopment and Infill Projects

October 2001

Center for Watershed Protection

About the Center for Watershed Protection

Founded in 1992, the Center for Watershed Protection (CWP) is a non-membership, nonprofit 501(c)3 corporation dedicated to providing objective and scientifically sound information on effective tools and techniques for watershed planning, protection and restoration. CWP implements this mission in several ways, including providing technical assistance to federal and local governments as well as non-profits and other organizations.

For more information on the CWP and our current projects, visit our websites at www.cwp.org and www.stormwatercenter.net.

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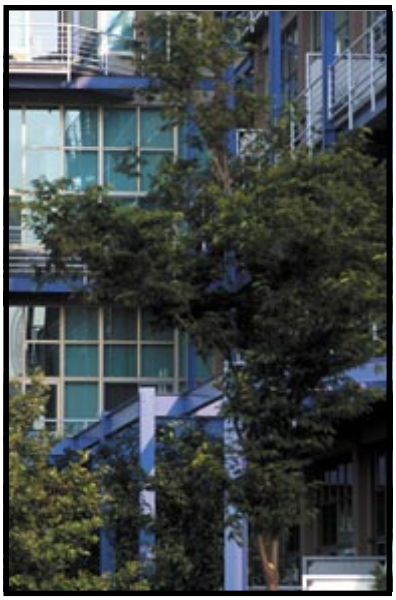
Introduction



Canton Cove: *Baltimore, MD*
* Adaptive reuse project
* First water quality project on the Harbor
* Existing structure salvaged
* Original building footprint retained
* Garden courtyard used for stormwater management

Photo courtesy: Cho, Benn & Holback Architects

While the U.S. is expected to grow by an additional ten million households over the next ten years, the proportion of people living in many of our city centers is actually declining. In fact, homeowner and rental vacancy rates are 20% higher in many city centers compared to their suburban counterparts (U.S. Census Bureau, 1999). This population shift leaves urban watershed managers with the challenge of protecting some areas from further development while at the same time restoring watersheds that are already severely impacted. Increasingly, urban redevelopment and infill projects are emerging as a means to help rejuvenate sagging city centers while simultaneously providing opportunities for more environmentally-friendly growth.

However, making redevelopment and infill projects a successful reality requires multiple stakeholders at various levels to evaluate the types of programs and practices necessary to help achieve various economic, environmental and social goals. From a development standpoint, the challenges of any particular project might require charting unknown territories, which can result in higher development costs. From an environmental perspective, the location of infill and redevelopment projects can further impact existing water resources. In addition, current building, zoning and other regulations need to be investigated, adapted, and integrated with issues of stormwater, water quality, air quality and habitat, along with the regulatory issues and politics of stormwater management and brownfields.

Municipal Parking Lot: *Prince George's County, MD*
* Previously untreated parking lot
* Redesigned to locate a bioretention facility

Recognizing that many interests need to be coordinated to promote Smart Growth, the Center for Watershed Protection convened the Redevelopment Roundtable, a group of national and local stakeholders who participated in a process to develop Smart Site Practices specifically for redevelopment and infill sites. This year-long process produced 11 practices to help reduce pollutants and improve the environmental quality of development sites in highly urban watersheds. Applied together, these practices have benefits for all local stakeholders, including developers, local government, community residents, and others who are interested in designing redevelopment and infill sites to better protect local streams, lakes, wetlands, and estuaries.

Potomac Yard: *Alexandria, VA*
* Redevelopment project
* Incorporates narrow sidewalks
* Incorporates small front setbacks
* Incorporates native vegetation
* Applies several stormwater management techniques

Photo courtesy: Larry Gavan

CWP Office Building: *Ellicott City, MD*
* Old filling station converted to a two-story office building
* Illustrates the efficient use of impervious cover

What Is the Redevelopment Roundtable?

The Redevelopment Roundtable represents a one-of-a-kind effort to engage a diverse spectrum of national and local stakeholders in a consensus process to address site level redevelopment and infill issues. The Roundtable was created to assure local communities that stakeholders in the redevelopment arena can agree on specific practices and programs that can help protect our existing natural resources and help build better communities. The Redevelopment Roundtable reached consensus on the 11 Smart Site Practices for Redevelopment and Infill.

What Are the 11 Smart Site Practices?

The term "Smart Site Practices" refers to site planning practices that can be used to mitigate watershed impacts in highly urban watersheds. Designed primarily with the developer in mind, the smart site practices represent the best techniques for protecting water quality and habitat in the highly constrained setting of urban infill and redevelopment. These practices are intended to complement municipal actions under the Smart Watersheds plan.

What Type of Redevelopment and Infill Projects Do Smart Site Practices Address?

The Redevelopment Roundtable recognizes that a vast array of redevelopment and infill projects exist. For the purposes of this project, redevelopment is defined as the process by which an existing developed area is adaptively reused, rehabilitated, restored, renovated and/or expanded. Infill, on the other hand, is development that occurs on smaller parcels that remain undeveloped but are within or very close to existing urban areas. In both cases, the development relies on existing infrastructure, and does not require an extension of water, sewer or other public utilities. In addition, the project must be located in a highly developed watershed, encouraged by the public sector, and water quality limited or biologically impaired. Example of redevelopment and infill projects are listed in the table below.

Various Types of Redevelopment and Infill Projects	
* Historic preservation	* Downtown business district
* Waterfront development	* Multifamily
* Brownfields	* Suburban commercial
* Residential infill	* Mixed use development
* Adaptive reuse	* Roadway expansion

SARB_003821

How Can the Smart Site Practices Be Applied?

While the Smart Site Practices were developed primarily as a tool for designers, they can be used by developers, local government officials, planners, and environmentalists alike. For example, developers who are concerned about larger community environmental issues can refer to the Smart Site Practices for guidance on how their projects might be better designed to address watershed impacts. Local governments can utilize the Smart Site Practices to develop better criteria on which to gauge the potential impact of a development site. Lastly, communities can utilize the Smart Site Practices to gain insights on redevelopment and infill from a watershed protection perspective.

Barrister Court: *Baltimore, MD*
* Historic preservation project
* Used alternative pavers
* Parking lot transformed into a garden

Photo courtesy: Cho, Benn & Holback Architects

The Smart Site Practices

Practice #1: Redevelopment and infill planning should include environmental site assessments that protect existing natural resources and identify opportunities for restoration where feasible.

Rationale: Requirements under existing brownfields and Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) legislation, as well as bank purchase and loan requirements, help to mitigate the impact of some pollution sites by requiring basic site history investigation and surface soil and water testing and cleanup. A more thorough environmental site assessment, which includes the production of a base map that outlines existing buildings, transportation networks, utilities, floodplains, wetlands, streams, and other natural features, can help address existing environmental constraints and highlight opportunities for restoration and reclamation at a site.

Practice #2: Sites should be designed to utilize impervious cover efficiently and to minimize stormwater runoff. Where possible, the amount of impervious cover should be reduced or kept the same. In situations where impervious cover does increase, sites should be designed to improve the quality of stormwater runoff at the site or in the local watershed.

Canton Square Development:
Baltimore, MD
* Previously undeveloped lot
* Townhouse development infill site
* Walking distance to transportation and amenities
* Centrally located park with natural area

Rationale: The amount of impervious cover is known to have a direct impact on annual runoff volume, and consequently affects annual pollutant loads, flooding frequency, stream channel degradation, and a host of other impacts. Some of these impacts can be mitigated by making efficient use of the existing impervious cover and reducing or keeping it the same when possible. Managing stormwater runoff can also help to reduce these impacts.

Practice #3: Plan and design sites to preserve naturally vegetated areas and to encourage revegetation, soil restoration and the utilization of native or non-invasive plants where feasible.

Rationale: Remaining natural areas have particular value in the urban environment, but are also strongly influenced by adjacent uses. Often found in small fragments, these areas can also suffer from poor quality soils, invasive plant species, dumping and extensive alteration by past development. Collecting and mapping natural features, working toward preserving these areas in a consolidated manner, and evaluating the site for potential stormwater management, revegetation, and passive recreational benefits can provide both environmental, economic and aesthetic benefits.

Practice #4: Establish mechanisms to guarantee long term management and maintenance of all vegetated areas.

Rationale: Guaranteed long-term management, financing and maintenance plans can assure continuous enjoyment and function of vegetated areas over the long run. Innovative partnerships, conservation easements, or donations to land trusts can help land owners ensure that intensively used vegetated areas on urban lands are actively kept up.

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Practice #5: Manage rooftop runoff through storage, reuse, and/or redirection to pervious surfaces for stormwater management and other environmental benefits.

Rationale: Reducing the runoff generated from urban rooftops can reduce pollutant loads, flooding, channel erosion, and many other stream impacts. In addition, many rooftop runoff management practices can help conserve water and improve aesthetics. Examples of rooftop runoff management techniques include green rooftops, rooftop gardens, rain barrels and downspout disconnection. The design, slope and architecture of rooftops can reduce the volume of rooftop runoff as well.

26th Street Gateway: *Philadelphia, PA*
* Transformed post-industrial wasteland
* Preserved natural areas
* Planted native vegetation

Photo courtesy: Philadelphia Horticultural Society

Practice #6: Parking lots, especially surface lots, should be minimized and designed to reduce, store and treat stormwater runoff. Where site limitations or other constraints prevent full management of parking lot runoff, designers should target high use areas first.

Rationale: While adequate parking is often considered a critical ingredient to the success of most infill and redevelopment projects, parking lots are often one of the greatest sources of stormwater runoff. In addition, many older parking lots that are being redeveloped were designed with little regard to landscaping, actual parking demand, or effective stormwater treatment. Some of the techniques that can be utilized for managing parking lot runoff include making parking lots incrementally smaller, providing more functional landscaping, and where possible, treating the quality of stormwater runoff.

Practice #7: Utilize a combination of Better Site Design techniques with infill projects to minimize stormwater runoff and maximize vegetated areas.

Buckman Heights Apts.: Portland, OR
* Converted vacant parking lots to affordable rental apartments
* Rooftop runoff captured by courtyard
* Incorporates on-site stormwater management and native plants
* Walking distance to many amenities and public transportation

Photo courtesy: Prendergast & Associates

Rationale: Many single lot or small multi-lot infill projects contribute to "impervious creep," which is defined as the increase in impervious cover seen over time in highly developed areas. On-site improvements, such as house additions, expanded driveways, new housing, and sidewalks all contribute to impervious creep. Typically, there are few or no requirements to manage stormwater runoff or preserve or restore natural features associated with these small and incremental projects. Better Site Design refers to a design approach that seeks to reduce the amount of impervious cover associated with development, increase the natural lands set aside for conservation, use pervious areas for more effective stormwater treatment, and achieve a marketable, cost-effective product. Better Site Design consists of a series of benchmarks that fall under three categories: parking lot and street design, lot development, and natural areas conservation. Many of these benchmarks are applicable to infill development that can be described as: 1) single lot or small multi-lot infill (up to 3 lots) and 2) larger infill subdivisions (10 to 30 lots). While infill development occurs on smaller lot sizes (10,000 square feet or less), it is often still possible to effectively cluster lots to provide more open space and reduce impervious cover.

Practice #8: Utilize proper storage, handling and site design techniques to avoid the contact of pollutants with stormwater runoff.

Community Garden: Seattle, WA
* Features a garden irrigation system
* Fueled by rooftop runoff from a nearby daycare center

Rationale: Opportunities exist to improve water quality by preventing contact of rainfall with pollutant sources stored or handled at the site of redevelopment and infill projects. Controlling pollutants at the site (source control) is usually the simplest and most cost-effective way to reduce stormwater pollution at many commercial sites. Source control measures include: 1) proper handling and storage of pollutants and 2) site design practices. Handling and storage practices focus on the storage of materials and vehicles in outdoor areas, while site design practices include designing better loading docks, covering materials stored outdoors, and containing dumpsters and fueling areas. Other source control opportunities exist at fleet parking areas, outdoor maintenance areas, landscaping areas and above ground storage tanks.

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Practice #9: Design the streetscape to minimize, capture and reuse stormwater runoff. Where possible, provide planting spaces to promote the growth of healthy street trees while capturing and treating stormwater runoff. In arid climates, xeriscapes should be used to achieve similar benefits.

Rationale: With proper design and consideration, the interface between the street, sidewalk and other structures, known as the streetscape, can provide opportunities to manage stormwater runoff while providing many other environmental and aesthetic benefits. For example, streets can be made more narrow, and landscaped areas and/or trees can be incorporated into the street front and created so that they function to treat stormwater runoff. In addition, when tree pits are provided along with adequate soil and rooting space, street trees can provide additional stormwater capture and other numerous environmental benefits. Alternatively, xeriscaping (the practice of landscaping to conserve water) can be an important tool in more arid climates.

Cottage Creek: Albany, OR
* Restored area stream with species survey
* Replaced exotic plans with native plants to restore habitat
* Converted a semi-wild urban lot to affordable senior housing

Photo courtesy: Glenn Rea Company

Practice #10: Design courtyards, plazas, and amenity open space to store, filter or treat rainfall.

Rationale: Much of the open space found in redevelopment and infill projects consists of hard surfaces that are impervious to rainfall. Using creative site plans, these courtyards, plazas, and other hard open spaces can be designed to store, filter and treat rainfall. Examples include the use of alternative pavers, bioretention areas, and planting boxes.

Village Weistoria: Bend, OR
* Urban infill development, single-family residential
* Preserved large public green spaces
* Features narrow streets and short setbacks
* Most amenities within walking distance

Photo courtesy: Village Development Corps.

Practice #11: Design sites to maximize transportation choices in order to reduce pollution and improve air and water quality.

Rationale: Designing redevelopment and infill sites to increase connections to adjacent land uses, parks and public spaces through non-automotive related transportation choices (bike paths, pedestrian walkways, etc.) can improve environmental quality. Sites should also seek to provide links to mass transit when available, and provide commuter amenities such as bus shelters or bike racks. In addition, site designers may also wish to explore alternate pathway options for pedestrian movement, rather than the traditional sidewalk on both sides of the street.

Consensus Statement

As members of the Redevelopment Roundtable, we acknowledge the Smart Site Practices as sound and practical redevelopment and infill techniques that can help maintain natural areas, reduce the effects of stormwater runoff, and protect local streams, lakes, wetlands and estuaries. We believe that the technical and case study information provided in these Smart Site Practices are based on sound research and encourage developers, environmental organizations, government agencies and the general public to utilize and promote the dissemination of the practices. The recommendations of the Redevelopment Roundtable reflect our professional and personal experience with redevelopment and infill and do not necessarily carry the endorsement of the organizations and agencies represented by their members.

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Struever Brothers, Eccles & Rouse

Kathy Blaha
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U.S. EPA Brownfields Program

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Unless otherwise noted, photographs were contributed by Center staff.

Resources

Title: *Smart Site Practices: Designing More Environmentally Sensitive Redevelopment and Infill Projects*
By: Center for Watershed Protection, 2001
URL: www.cwp.org
This resource provides some of the detailed technical background and information behind the 11 Smart Site Practices.

Title: *About Brownfields*
By: EPA Office of Solid Waste and Emergency Response, Brownfields Program
URL: www.epa.gov/brownfields

Title: *Brownfields Redevelopment: A Guide for Local Governments and Communities*
By: International City/County Managers Association and Northeast Midwest Institute, 1997
URL: www.icma.org

Title: *Exploring the Ecology of Greenroof Architecture*
By: Linda Velazquez, University of Georgia School of Environmental Design, 2000
URL: www.greenroofs.com

Title: *Financing Brownfields Redevelopment Projects– A Guide for Developers*
By: EPA Smart Growth Network, 2000
URL: www.smartgrowth.org/information/whatsnew.html

Title: *Parking Supply Management*
By: Federal Transit Administration
URL: www.fta.dot.gov/library/planning/tdmstatus/FTAPRKSP.HTM

Title: *Smart Growth: Building Better Places to Live, Work & Play*
By: National Association of Homebuilders, 2000
URL: www.nahb.org

Title: *Smart Growth Toolkit*
By: David O'Neill, Urban Land Institute, 2000
URL: www.uli.org

Title: *Urban Parks Online*
By: LWRD Urban Parks Institute and Project for Public Spaces, 1997
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Title: *Smart Growth Network*
By: Network of stakeholders working to promote smart growth
URL: www.smartgrowth.org

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Model Post-Construction Stormwater Runoff Control Ordinance

This document is downloadable in WordPerfect format.

This model ordinance is intended to be a tool for communities who are currently or may soon be responsible for meeting the stormwater management requirements of the National Pollutant Discharge Elimination System (NPDES) regulations. The goal of providing this model ordinance is to assist communities in creating their own stormwater management ordinance. In designing a model stormwater ordinance for a national audience, we purposely avoided creating too complex an ordinance, and instead tried to include suggestions for standard language and concepts that we believe a good stormwater management ordinance should contain. This ordinance should not be construed as an exhaustive listing of all the language needed for a local ordinance, but represents a good base that communities can build upon and customize to be consistent with the staff resources available in their locality. We recommend that you use this document in conjunction with other sources, such as existing ordinances created by other stormwater management programs in your geographic region that have objectives similar to your program's.

Feel free to download and alter any and all portions of this document to meet your needs. Throughout the ordinance, there are sections in which you must insert the name of the agency that you have given regulatory power over stormwater management issues in order to customize it. These sections are denoted by **bold** text placed in brackets. By using this ordinance and customizing these sections, you can create a viable local ordinance with minimal editing.

Italicized text with this symbol should be interpreted as comments, instructions, or information to assist the ordinance writer. This text *should not appear* in your final ordinance.

Model Ordinance for the Control of Post Construction Stormwater Runoff

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Section 1. General Provisions

1.1. Findings of Fact

It is hereby determined that:

Land development projects and associated increases in impervious cover alter the hydrologic response of local watersheds and increase stormwater runoff rates and volumes, flooding, stream channel erosion, and sediment transport and deposition;

This stormwater runoff contributes to increased quantities of water-borne pollutants, and;

Stormwater runoff, soil erosion and nonpoint source pollution can be controlled and minimized through the regulation of stormwater runoff from development sites.

Therefore, the **(jurisdictional stormwater authority)** establishes this set of water quality and quantity policies applicable to all surface waters to provide reasonable guidance for the regulation of stormwater runoff for the purpose of protecting local water resources from degradation. It is determined that the regulation of stormwater runoff discharges from land development projects and other construction activities in order to control and minimize increases in stormwater runoff rates and volumes, soil erosion, stream channel erosion, and nonpoint source pollution associated with stormwater runoff is in the public interest and will prevent threats to public health and safety.

1.2. Purpose

The purpose of this ordinance is to establish minimum stormwater management requirements and controls to protect and safeguard the general health, safety, and welfare of the public residing in watersheds within this jurisdiction. This ordinance seeks to meet that purpose through the following objectives:

(1). minimize increases in stormwater runoff from any development in order to reduce flooding, siltation, increases in stream temperature, and streambank erosion and maintain the integrity of stream channels;

(2). minimize increases in nonpoint source pollution caused by stormwater runoff from

development which would otherwise degrade local water quality

(3). minimize the total annual volume of surface water runoff which flows from any specific site during and following development to not exceed the pre-development hydrologic regime to the maximum extent practicable.

(4). reduce stormwater runoff rates and volumes, soil erosion and nonpoint source pollution, wherever possible, through stormwater management controls and to ensure that these management controls are properly maintained and pose no threat to public safety.

The above list is a general set of objectives to reduce the impact of stormwater on receiving waters. The local stormwater authority may wish to set some more specific objectives, based on priority water quality and habitat problems (e.g., to reduce phosphorus loads being delivered to recreational lakes, to sustain a class X trout fishery)

1.3. Applicability

This ordinance shall be applicable to all subdivision or site plan applications, unless eligible for an exemption or granted a waiver by the **(jurisdictional stormwater authority)** under the specifications of Section 4 of this ordinance. The ordinance also applies to land development activities that are smaller than the minimum applicability criteria if such activities are part of a larger common plan of development that meets the following applicability criteria, even though multiple separate and distinct land development activities may take place at different times on different schedules. In addition, all plans must also be reviewed by local environmental protection officials to ensure that established water quality standards will be maintained during and after development of the site and that post construction runoff levels are consistent with any local and regional watershed plans.

The size of the site development to which post-construction stormwater management runoff control applies varies but many communities opt for a size limit of 5000 square feet or more. For sites less than 5000 square feet, local officials may wish to grant an exemption as long as the amount of impervious cover created does not exceed 1000 square feet.

To prevent the adverse impacts of stormwater runoff, the **(jurisdictional stormwater authority)** has developed a set of performance standards that must be met at new development sites. These standards apply to any construction activity disturbing or more square feet of land. The following activities may be exempt from these stormwater performance criteria:

1. Any logging and agricultural activity which is consistent with an approved soil conservation plan or a timber management plan prepared or approved by the **(appropriate agency)**, as applicable.

2. Additions or modifications to existing single family structures

3. Developments that do not disturb more than square feet of land, provided they are not part of a larger common development plan;

- Repairs to any stormwater treatment practice deemed necessary by **(jurisdictional stormwater authority)**.

When a site development plan is submitted that qualifies as a redevelopment project as defined in Section 2 of this ordinance, decisions on permitting and on-site stormwater requirements shall be governed by special stormwater sizing criteria found in the current stormwater design manual. This criteria is dependent on the amount of impervious area created by the redevelopment and its impact on water quality. Final authorization of all redevelopment projects will be determined after a review by **(jurisdictional stormwater authority)**.

There are a number of decisions to be made by local communities when addressing the issue of redevelopment and stormwater treatment. The first is defining exactly what qualifies as redevelopment. The definition in Section 2 is from the current Maryland Stormwater Management regulations, and uses the square foot size of the project and its land use classification to establish the definition of a redevelopment project. The second decision involves to what level of stormwater management standards redevelopment projects will be held. Providing cost effective stormwater treatment at redevelopment sites is often a difficult task, and these projects may be given reduced criteria to meet to allow for site constraints. The State of Maryland currently requires that proposed redevelopment project designs include either at least a 20 percent reduction in existing site impervious area, management of at least 20 % of the water quality volume, or some combination of both.

1.4. Compatibility with Other Permit and Ordinance Requirements

This ordinance is not intended to interfere with, abrogate, or annul any other ordinance, rule or regulation, stature, or other provision of law. The requirements of this ordinance should be considered minimum requirements, and where any provision of this ordinance imposes restrictions different from those imposed by any other ordinance, rule or regulation, or other provision of law, whichever provisions are more restrictive or impose higher protective standards for human health or the environment shall be considered to take precedence.

1.5. Severability

If the provisions of any article, section, subsection, paragraph, subdivision or clause of this ordinance shall be judged invalid by a court of competent jurisdiction, such order of judgment shall not affect or invalidate the remainder of any article, section, subsection, paragraph, subdivision or clause of this ordinance.

1.6. Development of a Stormwater Design Manual

The **(jurisdictional stormwater authority)** may furnish additional policy, criteria and information including specifications and standards, for the proper implementation of the requirements of this ordinance and may provide such information in the form of a Stormwater Design Manual.

This manual will include a list of acceptable stormwater treatment practices, including the specific design criteria and operation and maintenance requirements for each stormwater practice. The manual may be updated and expanded from time to time, at the discretion of the local review authority, based on improvements in engineering, science, monitoring and local maintenance experience. Stormwater treatment practices that are designed and constructed in accordance with these design and sizing criteria will be presumed to meet the minimum water quality performance standards.

Local communities will need to select the minimum water quality performance standards (e.g., 80% TSS, 40% P) they will require for stormwater treatment practices and place these in their design manual. The 80% removal goal for total suspended solids (TSS) is a management measure developed by EPA as part of the Coastal Zone Act Reauthorization Amendments of 1990. It was selected by EPA for the following factors: (1) removal of 80% is assumed to control heavy metals, phosphorus, and other pollutants; (2) a number of states including DE, FL, TX, MD, and MA require/recommend TSS removal of 80% or greater for new development; and (3) data show that certain structural controls, when properly designed and maintained, can meet this performance level. Further discussion of water quality standards for stormwater management measures can be found in the CZARA Coastal Zone 6217(g) management measures document entitled "Guidance Specifying Management Measures for Sources of Nonpoint Pollution in Coastal Waters" (US EPA, 1993).

There are a number of good stormwater design manuals available around the country that communities may wish to refer to in creating their own local manual. Two examples are the new Maryland Department of the Environment 2000 Maryland Stormwater Design Manual Volumes I & II available online at http://www.mde.state.md.us/environment/wma/stormwatermanual/ and the Stormwater Management Manual for Western Washington, Volumes 1-5 available online at http://www.ecy.wa.gov/programs/wq/stormwater/manual.html.

*Local communities may also wish to consult a new resource available on the Internet called the **Stormwater Managers Resource Center (SMRC)**. This site is dedicated to providing information to stormwater management program managers in Phase II communities to assist in meeting the requirements of the new National Pollutant Discharge Elimination System Phase II regulations. Among the resources available at the website will be a section devoted to supplying guidance on how to build a stormwater manual, including sizing and design criteria. The SMRC website and the manual-builder resources are located at http://www.stormwatercenter.net.*

Section 2. Definitions

"Accelerated Erosion" means erosion caused by development activities that exceeds the natural processes by which the surface of the land is worn away by the action of water, wind, or chemical action.

"Applicant" means a property owner or agent of a property owner who has filed an application for a stormwater management permit.

"Building" means any structure, either temporary or permanent, having walls and a roof, designed for the shelter of any person, animal, or property, and occupying more than 100 square feet of area.

"Channel" means a natural or artificial watercourse with a definite bed and banks that conducts continuously or periodically flowing water.

"Dedication" means the deliberate appropriation of property by its owner for general public use.

"**Detention**" means the temporary storage of storm runoff in a stormwater management practice with the goals of controlling peak discharge rates and providing gravity settling of pollutants.

"Detention Facility" means a detention basin or alternative structure designed for the purpose of temporary storage of stream flow or surface runoff and gradual release of stored water at controlled rates.

"Developer" means a person who undertakes land disturbance activities.

"Drainage Easement" means a legal right granted by a landowner to a grantee allowing the use of private land for stormwater management purposes.

"Erosion and Sediment Control Plan" means a plan that is designed to minimize the accelerated erosion and sediment runoff at a site during construction activities.

"Fee in Lieu" means a payment of money in place of meeting all or part of the storm water performance standards required by this ordinance.

"**Hotspot**" means an area where land use or activities generate highly contaminated runoff, with concentrations of pollutants in excess of those typically found in stormwater.

"**Hydrologic Soil Group (HSG)**" means a Natural Resource Conservation Service classification system in which soils are categorized into four runoff potential groups. The groups range from A soils, with high permeability and little runoff production, to D soils, which have low permeability rates and produce much more runoff.

"**Impervious Cover**" means those surfaces that cannot effectively infiltrate rainfall (e.g., building rooftops, pavement, sidewalks, driveways, etc).

"**Industrial Stormwater Permit**" means an National Pollutant Discharge Elimination System permit issued to a commercial industry or group of industries which regulates the pollutant levels associated with industrial stormwater discharges or specifies on-site pollution control strategies.

"**Infiltration**" means the process of percolating stormwater into the subsoil.

"**Infiltration Facility**" means any structure or device designed to infiltrate retained water to the subsurface. These facilities may be above grade or below grade.

"**Jurisdictional Wetland**" means an area that is inundated or saturated by surface water or groundwater at a frequency and duration sufficient to support a prevalence of vegetation typically adapted for life in saturated soil conditions, commonly known as hydrophytic vegetation.

"Land Disturbance Activity" means any activity which changes the volume or peak flow discharge rate of rainfall runoff from the land surface. This may include the grading, digging, cutting, scraping, or excavating of soil, placement of fill materials, paving, construction, substantial removal of vegetation,, or any activity which bares soil or rock or involves the diversion or piping of any natural or man-made watercourse.

"Landowner" means the legal or beneficial owner of land, including those holding the right to purchase or lease the land, or any other person holding proprietary rights in the land.

"**Maintenance Agreement**" means a legally recorded document that acts as a property deed restriction, and which provides for long-term maintenance of storm water management practices.

"**Nonpoint Source Pollution**" means pollution from any source other than from any discernible, confined, and discrete conveyances, and shall include, but not be limited to, pollutants from agricultural, silvicultural, mining, construction, subsurface disposal and urban runoff sources.

"**Offset Fee**" means a monetary compensation paid to a local government for failure to meet pollutant load reduction targets.

"**Off-Site Facility**" means a stormwater management measure located outside the subject property boundary described in the permit application for land development activity.

"**On-Site Facility**" means a stormwater management measure located within the subject property boundary described in the permit application for land development activity.

"**Recharge**" means the replenishment of underground water reserves.

"**Redevelopment**" means any construction, alteration or improvement exceeding square feet in areas where existing land use is high density commercial, industrial, institutional or multi-family residential.

"**Stop Work Order**" means an order issued which requires that all construction activity on a site be stopped.

"**Storm Water Management**" means the use of structural or non-structural practices that are designed to reduce storm water runoff pollutant loads, discharge volumes, peak flow discharge rates and detrimental changes in stream temperature that affect water quality and habitat.

"**Storm Water Retrofit**" means a stormwater management practice designed for an existing development site that previously had either no stormwater management practice in place or a practice inadequate to meet the stormwater management requirements of the site.

"**Stormwater Runoff**" means flow on the surface of the ground, resulting from precipitation.

"**Stormwater Treatment Practices (STPs)**" means measures, either structural or nonstructural, that are determined to be the most effective, practical means of preventing or reducing point source or nonpoint source pollution inputs to stormwater runoff and water bodies.

"**Water Quality Volume (WQ_v)**" means the storage needed to capture and treat 90% of the average annual stormwater runoff volume. Numerically **(WQ_v)** will vary as a function of long term rainfall statistical data.

"Watercourse" means a permanent or intermittent stream or other body of water, either natural or man-made, which gathers or carries surface water.

Section 3. Permit Procedures and Requirements

3.1. Permit Required.

No land owner or land operator shall receive any of the building, grading or other land development permits required for land disturbance activities without first meeting the requirements of this ordinance prior to commencing the proposed activity.

The intent is to ensure that no activities that disturb the land are issued permits prior to review and approval of the stormwater management plan. Communities may elect to issue a stormwater management permit separate of any other land development permits required, or, as in this ordinance, tie the issuing of construction permits to the approval of a final stormwater management plan.

3.2. Application Requirements

Unless specifically excluded by this ordinance, any land owner or operator desiring a permit for a land disturbance activity shall submit to the **(jurisdictional stormwater authority)** a permit application on a form provided for that purpose.

Unless otherwise excepted by this ordinance, a permit application must be accompanied by the following in order that the permit application be considered: a stormwater management concept plan; a maintenance agreement; and a non-refundable permit review fee.

The stormwater management plan shall be prepared to meet the requirements of Sec. 5 of this ordinance, the maintenance agreement shall be prepared to meet the requirements of Sec. 9 of this ordinance, and fees shall be those established by the **(jurisdictional stormwater authority)**.

3.3. Application Review Fees

The fee for review of any land development application shall be based on the amount of land to be disturbed at the site, and the fee structure shall be established by the **(jurisdictional stormwater authority)**. All of the monetary contributions shall be

credited to a local budgetary category to support local plan review, inspection and program administration, and shall be made prior to the issuance of any building permit for the development.

Local communities can use these review fees to raise funds for staff and resources to further their stormwater management programs.

3.4. Application Procedure

- Applications for land disturbance activity permits must be filed with the **(appropriate review agency)** on any regular business day.
- A copy of this permit application shall be forwarded to **(jurisdictional stormwater authority)** for review
- Permit applications shall include the following: two copies of the stormwater management concept plan, two copies of the maintenance agreement, and any required review fees.
- Within business days of the receipt of a complete permit application, including all documents as required by this ordinance, the **(jurisdictional stormwater authority)** shall inform the applicant whether the application, plan and maintenance agreement are approved or disapproved.

Local officials will need to decide the appropriate time frame for review of an application. This will often be determined by the staff available for permit review and for an inspection of sites undergoing construction.

- If the permit application, stormwater management plan or maintenance agreement are disapproved, the applicant may revise the stormwater management plan or agreement. If additional information is submitted, the **(jurisdictional stormwater authority)** shall have business days from the date the additional information is received to inform the applicant that the plan and maintenance agreement are either approved or disapproved.
- If the permit application, final stormwater management plan and maintenance agreement are approved by the **(jurisdictional stormwater authority)**, all appropriate land disturbance activity permits shall be issued.

3.5. Permit Duration

Permits issued under this section shall be valid from the date of issuance through the date the **(jurisdictional stormwater authority)** notifies the permitholder that all

stormwater management practices have passed the final inspection required under permit condition.

Section 4. Waivers to Stormwater Management Requirements

4.1. Waivers for Providing Stormwater Management

Every applicant shall provide for stormwater management as required by this ordinance, unless a written request is filed to waive this requirement. Requests to waive the stormwater management plan requirements shall be submitted to the **(jurisdictional stormwater authority)** for approval.

The minimum requirements for stormwater management may be waived in whole or in part upon written request of the applicant, provided that at least one of the following conditions applies:

- It can be demonstrated that the proposed development is not likely to impair attainment of the objectives of this ordinance.

2. Alternative minimum requirements for on-site management of stormwater discharges have been established in a stormwater management plan that has been approved by the **(jurisdictional stormwater authority)** and the implementation of the plan is required by local ordinance.

- Provisions are made to manage stormwater by an off-site facility. The off-site facility is required to be in place, to be designed and adequately sized to provide a level of stormwater control that is equal to or greater than that which would be afforded by on-site practices and there is a legally obligated entity responsible for long-term operation and maintenance of the stormwater practice.

- The **(jurisdictional stormwater authority)** finds that meeting the minimum on-site management requirements is not feasible due to the natural or existing physical characteristics of a site.
- Non-structural practices will be used on the site that reduce: a) the generation of stormwater from the site, b) the size and cost of stormwater storage and c) the pollutants generated at the site. These non-structural practices are explained in detail in the current design manual and the amount of credit available for using such practices shall be determined by the **(jurisdictional stormwater authority)**.

In instances where one of the conditions above applies, the **(jurisdictional stormwater authority)** may grant a waiver from strict compliance with these stormwater management provisions, as long as acceptable mitigation measures are provided. However, to be eligible for a variance, the applicant must demonstrate to the

satisfaction of the **(jurisdictional stormwater authority)** that the variance will not result in the following impacts to downstream waterways:

- Deterioration of existing culverts, bridges, dams, and other structures;
- Degradation of biological functions or habitat;
- Accelerated streambank or streambed erosion or siltation;
- Increased threat of flood damage to public health, life, property .

Furthermore, where compliance with minimum requirements for stormwater management is waived, the applicant will satisfy the minimum requirements by meeting one of the mitigation measures selected by the jurisdictional stormwater authority. Mitigation measures may include, but are not limited to, the following:

- The purchase and donation of privately owned lands, or the grant of an easement to be dedicated for preservation and/or reforestation. These lands should be located adjacent to the stream corridor in order to provide permanent buffer areas to protect water quality and aquatic habitat,
- The creation of a stormwater management facility or other drainage improvements on previously developed properties, public or private, that currently lack stormwater management facilities designed and constructed in accordance with the purposes and standards of this ordinance,
- Monetary contributions (Fee-in-Lieu) to fund stormwater management activities such as research and studies (e.g., regional wetland delineation studies, stream monitoring studies for water quality and macroinvertebrates, stream flow monitoring, threatened and endangered species studies, hydrologic studies, and monitoring of stormwater management practices.

4.2. Fee in Lieu of Stormwater Management Practices.

Where the **(jurisdictional stormwater authority)** waives all or part of the minimum stormwater management requirements, or where the waiver is based on the provision of adequate stormwater facilities provided downstream of the proposed development, the applicant shall be required to pay a fee in an amount as determined by the **(jurisdictional stormwater authority)**.

When an applicant obtains a waiver of the required stormwater management, the monetary contribution required shall be in accordance with a fee schedule (unless the developer and the stormwater authority agree on a greater alternate contribution) established by the **(jurisdictional stormwater authority)**, and based on the cubic feet of storage required for stormwater management of the development in question. All of the monetary contributions shall be credited to an appropriate capital improvements program project, and shall be made by the developer prior to the issuance of any building permit for the development.

4.3. Dedication of land

In lieu of a monetary contribution, an applicant may obtain a waiver of the required stormwater management by entering into an agreement with the **(jurisdictional stormwater authority)** for the granting of an easement or the dedication of land by the applicant, to be used for the construction of an off-site stormwater management facility. The agreement shall be entered into by the applicant and the **(jurisdictional stormwater authority)** prior to the recording of plats or, if no record plat is required, prior to the issuance of the building permit.

Section 5. General Performance Criteria for Stormwater Management

Unless judged by the **(jurisdictional stormwater authority)** to be exempt or granted a waiver, the following performance criteria shall be addressed for stormwater management at all sites:

(A). All site designs shall establish stormwater management practices to control the peak flow rates of stormwater discharge associated with specified design storms and reduce the generation of stormwater. These practices should seek to utilize pervious areas for stormwater treatment and to infiltrate stormwater runoff from driveways, sidewalks, rooftops, parking lots, and landscaped areas to the maximum extent practical to provide treatment for both water quality and quantity.

There are several sources of climatological references that can be consulted to find the rainfall depths for the appropriate design storm intervals (1, 10, 25, and 100 year). The NOAA National Climatological Data Center has a "Summary of the Day" database that can provide rainfall numbers for most major cities and airports in the country. Another possible source is the Urban Hydrology for Small Watersheds, TR-55 (Technical Release 55) published by the Engineering Division, United States Natural Resource Conservation Service (formerly known as the Soil Conservation Service) United States Department of Agriculture, June 1986.

(B). All stormwater runoff generated from new development shall not discharge untreated stormwater directly into a jurisdictional wetland or local water body without adequate treatment. Where such discharges are proposed, the impact of the proposal on wetland functional values shall be assessed using a method acceptable to the **(jurisdictional stormwater authority)**. In no case shall the impact on functional values be any less than allowed by the Army Corp of Engineers (ACE) or the **(Appropriate State Agency)** responsible for natural resources.

(C). Annual groundwater recharge rates shall be maintained, by promoting infiltration through the use of structural and non-structural methods. At a minimum, annual recharge from the post development site shall mimic the annual recharge from pre-

development site conditions.

Recharge is a relatively new stormwater criteria, and has been implemented so far in the Massachusetts coastal zone and in Maryland. The recharge criteria requires considerable effort to use existing pervious areas for stormwater treatment and infiltration, which means that it must be considered very early in the site design process when basic decisions about layout and vegetative cover are made. For additional discussion of recharge criteria, consult the manual builder on the Stormwater Managers Resource Center (SMRC) at www.stormwatercenter.net.

(D). For new development, structural stormwater treatment practices shall be designed to remove % of the average annual post development total suspended solids load (TSS). It is presumed that a STP complies with this performance standard if it is:

- Sized to capture the prescribed water quality volume (WQ_V).

designed according to the specific performance criteria outlined in the local stormwater design manual, constructed properly, and maintained regularly.

For post construction stormwater runoff, the ability of stormwater management programs to meet federal guidelines under the NPDES regulations will become increasingly important. A local government seeking to manage runoff to achieve water quality standards has a number of options for reaching their goal. The options are listed below, from the most typical standard stormwater quality practice to more advanced program options. Each option has an associated level of effort for the management of stormwater, and the likelihood of realizing water quality treatment goals depends on the option a local government selects. Local governments should assess the option they wish to select in light of new Phase II regulations and the current ability of their stormwater management staff to meet more extensive local/state staff review and inspection requirements.

Option 1. Require Stormwater Treatment Practices for Stormwater Quality

Many current stormwater programs simply require that the developer install stormwater treatment practices, but do not specify a target for specific pollutant reduction performance. These programs simply require that a standard volume of stormwater be treated (e.g., a half-inch of runoff). Many of these programs also have generous waiver and exemption provisions, so that as much as 25% of all new development can avoid criteria for water quality. Unless the target removal goals are very low, these communities cannot expect their current programs to eliminate net additional pollutants associated with future development.

(See City of Knoxville, TN Stormwater and Street Ordinance, at

http://www.ci.knoxville.tn.us/)

Option 2. Institute More Rigorous Design Standards for Stormwater Practices.

A number of communities have improved their stormwater programs by strengthening their design standards for stormwater practices. This has involved narrowing the list of acceptable practices to those with a proven ability to remove particular pollutants, increasing the volume of runoff that is treated by each practice (e.g, treat first 1" of stormwater runoff), clamping down on waivers and exemptions (or requiring a fee-in-lieu), and requiring design features that reduce maintenance problems.

The advantage of this program option is that compliance can be presumed as long as designers follow the design rules. It does require a good stormwater manual and more extensive local/state staff review and training. It can achieve significant reduction for some pollutants, such as sediment and nutrients. The disadvantage of the program option is that current stormwater technology may not be effective enough for some pollutants (e.g., bacteria), or capable of reducing the net additional load for high levels from future development.

(For an example see Maryland Department of the Environment 2000 Maryland Stormwater Design Manual available at http://www.mde.state.md.us/environment/wma/stormwatermanual/ . The states of New York and Vermont are in the process of adopting similar design standards for their manuals).

Option 3. Require On-Site Load Calculation

A handful of communities have adopted an approach whereby the design engineer must calculate pre- and post- development loads for a particular pollutant, and then design a system of practices to meet a load reduction target, based on STP removal rates. Phosphorus has been used in most cases, and the load reduction target varies. This option results in more directed design geared more specifically to the pollutant of concern.

The on-site load calculation option has several disadvantages. First, designers can select to use math modeling to their advantage to reduce costs and come into compliance. Second, technical data to support the program option are limited to just a few parameters, such as phosphorus, nitrogen and sediment. Third, the removal rates for the stormwater practices seldom account for factors where pollutant load removal is compromised, and tend to be optimistic. Lastly, this program option is very intensive in terms of local review and compliance, and requires more staffing to implement.

(For an example of on-site load calculation see the publication Phosphorus Control in

Lake Watersheds: A Technical Guide to Evaluating New Development by the Maine Department of Environmental Protection. Another example where this option has been applied is for New York City water supply areas).

Option 4. Load Calculation w/ Stormwater Offset Fee to Provide Retrofits on Existing Development

In this program option, a community requires the on-site load calculation described in Option 3, but is very conservative in the assumptions it allows on loading and removal efficiency. Consequently, designers at most sites cannot fully comply with the load reduction for the requirement at their site. To fully comply, they must pay an offset fee to the local government which is used to support design and construction of stormwater retrofits at existing development in the watershed. The fee is set at the cost of providing an equivalent amount of pollutant removal elsewhere (dollars/pound).

The advantage of this approach is that it provides a means of financing the stormwater retrofits needed to reduce pollutant loads from existing development. It does require greater local staffing to find, design and build the retrofits which offset the loads from new development. If administered properly, this program option can potentially eliminate the net additional load from new development. Several communities currently provide this option for developers, but it is not clear how much revenue has been collected so far.

(This option has been applied in Maryland Critical Areas and Virginia Chesapeake Bay resource management areas. For more information, see the website regarding the Maryland Critical Area Act at http://www.dnr.state.md.us/criticalarea/ and the Virginia Chesapeake Bay Preservation Area Regulation at http://www.cblad.state.va.us/regs.htm)

(E). To protect stream channels from degradation, a specific channel protection criteria shall be provided as prescribed in the current stormwater manual.

Channel protection is a relatively new criteria, but is increasingly viewed as a critical one due to the mounting evidence that stream channels enlarge in response to watershed development. Studies have found higher bank erosion rates and increased instream sediment loads for urban streams when compared to the 5-20% estimate for the annual sediment budget attributable to bank erosion in rural streams (Walling and Woodward, 1995; Collins et al., 1997). Research also indicates that channel enlargement can begin at a relatively low level of watershed development, as indicated by the amount of impervious cover. One study estimated that channel erosion rates were three to six times higher in a moderately urbanized watershed (14% impervious cover) than in a comparable rural one, with less than 2% impervious cover (Neller, 1988).

The basic methodology to calculate channel enlargement relies on obtaining historical cross-sectional data from past surveys (often obtained from transportation agencies or public works departments that conducted surveys at the time of road construction or improvement projects) and comparing these with current cross-sectional data obtained from field surveys conducted at the time of the study. The approach also utilizes predictive (i.e., empirical) equations to estimate an ultimate channel enlargement ratio once the channel has enlarged sufficiently to be in balance with its hydrological forces.

Basic Options for Stream Channel Protection

Many different design criteria have been suggested to protect downstream channels from erosion. It should be clearly noted that none of these criteria have yet been monitored in the field to demonstrate their effectiveness, and most are based on hydrologic or hydraulic modeling of streams. The three options that appear to hold some promise are:

***24 hour detention of the one year storm event**. This criteria would result in up to 24 hours of detention for runoff generated by a rainfall depth based on annual rainfall for a region. Smaller storms events would also experience some detention, but probably much less than 24 hours. The premise of this criteria is that runoff would be stored and released in such a gradual manner that critical erosive velocities would seldom be exceeded in downstream channels. The required volume needed for 1 year extended detention is significant; it is roughly equivalent to about 90 to 95% of the required volume needed for ten year peak discharge control. Consequently, the need for two year peak discharge management would be eliminated when the 1 year ED is provided, as long as the ten year peak discharge control is achieved.*

(For an example, see Maryland Department of the Environment 2000 Maryland Stormwater Design Manual available at http://www.mde.state.md.us/environment/wma/stormwatermanual/ . The states of New York and Virginia also use this design criteria for stream channel protection in their stormwater design manuals).

***Distributed runoff control (DRC):** This criteria has been developed by MaCrae (1993) and involves complex field assessments and modeling to determine the hydraulic stress and erosion potential of bank materials. The criteria states that channel erosion is minimized if the alteration in the transverse distribution of erosion potential about a channel parameter is maintained constant with predevelopment values, over the range of available flows, such that the channel is just able to move the dominant particle size of the bed load. This Canadian method holds promise, but has not been tested extensively in the United States and requires significantly greater data collection and modeling then any of the other methods.*

(For a discussion of this criteria, see the Vermont Stormwater Management Handbook Technical Support Document- Appendix B, November 2000).

Bankfull capacity/duration criteria: *This criteria has been advanced by Tapley et al 1996, and states that the post-development, bankfull flow frequency, duration and depth must be controlled to predevelopment values at a designated control point(s) in the channel. The Rule of thumb for selecting control point(s) is to use a 10: 1 ratio of peak discharge from the one year storm for the developed site to the discharge from the stream for the same frequency storm (Tapley et al, 1996). In theory, this criteria should result in a high level of downstream protection. The practical problem is in defining how the criteria is to be interpreted; whether sub-bankfull events (that typically erode the toe of the streambank) should also be considered; and precisely where the "bankfull" should be measured. For example, the channel of many streams have been modified in the past by prior land uses and channelization, and may not represent the "true" channel. In other cases, the stormwater outfall discharge laterally to a stream, and it is therefore difficult to assign which flows the developer is actually responsible for controlling.*

Pros and Cons of Channel Protection Sizing Criteria.

Each of the three options has some limitations. For example, both the DRC and bankfull capacity sizing criteria options lack widely accepted or universal design methodologies. In each case, local stream cross-section and/or soil measurements are needed, and considerable contention between the designer and the reviewer can be expected on how and where the analysis should be performed. Given the many operational problems currently associated with either option, and the lack of a tested design methodology at present, the two options probably deserve further study, but are not ready for wide application.

This leaves only one remaining option-- the one-year 24 hour detention criteria. It, too, has some limitations:

results in unacceptably small diameter orifices for sites less than ten acres in size.

requires a storage volume roughly equivalent to that needed for two year control.

- *has not been "tested" by continuous simulation modeling to determine if acceptable detention times can be achieved for smaller storms can be achieved (1.0 to 1.5 inches).*

is only needed in streams that are susceptible to bank erosion.

Based on the foregoing, it appears that the best option to provide channel protection

(Cp_v) is 12 to 24 hour extended detention of the one-year 24 hour storm event. This Cp_v requirement only applies to sites greater than ten acres in size. Local governments may wish to retain the option of employing the DRC or bankfull capacity/duration criteria as an alternative, should their analytical and design requirements become more simplified and refined in the future

There are some basic exemptions to where the channel protection criteria should be applied (small drainage areas, direct discharge to tidal waters or a lake, flat terrain etc), and communities must decide how and when this criteria will be required.

(F). Stormwater discharges to critical areas with sensitive resources (i.e., cold water fisheries, shellfish beds, swimming beaches, recharge areas, water supply reservoirs) may be subject to additional performance criteria, or may need to utilize or restrict certain stormwater management practices.

(G). Certain industrial sites are required to prepare and implement a stormwater pollution prevention plan, and shall file a notice of intent (NOI) under the provisions of the National Pollutant Discharge Elimination System (NPDES) general permit. The stormwater pollution prevention plan requirement applies to both existing and new industrial sites.

Applicants and local communities may wish to consult the Environmental Protection Agency website at http://www.epa.gov/owm/swm/phase2 for more information on Phase II requirements.

(H). Stormwater discharges from land uses or activities with higher potential pollutant loadings, known as "hotspots", may require the use of specific structural STPs and pollution prevention practices.

(I). Prior to design, applicants are required to consult with the **(jurisdictional stormwater authority)** to determine if they are subject to additional stormwater design requirements.

(J). The calculations for determining peak flows as found in the Stormwater Design Manual shall be used for sizing all stormwater management practices.

Section 6. Basic Stormwater Management Design Criteria

Rather than place specific stormwater design criteria into an ordinance, it is often preferable to fully detail these requirements in a stormwater design manual. This allows specific design information to change over time as new information or techniques become available without requiring the formal process needed to change

ordinance language. The ordinance can then require those submitting any development application to consult the current stormwater design manual for the exact design criteria for the stormwater management practices appropriate for their site.

In the Maryland Stormwater Design Manual, for example, there are a set of specified performance criteria for each stormwater management practice, based on six factors:

- *Site Design Feasibility -*
- *Conveyance Issues -*
- *Pretreatment Requirements -*
- *Treatment/Geometry Conditions*
- *Environmental/Landscaping Standards*
- *Maintenance Needs*

Each community will need to decide the specific design and sizing criteria for the stormwater management practices they allow, and select a storm event frequency(1, 2, 10, 100 year) that they believe will meet their stormwater quality and quantity control requirements.

6.1. Minimum Control Requirements

All stormwater management practices will be designed so that the specific storm frequency storage volumes (e.g., recharge, water quality, channel protection, 10 year, 100 year) as identified in the current stormwater design manual are met, unless the **(jurisdictional stormwater authority)** grants the applicant a waiver or the applicant is exempt from such requirements.

In addition, if hydrologic or topographic conditions warrant greater control than that provided by the minimum control requirements, the **(jurisdictional stormwater authority)** reserves the right to impose any and all additional requirements deemed necessary to control the volume, timing, and rate of runoff.

6.2 Site Design Feasibility

Stormwater management practices for a site shall be chosen based on the physical conditions of the site. Among the factors that should be considered:

- Topography
- Maximum Drainage Area
- Depth to Water Table
- Soils
- Slopes
- Terrain

- Head
- Location in relation to environmentally sensitive features or ultra-urban areas

Applicants shall consult the Stormwater Design Manual for guidance on the factors that determine site design feasibility when selecting a stormwater management practice.

6.3. Conveyance Issues

All stormwater management practices shall be designed to convey stormwater to allow for the maximum removal of pollutants and reduction in flow velocities. This shall include, but not be limited to:

- Maximizing of flowpaths from inflow points to outflow points
- Protection of inlet and outfall structures
- Elimination of erosive flow velocities
- Providing of underdrain systems, where applicable

The Stormwater Design Manual shall provide detailed guidance on the requirements for conveyance for each of the approved stormwater management practices.

6.4. Pretreatment Requirements

Every stormwater treatment practice shall have an acceptable form of water quality pretreatment, in accordance with the pretreatment requirements found in the current stormwater design manual. Certain stormwater treatment practices, as specified in the Stormwater Design Manual, are prohibited even with pretreatment in the following circumstances:

A. Stormwater is generated from highly contaminated source areas known as "hotspots"

B. Stormwater is carried in a conveyance system that also carries contaminated, non-stormwater discharges

C. Stormwater is being managed in a designated groundwater recharge area.

D. Certain geologic conditions exist (e.g., karst) that prohibit the proper pretreatment of stormwater.

6.5. Treatment/Geometry Conditions

All stormwater management practices shall be designed to capture and treat stormwater runoff according to the specifications outlined in the Stormwater Design Manual. These specifications will designate the water quantity and quality treatment criteria that apply to an approved stormwater management practice.

6.6. Landscaping Plans Required

All stormwater management practices must have a landscaping plan detailing both the vegetation to be in the practice and how and who will manage and maintain this vegetation. This plan must be prepared by a registered landscape architect or soil conservation district.

6.7. Maintenance Agreements

All stormwater treatment practices shall have an enforceable operation and maintenance agreement to ensure the system functions as designed. This agreement will include any and all maintenance easements required to access and inspect the stormwater treatment practices, and to perform routine maintenance as necessary to ensure proper functioning of the stormwater treatment practice. In addition, a legally binding covenant specifying the parties responsible for the proper maintenance of all stormwater treatment practices shall be secured prior to issuance of any permits for land disturbance activities.

6.8. Non-Structural Stormwater Practices

The use of non-structural stormwater treatment practices is encouraged in order to minimize the reliance on structural practices. Credit in the form of reductions in the amount of stormwater that must be managed can be earned through the use of non-structural practices that reduce the generation of stormwater from the site. These non-structural practices are explained in detail in the current design manual and applicants wishing to obtain credit for use of non-structural practices must ensure that these practices are documented and remain unaltered by subsequent property owners.

Section 7. Requirements for Stormwater Management Plan Approval

7.1. Stormwater Management Plan Required for All Developments.

No application for development will be approved unless it includes a stormwater management plan detailing in concept how runoff and associated water quality impacts resulting from the development will be controlled or managed. This plan must be prepared by an individual approved by the **(jurisdictional stormwater authority)** and must indicate whether stormwater will be managed on-site or off-site and, if on-site, the general location and type of practices.

The stormwater management plan(s) shall be referred for comment to all other interested agencies, and any comments must be addressed in a final stormwater management plan. This final plan must be signed by a licensed professional engineer (PE), who will verify that the design of all stormwater management practices meet the submittal requirements outlined in the Submittal Checklist found in the stormwater

design manual. No building, grading, or sediment control permit shall be issued until a satisfactory final stormwater management plan, or a waiver thereof, shall have undergone a review and been approved by the **(jurisdictional stormwater authority)** after determining that the plan or waiver is consistent with the requirements of this ordinance.

One way to handle the submittal requirements for both the concept plan and the final design plan is to place Submittal Checklists in the stormwater design manual and require that they are used for submission of any plan. The benefit of this is that changes in submittal requirements can be made as needed without needing to revisit and alter the original ordinance. Three model checklists can be found on the Stormwater Managers Resource Center (SMRC) website at www.stormwatercenter.net.

7.2. Stormwater Management Concept Plan Requirements

A stormwater management concept plan shall be required with all permit applications and will include sufficient information (e.g., maps, hydrologic calculations, etc) to evaluate the environmental characteristics of the project site, the potential impacts of all proposed development of the site, both present and future, on the water resources, and the effectiveness and acceptability of the measures proposed for managing stormwater generated at the project site. The intent of this conceptual planning process is to determine the type of stormwater management measures necessary for the proposed project, and ensure adequate planning for management of stormwater runoff from future development. To accomplish this goal the following information shall be included in the concept plan:

- A map (or maps) indicating the location of existing and proposed buildings, roads, parking areas, utilities, structural stormwater management and sediment control facilities. The map(s) will also clearly show proposed land use with tabulation of the percentage of surface area to be adapted to various uses; drainage patterns; locations of utilities, roads and easements; the limits of clearing and grading; A written description of the site plan and justification of proposed changes in natural conditions may also be required.

This project description and site plan requirement includes information normally found in an Erosion and Sediment Control plan. For local governments that do not currently have ESC plan requirements or are looking to upgrade their ESC ordinance language, there is a model Erosion and Sediment Control ordinance located at the SMRC website.

- Sufficient engineering analysis to show that the proposed stormwater management measures are capable of controlling runoff from the site in compliance with this ordinance and the specifications of the Stormwater Design Manual.
- A written or graphic inventory of the natural resources at the site and surrounding

area as it exists prior to the commencement of the project and a description of the watershed and its relation to the project site. This description should include a discussion of soil conditions, forest cover, topography, wetlands, and other native vegetative areas on the site. Particular attention should be paid to environmentally sensitive features that provide particular opportunities or constraints for development.

- A written description of the required maintenance burden for any proposed stormwater management facility.
- The **(jurisdictional stormwater authority)** may also require a concept plan to consider the maximum development potential of a site under existing zoning, regardless of whether the applicant presently intends to develop the site to its maximum potential.

For development or redevelopment occurring on a previously developed site, an applicant shall be required to include within the stormwater concept plan measures for controlling existing stormwater runoff discharges from the site in accordance with the standards of this Ordinance to the maximum extent practicable.

7.3. Final Stormwater Management Plan Requirements

After review of the stormwater management concept plan, and modifications to that plan as deemed necessary by the **(jurisdictional stormwater authority)**, a final stormwater management plan must be submitted for approval. The final stormwater management plan, in addition to the information from the concept plan, shall include all of the information required in the Final Stormwater Management Plan checklist found in the Stormwater Design Manual. This includes:

1. Contact Information

The name, address, and telephone number of all persons having a legal interest in the property and the tax reference number and parcel number of the property or properties affected.

2. Topographic Base Map

A 1" = 200' topographic base map of the site which extends a minimum of_feet beyond the limits of the proposed development and indicates existing surface water drainage including streams, ponds, culverts, ditches, and wetlands; current land use including all existing structures; locations of utilities, roads, and easements; and significant natural and manmade features not otherwise shown.

3. Calculations

Hydrologic and hydraulic design calculations for the pre-development and post-development conditions for the design storms specified in this ordinance. Such calculations shall include (i) description of the design storm frequency, intensity and duration, (ii) time of concentration, (iii) Soil Curve Numbers or runoff coefficients, (iv) peak runoff rates and total runoff volumes for each watershed area, (v) infiltration rates, where applicable, (vi) culvert capacities, (vii) flow velocities, (viii) data on the increase in rate and volume of runoff for the design storms referenced in the Stormwater Design Manual, and (ix) documentation of sources for all computation methods and field test results.

4. Soils Information

If a stormwater management control measure depends on the hydrologic properties of soils (e.g., infiltration basins), then a soils report shall be submitted. The soils report shall be based on on-site boring logs or soil pit profiles. The number and location of required soil borings or soil sits shall be determined based on what is needed to determine the suitability and distribution of soil types present at the location of the control measure.

5. Maintenance and Repair Plan

The design and planning of all stormwater management facilities shall include detailed maintenance and repair procedures to ensure their continued function. These plans will identify the parts or components of a stormwater management facility that need to be maintained and the equipment and skills or training necessary. Provisions for the periodic review and evaluation of the effectiveness of the maintenance program and the need for revisions or additional maintenance procedures shall be included in the plan.

- Landscaping plan

The applicant must present a detailed plan for management of vegetation at the site after construction is finished, including who will be responsible for the maintenance of vegetation at the site and what practices will be employed to ensure that adequate vegetative cover is preserved. This plan must be prepared by a registered landscape architect or by the soil conservation district.

- Maintenance Easements

The applicant must ensure access to all stormwater treatment practices at the site for the purpose of inspection and repair by securing all the maintenance easements needed on a permanent basis. These easements will be recorded with the plan and will remain in effect even with transfer of title to the property.

- Maintenance Agreement

The applicant must execute an easement and an inspection and maintenance agreement binding on all subsequent owners of land served by na on-site stormwater management measure in accordance with the specifications of this ordinance.

- Erosion and Sediment Control Plans for Construction of Stormwater Management Measures

The applicant must prepare an erosion and sediment control plan for all construction activities related to implementing any on-site stormwater management practices.

- Other Environmental Permits

The applicant shall assure that all other applicable environmental permits have been acquired for the site prior to approval of the final stormwater design plan.

7.4. Performance Bond/Security

The **(jurisdictional stormwater authority)** may, at its discretion, require the submittal of a performance security or bond prior to issuance of a permit in order to insure that the stormwater practices are installed by the permit holder as required by the approved stormwater management plan. The amount of the installation performance security shall be the total estimated construction cost of the stormwater management practices approved under the permit, plus 25%. The performance security shall contain forfeiture provisions for failure to complete work specified in the stormwater management plan.

The installation performance security shall be released in full only upon submission of "as built plans" and written certification by a registered professional engineer that the stormwater practice has been installed in accordance with the approved plan and other applicable provisions of this ordinance. The **(jurisdictional stormwater authority)** will make a final inspection of the stormwater practice to ensure that it is in compliance with the approved plan and the provisions of this ordinance. Provisions for a partial pro-rata release of the performance security based on the completion of various development stages can be done at the discretion of the **(jurisdictional stormwater authority)**.

Some communities elect to also require a maintenance performance security. This bond typically is set at the maintenance costs estimated in the stormwater plan for the period during which the permit holder has maintenance responsibility and is released when the responsibility for practice maintenance is passed on to another party, via an approved maintenance agreement.

Section 8. Construction Inspection

8.1. Notice of Construction Commencement

The applicant must notify the **(jurisdictional stormwater authority)** in advance before the commencement of construction. Regular inspections of the stormwater management system construction shall be conducted by the staff of the **(jurisdictional stormwater authority)** or certified by a professional engineer or their designee who has been approved by the jurisdictional stormwater authority. All inspections shall be documented and written reports prepared that contain the following information:

- The date and location of the inspection;
- Whether construction is in compliance with the approved stormwater management plan
- Variations from the approved construction specifications
- Any violations that exist

If any violations are found, the property owner shall be notified in writing of the nature of the violation and the required corrective actions. No added work shall proceed until any violations are corrected and all work previously completed has received approval by the **(jurisdictional stormwater authority)**.

8.2. As Built Plans

All applicants are required to submit actual "as built"plans for any stormwater management practices located on-site after final construction is completed. The plan must show the final design specifications for all stormwater management facilities and must be certified by a professional engineer. A final inspection by the **(jurisdictional stormwater authority)** is required before the release of any performance securities can occur.

8.3. Landscaping and Stabilization Requirements

Any area of land from which the natural vegetative cover has been either partially or wholly cleared or removed by development activities shall be revegetated within ten (10) days from the substantial completion of such clearing and construction. The following criteria shall apply to revegetation efforts:

Reseeding must be done with an annual or perennial cover crop accompanied by placement of straw mulch or its equivalent of sufficient coverage to control erosion until such time as the cover crop is established over ninety percent (90%) of the seeded area.

Replanting with native woody and herbaceous vegetation must be accompanied by placement of straw mulch or its equivalent of sufficient coverage to control erosion until the plantings are established and are capable of controlling erosion.

Any area of revegetation must exhibit survival of a minimum of seventy-five percent (75%) of the cover crop throughout the year immediately following revegetation. Revegetation must be repeated in successive years until the minimum seventy-five percent (75%) survival for one (1) year is achieved.

In addition to the above requirements, a landscaping plan must be submitted with the final design describing the vegetative stabilization and management techniques to be used at a site after construction is completed. This plan will explain not only how the site will be stabilized after construction, but who will be responsible for the maintenance of vegetation at the site and what practices will be employed to ensure that adequate vegetative cover is preserved. This plan must be prepared by a registered landscape architect or by the soil conservation district, and must be approved prior to receiving a permit.

Section 9. Maintenance and Repair of Stormwater Facilities

A model operation and maintenance ordinance for stormwater facilities is also available at the SMRC website. This ordinance goes into greater detail on the elements needed to create an effective stormwater maintenance ordinance. Requirements for inspection are also included in the model.

9.1. Maintenance Easement

Prior to the issuance of any permit that has an stormwater management facility as one of the requirements of the permit, the applicant or owner of the site must execute a maintenance easement agreement that shall be binding on all subsequent owners of land served by the stormwater management facility. The agreement shall provide for access to the facility at reasonable times for periodic inspection by the **(jurisdictional stormwater authority)**, or their contractor or agent, and for regular or special assessments of property owners to ensure that the facility is maintained in proper working condition to meet design standards and any other provisions established by this ordinance. The easement agreement shall be recorded by the **(jurisdictional stormwater authority)** in the land records.

9.2. Maintenance Covenants

Maintenance of all stormwater management facilities shall be ensured through the creation of a formal maintenance covenant that must be approved by the **(jurisdictional stormwater authority)** and recorded into the land record prior to final plan approval.

As part of the covenant, a schedule shall be developed for when and how often maintenance will occur to ensure proper function of the stormwater management facility. The covenant shall also include plans for periodic inspections to ensure proper performance of the facility between scheduled cleanouts.

The **(jurisdictional stormwater authority)**, in lieu of an maintenance covenant, may accept dedication of any existing or future stormwater management facility for maintenance, provided such facility meets all the requirements of this chapter and includes adequate and perpetual access and sufficient area, by easement or otherwise, for inspection and regular maintenance.

9.3. Requirements for Maintenance Covenants

All stormwater management facilities must undergo, at the minimum, an annual inspection to document maintenance and repair needs and ensure compliance with the requirements of this ordinance and accomplishment of its purposes. These needs may include; removal of silt, litter and other debris from all catch basins, inlets and drainage pipes, grass cutting and vegetation removal, and necessary replacement of landscape vegetation. Any maintenance needs found must be addressed in a timely manner, as determined by the **(jurisdictional stormwater authority)**, and the inspection and maintenance requirement may be increased as deemed necessary to ensure proper functioning of the stormwater management facility.

9.4. Inspection of Stormwater Facilities

Inspection programs may be established on any reasonable basis, including but not limited to: routine inspections; random inspections; inspections based upon complaints or other notice of possible violations; inspection of drainage basins or areas identified as higher than typical sources of sediment or other contaminants or pollutants; inspections of businesses or industries of a type associated with higher than usual discharges of contaminants or pollutants or with discharges of a type which are more likely than the typical discharge to cause violations of state or federal water or sediment quality standards or the NPDES stormwater permit; and joint inspections with other agencies inspecting under environmental or safety laws. Inspections may include, but are not limited to: reviewing maintenance and repair records; sampling discharges, surface water, groundwater, and material or water in drainage control facilities; and evaluating the condition of drainage control facilities and other stormwater treatment practices.

9.5. Right-of-Entry for Inspection

When any new drainage control facility is installed on private property, or when any new connection is made between private property and a public drainage control system,

sanitary sewer or combined sewer, the property owner shall grant to the **(jurisdictional stormwater authority)** the right to enter the property at reasonable times and in a reasonable manner for the purpose of inspection. This includes the right to enter a property when it has a reasonable basis to believe that a violation of this ordinance is occurring or has occurred, and to enter when necessary for abatement of a public nuisance or correction of a violation of this ordinance.

9.6. Records of Installation and Maintenance Activities.

Parties responsible for the operation and maintenance of a stormwater management facility shall make records of the installation and of all maintenance and repairs, and shall retain the records for at least years. These records shall be made available to the (jurisdictional stormwater authority) during inspection of the facility and at other reasonable times upon request.

9.7 Failure to Maintain Practices

If a responsible party fails or refuses to meet the requirements of the maintenance covenant, the **(jurisdictional stormwater authority)**, after reasonable notice, may correct a violation of the design standards or maintenance needs by performing all necessary work to place the facility in proper working condition. In the event that the stormwater management facility becomes a danger to public safety or public health, the **(jurisdictional stormwater authority)** shall notify the party responsible for maintenance of the stormwater management facility in writing. Upon receipt of that notice, the responsible person shall have days to effect maintenance and repair of the facility in an approved manner. After proper notice, the **(jurisdictional stormwater authority)** may assess the owner(s) of the facility for the cost of repair work and any penalties; and the cost of the work shall be a lien on the property, or prorated against the beneficial users of the property, and may be placed on the tax bill and collected as ordinary taxes by the county.

Section 10. Enforcement and Penalties.

10.1. Violations

Any development activity that is commenced or is conducted contrary to this Ordinance, may be restrained by injunction or otherwise abated in a manner provided by law.

10.2. Notice of Violation.

When the **(jurisdictional stormwater authority)** determines that an activity is not being carried out in accordance with the requirements of this Ordinance, it shall issue a

written notice of violation to the owner of the property. The notice of violation shall contain :

(1) the name and address of the owner or applicant;

(2) the address when available or a description of the building, structure or land upon which the violation is occurring;

(3) a statement specifying the nature of the violation;

(4) a description of the remedial measures necessary to bring the development activity into compliance with this Ordinance and a time schedule for the completion of such remedial action;

(5) a statement of the penalty or penalties that shall or may be assessed against the person to whom the notice of violation is directed;

(6) a statement that the determination of violation may be appealed to the municipality by filing a written notice of appeal within fifteen (15) days of service of notice of violation.

10.3. Stop Work Orders

Persons receiving a notice of violation will be required to halt all construction activities. This "stop work order" will be in effect until the **(jurisdictional stormwater authority)** confirms that the development activity is in compliance and the violation has been satisfactorily addressed. Failure to address a notice of violation in a timely manner can result in civil, criminal, or monetary penalties in accordance with the enforcement measures authorized in this ordinance.

10.4. Civil and Criminal Penalties

In addition to or as an alternative to any penalty provided herein or by law, any person who violates the provisions of this Ordinance shall be punished by a fine of not less than Dollars ($xx) or by imprisonment for a period not to exceed (xx) days, or both such fine and imprisonment. Such person shall be guilty of a separate offense for each day during which the violation occurs or continues.

10.4. Restoration of lands

Any violator may be required to restore land to its undisturbed condition. In the event that restoration is not undertaken within a reasonable time after notice, the **(jurisdictional stormwater authority)** may take necessary corrective action, the cost of which shall become a lien upon the property until paid.

10.5. Holds on Occupation Permits

Occupation permits will not be granted until a corrections to all stormwater practices have been made and accepted by the **(jurisdictional stormwater authority)**.

Approved by: _____ Date _____

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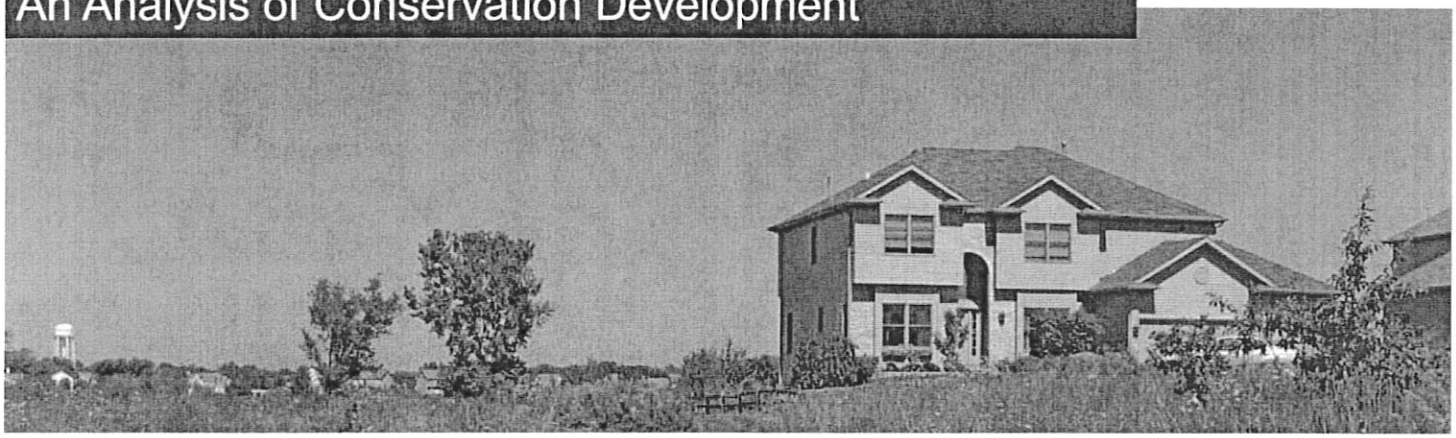
Changing Cost Perceptions:

An Analysis of Conservation Development



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Executive Summary

While the environmental benefits of conservation approaches to development are well known, cost-sensitive municipalities and developers are often reticent to try a conservation approach. A common concern about alternative development approaches is the perception of increased cost. A project group, spearheaded by the Conservation Research Institute, came together to investigate this issue. Developers, local officials, policy analysts and staff from several development consulting firms helped to fill information gaps on the costs of conservation development.

This project was conceived to support the implementation of the Chicago Wilderness Biodiversity Recovery Plan, by informing players about the feasibility of development alternatives that can minimize damage to the ecosystems of the Midwest. The project set out to answer the following questions: Does conservation development, which helps to address the issue of environmental protection, have the potential to help mitigate the problem of the high cost of development? Or, does it exacerbate the current trend of rising costs, especially for stormwater management?

The conservation approach addresses stormwater on-site by distributing the water across the landscape, thereby mimicking or restoring the historical hydrological regime. The result is a range of environmental benefits: groundwater recharge, improved surface water hydrology, improved water quality, habitat protection, and others. On the other hand, conventional practices such as engineered stormwater ponds or concrete-lined drainage ditches have sometimes shown negative environmental impacts not present with conservation tools, such as increased flooding or decreased water quality.

To compare the stormwater management costs of conservation with conventional development, this project undertook three studies: a literature review, an analysis of built-site case studies, and a cost analysis of hypothetical conventional and conservation design templates, or layouts.

Literature Review

The literature consistently raised examples of how conservation development methods can save money in both construction and maintenance, from the broad metropolitan scale down to the site level, and further down to a comparison of specific Best Management Practices (BMPs). Here is a brief summary of conclusions from the literature:

1. Public infrastructure costs are higher when a development is built within the context of urban sprawl, as compared to smart growth patterns that conserve land.
2. At the site level, significant cost savings can be achieved from clustering, including costs for clearing and grading, stormwater and transportation infrastructure, and utilities.
3. Installation costs can be between $4,400 and $8,850 cheaper per acre for natural landscaping than for turf grass approaches.
4. Maintenance cost savings range between $3,950 and $4,583 per acre per year over ten years for native landscaping approaches over turf grass approaches.
5. Better site design can reduce paving costs.
6. While conventional paving materials are less expensive than conservation alternatives, porous materials can help total development costs go down, sometimes as much as 30%, by reducing conveyance and detention needs.
7. Swale conveyance is cheaper than pipe systems, by some claims as much as 80%.
8. The literature is not clear enough to resolve the cost differences between discrete detention and retention tools by themselves.
9. Costs of retention or detention cannot be examined in isolation, but must instead be analyzed in combination with conveyance costs, at which point conservation methods generally have a cost advantage.
10. Green roofs are currently more expensive to install than standard roofs. Yet costs are highly variable and going down. Green roofs also have significant cost advantages when looking at life-cycle costs.
11. Several specific conservation tools can actually have multiple positive economic effects by themselves, both directly and indirectly.

Perhaps the most significant theme gleaned from the literature is that, by *combining* multiple tools, such as clustering

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with native landscaping, bio-swales, and other practices, deeper cost savings can be achieved from the resulting opportunities to downsize the infrastructure. When techniques are applied together, the individual benefits of specific tools cannot be separated from the overall benefits of a complete site design, but the cumulative economic benefits of site design can be impressive. Across ten case studies examined here, holistic conservation design treatments saved an average of 36% over conventional practices.

Built-Site Cost Analysis

Built-site analyses provide case studies from the real world to complement the lessons from the literature research. By analyzing engineering data and construction costs from actual built projects, this report compared specific aspects of development costs more closely to find from where cost-savings are derived between conventional and conservation developments.

Mill Creek and Sunset Prairie are similar subdivisions in Kane County, Illinois. Sunset Prairie was built conventionally, whereas Mill Creek used several conservation practices. Based on the cost results, about $3,700 per foot was saved in the conservation development relative to the conventional approach. Approximately 53% of the savings came from stormwater management construction costs and 21% come from site preparation costs.

Three Bielinski Homes residential subdivisions from Southeastern Wisconsin were analyzed for their estimated conventional cost scenarios and for actual cost of conservation construction. Total cost savings ranged from $563,764 to $1,288,646 and averaged $876,913 across the three Wisconsin sites. Overall, every item in construction cost less under conservation development except for landscaping costs, which were higher in Auburn Hills and Laurel Springs. Overall site preparation saved 23 to 32% of conventional development costs when built with conservation techniques. Savings ranged from 47 to 69%, or about $2,500, to $3,300 per unit where vegetated swales or bioswales substituted for storm sewers.

At Prairie Crossing, in Grayslake, Illinois, cost savings generated from conservation development were found in several areas: stormwater management, curb and gutter, site paving, sidewalks, and landscaping. Conservation development savings were $3,798 per lot for construction.

Prior to construction of a conservation designed corporate campus, Tellabs, in Naperville, Illinois, compared costs between conservation and conventional scenarios on the same site. In this case, earthwork, stormwater management, and landscaping were the design components that drove most of the differences between conventional and conservation scenarios. Total savings for capital costs were $564,473, or just over 12 percent. Savings of site preparation from conservation development were as much as $214,500 (or $3,900 per acre) less than the conventional scenario, and the conservation design preserved six more acres with minimum disturbance. Integrated stormwater management and landscaping in conservation site design helped save money in the beginning because of the combined integrity present by concurrent installation of the bioswales, wetlands, and native landscaping.

Seattle's Street Edge Alternatives program used natural drainage systems in an urban residential retrofit context to allow infiltration and detention as part of their stormwater management system. Seattle's conservation streets cost $217,253 less than a conventional street would have on overall construction costs, which is equivalent to $329 savings per foot. Savings resulted from use of conservation alternatives for conveyance, detention, paving, and street design.

The largest cost savings across all built-site case studies were mainly derived from site preparation, stormwater management, site paving and sidewalks. Two conservation techniques appear to have the most direct and significant influence on cost savings: clustered site design and naturalized stormwater management systems.

Template Cost Analysis

These cost evaluations were prepared as a follow-up to the recent Blackberry Creek Watershed Alternative Futures Analysis project, where templates, or design models, were developed to illustrate the differences between conservation and conventional site design and stormwater management approaches. The templates were based on a hypothetical forty acre site in the Blackberry Creek Watershed in northern Illinois. This cost analysis compared the capital costs associated with developing a land parcel using a conservation design template versus a conventional one, using real unit-costs from the Midwestern development industry. The design templates were categorized by land use and reflected the same densities for both the conservation and conventional designs within each category. Conservation and conventional template costs were compared for four land-uses: moderate density residential, rural residential, estate residential, and commercial/industrial.

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For a Moderate Density Residential land use, overall capital cost savings from conservation were 15% of conventional. The conventional form exhibited wide roads, no public open space, storm sewers, and turf detention basins, whereas the conservation template had narrow streets, integrated natural stormwater system, clustering and open space.

Rural Residential Development cost slightly less for the conservation alternative. The conventional form included cul-de-sacs, drained with traditional roadside swales and culverts into a detention basin. The conservation alternative had narrower drives, naturalized stormwater system, trails and open space.

The Estate Residential Conservation template saved 40% of conventional costs. Both had the same cul-de-sac pattern, lot lines, and open swale systems. In the conservation alternative, natural areas beyond the building footprint were preserved or restored, and driveways shortened.

The Commercial/Industrial alternatives were nearly equivalent, except for a "premium" conservation alternative, which added a green roof, thereby increasing costs over conventional. The conventional form was an auto-access strip mall with two single-story big box retail, isolated outlets, parking and detention. The conservation template also had big box retails, but in a "main street" retail setting with plaza, permeable paving and bioswales.

A majority of the conservation template designs are cost competitive or even more economical than the conventional forms. Plus, the land-uses show a general correlation where, as density decreases, the percentage of capital cost savings for conservation design increases. The largest potential cost savings are in stormwater management infrastructure.

Cumulative Discussion and Recommendations

By looking across all three analyses, a set of common conclusions can be offered. Perhaps most importantly, these results contradict the notion that conservation design is always more expensive than conventional practices. Not only do the three analyses show conservation is cost-competitive, but they also raise many situations where conservation methods can save the developer significant expense that translates directly to their bottom lines. In terms of overall approaches then, a gentle footprint on the land will reduce construction costs. Clustering and minimal site disturbance go a long way to cut infrastructure costs significantly, especially for stormwater management.

These conclusions call out for significant consideration of conservation development across the spectrum of development forms. Yet, even in the light of these conclusions, it is critical to point out that favorable cost comparisons are only one reason to consider conservation development. Ecological and social reasons should also be considered and, while not components of this study, they can complement and in some cases may even outweigh cost considerations.

Given the wide variety of conservation approaches that can be used in isolation or combination, the analyses reveal that there is a continuum of choices; in other words conservation design is not all or nothing. A spectrum of approaches and mixes of conservation tools can be considered for every budget and every site. BMPs, such as rain gardens and infiltration trenches, are more easily adapted to suburban and rural development sites. Tools such as porous pavements and green roofs may be more appropriate for urban sites, where land area is at a much greater premium and cannot be utilized economically for stormwater detention basins.

Further research work is needed on several fronts. The next steps should include:

- Gathering and analyzing information on operation and maintenance costs of conservation development, where possible, using life-cycle cost analyses as a method of comparison to conventional methods.
- Taking into account systematically both cost and effectiveness in future analyses of conservation design alternatives.
- Analyzing conservation development costs in a higher-density context where tools such as porous pavement and green roof are generally perceived to be more competitive.
- Conducting more economic benefit studies that can provide information on the economic values obtained by conservation development, as guidance for planning efforts.

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Even where costs are competitive, incentives for conservation development should be offered by municipalities and governing agencies two reasons: 1) to help communities and developers overcome market inertia that can become entrenched, even when they have supporting information for change; 2) to enable financing mechanisms to pilot innovative approaches in new locations, especially as part of larger municipal stormwater management programs.

The project team recommends outreach and dialog with municipalities and developers. Use of the Internet could provide this cost information and new reports as they become available in the form of a clearinghouse for costs and benefits. Such a website could include a relational database that helps users tailor the information to their needs.

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Introduction

In 2002, Chicago Wilderness provided funding support to Conservation Research Institute (CRI) for a "Cost Analysis of Conservation versus Conventional Development in Northeastern Illinois and Northern Indiana." The project was motivated by the need to explore the potential roles for development as a risk to, and opportunity for, protection of biodiversity in the Chicago Region, and conceived specifically to provide information to support the implementation of the Chicago Wilderness Biodiversity Recovery Plan.

This report is unprecedented. Developers, local officials, policy analysts and staff members from several development consulting firms came together to advise the work of filling information gaps on the costs of conservation development. The advisors were of one mind that good development practices require good cost information placed in the hands of developers and municipalities.

Carefully implemented conservation developments are of interest to advocates for biodiversity conservation for a range of reasons. They can protect open space and natural areas, recharge groundwater, complement ecological restoration efforts with native landscaping, reduce downstream stormwater damage, and help preserve or re-establish historical hydrological regimes to which native species are adapted.

Across the country, municipalities face at least three stormwater-related problems with development:
1) Flood waters are an increasingly significant stressor on biodiversity and property. Rural and suburban areas that feel significant growth pressure face increasing environmental and property costs from the stormwater that accompanies that growth;
2) At the same time, through the 1990s, the costs of providing a cubic-foot of stormwater pond storage climbed by over 30% after inflation (Schueler and Holland, p. 401); and
3) Maintenance costs for traditional stormwater controls have become a significant cost burden for local governments and communities, in some cases equaling or exceeding the initial construction cost (Prince George's County (a), p. 4.5).

For developers, these bottom-line cost realities, understandably, can outweigh any marginal environmental improvements from alternative development methods as they consider their stormwater management choices. They need to act based on the cost realities of the available options.

This project tries to answer the questions: Does conservation development, which helps address the issue of environmental protection, have the potential to mitigate the problem of the high cost of development? Or does it exacerbate the current trend of rising costs, especially for stormwater management? Many advocates quote widely-used cost savings figures from specific pilot conservation developments such as Village Homes, in Davis, California (e.g., Browning and Hamilton). Such summary information has been trickling out through various avenues. But there has been very little detailed information to answer whether or not such savings are exceptions or the general rule. Developers and planners need to see data, assumptions, and analyses to judge whether or not it is worthwhile to consider alternatives to what have become standard practices.

Conservation Development, also called Low-Impact Development (LID), represents a suite of those alternative methods. The conservation approach addresses stormwater on-site by distributing the water across the landscape, thereby mimicking or restoring the historical hydrological regime. The result is a range of environmental benefits: groundwater recharge, improved surface water hydrology (i.e., less flooding and higher low-flows), improved water quality, habitat protection, and others. Yet cost-sensitive municipalities and developers are often reticent to try these approaches, in part, because of the perceived premium price tag for these fairly new methods.

On the other hand, engineered stormwater ponds are a popular conventional approach. While most people agree that some detention is better than nothing, conventional practices have sometimes shown negative environmental impacts not present with conservation tools, such as unnatural water temperatures, hydrological disruption, and loss of stream reaches and wetlands (Schueler and Holland, Article 79). This approach conveys water to storage areas where it can be detained long enough to dispose of into local streams and rivers at a legally-acceptable rate.

To compare the costs of conservation with conventional development, this project undertook three studies: a literature review, an analysis of built-site case studies, and a cost analysis of hypothetical conventional and conservation land-use development templates. This report presents all three products as separate chapters. The three analyses are followed by a discussion of some overall conclusions and recommendations for further work. Also included are a bibliography and several appendices with more detailed information relating to the three analyses.

To the extent possible, the three approaches focused attention similarly on both construction costs and operation and maintenance costs (where such costs were available). However, the information available for these studies differed substantially, resulting in different emphases in each product. The project concentrated as much as possible on information sources tailored to a Midwestern audience. This was not possible throughout the analyses, and national information was added, where appropriate, to increase the depth of analysis. A glossary is provided in Appendix 1.

This project did not compare the effectiveness of conservation and conventional development in meeting environmental goals. Rather, this report shines a spotlight on cost as a concern, so that perceptions about cost can be either confirmed or changed in order for municipal planners, designers, and developers to consider alternative methods. Also, several practices that address only water quality, such as sweeping and sand filters, are not covered in this report. Instead, the analyses are concentrated on Best Management Practices (BMPs) that have an impact on runoff rate and volume. This makes sense given our targeted audience, when the literature includes evidence for claims such as: "In general, about a third of every dollar spent on stormwater pond construction was devoted to water quality control, with the remainder spent on flood control storage." (Schueler and Holland, p. 401.) Also, because strategies to decrease runoff volumes are also effective in addressing water quality, a focus on hydrology has broad ranging benefits.

Yet, the effectiveness of each tool in pollution control also needs to be considered by municipalities and developers in addition to just costs. While water quality effectiveness is not covered by this report, there is growing evidence that many of the LID or Conservation Development alternatives to conventional methods can be equally or more effective in achieving water quality goals (e.g., Schueler and Holland, pp 515-520; Liptan and Brown; Schueler 2000).

The focus on costs also implies the team did not intend to deal comprehensively with benefits, although they are touched on occaisionally. Similarly, off-site costs and benefits to downstream interests and the broader community should be considered to complete the picture of comparison.

Also left out of this analysis is the cost of overcoming local misperceptions, reticence by zoning officials, and changes in ordinances that sometimes prohibit or at least discourage innovation. Today, in many places, many innovative tools cannot be utilized even if they are better and cheaper. Changing ordinances requires a steady stream of information on cost and environmental effectiveness of conservation techniques, as well as information on the many community benefits of these innovative alternatives. Both additional research and increased outreach to developers and municipal officials are needed to show that the tools work before anyone can revise the rules of the game.

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Literature Review

Regional Context and Approaches

A large body of smart growth literature from the past ten years compares costs of conventional, sprawling growth patterns to smart growth forms at the regional level. They show higher costs for the conventional patterns as compared to smart growth across watersheds and metropolitan areas. (For smart growth principles, see ICMA). Many reports describe the cost inefficiencies of sprawling development patterns in comparison with managed growth (e.g., Bank of America; Ewing, et al.; Hulsey; Burchell; Brabec, 1992). These studies generally focus on public infrastructure for roads and water, as well as municipal services, and do not delve into construction or maintenance costs of specific methods (for smart growth literature, visit www.smartgrowth.org).

For example, the Southeast Michigan Council of Governments compared resource consumption for current low-density sprawl versus compact development patterns at the scale of multiple communities within a metropolitan context. Costs compared are not site-specific technologies, but at a broad level of analysis for population, housing, and broad infrastructure trends. Infrastructure savings from compact development were estimated at 25 percent for roads, and 15 percent for utilities, including water supply and sewer. (SEMCOG).

Some literature points to immense cost savings of implementing conservation techniques at this regional scale (US Water News). For example, in the Atlanta metro region, 20 percent loss of trees and natural vegetation, and their replacement with urban manmade structures, produced a 4.4 billion cubic foot increase in stormwater runoff. It would cost at least $2 billion to build containment for this amount of excess water.

Notably, some conservation developments pay close attention to site aspects only to miss taking advantage of smart growth principles in terms of where the development is located at a regional scale.

At the municipal scale, Bellevue, Washington considered on-site techniques as components in their system-wide stormwater management approaches. They decided to "augment natural drainage systems to handle urban stormwater, rather than build extensive new underground piped systems." The City estimated its open space system, which uses on-site methods applied across the whole watershed, cost the City 75% less to construct than underground storm sewers (Girling).

Other cities have also recognized the value of open space preservation for stormwater management at a regional level. The potential for cost savings over enhancements to highly engineered systems is not lost on financially-strapped local governments. The City of Milwaukee has been identifying and protecting open spaces that can prove helpful in this regard. (O'Leary).

Regional Context Conclusion

The literature describes higher costs for public infrastructure, when built within the context of urban sprawl, as compared to smart growth development patterns.

Site Context and Approaches

The site component generally refers to the placement of buildings, how the site is managed, and the consequences of those decisions. A traditional development layout often spreads the buildings equally across the landscape, and primarily applies turfgrass everywhere in between. Conservation development tends to cluster the buildings in one area to minimize the disturbance to the site as a whole. Clustering and open space management are often used interchangeably in the literature. Building in this manner provides perhaps the largest cost savings of all the conservation tools. The differences between clustering and traditional site layout receive more attention in the smart growth literature than any of the other techniques analyzed here. There are two basic cost-saving themes: 1) Clearing and Grading, and 2) Infrastructure and Services, with a good deal of literature discussing the cumulative savings that can occur.

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Clearing and Grading

Citing earlier work, Schueler and Holland claim that cluster development can reduce the need to clear and grade by 35 to 60 percent from the upper range of conventional costs, and provide $5,000 per acre in savings from erosion control at the same time. (Schueler and Holland, p 174). A USEPA case study corroborates this view. By preserving natural existing site contours, clustering decreased site preparation costs and at the same time reduced need for stormwater control measures. (USEPA(b) p. 24).

Infrastructure and Services

The Center for Watershed Protection (CWP) used a simple model to compare several conventionally-built sites with a redesign of the same site using better techniques (preserving more open space). The techniques used in the redesign resulted in reduced impervious surface area and therefore reduced stormwater amounts. Total infrastructure costs included stormwater management, storm drainage, paving, sidewalk, curb and gutter, landscaping and reforestation, water, sewer and septic systems. (Sanitary sewer and water supply costs savings are explored further in the built-site and template cost analysis.) The biggest cost savings came from the use of clustering, with the resulting reduction in road and stormwater management conveyance costs. Estimated infrastructure cost savings ranged between 12% and 64%. (Zielinski, et al, pp. 202-203). The following table illustrates this point:

Residential Development	Construction Savings (%)	Notes
Remlik Hall [1]	52	Includes costs for engineering, road construction, and obtaining water and sewer permits
Duck Crossing [2]	12	Includes roads, stormwater management, and reforestation
Tharpe Knoll [3]	56	Includes roads and stormwater management
Chapel Run [3]	64	Includes roads, stormwater management, and reforestation
Pleasant Hill [3]	43	Includes roads, stormwater management, and reforestation
Rapahannock [2]	20	Includes roads, stormwater management, and reforestation
Buckingham Greene [3]	63	Includes roads and stormwater management
Canton, Ohio[4]	66	Includes roads and stormwater management
CWP(a). Cited Sources: [1] Maurer, 1996; [2] CWP, 1998; [3] Delaware DNREC, 1997; [4] NAHB, 1986		

TABLE 1. Estimated Infrastructure Cost Savings Between Conventional and Conservation Developments

By reducing road lengths, clustering means that costs for utilities such as gas, water and electricity can also be decreased. Maintenance costs would decrease correspondingly (CWP, 1998, p. 99; Brabec, 1992; Dreher and Price, p. 48). Schueler and Holland estimate that cluster development can reduce the capital cost of residential subdivision development by 10-33% by reducing the length of infrastructure needed (citing NAHB 1986, Maryland Office of Planning 1989, and Schueler 1995).

Summarizing the work of others, Schueler states that at least 60% of development costs are variable, related directly to the length and layout of roads. The result is that clustering large-lot developments saves 25% or more (the size was not specified), with smaller savings of 10% when smaller (e.g., half-acre) lots are clustered (Schueler, 1995, p. 64).

By minimizing natural-area clearing and grading, clustering also saves in stormwater management costs through decreasing the volume of runoff generated. The literature supports the idea that such savings are amplified when other conservation methods are used in tandem. When a cluster project combines such infrastructure savings with the results from clearing and grading, and other conservation tools, the benefit to the bottom line can add up. Dreher and Price make this point, also citing the NAHB 1986 report. They point to a case study where 34 percent savings were achieved when combining costs of a whole suite of development components: street pavements, curbs, gutters, trees, driveways, drainage, water distribution, sanitary sewer, grading, clearing, sidewalks for a site in Ohio (Dreher and Price, p. 49).

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Similarly, according to the Stormwater Center's Open Space Design Fact Sheet, benefits from clustering, or open space design, "can be amplified when it is combined with other better site design techniques such as narrow streets, open channels and alternative turnarounds."

Maintenance

Maintenance costs for clustering should also be lower because of reduced infrastructure, lawn areas, streets, etc. (Dreher and Price, p.49). However, no literature was found that compares specific maintenance costs between conventional and conservation methods at the site level.

Site Context Conclusions

At the site level, the literature points to significant cost savings from clustering for clearing and grading activities, as well as for the costs of supplying infrastructure for stormwater, transportation, and utilities.

Best Management Practices

Landscaping

One of the clearest distinctions made between conventional and conservation methods is in the landscape forms they employ. Conventional landscaping generally implies site design and preparation (e.g., grading) to enable the use of turfgrass lawns, while conservation landscaping implies preservation of any existing natural areas and installation of native landscaping instead of lawns. Schueler and Holland cite a 1992 WHEC study showing corporate land owners can save between $270 to $640 per acre by reserving their open lands for natural areas instead of turfgrass campuses. But even where preserving natural areas is not an option, currently-available information points to cost savings obtained for both installation and maintenance of native landscaping.

Installation

Some detailed cost information is available for the Midwest. In 2001, Conservation Design Forum (CDF) compared the installation costs for 10 acres of corporate landscape with native landscaping versus traditional turf-based landscaping methods. That comparison breaks out specific labor, materials, monitoring, and design costs:

	Sustainable (Native)	**Traditional** (Turf)	**Note**
Up-Front Installation	$141,000*	269,000	The difference is mostly in direct construction costs that include grading, irrigation system, etc.

TABLE 2. Installation Cost of Native versus Turf Landscape at 10 Acre Corporate Campus (2001)
*No ranges were provided. The figures were based on estimated values using the firm's unit cost experience with landscaping projects. This information is not published, but is posted in detail at www.cdfinc.com

NIPC's 1997 natural landscaping report also provides a set of estimates to compare the costs per acre of turf-grass landscapes to native landscaping. This information was recently updated (see Appendix 2 for more detail). The sources are all local suppliers of natural landscaping services, and they agree that turf grass is more expensive for both installation and maintenance costs than more native systems. However, the direct experience of one developer reached for comment contradicts these conclusions. The difference perhaps is in assumptions about irrigation. For residential sites that do not include irrigation systems, seeded turf may be competitive, but for highly maintained corporate or residential landscapes that require irrigation systems to achieve a certain level of turf quality, native landscaping should be more cost competitive. Further analysis of assumptions and site-specific case studies is warranted.

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Year 1 Dollar Costs Per Acre*			
Landscape Treatment	**Low End Estimate**	**High End Estimate**	**Note**
Turf Grass	$7,800	$14,825	Depends upon 1st year maintenance assumptions
Native Landscaping	$3,400	$5,975	Depends upon use of seed versus plugs, & 1st year maintenance assumptions
Difference (Savings from Native Landscaping)	$4,400	$8,850	

TABLE 3. Year 1 Installation Costs for Native versus Turf Landscapes (1997)
* Sources: Conservation Design Forum, Applied Ecological Services, Pizzo and Associates, through the Northeastern Illinois Planning Commission, 2004.

Maintenance

CDF's 2001 cost comparison of corporate campus landscapes also provided a comparative estimate of longer-term maintenance costs for ten acres:

	Sustainable (Native)	**Traditional** (Turf)	**Note**
Ten Years Maintenance Total	162,000	315,000	Native is slightly less in first 5 years. Significantly less thereafter, as site is more established. The only significant long-term management expense is annual burning.

TABLE 4. Total Long-Term Maintenance Costs for Native versus Turf Landscape (2001)

The NIPC sources provided a similar set of maintenance cost estimates (see Appendix 2 for details) over a series of years. The numbers fluctuate from year to year, depending upon the assumed activities (e.g., burning, aeration, and other scheduled maintenance). However, when looking at their numbers over the entire 10 years, they are surprisingly similar. They are averaged below:

10 Year Average Maintenance Cost per Acre*		
Landscape Treatment	**Low End Estimate**	**High End Estimate**
Turf Grass	$5,550	$6,471
Native Landscaping	$1,600	$1,788
Difference (Savings from Native Landscaping)	$3,950	$4,683

TABLE 5. 10-Year Maintenance Costs for Native versus Turf Landscapes
* Sources: Conservation Design Forum, Applied Ecological Services, Pizzo and Associates, through the Northeastern Illinois Planning Commission, 2004.

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These documents and others attribute the lower maintenance costs for native landscapes to a number of factors, including higher maintenance costs for turfgrass landscapes because of the need to mow, irrigate, fertilize, and weed. Those costs generally include labor and materials. (See also CWP(a); Dreher and Price; USEPA(a).)

Landscaping Conclusions

NIPC's cost analyses show that installation costs can be between $4,400 and $8,850 cheaper per acre for native landscaping than for turf grass approaches. A ten-year average savings for maintenance ranges between $3,950 and $4,683 per acre per year for native landscaping approaches over turf grass methods.

Streets and Parking

The cost difference for streets and parking requires a little more explanation than for landscaping. Impervious surfaces are an inevitable part of all but the most innovative developments. However, conservation development techniques minimize the impervious surface areas of streets, sidewalks, and parking through 1) better site design, and 2) alternative materials. The direct cost implications relate to these two factors.

Designed Layout

The first comparison found in the literature is between the layouts of conventional designs and conservation design, which minimizes the amount of impervious surface by reducing the size or amount of roads or parking, Several conservation methods can decrease the square footage or area needed in pavement, thereby decreasing costs noticeably, regardless of the materials used. The conventional cost to treat an acre of impervious surface runoff for both quality and quantity can range from $30,000 to $50,000. So, by reducing impervious surface area, clustering can reduce costs for stormwater conveyance and treatment. (Schueler and Holland, pp174-7, 404-5). However, this strategy is not limited simply to clustering. It can also include designs that challenge the necessity of certain road widths and number of parking spaces.

Smart Growth and New Urbanism advocates claim that narrower roads can be designed to accommodate traffic and address safety concerns and emergency vehicles. Narrower pavement widths can also reduce impervious surfaces reduction and assist with traffic calming (Burden and Zykofsky).

Dreher and Price describe some of the cost savings from decreasing the lengths and widths of streets, driveways, and sidewalks. If the width of a typical residential street installation, which costs $20 per square yard, was reduced from 34 feet to 26, the cost savings would be $94,000 per mile, or $500 per 60-ft-frontage residence.

Similarly, a typical driveway installation is $13,000. Reducing the driveway length from 30 to 20 feet would save $230 per residence, based on a 16 foot width. Plus, reducing building setbacks lowers the length and cost of utility lines, especially for water and sanitary sewer services. Finally, when a typical sidewalk installation is $3.00 per square foot, reducing sidewalk width from five to four feet saves $180 per lot. Combined, these would save $910 per lot (Dreher and Price, p.40).

Such cost savings are also described in CH2M-Hill, 1993; Schueler, 1995; Schueler and Holland; CWP(a); USEPA(a), and USEPA(b). Again, when impervious cover is reduced by layout design, cost savings accumulate, not only in road-building, but also in storm drainage, and water/sewer service.

Reducing the number of parking spaces in a particular area will also reduce impervious surface. One case study showed that the required parking lot area for an Iowa City Shopping Center was only 74% full at its peak occupancy rate just before Christmas (USEPA(a), pp 50 – 51). By re-examining the assumptions and presumed needs for conventionally planned parking facilities, the Center for Watershed Protection finds that reductions in the office-parking space ratio are often justified (CWP(a), p. 63). Shared parking facilities are possible with mixed use developments where peak parking demand varies between uses. The savings from constructing a smaller lot can be significant. The cost of a single parking space can be $1,100. Additional costs savings would also accrue from lower storm drain, BMP, and land costs (Schueler 1995, p. 167). When maintenance is included, lifetime savings for each parking space eliminated can be $5,000 to $7,000 per space. (from CH2M-Hill,1993 in Schueler, 2000 Schueler and Holland, p. 175).

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Materials

Conventional surfacing materials for roads and parking lots generally include asphalt or concrete. The conservation alternative is a range of porous pavement products that contribute to on-site water management. A simple comparison of these alternatives in the literature shows that conventional paving, most explicitly asphalt, is significantly cheaper per linear foot, or per acre, than porous paving.

Paving System	Installation costs per square foot (quotes from suppliers)
Asphalt	$0.50 - $1.00
Porous concrete	$2.00 - $6.50
Grass/gravel pavers	$1.50 - $5.75
Interlocking concrete paving blocks	$5.00 - $10.00

TABLE 6. Typical Paving Costs. Low-Impact Development Center (LIDC), 2002. Definitions were not provided.

Several sources raise the question of indirect cost implications – in this case, whether or not the material choice can contribute to cost reductions elsewhere on the project. When porous paving is used, the size of required stormwater detention facilities can be decreased. A smaller basin can then be built, thereby saving construction costs while making more land available for other uses (LIDC, 2002). Likewise, conveyance costs can be reduced, helping to offset the cost of porous paving choices further. (CWP, 1998, p. 77; USEPA(d), p. ii). LIDC describes even more potential savings by eliminating the need for underground storm drain pipes.

According to the LIDC, porous asphalt costs about 10% more than non-porous, yet it helps total costs decrease by 30% at favorable sites. So, when all factors are considered together as a system, permeable pavers can become cost-effective. (LIDC, 2002).

Paving System	Installation costs per square foot (quotes from suppliers)
A permeable paver stormwater management system (including drains, reinforced concrete pipes, catch basins, outfalls, storm sewer connections)*	$4.50 – 6.50
A conventional concrete stormwater management system. (including drains, reinforced concrete pipes, catch basins, outfalls, storm sewer connections)	$9.50-11.50

TABLE 7. Cost Comparison between Permeable Paving and Concrete Paving.
*(Presumably, less storm sewer infrastructure is needed in this system)

Operations and Maintenance

This is yet another category where little information exists in the literature, and the gap is often acknowledged.

Roads and Streets

Deductive reasoning was evidently applied in a few documents to make the point that less impervious surface means less direct maintenance of those remaining surfaces, and less cost for ongoing stormwater management as well. For example, USEPA claims there will be less maintenance and repair cost for roadways in their case study because of the lanes being reduced from four to two (USEPA(b), p. 34.)

Likewise, maintenance regimes for materials are only briefly mentioned (e.g., England; CWP(a), p. 90). Porous pavement should receive annual cleaning with a vacuum truck to unclog it from dirt and oil. Also, periodic replacement of fine gravel joint filler is recommended between pavers. However, no cost comparisons are made here.

The Stormwater Center's Alternative Pavers fact sheet compares maintenance costs for several alternatives (without explanation):

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Material	Maintenance Cost
Conventional Asphalt/ Concrete	Low
Brick (in a loose configuration)	Medium
Natural Stone	Medium
Gravel	Medium
Wood Mulch	Medium
Cobbles	Medium

TABLE 8. Cost Comparison for Paving Maintenance. (Stormwater Center, citing the Bay Area Stormwater Management Agencies Association)

Rocky Mountain Institute provided a parking lot case study at a Connecticut mall expansion. With a one-million dollar estimate for a conventional detention pond, the builders instead used turf paving and an underground tank for water reuse. This technique was more expensive than asphalt for construction, but avoided the need for the original detention pond, saving $500,000. Plus, the grass paving and asphalt were equal in cost after five years, with the cost advantage tipping to grass beyond five years (Wilson, et al., p. 144).

There are some perceptions that permeable surfaces are difficult to maintain. For example, some have voiced concern about the ease of plowing snow on porous pavement. The current literature does not clearly address these concerns.

Streets and Parking Conclusions

Better site design can lower paving costs by reducing the length and area of impervious surfaces within a development. Conventional materials, however, are less expensive per unit than permeable paving. Yet, the use of porous materials can help total development costs go down, sometimes by as much as 30 percent, by contributing to conveyance and detention cost reductions.

Water Conveyance: Swales Versus Curb and Gutter

The search results for literature dealing with conveyance costs shows more obvious examples of savings. Here, the primary distinction is between the use of bio-swales in conservation development instead of the more conventional curb, gutter, and sewer pipe. The Stormwater Center's "Stormwater Management Fact Sheet: Grassed Channel" describes the conservation approach:

> The term 'swale' (a.k.a., grassed channel, dry swale, wet swale, biofilter) refers to a series of vegetated, open channel practices that are designed specifically to treat and attenuate stormwater runoff for a specified water quality volume. As stormwater runoff flows through the channels, it is treated through filtering by the vegetation in the channel, filtering through a subsoil matrix, and/or infiltration into the underlying soils.

All the literature reviewed argued that conveyance by swale is cheaper than curb, gutter, and storm sewer. The qualification is that *where* they are used can significantly change the cost because of land values. In addition, bio-swales will have an added water quality benefit from filtering by the plant material. Piped conveyance systems do nothing to treat stormwater runoff.

Construction

According to both Fan et al., and Backstrom et al., swales are not necessarily practical in more urban settings. Costs will vary depending upon the price and availability of land. Land prices make swale systems more viable in areas where land prices are generally less than $9.70 per square meter. However, if swale alternatives can be accommodated within existing landscaping requirements, then the cost of land is irrelevant.

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Backstrom et al. compared swale and pipe systems in Europe and showed pipe systems to be 34% to 80% more expensive than swale systems in areas with poor topsoils. The study compared stormwater pipe buried beneath a paved surface versus a grassed swale close to a paved surface. Curb and gutter components were not part of this analysis, which started from the inlet. Including curb and gutter would add even more cost to the conventional system. Pipe system costs included excavation, pipe, stormwater inlets, and pipe trench. Land costs were not included. Results showed:

- pipe system – previously undeveloped areas - $79/meter (or $24/foot)
- pipe system – replacing another pipe -- $106/m ($32/ft)
- swale system – poor soil area -- $59/m ($18/ft)
- swale system – good soil -- $17/m ($5/ft)

Estimates from EPA show seeded swales averaged $6.5 per linear foot, while sodded swales averaged $20 per linear foot. Capital costs for a swale or filter strip include mobilization, site preparation and development, inlet and outlet structures, design, legal and contingencies. (Ferguson, et al.)

On the other hand, a traditional structural conveyance system (curb and gutter with stormdrain inlet and pipe systems) costs $40-50 per running foot, 2-3 times more expensive than grass swales (USEPA(d), p. 7; CWP(a), p. 59). These reports undoubtedly used different methodologies and assumptions, but the rough comparison agrees with other literature.

USEPA's North Carolina campus case study shows construction cost savings added up to $500,000 by using grassy swales, water quality ponds and bioretention instead of curb and gutter with oil grit separators. (USEPA(b), p 34.)

More locally, Dreher and Price also argued that roadside swales with culverts at crossings are less costly than curb/gutter/sewers, but that the cost differential is reduced with more crossings. For a typical residential subdivision with ½ acre lots in Lake County, Illinois, the construction savings was estimated to be $70,000 per mile, or $800 per residence. But, while construction time is less, the vegetation may need more time to get established (Dreher and Price, pp. 14-15).

The literature sometimes blurs the distinction between conveyance, retention, and detention, especially in conservation developments which combine design elements that play multiple roles. This is discussed more under Detention and Retention (see below).

Maintenance

Dreher and Price also posited that the maintenance regime is probably less for swales than curb, gutter and sewer systems. And Backstrom agreed that pipe systems cost more for maintenance. In its fact sheets on vegetative practices, the Canada Mortgage and Housing Corporation provided the same perspective, noting that vegetative BMPs are cheap to establish and maintain, and that grassed swales are more economical than curb and gutter from both capital and operations perspective. Unfortunately, the maintenance literature for conveyance seems to be limited primarily to a handful of anecdotal claims.

Dreher and Price reported that replacement costs are virtually non-existent for swales -- that they generally do not need replacement. However, some professionals disagree with this view, claiming the eventual need for rehabilitation (personal communication with advisory team members). Culverts will occasionally need to be replaced, although the cost is typically borne by the property owner. Storm sewers may need replacement after roughly 100 years and curb/gutter/inlets every 50 years.

Today, the field is experiencing a further shift in innovation with the distinction between turf grass swales, and naturalized, or bio-swales. In rural settings, grass swales are the standard in actual practice, and the conservation alternative is naturalized swales, moving away from turf grass to more native species (personal communication with CDF). This distinction was not found in the literature, nor was there any cost information on naturalized swales. It is reasonable to presume that grass swales and naturalized swales compare similarly for construction and maintenance costs to the comparison between native landscaping and turfgrass lawns.

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Conveyance Conclusions

The literature holds a significant degree of agreement that swale conveyance is cheaper than pipe systems, by some claims as much as 80 percent.

Retention and Detention

Separating out this function from conveyance is problematic because numerous methods accomplish both purposes at once. Because purposes are blurred between retention, detention, infiltration, and conveyance tools, the literature shows that there is, in fact, a continuum of approaches to detention/retention, from conventional to conservation. The conservation end of this continuum emphasizes more on-site retention, infiltration, native plants, and constructed wetlands used in combination with other tools. The other end is characterized by collection and conveyance to larger centralized stormwater detention basins systems.

The difference between conservation and conventional methods for this category stems largely from their different purposes. This difference is not expressed well in the literature reviewed for this study. Conventional water management treats stormwater as a nuisance or waste which needs to be disposed of as quickly as possible, as allowed by regulation. The conventional method temporarily stores the stormwater and moves it offsite and into the local watershed in accordance with the acceptable discharge rate.

Conservation methods, on the other hand, manage stormwater as close to the source as possible. These techniques restore or mimic natural hydrologic patterns, where stormwater has a chance to infiltrate into the ground or evapotranspirate through plant life back into the atmosphere. Generally, this means incorporating several tools throughout a site that will greatly decrease or even eliminate the need for conventional detention or retention facilities. For example, bioretention or rain gardens are sometimes installed as a system together with bioswales, porous pavement, green roofs, natural landscaping, and other methods to slow, cleanse, infiltrate, and evapotranspire stormwater. Bioretention is a conservation approach that relies on plants for added efficiency in retention, for infiltration and transpiration, as well as cleansing. Typical bioretention methods include naturalized swales with or without infiltration trenches, constructed wetlands, rain gardens, and green roofs.

A great deal of literature compares conventional methods with each other, but it does not include conservation approaches. Further complicating these comparisons in a significant amount of literature is that they use units of measurement not easily comparable, and in regions not necessarily comparable (e.g., the cost of an acre-foot of detention storage in Maryland cannot easily be compared with the cost of a linear foot of swale in the Midwest). Few studies, if any, compare costs across the whole continuum of alternatives. Different assumptions and unit measurements make comparisons between studies difficult.

The combination of tools and overlap of functions contributes as well to the difficulty of comparing costs by discrete tools, and that is reflected by the brevity of sources in the literature. Instead, the literature has several examples of site-specific, whole-system comparisons, which are discussed below.

Not surprisingly, the complexity of this issue results in different cost conclusions across the literature, often without enough explanation to draw conclusions between studies.

Construction

Only a few studies claim explicitly that conservation alternatives cost less than conventional approaches. For example, according to Dreher and Price, a natural wet bottom detention basin should cost less than a conventional wet basin. Conventional basins use riprap ($11/ft) for shorelines, naturalized basins uses perennial plantings ($1.5/ft). Wetland shelves can reduce excavation costs, $35, 000 in savings was shown in one study for a 40-acre residential development. Overall estimated costs (minus land) for constructing a naturalized wet detention basin is about $22,000 per acre-foot of active detention storage. A natural design could save approximately $275 per household for a wet basin in a 40-acre residential development. Costs for constructed wetland or dry bottom basins are less than for wet bottom basins because permanent pools require more excavation. The cost of constructing a shallow marsh wetland detention basin is $17,000 per acre foot of active detention storage. The estimated cost to construct a dry detention basin is $7, 200 per acre-foot, not including cost of underdrains which are sometimes required. Dry basins cost less to excavate, but need more land area due to the volume lost to the 2% bottom slope –

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approximately 50 percent additional land, relative to a wet or constructed wetland detention basin. So, depending upon land costs, a constructed wetland basin may be less than or equal to cost of a dry basin.(Dreher and Price pp. 20-21)

However, more documents concentrate on the indirect cost savings of conservation retention, especially in terms of reduced pipe and sewer costs. The main point is that bioretention reduces the need for storm sewers, so retention cannot be examined in isolation, but must instead be analyzed in combination with conveyance costs. While a common perception may be that onsite management is more expensive than management offsite at a regional facility, bioretention facilities and other onsite facilities can significantly reduce the need for storm sewers, thus reducing stormwater infrastructure costs. (CWP, 1998, p. 88)

Other reports support this, arguing that the construction of bioretention and rain gardens costs less than conventional methods (e.g., CWP(a) p. 88; Hager; Liptan and Brown) because of savings in conveyance infrastructure. A case of bioretention at a medical office in Prince George's County reduced the amount of storm drain pipe required from 800 feet to 230 feet, thereby saving $24,000 (50%) of overall drainage costs (USEPA(d), p. 5).

Hager claims that bioretention's overall LID costs are at the most equal to conventional stormwater management. She describes a case where planned storm sewers and detention ponds would have cost $300,000 more than the rain gardens that were used instead. The savings were due to the elimination of curbs, sidewalks and gutters.

But cost savings vary widely depending upon site conditions. Greater efficiencies are achieved when bioretention is integrated into the landscaping. For residential and commercial sites, 10 to 25% savings have been achieved (Coffman and Winogradoff, p. 263). Other lot-level approaches that use bioretention have shown cost reductions of 25-30% in decreased site development, stormwater fees, and residential site maintenance. And the Somerset development in Maryland installed rain gardens whose implementation cost of $100,000 compared to $400,000 for planned detention ponds (Hager).

Some literature conflicts with this lower-cost message about conservation forms. Stormwater Center fact sheets claim extended detention wet ponds are the most cost effective ($0.96 per cubic foot storage), with bioretention more expensive ($6.80 per cubic foot storage). However, the fact sheets do not provide enough information to judge the accuracy of this view, and the comparison is limited to specific detention tools, not whole-site designs.

Such lower-cost claims for conventional ponds are based generally on economies of scale arguments, i.e., the bigger the pond, the cheaper per unit of storage. In 1996, the Center for Watershed Protection surveyed 73 stormwater practices in the Mid-Atlantic area for cost information, gathering estimates from 14 private engineering firms and public agencies in Maryland and Virginia. In comparing 41 different pond systems, both dry and wet, with bioretention, they concluded that ponds do have economies of scale, whereas bioretention areas do not; they are sized based on a flat percentage of site area. Unfortunately, that study did not actually compare the costs of these two techniques, and different units were used to describe both. While the paper concludes that ponds are the most cost-effective option for stormwater quantity and quality control, it also stresses that ponds are not effective for smaller sites, where needed detention often has to go underground. (Schueler and Holland, pp. 401-405).

As with conveyance, bioretention may be placed in underutilized spaces such as setbacks, parkways, and traffic islands, and allowing the inclusion of other features to property or development of space that would otherwise have been dedicated to a stormwater pond (CWP(a), p 88; Stormwater Management Center Bioretention Fact Sheet).

All these sources also acknowledge the point made earlier, that overall savings result from looking beyond the comparison of retention/detention tools by themselves.

The US Department of Transportation (USDOT) lies in-between the two extremes of cost conclusions. The Department compares costs for stormwater BMPs in urban settings or areas directly connected to roadways. While lacking definitional clarity, this report shows bioretention to be comparable to detention ponds in capital costs. However, some of this chart contradicts information elsewhere in the literature (e.g., porous pavement is generally not considered to have low capital costs).

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BMP	Capital costs
Infiltration trench	Moderate to high
Infiltration basin	Moderate
Bioretention	Moderate
Detention ponds	Moderate
Wetlands	Moderate to high
Veg swales	Low
Veg filter strips	Low
Porous pavement	Low

TABLE 9. USDOT Costs for Stormwater BMPs.
Adapted from Young, et al, 1996; Claytor and Schueler, 1996; USEPA(c) and several others. The ranking conclusions were not explained. Only those BMPs that have an impact on quantity are listed here.

Maintenance

Conceptually, this report should include maintenance information as well as the expected life-span or effective life of the retention facility. Unfortunately, again, there is very little information comparing maintenance costs. Because low-impact development projects are often in pilot stages at this point, the full maintenance costs and lifespans have not been fully examined yet. The information currently available often consists of claims without citing rigorous study to support them, but a few sources do point to lower maintenance costs for some conservation methods. The Center for Watershed Protection, for example, claims that bioretention requires less maintenance when it is replacing detention basins with turfgrass (CWP(a), p. 88).

Also, the Canada Housing Information Center claims that operations and maintenance costs can be less than retention ponds and other conventional alternatives. Additionally, operations and maintenance costs for constructed wetlands, once established, can be lower than for the alternatives and are "generally less than $1,500/ha/year, including the cost of pumping, mechanical maintenance, and pest control."

Hager describes how lower bioretention costs often result from the owner paying for the maintenance. This raises the question of the consistency and quality of maintenance over time. Some LID site designs cost nothing for maintenance (e.g., maintaining existing sandy soils) but even when adding costs back in by adding bioretention, overall maintenance costs for LID are still equal to or less than conventional stormwater management.

No comparisons were found to claim that maintenance for conservation methods is more expensive than for conventional approaches. However, Stormwater Center fact sheets point out that infiltration basins have a fairly high failure rate when compared with other stormwater treatment practices, resulting in a shorter expected life span. Infiltration basin maintenance costs are estimated to be between 5 and 10 percent of construction costs, but dry extended detention ponds are estimated at 3 to 5 percent. The documents do not give a basis for these percentages.

USDOT's BMP comparison shows bioretention again to be comparable to detention ponds in O&M costs as well. However, their comparison shows a longer effective life for detention ponds than for bioretention. Swales and other bioretention tools are comparable to detention, and are listed separately, making it difficult to generalize from the findings.

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BMP	Maintenance	O&M	Effective Life*
Infiltration trench	sediment/debris removal	Moderate	5-10
Infiltration basin	mowing	Moderate	5-10
Bioretention	mowing/plant replacement	Low	5-20
Detention ponds	annual inspection	Low	20-50
Wetlands	annual inspection/plant replacement	Moderate	20-50
Veg swales	mowing	Low	5-20
Veg filter strips	mowing	Low	20-50
Porous pavement	semi-annual vacuum cleaning	Moderate	15-20

TABLE 10. USDOT BMP Maintenance Cost Comparison.
*"Effective life" is not defined in the document, but it assumes "regular maintenance, occasional removal of accumulated materials, and removal of any clogged materials." (USDOT)

Retention/Detention Conclusions

Wetlands are raised in several publications as a BMP. But this literature does not generally distinguish between existing natural wetlands and constructed wetlands. Yet, from a biodiversity perspective, this distinction is critical. While society increasingly recognizes the value of wetlands, the biodiversity found in remaining natural wetlands will be lost if those wetlands are subject to inundation from polluted surface runoff for detention. Conservation Development stresses that natural area wetlands should be protected from increased runoff. The only "wetlands" that should be used as part of a stormwater management system are facilities specifically constructed for that purpose (personal communication with Conservation Design Forum).

The literature is not clear enough to resolve the cost differences between specific storage methods. Instead, it sends the message that costs of retention or detention cannot be examined in isolation, but must instead be analyzed in combination with conveyance costs. Except for a handful of sources that point to economies of scale for conventional detention, most claim that construction costs for bioretention are less than, or at the most the same as, conventional methods when factoring in the savings in conveyance infrastructure. There is almost no information comparing maintenance costs because low-impact development projects are still young and the full maintenance costs and life-spans have not yet been fully examined.

Roofing Systems

Because conventional roofs account for such a large proportion of imperviousness in more urban settings, they can provide a sizable contribution to stormwater runoff. Therefore, roofing alternatives can have a significant impact on the rate and volume of stormwater runoff. Green roofs, or vegetated roof systems, are a conservation alternative to conventional roofing that has been growing rapidly in the past five years. However, because of the infancy of the American green roof industry, there are only a handful of professional papers (in English) on green roof costs. A good deal of the existing information on green roofs is from the green roof industry itself. Nevertheless, there is enough information to make some observations. The green roof literature surveyed here covers climates from Singapore to northern Europe, Canada, and the Pacific Northwest.

Conventional roofing often consists of asphalt shingles for residential developments, and a membrane with gravel ballast for commercial roofs. A green roof generally consists of a light-weight growing medium over a drainage layer and waterproofing. Plant species are selected for their tolerance of the climatic extremes found in roof-top environments. The literature distinguishes between extensive roofs, which generally consist of low-lying, drought tolerant plants in a thin growing medium, and intensive roofs, sometimes called rooftop gardens, which have deeper substrates and more plant diversity, even to the point of including trees (e.g., Liptan and Strecker).

Installation Costs

Green roofs are generally more expensive to install than standard roofs. According to Liptan and Strecker, extensive green roof, or "ecoroof," costs are highly variable, from $5-12 per square foot for new construction and $7-20 for retrofits. They point out that standard roofs are also highly variable from $2-10 per square foot for new, and $4-15 for retrofitting. Scholz-Barth provides a higher estimate for extensive roofs in the US, from $15 to $20 per square foot. The cost difference is primarily from additional material needs over a conventional ballast roof and labor for the installation of those materials.

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In one of the few European articles in English, a five cm gravel layer is 5 Euros per square meter versus a 12 cm extensive roof layer, which approaches 20 Euros per square meter. (Giesel). Greenroofs.com explains that initial extra capital costs include structural preparation, soil media preparation, and planting.

While conventional roofing systems tend to be cheaper than green roofs for up-front costs, the green roof market in the US is quite young and construction prices are falling (personal communication with Conservation Design Forum; Scholz-Barth). As the market matures, and competition increases, it is reasonable to expect the upfront costs of green roofs to fall to more comparable levels.

Maintenance and Life-Cycle Costs

Initial, higher short term capital costs for green roofs can be offset most significantly through long-term energy and maintenance savings. A green roof can extend the lifespan of a roof membrane by two to three times (greenroofs.com). Wong, et al., computed a life-cycle cost analysis for extensive green roofs which supports this claim. Life-cycle costs for extensive green roofs, even without considering energy costs, are lower than those of exposed flat roofs in Singapore, despite higher initial costs. In Europe, Giesel calculates that, from a life-cycle perspective, a green roof prolongs the life of the sealing membrane from 20 to at least 40 years with a total savings in repair costs of 31,500EUR. Maintenance is primarily annual weed removal.

Intensive roof gardens require more irrigation and maintenance, so on-going costs tend to be greater than for extensive green roofs or standard roofs (Liptan and Strecker).

Other Benefits and Cost Offsets

The indirect benefits of green roof systems mentioned in the literature can be so significant that they should not be ignored when comparing costs with conventional roofs. Liptan and Strecker, Scholz-Barth, and Greenroofs.com all describe multiple benefits – reduction of stormwater infrastructure needs, energy savings, mitigation of heat island effects, aesthetics, habitat enhancements, increased property value, and others. These benefits are hard to estimate and do not necessarily accrue to the developer.

Giesel describes extra cost savings in Germany that come from the effective thermal insulation effect of green roofs. But, the German example may not be indicative of the degree of savings from reduced energy use in the United States because energy costs are significantly lower here.

Giesel's life cycle analysis concludes that an extensive green roof saves about 30% of total costs over 40 years, when compared with a gravel roof. However, most of that cost reduction is due to savings in stormwater disposal fees, which are also more significant in Germany than the United States.

Wong, et al showed that, in Singapore, the project payback period was 10 years for extensive roofs, when energy savings was included. This stresses the importance of including energy savings in any life-cycle analysis. It also stresses the need for more locally-derived studies.

Reduced heating and cooling costs may point to niche markets that make more immediate sense for green roof installation. The National Research Council Canada suggests targeting hospitals and industries with high cooling costs.

Unfortunately, at the time of this literature analysis, there was not much rigorous information on these benefits. Many sources only listed such benefits without providing any quantitative support. However, any literature search attempted today should produce a new crop of studies, as information on green roofs seems to be rapidly expanding with real-world examples that highlight the benefits for a domestic audience.

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Roofing Conclusions

Green roofs are currently more expensive to install than standard roofing. Yet, costs are highly variable and going down. The literature also shows that green roofs have significant life-cycle cost advantages. For example, they can extend the life of the roof membrane by two or three times.

Discussion of Literature

Much of the literature warns that all costs are site-specific. Both cost and performance efficiency depend upon many site-specific variables, including soil types, climate, surrounding land use, cost of land and property values, regulatory requirements, other methods also in use, and a host of other factors. An ideal study might be to compare a specific set of alternatives and their costs for a suite of locations one site at a time. Are conservation costs calculated for covering the same size area as the conventional developments they are compared with? Are they at similar points on the urban-suburban continuum? No rigorous studies were found in the literature that have accounted systematically for these kinds of site variables. The built-site analysis, which follows, attempts to do this for a few cases.

The Blackberry Creek templates used in the template cost analysis (see below) did not include a higher-density iteration. Yet, denser urban and redevelopment situations can result in very different costs because of higher land prices and increased imperviousness for each site.

The literature search did not provide much comparative cost information either, for the higher-density context (a couple of exceptions are USDOT, and Sear and Bay). But where it is raised, land cost becomes the primary driver. In such a setting, several conservation development approaches, such as porous pavement and green roofs, may become increasingly relevant. Porous pavement can become cost-effective where underground vaults are the only alternative for stormwater detention. In such cases, rights-of-way are usually minimized, making space even more limited (USDOT, Section 2.2.4). When such expensive alternatives are being considered, conservation tools such as green roofs or porous pavement, which likely have higher first costs in a suburban setting, may become cost-competitive on first costs alone. According to Landphair, "when land costs and construction variations required to meet site conditions are factored in, costs can quickly escalate making some seemingly expensive solutions more cost-effective for a particular situation" (Landphair, p.91).

As reflected in the discussions above, specific conservation tools can have multiple economic effects by themselves. To review this point, the best examples are clustering and green roofs. Multiple cost savings are summarized in the following table:

Tool	Multiple Effects
Clustering (e.g., Schueler, 1995)	· Decreased impervious surface costs · Lower storm drain and sewer line costs · Less grading costs · less clearing · less erosion control · decreased lengths of utility lines · increased land value
Green Roof (e.g., Scholz-Barth)	· increased insulation · decreased heat island effect · decreased stormwater volumes and rates · decreased long-term replacement costs · increased property value · downsizing HVAC

TABLE 11. Economic Effects of Conservation Tools

Furthermore, as shown in the retention literature, comparing discrete tools can be misleading, even when accounting for their multiple effects. By combining multiple tools, such as clustering with native landscaping, bio-swales, and

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other practices, deeper cost savings can be achieved from the resulting opportunities to downsize significantly the infrastructure. Some are cheaper in construction only if used in concert with a suite of tools at a specific site. Zielinski describes how the cumulative benefits of site design can be impressive. But when techniques are applied together, the individual benefits of specific tools cannot be separated from the overall benefits of a complete site design. The literature is rich with case studies that underscore this point. For example, stressing the multifunctional nature and the cumulative benefits of their features, Coffman and Winogradoff present case studies that show at least 25%in reductions to site development and maintenance costs achieved by less grading, pipes, ponds, curbs and paving. Their Somerset example saved $4,500 per lot, or $900,000 overall by eliminating need for curbs, ponds, and drainage structures.

The Center for Watershed Protection (d) used four actual development sites to compare conventional and innovative design techniques. The first comparison was between two medium-density residential site plans for the same site (a typical Virginia Piedmont site) with the same number of units (108). One is a conventional design with uniform lots, wide streets, and a dry extended detention facility. The other is an "innovative" open space design that incorporates clustering, avoidance of natural features, buffering, shorter and narrower streets, bioretention with a wet extended detention pond, and minimization of turf and other features. The result showed a conservation benefit of about $300,000 (20%):

Costs	Conventional Design	Innovative
Infrastructure	1,390,198	992,780
BMPs	149,100	245,020
Landscaping/Reforestation	-- (??)	951
Total	1,539,298	1,238,751
Savings		$300,547 (20%)

TABLE 12. Medium Density Residential Comparison

Low density residential site designs were also compared for an eight lot development, typical of Maryland's Eastern Shore. The conventional design included large lots, septic, no open space, wide streets, curb and gutter, turf. The innovative design included clustering, sharing septic fields with sand filters, sharing driveways, bioretention and dry swales.

Costs	Conventional Design	Innovative
Infrastructure	102,769	77,768
BMPs	2,421	16,502
Landscaping/Reforestation	2,363	960
Septic	36,000	31,200
Total	143,553	136,430
Savings		$7,123 (5%)

TABLE 13. Low Density Residential Comparison

Retail designs were also compared for a site with two large retail stores, another retail space, a gas station and a bank. The conventional retail center is a strip development, with large paved parking areas. The innovative alternative preserves open space and reduces impervious cover, with fewer parking spaces, pervious overflow areas, and buildings positioned to reduce walking distances.

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Costs	Conventional Design	Innovative
Infrastructure	708,064	643,452
BMPs	72,000	100,556
Landscaping/Reforestation	2,388	2,263
Total	782,452	746,270
Savings		$36,182 (5%)

TABLE 14. Retail Comparison.

Designs for a commercial office park were also compared. Again, the site was typical for the Chesapeake Bay watershed. 12.2 acres held two five-story buildings covering 1.37 acres. The conventional building was surrounded by parking, with almost no natural open space, and two stormwater detention ponds. The innovative design moved buildings closer to the road, reduced the parking space ratio and the number of spaces (because of transit nearby). Overflow parking was designed with porous paving. Bioretention and dry swales were used in combination with a wet retention pond.

Costs	Conventional Design	Innovative
Infrastructure	856,242	631,164
BMPs	88,441	153,859
Landscaping/Reforestation	4,217	3,409
Total	948,900	788,432
Savings		$160,468 (17%)

TABLE 15. Commercial Comparison.

These holistic examples would probably save even more than indicated, because the comparisons did not include grading, erosion and sediment control costs, which are anticipated to be less for conservation approaches.

In an often-quoted paper, Liptan and Brown presented several holistic site comparisons for conventional versus low-impact, or what they refer to as "water-quality" designs, for estimated or actual construction cost savings. The following chart summarizes these case studies, which illustrate the combinations of tools in site-specific conditions.

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Case Study	Conventional	Water-Quality	Savings
6-Acre Commercial Parking Lot	Landscape medians designed to shed runoff.	Landscape medians re-designed as swales to accept runoff and filter pollutants. Eliminated manholes, pipes, trenching and catch basins.	About $78,000
2-Acre Light Industrial Site	Site built with mounded medians and landscapes, pipe, catch basins, curb and gutter to convey runoff into city storm drain system.	Water Quality site plan included bioswales and depressions instead of mounds, regrading to drain pavement into bioswales, reduction of catch basins, roof configuration to drain into bioswale, native vegetation.	Over $10,000, despite higher excavation costs.
Residential Community (Village Homes)	Conventional approach with curb and gutter, piping, catch basins.	Meandering vegetated swales feeding into a city detention pond.	$800 per unit
2-Acre Office & Parking Garage	Inlet and pipes.	Landscape Swales.	0 (equal cost)
3.2 Acre Office and Parking lot	Catch basins and pipes.	Reduced piping and catch basins, conversion of landscapes to swales.	$24,000 or 71%
2.2 Acre Educational Facility & Parking	Piping, catch basins and mounded landscape.	Swales with minimal piping and catch basins.	$21,000 or 68%
Four row houses on 0.2 acres	Soakage trench with catch basin and piping to city storm drain.	Smaller trench and catch basin in front, adding landscape filtration area in rear of lot.	$4,000 or 44%
5-acres with 31 homes + 3 acres riparian area	Significant piping and some bioswales.	Open channel bioswales replacing piping for conveyance.	$21,000 ($680/unit, 27%)
One acre parking lot	lot sloping to drain through catch basin and pipe to an on-site infiltration drywell. $10,000 added costs.	Drainage to perimeter landscapes designed to accept water and allow infiltration. No added costs.	$10,000 or 100%

TABLE 16. Cost Comparisons for Conventional versus Low-Impact Developments

Although detailed evidence is lacking, conservation tools often compare favorably in the literature from a Life-Cycle Analysis perspective (e.g., USEPA(e); USEPA(g); Prince George's County(a); Wilson). One notable exception is the infiltration basin, described previously. Because of the reliance on natural areas and native plantings, maintenance costs can be significantly low for some of these techniques.

For maintenance costs, Liptan and Brown chronicled a six-acre commercial parking lot facility that includes maintenance of swales as part of their landscape costs and resulted in no more costs than for other areas. However, some poorly-constructed curb cuts required modification. And for a two-acre light industrial site, they estimated conventional and water quality approaches to be about the same. The water-quality approach would have reduced costs for catch basin inspections and maintenance, and would have reduced landscaping costs for native plants, but it would have increased costs for sediment removal (Liptan and Brown).

Life cycle cost analysis is a critical tool for selling such green technologies because there are many broad claims that significant savings may occur over time, whether or not first costs are less. These claims need to be supported. This literature review faced a large gap in information along these lines. Rigorous life cycle analyses, both economic and ecological, can go a long way to provide rigorous information on all these time-dependent factors.

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Costs cannot be judged fairly without the context of benefits, and the literature discusses numerous benefits of conservation development, which are not necessarily shared with conventional tools. While details on these benefits are outside the scope of this project, a partial list of benefits here provides a flavor of the additional selling points for developers and communities.

Benefit	Sampling of References
Higher Property Values—increased sales, higher sale & resale prices, shorter time on market, etc.	Schueler and Holland; Trust for Public Land; Haugland; Brabec, 1992; Gilroy; Ewing; Center for Watershed Protection 1995; Farnsworth; Emmerling-Dinovo, 1995; Lacey and Arendt; USEPA(h)
Increased tourism and recreation	Trust for Public Land; Gilroy; Brabec & Kirby
Increased tax revenue	Trust for Public Land; Brabec, 1992
Downstream Economic Benefits (reduced flooding damages, treatment costs, increased property values, etc.)	Braden & Johnston; Braden, Johnston & Price; Stormwater Center Open Space Design Fact Sheet; Trust for Public Land; Gilroy
Land released back to developer for additional returns	Prince George's County (a)
Reduced needs for infrastructure project bonding	Prince George's County (a)

TABLE 17. Benefits of Conservation Development and References.

Literature Analysis Conclusions

The literature consistently raises examples of how conservation development methods can save money in construction and maintenance costs from the metropolitan scale to the site level and down to a comparison of specific BMPs. Here is a summary of conclusions:

1. Public infrastructure costs are higher when a development is built within the context of urban sprawl, as compared to smart growth patterns.
2. At the site level, significant cost savings can be achieved from clustering, including costs for clearing and grading, and for stormwater and transportation infrastructure, as well as utilities.
3. Installation costs can be between $4,400 and $8,850 cheaper per acre for natural landscaping than for turf grass approaches.
4. Maintenance cost savings range between $3,950 and $4,583 per acre per year over ten years for native landscaping approaches over turf grass approaches.
5. Better site design can reduce paving costs.
6. While conventional paving materials are less expensive than conservation alternatives, porous materials can help total development costs go down, sometimes as much as 30%, by reducing conveyance and detention costs.
7. Swale conveyance is cheaper than pipe systems, by some claims as much as 80%.
8. The literature is not clear enough to resolve the cost differences between discrete detention and retention methods. Yet, costs of retention or detention cannot be examined in isolation, but must instead be analyzed in combination with conveyance costs, at which point conservation methods generally have a cost advantage.
9. Green roofs are currently more expensive to install than standard roofs. Yet costs are highly variable, and going down. Green roofs also have significant cost advantages when looking at life-cycle costs.

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Finally, time and again the literature stresses that, by combining multiple conservation tools at a single site, even deeper cost savings can be achieved, creating impressive cumulative benefits. Across ten of the case studies examined here (see Tables 12 - 16), holistic design treatments with a mixture of conservation tools saved an average of 36% over conventional practices.

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BUILT-SITE COST ANALYSES

These built-site analyses provide case studies from the real world to complement the lessons from the literature research and the template cost estimates (see below). By analyzing actual engineering data on construction costs, they compare specific aspects of development costs more closely to understand from where the exact cost-savings and benefits are derived between conventional and conservation developments. In addition, examples from the Midwest can help local governments, developers, homeowners, and other interest groups to learn about, compare, and examine the feasibility of conservation development in the region.

Both residential and commercial case studies are provided. The residential cases include Mill Creek and Sunset Prairie subdivisions in or near the city of Geneva, Illinois, Prairie Crossing in Grayslake, Illinois, and three Bielinski Homes developments in Wisconsin. Tellabs Corporation in Naperville, Illinois, provides an example of a commercial/industrial development. Finally, the Street Edge Alternative Streets project in Seattle, Washington, illustrates retrofitting of urban streetscapes with conservation stormwater management strategies.

This analysis used two approaches: first, compare two different sites when one represents conventional development and the other conservation development; second, compare two scenarios on the same site. In the first approach, criteria for selecting sites included: the degree of comparability between sites, the availability of data, and the representative nature of the project types. When comparing two locations, several aspects were taken into account, including similarity of environmental context, density, size, and construction periods, to minimize the number of variables in play. When the same site was estimated for both conservation and conventional scenarios, the comparison relied on actual construction bidding and budget documents for the two forms, when the conservation scenario was eventually built.

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FIGURE 1. Mill Creek subdivision plat.

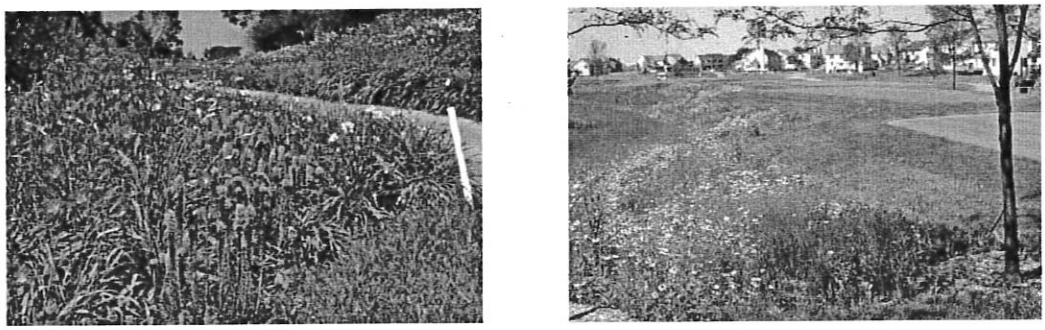

FIGURE 2. Mill Creek Subdivision Site Photos. Images courtesy of Conservation Design Forum

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CASE STUDY 1: Mill Creek Subdivision vs. Sunset Prairie Subdivision

Background

Kane County suffered a serious flood in the Blackberry Creek Watershed area in 1996 when thousands of homes filled with water and millions of dollars washed away. At the same time, the county has been experiencing population growth, the third most rapid in the state, behind Will and DuPage Counties (U.S. Census). To address water quality, open space protection, and urban sprawl, the Kane County 2020 Land Resource Management Plan and several watershed and resources management plans were developed to control growth and negative development-related impacts by designating conservation development as a preferred alternative.

The Mill Creek development is located in unincorporated Kane County, Illinois near the City of Geneva. The neighborhood is in the Batavia School and Park Districts. Sunset Prairie subdivision is located in the City of Geneva about one mile from Mill Creek and is in the Geneva School District and the Geneva Park District.

The Mill Creek development is a large-scale, planned community with large area of contiguous open space, a wide range of housing types, neighborhood retail centers, and recreation amenities. It embodies many of the conservation planning principles espoused by the 2020 Plan. Its adjacent land uses are primarily farmlands. The Sunset Prairie subdivision is approximately 5 miles due west of downtown Geneva and is a typical single family residential development for many areas of Kane County that are within the corporate limits of municipalities. Public parks are adjacent to the south and east of the Sunset Prairie subdivision.

Method

To strengthen the comparability of the two sites using available data, this case study selected only a portion of each subdivision with similar gross density. Sunset Prairie's Subdivision Unit 1 consists of 55 lots in 30.6 acres and is equivalent to a gross density of 1.7 units per acre or 25,600 square feet per lot. Mill Creek's Neighborhood U has a gross density of 1.6 units per acre or 27,400 square feet per lot, calculated from 66 lots on 41.5 acres, which is only a portion of the roughly 1,500 acres and 2,000 homes in the entire development.

The following summarizes background information for both sites:

Site:	Sunset Prairie Subdivision	Mill Creek Subdivision
Model Type:	Conventional Development	Conservation Development
Location:	About 5 miles west of downtown Geneva, Illinois	About 5 miles west of downtown Geneva, Illinois
Surrounding Land Uses	Subdivisions, Parks	Farmlands
Density:	1.7 unit/acre or 25,600 sf/lot	1.6 unit/acre or 27,400 sf/lot
Size:	30.6 acres	41.5 acres
# of Lots:	52	66
Construction Year:	2002	2002

TABLE 18. Sunset Prairie and Mill Creek Subdivision Site Data.

The cost analysis was generated from probable construction costs provided by the project civil engineers, Cemcon, Ltd., for Sunset Prairie, and Sheaffer & Roland, Inc. for Mill Creek. In an effort to analyze roughly comparable items, cost items that are present in one project but not in the other or categories where differences were so great it was obvious that they did not cover the same items were eliminated. For example, earthwork improvements for Sunset Prairie included earth excavation, tree removal, grading, and topsoil strip and placement that totaled about $255,000. In Mill Creek, topsoil re-spreading was the only item listed under excavation and cost about $35,000. Because of the extreme cost mismatch, the item of earthwork improvements was not included in this analysis.

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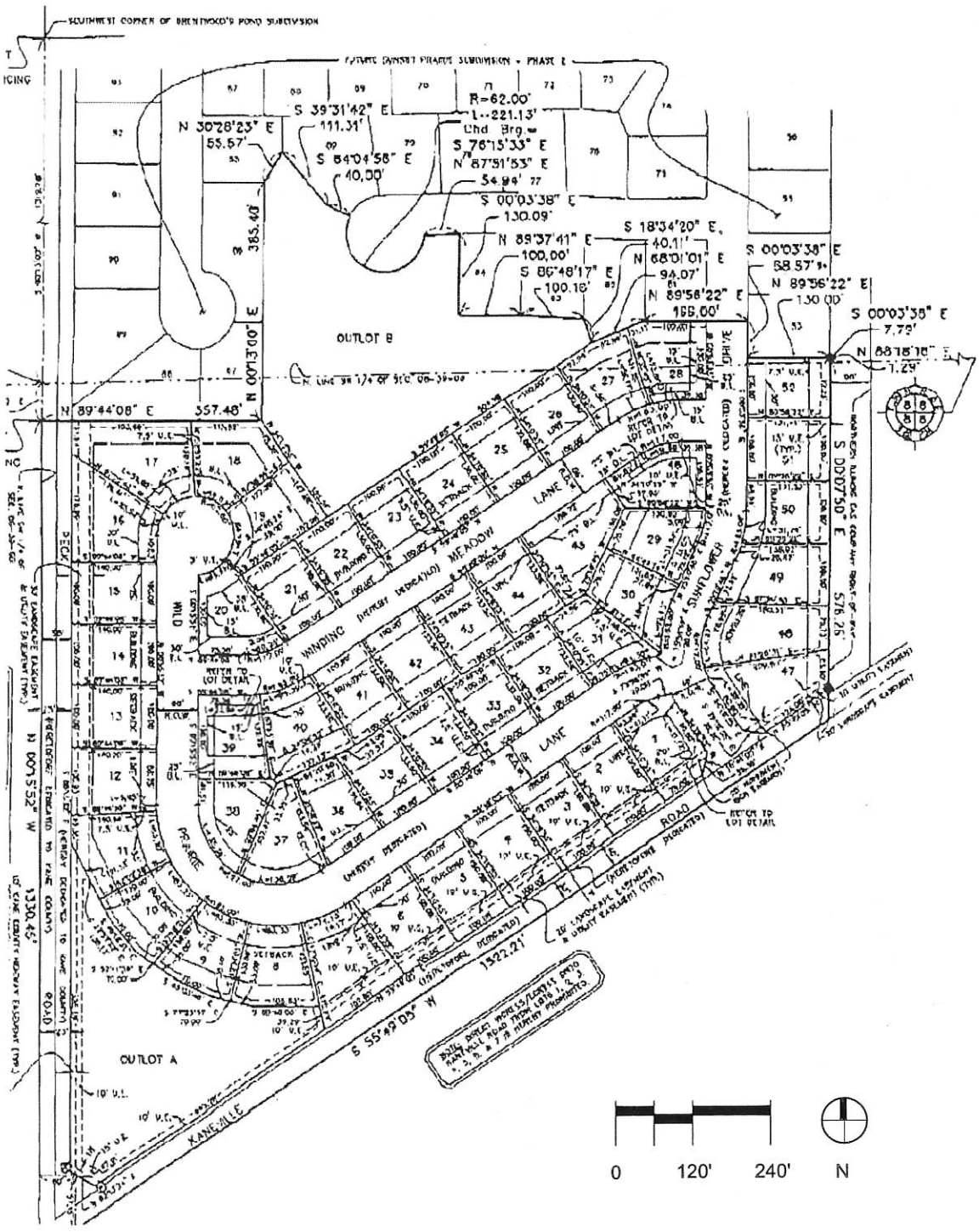

FIGURE 3. Sunset Prairie Subdivision Plat.

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Nevertheless, it is worth noting that such cost reductions are typically found in conservation developments.

Also, to clarify the comparison, the costs are shown both as a total and per lot. The detailed cost analysis can be found in Appendix 3.

Results & Discussion

The analysis results are summarized in Table 19. Based on per-lot cost results, about $3,700 per lot is saved in the conservation development relative to the conventional approach. Approximately 53% of the savings came from stormwater management construction costs and 21% come from site preparation costs. The following describes and discusses the results of each item.

Site Preparation

Site preparation included topsoil removal and stockpiling and erosion control. As shown in Table 19, construction costs for erosion control (silt fence and temporary seeding) did not differ significantly between conservation and conventional developments whereas topsoil removal and stockpiling was more than double for the Sunset Prairie development relative to Mill Creek. In this case, conservation development shows that a fair amount of topsoil removal (871 cubic yard per lot) was avoided. Topsoil removal was reduced from 1,118 cubic yards to 247 cubic yards per lot, and saved $960 per lot from the conservation development. Based on the literature findings, conservation design is intended to minimize grading, site excavation, topsoil removal, and earth work, and thus save construction costs for site preparation. This result implies that more lands were preserved from disturbance for open space.

Stormwater Management

As shown in Table 19, conservation methods of stormwater management contributed to the greatest savings with more than half (53%) of the total savings per lot. To look closely, installation of storm sewers and sump pump connections was reduced from 164.2 linear feet to 85.2 linear feet per lot and thus saved $1,623 per lot. Plus, trench backfill was reduced from 20 cubic yards per lot to 3.7, saving $232 per lot. Additional infrastructure costs in the conventional development included catch basins, slope inlet boxes, and cleanout structures, which totaled $23,783, or $457 per lot.

In accordance with literature, this case showed significant reductions in stormwater sewer pipes and associated infrastructure costs, making up more than half of the total savings.

Sanitary Sewer

Sanitary sewer includes piping and bedding, sanitary manholes, trench backfill, and other related infrastructures. As can be seen in Table 19, lump sum cost-savings per lot were as much as $579, which represents 17% of the total savings.

The total cost of sanitary sewer (8" in diameter PVC pipe) was similar in both subdivisions although cost per individual lot was higher in the conventional development, due to the greater length of the infrastructure (74 linear feet per lot versus 58 linear feet per lot). In addition, $257 per lot was saved from the operation costs of trench backfill in the conservation development (23 versus 5 cubic yard per lot). This supports the literature claims that clustering design can reduce street length, and thus reduce required sanitary pipe length, thereby lowering costs.

Water Distribution

Water distribution includes water main, hydrant, valve in vault, water service pipes, trench backfill, and connections to the existing water main. The results demonstrated that conservation development saved $369 per lot. Although the Mill Creek subdivision presented about $14,000 more in this item, fourteen more lots resulted in lower costs per lot.

Again, the results of this case study agree with literature findings that the clustering at Mill Creek did save money on water distribution infrastructure costs.

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		Sunset Prairie (CONVENTIONAL)			Mill Creek (CONSERVATION)				
COST	ITEM	cost per item	cost per item per lot[2]	% per total cost	cost per item	cost per item per lot[2]	% per total cost	cost-savings per lot	cost-savings percentage
CAPITAL COSTS[1]	1. Site Preparation[3]	$ 106,350	$ 2,045	11%	$ 71,690	$ 1,086	8%	$ 959	22%
	2. Stormwater Management[4]	$ 235,826	$ 4,535	25%	$ 145,486	$ 2,204	16%	$ 2,331	53%
	3. Sanitary Sewer	$ 144,477	$ 2,778	15%	$ 145,156	$ 2,199	16%	$ 579	13%
	4. Water Distribution	$ 142,498	$ 2,740	15%	$ 156,492	$ 2,371	17%	$ 369	8%
	5. Site Paving and Sidewalks	$ 308,338	$ 5,930	33%	$ 383,418	$ 5,809	42%	$ 120	3%
TOTAL		$ 937,489	$ 18,029	100%	$ 902,241	$ 13,670	100%	$ 4,358	100%

NOTES:

[1] Exclude offsite improvements, landscaping costs, and construction contingency cost

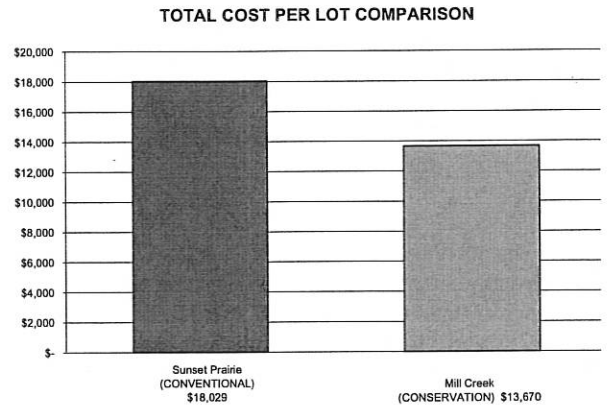
[2] Based on 52 lots for Sunset Prairie Subdivision and 66 lots for Mill Creek Subdivision

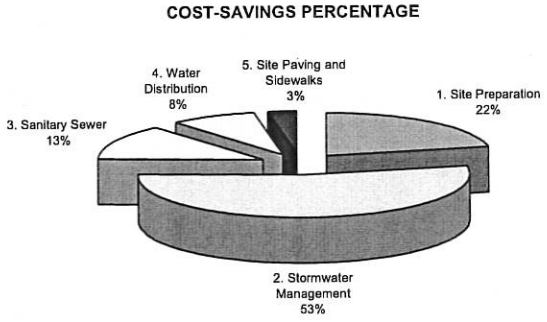
[3] Earthwork costs that are not available for Mill Creek were excluded from both sites in the table

[4] Detention cost is not available for Mill Creek and were excluded from both sites in the table

[5] Acreage for Sunset Prairie is 30.56 acres whereas Mill Creek is 41.5 acres

[6] Property values varies upon location of sites and design of the site. Locality is often the major driving force for property values; however, if comparing site design only, conservation development would have greater property values than conventional one as a result of open space and community benefits derived from conservation planning and design.





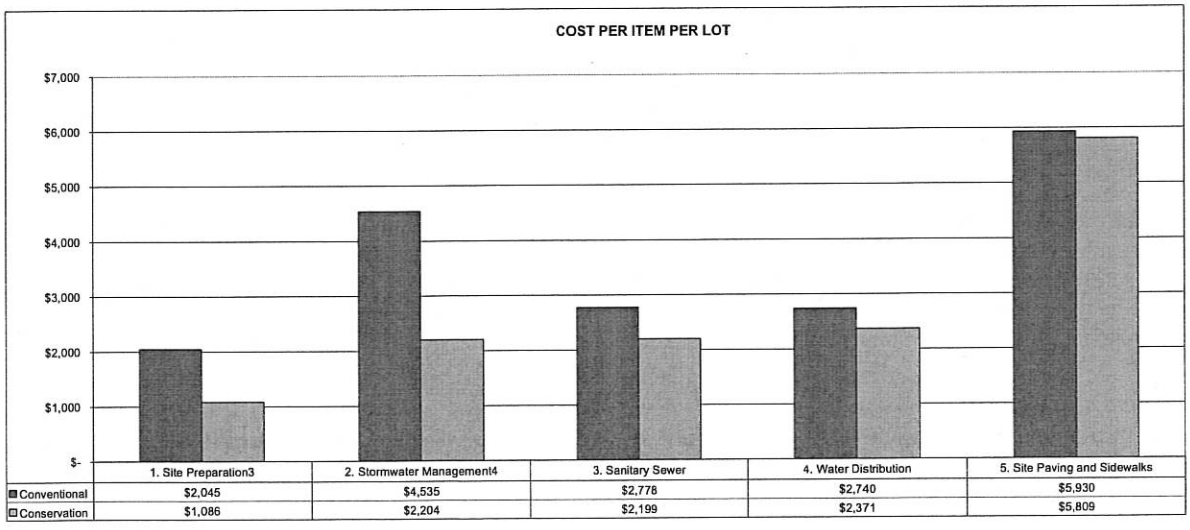


TABLE 19. Sunset Prairie versus Mill Creek Cost Comparison Summary.

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Site Paving and Sidewalks

Table 19 shows that conservation development resulted in $120 less per lot from site paving and sidewalk construction costs, representing 3% of the total savings.

Construction costs for asphalt paving were $226 per lot less in the conservation development. In addition, $113 per lot was saved by reducing 42 linear feet of sidewalk per lot in the conservation development. The cost of street paving was lower for Mill Creek due to both reduced street length and width relative to Sunset Prairie. Costs of curb and gutter, conversely, increased 35 linear feet per lot in conservation development, or about $219 per lot. However, a cost increase on curb and gutters implies that other unknown factors of design may be concealed in this case, thus limiting the comparison results.

Sidewalks were put on both sides of the streets in both subdivisions, making the results comparable for length of sidewalk per lot and associated cost-savings derived from the site design. Shorter sidewalk lengths per lot is evidence of clustered design in Mill Creek and magnified the savings on construction costs from conventional development.

Property Values

Marketing information from both subdivisions shows that lot prices vary according to location within the subdivision and proximity to open space, recreational facilities, train stations, and downtown facilities. In Neighborhood U at Mill Creek, a $3,000 premium occurs when lots are adjacent to walking/biking trails, and $10,000 or $17,500 premiums apply when lots are adjacent to or have views of open space.

In Sunset Prairie, Phase I, the only open space on the site is a detention pond in the middle of the overall development and a turf lawn at one of the street intersections. Surrounding parks and a biking trail between adjacent subdivisions, however, allow Sunset Prairie to borrow views as well as recreational uses of nearby amenities. For this reason, premium lots are generally distributed around the detention pond and adjacent to the biking trail. The lot premiums ranged from $5,000 to $39,000.

Open Space

Within 1,500 acres, 40 percent of the land is designated as open space in Mill Creek, of which 27 acres are a public golf course, 127 acres are forest preserve with quality wetlands, 195 acres are public parks, and 15 miles of walking/biking trails are placed in the 123 acres of roads, trails and easements.

As alluded to in the literature analysis, open space not only increases aesthetic values and provides recreational facilities but also helps to protect significant natural features from further development. In addition, conservation development that integrates stormwater management into open space can help to reduce stormwater runoff volume and improve water quality as well. Furthermore, residents feel safe and possess convenient access to open space near by.

Conclusion

Cost savings of $3,700 per lot were estimated for the conservation approach, with 53% from stormwater management as the largest contributing factor to those savings.

Although there are differences, this comparison is as close to an apples-to-apples look at identical sites as can be found practically. Similarities include: proximity to downtown and transit, adjacent land uses, timing of construction, and the overall planning and design for the entire subdivision.

Although some uncertainty is inherent in this case study, it still provides a valuable demonstration of real world costs. The comparison between Sunset Prairie and Mill Creek supports the proposition that conservation developments in residential subdivisions can save money during construction, especially in site preparation and the installation of stormwater management infrastructures.

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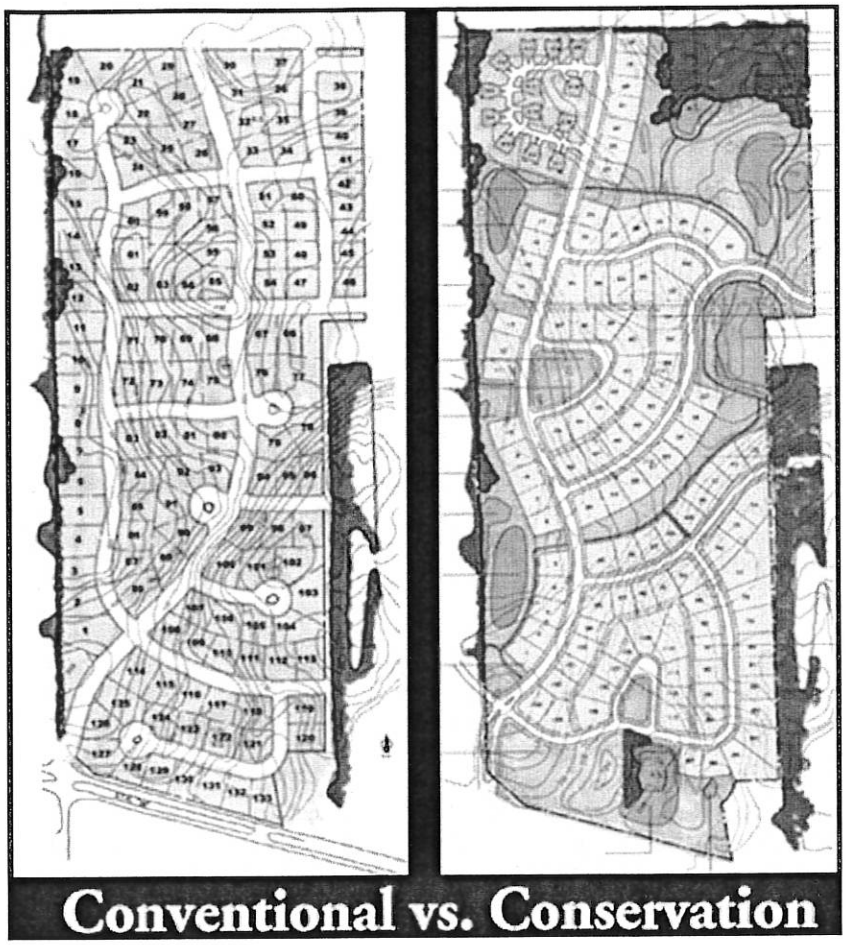

FIGURE 4. Auburn Hills subdivision plats. Image courtesy of Bielinski Homes

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CASE STUDY 2: Bielinski Homes- Auburn Hills, Laurel Springs, and Prairie Glen Subdivisions

Background

Three residential subdivisions, built by Bielinski Homes, were analyzed for actual conservation costs in relation to estimated conventional costs. Prairie Glen, in Germantown, Wisconsin, is considered a national model for Conservation Communities by the Conservation Fund. 59 percent of the land was preserved as open space, with native plants and wildlife habitat reintroduced. Hiking trails and site layout were designed for easy access to the natural areas. Street widths were minimized to reduce runoff, and wetland areas were created to help manage the stormwater.

Auburn Hills, also in southwestern Wisconsin, is one of Bielinski Homes' Conservation Neighborhoods that provides common open space, which preserves 40 percent of the site from development, and includes wetlands, natural plant landscaping and green space, along with a network of walking paths. And Laurel Springs, a residential subdivision in Jackson, Wisconsin, is a third low impact conservation design, which preserved open space, minimized grading, paving and stormwater sewer systems.

Method

In this case study, three subdivisions were analyzed respectively for their estimated conventional costs and for actual cost of conservation development. Cost comparisons are analyzed separately, and then discussed together.

According to Bielinski Homes, infrastructure costs were divided into nine categories. To make this case study comparable to the template cost analysis, comparison items were reorganized as: 1) Site Preparation, including grading and miscellaneous (demolition, erosion control, etc.); 2) Stormwater Management, which refers to storm sewer; 3) Sanitary Sewer; 4) Water Distribution, which refers to watermain; 5) Utilities; 6) Site Paving and Sidewalks, including paving and concrete; and 7) Landscaping.

As a developer, Bielinski Homes compared costs not only in construction but also development-related finances, such as impact or permit fees required by municipalities or counties, professional expenses for site analyses and site planning and design, financing expenses such as loans and legal fees, and real estate taxes that developers are required to pay. Because impact fees are so site-specific and require more in-depth study, they were considered outside the scope of this limited analysis. For similar reasons, land costs were not included in this analysis.

Results & Discussion

Table 20 summarizes cost comparisons and percentage savings of each item among the three sites while their detailed cost analyses are included in Appendix 4. The following discussion details each category of construction costs as well as overall costs.

Site Preparation

This case study supports the literature analysis findings that clearing and grading can be reduced when cluster design is applied. Overall site preparation costs for conservation development were reduced by 23 to 32% of conventional development costs. Within those savings, grading contributed almost 100%, as miscellaneous costs of demolition and erosion control were the same or less than ten percent of total savings.

Stormwater Management

Among the cost analysis items, stormwater management is the largest area of cost savings for conservation development. Savings ranged from 47 to 69%, or about $2,500 to $3,300 per unit where vegetated swales or bioswales substituted for storm sewers. This also agrees with the conveyance literature analyzed previously as being one of the greatest cost savings, thereby endorsing the use of this incentive by real world examples from a developer's point of view.

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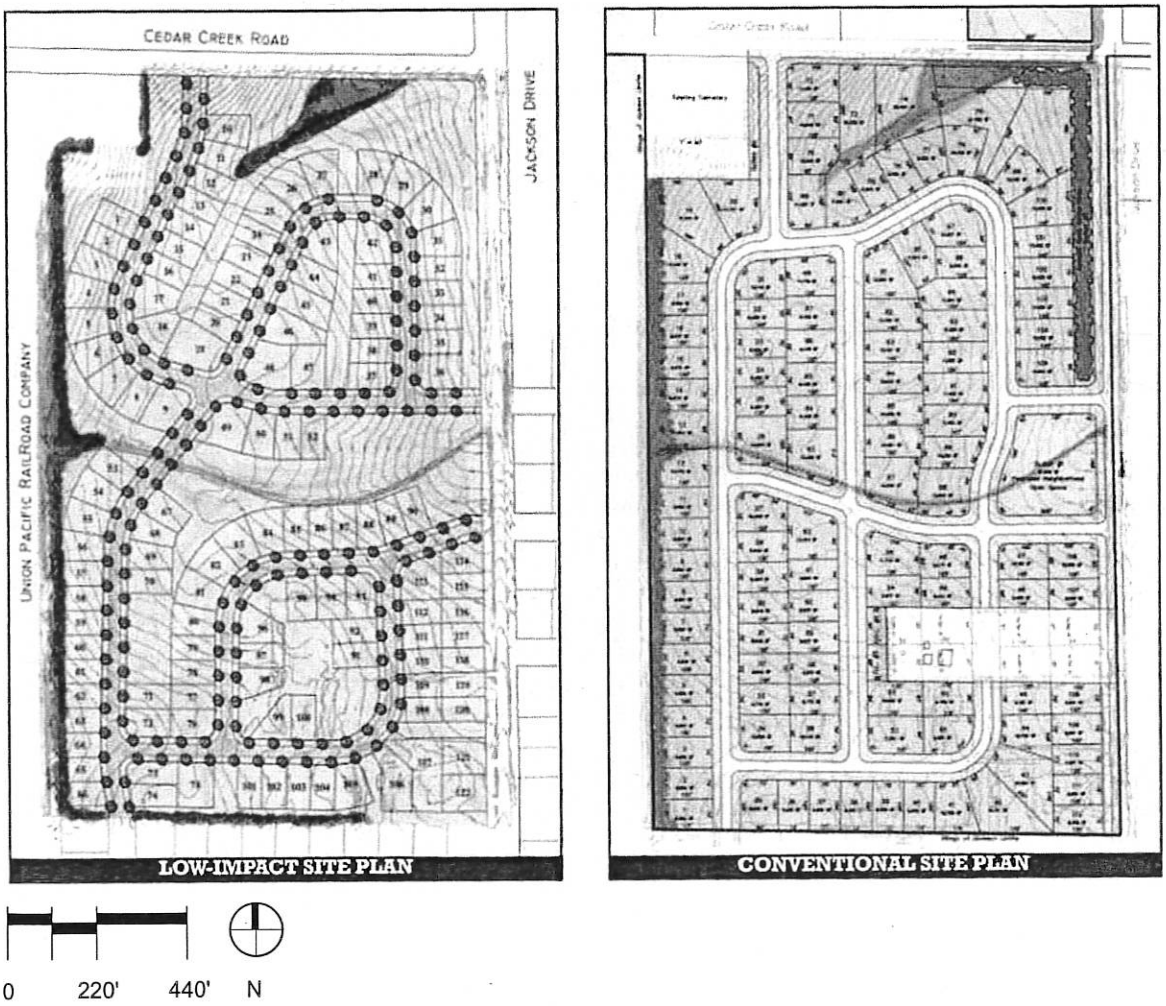

FIGURE 5. Laurel Springs subdivision plats. Image courtesy of Bielinski Homes

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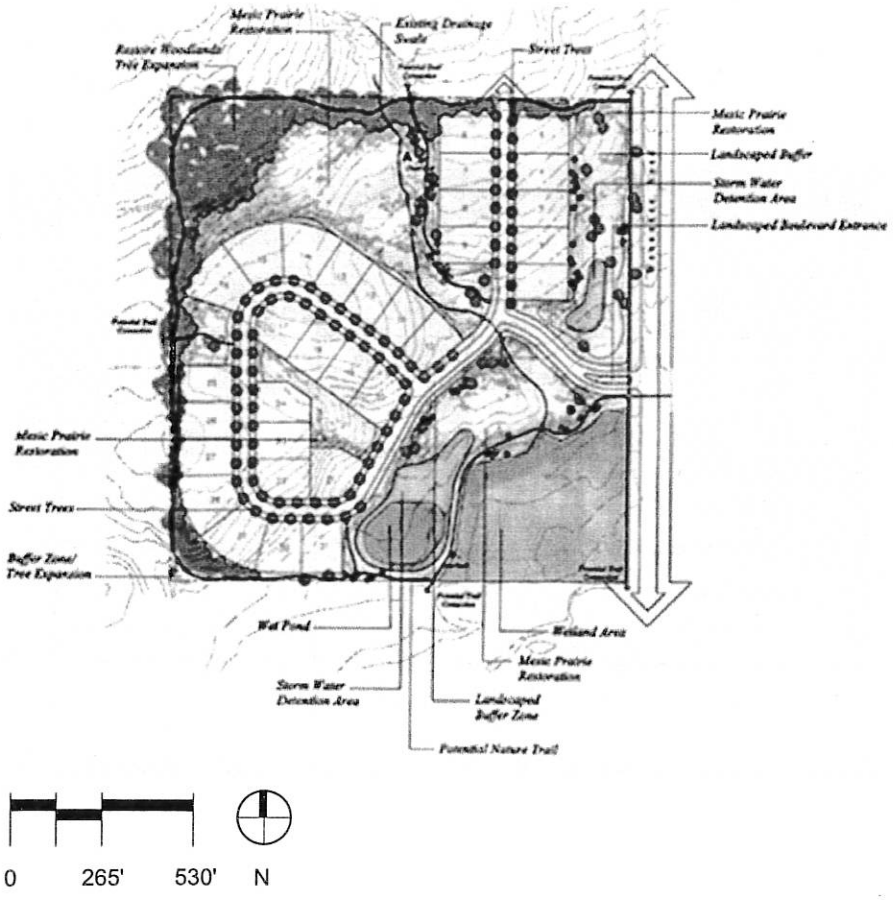

FIGURE 6. Prairie Glen subdivision plat. Image courtesy of Bielinski Homes

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Description	Auburn Hills			Laurel Springs			Prairie Glen			Comments
	Conventional Cost	Conservation Cost	Cost Savings %	Conventional Cost	Conservation Cost	Cost Savings %	Conventional Cost	Conservation Cost	Cost Savings %	
Site Preparation	$699,250	$533,250	24%	$441,600	$342,000	23%	$277,043	$188,785	32%	reduced lot grading for conservation
Stormwater Management	$664,276	$241,497	64%	$439,956	$136,797	69%	$215,158	$114,364	47%	storm sewers vs. treatment swales
Sanitary Sewer	$671,020	$485,520	28%	$415,600	$385,280	7%	$189,402	$166,827	12%	reduced street lengths
Water Distribution	$858,670	$777,160	9%	$412,460	$384,240	7%	$166,260	$146,868	12%	
Utilities	$290,510	$177,920	39%	$270,000	$161,280	40%	$64,790	$39,680	39%	
Site Paving and Sidewalks	$771,859	$584,242	24%	$607,465	$515,755	15%	$463,547	$242,707	48%	reduced street lengths and widths
Landscaping	$225,000	$240,000	-7%	$165,000	$155,000	6%	$50,100	$53,680	-7%	
Construction Cost Subtotal	**$4,180,585**	**$3,039,589**	27%	**$2,752,081**	**$2,080,352**	24%	**$1,426,300**	**$952,911**	33%	
Impact Fee / Permits	$80,000	$47,500	41%	$51,500	$35,000	32%	$33,100	$17,600	47%	
Professional Services	$218,750	$217,600	1%	$192,500	$184,400	4%	$90,000	$82,500	8%	
Financing Expenses	$358,000	$244,000	32%	$244,000	$159,000	35%	$154,425	$87,050	44%	
Real Estate Tax	$69,500	$69,500	0%	$60,000	$63,000	-5%	$54,560	$54,560	0%	
Finance Cost Subtotal	**$726,250**	**$578,600**	20%	**$548,000**	**$441,400**	19%	**$332,085**	**$241,710**	27%	
Total Costs	**$4,906,835**	**$3,618,189**	**26%**	**$3,300,081**	**$2,521,752**	**24%**	**$1,758,385**	**$1,194,621**	**32%**	
Summary	10138 Lf. of roads in conservation vs. 11500 Lf. in conventional			6560 Lf. of roads in conservation vs. 6860 Lf. in conventional			3125 Lf. of roads in conservation vs. 3450 Lf. in conventional			
	Construction Cost per foot of roadway: $357 conventional vs. $427 conservation			Construction Cost per foot of roadway: $384 conservation vs. $481 conventional			Construction Cost per foot of roadway: $357 conservation vs. $475 conventional			
	Construction Cost per unit: $26,030 conservation vs. $38,943 concentional			Construction Cost per unit: $20,337 conservation vs. $27,501 conventional			Construction Cost per unit: $35,790 conservation vs. $52,879 conventional			
	113 lots/13 duplex condos in conservation vs. 126 lots conventional			110 lots/7 duplex condos in conservation vs. 120 lots conventional						
				On-site detention in conservation vs. 5 acre off-site lot in conventional						

Date: 11/4/2003
Source: Bielinski Homes
Edited by: CDF

TABLE 20. Cost Comarison Summary of Auburn Hills, Laurel Springs, and Prairie Glen Subdivisions.

SARB_003907

Sanitary Sewer

Sanitary sewer cost savings range from 7% to 28%. These savings may have resulted from the reduced street length in the clustering design, which then reduced the length of infrastructure. 1,878 linear feet of 8-inch diameter sanitary sewer pipes were saved in the Auburn Hills subdivision, 250 linear feet were saved in Laurel Spring, and 893 linear feet of 15" and 8" sanitary sewer pipes combined were saved in Prairie Glen.

Water Distribution

Though clustering design differs from site to site, in general, these case studies provide evidence that conservation development helps to save on water distribution infrastructure costs. Yet, cost savings from water mains are relatively low when compared to other construction cost items. Around 9% to 12 % of the conventional costs are saved with conservation design. 2,300 linear feet of 8" water main pipe are saved in Auburn Hills, while 300 and 460 linear feet of 8" and 12" water main pipes combined are saved in Laurel Spring and Prairie Glen respectively. The cost of water distribution infrastructure also depends on the length of roads, so that clustering design helps to save these construction costs.

Utilities

Utilities included electricity and cable television infrastructure in this case study. Cost savings on this item are about 40% across the three sites.

Site Paving and Sidewalks

Paving and concrete cost savings range from 15% to 48%, or nearly half the conventional development. In Auburn Hills, 1,312 linear feet of road are saved, which equals $70 per foot of roadway, or $91,840 total savings. 300 linear feet of road or $97 per foot are saved in Laurel Springs, and 325 linear feet or $118 per foot are saved in Prairie Glen.

Costs for concrete included curb and gutter for all three sites and sidewalks in both Laurel Springs and Prairie Glen. Curbs with gutters are 3,224 and 600 linear feet less in Auburn Hills and Laurel Springs respectively, whereas the costs stay the same for both scenarios in Prairie Glen. As for sidewalks, Laurel Springs saved 2,970 square feet while 61,824 square feet were saved in Prairie Glen.

Total cost savings from concrete are not significant except in Prairie Glen where a substantial amount of sidewalks (72%) were added in the conventional development. Cost savings on street paving, on the other hand, appears more consistent among the three sites. Again, those savings were derived from the reduced street length and width in the clustering design.

Landscaping

Landscaping costs include site landscaping (including native landscape restoration in the conservation development cases) and street cleaning. Overall, unlike other cost items, landscaping costs were slightly more in the conservation developments, due to the increased amount of community green space that must be landscaped. As shown in the detailed cost analyses (in Appendix 4), street cleaning costs more (about 70%) in the conventional development. Site landscaping costs about 29% more in both Auburn Hills and Prairie Glen, whereas the costs were the same in Laurel Hills.

Conclusion

Total cost savings ranged from $563,764 to $1,288,646 and averaged $876,913 across the three Wisconsin sites, and the average percentage savings was 27%. Overall, every category of construction costs is lower under conservation development except for landscaping costs, which were higher in Auburn Hills and Laurel Springs. Those savings trends are in agreement with findings in the literature analyses where costs of clearing and grading, infrastructure (including sanitary sewer, water main, and utilities), stormwater management, and street paving are less as a result of clustering design. Conservation design principles that minimize disturbance on site, reduce street length and width, and employ bioswales instead of storm sewer piping contribute a significant amount of savings during construction.

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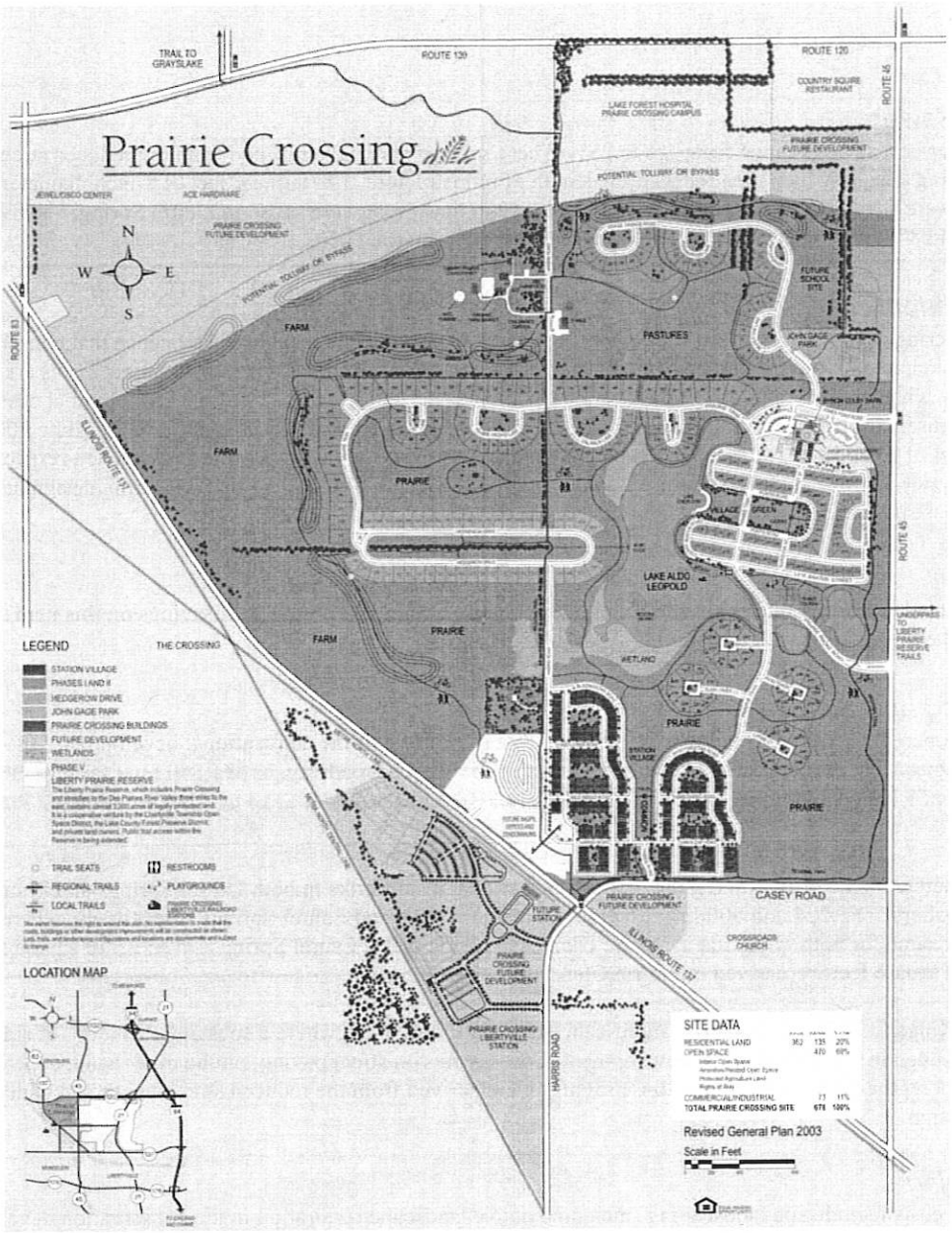

FIGURE 7. Prairie Crossing Subdivision Master Plan. Image courtesy of Prairie Crossing.

FIGURE 8. Prairie Crossing Subdivision Site Photo. Image courtesy of Prairie Crossing

SARB_003909

CASE STUDY 3: Prairie Crossing

Background

The Prairie Crossing Subdivision, in Grayslake, Illinois, was initiated by a group of visionary landowners who saw an alternative development that would celebrate community and provide a high quality of life. They planned for 362 homes on 678 acres with 470 acres of open space and 73 acres of commercial space, accompanied by schools, a community center, an organic farm, a lake and beach, biking trails, and two commuter train stations across the street. After nearly a decade, Prairie Crossing has become one of the best known examples of conservation development in the Midwest.

Method

The data acquired from Prairie Crossing are not broken out by the construction categories used elsewhere in this report. Rather, an estimated lump sum cost savings was completed in 1993 for the two different construction approaches, conventional and conservation. The assumptions for these data are:

- Both conventional and conservation development cost summaries assume the same layout.
- Storm sewers are sized per village code and Lake County Stormwater Management Commission requirements (alternative stormwater management techniques such as bioswales for water conveyance are employed in the conservation development).
- Curb and gutter are installed for all streets and alleys (curb and gutters are avoided when sheet flow applies and open swales are used in the conservation development).
- Street width meets village codes (27 and 36 feet wide according to codes, versus 16, 18, 20, 24, and 32 feet wide in conservation development).
- Sidewalks are installed in front of every house (portions of sidewalks are replaced with alternative pedestrian and biking trails in the conservation development).
- Open space areas are planted with turf (or in the conservation development, native prairie and wetland species are planted or restored).

In addition to construction costs, the data also compares maintenances costs. Turf grass expenses included costs of seed, mulch, and fertilizers, and maintenance costs over five years include the expenses of mowing, fertilizer application, irrigation system, municipal water, and aerating or de-thatching (every other year). Expenses for native prairie included expenses of seeding, plugs, and mulching while its maintenance requires mowing in the first two years, spot herbicide treatment over five years, and prescribed burn in the second, third, and fifth year.

Results & Discussion

Since the layout of both scenarios is the same, they shared the same street length and an equal amount of open space. Therefore, this case study focused on construction costs when alternative stormwater management and grading design approaches are applied. Cost savings generated from conservation development were found in four areas: stormwater management, curb and gutter, site paving, and sidewalks. Total net savings from these construction items were estimated at $1,375,000 (approximately $3,798 per lot or $2,028 per acre) for the overall site (see Table 21).

Stormwater Management

The amount of reduced storm sewer pipes saved a total of $210,000 in the conservation development, which agrees with the literature analyses that shows conservation methods are responsible for significant savings in conveyance costs.

Curb and Gutter

Alternative street edge treatment that apply open water conveyance systems and replace curb and gutter contributed a quarter of the total estimated savings over the conventional approach, equaling $339,000. (See also Case Study 5 for Street Edge Alternative projects).

Site Paving

Reduced street width alone made up $178,000 or $263 per acre cost savings in the conservation development,

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SAVINGS	ITEM	Savings Per Item	Savings Percentage
NET SAVINGS	Reduced Road Width[1]	$ 178,000	12.9%
	Curb and Gutter[2]	$ 339,000	24.7%
	Sidewalk[3]	$ 648,000	47.1%
	Storm Sewer[4]	$ 210,000	15.3%
TOTAL SAVINGS		**$ 1,375,000**	**100.0%**
	Total Savings Per Lot	**$ 3,798**	
	Total Savings Per Acre	**$ 2,028**	
LANDSCAPING SAVINGS From Prairie (Conservation) v.s. Turf (Conventional)	Year One per acre	$ 4,695	27.6%
	Year Two per acre	$ 2,275	13.4%
	Year Three per acre	$ 2,015	11.8%
	Year Four per acre	$ 5,365	31.5%
	Year Five per acre	$ 2,680	15.7%
TOTAL SAVINGS	**Average Savings Per Year Per Acre**	**$ 3,406**	**100.0%**
	Total Prairie Landscaping Savings Per Year	**$ 572,889.2**	

Data source: Prairie Crossing

Assumptions for Conventional comparison:

[1] Street widths to meet village code in Conventional Scenario

[2] Curb and gutter for all streets and alleys in Conventional Scenario only

[3] Assume sidewalks in front of all houses and along roads in Conventional Scenario versus trails systems are developed in Conservation Scenario

[4] Storm sewer sized per village code and Lake County Stormwater Management Commission requirements in Conventional Scenario versus natural drainage and stormwater management system are established in Conservation Scenario

Site Data	# of Lots	# of Acres	% of Total
Residential Land	362	135	20%
Open Space		470	69%
agriculture	116	25%	
lawn	28	6%	
prairie	168	36%	
wetland	28	6%	
Hedgerow	16	3%	
Other	114	24%	
Commercial/Industrial		73	11%
Total Site		**678**	**100%**

Site Construction Net Savings Between Conservation and Conventional Scenarios

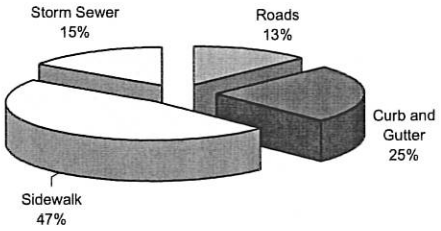

TABLE 21. Prairie Crossing Estimated Savings Between Conventional and Conservation Scenarios.

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confirming the cost-effectiveness of conservation design principles on this issue.

Sidewalks

Table 3 shows that cost savings for sidewalks contributed the greatest amount among the construction items analyzed (nearly half of the total cost savings). This reduced cost may be attributable to alternative paving materials such as the replacement of concrete sidewalks with crushed limestone trails.

Landscaping

As shown in Table 21, landscaping cost savings range from $2,000, with prescribed burns on native prairie, to $5,400, when burning is not required. Over five years, the native prairie landscaping can save $7,990,000 in total open space area (or $1,598,000 annually), which equals $17,000 per acre over five years or $3,400 per acre annually.

Irrigation systems and water bills can create excessive installation expenses as well as maintenance expenses. Additionally, mowing represents about half of the overall expenses in the subsequent years after installation and continues to be a substantial expense over time. On the other hand, the native prairie landscapes of this site cost less up front as well as for subsequent maintenance. Installation of prairie cost about half (56%) of the turf installation, primarily as a result of the difference of irrigation costs. As for maintaining prairie landscapes, the only major expense is from prescribed burning that has been done every year or two.

Conclusion

Conservation development savings at Prairie Crossing were $3,798 per lot for construction. Unfortunately, detailed cost comparison data was not available at the time of this project so that cost savings from specific items could not be analyzed. Furthermore, since this development did not count clustering design as an alternative approach in the scenario comparisons, site planning and design factors could not be analyzed and the study compares only construction costs for different approaches.

This case supports the argument that the alternative design strategies of conservation development do indeed help to reduce construction costs up front, and save dollars in the long run in terms of maintenance for landscaping. These findings agree with the literature analyses that stormwater conveyance, site paving, and sidewalks are significant cost saving-factors.

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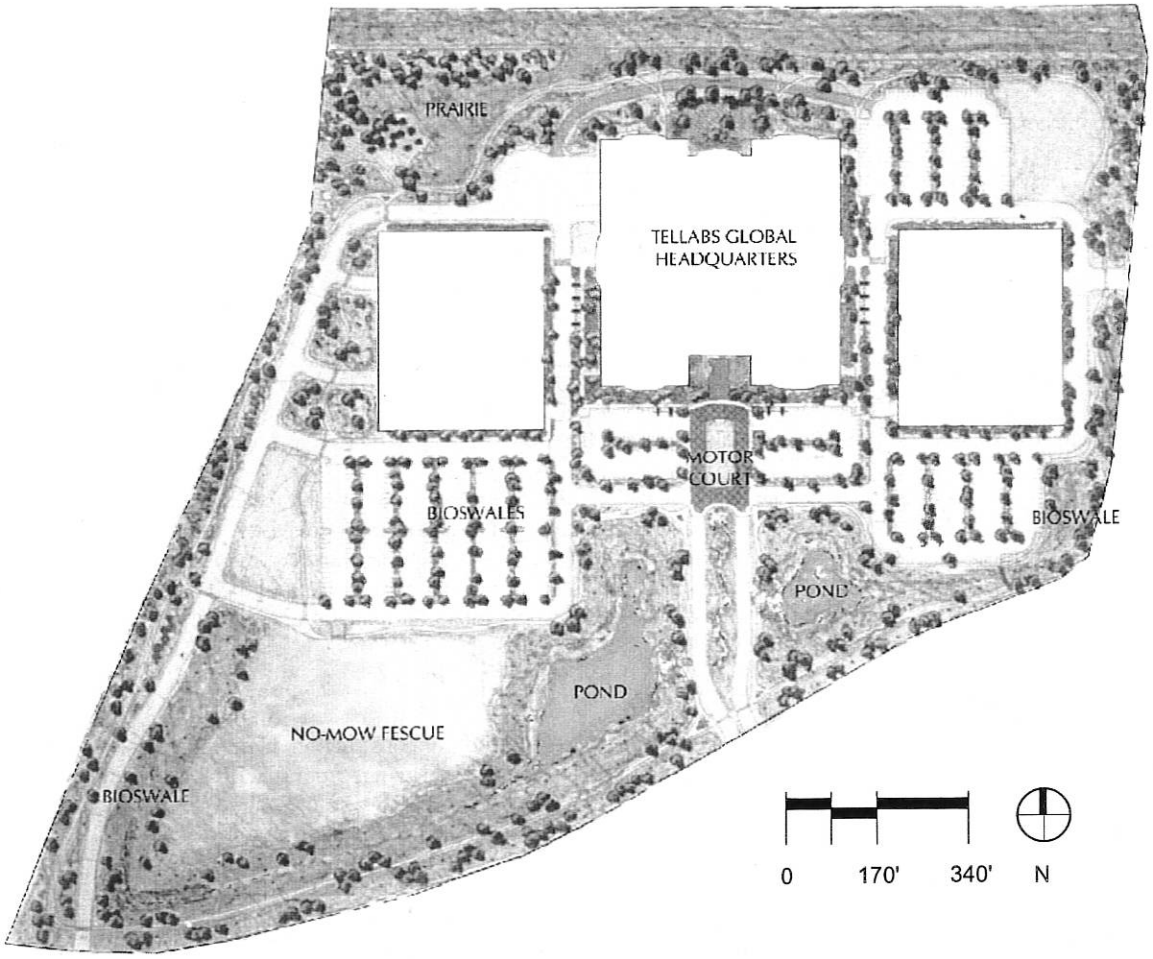

FIGURE 9. Tellabs Master Plan. Image courtesy of Conservation Design Forum

FIGURE 10. Tellabs Site Photo. Image courtesy of Conservation Design Forum.

SARB_003913

CASE STUDY 4: Tellabs Corporate Campus

Background

Located in Naperville, Illinois, Tellabs Headquarters campus consists of 332,500 square feet of office space situated on a 55 acres site. At the beginning of the planning process for the new campus, the engineering and landscape architecture consultants undertook cost comparisons between conservation and conventional scenarios on the project site. Based upon the data, Tellabs chose the conservation approach for the campus design, especially after they compared its construction and maintenance costs to other campuses that had been constructed conventionally in the region. As a result, the conservation design was built, making Tellabs a valuable case study of commercial/office/ industrial conservation development possibilities in the region.

Method

In this case, earthwork, stormwater management, and landscaping were the design components that drove most of the differences between conventional and conservation scenarios. Therefore, construction costs of other design elements such as sanitary sewer, water distribution, and site paving and sidewalks were omitted from this section. The detailed cost analysis can be found in Appendix 5.

National Survey & Engineering provided construction costs for the conventional scenario. Conservation Design Forum, as the landscape architecture and ecological engineering consultant, produced the actual cost figures for conservation development and compared them to the conventional costs.

Results & Discussion

The results are shown in **Table 22**.

Site Preparation

Site preparation included mass earthwork, grading, tree removal/relocation, and retaining walls for grading and elevation differences. Total savings of site preparation from conservation development were as much as $214,500 (or $3,900 per acre) less than the conventional scenario, and conservation preserved six more acres with minimum disturbance.

Conservation design principles minimized earthwork and followed natural drainage and topography as much as possible, providing much of the savings on grading and earthwork. Unit cost differences were $35,000 per acre in grading. Six fewer acres graded, therefore, reduced the overall grading costs by $210,000. Although retaining walls were required in the conservation scenario (slopes in some areas were preserved, leaving elevation differences), savings from earthwork remained greater than the cost for construction of those walls.

Stormwater Management

Stormwater management in the conventional scenario included storm sewer piping, bedding, and excavation of a detention pond. Conservation development included the costs of stormwater infiltration techniques such as level spreaders, parking lot bioswales, and overland bioswales. Associated construction costs for the bioswales included mass earthwork for excavation to accommodate the overland flow, native vegetation plugs in the bioswales, and a bridge across an overland swale.

Total savings from conservation development in this case were $62,910, mainly by eliminating 920 linear feet of storm sewer pipe. The total construction cost for the parking lot bioswales was $104,400 (or $29 per linear foot) and the total cost for an overland bioswale was $135,500 (or $45,167 per acre-foot). The parking lot bioswales were designed as part of the stormwater management system in the conservation development. This difference is shown in the following landscaping section.

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COST	ITEM[1]	CONVENTIONAL	CONSERVATION
CAPITAL COSTS	1. Site Preparation	$ 2,178,500	$ 1,966,000
	2. Stormwater Management	$ 480,910	$ 418,000
	3. Sanitary Sewer	$ 71,750	$ 71,750
	4. Water Distribution	$ 155,900	$ 155,900
	5. Site Paving and Sidewalks	$ -	$ -
	6. Landscape Development	$ 502,750	$ 316,650
	Construction Contingency[2]	$ 847,453	$ 732,075
	Design Contingency[3]	$ 338,981	$ 351,396
TOTAL CAPTIAL COST		**$ 4,576,244**	**$ 4,011,771**
PER SQ FT RETAIL[4]		**$ 10**	**$ 8**

NOTES:

[1] Cost for items 3-Sanitary Sewer, 4-Water Distribution, and 5-Site Paving and Sidewalks are assumed the same for both scenario:

[2] Assumed25% for both scenarios.

[3] Assumed 10% for conventional scenario and 12% for conservation scenario.

[4] Based on 332,500 sf multi-use retail space.

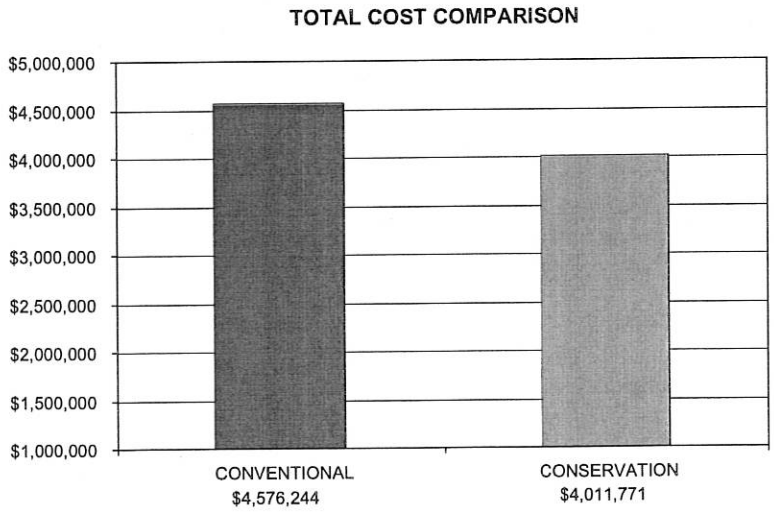

TABLE 22. Tellabs Cost Analysis Summary.

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One of the major cost additions in the conservation scenario was for an ornamental footbridge to cross the main bioswale. This cost was not directly related to the stormwater management function, but necessary due to Tellabs' desire to allow their employees and guests to enjoy the ability to walk and jog amongst the restored landscape.

Landscaping

The most visible difference between the conservation and conventional site development approaches is in the landscape. The conservation landscape that was installed at Tellabs includes areas of native prairie and wetland restoration, complimented with transitional areas and stormwater landscapes that are more naturalized. Areas adjacent to the building and pavement are more manicured to keep a neat, intentional appearance consistent with Tellabs' corporate image. The majority of the landscape is passive, low-maintenance naturalized or native planting, in contrast with the typical conventional approach that would include acres of high-maintenance turf grass lawns, clipped shrubs, and annual flowers. Both scenarios included landscaping for the parking lot islands. In the conventional scenario, the islands were strictly ornamental, and their cost is included under the landscape category only. In the conservation scenario, the islands served as both ornamental landscape and as a bioswale stormwater management feature. Thus, the excavation and gravel and soil backfill required for the stormwater aspect are included under stormwater and the planting is included under landscape.

Landscaping in this case also included a 0.47-acre wetland mitigation. The cost for the purchase of off-site wetland mitigation credits was avoided because the conservation scenario offered the option of integrating wetland re-creation and pond edge enhancement that would meet the mitigation requirements into the overall landscape scheme for the site. Since the wetland mitigation was integrated into an overland swale of the conservation scenario, earthwork for creating the wetland area was included in overall site preparation and planting, which was included in the overall landscape budget. Incorporating the wetland mitigation into a naturalized drainageway of the site was acceptable from a regulatory standpoint only because the runoff received pre-treatment in the bioswales before discharging to the wetland swale.

Site landscaping included all the trees, shrubs, perennials, lawns, and prairies (in conservation only). The total for plant materials alone in the conservation development was $44,150 more than the conventional total. However, in the conservation development, irrigation systems are not required because stormwater is allowed to infiltrate onsite directed to planted areas and the native prairie plants tolerate drought conditions. The irrigation systems required in the conventional scenario cost an extra $150,000, in addition to plants. As a result, the overall cost savings from conservation development for landscaping was $105,850.

Landscaping in parking lot islands cost $72,750 in the conventional scenario. As discussed earlier, parking lot islands in the conservation case were replaced by bioswales as a part of stormwater management (The built cost within that context was $104,400.)

Landscape Maintenance

The literature analysis described significant savings from conservation development for landscape maintenance. In this case, Tellabs monitored annual costs spent on maintaining conventional lawn versus a conservation landscape over ten years for the same 27 acres. As shown in **Table 23**, a traditional landscape would have required $842,000 for maintenance, whereas the native prairie landscape in a corporate setting needed only $437,100. After ten years, a traditional landscape would require an average of $81,000 per year to maintain the campus, when only $14,715, or 18% of the conventional landscape cost, is needed for the conservation landscape.

SARB_003916

	Conventional Landscape	Conservation Landscape
Year 1	$81,000	$51,000
Year 2	$89,000	$86,400
Year 3	$89,000	$45,900
Year 4	$89,000	$81,000
Year 5	$89,000	$40,500
Year 6	$81,000	$35,100
Year 7	$81,000	$13,500
Year 8	$81,000	$35,100
Year 9	$81,000	$13,500
Year 10	$81,000	$35,100
Ten-Year Total	**$842,000**	**$437,100**
Subsequent Years	$81,000	$14,715

TABLE 23 Annual Landscape Maintenance Fees. (source: Tellabs)

The lower-cost figures arrived at by Tellabs supports the proposition that conservation development is not only cost-effective but also affords room for additional amenities that are truly beneficial. The landscape development for Tellabs included a number of programs and features to enhance the ability to appreciate the campus. Aesthetic embellishments such as pedestrian paths, bridges, and overlooks provide the opportunity for employees and visitors to enjoy naturalized walking trails and preserved trees and open space.

Conclusion

Total savings in capital costs were $564,473, or just over 12% in favor of the conservation design. Complete conclusions from Tellabs' conservation development data are somewhat limited due to the lack of detailed civil engineering estimates of the construction costs for the conventional scenario. For this reason, certain construction costs were not analyzed in this case study (e.g., water distribution, site paving and sidewalks, and other utilities).

The Tellabs case study does show that commercial developments can certainly benefit from conservation development cost savings, especially from earthwork, stormwater management, and landscaping. In this case, the multiple functions of the integrated stormwater management and landscaping in the conservation site design, which included bioswales, wetlands, and native landscaping, helped save up-front construction costs and long-term maintenance liabilities. Conservation development also provided substantial ecological and environmental benefits by providing clean site water, stable hydrology, and habitat for a wide diversity of plants and animals.

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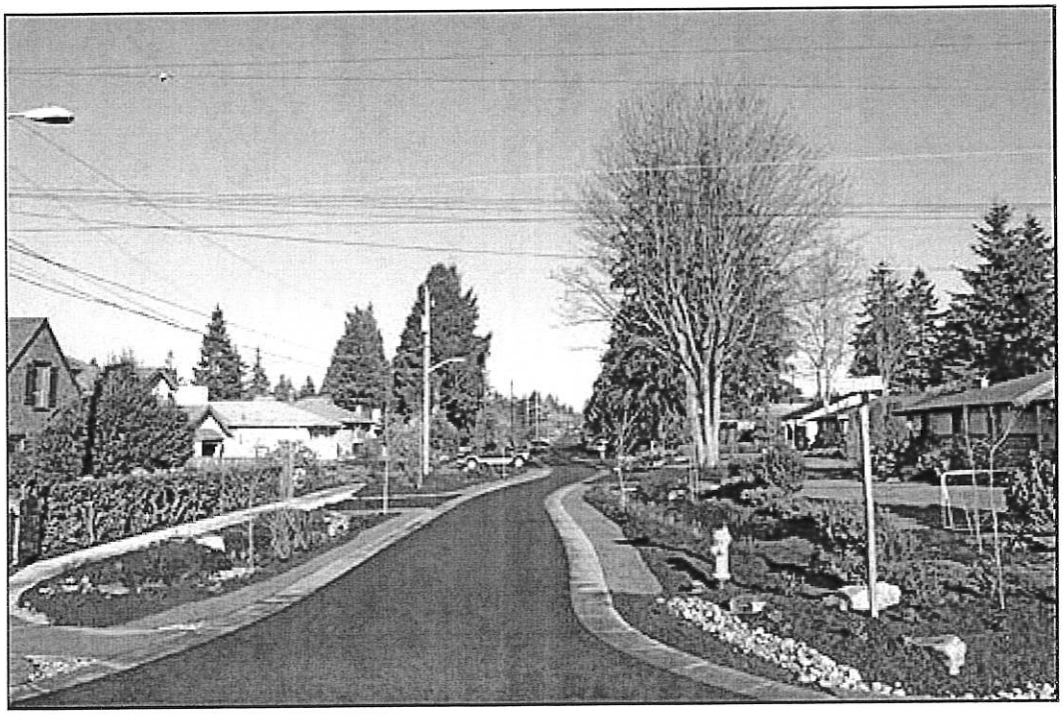
Before



After

FIGURE 11. SEA Street Project Before and After Photos.

SARB_003919

CASE STUDY 5: Street Edge Alternatives Streets

Background

For nearly a decade, the City of Seattle has researched alternative street edge treatments, which use natural drainage systems to allow infiltration and detention as part of their stormwater management system. The momentum began when the City was renovating 2nd Avenue. The costs for alternative street edge and stormwater management designs were compared to traditional stormwater piping systems. As a result, an effort known as the Street Edge Alternatives (SEA) Streets Project was born.

Method

Seattle Public Utilities provided cost data for the SEA Streets project (conservation streets) and the traditional pipe alternative (conventional streets) based on a 660-foot block. In both scenarios, the same drainage area and goals for stormwater detention and water quality were applied. Both scenarios envisioned the replacement of the street and sidewalk paving. Original data includes not only construction costs but also costs for planning, design, and close-out phases (see Appendix 6). The following focuses on construction costs only.

Results & Discussion

The results of the cost analysis are shown in Table 6. It shows that Seattle's conservation streets cost $217,253 less than a conventional street would have on overall construction costs, which is equivalent to $329 savings per foot.

Site Preparation

For this category, site preparation included temporary erosion and sediment control (TESC), and removals and adjustments. Conservation streets cost $88,173, or $134 per foot, in comparison with $65,084 for preparation costs, or $99 per foot, for a conventional street. The $35 per foot difference may be due to aesthetic enhancements.

Stormwater Management

In this case, stormwater management refers to drainage. Conservation streets saved $165 per foot and $108,776 in total on this item. Instead of storm sewer piping, SEA Streets applied vegetated swales and an interconnected underground detention and drainage system to allow infiltration and help to store stormwater volumes. The cost savings from reduced pipes was one of the primary contributions to the overall cost savings.

Site Paving and Sidewalks

The conservation streets cost $223 per foot, in comparison with $436 per foot for conventional streets, for a reduction of $213 per foot. The higher cost for conventional streets is likely related to wider paving for more total paved surface. Sidewalks were planned on both sides of the conventional street and just one side of the conservation street.

Landscaping

The conservation streets cost $52 per foot more for landscaping than the conventional streets. In the conventional street landscape, trees, sod, and minimal plantings were designed as required by city codes, whereas the conservation street landscape design included more diversity of native plants for both aesthetic reasons and for stormwater cleansing functions. The selection and higher maturity of plants needed to achieve those functions resulted in greater installation costs.

Miscellaneous

Miscellaneous costs included mobilization and traffic control. The conservation streets cost only 60% of conventional street costs, which saved $39 per foot. Traffic control for streets may include various traffic calming strategies such as speed bumps, curves, varying paving materials, planting islands, etc. For SEA Streets, the conservation street design employed winding or curved edges so that standard traffic control devices were deemed unnecessary.

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COST	ITEM[1]	CONVENTIONAL[1]	CONSERVATION[2]
CAPITAL COSTS	TESC Measures	$ 20,621	$ 27,273
	Removals and Adjustments	$ 44,463	$ 60,900
	Drainage	$ 372,988	$ 264,212
	Paving	$ 287,646	$ 147,368
	Landscaping	$ 78,729	$ 113,034
	Misc. (mobilization, traffic control)	$ 64,356	$ 38,761
TOTAL CAPTIAL COST		**$ 868,802**	**$ 651,549**

NOTES:

[1] Swales providing detention and water quality treatment.

[2] Drainage area comparable to SEA Streets.

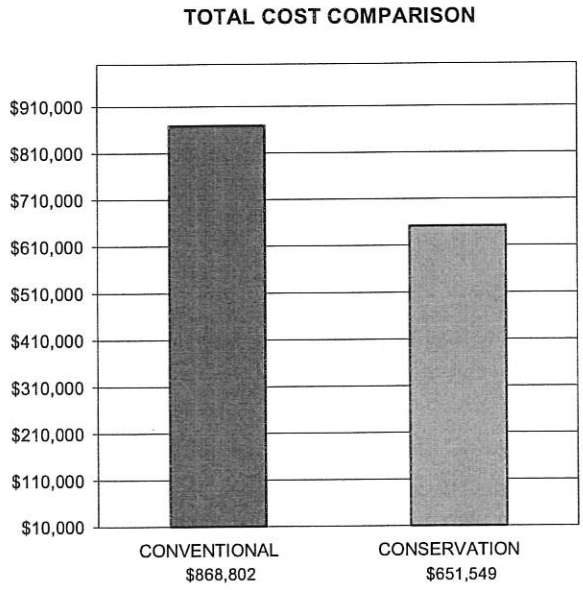

TABLE 24. SEA Street Cost Analysis.

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Limitations

Since the SEA Streets project is on the west coast, it may be questionable to directly transfer conclusions to the Midwest, although this is not meant to imply that the alternative street edge treatment cannot be implemented in the Midwest. Further assessment should be conducted on codes and ordinances and the applicability of these stormwater management techniques in a Midwestern climate.

Conclusion

In this case, construction of the conservation design saved $217,253, or $329 per foot over the conventional costs. The SEA Streets success has helped to change people's perceptions about conventional storm sewer design by showing conservation BMPs with naturalistic streetscapes actually functioning for stormwater management. Not only were construction costs reduced with conservation BMPs, but water quality was improved (see Horner, et al.).

Built-Site Conclusions

The case studies provide a valuable view of real-world practices that support the proposition that conservation development can generally be cost-effective and result in other value-added benefits. The largest cost savings across all cases were mainly derived from site preparation, stormwater management, site paving and sidewalks. The benefits included long-term landscaping maintenance savings, potentially higher real estate values, the advantages of additional open space, and well-planned community-oriented site components and layouts. These cases suggest that the relative cost benefits are roughly similar for a wide range of development types and scales, whether they are moderate-density or rural residential, commercial, or streetscape (see also the following template analysis).

Two conservation techniques appear to have the most direct influence on cost savings: clustering design, which reduces street length and width, and stormwater management. In agreement with the literature review, the built-sites analysis shows that clustering design contributes a significant cost savings for site paving and sidewalks and for stormwater management. The degree of savings depends on the intensity of clustering, which is very site and project dependent.

The costs and benefits of conservation development also depend on how many "green" techniques are implemented on a particular site. These built-site cases primarily employed many of the more basic "green" techniques such as reduced street width and length, bioswales, and native landscaping. More "advanced" conservation design techniques such as porous paving and green roofs were not seen in these case studies (see the Literature Review and Commercial Template analyses). More case studies are needed to analyze the potential benefits and cost efficiencies of a broader suite of conservation techniques.

Finally, it is worth noting that conservation development is not limited to engineering for stormwater management, or to landscape practices. All methods of land and resource management that lead to a sustainable future, ranging from energy conservation to local organic farming to transportation alternatives should be considered for new developments because of the host of benefits they can provide to residents, business owners, and communities. While they were not directly a part of the built-site analysis, long-term maintenance and life-cycle analysis for conservation practices should also be considered.

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Template Cost Analysis

These cost evaluations were prepared as a follow-up to the Blackberry Creek Watershed Alternative Futures Analysis project (Conservation Design Forum, 2003; hereafter, the BBC Watershed Analysis. See Appendix 7). A follow up question from this study was: What would these conceptual template designs cost a developer if they choose to implement these 'green' conservation-based designs?

Under the initial project, two density-neutral design templates were developed to illustrate the differences between conservation and conventional site design and stormwater management approaches. The conventional and conservation templates were then evaluated to estimate the differences in runoff response for each of four template land uses (commercial, moderate density residential, rural residential, and estate residential). Higher urban densities were not part of the initial project scope, and so could not be analyzed for costs in this study. "Conservation" for this study refers to techniques and best management practices (BMPs) that are based on ecologically-sensitive design and planning principles with a particular focus on stormwater management. Generally conservation templates use integrated, state-of-the-art technologies, designs, and site planning to achieve stormwater, habitat, livability, restoration, and other ecological goals.

As explained at the beginning of this report, conventional development refers to practices typical in land development and building construction today in northeastern Illinois. Even though conservation and conventional designs may both be allowed by code, conventional design techniques represent the default designs and practices for a majority of communities and developers.

This analysis compares costs between conventional and conservation construction for typical land uses in the region based on the previously published conceptual template site designs. For this study, stormwater management and water quality are the driving principals in the conservation design approach. Many other social and cultural benefits have been documented, but do not play a role in determining the template costs evaluated here.

The real-life research and actual built-site comparisons of the previous two sections reveal much about the costs and design trends associated with conservation design. However, due to the varying conditions of site and region, the review cannot directly compare the capital costs associated with developing a particular land parcel using one design approach versus another. Therefore, this analysis attempts to control for outside forces such as differing community benefits, agency regulations, topography and other site conditions, land costs that vary with location and construction time, associated traffic costs, and infrastructure connection costs.

The analysis attempts to: 1) compare similar infrastructure-based divisions within each set of templates, using real unit-costs in the Midwest; 2) determine the potential savings or additional expenses associated with the overall design concepts; and 3) determine which infrastructure divisions are shown to be most cost-effective. It hypothesizes that conservation design can generally be more economical, or similarly as affordable for the immediate capital construction costs for different land uses. The template analysis will, therefore, help determine and clarify the degree of cost-effectiveness for conservation design approaches in each land-use type.

Limitations

- This cost comparison is limited to the stormwater infrastructure and related systems of site design. All water entering into the system and leaving the system is considered. Building costs and auxiliary utilities have not been included.
- No effort was made to minimize costs. The Blackberry templates were intended to illustrate a maximum application of conservation approaches and practices. This is most evident in the commercial land-use template, where every attempt was made to prevent stormwater impacts for a traditionally impervious land use. As described in the Alternative Futures Analysis report, this goal was largely achieved. In reality, most new developments will implement a subset of the measures identified in the templates. That subset may not achieve the same level of benefits as illustrated in the Alternatives report. However, significant benefits can still be achieved and development costs mitigated.
- The cost analysis does not consider the actual value of the land. Land value is typically a greater factor in

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higher density areas where land devoted to detention land requirements plays a larger factor in overall cost. Under current regulations prevalent in northeastern Illinois, the higher-cost techniques will be most cost-effective on such sites, where the space required for conventional detention is expensive and limits development potential.

- Due to the conceptual nature of these comparisons, a life-cycle cost analysis was too extensive to include. However, life-cycle cost analysis is a critical part of the forward thinking required to analyze true conservation design. As alluded to in the literature analysis, the importance of life-cycle analysis should not be diminished by its omission from this study.
- Unit costs for construction vary with season and demand. Typical unit costs for northeastern Illinois were used for comparison purposes. Unit costs were based on RS Means 2003 for much of the pricing, while local suppliers and local bid costs were also used. Pricing errors associated with the assumed unit cost should not have a significant impact on the relative cost of the conventional or conservation designs since most unit prices are transferable or similar in both cost estimates.
- The ecological and social benefits of 'green' design are significant driving factors for those who choose conservation design; however they are not addressed directly in this analysis.
- Costs associated with private driveways and private landscaping are not included in the residential templates.

Template Designs

Each template was designed for a hypothetical 40-acre site in the Blackberry Creek Watershed, due to its predominance as a common parcel size. The templates were categorized by land use according to the Kane County 2020 Land Use Plan. Costs were estimated for the following land uses:

Moderate Density Residential (identified as Urban Residential in the Kane County Plan; at 2.2 units per acre gross density),
Rural Residential (0.55 units per acre gross density),
Estate Residential (0.20 units per acre gross density), and
Commercial/Industrial.

Each of the four land use templates has two versions - a conventional and a conservation - for a total of eight templates. Both templates in each category are density neutral, using identical numbers of units, commercial square footage, etc., but are arranged and organized in different ways over the site to illustrate different stormwater management and landscaping techniques.

The conservation templates incorporated the following Environmental Design Principles:

1. Development should avoid, to the extent possible, natural features, including streams, wetlands, remnant natural areas, and critical habitats.
2. The site plan should respect site topography, utilizing natural drainage patterns to minimize site grading and the need for built infrastructure.
3. Clustering of built areas, a range of lot sizes, and other design techniques should be used to create views, privacy, and amenities for each home site. This also facilitates protection of site natural areas, efficient utilization of site topography, integration of naturalized storm-water management systems, and provision of common open space.
4. Created native landscapes should be integrated into the stormwater management system to utilize their natural filtration, infiltration, storage, and transpiration processes.
5. Where appropriate, engineered systems based on natural processes should be utilized as part of the stormwater management system for the purpose of enhancing groundwater recharge, stabilizing site and regional hydrology, and minimizing irrigation needs.
6. Stormwater should be managed as close to its source as feasible.

Cost Comparisons

This analysis includes: 1) a description of the proposed infrastructure for both conventional and conservation designs; 2) a cost estimate summary; 3) an evaluation of the cost and trends presented; 4) the conceptual illustration for each template; and 5) a detailed unit-cost based analysis (see Appendix 8).

Each cost comparison is organized by standard construction divisions related to site design and stormwater

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infrastructure. Due to the different site layout and planning techniques used, the site hardscape and street layout will also differ. For this reason, water and sewer have been included due to their direct relation to street layout. A cost premium for green roof installation was used in the conservation template for commercial/industrial, since roofs are typically not included as part of site costs. Infrastructure divisions include:

- Site Preparation
- Stormwater Management
- Sanitary Sewer
- Water Distribution
- Site Paving and Sidewalks
- Landscape Development
- Green Roof (Commercial/Industrial Only)

Typical design cost for each development was assumed to be 10% of construction costs. However, for the Commercial/Industrial and Moderate Density templates, conservation designs were assumed to be 12% of construction costs. The greater costs were assumed because of two factors. First, additional time is typically required to educate local officials and work with existing code that is not structured to consider the benefits of conservation design and the related stormwater BMPs. This has not been found to prevent conservation design, yet it increases the amount of discussions and meetings, submittals, and back-up information required. As local officials and permit reviewers become more familiar with innovative stormwater techniques and the basis of conservation design, the time investment is expected to decrease and should become less of a factor.

Second, many still debate whether or not conservation construction reduces stormwater infrastructure cost. Therefore, this study assumes that site and stormwater design costs will increase slightly due to the increased need for information about the land and more complex modeling of the site that is often required.

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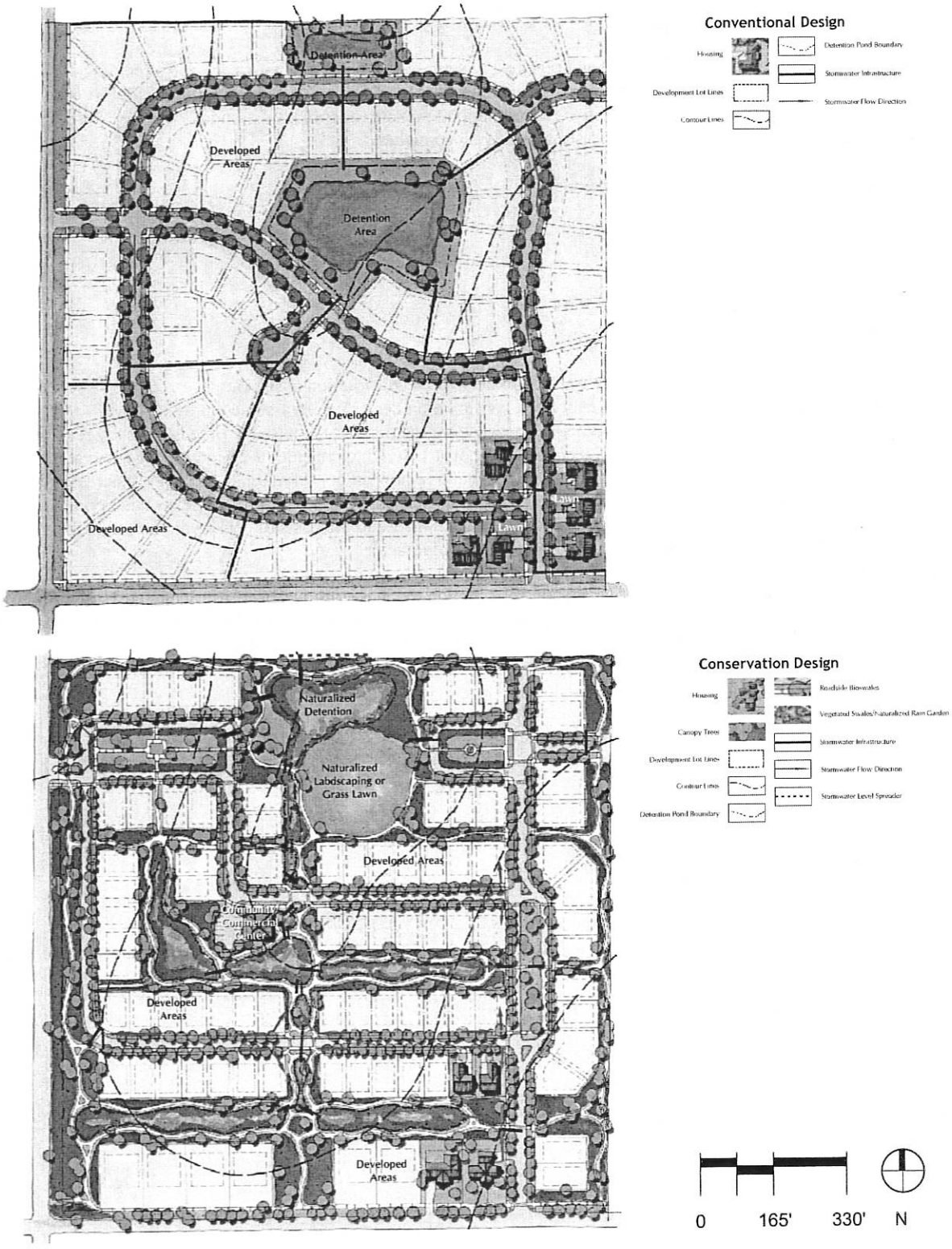

FIGURE 12. Moderate Density Template- Conventional & Conservation. Image courtesy of Conservation Design Forum

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Moderate Density Residential Templates

Moderate density residential development is defined for this project as having a gross density of approximately two units per acre with single family lot sizes ranging from 6,000 to 15,000 square feet which are planned to be served with municipal water and sewer services. As previously stated, the two template versions are density neutral with a total of 89 lots developed into each template site.

Conventional Description

The Conventional Template includes wider roads, no public open space, and storm sewers discharging into turf and/or rip-rap lined detention basins. Due to the impervious surfaces and infrastructure-based drainage systems, hydrology is shifted from groundwater dominated to surface water dominated.

Site Preparation

General site preparation techniques include clearing and grubbing and fine grading of the entire site as well as clearing and grading techniques that may balance, yet also flatten, the site for ease of construction.

Stormwater Management

Conventional Moderate Density Residential template development has been designed to direct runoff from streets, driveways, and lawns via piping to temporary detention basins before releasing it offsite. The entire development is served by curb, gutter, and storm sewer drainage. While detention is quite effective at controlling the rate of runoff, it does little to address the increased volume of runoff, and hence its effectiveness decreases with increasing watershed size.

Modeling conducted in the BBC Watershed Analysis determined that 15 ac-ft of detention must be provided. Detention basins were assumed to be edged with rip rap and do not create a recreation or aesthetic amenity for the neighborhood.

Sanitary Sewer

A traditional sanitary sewer system was laid out to serve all homes and assumed to require the same length of piping as road length with one connection to the existing sanitary trunk line.

Water Distribution

A traditional 8-inch water distribution system was laid out to serve all homes and assumed to require the same length of piping as road length and one connection to the existing water main. Fire hydrants were installed on the water main as required by code.

Site Paving and Sidewalks

Residential roadways were assumed to be 32-foot for both the local and collector roads. A 5-foot concrete sidewalk and curbing along both sides was included for all roads. Asphalt parking areas for residences are paved and include exterior parking space, with room for at least two cars per single family housing unit. This driveway layout was assumed to be identical for both templates and not included into the cost estimate.

Landscape Development

Public open space is often limited to road rights-of-way and small isolated park lands. Lot sizes were standardized with little variety. Street trees were placed on within the parkway approximately 50 feet apart based upon a typical subdivision code requirement. Seeded turf grass was assumed for all common spaces. The cost comparison did not include any on-lot landscaping, typically consisting of shrub, tree, lawn, and perennial plantings and irrigation.

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COST	ITEM	CONVENTIONAL	CONSERVATION
CAPITAL COSTS	1. Site Preparation[1]	$ 938,000	$ 529,000
	2. Stormwater Management	$ 437,000	$ 395,000
	3. Sanitary Sewer	$ 309,000	$ 282,000
	4. Water Distribution	$ 330,000	$ 315,000
	5. Site Paving and Sidewalks	$ 873,000	$ 751,000
	6. Landscape Development	$ 109,000	$ 249,000
	Design Contingency[2]	$ 305,000	$ 309,000
TOTAL CAPITAL COST		**$ 3,350,000**	**$ 2,880,000**
PER LOT[3]	Not Including Building, Site Appurtenances, and Land Costs	**$ 38,000**	**$ 32,000**

NOTES:
[1] Assume less overall grading disturbance per acre.
[2] Design cost contingency assumed at 10% for Conventional and 12% for Conservation.
[3] Based on 89 lots per 40 acres.

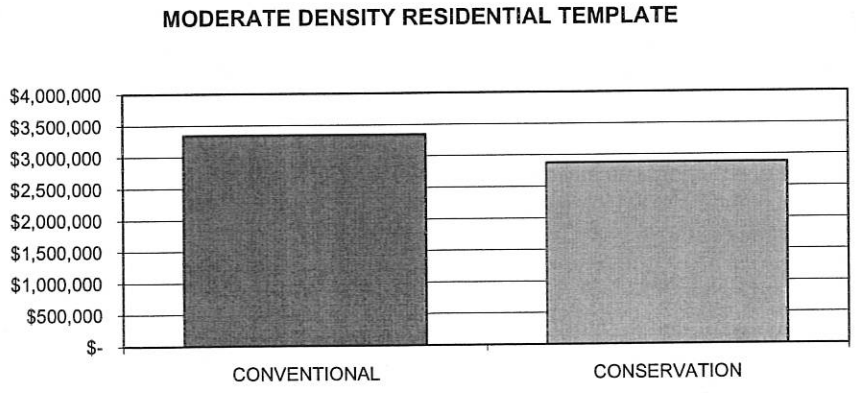

TABLE 25. Moderate Density Residential Template Summary.

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Conservation Description

The Conservation template includes narrower streets and an integrated, naturalized stormwater system in community space that hosts public trails and locates each residential lot adjacent to open space. Conservation moderate-density residential developments can take to form of cluster housing, with varied lot sizes at the same gross density as the conventional development while preserving and/or creating ecological and stormwater corridors. Clustering creates opportunities to develop neighborhood amenities, including parks and recreation facilities.

Site Preparation

General site preparation techniques are also incorporated into conservation design. This, however, includes clearing and grubbing only 27 acres of the site due to the clustering of homes and restored conservation areas. Clearing and grading techniques to balance the site are reduced by designing with site topography in mind as well as a reduced area of disturbance.

Stormwater Management

The street and front yard runoff are directed to shallow street parkway bioswales, with an infiltration trench beneath. The excess surface runoff from the roadway bioswales, runoff from the backyards, and roof runoff are conveyed to the vegetated swale - rain garden in the common space. An area averaging 35-foot in width is planned between the trails to enhance adsorption of the runoff.

Modeling conducted for the BBC Watershed Analysis determined that 6 ac-ft of detention is needed. Detention areas are naturalized and designed to mimic natural wetlands and are part of a network of open space within and outside the development.

Sanitary Sewer

A traditional sanitary sewer system was laid out to serve all homes. It was assumed to require the same length of piping as road length with one connection to the existing sanitary trunk line.

Water Distribution

A traditional 8-inch water distribution system was laid out to serve all homes and assumed to require the same length of piping as road length and one connection to the existing water main. Fire hydrants were installed on the water main as required by code.

Site Paving and Sidewalks

Streets are narrowed to reduce traffic speeds and decrease impervious cover. Local residential roadways were narrowed to 27 feet wide while the collector remained at 32 feet wide.

A 5 ft sidewalk and a street cross section without curbing has been designed along both sides the 27 ft roadway. The streets were lined with stormwater conveyance swales. A secondary pedestrian system was designed with limestone screening pathways running within the internal open space parkway.

A 5 ft concrete sidewalk along one side and concrete curbing was designed along the main collector road.

Landscape Development

A natural area buffer and prairie/savanna restoration were planned for 17 acres of common space. Street trees were planned in the parkway spaced every 50 feet or so based upon typical subdivision code requirement.

Clustering and decreased lot sizes allowed for every lot to adjacent to naturalized open space and/or turf park land that is also part of the drainage system. Common area parks and naturalized

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open space were designed with an interwoven pattern across the entire development to connect habitats, provide stormwater infiltration and conveyance, and provide recreational opportunities to residents.

Typical on-lot landscaping was not included in the cost comparison (e.g., shrub, tree, perennial plantings and irrigation).

Results and Discussion

This cost comparison shows that the incorporation of conservation design into developed sites like the Moderate Density Residential template will result in overall capital cost savings consistent throughout most of the cost divisions. The general per-lot site cost for the conventional development is $38,000 per lot versus $32,000 for the conservation approach, a savings of just over 15 percent. This cost savings trend is comparable to, but not as high as the overall cost saving in the Bielinski Home Case Study (see the Built Site Analysis).

Site preparation for the moderate density residential site is expected to be less for the conservation design, since nearly 13 acres of site are minimally disturbed due to the reduced land requirements for clustering of homes. Savings can be achieved by minimizing the required clearing and grading by designing around the grades and fitting the site plan to the land.

Stormwater management systems are nearly similar for conventional and conservation design. Cost savings due to the reduction of detention and buried infrastructure are slightly greater than the increased cost of localized and naturalized stormwater management practices. Only 60% of the conventional detention volume is required for the conservation design due to localized stormwater management techniques.

Sewer and Water infrastructure costs vary with the degree of clustering and length of roadway. Both sanitary sewer and water infrastructure costs range from slightly less to nearly similar for both conventional and conservation development.

Even with the added pedestrian corridors, recreational limestone paths and improved sidewalk access, Site Paving and Sidewalk costs were less for the conservation design. Savings can be attributed to the narrowed streets and reduction of curbing throughout all residential streets.

Landscape costs for the conservation design were greater than for the conventional design due to the increase in the amount of common space that is a development cost, as opposed to on-lot landscape costs, which are generally borne by the home purchaser. These common areas were planned with native prairie plantings, and naturalized plantings in rain gardens and swales.

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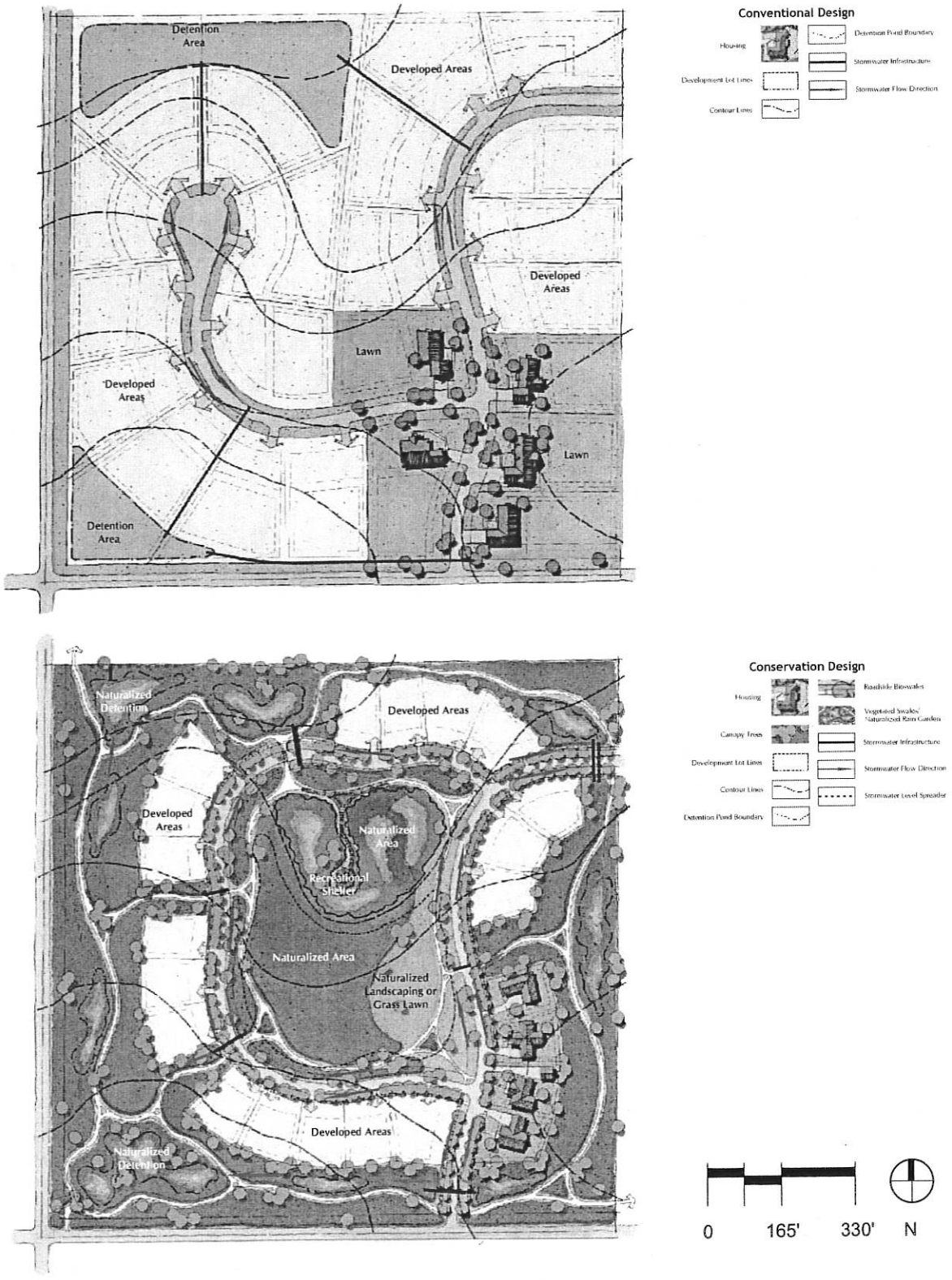

FIGURE 13. Rural Residential Template- Conventional & Conservation. Image courtesy of Conservation Design Forum

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Rural Residential Templates

The Rural Residential Templates have single family lots which average approximately 1.25 acres, and a gross density of 0.55 units per acre. It is assumed that on-site water supply and wastewater treatment will be necessary. A total of 22 lots are shown in each version.

Conventional Description

The Conventional Rural Residential Template is planned with a cul-de-sac drained with traditional roadside swales and storm culverts discharging into large detention basins.

Site Preparation

General site preparation techniques include clearing and grubbing and fine grading of 36 acres of the site. Typically most of the site will be disturbed. Clearing and grading techniques may balance, but tend to flatten the developed portion of the site for easy construction.

Stormwater management

Many developments at this density are served by open drainage systems, yet many large-lot developments within municipalities have been increasingly using curb and gutter drainage with storm sewers. For this study, the development is assumed to be served by traditional road side swale systems with storm culvert drainage for consistency between templates.

The detention basins are assumed at the edge of the development with turf and rip rap reinforcement at the shoreline. Modeling conducted in the BBC Watershed Analysis determined that 10 ac-ft of detention volume must be provided.

Sanitary Sewer

Individual septic systems have been assumed to serve all 22 homes.

Water Distribution

Individual private wells have been assumed to serve all 22 homes.

Site Paving and Sidewalks

In these relatively low-density subdivisions, winding streets with cul-de-sacs and few connections to major collector roadways are the commonly used planning idiom. These plans are often criticized for issues that are beyond the scope of this study, such as the creation of disjointed neighborhoods, resulting in traffic congestion. As is common with this density, roads are also generally wider than necessary for the traffic they support, increasing stormwater runoff and encouraging higher speeds. This template assumed a 27-foot residential road with a 32-foot collector.

Although sometimes sidewalks are included in conventional large lot developments, typically they are not unless required by code. Therefore no sidewalks were included here. Setbacks are large, necessitating long paved driveways which further increases impervious cover.

Landscape Development

Lot sizes were standardized with little variety. Street trees were planned based on typical subdivision code requirements. Seeded turf grass was planned as landscape cover for the common open spaces. Typical on-lot landscaping (e.g., shrubs, trees, perennial plantings and irrigation) was not included in the cost comparison.

Conservation Description

The Conservation Rural Residential Template includes narrower drive lanes and a naturalized stormwater system

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COST	ITEM	CONVENTIONAL	CONSERVATION
CAPITAL COSTS	1. Site Preparation[1]	$ 609,000	$ 353,000
	2. Stormwater Management	$ 227,000	$ 102,000
	3. Sanitary Sewer[2]	$ 99,000	$ 200,000
	Constructed Wetland Premium		*$ 101,000*
	4. Water Distribution	$ 98,000	$ 98,000
	5. Site Paving and Sidewalks[3]	$ 253,000	$ 358,000
	6. Landscape Development	$ 102,000	$ 184,000
	Design Contingency[4]	$ 142,000	$ 133,000
TOTAL CAPITAL COST		**$ 1,570,000**	**$ 1,470,000**
PER LOT[5]	Not Including Building, Site Appurtenances, and Land Costs	**$ 71,000**	**$ 67,000**

NOTES:
[1] Assume clearing grubbing non-open space areas only and less overall grading disturbance per acre.
[2] Traditional septic versus constructed wetland with land application.
[3] Includes community enhancing site amenities such as secondary limestone paths, sidewalks and boardwalk.
[4] Design cost contingency assumed at 10% for Conventional and 12% for Conservation.
[5] Based on 22 lots per 40 acres.

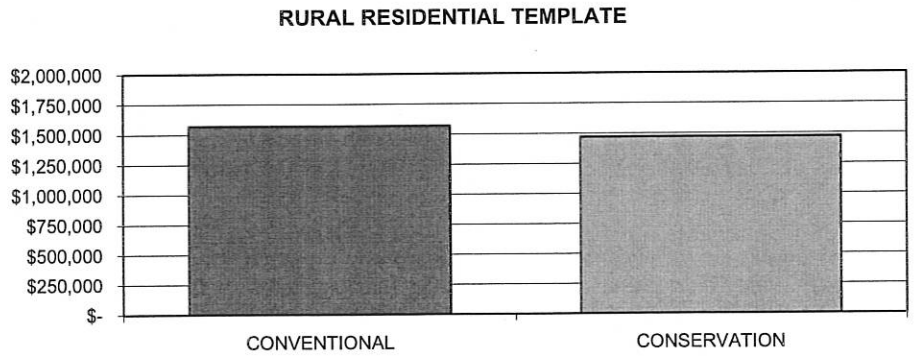

TABLE 26. Rural Residential Template Summary.

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using the landscape to filter, evapotranspire, and absorb runoff. The layout includes walking/ biking trails for greater pedestrian use. The conservation rural residential development has the same gross density as the conventional development template. However, reduced lot sizes and clustering are employed to create shared common open space, and conservation easements are used to protect natural areas and create native landscape-based habitat and stormwater infiltration corridors.

Site Preparation

General site preparation techniques are also incorporated into the conservation design. This includes clearing, grubbing and fine grading of only 18 acres of the 40 acre site due to the clustering of homes and created conservation areas. Clearing and grading techniques to balance the site are also reduced by minimizing the impact to the site by designing with site topography in mind.

Stormwater management

The objective of the stormwater system is to utilize the significant amount of common open space to filter and absorb runoff and replicate the natural site hydrology. Stormwater is conveyed via naturalized roadside bioswales. Detention areas are naturalized, enhancing overall ecological integrity, while at the same time improving the aesthetic quality and rural character of the site.

Both the interior and perimeter roads were drained with prairie-vegetated swales. Detention areas were naturalized and designed to mimic natural wetlands. Modeling conducted for the BBC Watershed Analysis determined that 2.5 ac-ft of detention volume is required.

Sanitary Sewer

The wastewater system consists of individual septic tanks that flow to a common treatment system incorporating subsurface constructed wetlands with land application. This system is one of a variety of on-site wastewater recycling and reuse technologies that have been installed and operated in the Midwest as an alternative to individual septic fields and create the opportunity for clustered development in an ecologically sound fashion.

Water Distribution

Individual private wells have been assumed to serve all 22 homes.

Site Paving and Sidewalks

Roads in low density conservation developments are generally narrower on average, are designed at a more human scale, and for slower, safer speeds for neighborhoods. Road widths have been shown at 24 feet for the residential and 27 feet for the collectors. Sidewalks are included along all roadways for pedestrian access.

Several site amenities have been included in the conservation approach to improve community connection between neighbors and their land. Trail systems are located in the natural areas and roadways. A boardwalk into the naturalized area has been included into the design as a central feature.

Landscape Development

Street trees were planned in the parkway based upon typical subdivision code requirements. Seeded turf grass was planned for the central park common area. Typical on-lot landscaping (shrubs, trees, perennial plantings and irrigation) was not included in the cost comparison.

Wildlife habitat, native landscaping, and common space occur on over 21 acres in the central space and in the perimeter, visible from the front and rear of all of the homes. Over 50 percent of the entire parcel is set aside for common space. Most of the common areas were planned as restored

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prairie and swales with the exception of a small community turf play area. This centralized area of the site is also required for the constructed wetlands and disposal fields (leach/drip irrigation). Since these areas have been set aside for common space, the planting costs are assumed as development expenses in this template.

Results and Discussion

This analysis shows that development costs for this conservation design are slightly less than the costs associated with typical conventional design for Rural Residential sites. Additionally, the conservation design approach assumes many community amenities that have not been included in the conventional approach. These amenities include added sidewalks, pathways, a nature boardwalk, community spaces, and views of restored prairie.

Savings are realized in site preparation and stormwater management, and can be attributed to: 1) improved stormwater quality through naturalization; 2) enhanced wastewater treatment leading to improved groundwater quality; and 3) increased community and pedestrian circulation. The general per-lot costs for the conventional development are shown to be $71,000 per lot versus $67,000 per lot for the conservation approach, a savings of 5.6 percent.

Site preparation costs have been assumed to be consistent with the other land-use templates. While these costs are relative based upon existing conditions, they are generally reduced from conventional to conservation in the rural templates, due to the additional 18 acres that have been set aside for prairie restoration and open space, thereby greatly minimizing the disturbed parcel area. Savings are again seen by minimizing the required clearing and grading in the disturbed areas by designing with the grades and minimizing fine grading.

Over 50% cost savings are realized for a conservation stormwater management system. These large cost savings are due to the 75% reduction of detention volume requirement and minimized piping costs by using localized stormwater management BMPs. This reduction of cost is complimented by the improved aesthetic aspects of the design, which are arguably more "rural" in character, and therefore create greater real estate value.

Both sanitary sewer and water infrastructure costs would be expected to be nearly similar for both conventional and conservation development if they utilized identical systems. However, an enhanced naturalized wastewater treatment design was included in the conservation template to allow clustering and create an ecologically superior water treatment approach. Yet, even with a doubling of the cost for enhanced onsite wastewater treatment, the overall site development cost is nearly the same. While the cost for individual well and septic fields is typically borne by the home builder or buyer, the lot price of the collective system in the conservation approach could reflect the benefit of already having these systems in place. An expected savings in overall cost of $101,000 (over ten percent) over a conventional approach could be realized by implementing the conservation approach. This result matches conservation designs presented in the Built Site Analysis Section.

Site Paving and Sidewalk costs are increased for conservation design because pedestrian corridors were added to the basic construction and planning practices assumed by the conventional template. Also, due to the large amounts of land in common space in the conservation approach, which are planned to be restored into prairie and wetland, landscape costs are greater than for the conventional approach. These are both value-added aspects that could be marketed for premiums and/or increase sales velocity over conventional subdivisions.

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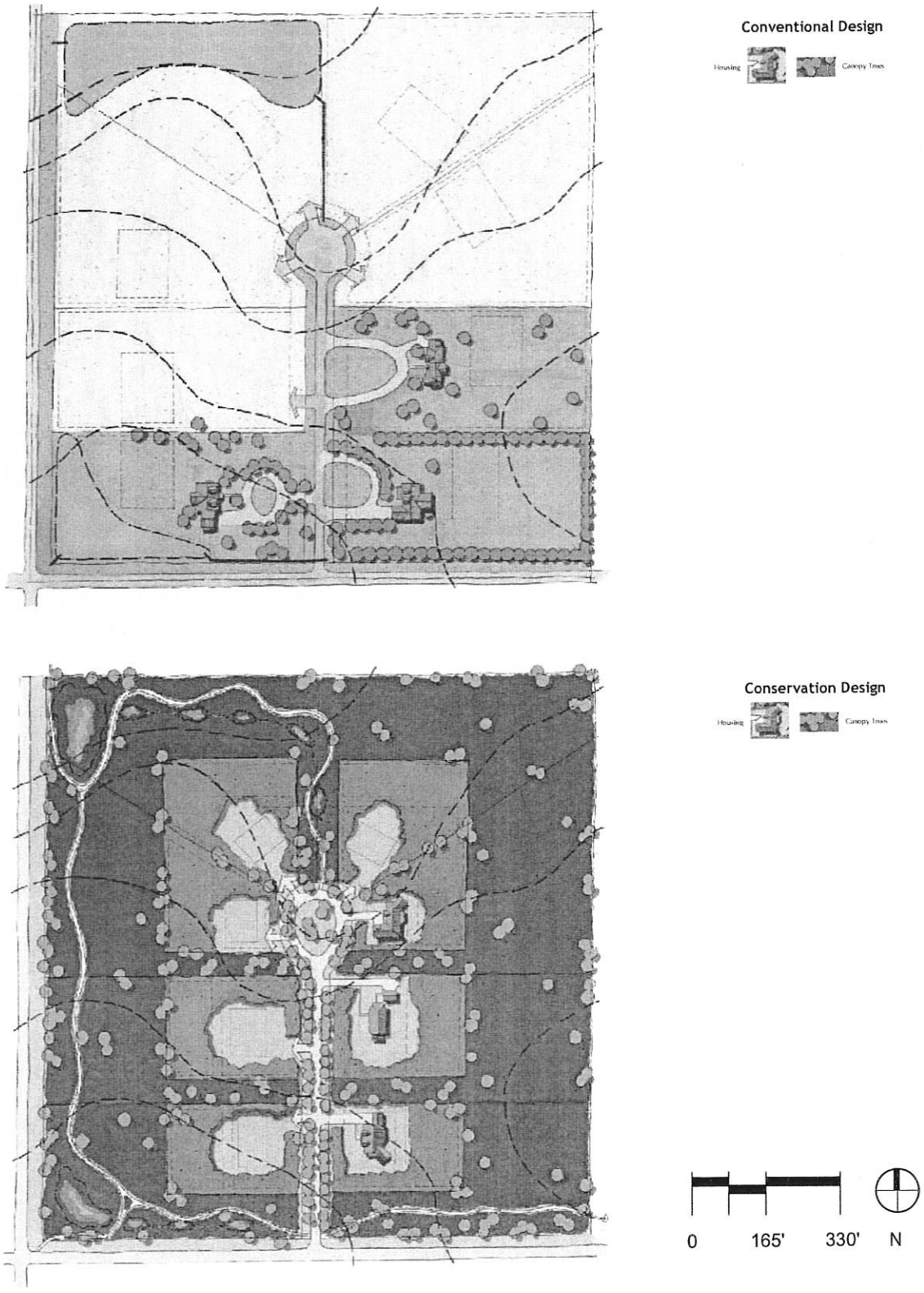

FIGURE 14. Estate Residential Template- Conventional & Conservation. Image courtesy of Conservation Design Forum

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Estate Residential Template

The Estate Residential Templates are planned with single family lots averaging approximately 2.5 acres in size, or approximately 0.2 units per acre, which are served by private well and septic systems. A total of eight lots are shown on the parcel. Both conventional and conservation templates have been laid out with essentially the same cul-de-sac road pattern and lot lines. Open swale drainage systems were used in both versions of the Estate Residential Template.

Conventional Description

The Conventional Template has typical house placements centered in the lots, resulting in generally longer driveways. The lots are primarily landscaped with manicured lawns.

Site Preparation

General site preparation techniques include clearing, grubbing and fine grading for the entire site. Clearing and grading is minimal for each, however it has been assumed that the developed portion of the site has been leveled for ease of construction. Fine grading is required over the entire site devoted to lawn landscape.

Stormwater management

Requirements for stormwater detention are met through the provision of turf grass depressions and/or constructed ponds. Stormwater is conveyed via roadside turf swales and culverts to the detention pond. Roads are to be drained by turf swales approximately 10 feet wide. The required detention pond has been modeled with eight acre-feet of volume.

Sanitary Sewer

Individual septic systems have been assumed to serve all 8 homes.

Water Distribution

Individual private wells have been assumed to serve all 8 homes.

Site Paving and Sidewalks

The cul-de-sac roadway has been shown as 24' wide. No sidewalks or curbs are required or included for this type of development. Driveways in conventional estate residential developments tend to be long and paved with standard impermeable asphalt and may include a drop off area and several outdoor parking spaces.

Landscape Development

Turf lawns are the dominating landscape feature of these subdivisions and have been assumed for the entirety of the lots based upon conventional practice. Irrigation was assumed for front yards and landscaped areas, or 10% of the site. The cost does not include typical shrub, tree and perennial plantings.

Conservation Description

The Conservation Estate Residential development is laid out in a similar pattern to the conventional template, but is very different ecologically. Although the same gross density is maintained and actual lot sizes are the same, the area impacted by development is much smaller as only the ground necessary for structures and septic systems is disturbed by equipment. The remaining areas are preserved or restored to a native landscape. The template has shorter driveways and uses native plantings and conservation easements.

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COST	ITEM	CONVENTIONAL	CONSERVATION
CAPITAL COSTS	1. Site Preparation[1]	$ 548,000	$ 329,000
	2. Stormwater Management	$ 158,000	$ 29,000
	3. Sanitary Sewer	$ 36,000	$ 36,000
	4. Water Distribution	$ 36,000	$ 36,000
	5. Site Paving and Sidewalks	$ 63,000	$ 91,000
	6. Landscape Development	$ 570,000	$ 256,000
	Design Contingency[2]	$ 145,000	$ 81,000
TOTAL CAPITAL COST		**$ 1,590,000**	**$ 900,000**
PER LOT[3]	Not Including Building, Site Appurtenances, and Land Costs	**$ 200,000**	**$ 110,000**

NOTES:
[1] Assume less overall grading disturbance per acre.
[2] Design cost contingency assumed at 10% for Conventional and 12% for Conservation.
[3] Based on 8 lots per 40 acres.

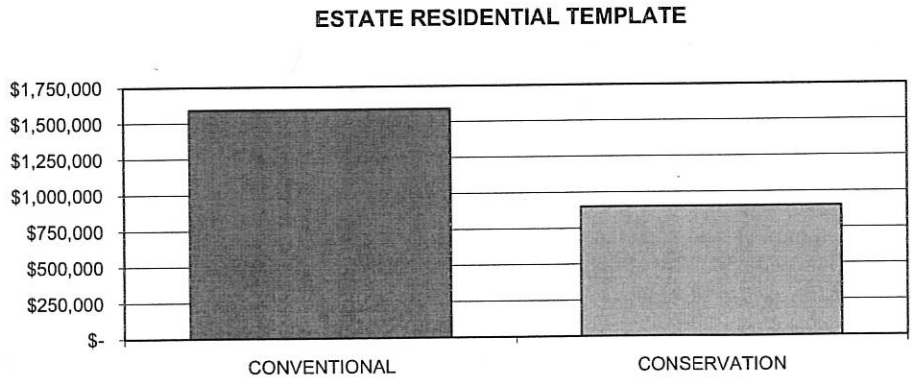

TABLE 27. Estate Residential Template Summary.

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Site Preparation
General site preparation techniques include clearing and grubbing of 18 acres of the site and with fine grading for only 8.5 acres, since fine grading is not required for prairie restoration and natural buffer areas. Clearing and grading are balanced and minimal.

Stormwater Management
The goal for stormwater is to preserve and replicate the natural site hydrology. This is achieved by minimizing disturbed areas, using existing natural drainageways, and utilizing native landscapes to filter and retain runoff. Retention areas are designed as natural elements of the overall landscape. The road was assumed to be drained by prairie-vegetated swales with an interior cul-de-sac rain garden. The vegetated swales drain to the detention areas via wide prairie areas with minimal piping.

Sanitary Sewer
Individual septic systems were assumed to serve all 8 homes.

Water Distribution
Individual private wells were assumed to serve all 8 homes.

Site Paving and Sidewalks
The conservation estate road system is similar to the conventional, but the cul-de-sac has been designed with a vegetated island in the middle as part of the stormwater retention system. No curbs are incorporated into this plan (or in the convention version). Limestone screening paths are incorporated into pedestrian easements, which allow low-impact access to natural areas and other nearby neighborhoods.

Landscape Development
Design features are used to enhance the conservation estate development. Structures are moved slightly closer to the road to increase the amount of contiguous conservation easement land in the rear of lots.

Turf grass is included and limited to lawn areas immediately surrounding the home, while deep-rooted native plants occupy outer lawn areas and restored prairie conservation easements to the perimeter. One quarter of the non-impervious front yard was assumed to be planted in prairie vegetation and the remainder was assumed to be turf. Three quarters of the back yard was assumed to be prairie. Irrigation was included as lush green lawn is still assumed for this real estate market segment. Since the total area of lawn is much smaller, only 20 percent of the front lawn area is irrigated.

Costs do not include typical shrub, tree and perennial plantings, or other on-lot landscape expenses.

Results and Discussion
This cost analysis shows that the conservation design could save about 45% over conventional design for Estate residential sites. Savings are realized in stormwater management, site preparation, and landscape development. The general per-lot site costs for conventional is $200,000 per lot vs. $110,000 for the conservation approach.

As consistent with the previous templates, site preparation, is expected to be reduced for conservation. Fine grading is minimized due to the natural area buffer and prairie. Also, savings are seen because the required clearing and grading is minimized by designing around the grades and preserving open space.

The stormwater management system for the conservation approach is around one-fifth the cost as would be required

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for conventional practices. These significant cost savings are due to detention volume requirements that were reduced by a factor of eight. Localized stormwater management BMPs reduce cost and increase the natural aesthetics of the neighborhood.

Both sanitary sewer and water infrastructure costs were identical for both conventional and conservation versions.

However, site paving and sidewalk costs were over 40% higher for the conservation template, due to the basic community-based design approach and the added pedestrian corridors with recreational limestone paths and use of sidewalks. This cost increase is may be offset by the perceived aesthetic and recreation value of the homesites of a standard subdivision.

Turf and irrigation cost for conventional design is over twice the cost of conservation design landscaping, due to the traditional aesthetic need for large-expansive-green lawns for estate residential. The conservation aesthetic incorporates nearly 33 acres of land into prairie and savanna restoration or conservation easements for recreational use and pleasure. Both approaches assume full ground cover landscaping and partial irrigation as part of the development costs. While on-lot landscape for rural subdivisions is normally borne by the home builder or buyer, these costs could be included in the home purchase price, or the naturalized landscapes could be required to be installed by whoever is building the home.

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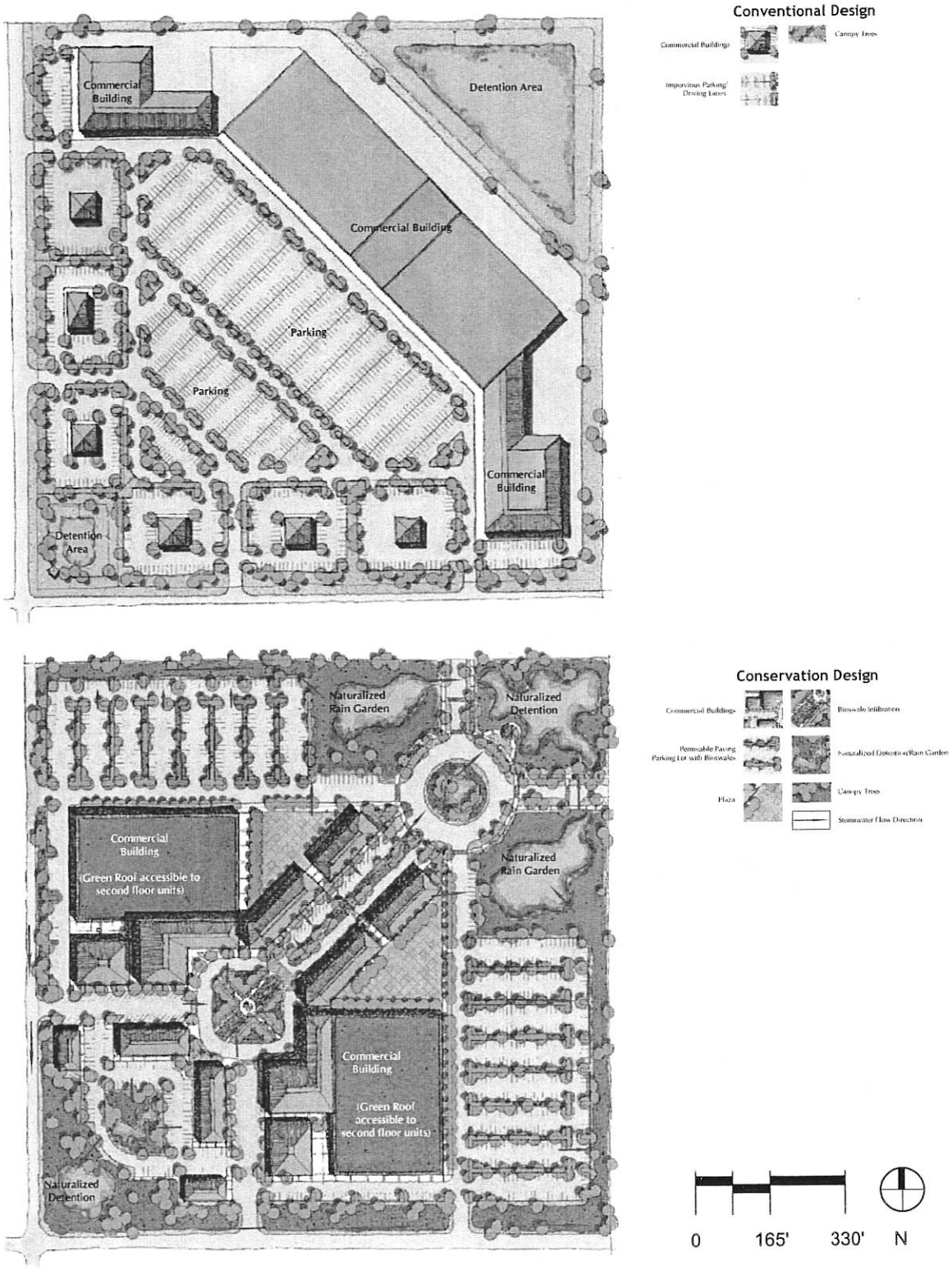

FIGURE 15. Comercial Industrial Templates- Conventional & Conservation. Image courtesy of Conservation Design Forum

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Commercial/Industrial Templates

Commercial/Industrial developments include retail, light industrial and offices in various scales from large scale "big box" retail stores and light industrial and office park development, to smaller scale restaurants, shops, and individual offices. The Commercial/Industrial Templates were evaluated for construction costs based on the two templates shown in the illustrations. For this land use only, a third cost analyses based on the original conservation design was conducted to evaluate a commercial site without the benefit or additional cost of green roofs (template not shown). All assumptions for these conservation templates are identical with exception to the green roof. The original conservation template has been designated 'Premium Conservation' and the conservation cost template without the green roof system has been designated 'Base Conservation'. The three analyzed templates are:

Conventional
Premium Conservation
Base Conservation (No Green Roof)

Like the other templates, the development units were held constant between the conventional and conservation versions of the commercial template. For this template, the square footage of commercial space and the number of parking spaces were held constant. However, because of the efficiency of the conservation template stormwater management systems, there is room within the conservation template for additional commercial space and parking. The value of this potential additional space was not factored into cost analysis due to the high degree of variability in rental rates based on location and use. However, this factor should be considered when evaluating the templates costs.

Conventional Description

The Conventional Template is laid out as a typical automobile-accessed strip mall, with two single-story "big box" retail stores, smaller shops, franchise outlots, and parking, landscaping and stormwater detention according to code. These sites typically have a large amount of surface parking, which often exceeds the needs of the businesses during the vast majority of hours of operation throughout the week and seasonally.

Site Preparation

General site preparation techniques include clearing and grubbing of the entire site, as well as clearing and grading techniques that may balance, yet also level the site for ease of construction.

Stormwater Management

Stormwater is conveyed via traditional storm sewer systems including one catch basin per developed acre and that discharge to large detention basins on the development fringe. Pipe sizing was estimated as a 12-inch average storm sewer size. Because of the large amount of impervious cover, water level fluctuations in the detention basins are often large and frequent, leading to the need for rip-rap to protect the shoreline from erosion. Modeling conducted in the BBC Watershed Analysis determined that 22 ac-ft of detention volume is required.

Sanitary Sewer

A traditional sanitary sewer system was laid out to serve all building structures using the most direct layout and two connections to the existing sanitary trunk line.

Water Distribution

A traditional 8-inch water distribution system was laid out to serve all building structures using the most direct layout and two connections to the existing water main. A fire loop was installed around the buildings with one hydrant every 400 feet.

Site Paving and Sidewalks

Typically, the perimeter outlots are developed for fast food, banks, and other businesses. These outlots generally have their own parking, and are not easily accessed by pedestrians, even those shopping in the same center. The site was designed with a 24-foot wide access road and a 32-foot delivery road to

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the back of the buildings. All roadways and raised parking islands were designed with standard curbing. Sidewalks were assumed to be 5-foot within the site and 12-foot adjacent to the stores and malls. All drivable and parking surfaces were covered with asphalt. Curbing was used to edge all roadways, parking areas and islands.

Landscape Development

Landscaping was limited to raised islands at the ends of parking isles and the exterior landscape perimeter adjacent to the main roadway. Standard small-diameter shrub and tree plantings were assumed throughout the site as are typically required. Turf grass was shown around detention basins and within the strip between the access roads and the parking lot and the buildings. Irrigation use was limited to only the front roadway/mall buffer landscape areas for plant establishment and maintenance.

Roof

Commercial and industrial developments are typically installed with flat asphalt or membrane roofs.

Premium Conservation Description

The Premium Conservation Template also has two "big box" retail stores, but in the conservation design, green roofs have been installed on the main structures and are designed as part of a "Main Street" retail setting, with a pedestrian plaza and both on-street and off-street parking. Sustainable technologies and designs are incorporated into conservation commercial developments to minimize the impact of impervious surfaces. Permeable paving systems are used in the parking lots along with stormwater infiltration bioswales as part of a naturalized and landscaped stormwater system.

Interconnected street systems with pedestrian and bicycle connections and infrastructure throughout provide public access to a variety of transportation alternatives. Conservation commercial developments can potentially be designed to fit any scale, and mix uses to encourage trip linking, day and night activity and reduced peak parking demands.

Site Preparation

General site preparation techniques are assumed in this conservation template. This includes clearing and grubbing of the entire site; however, clearing and grading requirements to balance the site could be somewhat reduced by minimizing the average excavation impact to the site by respecting existing site topography.

Stormwater management

Green roofs, biofiltration swales, rain gardens, porous pavement, and naturalized detention ponds are incorporated into the stormwater management of this template. A bioswale running down the center of the "main-street" area of the template was assumed to treat runoff from the adjacent roofs, walks, and roads. Rain gardens in a number of locations were used to filter and absorb runoff from adjacent impervious areas. The runoff from the impervious patio areas behind the main-street buildings was assumed to drain to the large rain gardens on either side of the traffic circle. These rain gardens are actually much larger than was necessary to achieve the stormwater objectives. Thus, there would be an opportunity to reduce the area of these rain gardens to provide additional commercial or parking space.

Porous pavement has been utilized within the north and west parking lots along with parking island bio-infiltration swales to minimize the impact of stormwater runoff associated with typically large impervious areas. There is considerable runoff storage within the aggregate beneath the permeable pavers, leading to a significant reduction in the amount of conventional detention required to meet local stormwater release rate requirements.

Modeling conducted in the BBC Watershed Analysis determined that 12 ac-ft of detention volume would be needed, a reduction of nearly 50% as compared to the conventional approach. This reduction in conventional detention requirements is largely the result of the large amount of storage distributed throughout the site beneath the permeable paving and within the bio-infiltration swales. Naturalized detention ponds have been assumed using native plantings and natural erosion control techniques.

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Sanitary Sewer

A traditional sanitary sewer system was laid out to serve all building structures using the most direct layout and two connections to the existing sanitary trunk line.

Water Distribution

A traditional 8-inch water distribution system was laid out to serve all building structures using the most direct layout and two connections to the existing water main. A fire loop was installed around the buildings with one hydrant every 400 feet.

Site Paving and Sidewalks

Most parking areas are assumed to be paved with interlocking permeable concrete pavers for infiltration. Pedestrian access through the site is improved through the increased use of 5-foot sidewalks. Larger 8-foot sidewalks adjacent to all storefronts have been shown. A large paved plaza is shown in the central shop area for pedestrian gathering and was assumed as half paving and half landscaping. Access and delivery roadways were narrowed where possible and shown as asphalt pavement. Concrete curbing is utilized throughout.

Interlocking permeable concrete pavers were specified for this template due to their longevity, maintainability, and resistance to surface coating with impermeable sealers. However, a lower capital cost option would be use of permeable asphalt. Permeable asphalt has been used in other northern climates with good results. Permeable asphalt's greatest drawbacks are reduced longevity relative to pavers (but same as conventional asphalt) and its potential for seal coating, rendering it impervious.

Landscape Development

Landscape costs assumed a similar intensity of shrub and tree plantings as the conventional version throughout the site. However all landscape buffer strips around detention basins and between the access roads and the parking lot and the buildings are planned with a naturalized planting approach. No irrigation is needed in these naturalized buffer areas.

Green Roof

Green roofs were planned into the two main commercial buildings to intercept and absorb a portion of the rainfall. The two largest buildings were assumed to have shallow extensive green roof systems installed (approximately 3" soil media depth). For cost comparison, the green roof was estimated as an additional cost premium above and beyond traditional roofing cost. This cost was incorporated into the site design due to the stormwater detention and retention capabilities of the system.

Base Conservation Description

The Base Conservation evaluation assumes an identical layout, site materials, and stormwater best management practices as the Premium Conservation Design with the exception of the green roof. The green roof was removed from the base design first-cost option to evaluate the effect of green roof on the overall cost, stormwater mitigation, and to offer a more economical option for conservation design for developer and property owners.

Site Preparation, Sanitary Sewer, Water Distribution, Site Paving and Sidewalks, and Landscape Development

All site items within these five (5) divisions have been assumed to be identical as the Premium Conservation design approaches.

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COST	ITEM	CONVENTIONAL	PREMIUM CONSERVATION	BASE CONSERVATION
CAPITAL COSTS	1. Site Preparation[1]	$ 1,538,000	$ 1,229,000	$ 1,229,000
	2. Stormwater Management	$ 708,000	$ 495,000	$ 591,000
	3. Sanitary Sewer	$ 140,000	$ 127,000	$ 127,000
	4. Water Distribution	$ 229,000	$ 219,000	$ 219,000
	5. Site Paving and Sidewalks[2]	$ 2,550,000	$ 3,139,000	$ 3,139,000
	Machine Laid Porous Paving	*N/A*	*$ 2,020,000*	*$ 2,020,000*
	6. Landscape Development	$ 285,000	$ 178,000	$ 178,000
	7. Green Roof Premium[3]	$ -	$ 1,325,000	$ -
	Design Contingency[4]	$ 545,000	$ 805,000	$ 658,000
TOTAL CAPITAL COST	Base Costs	**$ 6,000,000**	**$ 6,195,000**	**$ 6,140,000**
	Green Roof Premium	**$ -**	**$ 1,325,000**	**$ -**
	TOTAL CAPITAL COST	**$ 6,000,000**	**$ 7,517,000**	**$ 6,141,000**
PER SQ FT RETAIL[5]	Not Including Building, Site Appurtenances, and Land Costs	**$ 18**	**$ 23**	**$ 18**

NOTES:
[1] Assume less overall grading disturbance per acre.
[2] Includes cost of machine laid interlocking permeable concrete pavers
[3] Green roof cost above and beyond traditional high reflective roofing cost.
[4] Design cost contingency assumed at 10% for Conventional and 12% for Conservation.
[5] Based on density neutral 332,500 sf multi-use retail space.

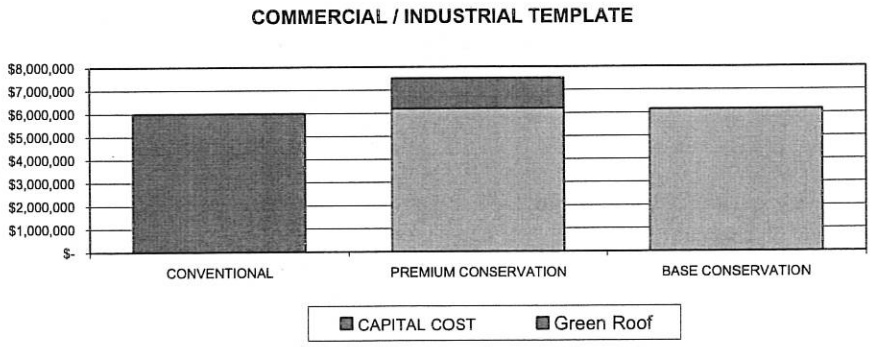

TABLE 28. Commercial/Industrial Template Summary.

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Stormwater Management

Biofiltration swales, rain gardens, porous pavement, and naturalized detention ponds are incorporated into the stormwater management of the site. The green roof has been removed to reduce development capital cost. The removal of the green roof would increase the volume of detention required as presented in the premium design. Based on the NIPC BMP Course Manual detention sizing nomagraph, the overall required detention volume can be expected to increase to approximately 6 ac-ft.

Green Roof

Green roofs were removed from the two main commercial buildings, therefore reducing capital cost yet increasing runoff as compared with the Premium Conservation version.

Results and Discussion

This cost analysis shows that the Premium Conservation design for commercial or industrial sites will likely cost more to the developer or property owner (due to the green roofs on the large stores) than a conventionally-built development of similar scale. However, the Base Conservation approach as contrasted with the conventional design should be nearly equivalent in cost. So, in this hypothetical case, a highly-intensive green design may be more expensive for initial development and building construction costs. However, it is not conclusive as to which conservation approaches are beneficial and cost effective in all cases. A real-life development scenario would evaluate the relative costs and benefits and conclude the best combination for that situation. Land prices, local regulations, and other factors would weigh into those decisions. As stated previously, the conservation design practices incorporate storage throughout the site and therefore have the potential to provide additional developable square footage, which was not factored into the cost comparisons.

The site preparation for a commercial site is expected to be similar for both conventional and conservation designs since most, if not all, of the site would be heavily disturbed. Small but not insignificant savings are expected by minimizing the clearing and grading required by designing with greater respect to the existing grades and fitting the structure to the land. This practice has been relatively disregarded in most conventional commercial designs.

Stormwater management systems are shown to be greatly reduced in both the conservation designs due to the heavy reduction in buried infrastructure. Large amounts of money are saved due to a nearly 50% reduction in detention facility volume (Premium Conservation) and reduced conveyance piping. These cost savings are offset somewhat by the cost increase for localized stormwater BMPs and stormwater system planting to improve water quality (shown in the Landscape Development category).

Both sanitary sewer and water infrastructure costs can be expected to be similar for both conventional and conservation development. The costs for these templates show that the infrastructure cost is proportional to amount of clustering of buildings; the more spread out the structures, the higher the infrastructure piping costs.

Due to added pedestrian corridors, sidewalks, and a heavy premium on porous paving, Site Paving and Sidewalk costs are over double the cost for both conservation templates. Permeable interlocking concrete pavers, however, provide the benefits of stormwater mitigation, increased longevity, and improved aesthetics. The stormwater benefits could be retained while reducing construction costs if permeable asphalt was used instead of interlocking pavers. However, the longevity and aesthetic benefits would be lost when using permeable asphalt.

Landscape costs for both conservation design approaches are 40% less than the cost associated with conventional design. The cost for conventional turf installation and irrigation along the main buffers is much greater than the low maintenance native prairie buffer in the conservation designs that does not require irrigation and the associated water and energy infrastructure.

Roofing is the second largest cost variance (after porous pavement) for the conservation template. The comparison between the Premium and Base Conservation designs shows that it may be difficult to justify the increased cost of a green roof based on stormwater alone, at least for "greenfield" sites where available space and land costs are not

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significant constraints. Where space is a restricted and the amount of required detention can reduce the amount of space available for development, green roofs can be very cost effective since the amount of detention required for green roofs can be as low as 20% of the volume required for conventional roofs. As discussed in the literature analysis, although a premium, green roofs have the benefits of stormwater quality improvement and mitigation, increased roof longevity, added aesthetics, reduced heating and cooling costs, and reduced heat island effects.

The general stormwater-based site costs for the Conventional and Base Conservation approaches are shown to cost per square-foot of retail space around $18 versus $23 for the Premium Conservation based approach. Although the costs for the premium conservation design are higher, there are several mitigating factors that have not been integrated into the design that would make the conservation approach more cost effective even with the green roof as part of the design.

- To illustrate a variety of stormwater management approaches, naturalized rain gardens were used to treat the runoff from the paved areas behind the main-street buildings. A more space-efficient approach would have been to use porous paving in these areas or a perimeter bioswale. If this approach were utilized the large areas associated with the rain gardens could have been utilized for additional building and/or parking. This variation would result in substantially greater leaseable space. It was the intention of the BBCW study to illustrate templates that had the same yield. Therefore, even though the Conservation versions could accommodate additional square footage, it was not shown, with the exception of possible second-story office or residential space above the Main Street stores.
- The design envisioned that the green roof areas would be accessible to an adjacent second story office space. Because of this outdoor space, it is likely that these units could be rented at a substantial premium. (A second story was not included in the analysis to retain the density neutral and identical footprint comparison)

Template Conclusions

Upon comparing the costs associated with each of the eight templates, this analysis raises observations on two topics: 1) land-use types most beneficial to conservation design, based strictly on capital cost; and 2) infrastructure concerns.

Land Use

Site preparation and mass grading can be a large cost on many site development projects. Costs can be reduced by using the existing topography as a basis to design the layout. Also, conservation easements and naturalized landscapes can reduce the amount of preparation and fine grading required since minimal land preparation is generally required to establish these landscapes.

A majority of the conservation templates, as designed for the BBC Watershed Analysis, are expected to cost the same or less with the exception of the 'Premium' Commercial/Industrial Template. The templates show a general correlation where, as density decreases, the percentage of capital cost savings for conservation design increases. However, as with all designs, each element and technique should be considered to support the overall project and community goals for whatever program, land use, or density is developed.

Commercial/Industrial

The Premium Conservation design is very much towards the green end of the development spectrum. As has been mentioned, each real-life project is unique, and must be planned according to the specific realities of the site, context, program, community, and other elements. Generally, conservation design can be cost competitive for dense and complete systems as long as a feasibility study is conducted to determine the cost-to-benefit ratio of the different components, and especially when long-term maintenance, energy use, employee satisfaction, and other factors are taken into account.

In the Commercial/Industrial template significant cost savings were associated with reducing the required detention volume by providing stormwater attenuation with green roofs, porous paving, and bioinfiltration swales. In reducing the required detention area by half, a sizable acreage of land could be freed development. The conservation template focused on increased stormwater quality and aesthetic value while maintaining a constant building square footage. Obviously, the ability to increase building square footage would increase the overall value of the development, and would be a preferred option for most developers.

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Moderate Density, Rural and Estate Residential

These conservation design templates show a slight cost savings to the owner. In general, the cost saving associated with Moderate Density Residential and Rural Residential are comparable to the trends presented in the Built-Site Cost Analysis.

Estate Residential

The Estate Residential conservation template proves to be cost effective. This is largely due to the lower cost to establish natural landscape over the majority of the properties, rather than installing and maintaining manicured lawns throughout. The stormwater management costs are also greatly reduced.

Summary

The research and results derived from evaluating the costs to implement these specific designs help reinforce the evidence in the literature and built-site analyses that conservation design can be cost-effective. And, while highly intense green designs may not always be cost-effective in terms of initial capital costs, they can often be compared favorably with conventional forms using long term life-cycle costs, land value, marketing return, and desired aesthetic effects.

Infrastructure

Stormwater management infrastructure costs for the conservation templates are consistently more economical, ranging from a 10% to 80% reduction for Moderate Density Residential and Estate Residential, respectively. The added cost associated with swales, infiltration bioswales, and rain gardens is offset with cost savings associated with reduced stormwater infrastructure and reduced detention volume requirements. These costs do not include landscape planting in swale or detention ponds or costs associated with indirect BMPs such as green roofs and porous paving.

Both water supply and sanitary sewer systems can be expected to be similar for all conservation approaches. The exception is the example that uses enhanced waste water treatment on-site, which may or may not be economically viable depending upon the circumstances. Overall utility costs vary, depending on the clustering or spread of buildings and treatment level of wastewater. These decisions can be made between the owner and the regulatory agencies on a site-by-site basis.

Site paving and sidewalks are generally higher in cost for the choices made in the conservation templates, with the exception of the Moderate Density Development. Costs associated with asphalt paving in roadways and concrete curbing is often reduced due to roadway layout and width. However, the conservation design approach promoted increased pedestrian access through the incorporation of a network of sidewalks and secondary limestone chip paths. As shown in the literature, porous paving will increase the initial cost when directly compared to the use of asphalt, yet this cost increase will be somewhat mitigated through the reduced stormwater management costs and long term maintenance savings. Porous paving is not generally economical as a broad tool for all roadway applications, but can be extremely effective as a selective tool. Its cost-effectiveness depends in part on life-cycle benefits due to paver longevity and reduced maintenance.

Landscape development costs are generally higher for traditional land-use templates where large turf lawns and irrigation systems are installed. This is consistent with the Built Site Cost Analysis. Costs for low-maintenance, naturalized landscapes that perform multiple functions including stormwater cleansing and infiltration, passive recreation, and habitat restoration are generally lower that for highly maintained landscapes. However, the conservation templates typically include a higher ratio of common space as compared with conventional development. Therefore, there can be higher overall landscape establishment costs for the conservation alternatives. These discrepancies must be addressed in the overall site budget and the sale or lease price of the associated real estate in order to be cost competitive. The fact that some of the conservation site development techniques require greater up-front developer participation and a more sophisticated marketing and sales approach that conventional developments is perhaps one reason that it has taken longer for some of these ideas to become more prevalent.

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Cumulative Discussion And Recommendations

By looking across all three analyses, a set of common conclusions can be offered. Perhaps most importantly, these results certainly contradict the notion that conservation design is always more expensive than conventional practices. Not only do the three analyses show conservation is cost-competitive, they also illustrate many situations where conservation methods can reduce development costs significantly compared to conventional techniques. In terms of overall approaches, a reduced footprint on the land will generally lower construction costs. Clustering and minimal site disturbance can go a long way to cut infrastructure costs significantly, especially for stormwater management.

These cost conclusions call out for significant consideration of conservation development across the spectrum of development forms. Yet, even in the light of these conclusions, it is critical to point out that favorable cost comparisons are only one reason to consider conservation development. Ecological and social reasons should also be considered. While not components of this study, such reasons can complement and in some cases can even outweigh cost considerations.

Given the wide variety of conservation approaches tried in isolation and in combination, the three analyses reveal that there is really a continuum of choices – conservation design is not all or nothing. A range of approaches and mixes of conservation tools can be considered for every budget and every site. BMP's such as rain gardens and infiltration trenches are more easily adapted to suburban and rural development sites. Tools such as porous pavements and green roofs may be more appropriate for more urban sites, where land area is at a much greater premium, and cannot be utilized economically for stormwater detention basins.

The literature review conflicts with the results of the template analysis on landscape costs. In the template analysis, landscape development costs are consistently higher for conservation, but this is mainly due to the increase in common space allocation. These areas are typically planted with prairie / savanna restorations or naturalized stormwater water management system plantings. However, cost figures presented from several sources in the literature use data that points to the cost effectiveness of native plantings. Further analysis is warranted to flesh out the assumptions and conditions behind these perspectives. Some of the difference in results may be related, either to the incorporation (or lack thereof) of irrigation systems into the template descriptions, or to whom the costs accrue, the land developer or the lot/home purchaser.

The amount and quality of information varies greatly across the development components analyzed. One concern raised about the literature, for example, is that there is a heavy reliance on a small group of sources (Center for Watershed Protection, Prince George's County, Portland, Northeastern Illinois Planning Commission) for information. This increases the significance of the built-site and template analyses because they provide new information to the field. However, those analyses were unable to augment the scant information on maintenance in the literature.

Further Research work is needed on several fronts:

- To gather and analyze information on operation and maintenance costs of conservation development, where possible, using life-cycle cost analysis as a method of comparison to conventional methods.
- To take into account systematically both cost and effectiveness in the future analyses of conservation design alternatives. One possible way to do this is reflected in the study by Sear and Bays, who created a production and cost function to analyze efficiency and cost together, i.e., minimizing cost for a fixed pollutant removal (looking only at Total Suspended Solids), or maximizing pollutant removal for a fixed cost. They compared five stormwater treatment technologies (street sweeping, dry bottom retention ponds, curb-cut swales, wet detention ponds, and wetlands) across 16 potential stormwater pond sites. Such an approach could be expanded to include volume and attention to the more innovative methods being addressed here. The problem with such quantitative analyses is that they occur in a vacuum, focusing on discrete tools for analytical ease. It would be too analytically cumbersome to include all the inter-relationships of conservation site approaches that use multiple tools in the holistic examples in this report.

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- To analyze conservation development costs in a higher-density context where tools such as porous pavement and green roof are generally perceived to be more competitive.
- To conduct more economic benefit studies that can provide information on the values obtained by conservation development as guidance for planning efforts.
- To analyze the difficulties in trying to implement innovative projects, such as design fees, misperceptions, and variances, and seek ways to overcome or minimize them.

Even where conservation costs are competitive, municipalities and other governments should offer incentives to encourage conservation development for two reasons: 1) to help communities and developers overcome market inertia, which often exists even when they have information that supports change; and 2) to enable financing mechanisms for tools or combinations of tools to be piloted or implemented, especially as part of larger municipal stormwater management programs. Pagano and Weber discuss market incentives and financing for both public and private investment in green infrastructure for municipalities in the Chicago Region. When a package of conservation tools has higher capital costs for the developer, the benefits need to be illustrated more clearly. Those tools should be the target for incentive programs.

The project team recommends a second phase of this project that would concentrate on outreach and dialog with municipalities and developers. Use of the Internet could provide this cost information and new reports as they become available in the form of a clearinghouse for costs and benefits. Such a website could include a relational database that helps users tailor the information to their needs.

Yet, the most productive use for the information presented in this report is to share and discuss these findings face-to-face with developers and municipal officials as they begin to consider new developments.

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Low Impact Development Technologies

by Anne Guillette, LEED Accredited Professional
Low Impact Design Studio (formerly with the Low Impact Development Center)

INTRODUCTION

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A. Low Impact Development: An Alternative Site Design Strategy

Low Impact Development (LID) is an alternative site design strategy that uses natural and engineered infiltration and storage techniques to control storm water where it is generated. LID combines conservation practices with distributed storm water source controls and pollution prevention to maintain or restore watershed functions. The objective is to disperse LID devices *uniformly* across a site to minimize runoff.

LID reintroduces the hydrologic and environmental functions that are altered with conventional storm water management. LID helps to maintain the water balance on a site and reduces the detrimental effects that traditional end-of-pipe systems have on waterways and the groundwater supply. LID devices provide temporary retention areas; increase infiltration; allow for nutrient (pollutant) removal; and control the release of storm water into adjacent waterways.

Some examples of LID technologies include:

- ***Engineered systems*** that filter storm water from parking lots and impervious surfaces, such as bio-retention cells, filter strips, and tree box filters;
- ***Engineered systems*** that retain (or store) storm water and slowly infiltrate water, such as sub-surface collection facilities under parking lots, bio-retention cells, and infiltration trenches;

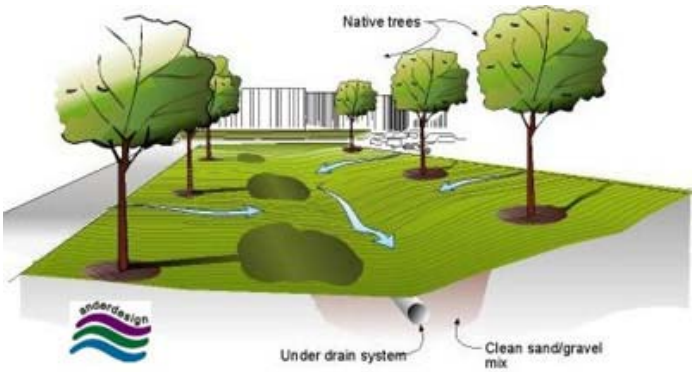

Fig. 1: Bio-swale schematic
Courtesy Pierce County, /WSU Extension

- ***Modifications to infrastructure*** to decrease the amount of impervious surfaces such as curbless, gutterless, and reduced width streets;
- ***Low-tech vegetated areas*** that filter, direct, and retain storm water such as rain gardens and bio-swales;

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- ***Innovative materials*** that help break up (disconnect) impervious surfaces or are made of recycled material such as porous concrete, permeable pavers, or site furnishings made of recycled waste;
- ***Water collection systems*** such as subsurface collection facilities, cisterns, or rain barrels; and
- ***Native or site-appropriate vegetation***.

B. Conventional Design

Figs. 2-3, *Left to right:* Conventional and LID site design comparison
Courtesy PGDER

Conventional storm water management techniques direct all of the storm water to storm drains to remove it from the site as quickly as possible. End-of-pipe facilities are typically designed to store and detain runoff to reduce peak flows for storm events that are infrequent, such as the 10 year, 24-hour storm. Controls are often not in place to reduce flows for smaller, more frequently occurring events. Controls also are not structured to address non-point source pollution problems or to recharge the groundwater. Since runoff needs to be managed on the site, large ponds, or a series of ponds, are required. These controls take up a significant portion of land.

Storm water ponds are characteristically constructed with fences around the periphery for health and safety reasons. The outbreak of the West Nile virus and concern about fecal droppings of migratory birds has heightened concern about the suitability and maintenance of retention ponds. Ponds require annual maintenance and can require expensive long-term rehabilitation costs.

In contrast, the requirement for storm water retention is achieved with LID through the use of distributed controls. The retention areas are designed into the open space, or below existing infrastructure (such as parking lots), and create opportunities for new design configurations that are less dependent on inlets, pipes, and ponds. Additionally, LID technologies eliminate the need for costly maintenance contracts, typically requiring only routine landscape maintenance, with the exception of engineered systems such as tree box filters and sand filters.

The graphics show a conventional site design and a LID site design. The LID approach illustrates the potential for innovative site design alternatives with the elimination of retention ponds. The comparison exemplifies how land used for retention ponds could be allocated differently with the implementation of a distributed storm water program.

C. Economic Indicators and the "Greening" Movement

Economic indicators signify a shift in consumer and corporate purchasing toward "green" building. Homeowners are willing to pay a higher premium for homes that are more energy efficient and for properties that are adjacent to open space. Likewise, corporations are inclined to spend more on energy-efficient buildings with enhanced site amenities as they improve employee performance. This is causing builders, developers, and product manufacturers to take notice. LID can assist in reducing the bottom line while providing significant environmental benefits.

Some benefits of a LID site design strategy include:

- Reduced infrastructural costs for ponds, curbs and gutters, inlets, and pipes
- Increased lot yield,
- Reduced life-cycle costs,
- Increased marketability, and
- Increased property values.

D. Examples of Profitable LID Development

1) Somerset Community—A $916,382 Cost Savings

One of the oldest communities in the United States to implement LID on a large scale is the Somerset Community in Prince Georges County, Maryland. The developer successfully integrated LID technologies into the 60-acre development in 1995, where 199 homes were sited on 10,000 square foot lots. The alternative development pattern that used distributed storm water management systems yielded 6 additional lots, which resulted in increased revenues at $40,000 each. The final cost breakdown was:

a. $300,000 savings on LID vs. storm water ponds
   LID Cost: $100,000
   Conventional Cost: $400,000
b. $240,000 additional revenue on 6 additional lots (space previously allocated to ponds) 6 lots x $40,000 Net
c. $916,382 overall cost savings or $4,600 savings per lot

Fig. 4: Aerial view of Somerset Community
Courtesy PGDER

The streets in Somerset have no curbs or gutters and use shallow swales adjacent to the streets to store and infiltrate storm water. Every lawn has a bio-retention cell (or rain garden). The swales and bio-retention cells are important because they handle the first flush of a storm, which contains the greatest amount of pollutants, and they allow the water to be stored (for less than 24 hours) and infiltrate into the ground. A conventional system does not filter the storm water from the streets and sends large amounts of untreated water into nearby waterways, via one or more detention ponds.

The downspouts of the roofs direct rainwater into vegetated areas or rain barrels. The groundwater supply is recharged and collected rainwater satisfies irrigation needs. Community cooperation has been positive as the residents understand their role in preserving the Chesapeake Bay. Ongoing community participation and upkeep of the bio-retention cells has been positive, as shown in the recent photos.

Fig. 5-6: Bio-retention cells in Somerset Community
Photo Credit: The Low Impact Development Center

Although the streets do not have curbs and gutters, they are exceptionally wide (36') due to building regulations at the time of development. This is not a recommended practice; minimizing impervious cover is a LID concept. Eliminating one lane of on-street parking in this subdivision could have resulted in a substantial savings.

2) Northridge Community—The Sustainable Alternative

Northridge Community, also in Prince Georges County, Maryland, is an example of a subdivision with reduced street widths, bio-swales adjacent to curbless streets, and a substantial tree preservation program. In 1988 the developer, Michael T. Rose, spent $23 million dollars on the 855 unit, 356 acre development. In lieu of conventional infrastructure costs (wider streets, detention ponds, catch basins, curbs and gutters) the developer spent the cost differential on a community center, a lake, and additional open space. Although a regulatory and permitting challenge, the project was instrumental in advancing forest conservation programs and the use of LID technologies.

Northridge has received a considerable amount of certificates and awards both in the environmental and business realms.

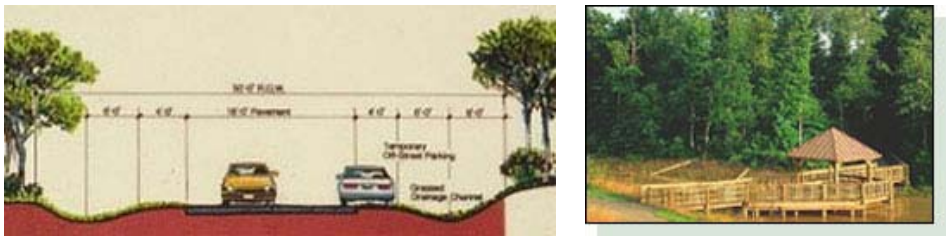

Fig. 7-8: Curbless roads and amenities in Northridge Community
Courtesy of The Michael T. Rose Family of Companies

E. Benefits of the LID Site Design Strategy

Benefits of LID:

1. Reduce infrastructural costs for ponds, curbs, and gutters
2. Increase the lot yield
3. Reduce life-cycle costs,

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4. Increase marketability, and
5. Increase property values.

1) LID Reduces Infrastructure Costs and Increases Lot Yield

In the LID site design strategy buildings, roads, sidewalks, and open space are used for multiple purposes and are designed to maximize site functions. The use of distributed LID technologies reduces or eliminates the need for large-scale, end-of-pipe systems and thus reduces the infrastructural costs of a network of pipes, gutters, and ponds. Space traditionally set aside for detention ponds can now be designated for an alternative use, such as architectural, entertainment/recreational, or reforestation/conservation.

Small-scale LID technologies are positioned in precise locations to accomplish specific water quality or water quantity objectives. (See Table 1 below.) The most effective location of the devices is close to the source. For example, bio-retention cells (or rain gardens) are located adjacent to parking lots so that they can filter and treat runoff directly. Tree box filters are located on streets that require curbs and gutters to filter and treat surface runoff before it enters the waterways. Vegetated swales are placed adjacent to curbless roads and are effective at filtering and infiltrating storm water and recharging the groundwater supply. Rain barrels or cisterns collect rainwater off rooftops to irrigate landscaped areas. Subsurface collection facilities (under parking lots or sidewalks) constructed at varying depths accommodate large storms and filter, retain and/or store water for reuse or for slow-release infiltration.

2) Enhanced Livability = Increased Property Value

Improved site design has a direct correlation to enhanced livability and community aesthetics. LID not only facilitates the stabilization of the hydrologic condition of a site, but it improves the market appreciation.

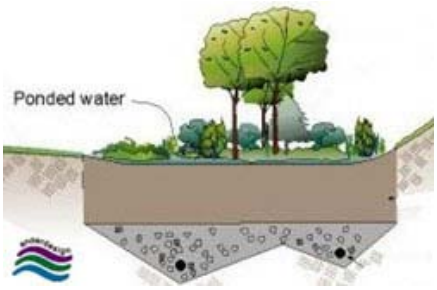


Fig. 9: Open space is used for storm water control via a Bio-retention Cell
Courtesy Pierce County, WA/WSU Extension

The management of the site through the distributed controls allows for unprecedented design schemes. Consider the intangible benefits that result from "whole site design controls" as shown in the graphic to the right. It demonstrates that a bio-retention cell can be constructed to provide retention and also beautify the open space. The graphic below illustrates how space can be used for multiple purposes. A common area between homes that accommodates a bio-retention cell to store and infiltrate water during storms, is suitable for light recreation (e.g., walking on trails) during dry periods.

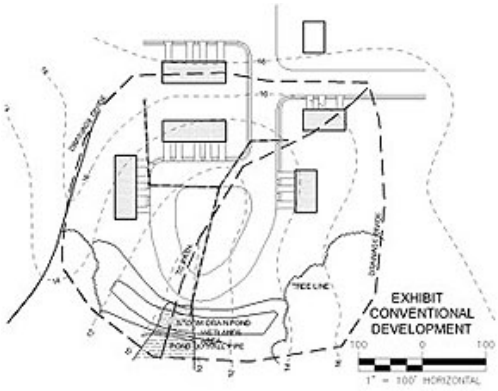
Fig. 10: A Bio-retention cell can be used for light recreation
Courtesy Pierce County, Washington and AHBL, Inc.

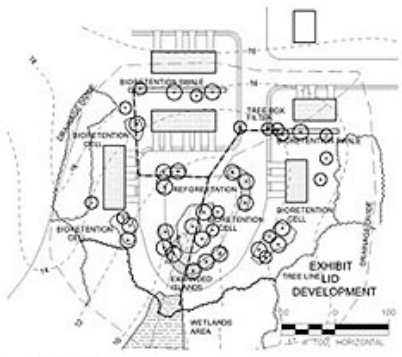
F. LID Site Design Examples

1) Community Design—Townhomes

These illustrations compare a conventional site design with a LID site design. The building footprint and circulation are identical in each. The LID site design addresses the unique conditions of the site and uses an arrangement of distributed LID controls to meet storm water management requirements. It also utilizes the existing wetlands to function as a natural filtration zone, as they have historically. There is no need to add a retention pond, as the site is configured to make an allowance for the added impervious surfaces and balance the hydrologic requirements.

The site is arranged with rain gardens, bio-retention cells, and bio-swales. Other LID options not represented in this site design include reduced street widths, curbless roads, permeable parking bays, permeable sidewalks, cisterns, and rain barrels.





Figs. 11-12: Site design comparison
Courtesy PGDER

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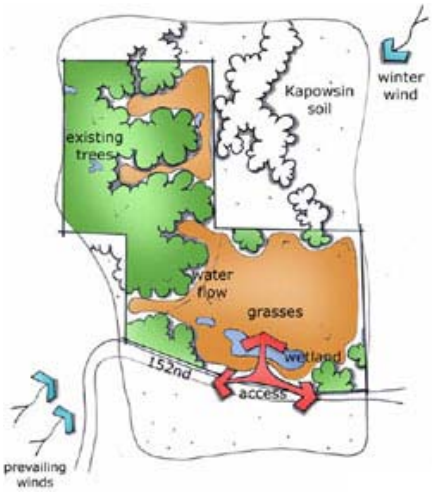

Left: Fig. 13: Site inventory *and Right:* Fig. 14: Conventional site design
Images courtesy Pierce County, Washington and AHBL, Inc.

2) Community Design—Single Family Homes

Pierce County, Washington, developed a storm water management manual for developers, engineers, planners, and designers that demonstrate the LID site design strategy. The drawings were produced for Kensington Estates community to compare the conventional design approach with the LID design. The project also included a thorough cost comparison.

The 24-acre development yielded 103 lots with the conventional scheme. The LID redesign, which integrated conservation practices, yielded 103 lots at 4 units per acre. This design preserved the density while designating half of the site as open space. The cost comparison showed that the LID design achieved a 20% cost savings on construction.

Left above: Fig. 15: LID site design; *Right above:* Fig. 16: Site drainage pattern;

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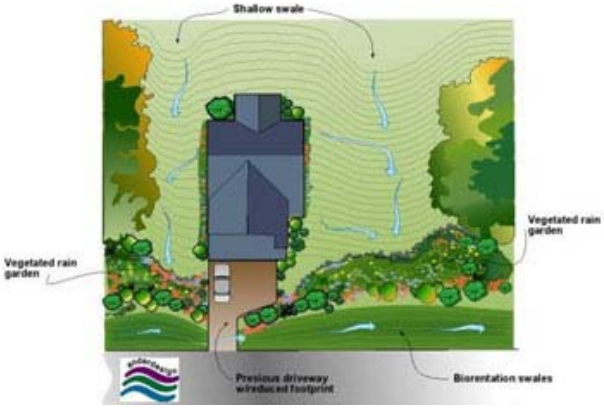

and Left: Fig. 17: LID lot design
Images courtesy Pierce County, Washington and AHBL, Inc.

Fig. 13 illustrates the site inventory with existing vegetation, wind patterns, wetlands, drainage patterns, soil types, and view sheds.

Fig. 14 shows a conventional development pattern with roads and lots placed on the land to maximize the available space. The existing hydrologic patterns are not preserved, nor are the existing forests conserved. The storm water will be managed in a conventional manner.

Fig. 15 shows a LID design strategy. The existing natural resources are the point of departure for the design: the placement of lots, roads, and open space is dictated by existing drainage patterns and forested areas. The decision to design within the land composition influenced the lot size. In the LID scheme it was determined that the best use of the property was smaller lots and greater density.

Fig. 16 shows the overall LID drainage pattern. The open space is designated as the infiltration/overflow area. The hydrologic integrity of the site is maintained by conforming the development to pre-development patterns.

Each lot in the community manages storm water for the most frequent storm events at the source with rain gardens, swales, bio-retention cells, pervious driveways, and conservation areas, as seen in Fig.17. However, engineered swales and infiltration areas (typically in the open space) are integrated into the design to accommodate large storms.

The developer pursued the conventional scheme, but in the end had to purchase 2 additional acres off-site to achieve the required storm water management controls. They were fortunate to have been grandfathered in under the old storm drain rules. Otherwise the current regulations would have required them to purchase 6 additional acres and lose 10 housing units at a cost of $1 million. The LID cost savings under the new storm drain rules are even more significant.

G. The Storm Water Utility Fee

Of concern to developers, designers, and engineers is the national trend toward storm water utility fees, or taxes, for storm water that exits a property. Fees are typically calculated on the impervious area of a lot, such as roofs, roads, and driveways. LID will reduce or eliminate storm water utility fees by reducing impervious surfaces or mitigating their impact, promoting infiltration, and dispersing flows. LID site design

lowers the volume of runoff leaving a site. This should be considered as an additional cost savings beyond reduced maintenance costs.

H. LID: An Urban, Suburban, or Rural Solution

LID can be incorporated into any development scenario, whether urban, ultra urban, suburban, or rural. The range of sizes and scales of the devices allows for unlimited configurations even where space is limited. LID is particularly effective for targeting non-point source pollution in dense, urban areas, because the LID controls can be used below paved surfaces, in easements or right-of-ways, and in open space to increase the site's storage and infiltration capacity.

DESCRIPTION OF LID TECHNOLOGIES

A. LID Practices and Benefits

The LID site design approach is a precise arrangement of natural and engineered technologies. The devices, or Integrated Management Practices (IMPs), function as a comprehensive system across the site to achieve the goals of:

- Peak flow control
- Volume reduction
- Water quality improvement (filter and treat pollutants), and
- Water conservation.

Table 1 illustrates several LID technologies and their associated benefit (s). A brief description of commonly used LID practices and suitable applications follows.

Fig. 18: Curb cut schematic
Courtesy Pierce County, Washington and AHBL, Inc.

Table 1: LID Practices and Benefits

LID PRACTICE / DEVICE	Peak Flow Control	Volume Reduction	Water Quality Improvement	Water Conservation
Bio-retention Cell	•	•	•	
Cistern	•	•		•
Curbless Parking Lot Islands	•	•	•	
Downspout Disconnection	•	•	•	
Grassed Swale	•	•	•	

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Green Roof	•		•	
Infiltration Trench	•	•	•	
Narrow Road Design	•	•	•	
Permeable Pavers/Pavement	•	•	•	
Rain Barrel	•	•		•
Rain Garden	•	•	•	
Sand Filter	•		•	
Tree Box Filter	•		•	
Tree Planting	•	•		

B. Common LID Practices

Below are examples of common LID practices. A brief overview of the storm water controls that can be implemented on a project is also included. The techniques should be evaluated for their suitability for each project.

1) Bio-retention Cell (Rain Garden)

A bio-retention cell (strip or trench) is an engineered natural treatment system consisting of a slightly recessed landscaped area constructed with a specialized soil mixture, an aggregate base, an underdrain, and site-appropriate plant materials that tolerate both moist and dry conditions. The site is graded to intercept runoff from paved areas, swales, or roof leaders. The soil and plants filter and store runoff, remove petroleum products, nutrients, metals, and sediments, and promote groundwater recharge through infiltration. The cells are designed to drain in 24 hours, with no risk of standing water and breeding of mosquitoes.

A rain garden typically does not have the full spectrum of engineered features that bio-retention cells have, such as underdrains and the entire soil mix. They can be designed and built by homeowners and located near a drainage area, such as a roof downspout.

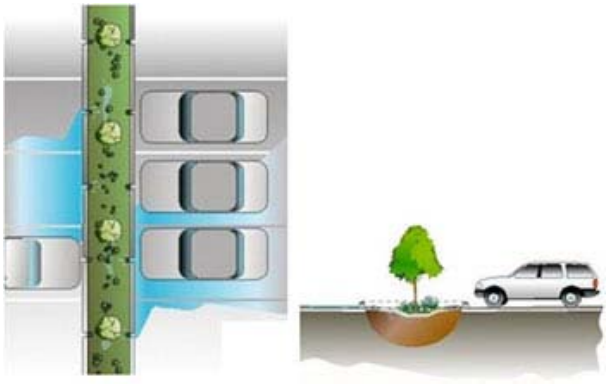

Fig. 19: Bio-retention cell schematic
Courtesy Pierce County, Washington and AHBL, Inc.

Typical Uses: Parking lot islands, edges of paved areas (roads or parking lots), adjacent to buildings, open space, median strips, swales.

Land Use: Ideal for commercial, industrial, and residential (urban,

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suburban, ultra-urban). They are widely used in transportation projects (highway medians and rail projects).

They are suitable for new construction and retrofit projects.

Approximate Cost: Residential costs average $3-$4 per square foot of size plus excavation and soil amendment costs. Plant materials are comparable to conventional landscaping costs.

Commercial, industrial, and institutional site costs can range from $10-$40 per square foot, based on the need for control structures, curbing, storm drains, and underdrains.

Maintenance: Routine maintenance is required and can be performed as part of the regular site landscaping program (i.e., biannual evaluation of trees and shrubs, regular pruning schedule). The use of native, site-appropriate vegetation reduces the need for fertilizers, pesticides, excessive water, and overall maintenance requirements.

Additional Benefits: Easily customized to various projects (size, shape, and depth) and land uses; enhances aesthetic value of site; uses small parcels of land, easements, right-of-ways; easily retrofitted into existing buildings/open space.

Design Specs and Supplementary Information:

Bayscapes at the U.S. Army Environmental Center
Low Impact Development Center—Bio-retention Specification page
Prince George's County Bio-retention Design Specifications and Criteria
Prince George's County Bio-retention resource page

2) Vegetated Swale (Bio-swale)

A vegetated or grassed swale is an area with dense vegetation that retains and filters the first flush of runoff from impervious surfaces. It is constructed downstream of a runoff source. After the soil-plant mixture below the channel becomes saturated, the swale acts as a conveyance structure to a bio-retention cell, wetland, or infiltration area.

There is a range of designs for these systems. Some swales are designed to filter pollutants and promote infiltration and others are designed with a geo-textile layer that stores the runoff for slow release into depressed open areas or an infiltration zone.

Alternative Devices: Filter strip or vegetated buffer.

Typical Uses: Edges of paved areas (roads or parking lots), parking lot islands, intermediary common spaces, open space, or adjacent to buildings.

Land Use: Commercial, industrial, residential (urban, suburban, ultra-urban); transportation projects (highway medians and rail projects); new construction and retrofit projects.

Approximate Cost: $0.25 per square foot for construction only; $0.50 per square foot for design and construction.

Maintenance: Routine maintenance is required. Maintenance of a dense, healthy vegetated cover; periodic mowing; weed control; reseeding of bare areas; and clearing of debris and accumulated sediment.

Additional Benefits: Easily customized to various projects (size, shape, and depth) and land uses; enhances aesthetic value of site; uses small parcels of land, easements, right-of-ways; easily retrofitted into existing buildings/open space.

Design Specs and Supplementary Information:

Virginia Dept of Conservation and Recreation Storm Water Management Program

3) Permeable Pavement

Left: Fig. 20: Belgium block pavers in parking bays
(Photo Credit: The Low Impact Development Center)
Right: Fig. 21: Permeable parking bays
(Courtesy Cahill Associates, Inc.)

Disconnecting impervious areas is a fundamental component of the LID approach. Roofs, sidewalks, and paved surfaces are disconnected from each other to allow for more uniform distribution of runoff into pervious areas. Conveying runoff into vegetated areas keeps the water from directly entering the storm drain network, reduces runoff volume, and promotes distributed infiltration.

Since paved surfaces make up a large portion of the urban (or developed) landscape, the use of permeable pavement is very effective at stabilizing the hydrologic condition of a site. Permeable surfaces can be used in conjunction with subsurface infiltration galleries (subsurface retention facilities) as seen in Section 6.

A secondary benefit of permeable paving is its performance in snowy conditions. Cahill Associates reports an increase in demand for the installation of permeable asphalt in the Northeast as a result of reduced maintenance costs (snow shoveling and desalting) due to rapid snowmelt on permeable surfaces.

Types of permeable pavement include permeable asphalt, permeable concrete, grid block pavers, plastic grids, vegetated grids, Belgium block (in photo), turf block, gravel, cobbles, brick, natural stone, etc.

Typical Uses: Parking bays, parking lanes, sidewalks, roads. Blocks and porous pavement are generally used in high traffic parking and roadway applications; respectively grid systems are more commonly used in auxiliary parking areas and roadways.

Land Use: Ideal for commercial, industrial, and residential (urban, suburban, ultra-urban); suitable for new construction and retrofit projects.

Approximate Cost: Varies according to product. Typically, the cost is higher than conventional paving systems; however, they help reduce the overall storm water infrastructure costs.

Maintenance: Varies according to product. Routine street sweeping will sustain the infiltration capacity of voids. Porous concrete/asphalt require annual vacuuming, to remove accumulated sediment and dirt.

Additional Benefits: Easily customized to various projects and land uses; enhances aesthetic value of site; easily retrofitted into existing paving configurations.

Design Specs and Supplementary Information:

Ford Rouge River Manufacturing Plant (Cahill Associates)
Permeable Paver Specification (Low Impact Development Center)
Porous Asphalt with Subsurface Infiltration/Storage Bed (Cahill Associates)
Porous Concrete with Subsurface Infiltration/Storage Bed (Cahill Associates)
Toolbase Services (National Association of Home Builders)

4) Subsurface Retention Facilities

Subsurface retention facilities are typically constructed below parking lots (either permeable or impervious) and can be built to any depth to retain, filter, infiltrate, and alter the runoff volume and timing. This practice is well suited to dense urban areas. Subsurface facilities can provide a considerable amount of runoff storage.

Fig. 22 shows that the porous parking bay has an infiltration gallery (with 40% void space) below it for storm water retention. The water is filtered through the stone aggregate and infiltrates into the ground. An alternative strategy is to construct the subsurface facility with a filtering and pumping mechanism so that collected water can be reused for non-potable uses such as irrigation or flushing of toilets.

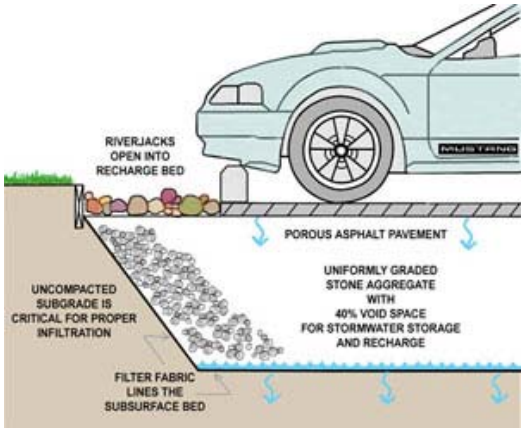

Fig. 22: Cross section of porous asphalt pavement
Courtesy Cahill Associates, Inc.

Similar techniques include gravel storage galleries, sand filters, infiltration basins, and infiltration trenches (for areas with space

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constraints).

Typical Uses: Parking lots, sidewalks, and roads.

Land Use: Ideal for commercial, industrial, and residential (urban, suburban, ultra-urban); suitable for new construction and retrofit projects.

Approximate Cost: Costs are typically higher than conventional paving systems; however, they help reduce the overall storm water infrastructure costs (land allocated for ponds, cost of pipes, inlets, curbs/gutters).

Maintenance: Varies according to manufacturer; routine street sweeping and vacuuming will retain infiltration capacity of voids.

Additional Benefits: Easily customized to various projects and land uses; enhances aesthetic value of site; easily retrofitted into existing paving configurations.

Design Specs and Supplementary Information: These are specialized systems and should be designed by, or under the direct supervision of, an appropriate licensed professional.

Porous Asphalt with Subsurface Infiltration/Storage Bed (Cahill Associates)

The reduction of street widths (i.e., from 36' to 24') can result in a cost savings of approximately $70,000 per mile in street infrastructure costs (estimated paving cost = $15 per square yard).

Land Use: Residential, commercial, industrial.

Design Specs and Supplementary Information: Green Cove Basin, Olympia, Washington

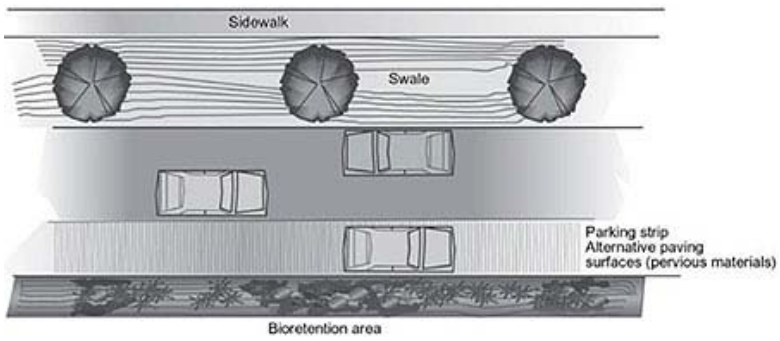

Fig. 23: Reduced road widths and vegetated swales
Courtesy Pierce County, Washington and AHBL, Inc.

5) Tree Box Filter

Tree box filters are essentially 'boxed' bio-retention cells that are placed at the curb (typically where storm drain inlets are positioned). They receive the first flush of runoff along the curb and the storm water is filtered through layers of vegetation and soil before it enters a catch basin. Tree box filters also beautify the streetscape with landscape plantings such as street trees, shrubs, ornamental grasses, or perennials

and can be used to improve the appearance of an area or to provide habitat.

Typical Uses: Positioned along the curb of a street; particularly effective at targeting point source pollution in urban areas by retrofitting/ replacing existing storm drains.

Land Use: Commercial, residential (urban, suburban, ultra-urban), and industrial areas.

Approximate Cost: Approximately $6,000 per unit per 1/4 acre of impervious surface. This estimate includes two years of operating maintenance and filter material and plants. Additional costs include installation and annual maintenance. Installation is approximately $1,500 per unit (varies with each site).

Maintenance: Tree box filters require more specialized maintenance to ensure filter media is not clogged and there is no accumulation of toxic materials, such as heavy metals. Maintenance is typically performed by Departments of Transportation or agencies responsible for storm drain maintenance. Annual manufacturer maintenance is $500 per unit; owner maintenance costs are approximately $100 per unit.

Additional Benefits: Improves water quality and enhances the community.

Design Specs and Supplementary Information:

Specification of Tree Box Filters (Low Impact Development Center)
Sizing of Tree Box Filters (Low Impact Development Center)
Filterra by Americast
Virginia Storm Water Management Program, Technical Bulleting #6

6) Disconnected Downspouts

Downspouts can be disconnected from underdrains and the runoff directed to vegetated areas to reduce runoff volume, promote infiltration, and change runoff timing.

7) Rain Barrels and Cisterns

Rain barrels are placed outside of a building at roof downspouts to collect and store rooftop runoff for later reuse in lawn and garden watering. They can be used to change runoff timing and to reduce runoff volume. Rain barrels have many advantages in urban settings. They take up very little space, are inexpensive, and are very easy to install.

Cisterns are larger storage facilities for non-potable use in residential, commercial, or industrial applications. They store water in manufactured tanks or underground storage areas. They can be used with any type of roof structure to intercept runoff and reduce runoff volume. The water can be treated and used for domestic purposes, fountains, pools, gray water, air conditioning, and other purposes. Both cisterns and rain barrels can be implemented without the use of pumping devices, instead relying on gravity flow.

Typical Uses: Placed outside of homes or businesses to irrigate

landscaping.

Land Use: Residential, commercial, industrial.

Approximate Cost: Rain barrels cost approximately $120; the cost of cisterns varies depending on their size, material, location (above or below ground), and whether they are prefabricated or constructed on site. They range in volumes from hundreds of gallons for residential use to tens of thousands of gallons for commercial and industrial use.

Maintenance: Rain barrels require regular maintenance by the home/ business owner, including draining after rainstorms and removal of leaves and debris collected on screens. Cisterns, along with all their components and accessories, should undergo regular inspection at least twice a year.

Design Specs and Supplementary Information:

Rainscapes

8) Site Appropriate Landscaping

When selecting plants for a landscape design, it is important to have knowledge of the site conditions. Plant materials should be selected for their form, color, and texture, as well as solar, soil, and moisture requirements. Plants that do well in various micro-climates on a site are considered "site appropriate."

Fig. 24: Native plants thrive in dry conditions
Photo Credit: Chesapeake Native Nursery

It is increasingly recommended that native plants (vegetation that grows naturally in particular climates or regions) be used because of their performance, site enhancement, and life-cycle cost benefits. Native plants typically cost more initially (depending on local availability); however, they are more cost-effective in the long run because they require less water and fertilizer, and are more resistant to local pests and diseases than non-native ornamentals. Life-cycle costs are reduced due to reduced maintenance and replanting requirements. Native plants are also known to be very effective in managing storm water because many species have deep root systems which stabilize soil and facilitate the infiltration of storm water runoff. Additionally, native plants provide habitat for local/regional wildlife.

Care should be taken to not plant invasive species as they tend to crowd out the native species. Some common groundcovers, shrubs, and vines are invasive and are prohibited from being planted. Refer to your state list of invasive plants.

Design Specs and Supplementary Information:

Chesapeake Bay Foundation Bay Friendly Landscaping
Lady Bird Johnson Wildflower Center Native Plant Database
Plant Species Appropriate for Use in Bio-retention Cells (Prince Georges Department of Environmental Resources)

9) Other LID Technologies Include:

a. *Green Roofs*—Vegetated rooftops that use a plant-soil complex to store, detain, and filter rainfall. They reduce runoff volume and improve runoff timing. These multilayered systems use a lightweight soil mixture and sedums (not grass) to provide energy conservation benefits and aesthetic improvements to buildings. They can be used on expansive concrete roof buildings ("big boxes") or small-scale residential roof structures. See WBDG Extensive Green Roofs
b. *Soil Amendments and Aeration*—Soil amendments increase the infiltration and water storage capabilities to reduce runoff from a site. Additionally, the compost, lime, or organic materials alter the physical, chemical, and biological characteristics of the soils to improve plant growth. Aeration of the soil, which can be done in conjunction with routine mowing activities, can increase the storage, infiltration, and pollutant filtering capabilities of grassed areas. See Soil Amendment/Compost Specification (Low Impact Development Center)
c. *Pollution Prevention Lawn Care*—Proper fertilizer and pesticide applications will significantly contribute to lowering nutrients and chemical impairments. These include fall fertilization to decrease nutrient runoff.

LOW IMPACT DEVELOPMENT TECHNOLOGIES

Refer to *Achieving Sustainable Site Design through Low Impact Development Practices* Resource Page for more detailed descriptions about the LID site design approach, the site design process, and case studies.

RELEVANT CODES AND STANDARDS

Regulatory Compliance

Chesapeake Bay Agreement 2000
Clean Water Act

- Section 303. Total Maximum Daily Loads
- Section 311. Spill Prevention, Control, and Countermeasure Requirements
- Section 319. State Non-Point Source Management Program
- Section 401. Certification and Wetlands
- Section 402. National Pollutant Discharge Elimination System (NPDES) Program
- Section 404. Regulation of Dredged or Fill Material

Coastal Zone Management Act
Energy Policy Act of 1992
Estuaries and Clean Waters Act of 2000
National Environmental Policy Act of 1969
Safe Drinking Water Act Wellhead Protection Program

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Sikes Act

Federal Directives

Executive Order 13423, "Strengthening Federal Environmental, Energy, and Transportation Management"

ADDITIONAL RESOURCES

WBDG

Design Objectives
Sustainable, Sustainable—Protect and Conserve Water

Products and Systems
Building Envelope Design Guide: Below Grade Systems, Foundation Walls, Floor Slabs
Federal Green Construction Guide for Specifiers
- 32 10 00 (02700) Bases, Ballasts, Paving
- 32 12 43 (02795) Porous Paving
- 32 90 00 (02900) Planting
- 31 25 73 (02635) Stormwater Management by Compost
- 32 71 00 (02670) Constructed Wetlands
- 07 33 63 (02930) Vegetated Roof Covering
- 07 55 63 (07530) Vegetated-Protected Membrane Roofing
- 33 16 20 (11201) Rainwater Harvesting

Associations

National Association of Homebuilders-Low Impact Development Practices for Storm Water Management

Organizations

Low Impact Development Center, Inc.
Puget Sound Action Team
Sustainable Buildings Industry Council (SBIC)
U.S. Green Buildings Council (USGBC)

Publications

GSA LEED® Applications Guide
GSA LEED® Cost Study
Natural Approaches to Storm Water Management
The Practice of Low Impact Development National Association of Home Builders (NAHB) for the Dept. of HUD order 1-800-245-2691; helpdesk@huduser.org or NAHB
"Reducing Combined Sewer Overflows—Toward Clean Water in Washington, DC" (PDF 415 KB)
"Out of the Gutter—Reducing Polluted Runoff in the District of Columbia" (PDF 1.4 MB) (NRDC)
Low Impact Development
Low Impact Development—Protecting Water Resources as Our Cities Grow (PDF 2.78 MB)

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Design and Analysis Tools

Bioretention Design Software
Bioretention Facility Design References
LID Design Software
Low Impact Development Urban Design Tools
Prince Georges County—Low Impact Development

Training

American Society of Civil Engineers (ASCE) Training
Applied Stormwater Management Design Training
Low Impact Development Conferences
Low Impact Development Conference 2001 (Puget Sound)
Low Impact Development Training Workshops

Other

Environmental Protection Agency (EPA)
EPA—Low Impact Development
EPA—Storm Water Management
EPA—Storm Water Management at the EPA Headquarters Office Complex
National Association of Homebuilders Research Center LID Web Resources
Puget Sound Action Team LID Web Resources

Updated: 04-03-2007

Comment on this page

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Achieving Sustainable Site Design through Low Impact Development Practices

by Anne Guillette, LEED Accredited Professional
Low Impact Design Studio (formerly with the Low Impact Development Center)

INTRODUCTION

A. Definition of Low Impact Development (LID)

Low Impact Development (LID) is a sustainable storm water management strategy that is gaining rapid acceptance in the United States to meet regulatory compliance and resource protection goals and is practiced extensively in Europe. The increased use of LID is in response to burgeoning infrastructural costs of new development and redevelopment projects, more rigorous environmental regulations, concerns about the urban heat island effect, and the impacts of natural resources due to growth and development. The frequency of droughts and concern about water quality issues have also prompted interest in the treatment and the reuse of storm water as a viable resource and has resulted in a shift in the way planners, developers, architects, engineers, and the public approach the control of storm water and conservation of rainwater. Many municipalities across the nation have embraced LID due to its holistic approach to site design and overall sustainable design. There are countless examples of jurisdictions that have proactively revised their development policies, codes, growth and management plans and implemented LID technologies to manage storm water at its source and collect rainwater for secondary use.

The LID strategy controls water at the source—both rainfall and storm water runoff—which is known as 'source-control' technology. It is a decentralized system that distributes storm water across a project site in order to replenish groundwater supplies rather than sending it into a system of storm drain pipes and channelized networks that control water downstream in a large storm water management facility. The LID approach promotes the use of various devices that filter water and infiltrate water into the ground. It promotes the use of roofs of buildings, parking lots, and other horizontal surfaces to convey water to either distribute it into the ground or collect it for reuse.

The LID approach differs from conventional conveyance systems as it promotes the highest and best use of the intrinsic land form and built structure(s) to both distribute storm water and collect rainwater. The uniqueness of LID is the interaction and function of water on a site. It capitalizes on the integration of infrastructure, architecture, and landscape in order to create a balanced, hydrologically functional and sustainable site. The LID approach handles water like the valuable and viable resource that it is, for the water that reaches a project site is a valuable commodity and can be used in innumerable ways.

LID encompasses the use of structural devices (engineered systems)

and non-structural devices (vegetated, natural systems). It uses a combination of these technologies, or a "suite of technologies," to maintain or restore the natural hydrologic functions on a site with the goal of reducing the impact of development. The goal is to structure the development of a site so that the pre-development conditions are not altered excessively. Of particular concern are the rate of storm water runoff, the pollutants in the water, and recharge of water into the ground. By reducing water pollution and increasing groundwater recharge, LID helps to improve the quality of receiving surface waters and to stabilize the flow rates of nearby streams. The integrated LID devices that are available allow the designer to restructure the built environment to control storm water and capture rainwater in order to minimize the impact of development. The integration of LID devices permits the developer and designer to use an array of storm water management devices that are both cost-effective and environmentally sound. The LID strategy is not a static design approach, however, is very dynamic and adaptable. LID has been proven to reduce development and infrastructure costs, minimize operations and maintenance costs, and improve the marketability of projects.

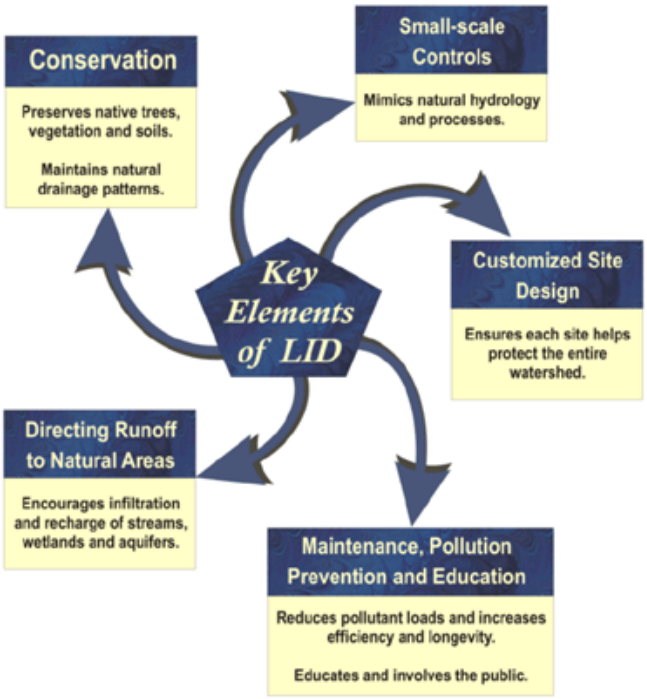

Fig. 1: Key Elements of LID

B. Background of LID

LID was pioneered in the 1990's by the Prince George's County, Maryland Department of Environmental Resources. The LID effort in Prince George's County began with the development and use of bioretention cells. The County's initial experience with bioretention led to a full-scale effort to incorporate LID into the County's resource protection program. In 1998, the County produced the first municipal LID manual. This was later expanded into a nationally distributed LID manual that was published in 2000. A feasibility study was prepared by the LID Center in 2002 that provided guidance on how LID could be used to retrofit urban areas. Since then the LID Center, other water research organizations, and universities have been developing tools,

strategies, and techniques to incorporate LID into research and regulatory programs.

C. The Benefits of LID

The primary benefits of LID are:

1. To prevent degradation of water quality and natural resources,
2. To manage storm water more efficiently and cost effectively,
3. To protect groundwater and drinking water supplies, and
4. To help communities grow more attractively.

D. Models of Ingenuity

There still are many barriers to using LID technologies, primarily because of unfamiliarity with the technologies, and obstacles in the administrative and permitting process. However, many models already exist that illustrate the ingenuity of municipalities across the country to incorporate sustainable practices into their development codes and policies to protect their natural resources and manage storm water. Many communities have streamlined processes and revised their regulations and development codes to promote LID storm water management applications.

One popular practice among planning departments is extending provisional variances or waivers of standards to developers, engineers, and architects for projects that demonstrate the use of LID technologies. Many areas of the country that are progressive with respect to alternative storm water management applications are beginning to adapt their local codes and zoning laws as a result of successful pilot programs. Demonstration projects have repeatedly stimulated interest in LID practices and have prompted the passage of ordinances, revisions to development policies and codes, amendments to storm water management guidelines, and often influenced modifications to growth and management goals or Comprehensive Land Use Management Plans. Municipalities have used the pilot projects to:

- Demonstrate sustainable materials and products,
- Monitor storm water runoff,
- Measure the impact to adjacent waterways,
- Determine cost benefits,
- Streamline permitting and administrative approval processes, and
- Evaluate public involvement and acceptance.

E. The Challenge of LID

LID is in the early stages of adoption in the United States and a challenge exists to assist municipalities in adapting these approaches and techniques. Although the technologies are relatively new to planners in this country and innovative in their response, they have been successfully used in Europe and Asia for many years. The technologies are not experimental; rather they are proven and tested. The challenge is to implement these technologies in inventive configurations. However, the pursuit of innovative technologies is not a foreign concept to developers, engineers, and architects that advocate and promote green building and sustainable design.

F. Case Studies and Pilot Projects

There are many exemplary programs that have used a broad range of planning methods and systematic approaches to develop policies, practices, and procedures to meet local water quality regulations and environmental challenges. Municipalities such as Portland, Oregon have incorporated LID techniques into their urban resource protection programs. Local governments throughout the Puget Sound (Washington State) have revised ordinances, or passed new ordinances, to allow for and encourage LID practices. Several successful pilot projects have been constructed locally and nationally and have demonstrated the effectiveness of managing runoff, reducing construction and maintenance costs, and enhancing communities. As a result, they have created significant interest in LID. *Refer to Section IV for more detailed descriptions on case studies and pilot projects.*

DESCRIPTION

A. LID Site Design Goals

The goal of LID site design is to minimize the generation of storm water runoff and to treat pollutant loads where they are generated. This is accomplished by directing storm water towards small-scale systems that are dispersed throughout the site with the purpose of managing water in an evenly distributed manner. These distributed systems allow for downsizing or elimination of storm water ponds, curbs, and gutters, thus saving on infrastructure and storm conveyance costs. Eliminating (or reducing the size of) ponds makes available additional land for open space, lots, or supplementary building footprint.

Because LID embraces a variety of useful techniques for controlling runoff, designs can be customized according to local management requirements and site constraints. Designers and developers can select the LID technologies that are appropriate to a site's topographic and climatic conditions and are appropriate to meet storm water control requirements. New projects, redevelopment projects, and capital improvement projects are all candidates for implementation of LID.

B. LID Site Design Strategies

Site design strategies for every design project address the arrangement of buildings, roads, parking areas, site features, and storm water management plans. LID builds on conventional design strategies by exploiting every surface in the infrastructure—natural and hardscape—to perform a beneficial hydrologic function. The surfaces are used to retain, detain, store, change the timing of, or filter runoff in a number of different configurations and combinations. Some of the more prevalent site design techniques include:

- Reduce imperviousness by using permeable paving or landscaping to break up expanses of impervious surfaces.
- Direct runoff into or across vegetated areas to help filter runoff and encourage groundwater recharge.
- Preserve, or design into the infrastructure, naturally vegetated

areas that are in close proximity to parking areas, buildings, and other impervious expanses in order to slow runoff, filter out pollutants, and facilitate infiltration.

- Reduce street widths.
- Remove curbs and gutters from streets, parking areas, and parking islands to allow storm water sheet flow into vegetated areas.
- Use devices such as bioretention cells, vegetated swales, infiltration trenches, and dry wells to increase storage volume and facilitate infiltration.
- Grade to encourage sheet flow and lengthen flow paths to increase the runoff travel time in order to modify the peak flow rate.
- Disconnect impervious areas from the storm drain network and maintain natural drainage divides to keep flow paths dispersed.
- Disconnect roof downspouts and direct storm water into vegetated areas or into water collection devices.
- Install cisterns or sub-surface retention facilities to capture rainwater for use in irrigation and non-potable uses.
- Install vegetated roofs or garden roofs.
- Use native plants (or adaptable species) to establish an adaptable and low maintenance landscape that requires less irrigation and are appropriate for the climatic conditions.
- Use naturally occurring bio-chemical processes in plants located in tree box filters, swales, planter boxes.
- Divert water away and disconnect from the storm drain or CSO using correctional drainage techniques.

C. LID Site Planning Process

This following is a model LID design strategy. It is important to have a clear idea of the sustainability goals in order to develop an effective LID storm water management program. Once strategies and LID technologies are identified, a master plan can be prepared.

Fig. 2: LID Design Development and Planning

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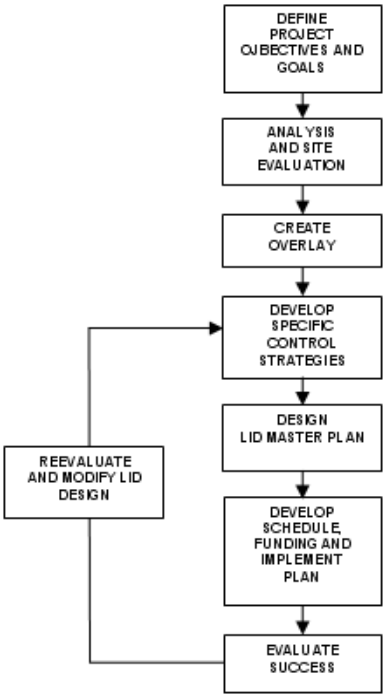

Process

A step-by-step process for LID design development is described below:

Step 1: Define Project Objectives and Goals

a. Identify the LID objectives for the entire project.
b. Determine the goals and feasibility for water quality, water quantity, peak runoff control, and on-site use of storm water.
c. Determine project character/aesthetic. Identify the baseline principles from which LID design decisions will be made by defining the LID technologies that support the concept and visual aesthetic. Determine if it is a goal to irrigate open space with captured rainwater, or whether rain barrels are a suitable aesthetic for front or back yards. Determine if it is important to offer residential homeowners the ability to use rain barrels for private irrigation needs, or use subsurface detention facilities for carwashes. Consider whether green roofs or roof gardens are consistent with the envisioned architectural design.
d. Prioritize and rank basic objectives.

Step 2: Analysis and Site Evaluation

A site evaluation will facilitate LID design development by providing infrastructural, contextual, cultural, and community clues that will assist in the development of a LID program.

a. Conduct a detailed investigation of the site through collected materials such as drainage maps, utilities information, soils maps, land use plans, and aerial photographs.
b. Perform an on-site evaluation highlighting opportunities and constraints, such as pollutant hot spots, potential disconnects from Combined Sewer Overflows (CSOs), slopes, critical drainage areas, sunlight, shade, wind, habitat, potential green corridors, circulation, power lines, and storm drains. Make note of potential

LID practices and areas where water quality and quantity controls could be installed.

Step 3: Create Overlay

a. Classify the land use on the project site.
b. Review the proposed architectural plan to identify buildings and structures, open or vegetated space, parking lots, parking lot islands, side yards, vegetated strips adjacent to sidewalks, and buffer areas.
c. Create an overlay that identifies opportunities for LID devices.

Step 4: Develop LID Control Strategies

a. Develop a list of LID control strategies that potentially fulfill the objectives. Determine the appropriate number of LID controls needed. Identify specific LID technologies for the project site and determine how to integrate them, keeping in mind the optimum location, to meet their design objectives.
b. Specify LID technologies for each land use component.

Step 5: Design LID Master Plan

a. Sketch a design concept that distributes the LID devices uniformly around the project site. Keep in mind that some LID technologies can be used to capture storm water from adjacent impervious areas. Consider where public recreation areas can be provided, such as networks of open space or green corridors. Take into account using all surfaces (built, hardscape, and landscape). Keep in mind the multifunctional aspect of LID technologies (i.e., parking lot with sub-surface detention facility).
b. Develop a master plan that identifies all key control issues (water quality, water quantity, water conservation) and implementation areas. Specify specific LID technologies and any connections they have to storm water overflow units and sub-surface detention facilities.
c. Finalize the plan.

Step 6: Develop Schedule, Funding, Construction, and Implementation Plans

The development process is not a linear or static process but one that is dynamic and adaptable.

Step 7: Evaluate Success or Modify Design

Developing a storm water management program using LID principles and practices is a dynamic process. Evaluate the design to see if it meets project storm water management objectives. This will be achieved by:

a. Conducting modeling and/or calculations to determine if the master plan meets storm water control objectives. If the design does not meet the requirements, consider alternative strategies and repeat Steps 4, 5, and 6.
b. Periodically reevaluate the plan during the implementation process to determine if revisions need to be made to the storm water management program.

D. LID Technologies and Water Conservation

The following example addresses a way to determine the goals for on-site reuse of rainwater and water conservation. Determine which level of on-site reuse and water conservation is consistent with project objectives. A list of suitable LID technologies is suggested for the different water conservation levels.

1. Level One: Distribution
Storm water runoff is distributed using open and vegetated areas to increase infiltration and reduce the amount of storm water that enters the storm drains. This requires minimal infrastructural modifications/additions.
LID Technologies: Sheet flow to rain gardens, bioswales, bioretention cells, tree box filters, soil amendments, structural soil, native and sustainable ornamental plants

2. Level Two: Hardscape Materials and Curbs
Replace hardscape materials with permeable materials. Construct sidewalks, parking bays, and internal alleys with materials, such as permeable concrete or green grids, that allow water to infiltrate. Slope roads in the directions of the parking lot islands, and construct curb-less islands to allow water to flow into the island. Minimal infrastructural alterations/additions are required.
LID Technologies: Permeable paving, curb-less parking lot islands, porous concrete parking bays, and above listed technologies

3. Level Three: Recycling Rainwater and Runoff
This level uses above-ground LID devices to channel and collect rainwater from roofs, and uses sub-surface facilities to treat and collect runoff from roads and sidewalks. The recycled and stored water is used for irrigation and other non-potable purposes. The devices are integral with the buildings and infrastructure. Significant infrastructural alterations/additions are required.
LID Technologies: Disconnected roof drains, cisterns, sub-surface storm water retention facility (below parking lots), rooftop channels, rain barrels, and above listed technologies

LID can be thought of as a component of the larger approach to sustainable design and water conservation. LID makes use of the rainfall and storm water that reaches a site, filtering it and directing it for reuse. LID site design technologies can be incorporated into the overall LEED Water Efficiency and Innovative Wastewater Technology goals pertaining to water use, recycling grey water, and water sewage treatment.

This analysis was compiled through a grant through the National Fish and Wildlife Foundation.

APPLICATION

LID Implementation Examples

Many municipalities in the U.S. have been very proactive in using on-site source control methods to manage storm water, such as in

Maplewood, Minnesota. In 1995, Birmingham Street, in Maplewood, was retrofitted with rain gardens adjacent to curb-less streets, instead of conventional curb and gutter, and became a precedent for future streetscape improvement projects in the county. The City of Olympia, Washington, has been very proactive in requiring certain sustainable storm water management practices to reduce the impact of impervious areas (e.g., narrower streets and permeable parking bays) and have adopted new codes and development guidelines. The City of Portland, Oregon, has revised zoning codes for parking lots to reduce the minimum size of parking bays and increase the required interior landscaping. Santa Monica, California, has modified its municipal code to encourage the use of sustainable practices including a number of site, landscape and water conservation technologies.

Some successful LID design and program development models include:

1. Olympia, Washington—Green Cove Basin

Key Goals:

- Designate Green Cove Creek as a sensitive drainage basin.
- Adopt low impact development regulations within designated sensitive drainage basins which may include storm water standards, critical area regulations, zoning designations, and other development standards.
- Protect critical areas in designated sensitive drainage basins.
- Direct development away from sensitive areas.

Key Elements:

- Increases allowable residential densities from single-family to duplex and multi-family uses.
- Limits maximum impervious surface coverage per lot.
- Reduces lot widths and setbacks.
- Increases maximum building heights.
- Changes zoning to allow multiple uses.
- Allows use of pervious materials on driveways and sidewalks.
- Requires use of pervious materials on new parking areas.
- Reduces width of local access streets to 18 feet.
- Reduce width of neighborhood collector streets to 25 feet.
- Increases width of sidewalk planters to 25 feet.
- Requires use of a rock infiltration gallery/conveyance system on roads where street slopes are less than 5 percent.
- Increases minimum tree density to 220 trees per acre (approx. 55%).

Comments:
The ordinance requires the use of one technique to handle street runoff, rather than providing a suite of technologies that might be more adaptable to different situations. The ordinance does not specifically address the treatment or capture of runoff from buildings.

2. Portland, Oregon—Amendments to Zoning Code

Objective:

To promote integration of storm water management facilities into parking lot layouts, to decrease the size of parking stalls and aisles, and to increase parking lot landscaping.

Key Elements:

- Promotes management of parking lot runoff within parking lot landscaping.
- Reduces parking space dimensions to 16 feet x 18½ feet for 90-degree parking.
- Reduces aisle width to 20 feet.

Comments:
An effort was made to permit and promote the management of parking lot runoff within interior landscaping, but to avoid creating excessive complications for retrofits of existing parking lots. The zoning code does not explicitly require that storm water runoff be managed within parking lot landscaping. The regulation of storm water management is left to the Bureau of Environmental Services. Specific requirements for parking lot runoff management are included in the city's *Storm Water Management Manual*.

3. Santa Monica, California

Objective:
To reduce runoff volume and contamination from both existing properties and future developments.

Key Elements:

- Establishes "Good Housekeeping Requirements" for existing properties, including the removal of hazardous substances from areas susceptible to runoff and restrictions on the washing down of paved areas.
- Requires all new developments and substantial remodels to submit an "Urban Runoff Mitigation Plan", and to reduce projected runoff for a project site by twenty percent. Provides a list of recommended design elements, including, but not limited to:
    - Maximize infiltration using:
        - biofilters
        - green strips
        - swales
        - permeable materials in lieu of hardscapes
    - Maximize amount of runoff directed permeable areas
    - Orient roof runoff toward permeable surfaces or structural BMPs
    - Modify grading to divert flow to permeable areas
    - Design curbs to minimize isolation of permeable or landscaped areas
    - Maximize storm water reuse
    - Use cisterns, retention structures or green rooftops to store runoff for reuse
    - Install BMPs to remove pollutants from runoff
    - Urban Runoff Mitigation Plan must include maintenance plan and applicant's signed statement accepting responsibility for

all BMP maintenance.
- Downspouts and subsurface pipes directing storm water to the curb must be fitted with a French drain system of perforated pipe and gravel.

Comments:
Substantial differences exist between the ordinance as adopted in 1992 and the most recent revision (2000). Both versions are included for the purpose of comparison. At some point, it may be instructive to research the reasons for changes in language and specific requirements.

4. King County, Washington-LID / Built Green™ Demonstration Projects

Objective:
To create three safe, healthy, and diverse communities that are sustainable and affordable, and to study the efficiency of the development review process as it affects project affordability.

Key Goals:
The three (3) pilot projects will:
- Demonstrate environmentally-friendly storm water management techniques (low impact development) that use landscaping and small-scale hydrologic devices to capture, filter, and infiltrate storm water runoff.
- Demonstrate ecologically sound approach to managing the built environment using Built Green™ construction principles.
- Feature recycled materials, energy efficiency, and natural habitat protection.

The three projects are:
1. *Hope VI Park Lake Homes in White Center:* An urban infill mixed-use redevelopment site of 900 units: new single family and multi-family housing units; developed by King County Housing Authority
2. *Shamrock in Renton:* An urban single family residential project of 100 single family housing units developed by Camwest, a private developer
3. *Sunflower Development on Vashon Island:* A housing project of 14 single family homes

Key Elements:
The modifications and waivers to standard development regulations that may be modified for the low impact development and Built Green™ demonstration projects may include:
- Zoning
- Density and dimensions
- Design requirements
- King County road standards
- Parking and circulation
- Landscaping and water use
- Drainage review requirements
- Environmentally sensitive areas
- Signs

5. Maplewood, Minnesota

Objective:
Adopted LID storm water management techniques as an alternative to conventional curb and gutter infrastructure in a 1950s residential community slated for a street improvement project.

Key Goals:

- Retrofit two blocks of existing streets and front yard municipal storm water easements with rain gardens that infiltrate storm water.
- Reduce capital costs for municipal infrastructure by avoiding curb and gutter installation.
- Build an ecologically friendly landscape that supports biodiversity.
- Create a culturally sustainable landscape through community involvement.
- Enhance the aesthetic of the neighborhood.

Key Elements:
The landscape retrofits include:

- Grassed swales in storm water easements.
- Rain gardens in front yards of volunteer residents. Residents selected from seven types of garden designs that use native plants, such as "easy shrub," "butterfly and friends," or "Minnesota prairie garden". The city provided the landscape design and all of the plants required for their garden.
- French drains installed at key locations to increase infiltration capacity.
- The front yard gardens create a landscape corridor up and down the street.
- An abandoned lot was used as a storm water retention area and has become a community nature garden.
- The program is supported by community education and outreach programs and promotes public involvement.
- Questionnaires address homeowners' uncertainties about design, the use of the storm water easement in their front yard, maintenance, and care.
- Annual community "planting days" are scheduled where city personnel and residents demonstrate how to plant and maintain rain gardens.

This analysis was compiled through a grant through the Summit Fund of Washington.

Low Impact Development Technologies

Refer to the Low Impact Development Technologies Resource Page for more detailed descriptions about specific LID technologies, cost comparisons, benefits, and their use.

RELEVANT CODES AND STANDARDS

Regulatory Compliance

Chesapeake Bay Agreement 2000
Clean Water Act

- Section 303. Total Maximum Daily Loads
- Section 311. Spill Prevention, Control and Countermeasure Requirements
- Section 319. State Non-Point Source Management Program
- Section 401. Certification and Wetlands
- Section 402. National Pollutant Discharge Elimination System (NPDES) Program
- Section 404. Regulation of Dredged or Fill Material

Safe Drinking Water Act Wellhead Protection Program
Coastal Zone Management Act
Energy Policy Act of 1992
Estuaries and Clean Waters Act of 2000
National Environmental Policy Act of 1969
Sikes Act

Federal Directives

Executive Order 13423, "Strengthening Federal Environmental, Energy, and Transportation Management"

ADDITIONAL RESOURCES

WBDG

Design Objectives
Sustainable, Sustainable—Protect and Conserve Water

Product and Systems
Building Envelope Design Guide: Below Grade Systems, Foundation Walls, Floor Slabs, Plazas, Tunnels, Vaults
Federal Green Construction Guide for Specifiers
32 10 00 (02700) Bases, Ballasts, Paving
32 12 43 (02795) Porous Paving
32 90 00 (02900) Planting
31 25 73 (02635) Stormwater Management by Compost
32 71 00 (02670) Constructed Wetlands
07 33 63 (02930) Vegetated Roof Covering
33 16 20 (11201) Rainwater Harvesting

Associations

National Association of Homebuilders-Low Impact Development Practices for Storm Water Management

Organizations

SARB_003995

Low Impact Development Center, Inc.
Puget Sound Action Team
Sustainable Buildings Industry Council (SBIC)
U.S. Green Buildings Council (USGBC)

Publications

GSA LEED® Applications Guide
GSA LEED® Cost Study
Natural Approaches to Storm Water Management (PDF 1.2 MB)
The Practice of Low Impact Development publication (NAHB for the Dept of HUD); order 1-800-245-2691; helpdesk@huduser.org or NAHB
"Reducing Combined Sewer Overflows—Toward Clean Water in Washington, DC" (PDF 415 KB)
"Out of the Gutter—Reducing Polluted Runoff in the District of Columbia" (PDF 1.4 MB) (NRDC)
Low Impact Development
Low Impact Development—Protecting Water Resources as Our Cities Grow (PDF 2.7 MB)

Design and Analysis Tools

Bioretention Design Software
Bioretention Facility Design References
LID Design Software
Low Impact Development Urban Design Tools
Prince Georges County—Low Impact Development

Training

American Society of Civil Engineers (ASCE) Training
Applied Stormwater Management Design Training
Low Impact Development Conferences
Low Impact Development Conference 2001 (Puget Sound)
Low Impact Development Training Workshops

Other

Environmental Protection Agency (EPA)
EPA—Low Impact Development
EPA—Storm Water Management
EPA—Storm Water Management at the EPA Headquarters Office Complex
National Association of Homebuilders Research Center LID Web Resources
Puget Sound Action Team LID Web Resources

Updated: 04-03-2007

Comment on this page

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Low Impact Development

Dwane Jones

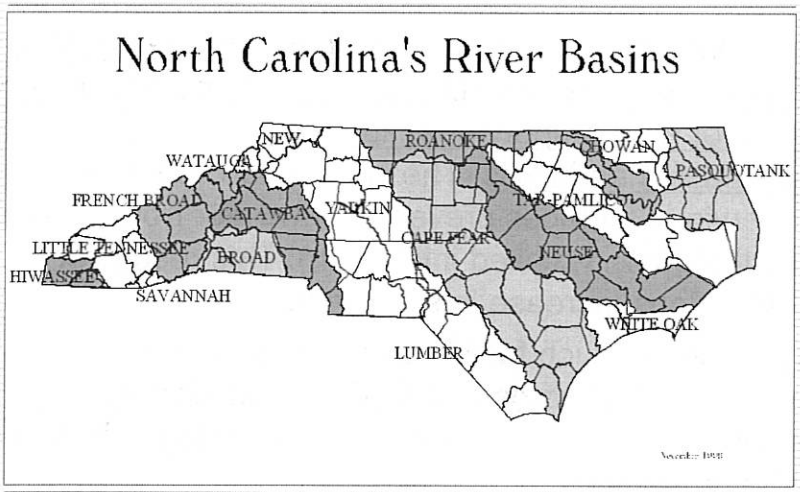
North Carolina State University

Cooperative Extension

dwane_jones@ncsu.edu

252.747.5831

17 Major River Basins



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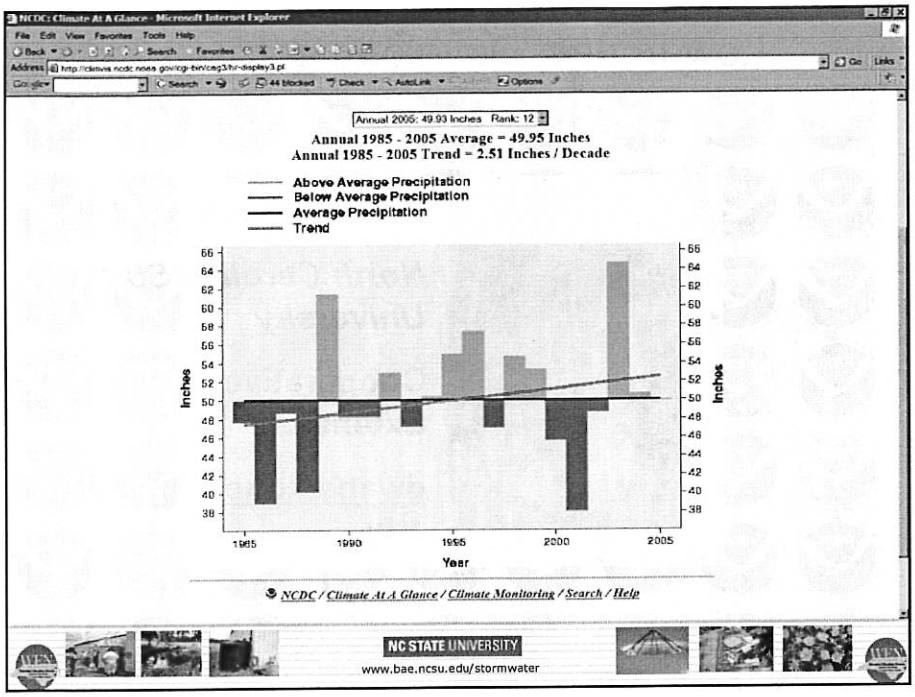
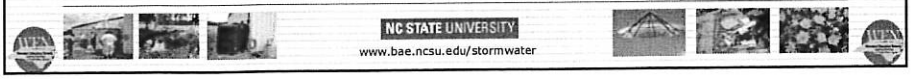


Conventional Development

Conventional land development involves removal of all vegetation, compacting the soil and putting in large areas of hard (impervious) surfaces like roads, parking lots and roofs. The compacted soil and impervious surfaces prevent stormwater from soaking into the ground (called infiltration). This results in a tremendous increase in surface runoff.

By traveling much faster, stormwater runoff overwhelms streams causing flooding, damaging public and private property and destroying habitat for fish and wildlife.



Conventional Development

Further, conventional practice collects and conveys stormwater runoff through storm drains and pipes to a centralized, manmade stormwater facility to manage stormwater flow and remove pollutants. This requires a lot of pipes and sometimes large, costly, stormwater best management practices.

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Low Impact Development

Design, construct, & maintain each development site to protect, or restore, the natural hydrology (the scientific study of the properties, distribution, and effects of water on the earth's surface) of the site so that the overall integrity of the watershed is protected. This is done by creating a "hydrologically" functional landscape.

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Low Impact Development (Benefits)

-Protection of Water Quality

-Reduction of Impervious Surfaces

-Increased Open Space

-Protection of Trees

-Reduced Land Disturbance

-Decrease in Infrastructure Costs

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Low Impact Development (Technologies)

LID PRACTICE / DEVICE	Peak Flow Control	Volume Reduction	Water Quality Improvement	Water Conservation
Bio-retention Cell	•	•	•	
Cistern	•	•	~~> • <~~	•
Curbless Parking Lot Islands	•	•	•	
Downspout Disconnection	•	•	•	
Grassed Swale	•	•	•	
Green Roof	•		•	
Infiltration Trench	•	•	•	
Narrow Road Design	•	•	•	
Permeable Pavers/Pavement	•	•	•	
Rain Barrel	•	•		•
Rain Garden	•	•	•	
Sand Filter	•		•	
Tree Box Filter	•		•	
Tree Planting	•	•		

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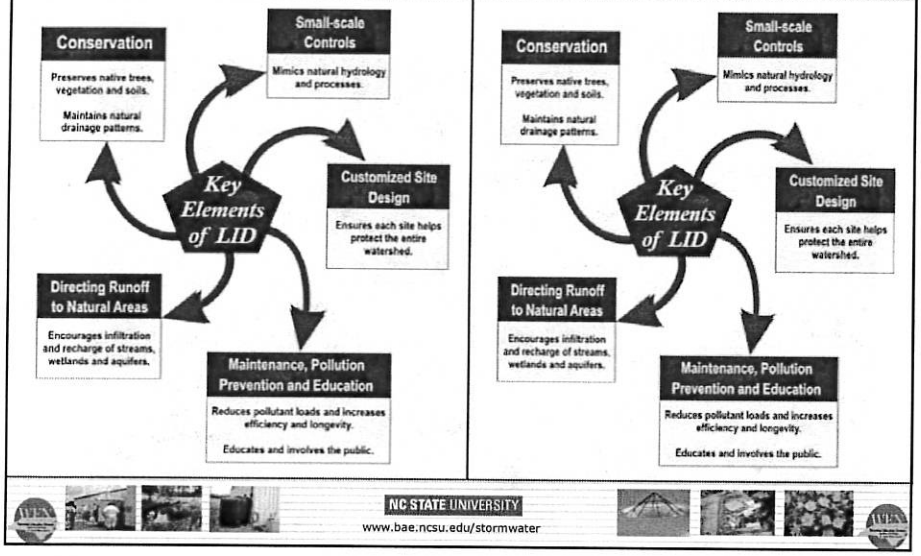
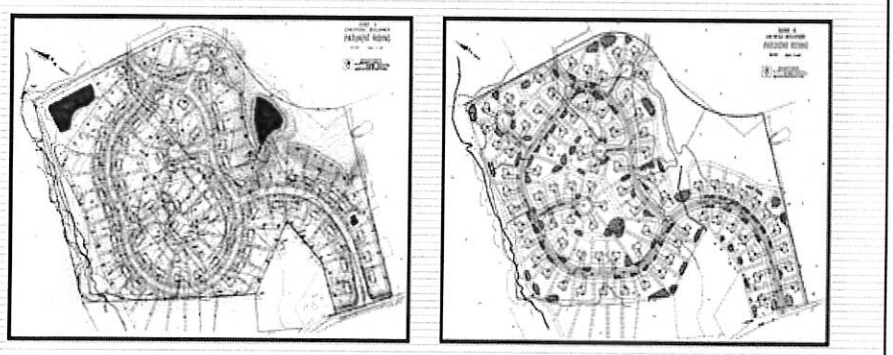
Low Impact Development



Low Impact Development

Conventional Development

LID Subdivision



Small-scale Controls: Bioretention

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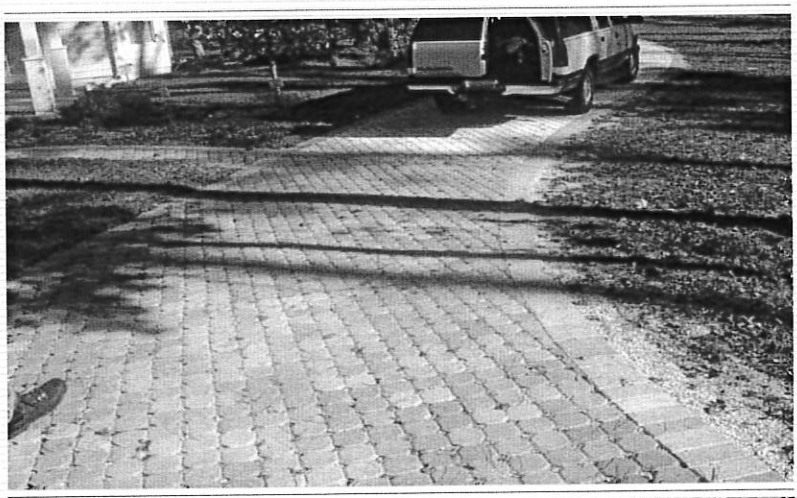
Small-scale Controls: Permeable Pavement



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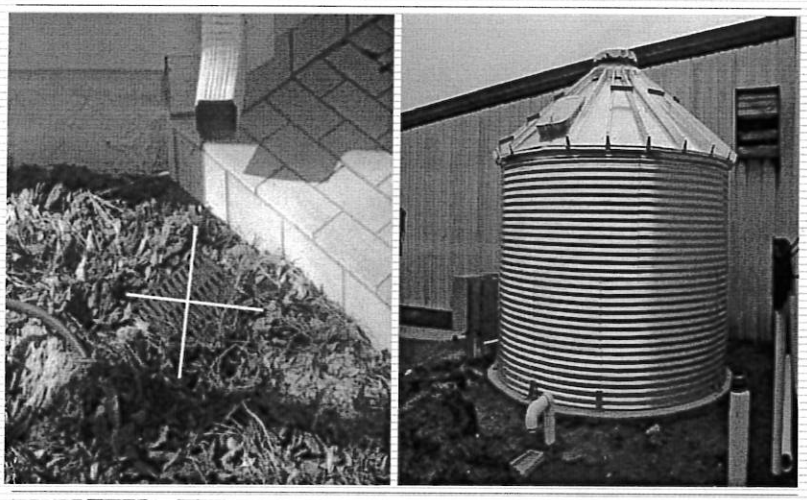
Small-scale Controls: Disconnected Downspouts and/or Cisterns



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Small-scale Controls: Green Roofs

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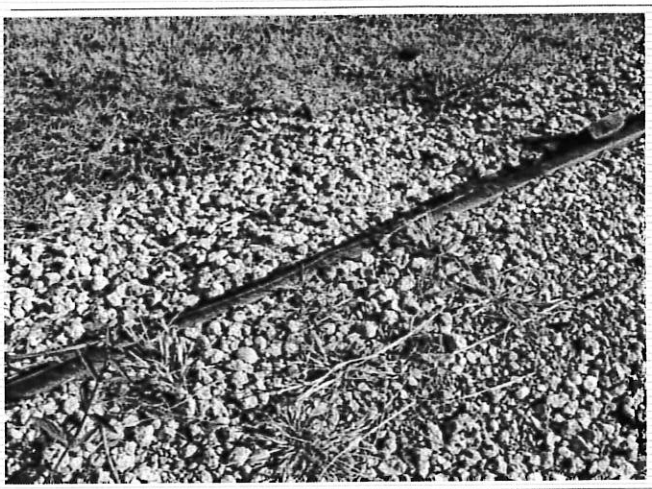
Small-scale Controls: Level Spreader



-Diffuse Flow

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Conservation: Landscape Vegetation

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Directing Runoff:
Encourage Infiltration
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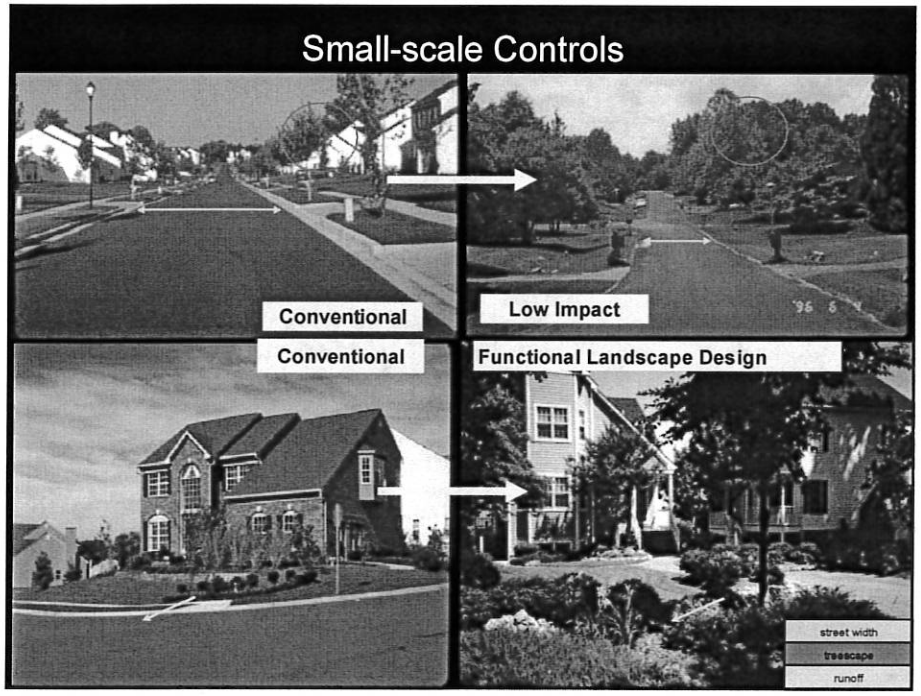
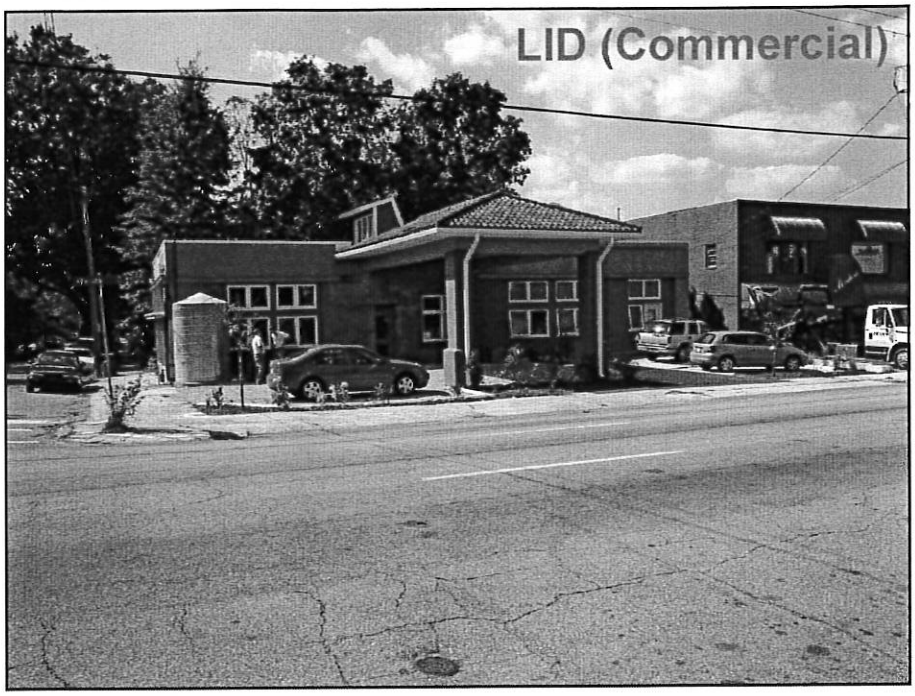
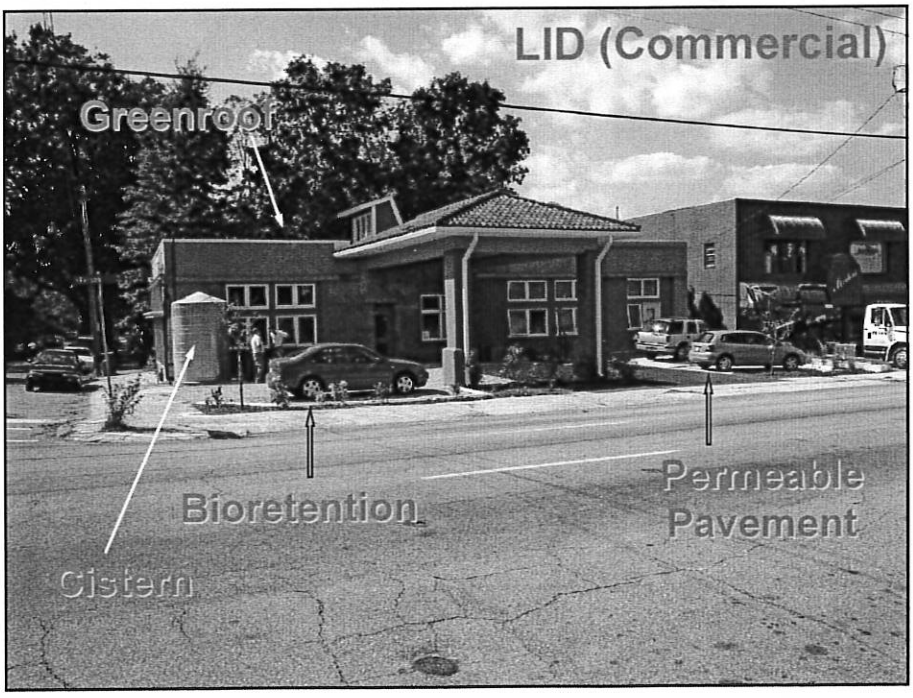
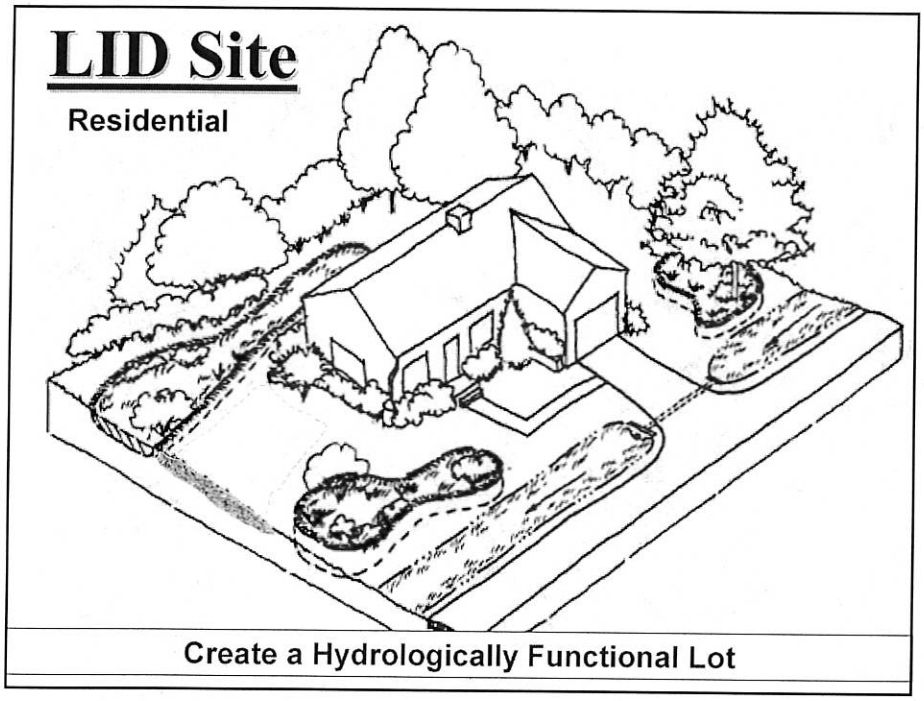
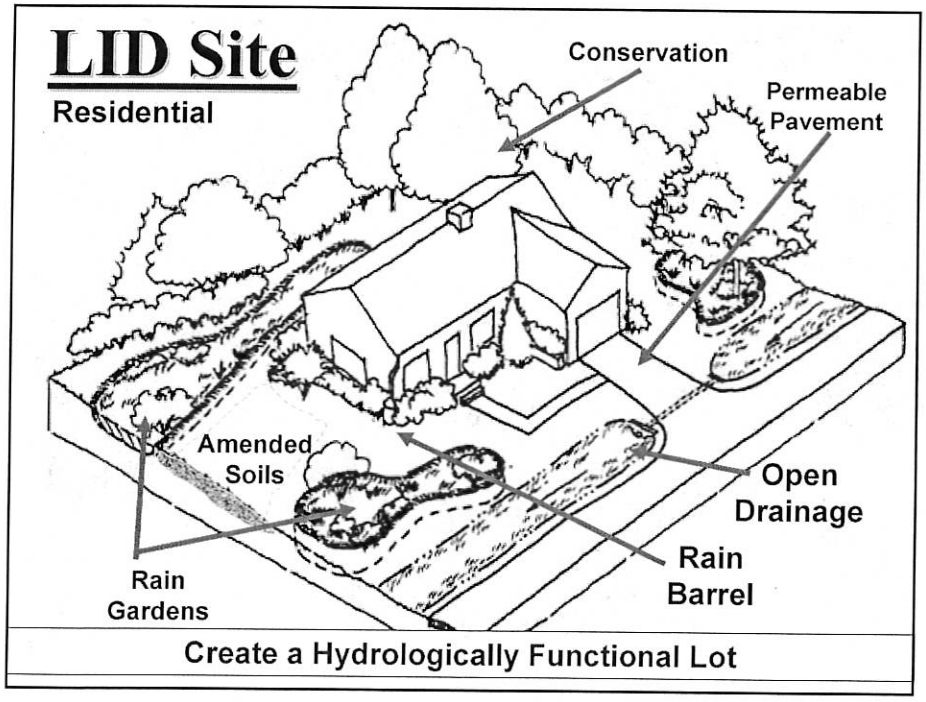
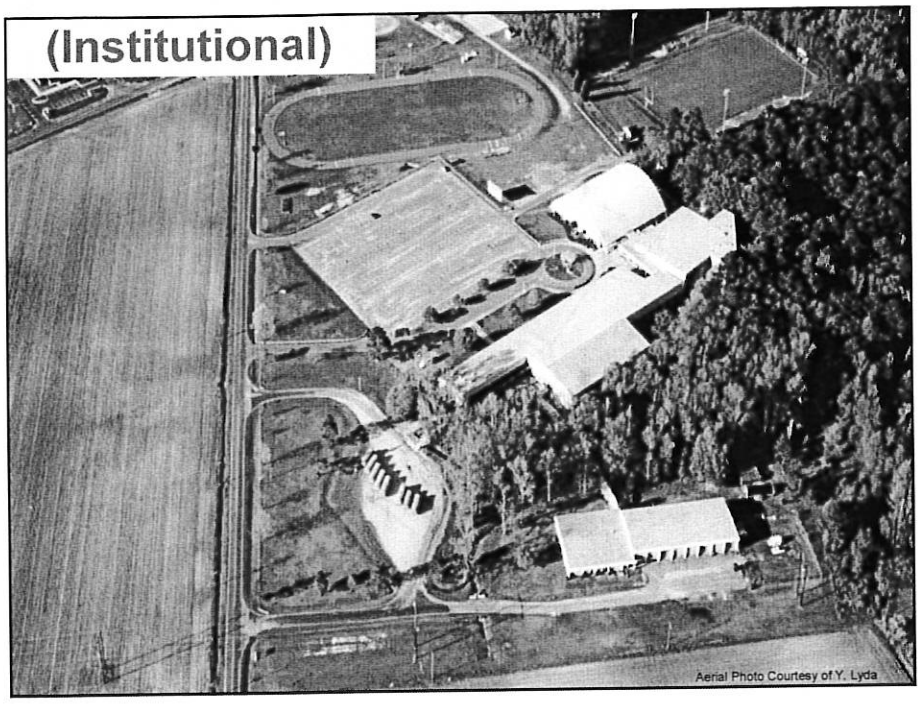

Small-scale Controls
Conventional
Low Impact
Conventional
Functional Landscape Design
street width
treescape
runoff


LID (Commercial)


LID (Commercial)
Greenroof
Bioretention
Permeable
Pavement
Cistern


LID Site
Residential
Create a Hydrologically Functional Lot


LID Site
Residential
Conservation
Permeable Pavement
Amended Soils
Open Drainage
Rain Barrel
Rain Gardens
Create a Hydrologically Functional Lot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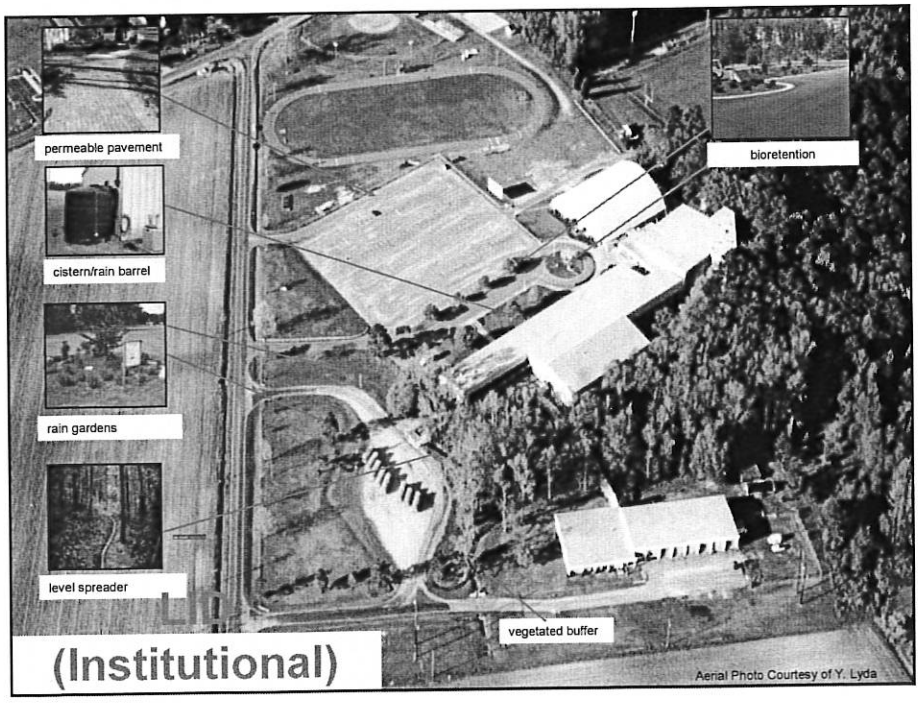
Aerial Photo Courtesy of Y. Lyda


permeable pavement
cistern/rain barrel
rain gardens
level spreader
bioretention
vegetated buffer
(Institutional)
Aerial Photo Courtesy of Y. Lyda

Challenges to LID

-*Local Ordinances & Site Plan Review Process (often antiquated)

**The developer may request a variance, but often, these can be time-consuming.*

-Local Opposition from Governing Body

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City of XXXXX-Article II: "Streets Generally"

Any area to be paved, stabilized, or otherwise made impervious to storm water which shall exceed 2500 square feet shall be so graded that stormwater is collected at a low point at least 10 feet behind the property line and conducted through underground pipes of sufficient size to the nearest storm drain, provided the nearest storm drain is within one block or 500 feet of the above-mentioned point…it will be permissible to drain the low spot by installing pipes through the curb and discharge into the gutter.

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City of XXXX-Subdivision Ordinance, Sidewalks, Walkways, and Bikeways.

Sidewalks shall be required to be constructed in the following circumstances:

(1) On a minimum of one side of the right-of-way of all thoroughfares such as freeways, expressways, arterials, or collector streets which are adjacent to property to be developed;

(2) On each side of the right-of-way…if the subdivider intends to construct any portion of the thoroughfare as access to his development;

Local Government Commission

"The LGC is a nonprofit organization working to build livable communities."

The Ahwahnee Water Principles for Resource Efficient Land Use

Preamble

Cities and counties are facing major challenges with water contamination, storm water runoff, flood damage liability, and concerns about whether there will be enough reliable water for current residents as well as for new development. These issues impact city and county budgets and taxpayers. Fortunately there are a number of stewardship actions that cities and counties can take that reduce costs and improve the reliability and quality of our water resources.

The Water Principles below complement the Ahwahnee Principles for Resource-Efficient Communities that were developed in 1991. Many cities and counties are already using them to improve the vitality and prosperity of their communities.

Community Principles

1. Community design should be compact, mixed use, walkable and transit-oriented so that automobile-generated urban runoff pollutants are minimized and the open lands that absorb water are preserved to the maximum extent possible. (See the Ahwahnee Principles for Resource-Efficient Communities)
2. Natural resources such as wetlands, flood plains, recharge zones, riparian areas, open space, and native habitats should be identified, preserved and restored as valued assets for flood protection, water quality improvement, groundwater recharge, habitat, and overall long-term water resource sustainability.
3. Water holding areas such as creek beds, recessed athletic fields, ponds, cisterns, and other features that serve to recharge groundwater, reduce runoff, improve water quality and decrease flooding should be incorporated into the urban landscape.
4. All aspects of landscaping from the selection of plants to soil preparation and the installation of irrigation systems should be designed to reduce water demand, retain runoff, decrease flooding, and recharge groundwater.
5. Permeable surfaces should be used for hardscape. Impervious surfaces such as driveways, streets, and parking lots should be minimized so that land is available to absorb storm water, reduce polluted urban runoff, recharge groundwater and reduce flooding.
6. Dual plumbing that allows graywater from showers, sinks and washers to be reused for landscape irrigation should be included in the infrastructure of new development.
7. Community design should maximize the use of recycled water for appropriate applications including outdoor irrigation, toilet flushing, and commercial and industrial processes. Purple pipe should be installed in all new construction and remodeled buildings in anticipation of the future availability of recycled water.
8. Urban water conservation technologies such as low-flow toilets, efficient clothes washers, and more efficient water-using industrial equipment should be incorporated in all new construction and retrofitted in remodeled buildings.
9. Ground water treatment and brackish water desalination should be pursued when necessary to maximize locally available, drought-proof water supplies.

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Implementation Principles

1. Water supply agencies should be consulted early in the land use decision-making process regarding technology, demographics and growth projections.
2. City and county officials, the watershed council, LAFCO, special districts and other stakeholders sharing watersheds should collaborate to take advantage of the benefits and synergies of water resource planning at a watershed level.
3. The best, multi-benefit and integrated strategies and projects should be identified and implemented before less integrated proposals, unless urgency demands otherwise.
4. From start to finish, projects and programs should involve the public, build relationships, and increase the sharing of and access to information.
5. Plans, programs, projects and policies should be monitored and evaluated to determine if the expected results are achieved and to improve future practices.

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Editor: Judy Corbett

(Adopted in 2005)

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Urban Stormwater Management

"Fines for violating new EPA runoff regulations are costly; traditional treatment methods are expensive. But there is another approach."

Art Baggett, Boardmember, State Water Resources Control Board

A New Era of Stormwater Management

Urban runoff has escalated throughout the 20th century. The thousands of acres of paved surfaces that comprise our urban landscape today prevent rain and other sources of water from penetrating the soil. Instead, water rushes over impervious surfaces with escalating speed and volume, picking up an assortment of pollutants. Ultimately, this polluted water flows into gutters, channels and pipes and is delivered untreated into local waterways.

In the past, local government and developers relied upon engineering solutions to move stormwater as quickly as possible into concrete channels toward discharge locations.

As a result, the pollution and sporadic overload of water entering waterways created significant environmental costs. Today, in the current climate of water quality regulation, these costs must be addressed.

New, more acceptable stormwater management techniques use nature's systems to handle drainage. They both improve water quality and reduce the risk of local flooding. They can be counted as best management practices for the purpose of National Pollution Discharge Elimination System (NPDES) permits.

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Runoff Pollution and Local Liability

The National Pollutant Discharge Elimination System (NPDES) has brought stormwater management to the forefront of local government agendas.

Municipalities are responsible for controlling pollution from urban runoff that enters waterways through stormwater systems. Cities, counties and the developers doing business in our communities must apply for permits to discharge urban runoff into waterways, and are subject to penalties from regulatory agencies if they discharge polluted water.

According to state documents, one California city was fined $468,000 in 2004 for illegally discharging polluted urban runoff into the San Joaquin River.

Urban Runoff Tied to Pollution and Flooding

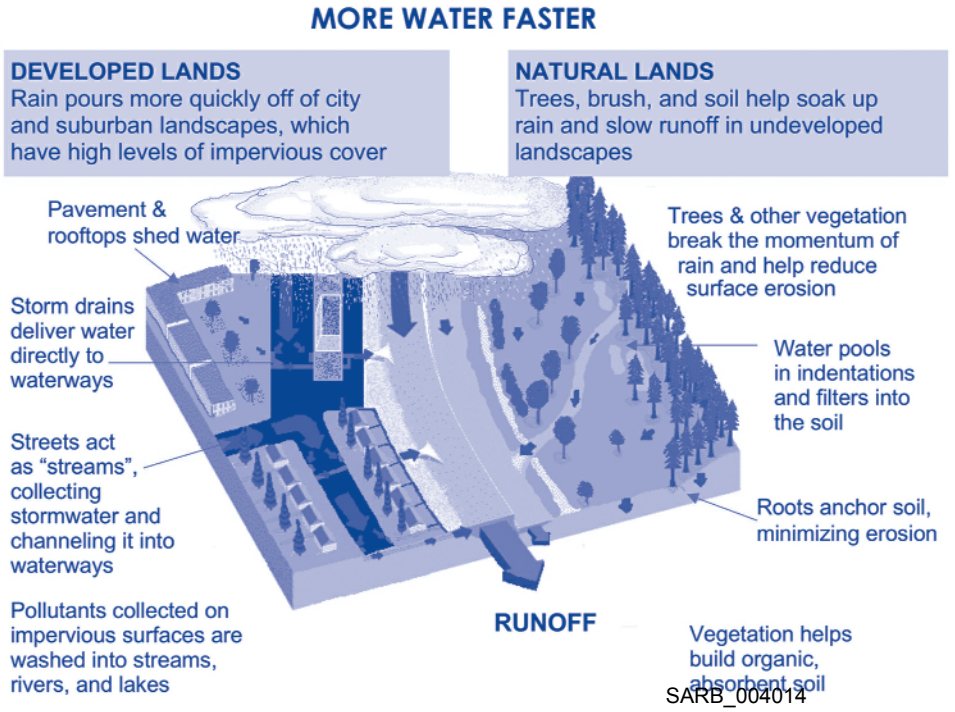
Urban stormwater runoff is water from precipitation and landscape irrigation that does not infiltrate into the soil. It flows over roadways and other hard surfaces in our urban landscape, picking up pollutants along the way.

Ultimately, this polluted water flows into gutters, channels and pipes, and becomes a concentrated "stew" of polluted water that is delivered – untreated – into local waterways.

As we cover over more land, less water can be absorbed by the soil. Thus, the volume of urban stormwater is increasing. This escalating volume of urban runoff not only increases pollution, it elevates the risk of flooding.

Urban runoff dramatically increases the risk of local flash floods.

Sun Valley – a city in the San Fernando Valley known for serious and chronic flooding – is developing a long-range plan to capture storm water to solve their chronic flooding problems. The City is creating much-needed park, recreation and wildlife habitat areas that will hold and absorb water during periods of heavy rain.



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Economic Benefits of Reducing Urban Runoff

- **A natural drainage system often costs less to construct.**

Example: The City of Seattle is redesigning residential streets with natural drainage systems by replacing paved street edges with tree-planted vegetated swales, cascades and small wetland ponds. The City is finding that natural drainage is 25% cheaper to build than conventional roadside drainage systems. These systems can also be less costly to maintain than the usual stormwater system that tends to get clogged with leaves during fall rains.

- **Replenishing local groundwater supplies using natural drainage can help avoid the purchase of more expensive water supplies.**

Example: The Los Angeles Basin Water Augmentation Study, completed in April 2005, concluded that increasing infiltration of urban stormwater runoff for recharge of groundwater offers a viable alternative to relying solely on purchased water.

- **Using a natural drainage system avoids the extraordinary costs that result from floods.**

Example: Over 20 community-based organizations came together to develop a plan to address the dual challenges of restoring the health of the Napa River and implementing a flood management strategy to protect Napa Valley communities.

This effort received the 1998 National Planning Honor Award from the American Society of Landscape Architects for its revolutionary solution to flood control – removing the existing systems of dikes and levees and allowing the river to run free.

The region expects to save $26 million annually by protecting 2,700 homes, 350 businesses and more than 50 public properties from flooding.

Village Homes Is Model for Urban Runoff

Featuring narrow streets, ample open space, large trees and other native vegetation, as well as an above-ground, natural stormwater system, Village Homes in Davis, CA – a residential mixed-use development of 240 residential units – is a model for integrating stormwater management into development.

A network of vegetated swales winds thorough the community, functioning as common open space most of the year. During a storm, this system captures and treats runoff as it is filtered through catchments, and into soils.

The system was designed to carry remaining water slowly to the City's municipal facility; however, it works so well that the water never actually makes it there.

For more information or to set up a tour: www.lgc.org

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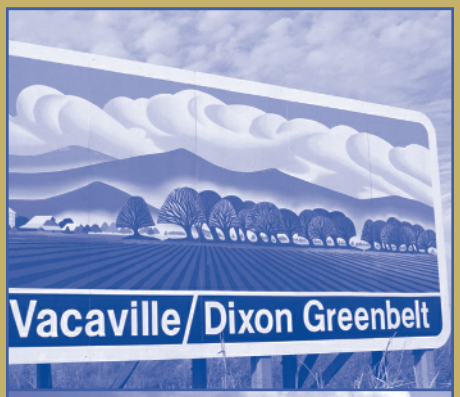
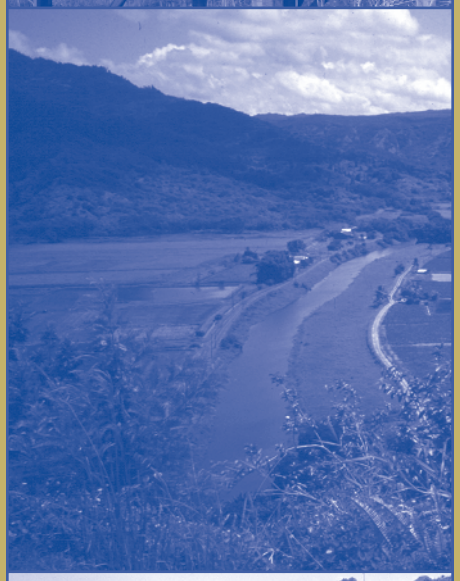
Local Strategies for Controlling Urban Runoff

TWO GOALS

Opportunities exist to control urban runoff at different scales – from an individual site to the neighborhood, to the region or watershed. At each scale, there are two goals that guide planning and design:

1. **Protect and restore natural areas.**
2. **Use site design that minimizes imperviousness and maximizes permeability.**





Work regionally to preserve open space.

Cluster development to maximize unpaved areas.

Pave using pervious materials.

Day-light creeks, and restore wetlands.

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Use minimum width streets.

Reduce the area of parking lots.

Design recreation areas that can hold runoff.

Protect and plant trees – they reduce runoff.

Direct runoff from pavement and buildings to vegetation-lined channels.

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Ideas for Implementation

- **Develop form-based codes that incorporate natural stormwater management techniques into community design.**

Example: The City of San Jose is currently developing a form-based code that will design the water infrastructure for a 7,000-acre new development – Coyote Valley. The plan will allow rainwater to be captured and used to recharge the groundwater, the sole source of potable water for the new development. At the same time, the landscape plan will address problems of flooding on the site through the integrated use of swales, a lake, the restoration of a creek, and the creation of riparian corridors.

- **Develop new parking standards that reduce impervious surface area.**

Example: The City of San Diego has developed new parking standards for intensive commercial zones. The revised standards include smaller parking spaces and driveways as well as guidelines to reduce imperviousness.

- **Require runoff to be held on site.**

Example: The City of Emeryville requires that all projects creating one acre or more of impervious surface area incorporate post-construction stormwater treatment controls on site. Beginning in August 2006, these requirements will apply to all projects creating 10,000 square feet or more of impervious area. (ci.emeryville.ca.us/publicworks)

LEAGUE OF CALIFORNIA CITIES

Water Boards

This fact sheet was funded by the California State Water Resources Control Board.

Ahwahnee Water Principles

Preamble

Cities and counties are facing major challenges with water contamination, stormwater runoff, flood damage liability, and concerns about whether there will be enough reliable water for current residents as well as for new development. These issues impact city and county budgets and taxpayers. Fortunately there are a number of stewardship actions that cities and counties can take to reduce costs and improve the reliability and quality of water resources.

Principle 3

Water holding areas such as creek beds, recessed athletic fields, ponds, cisterns, and other features that serve to recharge groundwater, reduce runoff, improve water quality and decrease flooding should be incorporated into the urban landscape.

Principle 4

All aspects of landscaping from the selection of plants to soil preparation and the installation of irrigation systems should be designed to reduce water demand, retain runoff, decrease flooding, and recharge groundwater.

Principle 5

Permeable surfaces should be used for hardscape. Impervious surfaces such as driveways, streets, and parking lots should be minimized so that land is available to absorb stormwater, reduce polluted urban runoff, recharge groundwater and reduce flooding.

- www.lgc.org/ahwahnee/ h2o_principles.html
- **First Stop Shop for Water Resources**
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editing / design: dave davis

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WADING IN WASTE

Thanks to unchecked development along America's coasts, disease-causing microbes are increasingly fouling beaches and shellfish beds

By Michael A. Mallin

America's stunning, sinuous coastlines have long exerted an almost mystical pull on the imaginations of the country's citizens. The irresistible attraction is perhaps best described by Herman Melville in the opening pages of *Moby Dick:* "Nothing will content them but the extremest limit of the land.... They must get just as nigh the water as they possibly can without falling in." In recent years, millions of Americans have moved to coastal areas, particularly in the Southeast, to take advantage of their balmy climate, recreational opportunities and natural beauty. Unfortunately, rapid and poorly planned development is spoiling this beauty in a shocking way: a growing number of beaches and shellfish beds along the coast have been contaminated by disease-causing microorganisms coming from animal and human wastes.

According to a recent report by the Natural Resources Defense Council, in 2004 coastal states ordered 19,950 days of closures and pollution advisories affecting 1,234 ocean and freshwater beaches, or about one third of all the beaches regularly monitored by health officials. The total number of beach days covered by the regulatory actions was 9 percent higher than the total for 2003 (which, in turn, was 50 percent higher than the 2002 total, although that jump was partly caused by changes in federal monitoring rules). The reason for 85 percent of the closures and advisories was the detection of excessive counts of fecal bacteria in the beach waters.

Moving downstream with animal feces in storm water runoff or with human waste in sewage overflows and septic-tank leaks, the waterborne microbes can cause liver disease, respiratory infections and potentially fatal gastrointestinal disorders. Such illnesses are common in Third World countries with poor sanitation, but in the U.S. the problem stems from unwise growth, not poverty. The construction of so many homes, roads, shopping centers and parking lots has disrupted the natural drainage systems in coastal areas, and wastes that were once filtered by forests or wetlands are now regularly fouling marinas and beaches.

How can coastal states and communities reduce microbial pollution? The issue has led to conflicts pitting developers and pro-growth politicians against regulatory authorities, commercial and recreational shellfishers, surfers, swimmers, divers and conservationists. Fortunately, some innovative solutions are available. "Smart growth" strategies can restore polluted coastlines and pro-

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vide economic benefits as well. Because frequent beach closures can dampen tourism and depress real estate values, the adoption of reasonable controls on coastal development would safeguard the shoreline economy as much as it would protect the public's health.

The Coastal Boom

IN ITS 2004 Coastal Trends Report, the National Oceanic and Atmospheric Administration noted that 153 million Americans—or 53 percent of the country's population—lived in the counties bordering the seacoasts and the Great Lakes, which make up only 17 percent of the continental U.S. land area [*see box on page 57*]. What is more, another seven million people are expected to join the coastal population by 2008, and the total is seasonally expanded by hordes of vacationers. Large areas that used to be forests or farmland are being turned into resorts, residential subdivisions, strip malls, restaurants, office complexes and industrial parks. In the process, construction companies are draining wetlands and covering formerly vegetated soils with asphalt, concrete and housing materials.

The resulting landscape is dominated by impervious surfaces—parking lots, roads, sidewalks, rooftops and construction sites compacted by heavy equipment—that do not let water soak through. When it rains, the water flows over these surfaces, picking up animal feces and other pollutants and washing them into drainage ditches or storm drains, many of which lead directly to urban lakes, coastal creeks or beach areas. Whereas sewage treatment plants remove harmful bacteria and other contaminants from their effluent, storm water runoff is usually untreated. Because this runoff emanates from a wide area rather than a single source, it is classified as nonpoint source pollution. The Environmental Protection Agency has stated that this type of pollution is the leading remaining cause of water-quality problems in the U.S.

Storm water runoff carries fertilizers, pesticides, heavy metals and petrochemicals, but it is the disease-causing microbes—the bacteria, viruses and protozoa derived from feces—that pose the principal threat to human health. A single gram of dog feces, for example, contains an estimated 2.3 million bacteria. (And for certain particularly hazardous bacteria, as few as 10 organisms can cause an infection.) Urban and suburban watersheds receive a steady influx of manure from domestic animals such as dogs and cats and from wildlife such as raccoons and squirrels. In vegetated areas, rainwater and runoff trickle through the soil, which cleanses the water of fecal bacteria and viruses, as well as many other pollutants. In contrast, impervious surfaces accumulate pollutants during dry periods and funnel high concentrations of the contaminants downstream when it rains.

The problem is particularly worrisome along the coast because the microbes pollute shellfish beds and areas used for recreation. Shellfish are primarily filter feeders, meaning that they strain large volumes of seawater through their bodies to concentrate food material such as microscopic algae. But they also concentrate the potentially harmful organisms that are present in the water. If humans consume raw or poorly cooked shellfish from waters contaminated with fecal microbes, they run the risk of contracting gastroenteritis (a disease characterized by vomiting, diarrhea and stomachache) as well as more severe, life-threatening illnesses.

To protect shellfish consumers, state agencies are required to post signs in polluted shellfish beds notifying the public that harvesting clams, mussels or oysters there is illegal. The U.S. Public Health Service has set a nationwide safety standard for shellfish beds using measurements of fecal coliform bacteria, a broad category of microorganisms found in the intestines of humans and animals. Shellfish cannot be harvested from the area if the geometric mean of the bacterial counts in 30 sets of samples is higher than 14 colony-forming units (CFU) per 100 milliliters of seawater. (A geometric mean is a type of average that minimizes the effects of outlying values.) In 1995, which was the last time NOAA compiled a national shellfish register, harvesting was restricted or prohibited in 31 percent of the country's shellfish-growing areas. The agency reported that urban runoff was the most commonly cited source of the pollution invading shellfish beds.

The reason for 85 percent of BEACH CLOSURES and advisories is the detection of excessive fecal bacteria.

Overview/*Microbial Pollution*

- Because of booming growth in U.S. coastal regions, much of the area near the shoreline is covered with impervious surfaces such as parking lots, roads and sidewalks. When it rains, storm water runoff from these surfaces can carry animal feces and their accompanying microbes into drainage ditches that lead directly to lakes, streams and beaches.
- Contamination by fecal bacteria is the leading cause of beach closures and advisories, which now affect one third of the country's monitored beaches. Hazardous microbes also plague marinas, tidal creeks and shellfish beds.
- To fight microbial pollution, coastal communities can encourage the preservation of green spaces, install filters in storm drains and prevent the placement of septic tanks in areas with porous soils.

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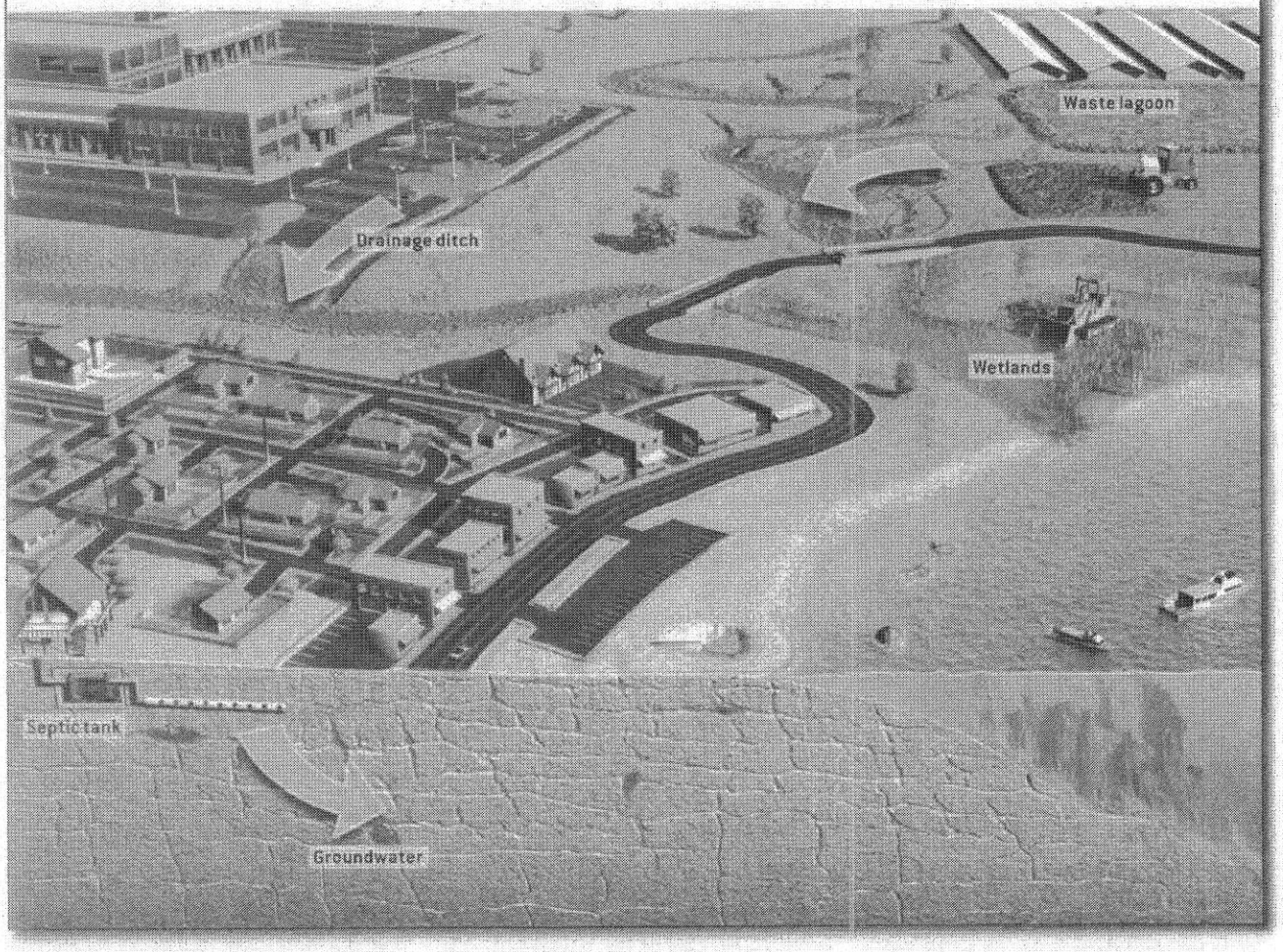
FECAL MICROBES ON THE MOVE

Poorly planned development is the primary cause of microbial pollution in coastal areas. Most shopping centers, for example, are surrounded by enormous parking lots that funnel waste-laden runoff to drainage ditches. In many coastal residential developments, the effluent from septic tanks flows into fissured limestone or sandy soils that allow fecal microbes to seep into the groundwater. Industrial-style livestock operations typically spread their manure over fields or store it in lagoons; heavy rains can wash the wastes into nearby streams. And new construction often destroys the wetlands that filter disease-causing organisms from the water before they can reach beaches and shellfish beds.



DAVID FIERSTEIN

More recently, my laboratory at the University of North Carolina, Wilmington, analyzed data from five coastal North Carolina counties and found a strong correlation between human population growth and the closure of shellfish beds. In 1984, when 352,125 people lived in the five counties, 35,275 acres of shellfish waters were closed; by 2003, the combined population had risen to 501,596 and the closed acreage had grown to 42,304.

Microbial pollution also poses a serious danger to people involved in common recreational activities such as swimming, surfing, wading, diving, snorkeling, waterskiing and boating. If fecal organisms contaminate a lake, stream or seashore, anyone in the water risks infection by microbes entering through the mouth, nose, eyes or open wounds. Some of the illnesses caused by water contact include gastroenteritis, conjunctivitis (eye infections), cellulitis (skin irritations such as swimmer's itch), ear infections, respiratory infections and more serious diseases such as hepatitis and Guillain-Barré syndrome, an inflammatory disorder of the peripheral nerves that can induce paralysis. Some of the waterborne bacteria that can cause these health problems are *Escherichia coli*, *Clostridium perfringens* and various species of *Enterococcus*, *Aeromonas*, *Campylobacter*, *Salmonella*, *Shigella* and *Yersinia*. Among the many waterborne disease-causing viruses are hepatitis A and Norwalk; the pathogenic protozoa include *Cryptosporidium*, *Entamoeba* and *Giardia*.

Don't Drink the Water

IN RECENT YEARS, several of these microbes have triggered severe disease outbreaks in the U.S. and Canada. In

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1993 *Cryptosporidium* protozoa infected the Milwaukee drinking water system, leading to more than 100 deaths and 400,000 illnesses. In 1999 an outbreak of *Escherichia coli* and *Campylobacter* resulted in two deaths and 116 illnesses among fairgoers in New York's Washington County after they drank water contaminated by runoff from a cattle barn. In 2000 residents of Walkerton, Ontario, fell victim to infections by *E. coli* and *Campylobacter* that caused 2,300 illnesses and seven deaths, mostly among the elderly and infants. Again, the contamination was traced to microbe-laden runoff from a cattle feedlot that entered the town's water supply.

Health officials measure the concentrations of various indicator bacteria to assess the danger from waterborne pathogens, especially along beaches. When the bacterial counts get too high, the authorities issue polluted-water advisories or close beaches to swimming and other recreational activities. The EPA recommends that states use *Enterococcus* bacteria as the safety indicator for ocean and bay water. Under the EPA's standards, seawater is considered unsafe if the geometric mean of five *Enterococcus* samples collected within 30 days is greater than 35 CFU per 100 milliliters or if any individual sample is above 104 CFU per 100 milliliters. In freshwater, the EPA limits on mean concentrations are 33 CFU per 100 milliliters for *Enterococcus* and 126 CFU per 100 milliliters for *E. coli*. These standards, however, may be too lax. The EPA has estimated that swimming in seawater with the maximum acceptable counts will cause 2 percent of bathers to fall ill.

Up the Creek

RESEARCHERS HAVE BEEN studying the environmental damage caused by impervious surface coverage since the late 1980s, but my laboratory was the first to examine the effects on fecal bacterial counts. We focused on New Hanover County, a rapidly growing area in North Carolina. From 1990 to 2000 the county's population increased by 25 percent, and it is expected to rise another 31 percent by 2020. My research team has studied the water quality of six urbanizing tidal creeks in the county for the past decade. We collected and analyzed more than 1,000 samples of fecal coliform bacteria and *E. coli* taken throughout the creeks and looked for correlations between the bacterial counts and various demographic and landscape attributes of the creek watersheds.

We found that the average fecal coliform counts were generally higher in the creeks with more people and with a larger percentage of developed land in their watersheds. But the bacterial counts were most strongly correlated with the prevalence of impervious surfaces. In Futch Creek—where impervious surfaces covered only 7 percent of the surrounding land—the average coliform count was 12 CFU per 100 milliliters, but in Bradley Creek—where asphalt and concrete blanketed 22 percent of the watershed—the count was more than seven times higher [*see box on page 58*]. The correlation between *E. coli* abundance and the percentage of impervious surface in the watershed was also very strong. Ours was not an isolated finding: A. Fred Holland, Denise M. Sanger and their colleagues at the South Carolina Department of Natural Resources later reported a significant correlation between fecal coliform counts and impervious surface coverage in the watersheds of 22 tidal creeks in the Charleston metropolitan area.

The results suggest that storm water runoff from developed areas may have a multiplier effect on bacterial concentrations downstream. The abnormally high flows coming from large parking lots or subdivisions may erode the drainage ditches and stream banks, bringing suspended sediments into the water. These sediments are also readily washed off construction sites where the soils have been stripped of vegetation. The suspended sediments and other particles cloud the receiving waters. (The degree of cloudiness is called turbidity.) What is more, the sediments, particularly clays, can physically and chemically bind with pollutants such as ammonium, phosphate, metals, and fecal bacteria and viruses.

Binding to soils protects bacteria from ultraviolet radiation that would normally kill the organisms. Bacteria can also obtain carbon, nitrogen and phosphorus nutrients from the soil particles, and the microbes can hitch long-distance rides as they travel downstream with the sediments. In our study of the tidal creeks in New Hanover County, we found a highly significant correlation between turbidity and the abundance of fecal coliform bacteria. Other studies performed in the Chesapeake Bay, western Florida, the Mediterranean coast and Australia have yielded similar findings.

The sediments lying at the bottom of shallow coastal waters are also a reservoir for fecal bacteria and other microbes. A research team led by Lawrence B. Cahoon, my collaborator at U.N.C. Wilmington, has found high concentrations of disease-causing organisms—including fecal coliform bacteria, enterococci and streptococci—in tidal creek sediments. The microbes can

Fecal microbes from SEPTIC SYSTEMS in the Florida Keys can enter coastal waters within hours.

THE AUTHOR

MICHAEL A. MALLIN is an aquatic ecologist who has extensively studied pollution in freshwater, estuarine and coastal marine systems. Currently a research professor at the Center for Marine Science at the University of North Carolina, Wilmington, Mallin received his Ph.D. in marine and estuarine biology from U.N.C. Chapel Hill. His research interests include analyzing the impact of land-use practices on water quality as well as studying the effects of nutrient loading and catastrophic weather events.

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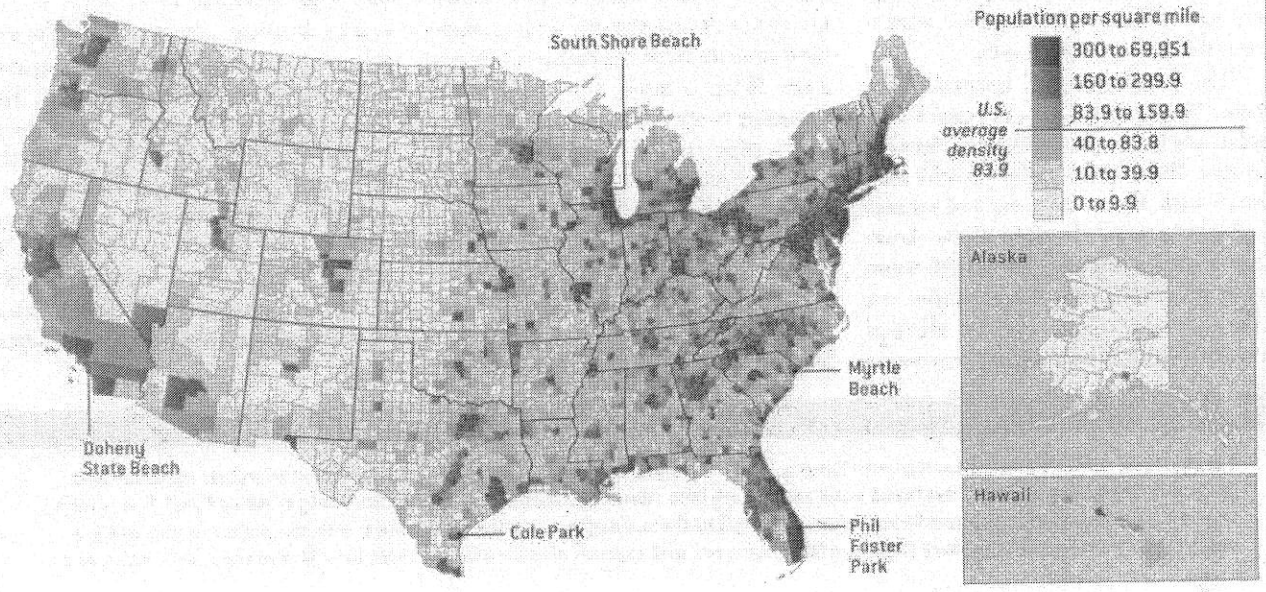
AMERICA'S SULLIED BEACHES

The most polluted beaches and bays in the U.S. are generally located in densely populated coastal counties. Bacterial contamination prompted the closures and advisories at the areas listed below in 2004 (the last year for which nationwide records are available). The highest counts measured at each beach were far above the safety standards for individual samples of *Enterococcus* and *Escherichia coli*, 104 and 235 colony-forming units (CFU) per 100 milliliters, respectively.



BEACH LOCATION	TYPE OF BACTERIA MEASURED	HIGHEST COUNT (CFU PER 100 MILLILITERS)	NUMBER OF CLOSURE OR ADVISORY DAYS IN 2004
Doheny State Beach Orange County, California	*Enterococcus*	38,800	312
Phil Foster Park Palm Beach County, Florida	*Enterococcus*	600	108
South Shore Beach Milwaukee County, Wisconsin	*Escherichia coli*	2,419	72
Myrtle Beach Horry County, South Carolina	*Enterococcus*	1,130	54
Cole Park Nueces County, Texas	*Enterococcus*	14,400	53

SOURCES: U.S. CENSUS BUREAU (map); U.S. ENVIRONMENTAL PROTECTION AGENCY, NATURAL RESOURCES DEFENSE COUNCIL, ORANGE COUNTY OCEAN WATER PROTECTION PROGRAM, WISCONSIN BEACH HEALTH AND TEXAS GENERAL LAND OFFICE (table)

survive for extended periods in the sediments because they are protected from ultraviolet radiation and have ready access to nutrients. And because the tidal creeks are generally shallow, agitating the sediments at the bottom can suspend enough bacteria in the water to exceed the safety standards for human contact. Windy conditions or wading children and pets can easily pollute the water just by kicking up the creek's muddy bottom. Furthermore, our students have found high concentrations of fecal microbes in the sediments near several public boat ramps; such ramps are ubiquitous and heavily used in the coastal regions of the Southeast.

Sand and Sewage Don't Mix

POORLY DESIGNED sanitation systems in coastal regions can also contribute to microbial pollution. In communities where storm drains feed into sewer pipes, heavy rains can cause overflows that dump untreated human waste into rivers, lakes and bays. Many municipalities are now tackling this problem by separating their sewer and storm water systems. A new dilemma is emerging, however, in coastal areas where residents do not have sewage hookups and must put their wastes in septic tanks instead.

One such area is the Florida Keys, which is home to more than 25,000 septic systems. The predominant terrain in the Keys is karst topography—the underlying soils consist primarily of limestone, with many cracks and sinkholes caused by erosion. This geologic forma-

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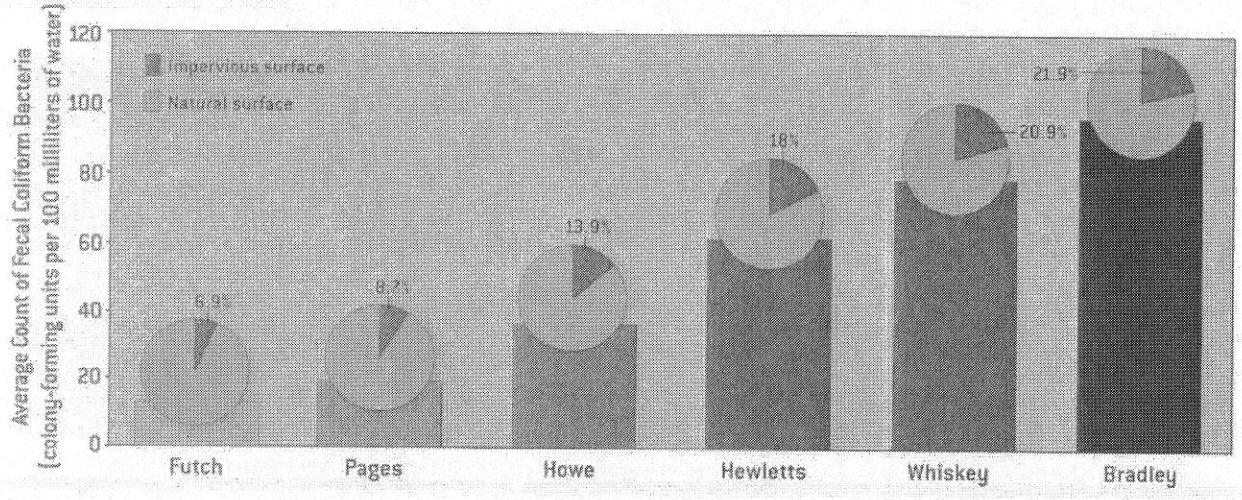
tion is very porous and hence cannot effectively filter the bacteria-rich effluent from septic tanks. In 1995 a research team led by John H. Paul and Joan B. Rose of the University of South Florida found that fecal microbes from septic systems in the Keys readily pass through the soil and can enter coastal waters near the shore within hours.

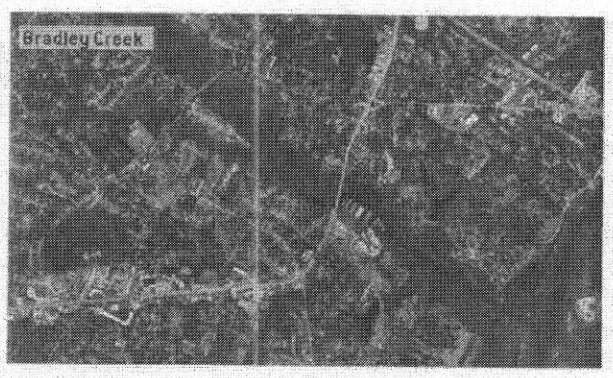
The problem is not limited to the Keys. Sandy soils along the coast have relatively large spaces between the sand grains. When these soils become saturated with water, bacteria and viruses can easily move through them. Areas containing sandy soils and a high water table are thus unsuitable for septic systems, yet poor planning has allowed their presence in many rapidly growing coastal regions, including some of the sandy barrier islands along the Atlantic and Gulf coasts. In a study of water quality in Brunswick County, North Carolina, which has many septic tanks in the sandy soil (up to 20 per hectare), Cahoon found high fecal coliform counts in the freshwater and seawater downstream from the dense residential sites. What is more, the ditching and drainage systems serving the developed areas appeared to facilitate the discharge of fecal bacteria into nearby waters, including shellfish beds.

Other investigators have identified distinctive patterns in the severity of microbial pollution. Erin K. Lipp, now at the University of Georgia, and her colleagues determined that in Florida Gulf Coast communities such as Charlotte Harbor and Sarasota Bay, fecal bacteria counts in bays and tributaries increase sharply with the outgoing tide. The microbes move readily through the sandy, saturated soils surrounding the crowded fields of septic tanks into nearby creeks draining into the bays. The pattern not only is tidal but varies according to weather conditions as well. The researchers discovered that in wet years corresponding to El Niño events, the water in Tampa Bay is significantly more polluted by fecal bacteria and viruses than it is in dry years. This effect is again the result of increased runoff and subsurface movement through saturated soils around improperly sited septic tanks.

THE EFFECTS OF CONCRETE AND ASPHALT

A study of six tidal creeks in New Hanover County, North Carolina, found a strong correlation between microbial pollution and the prevalence of impervious surfaces such as parking lots, roads and sidewalks. In the relatively pristine Futch Creek (*left*), where impervious surfaces covered less than 7 percent of the watershed, the average counts of fecal coliform bacteria were much lower than in Bradley Creek (*right*), where concrete and asphalt blanketed more than one fifth of the surrounding area.





LUCY READING-IKKANDA; MICHAEL A. MALLIN (*left*); NEW HANOVER COUNTY PLANNING DEPARTMENT (*right*)

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In southern California, where large amounts of urban runoff flow into the Pacific Ocean, Rachel Noble of U.N.C. Chapel Hill and her colleagues found that the extent of shoreline water that failed to meet safety standards was 10 times greater following rainfall than it was during dry periods. Nationwide, many shellfish beds are automatically closed for a few days or weeks after a rainfall, because these areas are subject to bacterial pollution from storm water runoff.

But urban runoff and septic seepage are not always the main culprits behind microbial pollution. In coastal streams draining rural areas, the driving factor is often the waste from livestock farms. On the coastal plain that extends from Maryland to Florida and in certain Gulf Coast areas as well, traditional livestock farms have been largely supplanted by giant, industrial-style facilities where huge numbers of swine, poultry and cattle are raised in close confinement. The facilities dispose of the vast amounts of manure by either spraying it as a liquid or spreading it as litter on nearby fields. If the spraying or spreading occurs shortly before or during a rainstorm, fecal microbes from the waste can enter nearby streams via overland runoff.

A Cleaner Future

TO PROTECT America's coastal waters, developers and builders clearly need to move away from their current destructive practices—including clear-cutting, wetlands drainage and extensive use of pavement—and switch to smart-growth strategies. When planning new resorts, shopping centers, office complexes and residential subdivisions, the designers must minimize the use of impervious surfaces and maximize the amount of vegetated areas. A site with plenty of green spaces among the paved areas will have less runoff, and percolation through the soil will remove many of the contaminants swept from the asphalt and concrete.

In particular, wetlands need to be preserved and, if possible, enlarged to maintain the natural filtering of storm water runoff. In a study of 11 streams in the coastal plain of eastern North Carolina, my laboratory found that in the watersheds where the wetland coverage was relatively large—in this case, greater than 13.5 percent—periods of rainfall did not substantially increase the fecal coliform bacteria counts. The results indicate that preserving wetlands (and presumably expanding them) is an effective way to guard downstream waters from suspended sediments and microbial pollution. Builders can help the effort by curtailing the runoff of sediments from construction sites.

Developers should take advantage of new technologies that can reduce the amount of storm water runoff and even treat it on-site. For example, parking lots can now be paved with porous concrete, a semipervious substance that allows water to pass into the soil below and yet provides enough structural support for automobiles. And new collection systems can funnel storm water runoff from parking lots to filters that use layers of absorbent minerals and organic material to cleanse the polluted water. (Large parking lots can also be downsized, because most were built to accommodate holiday shopping rather than day-to-day traffic.) These technologies could be applied to existing developments as well as new ones. If a community wishes to reduce runoff pollution to revitalize its beaches or save the local shellfish industry, it can install filters in all its parking lots, create vegetated buffer zones along streams and ditches, and reconstruct wetlands in selected locations.

The poor performance of septic systems in sandy soils and in areas of karst topography is a clear indication that coastal regions require more advanced sewage treatment systems. Some conservation groups have pointed out, however, that the construction of centralized sewage systems will lead to even denser development and more water pollution. Thus, when coastal communities build sewage systems, the municipal authorities should put restrictions on impervious surface coverage in new developments, limiting it to, say, 10 to 15 percent of the total area (especially near shellfish beds).

America's coasts can be a wonderful destination, both for vacation travel and for relocating homes and businesses. But without careful planning and the political will to protect coastal resources, the gorgeous beaches, sparkling bays and tranquil tidal creeks will become nothing but hazardous receptacles of our waste. We must ensure that unchecked development does not ruin the very qualities that brought people to the coast in the first place.

PRESERVING WETLANDS is an effective way to guard downstream waters from microbial pollution.

MORE TO EXPLORE

Effect of Human Development on Bacteriological Water Quality in Coastal Watersheds. Michael A. Mallin, Kathleen E. Williams, E. Cartier Esham and R. Patrick Lowe in *Ecological Applications*, Vol. 10, pages 1047–1056; 2000.

Demographic, Landscape, and Meteorological Factors Controlling the Microbial Pollution of Coastal Waters. Michael A. Mallin, Scott H. Ensign, Matthew R. McIver, G. Christopher Shank and Patricia K. Fowler in *Hydrobiologia*, Vol. 460, pages 185–193; 2001.

Linkages between Tidal Creek Ecosystems and the Landscape and Demographic Attributes of Their Watersheds. A. F. Holland, D. M. Sanger, C. P. Gawle, S. B. Lerberg, M. S. Santiago, G.H.M. Riekerk, L. E. Zimmerman and G. I. Scott in *Journal of Experimental Marine Biology and Ecology*, Vol. 298, pages 151–178; 2004.

More information can be found online at **www.nrdc.org/water/oceans/gttw.asp** and **www.epa.gov/beaches/**

SARB_004025

GREEN from the Ground Up

Nature-friendly design practices for land-savvy developers

This fact sheet is one of a series on nature-friendly development practices created by Metro through its Nature in Neighborhoods initiative.

Nature-friendly development practices minimize the impact of development on natural resources, and can help developers save money and add value to their properties.

Metro's Nature in Neighborhoods initiative is a long-term effort to conserve and restore nature throughout the urban area and ensure that every citizen in the region has access to nature.

Keep Nature in Neighborhoods METRO

www.metro-region.org/nature

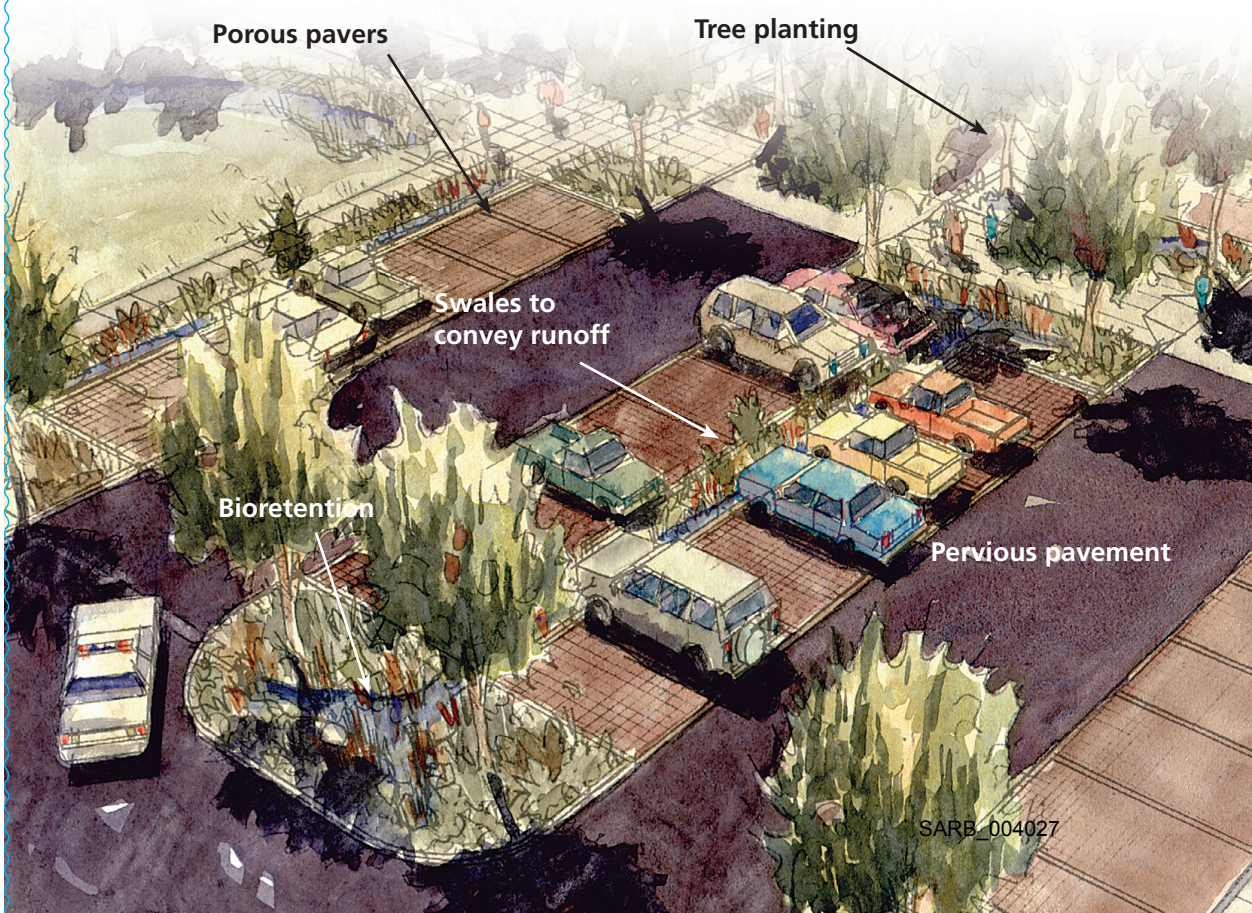
Nature-friendly design

Protecting our natural assets as we grow

In an average week, the Portland metropolitan area gains more than 500 new residents. Metro's most recent population projections show that about a million more people will be living in the area by 2030. Accommodating growth while protecting our natural resources and quality of life presents major challenges. Growth results in more rooftops, pavement and stormwater runoff. Traditional ways of protecting water resources from stormwater runoff have not proven fully effective, and our streams and rivers are threatened by storm flows and pollutants carried by stormwater.

Nature-friendly design practices. Approaching land development and stormwater management in a way that mimics nature's processes can help. In a mature Pacific Northwest forest, very little rainwater runs off the land. Instead, it soaks into the ground where the soils remove pollutants naturally. The water nourishes trees and plants and recharges streams, wetlands and groundwater. Or the water collects on leaves and branches evaporating and becoming rainfall again.

Parking lot using nature-friendly design practices



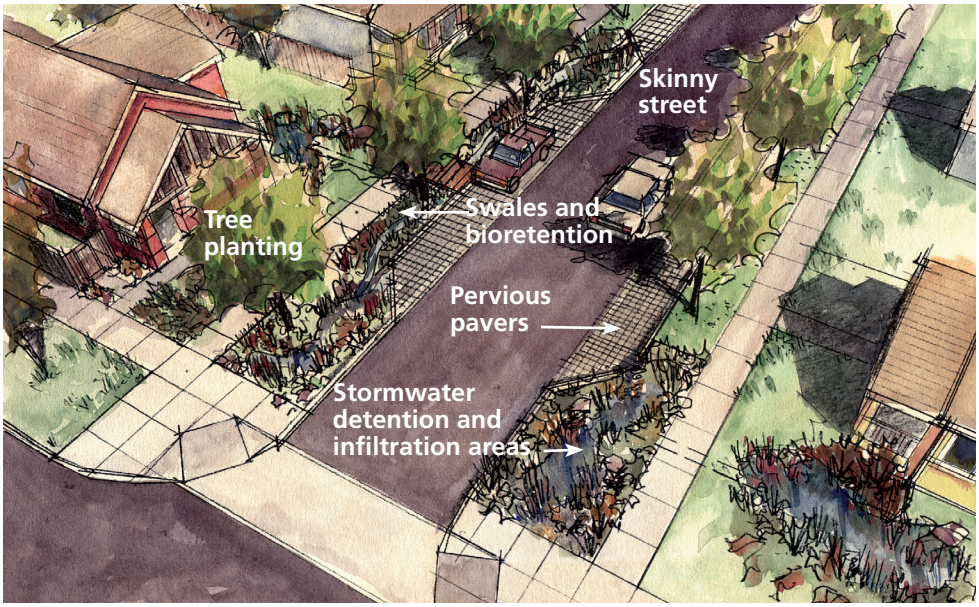
Some of the key features of nature-friendly development practices include:

- replanting or protecting existing vegetation
- reducing impervious surfaces such as roads, parking lots and rooftops that produce runoff
- using bioretention, pervious pavement and other small-scale stormwater controls
- clustering houses and other buildings on a site so stormwater can follow more natural drainage patterns and valuable habitat and wildlife corridors can be preserved.

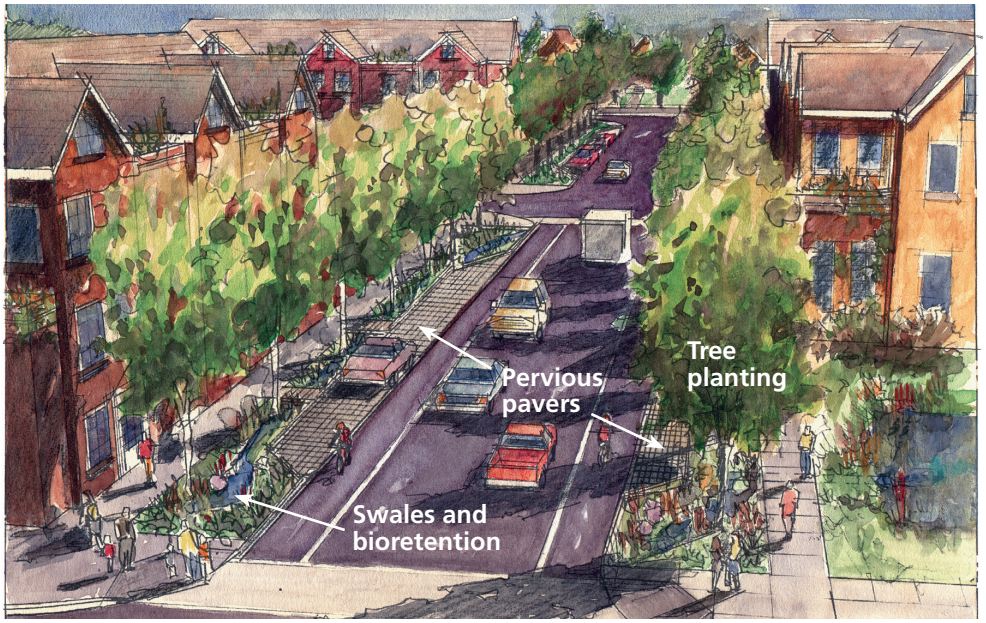
Nature-friendly development practices not only manage stormwater and conserve valuable fish and wildlife habitat, they make neighborhoods look greener and more beautiful. In some cases these projects are less expensive to build and maintain. And because they are more attractive, they may also sell more quickly and command a higher price.

These illustrations show examples of how such practices can be integrated into developments and put nature in every neighborhood.

Single family neighborhood



High density neighborhood



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GREEN
from the Ground Up
Seminars for land-savvy developers

For more information on nature-friendly development practices or Metro's Nature in Neighborhoods initiative, visit **www.metro-region.org/nature**, e-mail nature@metro.dst.or.us or call (503) 797-1588.

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ISSUES: WATER

Stormwater Strategies
Community Responses to Runoff Pollution

This May 1999 report from the Natural Resources Defense Council documents some of the most effective strategies being employed by communities around the country to control urban runoff pollution, which is among the top sources of water contamination in the country today. The collection of 100 case studies compiled and evaluated here is intended to serve as a guide for local decisionmakers, municipal officials, and environmental activists; it is also a resource for citizens concerned about the quality of their local environment. Added in October 2001 is a new chapter on low-impact development, which has emerged as a simple, effective and economical stormwater strategy that also carries a broader aesthetic appeal.

OVERVIEW & QUICK REFERENCE

Summary: Case Studies of Urban Stormwater Solutions
Fact Sheet: The Problem of Urban Stormwater Pollution

For printed copies of the original report, or a CD ROM that includes color photographs and the new chapter on low-impact development, see our Publications List.

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ROOFTOPS TO RIVERS

Green Strategies for Controlling Stormwater and Combined Sewer Overflows

Project Design and Direction
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NATURAL RESOURCES DEFENSE COUNCIL
June 2006

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ABOUT NRDC

The Natural Resources Defense Council is a national nonprofit environmental organization with more than 1.2 million members and online activists. Since 1970, our lawyers, scientists, and other environmental specialists have worked to protect the world's natural resources, public health, and the environment. NRDC has offices in New York City, Washington, D.C., Los Angeles, San Francisco, and Beijing. Visit us at www.nrdc.org.

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EXECUTIVE SUMMARY

As an environmental strategy, green infrastructure addresses the root cause of stormwater and combined sewer overflow (CSO) pollution: the conversion of rain and snow into runoff. This pollution is responsible for health threats, beach closings, swimming and fishing advisories, and habitat degradation. Water quality standards are unlikely to be met without effectively managing stormwater and CSO discharges. Green infrastructure—trees, vegetation, wetlands, and open space preserved or created in developed and urban areas—is a strategy for stopping this water pollution at its source.

The urban landscape, with its large areas of impermeable roadways and buildings—known as impervious surfaces—has significantly altered the movement of water through the environment. Over 100 million acres of land have been developed in the United States, and with development and sprawl increasing at a rate faster than population growth, urbanization's negative impact on water quality is a problem that won't be going away. To counteract the effects of urbanization, green infrastructure is beginning to be used to intercept precipitation and allow it to infiltrate rather than being collected on and conveyed from impervious surfaces.

Each year, the rain and snow that falls on urban areas in the United States results in billions of gallons of stormwater runoff and CSOs. Reducing runoff with green infrastructure decreases the amount of pollution introduced into waterways and relieves the strain on stormwater and wastewater infrastructure. Efforts in many cities have shown that green infrastructure can be used to reduce the amount of stormwater discharged or entering combined sewer systems and that it can be cost-competitive with conventional stormwater and CSO controls. Additional environmental benefits include improved air quality, mitigation of the urban heat island effect, and better urban aesthetics.

Green infrastructure is also unique because it offers an alternative land development approach. New developments that use green infrastructure often cost less to build because of decreased site development and conventional infrastructure costs, and such developments are often more attractive to buyers because of environmental amenities. The flexible and decentralized qualities of green infrastructure also allow it to be retrofitted into developed areas to provide stormwater control on a site-specific basis. Green infrastructure can be integrated into redevelopment efforts ranging from a single lot to an entire citywide plan.

Case Study Program Elements and Green Infrastructure Techniques

	PROGRAM ELEMENTS		TYPE OF GREEN INFRASTRUCTURE USED				
City	Used for Direct CSO Control	Established Municipal Programs & Public Funding	Green Roofs	Rain Gardens/ Vegetated Swales & Landscape	Permeable Pavement	Downspout Disconnection/ Rainwater Collection	Wetlands/ Riparian Protection/ Urban Forests
Chicago	✔	✔	✔	✔	✔	✔	
Milwaukee	✔	✔	✔	✔			✔
Pittsburgh	✔		✔	✔		✔	✔
Portland	✔	✔	✔	✔		✔	
Rouge River Watershed			✔	✔	✔		✔
Seattle	✔	✔	✔	✔		✔	
Toronto		✔	✔			✔	✔
Vancouver		✔	✔	✔	✔		✔
Washington			✔	✔	✔		

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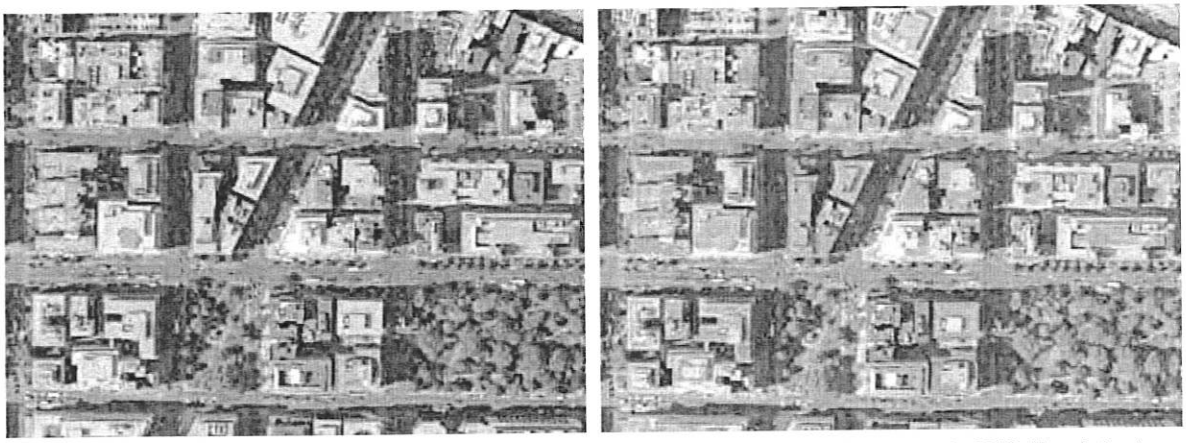


The aerial photograph at left of Washington, DC, shows the amount of green space and vegetation present in 2002. The photo at right shows how this same area would look in 2025 after a proposed 20-year program to install green roofs on 20% of city buildings over 10,000 square feet.

PHOTOS COURTESY OF THE CASEY TREES ENDOWMENT FUND

Nonetheless, wider adoption of green infrastructure still faces obstacles. Among these is the economic investment that is required across the country for adequate stormwater and CSO control. Although green infrastructure is in many cases less costly than traditional methods of stormwater and sewer overflow control, some municipalities persist in investing only in existing conventional controls rather than trying an alternative approach. Local decision makers and organizations must take the lead in promoting a cleaner, more environmentally attractive method of reducing the water pollution that reaches their communities. NRDC recommends a number of policy steps local decision makers can take to promote the use of green infrastructure:

1. Develop with green infrastructure and pollution management in mind. Build green space into new development plans and preserve existing vegetation.

2. Incorporate green infrastructure into long-term control plans for managing combined sewer overflows. Green techniques can be incorporated into plans for infrastructure repairs and upgrades.

3. Revise state and local stormwater regulations to encourage green design. A policy emphasis should be placed on reducing impervious surfaces, preserving vegetation, and providing water quality improvements.

The case studies that begin on page 17 offer nine examples of successful communities that have reaped environmental, aesthetic, and economic benefits from a number of green infrastructure initiatives.

The table on page v provides a summary of information contained within the case studies.

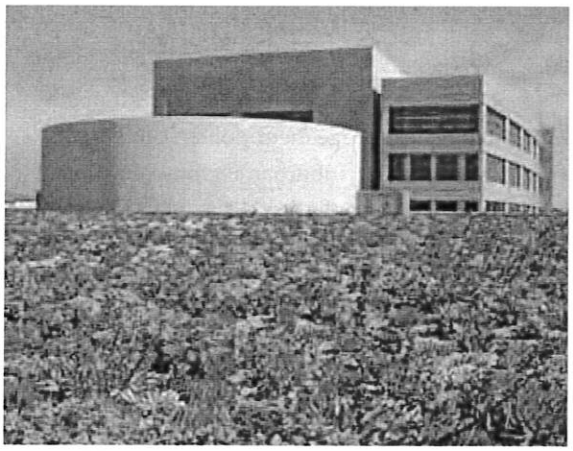
CHAPTER 1

INTRODUCTION

Water pollution problems in the United States have evolved since the days when Ohio's Cuyahoga River was on fire. Increasingly, water pollution from discrete sources such as factory pipes is being overshadowed by overland flows from streets, rooftops, and parking lots, which engorge downstream waterways every time it rains. This stormwater has nowhere to go because the natural vegetation and soils that could absorb it have been paved over. Instead, it becomes a high-speed, high-velocity conduit for pollution into rivers, lakes, and coastal waters.

Most U.S. cities have separate stormwater sewer systems through which contaminated stormwater flows directly into waterways through underground pipes, causing streambank scouring and erosion and dumping pet waste, road runoff, pesticides, fertilizer, and other pollutants directly into waterways. In older cities, particularly in the Northeast and Great Lakes regions, stormwater flows into the same pipes as sewage and causes these combined pipes to overflow—dumping untreated human, commercial, and industrial waste into waterways. Stormwater pollution has been problematic to some extent for as long as there have been cities, but the volume of stormwater continues to grow as development replaces porous surfaces with impervious blacktop, rooftop, and concrete.

Contaminated stormwater and raw sewage discharges from combined sewer overflows (CSOs) are required to be controlled under the Clean Water Act, but progress is slow because the problems are large and multi-faceted and because the solutions are often expensive. A substantial influx of additional resources is needed at the federal, state, and local levels, but fresh thinking is needed also. Some U.S. cities are already taking steps to successfully build green infrastructure into their communities.



The green roof at Ford Motor Company's Premier Automotive North American Headquarters in Irvine, CA, was designed to visually mimic the natural landscape. PHOTO COURTESY OF ROOFSCAPES, INC.

Emerging green infrastructure techniques present a new pollution-control philosophy based on the known benefits of natural systems that provide multimedia pollution reduction and use soil and vegetation to trap, filter, and infiltrate stormwater. The cities already using green infrastructure are finding that it is a viable alternative to conventional stormwater management. Although used widely overseas, particularly in Germany and Japan, the use of green infrastructure in the United States is still in its infancy; however, data indicate that it can effectively reduce stormwater runoff and remove stormwater pollutants, and cities that have implemented green design are already reaping the benefits (see the case studies on page 17).

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CHAPTER 2

THE GROWING PROBLEM OF URBAN STORMWATER

Development as we have come to know it in the United States—large metropolitan centers surrounded by sprawling suburban regions—has contributed greatly to the pollution of the nation's waters. As previously undeveloped land is paved over and built upon, the amount of stormwater running off roofs, streets, and other impervious surfaces into nearby waterways increases. The increased volume of stormwater runoff and the pollutants carried within it continue to degrade the quality of local and regional water bodies. As development continues, nature's ability to maintain a natural water balance is lost to a changing landscape and new impervious surfaces.

The trees, vegetation, and open space typical of undeveloped land capture rain and snowmelt, allowing it to largely infiltrate where it falls. Under natural conditions, the amount of rain that is converted to runoff is less than 10% of the rainfall volume.[1,2] Replacing natural vegetation and landscape with impervious surfaces has significant environmental impacts. The level of imperviousness in a watershed has been shown to be directly related to the health of its rivers, lakes, and estuaries. Research indicates that water quality in receiving water bodies is degraded when watershed imperviousness levels are at or above 10% and that aquatic species can be harmed at even lower levels.[3]

Both the National Oceanic and Atmospheric Administration (NOAA) and Pennsylvania State University estimate that there are 25 million acres of impervious surfaces in the continental United States.[4] This quantity represents nearly one-quarter of the more than 107 million acres—almost 8% of non-federal land in the contiguous United States—that had been developed by 2002.[5] In urban areas, it is not uncommon for impervious surfaces to account for 45% or more of the land cover.

This combination of developed land and impervious surfaces presents the primary challenge of stormwater mitigation. Existing stormwater and wastewater infrastructure is unable to manage stormwater in a manner adequate to protect and improve water quality. Standard infrastructure and controls fail to reduce the amount of stormwater runoff from urban environments or effectively remove pollutants.

TABLE 1: Effects of Imperviousness on Local Water Bodies[a,b,c]

Watershed Impervious Level	Effect
10%	• Degraded water quality
25%	• Inadequate fish and insect habitat • Shoreline and stream channel erosion
35%–50%	• Runoff equals 30% of rainfall volume
>75%	• Runoff equals 55% of rainfall volume

[a] Environmental Science and Technology, *Is Smart Growth Better for Water Quality?*, August 25, 2004, http://pubs.acs.org/subscribe/journals/estjag-w/2004/policy/jp_smartgrowth.html (accessed December 6, 2004).
[b] U.S. EPA, *Protecting Water Quality from Urban Runoff*, Nonpoint Source Control Branch, EPA 841-F-03-003, February 2003.
[c] Prince George's County, Maryland Department of Environmental Resources, *Low-Impact Development Design Strategies*, January 2000.

THE DEFICIENCIES OF CURRENT URBAN STORMWATER INFRASTRUCTURE

Stormwater management in urban areas primarily consists of efficiently collecting and conveying stormwater. Two systems are currently used: separate

Bioswales on Portland's Division Street infiltrate and treat stormwater runoff.
PHOTO COURTESY OF THE PORTLAND BUREAU OF ENVIRONMENTAL SERVICES

stormwater sewer systems and combined sewer systems. Separate stormwater sewer systems collect only stormwater and transmit it with little or no treatment to a receiving stream, where stormwater and its pollutants are released into the water. Combined sewer systems collect stormwater in the same set of pipes that are used to collect sewage, sending the mixture to a municipal wastewater treatment plant.

Separate Stormwater Sewer Systems

The large quantities of stormwater that wash across urban surfaces and discharge from separate stormwater sewer systems contain a mix of pollutants, shown in Table 2, deposited from a number of sources.[6,7] Stormwater pollution from separate systems affects all types of water bodies in the country and continues to pose a largely unaddressed threat. In 2002, 21% of all swimming beach advisories and closings were attributed to stormwater runoff.[8] Table 3 shows the percentage of assessed (monitored) waters in the United States for which stormwater has been identified as a significant source of pollution.[9]

Combined Sewer Systems

While pollution from separate sewer systems is a problem affecting a large majority of the country, pollution from combined sewer systems tends to be a more regional problem concentrated in the older urban sections of the Northeast, the Great Lakes

TABLE 2: Urban Stormwater Pollutants

Pollutant	Source
Bacteria	Pet waste, wastewater collection systems
Metals	Automobiles, roof shingles
Nutrients	Lawns, gardens, atmospheric deposition
Oil and grease	Automobiles
Oxygen-depleting substances	Organic matter, trash
Pesticides	Lawns, gardens
Sediment	Construction sites, roadways
Toxic chemicals	Automobiles, industrial facilities
Trash and debris	Multiple sources

TABLE 3: Urban Stormwater's Impact on Water Quality

Water Body Type	Stormwater's Rank as Pollution Source	% of Impaired Waters Affected
Ocean shoreline	1st	55% (miles)
Estuaries	2nd	32% (sq. miles)
Great Lakes shoreline	2nd	4% (miles)
Lakes	3rd	18% (acres)
Rivers	4th	13% (miles)

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TABLE 4: Pollutants in CSO Discharges[a]

Pollutant	Median CSO Concentration	Treated Wastewater Concentration
Pathogenic bacteria, viruses, parasites • Fecal coliform (indicator bacteria)	215,000 colonies/100 mL	< 200 colonies/100mL
Oxygen depleting substances (BOD_5)	43 mg/L	30 mg/L
Suspended solids	127 mg/L	30 mg/L
Toxics • Cadmium • Copper • Lead • Zinc	 2 µg/L 40 µg/L 48 µg/L 156 µg/L	 0.04 µg/L 5.2 µg/L 0.6 µg/L 51.9 µg/L
Nutrients • Total Phosphorus • Total Kjeldahl Nitrogen	 0.7 mg/L 3.6 mg/L	 1.7 mg/L 4 mg/L
Trash and debris	Varies	None

[a] U.S. EPA, Report to Congress: Impacts and Control of CSOs and SSOs, Office of Water, EPA-833-R-04-001, August 2004.

region, and the Pacific Northwest. Combined sewers, installed before the mid-twentieth century and prior to the use of municipal wastewater treatment, are present in 746 municipalities in 31 states and the District of Columbia.[10] They were originally used as a cost-effective method of transporting sewage and stormwater away from cities and delivering them to receiving streams. As municipal wastewater treatment plants were installed to treat sewage and protect water quality, the limited capacity of combined sewers during wet weather events became apparent.[11]

During dry periods or small wet weather events, combined sewer systems carry untreated sewage and stormwater to a municipal wastewater treatment plant where the combination is treated prior to being discharged. Larger wet weather events overwhelm a combined sewer system by introducing more stormwater than the collection system or wastewater treatment plant is able to handle. In these situations, rather than backing up sewage and stormwater into basements and onto streets, the system is designed to discharge untreated sewage and stormwater directly to nearby water bodies through a system of combined sewer overflows (CSOs). In certain instances, despite the presence of sewer overflow points, basement and street overflows still occur. Even small amounts of rainfall can trigger a CSO event; Washington D.C.'s combined sewer system can overflow with as little as 0.2 inch of rainfall.[12]

Because CSOs discharge a mix of stormwater and sewage, they are a significant environmental and health concern. CSOs contain both expected stormwater pollutants and pollutants typical of untreated sewage, like bacteria, viruses, nutrients, and oxygen-depleting substances. CSOs pose a direct health threat in the areas surrounding the CSO discharge location because of the potential exposure to bacteria and viruses. Estimates indicate that CSO discharges are typically composed of 15–20% sewage and 80–85% stormwater.[13,14] An estimated 850 billion gallons of untreated sewage and stormwater are discharged nationally each year as combined sewer overflows.[15] Table 4 shows the concentration of pollutants in CSO discharges.

POPULATION GROWTH AND NEW DEVELOPMENT CREATE MORE IMPERVIOUS SURFACES

Current levels of development and imperviousness are a major, and largely unabated, source of water pollution. Projections of population growth and new development indicate that this problem will get worse over time and that mitigation efforts will become more costly and difficult. Although the nation has collectively failed to adequately address the current levels of stormwater runoff and pollution, we have also failed to implement emerging strategies that would minimize further pollution increases. Absent the use of state-of-

the-art stormwater controls, each new acre of land developed and each new parcel of impervious surface will introduce new pollution into our waterways.

Recent studies also indicate that stormwater pollution may soon start to increase at a higher rate than in the past. Over the past two decades, the rate of land development has been two times greater than the rate of population growth. Between 1982 and 1997, while the U.S. population grew 15%, the amount of developed land in the continental United States grew 34%, an increase of 25 million acres.[16,17] The 25 million acres developed during this 15-year period represent nearly 25% of the total amount of developed land in the contiguous states. This rapid development pattern is alarming not only because of the conversion of a large and growing percentage of the remaining undeveloped land, but also because of the increase in stormwater runoff that accompanies development.

If the relationship between land development and population growth continues, a significant amount of land will be developed in the coming decades. The anticipated 22% growth in U.S. population from 2000 to 2025 will add an additional 68 million acres of development.[18] By 2030, half of the total square footage of buildings—200 billion square feet—will have been built after the year 2000.[19]

Much of this population growth and new development will occur in coastal regions, a particular concern because urban stormwater runoff is already the largest source of ocean shoreline water pollution. Although coastal counties comprise only 17% of the total acreage of the contiguous United States they are home to more than 50% of the U.S. population. Because of high population concentrations on limited land areas, coastal counties contain a higher percentage of development than interior counties. In 1997, 27 million acres of coastal counties had been developed, accounting for nearly 14% of the total land area. By contrast, 71 million acres, about 4% of the total land area of interior counties, had been developed.[20] Based on these trends, increased population and development in these coastal environments is likely to not only lead to greater amounts of impervious surfaces in coastal watersheds, but also higher percentages of imperviousness. Conventional methods of stormwater control will not be able to adequately manage the higher amount of stormwater pollution implied by this increased imperviousness.

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CHAPTER 3

CONTROLLING STORMWATER IN URBAN ENVIRONMENTS

The foremost challenge of reducing stormwater pollution and CSO discharges is finding an effective method of reducing the amount of stormwater created in urban environments. Methods currently used to manage stormwater largely fail to address the underlying problem of imperviousness.

Stormwater collected in separate systems typically is not treated before being discharged. In instances where treatment is provided, it usually consists of filtration to remove suspended solids, debris, and floatables. Because dissolved materials and nutrients are difficult to treat in urban stormwater and little has been done to abate the scouring, erosion, and other physical impacts of stormwater discharges, treatment efforts have been largely ineffective at diminishing stormwater-related water pollution.

Most municipal stormwater discharges are regulated as point sources under the Clean Water Act (CWA) and require a National Pollutant Discharge Elimination System (NPDES) permit. However, end-of-pipe treatment and control typical of other permitted point-source discharges are often impractical for urban stormwater, because of the large volumes of stormwater; generated and space constraints in urban areas. Permits for urban stormwater require municipalities to develop a stormwater management plan and to implement best management practices.[1] These management measures are typically used in lieu of specific pollutant removal requirements. "Performance-based" standards are generally not required, and minimum control measures are sufficient for compliance.

As a result, compliance with urban stormwater permits does not necessarily result in improved water quality. Municipalities that develop programs to actually reduce stormwater pollution are motivated to do so because of their proximity to unique or valued water bodies or because of a need to protect drinking water supplies. Some of the more aggressive and innovative stormwater programs are located around sensitive or important water bodies like the Chesapeake Bay, the Great Lakes, or Puget Sound. Federal regulations require states to identify quality-limited waterways and determine the reduction in the Total Maximum Daily Load (TMDL) of those pollutants necessary to meet water quality standards, but these pollutant load-reduction requirements are not often translated into effective stormwater management programs.[2]

Municipalities are required to implement short-term and long-term strategies to reduce overflows from combined sewer systems, but significant numbers of overflows continue to occur. The CWA prohibits the dry weather discharge of untreated sewage and requires wet weather CSO discharges to be limited and to control discharges of solids and floatables. Federal regulations also require that municipalities develop long-term CSO control plans that detail procedures and infrastructure modifications necessary to minimize wet weather overflows and meet water quality standards.[3] The long-term control plans focus primarily on managing stormwater impacts on combined sewer systems.

Mitigating CSOs is costly. The 2000 Clean Watersheds Needs Survey (CWNS) estimated that $56 billion (2005 dollars) in capital investment was needed for CSO control.[4] Separating combined sewer lines

and building deep storage tunnels are the two currently preferred methods of CSO control. The costs for separating combined sewers, disconnecting stormwater inlets from the combined sewer system, and directing them to a newly installed separate storm sewer system range from $500 to $600 per foot of sewer separated, or $2.6 million to $3.2 million for each mile of combined sewer to be separated.[5] While sewer separation will eliminate CSO discharges and the release of untreated sewage, the trade-off is an increase in the volume of untreated stormwater discharges.

Deep storage systems are large underground tunnels with millions of gallons of storage capacity that are built to hold the excess surge of combined sewer stormwater during wet weather events. These systems eventually direct the detained wastewater to the municipal treatment plant as combined sewer flow rates subside. If sized, constructed, and operated properly, deep tunnels can significantly reduce CSO discharges. However, deep tunnels take many years to build and are very costly. Several cities have begun or plan to begin deep tunnel projects costing hundreds of millions or billions of dollars, as outlined in Table 5.

Current stormwater management for separate and combined sewer systems is ineffective because it focuses on the symptoms (large stormwater volumes) rather than the problem (development patterns and imperviousness). Capturing, retaining, and trying to improve the quality of vast quantities of urban stormwater runoff is often more difficult and expensive than reducing the amount of stormwater generated from the outset through strategies to reduce imperviousness and maximize infiltration and filtration. On a municipal level, costs can be decreased when these techniques are incorporated into redevelopment and ongoing infrastructure replacement efforts. Comprehensive stormwater management programs can be used to minimize the effect of impervious surfaces and manage precipitation and stormwater with the use of natural processes. These "green" approaches are often less expensive and more effective than current stormwater and CSO controls.

GREEN ALTERNATIVES

Newer, flexible, and more effective urban stormwater and CSO strategies are being adopted in North America. Cities are beginning to introduce green infrastructure as a component of comprehensive stormwater management plans aimed at reducing stormwater runoff, CSOs or both. This approach is significant in that it can be used to address the stormwater problem "at the source" through efforts aimed at restoring some of the

TABLE 5: Examples of Deep Storage Tunnel Projects

City	Project Duration	Completion Date	Storage Capacity	Cost
Chicago, IL[a,b]	40+ years	2019	18 billion gallons	$3.4 billion
Milwaukee, WI[c,d]	17 years (Phase 1)	1994	405 million gallons	$2.3 billion
	8 years (Phase 2)	2005	88 million gallons	$130 million
Portland, OR[e]	20 years	2011	123 million gallons	$1.4 billion
Washington, DC[f]	20 years after construction begins	n/a	193.5 million gallons (proposed)	$1.9 billion (projected)

[a] Tudor Hampton, "Chicago Engineers Move Fast to Finish Epic Tunneling Feat," *Engineering News-Record*, August 18, 2003, http://www.enr.com/news/environment/archives/030818a.asp (accessed February 16, 2005).

[b] Metropolitan Water Reclamation District of Greater Chicago, *Combined Sewer Overflow Public Notification Plan*, http://www.mwrd.org/mo/csoapp/CSO/cso.htm (accessed December 15, 2005).

[c] Milwaukee Metropolitan Sewerage District, *Collection System: Deep Tunnel System*, http://www.mmsd.com/projects/collection8.cfm (accessed November 11, 2004).

[d] Milwaukee Metropolitan Sewerage District, *Overflow Reduction Plan*, http://www.mmsd.com/overflows/reduction.cfm (accessed November 11, 2004).

[e] Portland Bureau of Environmental Services, *Working for Clean Rivers*, http://www.portlandonline.com/bes/index.cfm?c=32123 (accessed November 15, 2004).

[f] D.C. Water and Sewer Authority, "WASA Proposes Plan to Control Combined Sewer Overflows to Local Waterways: Combined Sewer Long Term Control Plan," *The Reporter*, Summer 2001.

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Street planters in Portland, OR, are used in highly developed urban areas to introduce green space and manage stormwater runoff.
PHOTO COURTESY OF THE PORTLAND BUREAU OF ENVIRONMENTAL SERVICES

natural hydrologic function of areas that have been urbanized. Green infrastructure can also be used to limit development in sensitive headwaters regions and groundwater recharge areas to avoid the segmentation and isolation of natural environmental areas and resources.

Green infrastructure can be applied in many forms. It traditionally has been thought of as the interconnected network of waterways, wetlands, woodlands, wildlife habitats, and other natural areas that maintain natural ecological processes.[6] In practice, installing green infrastructure means preserving, creating, or restoring vegetated areas and natural corridors such as greenways, parks, conservation easements, and riparian buffers. When linked together through an urban environment, these lands provide rain management benefits similar to natural undeveloped systems, thereby reducing the volume of stormwater runoff. With green infrastructure, stormwater management is accomplished by letting the environment manage water naturally: capturing and retaining rainfall, infiltrating runoff, and trapping and absorbing pollutants. For example, the Village Homes community in Davis, California, uses a system of vegetated swales and meandering streams to manage stormwater. The natural drainage system is able to infiltrate and retain a rainfall volume greater than the 10-year storm without discharging to the municipal storm sewer system.

Green infrastructure can be used to restore vegetation and green space in highly impervious city areas. Planting street trees and other urban forestry initiatives can reduce stormwater runoff because urban tree canopies intercept rainfall before it hits the pavement and is converted to stormwater. Trees with mature canopies can absorb the first half-inch of rainfall.[7]

Recently the concept of green infrastructure has been broadened to include decentralized, engineered stormwater controls. These green techniques are designed to mimic the functions of the natural environment and are installed to offset the impacts of urbanization and imperviousness. Green management techniques are used to minimize, capture, and treat stormwater at the location at which it is created and before it has the opportunity to reach the collection system. Engineered systems commonly used in urban areas include green roofs, rain gardens, rain barrels and cisterns, vegetated swales, pocket wetlands, and permeable pavements.

Most green stormwater controls actually consist of green growth, including vegetated systems like green roofs and rain gardens, but other "green"

Urban trees intercept rainfall before it hits the ground and is converted to stormwater runoff.
PHOTO COURTESY OF THE LOW IMPACT DEVELOPMENT CENTER

controls, like permeable pavements, are not vegetated but designed to provide the water detention and retention capabilities of natural systems. Green infrastructure also encourages downspout disconnection programs that redirect stormwater from collection systems to vegetated areas or that capture and reuse stormwater, such as rain barrels. Downspout disconnection removes stormwater volume from collection systems and allows green infrastructure components to manage the runoff.

Green infrastructure offers numerous benefits when used to manage stormwater runoff. Many green techniques reduce both stormwater volume and pollutant concentrations and, in contrast to conventional centralized controls, provide flexibility in how and where stormwater management is accomplished. The use of green infrastructure protects natural resources and lessens the environmental impacts of development by not only addressing stormwater, but also by improving air quality and community aesthetics.

1. Stormwater volume control and pollutant removal. Green infrastructure is effective for managing stormwater runoff because it is able to reduce the volume of stormwater and remove stormwater pollutants. Reducing the amount of urban runoff is the most effective stormwater pollution control. This reduces the amount of stormwater discharged from separate stormwater sewer systems and aids combined sewer systems by decreasing the overall volume of water entering the system, thus reducing the number and size of overflows. Another large benefit of green infrastructure is that nearly every green technique results in the removal of stormwater pollutants. The natural processes employed by green infrastructure allow pollutants to be filtered or biologically or chemically degraded, which is especially advantageous for separate storm sewer systems that do not provide additional treatment before discharging stormwater. The combination of runoff reduction and pollutant removal is an effective means of reducing the total mass of pollution released to the environment. Because of this, open areas and buffer zones are often designated around urban streams and rivers to provide treatment and management of overland flow before it reaches the waterway.

2. Decentralized, flexible, site-specific solution. Green infrastructure differs from other stormwater management methods because it provides the opportunity to manage and treat stormwater where it is generated. This decentralized approach allows green infrastructure

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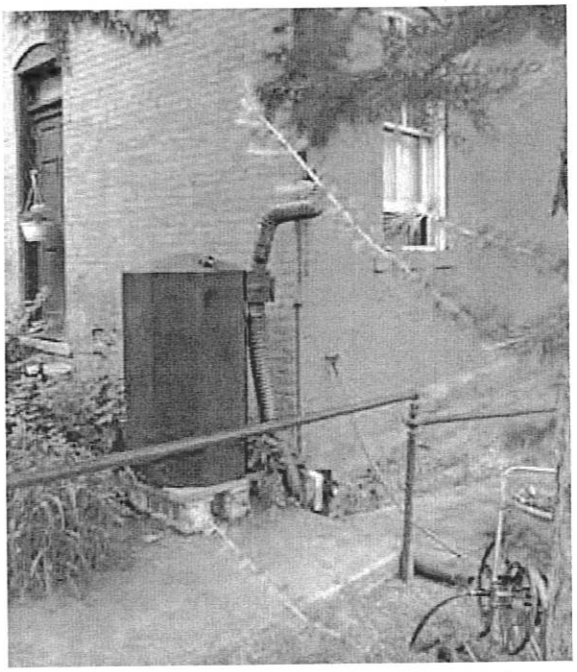


A RiverSafe RainBarrel installed at the Jane Holmes nursing residence in Pittsburgh, PA, by the Nine Mile Run RainBarrel Initiative. PHOTO COURTESY OF RIVERSIDES

techniques to be installed at numerous locations throughout the city. Green infrastructure is flexible, allowing it to be applied in a wide range of locations and circumstances, and can be tailored to newly developed land or retrofitted to existing developed areas. This enables green infrastructure to be used on individual sites or in individual neighborhoods to address localized stormwater or CSO problems, or incorporated into a more widespread municipal stormwater management program.

3. Green design and the development problem. Projected population growth and development will strain an aged and often inadequate infrastructure system by introducing new areas of imperviousness and additional volumes of stormwater. Strategies will need to be adopted to manage urban growth and its impacts on water quality. The use of green infrastructure offers an alternative to existing development patterns and a new method of developing urban areas. Green infrastructure currently is being used to manage existing stormwater problems, but has the potential to significantly effect how future development contributes to stormwater and sewer overflow problems by preserving and incorporating green space into newly developed areas and by addressing the established connection between imperviousness and stormwater pollution.

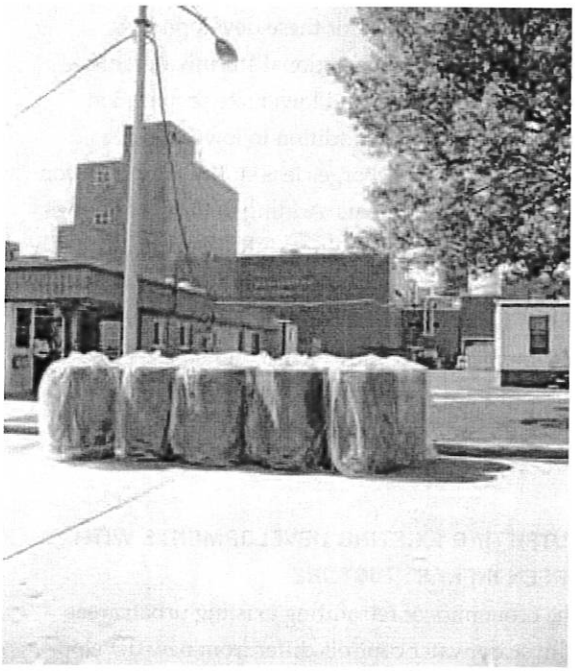
4. Ancillary benefit. Green infrastructure is also attractive because it can be used to achieve multiple environmental goals. Funds spent on conventional stormwater management are used only for water infrastructure. In addition to stormwater management benefits, green infrastructure improves air quality by filtering air pollution and helps to counteract urban heat island effect by lowering surface temperatures. For example, many of the green infrastructure projects in Chicago, while also providing stormwater management, were initially installed to mitigate urban temperature increases and improve energy efficiency. Green infrastructure also improves urban aesthetics, has been shown to increase property values, and provides wildlife habitat and recreational space for urban residents. This multi-benefit environmental approach ultimately provides control programs that are more diverse and cost-effective than projects aimed solely at stormwater control.

CHAPTER 4

ECONOMIC BENEFITS OF GREEN SOLUTIONS

The cost of stormwater control is a major factor in the successful implementation of pollution control programs. A large investment is required to adequately address CSOs and stormwater runoff. In addition to the $56 billion necessary to control CSOs, the Environmental Protection Agency (EPA) has identified $6 billion of documented needs for municipalities to develop and implement stormwater management programs required by the Phase I and II stormwater regulations, as well as $5 billion in documented needs for urban runoff control.[1,2] However, the EPA estimates that while $5 billion has been documented, up to $16 billion may be needed for urban runoff control.[3] These costs present a significant burden to municipal governments challenged with funding these programs.

Of course, natural stormwater retention and filtration is provided by Mother Nature for free. The high costs associated with urban stormwater result from the destruction of free, natural stormwater treatment systems—trees, meadows, wetlands, and other forms of soil and vegetation. For example, researchers at the University of California at Davis have estimated that for every 1,000 deciduous trees in California's Central Valley, stormwater runoff is reduced nearly 1 million gallons—a value of almost $7,000.[4] Clearly, preserving trees reduces polluted stormwater discharges and the need for engineered controls to replace those lost functions. When those trees are cut down and their functions are lost, those costs are passed on to municipal governments, which then pass them on to their citizens. So, while the bulk of this report is about how to integrate green infrastructure into the developed world, protecting and enhancing those areas that have not yet been developed is often the cheapest, most effective way to keep contaminated stormwater out of urban and suburban streams.



The Nine Mile Run RainBarrel Initiative used 500 RainBarrels to achieve CSO reduction for the ALCOSAN treatment plant in Pittsburgh. PHOTO COURTESY OF RIVERSIDES

THE COSTS OF BUILDING GREEN IN NEW DEVELOPMENTS

Green infrastructure in many instances is less costly than conventional stormwater management programs or centralized CSO approaches and may

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provide an opportunity to decrease the economic burden of stormwater management. Studies in Maryland and Illinois show that new residential developments using green infrastructure stormwater controls saved $3,500 to $4,500 per lot (quarter- to half-acre lots) when compared to new developments with conventional stormwater controls.[5,6] These developments were conceived and designed to reduce and manage stormwater runoff by preserving natural vegetation and landscaping, reducing overall site imperviousness, and installing green stormwater controls. Cost savings for these developments resulted from less conventional stormwater infrastructure and paving and lower site preparation costs. Importantly, in addition to lowering costs, each of the sites discharges less stormwater than conventional developments. Adding to the cost savings, developments utilizing green infrastructure normally yield more lots for sale by eliminating land-consuming conventional stormwater controls, and lots in green developments generally have a higher sale price because of the premium that buyers place on vegetation and conservation development.[7,8]

OUTFITTING EXISTING DEVELOPMENTS WITH GREEN INFRASTRUCTURE

The economics of retrofitting existing urban areas with stormwater controls differ from new development. Urban stormwater retrofits can be expensive and complicated by space constraints, although this is not always the case. Based upon the costs of their pilot projects, city officials in Seattle and Vancouver (discussed in the case studies on pages 29 and 33), believe that the costs of future green infrastructure installations will be similar to or slightly more than conventional stormwater controls.[9,10] The analysis conducted by the city of Vancouver indicates that retrofitting green infrastructure into locations with existing conventional stormwater controls will cost only marginally more than rehabilitating the conventional system, but introducing green infrastructure into new development will cost less.[11] However, while green infrastructure may be more expensive in some instances, municipalities believe that the additional benefits of green controls—including the creation of more aesthetic city space and the significant reduction in water pollution—justify the added cost. In addition, green infrastructure can be incrementally introduced into urban environments, allowing the costs to be incurred over a longer period of time.

TABLE 6: Cost of Conventional Urban Stormwater and CSO Controls[a]

Control	Cost Equation[b]	Cost to Manage 10 Million Gallons
Surface storage	$C = 5.184V^{0.826}$	$35 million
Deep tunnels	$C = 7.103V^{0.795}$	$44 million
Detention basins	$C = 62{,}728V^{0.69}$	$300,000
Retention basins	$C = 69{,}572V^{0.75}$	$390,000

[a] James Heaney, et al., *Costs of Urban Stormwater Control*, National Risk Management Research Laboratory, Office of Research and Development, EPA-600/R-02/021, January 2002.

[b] Cost equations adjusted to 2005 dollars. Volume equals millions of gallons. Cost for surface storage and deep tunnels is millions of dollars.

The EPA has developed cost curves for conventional urban stormwater controls relating stormwater storage capacity to control cost. The costs in Table 6 do not include any associated costs for construction and infrastructure. These costs represent the generally accepted costs of stormwater control and provide a baseline to which green infrastructure costs can be compared.

In many instances, green infrastructure costs compare favorably with the costs of conventional controls. However, cost comparisons for individual, small-scale retrofit projects are not likely to favor green controls. In urban areas, green infrastructure will be most cost-effective when it is incorporated as part of an overall redevelopment effort or when large improvements to infrastructure are required. In these instances, the costs of green infrastructure are minimized relative to the scope and costs of the overall project. While green infrastructure may be more costly than conventional stormwater or CSO controls in certain instances, the added costs should be weighed against the enhanced stormwater control and other environmental benefits gained from their use.

CHAPTER 5

POLICY RECOMMENDATIONS FOR LOCAL DECISION MAKERS

Although green infrastructure has been shown to reduce stormwater runoff and combined sewer overflows and improve water quality, its adoption across the country has been slow. Cities that have incorporated green infrastructure into their stormwater management programs have often done so because of direct efforts to encourage alternative stormwater approaches. The following recommendations can be used to encourage the use of green infrastructure in municipalities.

1. Get development right the first time. Reducing or preventing stormwater runoff is the most effective way to minimize pollution because it prevents pollutants from being transported to water bodies. Incorporating green infrastructure into the earliest stages of community development can negate or limit the need for larger-scale, more expensive stormwater controls. Minimizing imperviousness, preserving existing vegetation, and incorporating green space into designs all decrease the impact that urbanization has on water quality. Used in this way, green infrastructure design is a more cost-effective strategy, often costing less to develop per lot while yielding more lots at an increased sale price.[1,2]

2. Incorporate green infrastructure into long-term control plans for managing combined sewer overflows. Cities with combined sewer systems are required to develop long-term plans to reduce sewer overflows enough to meet water quality standards.[3] Green infrastructure has proven to be valuable in reducing inflows into combined sewer systems and should be integrated into such plans. Rather than relying solely on conventional, centralized storage projects to reduce CSO volumes, municipalities should considering using green techniques, which can be integrated into redevelopment projects and infrastructure repairs and upgrades. Each year Portland, Oregon's downspout disconnection program diverts 1 billion gallons of stormwater from the collection system and has been used to help alleviate localized combined sewer system backups in city neighborhoods.[4]

3. Revise state and local stormwater regulations to encourage green design. Most state and local stormwater regulations focus on peak flow rate control. To encourage more effective stormwater management, these regulations should be revised to require minimizing and reducing impervious surfaces, protecting existing vegetation, maintaining predevelopment runoff volume and infiltration rates, and providing water quality improvements. These requirements encourage green infrastructure because it can meet each of these objectives. Portland, Oregon, requires on-site stormwater management for new development and redevelopment in both CSO and separate sewer areas of the city and encourages use of green infrastructure to comply with the regulation (more details about Portland's development regulations can be found in the case study on page 24).

New Jersey's stormwater management standards require 300-foot riparian buffers and stipulate a preference for nonstructural best management

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The vegetated infiltration basins in the Buckman Heights Apartments courtyard in Portland, OR, receive and infiltrate stormwater from building roofs and sidewalks.

PHOTO COURTESY OF PORTLAND BUREAU OF ENVIRONMENTAL SERVICES

practices (BMPs). These standards also institute water quantity as well as *quality* regulations. The water quantity standards require no change in groundwater recharge volume following construction and that infiltration be used to maintain pre-development runoff volumes and peak flow rates. Any increase in runoff volume must be offset by a decrease in post-construction peak flow rate. Water quality standards require a reduction in stormwater nutrient loads to the "maximum extent feasible" and total suspended solids (TSS) reductions of 80%. If the receiving water body is a high-quality water or tributary, the required TSS reduction is 95%.[5]

Berlin, Germany, has incorporated the Green Area Factor (GAF) into its regulations. Based on land use and zoning, the GAF sets a greening target for each property that provides the required ratio of vegetated elements to impervious surface. Once property owners apply for a building permit, they are required to satisfy the green target goal. Property owners select green infrastructure practices from an approved list and determine compliance by calculating the proportion of the property dedicated to the greening target. Selected green infrastructure practices are weighted according to their effectiveness at meeting environmental goals.[6]

To date, the U.S. federal government has declined to set performance standards for stormwater discharges from development or to add specifics to the "maximum extent practicable" standard set by the Clean Water Act for discharges from municipalities.[7] Since the federal government has failed to show leadership in this area, state and local entities must do so.

4. Establish dedicated funding for stormwater management that rewards green design. Adequate funding is critical for successful stormwater management programs. The billions of dollars necessary to mitigate stormwater pollution and combined sewer overflows require federal funding to augment state and municipal funding. To encourage its use, dedicated stormwater funding sources could identify a preference for green infrastructure or establish a funding scale based upon the relative use of green management techniques.

Many jurisdictions are creating stormwater utilities similar in function to water and wastewater utilities. Stormwater utilities allow for the assessment and collection of a user fee dedicated to a stormwater management program. Other jurisdictions dedicate a certain portion of collected local tax revenue to a

stormwater fund. Establishing a dedicated fund removes stormwater management from general revenue funding, which is subject to variable funding and competes with other general taxation programs for money. Stormwater utilities, where allowed by enabling legislation, are popular because of the ability to determine a user rate structure and as a complement to incentive programs.[8,9]

5. Provide incentives for residential and commercial use of green infrastructure. Various incentives are already in place to encourage green infrastructure use in a number of cities. For example, Portland, Oregon, allows additional building square footage for buildings with green roofs, and Chicago provides a density bonus option for buildings with vegetative cover on the roof.[10,11] The city of Chicago also provided 20 $5,000 grants to install small-scale commercial or residential green roofs in early 2006.[12] Also beginning in 2006, Portland will provide up to a 35% discount in its stormwater utility fee for properties with on-site stormwater management.[13] Maryland provides credits for using green infrastructure when determining compliance with its stormwater regulatory requirements. Six different credits, all related to green infrastructure design, are available.[14] Several cities fund or subsidize downspout disconnection programs; Portland's program pays homeowners $53 per downspout disconnected or the city will disconnect the downspouts for free.

6. Review and revise local development ordinances. Local zoning requirements and building codes often inadvertently discourage the use of green infrastructure. Provisions requiring downspouts to be connected to the stormwater collection system prohibit disconnection programs and the use of green space for treatment of rooftop runoff. Mandatory street widths and building setbacks can unnecessarily increase imperviousness. Stormwater treatment requirements that favor centralized collection and treatment and prescribe treatment options offer little opportunity or incentive to use green infrastructure. Jurisdictions should review their applicable stormwater and wastewater ordinances and revise them to remove barriers to green infrastructure use and encourage more environmentally friendly regulations.[15]

7. Preserve existing trees, open space, and stream buffers. Too often, development removes nearly all existing natural features. Simply preserving trees, open space, and stream buffers and incorporating them into the community will help maintain water quality and manage stormwater runoff while lessening the need for additional stormwater controls. For example, New Jersey's stormwater management standards require 300-foot riparian buffers for new developments and redevelopments to protect water quality.[16]

8. Encourage and use smart growth. Smart growth can be used to limit sprawl and reduce the introduction of impervious surfaces. Smart growth policies can identify and protect sensitive environmental areas and direct development to locations with adequate infrastructure. By limiting sprawl and discouraging development in sensitive areas, smart growth may increase population densities and imperviousness in previously urbanized areas. Smart growth strategies should be coupled with green infrastructure to limit the stormwater and infrastructure effects of a potential increase in urbanization.

9. Get the community involved. Green infrastructure presents an opportunity for community outreach and education. Downspout disconnections, rain barrels, rain gardens, and green roofs may individually manage a relatively small volume of stormwater but collectively can have a significant impact. Portland's downspout disconnection program, for example, now diverts 1 billion gallons of stormwater away from the combined sewer system each year. Green infrastructure can be introduced into a community one lot at a time.

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CHAPTER 6

CONCLUSION

While development, imperviousness, and urbanization have all taken their toll on downstream waterways, current stormwater and combined sewer overflow (CSO) mitigation efforts have failed to adequately address the problem or improve water quality because they are focused on end-of-pipe solutions. Current levels of development and imperviousness have degraded the nation's water quality, and future population growth and development will only exacerbate the problem. Additional development will make stormwater and CSO control solutions even more difficult and costly.

Green infrastructure offers the opportunity to not only develop new areas in a more environmentally efficient manner, but also to rehabilitate existing developed areas. Urbanization and development alter how water is distributed throughout the environment. Much greater volumes of stormwater are generated and discharged to receiving water bodies in developed areas than would be in the natural environment. Green infrastructure is providing measurable water quality improvements, most notably in stormwater volume reduction and CSO mitigation.

Some jurisdictions and cities have chosen green infrastructure as a preferable method of stormwater or CSO control based upon the specific needs and goals of the municipality. Others have installed green infrastructure to experiment with innovative stormwater or combined sewer overflow pilot projects. But all of these efforts demonstrate how it can be successfully integrated into urban communities.

A common driver among the cities using green infrastructure is compliance with regulatory requirements. The catalyst for Portland, Oregon's active program, for example, is a need to satisfy a number of environmental commitments, including a consent decree to limit CSO discharges, Safe Drinking Water Act standards influencing the quality of infiltrated stormwater, and emerging TMDL load and waste load allocations.[1] Other cities with combined sewer systems, or those that discharge stormwater to sensitive receiving waters, face similar requirements. Such regulations only increase the opportunities for creativity and willingness on the part of municipal decision makers to actively promote and introduce green infrastructure. City leaders are finding that when faced with the simultaneous challenges of regulatory requirements, infrastructure limitations, and financial constraints, green infrastructure often emerges as an appropriate means of satisfying each.

Another commonality among cities that have incorporated green infrastructure into their stormwater and CSO control plans is a commitment from city personnel. Whether elected officials or professional staff, these city leaders have recognized the benefits of green infrastructure and have successfully communicated its value to the public. These cities have also been innovative with their regulations and environmental policies, looking for existing and alternative avenues to encourage adoption of new stormwater and CSO control strategies. These efforts are often popular because of the public's positive response to the "greenscaping" that has accompanied the programs. As many local decision makers have already found, using green infrastructure in place of or in combination with less effective conventional methods of handling stormwater runoff can have benefits beyond just economic cost savings and reduced pollution.

CHAPTER 7

CASE STUDIES

The following nine case studies illustrate efforts in North America to incorporate green infrastructure into urban stormwater and combined sewer overflow (CSO) control strategies, but this is not an exhaustive list. Several factors were used to select case-study cities. Among them were extent and duration of program efforts, availability of information and quantifiable data, geographic location, and the number and type of green infrastructure elements practiced.

Chicago, Illinois

Progressive environmental change through creative use of green infrastructure

Population: 2.9 million

Type of green infrastructure used: green roofs; rain gardens, vegetated swales, and landscape; permeable pavement; downspout disconnection/rainwater collection

Program elements: used for direct CSO control; established municipal programs and public funding

Historically, Chicago has been known more for its industrial horsepower than for progressive environmental ideas. Rivers like Bubbly Creek still bear the names they earned from the pollution they once contained. Stories of the city's sewage and pollution problems from as early as the 1880s still persist as popular legends. However, recent initiatives show that Chicago is emerging as a leader in green development, with an extensive green roof program, environmentally sensitive demonstration projects, and municipal policies that encourage decentralized stormwater management. The city has been particularly creative in its approach, using green infrastructure projects to not only manage stormwater runoff but also to address other environmental issues, such as mitigating urban heat island effects and improving energy efficiency in buildings.

Stormwater Collection Through Expansion of the Combined Sewer System

While the city's past environmental infrastructure projects have had dubious goals, the water quality of Lake Michigan, the city's drinking water source, has long been a concern. In the early 1900s, sewage and stockyard pollution from the Chicago River prompted Chicago officials to reverse the course of the South Branch of the river away from Lake Michigan and to the Mississippi River in an effort to improve the lake's water quality.[1] Water issues remain a concern for the city more than a century later. The city manages one of the largest wastewater collection and treatment systems in the world and contends with flooding, surface water quality impairment, and CSOs. Urban runoff challenges are exacerbated by the magnitude of infrastructure needed to serve Chicago's population. The city itself has over 4,400 miles of sewage infrastructure that cost about $50 million annually to maintain.[2] Approximately 3 million people call Chicago home, and the population of the entire six-county metro region surrounding the city exceeds 8 million; the region's population is projected to increase 20% by 2030.[3] Impervious surfaces cover approximately 58% of the city.[4]

Chicago has pursued a number of initiatives to improve stormwater collection, the most ambitious being a $3.4 billion project to collect and store stormwater and sewage from the combined sewer system.[5]

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The green roof at Chicago's City Hall introduces vegetation in the heart of downtown. Temperatures above the Chicago City Hall green roof average 10° to 15°F lower than a nearby black tar roof. During the month of August this temperature difference may be as great as 50°F. The associated energy savings are estimated to be $3,600 per year.
PHOTO COURTESY OF ROOFSCAPES, INC.

In the 1970s, the Metropolitan Water Reclamation District began construction of the primary control solution for CSOs—the Tunnel and Reservoir Plan (TARP). In 2003, with only part of the system operational, more than 44 billion gallons of stormwater were captured; 10 billion gallons, however, were released as CSOs.[6] Approximately 2.5 billion gallons of storage are currently available in the TARP system. An additional 15.6 billion gallons of storage will be available when two more reservoirs are added to the system; construction is scheduled for completion in 2019.[7,8] When complete, the system will handle most of Chicago's CSO discharges, storing combined runoff and sewage until it can be sent for secondary treatment at a wastewater treatment plant.

Chicago's Green Roof Program

Although the Metropolitan Water Reclamation District has committed to this massive public works project, the city has also pursued several initiatives to install green infrastructure that promotes on-site stormwater management, including green roofs, permeable paving projects, rain barrels, and green buildings. Much of this investment in green infrastructure has paralleled the increase in population and building within the city over the last decade. And, unlike the past, the Chicago River is now seen as a public amenity rather than a liability.

Chicago's thriving green roof program began with a 20,300 square foot demonstration roof on its own city hall. The green roof retains more than 75% of the volume from a one-inch storm, preventing this water from reaching the combined sewer system.[9] The program has led to more than 80 green roofs in the city, totaling over one million square feet.[10] A 2003 Chicago Department of the Environment study found that runoff from green roof test plots was less than half of the runoff from conventional stone and black tar roof plots; the difference was even larger for small storms. The city encourages the use of green roofs by sponsoring installations and demonstration sites and by providing incentives. A density bonus is offered to developers who cover 50% or 2,000 square feet (whichever is greater) of a roof with vegetation. In early 2006, the city provided 20 $5,000 grants for green roof installations on small-scale commercial and residential properties.[11]

Other Green Infrastructure Innovations: Chicago's Citywide Commitment

Chicago has employed other green technologies to reduce urban runoff. To address localized flooding caused by runoff from one alley, the city removed the

asphalt from the 630 foot long, 16 foot wide alley and replaced it with a permeable paving system. Now, instead of generating stormwater runoff, the alley will infiltrate and retain the volume of a three-inch, one-hour rain event.[12] The permeable pavement requires little maintenance and has a life expectancy of 25 to 35 years.[13] In this same ward, vegetated swales are also being used for stormwater management.

In June 2004, Chicago has embarked on a city-wide green building effort. Chicago Mayor Richard M. Daley presented The Chicago Standard, a set of construction principles designed for municipal buildings. The standards are based on the Leadership in Energy and Environmental Design (LEED™) Green Building Ration System[14] and emphasize sustainability, water efficiency, energy effects, and indoor air quality as well as stormwater management. For both the green roof and green building efforts, Chicago has created municipal demonstration projects to develop professional expertise in the city on these technologies.

Chicago Center for Green Technology. The centerpiece of the city's green building efforts is the Chicago Center for Green Technology. The Chicago Department of Environment transformed this property from a 17-acre brownfield full of construction debris to the first municipal building to receive the LEED™ platinum rating.[15] The 34,000 square foot center serves as an educational facility and rental space for organizations and businesses with an environmental commitment. Four 3,000 gallon cisterns capture stormwater that is used for watering the landscaping. The site also features a green roof, bioswales, permeable paving, and a rain garden. Chicago Department of Environment models indicate that Green Tech's stormwater management technologies retain more than 50% of stormwater on site—for a three-inch storm, the site releases 85,000 gallons of stormwater to the sewer system instead of the expected 175,000 gallons.[16] The success of the Green Tech project spurred several other green building projects, including three new green libraries; a new police station to be monitored for a national case study; green renovations on a firehouse and police headquarters; and the Green Bungalow Initiative, a pilot project to affordably retrofit four of Chicago's historic bungalows with green technologies and monitor any corresponding energy savings. The program has thus far shown average energy savings for the green bungalows of 15% to 49%.[17]

The city has also pursued public outreach programs, engaging homeowners through its recent rain barrel and rain garden programs. In the fall of 2004 city residents purchased more than 400 55-gallon rain barrels for $15 each.[18] The program cost the city $40,000 excluding city labor. The Department of Environment estimates the pilot project has the potential to divert 760,000 gallons annually from the combined sewer system, a relatively small number compared to the total amount of stormwater runoff in the city. However, the program was targeted to areas with a high frequency of basement flooding, meaning the program may have a more significant impact in these localized areas. Since the water in rain barrels can be used for other purposes such as landscaping, this program has additional conservation benefits as well. The city also began a complementary rain garden program, planting four rain gardens along with signage explaining benefits.

Chicago has also complemented its ground-level initiatives with two studies on the effectiveness of green infrastructure technologies. The first is the monitoring study of the green roof box plots. The second is a 2004 Department of Environment Stormwater Reduction Practices Feasibility Study that used hydraulic modeling to assess the effectiveness of best management practices for the Norwood Park sewershed. The study found that downspout disconnection would achieve peak flow reductions in the 1,370-acre area by 30% for a six-month or one-year storm if all homes in the 80% residential area disconnected their downspouts from the sewer system.[19,20] This would potentially reduce peak flow in the CSO outfall pipe by 20% and water levels in the sewer system by eight inches to two feet. The study also showed that three-inch and six-inch-deep rain gardens installed at each home could reduce total runoff by approximately 4%

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and 7%, respectively, for the same six-month or one-year storm events.

For Additional Information

Chicago Department of the Environment: http://egov.cityofchicago.org/city/webportal/portalEntityHomeAction.do?entityName=Environment&entityNameEnumValue=05

Milwaukee, Wisconsin

Investing in green infrastructure to improve water quality

Population: 587,000

Type of green infrastructure used: green roofs; rain gardens, vegetated swales, and landscape; wetlands, riparian protection, or urban forests

Program elements: used for direct CSO control; established municipal programs and public funding

Like many municipalities with a combined sewer system, Milwaukee has a history of exposure to frequent CSO events and was faced with finding a viable overflow control strategy. To reduce the number of CSOs and their impact on the water quality of Lake Michigan and its tributaries, the Milwaukee Metropolitan Sewerage District (MMSD), the regional wastewater treatment agency, built a deep tunnel storage system in the 1980s and 1990s. MMSD invested $3 billion during this period to reduce overflows. As a complement to this large capital investment, MMSD is investing in green infrastructure projects to reduce stormwater inflow into the combined sewer system and mitigate stormwater runoff.

MMSD manages wastewater from 28 municipalities with a combined population of about 1.1 million people in a 420 square mile service area. All 28 communities own and operate their own sewer systems, which drain into 300 miles of regional sewers owned by MMSD. The district's two wastewater treatment plants each process about 80 to 100 million gallons of wastewater on a dry day.[21] Treated wastewater is discharged to Lake Michigan, which also serves as the city's drinking water supply.[22] The city of Milwaukee and the village of Shorewood own and operate combined sewers, which make up 5% of MMSD's total service area. Combined sewer overflow points are located along rivers that flow into Lake Michigan.[23] The $2.3 billion Deep Tunnel System project, completed by MMSD in 1994, provided 405 million gallons of underground sewer storage. Begun in 1986, the 19.4-mile-long system collects and temporarily stores the large quantities of stormwater and wastewater that are conveyed through the sewers during wet weather events.[24]

Prior to the system becoming operational, Milwaukee averaged 50 to 60 CSO events a year, which discharged 8 to 9 billion gallons of sewage and stormwater. The Deep Tunnel System was designed to limit CSOs to 1.4 events per year; in the first 10 years of operation, from 1994 until 2003, annual average CSO discharges were 1.2 billion gallons from 2.5 average annual events.[25,26] Heavy rains in the spring of 2004 resulted in 1 billion gallons of CSO discharges during a two-week period.[27] Although the Deep Tunnel System has substantially reduced CSO events, excessive quantities of stormwater can still trigger overflows, and MMSD has committed an additional $900 million to an overflow reduction plan.[28]

Milwaukee's Green Infrastructure Approach

As an additional strategy to limit CSO discharges, MMSD has begun to install green infrastructure within the combined sewer area to decrease the volume of stormwater entering the system. One of the first initiatives was a disconnection program that redirected building downspouts from the combined sewer system to rain barrels. Overflow from the rain barrels is directed to pervious areas and rain gardens. In a cooperative cost-sharing arrangement with public entities and private businesses in the city, MMSD partnered with others to install more than 60 rain gardens to receive and treat roof runoff. The total combined cost of these pilot projects was approximately $170,000.[29]

The Highland Gardens housing project. Seven green roofs have been installed in the Milwaukee region.

The green roof atop MMSD's headquarters, shown just after installation, demonstrates how stormwater flow into the city's sewer system could be reduced.
PHOTO COURTESY OF MMSD

One of these is at the Highland Gardens housing project, a 114-unit mid-rise for senior citizens and people with disabilities. A 20,000 square foot green roof was installed at a cost of $380,000. The roof will retain 85% of a two-inch rainfall. The remaining 15% of the water volume is directed to rain gardens and a retention basin used for on-site irrigation.[30] These management strategies prevent stormwater from being discharged to the collection system.

MMSD has installed or helped finance four other green roofs to reduce stormwater runoff. The first was a 3,500 square foot structure on the roof of MMSD's headquarters building in downtown Milwaukee. Native species of grasses and flowering plants were selected for the roof vegetation. The cost of the green roof was just under $70,000.[31] A second green roof was installed on the University of Wisconsin-Milwaukee's Great Lakes Water Institute. MMSD contributed $110,000 of the $233,000 needed to install the 10,000 square foot unit. A third green roof was installed on the city's Urban Ecology Center, with MMSD contributing $40,000 of the total project cost. The fourth green roof is at the Milwaukee County Zoo, to which MMSD contributed half of the $73,000 cost.[32]

Measuring the Effectiveness of Milwaukee's Green Infrastructure

The rain gardens and MMSD-financed green roofs were installed in 2003 and 2004. A monitoring program evaluating the effectiveness of the systems at managing stormwater is being conducted with initial results expected in early 2006. To determine the potential impacts of the green infrastructure program, MMSD conducted a modeling analysis. The modeling effort showed that application of downspout disconnection, rain barrels, and rain gardens in residential areas would reduce each neighborhood's contribution to the annual CSO volume 14% to 38%. Additional modeling results showed the volume of stormwater sent to the treatment plants from the neighborhoods was reduced 31% to 37% and stormwater peak flow rates were reduced 5% to 36%, depending upon the size of the rain event.[33] (The model assumed a high participation rate for residential areas. Volume and peak flow reductions would not be as great with a lower participation rate.)

The effect of green infrastructure in commercial areas was also modeled. The use of green roofs, rain gardens, and green parking lots is predicted to reduce commercial area contributions to CSO volume by 22% to 76%, but would not decrease—and could even increase—the volume of stormwater sent to the

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treatment plants. Stormwater peak flow rates from commercial areas are predicted to be reduced 13% to 69% with the introduction of green infrastructure.[34]

MMSD has allocated more than $5.5 million for fiscal years 2002 through 2014 for rain water rerouting programs intended to prevent stormwater from entering the combined sewer system. An additional $4.5 million has been allocated for fiscal years 2003 through 2009 to promote, install, and monitor green infrastructure practices aimed at reducing stormwater.[35]

MMSD is also purchasing and protecting open space to reduce stormwater runoff and improve water quality in its urban waterways. The capital budget designates funds to purchase privately owned wetlands to prevent development and establish conservation easements. More than $27 million has been allocated for fiscal years 2000 through 2011. As of fiscal year 2005, 775 acres had been purchased in three watersheds for just under $5.8 million.[36] A greenways initiative will identify lands that compose greenway connections, linkages between sites, delineated environmental corridors, isolated natural wetlands, open space, and riparian wetlands. Linkages between these areas will be acquired to protect and establish greenways along jurisdictional waterways or their tributaries. Preferential consideration is given to land that provides stormwater or flood management benefit.[37]

For Additional Information

Milwaukee Metropolitan Sewerage District: http://www.mmsd.com/home/index.cfm

Pittsburgh, Pennsylvania

"Restorative development" beautifies land and cleans water

Population: 325,000

Type of green infrastructure used: green roofs; rain gardens, vegetated swales, and landscape; downspout disconnection/rainwater collection; wetlands, riparian protection, or urban forests

Program elements: used for direct CSO control

Pittsburgh is a postindustrial city struggling to repair the environmental degradation wrought by its manufacturing past. The city's development as a steel powerhouse and mining center is intrinsically tied to its geographic and hydrologic setting. The city has developed around the confluence of three rivers—the Allegheny, the Monongahela, and the Ohio. Over the past two decades Pittsburgh's metropolitan population has declined, partly due to the collapse of the steel industry. The city's population decreased by 9.5% in the 1990s and the entire metropolitan area saw a decline of 1.5%, trends that were significantly greater than other same-size cities in the northeastern central area.[38] The "steel city" is left with pollution nuisances like brownfields and slag heaps, as well as a shrinking urban center and a considerable sewage overflow problem.

It is precisely because of this industrial reputation and declining urban center that Pittsburgh has had the opportunity and the incentive to redevelop and reclaim large land parcels and turn them into greenways and parks. The restoration, described as "restorative redevelopment," is motivated by a desire to restore habitat, beautify land, increase parkland, and raise property values—in all, generally making Pittsburgh a more attractive city.[39] Pittsburgh's efforts in alternative stormwater management have been a combination of government-sponsored restoration of green space and privately funded demonstration sites. The impetus for Pittsburgh's green restoration comes largely from the private sector, charitable foundations, and citizens' groups.

Water Pollution from Pittsburgh's Sewer System

Pittsburgh clearly has a need for supplemental stormwater management projects. The city's stormwater runoff contributes to frequent CSOs. In 2003, red-flag advisories for impaired water quality were issued on 111 out of 139 summer recreation days (from May 15 to October 1). In 2004, 125 red-flag advisories were issued.[40] The metropolitan area contains more than 300 combined sewer outfalls and over 4,000 miles of underground pipes. Many of these outfalls are upstream of drinking water intakes. Solving Pittsburgh's wet weather sewage problems is a complicated problem that is

The green roof surrounding the executive offices on the Heinz 57 Center in Pittsburgh not only provides environmental benefits, but also creates green space for outdoor meetings and employee enjoyment 14 stories above the ground.
PHOTO COURTESY OF ROOFSCAPES, INC.

exacerbated by the fragmented nature of the collection and treatment system. While there is one treatment plant operated by the Allegheny County Sanitary Authority (ALCOSAN) in the metro area, there are 83 separate municipalities, each responsible for maintaining their own collection system. Many pipes are in a state of disrepair, and ALCOSAN estimates that repairing the system using traditional sewage infrastructure strategies will cost more than $3 billion. This investment includes an expansion of the wastewater treatment plant capacity over the next 20 years from 225 million gallons per day (mgd) to 875 mgd to reduce CSOs. However, 565 mgd of this increased capacity would only provide primary treatment.[41]

Against this troubled environmental background, the private sector and citizens' groups in Pittsburgh have taken an active role to design and implement green infrastructure projects. Several demonstration projects have focused specifically on stormwater capture or treatment.

Pittsburgh's Green Infrastructure Commitment

Pittsburgh's Phipps Conservatory and Botanical Gardens is undergoing a major expansion and, when complete, will boast over 15,000 square feet of green roofs.[42] The conservatory will capture rainwater from its glass roofs and store it in a cistern to be used later to regulate water levels in ornamental ponds. The facility will feature a green roof test garden and a 30-by-100-foot rain garden in a low-lying site near the impervious parking areas.[43]

The McGowan Institute for Regenerative Medicine, built on a brownfield site, collects rainwater from the roof for gray water needs and irrigation. The facility reuses 57% of rainwater falling on the site, retaining 168,000 gallons of stormwater annually.[44]

As a LEED™ Gold certified building, Pittsburgh's David L. Lawrence Center is the world's first certified green convention center. Through stormwater reclamation, the facility reduces its potable water use by approximately 60%. It has an in-house water treatment plant to recycle black water and features a stainless steel roof that reduces total suspended solids in stormwater runoff.[45] By capturing and reusing rainwater on-site, each of these projects decreases the amount of stormwater that would have otherwise entered the combined sewer system.

Nine Mile Run and Frick Park. One of Pittsburgh's key restoration efforts is the $7.7 million project currently under way at Nine Mile Run, one of the

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last remaining daylit streams in the city. [46] The stream flows underground through several neighborhoods and daylights in Frick Park, a 455-acre natural and recreation area. Before its confluence with the Monongahela River, Nine Mile Run collects stormwater runoff from a seven-mile watershed with 43% impervious surfaces.[47] A number of environmental problems contribute to the stream's impairment. To accommodate development, Nine Mile Run was culverted and no longer flows in its natural meandering pattern, inhibiting its function as a wildlife habitat. In wet weather conditions, stormwater discharges increased stream flow in Nine Mile Run, eroding much of the stream bank. The altered hydrology in the watershed leaves little water in the stream during dry weather conditions, making it unable to support aquatic life. The stream also borders a 238-acre mountain of slag; runoff from the slag increased the natural pH of the stream. As with most Pittsburgh waterways, Nine Mile Run is also the conduit for many combined sewer overflows.

The Army Corps of Engineers is undertaking the main portion of the project to clean up Nine Mile Run under authority of Section 206 of the Water Resources Development Act of 1996. The project is a large-scale effort that will include the construction of woody and herbaceous wetlands to provide both wildlife habitat and stormwater filtration. The stormwater management component of the project takes advantage of Pittsburgh's porous and permeable soils to capture recharge and attempts to prevent pollutants in stormwater from reaching the stream. In an effort to repair the stream and re-create more natural conditions, the new river design adds meanders and pool and riffle sequences, undoing channelization. The project also fits into the city of Pittsburgh's larger Riverfront Development Plan, which includes land conservation along stream banks to prevent runoff and erosion and increased set-asides for recreational trails along Nine Mile Run.[48] The restoration effort will add an estimated 100 acres to Frick Park.

The restoration would not be as effective without corresponding attempts to reduce sources of wet weather pollution to Nine Mile Run. The municipal contribution to the project, $2.7 million, is designated to repair sewer lines, preventing leakages due to old, failing pipes. The city has also partnered with a developer to transform the slag heap, a brownfield site, into a 710-home residential development. Aiding in this effort are groups like 3 Rivers Wet Weather Demonstration Program and the Nine Mile Run Watershed Association. The community groups commissioned an engineering study to determine where rain barrels would be most effective in reducing the stormwater runoff that contributes to CSOs. The organizations installed 500 large rain barrels (132 gallons each) in critical neighborhoods.[49] The groups focused on the educational component of the project to make homeowners aware of lot-level solutions to stormwater management.

For Additional Information

Nine Mile Run Watershed Association:
http://www.ninemilerun.org/

Portland, Oregon

Making green infrastructure a policy priority

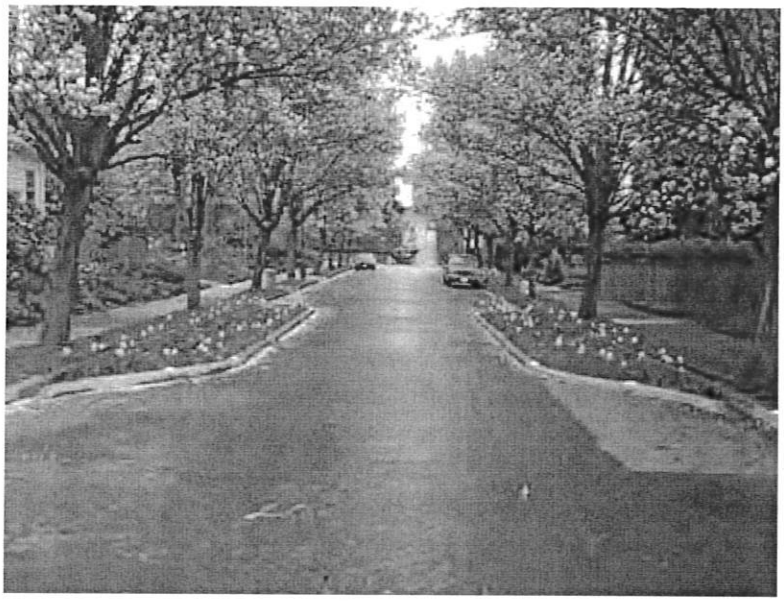
Population: 539,000

Type of green infrastructure used: green roofs; rain gardens, vegetated swales, and landscape; downspout disconnection/rainwater collection

Program elements: used for direct CSO control; established municipal programs and public funding

Portland has actively promoted funding and education for innovative stormwater management since 1998 and boasts numerous green applications throughout the city. These projects feature many types of green infrastructure technologies, including bioswales, green roofs, infiltration planters, and sustainable street design. The city has been at the leading edge of the green infrastructure movement and is beginning to accumulate significant data on the effectiveness of decentralized stormwater management technologies.

As with many cities, part of the motivation to achieve more successful stormwater strategies comes from a history of pollution and a desire to repair nearby ecosystems. One of Portland's primary



Vegetated curb extensions decrease stormwater runoff in Portland neighborhoods.

PHOTO COURTESY OF THE PORTLAND BUREAU OF ENVIRONMENTAL SERVICES

ecological concerns is the Willamette River, which in the course of its flow takes with it a considerable volume of combined sewer overflow. In 2004, Portland experienced 50 overflow events and discharged 2.8 billion gallons of combined overflow into local waterways.[50] In some areas, undersize combined sewers cause basement sewer backups, requiring homeowners to sanitize their basements after sewage backs up into their homes. Stormwater has also transported toxic pollution into area water bodies. Portland Harbor, the industrialized lower portion of the Willamette, was designated an EPA superfund site for contaminated sediments. Investigations into the contribution of overland stormwater flow and other sources of this heavy-metal pollution are under way.

Portland's Dual Approach to Managing CSOs

To alleviate these pressing CSO management problems, Portland has pursued a dual approach, expanding its public infrastructure and pursuing lot-level strategies to manage stormwater.[51] The "Big Pipe" is Portland's primary combined sewage control solution, adding capacity to the overloaded sewer system. In recent years, the city has made considerable progress toward reducing overflows. The constructed capacity, along with other projects, has virtually eliminated CSOs to the Columbia Slough, which discharges into the Willamette River, and has eliminated or controlled eight Willamette River CSO outfalls. When the projects are completed in 2011, CSOs to the Willamette will be reduced by 94%.[52] These strategies are estimated to cost around $1.4 billion and are funded by local sewer charges.[53]

To complement the large infrastructure projects, Portland is installing green infrastructure as an innovative stormwater management approach. Green infrastructure is gaining popularity in Portland for several reasons, including climate, development patterns, and policy institutionalization. Portland's rainfall occurs mostly in small frequent storms, exactly the type of precipitation event green infrastructure technologies are most successful at mitigating. About half of Portland's land area is impervious, 25% attributable to streets, and 40% attributable to rooftops.[54,55] These surfaces create an opportunity and a need for green infrastructure development.

Portland has also encouraged sustainable stormwater management through a series of policy initiatives. City code now requires on-site stormwater management for new development and

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redevelopment. Portland's stormwater manual encourages the use of green infrastructure techniques to meet this objective. Together, the city of Portland's Bureau of Environmental Services (BES) and the EPA jointly fund the Innovative Wet Weather Program, a grant program for stormwater management projects that focus on water quality improvement. In 2004, budgeted expenditures for a long list of proposed projects totaled almost $3 million.[56] New city-owned buildings are required to have a green roof that covers at least 70% of the roof area; the remaining roof area must be covered with Energy Star roofing material.[57] The city offers a zoning bonus, allowing for additional square footage for buildings featuring a green roof, and in 2006 it will begin offering a stormwater fee discount of up to 35% for properties with on-site stormwater management.[58,59] These programs are built upon the successful participation in the downspout disconnection program, in which homeowners can receive $53 per downspout disconnected from the combined sewer system. The city estimates that more than 45,000 households participate in the program, allowing infiltration of more than 1 billion gallons of stormwater annually.[60,61] The on-site stormwater management requirement, along with incentive programs for installing green infrastructure, will likely lead to more widespread applications throughout the city.

Street-level stormwater management. In 2003, Portland installed the Northeast Siskiyou Street vegetated curb extensions to capture stormwater while creating an attractive landscaped area. To assess the effectiveness of the technology and gather data for future projects, the city conducted flow tests to ensure water would be infiltrated in the right-of-way. The vegetated curb extensions reduced peak flow from a 25-year storm event (approximately two inches in six hours) by 88%.[62] This is enough retention to protect local basements from flooding. The curb extensions also reduced total runoff (2,000 gallons in the simulation) to the combined sewer system by 85%.[63] The project took about two weeks to install and cost approximately $15,000.[64] Portland has also installed curb extensions on Southeast Ankeny Street and is planning additional green street projects at the intersection of Southwest 12th Avenue and SW Montgomery Street and the intersection of Northeast 131st Avenue and Northeast Fremont Street.

Portland's "ecoroofs." In 1996, the first green roof in Portland was installed. In the years since, Portland has begun an initiative to install and monitor green roofs at sites throughout the city. The city prefers the term "ecoroofs" to illustrate that even in the dry season when roofs are not as green, the roofs can still perform well.[65] Portland also uses the term to emphasize the economic benefits of the vegetated technology. The city conducted extensive monitoring studies on Hamilton West Apartments, a 10-story building with two ecoroof components, one measuring 2,520 square feet and the other 2,620 square feet. Based on two years of monitoring data, BES found that the four- to five-inch thick, 25-pound-per-square-foot ecoroof retained 58% of rainfall, preventing it from becoming stormwater runoff. Monitoring has also shown that the ecoroofs absorb almost 100% of the rainfall from Portland's warm season precipitation events.[66]

Some of Portland's other interesting stormwater sites include the Oregon Museum of Science and Industry, where swaled medians were installed around the museum parking lot to capture stormwater. The museum saved $78,000 by installing the green infrastructure technology over a traditional collection system.[67] The Liberty Centre Parking Garage installed infiltration planters as a stormwater retrofit. These planters accept runoff from more than 36,000 square feet of impervious surfaces and can retain the entire volume of a storm slightly smaller than the typical two-year storm event. The cost for this retrofit was $75,500.[68] The Oregon Convention Center rainwater garden collects stormwater from 5.5 acres of roof area.[69] The garden simulates a mountain stream, doubling as an attractive landscape space. The project is designed to handle the runoff from a 25-year storm. A recent stormwater management project is a ring of interconnected bioswales

around the New Seasons Market at Seven Corners Southeast Division Street. This project reduces impervious surfaces and will remove 1 million gallons of stormwater annually from the combined sewer system.[70] All of these projects will be eligible to apply for the stormwater fee discount when it is fully implemented in mid-2006.

New Directions in Portland's Green Infrastructure: The Stormwater Trading Program

The city was recently awarded a $288,000 U.S. EPA grant for a feasibility study to determine the viability of a stormwater trading program. As conceptualized, the trading program would allow developers who were unable to satisfy the on-site stormwater management requirement to privately finance or buy credits for stormwater mitigation elsewhere within the city, provided that the purchased credit met water quality and discharge volume requirements. The initial cost of the stormwater credits would likely be based on the cost of a publicly financed program. The first phase of the study will determine if the approach is economically beneficial and if the program can provide acceptable environmental results. If the trading approach is determined to be feasible, later phases of the study will outline the model approach, determine the geographic trading area, select appropriate best management practices, and develop economic models for program valuation. In later phases, the city also plans to demonstrate the operation of the trading system through pilot program implementation.[71]

For Additional Information

Portland Bureau of Environmental Services: http://www.portlandonline.com/bes

Rouge River Watershed, Michigan

Cleaning up the watershed with green approaches to stormwater management

Population: 1.5 million

Type of green infrastructure used: green roofs; rain gardens, vegetated swales, and landscape; permeable pavement; wetlands, riparian protection, or urban forests

The Rouge River Watershed in southeast Michigan covers nearly 450 square miles and is home to the historically industrial city of Detroit. Fifty percent of the watershed is urbanized, and more than 1.5 million people live within its boundaries.[72] As a tributary and major pollution source to the Detroit River, the Rouge River was designated an Area of Concern by the International Joint Commission in the Great Lakes.[73,74] With industrial and municipal wastewater discharges believed to be effectively permitted and controlled, the focus of the water restoration efforts in the watershed has shifted to addressing wet weather pollution. Stormwater runoff was responsible for creating excessive flow within the river, damaging stream banks and riparian habitat, introducing pollutants, and causing CSOs.

In 1992, the Wayne County, Michigan Department of the Environment initiated the Rouge River Project to address wet weather pollution within the watershed. The project is funded by U.S. EPA grants and municipal funding and serves as a national demonstration project for reclaiming degraded urban rivers.[75] An assessment of the watershed in the mid-1990s found that stormwater runoff had many deleterious effects on water quality and river health. Increased river flows from stormwater discharges had eroded 60% to 90% of the river banks on the Rouge River's major branches.[76] Soil washed from the river banks was deposited along the river bottom downstream, degrading natural stream habitats. Stormwater runoff and pollution had not only contributed to a decline in river fish populations, but also a number of consumption bans and advisories. Nutrient loadings caused seasonal decreases in river oxygen levels, and increased river bacteria counts and resulted in swimming advisories.[77]

Evaluating the most effective means of improving the water quality of the river, the Rouge River Project adopted a watershed-based approach for wet weather pollution control. The first step in this approach was the 1997 adoption of the Michigan NPDES General Stormwater Permit. The permit is unique because the watershed communities requested permission from the U.S. District Court overseeing the river cleanup to develop a draft permit acceptable to the communities and state and federal regulators. The

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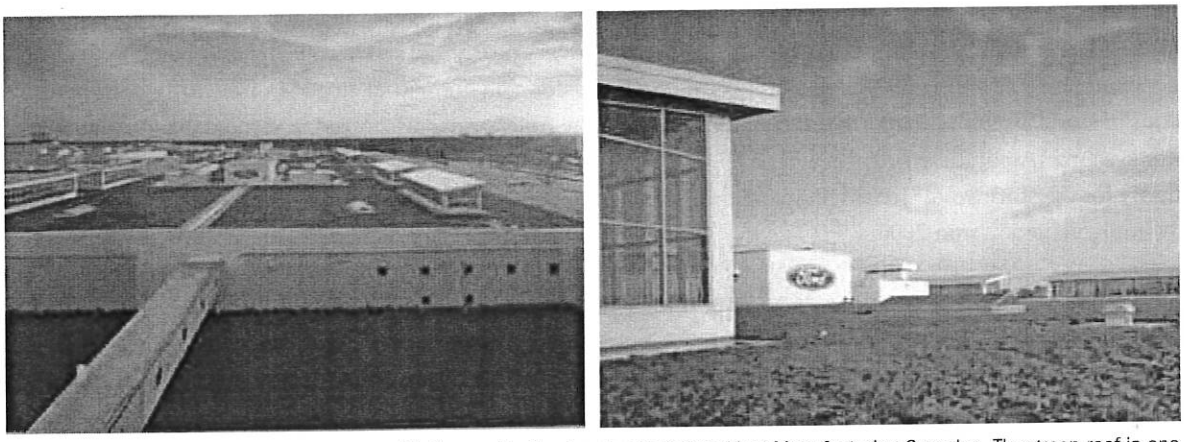

At more than 10 acres, the largest green roof in the world sits atop Ford's Rouge River Manufacturing Complex. The green roof is one component of a renovation designed to make the facility more environmentally sustainable. PHOTOS COURTESY OF GREEN ROOFS FOR HEALTHY CITIES

consensus effort resulted in a watershed-based permit that required each community to develop a watershed management plan and stormwater pollution prevention initiative. The U.S. EPA has supported Michigan's request to continue to use the general permit in lieu of permits that would be required by the Phase II regulations.[78,79]

Watershed Restoration Through Green Infrastructure

Green infrastructure practices have been used as part of watershed management plans to address stormwater pollution. Although highly urbanized, more than 50 miles of riparian parklands are publicly maintained with the watershed.[80] Watershed restoration efforts have also included the use of created and existing wetlands for stormwater management. The Inkster Wetlands demonstration project uses 14 acres of wetlands adjacent to the Rouge River to treat stormwater before it enters the river. Three separate wetlands areas are part of the project and are composed of forested, emergent, scrub, and open water wetlands. Approximately nine of the 14 acres are constructed wetlands.[81] Prior to the project, discharge pipes routed stormwater past the existing wetlands and directly to the river. In addition to creating new wetlands for stormwater treatment, the demonstration project rerouted stormwater through the existing wetlands. The project was completed in 1997 at a cost of $465,000.[82] A five-year monitoring study evaluated the effectiveness of the wetlands at improving the quality of the stormwater runoff. In addition to dampening stormwater flows, the wetlands reduced concentrations of total suspended solids by 80%, total phosphorus by 70%, BOD by 60%, and heavy metals by 60%.[83]

Ford Motor Company's green roof. Located along the Rouge River, Ford Motor Company's 88-year-old, 600-acre Rouge River Manufacturing Complex in Dearborn, Michigan, recently underwent a $2 billion renovation. The renovation of Rouge River was unique because of Ford's decision to make the manufacturing plant a more environmentally sustainable facility. Green infrastructure was an important component of this effort. The complex includes a 450,000 square foot green roof to retain stormwater, lower energy costs, and extend roof life.[84,85] At over 10 acres, the green roof is the largest in the world and is anticipated to absorb the first inch of rainfall.[86] Vegetated swales, planted with indigenous species, are used throughout the site to reduce stormwater discharges and encourage infiltration. New trucks rolling off the assembly line are taken to an outdoor parking lot paved with permeable pavement. A two- to three-foot gravel storage bed beneath the lot filters pollutants from the stormwater and provides storage capacity.[87] The renovation of the site also included the planting of more than 1,500 trees, 20,000 bushes, and 85,000 flowering perennials.[88,89]

For Additional Information

Rouge River Wet Weather Demonstration Project: http://www.rougeriver.com

Seattle, Washington

Using green infrastructure solutions to save sensitive waters

Population: 587,000

Type of green infrastructure used: green roofs; rain gardens, vegetated swales, and landscape; downspout disconnection/rainwater collection

Program elements: used for direct CSO control; established municipal programs and public funding

Located along the shores of Puget Sound and home to rivers and creeks that serve as salmon spawning grounds, Seattle is connected to the vitality of its water bodies. The 84 square mile city is highly urbanized and has an average annual rainfall of 37 inches, which occurs primarily during the region's wet months from November to February.[90] Stormwater runoff has long been identified as a threat to the aquatic habitat of Puget Sound and the sensitive salmon streams. Controlling stormwater in the urban watersheds is a complicated task in a city where the majority of development predated stormwater regulations.[91] Consequently, water quality in the region has been impaired and the hydrology of rivers and creeks has been altered because of increased stormwater volumes and flow rates.

Using Natural Drainage Systems to Manage Stormwater Runoff

In the late 1990s, the city decided to install green infrastructure in an effort to mitigate urban stormwater runoff. Seattle Public Utilities (SPU), the agency responsible for water and stormwater programs, developed pilot projects using the concept of natural drainage systems (NDS). The NDS program's goal was to develop a stormwater management system that resembled natural hydrologic functions lost to urbanization.[92] The initial outcome of this program has been innovative neighborhood and stormwater system designs with results exceeding initial expectations.

The Viewlands Cascade. Early this decade four NDS pilot projects were completed and have since been monitored to determine their effectiveness. These projects were designed to reduce stormwater runoff to Pipers Creek, a tributary of Puget Sound and home to wild coho salmon and both steelhead and cutthroat trout. The Viewlands Cascade was the first of these projects and uses a series of 16 stepped vegetated cells to collect stormwater runoff from approximately 72 acres. The system was designed to reduce the volume and flow rate of stormwater runoff by encouraging infiltration and vegetative uptake. The estimated construction cost was $225,000.[93]

Hydrologic monitoring of the Viewlands Cascade indicates that the system decreases stormwater runoff volume 75% to 80% and peak flow rates by 60%.[94] Performance is greater than average for small and medium storm events and considerably less than average for large events. Overall, during a three-year monitoring period, half of the total volume of stormwater that entered the cascade system was retained and not discharged to Pipers Creek.[95] The Viewlands Cascade replaced a partially concrete drainage ditch. Modeling indicates that the new cascade system retained three times as much stormwater volume and held stormwater in the system over 2.5 times longer when compared to the original drainage ditch.[96] In addition, the water quality of the stormwater discharged has improved because of the natural vegetation's biological and chemical removal capabilities.

The SEA Street Project. The 2nd Avenue Street Edge Alternative (SEA) Street project was the second pilot project and one of the better known green infrastructure projects in the country. The project redesigned an entire 660-foot block of 2nd Avenue with a number of green infrastructure techniques, with the goals of reducing stormwater runoff and providing a livable community. SPU worked collaboratively with residents during the process to develop the final street design.

The original 25-foot-wide straight street was replaced with a 14-foot-wide curvilinear street. Vegetated swales, designed to infiltrate and treat

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This private residence in Seattle, WA, incorporates stormwater controls and vegetative gardens.

PHOTO COURTESY OF SEATTLE PUBLIC UTILITIES

stormwater, were installed within the right-of-way on both sides of the street. Street parking was replaced with designated angled parking slots, and a sidewalk was installed on one side of the street. The final constructed design reduced imperviousness more than 18% and added 100 evergreen trees and 1,100 shrubs.[97] The original construction cost bid was $244,000. The final total project cost was approximately $850,000, with the substantial increase attributed to costs associated with significant community outreach and coordination as well as design modifications to address community concerns.[98]

Hydrologic monitoring of the project indicates a 99% reduction in total potential surface runoff. Stormwater retention capacity has increased since the project was completed. Stormwater runoff has not been recorded at the site since December 2002, a period that included the highest ever 24-hour recorded rainfall at SeaTac Airport. Reasons for the increased stormwater retention are unclear, but it is speculated that the maturing vegetation takes up more water and increasingly aids infiltration.[99]

Design estimates originally anticipated that the site would attenuate up to 0.75 inches of rain. Monitoring has indicated that the site is able to attenuate a substantially larger rainfall amount. The SEA Street design was expected to reduce total stormwater discharge from the site by 42% and by 66% when compared to a conventional Seattle street with curb and gutter. A modeling analysis indicates that if a conventional curb and gutter system had been installed along 2nd Avenue instead of the SEA Street design, 98 times more stormwater would have been discharged from the site.[100] The SEA Street design has been so popular that local residents have requested that their traditional streets be retrofitted.

Both the Viewlands Cascade and 2nd Avenue SEA Street have been successful at managing stormwater runoff. There is, however, a large functional difference between the two projects. The Viewlands Cascade collects and treats runoff from a designated drainage area once it has been generated as an end-of-pipe treatment focused on reducing peak stormwater flows; the 2nd Avenue SEA Street is designed as a source control strategy intended to prevent the discharge of stormwater from the project site. The success of both projects demonstrates that green infrastructure is adaptable and may be used in various capacities. SPU has incorporated both designs into a number of projects recently completed or currently under construction.

The 110th Street Cascade. The 110th Street Cascade is also located in the Pipers Creek Watershed and is

designed to treat runoff from a 28-acre drainage basin. Monitoring at the cascade is measuring flow rate and water quality.[101] Completed in early 2005, the Broadview Green Grid project reconstructed an entire neighborhood's drainage system in a 32-acre sub-basin in the Pipers Creek Watershed. The project used both SEA Street designs and cascade systems. The north-south streets in the project area were reconstructed using the SEA Street design. Each of these streets discharges to an east-west flowing system of vegetated swales and cascades.[102] The Pinehurst Green Grid, a second neighborhood scale reconstruction project, is in the construction phase.

The High Point Redevelopment is under construction and is one of the city's largest recent redevelopment efforts. Forty blocks will be redeveloped in a 129-acre mixed income housing area to eventually contain 1,600 units. The project area is 65% impervious and densely populated. The NDS design will incorporate approximately 22,000 feet of vegetated and grassy swales and is scheduled for completion in 2007.[103] In 2004, the NDS program received an Innovations in American Government Award from Harvard University's Kennedy School of Government. The award, accompanied by a $100,000 grant, highlights effective government projects.[104]

In addition to the NDS design concept, the city of Seattle also promotes rainwater harvesting. The 327,000 square foot King Street Center uses three 5,400 gallon tanks to collect rainwater from the building's roof. The collected rainwater is filtered and pumped through a dedicated piping system for toilet flushing and landscaping needs. The system provides 1.4 million of the approximately 2.2 million gallons—60%—of the toilet flushing water needed annually and reduces the stormwater discharged from the building by the same amount.[105]

In March 2005, SPU began the second phase of a subsidized rain barrel and cistern program intended to distribute the rainwater-harvesting devices throughout the city. The first phase of the program distributed 1,500 rain barrels at a reduced rate to private homeowners.[106] In addition, SPU initiated the Freemont rainwater harvesting study on March 1, 2005. The project, conducted with the cooperation of 10 single-family residential homeowners in the combined sewer area, is studying the effectiveness of slowly draining cisterns to retain peak stormwater runoff. The costs of the program will be compared to the costs of detaining an equal volume of wastewater in centralized vaults before being metered out to the municipal wastewater treatment plant. The project will also test the acceptance and effectiveness of rain gardens in the residential area.[107]

Another approach to mitigating stormwater runoff is green roofs. The city of Seattle has installed four green roofs over the past several years. In order to evaluate the ability of these green roofs to reduce stormwater runoff, the city is embarking on a multiple-year data collection initiative. The goal is to provide information that can be used to modify the city's stormwater code and potentially provide incentives to encourage the construction of green roofs in both public and commercial applications.

Seattle has also begun an urban forestry initiative to reduce stormwater runoff. A master plan for planting trees on city streets implemented in 1999 established a goal of increasing the city's tree canopy from 27% of city surface area to 40%.[108]

For Additional Information

Seattle Public Utilities Natural Drainage Systems: http://www.ci.seattle.wa.us/util/About_SPU/Drainage_&_Sewer_System/Projects/Natural_Drainage_Systems/NATURALDR_20031203121352.asp

Toronto, Ontario, Canada

A long-term "Water Pollution Solution" focuses on green infrastructure

Population: 2.5 million

Type of green infrastructure used: green roofs; downspout disconnection/rainwater collection; wetlands, riparian protection, or urban forests

Program elements: established municipal programs and public funding

Covering 240 square miles along the shores of Lake Ontario, Toronto is the largest city in Canada,

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with 2.5 million residents. The entire Toronto metropolitan region has a population of 4.5 million people spread out over 560 square miles. This vast urban expanse is also home to an extensive infrastructure network with 2,800 miles of storm sewers and over 2,600 outfalls.[109] Like the Great Lakes cities in the United States, Toronto's urban stormwater is a leading cause of water pollution in Lake Ontario and its tributaries and necessitates expensive investments directed toward CSO mitigation and stormwater management. Toronto and its surrounding watersheds are part of an Area of Concern under a Remedial Action Plan (RAP), a policy designation derived from amendments to the 1972 bilateral Canada-U.S. Great Lakes Water Quality Agreement. The Toronto RAP covers Toronto Bay and six watersheds: Etobicoke Creek, Mimico Creek, Humber River, Don River, Highland Creek, and Rouge River. Goals include the restoration of drinkable, fishable, swimmable, and aesthetically pleasing water and habitat areas.[110] The RAP explicitly highlights pollution from urban stormwater runoff as one of the primary sources of ecosystem degradation to this region.[111]

Faced with the difficult challenge of limiting stormwater runoff and pollution, Toronto has developed a unique policy approach for managing stormwater with the goal of eliminating adverse effects of wet weather flows and achieving measurable improvement in ecosystem health within the watershed.[112] In July 2003, Toronto's City Council approved a 25-year stormwater plan, the Water Pollution Solution, formerly called the Wet Weather Flow Management Plan. This plan is a comprehensive strategy to deal with surface water quality and quantity, sewage overflows, and habitat protection. Toronto's approach includes increasing traditional methods of stormwater storage capacity and improving conveyance structures, but it also includes greener approaches, especially for some short-term solutions.

Toronto's Four Principles of Stormwater Management

The Wet Weather Plan is explicitly based on four innovative principles for stormwater management: (1) recognizing rainwater and snowmelt as a valuable resource; (2) managing wet weather flows on a watershed basis; (3) implementing the hierarchy of wet weather practices beginning with "source," then "conveyance," and lastly, "end-of pipe" solutions; and (4) educating communities and involving the public.[113] Capital costs for the program are estimated to be around $800 million; operational and maintenance costs are expected to be around $13 million annually.[114] The city has earmarked $200,000 annually for community projects that contribute to the Water Pollution Solution.[115]

Toronto's program involves a significant downspout disconnection effort to prevent runoff from entering both the stormwater and combined sewer systems. The city will disconnect residences for free and provide splash guards or rain barrels to protect residential foundations. As of June 2000, Toronto estimated that approximately 20,000 homes had been disconnected.[116] Downspout disconnection efforts have been targeted at areas that either experience localized flooding or have a significant runoff impact on Toronto's beaches.

Toronto has made extensive use of the natural filtering and flood control capacity of wetlands and vegetated areas to help achieve the goals of the RAP. The city has embarked on wetland and stream restoration programs to facilitate stormwater management that will achieve cleaner streams and enhanced wildlife habitat. Toronto is committing $106 million for the capital costs to restore over 40 miles of streams, and expects operation and maintenance costs for this stream restoration to be roughly $500,000 per year.[117] Several wetlands have already been restored, including Chester Springs Marsh, a 7.5 -acre wetland restored on the site of an old landfill. This particular wetland was restored specifically to prevent nutrients and pollutants from reaching the Don River. Wetlands originally performed this filtering function before the Don was channeled in the late 19th century.[118] The recovered area has witnessed a substantial increase in the number of species that visit the site, spurring city plans to build and restore several more wetlands.

Toronto's green roofs. Toronto has also become a center for green roof technologies. While not explicitly part of the stormwater plan, the green roof initiatives are expected to have an impact on stormwater mitigation. Based on an Environment Canada study, the nonprofit industry association Green Roofs for Healthy Cities estimates that greening 6% of Toronto's roofs would cost about $36 million over 10 years and would retain almost 1 billion gallons of stormwater annually.[119] In 2002, several Canadian organizations announced the Green Roof Infrastructure Demonstration Project, a public-private partnership that will fund more than $800,000 in green roof costs.[120]

Toronto currently has over 100 green roofs, including an intensive installation on the Toronto City Hall and an extensive installation on the gymnasium roof of the Eastview Neighbourhood Community Centre.[121] The National Research Council's Institute for Research in Construction installed a monitoring system on the Eastview roof to measure both quality and quantity of stormwater runoff.[122] Early findings from an upcoming study to investigate the potential for widespread green roof installations in Toronto (*The Municipal Cost Savings Benefits of Green Roofs*) indicate 57% average annual flow reductions from the Eastview green roof plots compared to traditional roofs.[123] The plots also showed peak flow rates of 25% to 60% during summer and 10% to 30% in late fall of those measured from conventional roofs.[124] These preliminary monitoring results were achieved before vegetation had reached maturity.

A Ryerson University study evaluated the municipal level benefits and costs of wide-scale implementation of green roofs in Toronto. For the study, a Geographic Information Systems (GIS) database was used to model and aggregate environmental benefits and a methodology was developed to monetize these benefits. The study assumed that green roofs would be installed on all city flat roofs more than 3,750 square feet and would cover at least 75% of the roof. Using this assumption, more than 12,000 acres of green roofs, representing 8% of the total land area in the city, could be installed in Toronto.[125]

The study findings estimated nearly $270 million of municipal capital cost savings and more than $30 million in annual savings with this number of installed green roofs. Five primary benefits were quantified in the study: (1) reduced stormwater flows into the separate storm sewer system, (2) reduced stormwater flows into the combined sewer system, (3) improved air quality, (4) mitigated urban heat island effects, and (5) reduced energy consumption. The study estimated more than $100 million in stormwater capital cost savings, $40 million in CSO capital cost savings and nearly $650,000 in CSO annual cost savings.

The researchers anticipate that the only costs to the city will be those to promote green roofs, although the city will also likely incur costs to monitor design and construction of the green roofs. The cost to retrofit existing roofs with green roofs is likely to be borne by private industry during the normal maintenance cycle. Recent green roof projects in Canada have averaged $6 to $7 per square foot, suggesting a total cost of $3 billion to $3.7 billion for 12,000 acres of green roofs.[126,127] While the total cost to install the green roofs is large, it would be spread across numerous building owners and developers. The additional cost of a green roof for the minimum area roof in the study, 3,750 square feet, would be $22,000 to $27,000.

For Additional Information

City of Toronto—Protecting Water Quality: http://www.toronto.ca/water/protecting_quality/index.htm

Vancouver, B.C., Canada

Creative green design for city parks and roads

Population: 600,000

Type of green infrastructure used: green roofs; rain gardens, vegetated swales, and landscape; permeable pavement; wetlands, riparian protection, or urban forests

Program elements: established municipal programs and public funding

Situated 25 miles north of the U.S.-Canadian border and bounded on three sides by water,

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Vancouver is the third largest city in Canada. While the city covers an area of 44 square miles, the entire metropolitan area is nearly 1,100 square miles and home to approximately 2 million people.[128] Almost 90% of the 44 square mile city center is developed.[129] Often recognized as one of the best cities in the world in which to live, Vancouver was ranked third in a 2005 survey assessing the quality of life in 215 cities worldwide.[130] However, even one of the world's most highly regarded cities is not immune to the effects of urbanization and stormwater runoff.

Vancouver sits in the Fraser River Valley, the most productive salmon fishery in the world. An estimated 800 million juvenile salmon from five different species migrate along the Fraser River each year. Eighty additional species of fish and 79 species of birds rely on the Fraser River and its estuary for critical habitat and migratory routes.[131,132] With Rocky Mountain snow melt composing the majority of the source water in Vancouver, good water quality has historically been an attribute of Vancouver area watersheds. But within the past half century, urbanization and stormwater have begun to degrade the area's waters. Combined sewers constitute more than 60% of the city's collection system, and combined sewer overflows and separate stormwater runoff have been identified as leading causes of local water pollution.

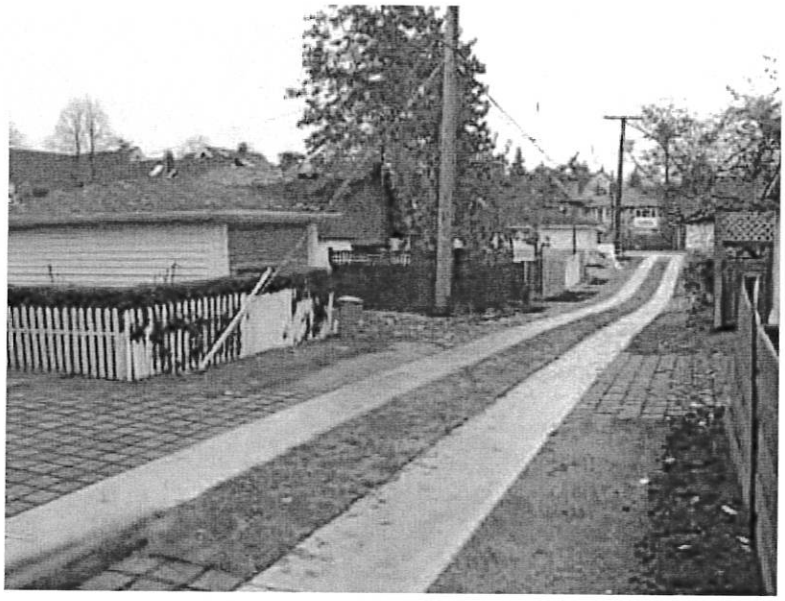
Creating More Permeable, Pedestrian-Friendly Green Space

The city has begun using green infrastructure to address a range of environmental problems. Because Canada is a signatory of the Kyoto Protocol, many of Vancouver's green infrastructure efforts are focused on climate and air benefits, but some are specifically targeted at stormwater. To address stormwater runoff from roadways, Vancouver has initiated a number of innovative street design projects as part of the city's Greenways Program. The program is focused on introducing pedestrian-friendly green space into the city to connect trails, environmental areas, and urban space. This greenway initiative has also developed innovative strategies to manage roadway stormwater. One of these projects is the Crown Street redevelopment project.

Prior to the redevelopment project, stormwater runoff from Crown Street flowed untreated into the last two remaining salmon-bearing creeks in Vancouver.[133] In 2001, residents along a 1,100-foot block of the street petitioned the city to rehabilitate the deteriorating street using conventional curb and gutter. In response, the city recommended a naturalized streetscape

Crown Street just after construction and prior to swale planting.

PHOTO COURTESY OF CITY OF VANCOUVER GREENWAYS PROGRAM



Vancouver's first Country Lane installed in 2002.

PHOTO COURTESY OF CITY OF VANCOUVER GREENWAYS PROGRAM

design modeled after the Seattle SEA Street design. The naturalized design narrowed the impervious street width from 28 feet to 21 feet (certain one-way sections of the road were narrowed to 10 feet) and incorporated roadside swales with structurally supported grass to collect and treat stormwater through infiltration. The redesigned street will retain 90% of the annual rainfall volume on site; the remaining 10% of runoff will be treated through a system of vegetated swales before discharging.[134,135] Construction was completed in early 2005 at a cost of $707,000.[136] A conventional curb and gutter design would have cost approximately $364,000; however, because Crown Street was the first of its kind in the city, an estimated $311,000 was spent on additional aesthetic design features and consultant fees that would not be necessary for future projects. Eliminating the project-specific additional costs would bring the cost of retrofitting existing streets with naturalized street design projects in line with conventional drainage systems; however, the city estimates that installing naturalized street designs in new developments will be less expensive than conventional drainage systems.[137,138] In cooperation with the University of British Columbia, Vancouver will monitor the street for the next five years to assess the quality of stormwater runoff. Results will be compared with a nearby curb and gutter street to confirm modeling projections.

The Country Lane Program. Another example of green design within Vancouver's Streets Department is the Country Lane Program to replace traditional highly impervious alleys and lanes with a more permeable alternative. Asphalt lanes are replaced with two concrete or gravel strips surrounded by structural grass (structural grass is supported by a grid and soil structure that prevents soil compaction and root damage). Connections from the country lane to residences are constructed of permeable materials, including paving blocks, broken concrete sections, and structural grass or gravel. Three Country Lanes were installed as a pilot project to introduce green space and encourage on-site infiltration of stormwater. The initial cost of a Country Lane was approximately $71 per linear foot, which is four times greater than the typical alley cost of $18 per foot.[139,140] The city estimates that the cost of a Country Lane in 2006 will decrease to $30 per linear foot.[141,142]

The city is also installing infiltration bulges along roadways to collect and infiltrate street stormwater runoff. These installations are being done in conjunction with the Greenways program's efforts to improve

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Infiltration bulges capture and infiltrate stormwater before it reaches the collection system.

PHOTO COURTESY OF CITY OF VANCOUVER GREENWAYS PROGRAM

transportation corridors by making them more pedestrian friendly. The city is extending curbs at intersections out into the street to lessen the crossing distance and improve the line of sight for pedestrians. The city's stormwater catch basins are located at roadway intersections; when the bulges were constructed, the city was initially relocating these catch basins outside of the bulges. Now, in certain instances, the Streets Department is installing permeable soils and vegetation within these bulged sections to introduce green space and collect stormwater. The catch basins are left in place within the bulges and any stormwater that does not infiltrate into the soil overflows into the stormwater system. This new design not only reduces the amount of stormwater runoff, but is also less costly for the city. Because the stormwater infiltration bulges are installed in conjunction with planned roadway improvements, the only additional costs associated with the stormwater project are the costs of a steel curb insert to allow stormwater to enter the bulge and additional soil excavation costs. These additional costs are more than offset by the $2,400 to $4,000 cost of relocating the catch basins. To date, the city has installed nine infiltration bulges, three of which are maintained by local volunteers as part of a Green Streets program where local residents adopt city green space.[143]

Vancouver's green roofs. In addition to the street initiatives, Vancouver has also used green infrastructure in other applications. Green roofs have been used extensively in the greater Vancouver area, with more than 30 installations.[144] One of the best known of these roofs is installed on the Vancouver Public Library's Central Branch building. The 20,000 square foot green roof was installed in 1995 and planted as an artistic representation of the Fraser River. Monitoring of the roof during an eight-month period in 2003 and 2004 showed a 48% reduction in the volume of stormwater runoff from the roof when compared to a conventional roof. Peak stormwater flows were also reduced between 5% and 30% during the region's wet winter months; in the drier summer, peak flows were reduced more than 80%. As with other green roofs, peak reductions were the greatest for smaller, less intense storms and least for larger rain events.[145]

Biofiltration in Vancouver's parks. Vancouver has designed and installed two biofiltration systems, utilizing natural and reclaimed green space to treat stormwater runoff. One hundred sixty-seven acres of neglected, largely paved land were reclaimed and re-greened to create Hastings Park. The park provides Vancouver residents with green space in

a highly urbanized section of the city. Within the park is the biofiltration system referred to as the Sanctuary. This system receives stormwater runoff from a 300-acre residential area to the south of the park and uses natural biological processes to treat the runoff prior to discharging it to the Burrard Inlet.[146] The biofiltration pond was designed in conjunction with the sewer separation project that installed a new separate stormwater collection system in the neighborhood bordering the park. The Sanctuary also provides additional aesthetic and environmental benefits by serving as valuable habitat for wildlife and birds.[147,148]

A second biofiltration system is used in Stanley Park, a 1,000-acre urban park in Vancouver. The park is bisected by the Stanley Park Causeway, a major commuter route. Prior to the construction of the biofiltration wetlands, causeway runoff flowed untreated into the Lost Lagoon, Beaver Lake, and adjacent forests. To manage and treat this stormwater, runoff was directed to a wetland constructed within the Lost Lagoon. The wetland uses natural filtration and biological processes to treat the stormwater before it is discharged to the lagoon. The innovative stormwater wetland was built to harmonize with the existing green space of the park and to provide habitat for plants and wildlife. Areas of the wetland not open to the public provide necessary space for birds to remain undisturbed by human activity.[149,150]

For Additional Information

City of Vancouver Streets Design—Environmentally Sustainable Options: http://www.city.vancouver.bc.ca/engsvcs/streets/design/enviro.htm#lanes

Washington, D.C.

Using green infrastructure to combat years of river pollution

Population: 563,000

Type of green infrastructure used: green roofs; rain gardens, vegetated swales, and landscape; permeable pavement

Washington, D.C., sits at the confluence of the Potomac and Anacostia rivers and is home to a third, Rock Creek. These rivers in the nation's capital have historical and symbolic importance. The Potomac River is designated an American Heritage River and is often synonymous with the seat of the country's federal government. Unfortunately, Washington's rivers are also significantly affected by the large amount of urbanization surrounding them. Approximately 65% of the District is covered with impervious surfaces.[151] Development and urbanization have taken a toll on the natural features within the city; over the past 30 years, the District has lost 64% of its areas with heavy tree cover and experienced a 34% increase in stormwater runoff.[152]

Cleaning Up Washington's Most Polluted Waters Through Green Infrastructure

One-third of the city is served by a combined sewer system dating to the beginning of the 1900s and earlier. Estimated annual CSO discharges to the city's three rivers are 2.5 billion gallons.[153,154] The Anacostia River, which receives 60% of the CSO discharges, is one of the most polluted in the nation. Fifty percent of brown bullhead catfish collected for study from the river had cancerous liver tumors and approximately 25% had cancerous skin tumors.[155] The city's approved long-term CSO control plan (LTCP) will cost approximately $1.9 billion and focuses primarily on a deep tunnel system and sewer separation, but also recognizes the importance of incorporating green infrastructure within the city.

Low Impact Development at the Navy Yard on the Anacostia River. The Washington Navy Yard, along the banks of the Anacostia River, has been a notorious source of the river's water quality problems. The base has been subject to decades of military pollution and has been a main source of toxic water pollution. In 2001, the Navy Yard installed a number of green infrastructure pilot projects to manage stormwater runoff. Downspouts were disconnected and directed to rain barrels, and permeable pavement, rain gardens, and tree box filters were installed. These

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The first commercial high-elevation green roof in Washington, DC, will be monitored to determine how much it lowers air temperature.

PHOTO COURTESY OF THE CASEY TREES ENDOWMENT FUND

retrofits cost approximately $500,000 and are providing on-site management of stormwater previously directed to the combined sewer system. Monitoring of the site is ongoing and is determining the stormwater volume reductions, stormwater discharge frequency, and water quality improvements.[156]

Washington's green roofs. Washington's first commercial high-elevation green roof was installed in 2004. The 3,500 square foot green roof was a collaborative effort between two nonprofit organizations and the real estate company that owns the building. The air temperature of the green roof is being monitored and compared to the temperature of a 1,000 square foot section of the roof that was not converted.

Installing green roofs across the District is projected to provide a significant reduction of stormwater runoff and CSO volume. Based on computer modeling by Limno-Tech, Inc., Casey Trees has measured the effects of installing 20 million square feet of green roofs, 20% of the roof area for all city buildings over 10,000 square feet, over the next 20 years. Modeling results based on this coverage scenario show a citywide reduction in runoff of 1% and CSO discharges of 15%. The green roofs are anticipated to retain and store 430 million gallons of rainwater annually and increase proposed deep tunnel storage capacity by 30 million gallons because of the decrease in rooftop runoff.[157]

Incorporating green infrastructure into DC's CSO and stormwater programs. The District's efforts with green infrastructure have not progressed as far as those in other case-study cities. However, a convergence of events presents the city with an opportunity to integrate green approaches into its overall stormwater and CSO control efforts. The 20-year implementation schedule to complete the LTCP provides an ideal window to incorporate green infrastructure into the District's pollution control plans. The District of Columbia Water and Sewer Authority (WASA), the regional agency responsible for implementing the LTCP, has allocated $3 million of the overall LTCP budget for advocating and assisting with green infrastructure retrofits.[158] Major redevelopment is also planned along the Anacostia River to complement the construction of the city's new baseball stadium.

Some of the most significant barriers to incorporating green infrastructure, or any stormwater or CSO controls, into existing urban areas are the cost and challenge of retrofitting these systems into built-out and space-constrained areas. The LTCP work and

Anacostia redevelopment lower these barriers because of the large capital investment that will accompany the projects and substantial overhaul and upgrade of associated infrastructure. These projects offer the opportunity to integrate green infrastructure from the start and take advantage of the associated cost savings. The city will also have the opportunity to learn from several major cities that have been successfully integrating green infrastructure into stormwater and CSO mitigation plans.

A number of the policy recommendations described earlier in this report could be used effectively to encourage green infrastructure. The District currently charges a nominal stormwater fee to its residents and commercial properties located in the separate sewer area. The stormwater fee could be restructured, similar to Portland, Oregon's model, to allow a rate reduction for those properties that install green infrastructure or manage stormwater on site. To be an adequate incentive, the current annual stormwater fee would need to be significantly increased. A similar system could be adopted in the combined sewer area as well. Private grant programs, like the Chesapeake Bay Foundation's green roof grant program, currently exist as an incentive to install green infrastructure in the city. The District should complement these efforts with a city-administered financial assistance program for green infrastructure.

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SARB_004082

Low Impact Development (LID)

A Sensible Approach to Land Development and Stormwater Management

An educational program for land use decision makers that addresses the relationship between land use and natural resource protection.

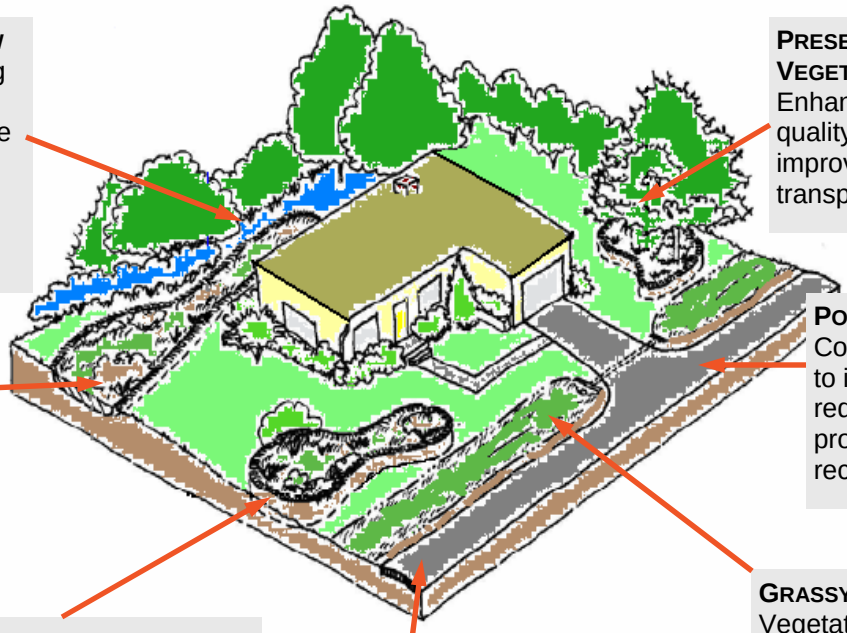
What is Low Impact Development (LID)?

LID is an alternative method of land development that seeks to maintain the natural hydrologic character of the site or region. The natural hydrology, or movement of water through a watershed, is shaped over centuries under location-specific conditions to form a balanced and efficient system. When hardened surfaces such as roads, parking lots, and rooftops are constructed, the movement of water is altered; in particular, the amount of runoff increases and infiltration decreases. This results in increased peak flow rate and volume, and pollution levels in stormwater runoff. LID designs with nature in mind: working with the natural landscape and hydrology to minimize these changes. LID accomplishes this through source control, retaining more water on the site where it falls, rather than using traditional methods of funneling water via pipes into local waterways. Both improved site design and specific management measures are utilized in LID designs. LID has been applied to government, residential, and commercial development and redevelopment, and has proven to be a cost-efficient and effective method for managing runoff and protecting the environment.

Using LID Tools in Residential Development

Natural Drainage Flow
Reduces need for grading and constructed drainage systems by building house in a location that permits preservation of natural pattern of stormwater drainage

Preserved Native Vegetation
Enhances the aesthetic quality of community and improves the evaporation-transpiration rate



Porous Pavement
Concrete that allows rain to infiltrate, thereby reducing runoff and promoting groundwater recharge

Bioretention Cell or Rain Garden
Depressions that contain soil amendments that promote infiltration of stormwater

Grassy Swale
Vegetated channels that slow stormwater runoff and promotes infiltration, traps sediment, and helps treat pollutants

Amended Soil
Soil enriched with sand and organic materials increases the capacity of soil to infiltrate water

Reduced Hardscape
Narrower streets, sidewalks, and driveways increases pervious areas and open spaces

Diagram adapted from Prince George's County Maryland Low-Impact Development Design Strategies

Traditional vs. LID Stormwater Management

Historically, in the U.S., the motto for stormwater management has been **"conveyance:"** move water away from the site where it falls as quickly and efficiently as possible. Traditional management tools include street gutters and curbs, pipes, and canals to remove water from the developed areas. To receive this increased volume, creeks and rivers are re-shaped and lined with concrete. Detention ponds, some with water quality filtration devices, regulate discharge to reduce peak flow impacts on receiving waters. For the most part, these practices reduce flood impacts, but do not completely address water quality, and aquatic and riparian habitat degradation issues.

In contrast with the traditional approaches, the guiding principle of low impact development approaches is not conveyance; it is **"source control and infiltration"**. LID techniques seek to maximize the area available for infiltration so that runoff volume and pollutant concentrations are reduced. This is achieved through a variety of site design and engineered infiltration techniques. Site design techniques include locating open spaces in low-lying areas to serve as a detention/retention basin and avoid development on permeable soils to promote infiltration and groundwater recharge. Engineered techniques include the use of grassy swales, bioretention cells, and porous pavement.

LID Benefits

Water Quality
- Contributes to groundwater recharge through infiltration
- Improves surface water quality
- Protects stream and lake quality from large volumes of polluted runoff

Meets Clean Water Act Requirements
- Source control reduces the pollutant level and volume of runoff entering a water body, complying with National Pollutant Discharge Elimination System (NPDES) and anti-degradation policy;
- This also aids in complying with 401 certification requirements

Flood Control
- Reduces frequency & severity of floods
- Reduces peak flow volume & velocity

Habitat Protection
- Preserves stream & riparian habitats
- Preserves regional trees & vegetation
- Reduces eroded sediment loading into streams & lakes

Community Value
- Increases aesthetics and recreational opportunities in protected riparian habitats
- Increases land value by having a cleaner environment
- Increases public/private collaborative partnerships

LID Challenges

Lack of Information
- Many municipal planners, consultants and the general public are unfamiliar with the benefits of LID practices and how to utilize them in different environments.

Inflexible Regulations/Ordinances
- Existing rules often lack the flexibility to implement LID solutions

Maintenance
- Some LID tools require maintenance by homeowners and local public works departments to function properly

Presence of Contaminants
- Use of filtration practices can threaten groundwater quality if high levels of soil contaminants are present.

Stormdrain leading to bioretention cell

Roof runoff drains to grassy swale

www.main.nc.us/riverlink/content/12chap/chap12.htm

Economic Issues

The **economic benefits** of LID include:

- Reduced costs of stormwater infrastructure, including curbs and gutters
- Reduced stormwater utility fees
- Increased land value
- Decreased spending on current and future environmental conservation programs

Specific cost savings vary on a case by case basis. There can be **additional costs**:

- Higher installation costs for certain soil types and gradients
- Increased landscape maintenance costs

Issue	Savings
Higher Lot Value	$3000 more per lot
Lower Cost Per Lot	$4800 less cost per lot
Enhanced Marketability	80% of lots sold in first year
Added Amenities	23.5 acres of green-space/parks
Recognition	National, state, and professional
Total Economic Benefit	Over $2,200,000 added to profit

The above table, from **Gap Creek residential subdivision,** Sherwood, AR, illustrates the financial benefits of using LID methods. *Tyne & Associates, North Little Rock, AR*

Addressing LID Implementation Challenges

Solutions

Clay Soils/Limited Space

The combination of clay soils and small lot sizes can work well together. As clays are naturally less pervious, less engineering and land is required to achieve predevelopment infiltration rates. Use integrated stormwater management techniques, a combination of traditional and LID approaches. Significant stormwater runoff reduction can still be achieved.

Local Codes Aren't LID-friendly

Revise local codes & ordinances to support use of LID techniques. Check out the Center for Watershed Protection's website for suggested guidelines (www.cwp.org/COW_worksheet.htm).

Don't know what would work and where

Educate planning & public works staff. Numerous references are available on the use of LID in a variety of settings (see Online References).

Some communities that have found solutions

Hercules has modified stormwater management guidelines that fit LID principles, city codes that allow administrative approval for LID projects, and limited street lengths.

Contra Costa incorporated LID measures into their Standard Urban Stormwater Management Plan (SUSMP) for new development (http://www.cccleanwater.org/construction/nd.php). **Sacramento**, likewise, is publishing their own design manual in Fall, 2006 that includes LID measures.

San Diego has new parking standards for intensive commercial zones that include smaller parking spaces and driveways, plus new guidelines requiring reduced imperviousness for parking spaces.

Santa Monica encourages LID by requiring that all new developments and substantial remodels submit an "Urban Runoff Mitigation Plan", and reduce projected runoff for the site by 20%. The city recommends LID technologies.

LID as a Re-design Strategy

Retrofit a Parking Lot to increase permeability. Over sixty-five percent of impervious areas are associated with "habitat for cars". Using porous pavement in parking lots is a simple way to increase infiltration and reduce runoff. When the US Navy Yard in Washington, D.C. needed to repave its parking lot, they used porous pavers. They also added bioretention cells to the landscaped areas and disconnected downspouts. The re-design did not alter the amount of parking spots, but reduced peak runoff and pollution, thus protecting and helping to restore the Anacostia and Potomac Rivers and the Chesapeake Bay.

Porous pavement covers about 1/3 of each parking space in the D.C. Navy Yard parking

LID street design: vegetated swales, no curbs, and narrower streets promote infiltration of stormwater.

Alter street design to increase infiltration. In a landmark project in Seattle, the Street Edge Alternative or SEA project involved building vegetated swales, bioretention cells, and narrower streets without curbs to promote an effective drainage and filtration system. The system reduced peak runoff for the 2 year flood event by 98%, and is capable of conveying the 25 year flood event. The local watershed provides spawning habitat for endangered salmon. The project was so successful that similar ones are being planned throughout the city.

Replace lawns with rain gardens. Rain gardens are small bioretention cells landscaped with plants, trees, and grasses. They are a particularly good way for individual homeowners to enhance their landscaping while protecting water quality. By planting easy-care native wildflowers, hardy perennials and grasses, attractive gardens can be constructed that have the added environmental benefits. More information on rain gardens is available at: http://www.healthylandscapes.org/raingarden.htm. Information on plants compatible for use in a California rain garden is posted at: http://www.bbg.org/gar2/topics/design/2004sp_raingardens.html.

Rain garden in a small backyard that collects runoff from roof and patio.

LID as a Design Strategy

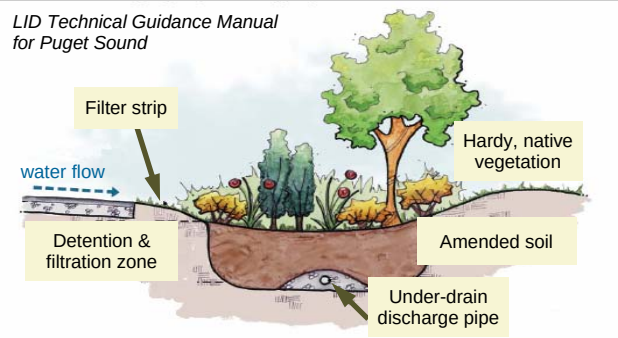
LID is more than a collection of engineered tools. It is a comprehensive design technique incorporating site planning and integrated management measures.
LID design principles include:

- Extensive site assessment of hydrology, topography, soils, vegetation and water features;
- Higher density, clustered housing, preserving open spaces to facilitate infiltration and protect habitats;
- Street layout that minimizes road length and width, calming traffic while allowing safe access of emergency vehicles.

LID Technical Guidance Manual for Puget Sound

In this example, LID design reduces imperviousness by changing the cul-de-sac design, reducing street width and lot size, and instead clustering houses around common green spaces that also serve as infiltration sites and preserving natural features.

Examples of LID



Basic Components of a Bioretention Cell
To see how to engineer bioretention cells with the proper gradient and components visit: www.lowimpactdevelopment.org/epa03/biospec.htm

Rain Gardens and grass swales between houses are used at Douglas Ranch, Granite Bay, CA to catch and filter runoff from roofs and driveways before entering a local stream.

Curb Cuts permit stormwater to flow into grassy swales to reduce roadway contaminants that flow into nearby waterways. They can also be used in *existing* landscaped areas.

Hollywood Driveways have a dividing strip of grass in order to reduce the amount of impervious surface. Another way to reduce driveway space is to share one with a neighbor.

Online Resources

Low Impact Development Center	www.lowimpactdevelopment.org
U.S. Environmental Protection Agency	www.epa.gov/owow/nps/urban.html
Stormwater Manager's Resource Center	www.stormwatercenter.net
National NEMO Network	www.nemonet.uconn.edu
LID Urban Design Tools	www.lid-stormwater.net
National Association of Home Builders	www.toolbase.org/index-toolbase.asp
California Stormwater Quality Association	www.cabmphandbooks.com

Prepared by Office of Environmental Health Hazard Assessment & the California Water & Land Use Partnership (CA WALUP)
Written by E. Ruby & D. Gillespie, student interns, OEHHA. For more information contact Barbara Washburn: bwashburn@oehha.ca.gov.

CA WALUP is an educational program for land use decision makers addressing the relationship between land use and natural resource protection. The CA WALUP is a Charter Member of the National NEMO Network. CA WALUP website: http://cawalup.usc.edu

Low Impact Development

Local Regulation Assistance Project 2005

Low Impact Development home page

Local Government Low Impact Development Ordinances and Regulations

Low Impact Development Publications and Fact Sheets

Low Impact Development Resources

Low Impact Development Web Resources

Low impact development (LID) techniques offer many **benefits** for managing stormwater. However, most local government regulations in Puget Sound still discourage or even prohibit the use of many LID techniques in development projects.

For example, many local regulations require curbs and gutters along residential streets, or prohibit the use of permeable pavement. This is largely because traditional stormwater management practices have long relied on storm drains, pipes and ponds to manage stormwater.

Yet many builders, developers and other professionals in Puget Sound are eager to incorporate LID techniques in their projects. Citizens who want their communities to grow more attractively—while protecting resources—also appreciate the potential of LID.

So how can cities and counties respond to the growing demand for LID?

Last year, the Puget Sound Action Team offered an innovative solution: Find some local governments in the region anxious to work with an engineering firm to revise their municipal codes and development standards to include LID. Then, provide support to city and county staff when they meet with elected officals to propose adopting new LID regulations.

Through two competitive processes, the Action Team selected **five cities and six counties** and an engineering firm—**AHBL**. In 2005, AHBL worked with local government staff to identify regulations, review development standards, rewrite specific language and develop new ordinances, maintenance guidance and drawings.

For a final product, AHBL provided each participating local government with a massive binder and a CD-ROM version containing:

- Summaries of assistance provided to all the participating local governments.
- Regulations reviewed.
- Recommendations for specific language changes.
- New ordinances.
- Engineering drawings.
- Maintenance considerations.

What's next? Each team of local government staff will review the recommendations and develop a package for their elected officials to consider for adoption. The Action Team will follow their progress and report back on this Web page.

Read a condensed version of all the recommendations in one file.
>> Summary memo | PDF file

All of the recommendations are not currently on this site due to the size of the files. To request a CD-ROM of the complete set of recommendations for the 2005 LID local regulation assistance project, please call **800-54-SOUND**.

Summaries for each jurisdiction that participated in the LID Local Regulation Assistance Project in 2005: (PDF files)

Cities: **Counties:**

SARB_004088

- Bellingham
- Issaquah
- Marysville
- Poulsbo
- Redmond
- Clallam
- Jefferson
- Kitsap
- Snohomish
- Thurston
- Whatcom

Appendices | PDF files

- Maintenance Specifications
- Sample Maintenance Requirements (King County, WA)
- Sample Maintenance Agreement (King County, WA)
- Sample Maintenance Agreement (Prince George's County, MD)
- LID Cost Comparisons
- Natural Drainage System Costs (Seattle Public Utilities)
- LID Incentives Menu
- Roadway Comparison
- Permeable Pavement Comparison (City of Seattle)
- LID Street Section (Pierce County, WA)
- Typical LID Street Cross Section (Seattle Public Utilities)
- NE Siskiyou Green Street Plans (Portland, OR)
- Rustic Street Standards (City of Redmond)
- Parking Comparison
- Impervious Surface Comparison
- Site Analysis Sample Drawings

To order a FREE copy of the CD-ROM containing the complete recommendations: Contact info@psat.wa.gov, or call 360-725-5444.

For more information about the Low Impact Development Local Regulation Assistance Project, contact Bruce Wulkan, Action Team stormwater program manager, by e-mail or call 360-725-5455.

Funding for the program:
The 2005 LID Local Regulation Assistance Project was made possible with $45,000 in funding from the Department of Ecology's Direct Implementation Fund (DIF) Section 319 Grant. The Action Team originally set out to find three to five local governments to work with. But overwhelming interest from all over the Sound led the Action Team to seek more funding for the project. Help came from the U.S. Environmental Protection Agency Region 10 and the State Water Quality Account, which provided an additional $66,000, allowing the Action Team to work with a total of 11 local governments.

Assistance for 2006
Six cities and one county will be working with AHBL in 2006 on another round of LID Local Regulation Assistance.

- Kirkland
- Woodinville
- Lacey
- Edmonds
- Port Orchard
- Port Angeles
- Normandy Park
- Mason County.

ABHL and the local jurisdictions were selected by the Action Team through a competitive process. This year's project is scheduled to run April – November.

NATIONAL ESTUARY PROGRAM
Access Washington Official State Government Web Site
ANEP

Puget Sound Action Team
Office of the Governor

SARB_004089

P.O. Box 40900, Olympia, Washington 98504-0900
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Natural Approaches to Stormwater Management

Low Impact Development in Puget Sound

Puget Sound Action Team
Office of the Governor

March 2003

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Natural Approaches to Stormwater Management

Low Impact Development in Puget Sound

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Cover photos
Clockwise from top: High Point Natural Drainage Systems study, page 29; rain garden installation, page 5 and pervious driveway, page 17.

March 2003

If you would like this document in an alternate format, call
(360) 407-7300, (800) 54-SOUND, or the TDD number: (800) 833-6388.

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Natural Approaches to Stormwater Management:
Low Impact Development in Puget Sound

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Acknowledgements

Puget Sound Action Team staff could not have produced this book without the cooperation of the landowners, developers, engineers and local government staff whose work and properties are featured in these examples. The Action Team extends its gratitude to them for their assistance and willingness to be innovative and to take risks that benefit us all as our region works to transform development practices in Puget Sound.

For more information on low impact development:
http://www.wa.gov/puget_sound/Programs/LID.htm

SARB_004096

Introduction

Puget Sound planners, developers, engineers and others are in the early stages of transitioning to an innovative approach to land development and stormwater management. The innovative approach—low impact development (LID)—offers potential answers to the question: "How can we significantly reduce the harm from development to Puget Sound while accommodating the inevitable growth that is occurring throughout the region?" The Puget Sound Action Team produced this book to showcase early examples of this transition.

Keeping it natural—and more effective

LID is a more natural approach to land development and stormwater management. Conventional land development typically involves clearing and grading a site, resulting in the removal of all vegetation. The next development steps traditionally include paving areas for roads and parking, building structures and landscaping areas. Engineers then design stormwater facilities, such as ponds, to manage stormwater flow, remove pollutants, and infiltrate to recharge aquifers, streams and wetlands.

Research shows that these conventional techniques have not proven entirely effective at managing stormwater to prevent damage to water quality and natural resources. Conventional practices are especially inadequate at removing bacteria from stormwater runoff. Pavement and other impervious surfaces greatly limit or prevent infiltration. High stormwater flows cause flooding, damage public and private property, and destroy habitat for salmon and other fish and wildlife.

In contrast, LID design uses a site's natural features and specially designed best management practices to manage stormwater. These principles include the following design steps:

- **Assess and understand the site.** Assess the site's topography, soils, vegetation and natural drainages, and divide the site into protected and developable areas. Protected areas include streams, wetlands and other critical areas. Apply adequate buffers to protect these areas.
- **Protect native vegetation and soils.** Set aside a portion of the site's native vegetation and areas with soils that have a high infiltration capacity. These natural areas are nature's own excellent stormwater management systems and, if left undisturbed, will continue to manage runoff quite well. To protect native vegetation, cluster buildings in the area to be developed.
- **Minimize and manage stormwater at the source.** Minimize areas of impervious surfaces such as roads, rooftops and parking areas by designing shorter, more narrow roads, using various permeable pavements, and installing green roofs or rainwater catchment systems. Manage remaining runoff by disconnecting the impervious surfaces from one another, and directing runoff to bioretention areas (or rain gardens), amended soils, native vegetation or other types of infiltration areas. This can greatly reduce the need for pipes and other conveyance infrastructure.

The home, business or development that includes LID design practices causes less harm to area streams, wetlands and wildlife habitat. Rainwater can better infiltrate into the ground to recharge drinking water supplies, streams and wetlands. The site is greener and more attractive, with open spaces that appeal to potential buyers. The developer or municipality may save money because the overall infrastructure costs are often less.

A variety of approaches

LID practices are appropriate for individual homes, residential subdivisions or businesses. LID works for new developments or as part of a retrofit project to fix existing drainage problems.

The examples highlighted in this publication reflect a broad range of LID applications—including local government ordinances, individual practices, entire residential subdivisions and new state highway designs. To date, developers and local governments have designed most of the projects in more urbanized areas. However, the projects are also applicable to rural areas, which often have more extensive stretches of undisturbed forest.

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Introduction, *continued*

Specific practices highlighted in this publication include a broad range of LID techniques, including:
- Various types of permeable pavement.
- Rooftop rainwater collection systems.
- Bioretention areas.
- Soil amendments.
- Green roofs.
- Open road sections with vegetated swales.
- Innovative building foundations.
- Homemade bog garden.

Municipalities and developers choose LID techniques for a variety of reasons:
- To better protect streams, wildlife habitat, wetlands and other natural resources.
- To protect groundwater and drinking water supplies.
- To help communities grow more attractively.
- To manage stormwater in a more efficient, cost-effective manner.

Because LID is in the early stages in Puget Sound, many examples describe projects that use a single practice or technique rather than a complete LID design. This publication also features several projects from British Columbia, Canada to provide a broader view of the level of activity in the Puget Sound/Georgia Basin region.

A few examples feature practices that might be more accurately defined as "green building," such as the use of recycled building materials or increased energy efficiency. Several examples also include land use elements of "smart growth," such as mixed-use zoning and urban revitalization. LID-designed developments sometimes incorporate elements of each of these approaches.

LID is compatible with the sustainable approach of both green building and smart growth. As "green infrastructure," LID is best distinguished by its central focus on stormwater management. LID does not replace local land use planning; rather, it is a set of tools to better manage stormwater from areas appropriately designated for growth.

Bringing LID to Prime Time

Despite the promise of LID, the vast majority of new development projects each year still rely on traditional stormwater management facilities without considering LID techniques. One reason is that most local government development regulations do not allow for certain LID practices, such as narrower roads or open road sections without curbs and gutters. Another reason is that many engineers and developers aren't familiar with LID techniques and continue to rely on better-known conventional practices.

To address these challenges, the *2000 Puget Sound Water Quality Management Plan* calls on every city and county in Puget Sound to revise existing ordinances or pass new ordinances that allow for and encourage LID practices. Several local governments have passed LID ordinances (see pages 39-49).

The Puget Sound Action Team has educated more than 800 planners, developers, engineers and others at LID conferences and regional workshops throughout Puget Sound. The Action Team has developed an assortment of educational materials on the subject, such as this publication. A number of other organizations now also offer training on LID. The Action Team posts these training opportunities and links to other resources on its website.

The Action Team hopes you enjoy reading *Natural Approaches to Stormwater Management: Low Impact Development in Puget Sound.* The goal of this publication is to provide you with ideas and inspiration to learn about and use low impact development practices in your community.

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Amended Soils at Redmond Ridge

King County

Background

The Quadrant Corporation is developing Redmond Ridge as a mixed-use, fully contained community within the Novelty Hill Area of the Bear Creek Community in King County. The 1,046-acre site will include a full range of residential densities, employment, retail and business services, parks and public utilities. As mitigation for land clearing at the site, Quadrant is amending soils and revegetating landscaped areas with native plants. This will reduce stormwater runoff volumes and help maintain the water quality of the receiving native wetlands and forests.

Description

The development permits for Redmond Ridge describe a total water management program, from site clearing to educating residents about water conservation. Conserving native soils and restoring soils through amendment play an important part in the water management program.

After removing trees and stripping roadway corridors and development areas, the contractor will remove the top layer of forest duff, stockpiling it for use as amended soil material or to refill borrow areas. Plans call for all landscape soils to be amended to a depth of 12 inches to improve retention of stormwater. King County required Quadrant to use one of two guidelines when amending soils:

- Washington State Department of Ecology's On-Site Residential Stormwater Management Alternatives, November 1995 Edition. If Quadrant uses this guideline, the soil-to-compost mix will have a ratio of 1 part compost to 2 parts soils. The topsoil product must be suitable for placement 12-inches deep in nonstructural fills and landscaped areas.
- King County Executive Proposed Site Alterations Code Ordinance (not yet adopted by the King County Council). This ordinance calls for adding nine inches depth of amended topsoil consisting of native soils mixed with organic matter (mixed at a content rate of eight to thirteen percent dry weight) over existing scarified till soils. (Although the ordinance calls for a depth of nine inches of amended soils, if Quadrant chooses to use this guideline they must still amend soils to a depth of 12 inches, using the content rate spelled out in the ordinance.)

October 2002.

Aerial Photo of Redmond Ridge where landscaped areas will be amended to a depth of 12 inches to improve retention of stormwater.

A Water Conservation Plan will identify landscaped areas and uses, classify landscaped areas according to hydrozone and discuss soil preparation techniques, including soil amendments. Quadrant will educate all developers about soil amendment during the sale process. All lot purchase and sale documents will require land purchasers to comply with the soil amendment requirements.

To educate homeowners, Quadrant will prepare educational materials and

Redmond Ridge, *continued*

programs on landscape management for water conservation, surface water management, water conservation and groundwater quality. Quadrant will also install a landscape plan for a single detached model home and a demonstration garden.

Quadrant is monitoring the erosion control measures related to site construction and the quality of the receiving wetland waters. King County Water and Land Recourses Division is monitoring the function of the storm system and water quality of the native wetlands.

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Bog Garden

City of Shoreline

Background

Bog garden before

A homeowner in the city of Shoreline installed a bog garden to direct stormwater flows away from the foundation of his house. His objective was evapo-transpiration and infiltration of rooftop drainage rather than discharging it to the stormwater system. The bog garden serves as a model for other residential homeowners.

Description

Bog garden (after) handles approximately 10,800 gallons of rooftop runoff each year.

The Bog Garden serves a 1/4-acre residential property and collects roof runoff for infiltration and evapotranspiration with wetland vegetation. The homeowner backfilled a lined retention pond (12-feet long by 8-feet wide by 3-feet deep) with three-way garden mix, coconut husk fiber and peat moss. He then planted more than 30 species of native and non-native (to the Pacific Northwest) wetland facultative plants on the site. As the garden functions, there is no standing water, but the soils are saturated much of the time. Unlike many similar systems, this one promotes evaporation and transpiration; the impermeable liner prevents infiltration. Excess water flows into a constructed dry streambed.

Results

The Bog Garden is an aesthetically pleasing, affordable garden that provides an effective visual barrier to the street. The installation reduced impermeable lawn surface while directing water away from the house foundation. Very little excess flow discharges from the bog garden, and what does flow out quickly infiltrates within a few feet of its point of discharge.

The builder estimates that the Bog Garden will handle 10,800 gallons per year (based on 2,000 square feet of roof area divided by 4, times 36 inches per year precipitation = 10,800 gallons per year).

Costs

The project cost approximately $600. The homeowner could have used a traditional French drain for a similar cost, but it would not have been as aesthetically pleasing.

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Reining in the Rain: Parking Lot Rain Garden

Bellingham City Hall

Background

Whatcom Creek flows through the city of Bellingham (population 70,000) and eventually enters Bellingham Bay. Urban stormwater runoff entered the creek, causing high flows and degrading water quality. A catch basin in a parking lot behind city hall was one of the sources of stormwater. The city decided to construct a rain garden (bioretention cell) that would treat runoff from the parking lot and also demonstrate the rain garden technology to businesses and property owners. Project funding came in part from the Public Involvement and Education (PIE) program administered by the Puget Sound Action Team.

Installing first layer.

Description

The city hall parking lot lies between Whatcom Creek on the north and city hall on the south. In creating the rain garden, the city gave up three of the 60 parking spaces in the rectangular lot.

Rain gardens involve layering different types of gravel, soils and mulch—much like layers in a cake. The top layer includes vegetation selected for filtration of contaminants. The rain garden will clean the parking lot runoff by filtering some of the pollutants (such as oil drips from cars) and slowing down the rate at which it flows into the creek.

Costs

Asphalt	$1,056
Concrete	800
Gravel	12
Labor	1,690
Equipment	942
Total cost	**$4,500**

Results

City staff report that the water appears less turbid than before the rain garden was built. The rain garden also performs a public education function as it is in a high profile location and includes educational signage about the water quality and habitat benefits.

Vegetation laid out waiting to be planted.

Challenges

City staff were reluctant to give up their coveted parking spaces behind city hall.

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Planting rain garden.

Natural Drainage Systems

City of Seattle

Background

The city of Seattle has a population of 516,259 and covers an area of 84 square miles. As the city's population grows, stormwater from impervious surfaces such as streets and rooftops speeds toward area creeks, causing floods and scoured habitat in the winter months, and inadequate creek flows in the dry, summer months. To address this, Seattle Public Utilities (SPU) staff are developing prototype "Natural Drainage System" projects to meet multiple goals within street right-of-ways. These goals include infiltrating and slowing stormwater flow, filtering pollutants by soils and plants, reducing impervious surface, increasing tree cover and improving the safety of pedestrian paths. These projects use constructed features such as open, vegetated swales and stormwater cascades to mimic the functions of natural forests.

Seattle SEA Streets Project. Graded swales with amended soils reduced stormwater volume by 97 percent for two consecutive years.

SEA Streets Project

Seattle's Street Edge Alternative (SEA) Streets Project manages stormwater and improves water quality drainage on individual blocks of low-traffic streets. The project reconfigures the street and right-of-way and uses swales on both sides of the street. SEA Streets began with a retrofit of an urban block in the Broadview section of Seattle in the Pipers Creek watershed. The specific objectives are to:

- Decrease runoff peak flow and volume.
- Minimize impervious area.
- Improve water quality.
- Document effects of alternative design.
- Minimize maintenance through design and stewardship.
- Design watershed and neighborhood friendly streets.
- Change the traditional view that curbs, gutters and sidewalks are necessary.

SPU staff selected the Broadview neighborhood through a process that considered community interest and technical feasibility. The site is on 2nd Ave. NW, between N. 117th and N. 120th streets. Key elements of the project include street improvements, drainage improvements, landscaping and neighborhood amenities. The new street design has a curvilinear form to allow more flexibility in designing the water quality improvements. The block has a sidewalk on just one side of the street. In addition to the water quality benefits, the design calms traffic and provides a more interesting streetscape. Neighbors were involved in the design process, from choosing the number of parking spaces to selecting and planting the trees and shrubs.

The graded swales direct and slow the flow of stormwater and provide detention during larger storms. Newly planted trees will eventually help to restore the evapotranspiration that was present before development. Amended soils in the landscaped areas have proved to be effective in retaining stormwater. The native wetland plants in the drainage swales also help filter and slow the flow of stormwater.

Results

The SEA Street design resulted in reduced total volume of stormwater within its two-block, 2.3-acre area by 97 percent for two consecutive years. The project met its design goal of virtually eliminating stormwater for the level of storms that can

SARB_004102

be expected to occur every two years. Residents of this neighborhood enjoy walking along SEA Streets because it is a natural, soft-edged environment, as opposed to the hard edges of traditional linear streets. More tree cover helps reduce summer heat while absorbing air pollutants and rainfall.

Challenges

The street and sidewalk design required deviations from the city's building standards. The original design proposed to retain flows and allow infiltration into the native soils throughout the length of the block. This was not possible because part of the site had an existing problem with groundwater intrusion into basements. To limit the potential for stormwater to exacerbate these problems, some swales included an impermeable clay liner to divert stormwater away from problem areas.

Costs

The budget for the project was $800,000 and was funded by drainage fees. This included a more extensive design and communications budget due to the out-of-the-box nature of the project and the need to work closely with residents. The cost of future projects should compete favorably with the cost of traditional street improvement projects. City staff estimate the cost of future SEA Street prototype projects to be $710,000, while an equivalent conventional drainage and street improvement project would cost approximately $840,000. Staff are currently working on an improved SEA Street prototype design to lower construction costs.

Cascade Prototype

SPU staff designed the Cascade Prototype to be used on steep, residential streets with high stormwater runoff from watersheds of five to 50 acres in area. The design includes large cascading swales, sediment trap chambers and intensive vegetative cover. Traditional drainage infrastructure such as pipes, culverts and catch basins work in conjunction with more natural elements to create a balanced approach to drainage design.

The Cascade Prototype project at N. 110th St. after most of the construction has been completed and before planting.

Construction of the first Cascade project began in late 2002 on N. 110th, between Greenwood Ave. N. and 3rd Ave. NW. This project covers four blocks and manages stormwater runoff from a 21-acre catchment area. The primary objectives of the Cascade prototype are to:

- Reduce the velocity of stormwater flow.
- Improve water quality.
- Decrease runoff peak flow and volume.
- Provide additional tree and vegetative cover.

SPU is moving forward with projects of both the SEA Street and Cascade type on 15 city blocks in 2003. These new projects will include a monitoring program for water quality and stormwater quantity and flow.

Contact

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Seattle Public Utilities website:
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Stormwater Treatment on Highway Slope

Interstate 5 Tumwater to Maytown, Thurston County

Background

Interstate 5 between Tumwater and Maytown in Thurston County originally had four lanes. By 1998, it was serving 50,000 vehicles per day and needed to be widened. Typically, such a project would require adding stormwater detention and treatment ponds. However, this section of I-5 runs through wetlands, and using additional wetland area for stormwater treatment would be problematic.

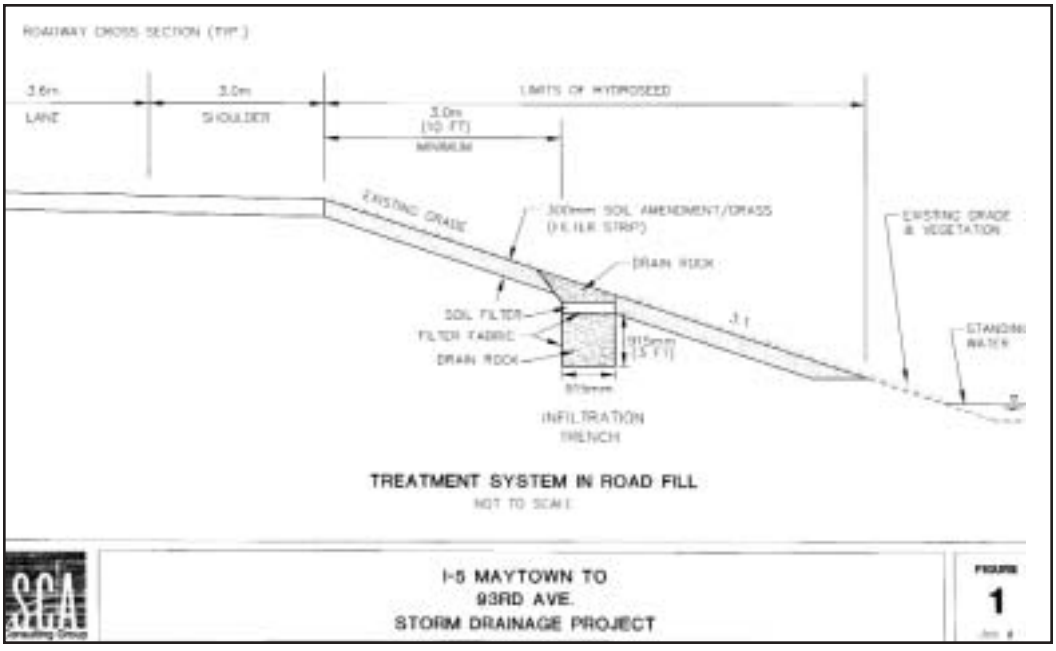
The Washington State Department of Transportation (WSDOT) and SCA Consulting Group solved this problem by developing a new stormwater management technique that treats stormwater on the side slope of the highway itself. The result is a low impact best management practice (BMP) that infiltrates the majority of the runoff from frequent storm events. This is a key principle of low impact development.

Description

The roadway for I-5 south of Tumwater runs through two miles of wetlands and is constructed on fill averaging about 6 feet. The widening project expanded the roadway into the existing median so it did not require additional right-of-way. However, the project still needed to provide stormwater treatment, and the adjacent wetlands limited available space.

Conventional alternatives would have involved expensive facilities such as pipe vaults or centrifuge manholes. These systems would require a lot of maintenance and closure of highway lanes for access. Furthermore, the data indicated that these devices would only be effective in treating runoff during low flow storm events.

To solve the problem, WSDOT and SCA Consulting Group created a new BMP using the highway side slope. The crew amended the soil on the slope with



Originally designed for water quality treatment, this system should also retain small storm events, according to SCA Consulting Group and the Washington State Department of Transportation.

compost and planted grass to provide pre-treatment of water leaving the road. Lower down near the toe of the slope, they constructed a shallow trench and filled it with a sand/gravel mix to provide final filtering. The existing fill slopes were about 1:6 (vertical: horizontal), making it difficult to keep the trench within the vertical limits of the fill, away from the shoulder and out of the wetlands. (Note: because steep saturated fill slopes can be unstable, the technique should not be used on slopes steeper than 1:3.)

Results

WSDOT and SCA originally designed the new BMP as a water quality treatment system. However, the BMP has infiltrated nearly all the runoff for frequent small storm events. Because of the success on this site, WSDOT has adopted this BMP for use in future projects on state roadways that pass through wetlands. While there is no formal monitoring plan, WSDOT may perform monitoring in the future.

Costs

Both the initial and maintenance costs should be significantly lower than for conventional systems. The system's designers hope that routine mowing will be the only maintenance required for the system.

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Tahoma Vista Ranch

Rainier, Thurston County

Background

The Rainier Development Corporation is developing a large-lot residential subdivision called Tahoma Vista Ranch near the town of Rainier in Thurston County. Phase I of the project is under construction and contains nine 40-acre lots. Phase II will include 36 10-acre lots. Due to the large size of the lots, all runoff from structures can easily be infiltrated on-site. The remaining challenge is to design the access road for zero runoff.

Description

The Tahoma Vista site sits on a flat bluff overlooking the Deschutes River at 159th Ave SE and Vail Road. Design of the access road was a challenge because the site is very flat and mostly covered by shallow soils over hardpan (Class C, till soils). Several large wetlands on the site are not appropriate for discharge of stormwater. Traditional stormwater conveyance systems and ponds in this type of area with very flat gradients would require deep cuts into the hardpan.

SCA Consulting Group developed a low impact design road for the site that will feature bioretention swales on each side of the road. The treatment area of the swales will be 1.5 times the width of the road tributary to it. At the bottom of the swales, soil will be restored to a depth of 2 to 4 feet and planted with hydrophilic vegetation to treat stormwater runoff as it passes through the soil. Water reaching the till layer will infiltrate slowly through pockets or fissures in the till.

Results

This best management practice should infiltrate 100 percent of all storm events up to the 100-year, 24-hour storm. Plans include beginning construction on the project in late 2002.

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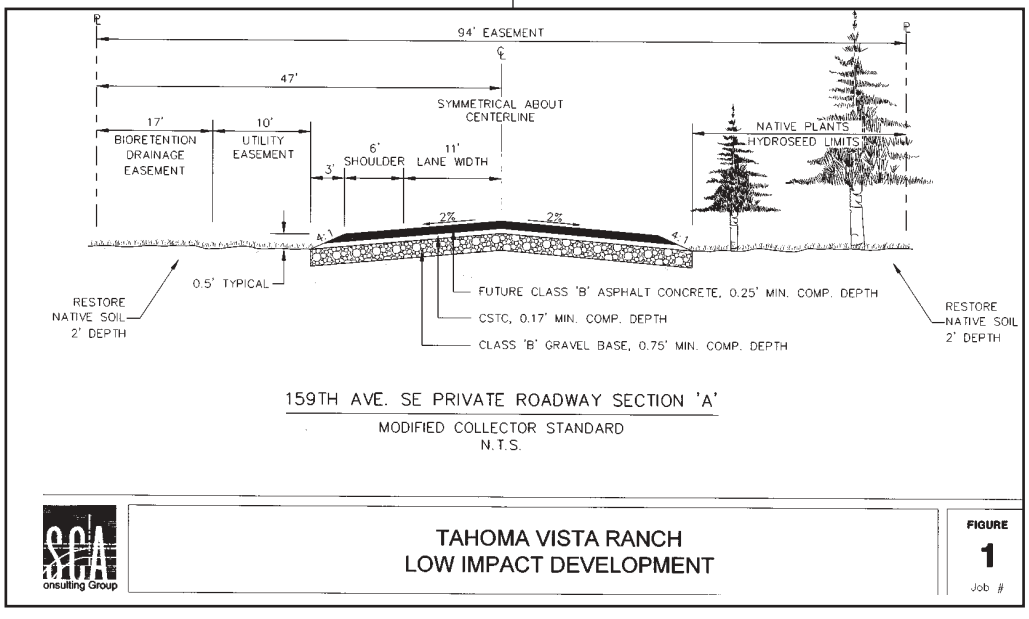

SCA Consulting Group designed this system to infiltrate all storm events up to the 100-year, 24-hour storm.

Country Lanes

Vancouver, B. C.

Background

Alleys or back lanes in Vancouver, B.C. provide access to garages and are used for public services such as garbage pickup. Consequently, both passenger vehicles and heavy trucks frequently use these lanes. The city of Vancouver developed an environmentally sustainable "Country Lane" design that makes back lanes greener and more attractive. This alternative to paving asphalt lanes to full width is a response to the city's goal to reduce environmental impacts and to create a more livable community. The city also hopes to increase public awareness of stormwater issues.

Description

Country Lanes feature two narrow strips of concrete that provide a smooth driving surface. A plastic grid is placed between and beside these concrete strips and covered with topsoil and grass. This structural grass can support vehicles and prevents the grass roots from being compacted and creating ruts in the soil. The road base is a mixture of aggregate, which provides structural stability, and a sand/soil mixture that allows for drainage and provides the soil components required for grass growth.

Results

Country Lanes provide several benefits:

- Controlling stormwater at the source means less change to stream hydrology.
- Surface water infiltration recharges groundwater.
- Topsoil filters pollutants naturally.
- Adding green space improves air quality.
- Replacing asphalt with grass reduces the "heat island effect," where warmer temperatures occur due to pavement.

Vancouver is building three of these lanes as a demonstration project. With the success of these demonstration projects, this design will become available as a standard local improvement lane project.

Preparing structural grass.

Costs

The costs are approximately 50 percent higher than conventional lane paving. However, as builders and regulators gain more experience with this approach, they will be able to refine the design and construction process and costs should drop.

Vancouver Country Lane completed.

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Pervious Paving Parking Lots Modification Project

The Evergreen State College, Olympia

***Zero Impact** is a project that adheres to the 65/0 (65 percent forest cover preserved/zero effective impervious surface) development standard and is constrained by characteristics of a healthy watershed as described in the Salmon in the City Conference Abstracts.

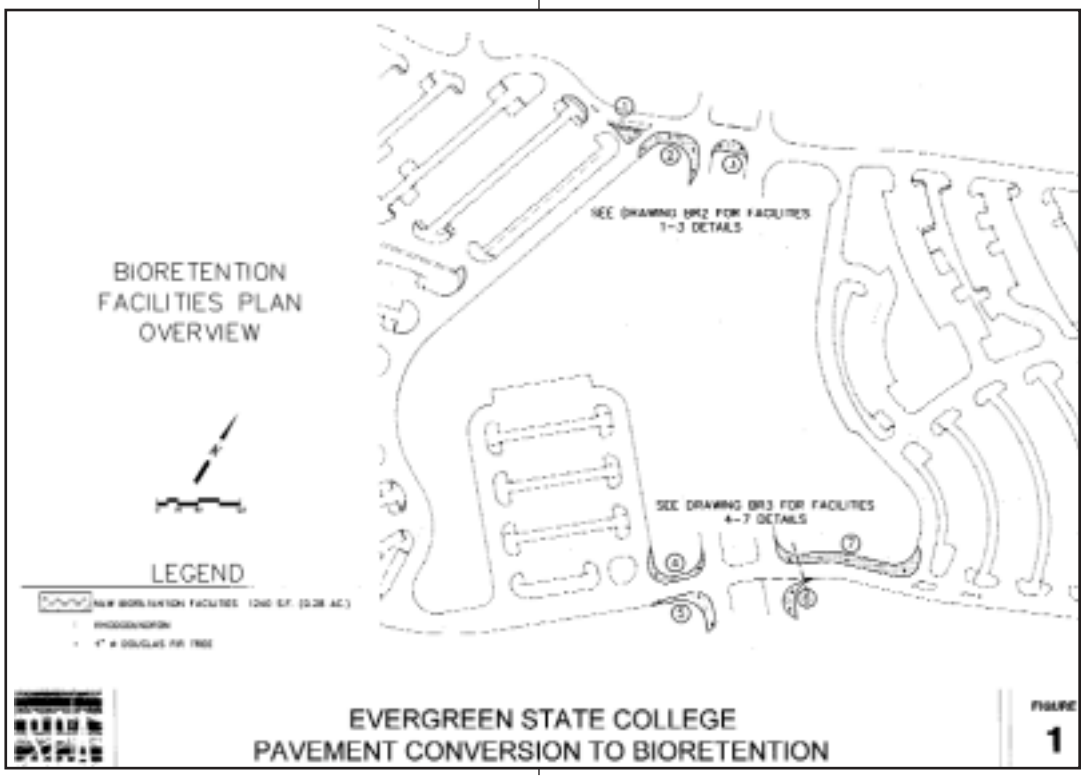
Background

New building construction at The Evergreen State College requires additional parking capacity. The philosophy of Evergreen is to reduce the impact of the campus on the environment with every maintenance or redevelopment project, wherever practical. In addition to reducing the environmental impact, "soft" drainage systems will provide monitoring and teaching opportunities for students in the college's environmental studies program. Based on a Zero Impact* Feasibility Study (see page 27), the college decided to intensify its use of existing parking areas rather than clearing more forest.

Description

The Parking Lots Modification Project will provide additional parking in lots B and C on either side of the main entrance to the campus. Runoff from the parking lots currently discharges to the East Fork of Houston Creek without treatment or detention. The innovative design adds new parking by removing and reshaping planting islands and reorganizing lanes. Pervious paving systems will replace approximately 34,000 square feet of existing landscaping for new parking stalls. The combination of adding new pervious paving and converting existing paving to pervious surfaces will result in a net reduction of runoff to Houston Creek.

The paving bid package includes three alternative paving systems, including EcoStone® by UniGroup, Gravel Pave 2™, and a system of crushed rock with cellular confinement. The design for the pavement includes infiltration to the subgrade and storage in rock ballast under the pavement. The objective is to infiltrate the 100-year, 24-hour storm without surface



Approximately 9,000 square feet of impervious parking area at The Evergreen State College will be converted to bioretention areas (numbered in plan at right).

runoff. A sand filter providing water quality treatment is located directly below the paving system.

Approximately 9,000 square feet of parking lot access lanes will be converted to bioretention facilities. The design provides for soil restoration to a depth of two feet. The objective is to provide bioretention areas with sufficient surface and subsurface storage volume to infiltrate runoff from all events up to the 100-year, 24-hour storm.

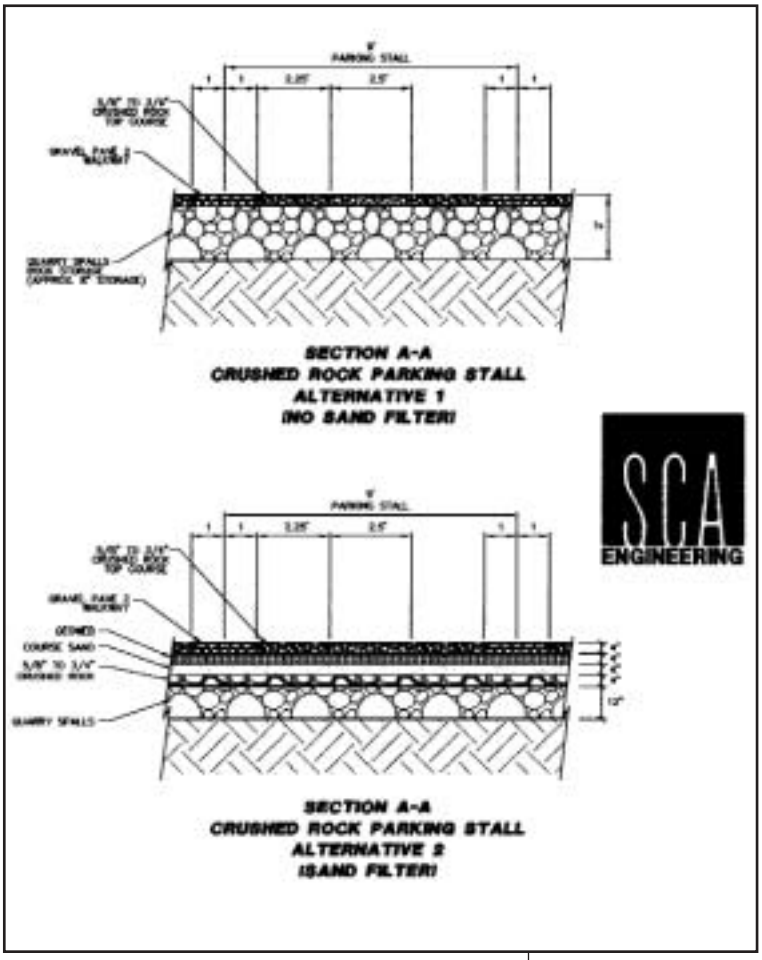
Evergreen may also build a motorcycle parking structure with a vegetated roof that will be a study focus for students in the environmental studies program. The motorcycle port will have approximately 6 inches of soil on the roof with plants selected for their tolerance to extreme wet and dry conditions.

Challenges

One complication of the project was old fill material found under the existing pavement. Because it is unsuitable for pavers or bioretention facilities, contractors had to remove and dispose of it. This cost would not have occurred with the asphalt paving alternative.

Costs

The cost of the zero discharge parking retrofits is the same as, or lower than, traditional alternatives using new treatment and detention systems. Costs for green roofing will be higher, but the increased life of the roof will help offset these costs. An important factor in choosing the pervious paving systems is that this approach negates the need to clear and grade surrounding forest areas for detention ponds.



Pervious paving materials vary according to the intensity of use in parking lots. In the above diagram, a cellular confinement system stabilizes a parking surface of crushed rock.

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Grass Parking Lot and Performance Area

Whidbey Island and City of Bellingham

Background

A farmers' market and community hall at Bayview Corner on Whidbey Island needed weekend parking. 2020 Engineering designed a reinforced grass pavement system that makes the area look like open space when not used for parking.

In Bellingham, the owner of the Boundary Bay Brewery wanted to expand the winter parking area and to provide a summer beer garden and performance area.

Description

The grass parking lots use an interlocking plastic grid (GeoBlock™ at Bayview Corner and Grassy Pavers™ at Boundary Bay Brewery). The grid was filled with a mixture of sand and chicken compost and planted with grass.

Results

The parking lot designs meet standards for traditional traffic loading. The grass parking replicates natural conditions for slowing and infiltrating stormwater runoff and eliminates the need for conventional detention/treatment systems.

Costs

The cost for both lots was $3 to $4 per square foot, installed.

Contact

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Grass parking lot design meets standards for traditional traffic loads and resembles open space when not used for parking.

Bayview corner, Whidbey Island. Top photo: after construction. Lower photo: during construction.

Boundary Bay Brewery, Bellingham. Top photo: during construction. Lower photo: after construction.

Pervious Concrete
Multiple Locations

Background
Builders have used pervious concrete nationally for more than 20 years. In the 1980s, several projects used pervious concrete in the Puget Sound basin, including at Husky Stadium and at a park in Redmond. In recent years, builders have used pervious concrete in several new projects and more are planned.

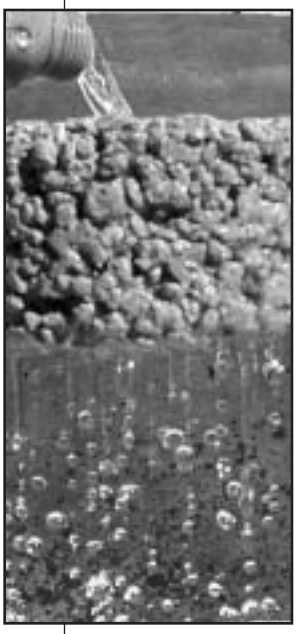
Description
Pervious concrete is a special structural concrete with the fine particles removed. This creates 15 to 20 percent voids so the concrete looks like a giant rice cake. The pavement will support traffic and allow water to pass through to a gravel layer underneath. The strength of pervious concrete is about 85 percent of conventional concrete, making it suitable for sidewalks, driveways, alleys, parking lots and residential streets. Designers and installers need special training to ensure structural integrity and porosity. Post-placement testing is important.

Pervious concrete is much more porous than underlying soils. Typical infiltration rates are 250 to 300 inches per hour; typical installations require soils with percolation rates of more than 1/2-inch per hour. A gravel bed placed underneath the concrete stores water before it moves into the soil or can provide a channel for movement of water to stormwater channels. A 4-inch bed of rock or aggregate 3/4 inches or larger with 30 percent voids will store 1.2 inches of water. In addition to its water quantity benefits, pervious paving can remove some pollutants through absorption, straining and microbial decomposition.

Following are some of the locations of recent pervious concrete installations around Puget Sound:

- Four blocks of sidewalks on N. 145th Street, Seattle.
- 400 feet of sidewalks at 100th Ave., Marysville.
- Six parking lots at Fort Lewis.
- Sidewalk on North Street in Olympia.
- Plaza at Greenwood Park, Seattle.
- Alley in Bellingham.
- Parking lot for the Washington Aggregates & Concrete Association office, Des Moines.
- Nine parking spaces at Bayview Corner, Whidbey Island.

Planning is currently underway for a residential subdivision to demonstrate the usefulness of permeable concrete for residential streets, driveways and sidewalks.



(Photo courtesy of Greg McKinnon)

Pervious concrete infiltrates water extremely well—typically 250 to 300 inches per hour.

Costs
The cost for pervious concrete is typically $6 to 9 per square foot. This is comparable to conventional concrete.

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Pervious Concrete Alley
City of Bellingham

Background
A residential homebuilder was interested in sustainable construction and decided to try pervious paving in an alley that provides access to homes. This was the first application of a pervious concrete roadway in a Whatcom County right-of-way.

Description
The alley provides access to two residential properties while minimizing environmental impacts. Porous concrete allows for the infiltration of stormwater runoff while providing the same structural capacity as conventional concrete. Engineers determined the depth of the crushed rock base material—used to support the concrete—based upon the type of underlying soil conditions and amount of water storage area needed to accommodate storm events. No fine materials were used.

Pervious concrete alley, Bellingham.

Since this project was the first of its kind, the city of Bellingham wanted to know about durability, load, treatment and maintenance requirements.

Results
Stormwater treatment occurs as water flows through the pervious concrete road section and underlying soils. Other characteristics, such as maintenance issues, are comparable to conventional pavement systems. The engineer used the Department of Ecology's *Stormwater Management Manual for Western Washington* as one of the guides to document the stormwater infiltration benefits of the project.

Costs
Materials cost approximately $1.50 per square foot. Installation costs were similar to conventional paving.

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SARB_004112

Pervious Driveway
City of Bellingham

Background
Stormwater runoff causes pollution in the Lake Whatcom watershed in Bellingham, as it does in many other developed areas. Because Lake Whatcom is the sole source of drinking water for the city of Bellingham, this can have serious consequences for the city's drinking water supply. A homeowner in the watershed wanted to demonstrate alternative sustainable building practices and decided to replace the existing impervious asphalt driveway with a pervious one.

Description
The homeowner installed a pervious paving system composed of individual interlocking paving blocks placed on a bed of fine gravel. The configuration of the pavement blocks provides a series of voids to allow stormwater to infiltrate.

Results
The new driveway has better structural properties than the replaced asphalt surfaced driveway. The pervious paver system replicates natural conditions for stormwater infiltration, provides treatment, and eliminates the need for conventional detention/treatment systems. The homeowner reports a significant reduction in the volume of stormwater flowing down the driveway and into the lake.

Costs
The cost was approximately $5 per square foot installed.

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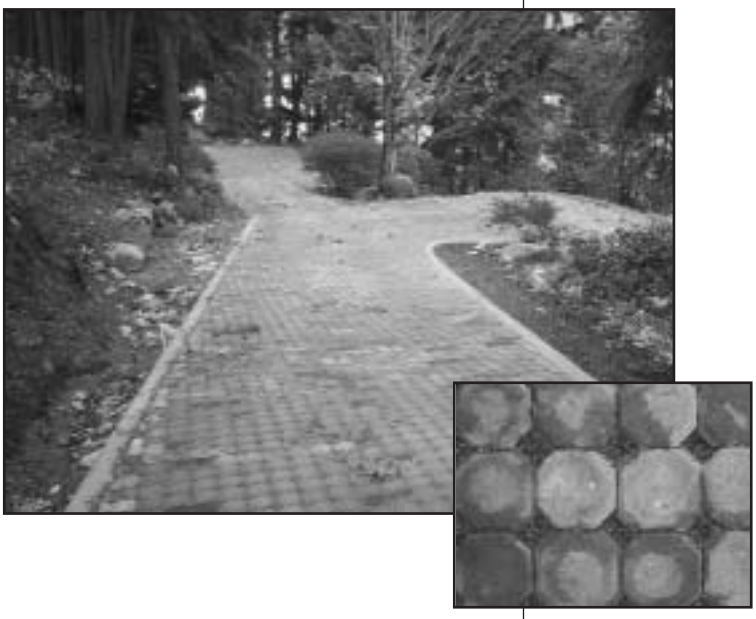
Pervious driveway, Bellingham.



The pervious paver system replicates natural stormwater infiltration, provides treatment and eliminates the need for conventional detention/ treatment systems.

King Street Center
City of Seattle

Background

King Street Center, at 201 S. Jackson Street, began as a typical office building project in downtown Seattle. However, the King County Department of Natural Resources and Parks, a major tenant, asked that the building include environmentally friendly and sustainable approaches in its design, construction and operation.

Rainwater collection system saves an estimated 1.4 million gallons of water each year.

Completed and occupied in September 1999, the 327,000-square-foot building houses 1,600 employees of the county's Department of Natural Resources and Parks and Department of Transportation. The center serves as a model and testing ground for sustainable practices and materials, including a system that collects stormwater and uses it within the building.

Collected rainwater irrigates landscaping and also flushes the building's toilets.

Description

In a first for a commercial building in Seattle, the King Street Center collects rainwater to flush its 105 toilets throughout the year. The unique and innovative system is designed to collect rainwater from the building's roof to fill each of three 5,400 gallon tanks. The water fills and passes through all three tanks and then small cylinders filter the water as it is pumped to toilets in the building through separate piping. If there is not enough rain to meet the building's flushing needs, the system automatically adds domestic water to the tanks. In addition, water diverted from the reclamation system fills much of the building's landscaping needs.

Results

Since rainwater is dumped into the city sewer system, King County is capturing water that would otherwise be wasted and avoids significant loadings to the sewer system. The building uses approximately 2.2 million gallons of flushing water per year. The new system saves an estimated 1.4 million gallons of water per year, meeting over 60 percent of the building's estimated annual water needs.

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Take a virtual tour on King County's website: **dnr.metrokc.gov/dnrp/ksc_tour/**

SARB_004114

Residential Rainwater Collection and Use

San Juan Island

Background

One method of reducing stormwater runoff and minimizing the strain on aquifers is collection and use of rooftop rainwater. Several major building projects in Puget Sound incorporate rainwater harvesting and use systems. (See King Street Center, opposite page, and Seattle Justice Center, page 24.) Some homeowners are also installing rainwater collection systems in residential homes, including using rainwater as a potable water supply, primarily in San Juan County where water shortages are a major concern.

Description

In the past four years, Northwest Water Source has installed 60 rainwater collection and use systems. Forty-eight of these provide drinking water and two serve homes that had access to community water supplies but chose not to connect to them. Northwest Water Source is also installing pilot systems in Seattle.

Depending on the design of a rainwater collection system, a variety of issues need to be resolved. These include: design of the collection and storage systems, disinfection, pumping, filtration, stormwater infiltration and groundwater recharge. Aboveground tanks can be made of polyethylene or galvanized steel with a polypropylene liner. Underground storage tanks can be made from polyethylene, fiberglass, or cement. Installers should choose roofing material based on how the rainwater will be used. Rainwater collected only for non-potable use such as irrigation, requires installers to avoid materials that can leach zinc or copper, which can damage landscape plants. Rainwater used for drinking purposes requires choosing roofing material carefully. Vendors of catchment systems have information on the best materials to use for specific collection purposes.

Storage tanks installed.

One house on San Juan Island provides a typical example. The house sits on a small lot, and seawater has contaminated the site's water supply well. With desalinization, delivered water, and rainwater collection as the only available

Steel roof with drain to storage tanks under deck.

Residential Rainwater Collection, *continued*

alternatives, the homeowner chose rainwater collection. Northwest Water Source designed the system to provide for the water needs of two people at 60 gallons/day/person, with storage for the 90-day dry summer period. (Northwest Water Source has a spreadsheet available on request for calculating a home's water budget.) The system will produce excess water during the wet season.

Storage tanks with a total capacity of 10,000 gallons collect rainwater from a 1,300 square foot standing-steam, enameled steel roof. The water passes through a filtration system before entering the storage tanks. Water pumped out of the tanks flows through a final sediment filter and a carbon block filter before treatment by a NSF-approved ultraviolet disinfection system.

San Juan County required the developer to get a water availability permit to acquire a building permit. The designer submitted a design for the rainwater collection system to the county health department, which signed off on the system as meeting the guidelines for an alternative water system. However, the county doesn't want legal responsibility for ensuring that systems are operated properly so they don't inspect the installations. The county does require that a restrictive covenant be recorded on the property deed along with a system diagram, water budget, maintenance and operations sheet, and list of materials used in construction. This ensures that potential buyers are fully informed about the system and know how to take care of it. Homeowners are solely responsible if systems are not maintained according to the guidelines and recorded documents.

Costs

The cost of this system was $10,000 and operating costs will be around $500 per year for new filter cartridges and ultraviolet bulbs. Electricity costs will be the same as for a well pump. Northwest Water Source estimates the cost of an average-depth well in San Juan County to be 75 to 90 percent of the cost of a comparable catchment system, if the well water is not very hard or contaminated.

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SARB_004116

Seattle Rainwater Resolution

Seattle

Description

In April 2002, the city of Seattle adopted Resolution 30454 on wastewater reuse and rainwater reclamation. While the major purpose for the resolution is to deal with water supplies, it provides additional benefits for reducing stormwater runoff. The resolution calls for addressing a number of issues relating to reuse of wastewater and rainwater, such as considering the full cost of reclaimed water, cost recovery, emerging state and national policy, and the effects on public health and the environment. The resolution also directs Seattle Public Utilities (SPU) to recommend changes to the city's land use and building codes that would encourage these programs and technologies.

City officials are considering several demonstration projects to test how to educate the public about water reuse and reclamation. City staff will survey near-term water reuse/reclamation opportunities and identify at least one rainwater reclamation demonstration project.

Several projects under consideration include a pilot program involving installing cisterns in up to 24 households to capture rooftop rainfall and slow its release into the stormwater system during the winter. In late spring and early summer the cisterns would retain water for garden irrigation during the dry season. As many as half of these households may test toilet-flushing systems using the captured rainwater. SPU is also looking at larger-scale rainwater capture at Sand Point Magnuson Park where the water would be used for a community garden, and the utility is looking at possible rainwater harvesting for irrigation around multi-family projects.

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To view the entire text of the resolution, visit the city's web page at:
www.seattle.gov.
Under the "City Council" section on the right, select "Legislative Search." Then select "Resolutions" and enter the resolution number, 30454.

Low Impact Foundation Technology

Multiple Locations

Background

In 1992, Pin Foundations, Inc. built a boardwalk for the Hood Canal Wetlands Preserve that was supported on piers installed without digging or heavy equipment. Since that time, Pin Foundations has been developing and testing a residential construction system based on the same low impact technology. Pierce County gave broad approval to the system in 2001. Builders are using this technology to install additions and detached single-family homes at Fox Island, Bainbridge Island, Olympia, Tacoma, Key Peninsula and Gig Harbor.

Homeowners in Olympia install a Low Impact Foundation Technology (L.I.F.T.) system as an alternative to a conventional foundation.

BuildingGreen, Inc., publisher of the *GreenSpec© Directory and Environmental Building News*, recently named Low Impact Foundation Technology (L.I.F.T.) as one of the top ten new green building products.

Description

L.I.F.T. requires little or no excavation. Sections of foundation wall are poured at grade and "pinned" into the ground using heavy-duty steel pins that extend deep enough to support the structure and prevent uplift. Grading is left to smaller equipment that simply "feathers" the existing surface soils without having to strip them all away. Lot-by-lot compaction is all but eliminated.

The advantage of the L.I.F.T. system for stormwater management is that the native soil structure continues to absorb and process rainwater. Runoff from roofs can be directed back into perimeter soils. Depending on the characteristics of the site, detention ponds, drywells and piping can be reduced in size. Less digging also reduces the size and impact of spoils piles and their contributions to erosion. Leaving healthy upper soil layers allows for better plant or sod growth that can also reduce the erosion potential of developed soils. Pin Foundations has created a mathematical model for civil engineers to use in calculating the volume of flows restrained in surface soils that are not compacted, and has conducted a case study to verify the values.

Homes built on L.I.F.T. foundations have conventional framing, floor plans and exterior styles. The framer works from a typical level concrete sill with familiar anchor bolting and earthquake strapping. Crawl spaces with standard plastic vapor barriers are vented in the typical manner,

and garage slabs are compacted and poured in the conventional way. The system is applicable for lot slopes up to 10 percent grade, and can be used in almost any penetrable soil.

Each building site has different conditions, so the specific configurations vary:

- **Gig Harbor:** A two-story home did not require grading or site manipulation, and builders poured the foundation to follow the grade of the site.
- **Key Peninsula:** Builders used a feathering approach where they bladed off surface sod. Soils shaped in benches and differing in height by just 4 inches were stepped down a 4-percent grade. Here the underlying soils were silts, which tend to be poor for conventional footings, especially when they become wet and soft.
- **Fox Island:** The goal on this low-bank beach was to avoid digging a conventional foundation pit that would trap water during flood tides.
- **Olympia:** Builders put in an addition to a home designed to minimize the disturbance to existing lawn, gardens and patio.

Costs

L.I.F.T. is comparable in cost to conventional systems. L.I.F.T. systems use 20 to 30 percent less concrete, reduce the amount of site materials such as drain pipe and imported gravels, and reduce trucking, excavator and bulldozer time. In one of the houses mentioned above, the L.I.F.T. system cost 5 percent more than the conventional system. Housing projects with 10 or more homes will realize the most substantial savings of the L.I.F.T. system.

L.I.F.T. foundation installation at Habitat for Humanity on the Key Peninsula.

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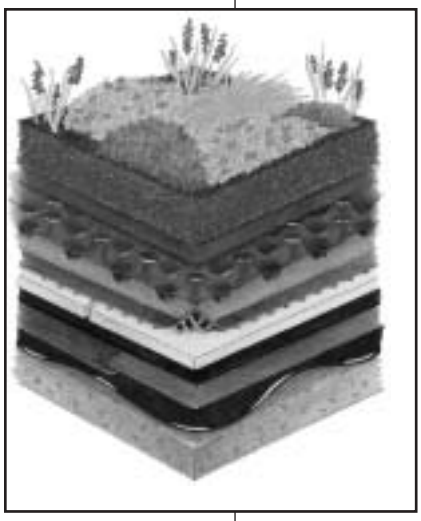
Justice Center Green Roof

City of Seattle

Background

The city of Seattle needed to replace the old Public Safety Building, which was seismically deficient and near the end of its useful life. Its replacement, the Justice Center, is one of the first city projects built to conform to the city's Sustainable Building Policy. To provide stormwater control and other benefits, a green roof—or living roof—was included in the design.



Graphic Courtesy of American Hydrotech

The green roof is made up of a multilayered waterproofing membrane that's integrated with a soil support system. The egg carton-shaped water retention liner helps retain moisture in the shallow soil between rainfalls.

Description

The Justice Center green roof consists of a multilayered waterproofing membrane integrated with a soil support system. The first layer in the system is the waterproofing component. Installed over a prepared roof surface, it is a flexible monolithic membrane composed of refined asphalts and synthetic rubbers. An extra layer of fabric reinforcement is included between two membrane applications. Additional layers over the waterproofing form the integrated soil support system, which comprises the root barrier, insulation, water-retention liner, filter fabric and a lightweight planting soil.

The egg-carton-shaped water-retention liner helps to retain moisture between rainfalls. Shallow cups hold water and alleviate some of the harsh conditions of the rooftop environment that can quickly dry because of the shallow soil profile. Rainwater not retained by the soil or water-retention liner flows through holes in the peaks of the liner cups, eventually making its way into subsoil runnels. The water then combines with runoff from the non-landscaped roof area and flows to a water-storage facility at street level. Captured rainwater irrigates landscaping at the base of the building.

The roof system plants will require little or no maintenance. The plants are drought resistant and do not require additional watering, fertilizing, mowing or pruning. With sustainability a top design criterion, designers rejected the idea of an irrigation system for the green roof. Hose bibs located nearby aid in establishing the plants for the first few years.

Green roof systems are generally divided into two categories: extensive and intensive. The Justice Center uses an extensive system, which is characterized by shallow soils typically 3- to 6-inches deep. The weight of an extensive system with saturated soils is not much heavier than that of conventional rooftop ballast applications, making additional structural support systems unnecessary.

An intensive green roof differs from an extensive green roof primarily in soil depth. Intensive green roof soils are deeper than 6 inches, allowing for larger plants. The additional soil produces a heavier roof load, which often requires additional structural support.

Benefits

The green roof's soil layer has a sponge-like quality. It will hold a significant quantity of water, as well as releasing water that it can't hold more slowly than a conventional roof. The slower release smoothes out or attenuates peak stormwater rates. Evaporation from the soil surface and transpiration by the plants will further reduce the total volume of water that flows from the roof. In the case of the Justice Center, water that does flow from the roof will be stored for irrigation at street level, reducing the total load to the city stormwater/sewer system.

The green roof also provides benefit in energy savings. Thermal insulation provided by the soil layer slows heat transfer to the structure in the summer and reduces heat loss in the winter.

Life-cycle analysis suggests that the waterproofing for a green roof will last longer than that of a conventional roof. By protecting the waterproofing from ultraviolet degradation, mechanical puncture and temperature extremes, green roofs are less susceptible to heat damage and cracking.

The green roof also provides potential fly-over habitat for birds, and reduces localized heat gain caused by dark, heat-absorbing roof surfaces. The green space will be a welcome environment for staff, visitors, and jurors, turning a former stormwater problem into a building amenity.

Photo Courtesy of SvR Design Company

The Justice Center's 12th-floor plaza transforms what would have been a conventional flat roof into a living system that will absorb rain and provide a rooftop oasis.

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Bayview Corner
Whidbey Island

Background
Goosefoot Community Fund is dedicated to preserving rural character and historic features and promoting sustainable development on Whidbey Island. To demonstrate non-traditional and sustainable development strategies, the fund developed a rural office and retail hub and learning center at Bayview Corner, on the southern part of the island.

The public restroom at Bayview Corner near Langley on Whidbey Island uses a number of cutting-edge sustainable design features.

Description
The fund constructed a public restroom facility from reclaimed and recycled materials to demonstrate cutting-edge sustainable building design. The building features solar panels, a 90-gallon rooftop water collection system, composting toilets, waterless urinals and gray water processing. Fund managers estimate that these practices save 10,000 to 15,000 gallons of water each year.

A renovated 1914 Sears Kit House demonstrates innovative techniques such as a Rastra® foundation, which uses insulated concrete forms made from recycled Styrofoam; old-growth redwood wainscoting milled from a salvaged water tower; and pervious concrete parking for nine parking spaces. For the permeable parking lot, they used a mix similar to regular concrete, but without the sand. This leaves air spaces in the slab, allowing water to pass through to the soil below.

Challenges
Part of the challenge in building these demonstration projects has been satisfying government permit requirements. Quite often, systems such as a septic system for the composting toilet building have been overbuilt to meet current building codes and have incorporated devices to monitor any usage. As a result, it is difficult to make any cost comparisons to traditional projects. As trust and relationships develops with regulators, projects will move more quickly and costs should decrease.

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The Evergreen State College Zero Impact Feasibility Study

City of Olympia

Background

The Evergreen State College on the outskirts of Olympia has 4,500 students on a 1,000-acre campus. The campus's storm drainage system—built before current standards—has no treatment or detention systems. In 1998, the college adopted a stormwater goal in the master plan: "For planning purposes the college should try to limit runoff on campus by minimizing hardened surfaces and maximizing undisturbed forest."

Evergreen then obtained a grant from U.S. EPA Region 10 to study the feasibility of disconnecting the college's storm drains from the streams around the campus. The campus seemed a good candidate for this study because the campus has 70 percent forest cover area, which is greater than the recommended minimum for "zero impact"* projects.

Prior to the study, there was no visible damage to streams in the area, in spite of the lack of stormwater treatment or detention. However, part of the campus discharges to Green Cove Creek, which the city of Olympia and Thurston County have singled out for special protection. Part of the campus also discharges to Houston Creek, a productive salmon stream. College officials also wanted to do the study to foster sustainability, to provide an example for the community, and to provide a teaching opportunity.

Description

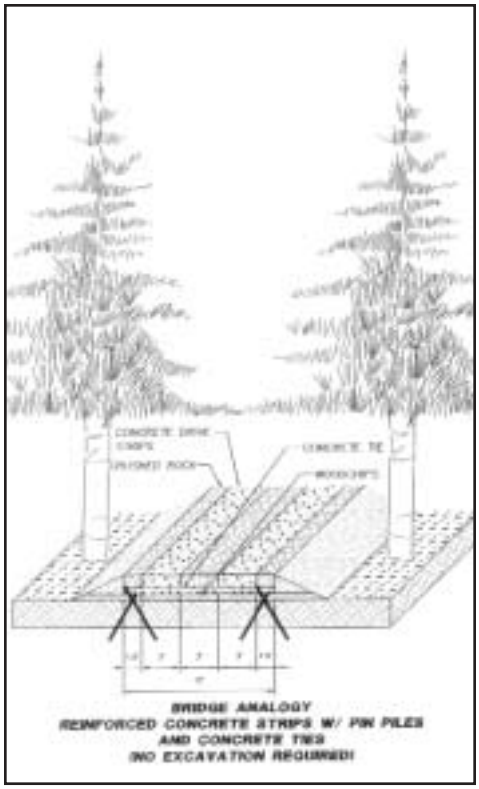
The college hired consultants to inventory stream conditions and review existing studies on fisheries and water quality. Consultants also reviewed the college's comprehensive plan and capital improvement program and engineering studies of campus soils, groundwater, geology and infrastructure. They produced two kinds of analyses:

- How to introduce zero impact development design to new structures.
- How to retrofit existing development during the course of major redevelopment projects.

The study identified five areas for the use of low impact techniques: roofs, parking, roads, walkways and landscaping.

Recommendations include:

- **Roofs.** Use of infiltration, collection and green roof systems.
- **Parking.** Alternatives include adding stormwater storage under parking areas and in landscape strips, and reducing impervious surfaces through use of pervious paving.



Road design concept that requires no excavation.

***Zero Impact** means a project that adheres to the 65/0 (65 percent forest cover preserved/zero effective impervious surface) development standard and is constrained by characteristics of a healthy watershed as described in Salmon in the City Conference Abstracts.

Evergreen State Feasibility Study, *continued*

- **Roads.** Use of pervious pavement, directing drainage to adjacent forests, amending the soils of side slopes, and disconnecting drainage from streams. Recommendations included new road design concepts, some of which did not require excavation of existing soils for their construction.
- **Walkways.** Many campus walkways serve more as architectural statements than transportation. Alternatives include removal, replacement with pervious walks, placing pervious buffers around catch basins, expanding planters, and adding grass-roofed covered walkways.
- **Landscaping.** While there is comparatively little formal landscaping on campus, the study recommended that some landscaped areas could be converted back to natural forest, with amendment of soils to repair compacted areas.

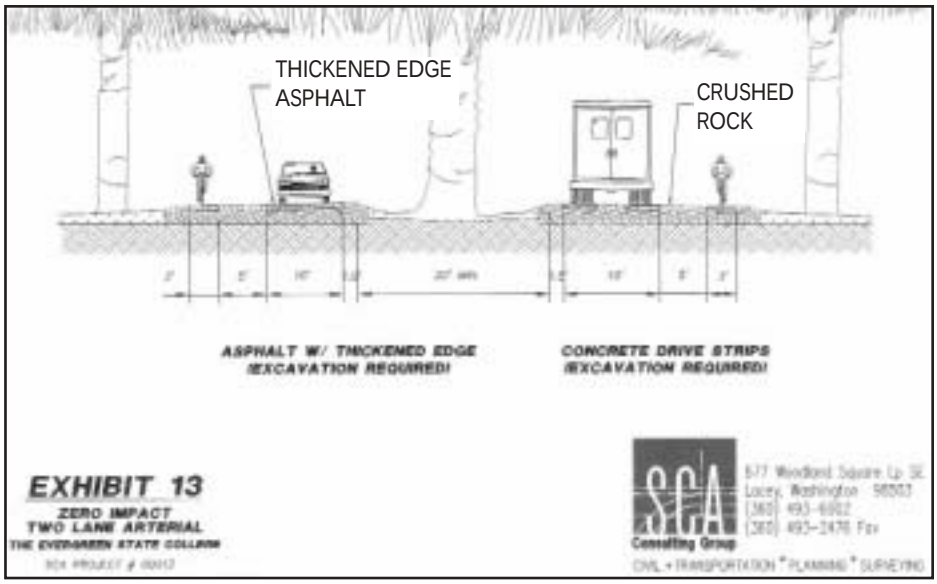
Results

The college has begun to implement the study by including a garden roof on its new Seminar 2 building (construction began in 2002). Soon, the college will rebuild portions of its parking lot using pervious pavement systems and may build a motorcycle parking structure with a vegetated roof. This would be a study focus for students in the environmental studies program.

Costs

The study estimated that the costs of zero impact roads and stormwater systems would be as much as 60 percent lower than traditional high impact systems. Conversion of car parking to pervious pavers would be the same as or lower than traditional alternatives, which require expensive new treatment and detention systems. Green roofing would be more expensive, but the life-cycle cost might be lower.

An important factor in choosing the pervious paving systems is that this approach negates the need to clear and grade surrounding forest areas for detention ponds. Implementing the study's recommendations has an additional benefit to the public because the drainage system



New road design concept for arterial roads features narrow roads and permeable shoulders.

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could eventually be disconnected from the local stream system.

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High Point Natural Drainage Systems Study

City of Seattle

BACKGROUND

Starting in 2003, the Seattle Housing Authority (SHA) will begin construction of a 120-acre mixed-income housing development in West Seattle. The development will include a new street grid complete with new utilities, sidewalks, and trees. Plans call for a natural drainage system to be integrated into the new street layout, creating a network of connected, vegetated and grass-lined swales. The site comprises one-tenth of the Longfellow Creek watershed, and this project is a once-in-a-lifetime opportunity to provide neighborhood enhancements and improve the health of the creek.

DESCRIPTION

Longfellow Creek watershed started feeling the effects of development in the early 1900s. Physical barriers, piping of sections of the creek and pollution reduced the return of chum, coho and chinook salmon. In recent years, the removal of barriers and development of the Legacy Trail along the creek corridor increased fish and wildlife populations and promoted community stewardship of the creek.

A naturalistic approach to planning features a network of grass-lined and vegetated swales.

Now SHA and Seattle Public Utilities (SPU) are going to the source of the problem by completely changing how they manage stormwater in the High Point neighborhood of West Seattle. Currently, a series of underground pipes collect stormwater and discharge it directly to Longfellow Creek, polluting its waters. SHA and SPU will redevelop the existing drainage system in this neighborhood with a new naturalistic approach. The approach to redeveloping the High Point neighborhood will provide guidelines for future construction of

High Point Study, *continued*

publicly and privately funded homes. High Point will feature 1,600 primarily low-rise rentals and owner-occupied homes on 120 acres.

Throughout 2002, SvR Design Company worked with the city, SHA, SPU, the Seattle Department of Transportation, and the community to develop a menu of natural drainage system options tailored to the needs of each neighborhood block. These options balance "people space" (playable space and garden walks) with stormwater management (infiltration, filtering and flow control). A network of grass-lined and vegetated swales will filter and moderate water flows entering the creek. This will reduce discharge of pollutants, decrease erosion, stabilize the creek water temperature, and ultimately improve the habitat for salmon and other wildlife in Longfellow Creek.

Expected Results

This new drainage approach will function as a natural system by increasing infiltration, improving water quality, and decreasing the volume and rate of runoff from the development. Rain falling on pavement will flow into the swales where vegetation will slow the water. Soils, amended with organic material to mimic a natural forest duff layer, will increase the rate of infiltration and water-holding capacity. Pollutants, pesticides and animal waste will be absorbed into vegetation and onto soil particles. Gravel under the modified soils will improve infiltration and increase water retention capacity. During smaller storms, rainwater will slowly infiltrate into the soils and eventually into the groundwater. During larger storms, water flow will be slowed before entering the creeks, thus reducing flooding and erosion of stream banks. SHA and SPU will also provide design guidance for amending the soils on homesites to reduce runoff from roofs and lots into the swale system.

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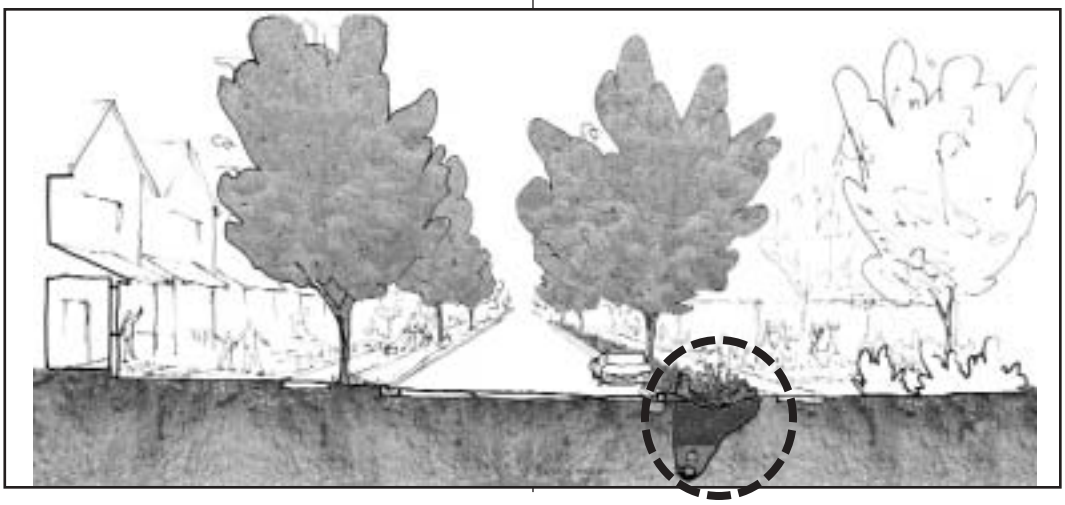

Bioretention swales (circled) will treat, reduce and slow stormwater runoff from impervious surfaces and function as a natural system.

SARB_004126

Low Impact Development Program
City of Chilliwack, British Columbia

Background
The city of Chilliwack, east of Vancouver, British Columbia, has a population of 70,000 and covers 281 square kilometers (108.5 square miles) and nine watersheds that drain primarily to the Fraser River. Most of Chilliwack sits on the valley floor, but there is pressure to develop on the steep hillsides. The city decided to promote low impact development to address growing problems with flooding, and to protect habitat and water quality, enhance salmon streams, and recharge ground water.

Description
City officials adopted an integrated master drainage plan that incorporates a development philosophy and design standards based on LID technologies. One objective of the plan is to "manage development to maintain stormwater characteristics that mimic the peak flows, duration of flows and water quality in the pre-development watershed."

City staff are working with developers to incorporate several low impact design principles, such as smaller lot sizes, narrower roads, and elimination of curbs, gutters, storm drains and sidewalks. Many developers are reluctant to use the principles for fear of not being able to market the lots. However, several developers have agreed to incorporate LID, and this experience will be instructive.

The developer built the **Peach Road Subdivision** with small lots, a narrow road and no storm drain for the street. Roof runoff goes into the yards and then drains to a surface swale for infiltration. The road has no storm drain; water runs down the road to an infiltration gallery. A major rainfall in January 2002 overwhelmed the capacity of the infiltration gallery, leading to some flooding and damage to a few houses. Although the developer remains committed to low impact development, he is building a detention pond on an adjacent subdivision to handle the largest storm events.

The Peach Road subdivision in Chilliwack, B.C. features small lots, a narrow road and no storm drains in the street.

Suncor Developments is another residential development following LID principles. Twenty-two lots, built as of December 2002, feature narrow roads, no sidewalks, and no curb or gutter. Road runoff flows to an infiltration gallery.

The **Russel Heights Townhouse Project** is located on a challenging site with steep slopes. Runoff from the lots will be directed to a large green area for infiltration. Road runoff will be directed to an infiltration gallery that will provide detention for medium storms. Large storms will bypass the infiltration gallery.

The city plans to install monitoring stations at each of these residential housing projects to monitor both runoff volume and water quality chemistry. Chemical parameters will include temperature, turbidity, dissolved oxygen, and pH.

Monitoring for two other LID projects will also begin in the coming year. Stream International has an existing 800-stall parking lot that discharges into an adjacent stream. After negotiations with the city, Stream agreed to help build an

Low Impact Development Program, *continued*

infiltration gallery on adjacent city property that will serve Stream as well as some other properties. At Village at Sardis Park a major green space will serve as an infiltration system and detention facility for road runoff.

Costs

Development costs for the LID residential projects are approximately $800 (Canadian) higher per lot than for conventional systems. The higher costs are due to requirements for redundant stormwater facilities in case the LID facilities don't perform as expected.

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Meadow on the Hylebos Residential Subdivision

Pierce County

Background

Pierce County is working with a developer and AHBL Engineering to bring low impact development technologies to the Meadow on the Hylebos—a sensitive residential development site in north Pierce County.

The site is located on an important stream system—the Hylebos Waterway. The intent of the project is to use a variety of LID technologies to demonstrate the potential benefits to managing runoff volume and protecting water quality. Due to the proximity to the Hylebos Waterway, the technologies also offer the potential to enhance wildlife values by preserving and reintroducing native vegetation.

Another project objective is to deliver a housing product that is attractive and affordable. The Meadow on the Hylebos establishes a design process and forum through which the developer and Pierce County can cooperate, understand challenges, and develop a design that meets the objectives of environmental protection and affordable housing.

Description

The Meadow on the Hylebos is an 8.9-acre site located between Milton and Fife in unincorporated Pierce County. The site is located at the intersection of SR 99 and 70th Street, at the geographic center of an urban growth area. It is well served by freeways and arterials. The site is highly visible, located on the hillside above the Puyallup Valley floor. With its relatively steep slopes, it offers panoramic views of the valley and Mt. Rainier. Soils on the site are primarily glacial till, offering a challenge for low impact design.

Construction on the project is due to begin in Spring 2004. The developer plans to build 35 residential units on the property. The drainage plan for the subdivision calls for the use of a variety of LID techniques, including narrower, open

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road sections with swales; bioretention areas; pervious pavement; and low impact foundation technologies to reduce building excavation. The homes will incorporate a number of green building techniques as well.

Once completed, the Meadow on the Hylebos will be an important demonstration project for the application of LID technologies in an integrated site design. The project will be the first in Pierce County to fully illustrate the range of LID technologies in a typical residential subdivision.

A consortium of public and private sector organizations is monitoring the site for pre- and post-development runoff volume to evaluate the effectiveness of the LID practices. Depending on available funding, the group will monitor water quality as well. Washington State University Cooperative Extension is leading the effort, and is partnering with Pierce County, AHBL, the University of Washington, Pacific Rim Soil and Water, and the Puget Sound Action Team.

Costs

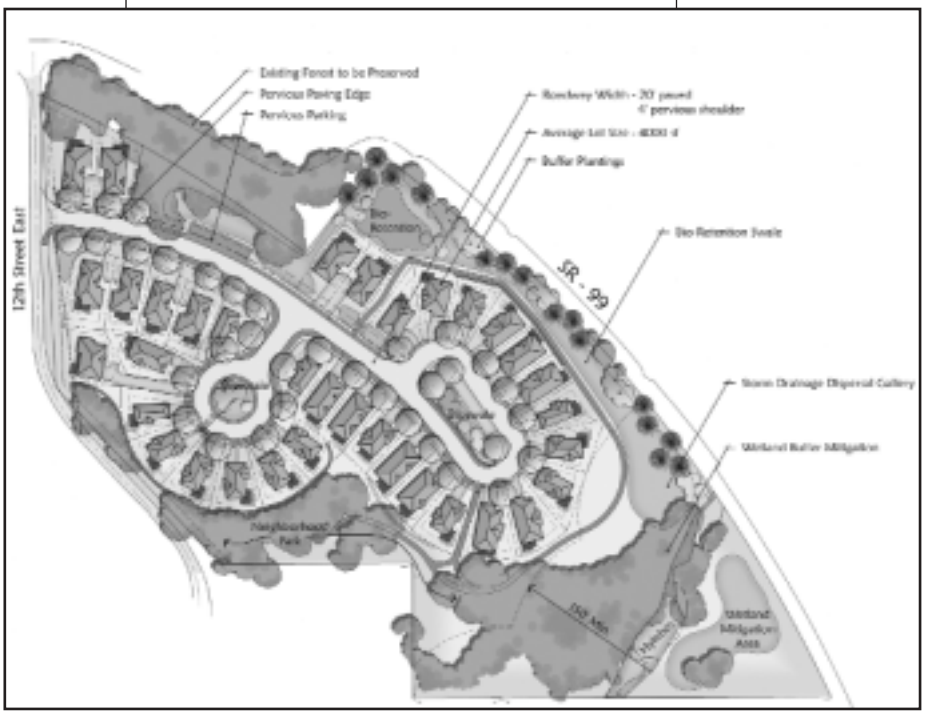
AHBL prepared a cost evaluation for the site for both the conventional design and LID preliminary plat design. The evaluation indicates a potential savings in construction costs of approximately 9 percent.

Kensington Estates

For another project in the county, AHBL analyzed a recently completed subdivision, Kensington Estates, to document the potential benefits that might have occurred if the subdivision had incorporated LID technologies rather than conventional techniques. AHBL applied the new drainage model in the Department of Ecology's *Stormwater Management Manual for Western Washington*, then outlined the LID process, chose appropriate control techniques, and conducted comparative cost analyses between LID and conventional stormwater management techniques. The resulting redesign of the project protected sensitive areas, provided additional green space, accommodated access for emergency vehicles, and maintained the same number of development lots. The results of the exercise showed an approximately 20 percent reduction in development costs.

Expected Results

The Meadow on the Hylebos project will demonstrate the benefits of using LID technologies in a residential subdivision. It will demonstrate individual techniques and show that the application of LID



The Meadow on the Hylebos design retains forests, clusters homes, uses bioretention swales and includes pervious parking.

Meadow on the Hylebos, *continued*

technologies in a residential setting results in attractive housing and green neighborhoods.

The Meadow on the Hylebos will provide the development community and Pierce County with a forum in which to explore the design and permitting process for an LID project. The project is a joint application between Pierce County and the developer. The project will improve protection of an important fish-bearing stream, deliver a housing product that is affordable, and establish a design process and forum through which the developer and jurisdiction can cooperate, understand challenges, and develop a design that meets the objectives of environmental protection and affordable housing.

In addition to potential construction cost savings, AHBL has found that application of LID technologies can help maintain project densities. Ecology's new drainage model can result in much larger detention ponds for conventional developments, reducing the number of buildable lots if developers don't incorporate LID practices. AHBL's design work indicates that projects could lose approximately 10 percent of their proposed net density if LID practices are not incorporated into new developments. The application of LID technologies thus gives communities a way to not only preserve the environment, but also maintain densities as mandated in the Growth Management Act.

Challenges

The first major challenge was to identify a potential piece of property and a willing developer to accomplish the demonstration project. The site's location on the Hylebos, within the geographic center of the urban growth area, and the interest of the developer to protect the environmental quality of the site all lent themselves to an LID project at this location.

The chief obstacle faced during project design was reconciling the many jurisdictional requirements while still maintaining the objectives of demonstrating LID technologies. For example, the Tacoma Fire Department insisted on a wider street profile to maneuver their emergency vehicles. AHBL modified the site plan to accommodate these concerns and still achieved the primary objectives of low impact design.

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SARB_004130

Salishan Public Housing Project
Zero Impact Development Feasibility Study
City of Tacoma

Background
The Tacoma Housing Authority plans to redevelop the 150-acre Salishan Public Housing Project. This will involve razing existing World War II vintage housing and replacing it with 1,200 new units for approximately 3,000 people.

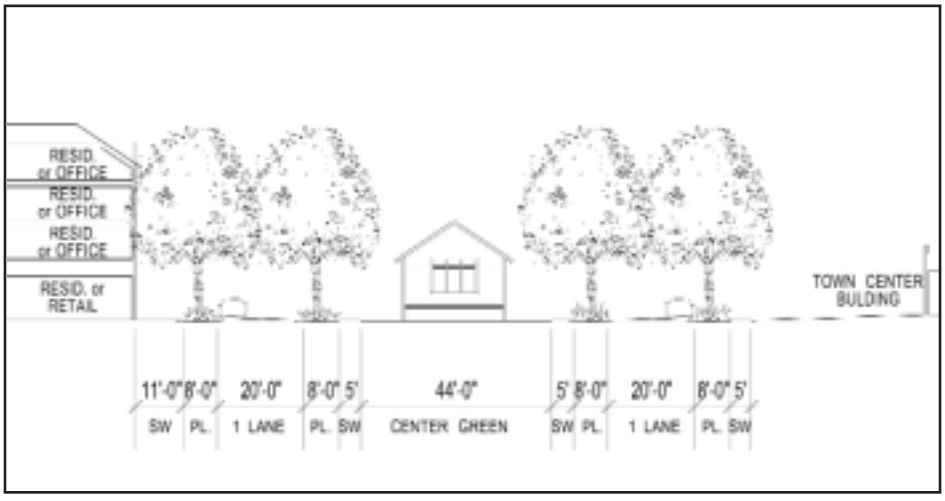
In addition to the housing benefits, Tacoma Housing Authority's goal is to reduce or eliminate Salishan's impact on tributaries to the Puyallup River. Historically, Swan Creek supported chinook salmon and other fish species. As a first step, Tacoma Housing Authority commissioned a feasibility study to determine if the project could be redeveloped using zero impact development* (ZID) standards and remain within the guidelines and cost constraints from the U.S. Housing and Urban Development funding requirements.

Description
A team of consultants led by Torti Gallas and Partners performed the feasibility study. Washington Department of Ecology provided grant funding for the study. SCA Consulting Group wrote the grant proposal, and served as project hydrologists, stormwater engineers, and road designers for the Torti Gallas study team. Consultants compiled ZID standards and design guidelines and compared these standards with existing city of Tacoma standards. This helped identify variances to existing development codes that would be needed to construct the project. One of the goals of the project was to retain 65 percent of the site in forest cover. The team considered every square foot of the project for retention, restoration and reforestation to meet the forest cover target.

The Salishan property straddles Swan Creek and T-Street Gulch canyons on Tacoma's Portland Avenue between 38th and 56th streets. These canyons provide a significant amount of forested area that could be preserved and counted toward the goal of 65 percent forest cover for the project.

Approximately 3.5 miles of new and existing streets will provide access to the project. Therefore, a major focus of the study was street design using pervious systems and roadside bioretention facilities. The consultants counted the bioretention facilities toward the forest

*** Zero Impact Development** means a project that adheres to the 65/0 development standard and is constrained by characteristics of a healthy watershed as described in the Salmon in the City Conference Abstracts."65/0" means 65% forest cover preserved / zero effective impervious surface.



The Salishan design calls for wide planter strips and a bioretention area in a center green space.

Salishan Public Housing Project, *continued*

The feasibility study recommended California strips, such as those pictured above, for use in alleys at Salishan.

cover goal. They also investigated the benefits and costs of pervious paving systems for parking lots, rooftop rainwater collection systems, green roofs, wastewater recycling and reforestation of open spaces.

Results

The study found that the cost of new street construction was lower than or comparable to conventional practices. However, soil restoration for the portions of the project that would be restored to forest added considerable cost to the project. This may put low impact redevelopment for this site at a cost-disadvantage compared to traditional high impact development practices. The draft study, including cost comparisons, is now available.

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SARB_004132

Vancouver Island Technology Park
Saanich Municipality

Background

The British Columbia Buildings Corporation is redeveloping the former Glendale Lodge Hospital in the Municipality of Saanich. The goal is to convert the 165,000 square-foot hospital into the Vancouver Island Technology Park to provide space for high-technology research and development businesses.

Saanich has a bylaw requiring all new developments to provide a stormwater management facility to handle the change in post-development stormwater runoff. The Vancouver Island Technology Park proposal presented an opportunity to simultaneously restore stream and wetland function to many previously degraded freshwater systems. The design incorporated LID stormwater management practices to prevent water quality degradation during and after development and to protect and restore riparian function. Aquatic and terrestrial wildlife habitat have both improved as a side benefit of these activities.

The Vancouver Island Technology Park project received the LEED Gold certification (version 2.0) from the U.S. Green Building Council. This was the first project outside the U.S. and the first retrofit anywhere to get Gold certification.

Description

The project consultant, Aqua-Tex, designs and builds ecologically functional stormwater treatment facilities. Aqua-Tex looks for opportunities to work with the development community to find cost-effective stormwater solutions that not only deal with on-site stormwater, but also address stormwater problems from neighboring sites (stormwater run-on). Aqua-Tex also seeks to regenerate or rebuild riparian areas.

A newly constructed stormwater pond. Designs are intended to manage stormwater and protect and restore riparian habitat function.

Project designs most closely resemble constructed wetlands, and are based on the Properly Functioning Condition criteria for streams and wetlands developed by the U.S. Department of Agriculture's Forest Service/Bureau of Land Management. The firm has adapted these criteria for urban use. Using these criteria in the design assures that the final project will function effectively over the long term without expensive maintenance. The criteria also serve as a checklist for addressing all critical aspects and avoid focusing on a single value such as fish habitat.

Aqua-Tex designed the stormwater management plan to deal with immediate redevelopment needs and a significant amount of run-on from adjacent properties. They created stormwater ponds and channels on two sides of the property to provide maximum detention and infiltration, and to capture runoff from adjacent parking areas at Camosun College and Layritz Park. Grassy swales and open channels, rather than piping, lengthened flow paths. Other practices

Vancouver Island Technology Park, *continued*

Site design of the Vancouver Island Technology Park includes extensive open space.

included splitting stormwater flows so they were not concentrated in one location, reconfiguring and vegetating existing drainage ditches to slow flows and trap sediment, and amending soils around stormwater ponds to better establish new plantings, improve infiltration, and reduce surface runoff. In addition, the design included shallow stormwater ponds within the forested area to avoid tree root damage and soil compaction.

Other design features also minimized stormwater runoff and improved ecosystem function. GrassPave™ and GravelPave™ provided parking surface for approximately 170 cars. The parking lot will handle the stormwater volume from a 10-year storm event. Using rainwater on site wherever possible minimized runoff; for example, dual plumbing allows collected rooftop rainwater to be used to flush the building's toilets. Though not currently in use, rainwater may in the future be used to flush toilets. Collaboration with the Horticulture Centre of the Pacific and Saanich Parks helped determine the location of walking trails outside the floodplain. The use of more natural materials in the stormwater facilities, such as large logs rather than concrete, helped restore Viaduct Creek.

Challenges

Coordinating this "green" project required extra effort for all parties. Communicating the requirements of the stormwater bioswales, wetlands and ponds to the design team, particularly the engineers, was problematic as they were unfamiliar with this approach.

Costs

Incorporating LID features into Vancouver Island Technology Park provided considerable cost savings. The LID approach cost $150,000 while a conventional stormwater treatment system would have cost $680,000. The savings are due to the pipes and excavation that are not needed in the LID approach.

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SARB_004134

Island County Stormwater Code Low Impact Development Requirements

Background

In December 1998, Island County adopted a stormwater ordinance that provides developers with the option of using low impact development practices. The design standards are based on *Low Impact Development Design Strategies—An Integrated Design Approach,* prepared by Prince Georges County, Maryland, January 2000.

Description

The Island County Stormwater and Surface Water Ordinance provides special performance requirements that developers must meet for their development proposals to qualify as LID. The code states:

A. Runoff Volume Control. The pre-development volume is maintained by a combination of minimizing the site disturbance from the pre-development to the post development condition and then providing distributed retention BMPs. Retention BMPs are structures that retain the runoff for the design storm event. A "customized" or detailed runoff curve number (CN) evaluation is required to determine the required runoff volume. The storage required to maintain the pre-development volume may also be sufficient to maintain the pre-development peak rate.

B. Peak Runoff Rate Control. Low-impact development is designed to maintain the pre-development peak runoff discharge rate for the selected design storm events. This is done by maintaining the pre-development time of concentration and then using retention and/or detention BMPs (e.g., rain gardens, open drainage systems, etc.) that are distributed throughout the site. The goal is to use retention practices to control runoff volume and, if these retention practices are not sufficient to control the peak runoff rate, to use additional detention practices to control the peak runoff rate.

C. Flow Frequency Duration Control. Since low-impact development is designed to emulate the pre-development hydrologic regime through both volume and peak runoff rate controls, the flow frequency and duration for the post development conditions will be almost identical to those for the pre-development conditions. The impacts on the sediment and erosion and stream habitat potential at downstream reaches can then be minimized.

D. Water Quality Control. Low-impact development is designed to provide water quality treatment control for the duration storm runoff from impervious areas using retention practices. The storage required for water quality control is compared to the storage required to control the increased runoff volume. The greater of the two volumes is the required retention storage. Low-impact development also provides pollution prevention by modifying human activities to reduce the introduction of pollutants into the environment. (Title 11.03)

The ordinance allows applicants who propose to use LID practices for development approvals a choice. Applicants of small development projects may accept permit conditions that fulfill

Island County Stormwater Code, *continued*

the best management practices for LID surface water rate control in lieu of submitting a drainage narrative. For major development activities and engineered grading projects, applicants who propose to use LID drainage controls may submit a drainage narrative instead of a preliminary drainage plan. The ordinance does not require a downstream analysis when the project design includes and is approved for using LID standards.

To date, LID practices have been partially applied in developments such as Bayview Corner (see page 26), but no major developments have used LID technologies in Island County.

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Stormwater Management Policy for Low Impact Development

City of Issaquah

Background

The city of Issaquah is growing rapidly. With annexations, the population could increase from 13,790 today to 47,000 by 2020. Two urban villages alone—Issaquah Highlands and Talus—could add more than 5,000 residential units, 3.5 million square feet of commercial and office space and 500,000 square feet of retail space. This growth will place heavy demands on already limited groundwater supplies, a congested road system and degraded stream ecosystems. Issaquah Creek is a regionally significant stream that provides habitat for the threatened Puget Sound chinook salmon. In 2000, the city of Issaquah adopted an update to the stormwater code (Title 13.28.055) that provides a process and criteria for evaluating low impact development proposals.

Description

The municipal code authorizes the Director of Public Works to authorize deviations from stormwater design standards to achieve "low impervious surface development." The director also has the option of requiring evaluation and monitoring of project elements. The code language is on the Municipal Research Services Center website (www.mrsc.org). Go to "Legal Resources," then "City and County Codes," then "City Codes" to Issaquah City Code Title 13.28.055.

Authorizations for deviation from design standards are to be based on the following criteria. The policy states:

1. The deviations will produce a compensating or comparable result in stormwater flow control and treatment that is in the public interest;
2. The deviations contribute to and are consistent with the goal of achieving low

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effective impervious surface area within a development;

3. The proposed development project offers reasonable assurances that low impervious surfaces will be achieved and maintained;
4. The deviations do not threaten public health or safety;
5. The deviations are consistent with generally accepted engineering and design practices;
6. The deviations promote one or more of the following:
   a. Innovative site or housing design;
   b. Increased on-site stormwater retention using native vegetation;
   c. Retention of at least 60 percent of natural vegetation conditions over the site;
   d. Improved on-site water quality beyond that required by current applicable regulations;
   e. Retention or re-creation of pre-development and/or natural hydrologic conditions to the maximum extent possible;
   f. The reduction of effective impervious surfaces to the maximum extent practicable;
7. The deviations do not allow density greater than what would otherwise be allowed under city regulations then in effect;
8. The deviations do not present significantly greater maintenance requirements at facilities that will be eventually transferred to public ownership;
9. There shall be submitted in conjunction with each such project, covenants, conditions and restrictions which will be binding upon the property all necessary native growth protection easements, impervious surface restrictions and such other critical features as the Director may require.

The Issaquah Municipal Code (Title 13.30) also provides an incentive for projects that infiltrate stormwater. Projects that infiltrate 100 percent of the stormwater can receive up to a 50 percent reduction in the stormwater utility fee.

On other fronts, the city is considering a more comprehensive sustainable development program, including incentives. Some of these provisions relate directly to LID, such as green streets, green roofs, and pervious pavers.

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Zero Effect Drainage Discharge Ordinance

City of Lacey

Background

In 1999, the Lacey city council enacted a "Zero Effect* Drainage Discharge" ordinance. Lacey, in Thurston County, has a population of 31,000 and an urban growth area of 31 square miles. City officials, understanding that even small increases in runoff can damage area streams, chose to encourage developers to achieve zero discharge of stormwater runoff. This could well be one of the very first ordinances of this kind passed in the nation.

Description

The goal of Lacey's ordinance is to retain the critical functions of a forest including evapotranspiration and infiltration after site development such that near zero effective impervious surface is achieved. The purposes of the ordinance show that city planners saw this as a new concept that would go through trial and evolution. The ordinance states:

A. Provide those developing land the opportunity to demonstrate zero effective impervious surfaces.

B. Improve the conditions of habitat and ground and surface waters within a watershed with innovative urban residential design and development techniques.

C. Foster broad community acceptance of the use of significantly less impervious surface and greater natural habitat conservation on sites.

D. Provide the opportunity to identify and evaluate potential substantive changes to land use development regulations which support and improve natural functions of watersheds.

The ordinance is flexible and establishes performance standards for development rather than specific design criteria. A committee of Lacey staff has the authority to grant administrative variances from traditional standards to achieve the ordinance's goal.

Projects must preserve 60 percent natural habitat area and achieve "near zero effective impervious surface." A variety of practices can contribute to meeting the provisions of the ordinance, such as:

- Constructing narrower roads without curb and gutter.
- Using pervious paving systems.
- Using native forest as the stormwater management system.
- Avoiding discharges from impervious surfaces to surface streams.

Expected Results

The intent of the ordinance is that projects constructed under this ordinance will eliminate overland flow discharges and have no measurable impact on receiving waters and aquatic life. Such projects will be more aesthetically pleasing, require little or no erosion control during construction, and add value to the city.

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Website for Chapter 14.31 Zero Effect Ordinance:
www.wa.gov/lacey/lmc/lmc_main_page.html

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*** Zero Effect (or Impact) Development** (ZID) means a project that adheres to the 60/0 development standard and is constrained by characteristics of a healthy watershed as described in the Salmon in the City Conference Abstracts. "60/0" means 60 percent forest cover preserved /zero effective impervious surface.

SARB_004138

Low Impact Development Strategy for Green Cove Basin

City Of Olympia

Background

Olympia, with a population of 41,000, is a rapidly growing city in Thurston County. Despite a variety of measures enacted in the 1980s and 1990s to increase density and protect environmental quality, the quality and diversity of aquatic habitat in the city continued to decline.

In 1998, Olympia undertook a process to "define the balance between human activities and protecting habitat" in its streams and watersheds. After reviewing all city watersheds, the city council decided to focus on the 2,600-acre Green Cove Creek watershed in west Olympia. In October 2001 the Olympia City Council adopted a unique set of mandatory low impact development regulations to prevent further damage to aquatic habitat from urban development in the Green Cove Basin.

Description

Olympia elected officials and staff went through a three-year process of research, analysis and peer review in designing the program for Green Cove Basin. Following is a summary of the major steps:

- Consultants developed criteria for evaluating the viability of aquatic habitat in Olympia's eight watersheds and recommended goals for growth and habitat based on the habitat potential of each basin.
- A team of scientists, including hydrologists and biologists, reviewed and concurred with the consultant's recommendations.
- The city council agreed to use the recommended approach in the Green Cove Basin as a pilot project and adopted interim standards for zoning density, stormwater management, timing of clearing and grading, and tree removal.
- Consultants developed alternate site plans for two proposed developments in the basin to determine whether they could achieve low impact objectives. The city also consulted with realtors, development engineers, bankers, and developers on the site plans.
- The science team reviewed the standards and proposed designs and confirmed that the proposed subdivision designs were generally consistent with scientific findings and that implementation would have the potential to maintain habitat conditions equivalent to the present.

Based on the above process, the Olympia City Council completed a comprehensive policy revision covering development density, impervious surface coverage, lot size, open space/tree retention, street design, street width, block sizes, parking, sidewalks, and stormwater management requirements. The following is an outline of key policy changes for the Green Cove Basin.

Comprehensive Plan Amendments

- Designate Green Cove Creek as a sensitive drainage basin.
- Avoid high-density development where new development would have a significant adverse impact upon the habitat within designated sensitive drainage basins.
- Administer development regulations that protect critical areas and designated sensitive drainage basins.
- Adopt low impact development regulations within designated sensitive drainage basins that may include

LID Strategy—Green Cove Basin, *continued*

stormwater standards, critical area regulations, zoning designations and other development standards.
- Establish street designs that minimize impacts to the natural environment especially within a designated sensitive drainage basin.

Olympia Municipal Code
- Establish a new zoning district with increased tree protection and replacement requirements.
- Establish residential densities of two to four units per acre; allow duplexes, townhouses, and multifamily uses.
- Reduce lot widths and rear setbacks and increase maximum building heights compared to other residential districts.
- Limit maximum impervious surface coverage per lot to 2,500 square feet.
- Allow several land uses, including duplexes and parking lots that are not typically permitted in single-family residential developments.
- Require a minimum tree density of 220 trees per acre (approximately 55 percent tree cover in any given development).

Development Guidelines and Public Works Standards
- Residential block perimeters cannot exceed 1,700 feet.
- Driveways and sidewalks can be constructed of pervious surfaces with city approval.
- Sidewalks are required on one side of local access streets.
- Sidewalk planter widths can be increased from the required eight feet to an optional 25 feet.
- Additional parking within low impact developments can be provided by the construction of pervious surface lots subject to city approval.
- A rock infiltration gallery/conveyance system is to be constructed when street slopes are 5 percent or less.
- Neighborhood collector streets are to be 25 feet wide, with parking provided on alternating sides of the street.
- Local access streets are to be 18 feet wide, with similar parking arrangements.

Drainage Design and Erosion Control Manual
- Stormwater discharge must be controlled by matching developed discharge durations to pre-developed durations, for the range of pre-developed discharge rates from 50 percent of the two-year peak flow to the 50-year peak flow.
- The city will allow clearing and grading within the basin only between May 1 and October 1 of any given year.

Since part of the Green Cove Basin is in Thurston County, the county adopted policy and regulatory changes to complement Olympia's program. This included changes to the county's comprehensive plan, zoning, and open space program.

Unlike LID ordinances in Lacey and Tumwater that are voluntary, Olympia's Green Cove regulations are mandatory. As of October 2002, the city has received two subdivision projects for development under the new policies.

Challenges

Several questions remain unresolved in the Green Cove basin process. The extra costs of non-standard development techniques have not been defined. One question is whether home buyers will buy homes in a "low impact" neighborhood with narrower streets, less parking, smaller home footprints, and regulatory limits to additions that would increase impervious surfaces. Finally, there are still questions about the environmental

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benefits of the development restrictions, given the overall pattern of development and previous disruption of the natural hydrology.

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For a more detailed case study and a CD-ROM containing project reports and ordinances, contact the City of Olympia.

Low Impact Development Regulations

Pierce County

Background

Unincorporated Pierce County has a population of 330,000 and a land area of 1,790 square miles. The county is exploring the use of low impact development techniques as a method to maintain natural hydrologic functions during the land development process and reduce impacts associated with conventional stormwater management methods. County staff is evaluating various LID methods for quality of performance and applicability. Development of an LID chapter within the county's Stormwater and Site Development Regulations will clarify what LID techniques are acceptable and will establish a performance goal and objectives. This chapter will also provide certainty to land developers and federal and state agencies in terms of performance measures and compliance with National Pollutant Discharge Elimination System requirements.

Description

Pierce County, in cooperation with Washington State University Cooperative Extension, is currently developing an LID chapter for the Stormwater Management and Site Development Regulations. A committee review of the proposal was underway at the time of this writing in late 2002.

The following draft chapter establishes a performance goal and objectives and prescriptive standards for LID.

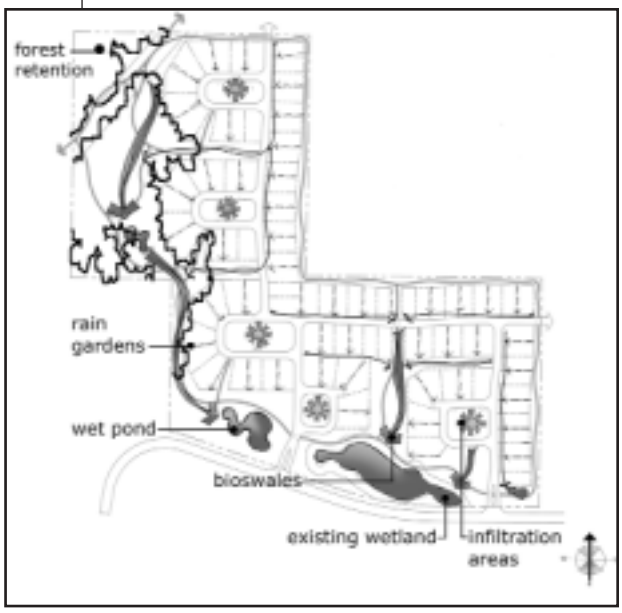
> The goal of Low Impact Development is to manage stormwater generated from new development and redevelopment so there will be no negative impacts to adjacent and/or downstream property owners and no degradation to groundwater or surface waters such as but not limited to streams, ravines, wetlands, potholes, and rivers.
>
> The Low Impact Development goal shall be achieved through adherence to the following objectives:
>
> - Maintain and/or restore the pre-developed, undisturbed stormwater flow volumes, flow frequencies and durations, and water quality from a developed site. In the Puget Sound lowlands, the predeveloped hydrologic condition is near

LID Regulations—Pierce County, *continued*

zero overland flow runoff. (Note: To provide a quantifiable and measurable standard for flow control, minimum requirement #7 Flow Control of the Department of *Ecology Stormwater Management Manual for Western Washington*, will be adhered to in addition to meeting the other objectives listed below. It states that stormwater discharges shall match developed discharge durations to predeveloped durations for the range of predeveloped discharge rates from 50% of the 2-year peak flow up to the full 50 year peak flow.)

- Establish the pre-developed condition of a site used for hydrologic modeling as the native vegetation and soils that existed on the site prior to 1800 A.D., which shall be a forested land cover unless reasonable, historic information indicates the site was prairie prior to settlement (modeled as "pasture" in the Western Washington Hydrology Model.)
- Retain or restore native soils and vegetation on 65% of the site area. Where 65% is not achieved the applicant will demonstrate how the combined use of other LID techniques will achieve the overall goal.
- Limit the effective impervious area of the site to no more than 10%.
- Retain and incorporate natural site features that promote infiltration of stormwater on a developed site.
- The use of traditional conveyance and pond technologies to manage stormwater quality and quantity should only be considered after all other LID techniques have been considered and used to the greatest extent possible.
- Use bioretention, pervious surfaces, open space surface water dispersion, soil restoration, and other dispersed facilities to control stormwater as close to the origin as possible.

Example of a site design using LID techniques.



To meet the goal and objectives, the draft chapter discusses how LID can be considered at each phase of development including: site planning; vegetation retention and reforestation; site clearing and grading; roads, parking and sidewalks; and building design. It also provides best management practices and monitoring requirements. In addition, the chapter will address ongoing management and maintenance needs, and education of homeowners.

Pierce County, in cooperation with Washington State Cooperative Extension, has entered into a partnership with a private developer to develop an LID pilot project. For more information on this project, see Meadow on the Hylebos, page 32, or call Len Zickler, AHBL, at (253) 383-2422.

SARB_004142

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(see Title 17A amendments)

Reduced Discharge Housing Demonstration Program
Snohomish County

BACKGROUND

In the 1990s, Snohomish County, with a population of 628,000, established a program to introduce different development schemes, such as mixed use, affordable housing and innovative designs. As part of this effort, the county adopted the Reduced Discharge Housing Demonstration Program (Ordinance 00-004) in April 2000. This program provides a three-year trial period for selecting and overseeing demonstration low impact development projects.

DESCRIPTION

The reduced discharge ordinance has five purposes:

1. Demonstrate the benefits of alternative development practices that reduce offsite discharge.
2. Improve the conditions of habitat, ground and surface waters.
3. Foster community acceptance of housing that conserves habitat and uses less impervious surface.
4. Allow flexibility in the development standards.
5. Identify and evaluate desirable changes to the land use code.

Requirements and guidelines in the ordinance provide for a variety of LID concepts, such as infiltration, tree retention, density bonuses, smaller footprints/taller house designs, permeable pavements, grass pavers, and minimizing grading and site disturbance.

The county established a special committee to oversee the program, select demonstration sites and recommend changes to the land use code. The committee includes representatives of county departments, environmental organizations, university faculty, and the development community. The committee began its work with a tour of low and reduced impact development sites in Snohomish and King counties. Snohomish County sites included the Canyon Park Business Center (which uses bioswales for water quality treatment and groundwater recharge) and the Harbor Point Master Planned Community (which recharges groundwater through a wetland).

Reduced Discharge Housing, *continued*

To guide submittal of development proposals, the committee developed an outline of minimum requirements and a project review checklist (available from the county on request). By the end of 2002, developers had proposed six project design concepts. The county accepted three of these projects into the system. The project rating system evaluates tree retention (minimum 60 percent of the site); impervious surfaces; infiltration (minimum 70 percent); visual impact; innovation; and the reputation of the developer.

One project proposal is for higher-end fourplex condominiums. The site is heavily forested with steep slopes and outwash soils. A vertical design with underground parking and narrower roads will save tree cover and reduce runoff. Permeable pavement will reduce impervious cover and soils will be amended with compost. The county will need to modify the zoning code from the current single-family classification to allow for this type of development in this area.

The second proposal, Wandering Creek, is for lower cost single-family housing. The site is bounded by wetlands on three sides. The upland area is on outwash soils and will drain to a wetland buffer. LID features include preserving overstory vegetation, working with topography, narrowing the road section, using permeable pavers, and reducing building footprints to 1,000 square feet.

A third proposal is in an existing plat where the developer proposes to revegetate a pasture area with trees.

County staff and the developers will jointly monitor each of the development projects for stormwater flows. Results will be available to the public once construction begins.

Challenges

The county's demonstration program has faced several challenges in implementation. Developers and engineers have proven reluctant to try new approaches and techniques. They also state that the Department of Ecology's *Stormwater Management Manual for Western Washington* limits the use of wetlands for infiltration.

Costs

Cost estimates for these LID projects are highly variable and site-dependent. The fourplex project on a steep slope will be expensive due to the vertical design and underground parking, but the site would be difficult to develop without the flexibility provided under the LID program. The single-family housing project is expected to be less expensive than a traditional development because of reduced road width and sidewalks on one side of roads. The developer is also receiving a density bonus, which allows him to add several housing units on the site.

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SARB_004144

Zero Effect Development Ordinance

City of Tumwater

Background

The city of Tumwater in Thurston County has a population of 12,730 and an area of 10.7 square miles. Several years ago, city officials and staff recognized the relationship between traditional development practices and stream degradation, and established alternative development standards to protect aquatic life in receiving waters.

Description

In 2000, Tumwater enacted the Zero Effect Drainage Ordinance (Title 13, Chapter 13.22). The city found that typical site development hinders stormwater retention, that stormwater discharges offsite adversely affect stream habitat, and that retaining forest canopy aids evapotranspiration and infiltration of stormwater runoff. The ordinance provides developers with the option of using zero impact development* practices in residential and commercial projects. A set of performance guidelines indicates the characteristics of an acceptable project.

While the ordinance contains design guidance it also allows design creativity. A committee reviews project proposals and can approve variances to the city's development code to accommodate nontraditional construction techniques. Projects approved under the ordinance must preserve 65 percent of forest area on the development site. Runoff must not be collected or discharged to surface water (thus achieving zero effective impervious area). The guidelines encourage looped one-way streets; narrow pervious driveways; small, pervious garage aprons; and small home footprints. Roof runoff must be infiltrated or mitigated. To compensate for narrower roads and reduced access for emergency vehicles, structures are required to meet more rigorous fire standards.

Costs

There is the potential for substantial cost savings for projects that might be approved under this ordinance, however no cost analysis was performed.

Contacts

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***Zero Impact Development** means a project that adheres to the 65/0 (65 percent forest cover preserved / zero effective impervious surface) development standard and is constrained by characteristics of a healthy watershed as described in the Salmon in the City Conference Abstracts.

Low Impact Development in the Highway Runoff Manual

Washington State Department of Transportation

Description

The Washington State Department of Transportation is currently revising its *1995 Highway Runoff Manual.* As part of this revision, the department will develop and reference three low impact development elements in the revised manual:

1. Permeable paving at park and rides, pedestrian paths, and lower speed roadways.
2. Bioretention along roadways.
3. Constructed wetlands for stormwater treatment.

The LID portion of the revised manual should be available for use by the end of September 2003 and will include plans, specifications, methodology for estimating costs, and a hydraulic design process.

Contacts

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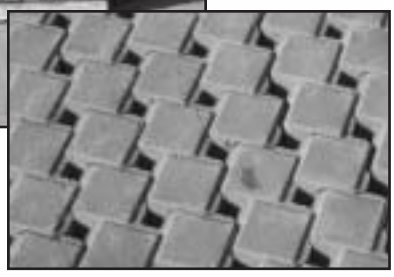
Website:
www.wsdot.wa.gov/fasc/
Follow the links to:
>Engineering Publications
>On-Line Technical Manual Library
>Highway Runoff Manual

Workers install Eco-Stone® permeable pavers at a municipal park and ride in Marysville. The Washington State Department of Transportation is considering using permeable pavement, such as Eco-Stone®, at its park and rides and on pedestrian paths.



Eco-stone detail.

SARB_004146

Green Building: Built Green™ and LEED™

Background

Green building refers to a series of practices and use of materials that result in a construction process and finished product that causes less harm to the environment, is more resource and energy efficient, and provides a healthier environment for its occupants. One way that the building industry and local governments are promoting green building is through green rating systems. In the Puget Sound Basin, two green rating systems are most prevalent:

- BUILT GREEN™ for residential developments, multifamily, and single family new construction and remodeling
- Leadership in Energy and Environmental Design (LEED™) for commercial projects.

Both programs are included here because each contains site design elements of low impact development.

BUILT GREEN™

BUILT GREEN™ programs are market-based (what the consumer will pay) approaches to promoting green building practices. Architects, builders, developers, subcontractors, suppliers, lenders, and real estate agents use a rating system of environmentally friendly practices to certify that their homes offer reduced impact on the environment and human health. Because each program sponsor develops checklists, considerable variability can occur between certification requirements.

BUILT GREEN™ programs are located in Denver and in King, Snohomish, Kitsap and Clark counties in Washington. Denver's program began in 1995 and includes more than 4,000 environmentally friendly homes. The Master Builders Association (MBA) of King and Snohomish Counties launched their program in 2000, and it already includes 1,753 new and remodeled homes. The association expanded its program to include multi-family residences and has certified more than 247 to date. Kitsap County's program, BUILT GREEN™/Build a Better Kitsap, started in 1997 and features 100 homes. Clark County began its Build a Better Clark program in 1998 and has certified more than 60 homes.

The Master Builders Association of King and Snohomish Counties launched its BUILT GREEN™ program in partnership with King County, Snohomish County and other government agencies.

Building projects are qualified using a BUILT GREEN™ checklist organized into six categories of regionally appropriate, environmentally friendly action items. One of the categories—"Site and Water"—includes elements of low impact development:

- Limiting heavy equipment to avoid compaction of soils.
- Preserving trees and existing vegetation.
- Protecting wetlands and other critical areas.
- Setting aside a portion of the site to be left undisturbed.

Built Green™ and LEED™, *continued*

- Amending soils with compost to a depth of 8 to 10 inches.
- Managing water so that groundwater will be recharged.
- Limiting effective impervious surface area to 0 percent for projects of five acres or more and less than 10 percent for projects less than five acres.
- Using pervious materials for at least one-third of all driveways, walkways and patios.
- Using green roofs.
- Avoiding impervious surfaces outside the building footprint.

Builders use this checklist prior to construction to determine which features to include in the home. When a builder completes construction, he or she sends a signed copy of the checklist to the MBA, certifying that the home contains the identified features. Based upon that builder certification and after reviewing the application, MBA will award the appropriate Certificate of Merit indicating that the home has received a 1-, 2-, or 3-star rating.

The city of Seattle and King County promote the use of the BUILT GREEN™ rating system by sponsoring exhibits and promoting the program through print, radio and TV media. In addition, Seattle City Light and Seattle Public Utilities sponsor a BUILT GREEN™ Incentive Program for multifamily projects. The program provides financial assistance to building owners and developers that incorporate sustainable building goals early in building, programming, and design decisions. Incentive funding is limited to covering incremental design costs, such as rating system documentation or hiring professionals for design input or process facilitation, and may not be used to cover construction costs. As part of this program, the city helps identify sustainable building services to offer to the private sector. BUILT GREEN™/Build A Better Kitsap grew out of a partnership between the Home Builders Association of Kitsap County and Kitsap County Public Works. Kitsap County Public Works and the Washington Department of Ecology provided financial support. BUILT GREEN™/Build A Better Kitsap addresses energy efficiency, indoor air quality, health and sustainable construction practices. There are separate checklists for homebuilders, remodelers, developers and light commercial. Each checklist has sections that relate to stormwater and include some low impact development practices, such as:

- Limiting impervious surfaces to 3,000 feet.
- Protecting 20 percent of the site from clearing and grading.
- Using permeable pavement for driveways, walkways and patios.
- Providing infiltration for rooftop runoff.
- Preserving existing native vegetation.

BUILT GREEN™/Build a Better Kitsap also produced brochures for homeowners on "How to Shop for a Fish Friendly Home" and "How to Maintain a Fish Friendly Home." The items listed in these brochures are different from those included on the BUILT GREEN™/Build A Better Kitsap certification checklist.

BUILT GREEN™ **CONTACTS:**

King/Snohomish Counties

General BUILT GREEN™ information:
www.builtgreen.net

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SARB_004148

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Home Builders Association
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Website: **www.kitsaphba.com/bbk.html**

Leadership in Energy and Environmental Design (LEED™)

LEED™ is a national rating system for commercial building projects sponsored by the U.S. Green Building Council. Projects achieve LEED™ Certified Silver, Gold or Platinum rating levels based on the number of points achieved in five different areas:

- Sustainable sites.
- Water efficiency.
- Energy and atmosphere.
- Materials and resources.
- Indoor environmental quality.

Version 2.1 (November 2002) contains elements of low impact development under the sustainable sites and water efficiency categories and includes: protecting open space, reducing the development footprint, exterior landscaping to reduce heat islands (such as a green roof), and use of water efficient landscaping (native plants). However, unlike many elements in other categories, the program does not require performance targets (such as protecting 50 percent of open space, or limiting impervious surface to by 10 percent) for these practices.

Certification is currently available for commercial projects, but the U.S. Green Building Council is developing rating systems for residential, commercial interior redesigns, and operations applications.

King County recently adopted the LEED™ Rating System as a standard for all buildings that the county constructs, remodels, and renovates. The city of Seattle's Sustainable Building Policy states that all new city-financed buildings and major remodels with more than 5,000 square feet of occupied space shall achieve the Silver Level using the LEED™ Rating System. Seattle City Light and Seattle Public Utilities also operate a LEED™ Incentive Program to encourage use of LEED™ in the private sector. Incentive funding is limited to covering incremental design costs, such as rating system documentation or hiring professionals for design input or process facilitation, and may not be used to cover construction costs. Buildings within City Light's service territory are eligible to apply.

LEED™ CONTACTS:

U.S. Green Building Council Website:
www.usgbc.org
Select the link to "LEED"

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website: **www.resourceventure.org**

King County website:
dnr.metrokc.gov/swd/bizprog/
Follow the link under Construction Recycling/Green Building to "Green Building Techniques."

SARB_004150

Glossary

amended soil	Soil with compost tilled in to restore natural capacities to treat, store and infiltrate water. Amending soil reduces runoff, promotes plant health and reduces needs for watering and application of fertilizers and herbicides. The *Stormwater Management Manual for Western Washington* (Best Management Practice T5.13) recommends tilling in 10 percent dry weight of compost into the top 8 inches of topsoil and breaking up at least 4 inches of subsoil below this.
bioretention	A vegetated depression located on the site that is designed to collect, store and infiltrate runoff. Typically includes a mix of amended soils and vegetation.
curvilinear	A curving street design that provides room for bioretention areas or other treatment systems, slows traffic and creates a more attractive street.
detention system	Temporary storage of stormwater to control the rate of release, allow for infiltration and provide treatment.
evapotranspiration	A process where vegetation absorbs, uses and releases water.
facultative plants	Plants capable of adapting to varying environments.
filtration	A process in which filtering, or treatment, takes place.
hydrology	Scientific study of the properties, distribution and effects of water on the Earth's surface, in the soil and underlying rocks, and in the atmosphere.
hydrophilic plants	Vegetation adapted to wet conditions.
impervious surfaces	Hard surfaces, such as rooftops, roads and parking areas, that prevent or slow infiltration of water. Lawns with underlying soils compacted by heavy machinery are considered impervious.
infiltration	Downward movement of water from land surfaces into the soil.
pervious or permeable surfaces	Soil or other material that allows infiltration or passage of water or other liquids.
Salmon in the City Conference	Conference sponsored by the American Public Works Association, Washington Chapter, in 1998 that featured presentations addressing the intersections of salmon, salmon habitat and urban development. Abstracts from this conference are available at: **http://depts.washington.edu/cwws/Research/Reports/salmoninthecity.pdf**.
Smart Growth	Collection of land use planning techniques that features compact, mixed-use, transit-oriented development with the objective of creating more attractive, livable, economically strong communities while protecting natural resources.
swales	Open, vegetated drainage channel designed to detain, treat and/or infiltrate stormwater.
turbid or turbidity	Sediment, organic matter or other particles that reduce the clarity of water. Excessive turbidity in streams and other surface waters can directly impair the growth of aquatic vegetation, and indirectly lead to degraded fish and wildlife habitat and decreased oxygen in waters.

LOW IMPACT DEVELOPMENT

for

BIG BOX RETAILERS

Prepared Under EPA Assistance Agreement # AW-83203101
For EPA Office of Water
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I. PURPOSE

This effort was funded by an EPA Assistance Agreement funded by the Office of Water. The recommendations or outcomes of this effort may or may not reflect the views or policies of EPA. The purpose of this project is to provide large building and site footprint high volume retailers with strategies that integrate innovative and highly effective Low Impact Development (LID) stormwater management techniques into their site designs for regulatory compliance and natural resource protection at the local levels. LID is an innovative approach to stormwater management that uses decentralized, or source, controls to replicate pre-development hydrology (stormwater) conditions. This approach can be used as an alternative or enhancement for conventional end-of-pipe stormwater pond technology. This alternative tool is important because of the potential to lessen the energy impacts of large concentrated volumes of runoff from conventional end-of-pipe approaches on receiving waters as well as reducing the development footprint and long-term maintenance considerations for end-of-pipe facilities.

The Center has partnered with the Target Corporation for this effort. Target provided input on typical industry planning, design, and operational considerations as well as review for the effort. The focus of the effort is to present these concepts and techniques in an easily understood format so that a dialogue between corporate developers, local engineers, and local governments can be initiated on how to adapt and integrate these strategies and techniques into the local regulatory and watershed protection programs.

II. DOCUMENT ORGANIZATION

The document includes prototypical designs and specifications that can be incorporated into corporate design manuals and design guidance memorandums for use by facility planners, operators, and local design planners and engineers. This includes information on the effectiveness of the practices and ancillary benefits, such as heat island reduction, water conservation, and aesthetics. Information on how to calculate and demonstrate the effectiveness of the practices and in-ground case studies is included. This information can also be used to show the benefits of these practices to municipal officials and stakeholders as part of the local permit process. The document is organized into the following areas:

- *Introduction to LID Strategies and Techniques:* A brief overview of LID is provided. This includes information on LID design strategies and Best Management Practices (BMPs) that are potentially suited for Big Box retailers.
- *LID Design Strategies:* This section includes lists of potential design strategies for large footprint retailers.
- *LID Design Techniques:* The effectiveness and selection of techniques is discussed in this section. This includes information on how the techniques can be used to meet specific water quality objectives.
- *Case Studies:* Typical design situations are presented and discussed.
- *Fact Sheets:* Detailed information on technologies are presented.

III. INTRODUCTION TO LID STRATEGIES AND TECHNIQUES

The following section presents an overview of Low Impact Development (LID) approaches that are appropriate for land development activities. Comprehensive descriptions of LID strategies and design analysis tools are available in print (USEPA, 2002) and on the internet.

III.1. LID Background

Low Impact Development (LID) is a design strategy that utilizes decentralized small-scale source control structural and/or non-structural stormwater practices to meet certain technical requirements of federal, state, and local government stormwater management regulations, as well as natural resource protection and restoration goals. The goal of LID is to maintain or replicate the pre-development hydrologic regime through the use of design techniques to create a functionally equivalent hydrologic site design. Hydrologic functions of storage, infiltration and evaporation, transpiration, ground water recharge, are used to control the volume and frequency of discharges through the use of integrated and distributed micro-scale stormwater practices. This includes structural and non-structural strategies such as retention and detention areas, reduction of impervious surfaces, and the lengthening of flow paths and runoffs time. Other strategies include the preservation/protection of environmentally sensitive site features such as riparian buffers, wetlands, steep slopes, valuable (mature) trees, flood plains, woodlands, and highly permeable soils. LID has also been used to meet targeted regulatory and resource protection objectives. The ability to use "customized" small scale source controls allows the designer to select BMPs that best meet the watershed goals and objectives. This approach also allows for a treatment train approach where there are multiple opportunities to reduce pollutant loads by using a system of different techniques. TLID techniques can also be used to meet ancillary goals such as energy efficiency, community aesthetics, and potential for job training and outreach. Many LID strategies and techniques can be used to achieve Leadership in Energy and Environmental Design (LEED) credits. The LEED program is used by many organizations and communities to certify buildings as being innovative and environmentally responsible.

These controls can be integrated into many common urban land uses on both public and private property to enhance flexibility in siting stormwater controls. This creates the opportunity for partnerships to address construction and maintenance considerations.

This document provides basic templates for an initial candidate set of ten (10) LID BMPs that can be used for Big Box sites. This list was derived by evaluation different Big Box development prototypes to determine which LID BMPs could easily be incorporated into the design without significant alteration of the prototype. The goal of the document is to provide sufficient information on each practice to provide large building and site footprint high volume retailers with strategies to integrate innovative and highly effective LID stormwater management techniques into their site designs. An additional fourteen BMPS are included in Appendix B. These additional BMPs may require significant modification or may not have as an immediate impact as those included in the initial list.

Each candidate BMP listed includes a one-page brief description of the practice as well as an overview consisting of design criteria, advantages/disadvantages, and maintenance. This is followed by a detailed description of information on water quantity/quality controls, location, design and construction materials, cost, maintenance, performance and inspection, potential LEED credits, links to additional information, and issues specific to large building and site footprint high volume retailers.

III.2. Big Box Development Considerations

The "Big Box" store is a relatively new approach to retail. There are numerous configurations and approaches to the planning, design, and construction of these facilities. In many communities the construction of these facilities have significant social and economic implications. They also can have significant hydrologic impacts for the development of the site and for the inertia they can potentially create for the development of surrounding properties. Some of the basic characteristics of Big Box Development can be as follows (adapted from Columbia, 2005):

- The building typically occupies more than 50,000 square feet, with typical ranges between 90,000-200,000 sq. ft.
- Derive their profits from high sales volumes rather than price mark up
- Large windowless, rectangular single-story buildings
- Standardized facades based on corporate standards
- Reliance on auto-borne shoppers
- Highly impervious with large parking and building footprints
- No-frills site development that eschews any community or pedestrian amenities.
- Varying market niches; categories include discount department stores and warehouse clubs

The site design of Big Boxes can be classified by the type of ownership and development of the property they are located on. These are important considerations when determining what are the appropriate site design and water quality protection. This is because the owner/operator of the Big Box may or may not have significant input into the design or selection of the water quality protection strategy based on the timing of their involvement in the project and the overall contribution of the drainage from the facilities. The developments can be classified as follows:

- *Stand Alone Centers:* These facilities are typically developed by the corporation. There is typically significant flexibility in the arrangement of buildings, parking, and infrastructure. This is subject to local codes and requirements for stormwater management, open space, building density, and lot coverage. Utility and physical site opportunities and constraints also apply. Figure One shows a typical Stand Alone Center.

Figure 1 – Stand Alone Center

- *Power Centers:* This is a grouping of several stores and is usually located in a large planned development. The sites are often leased and there is often only minimal input into the overall site design. These centers are often developed over

several years and much of the internal road circulation, drainage infrastructure and stormwater management are often in place to accommodate the development "pads" or sites for individual buildings. Figure Two shows a typical PowerCenter.

Figure 2 – PowerCenter

- *Infill Development:* These are sites that are located in highly urbanized areas. The buildings are either located in high rise structures at the surface level or built between several buildings and surrounded by streets and alleys. The parking is often in a garage that is shared with other users and there is minimal open space. Figure Three shows a typical Infill Center.

Figure 3 – Typical Infill Center

- *Retrofit:* This is a site where there is an existing building and infrastructure. The building is often torn down and expanded. The site may be repaved and reconstructed to accommodate circulation patterns or stormwater management regulations.

Generally Big Boxes require large impervious areas for parking and vehicular circulation, direct vehicular and pedestrian routes, separated truck loading areas, and large flat roofed building footprints. Most of the designs for these facilities are based on corporate prototypes that are designed to have predictable development costs and circulation patterns that are based on market preferences. This is essential for the successful management of the large-scale rapid construction process that many big box retailers require. The ability for a site to accommodate the basic circulation and infrastructure characteristics are often critical for the decision to build or develop a site. Modifications to the site design templates that are required to meet local codes and ordinances are given careful consideration. These design issues are often handled by a local engineering firm in order to insure the most efficient way to produce the final design and construction permit package.

III.3. Discussion of LID Opportunities for Big Boxes

Many communities have prescriptive stormwater management regulations, where there are specific runoff control rate and volume and water quality management requirements. These are often based on end-of-pipe controls for each development. In these situations the LID approach must be negotiated with the local government. The use of alternative designs are often administratively approved by waivers or modifications to the requirements. The advantages of using LID for the developer include, but are not limited to reducing the visual impact of large scale stormwater management facilities, have additional development area through the elimination of an end-of-pipe pond, utilize the landscape to provide stormwater management and reduce development costs, reduced stormwater utility fees by providing additional water quality.

Many communities are moving towards performance based standards. These can be as complex as limiting concentrations of runoff or reducing runoff volumes. LID can be used to meet these requirements by providing strategies and techniques with predictable removal efficiencies or reductions in runoff volume at the source.

In many instances, there is the requirement for additional or negotiated controls for reduction of the large-scale hydrologic and hydraulic impacts of the development. When there is the need for enhanced water quality, such as when impacts to wetlands or Waters of the U.S. occur, LID techniques can be used to meet the negotiated regulatory requirements. In large planned developments or in zoning categories where there may be the requirements for enhanced site design or environmental controls LID can be used to provide additional landscaping, visual amenities, and water quality enhancements.

III.4. LID Design Approach

The goal of LID site design is to reduce the hydrologic impact of development and to incorporate techniques that maintain or restore the site's hydrologic and hydraulic functions. The optimal LID site design minimizes runoff volume and preserves existing flow paths. This minimizes infrastructural requirements. By contrast, in conventional

site design, runoff volume and energy may increase, which results in concentrated flows that require larger and more extensive stormwater infrastructure.

The requirement for efficient access and circulation is critical to the success of the Big Box development. The design elements can be broken down into *Circulation and Customer Parking, Loading Areas,* and *Building Zones.* LID techniques can be incorporated into each of these areas. Some basic design concepts and recommendations include:

- *Circulation and Customer Parking.* These are areas in the front of the building. There is usually a main drive that feeds to the parking areas. The main drive is typically located in the center of the parking lot where possible. Its function is to provide rapid access to parking and loading that is located near the entrance to the building, distribute cares to the remainder of the parking lot, and provide stacking of vehicles at the entrance to the site. There is usually green space or islands that are located on the sides of these areas to provide stacking and accommodate turning movements to the parking isles. These are often landscaped to visually enforce movements. The parking area is sized to accommodate large numbers of vehicles that are present during peak hours and holiday seasons. A significant amount of the parking area may be under utilized during most of the year, but is critical during peak seasons. Most local codes and ordinances require internal and peripheral green space for parking.

- *Loading Areas.* These areas are often located at the rear of the sides of the building. They are often screened or not visible to the building entrance or parking. The loading areas require large open unobstructed pavement areas in order to accommodate truck turning movements and trailer storage. These areas can potentially have high pollutant loads due to the number of truck visits. Employee parking may also be located in or near these areas at the rear of the store.

- *Building Zones.* This is the building and the area immediately adjacent to the building. There is usually a sidewalk immediately in front of the building. It must be wide enough to provide a safe buffer between the building and front loading/drop off area. Cart storage may also be in these areas. This area is usually minimized in order to help move people quickly into the stores. The building itself typically is constructed with a lightweight flat steel structure. The roof drains are usually connected by piping that is hung on the rafters and connected to the site storm drainage system.

III.4.1. LID Planning and Design Objectives

The following are lists of the critical planning and design objectives that can be achieved by using some basic LID that can be incorporated into the planning and design process. Each principle includes a brief description of the key concepts or elements. This list is to be used as a basic design checklist or talking points for planners and designers to communicate the critical elements with building code and planning officials, public officials, and local designers.

LID Planning

These are some basic overall LID principles that are essential for community development and watershed issues.

LID Site Design:

- reduces the impacts of development with site-appropriate, ecologically sensitive technologies,
- achieves stormwater management goals,
- creates more livable places to shop, relax, and recreate. Interesting pavement patterns and landscapes can create successful public spaces.

LID decentralized strategies and techniques are:

- customizable to meet a wide range of stormwater management objectives,
- adaptable to the physical constraints of commercial or mixed-use sites.

Integrating LID controls into site design:

- reduces the impact that development has on the hydrologic water balance,
- restores or maintains the equilibrium of the natural systems,
- reduce the need for extensive stormwater conveyance infrastructure.

Site Design Elements

The following are some of the basic site design criteria that LID strategies and techniques can be used to achieve.

Stormwater Management Objectives

Use LID stormwater controls to meet compliance goals, as well as these stormwater management objectives:

- Runoff Volume Reduction
- Peak Discharge Rate Reduction
- Water Quality Improvement – remove pollutants, reduce sediment/nutrient loads, etc.

Site Functions

- *Operations* - Reduce infrastructure maintenance requirements
- *Circulation* - Visually reinforce or provide a physical framework for vehicular and pedestrian circulation
- *Curb Appeal* - Off-site visibility, marketing, public relations

Corporate and Community Development

Use LID stormwater controls to achieve these corporate programming goals and to provide ancillary community enhancement benefits:

- *"Open Space/Park Design"* – create park-like open space, promenades, etc.,
- *Beautification/Aesthetics* – create "groves," garden-like areas, etc…
- *Afforestation/Reforestation* – urban forest or park-like open space ("green infrastructure")
- *Green Building* – promote green building strategies (i.e., LEED: use of recycled materials, low VOC materials, certified woods, etc.)
- *Water Conservation/Energy Conservation* –promote conservation of natural resources (water) or use of on-site renewable energy (solar, wind, etc.)
- *Public Education* – increase community awareness of conservation and ecological stewardship.

LID Site Design Components

The following is a list of the opportunities and constraints that will effect the selection of LID strategies and techniques.

Site Conditions

Suitability of LID technologies to meet stormwater objectives depends on site conditions, including:

- Soil (i.e., infiltration capacity, degree of compaction)
- Groundwater table
- Topography / Slope
- Available open space (vegetated areas)
- Vertical location of sewers and utilities
- Solar heat
- Wind patterns
- Climate and annual rainfall

Planning Codes and Ordinances

Local master plans, municipal regulations, planning codes and ordinances dictate suitability of LID technologies, including:

- Development Regulations (Zoning, Site Development, Environmental, Critical Areas, Forestry, etc.)
- Construction and Infrastructure Regulations
- Site Development and Stormwater Drainage Regulations
- Design Standards and Guidance
- Comprehensive Planning Documents
- Planning and Land Services Fees
- Reductions in Impact or Utility Fees

III.4.2. LID Design Strategies and Techniques

In order to achieve these objectives site and building design strategies for these elements must be developed. This includes a combination of site design strategies in combination with non-structural and structural BMP techniques. The use of site design strategies will reduce the hydrologic and hydraulic impacts and reduce the need for BMPs. Some basic site design strategies include:

1. Disconnect Impervious Areas/Downspout Disconnection

Runoff from connected impervious surfaces commonly flows directly to a stormwater collection system with no possibility for infiltration into the soil. Highly efficient drainage systems contribute significantly change watershed timing and increase the peak runoff rate and energy that results from the development. For example, roofs and sidewalks commonly drain onto roads, and the runoff is conveyed by the roadway curb and gutter to the nearest storm inlet. Runoff from numerous impervious drainage areas may converge, combining their volumes, peak runoff rates, and pollutant loads. Disconnection decouples roof leaders, roadways and other impervious areas from stormwater conveyance systems, allowing runoff to be collected and managed on site or dispersed into the landscape. Runoff is redirected onto pervious surfaces such as vegetated areas, reducing the amount of directly connected impervious area and potentially reducing the runoff volume and filtering out pollutants.

2. Site Minimization/Fingerprinting/Impervious Areas Reduction

Site fingerprinting, also known as minimal disturbance techniques, is a practice that minimizes ground disturbance by identifying the smallest possible land area that can practically be impacted during site development. Minimizing the amount of site clearing and grading reduces the overall hydrologic impacts of site development. Ground disturbance is typically confined to areas where structures, roads, and rights-of-way will exist after construction is complete. Development is also placed away from environmentally sensitive areas, future open space, tree save areas, future restoration areas, and temporary and permanent vegetative forest buffer zones. Existing vegetated or open space may be preserved instead of clearing a portion of the site in order to create lawn areas.

A key component of minimizing overall site impacts is reducing impervious areas (both connected and disconnected). Typical techniques include limiting roadway lengths and widths, minimizing lot setbacks (which in turn minimize driveway lengths), installing sidewalks on only one side of private roadways, and by using alternative materials such as permeable paving blocks or porous pavements.

3. Time of Concentration Practices/Surface Roughening

Time of concentration (t_c) practices, such as surface roughening, increase the time it takes for runoff to flow across a site to the drainage point or a BMP. Slowing runoff velocity potentially reduces erosion and increases the potential for infiltration. Increasing t_c is also directly related to the disconnection of impervious areas.

4. Pollution Prevention

Pollution Prevention (P2) is a general term for any activity or management action that reduces or eliminates pollutants before they are propagated downstream. The goal of P2 is to incorporate programs and techniques to keep nonpoint source (NPS) pollutants out of

runoff. This helps to reduce pollutant loads entering BMPs, which enhances their performance and improves their longevity. Reduction of fertilizer, pesticide, and herbicide use and the implementation of regular street sweeping are some common P2 activities. P2 may also involve behavioral changes, such as keeping dumpster lids closed.

III.5. LID BMP Selection Criteria

Selection and sizing of BMPs depends upon a wide range of factors, including control objectives, receiving water quality, water quality parameters of interest, local (as well as federal) legislation. The importance of any of the criteria will vary from location to location, and affect the relative evaluation of overall water quality impacts projected for a big box retail location. Comprehensive selection of a BMP for use on a site depends upon:

- ability to meet regulatory requirements,
- projected system performance (pollutant removal effectiveness),
- public acceptance of the BMP,
- ability to be implemented (relative design constraints),
- institutional constraints,
- associated cost.

Proper BMP selection includes the assessment of the types of constituents found in the stormwater in order to determine the proper unit processes the BMP should employ in order to treat for those pollutants. However, it is also important to identify the sources and land areas contributing the additional stormwater volume and/or excessive loading of pollutants in order to identify source control measures, alternative development practices, and to determine BMP design and maintenance characteristics based upon identification of various land management and land use situations.

Generally, the addition of impervious area as a result of increased development leads to an increase in stormwater runoff volume, higher peak flows, higher average temperature of runoff, collection of a larger mass of pollutants (due to lack of infiltration capacity), and an increased flooding hazard for downstream waterways (Minton 2002, Lee 2002, Novotny 2003). Some impervious areas may be indirectly connected to the site drainage system by sheet flow over pervious and impervious surfaces for eventual discharge into gutters, catch basins, etc., while other areas may flow directly into the drainage system, such as roadways and roofs with attached roof drains.

Minimization of disconnected impervious area (DCIA) can be incorporated both into new design and retrofit scenarios. The use of LID practices for new development, such as porous pavement, planter strips, and eco-roofs, all minimize impervious areas on a site, thus allowing for reduced flow rates, increased infiltration, evapotranspiration (ET), and groundwater recharge rates and therefore a reduction in the pollutant load reaching a BMP system and receiving water body. Retrofit practices, such as the disconnection or relocation of roof drains, may be possible in some older development areas, specifically low density commercial areas (Urbonas and Stahre 1993). Disconnection and relocation of roof downspouts to pervious areas allows runoff to discharge first into grass for infiltration instead of directly into the sewer system or onto the pavement or roadway area (Urbonas and Stahre 1993). This practice is not a panacea, however, since concerns over possible groundwater contamination and localized drainage problems must be addressed.

The following is a “tool box” of LID BMPs that can be incorporated into development guidance manuals. The BMPs listed below were selected because of current industry interest and knowledge of the practice that is currently being used by large-scale Big Box developments. Because of the potentially large number of LID BMPs, including modifications and variations, it is important to develop this framework so that industry and plan reviewers can determine the most appropriate technologies for each land use.

The following table provides a list of ten tools useful to large building and site footprint high volume retailers. Complete fact sheets are provided in Appendix C for each of the ten LID BMPs listed below in Table 1.

Table 1 - LID BMPS

1	Bioretention Basins (Peak and Volume)
2	Bioretention Cells (Water Quality Only)
3	Bioretention Slopes
4	Bioretention Swales
5	Water Quality Swales
6	Permeable/ Porous Pavements (Asphalt, Concrete, Blocks)
7	Tree Box Filters
8	Planter Boxes
9	Cisterns/ Rain Barrels
10	Green Roofs

The function and use of these BMP must be considered in order to use them effectively. The following tables provide a potential listing and classification of the BMPs found in the appendices. The purpose of these lists is to provide an example of the development general criteria and guidance for the selection and use of the BMPS. These are not rigid lists or classifications, but are meant to demonstrate how the BMPs can be matched up to the most appropriate use. More detailed information on the unit processes and overall use can be found in decentralized stormwater guidance documents (WERF 2006). LID stormwater controls can be classified into two different *land development* types, new development and retrofit. Table 2 shows where LID practices can potentially be incorporated into the site design. Table 3 is a representative classification scheme Table 4 categorizes these BMPs into Power Center or stand alone uses. Table 5 demonstrates the effectiveness at meeting stormwater management objectives. Table 6 shows the BMP function and unit process.

Table 2 - Potential LID BMP Locations

BMP	Circulation and Parking	Building	Loading
Cisterns		x	
Conservation (Vegetation)	x		
Downspout Disconnection		x	
Filter Strips	x		
Infiltration Beds/Trenches or Dry Wells	x		
Pocket Wetlands			
Porous Pavement	x		
Rain Gardens	x		x
Reforestation (Vegetation)	x		
Sand Filters	x		x
Soil Amendments	x		
Vegetated Roof		x	
Water Conservation		x	
Pollution Prevention			x
Tree Box Filters	x		x
Bioretention Slopes	x		x

Table 3 - Suitability of BMPs for Land Development Types

BMP	New Development	Retrofit
Cisterns	●	●
Conservation (Vegetation)	●	○
Downspout Disconnection	○	●
Filter Strips	●	●
Infiltration Beds/Trenches or Dry Wells	●	◉
Pocket Wetlands	●	●
Porous Pavement	●	◉
Rain Gardens	●	●
Reforestation (Vegetation)	●	●
Sand Filters	●	●
Soil Amendments	●	●
Tree Box Filters	●	●
Vegetated Roofs	●	●
Vegetated Swales	●	●

Key: ● Highly Suitable ◉ Moderately Suitable ○ Not Suitable

Table 4 - Suitability of BMPs for Site Layout Types

BMP	"Power Centers"	Stand-Alone
Cisterns	●	●
Conservation (Vegetation)	●	○
Downspout Disconnection	○	○
Filter Strips	●	●
Infiltration Beds/Trenches or Dry Wells	●	●
Pocket Wetlands	●	●
Porous Pavement	●	●
Rain Gardens	●	●
Reforestation (Vegetation)	●	●
Sand Filters	●	●
Soil Amendments	●	●
Tree Box Filters	●	●
Vegetated Roofs	●	●
Vegetated Swales	●	●

Key: ● Highly Suitable ◉ Moderately Suitable ○ Not Suitable

Table 5 - Effectiveness of BMPs in Meeting Stormwater Management Objectives

BMP	Volume	Peak Discharge	Water Quality
Catch Basin Sump/Vault Filters	○		○
Downspout Disconnection	◉	◉	◉
Filter Strips	○	○	◉
Infiltration Practices	◉	○	◉
Pocket Wetlands	●	●	●
Porous Pavement	●	●	◉
Rain Barrels/Cisterns*	◉	○	○
Rain Gardens	●	●	●
Sand Filters	○	○	◉
Soil Amendments	◉	◉	◉
Tree Box Filters	◉	◉	●
Vegetated Roofs	◉	●	●
Vegetated Swales	◉	◉	●

Table 6 - Functional Classification

BMP	Volume Reduction	Peak Discharge	Water Quality	Source Control	Treatment Train	Design Storm
Cisterns	●	●	●	●	●	●
Conservation (Vegetation)	●	●	●	●	●	●
Downspout	○	○	●	●	●	●

Disconnection						
Filter Strips	●	●	●	●	●	●
Infiltration Beds/Trenches or Dry Wells	●	●	●	●	●	●
Pocket Wetlands	●	●	●	●	●	●
Porous Pavement	●	●	●	●	●	●
Rain Gardens	●	●	●	●	●	●
Reforestation (Vegetation)	●	●	●	●	●	●
Sand Filters	●	●	●	●	●	●
Soil Amendments	●	●	●	●	●	●
Tree Box Filters	●	●	●	●	●	●
Vegetated Roofs	●	●	●	●	●	●
Vegetated Swales	●	●	●	●	●	●

IV. LID CASE STUDIES

The following three case studies illustrate potential scenarios where Low Impact Development LID could be used to address stormwater quality and quantity management objectives. Each scenario presents a different development or redevelopment opportunity. The objective is to use the case studies to initiate a dialogue on the potential use and issues that need to be addressed in the location, design and review process and long-term administration and maintenance. The case studies do not present the entire range of possibilities or options. These are not to be viewed as comprehensive or complete drainage calculations and site plans, but are to be used to illustrate the concepts and feasibility of the approach. General assumptions on drainage areas, drainage characteristics topography, soils, land use, and other conditions that would potentially affect the hydrologic response of the site are used. A brief description of each case study is listed below.

Case Study One: Big Box Retail
This is a stand alone Big Box Store. These sites typically are large scale changes to the land use that results in large connected impervious areas. The concept design illustrates how to disconnect and distribute the drainage into smaller management facilities to meet water quality and stormwater quantity objectives.

Summary:

- Determine feasibility for water quality control and for providing storage volume to limit the 10-yr, 24-hr peak discharge rate to the pre-development condition.

- Use NRCS TR-55 graphical peak discharge method to determine storage volume.
- Drainage area is assumed to equal site area, 22.5 ac.

Existing Conditions

- Site is sloping from SE to NW at 2 to 5 percent.
- Moderate slope on western portion of side.
- 0.7 acres Woods and 21.8 Meadows.
- HSG C. Weighted CN is 65.
- Tc is 0.27 hours.
- Peak Discharge (CFS): 41.
- Runoff Volume (in.): 1.79.

Post-Development Conditions

- Afforestation and soil amendments on western portion of site. Increase infiltration capacity to HSG B and change in land cover.
- Conservation of woods.
- Credit bioretention areas as HSG B and Meadow.
- Weighted CN is 86.
- T_c is 0.25 hours.
- Peak Discharge (CFS): 92.
- Runoff Volume (in.): 3.65.

Results

- Detention volume: 2.1 acre feet or 1.1 inches using TR-55 graphical peak method.

BMPs

- Tree box filters provide majority of water quality control
- Green roof captures first 1" of roof runoff.
- Bioretention basins: 1.7 ac/ft storage is available.
  - Assume 6" surface storage and 1' subsurface storage is provided.
- Some bioretention basins include additional gravel underground storage.
  - 0.35 ac/ft is available in gravel storage.
- Some runoff is treated by soil amendment / bioslope areas.
- Pipes or other underground facilities provide 0.5 ac/ft storage.
- Additional storage can be provided in bioswales, amended soils, or cisterns.

Note

- See concept design on the next page.

LOW IMPACT DEVELOPMENT CASE STUDY
OCTOBER 2005
CASE STUDY
BIG BOX RETAIL SITE
Case Study Four: Big Box Development
• Determine feasibility for water quality control and for providing storage volume to limit the 10-yr, 24-hr peak discharge rate to the pre-development condition.
• Use NRCS TR-55 graphical peak discharge method to determine storage volume.
• Drainage area is assumed to equal site area, 22.5 ac.
Existing Conditions
• Site is sloping from SE to NW at 2 to 5 percent
• Moderate slope on western portion of site
• 0.7 acres Woods and 21.8 acres Meadow
• HSG C. Weighted CN is 65
• Tc is 0.27 hours
• Peak Discharge (cfs): 41
• Runoff Volume (in.): 1.79
Post-Development Conditions
• Afforestation and soil amendments on western portion of site. Increase infiltration capacity to HSG B and change in land cover
• Conservation of woods
• Credit bioretention areas as HSG B and Meadow
• Weighted CN is 86
• Tc is 0.26 hours
• Peak Discharge (cfs): 92
• Runoff Volume (in.): 3.65
Results
• Detention volume: 2.1 acre feet or 1.1 inches using TR-55 graphical peak method
BMPs
• Tree box filters provide majority of water quality control
• Green roof captures first 1" of roof runoff (Water quality volume = first 0.5" of roof runoff.)
• Bioretention basins: 1.7 ac/ft storage is available.
○ Assume 6" surface storage and1' subsurface storage is provided.
• Some bioretention basins include additional gravel underground storage.
○ 0.35 ac/ft is available in gravel storage.
• Some runoff is treated by soil amendment / bioslope areas
• Pipes or other underground facilites provide 0.5 ac/ft storage
• Additional storage can be provided in bioswales, amended soils, or cisterns.
100 0 100 200
1" = 100' HORIZONTAL
N
OUTFALL
TREELINE
BIOSWALE
BIOSWALE
VEGETATED ROOF
STORE
TREE BOX FILTER TYP.
BIORETENTION BASIN
EX. Tc PATH
PIPE/CELL STORAGE
BIO-SWALE
AFFORESTATION
TREE BOX FILTER TYP.
BIOSLOPE
TREE BOX FILTER TYP.
BIORETENTION BASIN W/GRAVEL STORAGE
ENERGY DISSIPATORS
BIORETENTION BASIN
SOIL AMENDMENTS

Case Study Two: Commercial Infill

This case study illustrates the potential for the retrofit of an existing strip shopping center with water quality management practices as part of a redevelopment plan. The redevelopment includes a drive through fast-food facility and a new retail strip. Stormwater quantity and quality control are provided for these areas. Retrofit of the existing impervious areas with water quality controls is also shown.

Summary:

The total site area is 20.5 acres. An existing strip mall is located on the eastern 14.75 acres.

The western 5.75 acres is being developed as a fast food drive through and small strip retail shops.

For the western 5.75 acres, demonstrate how to provide storage for the water quality volume (WQV) and to provide detention to limit the 10-yr, 2-hr peak discharge rate to the pre-development condition.

For the eastern 14.75 acres, add BMPs to provide water quality improvements and reduce runoff volume.

Assume that providing storage for 3" of runoff from the post-development impervious area will provide required detention storage for the 10-yr, 2-hr storm.

Existing Conditions

- The site drains from northeast to southwest. Slopes are from 2 to 3 percent.
- The eastern section has 8.9 acres of impervious area.
- The western section is undeveloped.

Post-Development Conditions

- The western section has 3.4 acres of impervious area.
- Soil amendments are added to 0.66 acres in the western section, increasing the area's infiltration capacity.
- 2.9 acres across the entire site are afforested.

Result – New Development

- Water quality volume = 6,200 C.F.
  - WQV = 0.5" / (12" per foot) * 3.4 acres* (43,560 S.F. per acre)
- Detention volume = 37,000 C.F.
  - Detention volume = 3" / (12" per foot) * 3.4 acres* (43,560 S.F. per acre)
- WQV is contained within the detention volume; therefore BMPs will be sized to contain the detention volume.

BMPs – New Development

- Use a combination of bioretention basins, bioswales, permeable pavement, and green roof.
- Bioretention basins and bioswales are designed so that surface ponding drains within 24 hours.
- BMPs are sized to collectively capture 3" of runoff from the post-development impervious area.

- One 11,000 S.F. green roof.
  - Covers entire 12, 000 S.F. roof of strip retail shops except utility areas and access points.
  - Assume 1.5’ storage within green roof media and no ponding.
  - Additional storage for roof runoff is provided in adjacent BMPs.
- Ten bioretention basins and one bioswale totaling 15,800 S.F.
  - Capture runoff from parking lot and both roofs.
  - Assume 6” surface storage and 1” subsurface storage is provided.
  - Paved areas are graded to drain to the nearest bioretention basin (or bioswale).
- Five section of permeable pavement totaling 8,000 S.F.
  - Capture Runoff from parking lots.
  - Assume 1.5” storage in gravel bed below permeable pavement.

BMPs – Remainder of Site (Existing Development)

- One 10,600 S.F. bioswale with yard inlet.
  - Capture runoff from existing roadway to improve water quality.
  - Assume 6” surface storage and 6” subsurface storage is provided.
  - Bioswale is 820’ long and 13” wide.
  - Can also provide conveyance for larger storms.
- Tree box filters provide water quality improvements for existing parking area in eastern section.

Note

- See concept design on the next page.

LOW IMPACT DEVELOPMENT CASE STUDY
OCTOBER 2005

CASE STUDY
EXISTING COMMERCIAL DEVELOPMENT
RETROFIT

Case Study Three: Existing Commercial Development Retrofit

- The total site area is 20.5 acres. An existing strip mall is located on the eastern 14.75 acres.
- The western 5.75 acres is being developed as a fast food drive through and small strip retail shops.
- For the western 5.75 acres, demonstrate how to provide storage for the water quality volume (WQV) and to provide detention to limit the 10-yr. 2-hr peak discharge rate to the pre-development condition.
- For the eastern 14.75 acres, add BMPs to provide water quality improvements and reduce runoff volume.
- Assume that providing storage for 3" of runoff from the post-development impervious area will provide required detention storage for the 10-yr, 2-hr storm.
- WQV = 0.5" of runoff over the impervious area.
- Assume drainage area for western section is limited to the 5.75 acres in that section (no offsite runoff, or runoff from the eastern section)

Existing Conditions

- The site drains from northeast to southwest. Slopes are from 2 to 3 percent.
- The eastern section has 8.9 acres of impervious area.
- The western section is undeveloped.

Post-Development Conditions

- The western section has 3.4 acres of impervious area.
- Soil amendments are added to 0.66 acres in the western section, increasing the area's infiltration capacity.
- 2.9 acres across the entire site are afforested.

Result – New Development

- Water quality volume = 6,200 C.F.
  - WQV = 0.5" / (12" per foot) * 3.4 acres * (43,560 S.F. per acre)
- **Detention volume = 37,000 C.F.**
  - Detention volume = 3" / (12" per foot) * 3.4 acres * (43,560 S.F. per acre)
- WQV is contained within the detention volume; therefore, BMPs will be sized to contain the detention volume.

BMPs – New Development

- Use a combination of bioretention basins, bioswales, permeable pavement, and green roof.
- Bioretention basins and bioswales are designed so that surface ponding drains within 24 hours.
- BMPs are sized to collectively capture 3" of runoff from the post-development impervious area.
- One (1) 11,000 S.F. green roof
  - Covers entire 12,000 S.F. roof of strip retail shops except utility areas and access points.
  - Assume 1.5" storage within green roof media and no ponding.
  - Additional storage for roof runoff is provided in adjacent BMPs.

BMPs – New Development (Continued)

- Ten (10) bioretention basins and one (1) bioswale totaling 15,800 S.F.
  - Capture runoff from parking lot and both roofs
  - Assume 6" surface storage and 1' subsurface storage is provided.
  - Paved areas are graded to drain to the nearest bioretention basin (or bioswale).
- Five (5) sections of permeable pavement totaling 8,000 S.F.
  - Capture runoff from parking lots
  - Assume 1.5' storage in gravel bed below permeable pavement.

BMPs – Remainder of Site (Existing Development)

- One (1) 10,600 S.F. bioswale with yard inlet
  - Capture runoff from existing roadway to improve water quality
  - Assume 6" surface storage and 6" subsurface storage is provided.
  - Bioswale is 820' long and 13' wide.
  - Can also provide conveyance for larger storms.
- Tree box filters provide water quality improvements for existing parking area in eastern section.

Case Study Three: Big Box Site Development

This case study illustrates the affects of minor changes in layout at a Super Center using LID. The following shows LID storage capacity as well as volume reduction for both a 2-year 24-hour storm event and a 10-year 24-hour storm event. These retrofits use decentralized LID methods to disconnect stormwater from a centralized stormwater system and runoff. LID practices reduce stormwater peak and volume flow while improving the water quality of the runoff.

Summary:

- Determine feasibility for water quality control and for providing storage volume to limit the 10-yr, 24-hr peak discharge rate to the pre-development condition.
- Use NRCS TR-55 graphical peak discharge method to determine storage volume.
- Drainage area is assumed to equal site area, 91 ac.
- Assume 85% imperious cover and a CN of 95
- Runoff using NRCS TR-55 graphical peak discharge method for the 2-year and 10-year Type II storm is 20 ac-ft and 34ac-ft, respectively.

Retrofit Conditions:

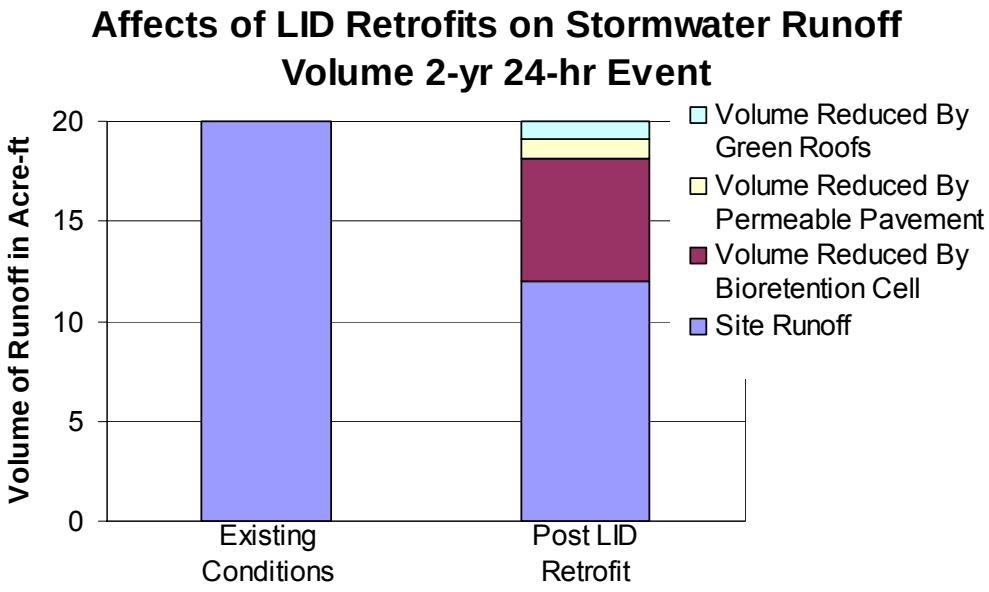
- 2.2 acres of afforestation on western portion of site. Increase infiltration capacity and change in land cover
- Conservation of woods
- Credit bioretention, permeable pavement, and green roofs areas as HSG B and Open Space

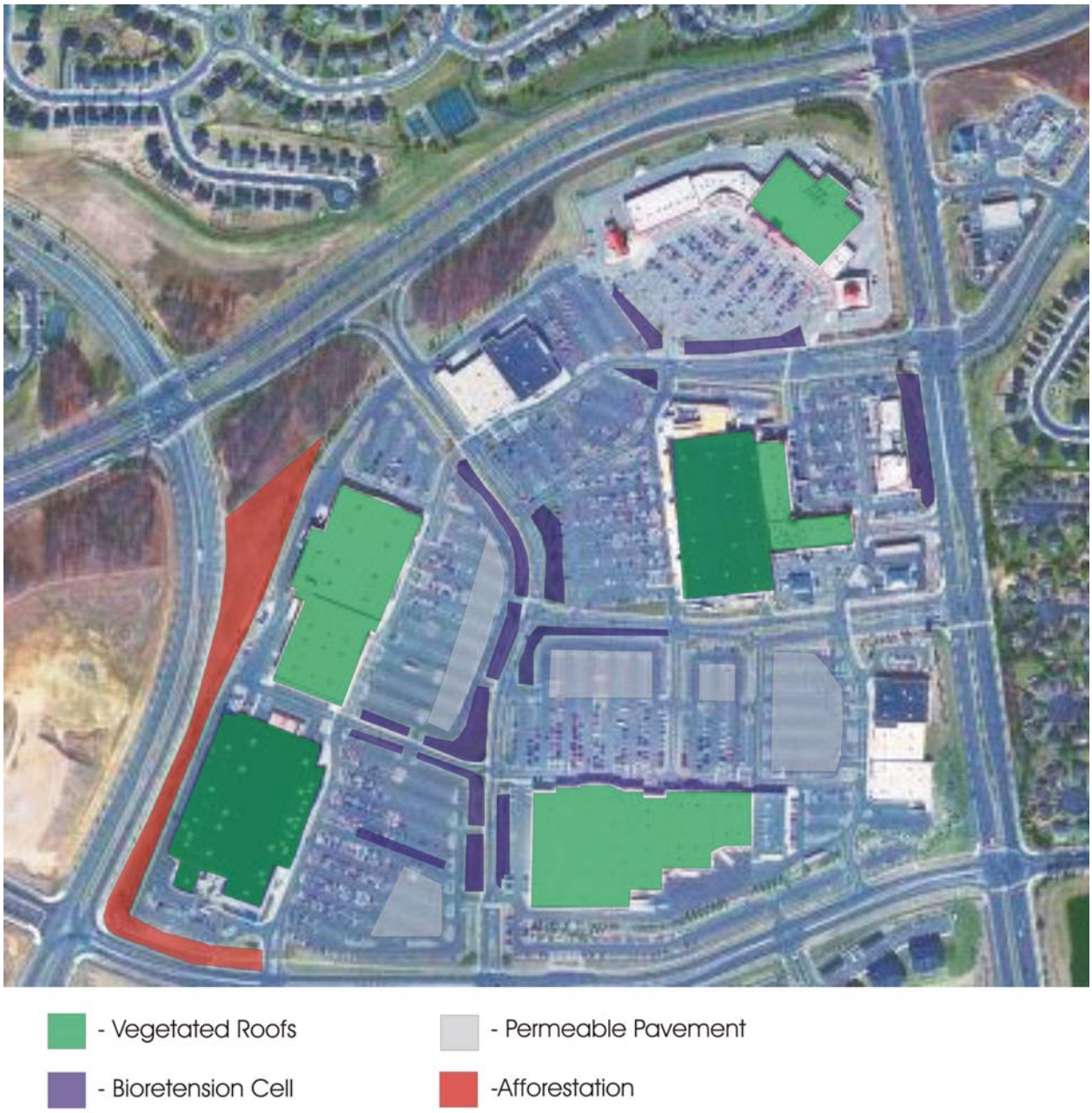
Results:

- Detention volume: 8 acre feet
- Green roofs reduce runoff volume by 17% for a 2 yr. 24 hr. storm and 9.5% for a 10 yr. 24 hr. storm.
- Green roofs, bioretention, and permeable pavers combine to offer benefits of a 23% for a 2 yr. 24 hr. storm and 15% for a 10 yr. 24 hr. storm.

BMPs:

- Green roof captures first 1” of roof runoff, 0.89 ac/ft of storage (Water quality volume = first 0.5” of roof runoff.)
- Bioretention basins: 6.1 ac/ft storage is available.
    - Assume 1’ surface storage and 2.5’ subsurface storage with a porosity of 0.3.
- Permeable Pavers: 1 ac/ft of subsurface storage
    - Assume subsurface storage porosity is 0.3
- Additional storage can be provided in bioswales, amended soils, or cisterns.
- Increase Time of Concentration


Affects of LID Retrofits on Stormwater Runoff
Volume 2-yr 24-hr Event
Volume of Runoff in Acre-ft
20
15
10
5
0
Existing Conditions
Post LID Retrofit
Volume Reduced By Green Roofs
Volume Reduced By Permeable Pavement
Volume Reduced By Bioretention Cell
Site Runoff



Case Study Three: Big Box Site Development

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VI. APPENDIX A – Brief description of 14 additional LID BMPs

1	BMP:	Disconnect Impervious Areas/ Downspout Disconnection
	Use:	Prerequisite
	Description:	Disconnection decouples roof leaders, roadways and other impervious areas from stormwater conveyance systems, allowing runoff to be collected and managed on site or dispersed into the landscape. Runoff is redirected onto pervious surfaces such as vegetated areas, reducing the amount of directly connected impervious area and potentially reducing the runoff volume and filtering out pollutants.
	Useful Links:	Natural Resources Defense Council, 2001: Stormwater Strategies: Community Responses to Runoff Pollution. http://www.nrdc.org/water/pollution/storm/stoinx.asp Milwaukee Metropolitan Sewerage District http://www.mmsd.com/projects/downspout.cfm DC Greenworks http://www.dcgreenworks.org/LID/downspout.html
2	BMP:	Fingerprinting/ Impervious Areas Reduction
	Use:	Prerequisite
	Description:	Site fingerprinting, also known as minimal disturbance techniques, is a practice that minimizes ground disturbance by identifying the smallest possible land area that can practically be impacted during site development.
	Useful Links:	Natural Resources Defense Council, 2001: Stormwater Strategies: Community Responses to Runoff Pollution. http://www.nrdc.org/water/pollution/storm/stoinx.asp Center for Watershed Protection. 1998. Better Site Design: A Handbook for Changing Development Rules in Your Community. Purdue University – Long-term impacts of Land Use Change http://www.ecn.purdue.edu/runoff/documentation/impacts/minimize.htm Guidance Specifying Management Measures for Sources of Nonpoint Pollution in Coastal Waters EPA 840-B-92-002 January 1993 http://www.epa.gov/owow/nps/MMGI/Chapter4/ch4-2c.html
3	BMP:	Pollution Prevention
	Use:	Prerequisite
	Description:	Pollution Prevention (P2) is a general term for any activity or management action that reduces or eliminates pollutants before they are propagated downstream. The goal of P2 is to incorporate programs and techniques to keep nonpoint source (NPS) pollutants out of runoff.
	Useful Links:	Natural Resources Defense Council, 2001: Stormwater Strategies: Community Responses to Runoff Pollution. http://www.nrdc.org/water/pollution/storm/stoinx.asp Water Related Best Management Practices (BMP's) in the Landscape, Center for Sustainable Design, Mississippi State University http://www.abe.msstate.edu/Tools/csd/NRCS-BMPs/pdf/water/source/prot_sd_hazwaste.pdf United States Environmental Protection Agency Office of Water. 1999. "Combined Sewer Overflow Management Fact Sheet: Pollution Prevention." Available at http://www.epa.gov/owm/mtb/pollutna.pdf EPA Pollution Prevention Program http://www.epa.gov/p2/
4	BMP:	Reforestation/ Afforestation
	Use:	Prerequisite
	Description:	Reforestation is the planting of trees in an area that was forested in the recent past (e.g. an area that was cleared for residential development). Afforestation is planting trees in an area where they were absent for a significant period of time (e.g. an old farm field or a riparian buffer). Plantings may be seeds, seedlings, or semi-mature trees.

	Useful Links:	Natural Resources Defense Council, 2001: Stormwater Strategies: Community Responses to Runoff Pollution. http://www.nrdc.org/water/pollution/storm/stoinx.asp Kentucky Division of Forestry – Reforestation Program http://www.forestry.ky.gov/programs/reforestation/ Reforestation Publications – NC State University College of Natural Resources http://www.ces.ncsu.edu/nreos/forest/reforestationpubs.htm
5	BMP:	Time of Concentration Practices/ Surface Roughening
	Use:	Secondary / Adjunct
	Description:	Time of concentration (t_c) practices, such as surface roughening, increase the time it takes for runoff to flow across a site to the drainage point or a BMP. Slowing runoff velocity potentially reduces erosion and increases the potential for infiltration. Increasing t_c is also directly related to the disconnection of impervious areas.
	Useful Links:	EPA Mid-Atlantic - National Environmental Policy Act (NEPA), LID http://www.epa.gov/reg3esd1/nepa/LID.htm New Low Impact Design: Site Planning and Design Techniques for Stormwater Management http://www.asu.edu/caed/proceedings98/Coffmn/coffmn.html
6	BMP:	Soil Amendments
	Use:	Secondary / Adjunct
	Description:	Soil amendments, which include both soil conditioners and fertilizers, make the soil more suitable for the growth of plants and increase water retention capabilities. Compost amendments and soils for water quality enhancement are also used to enhance native or disturbed and compacted soils. These measures change the physical, chemical, and biological characteristics of the soil allowing it to more effectively reduce runoff volume and filter pollutants. Soil amendments are valuable in areas with poor soils because they can help add available plant nutrients and sustain vegetative cover, reduce long-term erosion, and help reduce runoff peak volumes and discharges by absorption of rainfall and runoff.
	Useful Links:	Choosing a soil amendment, Colorado State University Cooperative Extension http://www.ext.colostate.edu/pubs/Garden/07235.html EarthWorks Soil Amendments, Inc. http://www.ewsa.com/ LID Center Soil Amendment Specification http://www.lowimpactdevelopment.org/epa03/soilamend.htm
7	BMP:	Environmentally Sensitive Landscaping
	Use:	Secondary / Adjunct
	Description:	Revegetating or landscaping a site using trees, shrubs, grasses, or other groundcover provides an opportunity to reintroduce native vegetation, which may be more disease-resistant and require less maintenance than non-native species. Long-term revegetation should only occur at sites at which future disturbance is not expected to occur.
	Useful Links:	Natural Resources Conservation Service. “Critical area planting.” Urban BMP's - Water Runoff Management. ftp://ftp-fc.sc.egov.usda.gov/WSI/UrbanBMPs/water/erosion/critareaplant.pdf Natural Resources Conservation Service. “Native revegetation - grasses, legumes, and forbs.” Urban BMP's - Water Runoff Management. ftp://ftp-fc.sc.egov.usda.gov/WSI/UrbanBMPs/water/erosion/natrevege_grasses.pdf Natural Resources Conservation Service. “Native revegetation - trees and shrubs.” Urban BMP's - Water Runoff Management. ftp://ftp-fc.sc.egov.usda.gov/WSI/UrbanBMPs/water/erosion/natrevege_trees.pdf
8	BMP:	Flow Splitters
	Use:	Secondary / Adjunct

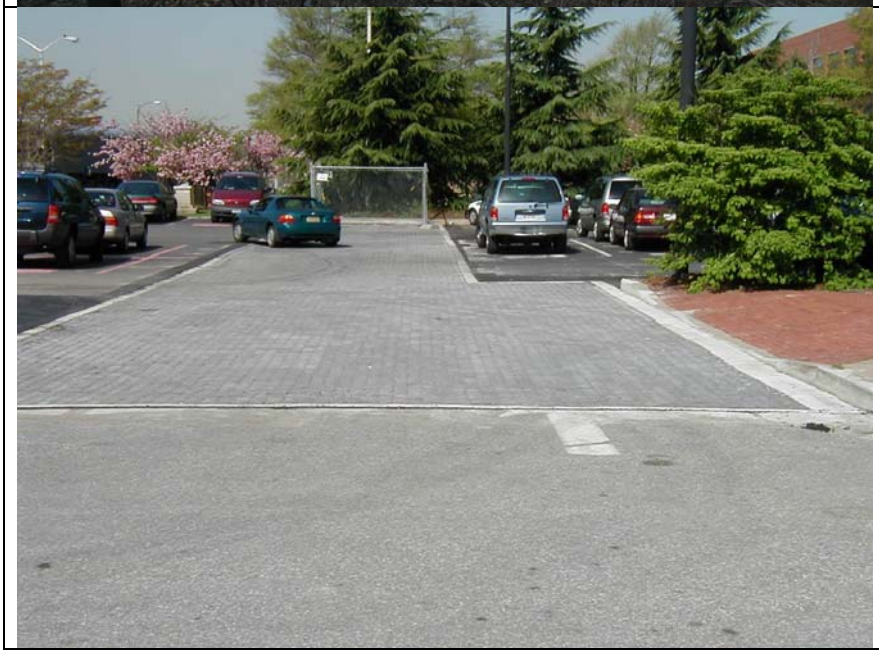
	Description:	A flow splitter allows the runoff volume from a drainage area to be split into two or more quantities ("sub-volumes"). Typically, flow splitters are used to isolate the water quality volume (WQV) in order to provide water quality treatment or manage a portion of a storm event with one or more BMPs. The WQV is typically defined as the first 0.5" to 1' of rain over the impervious drainage area. Alternately, a flow splitter can be used to divert high flows to prevent resuspension of captured pollutants in a BMP.
	Useful Links:	Split-flow Method http://www.forester.net/sw_0207_split.html Developing Split-flow Stormwater Systems http://www.epa.gov/owow/nps/natlstormwater03/11Echols.pdf Echols, S.P. 2002. Split-flow method: Introduction of a new stormwater strategy. Stormwater -The Journal for Surface Water Quality Professionals, 3(5): 16-32.
9	BMP:	Street Sweeping
	Use:	Secondary / Adjunct
	Description:	Street sweeping uses mechanical pavement cleaning practices to minimize pollutant transport to receiving water bodies. Sediment, debris, and gross particulate matter are the targeted pollutants, but removal of other pollutants can be accomplished as well. Street sweeping may also prevent pipes and outlet structures in stormwater detention facilities from becoming clogged with debris and trash. Different designs are available with typical sweepers categorized as (1) mechanical broom sweepers; (2) vacuum-assisted wet sweepers; and (3) dry vacuum sweepers. The effectiveness of street sweeping is very dependent upon when it is done and the number of dry days between storm events.
	Useful Links:	US EPA Office of Water http://www.epa.gov/owm/mtb/pollutna.pdf Low Impact Development Technologies http://www.wbdg.org/design/lidtech.php Protecting Water Quality from Urban Runoff, EPA 841-F-03-003 http://www.epa.gov/water/yearofcleanwater/docs/NPS_Urban-facts_final.pdf
10	BMP:	Dry Wells
	Use:	Limited / Occasional
	Description:	A dry well typically consists of a pit filled with large aggregate such as gravel or stone. Alternately, it may consist of a perforated drum placed in a pit and surrounded with stone. Dry wells capture and infiltrate water from roof downspouts or paved areas. The surface is typically at or just below existing grade. It may be covered by grass or other surface.
	Useful Links:	Massachusetts Low Impact Development Toolkit http://www.mapc.org/regional_planning/LID/Infiltration_trenches.html New Jersey Stormwater Best Management Practices http://www.state.nj.us/dep/watershedmgt/DOCS/BMP_DOCS/bmp2003pdfs/dec2003chap9_3.pdf Arizona Department of Environmental Quality http://www.ci.gilbert.az.us/environment/drywells.cfm
11	BMP:	Filtration Devices (Proprietary and Non-Proprietary)
	Use:	Limited / Occasional
	Description:	Filtration devices are installed in stormwater catch basins to remove mobilized pollutants before stormwater enters the collection system. These systems contain some type of filter media within a variety of configurations. Common filtration media includes fiberglass, activated carbon, and absorbent material. Geotextile materials may also be used both inside the basin or as curb inlet filters. Settling, filtration, absorption, and adsorption are the most common removal mechanisms. These devices are primarily intended to remove debris, trash, particulates, and oil and grease, but may also capture sediments.

	Useful Links:	Government of British Columbia, Ministry of Water, Land, and Air Protection: Water, Air, and Climate Branch http://wlapwww.gov.bc.ca/wat/wq/nps/BMP_Compendium/Municipal/Urban_Runoff/Treatment/Filter.htm Bioretention and LID, University of Maryland http://www.ence.umd.edu/~apdavis/Bio-research.htm
12	BMP:	Gutter Filters
	Use:	Limited / Occasional
	Description:	Gutter filters are linear pre-cast concrete gutter vaults containing gravel and finer (typically sand) filter media and an underdrain installed below grade at the curb line. They are especially useful for treating the "first flush" of roadway runoff, which contains elevated concentrations of many non-point source pollutants. A void space above the filter material captures trash and other debris that is able to pass through the surface grate while the gravel and sand filter media remove suspend solids and other pollutants. Filtered stormwater is conveyed by the underdrain from the gutter filter to the stormwater collection system. Gutter filters may be a stand-alone BMP or used in concert with other measures as part of a stormwater control strategy.
	Useful Links:	Virginia Department of Conservation and Recreation. 1999. "General intermittent sand filters." Virginia Stormwater Management Handbook, 3-12. http://www.dcr.virginia.gov/sw/docs/swm/Chapter_3-12.pdf

13	BMP:	Surface Sand Filters
	Use:	Limited / Occasional
	Description:	A sand filter is a flow-through system designed to improve water quality from impervious drainage areas by slowly filtering runoff through sand. It consists of one or more sedimentation and filtration chambers or areas to treat runoff. Pollutant removal in sand filters occurs primarily through straining and sedimentation. Treated effluent is collected by underdrain piping and discharged to the existing stormwater collection system. A sand filter occupies a small footprint compared to its drainage area. Surface and underground sand filters function similarly.
	Useful Links:	U.S. Environmental Protection Agency. 1999. Storm Water Technology Fact Sheet: Sand Filters. http://www.epa.gov/owm/mtb/sandfltr.pdf Naval Facilities Engineering Service Center. 2004. "Sand filter for treating storm water runoff." Joint Service Pollution Prevention Opportunity Handbook. http://p2library.nfesc.navy.mil/P2_Opportunity_Handbook/10-1.html Barrett, M.E. 2003. Performance, cost and maintenance requirements of Austin sand filters. Journal of Water Resources Planning and Management. May/June 2003: 234-242.
14	BMP:	Infiltration Strips (Percolation)
	Use:	Limited / Occasional
	Description:	Infiltration strips (also known as infiltration trenches, basins or galleries) are trenches that have been back-filled with stone. They collect runoff during a storm event and release it into the soil by infiltration.
	Useful Links:	US Environmental Protection Agency Office of Water. 1999. "Storm Water Technology Fact Sheet: Infiltration Trench." http://www.epa.gov/owm/mtb/infltrenc.pdf Stormwater Manager's Resource Center, Stormwater Management Fact Sheet: Infiltration Trench http://www.stormwatercenter.net/Assorted%20Fact%20Sheets/Tool6_Stormwater_Practices/Infiltration%20Practice/Infiltration%20Trench.htm

VII. APPENDIX B – Image Gallery

	IKEA Parking Lot ♦ Permeable Pavement ♦ Bioretention
	Super Target, Minnesota

	Safeway Parking Lot ♦ Bioretention
	Permeable Pavement

	Washington Navy Yard Bldg 166 Under Construction ♦ Permeable Pavement
	Washington Navy Yard Bldg 166 Completed ♦ Permeable Pavement

	♦ Green Roof
	♦ Bioretention Strip

	♦ Tree Box Filter
	♦ Bioretention Strip

VIII. APPENDIX C – Ten LID BMP Fact Sheets

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Fact sheets continue on next page.

VIII.1.Bioretention Basins

Bioretention incorporated into shopping center retrofit.
Source: LID Center

Design Criteria:

- Excavate to a minimum depth of one to three feet (deeper excavation can provide for additional storage in the soil or gravel layers, or more surface ponding)
- Cells ("rain gardens") contain grasses, perennials, shrubs, small trees and mulch
- A gravel layer provides temporary storage of stormwater, which will exit through an underdrain (if present) and/or through exfiltration into the subsoil.
- Underdrains and observation wells are recommended in areas with low subsoil permeability.
- Install surface or subsurface structure and high flow bypass to control discharge rate

Maintenance:

- Conduct routine periodic maintenance as required of any landscaped area.
- Inspect the treatment area's components and repair or replace them if necessary.
- Remove accumulated sediment and debris, replace any dead or distressed plants, and replenish mulch annually.
- Repair any eroded areas as soon as they are detected.
- The control structure should be inspected regularly for clogging and structural soundness.

Advantages:

- Useful for larger drainage areas than rain gardens
- Useful incorporated within impervious areas (e.g. parking lots, traffic medians)
- Effective for retrofit
- Enhance quality of downstream waters
- Improve landscape appearance, absorb noise, provide and wind breaks
- Maintenance needs similar to any other landscaped area

Disadvantages:

- Not appropriate where the water table is within 6 feet (1.8m) of ground level
- Not recommended for areas with steep slopes (> 20%)
- Not recommended for areas where mature tree removal would be required
- Not recommended for areas with high sediment loads
- Not appropriate where surrounding soil is unstable

Stormwater Management Suitability

Runoff Volume Reduction

Peak Discharge Rate Reduction

Water Quality

Water Quantity Controls

Bioretention basins can be used to control 2-year, 2-hour and 10-year, 2-hour storms. Drainage areas handled by bioretention basins should be small and distributed.

Stormwater can be stored through surface ponding and through storage in soil and gravel layers. Voids in these layers provide stormwater storage capacity. Depths of the layers are sized to meet storage requirements.

Exfiltration into the subsoil can potentially reduce the volume of stormwater that ultimately enters the primary stormwater conveyance system.

Volume reduction depends upon:

- available storage in the gravel layer and ponding area
- the maximum flow rate into the subsoil
- and the flow rate into the basin related to
- storm intensity

Water Quality Controls

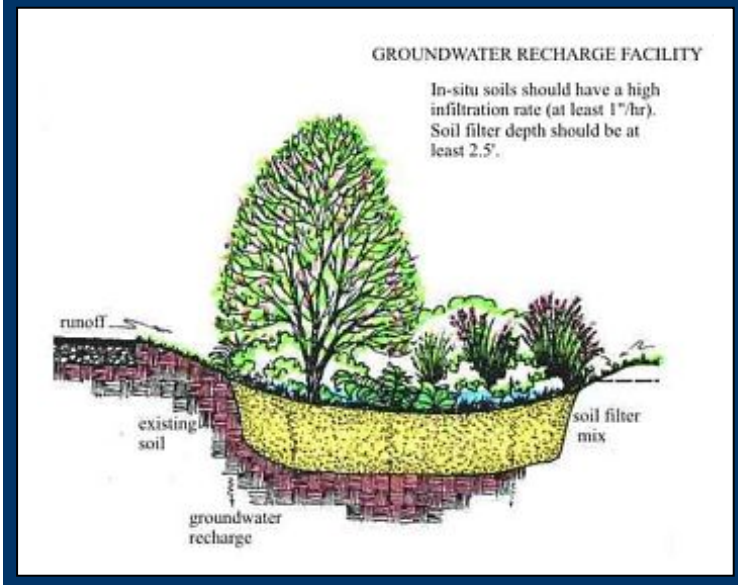
Typical phosphorus removal efficiencies for bioretention cells as follows:

- 50% removal for basins that capture 0.5” of runoff from impervious area
- 65% removal for basins that capture 1.0” of runoff from impervious area

Location

Bioretention cells can be used in commercial and industrial areas. Potential applications include median strips and parking lots.

Bioretention cells should not be located in areas of high sediment loads or where the site is not entirely stabilized.



Bioretention Cell Schematic
Source: DER - Prince Georges County, MD

Cost

The cost for a bioretention basin to treat runoff from ½ impervious acre consists of both the installation and annualized costs.

These cost calculations were based upon a bioretention basin with a surface area of 900 square feet, sized to treat the first 0.5" of runoff. A contingency of 50 percent was added to installation and replacement costs to account for additional excavation and materials needed to provide storage for larger storm events.

A bioretention basin is assumed to have a lifespan of 25 years, at which point it will be removed and replaced.

Design Construction and Materials

Bioretention basins are excavated to a depth of one (1) to three (3) feet, depending on the infiltration rate and depth to the seasonal high groundwater table or bedrock. Deeper excavation can provide more storage in soil and gravel layers or more surface ponding.

Underdrains are recommended in areas with low subsoil permeability (e.g. compacted or clay soils) or shallow soil profiles. Underdrains must tie into an adequate conveyance system. Observation wells should be installed if underdrains are used.

A gravel layer provides temporary storage of stormwater, which will exit through an underdrain (if present) and/or through exfiltration into the subsoil. If an underdrain is present, the gravel layer surrounds the underdrain pipe to minimize the chance of clogging.

The excavated area is filled with an engineered media classified as "sandy loam" or "loamy sand" that typically consists of:

- 50% sand
- 30% planting soil with minimal clay content, and
- 20% shredded hardwood mulch.

Depending on space constraints and drainage area characteristics, a pretreatment device (e.g. vegetated filter strip) can be created to intercept debris and large particles.

Item	Unit	Estimated unit cost (2005 Dollars)
Excavation	C.Y.	$8 - $10
Bioretention media	C.Y.	$40 - $60
Filter fabric	S.Y.	$1 - $5
Gravel	C.Y.	$30 - $35
Underdrain (perforated pipe 4" dia.)	L.F.	$8 - $15
Plants	Ea.	$5 - $20
Mulch	C.Y.	$30 - $35

Item	Required Cost per Year (2005 Dollars)												
	0	1	2	3	4	5	6	7	8	9	10	…	25
Installation[1]	15,000												
Mulching and Debris Removal		350	350	350	350	350	350	350	350	350	350		
Replace Vegetation		200	200	200	200	200	200	200	200	200	200		
Remove & Replace													15,000
Total Cost	**15,000**	**550**	**550**	**550**	**550**	**550**	**550**	**550**	**550**	**550**	**550**		**15,000**
Annualized Cost	$1,125 / year (includes replacement in year 25)												

[1]Developer Cost. Not included in annualized cost.

Maintenance

The primary maintenance requirement for bioretention cells is to inspect the treatment area's components and repair or replace them if necessary. Generally, maintenance is the same as the routine periodic maintenance that is required of any landscaped area

Removal of accumulated sediment and debris, replacement of any dead or stressed plants, and replenishment of the mulch layer is recommended on an annual basis. Also, any eroded areas should be repaired as soon as they are detected. The control structure should be inspected regularly for clogging and structural soundness.

Potential LEED Credits

Primary: Sustainable Sites – Credit 6 “Stormwater Management” (1-2 Points)

Other: Sustainable Sites – Credit 7 “Landscape & Exterior Design to Reduce Heat Islands” (1-2 Points)
Water Efficiency – Credit 1 “Water Efficient Landscaping” (1-2 Points)
Innovation & Design Process (1-4 Points)

Links to Additional Information

USEPA Office of Water
http://www.epa.gov/OW-OWM.html/mtb/biortn.pdf

Natural Resources Defense Council, 2001: Stormwater Strategies: Community Responses to Runoff Pollution.
http://www.nrdc.org/water/pollution/storm/stoinx.asp

United States Environmental Protection Agency, 2000: Bioretention applications: Inglewood Demonstration Project, Largo, Maryland, and Florida Aquarium, Tampa, Florida. Office of Water, Washington, D.C., EPA-841-B-00-005A

U.S. Environmental Protection Agency, 1995: Maryland developer grows 'Rain Gardens' to control residential runoff. Nonpoint Source News-Notes, 42 (August/September)
http://www.epa.gov/NewsNotes/issue42/urbrnf.html

Performance and Inspection

To ensure proper performance, visually inspect that stormwater is infiltrating properly into each bioretention cell. Water standing in a bioretention cell for more than 48 hours indicates operational problems.

Corrective measures include inspection for and removal of sediments, typically by backflushing.

Samples of bioretention media should be assessed if there is poor infiltration to determine the condition of the media (e.g. clay content).

Replacement of the bioretention media may be required to restore the flow rate through the cell. First, applying soil amendments can be attempted to restore permeability.

Perform inspection:

- o annually in spring
- o after severe weather events (e.g. hurricanes)

VIII.2.Bioretention Cells

Bioretention cell in a commercialr parking lot
Source: LID Center, Inc

Design Criteria:

- Excavated to a minimum depth of one to three feet (deeper excavation can provide for additional storage in the soil or gravel layers, or more surface ponding)
- Cells, or “rain gardens,” contain grasses and perennials, shrubs, and small trees
- A gravel layer provides temporary storage of stormwater, which will exit through an underdrain (if present) and/or through exfiltration into the subsoil.
- Underdrains are recommended in areas with low subsoil permeability. Observation (cleanout) wells should also be installed, if underdrains are used.

Maintenance:

- Conduct routine periodic maintenance as required of any landscaped area.
- Inspect the treatment area's components and repair or replace them if necessary.
- Remove accumulated sediment and debris, replace any dead or distressed plants, and replenish the mulch layer on an annual basis.
- Repair any eroded areas as soon as they are detected.

Advantages:

- Useful for small drainage areas
- Useful in impervious areas (e.g. parking lots, traffic medians)
- Effective for retrofit
- Enhance the quality of downstream water bodies
- Improve landscape appearance, absorb noise, provide shade and wind breaks
- Maintenance needs similar to any other landscaped area

Disadvantages:

- Not recommended for areas where mature tree removal would be required
- Not recommended for areas with high sediment loads
- Not appropriate where the surrounding soil stratum is unstable
- Not applicable for large drainage areas

Stormwater Management Suitability

Runoff Volume Reduction

Water Quality

Water Quantity Controls

Stormwater in excess of the water quality volume (WQV: see section below) can be detained by allowing additional ponding and/or subsurface storage in the bioretention cell, thereby reducing the runoff volume and peak discharge rate. Voids in the soil and gravel layers provide stormwater storage capacity.

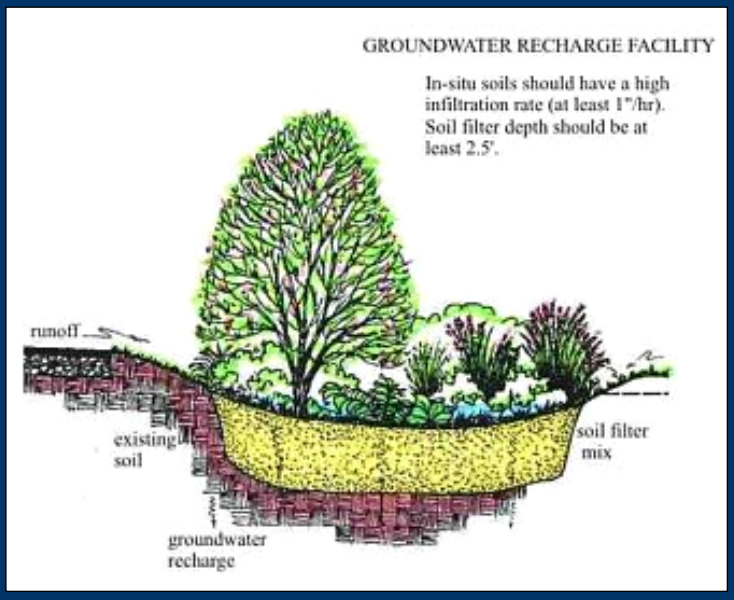
The depth of the gravel layer may be increased to add storage capacity. Exfiltration into the subsoil can reduce the volume of stormwater that ultimately enters the conveyance system. Volume reduction depends on the available detention storage in the gravel layer and ponding area. It also is a function of the flow rate into the cell and the maximum flow rate into the subsoil. These factors are related to the storm intensity and drainage area size.

Water Quality Controls

The water quality volume (WQV) is typically defined as the first one-half to one inch of runoff from impervious areas.

Typical phosphorus removal efficiencies for bioretention cells as follows:

- 50% removal for cells that capture 0.5” of runoff from an impervious area
- 65% removal for cells that capture 1.0” of runoff from an impervious area



Bioretention Cell Schematic
Source: DER - Prince Georges County, MD

Location

Bioretention cells can be used in commercial and industrial areas. Potential applications include median strips, parking lots, and swales.

Bioretention cells should not be located in areas of high sediment loads or where the site is not entirely stabilized.

Cost

Cost of a bioretention cell to treat runoff from ½ impervious acre consists of both installation costs and annualized costs.

Cost calculations were based upon a bioretention cell with a surface area of 900 square feet, sized to treat the first 0.5" of runoff.

A bioretention cell is assumed to have a lifespan of 25 years, at which point it would be removed and replaced.

Design Construction and Materials

Bioretention cells are excavated to a depth of one (1) to three (3) feet, depending on the infiltration rate and depth to the seasonal high groundwater table or bedrock. Deeper excavation can provide for more storage in soil or gravel layers.

Underdrains are recommended in areas with low subsoil permeability (e.g. compacted or clay soils) or shallow soil profiles. Underdrains must tie into an adequate conveyance system. Observation wells should be installed if underdrains are used.

A gravel layer provides temporary storage of runoff which may exit through an underdrain and/or through exfiltration into the subsoil. If an underdrain is present, the gravel layer surrounds the underdrain pipe to minimize the chance of clogging.
The excavated area is then filled with an engineered media classified as "sandy loam" or "loamy sand" that typically consists of:

- 50% sand
- 30% planting soil with minimal clay content, and
- 20% shredded hardwood mulch.

The area is then mulched and planted with shrubs, perennials, grasses, and small trees. The cell must provide for bypass flow into an inlet or overflow weir.

Bioretention cells typically consist of the cost components below.

Item	Unit	Estimated unit cost (2005 Dollars)
Excavation	C.Y.	$8 - $10
Bioretention media	C.Y.	$40 - $60
Filter fabric	S.Y.	$1 - $5
Gravel	C.Y.	$30 - $35
Underdrain (perforated pipe 4" dia.)	L.F.	$8 - $15
Plants	Ea.	$5 - $20
Mulch	C.Y.	$30 - $35

Item	Required Cost per Year (2005 Dollars)												
	0	1	2	3	4	5	6	7	8	9	10	…	25
Installation[1]	10,000												
Mulching and Debris Removal		350	350	350	350	350	350	350	350	350	350		
Replace Vegetation		200	200	200	200	200	200	200	200	200	200		
Remove & Replace													10,000
Total Cost	**10,000**	**550**	**550**	**550**	**550**	**550**	**550**	**550**	**550**	**550**	**550**		**10,000**
Annualized Cost	$925 / year (includes replacement in year 25)												

[1]Developer Cost. Not included in annualized cost.

Maintenance

The primary maintenance requirement for bioretention cells is to inspect the treatment area's components and repair or replace them if necessary. Generally, maintenance is the same as the routine periodic maintenance that is required of any landscaped area

Removal of accumulated sediment and debris, replacement of any dead or stressed plants, and replenishment of the mulch layer is recommended on an annual basis. Also, any eroded areas should be repaired as soon as they are detected.

Potential LEED Credits

Primary: Sustainable Sites – Credit 6 "Stormwater Management" (1-2 Points)

Other: Sustainable Sites – Credit 7 "Landscape & Exterior Design to Reduce Heat Islands" (1-2 Points)

Water Efficiency – Credit 1 "Water Efficient Landscaping" (1-2 Points)

Innovation & Design Process (1-4 Points)

Links to Additional Information

USEPA Office of Water
http://www.epa.gov/OW-OWM.html/mtb/biortn.pdf

Natural Resources Defense Council, 2001: Stormwater Strategies: Community Responses to Runoff Pollution.
http://www.nrdc.org/water/pollution/storm/stoinx.asp

United States Environmental Protection Agency, 2000: Bioretention applications: Inglewood Demonstration Project, Largo, Maryland, and Florida Aquarium, Tampa, Florida. Office of Water, Washington, D.C., EPA-841-B-00-005A

U.S. Environmental Protection Agency, 1995: Maryland developer grows 'Rain Gardens' to control residential runoff. Nonpoint Source News-Notes, 42 (August/September)
http://www.epa.gov/NewsNotes/issue42/urbrnf.html

Performance and Inspection

To ensure proper performance, visually inspect that stormwater is infiltrating properly into each bioretention cell. Water standing in a bioretention cell for more than 48 hours indicates operational problems.

Corrective measures include inspection for and removal of sediments, typically by backflushing.

Samples of bioretention media should be assessed if there is poor infiltration to determine the condition of the media (e.g. clay content).

Replacement of the bioretention media may be required to restore the flow rate through the cell. First, applying soil amendments can be attempted to restore permeability.

Perform Inspection:

- o annually in spring
- o after severe weather events (e.g. hurricanes)

VIII.3.Bioretention Slopes

Highway median: potential bioslope location
Source: LID Center

Design Criteria:

- **Construct a bioslope along the entire length of the sloped edge of its drainage area, having a width sufficient to provide treatment for the drainage area runoff**
- **Cover slope with an ecology mix soil having a minimum depth of one foot**
- **Install a gravel level spreader between the impervious surface and the slope**
- **Install a vegetated filter strip between the gravel and the bioslope, if pre-treatment is desired or needed**
- **Install a gravel underdrain trench and pipe at the base of the slope for temporary storage of stormwater.**
- **Plant (seed) the slope with grasses**

Maintenance:

- **Periodically remove debris accumulated on the gravel level spreader.**
- **Mow the grass filter strip with a retractable –arm mower to avoid compaction of the ecology mix.**
- **Reseed bare areas annually.**
- **Repair any eroded areas as soon as they are detected.**
- **Conduct periodic sampling and testing to assess adequate ongoing permeability of the ecology mix.**

Advantages:

- **Useful for medians and side slopes of access roads/sites**
- **Useful along edges of elevated impervious areas (e.g. parking lots)**
- **Effective for retrofit of standard fill slopes**
- **Enhance quality of downstream waters**
- **Reduce runoff volume and pollutant loads**

Disadvantages:

- **Not recommended for unstable slopes or those steeper than 4:1 (rise : run)**
- **Runoff must flow onto the bioslope via sheet flow only**
- **Bioslopes cannot handle high velocity and high discharge flows.**
- **Bioslopes are susceptible to erosion**
- **Requires specialized mowing equipment (retractable arm) to avoid compaction**

Stormwater Management Suitability

Runoff Volume Reduction

Peak Discharge Rate Reduction

Water Quality

Water Quantity Controls

Bioslope design is based on the ability of a slope area to absorb and treat a specified storm intensity. This assumed design rainfall intensity typically relates to the maximum anticipated intensity of the water quality storm event.

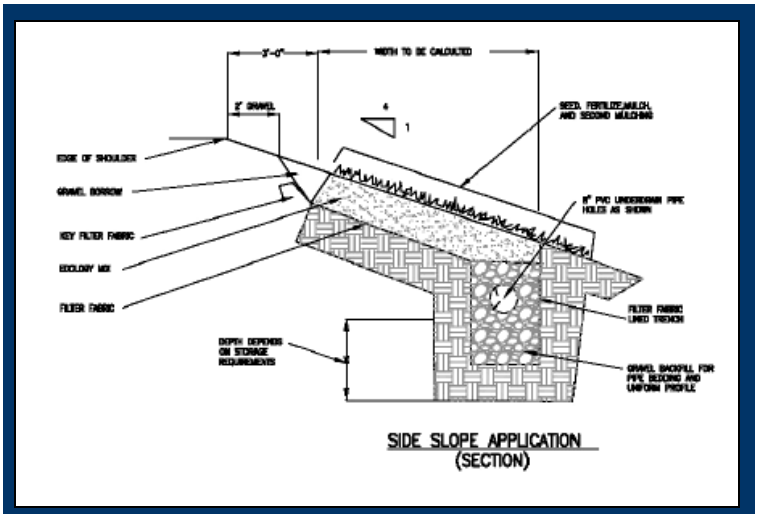
For storms with an intensity greater than the design rainfall intensity, some runoff will not be captured and infiltrated, but will flow over the surface of the bioslope. Stormwater not captured by the bioslope can be detained through additional (sub)surface storage at the base of the bioslope.

A ponding area or gravel storage bed (infiltration trench) can be constructed at the slope base to store excess runoff.
It is important to emphasize that storm intensity, not rainfall depth, will determine the volume of "excess" stormwater that will need to be stored at the base of the bioslope. For the bioslope itself and the auxiliary storage area, the permeability of the subsoil will determine whether captured runoff will exfiltrate into the subsoil or flow into an underdrain connected to a conventional conveyance system.

Additional subsurface storage can be provided within the bioslope itself by enlarging the gravel underdrain trench. This can be used to store water that would otherwise flow directly into the underdrain pipe.

Water Quality Controls

Research conducted by the Washington State Department of Transportation has found that bioslopes can remove 60 percent of phosphorus, 77 percent of metals, and 88 percent of total suspended solids (TSS) contained in stormwater runoff from a water quality storm event.



Bioslope Cross-Section
Source: Washington State Highway Runoff Manual

Location

Bioslopes are appropriate for use on medians and side slopes of access roads or sites but cannot be used where the side slope exceeds 4:1 (rise : run) or on unstable slopes.

To avoid erosion, stormwater must run onto the bioslope via sheet flow only. High velocity and high discharge flows must be diverted to conveyance channels.

Cost

The cost for a bioslope to treat runoff from ½ impervious acre is consists of both the installation and annualized costs.

These cost calculations were based upon a bioslope with a surface area of 3,000 square feet.

A bioslope is assumed to have a lifespan of 25 years, at which point it would be removed and replaced.

Design Construction and Materials

Bioslopes consist of a gravel level spreader next to the pavement to evenly distribute flows and trap sediments; an optional vegetated filter strip to provide additional pretreatment if space allows; an ecology mix bed which provides the majority of water quality improvement; and an optional gravel underdrain trench and pipe.

Underdrains may be needed on Hydrologic Soil Group (HSG) C and D soils. Observation/cleanout wells should be installed, if underdrains are used. Soil amendments may be used in the filter strip to increase its permeability.

When sizing a bioslope for its drainage area, the long-term flow rate through the ecology mix must be at least as great as the design peak discharge rate from the drainage area. Include a 50 percent safety factor when assigning a long-term conductivity rate to the ecology mix.
Basic bioslope dimensions are given below.

- The bioslope should be as long as the drainage area it is intended to treat and should run parallel along the sloped edge of the drainage area (e.g. roadway).
- The bioslope width must be sufficient to provide treatment for the adjacent drainage area.
- Dual bioslopes must be at least two feet (2') wide.
- The ecology mix soil bed should be one foot (1') deep or greater.
- The side slope of the bioslope should be no steeper than 4H:1V.
  - The gravel level spreader should be at least one foot (1') wide and at least 18 inches deep.
  - The gravel underdrain trench should be at least two feet (2') wide.

Item	Unit	Estimated unit cost (2005 Dollars)
Level spreader (gravel)	C.Y.	$30 - $35
Filter fabric	S.Y.	$1 - $5
Underdrain trench (gravel)	C.Y.	$30 - $35
Underdrain (perforated pipe 8" dia.)	L.F.	$8 - $15
Grass seed or sod	M.S.F.	$15 - $20
Ecology mix	C.Y.	$40 - $60

The ecology mix consists of the following components (per WSDOT standards).

Item	Required Cost per Year (2005 Dollars)												
	0	1	2	3	4	5	6	7	8	9	10	…	25
Installation[1]	10,000												
Mowing		150	150	150	150	150	150	150	150	150	150		
Reseeding		50	50	50	50	50	50	50	50	50	50		
Remove & Replace													10,000
Total Cost	**10,000**	**200**	**200**	**200**	**200**	**200**	**200**	**200**	**200**	**200**	**200**		**10,000**
Annualized Cost	$600 / year (includes replacement in year 25)												

[1]Developer Cost. Not included in annualized cost.

Maintenance

Periodically remove any debris that has accumulated on the gravel level spreader and mow the grass filter strip. Use a retractable-arm mower to avoid compaction of the ecology mix. Both activities can be incorporated into regular maintenance activities.

Reseed bare areas annually. Conductivity tests may be used periodically to determine whether the permeability of the ecology mix decreases over time.

Potential LEED Credits

Primary: Sustainable Sites – Credit 6 "Stormwater Management" (1-2 Points)

Other: Sustainable Sites – Credit 7 "Landscape & Exterior Design to Reduce Heat Islands" (1-2 Points)

Water Efficiency – Credit 1 "Water Efficient Landscaping" (1-2 Points)

Innovation & Design Process (1-4 Points)

Links to Additional Information

USEPA Office of Water
http://www.epa.gov/OW-OWM.html/mtb/biortn.pdf

Natural Resources Defense Council, 2001: Stormwater Strategies: Community Responses to Runoff Pollution.
http://www.nrdc.org/water/pollution/storm/stoinx.asp

United States Environmental Protection Agency, 2000: Bioretention applications: Inglewood Demonstration Project, Largo, Maryland, and Florida Aquarium, Tampa, Florida. Office of Water, Washington, D.C., EPA-841-B-00-005A

U.S. Environmental Protection Agency, 1995: Maryland developer grows 'Rain Gardens' to control residential runoff. Nonpoint Source News-Notes, 42 (August/September)
http://www.epa.gov/NewsNotes/issue42/urbrnf.html

Performance and Inspection

To ensure proper performance, visually inspect that stormwater is infiltrating properly into the bioslope. Problems are indicated by channelized flow down the slope or rill formation.

Corrective measures include inspection for accumulated sediments around the level spreader and their removal, if necessary.

If infiltration is poor, samples of the ecology mix should be assessed to determine the condition of the ecology mix. The mix may need to be replaced if it has deteriorated.

Perform inspection:

- annually in spring
- after severe weather events (e.g. hurricanes)

VIII.4.Bioretention Swales

Bioretention Swale
Source: Portland BES

Design Criteria:

- Depth shall be one (1) to three (3) feet, minimum (greater depth can provide more storage in soil or gravel layers or more surface ponding)
- Contains mulch, grasses and herbaceous annuals and perennials (typically natives)and special bioretention media
- A gravel layer provides temporary storage of stormwater, which will exit through an underdrain (if present) and/or through exfiltration into the subsoil.
- Underdrains are recommended in areas with low subsoil permeability. Observation (cleanout) wells should also be installed.
- Use inlets or overflow weirs for bypass flow, check dams for encouraging sheet flow

Maintenance:

- Conduct routine periodic maintenance including mowing (to design flow depth), verifying hydraulic efficiency of the channel, insuring dense, healthy cover
- Inspect the treatment area's components and repair or replace them if necessary.
- Remove accumulated sediment and debris, replace any dead or distressed plants, and replenish mulch annually.
- Repair any eroded areas as soon as they are detected. Reseed bare areas.

Advantages:

- Useful incorporated with linear impervious areas (e.g. roads)
- Improve on standard grassed swales by affording greater infiltration, water retention, nutrient/ pollutant removal
- Effective for retrofit
- Enhance quality of downstream waters, as well as reducing runoff volume and peak runoff rate
- Improve roadway corridor appearance

Disadvantages:

- Not recommended for areas where the slope in the direction of flow exceeds 5 percent due to risk of erosive velocities
- Not appropriate where the water table is within 6 feet (1.8m) of ground level
- Not appropriate where surrounding soil is unstable
- Not recommended for areas with high sediment loads

Stormwater Management Suitability

Runoff Volume Reduction

Peak Discharge Rate Reduction

Water Quality

Water Quantity Controls

Any volume of stormwater in excess of the water quality volume (WQV) can be detained by providing additional ponding and/or subsurface storage in the bioswale, thereby reducing the runoff volume and peak discharge rate.

The voids in the soil and gravel layers provide storage capacity. Additional storage may be provided by increasing the depth of the gravel layer. Exfiltration into the subsoil can potentially reduce the volume of stormwater that ultimately enters the conveyance system.

Volume reduction depends upon:

- available storage in the gravel layer and ponding area
- the maximum flow rate into the subsoil
- the flow rate into the basin related to
  - storm intensity
  - drainage area size

A bioswale's cross-section can be sized to provide conveyance for any given design storm, as required by applicable regulations.

Water Quality Controls

Phosphorus removal efficiency data specific to bioswales is not available. Similarities in design and function of swales to bioretention cells (see Section 2.2) allow phosphorus removal efficiencies for bioretention cells to be used as a reference for bioswales.

Therefore, bioswale phosphorus removal efficiencies are:

- 50 percent for swales that capture 0.5" runoff from the impervious area
- 65 percent for swales that capture 1.0" runoff from impervious the area

Location

Bioswales can be used in commercial and industrial areas. Use of pre-treatment BMPs in conjunction with bioswales may be advisable. Sediment capturing devices such as filter strips and vegetated filters are examples of these optional techniques.
Bioswales generally should not be located where there are high sediment loads or soils are not entirely stabilized.

Bioswale Maintenance
Source: LID Center

Cost

The cost for a bioswale to treat runoff from ½ impervious acre consists of both the installation and annualized costs.

Cost calculations were based upon a bioswale design having a surface area of 900 square feet.

A bioswale is assumed to have a lifespan of 25 years, at which point it would be removed and replaced.

Design Construction and Materials

Bioswales are excavated to a minimum depth of one (1) to three (3) feet, depending on the infiltration rate and depth to the seasonal high groundwater table or bedrock. Deeper excavation can provide for additional storage in the soil or gravel layers.

Underdrains are recommended in areas with low subsoil permeability (e.g. compacted or clay soils) or shallow soil profiles. Underdrains must tie into an adequate conveyance system. Observation/ cleanout wells should also be installed if underdrains are used.

A gravel layer provides temporary storage of stormwater, which will exit through an underdrain (if present) and/or through exfiltration into the subsoil.
If an underdrain is present, the gravel layer surrounds the underdrain pipe to minimize clogging. The excavated area is then filled with an engineered media classified as “sandy loam” or “loamy sand” that consists of:

- 50% sand
- 30% planting soil with minimal clay content, and
- 20% shredded hardwood mulch.

The swale area is then seeded to provide a plant community of warm season grasses, herbaceous annuals and flowering perennials.

The swale must provide for bypass flow into an inlet or overflow weir. Check dams may be used to act as flow spreaders to encourage sheet flow.
Bioswale slopes should be no greater than 5 percent. Gentle slopes and reduced velocities are critical to ensuring a stable, non-erosive swale.

Item	Unit	Estimated unit cost (2005 Dollars)
Excavation	C.Y.	$8 - $10
Grading	S.Y.	$0.10 - $0.15
Bioretention media	C.Y.	$40 - $60
Filter fabric	S.F.	$0.70 - $1.00
Underdrain trench (gravel)	C.Y.	$30 - $35
Underdrain (perforated pipe 8” dia.)	L.F.	$15 - $20
Seed	S.F.	$1 - $2

Item	Required Cost per Year (2005 Dollars)												
	0	1	2	3	4	5	6	7	8	9	10	…	25
Installation[1]	10,000												
Mowing		100	100	100	100	100	100	100	100	100	100		
Reseeding / Replanting		100	100	100	100	100	100	100	100	100	100		
Remove & Replace													10,000
Total Cost	**10,000**	**200**	**200**	**200**	**200**	**200**	**200**	**200**	**200**	**200**	**200**		**10,000**
Annualized Cost	$600 / year (includes replacement in year 25)												

[1]Developer Cost. Not included in annualized cost.

Maintenance

The primary maintenance requirement for bioswales includes routine inspections targeted at maintaining hydraulic efficiency of the channel, the treatment effectiveness of the bioretention components, and a dense, healthy vegetative cover. Inspections should also target erosion of the swale channel bottom.

Maintenance activities should include periodic mowing (with grass never cut shorter than the design flow depth), clearing of debris and blockages, and sediment removal. Reseed bare areas annually.

Potential LEED Credits

Primary: Sustainable Sites – Credit 6 “Stormwater Management” (1-2 Points)

Other: Sustainable Sites – Credit 7 “Landscape & Exterior Design to Reduce Heat Islands” (1-2 Points)
Water Efficiency – Credit 1 “Water Efficient Landscaping” (1-2 Points)
Innovation & Design Process (1-4 Points)

Links to Additional Information

USEPA Office of Water
http://www.epa.gov/OW-OWM.html/mtb/biortn.pdf

Natural Resources Defense Council, 2001: Stormwater Strategies: Community Responses to Runoff Pollution.
http://www.nrdc.org/water/pollution/storm/stoinx.asp

United States Environmental Protection Agency, 2000: Bioretention applications: Inglewood Demonstration Project, Largo, Maryland, and Florida Aquarium, Tampa, Florida. Office of Water, Washington, D.C., EPA-841-B-00-005A

U.S. Environmental Protection Agency, 1995: Maryland developer grows 'Rain Gardens' to control residential runoff. Nonpoint Source News-Notes, 42 (August/September)
http://www.epa.gov/NewsNotes/issue42/urbrnf.html

Performance and Inspection

To ensure proper performance, visually inspect that stormwater is infiltrating properly and is being conveyed through the length of the bioswale. Water standing in a bioswale for more than 48 hours indicates operational problems.

Corrective measures include inspection for and removal of sediments, typically by backflushing.

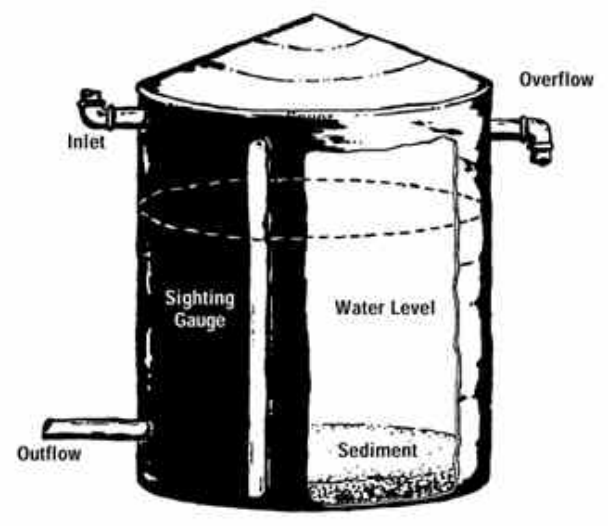
Samples of bioretention media should be assessed if there is poor infiltration to determine the condition of the media (e.g. clay content).

Replacement of the bioretention media may be required to restore the flow rate through the cell. First, applying soil amendments can be attempted to restore permeability.

Perform inspection:

- annually in spring
- after severe weather events (e.g. hurricanes)

VIII.5.Cisterns / Rainbarrels



Schematic of Cistern. Source: Texas Water Development Board- Rainwater Harvesting

Design Criteria:

- Rainwater catchment systems (RWCS) store roof runoff for reuse.
- Cisterns may store up to 10,000 gallons of stormwater runoff. Prefabricated systems offer greater reliability and ease of integration with plumbing systems. These can be placed on rooftops and drained by gravity. If installed in a basement, pumping is required. An overflow to the sanitary sewer should also be provided.
- Rain barrels typically store less than 100 gallons of runoff. Homemade rain barrels can be easily constructed from readily available materials.

Maintenance:

- **Rain Barrels**
  Inspect each unit and its components seasonally and after major rain events for clogging.
  Replace minor parts as needed.

- **Cisterns**
  Inspect for clogging and structural soundness - and test water quality - twice each year. Repair as needed.
  Remove accumulated sediment once annually.

Advantages:

- Allows capture and reuse of roof runoff – relatively clean, naturally "soft" water, free of most sediment and dissolved salts
- Reduces runoff volume, as well as peak discharge rate for small, frequent rain events
- Reduces potable water consumption:
  - landscape irrigation
  - HVAC coolant
  - toilet flushing
- Affords water quantity and quality control where space is scarce and land values are premium
- Effective for urban retrofit sites

Disadvantages:

- Unless provided in large quantities, rain barrels may not be able to handle the water quality volume (WQV)
- Regulatory and administrative obstacles may preclude the re-use of cistern water. This may reduce the attractiveness and feasibility of this BMP given space needs and costs.

Stormwater Management Suitability

Runoff Volume Reduction

Peak Discharge Rate Reduction

Water Quality

Water Quantity Controls

For any storm, the runoff volume will be reduced by an amount equal to the empty volume of the RWCS, which may be less than the total storage capacity. The peak discharge rate may be delayed or reduced, depending on captured volume.

Rain barrel sizing is relatively simple. Rain barrels usually store between 55 and 130 gallons and may be connected in series. Space constraints and frequency and volume of irrigation will determine the number of rain barrels used for a rooftop.

Cistern sizing depends on the water demand and on the collection volume: in other words, an analysis of the water input and output. Storage in addition to the WQV (water quality volume) may be needed if cistern water is not completely drawn down between storms. Per capita use of cistern water (e.g. toilet flushes per person per day) can be used to calculate the demand, i.e. the cistern outflow rate.

Water Quality Controls

Typically, to be considered a water quality BMP, a RWCS must collect the water quality volume (WQV), which is the first 0.5" of rainfall (NVPDC). Unless provided in large quantities, rain barrels may be unable to meet this requirement.

For all RWCS, settling of sediments will contribute to water quality improvements (however, resuspension during subsequent storms may be a concern). Additional pollutant removal ability will depend on the ultimate use of the water.

Since rain barrel water is typically used for landscape irrigation, pollutant removal rates approximate those of infiltration BMPs (see 2.2, bioretention cells). The same holds true for cistern water used for landscape irrigation.

If cistern water is used for toilet flushing or other applications in which it will ultimately be discharged to the sanitary sewer, the pollutant removal rate is the same as that of the wastewater treatment plant (WWTP). This efficiency is 95 to 100 percent for phosphorus and many other pollutants.

Location

RWCS can be used on any building site with sufficient space and structural capacity where there will be a reliable end use for collected rainwater. Cisterns may be installed for any land use. Rain barrels are often, but not exclusively, used for residential applications due to their small capacity.

Cost

Cost calculations were developed assuming the first 0.5" of rainfall is captured.
Cost for a large cistern to treat runoff from ½ impervious acre consists of installation and annualized costs.

For similar capacity, a series of 53 rain barrels (130 gal/each) would be required. Their primary purpose would be to increase visibility of the system in order to raise public awareness of stormwater issues.

Both cisterns and rain barrels are assumed to have a lifespan of 25 years, at which point they would be removed and replaced.

Design Construction and Materials

Cisterns and rain barrels may be constructed from available parts, but prefabricated systems may offer more reliability and greater ease of integration with the building's plumbing system. If adequate structural capacity exists, cisterns can be placed on rooftops and be drained by gravity. Another common installation location is a basement, in which case pumping is needed. Flow splitters can be used to divert the WQV to the cistern. An overflow to the sanitary sewer should also be provided.

If cisterns are used to supplement a building's potable plumbing system, a parallel plumbing system will need to be installed. The installation cost depends on the size and purpose of the system and will need to be considered in any cost-benefit analysis. Safety measures must be taken to ensure that cistern water not be used for potable purposes. Besides a parallel plumbing system, such measures include warning signs and lockable faucets.

Cistern/Rain Barrel Type	Small system	Large system
Galvanized steel	$225 → 200 gal.	$950 → 2000 gal.
Polyethylene	$150 → 130 gal.	$1100 → 1800 gal.
Fiberglass	$660 → 350 gal.	$10,000 → 10K gal.
Fiberglass/steel composite	$300 → 300 gal.	$10,000 → 5K gal.
Ferro-cement	Varies by location	Varies by location

Item	Required Cost per Year – Cistern[2] (2005 Dollars)												
	0	1	2	3	4	5	6	7	8	9	10	…	25
Installation[1]	13,000												
Debris Removal		250	250	250	250	250	250	250	250	250	250		
Replace Parts				500			500			500			
Water Quality Tests		500	500	500	500	500	500	500	500	500			
Remove & Replace													13,000
Total Cost	**13,000**	**550**	**550**	**550**	**550**	**550**	**550**	**550**	**550**	**550**	**550**		**13,000**
Annualized Cost	$1,400 / year (includes replacement in year 25)												

[1]Developer Cost (assumes 10,000 gallon fiberglass cistern). Not included in annualized cost.
[2]Comparable capacity using rain barrels results in installed cost of $7,950 and annualized costs of $720 including replacement.

Maintenance

Maintenance requirements for rain barrels are minimal. Each unit and its attachments should be inspected for clogging several times a year and after major storms. Minor parts such as spigots, screens, downspouts or leaders may need to be replaced periodically.

Cisterns should undergo water quality assessments (i.e. sediment, fecal coliform, bacteria, and heavy metals) and inspections for clogging and structural soundness twice each year. Accumulated sediment should be removed once annually. Costs associated with inspection and repair of the distribution system (parallel plumbing) are widely variable.

Potential LEED Credits

Primary:	Water Efficiency – Credit 1 "Water Efficient Landscaping" (1-2 Points) Water Efficiency – Credit 3 "Water Efficient Landscaping" (1-2 Points) Sustainable Sites – Credit 6 "Stormwater Management" (1-2 Points)
Other:	Innovative & Design Process (1-4 Points)

Innovation & Design Process (1-4 Points)

Links to Additional Information

Downspout Disconnection in Toronto,
www.city.toronto.on.ca/watereff/downspot.htm

Rainwater harvesting from Rooftop catchments
www.oas.org/usde/publications/Unit/oea59e/ch10.htm

Tanks Direct, Above ground and underground storage for water, petroleum, and chemical applications
www.storagetanks.com

The Texas Water Development Board-Rainwater Harvesting
www.twdb.state.tx.us/assistance/conservation/Rain.htm

Performance and Inspection

Inspect rain barrels once each season) and after extreme weather events, checking connections (e.g. inflow and outflow hoses) when removing debris.

Inspect cisterns twice each year for structural soundness; one of these times may coincide with annual sediment removal.

If there is a parallel plumbing system, it can be inspected at the same time as the conventional plumbing system.

Rain Barrel
Source: District of Columbia Water & Sewer Authority

VIII.6.Water Quality Swales

Grassed Swale
Source: LID Center

Design Criteria:

- **Broad, shallow channel vegetated along bottom and sides with grasses designed to accommodate peak flow of design storm**
- **Side slopes must be 3:1 (rise : run) or less**
- **Slope in flow direction must be 5 percent or less**
- **Grass along sides of channel is kept at a height greater than the maximum design stormwater volume**
- **Soils must have a minimum permeability rate of 0.27 inches per hour (SCS A/B soils groups) or be improved with amendments**
- **An optional gravel layer can provide storage of stormwater in excess of WQV; engineered soil can improve filtration**

Maintenance:

- **Conduct routine periodic maintenance that is required of any grassed area: mow, weed, water, aerate and reseed.**
- **Maintain grass height equal or greater to the design flow depth.**
- **Minimize or eliminate us of fertilizers, herbicides, and pesticides.**
- **Remove sediment and debris after severe storm events.**
- **Inspect swales (and check dams) for erosion and repair and reseed as needed.**

Advantages:

- **Useful for small drainage areas with low stormwater velocities**
- **Use existing natural low areas to treat stormwater**
- **Can be sized to convey any design storm required**
- **Reduce stormwater volume**
- **Enhance quality of downstream waters**
- **Reduce runoff velocity**
- **Minimal maintenance requirements**

Disadvantages:

- **Not applicable to large drainage areas in excess of 10 acres (much smaller areas are recommended)**
- **Not recommended for areas with slopes greater than 5% or where velocities exceed 3 to 4 feet per second --- without the use of check dams**
- **Not applicable where soil infiltration rates are less than 0.3 inches per hour**

Stormwater Management Suitability

Runoff Volume Reduction

Peak Discharge Rate Reduction

Water Quality

Water Quantity Controls

Any volume of stormwater in excess of the WQV can be detained by providing additional ponding and/or subsurface storage in the swale, thereby reducing the runoff volume and peak discharge rate. The voids in the soil and gravel layers provide stormwater storage capacity.

The depth of the gravel layer may be increased to add additional storage. Exfiltration into the subsoil can potentially reduce the volume of stormwater that ultimately enters the conveyance system.

Volume reduction depends on:

- available detention storage in the gravel layer and ponding area,
- the maximum flow rate into the subsoil,
- the flow rate into the swale,
  - storm intensity
  - drainage area size.

The cross-section of a water quality swale can be sized to provide conveyance for any given design storm, as required.

Water Quality Controls

Phosphorus removal efficiency is 15 percent if existing subsoil underlies the swale. However, the rate is 35 percent if an engineered soil mixture is used. Pollutant load reductions are achieved due to decreased volume of stormwater runoff.

Pollutant removal occurs in grassed swales through two mechanisms. Vegetation in the channel removes large and coarse particulates and sediment from stormwater. Pollutants are also removed by aerobic decomposition and chemical precipitation that occurs within the soil matrix while stormwater is infiltrating.

Location

Grassed swales should only be used where soils have infiltration rates of more than 0.3 inches per hour. Suitability of grassed swales depends on soil type, slope, imperviousness of the contributing watershed, dimensions and slope of the grassed swale system.

In general, grassed swales can be used to manage runoff from drainage areas that are less than 10 acres in size (although smaller areas are recommended), with slopes 5 percent or less, or velocities greater than 3 to 4 feet per second.

Grassed Swale
Source: VA DCR
PERMISSION PENDING

Cost

The cost for a water quality swale to treat runoff from ½ impervious acre consists of both the installation and annualized costs.

Cost calculations were based upon a water quality swale with a surface area of 900 square feet.

A water quality swale is assumed to have a lifespan of 25 years, at which point it would be removed and replaced.

Design Construction and Materials

Swale capacity should be able to accommodate the peak flow from the design storm. Soil Conservation Service (USDA-SCS) hydrologic group A and B soils are required for grassed swales unless a permeability rate of 0.27 inches per hour or greater can be achieved. Soil amendments can be used to increase permeability.

The side slopes of the swale shall be no steeper than 3:1(rise:run) and longitudinal slopes shall be 5 percent or less. Check dams may be used to increase the overall detention time provided by the system.

Grass should be selected and installed in order to ensure swale stability and to provide sufficient surface roughness and filtering. Grassed swales typically consist of the component listed below.

Item	Unit	Estimated unit cost (2005 Dollars)
Grading	S.Y.	$0.10 - $0.15
Erosion control material	S.Y.	$1 - $2
Sod	S.F.	$2 - $4
Grass seed	S.F.	$1 - $2

Item	Required Cost per Year (2005 Dollars)												
	0	1	2	3	4	5	6	7	8	9	10	…	25
Installation[1]	6,000												
Mowing		100	100	100	100	100	100	100	100	100	100		
Reseeding		50	50	50	50	50	50	50	50	50	50		
Aeration		50	50	50	50	50	50	50	50	50	50		
Remove & Replace													6,000
Total Cost	**6,000**	**200**	**200**	**200**	**200**	**200**	**200**	**200**	**200**	**200**	**200**		**6,000**
Annualized Cost	$425 / year (includes replacement in year 25)												

[1]Developer Cost. Not included in annualized cost.

Maintenance

Maintenance activities include periodic mowing (grass must be cut equal to or higher than the design flow depth), weed control, watering during drought conditions, reseeding of bare areas, and clearing of debris and blockages. Significant storm events can cause sediment to accumulate. Swales must be inspected regularly for signs of erosion (especially at the edges of check dams) and for sediment deposition.

Minimize or avoid using fertilizers and pesticides. Fertilizers should only be used to aid required reseeding. Grass cover should be thick and reseeded as necessary. Periodically, swales should be aerated and debris should be removed. Vehicular traffic or parking must not be allowed on or around swales to avoid compacting soils.

Potential LEED Credits

Primary: Sustainable Sites – Credit 6 "Stormwater Management" (1-2 Points)

Other: Sustainable Sites – Credit 7 "Landscape & Exterior Design to Reduce Heat Islands" (1-2 Points)

Water Efficiency – Credit 1 "Water Efficient Landscaping" (1-2 Points)

Innovation & Design Process (1-4 Points)

Links to Additional Information

USEPA Office of Water
http://www.epa.gov/OW-OWM.html/mtb/vegswale.pdf

Natural Resources Defense Council, 2001: Stormwater Strategies: Community Responses to Runoff Pollution.
http://www.nrdc.org/water/pollution/storm/stoinx.asp

United States Environmental Protection Agency, 2000: Bioretention applications: Inglewood Demonstration Project, Largo, Maryland, and Florida Aquarium, Tampa, Florida. Office of Water, Washington, D.C., EPA-841-B-00-005A

U.S. Environmental Protection Agency, 1995: Maryland developer grows 'Rain Gardens' to control residential runoff. Nonpoint Source News-Notes, 42 (August/September)
http://www.epa.gov/NewsNotes/issue42/urbrnf.html

Performance and Inspection

To ensure proper performance, visually inspect that stormwater is being conveyed through the entire water quality swale. Water standing in a water quality swale for more than 24 hours indicates operational problems.

If excessive ponding is observed, a swale should be inspected for any accumulated sediments. Any blockages should be removed.

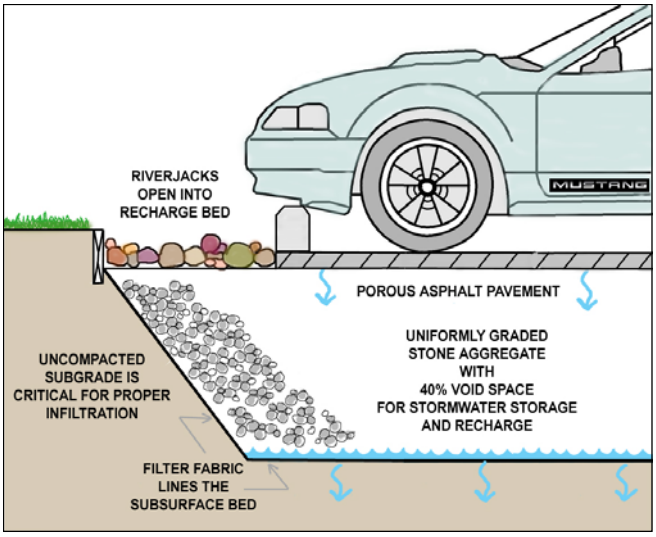
Aeration of a swale should be done every other year to maintain the function of the soils and aid infiltration. Annual inspections should be conducted to determine water infiltration and conveyance.

Reseeding or resodding may be required if the grass becomes diseased or damaged.

Perform inspection:

- annually in spring
- after severe weather events (e.g. hurricanes)

VIII.7.Permeable / Porous Pavement



Permeable pavement cross-section
Source: Cahill and Associates

Design Criteria:

- Asphalt or concrete with reduced fines and a special binder allowing water to pass through voids OR paving blocks installed with gaps between units that are filled with aggregate or soil and turf grass
- Porous paving is underlain with a subbase of aggregate comprised two layers:
  - Upper layer – fines
  - Lower layer – coarse aggregate
    - structural support
    - reservoir
- Geotextile fabric separates aggregate layers from the soil below
- Underdrains and cleanouts may be needed where infiltration rates are low

Maintenance:

- Primary Goal –
  Prevent clogging of voids by fine sediment particles
  - Vacuum pavement three (3) to four (4) times annually
  - DO NOT pressure wash pavement (forces particles deep into voids)
  - DO NOT apply abrasive materials as treatment for snow/ice safety hazards
- Inspect regularly for clogging as well as structural soundness.

Advantages:

- Useful in parking lots, driveways, road shoulders and paths
- Uses site features that cause stormwater management problems as part of a creative solution
- Conserves space allocated to storm-water management
- Effective for retrofit
- Enhance quality of downstream waters by decreasing runoff volume and peak discharge, as well as filtering pollutants and aiding recharge of groundwater

Disadvantages:

- Only feasible in areas level enough for vehicular and pedestrian uses
- Without adequate training, personnel can permanently damage structures
- Not feasible where sediment loads can not be controlled
- Not appropriate where the seasonal groundwater table – or bedrock - is within two (2) to four (4) feet of the bottom of the infiltration trench

Stormwater Management Suitability

Runoff Volume Reduction

Peak Discharge Rate Reduction

Water Quality

Water Quality Controls

Pollutant loads can be cut by decreasing stormwater volume discharged through the subbase aggregate and by increasing infiltration into substrate. The first method of calculating load reduction is to calculate the volume of stormwater retained in the aggregate subbase. Further reduction of pollutant loads requires analysis of other pollutant removal mechanisms.

If stormwater is able to infiltrate into the soil, pollutants will further adsorb and be absorbed by soil particles. Other processes such as aerobic decomposition and chemical precipitation will also decrease pollutants within the soil matrix. Sand layers below the aggregate may provide water quality treatment.

A determination of pollutant load reductions will require an analysis of adsorption and absorption rates for soluble pollutants as well as rates of decomposition and precipitation.

Reductions in particulates and suspended solids can be achieved by physical removal when filtering through subbase aggregate.

Nitrogen removals depend greatly upon stormwater infiltrating into the soil where microbial conversion of nitrogen is able to occur.

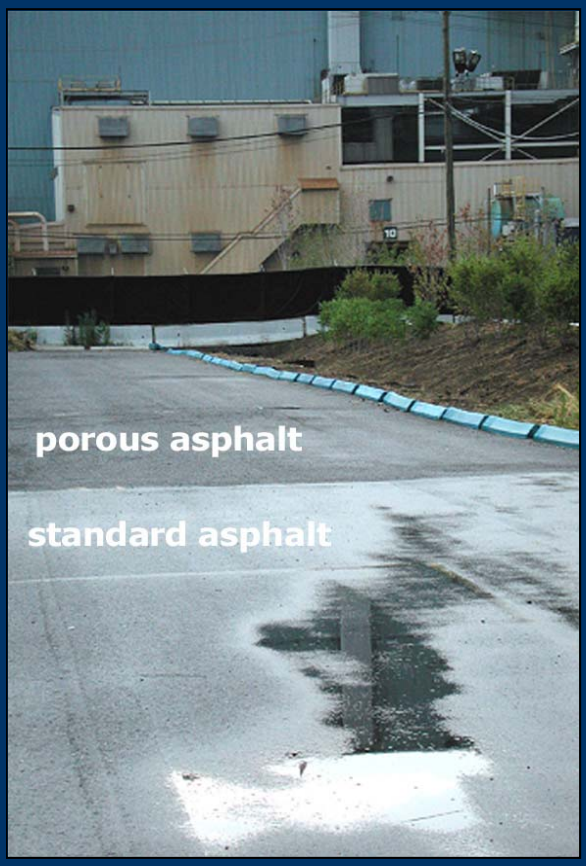
Water Quantity Controls

Porous pavements reduce stormwater runoff volume and peak discharge rates by providing a storage reservoir and an opportunity for subsurface infiltration. Stormwater volumes greater than WQV potentially can be stored.

Determining the reduction in stormwater volume requires determining the flow rate through the pavement, the response to the storm event, the volumetric storage area in the aggregate subbase, and the release rate. The interstitial voids provide stormwater storage. Permeability of surrounding soils adds storage capacity based upon infiltration rate. The depth of the aggregate subbase may be increased to add additional storage. The maximum depth of the aggregate subbase will be a function of the retention time desired, porosity of the selected aggregate, and soil infiltration rate.

Location

Permeable pavements may be used for parking lots, driveways, road shoulders and pedestrian paths. Such paving should not be used in areas with the potential for spills, such as gas stations or loading docks. Permeable pavement should not be used for roadways with traffic heavier or more frequent than that on residential roads.



Drainage in both types of pavement
Source: Cahill and Associates

Cost

The cost for porous or permeable pavement to treat runoff from ½ impervious acre consists of installation and annualized costs. Cost calculations were based upon permeable pavement being installed on 10% of a ½ acre parking lot.

Permeable pavement is assumed to have a lifespan of 25 years, at which point it would be removed and replaced.

Design Construction and Materials

Construction of permeable asphalt and concrete will be similar to that of conventional pavements. Installation of paving blocks may require additional labor costs for hand placement. Similar materials and construction techniques are required for permeable and conventional pavements.

The largest difference is the depth of the aggregate subbase and the addition of the geotextile material. Permeable pavement systems typically consist of the following components.

Perforated underdrains may be used when constructing permeable pavement in areas where soil infiltration rates are low. Observation/cleanout wells must be installed if underdrains are used. A clearance of at least two (2) to four (4) feet must be maintained between the bottom of the infiltration trench and the seasonal high groundwater table or bedrock, depending on site conditions.

Preventing overland runoff from flowing across permeable paving decreases sediment loading and maximizes lifespan and performance of the paving. This can be accomplished through the use of a perimeter berm or filter strip.

Item	Unit	Estimate unit cost (2005 dollars)
Excavation	C.Y.	$8 - $10
Porous asphalt	S.F.	$0.50 - $1.00
Porous concrete	S.F.	$2.00 - $6.50
Concrete paving blocks	S.F.	$5 - $10
Aggregate	C.Y.	$30 - $35
Geotextile fabric	S.F.	$0.70 - $1.00

Item	Required Cost per Year (2005 Dollars)												
	0	1	2	3	4	5	6	7	8	9	10	…	25
Installation[1]	12,000												
Vacuum Sediment		500	500	500	500	500	500	500	500	500	500		
Remove & Replace													12,000
Total Cost	**12,000**	**500**	**500**	**500**	**500**	**500**	**500**	**500**	**500**	**500**	**500**		**12,000**
Annualized Cost	$950 / year (includes replacement in year 25)												

[1]Developer Cost. Not included in annualized cost.

Maintenance

The main goal of a maintenance program for porous or permeable paving surfaces is to prevent clogging by fine sediment particles. Vacuum the pavement three (3) to four (4) times annually, depending on the average sediment loading.

DO NOT pressure wash the permeable/porous pavements, as this may force particles deeper into the pavement where it can no longer be removed by vacuuming.

Abrasive materials for snow treatment, such as sand, should be prohibited in order to prevent clogging of paving voids. Settlement of paving block systems may require resetting. Cracks and settlement in asphalt or concrete may require cutting and replacing the pavement section.

Potential LEED Credits

Primary: Sustainable Sites – Credit 7.1 “Landscape & Exterior Design to Reduce Heat Islands” (1 Point)
Sustainable Sites – Credit 6 “Stormwater Management” (1-2 Points)
Other: Innovation & Design Process (1-4 Points)

Links to Additional Information

USEPA Office of Water
http://www.epa.gov/owow/nps/pavements.pdf

LID Urban Design Tools
http://www.lid-stormwater.net/permeable_pavers/permpavers_benefits.htm

Performance and Inspection

To ensure proper performance, visually inspect that stormwater is infiltrating properly and is not ponding on the surface of the porous or permeable pavement.

Standing water on such pavement may indicate clogging of open void spaces. Annual visual inspections should be conducted to check for accumulated sediments.

Routine vacuuming should prevent clogging. If voids are clogged, vacuuming is necessary.
If this treatment does not restore permeability, the pavement might be clogged beyond repair and may need to be replaced.

VIII.8.Planter Box

Planter Box
Source: LID Center

Design Criteria:

- Elevated structures intercept, store and filter stormwater from routed downspouts
- Planter boxes are constructed of materials capable of containing runoff and echoing the environment; the architecture and/or streetscape
- Planter boxes contain:
  - aggregate substrate
  - soil matrix
  - mulch
  - herbaceous plants, shrubs and/or small trees
- Underdrains and observation wells are recommended to avoid overflow in the event of heavy wet weather

Maintenance:

- Inspect planter boxes for structural integrity and clogging on a regular basis
- Backflush the underdrain in the event that obstructions are found during inspection
- Inspect the soil matrix and aggregate substrate to evaluate root growth and to verify channel formation is not occurring
- Turn or till soil matrix if infiltration becomes slowed due to soil compaction
- Identify damaged components and repair or replace, if needed.

Advantages:

- Effective as part of an overall disconnection strategy in urban areas
- Provide capacity to store and filter runoff
- Enhance quality of downstream water bodies
- Offer "green space" in densely developed environments
- Stormwater provides resources to plantings effectively at low cost enhancing viability
- Effective for retrofit

Disadvantages:

- Space needed for planter boxes may not be available in all situations within the urban environments where they are most cost effective
- High attrition rates for plantings in stressful urban settings may necessitate vigilant maintenance and higher costs than less complex alternatives such as cisterns

Stormwater Management Suitability

Runoff Volume Reduction

Peak Discharge Rate Reduction

Water Quality

Water Quality Controls

Water quality benefits are similar to those for bioretention cells. Phosphorus removal is achieved at the rate of 50 percent for the first one-half inch (0.5”) of runoff that enters the planter box from impervious areas.

Planter boxes contribute to pollutant load reductions by minimizing the volume of stormwater generated. Rainfall is retained and stored in the special soil matrix and substrate. Rainfall is intercepted by plants which evapo-transpire moisture.

Concentrations of pollutants will also be reduced as stormwater infiltrates through planter box soil. Pollutants adsorb and are absorbed by the soil particles. Aerobic decomposition and chemical precipitation will also decrease concentrations of pollutants within the soil matrix.

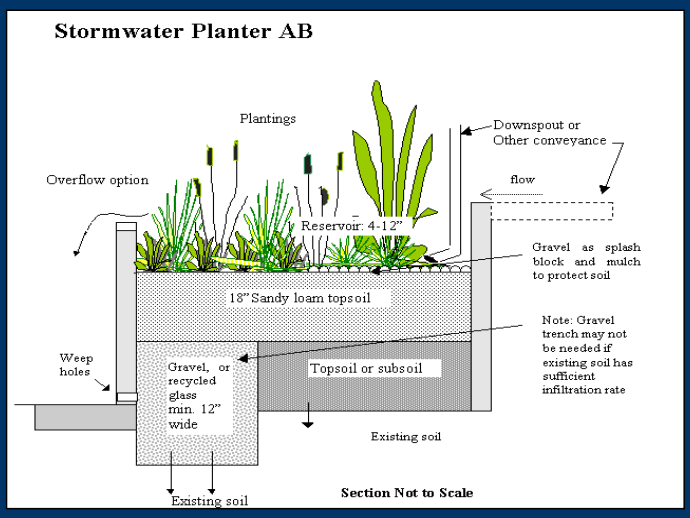
Determination of pollutant load reductions requires an analysis of adsorption and absorption rates for soluble pollutants, as well as decomposition and precipitation rates.

Reductions of suspended solids and particulates are achieved by physical removal when runoff is filtered through the aggregate.

Water Quantity Controls

Routing stormwater to planter boxes can reduce runoff volume and the rate of peak discharge by providing temporary ponding capacity, in addition to sub-surface soil storage.

Additional storage can be provided by constructing a gravel storage bed below the planting soil, similar to gravel layers in bioretention cells.



Planter Box Schematic
Source: LID Center

Location

Planter boxes are most commonly used in urban areas adjacent to buildings and along sidewalks. Locations close to roof downspouts are preferable when used as part of a downspout disconnection program.

Cost

The cost for a planter box system to treat runoff from ½ impervious acre is comprised of both installation cost and annualized costs. These calculations were based upon a planter box system with a total surface area of 500 ft^2.

A planter box is assumed to have a lifespan of 25 years, at which point it would be removed and replaced.

Design Construction and Materials

Planter boxes may be constructed of any durable material. When abutting a building, planter boxes are often made from materials used in the building's construction. They also might be constructed of concrete or other materials used in the nearby streetscape. Stand-alone units might be metal or fiberglass, or other appropriate materials.

An appropriate soil mix is needed to ensure adequate plant growth and vitality. Native plants are often preferred in order to maximize plant viability and to ease maintenance.

Underdrains can be installed to connect planter boxes to a runoff conveyance system. Observation/ clean-out wells should be installed if underdrains are used.

Item	Unit	Estimated unit cost (2005 Dollars)
Planter box construction (concrete)	C.Y.	$75 - $125
Vegetation planting	Ea.	$5 - $20
Soil media	C.Y.	$15 - $25
Underdrain - perforated pipe (4" dia.)	L.F.	$8 - $12

Item	Required Cost per Year (2005 Dollars)												
	0	1	2	3	4	5	6	7	8	9	10	…	25
Installation[1]	4,000												
Mulching, Weeding, and Debris Removal		300	300	300	300	300	300	300	300	300	300		
Replace Vegetation		100	100	100	100	100	100	100	100	100	100		
Concrete Repair						500					500		
Remove & Replace													4,000
Total Cost	**4,000**	**400**	**400**	**400**	**400**	**900**	**400**	**400**	**400**	**400**	**900**		**4,000**
Annualized Cost	$625/ year (includes replacement in year 25)												

[1]Developer Cost. Not included in annualized cost.

Maintenance

Maintenance activities entail routine inspections of the planter box structure and the underdrain. Soil matrix and substrate also need to be inspected to evaluate root growth and channel formation.

The soil media may need to be tilled to improve infiltration. Plants may need to be replaced. Back-flushing the underdrain may be able to remove obstructions. If these efforts are unsuccessful, the soil media and underdrain may need to be removed and replaced.

Potential LEED Credits

Primary: Sustainable Sites – Credit 6 "Stormwater Management" (1-2 Points)
Sustainable Sites – Credit 7 "Landscape & Exterior Design to Reduce Heat Islands" (1-2 Points)
Water Efficiency – Credit 1 "Water Efficient Landscaping" (1-2 Points)

Other: Water Efficiency – Credit 3 "Water Use Reduction" (1-2 Points)
Innovation & Design Process (1-4 Points)

Links to Additional Information

Natural Resources Defense Council, 2001: Stormwater Strategies: Community Responses to Runoff Pollution.
http://www.nrdc.org/water/pollution/storm/stoinx.asp

Achieving Sustainable Site Design through Low Impact Development Practices, Whole Building Design Guide
http://www.wbdg.org/design/lidsitedesign.php

Planter Boxes - City of Sandy Oregon
http://www.ci.sandy.or.us/pw/Storm/Planter_boxes.htm

Performance and Inspection

To ensure proper performance, visually inspect that stormwater is infiltrating properly into the planter box soil matrix and that there is discharge from the underdrain during heavy wet weather events. Ponding of rainwater in a planter box for more than 24 hours indicates operational problems.

If excessive ponding is observed, corrective measures include inspecting the soil matrix for signs of compaction, as well as the underdrain for signs of clogging.

VIII.9.Tree Box Filters

Tree box filter at the Pentagon
Source: LID Center

Design Criteria:

- **Tree box filters resemble typical urban street tree planters are installed below grade along a curb line. They consists of:**
  - **A pre-cast concrete box**
  - **Bioretention soil or growth media**
  - **A tree or shrub**
- **A standard curb inlet is set downstream from tree box filters. High volumes of stormwater will bypass the tree box filter, if full, and flow directly to the inlet.**
- **Plants should be selected based on local recommendations for street trees highly tolerant of high stress conditions. Natives are preferred.**

Maintenance:

- **Periodic, regular removal of trash and debris is required, preferably at least seasonally and after severe storm events**
- **Replenishment of the mulch layer is recommended once or twice annually.**
- **Inspect the tree box regularly for clogging and flush via the cleanout, if needed.**
- **During extreme droughts, water the tree or shrub just as any other landscape plants.**

Advantages:

- **Provide shade and shelter, absorb noise, filter air pollutants and improve the aesthetic value of urban landscapes**
- **Effective for retrofit**
- **Enhance quality of downstream waters**
- **Relatively small units can treat large areas (comparatively) and their runoff volumes**

Disadvantages:

- **Among LID practices and technology, tree box filters are one of the more expensive alternatives**
- **Tree box filters are effective for capture of the WQV (water quality volume) for only small, frequently occurring storms --- they cannot handle larger volumes, nor can they detain WQV for extended periods**
- **Additional storage systems are required downstream for large flow volumes --- with added installation and upkeep costs**

Stormwater Management Suitability

Runoff Volume Reduction

Peak Discharge Rate Reduction

Water Quality

Water Quantity Controls

Tree box filters can reduce the runoff volume and peak discharge rate for small, frequently-occurring storms by capturing the water quality volume (WQV). They are not intended to capture volumes larger than the WQV, or to detain the WQV for extended periods of time. Volumes larger than the WQV can be detained in a subsurface storage system downstream --- such as a gravel bed.

Water Quality Controls

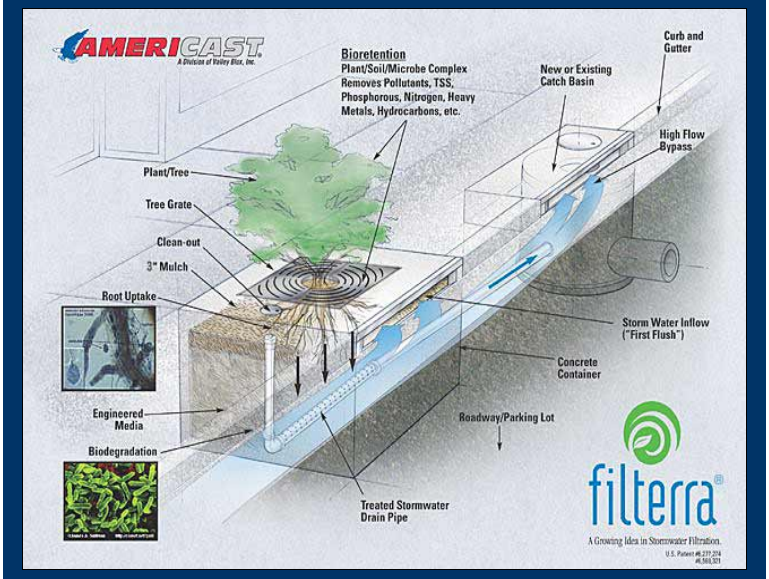
Tree box filters remove pollutants through the same biological, chemical, and physical mechanisms as bioretention cells.

Pollutant	Expected removal
Total suspended solids	85%
Total phosphorous	74%
Total nitrogen	68%
Total metals	82%

Source: Virginia Stormwater Minimum Standard 3.11C

Location

Tree box filters can receive stormwater runoff from streets and parking lots, as long as a downstream inlet or outfall is present. All land uses are suitable.



Tree box filter schematic
Source: Americast
PERMISSION PENDING

Cost

The cost for a tree box filter to treat runoff from ½ impervious acre is comprised of both the installation cost and annualized costs. These cost calculations were based upon installing two (2) 6' x 6' tree box filters.

A tree box filter is assumed to have a lifespan of 25 years, at which point it would be removed and replaced.

A tree box filter this size costs approximately $8,000, including two (2) years of maintenance, filter material, and plants. Installation costs about $1500 per unit for a total of $9500.

Annual maintenance is $500 per unit when performed by the manufacturer, but only $100 per unit if tended by the owner/operator.

Design Construction and Materials

To treat 90 percent of the annual runoff volume, the surface area of a tree box filter should be approximately 0.33 percent of the drainage area. Tree boxes must be regularly spaced along the length of a corridor to meet the annual treatment target. A curb inlet must be located downstream of the tree fox filter(s) to intercept bypass flow.

Tree box filters are off-line devices and should never be placed in a sump position (i.e. at a low point). Instead, runoff should flow *across* the inlet. Also, tree box filters are intended for intermittent flows and must not be used as larger event detention devices.

Tree box filters consist of a pre-cast concrete container, a mulch layer, bioretention media, observation and cleanout pipes, underdrain pipes, and a single tree or large shrub. A decorative grate is typically used to protect the device and the plant, as well as to intercept large debris. Pretreatment under normal conditions is not necessary.

Item	Required Cost per Year (2005 Dollars)												
	0	1	2	3	4	5	6	7	8	9	10	…	25
Installation[1]	19,000												
Mulching and Debris Removal		150	150	150	150	150	150	150	150	150	150		
Replace Vegetation						250					250		
Remove & Replace													19,000
Total Cost	**19,000**	**150**	**150**	**150**	**150**	**300**	**150**	**150**	**150**	**150**	**300**		**19,000**
Annualized Cost	$950 / year (includes replacement in year 25)												

[1]Developer Cost. Not included in annualized cost.

Maintenance

Maintenance of tree box filters typically entails annual inspection and regular removal of trash and debris. Mulch will need to be replenished one (1) to two (2) times per year. The cleanout pipe can be used to flush the system if the underdrain becomes clogged.

During extreme droughts, the tree or shrub may need supplemental water just as any other landscape plants. In these high stress environments, plants may need to be replaced every few years (5 years is the interval assumed for this cost estimate).

Potential LEED Credits

Primary: N/A

Other: Innovation & Design Process (1-4 Points)

Links to Additional Information

Natural Resources Defense Council, 2001: Stormwater Strategies: Community Responses to Runoff Pollution.
http://www.nrdc.org/water/pollution/storm/stoinx.asp

Sizing of Tree Box Filters - LID Stormwater
http://www.lid-stormwater.net/treebox/treeboxfilter_sizing.htm

LID Technologies, Whole Building Design Guide
http://www.wbdg.org/design/lidtech.php

Americast Filterra
http://www.americastusa.com/filterra.html

Performance and Inspection

To ensure proper performance, visually inspect each tree box filter to verify that stormwater is infiltrating properly. Excessive volumes of stormwater bypassing a tree box filter may indicate operational problems.

Corrective measures to restore performance include further detailed inspection to uncover accumulated sediments and debris and, then, removal, if needed.

In instances where the condition of the soil media has significantly degraded, the media and vegetation should be removed and replaced.

Inspection and maintenance should occur on an annual or semi-annual basis.

VIII.10.Green Roofs

Extensive green roof in Baltimore, MD
Source: Katrin Scholz-Barth Consulting.

Design Criteria:

- **Extensive green roofs are low profile and lightweight: thin sheaths of soils, mosses, sedums, herbs and other perennials**
- **Intensive green roofs use a greater depth of growth media and sturdier structures to support trees, shrubs and activity areas**
- **Green roofs consist of several layers:**
  - **Waterproof membrane***
  - **Root barrier**
  - **Insulation layer**
  - **Drainage layer**
  - **Growth medium**
  - **Vegetation**

Leak detection is optional

Maintenance:

- **Properly installed green roofs require little upkeep beyond typical conventional roofs**
- **Periodic weeding, as well as soil and plant replenishment are the primary upkeep tasks for extensive green roofs**
- **Intensive green roofs require more structural as well as horticultural upkeep**
- **EFVM systems are recommended for intensive green roofs in case leaks need to be discovered and repaired**
- **Conditions of draught or high wind may require supplemental watering/irrigation**

Advantages:

- **Reduce roof runoff volume**
- **Reduce runoff pollutant loads**
- **More durable than conventional roofs**
- ***Extensive* greenroofs are useful for retrofits**
- ***Intensive* greenroofs provide valuable urban open space**
- **Insulating properties absorb noise, reduce energy use/loss and ameliorate urban heat island effects --- resolving many urban issues simultaneously**

Disadvantages:

- **Among LID practices and technology, green roofs are one of the most expensive alternatives**
- **Designing green roofs requires uncommon professional expertise and additional design costs**
- **Maintenance of green roofs requires some degree of specialized training**

Stormwater Management Suitability

Runoff Volume Reduction

Peak Discharge Rate Reduction

Water Quality

Water Quantity Controls

Green roofs store rainwater in their soil layer, reducing the volume and peak discharge rate of roof runoff. The storage capacity can be estimated using the equation below.
Equation 1:
*Storage volume = (green roof area) * (soil depth) * (soil porosity)*

This equation is based on the fundamental principle of soil porosity and provides a general guideline for estimating storage capacity. More complex calculations can be used for further detailed analysis.
Green roofs are generally sized to store the water quality volume (WQV):
the first 0.5" of rainfall.

Additional soil depth can be used to increase a green roof's storage capacity.

Part of the stormwater will be retained on the roof and lost to evapo-transpiration. Part of the stormwater will percolate through the drainage layer and become surface runoff. The water retention capacity of the soil medium is dependent upon both the properties of the medium and characteristics of the vegetative cover, as well as climactic conditions.

Water Quality Controls

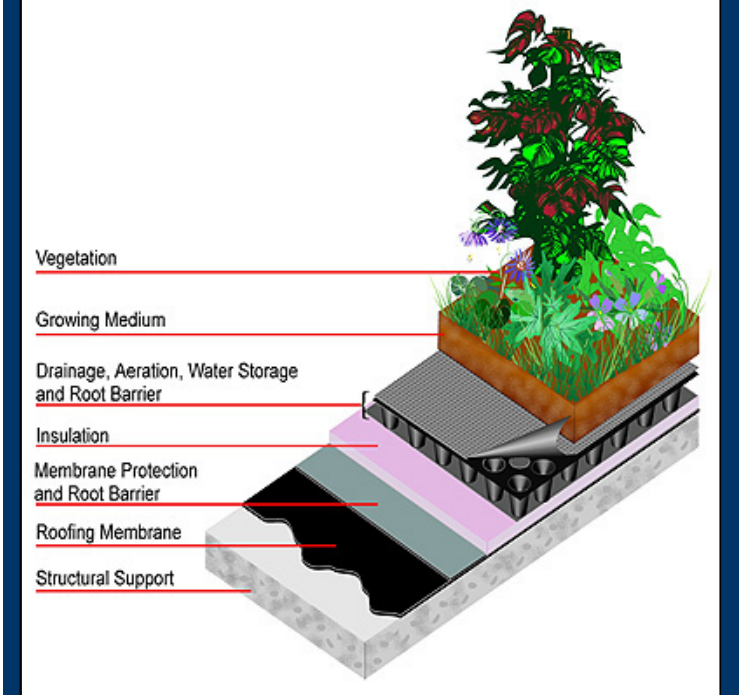
No conclusive water quality information can be presented at this time; research in this area is ongoing.

More Information:
Green Roofs for Healthy Cities
http://www.greenroofs.org/

Third Annual Greening Rooftops for Sustainable Communities Conference, Awards, & Trade Show, May 4th - 6th, 2005 - Washington, D.C.
http://www.greenroofs.org/washington/index.php

Location

Green roofs can be placed on any residential, commercial, or industrial roof surface that is not reserved for patio or utility access.



Extensive green roof cross-section
Source: American Wick Drain Corp.

Cost

Costs for ***extensive*** green roofs are $15 to $20 per square foot for all use types (e.g. high density residential or commercial/industrial). These costs include all green roof components, including waterproof membrane, growth medium, and plants.

The highest costs of green roof construction are the growth medium components and plants. Costs are higher if plants are placed individually rather than installed as vegetated mats.

Costs are given for an ***extensive*** green roof. The cost for a ½ acre (21780 ft^2) extensive green roof consists of both installation costs and annualized costs.

A green roof is assumed to have a lifespan of 25 years, at which point it would be removed and replaced.

Design Construction and Materials

Green roofs consist of several layers. Beginning with the bottom layer, they consist of a waterproof membrane, a root barrier, an insulation layer, a drainage layer, growing medium, and vegetation. A drainage layer is needed for flat roofs but may not be necessary for sloped roofs. A leak detection system below the membrane is optional.

Deciding whether to construct an intensive or extensive roof may be influenced by the property owner's desired maintenance level and by the roof's structural capacity. Soil depth is another design variable and determines water storage capacity. Plants recommended for use on green roofs are hardy, self-sustaining, drought-resistant plants.

Often, plants of the Sedum and Delosperma (common succulents) genuses are used for extensive green roofs. Many species ane varieties are available from a wide array of vendors.

Item	Required Cost per Year (2005 Dollars)												
	0	1	2	3	4	5	6	7	8	9	10	…	25
Installation[1]	250,000												
Weeding		500	500	500	500	500	500	500	500	500	500		
Infill with cuttings[2]						6000					6000		
Soil replenishment						1000					1000		
Remove & Replace													250,000
Total Cost	**250,000**	**500**	**500**	**500**	**500**	**7500**	**500**	**500**	**500**	**500**	**7500**		**250,000**
Annualized Cost	$11,600 / year (includes replacement in year 25). Excluding replacement: $1,600 / year												

[1]Developer Cost. Not included in annualized cost.

[2]Assume 5% of area needs replanting, and a density of 2 plugs per square foot.

Maintenance

Once a properly installed green roof is established, its maintenance requirements are generally minimal. The main requirements for ***extensive*** roofs are weeding, as well as periodic soil and plant replenishment. More structural and horticultural maintenance is required for ***intensive*** roofs because plantings are typically heavier and more elaborate.

Corrective actions for green roofs are generally localized repairs. Leaks need to be quickly repaired, if they should be detected. An electric leak survey (i.e. Electrical Field Vector Mapping) can be performed to locate leaks in the membrane. More complex green roof systems have monitoring devices installed with the waterproof membrane.
Long periods of drought or loss of soil to high winds may require replacement of growth media or replanting. If drought becomes an issue, corrective actions include installing an irrigation system or scheduling supplemental watering.

Potential LEED Credits

Primary: Sustainable Sites – Credit 7.2 "Landscape & Exterior Design to Reduce Heat Islands" (1 Point)
Sustainable Sites – Credit 6 "Stormwater Management" (1-2 Points)
Water Efficiency – Credit 1 "Water Efficient Landscaping" (1-2 Points)
Other: Innovation & Design Process (1-4 Points)

Links to Additional Information

Natural Resources Defense Council, 2001: Stormwater Strategies: Community Responses to Runoff Pollution.
http://www.nrdc.org/water/pollution/storm/stoinx.asp

Green Roofs for Healthy Cities
http://www.greenroofs.org/

Third Annual Greening Rooftops for Sustainable Communities Conference, Awards, & Trade Show, May 4th - 6th, 2005 - Washington, D.C.
http://www.greenroofs.org/washington/index.php

Resource Portal for Green Roofs
http://www.greenroofs.com/

Performance and Inspection

Soil stability and plant vitality are keys to the function of green roofs. Green roofs should be inspected annually for loss of growth medium due to erosion and to asssure plant health. However, wind or water erosion should not be a major concern because the plants' dense root structures provide stabilization. If any erosion should occur, add soil, replant, and install temporary erosion control fabric. Replace dead plants as needed.

Note: if slow-growing plants are selected, more than a single growing season may be needed to achieve full growth.

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South Whidbey Youth Connection
Whidbey Animals' Improvement Foundation
Langley Chamber
Freeland Chamber
Island County Government
So. Whidbey School Dist.
Sno-Isle Library System
Island County Historical Society
Genealogical Society of South Whidbey island

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Ferry Schedule
Island Transit
Community Transit (Everett)

Local Arts

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THE SOUTH WHIDBEY RECORD

BACK SEND TO A FRIEND FEEDBACK

Langley proposes new rules for homes

By BREEANA LAUGHLIN
Oct 22 2005

The city of Langley is proposing to lessen the impacts of development on the community and environment by adopting "low impact development" rules.

"Low impact development is intended to help local governments, developers and environmentalists reduce the impacts of development on the environment," said city planner Alice Schisel.

Low impact development, or LID, is a storm-water management and land-development strategy that emphasizes the conservation of on-site natural features.

At the last Langley City Council meeting, Schisel said outside planning experts were welcoming Langley's approach toward development. She read a letter from Linda Lyshall, who works for the Puget Sound Action Team, a partnership of state agencies and tribal and local governments. The team is working with local governments across the region to help the measures in place.

Lyshall encouraged the city to move forward with its plans.

"We applaud the planning advisory board's efforts to preserve the aesthetic and ecological values of Langleya, and for their forward thinking on future development," Schisel recounted.

Low impact development works to keep as many natural characteristics in place to soak up storm-water runoff from development, rather than relying solely on drains, pipes and large collection basins. These practices help control storm water by keeping it close to where it originates.

Low-impact measures include preserving trees and other native vegetation, and reducing the amount of hard surfaces being developed on the site being developed.

To launch the new approach, Langley is using the Low Impact Development Technical Guidance Manual. And the city's planning advisory board wants the guidance manual to be folded into the city's code.

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"We will require adherence to low-impact development measures before before more conventional measures can be considered in planning for storm-water management and in constructing roads," Schisel said.

"We have some pretty good codes in place right now," said Rick Hill, director of public works. "This just makes our codes that much stronger."

The low-impact measures will improve environmental controls on the site being developed, and on surrounding sites.

"When developers do studies, they don't just look at their piece of property." Hill said. "They have to look at their property and to areas downstream to it, all the way to the outfall."

Controlling storm-water runoff is one of the great challenges of development.

The state Department of Ecology estimates that one-third of all the polluted waters in the state are polluted by storm-water runoff.

When developers clear forests and put in roads, parking lots, roofs and other hard surfaces, rainfall can no longer soak into the ground.

When storm water runs over roads, parking lots and other hard surfaces, it picks up pollutants along the way and carries many of those substances into streams, wetlands and bays.

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DMLN

Technical Note 116

Housing Density and Urban Land Use as Indicators of Stream Quality

A large number of indicators exist to measure the amount of urbanization in a watershed, and in turn, predict stream quality. Impervious cover has traditionally been the primary indicator of watershed urbanization, but two recent studies from Ohio and Illinois focus on housing density, urban land use, and population density as indicators of urbanization. These studies provide some of the first real data on relationships between urbanization and stream quality in the Midwest.

Midwestern streams have many attributes unique to the area. Most Midwestern streams flow across the gently sloping till and outwash plains created after the last great ice sheets receded from North America 10,000 years ago. Typically, these streams are low gradient, shallowly entrenched, alluvial systems with extensive associated wetlands (McNab and Avers, 1994). In terms of aquatic diversity, the Midwest has historically had the highest diversity of freshwater mussels in North America. Prior to settlement, over 80 species of freshwater mussels were present in the state of Illinois alone (INHS, 1996).

Unfortunately, over half of the remaining mussel species existing in the Midwest are now classified as endangered, threatened, or of special state concern (USFWS, 1998). The formerly extensive wetlands of the Midwest have been reduced by over 80% and intensive agricultural and land development practices have led to the straightening, channelization, and impoundment of many streams. These practices have resulted in high rates of sedimentation and nutrient enrichment in the region's streams and rivers.

Land development pressures are increasing in many Midwestern communities, rendering urbanization an even greater threat to the region's aquatic resources. For example, between 1970 and 1990, the northeastern Illinois area population grew by a modest 4%, yet the amount of land in urban/suburban use grew by more than 33% (NIPC, 1998). This pattern of growth appears to be continuing: Census Bureau estimates indicate that the region's population has grown as much since 1990 as it had in the previous two decades (NIPC, 1998).

Numerous studies have demonstrated a link between increasing urbanization and stream degradation.

Over the past decade, numerous studies have linked increasing urbanization with stream degradation. The research by Chris Yoder and Ed Rankin perhaps best illustrates this relationship. They report, "Few if any, ecologically healthy watersheds exist in the older most extensively urbanized areas of Ohio and no headwater streams (i.e., draining <20 mi^2) sampled by Ohio EPA during the past 18 years in these areas have exhibited full attainment of the Warmwater Habitat (WWH) use designation" (Yoder, 1995; Yoder and Rankin, 1996).

A recent study by Yoder, Dale White, and Bob Miltner (1999) of the Ohio EPA further explored the effects of urbanization on a large number of Ohio streams. This study team utilized bioassessment techniques to link land uses with stream quality in two Ohio ecoregions. Fish, benthic macroinvertebrates, stream habitat and water chemistry were sampled in urban/suburban watersheds in the Cuyahoga River basin in northeastern Ohio and

Table 116.1. Sampling Parameters for the Cuyahoga and Area Streams

Sample Location	Drainage Areas (sq. mi.).	Macro-Invertebrate Samples	Fish Samples	Habitat Assessment	Water Chemistry Samples
Cuyahoga	2 - 700	80	82	82	103
Columbus	<35	0	80	80	0

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smaller subwatersheds in the Columbus metropolitan area of central Ohio. The Cuyahoga watersheds are characterized by extensive development, including a mix of older residential, commercial, and industrial land uses, along with more recent suburban development. The Columbus watersheds are characterized by residential urban land use, much of which has developed within the last two decades. However, a significant difference between the Cuyahoga and Columbus study areas is that many of the sample points in the Cuyahoga drainage were located in larger watersheds that were subjected to significant point source discharges. The smaller subwatersheds of the Columbus study area had far less influence from point source discharges. Table 116.1 summarizes the team's sampling effort.

The researchers chose housing density and urban land use as surrogates of watershed impervious cover. These two indicators were chosen because census data, for calculating housing density, and state land use information, for calculating percent urban land, were readily available. In addition to the effects of urbanization, the study also examined the potential effects of watershed scale and significant other stressors in the urban environment. Table 116.22 lists the predominant stressor types in the Cuyahoga basin.

Results

Data from the Columbus area streams showed a significant decrease in fish assessment scores when watersheds exceeded 33% urban land use, although there was considerable variation above and below this percentage among individual watersheds (Figure 116.1). At this level of urbanization, fish communities displayed a shift in community composition indicated by the loss of intolerant darters and sculpins, a decrease in insectivorous fish, and an increase in the proportion of tolerant species.

Overall, the Cuyahoga basin streams depicted a significant drop in fish index of biotic integrity (IBI) scores at around 8% urban land use (Figure 116.2). This relatively low level of urban land use was related to a significant impact to the biological community primarily because of watershed scale and the presence of other stressors not generally found in the Columbus area streams. The researchers found that when streams with a watershed size of less than 100 mi² were analyzed separately, the level at which fish IBI scores dropped significantly increased to around 15% urban land use (Figure 116.3). Figure 116.4 illustrates this data further broken down by the type of impact. The study showed that sites affected by combined sewer outfalls, significant wastewater treatment plant outfalls, and highly modified habitats (i.e., channelized, impounded) failed to attain their appropriate biocriteria regardless of the degree of urbanization.

Figure 116.1: Index of Biotic Integrity Scores Vs. Urban Land Use (quartiles) for All Columbus Area Samples

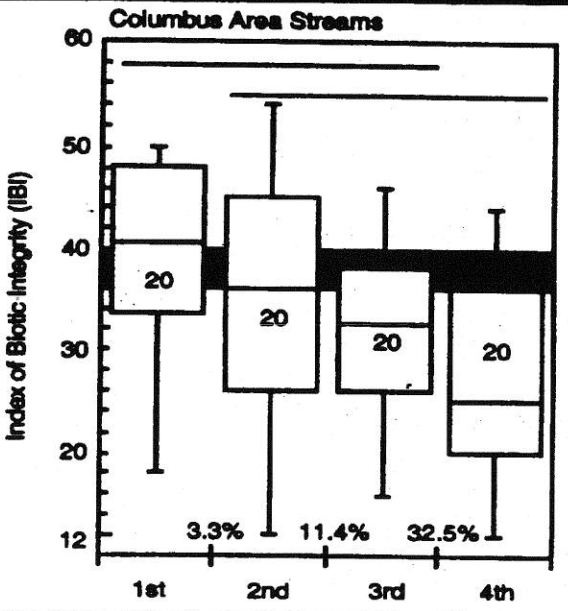

Figure 116.2: Index of Biotic Integrity Scores Vs. Urban Land Use (quartiles) for All Sites in the Cuyahoga Basin

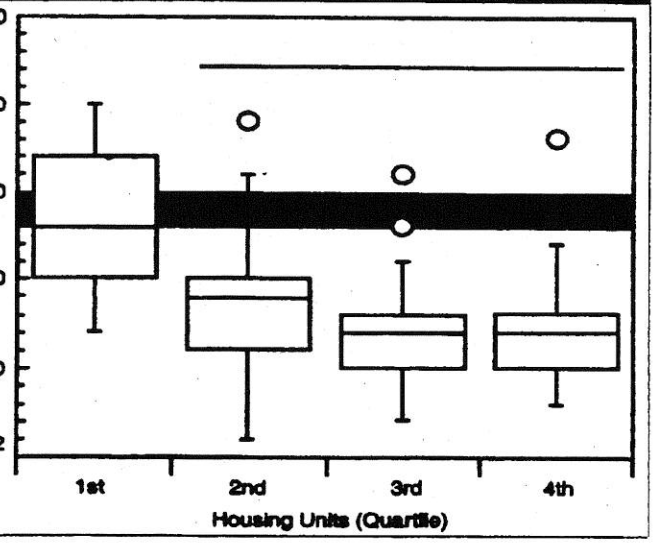

Table 116.2: Predominant Impact Types in the Cuyahoga Basin

Least impacted - large lot residential areas with significant open space
Gross in stream habitat alteration - gross channel modifications and/or impoundments
Combined sewer overflow discharges (CSOs)
Wastewater treatment plant discharges
Wastewater treatment plant discharges w/CSOs
Urbanization

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Housing density was also strongly linked to stream quality, but with somewhat differing results (Figure 116.5). While urban land use depicted a more or less continuous decline in stream quality with increasing urbanization, housing density displayed a threshold response coinciding with approximately one housing unit per acre, above which sites generally failed to attain their appropriate biological criteria.

Similar results were obtained in a study undertaken by Dennis Dreher (1997) of the Northeastern Illinois Planning Commission (NIPC). Dreher's study utilized a similar bioassessment approach with the main difference between the two studies being the choice of urbanization indicator. The Illinois study utilized population density as an indicator of urbanization, rather than housing density or urban land use.

The six-county Northeastern Illinois study area (Cook, DuPage, Kane, Lake, McHenry, and Will counties) includes the extensively urbanized Chicago metropolitan area and its adjacent suburbs, as well as large areas of outlying rural/agricultural land. Even though discharges from point sources and combined sewer overflows in this region have been reduced dramatically over the past 20 years, many of this region's waterways remain seriously impaired.

In this study, population density was chosen as the urbanization indicator for several reasons, the most notable being the difficulty in accurately quantifying the impervious cover in a large number of watersheds on a regional scale. In contrast, digital population data was readily available for the region and could be utilized with existing GIS resources. In addition, the author felt that local land use planners and government officials readily understand population density, perhaps more so than impervious cover.

Dreher found a strong correlation ($r^2 = 0.77$) between population density and fish community assessments for the Northeastern Illinois region (Figure 116.6). The majority of the streams assessed in urban/suburban watersheds with population densities of 1.5 to 8.0+ people per acre had community assessment scores in the fair to poor range, indicative of significant degradation. In contrast, nearly all the rural/agricultural streams (0.05 to 0.5 people/acre) had assessments scoring in the good or better range However, only two of the 13 rural/agricultural streams studied scored in the excellent range. The study also found that most "suburbanizing" watersheds in the range of 0.5 to 1.5 people per acre scored in the fair to good range. With substantial additional development still occurring, these watersheds are at risk of significant further degradation.

Conclusions

Both the Dreher study and the Yoder *et al.* study demonstrate that there is a strong negative relationship between increasing urbanization and stream quality in the Midwest and that bioassessment can play an important role in assessing and managing urban streams. As both studies used similar biological assessment methodologies, the efficiency and utility of the different urbanization indicators can be compared to determine which provides the best predictor of stream quality over a wide range of land use intensities and watershed scales. And indeed, all three indicators appear to pro-

Table 116.3: Comparison of Different Land Use Indicators and Their Applicability to Local Watershed Planning

Land use indicator	Typical value for low density residential use	Level at which significant impact observed	Advantage	Disadvantage	Appropriate scale	Utility for Local Watershed Planning
% Impervious Cover	10%	10-20%	Most accurate	Highest level of effort and cost	Sub-watershed or watershed	High
Housing Density	1 units/acre	>1 unit/acre	Low accuracy in areas of substantial commercial or industrial development, Moderately accurate at larger scales	Less accurate at smaller scales	Watershed or larger	Moderate
Population Density	2.5 people/acre	1.5 to 8+ people/acre	Low accuracy in areas of substantial commercial or industrial development, Moderately accurate at larger scales	Less accurate at smaller scales	Watershed or larger	Moderate
% Urban Land Use	10-100%	33% (variable)	Moderately accurate at larger scales	Does not measure intensity of urbanization	Watershed or larger	Low

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vide useful information. Population density and percentage of urban land use were found to depict a continuous negative response to urbanization. Housing density, on the other hand, depicted a threshold response to urbanization. This may indicate that housing density's utility for predicting stream quality at intermediate levels of urbanization is limited. However, additional investigation will be needed in this area.

Both studies appear to have derived similar conclusions regarding the level at which significant stream degradation occurs. In analyzing their results, Yoder and his colleagues identified a threshold at one housing unit per acre, beyond which fish and macroinvertebrate assessments increasingly fail to attain their appropriate biological criteria. Assuming that one unit per acre would represent a suburban medium to low density development (single-family detached homes), then 2.5 people per acre would be a reasonable estimate of population density (ULI, 1997). This would coincide with Dreher's category of 1.5 to 8+ people per acre, at which streams typically scored in the fair to poor range. Based upon the results of these studies, it appears that there is agreement between these two indicators of urbanization, at least in terms of a threshold for use attainment. However, population density may be a more useful tool for predicting stream quality due to its more continuous negative response to increasing urbanization.

Urban land cover was also found to be a good predictor of stream quality, but other factors such as historic development patterns, the level of direct channel alteration, and the array of land uses included as urban land may limit the precision of this indicator.

Figure 116.3: Index of Biotic Integrity Scores Vs. Urban Land Use (quartiles) for All Samples With Drainage Areas <100 mi² in the Cuyahoga Basin

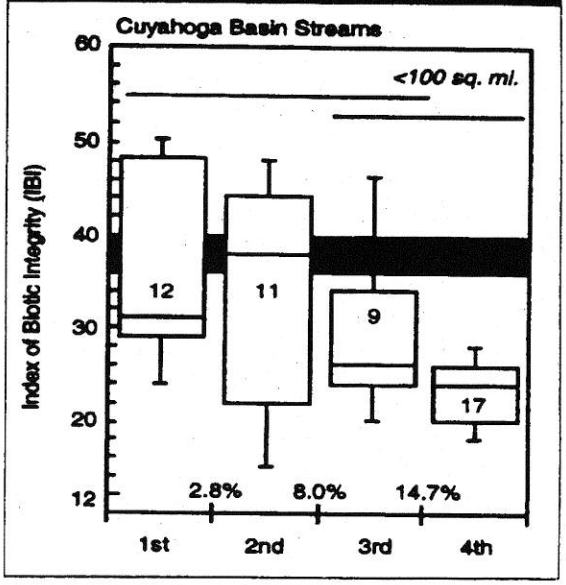

Figure 116.4: Index of Biotic Integrity Scores Vs. Percent Urban Land Use (quartiles) for Cuyahoga Streams With Drainage Areas <100 mi² by Stressor Groups

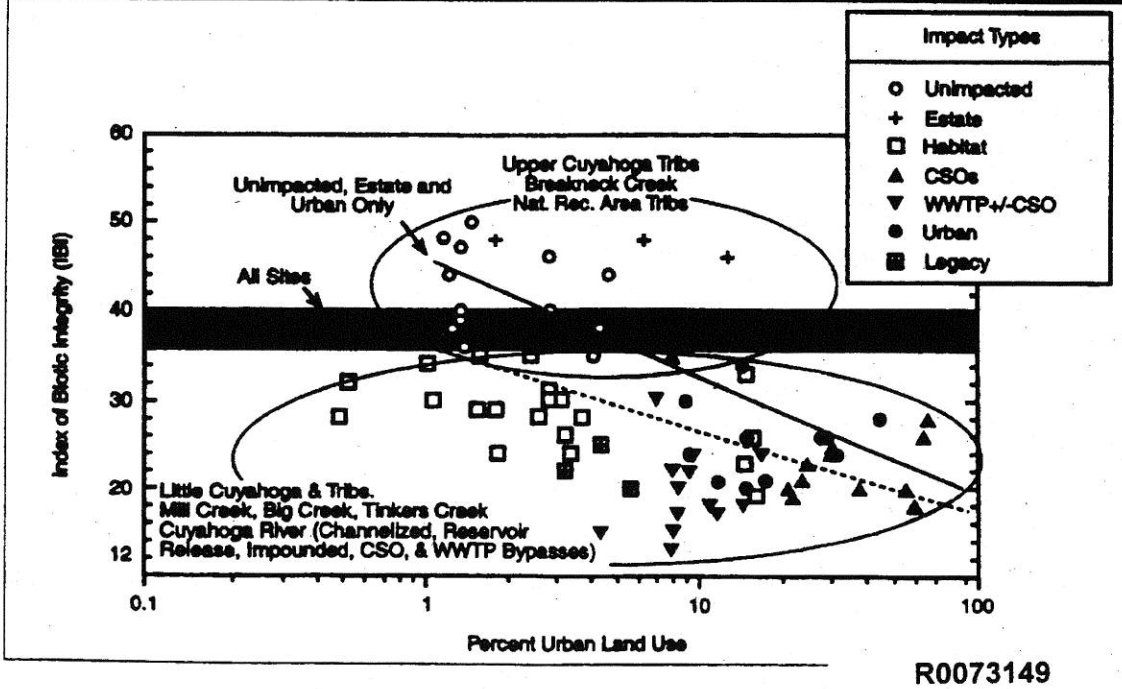

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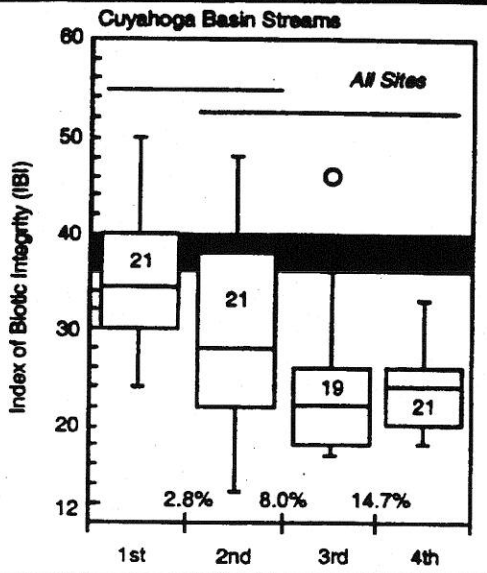
Figure 116.5: Index of Biotic Integrity Scores Vs. Housing Density (quartiles) for All Sites in the Cuyahoga Basin



The Dreher study and the Yoder *et al.* study, as well as others, have demonstrated a clear negative relationship between increasing urbanization and stream quality. However, most assessments of this type to date have been conducted on large regional scales. Robert Steedman of the University of Toronto (1988) found that watershed scale played a significant role in the ability of the urban land use indicator to predict stream degradation. He found that large watersheds, with an average size of 112 mi^2, had poor land use/stream quality correlations (r^2=.11) when compared to small watersheds with an average watershed size of just 6.5 mi^2 (r^2=.78). This would appear to reinforce the idea that watershed scale is an important factor in assessing the utility of indicators of urbanization. As land use decisions are generally made at the local level, land use planners need tools that are applicable to smaller scale local planning areas. More work is still needed in identifying and applying these indicators at smaller scales to determine their practical usefulness in local watershed planning and management. Table 116.3 summarizes some of the advantages and disadvantages of several indicators of urbanization.

Overall, the results of these two Midwestern studies reflect the substantial impacts conventional land use practices have had on the biological integrity of rivers and streams, and may be used to forecast future quality if conventional practices continue. This does not bode well for our streams and rivers, as development pressures continue to grow in many Midwestern communities. However, these relationships may not predict the future quality of our streams and rivers if watershed planning and management practices are implemented to control both point and non-point source pollution. But the authors caution that planning and management decisions should not be based upon a single indicator of urbanization, without considering significant other physical and chemical stressors (i.e., historic alteration, CSO's, failing septic systems, etc.) that may be acting on the system. - ***KBB***

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3	Chralowicz, D., *et al.*	Infiltration of Urban Stormwater Runoff to Recharge Groundwater Used for Drinking Water: A Study of the San Fernando Valley, California	6/01	www.bren.ucsb.edu/research/FinalDocs/2001/Stormwater-Final.pdf
4	Devinny, J.S., *et al* .	Alternative Approaches to Stormwater Quality Control	06/04	http://www.usc.edu/dept/geography/ESPE/documents/publication_stormwater.pdf
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January 7, 2005

California Smart Growth Advocate Receives National Planning Award

WASHINGTON, DC — While hers is not a household name, Judy Corbett's efforts to create safer, healthier and more livable communities have affected innumerable households throughout California and the nation. For nearly three decades, Corbett has promoted both resource-efficient land use and building design, and energy conservation in her quest to shape vibrant communities.

For her efforts, Judy Corbett has been selected the 2005 recipient of the American Planning Association's (APA) National Planning Award for Distinguished Leadership by a Citizen Planner. Corbett will be honored at a luncheon ceremony March 22 at the Moscone West convention center in San Francisco. In addition, a special 30-minute video about all of APA's 2005 National Planning Awards recipients will be shown at the luncheon. Accomplishments of the awardees also will be highlighted in the March 2005 issue of *Planning* magazine.

Corbett's Local Government Commission (LGC) is an institution that exists nowhere else in the country. It has successfully brought together politicians of all parties and ideologies for the sole purpose of solving global problems at the local level.

"As its founder and executive director, Ms. Corbett has built the Local Government Commission into a groundbreaking organization that fuels innovation in communities throughout California," said APA Awards Committee Co-Chair Bruce Knight, FAICP. "Although not a planner by training, Ms. Corbett has embraced and advanced planning concepts, carrying the planning message to municipalities both large and small."

"Ms. Corbett's work pushes the limits of current practice and challenges all of us to consider community viability in new and different ways," said APA Awards Committee Co-Chair Carol Rhea, AICP. "Her innovative approaches will continue to shape planning practice and community livability for years to come."

The LGC may be best known for its 1991 development of the "Ahwahnee Principles for Resource Efficient Communities." This set of 19 guidelines helped pave the way for the Smart Growth movement, which encourages cities and counties to adopt policies and plans that discourage sprawling development patterns. To encourage local government to adopt and implement the principles, the LGC established the Center for Livable Communities.

At least 200 California communities, and several other states, have incorporated the principles into their planning documents.

In 1998, the LGC drafted the "Ahwahnee Principles for Smart Economic Development," an innovative model that, among other things, recognized the economic value of natural and human capital, and embraced economic, social and environmental responsibility. The following year Corbett was named a "Hero for the Planet" by *Time* magazine.

Since developing its first set of Ahwahnee principles, LGC has drafted the "Ahwahnee Principles for Water," which will encourage local elected officials to develop greater self-sufficiency in community water resources.

In 2002, Corbett began producing an annual "New Partners for Smart Growth Conference," in partnership with the APA, the Urban Land Institute, EPA, and many others. This pioneering, national event took the smart growth and livable communities movement a step further by approaching the design of the urban environment from the perspective of public health and safety. More recent conferences have added new partners including seniors, youth, labor, air and water quality professionals. The 2005 conference will be held in Miami Beach, Florida, in January.

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Corbett's interest in sustainability dates back to 1974 while a graduate student in ecology at the University of California at Davis. At that time Corbett and her partner Michael Corbett planned and developed the 60-acre Village Homes, a resource-efficient neighborhood in Davis, California.

Village Homes combined residential, commercial and agricultural elements in what was, at the time, an unprecedented mix. The houses themselves used the latest in solar-heating technology and were built in clusters with backyards oriented towards large common areas. Green space and community gardens were maintained through water collected by natural drainage, with excess water flowing into ditches and ponds instead of concrete storm sewers. Corbett has authored several books describing the project including "Sustainable Development: Learning from Village Homes" and "Village Homes: Solar House Designs."

The APA National Awards for Planning are part of a proud tradition established more than 50 years ago. The awards program, which recognizes outstanding community plans, planning programs and initiatives, public education efforts and individuals for their leadership on planning issues, attracted more than 130 entries nationwide this year.

Contact
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California Environmental Protection Agency

STATE WATER RESOURCES CONTROL BOARD

Low Impact Development - Sustainable Storm Water Management

On January 20, 2005, the State Water Resources Control Board adopted sustainability as a core value for all California Water Boards' activities and programs, and directed California Water Boards' staff to consider sustainability in all future policies, guidelines, and regulatory actions.

Low Impact Development (LID) is a sustainable practice that benefits water supply and contributes to water quality protection. Unlike traditional stormwater management, which collects and conveys storm water runoff through storm drains, pipes, or other conveyances to a centralized storm water facility, LID takes a different approach by using site design and storm water management to maintain the site's pre-development runoff rates and volumes. The goal of LID is to mimic a site's predevelopment hydrology by using design techniques that infiltrate, filter, store, evaporate, and detain runoff close to the source of rainfall. LID has been a proven approach in other parts of the country and is seen in California as an alternative to conventional storm water management. The Water Boards are advancing LID in California in various ways:

- Regulation through site-specific and general permits;
- Providing advocacy and outreach to local governments through the Water Board's Training Academy and regional workshops;
- Researching how to incorporate LID language in to Standard Urban Storm Water Mitigation Plan (SUSMP) requirements;
- Funding LID related projects through the consolidated grants program; and
- Funding through CWA 319 funds to provide for further researching applicability of Impervious Surface Analysis Tool (ISAT) for land use planners and for the California Water and Land Use partnership (CaWaLUP) Center at U.C. Davis.

The Water Boards are key partners of the CaWaLUP, a collaborative effort made up of representative staff from government agencies, non profits, and academia, which aims to improve how water resource implications of land use are considered in California's local government decisions. For more information please go to http://cawalup.usc.edu/.

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SARB_004241

UNIVERSITY OF CALIFORNIA

Santa Barbara

Infiltration of Urban Stormwater Runoff to Recharge Groundwater Used for Drinking Water: A Study of the San Fernando Valley, California

A Group Project submitted in partial satisfaction of the requirements for the degree

of

Master of Environmental Science and Management

by

Donna Chralowicz

Alvaro Dominguez

Tessa Goff

Melissa Mascali

Emily Taylor

Committee in charge:

Professor Thomas Dunne

Professor Charles Kolstad

June 2001

Infiltration of Urban Stormwater Runoff to Recharge Groundwater Used for Drinking Water: A Study of the San Fernando Valley, California

As authors of this Group Project report, we are proud to archive it in Davidson Library so that the results of our research are available for all to read. Our signatures on the document signify our joint responsibility to fulfill the archiving standards set by Graduate Division, Davidson Library, and the Donald Bren School of Environmental Science and Management.

_____
Donna Chralowicz

_____
Alvaro Dominguez

_____
Tessa Goff

_____
Melissa Mascali

_____
Emily Taylor

The mission of the Donald Bren School of Environmental Science and Management is to produce professionals with unrivaled training in environmental science and management who will devote their unique skills to the diagnosis, assessment, mitigation, prevention, and remedy of the environmental problems of today and the future. A guiding principal of the School is that the analysis of environmental problems requires quantitative training in more than one discipline and an awareness of the physical, biological, social, political, and economic consequences that arise from scientific or technological decisions.

The Group Project is required of all students in the Master of Environmental Science and Management (MESM) Program. It is a three-quarter activity in which small groups of students conduct focused, interdisciplinary research on the scientific, management, and policy dimensions of a specific environmental issue. This Final Group Project Report is authored by MESM students and has been reviewed and approved by:

_____
Professor Thomas Dunne

_____
Professor Charles Kolstad

_____
Dean Dennis Aigner

May 2001

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Mr. Mark Mackowski, Assistant Watermaster, Upper Los Angeles River Area

Ms. Dorothy Green, Los Angeles and San Gabriel Rivers Watershed Council

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ABSTRACT

Our study explored the use of infiltration basins that capture urban stormwater runoff as a means of increasing the reliability of local groundwater resources used for drinking water in the San Fernando Valley of Los Angeles County. We first determined the volume of runoff that could be captured by infiltration basins using a calculation based on empirical studies. Model-based predictions were then used to evaluate the depth of soil necessary to sufficiently reduce stormwater contaminants in three different soil types. Finally, we analyzed the cost-effectiveness of this management option by comparing costs of infiltration basins with the value of recharged groundwater, equivalent to the value of the marginal source of drinking water.

We found that infiltration basins with a surface area of 0.1 acre or 0.5 acre with a depth of two feet or three feet, located in a five-acre drainage area, could capture a volume of stormwater runoff ranging from 0.90 to 1.87 acre-feet per year. Our results indicated that smaller basins are more efficient at capturing runoff than larger basins. Given depths to groundwater ranging between 66 feet and 361 feet, depending on soil type, there was no contamination of groundwater from infiltrated stormwater containing the contaminants that we considered.

However, we determined that infiltration basins are not a cost-effective method of increasing drinking water supplies, as the costs of constructing and maintaining an infiltration basin far exceed the value of the drinking water that it provides. Our cost-effectiveness analysis focused on the value of stormwater infiltration solely as a method of augmenting drinking water supplies. The inclusion of benefits of infiltration as a stormwater management strategy may make this method cost-effective.

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LIST OF ACRONYMS

ARAR	Applicable or Relevant and Appropriate Requirement
BMP	Best Management Practice
BTEX	Benzene, toluene, ethylbenzene, and xylene
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CWA	Clean Water Act
CWC	California Water Code
DHS	California Department of Health Services
DWR	California Department of Water Resources
EMC	Event Mean Concentration
EPA	United States Environmental Protection Agency
FIFRA	Federal Insecticide, Fungicide, and Rodenticide Act
LAA	Los Angeles Aqueduct
LACDPW	Los Angeles County Department of Public Works
LADWP	Los Angeles Department of Water and Power
LARWQCB	Los Angeles Regional Water Quality Control Board
MCL	Maximum Contaminant Level
MCLG	Maximum Contaminant Level Goal
MWD	Metropolitan Water District of Southern California
NPDES	National Pollutant Discharge Elimination System
NURP	Nationwide Urban Runoff Program
PAH	Polynuclear Aromatic Hydrocarbon
PRG	Preliminary Remediation Goal
RCRA	Resource Conservation and Recovery Act
SDWA	Safe Drinking Water Act
SUSMP	Standard Urban Stormwater Mitigation Plan
SWP	State Water Project
SWRCB	State Water Resources Control Board
TKN	Total Kjeldahl Nitrogen
TMDL	Total Maximum Daily Load
TSCA	Toxic Substances Control Act
ULARA	Upper Los Angeles River Area
USDA	United States Department of Agriculture

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INTRODUCTION

The City of Los Angeles has a large population and is located in a semi-arid region with a small amount of annual rainfall. As such, it is without an adequate local source of drinking water. To support its massive growth over the last hundred years, the City of Los Angeles has imported most of its water from the Owens Valley in northern California. The City also buys a small amount from the Metropolitan Water District, which imports water from the Colorado River and the Central Valley. Only 15% of the City's water supply comes from a local source, which is groundwater. The aquifer from which the majority of drinking water is extracted is the San Fernando Groundwater Basin, located in the San Fernando Valley of Los Angeles. Due to political and environmental constraints, imported sources may be inadequate to meet future demand, which is projected to increase by 20% by the year 2020. Enhancing existing groundwater aquifers in Los Angeles would reduce the city's dependence on imported water by allowing more water to come from a local source.

Groundwater is naturally recharged when rain infiltrates the ground and percolates downward. However, the impervious surfaces that cover most of Los Angeles have impeded the infiltration of stormwater and the subsequent recharge of aquifers. Stormwater that does not infiltrate the ground becomes runoff and is usually conveyed to storm drains and then to streams and oceans. As the stormwater moves along the ground, it picks up contaminants that may have negative ecological impacts on aquatic systems. Contaminated stormwater runoff poses a problem because of increasingly strict stormwater quality regulations and the high costs of treatment. One alternative to conveying runoff to storm drains is to divert it to a constructed stormwater infiltration basin, where it can infiltrate, be treated through natural soil processes, and recharge groundwater.

Due to the high demand for drinking water in Los Angeles, the option to use stormwater runoff to recharge groundwater used for drinking water is particularly appealing and could potentially solve two problems: those of contaminated stormwater and inadequate local water supplies. However, there is the possibility that the contaminants in stormwater runoff could adversely affect groundwater if not properly treated by the soil. Soil is generally considered to have the ability to remove contaminants from water, but the appropriateness of this management option depends on both stormwater and site characteristics. Therefore, it is necessary to identify the constraints surrounding this process to ensure that groundwater supplies are not contaminated.

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We approached our study of diverting stormwater runoff to an infiltration basin to recharge groundwater used for drinking water by asking three questions:

- What volume of stormwater could be captured by infiltration basins?
- What depth to groundwater is necessary to sufficiently reduce contaminant concentrations as stormwater infiltrates the soil?
- Are infiltration basins a cost-effective method of recharging groundwater used for drinking water?

Our report begins by describing the San Fernando Valley of Los Angeles County and discussing the groundwater basins, soils, land use distribution, and climate of this area. We present the demand for drinking water in the Los Angeles region and the sources of drinking water used to meet demand, including local groundwater. We discuss federal regulation of groundwater as well as groundwater management in California and groundwater rights in Los Angeles. We then discuss the generation of stormwater runoff and explain the typical contaminants that it contains. We also clarify the concept of an infiltration basin and describe current infiltration systems implemented in Los Angeles County.

Next, we explain our calculation of the volume of stormwater runoff that can be captured in infiltration basins of varying sizes. Depending on the infiltration rate of the soil upon which the basin is placed, and assuming that runoff is generated from a five-acre drainage area, a basin with a surface area of 0.1 acre and a depth of two feet can capture from 0.90 to 0.96 acre-feet of stormwater runoff; a basin with a surface area of 0.1 acre and a depth of three feet can capture from 1.10 to 1.18 acre-feet; a basin with a surface area of 0.5 acre and a depth of two feet can capture from 1.71 to 1.87 acre-feet; and a basin with a surface area of 0.5 acre and a depth of three feet can capture 1.87 acre-feet.

We then put forward the proportion of typical concentrations of contaminants removed as stormwater infiltrates three different soil types: silty clay loam, sandy loam, and clay loam. Based on these proportions, we conclude that, in order to meet the Maximum Contaminant Levels set for drinking water, depths to groundwater of 66 feet, 361 feet, and 131 feet in these three soil types, respectively, are required in order for the contaminant concentrations to be adequately reduced while infiltrating the soil.

Finally, we present the cost-effectiveness of stormwater infiltration basins constructed to recharge groundwater used for drinking water. We compare the costs of infiltration basins to the value of the marginal source of drinking water, provided by the Metropolitan Water District to the City of Los Angeles, and conclude that

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infiltration basins are not a cost-effective method of increasing drinking water supplies.

The results of our study will be presented to the Los Angeles and San Gabriel Rivers Watershed Council, a stakeholder group whose mission is to preserve, restore, and enhance the beneficial uses of the two watersheds for which it is named. The Watershed Council, in conjunction with the United States Bureau of Reclamation, will utilize our results as preliminary findings for a five-year study of groundwater recharge by stormwater runoff.

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BACKGROUND

AREA OF STUDY

The San Fernando Groundwater Basin in the San Fernando Valley of Los Angeles County was chosen as our area of study because it is a significant source of drinking water for the City of Los Angeles and the largest aquifer in the Los Angeles region.

THE CITY OF LOS ANGELES AND THE SAN FERNANDO VALLEY

With approximately 3.8 million people in its 465-square mile area, the City of Los Angeles is one of the most populous urban regions in the United States. The San Fernando Valley is located in the center of the City of Los Angeles. The Valley and its surrounding hills and mountains make up the Upper Los Angeles River Area (ULARA), which constitutes the entire watershed for the Los Angeles River (Blomquist, 1992). The ULARA is bordered on the north and northwest by the Santa Susana Mountains; on the north and northeast by the San Gabriel Mountains; on the east by the Verdugo Mountains; on the west by the Simi Hills; and on the south by the Santa Monica Mountains.

The ULARA is located almost entirely within Los Angeles County; the Los Angeles-Ventura County line runs through the far western hills of the watershed (see Figure 1). The region encompasses 328,500 acres (513 square miles), consisting of 122,800 acres (192 square miles) of valley fill (i.e., groundwater basins) and 205,700 acres (321 square miles) of hills and mountains. Cities and communities within this watershed include Hidden Hills, Calabasas, San Fernando, Universal City, Burbank, Glendale, La Crescenta, and La Canada-Flintridge (see Figure 2).

GROUNDWATER BASINS IN THE SAN FERNANDO VALLEY

Approximately 90% of groundwater extracted in Los Angeles comes from the ULARA, while the remainder comes from the Central and West[1] Basins, both of which are outside the ULARA. Four distinct groundwater basins make up the ULARA – the San Fernando, Sylmar, Verdugo, and Eagle Rock Groundwater Basins (see Figure 3). The City has groundwater extraction rights in all of these basins except Verdugo Basin. The San Fernando Groundwater Basin is the largest in the ULARA and supplies most of the City's groundwater. The Eagle Rock Basin is the smallest and, as it has no significant native yield, is not used by the City for groundwater supply. These groundwater basins are replenished by the infiltration of

[1] Also referred to as West Coast Basin.

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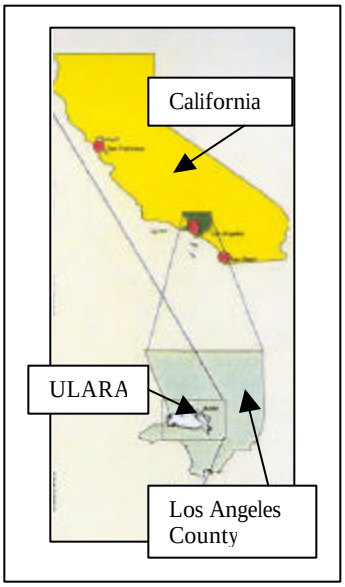
Figure 1: Location of ULARA Within Los Angeles County and California



Source: ULARA Watermaster, 2000.

rainfall, stormwater runoff, and water used within the basin (e.g., for irrigation) (ULARA Watermaster, 2000).

The San Fernando Groundwater Basin is 112,000 acres (175 square miles) in size, making up about 91% of the total valley fill. Its total capacity is estimated at 3.2 million acre-feet (AF)[2] (Blomquist, 1992). The San Fernando Groundwater Basin is bounded on the east and northeast by the San Rafael Hills, Verdugo Mountains, and San Gabriel Mountains; on the north by the San Gabriel Mountains and the eroded south limb of the Little Tujunga Syncline, which separates it from the Sylmar basin; on the northwest and west by the Santa Susana Mountains and Simi Hills; and on the south by the Santa Monica Mountains. The Los Angeles River emerges from the Los Angeles Narrows at the eastern end of the San Fernando Valley, fueled partly by groundwater flowing from east to west in the San Fernando Groundwater Basin (see Figure 4).

[2] In water resources planning and management, measurements of water are given in units of acre-feet. By definition, one acre-foot is the amount of water that would cover an acre of land to a depth of one foot, which equals 326,000 gallons. An acre-foot of water is about enough to supply one to two typical Southern California families with water to use in and around their homes for a year (LADWP, 2000).

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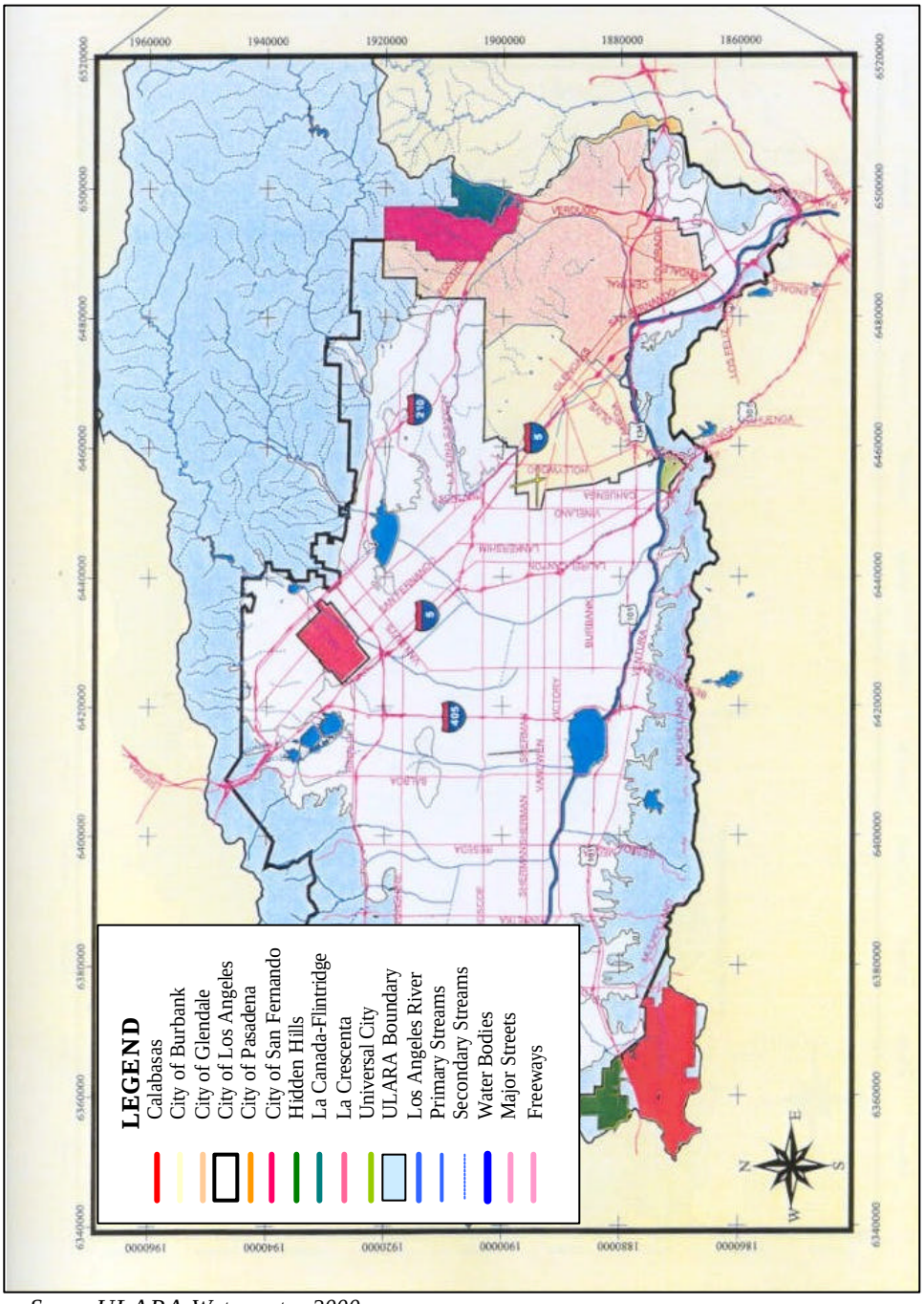
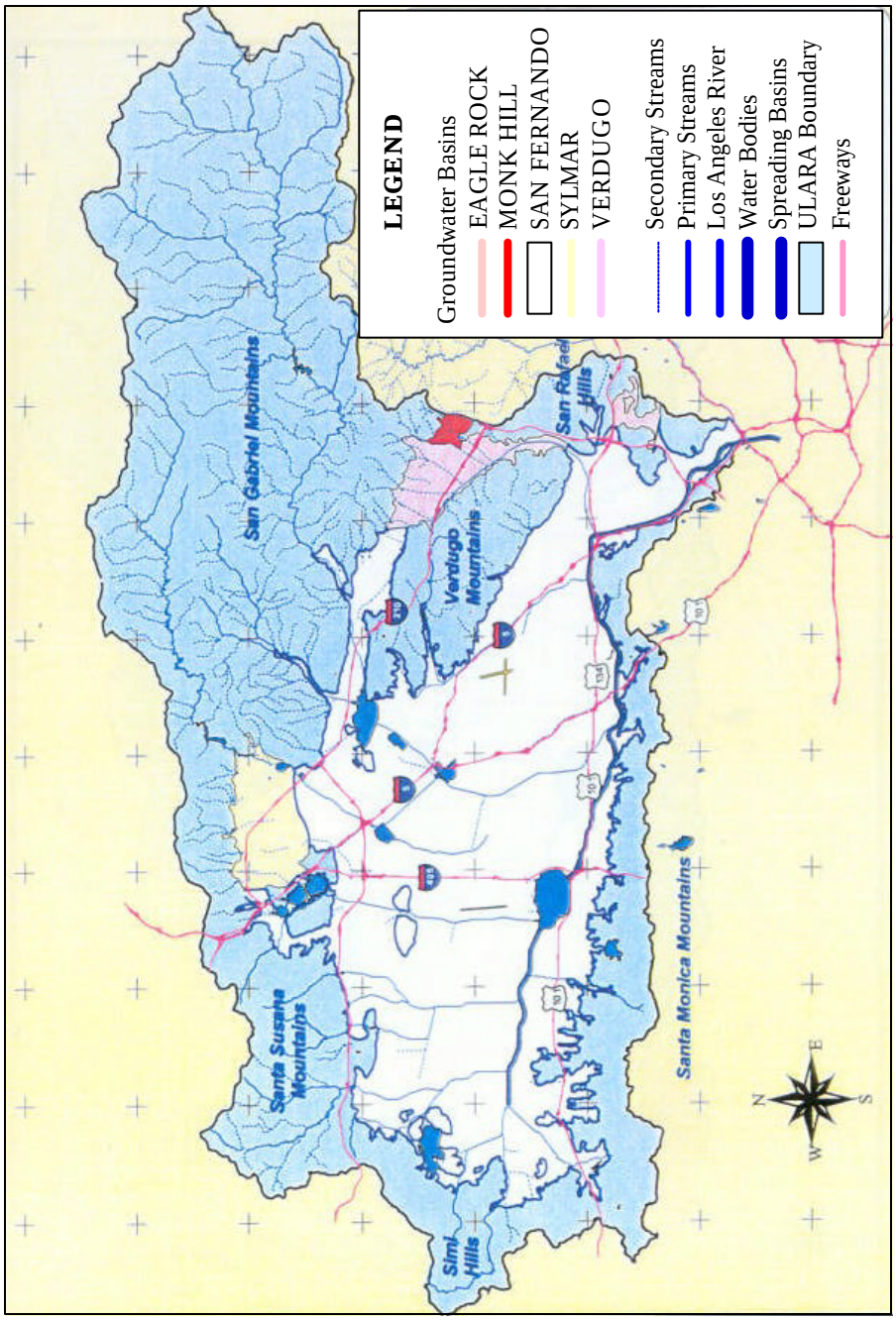
Figure 2: Cities in the ULARA Region



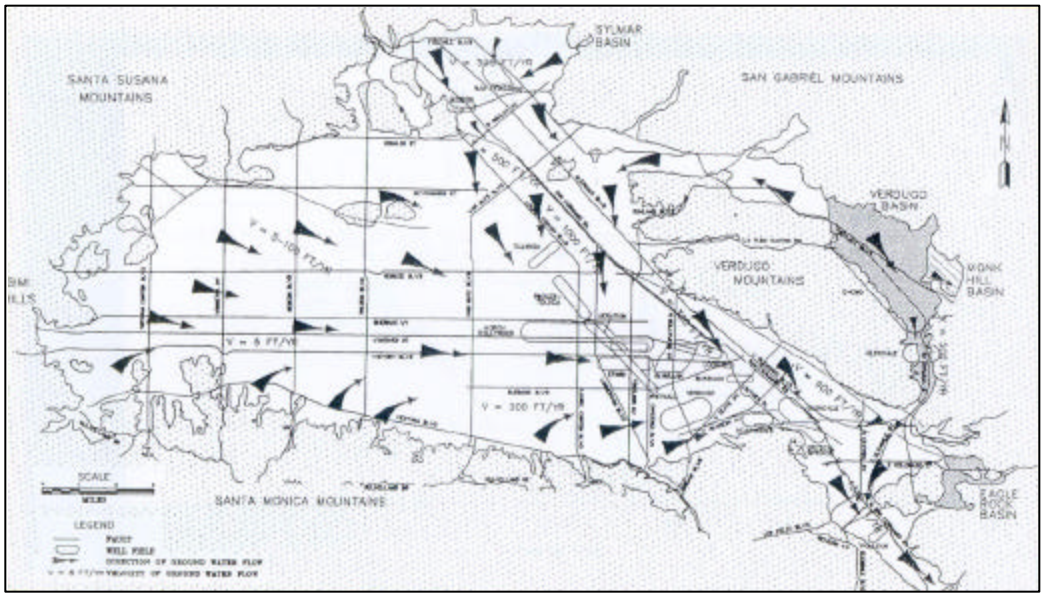
Source: ULARA Watermaster, 2000.

Figure 3: Groundwater Basins in the ULARA Region



Source: ULARA Watermaster, 2000.

Figure 4: Direction of Groundwater Flow in The ULARA

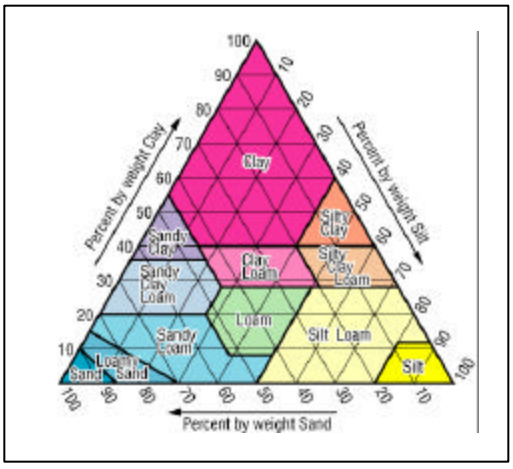


Source: ULARA Watermaster, 2000.

SOILS IN THE SAN FERNANDO VALLEY

There are nine major soil types in the San Fernando Valley. Soils are described by their texture, which is classified according to percent composition by weight of clay, sand, and loam. The United States Department of Agriculture (USDA) has developed a soil texture triangle that can be used to classify soil type (see Figure 5).

Figure 5: USDA Soil Texture Triangle



Source: Earth System Science Center, 1999.

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Three types of soils predominate the western San Fernando Valley: San Emigdio-Capistrano (sandy loam), Mocho-Conejo (clay loam), and Balcam-Xerorthents (silty clay loam), making up 21%, 23%, and 29%, respectively, of the soils in the western valley (See Table 1) (USDASCS, 1980). We focused on the western San Fernando Valley because groundwater in the San Fernando Basin flows from west to east. Therefore, water that infiltrates in the western valley has a longer residence time in the basin, providing a longer time period during which it can be extracted for drinking water. In addition, the city of interest – Los Angeles – is located in the western half of the San Fernando Valley, while the Cities of Glendale and Burbank are in the east.

Table 1: Soils in the Western San Fernando Valley Area

Soil Group	Soil Type	Proportion of Survey Area
Soils on alluvial plains, alluvial fans, and terraces		
Chualar	Sandy loam	5%
Cropley	Clay	4%
Mocho-Conejo	Loam and clay loam	23%
San Emigdio-Capistrano	Fine sandy loam and sandy loam	21%
Soboba-Tujunga	Sand and gravelly loamy sand	2%
Soils on foothills and mountains		
Balcom-Xerorthents	Silty clay loam	29%
Friant-Vista	Sandy loam	3%
Gaviota-Rock outcrop	Sandy loam	6%
Saugus-Soper-Millsholm	Loam and gravelly sandy loam	7%

Source: Derived from USDASCS, 1980

The San Emigdio-Capistrano soil group, or sandy loam soil type, is found throughout the San Fernando Valley and in narrow valleys that extend into the foothills. The soils were created in moderately coarse textured alluvium derived from sedimentary and granitic rock. This group covers 21% of the West San Fernando Valley Area. San Emigdio soils are well drained and consist of stratified sandy loam, coarse sandy loam, and loamy sand. Capistrano soils are well drained and consist of fine sandy loam (USDASCS, 1980).

The Mocho-Conejo soil group, or clay loam soil type, is found on alluvial fans and plains throughout the San Fernando Valley and on fans in small valleys that extend into the foothills. The soils formed in medium textured and moderately fine textured, recent alluvium derived mainly from sedimentary rock. This group covers 23% of the West San Fernando Valley Area. Mocho soils are well drained and consist mainly of loam. Conejo soils are well drained and consist of clay loam (USDASCS, 1980).

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The Balcom-Xerorthents soil group, or silty clay loam soil type, is found near the Santa Monica Mountains, Simi Hills, and Santa Susana Mountains. The soils formed in residuum from shale and sandstone. This group covers 29% of the West San Fernando Valley Area. Balcom soils, which make up the majority of this soil group, are well drained and consist of calcareous clay loam and silty clay loam. Xerorthents, which make up a much smaller portion of this soil ground, are disturbed soils that result from excavating, cutting, and filling operations, and properties vary (USDASCS, 1980).

LAND USE DISTRIBUTION

The chief land use in the ULARA is urban or built-up land, although rangeland is a close second (see Table 2). Most of the urban or built-up land occurs in the western half of the region, which is the San Fernando Valley itself, while range land and forest land, the third most prevalent land use, occur in the eastern half, which is mountainous (see Figure 6).

Table 2: Land Use Distribution in ULARA

Land Use	Area (acres)	Percentage of ULARA
Urban or Built-up Land	143,349	44%
Range Land	140,478	43%
Forest Land	30,773	9%
Agricultural Land	6,402	2%
Barren Land	5,732	2%
Water	459	--
Wetland	228	--
Unclassified	4	--
Total	327,425	--

Source: EPA, 1999a.

The urban or built-up land use category can be further broken down into residential, commercial, and other urban uses. Of these, residential use is the most prevalent, constituting over two-thirds of the urban or built-up land use category (see Table 3).

CLIMATE OF THE LOS ANGELES REGION

The Los Angeles region is characterized by a Mediterranean climate; summer months are usually dry with little or no rainfall, and most of the precipitation occurs between the months of November and April. Average annual precipitation is typically around 15 inches, although it varies from six inches in dry years to 24 inches in wet years. Droughts are common. In the coastal areas of Los Angeles,

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Table 3: Type of Urban or Built-Up Land in ULARA

Type of Urban or Built-up Land Use	Area (acres)	Percentage of Urban or Built-up Land Use Category
Residential	98,911	69%
Commercial	18,635	13%
Urban	25,803	18%
Total	143,349	100%

Source: EPA, 1999a.

temperatures are generally moderate, with warm days and cool nights. In the inland valleys, temperatures fluctuate between greater extremes, as winds from the desert in the late summer often cause temperatures to rise to over 100 degrees Fahrenheit.

DEMAND FOR AND SUPPLY OF DRINKING WATER

The average per capita consumption of water by Los Angeles residents is 135 gallons per day (LADWP, 1996), with annual water consumption in the City equaling about 660,000 AF (LADWP, 2000). The City's population is estimated to reach more than 4.8 million by the year 2020. By that time, water demand is projected to grow to between 750,000 to 800,000 AF per year, a 20% increase over present demand (LADWP, 2000). The Metropolitan Water District of Southern California (MWD) predicts that current water supplies imported to southern California will be sufficient to meet demand only for the next ten to fifteen years. Beyond that, an additional 300,000 AF will be needed annually (MWD, 1998).

The City of Los Angeles utilizes several sources of water. The Los Angeles Aqueduct (LAA) system, which imports snowmelt, surface runoff, and pumped groundwater from the Owens Valley and Mono Basin to the City, has a total capacity of about 560,000 AF per year. Since 1970, it has supplied an average of 400,000 AF of water annually, meeting about two-thirds of the City's water needs. However, because of concerns over environmental conditions in Owens Valley and Mono Basin, the California Department of Water Resources (DWR) predicts that water imported through the LAA will be reduced to between 300,000 AF and 350,000 AF per year (DWR, 1999a), serving the City with only half of its water needs.

Los Angeles also purchases water from MWD, which imports water from the Colorado River through the Colorado River Aqueduct, as well as from the Sacramento-San Joaquin Bay-Delta in northern California through the California Aqueduct, which is part of the State Water Project (SWP). MWD sells this water to its member agencies, including the City of Los Angeles. About 20% of Los Angeles's annual water needs, or 125,000 AF, are purchased from MWD (MWD, 2001).

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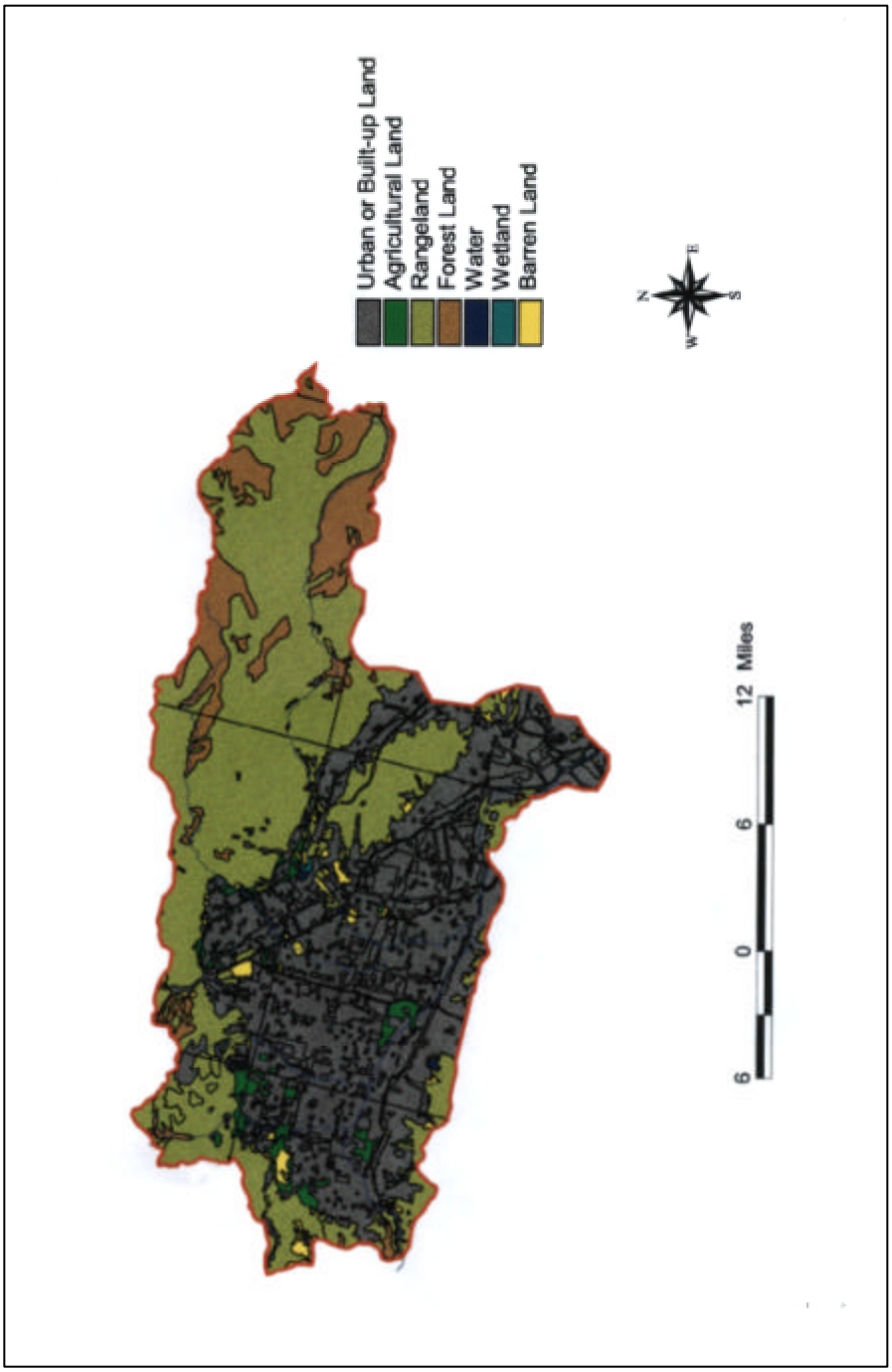
Figure 6: Land Use Distribution in the ULARA



Source: EPA, 1999a.

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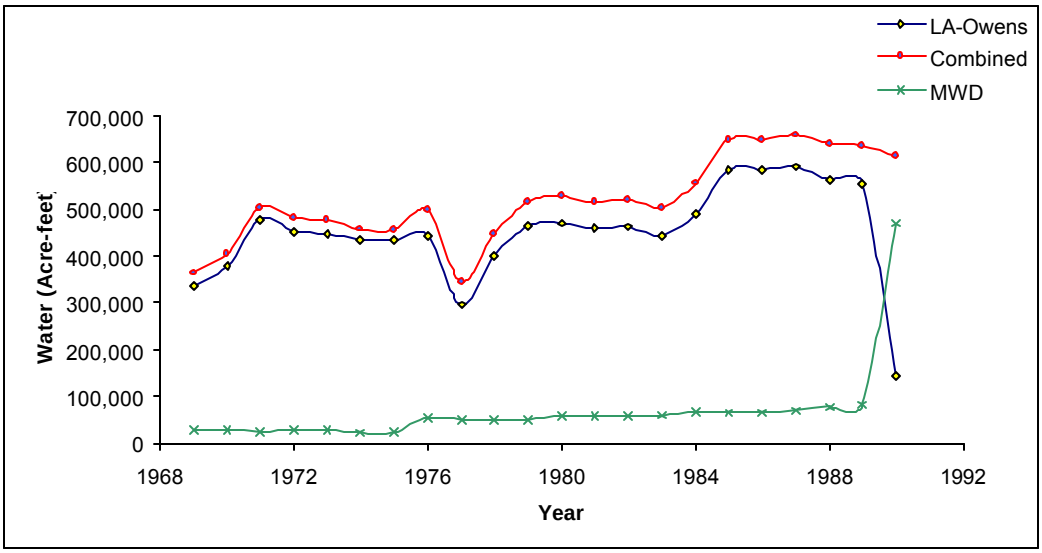
As demand for water in Los Angeles increases, supply from the Owens Valley decreases, and droughts reoccur, supplemental water purchases from MWD will continue to increase. It is projected that by 2015, the City will increase its reliance on MWD to total approximately 25% of its water supply during normal water years and as much as 45% during dry years. By 2020, MWD will most likely be providing nearly 300,000 AF annually to the City. Water purchases from MWD are largely dependent on water supply conditions from the Eastern Sierra Nevada, which determine how much water the City's aqueducts can deliver to Los Angeles. Wet conditions in the Eastern Sierra Nevada enable more water deliveries from the LAA and less reliance on MWD. Conversely, dry conditions in the Eastern Sierra Nevada result in less LAA deliveries and more reliance on MWD (MWD, 2001).

Figure 7 shows the volume of water imported to Los Angeles between 1969 and 1990 both through the Los Angeles Aqueduct (represented in the graph by "LA-Owens") and from MWD. Complete data are presented in Appendix A. LAA imports sharply declined from 1989 to 1990, while MWD imports increased correspondingly. This point marked the beginning of a drought period that seriously impacted surface water supplies in the Owens Valley. The imports from the north were dramatically reduced, necessitating an increase in deliveries from MWD, particularly from the Colorado River.

Figure 7: Water Imported Into ULARA (1969-1990)



Source: Derived from Blomquist, 1992.

Environmental concerns about the diversion of water from both the Sacramento-San Joaquin Bay-Delta and from the Colorado River have created cause for worry about the reliability of water supplies to Los Angeles. Furthermore, water rights issues involving allocation of water from the Colorado River may also threaten

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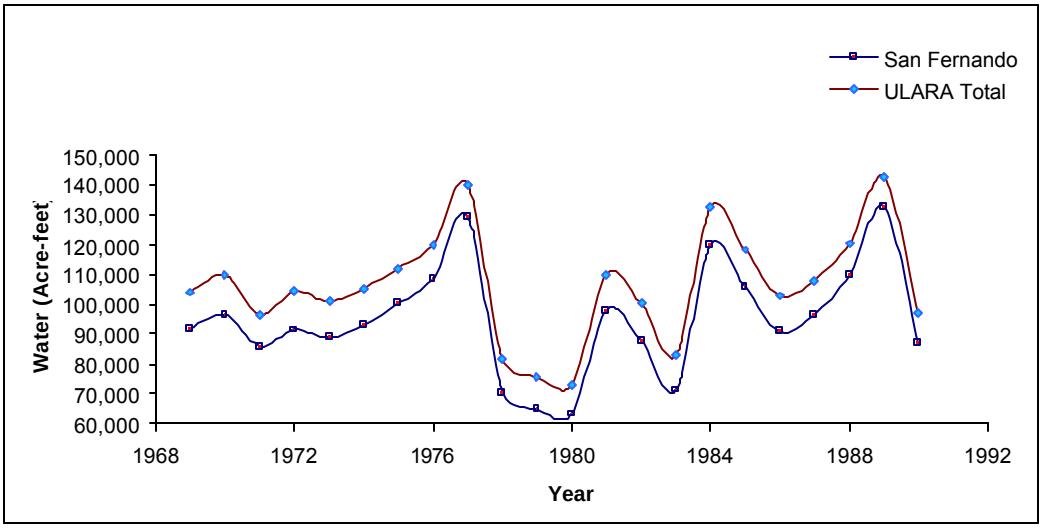
the state's supplies. The 1922 Colorado River Compact allotted 15 million AF per year of the river's water to the seven states through which it flows, including 4.4 million AF annually for California. Should a state not use its allotted share, the surplus water may be reallocated at the Interior Secretary's discretion. Because Arizona and Nevada tend to use less than their full entitlement, California has historically consumed about 800,000 AF more than its annual allocation (MWD, 2001). As Arizona and Nevada continue to grow, their need to reclaim the water allocated to them in 1922 increases, putting pressure on California to reduce its overconsumption. Efforts are currently underway to reduce California's reliance on the Colorado River through conservation, recycling, water storage, and the development of transfer programs (MWD, 2001). Despite the state's excessive consumption of Colorado River water, the City of Los Angeles rarely, if ever, purchases its full entitlement of MWD water (Mackowski, 2001).

The remaining 15% of the City's water needs are provided by local groundwater aquifers (LADWP, 1996), including the San Fernando, Sylmar, Central, and West Groundwater Basins. The San Fernando Groundwater Basin is the largest, providing water to approximately 500,000 Los Angeles residents in the metropolitan area. For the last few decades, the City has extracted about 95,000 AF annually from its groundwater basins (see Figure 8) and has rights to extract up to 110,000 AF during a typical year. Complete data are presented in Appendix B.

Figure 8: ULARA Groundwater Extractions (1969-1990)



Source: Derived from Blomquist, 1992.

In addition to supplying the annual water needs of the City, the San Fernando Groundwater Basin holds large quantities of stored water that can be extracted during droughts and replenished during years of surplus water supply. This

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storage of groundwater is becoming increasingly important in the City's water management structure. The coordinated use of groundwater and surface water to provide the City with increased reliability during dry years is known as conjunctive use. During wet years, the use of groundwater is limited (thus allowing groundwater levels to recover and storage credits to accumulate), but use is maximized during droughts when surface water imports are reduced. In the San Fernando Groundwater Basin, conjunctive use is essential to ensuring a reliable water supply for the City by providing a reserve for drought and emergency use.

The basin stores enough water to supply about one million people for two years during a drought. Large-scale spreading grounds are used to infiltrate into the basin water from the Los Angeles River and local creeks, in addition to surplus water from the LAA and MWD and treated wastewater (LADWP, 1996; ULARA Watermaster, 2000). Long-term annual supply in the San Fernando Groundwater Basin is projected to increase from 110,000 AF to 152,000 AF by 2015, largely as a result of the continuing operation and increasing capacity of spreading projects using reclaimed water for groundwater recharge and storage. As of June 1996, approximately 300,000 AF existed in storage in the San Fernando Groundwater Basin (LADWP, 1996).

GROUNDWATER MANAGEMENT

Given the local or regional scale of most groundwater basins and the differences in groundwater usage among states, comprehensive federal oversight of groundwater use and management is challenging. Although there are federal laws that allow for indirect federal regulation of some aspects of groundwater use and management, states have been left to develop their own policies of groundwater use and management.

FEDERAL REGULATIONS

There is no single federal groundwater statute that comprehensively addresses either groundwater quality protection or groundwater use and management (Benjamin and Belluck, 1994). However, provisions for groundwater quality protection do exist within some federal acts and regulations designed to address broader issues. The United States Environmental Protection Agency (EPA) is responsible for the implementation and oversight of six federal statutes that contain some language on groundwater protection, although most of them target remediation and cleanup rather than prevention of contamination. These statutes include the Clean Water Act (CWA); the Safe Drinking Water Act (SDWA); the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA); the Resource Conservation and Recovery Act (RCRA); the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA); and the Toxic Substances Control Act (TSCA).

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The CWA protects groundwater that is hydrologically connected to surface water systems by placing water quality requirements on the surface water. It also requires non-point source pollution prevention strategies to be developed, which can also protect groundwater quality. The SDWA identifies public drinking water standards and includes groundwater protection programs such as the Sole-Source Aquifer program, Underground Injection Control program, and the Wellhead Protection program. CERCLA focuses primarily on the remediation of contaminated groundwater sites, while RCRA focuses on preventing release of contaminants to groundwater aquifers through management standards and cleanup requirements. This act is instrumental in preventing groundwater contamination through solid and hazardous waste disposal. FIFRA and TSCA indirectly prevent groundwater contamination by regulating the use of pesticides on the surface through registration requirements and regulating the introduction or unrestricted use of new chemicals, respectively (Benjamin and Belluck, 1994).

GROUNDWATER MANAGEMENT IN CALIFORNIA

Unified state oversight of groundwater use is lacking in California. The California Legislature has consistently approached groundwater management law, particularly groundwater rights, with a "hands-off policy," and very few statutes regulating groundwater rights have been adopted (Blomquist, 1988). Instead, groundwater management in California is a local responsibility assigned by a number of court decisions and falls under the authority of the California Water Code (CWC), a body of state laws governing water supplies and resources. Several state and regional agencies have some authority over groundwater quality management and, as such, may play a role in the implementation of groundwater recharge projects (see Table 4).

Under present law, there are six methods by which to manage groundwater; management approaches may include one or more of these methods (DWR, 1999b). The first management method is through overlying property rights that allow anyone in California to build a well on their property in order to extract their correlative share of groundwater, which is not defined until the basin is adjudicated. Even though this is not a coordinated method of groundwater management, it has still been defined as such.

Second, in some parts of California, special legislation has been enacted to form groundwater management districts or water management agencies that may enact ordinances to limit or regulate groundwater extraction. Nine water management agencies in California acquired authority in this manner, and three acquired similar authority through amendments to the CWC.

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Table 4: Agencies Addressing Groundwater Quality in California

Activity Affecting Groundwater Quality	Agencies that Regulate These Activities						
	State					Local	Federal
	SWRCB RWQCB	DTSC	DHS	DWR	DOC	CCSD	EPA
Surface impoundments	X	X		X		X	X
Groundwater recharge	X		X				
Water reclamation and recharge	X			X	X	X	

SWRCB	State Water Resources Control Board
RWQCBs	Regional Water Quality Control Board
DTSC	Department of Toxic Substances Control
DHS	Department of Health Services
DWR	Department of Water Resources
DOC	Department of Conservation
CCSDs	Counties, Cities, and Special Districts
EPA	United States Environmental Protection Agency

Source: Derived from Bachman, 1997.

Alternatively, twenty-two types of districts or local agencies are identified in the CWC as having specific statutory provisions to manage surface water. Some of these agencies also have statutory authority to manage groundwater, although not all of them have done so.

Fourth, the CWC provides procedures for an existing local agency to develop a groundwater management plan. This gives the agency the powers of a water replenishment district, allowing it to raise revenue to pay for management of the basin. One hundred forty-nine agencies have adopted groundwater management plans in accordance with these procedures, while others are in the process of doing so.

In addition, cities and counties are also able to adopt ordinances to manage groundwater. Several counties in the state now have such management ordinances, although the nature and extent of the regulatory power of cities and counties to control groundwater is presently uncertain.

The sixth method of groundwater management currently permitted in California is adjudication, which results from a lawsuit brought to trial to determine water rights (e.g., *Los Angeles vs. San Fernando*). The court determines who will be able to extract groundwater and what quantity may be extracted, and it appoints a Watermaster to ensure that the basin is managed in accordance with the court's decree. There are sixteen adjudicated groundwater basins in California, including the

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San Fernando Groundwater Basin. In agreement with the 1979 *Los Angeles vs. San Fernando* decision, the ULARA has a court-appointed Watermaster, who is also an employee of the Los Angeles Department of Water and Power (LADWP), to manage the complex appropriation of its groundwater to user cities and agencies.

GROUNDWATER RIGHTS IN LOS ANGELES

The right of the City of Los Angeles to groundwater is a "pueblo right" granted in 1781, when Los Angeles was a pueblo settlement of the King of Spain (Blomquist, 1988). Under this right, the small pueblo of forty-six people – that eventually evolved into the highly populated 465-square mile City of Los Angeles – could use as much water as it needed from the Los Angeles River, along which it was located. Because the San Fernando Groundwater Basin is part of the Los Angeles River watershed, the pueblo right included that groundwater, too. Courts have upheld this right through the majority of cases brought either by or against Los Angeles in a series of litigation that began in 1933 and continued until the 1979 San Fernando decision permanently upheld the pueblo right of the City.

The 1979 San Fernando judgment produced an apportionment of the San Fernando Groundwater Basin waters among the cities of Los Angeles, Glendale, Burbank, and San Fernando. The Watermaster oversees parties' extractions and tracks each party's rights to native groundwater, import return water, and stored waters in the groundwater basin. The City of Los Angeles has pueblo rights to the entire native safe yield of the San Fernando Groundwater Basin (Blomquist, 1992); no other party may pump from the native waters of the Basin. Each of the four cities also has rights to a percentage of their import return flows in the San Fernando Groundwater Basin – that is, the amount of water that recharges the groundwater basin after being imported to the Valley from the LAA or MWD. Los Angeles can receive credit for and pump 20.8% of the water it imports into the Valley; Glendale, 20%; Burbank, 20%; and San Fernando, 26.3% (Blomquist, 1992). Import return flows that are not pumped in a given year by any of the cities can be accumulated as credit and pumped later when needed. Because Los Angeles has rights to all of the water that normally recharges the Los Angeles River via runoff from precipitation, any water that is recharged purposely in the Valley also belongs to Los Angeles.

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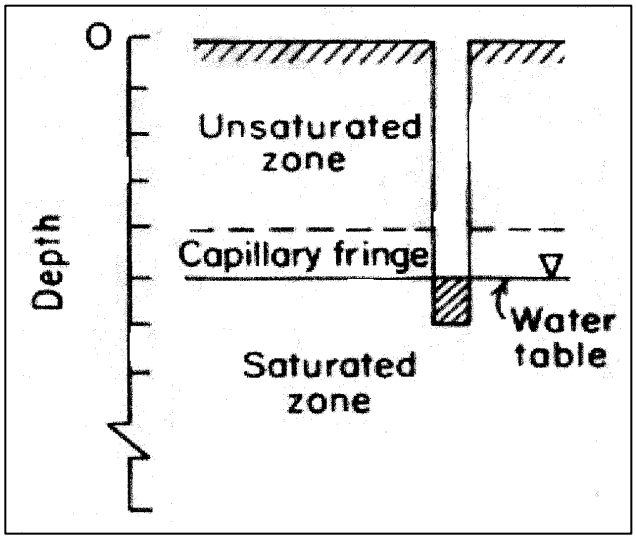
STORMWATER RUNOFF AND INFILTRATION BASINS

GENERATION OF STORMWATER RUNOFF

Infiltration is the movement of water into the soil. As rain falls, water percolates through the soil and fills the spaces (pores) between soil particles. Capillary forces retain some of this water, maintaining the soil moisture content. When soil pores are filled to capacity, infiltration may occur, and water flows downward into the soil by the force of gravity. The rate at which infiltration takes place depends on the texture and porosity (amount of pores) of the soil, which determine the soil's permeability. After water infiltrates, it moves through the unsaturated zone, or vadose zone, and may reach groundwater, which is defined as "subsurface water that occurs beneath the water table in soils and geologic formations that are fully saturated" (Freeze & Cherry, 1979).

Groundwater recharge is "the entry into the saturated zone of water made available at the water table surface, together with the associated flow away from the water table within the saturated zone" (Freeze & Cherry, 1979). The water table is the boundary between the unsaturated zone and the saturated zone, although this boundary is blurred by the presence of a saturated capillary fringe (see Figure 9). The depth of the water table, or distance to groundwater, varies depending on many factors, including amount of groundwater recharge, evapotranspiration, and flow of groundwater into streams (Freeze & Cherry, 1979).

Figure 9: Saturated and Unsaturated Zones



Source: Freeze and Cherry, 1979.

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Stormwater runoff occurs when rainfall intensity exceeds the infiltration rate of the surface on which raindrops land. When this happens, water will become runoff by ponding on the surface, flowing over the land, and traveling down slope. The traditional method of managing stormwater runoff in cities has been to construct a network of catch basins and storm drains to rapidly and efficiently move it away from the urbanized area into receiving streams that eventually reach the ocean. These types of storm drainage infrastructures were developed to limit nuisance and local floods caused by large volumes of stormwater runoff (Dallman and Piechota, 1999). In addition to entering streams as point sources after being conveyed through storm systems, stormwater runoff can enter streams as a non-point source from parking lots, highways, open land, rangeland, residential areas, and commercial areas (EPA, 1999b).

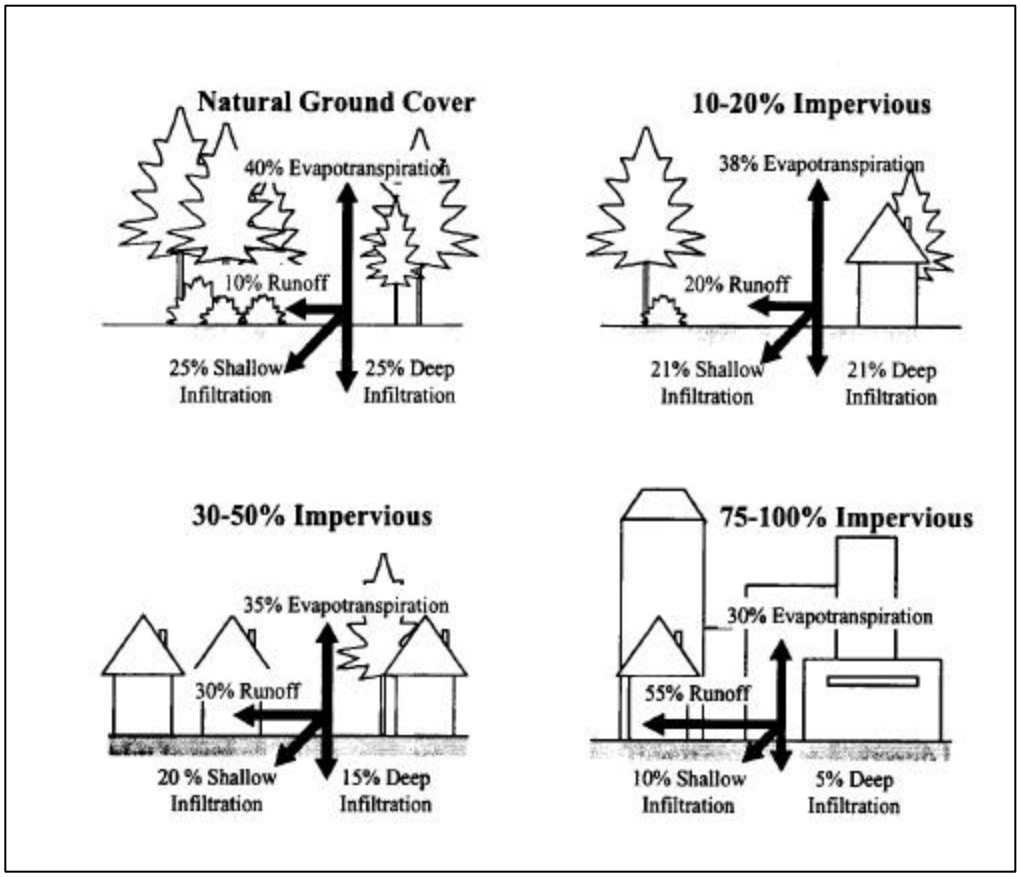
Water that moves over land as stormwater runoff does not infiltrate the soil and, therefore, will not recharge groundwater. Because stormwater runoff occurs when rain cannot infiltrate a surface, its generation is affected by the extent of impervious surfaces such as buildings, streets, parking lots, sidewalks, and roofs. Impervious surfaces, as their name implies, have a much lower infiltration capacity than soil and thereby increase both the rate of stormwater runoff generation and the amount of rainfall converted to runoff.

As open land is paved over, the natural hydrology of a watershed is altered. Water that previously ponded and infiltrated the soil, potentially entering groundwater, is now converted directly to stormwater runoff, as it cannot infiltrate. The average runoff volume from subdivisions has been reported to be more than ten times greater than that of typical pre-development agricultural areas (Madison et al., 1979). Because urbanization leads to increased impervious cover as the land is built up, less water infiltrates the ground and more stormwater runoff is generated, resulting in less groundwater recharge (see Figure 10). In the ULARA, the proportion of rainfall that becomes runoff has steadily increased with the increase in amount of impervious surfaces. From the 1930s to the mid-1960s, more than 80% of rainfall infiltrated the ground or evaporated, while less than 20% became runoff. Since then, as the area has become more and more developed, the proportion of rainfall that infiltrates or evaporates has decreased to less than 50%, and the proportion that becomes runoff has increased to over 50% (Dallman and Piechota, 1999).

The larger rates and volumes of runoff associated with urbanization not only decrease the amount of water that may recharge groundwater, but also increase the volumes of water carried by streams. Because the volume of water is proportional to its erosive force, an intensification of stream bank erosion occurs. As water flows over a surface, it picks up and carries different particulate and dissolved elements found on its path. Therefore, stormwater runoff also carries harmful contaminants

that may be transported into receiving water bodies (streams, lakes, and oceans), potentially causing detrimental ecological effects.

Figure 10: The Association Between Increased Impervious Cover and Decreased Groundwater Recharge



Source: EPA, 1999b.

CONTAMINATION OF STORMWATER RUNOFF

Several factors influence the quality and quantity of stormwater runoff, including land use and climate (Pitt and McLean, 1986). Land use affects the extent of impervious cover. Commercial and industrial land uses generally have higher impervious cover than residential areas, which may have more land devoted to parks, yards, and other pervious surfaces. Areas of high impervious cover have an associated increase in stormwater runoff. Land use also affects the type of contaminants carried by runoff. Stormwater runoff from lands used for agriculture will contain different contaminants than stormwater runoff from land used for industry, as different chemicals are used on different land uses. Additionally, through its effect on average rainfall intensity and storm duration, the climate of a region

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affects the concentration of contaminants in stormwater runoff. Areas such as the southwestern United States that have infrequent rainfall generally have runoff with higher concentrations of contaminants. Because it does not rain often, these contaminants may have been building up for long periods of time.

There are seven categories of potentially harmful contaminants associated with urban runoff: solids, organic materials, nutrients, metals, pathogens, oil and grease and hydrocarbons, and synthetic organic chemicals (Terrene Institute, 1994). (Our analysis of contaminant removal focuses on four of these categories: nutrients, metals, pathogens, and synthetic organic chemicals, as discussed in *Removal of Stormwater Contaminants*). These contaminants come from a variety of sources, including residential, industrial, and commercial areas; streets and parking lots; and atmospheric deposition (see Table 5).

Table 5: Sources of Contamination in Urban Stormwater Runoff

Contaminant	**Contaminant Sources**
Solids	Streets, lawns, driveways, roads, construction activities, atmospheric deposition, drainage channel erosion
Organic Materials	Residential lawns and gardens, commercial landscaping, animal wastes
Nutrients	Lawn fertilizers, atmospheric deposition, automobile exhaust, soil erosion, animal waste, detergents
Metals	Automobiles, bridges, atmospheric deposition, industrial areas, soil erosion, corroding metal surfaces, combustion processes
Pathogens	Lawns, roads, leaky sanitary sewer lines, sanitary sewer cross-connections, animal waste, septic systems
Oil and Grease and Hydrocarbons	Roads, driveways, parking lots, vehicle maintenance areas, gas stations, illicit dumping to storm drains
Synthetic Organic Chemicals	Residential lawns and gardens, roadsides, utility right-of-ways, commercial and industrial landscaped areas, soil wash-off

Source: EPA, 1999b.

Solids include litter, soil particles, sediments, and dust. They cause many water quality, habitat, and aesthetic problems in waterways, such as increased turbidity that results in decreased light penetration and plant growth. Solids that settle out can alter and eventually destroy habitat. Other contaminants, including metals and pathogens, can bind to solids and move with them. Organic materials are problematic because they decompose after runoff enters streams or oceans,

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demanding large quantities of oxygen as they do so. This may deplete oxygen to levels dangerous to aquatic life.

Primary nutrients are compounds or constituents that contain nitrogen, phosphorus, and other elements essential for plant growth. Nitrogen and phosphorus are the nutrients most commonly tested for and are found in several forms in stormwater runoff. Ammonia (NH_3) is the nitrogen form that is most toxic to aquatic life. Inorganic forms of nitrogen are nitrate (NO_3^-) and nitrite (NO_2^-), although little nitrite is found in stormwater runoff. Organic and ammonia nitrogen forms are measured by total Kjeldahl nitrogen (TKN). Most phosphate is present in stormwater as orthophosphate (HPO_4^-), the soluble and most biologically available form. Total phosphorus measures both soluble and insoluble forms. Excess nutrients in a water body can increase primary biological activity, resulting in an excessive growth of algae that leads to eutrophic conditions. When these algae die and decompose, they can further deplete dissolved oxygen levels.

Metals such as copper, lead, and zinc may be either dissolved or bound to sediments. They can be found in concentrations high enough to impair beneficial uses and cause acute and chronic toxic impacts for aquatic life. Pathogens are disease-causing organisms that present a potential human health threat when stormwater is discharged to recreational waters. The presence of harmful pathogens in stormwater is evaluated by the presence of indicator organisms such as fecal coliform bacteria or fecal streptococcus. However, few analyses of specific pathogenic microorganisms are made (NRC, 1994).

Oil and grease and hydrocarbons contain compounds that cause acute toxicity, such as the benzene, toluene, ethylbenzene, and xylene compounds (BTEX) and polynuclear aromatic hydrocarbons (PAH) found in gasoline. Synthetic organic chemicals include a variety of manufactured compounds such as pesticides, solvents, and household and industrial chemicals. Even though they may be found in low concentrations, these chemicals present a health threat to humans and aquatic life through direct ingestion or accumulation in the food chain.

The most comprehensive study of urban stormwater runoff is the EPA's Nationwide Urban Runoff Program (NURP), conducted between 1978 and 1983 to examine the characteristics of urban stormwater runoff and to determine any difference in contaminant concentration between land uses. In 28 NURP projects, sampling was conducted at 81 sites during over 2,300 storm events to determine median event mean concentrations (EMCs) for ten contaminants (see Table 6). The NURP study also detected concentrations of organic chemicals frequently found in stormwater runoff; these chemicals will be discussed further in *Removal of Stormwater Contaminants.*

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Table 6: Median Event Mean Concentrations for Different Land Uses

Contaminant	Units	Land Use			
		Residential	Mixed	Commercial	Open Space
BOD	mg/L	10	7.8	9.3	---
COD	mg/L	73	65	57	40
TSS	mg/L	101	67	69	70
Total Lead	µg/L	144	114	104	30
Total Copper	µg/L	33	27	29	---
Total Zinc	µg/L	135	154	226	195
Total Kjeldahl Nitrogen	µg/L	1900	1288	1179	965
Nitrate and Nitrite	µg/L	736	558	572	543
Total Phosphorus	µg/L	383	263	201	121
Soluble Phosphorus	µg/L	143	56	80	26

BOD Biological Oxygen Demand
COD Chemical Oxygen Demand
TSS Total Suspended Solids

Source: Derived from EPA, 1999b.

STORMWATER MANAGEMENT AND REGULATIONS

Historically, stormwater discharges have not been regulated under the Clean Water Act (CWA), the principal law governing pollution of the nation's surface waters that was first passed in 1972. The CWA established the National Pollutant Discharge Elimination System (NPDES) permit system for point source discharges to receiving waters, but it did not specifically address stormwater discharges.

In 1987, the CWA was amended to require NPDES permits for separate stormwater discharges[3]. In 1990, the EPA issued final regulations specifying a two-phase implementation of stormwater permits. During Phase I, permits must be obtained for all discharges from separate stormwater conveyance systems (storm drains) in municipalities with populations greater than 100,000 people. In addition, states were directed to develop and implement non-point source pollution management programs. In 1999, the EPA published a final rule mandating that municipalities with less than 100,000 people obtain an NPDES stormwater permit.

Amendments to the California Water Code (CWC) authorized California to administer the EPA's permit program. The state's nine Regional Water Quality Control Boards (Regional Boards), divisions of the California Environmental Protection Agency's State Water Resources Control Board (SWRCB), have primary responsibility for implementation and enforcement of the permits. Regional Boards are required to adopt a water quality control plan for their region. This plan is subject

[3] Stormwater may be conveyed either separately through storm drains or combined with sewage in combined sewer systems.

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to approval by the SWRCB and ultimately the EPA. Regional Boards implement the NPDES program by issuing discharge permits after certifying that the discharge will comply with applicable water quality standards (LARWQCB, 2000).

In anticipation of the 1990 regulations, Los Angeles County, in conjunction with 18 cities within the County, applied for and was issued a five-year NPDES permit for urban stormwater runoff discharges. It was issued in advance of the final Federal Regulations to allow for the development of a permit more suited to the County's extensive storm drain system (Lehman, 1994). Because the permit was vague and general, stormwater management programs varied widely from city to city (LACDPW, 2000). The permit was reissued in 1996 after one and a half years of discussions between the Los Angeles Regional Water Quality Control Board (LARWQCB), Los Angeles County, the City of Los Angeles, three smaller cities, and the environmental community. It sought to provide a more coordinated effort by specifying actions that are needed to comply with its requirements.

In 1994, the LARWQCB adopted an updated Water Quality Control Plan for its region, specifying the beneficial uses of receiving waters and providing both narrative and numerical water quality objectives. The Regional Board has implemented a watershed management approach to address water quality protection, emphasizing cooperative relationships between regulators, the regulated community, environmental groups, and other stakeholders in the watershed to achieve the greatest environmental improvements. To implement this approach and facilitate compliance, the County is divided into six watershed management areas. A stormwater management plan is established for each watershed management area and includes requirements with compliance dates to provide specificity and certainty of expectations. It also incorporates provisions that promote customized initiatives, both on a countywide and watershed basis, in developing and implementing cost-effective measures to minimize discharge of contaminants to the receiving water (LARWQCB, 2000).

In 2000, the EPA issued final regulations clarifying regulatory requirements for establishing Total Maximum Daily Loads (TMDLs) of contaminants at a level necessary to ensure that applicable water quality standards can be attained and maintained. States must identify water bodies for which the local wastewater discharge limits are not stringent enough to attain water quality standards, and then they must schedule, based on priority, the establishment of TMDLs for these water bodies over the next ten years. TMDLs include best estimates of pollution from point sources, such as industrial and municipal discharges, and non-point sources, including stormwater runoff. The maximum amount of pollution a water body can receive without violating water quality standards is outlined in TMDLs (Federal Register, 2000).

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TMDLs will be enforced through the issuance of NPDES permits that include contaminant limits and a schedule for compliance. Highly contaminated stormwater runoff can cause the limits of a TMDL to be exceeded. It is expensive to install new technology on point sources to further reduce their contaminant releases in order to meet the more stringent standards. Therefore, cities find it more cost-effective to control and treat stormwater runoff, as opposed to requiring new technology on point sources, to reduce contamination entering streams and oceans (Copeland, 1997). Infiltration basins are one method that may be used to manage contaminated stormwater runoff.

INFILTRATION BASINS

Infiltration basins are impoundments to which incoming stormwater runoff is diverted and allowed to gradually infiltrate the soil toward underlying aquifers (see Figure 11). This concept is presented in Figure 12. Infiltration basins reduce both the peak flow and the total amount of stormwater runoff that is conveyed downstream (Dallman and Piechota, 1999). They consist of open depressions produced by either natural site topography or excavation or may be formed by placing low head dams across natural waterways (O'Hare et al., 1986).

Once stormwater runoff infiltrates the soil, stormwater contaminants may be treated and removed in the subsurface soil through processes such as filtration, adsorption, and degradation, which will be discussed further in *Removal of Stormwater Contaminants.* The greatest environmental concern about the use of infiltration basins is groundwater contamination. Studies have shown that, given the right conditions, many contaminants will be removed by the soil as stormwater infiltrates, causing no adverse impacts on groundwater (EPA, 1999b).

Soil characteristics such as texture and composition determine both the infiltration rate and the proportion of contaminants removed and, as such, are important considerations when placing an infiltration basin. The ideal soil type for stormwater infiltration is one that allows for both complete removal of contaminants and rapid infiltration, preventing long periods of water impoundment. However, this soil type does not exist because the attributes required to reach one goal impede achievement of the other. Coarse-textured soils that transmit water readily have large pores that are inefficient at filtering or adsorbing contaminants. In contrast, fine-textured soils are efficient at contaminant adsorption and filtration but have low permeability and small pores that clog easily. Structured soils containing biological channels (e.g., worm holes, root paths) or cracks are permeable, but water will flow through these large flow paths and bypass the soil matrix. The best choice for soil is therefore a compromise, such as fine sand or sandy loam with relatively little structure (NRC, 1994).

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Figure 11: Infiltration Basin

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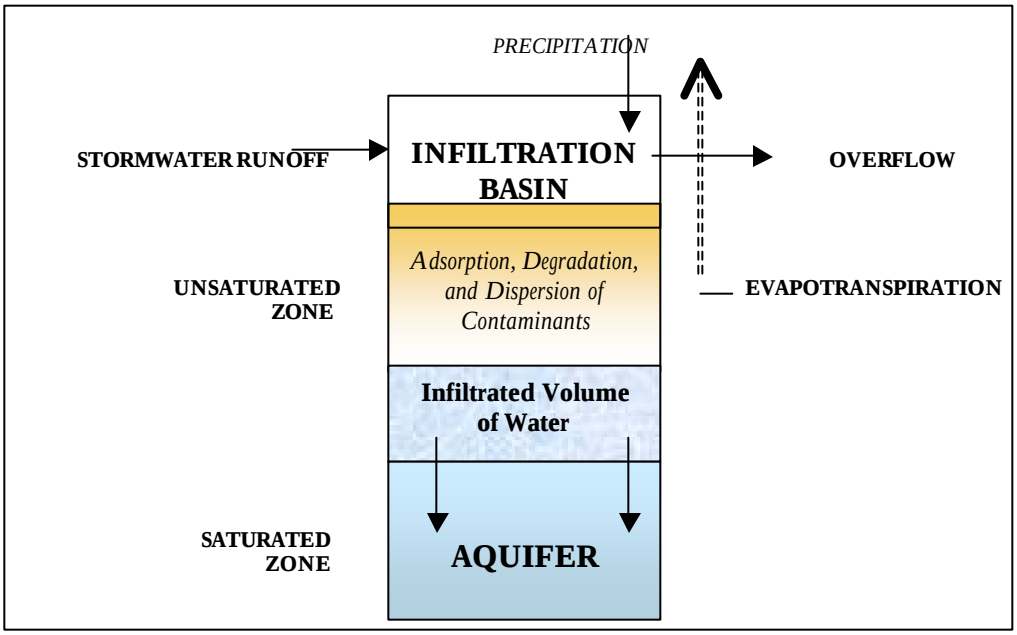
Figure 12: Conceptual Model of an Infiltration Basin



The success of infiltration basins as a method for groundwater recharge depends on both stormwater and site characteristics, including contaminant concentration, depth to groundwater, and antecedent soil moisture of the subsurface soil (EPA, 1999b). Depth to groundwater plays a critical role in the soil's pollution removal efficiency; an increase in depth is an increase in soil available to remove contaminants. Antecedent soil moisture is important since water will infiltrate wetter subsurface soil more quickly than it will drier subsurface soil, giving the contaminants less time to adsorb to soil particles and potentially resulting in less than adequate treatment.

It is also important to have a vadose zone without impeding layers, as restricting layers between the land surface and the aquifer could prevent the infiltrated stormwater from reaching groundwater (Schueler et al., 1992). In addition, infiltration basins must be placed above uncontaminated soil to prevent the infiltrate from collecting these contaminants and transporting them to groundwater (NRC, 1994).

STORMWATER INFILTRATION PROJECTS

The ULARA already contains several "spreading grounds," or large areas in which stormwater runoff or river water (of which a portion is stormwater runoff) is infiltrated. These centralized spreading grounds are designed for concentrating large volumes of water in a few large basins. Pacoima and Hansen Dams, which were

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originally built for flood control, are now used to regulate stormwater flows and divert them to downstream spreading basins operated by the LACDPW and the City of Los Angeles. There are 3,361 acres of spreading grounds used to recharge groundwater in Los Angeles County, 2,436 acres of which are operated by the LACDPW. During the 1998-99 season, the LACDPW infiltrated a total of 171,987 AF of water: 95,166 AF of stormwater runoff, 28,588 AF of imported water, and 48,233 AF of recycled water. Of this, 14,662 AF of stormwater runoff was infiltrated into the San Fernando Groundwater Basin; no imported water or recycled water was infiltrated into this aquifer. There are no spreading grounds in the other three ULARA groundwater basins (LACDPW, 2000).

The next section presents calculations of the volume of stormwater runoff that could be captured in infiltration basins of a much smaller size. We analyzed capture by infiltration basins with surface areas of 0.1 acre and 0.5 acre, varying basin depth and infiltration rate of the underlying soil.

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CAPTURE OF STORMWATER RUNOFF

INTRODUCTION

There are over 3,000 acres of large-scale spreading grounds that infiltrate almost 172,000 AF of water per year in Los Angeles County. Since these spreading grounds are so large, they can capture large volumes of water. However, their size also makes them difficult to place within the highly urbanized Los Angeles County, as there is a lack of large open spaces. Therefore, we determined the volume of stormwater runoff that could be captured from a five-acre drainage area by much smaller infiltration basins that have surface areas of 0.1 acre and 0.5 acre and depths of 2 feet and 3 feet. These smaller sizes allow them to be placed more easily into an area of urban or built-up land use, such as the San Fernando Valley.

The volume of stormwater runoff available for capture is affected by the extent of impervious surface cover, which is related to the land use distribution of the tributary drainage area. The extent of impervious cover affects the amount of stormwater that will infiltrate under natural conditions and, therefore, the amount that will run off and potentially be captured. The volume captured also depends on the frequency and magnitude of precipitation events; in general, more stormwater runoff occurs with larger storms and when soil is still moist from a previous storm.

PRECIPITATION DATA

We calculated the amount of stormwater runoff that could be generated from typical rainfall in the ULARA, using precipitation data gathered by the Los Angeles County Department of Public Works (LACDPW) over the last ten years for the city of Northridge, located in the western San Fernando Valley near the city of San Fernando. We assumed that precipitation in Northridge is representative of precipitation in the entire Valley and that ten years is a sufficient timeframe to represent precipitation patterns. Data for this station goes back to 1920. As shown in Figure 13, between 1920 and 2000, the precipitation depths that occur at the highest frequency range from 0.01 inch to 0.5 inch. Very few storm events were large enough to generate over one inch of precipitation.

BASIN SIZE

Given the high urban and built-up land use distribution in the San Fernando Valley, we assumed that stormwater runoff would be captured by relatively small infiltration basins that could more easily be placed into this urban environment. We considered basins with surface areas of 0.1 acre and 0.5 acre. Generally, infiltration basins have a cross-sectional trapezoidal shape (Malaysia Department of Irrigation and Drainage, 2000). Assuming a ratio of 1:0.8 between the surface area and the

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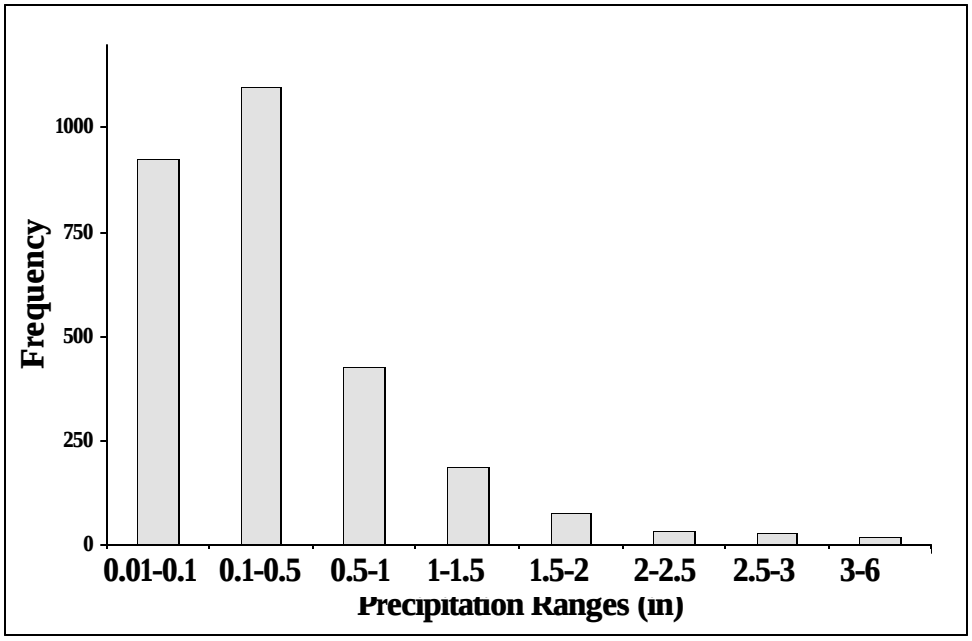
Figure 13: Frequency of Days with Precipitation Depths Ranging Between Selected Intervals (1920-2000)



Source: Derived from LACDPW, 2000.

bottom area of the basin, we calculated the maximum capacity of infiltration basins with these two surface areas and depths of 2 feet and 3 feet (see Table 7).

Table 7: Maximum Capacity of Four Infiltration Basins

Surface Area (acres)	Basin Volume (AF)	
	Basin Depth (ft)	
	2	3
0.1	0.18	0.27
0.5	0.90	1.35

THE SCS METHOD OF RUNOFF VOLUME ESTIMATION

To calculate the volume of stormwater runoff that could be captured, we used a method developed by the United States Department of Agriculture's Soil Conservation Service (SCS) to estimate the volume of runoff from small agricultural drainage areas. Although this equation, based on empirical studies and a simplified model of runoff and commonly referred to as the SCS Method, was not intended for small, urbanized drainage areas, it may be extended for this application (Dunne and Leopold, 1978). Therefore, it is appropriate for us to use this method in determining the volume of stormwater runoff that could be captured by infiltration basins in the urbanized San Fernando Valley.

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The following equation constitutes the SCS Method for runoff estimation:

$$Q = \frac{(P - I_a)^2}{(P - I_a) + S}, \text{ where}$$

Q = runoff depth (inches)

P = precipitation depth (inches)

I_a = initial abstraction (inches)

S = maximum retention potential (inches) once runoff begins.

The initial abstraction, I_a, is the amount of precipitation that is either infiltrated into the soil or retained in topographical depressions during the initial period of the storm, before runoff begins to occur. The maximum retention potential, S, represents the maximum amount of rainfall the soil can hold once the initial abstraction has been reached and the generation of runoff has begun. Although the initial abstraction is highly variable, the SCS developed an empirical relationship between the initial abstraction (I_a) and the maximum retention potential (S):

$$I_a = 0.2 \cdot S$$

Consequently, the SCS Method can be expressed as:

$$Q = \frac{(P - 0.2S)^2}{(P - 0.8S)}$$

CURVE NUMBER

Once rewritten like this, the SCS Method depends only on estimating the maximum retention potential of the soil, since actual precipitation data is already known. The maximum retention potential, S, is based on three parameters: soil type, which is further classified into soil hydrologic groups based on infiltration rate; surface cover; and antecedent soil moisture, which is affected by the total precipitation occurring within the preceding five days. These three factors are represented by an empirical rating, or curve number (CN). The SCS established an empirical relationship between the maximum retention potential of the soil and the curve number:

$$S = \frac{1000}{CN} - 10$$

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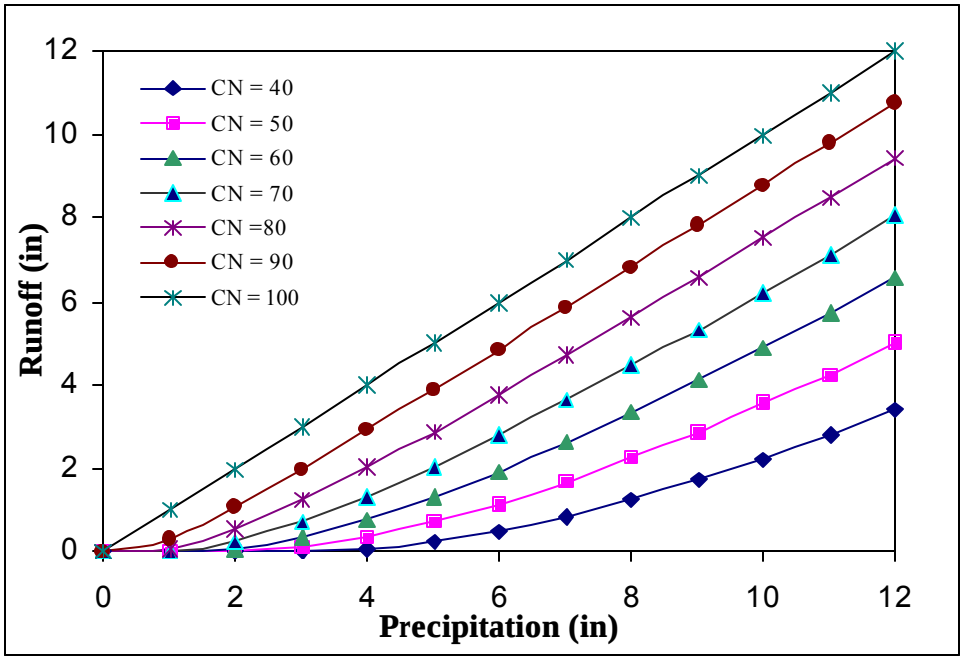
Curve numbers have been determined specifically for urban land uses based on the hydrologic soil groups that underlie the built-up land, as well as on the percentage of impervious cover, which affects the amount of precipitation and runoff that may infiltrate the soil (Dunne and Leopold, 1978). An increase in the curve number corresponds to an increase in stormwater runoff that may be generated by the same precipitation event (see Figure 14).

Figure 14: Relationship Between Curve Number and Generation of Stormwater Runoff



Source: Derived from Dunne and Leopold, 1978.

For residential drainage areas, the curve number depends on lot size, which affects the proportion of impervious cover on each lot. Lot size and percent impervious cover are inversely related; that is, a small residential lot is assumed to have a larger percent of impervious surface than a large residential lot. To illustrate, a larger proportion of a small residential lot is covered by the house and driveway than a large residential lot. For example, a $^{1}/_{8}$-acre residential lot is assumed to have an impervious cover of 65%. Its curve number ranges between 77 and 92, depending on the soil hydrologic group. However, a one-acre residential lot is assumed to have an impervious cover of only 20%; consequently, its curve number is smaller, ranging between 51 and 84 (Dunne and Leopold, 1978).

Other urban land uses have curve numbers that are independent of lot size. We assumed that commercial and business areas have an impervious cover of 85%; the curve number ranges from 89 to 95, depending on the soil hydrologic group.

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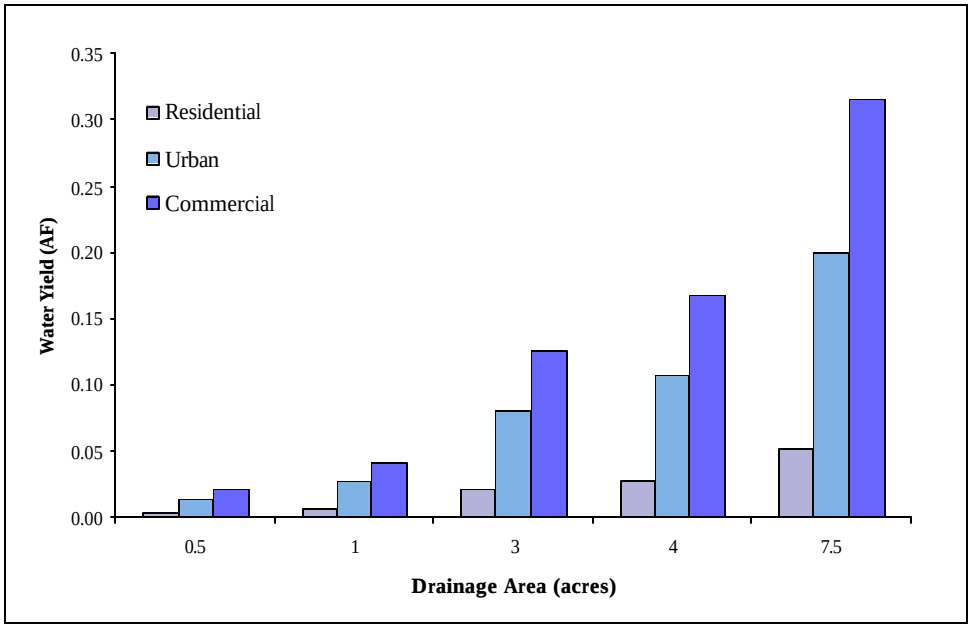
Paved parking lots, roofs and driveways have a curve number of 98 (Dunne and Leopold, 1978).

We made several assumptions about curve numbers in order to assess the volume of stormwater runoff that can be captured by an infiltration basin. Residential lots were assumed to be ½ acre in size with 25% impervious cover and a curve number of 80. This land use is characteristic of suburban developments that have relatively large lots and some pervious surfaces, such as yards and neighborhood parks. Commercial lots, representing areas with small businesses and shops, were assumed to have 85% impervious cover and a curve number of 92. Urban lots were assumed to be $^{1}/_{8}$ acre in size with 65% impervious cover and a curve number of 90. Urban land use represents areas that contain both commercial and residential land uses, although these residential lots are much smaller and mostly covered by impervious surfaces.

Since residential, commercial, and urban land uses have different curve numbers, the amount of stormwater runoff generated from each will vary. The amount of runoff also varies with the drainage area; larger drainage areas will generate relatively more runoff than smaller drainage areas under the same conditions. Figure 15 shows the dependence of volume of stormwater runoff on land use and size of drainage area. We assumed that infiltration basins captured stormwater runoff from a five-acre drainage area, as they are most effective for drainage areas of this size or smaller (CDOT, 2000).

Figure 15: Runoff Volume from Different Land Uses Located on Drainage Areas of Different Sizes



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THE EFFECT OF ANTECEDENT SOIL MOISTURE

The amount of runoff generated by a storm event is influenced by the initial moisture conditions of the soil. Soils with high antecedent soil moisture will yield runoff more rapidly than drier soils, since the initial abstraction, I_a, is less and the retention capacity is reached faster.

Antecedent soil moisture is dependent on the magnitude of and time interval between storm events and should be accounted for when determining the curve number. Curve numbers can be adjusted for antecedent soil moisture content based on the amount of precipitation that has fallen during the five preceding days. There are three classes of antecedent soil moisture conditions: Class I occurs when little rainfall has occurred during the five preceding days; Class II occurs when moderate rainfall has occurred; and Class III occurs when substantial rainfall has occurred (see Table 8) (Dunne and Leopold, 1978). The curve number for a drainage area is adjusted upward if there is over 1.1 inches of rain during these five days (e.g., more stormwater runoff may occur) and downward if less than 0.5 inch of rain occurs during this time period (e.g., less stormwater runoff may occur).

Table 8: Rainfall Limits for Estimating Antecedent Soil Moisture

Antecedent Soil Moisture Class	5-Day Total Antecedent Rainfall (inches)
I	< 0.5
II	0.5 – 1.1
III	> 1.1

Source: Dunne and Leopold, 1978.

When necessary, we adjusted the curve numbers for each of the three land uses based on the precipitation that fell during the five preceding days (see Table 9).

Table 9: Adjustment of Curve Numbers for Antecedent Soil Moisture, Class II, to Curve Numbers for Class I (Drier) and Class III (Wetter)

Type of Land Use	Curve Number for Antecedent Soil Moisture, Class II	Curve Number for Antecedent Soil Moisture, Class I	Curve Number for Antecedent Soil Moisture, Class III
Residential	80	63	91
Commercial	92	80	97
Urban	90	78	96

Source: Dunne and Leopold, 1978.

VOLUME OF STORMWATER RUNOFF CAPTURED

Although infiltration basins have a certain volume capacity, the actual volume of water that they capture depends not only on this size but also on the magnitude and frequency of the precipitation event and the infiltration rate of the soil. Large

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storms result in large volumes of stormwater runoff that may exceed the capacity of the infiltration basin. When the volume of runoff exceeds the capacity of the infiltration basin, we assumed that the excess was lost and only the volume capacity of the infiltration basin was captured.

Additionally, large storms commonly occur over several days. When a large volume of runoff is captured during a day, the maximum volume that may be captured the next day is restricted by the volume that remains in the basin from the previous day. The volume remaining from the previous day was determined by multiplying the depth captured the previous day (based on volume) by the rate at which that depth will infiltrate the soil, thereby draining the basin and allowing further volumes to be captured. For example, an infiltration basin with a surface area of 0.1 acre and a depth of two feet has a volume capacity of 0.18 AF. When a storm generates a volume of runoff that exceeds this capacity within a 24-hour period, the excess volume of runoff will be lost. Assuming an infiltration rate of 0.5 inch per hour (1 foot per day), the maximum volume that may be captured the following day is 0.09 AF, since only half of the 1.8 AF captured the previous day will have infiltrated.

Using ten years of precipitation data, from 1991-2000, we calculated the average volume of stormwater runoff that could be captured each year from a five-acre drainage area by basins of four different sizes. For each of the four basin sizes, we calculated volume capture under three infiltration rates common for the soils in this area: 0.5 inch per hour, 1 inch per hour, and 2 inches per hour (USDASCS, 1980). The curve number of each land use was adjusted according to the time interval between precipitation events and the magnitude of these events to account for the effects of antecedent soil moisture on the generation of stormwater runoff, as previously discussed.

In order to provide the maximum volume that could be captured, we did not account for any evapotranspiration that may occur. We assumed that the volumes of water captured by the basin and the volumes of water infiltrated by the basin occurred at the end of a 24-hour interval (i.e., the calculations do not account for a volume of runoff that will be infiltrating as the basin continues to capture additional runoff). We then weighted the resulting average volume captured per year by the land use of the drainage areas, according to the land use distribution in the ULARA. We assumed that each 5-acre drainage area contained 69% residential, 18% urban and 13% commercial land uses, as this is the characteristic distribution of the urban or built-up land use category in the ULARA (EPA, 1999a). Total volumes captured per year by each basin are presented in Table 10. Appendix C contains graphs depicting the volume of runoff captured by each basin from each homogeneous land use (purely residential, commercial, or urban) over the ten-year period, as well as the average volume weighted by land use distribution.

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Table 10: Volume of Runoff Captured Per Year

Basin Size (acres)	0.1		0.5	
Infiltration Rate (in/hr)	Basin Depth (ft)		Basin Depth (ft)	
	2	3	2	3
0.5	0.90	1.10	1.71	1.87
1.0	0.96	1.15	1.73	1.87
2.0	0.96	1.18	1.87	1.87

The results indicate that smaller basins capture stormwater runoff more efficiently than larger basins. Holding surface area constant, an increase in depth from two feet to three feet does not lead to a correspondingly large increase in volume captured. A five-fold increase in basin surface area (from 0.1 acre to 0.5 acre) results in less than double the runoff capture, and capture efficiency decreases with increasing infiltration rate. This suggests that smaller basins, even on soils with lower infiltration rates, are more efficient at capturing runoff than larger basins. These results are significant in the overall evaluation of this strategy, since the smaller the basin, the easier it is to place in an urban area.

CONCLUSION

We calculated the average volume of stormwater runoff that could be captured from a five-acre drainage area each year by infiltration basins of four sizes under a range of infiltration rates. A 0.1-acre infiltration basin with a depth of two feet can capture from 0.90 AF per year to 0.96 AF per year, depending on the infiltration rate, while an infiltration basin with the same surface area and a depth of three feet can capture from 1.10 AF per year to 1.18 AF per year. A 0.5-acre infiltration basin with a depth of two feet can capture from 1.71 AF per year to 1.87 AF per year. A 0.5-acre infiltration basin with a depth of three feet will capture 1.87 AF per year under the three infiltration rates that we studied.

The stormwater runoff captured by these basins contains contaminants that may adversely affect groundwater and, consequently, drinking water supplies. Therefore, the next step in our analysis was to determine if stormwater runoff, once infiltrated, would contaminate groundwater supplies. In the next section, we present our calculation of the depth to groundwater necessary to prevent contamination from occurring.

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REMOVAL OF STORMWATER CONTAMINANTS

INTRODUCTION

Since the ultimate goal of a groundwater recharge project is to resupply an aquifer with water that does not impair the quality of existing groundwater, the role of the unsaturated zone, or vadose zone, is to remove or transform harmful contaminants in the water as it moves through the soil toward groundwater. The unsaturated soil layer has the ability to remove contaminants from infiltrated stormwater, reducing potential health risks before it reaches the aquifer (NRC, 1994).

The unsaturated zone is a much more complex transport medium than the saturated zone. Soil pores are only partially filled with water, so chemicals with a high vapor pressure are able to move in the gas phase as well as in solution. In addition, the water flow rate can vary significantly, as the resistance by soil to the flow of water through a given soil volume is a non-linear function of the water content, while in the saturated zone it is a constant.

A relatively simple approach of modeling contaminant transport in the unsaturated zone is a one-dimensional equation that includes adsorption and degradation processes. This equation has been modified for use in the unsaturated zone. Using concentrations of stormwater contaminants from data gathered by the LACDPW and the EPA, we established the proportion that would be removed by different soil types in the San Fernando Valley. From this, we determined the depth to groundwater necessary to prevent aquifer contamination.

CONTAMINANT REMOVAL PROCESSES

Contaminant removal processes that occur in soil depend on characteristics of both the contaminants and the soil. The quality of infiltrated stormwater can change in the subsurface environment as a result of one or more of the following processes: filtration, adsorption, degradation, volatilization, precipitation, and complexation.

FILTRATION

Particulate contaminants include microorganisms (large pathogens such as parasites and some bacteria) and other undissolved materials. Particulates that infiltrate the subsurface are retained by filtration as they move through small pores. Filtration slowly clogs the medium and reduces its permeability if contaminants are not degraded (O'Hare et al, 1986, and NRC, 1984).

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ADSORPTION

Dissolved contaminants may be adsorbed by soil particles, impeding their movement. Adsorption involves the preferential partitioning of substances in the liquid phase onto the surface of a solid substrate. The substance is separated from the liquid and accumulates at the surface of a solid such as soil. The adsorbing solid is the adsorbent, and the material concentrated or adsorbed at the surface of that solid is the adsorbate. Physical adsorption is caused mainly by van der Waals forces and electrostatic forces between adsorbate molecules and the ions of the adsorbent surface. Therefore, adsorbents are characterized by surface properties such as surface area and polarity. A large specific surface area is preferable for providing large adsorption capacity. Surface polarity corresponds to affinity with polar substances such as water. Polar adsorbents are hydrophilic, as they are attracted to water and tend to remain in solution rather than adsorb. Conversely, non-polar adsorbents are generally hydrophobic and tend to come out of solution to sorb to soil surfaces (O'Hare et al., 1986).

DEGRADATION

Contaminants may be degraded by abiotic (chemical or physical) or biotic processes. Degradation involves the breaking of chemical bonds and the subsequent formation of new ones, offering the potential of permanent conversion into harmless products (Watts, 1998). Abiotic reactions include hydrolysis, oxidation-reduction, and photolysis. Hydrolysis is the addition of water to a molecule and is often enhanced by the presence of acids or bases. During oxidation-reduction (redox) reactions, a contaminant is either oxidized (the addition of oxygen or loss of electrons or a hydrogen atom) or reduced (the addition of a hydrogen atom or electrons). Redox reactions involve the transfer of electrons from one atom to another; electrons are neither created nor destroyed. Therefore, oxidation and reduction are linked, and it is impossible to have one without the other. The redox potential of the system depends on pH, dissolved oxygen concentration, and the presence of oxidizing or reducing agents such as ultraviolet light, ozone, and oxygen radicals. Photolysis is a light-induced redox reaction that has limited importance in the transformation of chemicals in the vadose zone because they are not exposed to light (Watts, 1998).

In biotic degradation, microorganisms metabolize contaminants through biochemical redox reactions. Microorganisms often use organic contaminants as a carbon source to make cellular material and as a source of energy for growth, reproduction, and motility. Of the common degradation mechanisms (hydrolysis, oxidation-reduction, photolysis, and biodegradation), biodegradation is the most significant process for the decomposition of organic contaminants in the natural environment (Bitton and Gerba, 1984). This process is likely to occur when microorganisms attach to surfaces and is enhanced if the soil is fine and has a high

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specific surface area, such as in sand or silt. However, fine soil may be clogged by bacterial growth. In coarse soil, biodegradation is less rapid and less extensive than in fine soil, but there is less chance of clogging (O'Hare et al., 1986)

VOLATILIZATION, PRECIPITATION, AND COMPLEXATION

Some chemicals volatilize, or move from the liquid phase to the gas phase within the soil, and then move upward and into the atmosphere. Volatile chemicals have a Henry's Law constant greater than 10^{-5} atmospheres per cubic meter per mole and a molecular weight of less than 200 grams per mole (EPA, 2000b). Other contaminants may precipitate out of solution if their concentration exceeds their solubility, meaning that the solid separates from the liquid. Contaminants may also attach to soil mineral or organic surfaces, forming complexes with these other particles. Metals often precipitate or form complexes; these processes will be discussed further below.

CONCENTRATIONS OF STORMWATER CONTAMINANTS

In order to determine the effect on groundwater quality from infiltration of contaminated stormwater, we analyzed the concentrations of stormwater contaminants contained in two data sets: 1998-99 Seasonal Event Mean Concentrations (EMCs) collected in Los Angeles County by the LACDPW and NURP data collected from areas across the nation by the EPA between 1978 and 1983. There are some overlaps in the LACDPW's data and the EPA's data; for example, each provides data for nutrients and metals. In this case, we chose to use the LACPDW data since it is specific to Los Angeles County. However, there are many contaminants that the LACPDW did not test for or did not detect above the detection limit in an appropriate number of cases. Therefore, we supplemented the LACPDW's data with NURP data, as the EPA tested for and detected more contaminants than the LACDPW.

The LACDPW monitored and assessed contaminants in stormwater runoff from eight land uses: high-density residential, light industrial, vacant, retail/commercial, multi-family residential, transportation, education, and mixed residential. These eight land uses were identified as the most significant land use categories in Los Angeles County and represent over 86% of all land use. Stormwater contaminants attributed to each land use category come from a drainage area comprised predominantly of this single land use (LACDPW, 1999). We considered data from three land uses – retail/commercial, education, and mixed residential – that were considered representative of land uses among which an infiltration basin would be placed. Retail/commercial land use is comprised of commercial office buildings, small shops, restaurants, hotels, and high-density apartments. Education land use is characterized by a university campus, and mixed residential land use includes apartments and single-family houses. These land uses were assumed to be

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comparable to the residential, urban, and commercial land uses for which we calculated volume of runoff that will be infiltrated.

Contaminants detected by the LACDPW in statistically meaningful concentrations included nutrients and metals: dissolved phosphorus, total Kjeldahl nitrogen, ammonia-nitrogen, nitrate-nitrogen, nitrite-nitrogen, suspended solids, total phosphorus, total and dissolved copper, total lead, total and dissolved nickel, and total and dissolved zinc. The LACDPW did not test for cyanide, oil and grease, total petroleum hydrocarbons, total phenols, and bacteria (fecal coliform, fecal enterococcus, fecal streptococcus, and total coliform). The LACDPW did not gather enough data above the detection limit to provide event mean concentrations of pesticides and organic chemicals (except Diazinon, which we did not consider since there is very little information available on its reaction in the environment). The full data set is shown in Appendix D.

Based on the availability of significant data, we considered seven contaminants detected by the LACDPW: nitrate-nitrogen, nitrite-nitrogen, dissolved phosphorus, dissolved copper, dissolved lead, dissolved nickel, and dissolved zinc. We did not consider suspended solids, oil and grease, or undissolved forms of phosphorus, copper, lead, nickel, or zinc, as these contaminants are likely to be deposited or filtered out at the surface and would not infiltrate the soil. We examined both the EMCs and seasonal maximum concentrations of these contaminants. Although it is commonly believed that the highest contaminant concentrations are found in stormwater from the first storm of the season, since contaminants have been building up since the last storm of the previous season, this was not necessarily the case.

We compared both mean and maximum stormwater concentrations with drinking water standards, known as Maximum Contaminant Levels (MCLs), set by the EPA and the California Department of Health Services (DHS). MCLs were established as part of the Safe Drinking Water Act (SDWA) to protect public health and are derived from Maximum Contaminant Level Goals (MCLGs), which are non-enforceable goals based on extremely low risk. The EPA has been given the directive to set MCLs as close to MCLGs as possible, but this is often infeasible due to the limits of water treatment technologies and analytical detection limits (Watts, 1998). There are both primary and secondary MCLs; primary MCLs are legally enforceable standards regulating contaminants that can adversely affect public health, while secondary MCLs are non-enforceable guidelines regulating contaminants that may cause cosmetic or aesthetic effects in drinking water (EPA, 2000a). All contaminants obtained from the LACDPW data have primary MCLs, except for zinc, which has only a secondary MCL. We set acceptable concentrations of stormwater contaminants after infiltration as each contaminant's primary MCL or, if no primary MCL had been set, secondary MCL.

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MCLs are used in hazardous waste management as Applicable or Relevant and Appropriate Requirements (ARARs) for groundwater cleanup criteria at Superfund sites. They are also used by many state and local regulatory agencies as de facto remediation standards for contaminated groundwater (Watts, 1998). Since they are often used as cleanup criteria, and since the infiltrated groundwater will be used as drinking water, MCLs are appropriate as a standard for comparison to mean and maximum concentrations of stormwater contaminants. These comparisons are shown in Table 11. Neither the EMCs nor the seasonal maximum concentrations of nutrients and metals found in stormwater by the LACDPW exceed MCLs.

Table 11: Comparison of LACDPW's Stormwater Contaminant EMCs and Seasonal Maximum Concentrations to MCLs

Contaminant	Units	Concentration from Different Land Uses Mean (Maximum)			
		Retail / Commercial	Education	Mixed Residential	MCL
Nitrate-Nitrogen	mg/L	0.59 (0.95)	0.91 (1.55)	0.90 (1.34)	10
Nitrite-Nitrogen	mg/L	0.17 (0.289)	0.06 (0.088)	0.10 (0.514)	1
Dissolved Phosphorus	mg/L	0.40 (0.89)	0.34 (0.218)	0.19 (0.357)	---
Dissolved Copper	µg/L	14.86 (42.5)	20.48 (39.8)	12.82 (22.8)	1300
Dissolved Lead	µg/L	n/m (8)	n/m (0)	n/m (0)	15
Dissolved Nickel	µg/L	n/m (7.2)	n/m (7.2)	n/m (0)	100
Dissolved Zinc	µg/L	182.58 (290)	95.87 (114)	114.94 (157)	5000*

n/m: not meaningful, not enough data above detection limit.
** Secondary MCL.*
Source: Derived from LACDPW, 1999; DHS, 2000; DHS, 2001; and EPA, 2000a.

Since the LACDPW tested for or detected in meaningful concentrations only nutrients and metals (and Diazinon, which we are not considering), we supplemented this Los Angeles-specific data with data for toxic contaminants collected by the EPA. During the National Urban Runoff Program, 121 stormwater samples from 17 cities in the United States were analyzed, and toxic compounds found in greater than 10% of stormwater outfalls were reported. Since the EPA did not find any regional differences in the toxic contaminants detected or in their concentrations (NRC, 1994), this data can be applied to Los Angeles, even though it is not specific to the region. The NURP data provides a range of concentrations of twelve toxic stormwater contaminants found in a significant number of outfalls. To be conservative, we analyzed the removal of the highest concentration of each contaminant.

If an MCL had been set for a contaminant, we compared it to the highest detected concentration of each contaminant. If no MCL existed, we compared the highest detected concentration of a contaminant to its Preliminary Remediation Goal

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(PRG) for Tap Water used by the EPA for planning purposes. PRG concentrations can be used as an initial cleanup goal for contaminated sites, as they provide an estimate of contaminant concentrations that protect human health. Concentrations above these levels do not automatically designate a site as contaminated; however, exceedance of a PRG suggests further evaluation of the potential risks that may be posed by these contaminants (EPA, 2000b). Table 12 shows a comparison of the highest reported concentration of each contaminant to its corresponding MCL or PRG.

Table 12: Comparison of the EPA's Toxic Stormwater Contaminant Concentrations to MCLs and PRGs

Contaminant	Concentration (mg/L)	MCL or PRG
Chlordane	0.01	0.002
Chrysene	0.010	0.0092*
α-Endosulfan	0.0002	0.22*
bis(2-Ethylhexyl) Phthalate	0.062	0.006
Fluoranthene	0.021	1.5*
Lindane	0.0001	0.0002
Methylene Chloride	0.015	0.005
4-Nitrophenol	0.037	---
Pentachlorophenol	0.115	0.001
Phenanthrene	0.010	---
Phenol	0.013	22*
Pyrene	0.016	0.18*

** PRG.*

Source: Derived from NRC, 1994; EPA, 2000a; and EPA, 2000b.

Neither phenanthrene nor 4-nitrophenol has an MCL or PRG. Since we had no standard to which to compare them, we did not analyze them. Of the ten other toxic contaminants detected by the EPA, five were found in a concentration exceeding their corresponding MCL or PRG: chlordane, chrysene, bis(2-ethylhexyl) phthalate, methylene chloride, and pentachlorophenol. Therefore, we analyzed the proportion of these five contaminants removed by the soil at different depths.

REMOVAL OF NUTRIENTS, METALS, AND PATHOGENS

The concentrations of contaminants obtained from LACDPW data did not exceed MCLs; thus, no further quantitative analysis of their removal in the soil was necessary, as they will not be present in groundwater in concentrations above the MCLs. However, it is important to understand the processes affecting these contaminants as they move through the subsurface. Nutrients and metals are both affected by several processes within the vadose zone, as are pathogens. Although Los Angeles County did not test for pathogens, they are a common component of stormwater, so they have also been considered.

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NUTRIENTS

Both nitrogen and phosphorus are cyclic elements that exist in compounds that may be decomposed or synthesized, resulting in a change from the original form (Pitt et al., 1996). If the surface of an infiltration basin is vegetated, the vegetation may take up nutrients from stormwater that infiltrates the root zone. Nutrient leachates usually move vertically through the soil and dilute rapidly downgradient from their source. During percolation through the soil, some nutrients are removed, significantly reducing the nutrient concentrations reaching groundwater. Phosphorus, in the form of soluble orthophosphate, may either precipitate from solution or adsorb onto soil surfaces through phosphorus fixation. This is a two-step reaction during which phosphorus sorbs onto exposed iron, aluminum, or calcium on solid soil surfaces and then converts into mineraloids or minerals (Pitt et al., 1996).

When nitrogen-containing compounds come into contact with soil, the potential exists for nitrate to leach into groundwater, as it is highly soluble and will stay in solution as it infiltrates toward groundwater. Under anaerobic conditions, nitrogen can be removed from the soil by denitrification, the transformation by bacteria of nitrate (NO_3^-) into nitrogen gas (N_2). Denitrifying bacteria consume organic matter while utilizing NO_3^- as their electron acceptor. The process can occur only in the presence of organic matter and these denitrifying bacteria.

METALS

Two main soil parameters that affect the mobility of metals are oxidation-reduction conditions and pH. In general, reduced forms of metals are more mobile than their oxidized counterparts, as most oxidized metals are significantly less soluble than those in lower oxidation states. Acidic environments promote metal mobility, as an increase in pH of the system decreases the solubility of metals and causes them to come out of solution. Undissolved particulate metals that are not dissolved are filtered out at the soil surface. Most metals are not very soluble at typical stormwater pH values and, therefore, are readily filtered by the soil (Pitt et al., 1996).

Dissolved metals will not be filtered at the surface, but may be removed through one of several processes: adsorption, ion exchange, precipitation, solid-state diffusion into soil minerals, complexation, and chelation. Dissolved metal ions are reduced from stormwater mostly by adsorption onto soil in the vadose zone. Partitioning of metals on soil surfaces decreases the aqueous concentration, and, correspondingly, metals' ability to move in the subsurface. Adsorption of metals to soils can occur through physical sorption due to the attraction of long-range Van der Waals forces. Metals have different affinities for solids; that is, they prefer to sorb to some solids much more than they prefer to sorb to others. In addition, sorbents have different affinities for metals; that is, they prefer to sorb to some metals much more

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than they prefer to sorb others. Competition between solids or between metals will affect the overall adsorption ability of various trace metals (Pitt et al., 1996).

Ion exchange is a kind of chemical sorption during which one ion displaces another that was originally present on the exchange surface. Most heavy metals have a positive charge in soil and a subsequent affinity to the negative charge of the soil. Clay surfaces have negative charges that must be balanced by cations in order to maintain the soil's neutral charge. However, cations that are present at any given time may be displaced by other cations that have a higher affinity for the soil surface. Although one metal may displace another on the exchange sites, these sites are always filled to maintain electroneutrality (Watts, 1998).

Another significant mechanism for the removal of metals from water is precipitation, in which the solubility of the metal is exceeded, causing it to come out of solution. This generally occurs at increased pH due to the corresponding decrease in solubility. A process similar to precipitation is co-precipitation, where a metal is enmeshed or sorbed to another species that is undergoing precipitation (Watts, 1998).

Metals may also undergo chelation in the soil. During this process, a bond is formed between a metal ion and an organic molecule. The resulting complex of metal bound to molecule, or chelate, binds the metal ion so firmly that it cannot escape. Metals may also form ligands or complexes with organic or inorganic anions. The ligand often carries a positive or negative charge and may not be highly hydrophobic. A range of sorption effects may be seen with complexes; the complex may have either a higher sorption affinity or a higher solubility than the free metal. Therefore, complexation complicates the partitioning of metals in soils and makes quantification difficult. In addition, organic molecules may be decomposed, freeing the metals and allowing them to react with other compounds that then become immobilized in the soil profile. These immobilization reactions are more pronounced at high pH and in an aerobic environment. Organic complexation of a metal may enhance the metal's ability to move freely through the soil, as organic complexes are either uncharged or negatively charged. Therefore, they are not attracted to negatively charged adsorption or ion exchange sites and are not easily removed from solution (Pitt et al., 1996).

PATHOGENS

Pathogenic microorganisms such as bacteria and viruses will move through soil in the liquid phase until they are filtered, adsorbed onto soil particles, or inactivated. Bacteria may be filtered out in the top layer of soil, while viruses tend to be transported farther into the soil because of their much smaller size. Soil characteristics affect the mobility of microorganisms in soil; fine-textured soils filter microorganisms more effectively than coarser-textured soils. Soils with higher

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organic content also retain microorganisms more effectively. If microorganisms are not filtered at the surface, they may be adsorbed or inactivated within the vadose zone.

Microbial adsorption is promoted by increased cation concentration, decreased pH, and low soluble organic content (Pitt et al., 1996). Cations increase adsorption because they reduce repulsive forces on both pathogens and surfaces of soil particles; however, large volumes of water reduce sorption because water has low conductivity. When water flow rate increases, fewer pathogens adsorb to soils. Low pH increases adsorption, as pathogens become more electropositive than the soil in acidic conditions (NRC, 1994). The presence of soluble organic chemicals reduces virus adsorption because these chemicals compete with viruses for adsorption sites.

Factors that affect the survival rates of bacteria and viruses in soil include pH, temperature, moisture content, dissolved oxygen levels, and organic content. Depending on a microorganism's specific adaptation mechanisms, changes in any one of these parameters may be detrimental to the microorganism, resulting in its inactivation. In general, environments of high acidity and high temperature reduce the survival time of pathogens. Higher dissolved oxygen levels lead to virus inactivation, as oxidation of its capsid destroys the virus. Drier soil conditions also promote inactivation (NRC, 1994); thus, pathogens may be inactivated deliberately by allowing the infiltration basin to dry out intermittently. As it dries, pathogens multiply until their food sources and oxygen are depleted. Once this occurs, they die and further growth is inhibited (O'Hare et al, 1986).

Survival rates of microorganisms can be calculated using a general exponential decay function. For specific sites, a stepwise regression can be performed in order to determine which physical and chemical characteristics of certain soils have the most significant effect on the survival rates of bacteria and viruses (Hurst, 1997).

REMOVAL OF ORGANIC CONTAMINANTS

Five contaminants detected by the EPA were present in stormwater in concentrations above their MCLs or PRGs. We calculated the concentrations of these contaminants as the infiltrated stormwater moves through the vadose zone, using an equation that accounts for adsorption, degradation, and dispersion. The equation does not consider volatilization, which is unnecessary since none of the five contaminants are volatile. It also does not consider remobilization of contaminants once they have been adsorbed, as they will not desorb. The following equation results in the ratio of contaminant at a certain time and distance away from the source to its initial concentration (Watts, 1998):

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$$\frac{C(y,t)}{C_0} = \frac{1}{2}[\exp(A_1) \cdot \text{erfc}(A_2)], \text{ where}$$

C_0 = initial contaminant concentration in water (mg/L)

C(y,t) = contaminant concentration in water (mg/L) at a certain time and depth

$$A_1 = \frac{y}{2D'_y}\left(v'_y - \sqrt{v'^2_y + 4D'_y k'}\right)$$

$$A_2 = \frac{y - t\sqrt{v'^2_y + 4D'_y k'}}{2\sqrt{D'_y t}}$$

$$D'_y = \frac{D_y}{R}$$

$$v'_y = \frac{v_y}{R}$$

$$k' = \frac{k}{R}$$

v_y = pore-water velocity (m/d)

D_y = groundwater dispersion coefficient (m^2)

k = first-order rate constant for contaminant degradation (d^{-1})

R = retardation factor (-)

t = time (d)

y = depth (m).

This equation was designed for use in the saturated zone; however, it can be applied to the unsaturated zone by using water content in place of porosity (Watts, 1998). A primary difference between the saturated zone and the vadose zone is the amount of water present in the pores. When this equation is applied to saturated soil, the value of porosity is used because, under saturated conditions, the pore space is equal to the volume of water within the soil. In unsaturated soil, however, the soil

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moisture content is used because water can travel through only pore spaces that are already wet. If the pore spaces are dry, water will remain to fill them rather than moving through them. Since we studied contaminant transport in the vadose zone, we modified the equation throughout by using soil moisture content in place of porosity.

This equation assumes that the inflow of contaminants through the infiltration basin is continuous throughout the storm season, instead of occurring only during and shortly after discrete precipitation events throughout the season. Although an infiltration basin would repeatedly fill and drain throughout the storm season, this equation does not take that into account and instead assumes that water would be infiltrating continually during each time period modeled. However, given the typical rainfall characteristics in the Los Angeles region, the basin would likely remain dry for extended periods of time.

We examined the removal of the five selected contaminants in the three types of soil that prevail in the San Fernando Valley region: silty clay loam, sandy loam, and clay loam (USDASCS, 1980). These soils differ in their bulk density (see Table 13) and other characteristics that affect their capability for removal of contaminants, as discussed below.

Table 13: Soil Bulk Densities of Three Soil Types

Soil Bulk Density (g/cm^3)		
Silty Clay Loam	**Sandy Loam**	**Clay Loam**
1.27	1.53	1.31

Source: Juma, 1999.

PORE-WATER VELOCITY

Contaminants move through the subsurface by two primary modes: advection and dispersion. Advection refers to the physical movement of fluids in response to gravitational gradients and can be described by pore-water velocity, which is the advective flux or the bulk movement (often considered the average movement) of the water. The pore-water velocity of the infiltrated stormwater must take into account the cross-sectional area of the soil through which it is flowing:

$$v = \frac{-K}{\Theta}, \text{ where}$$

K = unsaturated hydraulic conductivity (m/s), a non-linear function of θ

θ = soil moisture content (cm^3/cm^3).

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Hydraulic conductivity measures the ease with which a fluid passes through a porous media when submitted to a gradient. The greater the hydraulic conductivity, the more readily the fluid passes through the medium. Hydraulic conductivity depends on soil texture and the amount of fluid present in the soil.

Saturated flow occurs when the soil's total pore space is filled with water. Values of saturated hydraulic conductivity have been defined for different soil types and vary by several orders of magnitude, depending on soil type and degree of consolidation. A distinction must be made between hydraulic conductivity under saturated conditions and hydraulic conductivity under unsaturated conditions, as the latter parameter increases non-linearly with increasing soil moisture content until the soil reaches saturation. Therefore, saturated hydraulic conductivity cannot be used to describe water movement under unsaturated conditions.

In order for us to determine the ease with which stormwater will infiltrate the soil under a variety of soil moisture conditions, we calculated the unsaturated hydraulic conductivity for each selected soil type at several different soil moisture contents. Unsaturated hydraulic conductivity may be either measured directly through experimentation or estimated indirectly through prediction from more easily measured data. We used a mathematical model developed by the United States Department of Agriculture (USDA) to estimate unsaturated hydraulic conductivity from empirically determined surrogate soil data such as soil texture data and bulk density (Schaap, 1999).

The model allows prediction of unsaturated hydraulic conductivities from fitted retention parameters developed by van Genuchten (1980) (qtd. in Schaap, 1999): θ_r, θ_s, α, n, and L. Each soil type has a residual water content (θ_r), also called specific retention, which is a measure of the water-retaining capacity of the soil and is expressed quantitatively as a ratio of the total volume of pore space occupied by water that will be retained in these pores against the force of gravity to the total volume of the soil. Saturated water content (θ_s), also referred to as the total porosity, is defined as a ratio of the maximum volume of water occupying pore space to the total volume of the soil. Saturated water content is equivalent to total porosity, which is defined as a ratio of the maximum volume of pore space to the total volume of the soil. The parameters α and n are used to fit the equation, and L is an empirical parameter that represents tortuosity, or the convoluted path that the water must take as it moves through soil pores (Schaap, 1999).

For each soil type, the model uses average values of hydraulic parameters, as shown in Table 14. Values for θ_r, θ_s, α, and n were generated by computing the average values for each soil type based on the number of samples of each (140, 476, and 172 for clay loam, sandy loam, and silty clay loam, respectively). The USDA

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generated values for K_0 and L by inserting each soil type's average values of θ_r, θ_s, α, and n into another model.

Table 14: Class Average Values of Hydraulic Parameters

Soil Type	q_r (cm^3/cm^3)	q_s (cm^3/cm^3)	a (1/cm)	n ---	L ---
Clay Loam	0.079	0.442	0.0158	1.42	-0.763
Sandy Loam	0.039	0.387	0.0267	1.45	-0.861
Silty Clay Loam	0.090	0.482	0.00839	1.52	-0.156

Source: Derived from Schaap, 1999.

In order to calculate unsaturated hydraulic conductivity, we began by determining the relative saturation of the soil, using van Genuchten's water retention function rewritten to yield the relative saturation. Relative saturation, S_e, is defined as the percentage of soil saturation and depends on residual and saturated water contents. Although two different soils may contain the same absolute volume of water, their relative saturation will be different as their residual and saturated water contents are different. The following equation was used to find relative saturation:

$$S_e = \frac{q - q_r}{q_s - q_r}, \text{ where}$$

θ = actual moisture content of the soil.

Once the relative saturation was found, it was used to establish the hydraulic conductivity of the soil at that level of saturation. The USDA model combines the previous van Genuchten equation with Mualem's (1976) (qtd. in Schaap) pore-size distribution model to yield the van Genuchten-Mualem model (van Genuchten, 1980, qtd. in Schaap, 1999):

$$K(S_e) = Ko(Se)^L\{1-[1-S_e^{n/(n-1)}]^{1-1/n}\}^2$$

Soil may hold a volume of water ranging between residual water content and saturated water content. We found hydraulic conductivities for the three prominent San Fernando Valley soils at varying soil moisture contents. If a soil contains only its residual water content, there will be no movement of water through the pores. Therefore, we calculated unsaturated hydraulic conductivities for each soil at a value slightly above (0.01) residual water content. We then calculated hydraulic conductivities at a soil moisture content of 0.1, increasing in intervals of 0.1 until saturation point, at which point we calculated a hydraulic conductivity similar to saturated hydraulic conductivity. These hydraulic conductivities are shown in Table 15 as a function of soil moisture content; graphs of these hydraulic conductivities are shown in Appendix E.

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Table 15 : Unsaturated Hydraulic Conductivities of Three Soil Types as a Function of Soil Moisture Content

Soil Moisture Content (cm^3/cm^3)	Unsaturated Hydraulic Conductivity (cm/d)		
	Clay Loam	Sandy Loam	Silty Clay Loam
0.04	--	9.62E-15	--
0.08	1.92E-16	--	--
0.091	--	--	4.58E-16
0.1	1.64E-08	8.97E-05	2.24E-10
0.2	6.11E-04	2.14E-02	1.92E-04
0.3	2.57E-02	4.16E-01	8.38E-03
0.387	--	1.55E+01	--
0.4	4.10E-01	--	1.05E-01
0.442	5.00E+00	--	--
0.482	--	--	2.23E+00

DISPERSION

Dispersion is the other means by which a contaminant moves in the subsurface. When a dissolved contaminant disperses, it spreads down a concentration gradient, resulting in decreased concentration (Watts, 1998). Spreading occurs due to the water's interaction with soil particles and the difference in tortuosity, or crookedness of the path the water takes as it infiltrates the soil. Dispersion is a linear function of water velocity and distance traveled by the contaminant. The dispersivity coefficient (D_y) is usually estimated by multiplying the distance traveled by the pore-water velocity and by a factor of ten (Gelhar et al., 1992).

RETARDATION FACTOR

A contaminant that moves with water but has the ability to adsorb to soil will move with a different velocity than that of water. This effect is known as retardation and is represented by the retardation factor, which provides an estimate of the velocity of water in the subsurface relative to the velocity of the contaminant. The retardation factor is quantitatively described by the following equation:

$$R = 1 + \frac{r_B \cdot K_d}{\Theta}, \text{ where}$$

ρ_B = soil bulk density (g/cm^3)

K_d = soil distribution coefficient (mL/g)

θ = soil moisture content (cm^3/cm^3).

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The soil distribution coefficient, K_d, represents the degree to which a contaminant will partition between the sorbed and bulk soil-water phases. It is the ratio of mass of contaminant sorbed to soil (mg/g) to mass of contaminant dissolved in water (mg/mL). The most accurate representation of K_d is determined experimentally, as numerous site-specific soil characteristics affect soil sorptivity. Of these, soil organic carbon content has the highest correlation, since hydrophobic contaminants sorb strongly to the non-polar core material of soil organic matter (Watts, 1998). Because organic matter is the most common sorbent, K_d can be estimated mathematically using the following equation, which incorporates the amount of organic matter in soil:

$K_d = K_{oc} \cdot f_{oc}$, where

K_{oc} = soil adsorption coefficient (mL/g)

f_{oc} = fraction of organic content in soil.

The soil adsorption coefficient, K_{oc}, represents the degree to which a contaminant will partition between the organic carbon-sorbed and bulk soil-water phases. It is the ratio of mass of contaminant sorbed to the soil organic carbon (mg/g) to mass of contaminant dissolved in water (mg/mL). K_d is obtained by normalizing K_{oc} by the fraction of organic content in the soil. Although organic fraction varies from soil to soil, we assumed this percentage to be 2% for all soils, as this is a typical value (Watts, 1998).

General soil adsorption coefficients have not been determined for many chemicals, so it was necessary for us to calculate these coefficients. We used regression equations based on the hydrophobicity of each chemical as represented by the octanol-water partition coefficient, K_{ow}. Determined experimentally, K_{ow} is the ratio of the concentration of contaminant in water-saturated *n*-octanol (mg/L) to the concentration in *n*-octanol-saturated water (mg/L). Regression equations, shown in Table 16, were developed for compound classes to relate K_{oc} to K_{ow}. Once K_{oc} was

Table 16: Regression Equations for Determining Soil Adsorption Coefficients

Contaminant	Regression Equation	Log K_{ow}	Log K_{oc}	K_d
Chlordane	Log K_{oc} = 0.52 log K_{ow} + 0.64	6	3.76	11.5
Chrysene	Log K_{oc} = log K_{ow} – 0.21	5.71	5.50	633
bis(2-Ethylhexyl) Phthalate	Log K_{oc} = 0.544 log K_{ow} + 1.377	4.66	3.91	16.3
Methylene Chloride	Log K_{oc} = 0.544 log K_{ow} + 1.377	1.28	2.07	0.237
Pentachlorophenol	Log K_{oc} = 0.544 log K_{ow} + 1.377	4.41	3.78	11.9

Source: Derived from Watts, 1998.

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determined from K_{ow}, we could calculate K_d and therefore the retardation factor. Pore-water velocity, dispersion, and the first-order rate constant were all divided by the retardation factor to normalize for the effects of adsorption.

FIRST-ORDER RATE CONSTANT FOR CONTAMINANT DEGRADATION

A half-life is the time required for 50% of a contaminant to degrade. Contaminants will degrade at different rates under different degradation processes; therefore, half-lives vary depending upon which degradation process is being considered. In general, though, a contaminant is degraded by one dominant process.

For each contaminant, we used the half-life for this most important degradation pathway, which was usually biodegradation. To be conservative, we selected the lowest degradation rate of the range given for the most important pathway (Howard, 1991). The first-order rate constant, shown in Table 17, was determined from these half-lives through a modification of the first-order rate equation:

$C_t = C_0 e^{-kt}$, where

C_0 = initial concentration (mg/L)

C_t = concentration at time t (mg/L)

k = first-order rate constant (1/d)

t = time (d).

Table 17: Half-Lives of Selected Contaminants

Contaminant	Half-Life (d)	Degradation Rate (1/d)
Chlordane	1386	5.00E-4
Chrysene	1000	6.93E-4
bis(2-Ethylhexyl) Phthalate	23	3.02E-2
Methylene Chloride	28	2.48E-2
Pentachlorophenol	178	3.89E-3

Source: Derived from Howard, 1991.

DISTANCE AND TIME

We varied distance and time to provide an overview of resulting contaminant concentrations under different conditions. For each contaminant and each soil type (with five or six different soil moistures ranging from just above residual saturation to saturation), we modeled dissolved contaminant concentration at three different depths and three different time periods. Initial depths modeled were three meters (10 feet), five meters (16 feet), and 15 meters (49 feet).

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Concentrations were modeled for one day, 21 days, and 150 days. This equation assumes that the inflow of contaminants is continuous, as opposed to discrete occurrences throughout the season. Therefore, concentration will increase as time increases because there is more inflow of contaminants from the surface. The times modeled represent the time that water would be held in the basin, infiltrating into the subsurface. One day and 21 days much more accurately represent reasonable durations during which the infiltration basin would hold water inside it. Rainfall in Los Angeles occurs within a timeframe of approximately 150 days (between November and April), so modeling 150 days reflects this time period. However, because stormwater infiltrates between storms, it would not actually be present in the basin for that entire length of time. It would be present in the basin on discrete occasions within the 150-day timeframe, corresponding with rainfall occurrences and a short period of time thereafter. Because stormwater would not be infiltrating the soil at all times during this period, the concentrations for this time period are likely to be over-estimated.

RESULTS

We found that, in most cases, the organic contaminants were sorbed and degraded to the point that they did not exceed drinking water standards at the modeled depths and times. Appendix F contains full data on the concentration of each contaminant in water in each soil type at different soil moisture contents, different times, and different depths. Generally, concentrations exceeded the standards when the soil was saturated (the contaminated water was moving through as fast as possible, so there was less time for contaminants to sorb and degrade) and when time was long (150 days).

There were no exceedances of PRGs. Exceedances of MCLs in water in silty clay loam occurred at all depths at the highest pore-water velocity possible (at saturated soil moisture) (see Table 18). The unsaturated hydraulic conductivity of silty clay loam at a soil moisture content of 0.482 is 2.23 centimeters per day. Two contaminants were present in water at the depths that we studied: methlyene chloride and pentachlorophenol. Both have low K_d values of 0.237 and 11.9, respectively, meaning that they will not sorb easily to soil. As a result, they were present in concentrations exceeding their MCLs, despite having fairly short half-lives of 28 and 178 days, respectively. Given sufficient depth, pentachlorophenol sufficiently sorbed or degraded, although methylene chloride was still present at the greatest depth we studied after 150 days. All other contaminants were present in concentrations below their MCL.

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Table 18: Concentrations of Contaminants in Excess of MCLs in Water in Silty Clay Loam

Contaminant	Depth (m)	Time (d)	Soil Moisture	Concentration (mg/L)	MCL (mg/L)
Methylene Chloride	3	21	0.482	7.22E-3	5.00E-3
Methylene Chloride	3	150	0.482	9.44E-3	5.00E-3
Methylene Chloride	5	21	0.482	5.24E-3	5.00E-3
Methylene Chloride	5	150	0.482	8.14E-3	5.00E-3
Methylene Chloride	15	150	0.482	5.03E-3	5.00E-3
Pentachlorophenol	3	1	0.482	1.77E-3	1.00E-3
Pentachlorophenol	3	21	0.482	2.00E-3	1.00E-3
Pentachlorophenol	3	150	0.482	4.15E-3	1.00E-3

Exceedances of MCLs or PRGs in water in sandy loam occurred at the highest and second-highest pore-water velocities possible (at saturated and almost-saturated soil moistures) (see Table 19). At a soil moisture content of 0.3, the hydraulic conductivity in sandy loam is 0.416 centimeters per day and increases to 15.5 centimeters per day at a soil moisture content of 0.387. More contaminants were present in water in sandy loam than in silty clay loam due to the much higher hydraulic conductivity of sandy loam at saturation, which allows water and the contaminants it contains to infiltrate more rapidly. Both methylene chloride and pentachlorophenol were present on more occasions than in silty clay loam, because they moved more rapidly though sandy loam and had less chance to sorb or degrade. Bis(2-ethyl-hexyl) phthalate was also present at a shallow depth due to the soil's high hydraulic conductivity, despite its short half-life of 23 days.

Table 19: Concentrations of Contaminants in Excess of MCLs in Water in Sandy Loam

Contaminant	Depth (m)	Time (d)	Soil Moisture	Concentration (mg/L)	MCL (mg/L)
bis(2-Ethylhexyl) phthalate	3	150	0.387	9.30E-3	6.00E-3
Methylene Chloride	3	150	0.3	5.31E-3	5.00E-3
Methylene Chloride	3	21	0.387	1.28E-2	5.00E-3
Methylene Chloride	3	150	0.387	1.30E-2	5.00E-3
Methylene Chloride	5	21	0.387	1.17E-2	5.00E-3
Methylene Chloride	5	150	0.387	1.23E-2	5.00E-3
Methylene Chloride	15	21	0.387	7.83E-3	5.00E-3
Methylene Chloride	15	150	0.387	1.03E-2	5.00E-3
Pentachlorophenol	3	1	0.387	5.85E-3	1.00E-3
Pentachlorophenol	3	21	0.387	7.23E-3	1.00E-3
Pentachlorophenol	3	150	0.387	2.33E-2	1.00E-3
Pentachlorophenol	5	1	0.387	1.50E-3	1.00E-3
Pentachlorophenol	5	21	0.387	1.96E-3	1.00E-3
Pentachlorophenol	5	150	0.387	8.94E-3	1.00E-3

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Exceedances of MCLs or PRGs in water in clay loam occurred at the highest and second-highest pore-water velocities possible (at saturated and almost-saturated soil moistures) (see Table 20). The hydraulic conductivity of clay loam is 0.410 centimeters per day at a soil moisture content of 0.4 and 5.00 centimeters per day at a soil moisture content of 0.442. Bis(2-ethylhexyl) phthalate was present at the shallowest depth at the longest time, although its short half-life prevented any other occurrences. Methylene chloride was present at shallower depths at both short and long times, as well as at the deepest depth at 21 and 150 days, due to its small K_d and lack of affinity for adsorption. Pentachlorophenol was present at the shallowest depth at all times, although it was not present at the deepest depth, due to its fairly short half-life.

Table 20: Concentrations of Contaminants in Excess of MCLs in Water in Clay Loam

Contaminant	Depth (m)	Time (d)	Soil Moisture	Concentration (mg/L)	MCL (mg/L)
Methylene Chloride	3	150	0.4	5.06E-3	5.00E-3
Methylene Chloride	3	21	0.442	1.03E-2	5.00E-3
Methylene Chloride	3	150	0.442	1.12E-2	5.00E-3
Methylene Chloride	5	21	0.442	6.08E-3	5.00E-3
Methylene Chloride	5	150	0.442	1.02E-2	5.00E-3
Methylene Chloride	15	150	0.442	7.46E-3	5.00E-3
Pentachlorophenol	3	1	0.442	3.11E-3	1.00E-3
Pentachlorophenol	3	21	0.442	3.60E-3	1.00E-3
Pentachlorophenol	3	150	0.442	9.03E-3	1.00E-3
Pentachlorophenol	5	150	0.442	1.92E-3	1.00E-3

Chrysene was not present above its PRG in water in any soils at any soil moisture contents, depths, or times. Although it has a relatively long half-life (1000 days), it has an extremely high K_d (632.5) and, therefore will sorb rather than move through the soil.

Methylene chloride was the only contaminant present at a depth of 15 meters. Therefore, we calculated the potential for removal of this contaminant in three soil types at depths of 20 meters, 30 meters, and 40 meters. Complete results are shown in Appendix G. In silty clay loam, the MCL for methylene chloride was not exceeded at these depths. However, in water in sandy loam at all three of these depths with saturated soil, methylene chloride was present at these depths at levels above the MCL at times of 21 days and 150 days (see Table 21). This is because the contaminant has such a low K_d value that it will not sorb easily. In fact, because methylene chloride does not tend to sorb, and because sandy loam is such a permeable soil, it would take a depth of 110 meters to reduce methylene chloride to the MCL after a time period of 150 days when the soil is saturated.

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Table 21: Concentrations of Methylene Chloride in Excess of MCLs in Water in Sandy Loam

Contaminant	Depth (m)	Time (d)	Soil Moisture	Concentration (mg/L)	MCL (mg/L)
Methylene Chloride	20	21	0.387	7.46E-3	5.00E-3
Methylene Chloride	20	150	0.387	9.64E-3	5.00E-3
Methylene Chloride	30	21	0.387	8.08E-3	5.00E-3
Methylene Chloride	30	150	0.387	8.64E-3	5.00E-3
Methylene Chloride	40	150	0.387	7.88E-3	5.00E-3

In water in clay loam at depths of 20 meters and 30 meters with saturated soil, methylene chloride was present at levels above the MCL at a time of 150 days (see Table 22). Once depth to groundwater has increased to 40 meters, however, methylene chloride was no longer present in water in saturated soils.

Table 22: Concentrations of Methylene Chloride in Excess of MCLs in Water in Clay Loam

Contaminant	Depth (m)	Time (d)	Soil Moisture	Concentration (mg/L)	MCL (mg/L)
Methylene Chloride	20	150	0.442	6.64E-3	5.00E-3
Methylene Chloride	30	150	0.442	5.47E-3	5.00E-3

LIMITATIONS

In addition to previously stated assumptions, there are several limitations to our calculations. First, our equation considered only organic contaminants and only sorption and degradation as contaminant removal processes. Therefore, it cannot be used to model the removal of other contaminants, such as metals, that undergo other processes such as chelation and complexation. In addition, although pathogens may be sorbed and degraded, they cannot be modeled in this equation, as it does not account for death and growth rates and other influencing factors.

Second, we assumed that the soil horizon is homogenous and has the same characteristics and properties throughout. In reality, the soil horizon is heterogeneous, with each layer showing variability in properties that affect contaminant removal. The composition of the gas, solid, and solution phases of the soil in the vadose zone is dynamic, causing spatial and temporal variations in the chemical and biological reactions that transform chemicals. Soil heterogeneity is due to formation processes, tectonic activity, weathering, and chemical and biological processes. It is not appropriate to account for this heterogeneity by using average values for important properties. If the stratigraphy of heterogenous soil is known, this equation could be applied by taking a step-by-step process, changing the appropriate values after calculating the contaminant concentration in each stratum. We assumed that soil moisture content, and therefore unsaturated hydraulic

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conductivity and pore-water velocity, were constant throughout the soil under each scenario; this is not likely to be the case. Again, more accurate predictions could be made by taking a step-by-step approach after dividing the vadose zone into zones of different soil moisture content, an effort that is made more complicated by the dynamic nature of soil moisture.

Third, we assumed that all of the movement of water is within soil pores. This may not be true, however, especially in the upper few feet of the soil, which may contain macropores or larger channels such as root paths or holes created by biota (e.g., worm holes). If macropores or large channels are present, water could then bypass the soil pores and travel rapidly through the macropores instead, significantly reducing the time that the water is held within the soil matrix. This could lead to excessive concentrations of contaminants in groundwater, as rapid infiltration provides less time for adsorption and biodegradation. Since our equation did not make allowances for this rapid travel, actual contaminant concentrations could be much different if water moves through a larger flowpath.

Fourth, we addressed the effects of the soil on each contaminant individually. We could not determine the effects of the soil on the contaminants together, as the equation did not account for the simultaneous presence of another contaminant. It is possible that each additional contaminant may have a negative effect on the removal of another, causing concentrations to be much larger than predicted. It is also possible that contaminants may have positive interactive effects, or none at all. We did not have the capability to examine any interactive effects. In addition, we did not consider the formation and subsequent removal of degradation byproducts that could form when the main contaminants were broken down.

Fifth, we did not account for the change in the soil's removal capability over time, as these contaminants will accumulate in the soil. It is possible that, after receiving a certain amount of stormwater contaminants, the soil will lose its capacity to adsorb. Also, we did not account for differences in removal efficiency predicted by the equation and removal efficiency observed in the natural environment. Because actual infiltration basins are in a natural setting, the processes by which removal occurs are not completely efficient. Not all contaminants will be removed or degraded to the extent predicted by the equation.

CONCLUSION

In silty clay loam, under all times and soil moisture contents studied, bis(2-ethylhexyl) phthalate, chlordane, and chrysene were adequately removed in a soil depth of three meters (10 feet), while pentachlorophenol required five meters (16 feet) and methylene chloride required 20 meters (66 feet). In sandy loam, chlordane and chrysene were sufficiently reduced in a soil depth of three meters (10 feet); bis(2-ethylhexyl) phthalate in a depth of five meters (16 feet); pentachlorophenol in a

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depth of fifteen meters (50 feet); and methylene chloride in a depth of 110 meters (361 feet). In day loam, a soil depth of three meters (10 feet) was required to reduce bis(2-ethylhexyl) phthalate, chlordane, and chrysene to necessary levels; a depth of fifteen meters (50 feet) was required for pentachlorophenol; and a depth of 40 meters (131 feet) for methylene chloride.

Based on our assumptions and these calculations, we conclude that infiltration of stormwater containing the contaminants that we studied would not contaminate groundwater given a certain depth to the aquifer. This depth varies depending on soil type and soil moisture content. Although we analyzed the decrease in contaminant concentrations using various soil moisture contents and times, the most conservative assumption was that the soil is saturated, as water infiltrating the subsurface moves most rapidly through saturated soil, and that time is 150 days, as that is the longest time period during which there could be substantial rainfall. Therefore, a minimum depth to groundwater was set equal to the depth required to adequately reduce contaminant concentrations after a time period of 150 days when the soil is saturated.

In all three soils, methylene chloride was the contaminant that required the greatest depth for adequate reduction in concentration. In silty clay loam, under saturated conditions and with a time period of 150 days, this depth was 20 meters (66 feet); in sandy loam, 110 meters (361 feet); and in clay loam, 40 meters (131 feet). These depths are likely to be over-estimated because it is improbable that the soil will be saturated throughout the entire soil column during the entire 150-day time period. We conclude that, given the presence of these stormwater contaminants and concentrations, an infiltration basin could be placed in any of the three predominant soil types in the San Fernando Valley provided that these depths to groundwater are met.

Once we determined the conditions under which groundwater would not be contaminated by stormwater infiltration, we analyzed the costs and benefits of using infiltration basins to recharge groundwater. Our cost-effectiveness analysis is presented in the next section.

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COST-EFFECTIVENESS OF INFILTRATION BASINS

INTRODUCTION

We have ascertained that the volume of water available for capture from a five-acre drainage area ranges between 0.90 AF per year and 1.87 AF per year, depending on infiltration basin size and the infiltration rate of the soil. We have also concluded that given sufficient depth to groundwater, contaminant concentrations will be reduced to acceptable levels (MCLs or PRGs) as they move through the soil. However, the feasibility of using an infiltration basin to capture stormwater runoff for groundwater recharge depends not only on the volume of water captured by an infiltration basin and the proportion of contaminants removed, but also on the project's cost-effectiveness.

A project is determined to be cost-effective if its expected value exceeds its costs. In this case, that occurs if the costs of an infiltration basin are less than the current value of drinking water. Costs include land acquisition, construction, operation and maintenance, and groundwater pumping, treatment, and distribution. The costs of construction and operation and maintenance are related to the size of the infiltration basin; therefore, they vary with basin size. The costs of pumping, treating, and distributing groundwater are dependent upon the volume of infiltrated water, so they also vary with basin size.

We calculated the cost per AF of infiltrated water associated with each of the four basin sizes, 0.1 acre and 0.5 acre with depths of two feet and three feet. We then compared this cost to the current price of the next alternative source, or marginal source, of drinking water. Should the City's current drinking water supplies become inadequate, its next option is to import additional water from MWD, which is available at a price of $431/AF (Mackowski, 2001).

It should be noted that the costs presented here are general, but adequate for planning purposes. The costs do not account for any contingencies involved in planning, design, and administration, nor do they include legal and permitting fees, costs of geotechnical testing, or engineering expenses.

COSTS OF INFILTRATION BASINS

Land acquisition costs can vary greatly from site to site, making it perhaps the greatest variable influencing overall costs (EPA, 1999b). The price of land in the San Fernando Valley varies with the total square footage[4] of the lot. For example,

[4] One acre equals 43,560 square feet.

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lots that total around 5,000 square feet cost about $20 per square foot. Lots greater than 10,000 square feet cost between $12 and $15 per square foot (County of Los Angeles, Office of the Assessor, 2001).

The actual area of land necessary to construct an infiltration basin is greater than the size of the basin itself, because additional land around the perimeter of the basin is needed. Therefore, we added 20% to the surface area of each basin to determine how much land must be purchased. The 0.1-acre basin has a surface area of 4,356 square feet; increasing the surface area by 20% yields a size of 5,227 square feet. The 0.5-acre basin has a surface area of 21,780 square feet, and increasing this surface area by 20% results in a necessary purchase of 26,136 square feet. Because the 0.1-acre basin has an area less than 10,000 square feet, we used $20 per square foot to calculate the cost of land. We used a conservative value of $15 per square foot to calculate the cost of land for the 0.5-acre basin, since it is larger than 10,000 square feet. Given these numbers, the total land cost for the 0.1-acre basin is $104,560, and the total land cost for the 0.5-acre basin is $326,700.

Using the following equation (Schueler, 1987), we determined the costs of constructing the four sizes of infiltration basins, based on their surface areas and depths:

Cost (in 1985 dollars) = $10.7 \cdot V^{0.69}$, where

V = total basin volume (cubic feet).

This equation was developed over a decade ago, and there have been few recent studies on construction costs. However, it was cited as recently as 1999 in an EPA (1999b) report. Since the costs used to develop the equation were in 1985 dollars, we adjusted our results for inflation to 2001 dollars (Bureau of Labor Statistics, 2001).

Because infiltration basins exhibit economies of scale with regard to construction costs, the above equation is applicable to infiltration basins with a volume larger than 10,000 cubic feet in size (Schueler, 1987). Three of the basin sizes had volumes larger than this; the 0.1-acre basin with a depth of two feet has a smaller volume of 7,841 cubic feet, given on our prior assumption that there is a ratio of 1:0.8 between the surface area and the bottom area of the basin. Despite this smaller size, we applied the equation to this basin for purposes of consistency.

The maintenance of infiltration basins is essential for effective operation and typically includes inspection, debris and litter removal, erosion control, and sediment removal. Operation and maintenance costs have been estimated at 3-5% of the basin's initial construction costs (excluding land acquisition) (Schueler, 1987). Since construction costs depend on basin size, operation and maintenance costs also

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depend on basin size. To be conservative, we assumed that these costs would be 5% of construction costs.

It is also necessary to include the costs of pumping the infiltrated stormwater once it has reached the aquifer, as it must be retrieved from the ground before it has value as drinking water. Additionally, we included the costs of treatment and distribution of groundwater. Despite our previous findings that drinking water MCLs could be met when infiltration basins are placed in areas that have sufficient depth to groundwater, it is necessary that groundwater undergo the treatment process before it is distributed. Together, the costs of pumping, treatment, and distribution total around $100 per AF in current dollar values (Mackowski, 2000). We assumed that existing groundwater pumping facilities would be used, so it is not necessary to consider any additional capital costs for constructing this infrastructure. In addition, we assumed that all water captured by infiltration basins would infiltrate into groundwater and not evaporate or move laterally away from the groundwater basin. The total costs for each basin size are shown in Table 23.

Table 23: Costs of Infiltration Basins

Basin Size (acre)	**0.1**		**0.5**	
Type of Cost	**Depth (ft)**		**Depth (ft)**	
	2	**3**	**2**	**3**
Land Costs ($)	104,560	104,560	326,700	326,700
Construction Costs ($)	9,110	12,052	27,660	36,589
Operation and Maintenance Costs ($/yr)	456	603	1,383	1,829
Pumping, Treatment, and Distribution Costs ($/AF)	100	100	100	100
Total	114,226	117,315	355,843	365,218

VALUE OF INFILTRATED WATER

The value of the additional drinking water supplies that would result from this project is derived from the value of the next additional source, or marginal source, of drinking water for Los Angeles. By 2015, the City of Los Angeles is predicted to have increased its proportion of water delivered by MWD from the current 20% during normal water years to 45% (MWD, 2001). Since water delivered by MWD is the next available source, its value is a good proxy for the value of the recharged water resulting from this project. The current value of an additional AF of treated water from MWD is $431 (MWD, 2001), which includes the cost of treating the water to meet MCLs. Therefore, this drinking water source is comparable to pumped, treated groundwater that results from infiltrated stormwater.

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COST PER ACRE-FOOT OF INFILTRATED WATER

We calculated the cost per AF of water resulting from each infiltration basin over its estimated lifetime to determine how this management alternative would be valued today, assuming an operation period of 25 years. We expected that land acquisition and construction costs were incurred at the beginning of the project (i.e., the beginning of year 0) and that pumping of groundwater first happened at the beginning of year 1. Even though it would take time for infiltrated stormwater to actually recharge the aquifer, pumping could occur now in anticipation of future recharge.

We also anticipated that at the end of 25 years, the land could be returned to its previous condition; that is, the land has a salvage value equal to its original purchase price. To obtain in today's dollars the value of the land 25 years in the future (i.e., the salvage value), the purchase price was discounted over this time period using a real discount rate of 4.2% (The White House Office of Management and Budget, 2000), which accounts for any effects of inflation. Because land acquisition and construction costs are one-time costs occurring at the beginning of the project, these costs were added upfront to the present value of the salvaged land to give the present value of the capital (see Table 24).

Table 24: Cost of Land, Salvage Value of Land, and Present Value of Capital

Basin Size (acre)	Cost of Land ($)	Salvage Value ($)	Present Value ($)	
			Basin Depth (ft)	
			2	3
0.1	104,560	37,383	76,287	79,229
0.5	326,700	116,804	237,556	246,485

Note: Values are in 2001 dollars.

The results of the volume analysis discussed earlier for each basin scenario yielded an amount of water in AF per year; however, capital costs are in dollars and operation and maintenance costs are in dollars per year. Since our objective was to compare the cost per AF of water to the current value of water provided by MWD (in dollars per AF), we annualized the present value of the capital to provide a value in dollars per year. We used a 25-year annuity factor for a 4% interest rate (closest to the 4.2% rate we used to discount the salvage value above), which is 15.62 (Brealy et al, 1998). We then added the costs of operation and maintenance and groundwater pumping, treatment, and distribution (adjusted for number of AF per year) to the annualized present value of the capital to yield the total cost of the project per year. Next, we divided this by the volume of water infiltrated each year to provide the cost of the project in dollars per AF of infiltrated water, which is shown in Table 25.

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Table 25: Cost Per Acre-Foot of Infiltrated Water Resulting From Each Basin Scenario

Basin Size (acre)	0.1		0.5	
Infiltration Rate (in/hr)	Basin Depth (ft)		Basin Depth (ft)	
	2	3	2	3
0.5	$6,033	$5,259	$9,803	$9,517
1.0	$5,662	$5,035	$9,690	$9,517
2.0	$5,662	$4,910	$8,972	$9,517

It is apparent from these results that the cost per AF of water, given the parameters identified in our study, is much greater than the value of the water produced ($431/AF). Thus, stormwater infiltration is not a cost-effective method of increasing drinking water supplies in Los Angeles.

However, it is possible to reduce or eliminate the cost of land acquisition (and therefore the overall cost of infiltrated water) by designing the infiltration basin as a multi-use facility incorporated into existing open space. As such, it can serve multiple functions, including both recharge and recreation (see Figure 16). We have included a cost analysis of this situation to illustrate the difference in the cost of infiltrated water when land is not considered. Our study does not fully explore the feasibility of multiple-use infiltration basins in the San Fernando Valley, but it is nonetheless useful to present the results, given that land acquisition is the most expensive and most variable cost.

Without land acquisition costs, it was necessary to annualize only the upfront construction costs, using the same annuity factor we used earlier (15.62). Then, as before, we added the operation and maintenance costs and pumping costs to this annualized value and divided by the number of acre-feet of water produced per year. This greatly reduced the cost per AF of water from this recharge method, as shown in Table 26. Nonetheless, even without the costs of land acquisition, the cost per AF of infiltrated water greatly exceeds the value of water.

Table 26: Cost Per Acre-Foot of Infiltrated Water Resulting From Each Basin Scenario (Excluding Land Acquisition)

Basin Size (acre)	0.1		0.5	
Infiltration Rate (in/hr)	Basin Depth (ft)		Basin Depth (ft)	
	2	3	2	3
0.5	$1,255	$1,350	$1,944	$2,311
1.0	$1,183	$1,295	$1,923	$2,311
2.0	$1,183	$1,265	$1,787	$2,311

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Figure 16: Multiple-Purpose Infiltration Basin

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CONCLUSION

Our analysis shows that infiltration basins of the sizes we considered are not a cost-effective option for the recharge of groundwater with stormwater runoff, based on our assumptions about the costs of land acquisition, construction, and operation and maintenance. Even without the large capital cost of land, the volume of water that can be captured with these basins and the current value of water are not great enough to justify such a project. Water would have to be valued at a minimum of $1,183 per AF to make even one of the presented scenarios cost-effective.

Our cost-effectiveness analysis focused on the value of stormwater infiltration solely as a method of augmenting drinking water supplies. However, stormwater regulations are becoming more stringent, and municipalities are being forced to better manage their stormwater by methods such as infiltration basins. If the value of infiltration as a stormwater management strategy is taken into consideration in a cost-effectiveness analysis, infiltration basins may become cost-effective.

For example, infiltration basins that capture stormwater runoff play a role in flood control by limiting the volume and force of runoff, thereby reducing damage caused by flooding. Also, capturing and infiltrating stormwater runoff reduces the amount of contaminants entering streams and the ocean and lessens the impacts on these aquatic ecosystems. Consequently, infiltration basins may provide benefits in terms of reduced costs of compliance with stormwater permits or TMDLs. In addition, bacteria associated with stormwater runoff have resulted in beach closures due to human health risks. By retaining and infiltrating stormwater, infiltration basins reduce the amount of runoff reaching the ocean and may reduce the risk of beach closures.

It may also be possible to transfer the costs associated with infiltration basins from public agencies to private developers, who are required by existing regulations to mitigate stormwater runoff from developments. Pursuant to provisions within the NPDES permit under the Clean Water Act, Los Angeles County submitted a Standard Urban Stormwater Mitigation Plan (SUSMP) that addresses stormwater contamination from new developments and redevelopment by the private sector (LARWQCB, 2000). The SUSMP designates best management practices (BMPs) that must be used in seven categories of development projects, including: 100-plus home subdivisions; 10-plus home subdivisions; 100,000-plus square foot commercial developments; and hillside single-family dwellings. Developers are responsible for mitigating stormwater runoff either through treatment or infiltration of stormwater and for all costs of complying with the SUSMP. Therefore, groundwater recharge can potentially occur through infiltration basins paid for and constructed by a

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developer in order to comply with the SUSMP, rather than by the implementing public agency.

The costs in this situation cannot be ignored just because they are not borne by a public agency. Nonetheless, agencies can take advantage of the groundwater recharge that may occur through the requirement that developers mitigate stormwater runoff through the SUSMP. In addition, the accompanying benefits of this method as a stormwater management strategy could be quantified and incorporated into a cost-effectiveness analysis, thus increasing the cost-effectiveness of the infiltration basins. However, the analysis of these considerations was beyond the scope of this project.

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CONCLUSIONS AND RECOMMENDATIONS

Our study explored the use of infiltration basins that capture urban stormwater runoff as a means of increasing the reliability of local groundwater resources used for drinking water in the San Fernando Valley of Los Angeles County. We first determined the volume of runoff that could be captured by infiltration basins using a calculation based on empirical studies. Model-based predictions were then used to evaluate the depth of soil necessary to sufficiently reduce stormwater contaminants in three different soil types. Finally, we analyzed the cost-effectiveness of this management option by comparing costs of infiltration basins with the value of recharged groundwater, equivalent to the value of the marginal source of drinking water.

Our analysis established that an infiltration basin with a surface area of 0.1 acre and depths of two feet or three feet could capture from 0.90 to 01.18 AF per year, depending on the infiltration rate of the underlying soil. An infiltration basin with a surface area of 0.5 acre and depths of two feet or three feet can capture from 1.71 to 1.87 AF per year, depending on infiltration rate. Volumes were assumed to be captured from a five-acre drainage area with land use distribution representative of the San Fernando Valley. Our results indicated that smaller basins capture stormwater runoff more efficiently than larger basins, which is significant in the overall evaluation of this strategy, since the smaller the basin, the easier it is to place in an urban area.

In order for stormwater contaminants to be adequately reduced from typical concentrations to the Maximum Contaminant Levels set for drinking water, we found that necessary depths to groundwater are 66 feet in silty clay loam, 361 feet in sandy loam, and 131 feet in clay loam. These depths are based on the presence of methylene chloride, a contaminant that does not adsorb easily and therefore requires a greater depth of soil for its removal. All other contaminants were removed by a depth of 50 feet.

We also determined that infiltration basins are not a cost-effective method of increasing drinking water supplies. The costs associated with land acquisition, construction, and operation and maintenance of infiltration basins far exceed the value of the drinking water they would provide. In order for any of the four basin sizes that we analyzed to be cost-effective, water must be valued at greater than $1,183 per AF. However, our cost-effectiveness analysis focused on the value of stormwater infiltration solely as a method of augmenting drinking water supplies. Infiltration basins also have value as a stormwater management strategy, the benefits of which may be quantified and incorporated into a cost-effectiveness analysis, thereby increasing the cost-effectiveness of such a project. The analysis of these considerations was beyond the scope of this project.

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We also did not consider certain aspects that must be examined by agencies considering this management option. For example, bacteria in stormwater runoff may pose a health risk if allowed to infiltrate into groundwater used for drinking water. Contaminants may accumulate both on the surface of the infiltration basin and within the underlying soil. In addition, public reaction to this type of project may not be positive. These aspects were also beyond the scope of our project, and we recommend that they be studied.

In addition, we recommend that stormwater runoff in Los Angeles be sampled and monitored more thoroughly to provide a more accurate depiction of the types and amounts of contaminants. If infiltration basins are implemented for groundwater recharge, we also recommend monitoring for the presence of contaminants in groundwater and the accumulation of contaminants in the surface and underlying soils of the basin.

The analyses, discussions, results, and recommendations presented here will be beneficial to agencies and individuals considering the use of stormwater infiltration basins to recharge groundwater used for drinking water. Our study also provides a basis of discussion for those interested in stormwater infiltration as a stormwater management strategy.

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APPENDICES

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APPENDIX A: WATER IMPORTED INTO ULARA (1969-1990)

Year	Imported Water (AF)		
	LA-Owens	MWD	Combined
1969	335,235	28,500	363,735
1970	377,320	27,623	404,943
1971	478,535	24,866	503,401
1972	452,867	28,929	481,796
1973	447,034	28,344	475,378
1974	435,011	22,080	457,091
1975	433,683	22,940	456,623
1976	443,778	54,446	498,224
1977	296,101	49,468	345,569
1978	399,797	48,142	447,939
1979	464,701	51,089	515,790
1980	470,224	57,508	527,732
1981	458,178	56,170	514,348
1982	461,579	59,017	520,596
1983	444,017	59,761	503,778
1984	489,717	65,758	555,475
1985	584,835	64,809	649,644
1986	584,660	64,664	649,324
1987	589,945	68,888	658,663
1988	562,644	76,972	639,616
1989	554,502	81,517	636,019
1990	142,707	470,202	612,909

Source: Blomquist, 1992.

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APPENDIX B: ULARA GROUNDWATER EXTRACTIONS (1969-1990)

Year	Groundwater Extractions (AF)	
	San Fernando	ULARA Total
1969	91,785	104,070
1970	96,290	109,618
1971	85,936	96,556
1972	91,376	104,181
1973	88,770	100,906
1974	92,867	105,208
1975	100,373	111,966
1976	108,457	119,975
1977	129,439	140,019
1978	70,543	81,398
1979	64,645	75,483
1980	63,337	72,925
1981	97,789	109,730
1982	87,675	100,237
1983	71,312	82,855
1984	119,560	132,299
1985	105,782	118,151
1986	90,833	102,752
1987	96,604	107,788
1988	109,624	120,100
1989	132,581	142,559
1990	86,898	96,689

Source: Blomquist, 1992.

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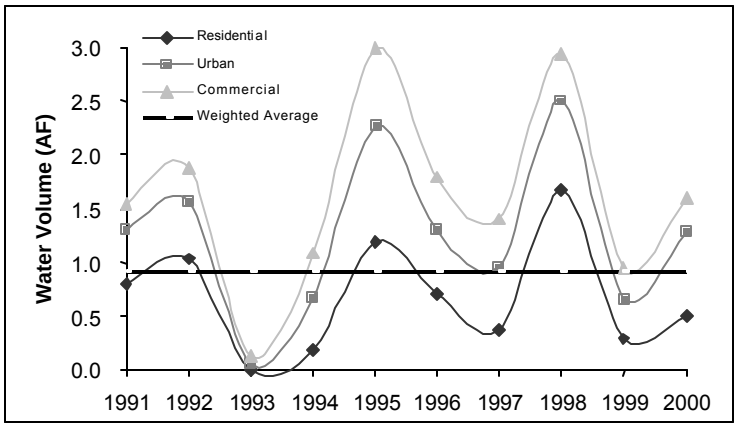
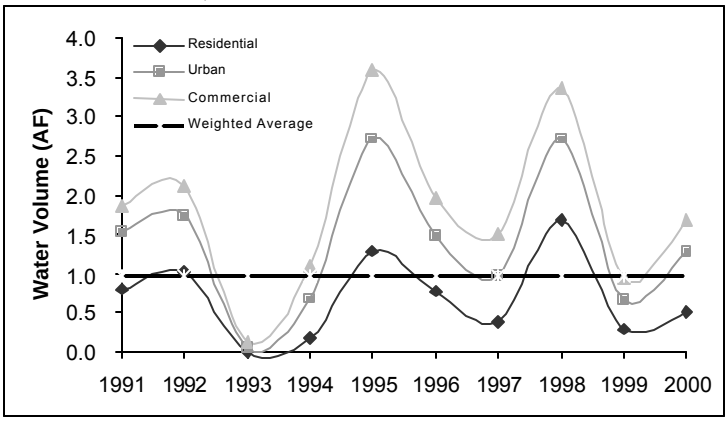
APPENDIX C: VOLUME OF WATER CAPTURED PER YEAR

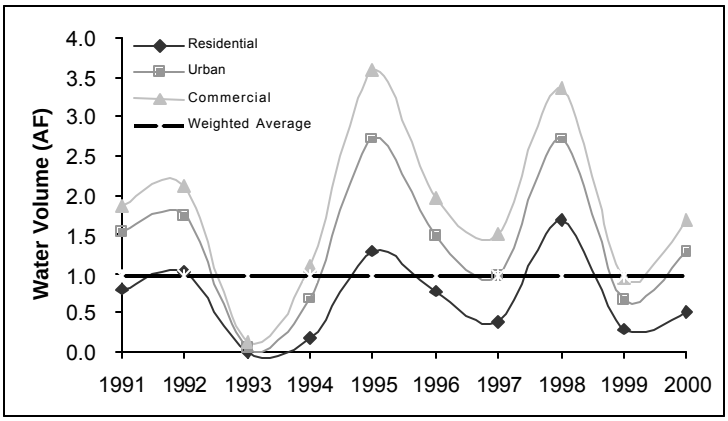
Volume of Water Captured Per Year In A 0.1-Acre Basin
DEPTH= 2 FEET, INFILTRATION RATE =0.5 INCH/HOUR



DEPTH = 2 FEET, INFILTRATION RATE =1.0 INCH/HOUR

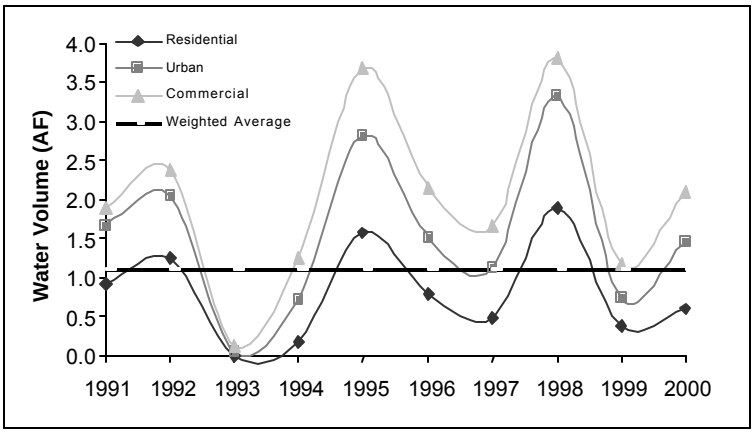


DEPTH = 2 FEET, INFILTRATION RATE =2.0 INCHES/HOUR

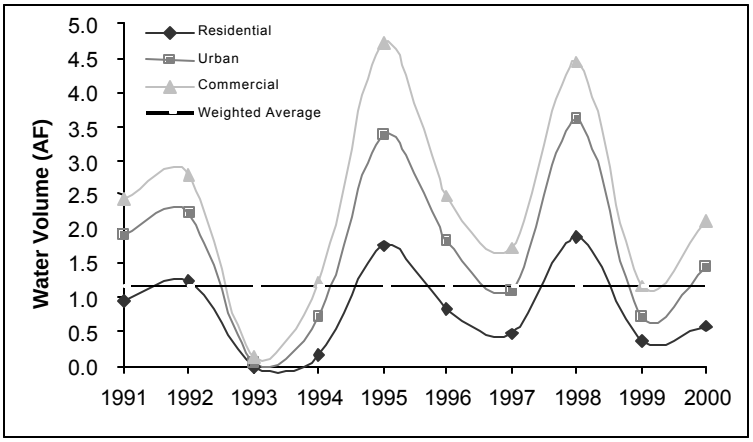


SARB_004329

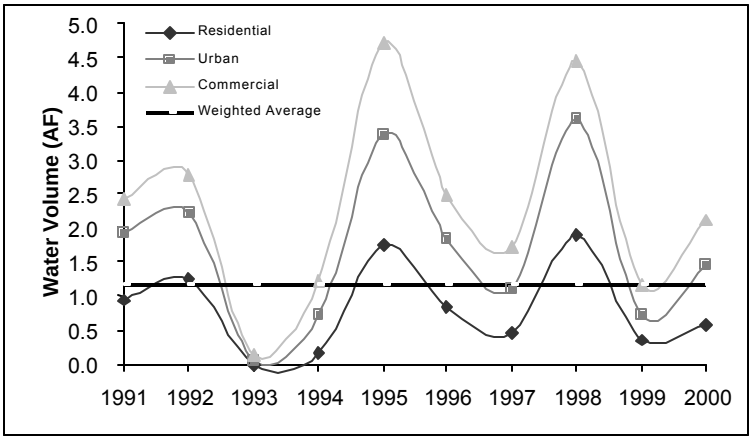
DEPTH = 3 FEET, INFILTRATION RATE =0.5 INCH/HOUR



DEPTH = 3 FEET, INFILTRATION RATE = 1.0 INCH/HOUR

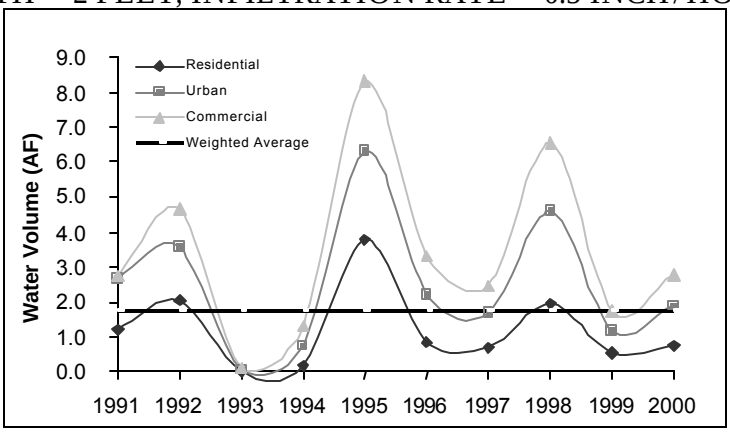


DEPTH = 3 FEET, INFILTRATION RATE = 2.0 INCHES/HOUR

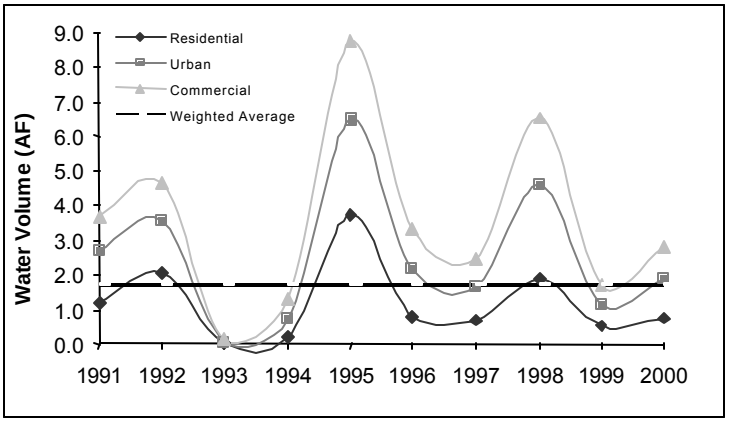


Volume of Water Captured Per Year In A 0.5-Acre Basin

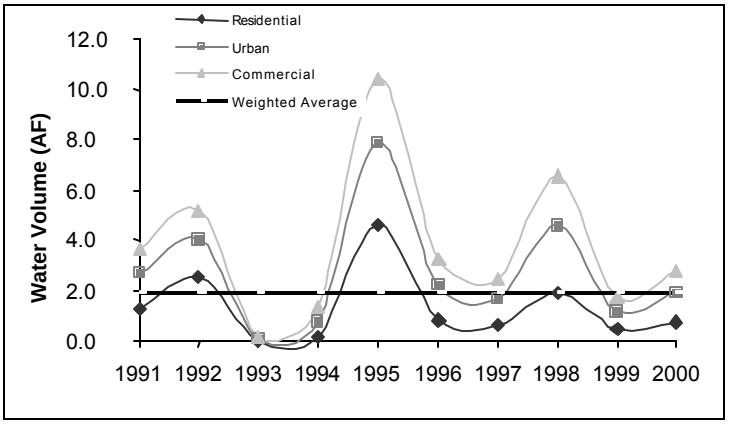
DEPTH = 2 FEET, INFILTRATION RATE = 0.5 INCH/HOUR



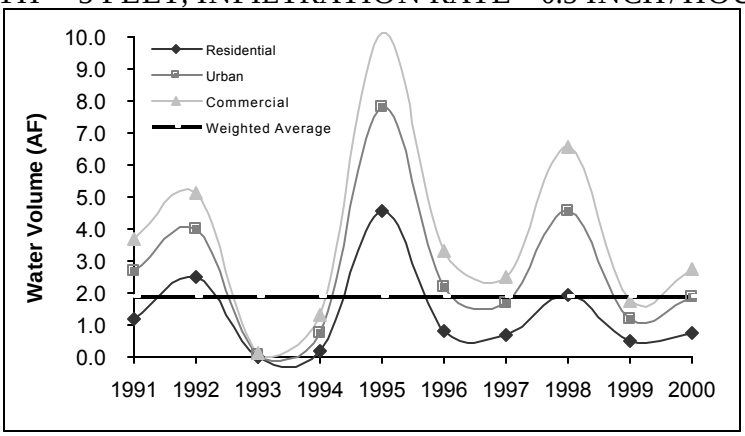
DEPTH= 2 FEET INFILTRATION RATE =1.0 INCH/HOUR



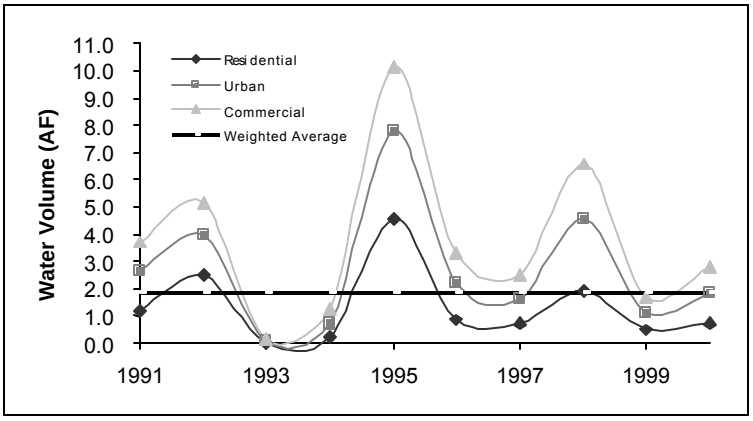
DEPTH = 2 FEET INFILTRATION RATE =2.0 INCHES/HOUR



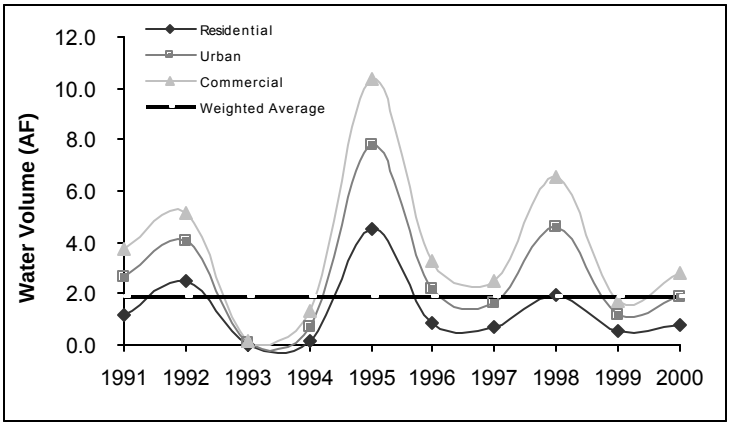
DEPTH = 3 FEET, INFILTRATION RATE =0.5 INCH/HOUR



DEPTH = 3 FEET, INFILTRATION RATE =1.0 INCH/HOUR



DEPTH = 3 FEET, INFILTRATION RATE =2.0 INCHES/HOUR



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APPENDIX D: LOS ANGELES COUNTY STORMWATER DATA

Table 4-15e

Seasonal EMCs
1998-99 Storm Season

GROUP	Constituent	Unit	High Density Residential	Light Industrial	Vacant	Retail/ Commercial	Multi-family Residential	Transportation	Education	Mixed Residential
GENERAL MINERALS	Dissolved Phosphorus	mg/ℓ	n/m	0.25	n/m	0.40	0.50	0.47	0.34	0.19
	Kjeldahl-N	mg/ℓ	n/m	3.36	0.65	5.59	3.51	2.45	2.13	5.14
	NH3-N	mg/ℓ	n/m	0.37	n/m	3.39	1.04	0.18	n/m	0.96
	Nitrate-N	mg/ℓ	n/m	0.74	0.53	0.59	2.13	0.96	0.91	0.90
	Nitrite-N	mg/ℓ	n/m	0.08	n/m	0.17	0.17	0.11	0.06	0.10
	Suspended Solids	mg/ℓ	n/m	182.18	12.35	78.91	93.79	75.12	46.67	67.61
	Total Phosphorus	mg/ℓ	n/m	0.30	n/m	0.48	0.58	0.49	0.42	0.28
HEAVY METALS (DISSOLVED)	Dissolved Cadmium	µg/ℓ	n/m	n/m	n/m	n/m	n/m	n/m	n/m	n/m
	Dissolved Chromium	µg/ℓ	n/m	n/m	n/m	n/m	n/m	n/m	n/m	n/m
	Dissolved Copper	µg/ℓ	n/m	12.39	n/m	14.86	6.93	35.04	20.48	12.82
	Dissolved Lead	µg/ℓ	n/m	n/m	n/m	n/m	n/m	n/m	n/m	n/m
	Dissolved Mercury	µg/ℓ	n/m	n/m	n/m	n/m	n/m	n/m	n/m	n/m
	Dissolved Nickel	µg/ℓ	n/m	3.29	n/m	n/m	n/m	4.04	n/m	n/m
	Dissolved Selenium	µg/ℓ	n/m	n/m	n/m	n/m	n/m	n/m	n/m	n/m
	Dissolved Silver	µg/ℓ	n/m	n/m	n/m	n/m	n/m	n/m	n/m	n/m
	Dissolved Zinc	µg/ℓ	n/m	391.05	n/m	182.58	111.38	226.95	95.87	114.94
HEAVY METALS (TOTAL)	Total Cadmium	µg/ℓ	n/m	n/m	n/m	n/m	n/m	0.86	n/m	n/m
	Total Chromium +6	µg/ℓ	n/m	n/m	n/m	n/m	n/m	n/m	n/m	n/m
	Total Copper	µg/ℓ	n/m	22.18	n/m	28.45	12.68	47.75	25.70	17.53
	Total Lead	µg/ℓ	n/m	6.22	n/m	5.97	n/m	5.50	n/m	3.67
	Total Mercury	µg/ℓ	n/m	n/m	n/m	n/m	n/m	n/m	n/m	n/m
	Total Nickel	µg/ℓ	n/m	5.06	n/m	4.14	6.95	7.71	n/m	n/m
	Total Selenium	µg/ℓ	n/m	n/m	n/m	n/m	n/m	4.16	n/m	n/m
	Total Silver	µg/ℓ	n/m	n/m	n/m	n/m	n/m	n/m	n/m	n/m
	Total Zinc	µg/ℓ	n/m	413.69	n/m	252.03	161.12	288.33	127.33	150.00
MISCELLANEOUS	Cyanide	mg/ℓ			n/m					
	Oil and Grease	mg/ℓ			n/m					
	Total Petroleum Hydrocarbons	mg/ℓ			n/m					
	Total Phenols	mg/ℓ			n/m					

Notes:
n/m : Not meaningful, not enough data above detection limit
Blank cells: No data available

Seasonal EMCs
1998-99 Storm Season (cont'd)

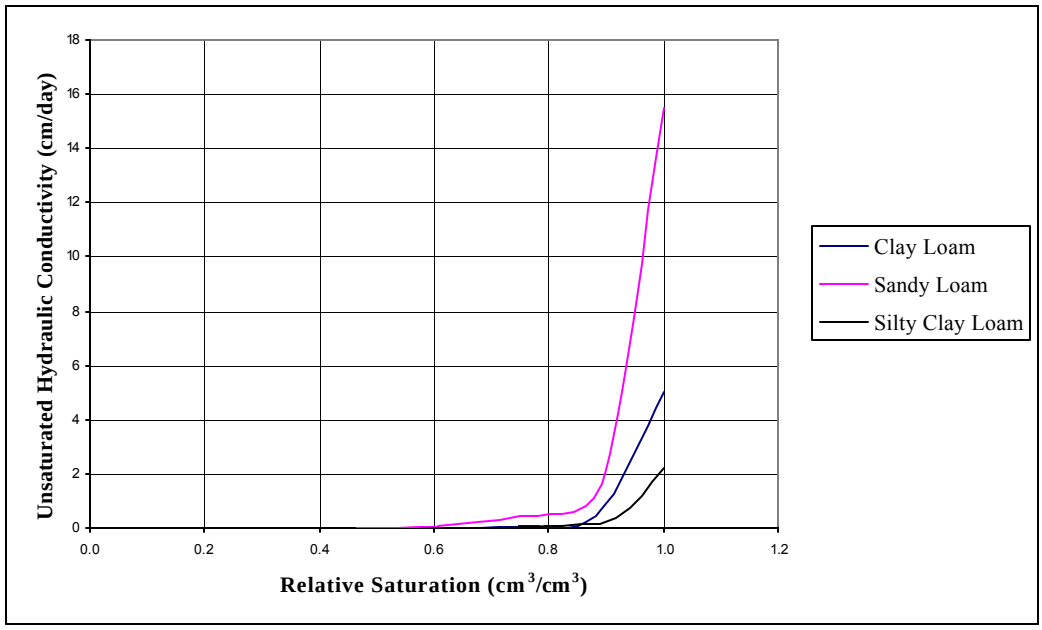
GROUP	Constituent	Unit	High Density Residential	Light Industrial	Vacant	Retail/ Commercial	Multi-family Residential	Transportation	Education	Mixed Residential
BACTERIA	Fecal Coliform	MPN/100mℓ			501.12					
	Fecal Enterococcus	MPN/100mℓ			1156.96					
	Fecal Streptococcus	MPN/100mℓ			1156.96					
	Total Coliform	MPN/100mℓ			2364.56					
PESTICIDES	Chlordane	µg/ℓ	n/m	n/m	n/m	n/m	n/m	n/m		n/m
	Chlorpyrifos	µg/ℓ	n/m	n/m	n/m	n/m	n/m	n/m	n/m	n/m
	Diazinon	µg/ℓ	n/m	n/m	n/m	0.32	n/m	n/m	n/m	11.90
	Malathion	µg/ℓ	n/m	n/m	n/m	n/m	n/m	n/m	n/m	n/m
	p,p' DDT	µg/ℓ	n/m	n/m	n/m	n/m	n/m	n/m		n/m
	PCB-1016	µg/ℓ	n/m	n/m	n/m	n/m	n/m	n/m		n/m
	PCB-1221	µg/ℓ	n/m	n/m	n/m	n/m	n/m	n/m		n/m
	PCB-1232	µg/ℓ	n/m	n/m	n/m	n/m	n/m	n/m		n/m
	PCB-1242	µg/ℓ	n/m	n/m	n/m	n/m	n/m	n/m		n/m
	PCB-1248	µg/ℓ	n/m	n/m	n/m	n/m	n/m	n/m		n/m
	PCB-1254	µg/ℓ	n/m	n/m	n/m	n/m	n/m	n/m		n/m
	PCB-1260	µg/ℓ	n/m	n/m	n/m	n/m	n/m	n/m		n/m
	Simazine	µg/ℓ	n/m	n/m	n/m	n/m	n/m	n/m	n/m	n/m
SEMIVOLATILES	Acenaphthene	µg/ℓ	n/m	n/m	n/m	n/m	n/m	n/m		n/m
	Acenaphthylene	µg/ℓ	n/m	n/m	n/m	n/m	n/m	n/m		n/m
	Antracene	µg/ℓ	n/m	n/m	n/m	n/m	n/m	n/m		n/m
	Benzo(a)anthracene	µg/ℓ	n/m	n/m	n/m	n/m	n/m	n/m		n/m
	Benzo(a)pyrene	µg/ℓ	n/m	n/m	n/m	n/m	n/m	n/m		n/m
	Benzo(b)fluorant	µg/ℓ	n/m	n/m	n/m	n/m	n/m	n/m		n/m
	Benzo(k)fluorant	µg/ℓ	n/m	n/m	n/m	n/m	n/m	n/m		n/m
	Chrysene	µg/ℓ	n/m	n/m	n/m	n/m	n/m	n/m		n/m
	Dibenz(a,h)anthrecene	µg/ℓ	n/m	n/m	n/m	n/m	n/m	n/m		n/m
	Fluoranthene	µg/ℓ	n/m	n/m	n/m	n/m	n/m	n/m		n/m
	Fluorene	µg/ℓ	n/m	n/m	n/m	n/m	n/m	n/m		n/m
	Indeno (1,2,3-cd) pyrene	µg/ℓ	n/m	n/m	n/m	n/m	n/m	n/m		n/m
	Naphthalene	µg/ℓ	n/m	n/m	n/m	n/m	n/m	n/m		n/m
	Phenanthrene	µg/ℓ	n/m	n/m	n/m	n/m	n/m	n/m		n/m
	Pyrene	µg/ℓ	n/m	n/m	n/m	n/m	n/m	n/m		n/m

Notes:
n/m : Not meaningful, not enough data above detection limit
Blank cells: No data available

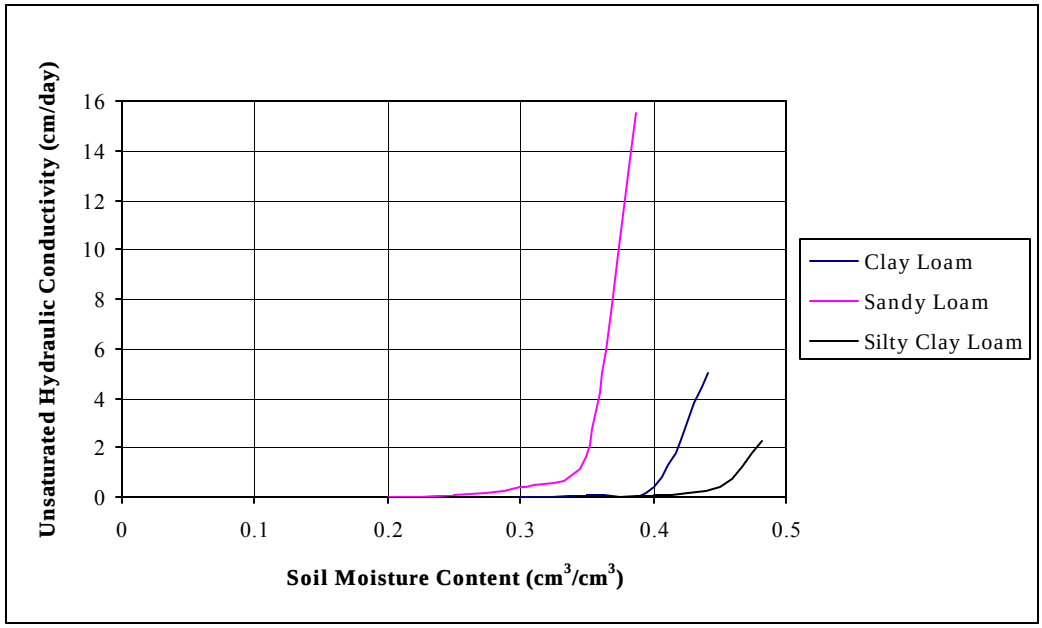
Source: LACDPW, 1999

APPENDIX E: UNSATURATED HYDRAULIC CONDUCTIVITIES OF THREE SOIL TYPES

Unsaturated Hydraulic Conductivities of Three Soil Types Based on Relative Saturation



Unsaturated Hydraulic Conductivities of Three Soil Types Based on Soil Moisture Content



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APPENDIX F: CONCENTRATIONS OF CONTAMINANTS IN WATER IN THREE SOIL TYPES

SILTY CLAY LOAM				Time: 1d			Time: 21d			Time: 150d	
Chlordane	Soil Moisture	Unsat.HC		Ratio	Concentration		Ratio	Concentration		Ratio	Concentration
Concentration: 0.01mg/L	0.091	4.58E-16		0.00E+00	0.00E+00		0.00E+00	0.00E+00		0.00E+00	0.00E+00
Standard: 0.002mg/L	0.1	2.24E-10		0.00E+00	0.00E+00		0.00E+00	0.00E+00		0.00E+00	0.00E+00
Depth: 3m	0.2	1.92E-04		2.99E-17	2.99E-19		2.99E-17	2.99E-19		2.99E-17	2.99E-19
	0.3	8.38E-03		1.09E-04	1.09E-06		1.09E-04	1.09E-06		1.09E-04	1.09E-06
	0.4	1.05E-01		5.06E-03	5.06E-05		5.06E-03	5.06E-05		5.42E-03	5.42E-05
	0.482	2.23E+00		2.76E-02	2.76E-04		2.94E-02	2.94E-04		4.19E-02	4.19E-04
Chlordane	Soil Moisture	Unsat.HC		Ratio	Concentration		Ratio	Concentration		Ratio	Concentration
Concentration: 0.01mg/L	0.091	4.58E-16		0.00E+00	0.00E+00		0.00E+00	0.00E+00		0.00E+00	0.00E+00
Standard: 0.002mg/L	0.1	2.24E-10		0.00E+00	0.00E+00		0.00E+00	0.00E+00		0.00E+00	0.00E+00
Depth: 5m	0.2	1.92E-04		1.90E-23	1.90E-25		1.90E-23	1.90E-25		1.90E-23	1.90E-25
	0.3	8.38E-03		3.53E-07	3.53E-09		3.53E-07	3.53E-09		3.53E-07	3.53E-09
	0.4	1.05E-01		7.45E-05	7.45E-07		7.45E-05	7.45E-07		8.64E-05	8.64E-07
	0.482	2.23E+00		2.30E-03	2.30E-05		2.50E-03	2.50E-05		4.28E-03	4.28E-05
Chlordane	Soil Moisture	Unsat.HC		Ratio	Concentration		Ratio	Concentration		Ratio	Concentration
Concentration: 0.01mg/L	0.091	4.58E-16		0.00E+00	0.00E+00		0.00E+00	0.00E+00		0.00E+00	0.00E+00
Standard: 0.002mg/L	0.1	2.24E-10		0.00E+00	0.00E+00		0.00E+00	0.00E+00		0.00E+00	0.00E+00
Depth: 15m	0.2	1.92E-04		0.00E+00	0.00E+00		0.00E+00	0.00E+00		0.00E+00	0.00E+00
	0.3	8.38E-03		0.00E+00	0.00E+00		0.00E+00	0.00E+00		0.00E+00	0.00E+00
	0.4	1.05E-01		0.00E+00	0.00E+00		0.00E+00	0.00E+00		0.00E+00	0.00E+00
	0.482	2.23E+00		0.00E+00	0.00E+00		0.00E+00	0.00E+00		0.00E+00	0.00E+00

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Methylene Chloride	Soil Moisture	Unsat.HC		Ratio	Concentration		Ratio	Concentration		Ratio	Concentration
Concentration: 0.015mg/L	0.091	4.58E-16		0.00E+00	0.00E+00		0.00E+00	0.00E+00		0.00E+00	0.00E+00
Standard: 0.005mg/L	0.1	2.24E-10		0.00E+00	0.00E+00		0.00E+00	0.00E+00		0.00E+00	0.00E+00
Depth: 3m	0.2	1.92E-04		1.43E-21	2.14E-23		1.59E-21	2.38E-23		2.44E-21	3.66E-23
	0.3	8.38E-03		1.65E-05	2.47E-07		2.51E-05	3.76E-07		2.04E-04	3.06E-06
	0.4	1.05E-01		4.37E-03	6.56E-05		1.40E-02	2.09E-04		1.13E-01	1.70E-03
	0.482	2.23E+00		8.69E-02	1.30E-03		4.81E-01	7.22E-03		6.29E-01	9.44E-03
Methylene Chloride	Soil Moisture	Unsat.HC		Ratio	Concentration		Ratio	Concentration		Ratio	Concentration
Concentration: 0.015mg/L	0.091	4.58E-16		0.00E+00	0.00E+00		0.00E+00	0.00E+00		0.00E+00	0.00E+00
Standard: 0.005mg/L	0.1	2.24E-10		0.00E+00	0.00E+00		0.00E+00	0.00E+00		0.00E+00	0.00E+00
Depth: 5m	0.2	1.92E-04		5.60E-29	8.39E-31		6.60E-29	9.90E-31		1.56E-28	2.33E-30
	0.3	8.38E-03		5.38E-08	8.07E-10		1.22E-07	1.82E-09		6.54E-06	9.81E-08
	0.4	1.05E-01		2.23E-04	3.35E-06		1.46E-03	2.20E-05		5.91E-02	8.86E-04
	0.482	2.23E+00		4.16E-02	6.24E-04		3.49E-01	5.24E-03		5.43E-01	8.14E-03
Methylene Chloride	Soil Moisture	Unsat.HC		Ratio	Concentration		Ratio	Concentration		Ratio	Concentration
Concentration: 0.015mg/L	0.091	4.58E-16		0.00E+00	0.00E+00		0.00E+00	0.00E+00		0.00E+00	0.00E+00
Standard: 0.005mg/L	0.1	2.24E-10		0.00E+00	0.00E+00		0.00E+00	0.00E+00		0.00E+00	0.00E+00
Depth: 15m	0.2	1.92E-04		0.00E+00	0.00E+00		0.00E+00	0.00E+00		0.00E+00	0.00E+00
	0.3	8.38E-03		0.00E+00	0.00E+00		0.00E+00	0.00E+00		0.00E+00	0.00E+00
	0.4	1.05E-01		0.00E+00	0.00E+00		0.00E+00	0.00E+00		5.51E-03	8.26E-05
	0.482	2.23E+00		6.76E-03	1.01E-04		9.11E-02	1.37E-03		3.35E-01	5.03E-03

Pentachlorophenol	Soil Moisture	Unsat.HC		Ratio	Concentration		Ratio	Concentration		Ratio	Concentration
Concentration: 0.115mg/L	0.091	4.58E-16		0.00E+00	0.00E+00		0.00E+00	0.00E+00		0.00E+00	0.00E+00
Standard: 0.001 mg/L	0.1	2.24E-10		0.00E+00	0.00E+00		0.00E+00	0.00E+00		0.00E+00	0.00E+00
Depth: 3m	0.2	1.92E-04		1.87E-44	2.15E-45		1.87E-44	2.15E-45		1.87E-44	2.15E-45
	0.3	8.38E-03		7.99E-09	9.19E-10		7.99E-09	9.19E-10		8.34E-09	9.60E-10
	0.4	1.05E-01		3.42E-04	3.93E-05		3.54E-04	4.07E-05		4.18E-04	4.81E-05
	0.482	2.23E+00		1.54E-02	1.77E-03		1.74E-02	2.00E-03		3.61E-02	4.15E-03
Pentachlorophenol	Soil Moisture	Unsat.HC		Ratio	Concentration		Ratio	Concentration		Ratio	Concentration
Concentration: 0.115mg/L	0.091	4.58E-16		0.00E+00	0.00E+00		0.00E+00	0.00E+00		0.00E+00	0.00E+00
Standard: 0.001mg/L	0.1	2.24E-10		0.00E+00	0.00E+00		0.00E+00	0.00E+00		0.00E+00	0.00E+00
Depth: 5m	0.2	1.92E-04		0.00E+00	0.00E+00		0.00E+00	0.00E+00		0.00E+00	0.00E+00
	0.3	8.38E-03		1.64E-11	1.89E-12		1.64E-11	1.89E-12		1.83E-12	2.10E-13
	0.4	1.05E-01		2.18E-06	2.50E-07		2.30E-06	2.64E-07		3.25E-06	3.74E-07
	0.482	2.23E+00		1.08E-03	1.24E-04		1.28E-03	1.47E-04		4.15E-03	4.78E-04
Pentachlorophenol	Soil Moisture	Unsat.HC		Ratio	Concentration		Ratio	Concentration		Ratio	Concentration
Concentration: 0.115mg/L	0.091	4.58E-16		0.00E+00	0.00E+00		0.00E+00	0.00E+00		0.00E+00	0.00E+00
Standard: 0.001mg/L	0.1	2.24E-10		0.00E+00	0.00E+00		0.00E+00	0.00E+00		0.00E+00	0.00E+00
Depth: 15m	0.2	1.92E-04		0.00E+00	0.00E+00		0.00E+00	0.00E+00		0.00E+00	0.00E+00
	0.3	8.38E-03		0.00E+00	0.00E+00		0.00E+00	0.00E+00		0.00E+00	0.00E+00
	0.4	1.05E-01		0.00E+00	0.00E+00		0.00E+00	0.00E+00		0.00E+00	0.00E+00
	0.482	2.23E+00		0.00E+00	0.00E+00		0.00E+00	0.00E+00		0.00E+00	0.00E+00

Chrysene	Soil Moisture	Unsat.HC		Ratio	Concentration		Ratio	Concentration		Ratio	Concentration
Concentration: 0.01mg/L	0.091	4.58E-16		0.00E+00	0.00E+00		0.00E+00	0.00E+00		0.00E+00	0.00E+00
Standard: 0.0092mg/L	0.1	2.24E-10		0.00E+00	0.00E+00		0.00E+00	0.00E+00		0.00E+00	0.00E+00
Depth: 3m	0.2	1.92E-04		0.00E+00	0.00E+00		0.00E+00	0.00E+00		0.00E+00	0.00E+00
	0.3	8.38E-03		7.25E-22	7.25E-24		7.25E-22	7.25E-24		7.25E-22	7.25E-24
	0.4	1.05E-01		6.13E-08	6.13E-10		6.13E-08	6.13E-10		6.13E-08	6.13E-10
	0.482	2.23E+00		1.32E-03	1.32E-05		1.32E-03	1.32E-05		1.32E-03	1.32E-05
Chrysene	Soil Moisture	Unsat.HC		Ratio	Concentration		Ratio	Concentration		Ratio	Concentration
Concentration: 0.01mg/L	0.091	4.58E-16		0.00E+00	0.00E+00		0.00E+00	0.00E+00		0.00E+00	0.00E+00
Standard: 0.0092mg/L	0.1	2.24E-10		0.00E+00	0.00E+00		0.00E+00	0.00E+00		0.00E+00	0.00E+00
Depth: 5m	0.2	1.92E-04		0.00E+00	0.00E+00		0.00E+00	0.00E+00		0.00E+00	0.00E+00
	0.3	8.38E-03		2.10E-29	2.10E-31		2.10E-29	2.10E-31		2.10E-29	2.10E-31
	0.4	1.05E-01		2.00E-11	2.00E-13		2.00E-11	2.00E-13		2.00E-11	2.00E-13
	0.482	2.23E+00		1.06E-05	1.06E-07		1.06E-05	1.06E-07		1.06E-05	1.06E-07
Chrysene	Soil Moisture	Unsat.HC		Ratio	Concentration		Ratio	Concentration		Ratio	Concentration
Concentration: 0.01mg/L	0.091	4.58E-16		0.00E+00	0.00E+00		0.00E+00	0.00E+00		0.00E+00	0.00E+00
Standard: 0.0092mg/L	0.1	2.24E-10		0.00E+00	0.00E+00		0.00E+00	0.00E+00		0.00E+00	0.00E+00
Depth: 15m	0.2	1.92E-04		0.00E+00	0.00E+00		0.00E+00	0.00E+00		0.00E+00	0.00E+00
	0.3	8.38E-03		0.00E+00	0.00E+00		0.00E+00	0.00E+00		0.00E+00	0.00E+00
	0.4	1.05E-01		0.00E+00	0.00E+00		0.00E+00	0.00E+00		0.00E+00	0.00E+00
	0.482	2.23E+00		0.00E+00	0.00E+00		0.00E+00	0.00E+00		0.00E+00	0.00E+00

Bis-2(ethylhexyl) phthalate	Soil Moisture	Unsat.HC		Ratio	Concentration		Ratio	Concentration		Ratio	Concentration
Concentration: 0.062mg/L	0.091	4.58E-16		0.00E+00	0.00E+00		0.00E+00	0.00E+00		0.00E+00	0.00E+00
Standard: 0.006mg/L	0.1	2.24E-10		0.00E+00	0.00E+00		0.00E+00	0.00E+00		0.00E+00	0.00E+00
Depth: 3m	0.2	1.92E-04		0.00E+00	0.00E+00		0.00E+00	0.00E+00		0.00E+00	0.00E+00
	0.3	8.38E-03		3.45E-23	2.14E-24		3.57E-23	2.21E-24		3.96E-23	2.45E-24
	0.4	1.05E-01		2.86E-08	1.77E-09		3.06E-08	1.90E-09		4.39E-08	2.72E-09
	0.482	2.23E+00		1.84E-03	1.14E-04		2.42E-03	1.50E-04		9.16E-03	5.68E-04
Bis-2(ethylhexyl) phthalate	Soil Moisture	Unsat.HC		Ratio	Concentration		Ratio	Concentration		Ratio	Concentration
Concentration: 0.062mg/L	0.091	4.58E-16		0.00E+00	0.00E+00		0.00E+00	0.00E+00		0.00E+00	0.00E+00
Standard: 0.006mg/L	0.1	2.24E-10		0.00E+00	0.00E+00		0.00E+00	0.00E+00		0.00E+00	0.00E+00
Depth: 5m	0.2	1.92E-04		0.00E+00	0.00E+00		0.00E+00	0.00E+00		0.00E+00	0.00E+00
	0.3	8.38E-03		4.56E-31	2.83E-32		4.56E-31	2.83E-32		5.66E-31	3.51E-32
	0.4	1.05E-01		1.11E-11	6.89E-13		1.31E-11	8.10E-13		2.58E-11	1.60E-12
	0.482	2.23E+00		5.79E-05	3.59E-06		8.90E-05	5.52E-06		8.58E-04	5.32E-05
Bis-2(ethylhexyl) phthalate	Soil Moisture	Unsat.HC		Ratio	Concentration		Ratio	Concentration		Ratio	Concentration
Concentration: 0.062mg/L	0.091	4.58E-16		0.00E+00	0.00E+00		0.00E+00	0.00E+00		0.00E+00	0.00E+00
Standard: 0.006mg/L	0.1	2.24E-10		0.00E+00	0.00E+00		0.00E+00	0.00E+00		0.00E+00	0.00E+00
Depth: 15m	0.2	1.92E-04		0.00E+00	0.00E+00		0.00E+00	0.00E+00		0.00E+00	0.00E+00
	0.3	8.38E-03		0.00E+00	0.00E+00		0.00E+00	0.00E+00		0.00E+00	0.00E+00
	0.4	1.05E-01		0.00E+00	0.00E+00		0.00E+00	0.00E+00		0.00E+00	0.00E+00
	0.482	2.23E+00		0.00E+00	0.00E+00		0.00E+00	0.00E+00		0.00E+00	0.00E+00

SANDY LOAM				Time: 1d			Time: 21d			Time: 150d	
Chlordane	Soil Moisture	Unsat.HC		Ratio	Concentration		Ratio	Concentration		Ratio	Concentration
Concentration: 0.01mg/L	0.04	9.62E-15		0.00E+00	0.00E+00		0.00E+00	0.00E+00		0.00E+00	0.00E+00
Standard: 0.002mg/L	0.1	8.97E-05		4.14E-26	4.14E-28		4.14E-26	4.14E-28		4.14E-26	4.14E-28
Depth: 3m	0.2	2.14E-02		5.59E-04	5.59E-06		5.79E-04	5.79E-06		5.79E-04	5.79E-06
	0.3	4.16E-01		1.12E-02	1.12E-04		1.16E-02	1.16E-04		1.28E-02	1.28E-04
	0.387	1.55E+01		6.45E-02	6.45E-04		7.77E-02	7.77E-04		1.96E-01	1.96E-03
Chlordane	Soil Moisture	Unsat.HC		Ratio	Concentration		Ratio	Concentration		Ratio	Concentration
Concentration: 0.01mg/L	0.04	9.62E-15		0.00E+00	0.00E+00		0.00E+00	0.00E+00		0.00E+00	0.00E+00
Standard: 0.002mg/L	0.1	8.97E-05		0.00E+00	0.00E+00		0.00E+00	0.00E+00		0.00E+00	0.00E+00
Depth: 5m	0.2	2.14E-02		3.25E-06	3.25E-08		3.25E-06	3.25E-08		3.41E-06	3.41E-08
	0.3	4.16E-01		3.00E-04	3.00E-06		3.14E-04	3.14E-06		3.63E-04	3.63E-06
	0.387	1.55E+01		1.84E-02	1.84E-04		2.24E-02	2.24E-04		6.39E-02	6.39E-04
Chlordane	Soil Moisture	Unsat.HC		Ratio	Concentration		Ratio	Concentration		Ratio	Concentration
Concentration: 0.01mg/L	0.04	9.62E-15		0.00E+00	0.00E+00		0.00E+00	0.00E+00		0.00E+00	0.00E+00
Standard: 0.002mg/L	0.1	8.97E-05		0.00E+00	0.00E+00		0.00E+00	0.00E+00		0.00E+00	0.00E+00
Depth: 15m	0.2	2.14E-02		0.00E+00	0.00E+00		0.00E+00	0.00E+00		0.00E+00	0.00E+00
	0.3	4.16E-01		0.00E+00	0.00E+00		0.00E+00	0.00E+00		0.00E+00	0.00E+00
	0.387	1.55E+01		3.66E-04	3.66E-06		4.25E-04	4.25E-06		1.27E-03	1.27E-05

Methylene Chloride	Soil Moisture	Unsat.HC		Ratio	Concentration		Ratio	Concentration		Ratio	Concentration
Concentration: 0.015mg/L	0.04	9.62E-15		0.00E+00	0.00E+00		0.00E+00	0.00E+00		0.00E+00	0.00E+00
Standard: 0.005mg/L	0.1	8.97E-05		2.52E-29	3.78E-31		2.61E-29	3.91E-31		3.31E-29	4.96E-31
Depth: 3m	0.2	2.14E-02		3.46E-04	5.19E-06		6.05E-04	9.07E-06		6.36E-03	9.53E-05
	0.3	4.16E-01		2.37E-02	3.55E-04		1.03E-01	1.54E-03		3.54E-01	5.31E-03
	0.387	1.55E+01		2.55E-01	3.83E-03		8.51E-01	1.28E-02		8.64E-01	1.30E-02
Methylene Chloride	Soil Moisture	Unsat.HC		Ratio	Concentration		Ratio	Concentration		Ratio	Concentration
Concentration: 0.015mg/L	0.04	9.62E-15		0.00E+00	0.00E+00		0.00E+00	0.00E+00		0.00E+00	0.00E+00
Standard: 0.005mg/L	0.1	8.97E-05		5.24E-39	7.86E-41		5.46E-39	8.19E-41		8.73E-39	1.31E-40
Depth: 5m	0.2	2.14E-02		4.15E-06	6.23E-08		1.12E-05	1.67E-07		8.75E-04	1.31E-05
	0.3	4.16E-01		4.37E-03	6.56E-05		3.56E-02	5.35E-04		2.58E-01	3.87E-03
	0.387	1.55E+01		2.11E-01	3.17E-03		7.80E-01	1.17E-02		8.19E-01	1.23E-02
Methylene Chloride	Soil Moisture	Unsat.HC		Ratio	Concentration		Ratio	Concentration		Ratio	Concentration
Concentration: 0.015mg/L	0.04	9.62E-15		0.00E+00	0.00E+00		0.00E+00	0.00E+00		0.00E+00	0.00E+00
Standard: 0.005mg/L	0.1	8.97E-05		0.00E+00	0.00E+00		0.00E+00	0.00E+00		0.00E+00	0.00E+00
Depth: 15m	0.2	2.14E-02		0.00E+00	0.00E+00		0.00E+00	0.00E+00		1.63E-09	2.44E-11
	0.3	4.16E-01		1.29E-05	1.94E-07		4.11E-04	6.16E-06		9.24E-02	1.39E-03
	0.387	1.55E+01		1.41E-01	2.12E-03		5.22E-01	7.83E-03		6.86E-01	1.03E-02

Pentachlorophenol	Soil Moisture	Unsat.HC		Ratio	Concentration		Ratio	Concentration		Ratio	Concentration
Concentration: 0.115mg/L	0.04	9.62E-15		0.00E+00	0.00E+00		0.00E+00	0.00E+00		0.00E+00	0.00E+00
Standard: 0.001mg/L	0.1	8.97E-05		1.25E-69	1.44E-70		1.25E-69	1.44E-70		1.25E-69	1.44E-70
Depth: 3m	0.2	2.14E-02		8.39E-07	9.64E-08		8.68E-07	9.98E-08		8.99E-07	1.03E-07
	0.3	4.16E-01		2.56E-03	2.94E-04		2.64E-03	3.04E-04		3.43E-03	3.94E-04
	0.387	1.55E+01		5.09E-02	5.85E-03		6.29E-02	7.23E-03		2.02E-01	2.33E-02
Pentachlorophenol	Soil Moisture	Unsat.HC		Ratio	Concentration		Ratio	Concentration		Ratio	Concentration
Concentration: 0.115mg/L	0.04	9.62E-15		0.00E+00	0.00E+00		0.00E+00	0.00E+00		0.00E+00	0.00E+00
Standard: 0.001mg/L	0.1	8.97E-05		4.35E-91	5.00E-92		4.35E-91	5.00E-92		4.56E-91	5.25E-92
Depth: 5m	0.2	2.14E-02		7.34E-10	8.44E-11		7.34E-10	8.44E-11		8.09E-10	9.30E-11
	0.3	4.16E-01		4.44E-05	5.10E-06		4.66E-05	5.36E-06		7.50E-05	8.62E-06
	0.387	1.55E+01		1.30E-02	1.50E-03		1.70E-02	1.96E-03		7.77E-02	8.94E-03
Pentachlorophenol	Soil Moisture	Unsat.HC		Ratio	Concentration		Ratio	Concentration		Ratio	Concentration
Concentration: 0.115mg/L	0.04	9.62E-15		0.00E+00	0.00E+00		0.00E+00	0.00E+00		0.00E+00	0.00E+00
Standard: 0.001mg/L	0.1	8.97E-05		0.00E+00	0.00E+00		0.00E+00	0.00E+00		0.00E+00	0.00E+00
Depth: 15m	0.2	2.14E-02		0.00E+00	0.00E+00		0.00E+00	0.00E+00		0.00E+00	0.00E+00
	0.3	4.16E-01		0.00E+00	0.00E+00		0.00E+00	0.00E+00		0.00E+00	0.00E+00
	0.387	1.55E+01		1.82E-04	2.09E-05		2.59E-04	2.98E-05		1.94E-03	2.23E-04

Chrysene	Soil Moisture	Unsat.HC		Ratio	Concentration		Ratio	Concentration		Ratio	Concentration
Concentration: 0.01mg/L	0.04	9.62E-15		0.00E+00	0.00E+00		0.00E+00	0.00E+00		0.00E+00	0.00E+00
Standard: 0.0092mg/L	0.1	8.97E-05		0.00E+00	0.00E+00		0.00E+00	0.00E+00		0.00E+00	0.00E+00
Depth: 3m	0.2	2.14E-02		8.70E-16	8.70E-18		8.70E-16	8.70E-18		8.70E-16	8.70E-18
	0.3	4.16E-01		1.76E-05	1.76E-07		1.76E-05	1.76E-07		1.82E-05	1.82E-07
	0.387	1.55E+01		7.75E-03	7.75E-05		7.75E-03	7.75E-05		8.02E-03	8.02E-05
Chrysene	Soil Moisture	Unsat.HC		Ratio	Concentration		Ratio	Concentration		Ratio	Concentration
Concentration: 0.01mg/L	0.04	9.62E-15		0.00E+00	0.00E+00		0.00E+00	0.00E+00		0.00E+00	0.00E+00
Standard: 0.0092mg/L	0.1	8.97E-05		0.00E+00	0.00E+00		0.00E+00	0.00E+00		0.00E+00	0.00E+00
Depth: 5m	0.2	2.14E-02		1.48E-21	1.48E-23		1.48E-21	1.48E-23		1.48E-21	1.48E-23
	0.3	4.16E-01		3.31E-08	3.31E-10		3.31E-08	3.31E-10		3.31E-08	3.31E-10
	0.387	1.55E+01		1.60E-04	1.60E-06		1.60E-04	1.60E-06		1.68E-04	1.68E-06
Chrysene	Soil Moisture	Unsat.HC		Ratio	Concentration		Ratio	Concentration		Ratio	Concentration
Concentration: 0.01mg/L	0.04	9.62E-15		0.00E+00	0.00E+00		0.00E+00	0.00E+00		0.00E+00	0.00E+00
Standard: 0.0092mg/L	0.1	8.97E-05		0.00E+00	0.00E+00		0.00E+00	0.00E+00		0.00E+00	0.00E+00
Depth: 15m	0.2	2.14E-02		0.00E+00	0.00E+00		0.00E+00	0.00E+00		0.00E+00	0.00E+00
	0.3	4.16E-01		0.00E+00	0.00E+00		0.00E+00	0.00E+00		0.00E+00	0.00E+00
	0.387	1.55E+01		0.00E+00	0.00E+00		0.00E+00	0.00E+00		0.00E+00	0.00E+00

Bis-2(ethylhexyl) phthalate	Soil Moisture	Unsat.HC		Ratio	Concentration		Ratio	Concentration		Ratio	Concentration
Concentration: 0.062mg/L	0.04	9.62E-15		0.00E+00	0.00E+00		0.00E+00	0.00E+00		0.00E+00	0.00E+00
Standard: 0.006mg/L	0.1	8.97E-05		0.00E+00	0.00E+00		0.00E+00	0.00E+00		0.00E+00	0.00E+00
Depth: 3m	0.2	2.14E-02		1.25E-16	7.73E-18		1.29E-16	8.00E-18		1.43E-16	8.86E-18
	0.3	4.16E-01		1.44E-05	8.95E-07		1.54E-05	9.56E-07		2.56E-05	1.59E-06
	0.387	1.55E+01		1.91E-02	1.19E-03		2.78E-02	1.72E-03		1.50E-01	9.30E-03
Bis-2(ethylhexyl) phthalate	Soil Moisture	Unsat.HC		Ratio	Concentration		Ratio	Concentration		Ratio	Concentration
Concentration: 0.062mg/L	0.04	9.62E-15		0.00E+00	0.00E+00		0.00E+00	0.00E+00		0.00E+00	0.00E+00
Standard: 0.006mg/L	0.1	8.97E-05		0.00E+00	0.00E+00		0.00E+00	0.00E+00		0.00E+00	0.00E+00
Depth: 5m	0.2	2.14E-02		1.4299E-22	8.87E-24		1.43E-22	8.87E-24		1.76E-22	1.09E-23
	0.3	4.16E-01		4.79E-08	2.97E-09		5.55E-08	3.44E-09		1.41E-07	8.73E-09
	0.387	1.55E+01		3.20E-03	1.99E-04		5.37E-03	3.33E-04		6.12E-02	3.79E-03
Bis-2(ethylhexyl) phthalate	Soil Moisture	Unsat.HC		Ratio	Concentration		Ratio	Concentration		Ratio	Concentration
Concentration: 0.062mg/L	0.04	9.62E-15		0.00E+00	0.00E+00		0.00E+00	0.00E+00		0.00E+00	0.00E+00
Standard: 0.006mg/L	0.1	8.97E-05		0.00E+00	0.00E+00		0.00E+00	0.00E+00		0.00E+00	0.00E+00
Depth: 15m	0.2	2.14E-02		0.00E+00	0.00E+00		0.00E+00	0.00E+00		0.00E+00	0.00E+00
	0.3	4.16E-01		0.00E+00	0.00E+00		0.00E+00	0.00E+00		0.00E+00	0.00E+00
	0.387	1.55E+01		7.23E-06	4.48E-07		1.55E-05	9.61E-07		1.01E-03	6.28E-05

CLAY LOAM				Time: 1d			Time: 21d			Time: 150d	
Chlordane	Soil Moisture	Unsat.HC		Ratio	Concentration		Ratio	Concentration		Ratio	Concentration
Concentration: 0.01mg/L	0.08	1.92E-16		0.00E+00	0.00E+00		0.00E+00	0.00E+00		0.00E+00	0.00E+00
Standard: 0.002mg/L	0.1	1.64E-08		0.00E+00	0.00E+00		0.00E+00	0.00E+00		0.00E+00	0.00E+00
Depth: 3m	0.2	6.11E-04		6.87E-11	6.87E-13		6.87E-11	6.87E-13		7.12E-11	7.12E-13
	0.3	2.57E-02		9.88E-04	9.88E-06		9.88E-04	9.88E-06		1.02E-03	1.02E-05
	0.4	4.10E-01		1.22E-02	1.22E-04		1.22E-02	1.22E-04		1.44E-02	1.44E-04
	0.442	5.00E+00		4.01E-02	4.01E-04		4.38E-02	4.38E-04		7.54E-02	7.54E-04
Chlordane	Soil Moisture	Unsat.HC		Ratio	Concentration		Ratio	Concentration		Ratio	Concentration
Concentration: 0.01mg/L	0.08	1.92E-16		0.00E+00	0.00E+00		0.00E+00	0.00E+00		0.00E+00	0.00E+00
Standard: 0.002mg/L	0.1	1.64E-08		0.00E+00	0.00E+00		0.00E+00	0.00E+00		0.00E+00	0.00E+00
Depth: 5m	0.2	6.11E-04		3.13E-15	3.13E-17		3.13E-15	3.13E-17		3.13E-15	3.13E-17
	0.3	2.57E-02		6.81E-06	6.81E-08		6.81E-06	6.81E-08		7.14E-06	7.14E-08
	0.4	4.10E-01		3.54E-04	3.54E-06		3.54E-04	3.54E-06		4.47E-04	4.47E-06
	0.442	5.00E+00		5.94E-03	5.94E-05		6.67E-03	6.67E-05		1.34E-02	1.34E-04
Chlordane	Soil Moisture	Unsat.HC		Ratio	Concentration		Ratio	Concentration		Ratio	Concentration
Concentration: 0.01mg/L	0.08	1.92E-16		0.00E+00	0.00E+00		0.00E+00	0.00E+00		0.00E+00	0.00E+00
Standard: 0.002mg/L	0.1	1.64E-08		0.00E+00	0.00E+00		0.00E+00	0.00E+00		0.00E+00	0.00E+00
Depth: 15m	0.2	6.11E-04		0.00E+00	0.00E+00		0.00E+00	0.00E+00		0.00E+00	0.00E+00
	0.3	2.57E-02		0.00E+00	0.00E+00		0.00E+00	0.00E+00		0.00E+00	0.00E+00
	0.4	4.10E-01		0.00E+00	0.00E+00		0.00E+00	0.00E+00		0.00E+00	0.00E+00
	0.442	5.00E+00		0.00E+00	0.00E+00		0.00E+00	0.00E+00		6.47E-06	6.47E-08

Methylene Chloride	Soil Moisture	Unsat.HC		Ratio	Concentration		Ratio	Concentration		Ratio	Concentration
Concentration: 0.015mg/L	0.08	1.92E-16		0.00E+00	0.00E+00		0.00E+00	0.00E+00		0.00E+00	0.00E+00
Standard: 0.005mg/L	0.1	1.64E-08		0.00E+00	0.00E+00		0.00E+00	0.00E+00		0.00E+00	0.00E+00
Depth: 3m	0.2	6.11E-04		3.04E-13	4.56E-15		3.37E-13	5.05E-15		7.24E-13	1.09E-14
	0.3	2.57E-02		4.29E-04	6.44E-06		8.68E-04	1.30E-05		1.07E-02	1.61E-04
	0.4	4.10E-01		2.20E-02	3.30E-04		1.06E-01	1.60E-03		3.38E-01	5.06E-03
	0.442	5.00E+00		1.49E-01	2.23E-03		6.84E-01	1.03E-02		7.50E-01	1.12E-02
Methylene Chloride	Soil Moisture	Unsat.HC		Ratio	Concentration		Ratio	Concentration		Ratio	Concentration
Concentration: 0.015mg/L	0.08	1.92E-16		0.00E+00	0.00E+00		0.00E+00	0.00E+00		0.00E+00	0.00E+00
Standard: 0.005mg/L	0.1	1.64E-08		0.00E+00	0.00E+00		0.00E+00	0.00E+00		0.00E+00	0.00E+00
Depth: 5m	0.2	6.11E-04		3.40E-18	5.09E-20		4.38E-18	6.56E-20		1.88E-17	2.82E-19
	0.3	2.57E-02		5.74E-06	8.61E-08		1.98E-05	2.97E-07		5.99E-04	8.99E-06
	0.4	4.10E-01		3.83E-03	5.75E-05		3.66E-02	5.50E-04		2.43E-01	3.64E-03
	0.442	5.00E+00		9.82E-02	1.47E-03		4.05E-01	6.08E-03		6.81E-01	1.02E-02
Methylene Chloride	Soil Moisture	Unsat.HC		Ratio	Concentration		Ratio	Concentration		Ratio	Concentration
Concentration: 0.015mg/L	0.08	1.92E-16		0.00E+00	0.00E+00		0.00E+00	0.00E+00		0.00E+00	0.00E+00
Standard: 0.005mg/L	0.1	1.64E-08		0.00E+00	0.00E+00		0.00E+00	0.00E+00		0.00E+00	0.00E+00
Depth: 15m	0.2	6.11E-04		0.00E+00	0.00E+00		0.00E+00	0.00E+00		0.00E+00	0.00E+00
	0.3	2.57E-02		0.00E+00	0.00E+00		0.00E+00	0.00E+00		6.42E-08	9.62E-10
	0.4	4.10E-01		7.90E-06	1.18E-07		3.69E-04	5.54E-06		8.31E-02	1.25E-03
	0.442	5.00E+00		3.91E-02	5.86E-04		2.68E-01	4.02E-03		4.97E-01	7.46E-03

Pentachlorophenol	Soil Moisture	Unsat.HC		Ratio	Concentration		Ratio	Concentration		Ratio	Concentration
Concentration: 0.115mg/L	0.08	1.92E-16		0.00E+00	0.00E+00		0.00E+00	0.00E+00		0.00E+00	0.00E+00
Standard: 0.001mg/L	0.1	1.64E-08		0.00E+00	0.00E+00		0.00E+00	0.00E+00		0.00E+00	0.00E+00
Depth: 3m	0.2	6.11E-04		2.27E-26	2.61E-27		2.27E-26	2.61E-27		2.35E-26	2.70E-27
	0.3	2.57E-02		3.98E-06	4.58E-07		3.98E-06	4.58E-07		4.41E-06	5.07E-07
	0.4	4.10E-01		3.05E-03	3.51E-04		3.16E-03	3.63E-04		4.49E-03	5.16E-04
	0.442	5.00E+00		2.70E-02	3.11E-03		3.13E-02	3.60E-03		7.85E-02	9.03E-03
Pentachlorophenol	Soil Moisture	Unsat.HC		Ratio	Concentration		Ratio	Concentration		Ratio	Concentration
Concentration: 0.115mg/L	0.08	1.92E-16		0.00E+00	0.00E+00		0.00E+00	0.00E+00		0.00E+00	0.00E+00
Standard: 0.001mg/L	0.1	1.64E-08		0.00E+00	0.00E+00		0.00E+00	0.00E+00		0.00E+00	0.00E+00
Depth: 5m	0.2	6.11E-04		3.20E-35	3.68E-36		3.20E-35	3.68E-36		3.35E-35	3.86E-36
	0.3	2.57E-02		5.51E-09	6.34E-10		5.51E-09	6.34E-10		6.40E-09	7.36E-10
	0.4	4.10E-01		5.62E-05	6.46E-06		6.18E-05	7.11E-06		1.14E-04	1.31E-05
	0.442	5.00E+00		3.43E-03	3.95E-04		4.33E-03	4.98E-04		1.67E-02	1.92E-03
Pentachlorophenol	Soil Moisture	Unsat.HC		Ratio	Concentration		Ratio	Concentration		Ratio	Concentration
Concentration: 0.115mg/L	0.08	1.92E-16		0.00E+00	0.00E+00		0.00E+00	0.00E+00		0.00E+00	0.00E+00
Standard: 0.001mg/L	0.1	1.64E-08		0.00E+00	0.00E+00		0.00E+00	0.00E+00		0.00E+00	0.00E+00
Depth: 15m	0.2	6.11E-04		0.00E+00	0.00E+00		0.00E+00	0.00E+00		0.00E+00	0.00E+00
	0.3	2.57E-02		0.00E+00	0.00E+00		0.00E+00	0.00E+00		0.00E+00	0.00E+00
	0.4	4.10E-01		0.00E+00	0.00E+00		0.00E+00	0.00E+00		0.00E+00	0.00E+00
	0.442	5.00E+00		0.00E+00	0.00E+00		0.00E+00	0.00E+00		1.20E-05	1.38E-06

Chrysene	Soil Moisture	Unsat.HC		Ratio	Concentration		Ratio	Concentration		Ratio	Concentration
Concentration: 0.01mg/L	0.08	1.92E-16		0.00E+00	0.00E+00		0.00E+00	0.00E+00		0.00E+00	0.00E+00
Standard: 0.0092mg/L	0.1	1.64E-08		0.00E+00	0.00E+00		0.00E+00	0.00E+00		0.00E+00	0.00E+00
Depth: 3m	0.2	6.11E-04		2.10E-75	2.10E-77		2.10E-75	2.10E-77		2.10E-75	2.10E-77
	0.3	2.57E-02		1.01E-13	1.01E-15		1.01E-13	1.01E-15		1.01E-13	1.01E-15
	0.4	4.10E-01		2.91E-05	2.91E-07		2.91E-05	2.91E-07		2.91E-05	2.91E-07
	0.442	5.00E+00		3.31E-03	3.31E-05		3.31E-03	3.31E-05		3.42E-03	3.42E-05
Chrysene	Soil Moisture	Unsat.HC		Ratio	Concentration		Ratio	Concentration		Ratio	Concentration
Concentration: 0.01mg/L	0.08	1.92E-16		0.00E+00	0.00E+00		0.00E+00	0.00E+00		0.00E+00	0.00E+00
Standard: 0.0092mg/L	0.1	1.64E-08		0.00E+00	0.00E+00		0.00E+00	0.00E+00		0.00E+00	0.00E+00
Depth: 5m	0.2	6.11E-04		1.53E-98	1.53E-100		1.53E-98	1.53E-100		1.53E-98	1.53E-100
	0.3	2.57E-02		6.84E-19	6.84E-21		6.84E-19	6.84E-21		6.84E-19	6.84E-21
	0.4	4.10E-01		6.06E-08	6.06E-10		6.06E-08	6.06E-10		6.06E-08	6.06E-10
	0.442	5.00E+00		4.06E-05	4.06E-07		4.26E-05	4.26E-07		4.26E-05	4.26E-07
Chrysene	Soil Moisture	Unsat.HC		Ratio	Concentration		Ratio	Concentration		Ratio	Concentration
Concentration: 0.01mg/L	0.08	1.92E-16		0.00E+00	0.00E+00		0.00E+00	0.00E+00		0.00E+00	0.00E+00
Standard: 0.0092mg/L	0.1	1.64E-08		0.00E+00	0.00E+00		0.00E+00	0.00E+00		0.00E+00	0.00E+00
Depth: 15m	0.2	6.11E-04		0.00E+00	0.00E+00		0.00E+00	0.00E+00		0.00E+00	0.00E+00
	0.3	2.57E-02		0.00E+00	0.00E+00		0.00E+00	0.00E+00		0.00E+00	0.00E+00
	0.4	4.10E-01		0.00E+00	0.00E+00		0.00E+00	0.00E+00		0.00E+00	0.00E+00
	0.442	5.00E+00		0.00E+00	0.00E+00		0.00E+00	0.00E+00		0.00E+00	0.00E+00

Bis-2(ethylhexyl) phthalate	Soil Moisture	Unsat.HC		Ratio	Concentration		Ratio	Concentration		Ratio	Concentration
Concentration: 0.062mg/L	0.08	1.92E-16		0.00E+00	0.00E+00		0.00E+00	0.00E+00		0.00E+00	0.00E+00
Standard: 0.006mg/L	0.1	1.64E-08		0.00E+00	0.00E+00		0.00E+00	0.00E+00		0.00E+00	0.00E+00
Depth: 3m	0.2	6.11E-04		3.03E-80	1.88E-81		3.03E-80	1.88E-81		3.14E-80	1.95E-81
	0.3	2.57E-02		1.83E-14	1.13E-15		1.89E-14	1.17E-15		2.24E-14	1.39E-15
	0.4	4.10E-01		2.33E-05	1.44E-06		2.66E-05	1.65E-06		5.09E-05	3.16E-06
	0.442	5.00E+00		6.06E-03	3.76E-04		8.36E-03	5.18E-04		3.97E-02	2.46E-03
Bis-2(ethylhexyl) phthalate	Soil Moisture	Unsat.HC		Ratio	Concentration		Ratio	Concentration		Ratio	Concentration
Concentration: 0.062mg/L	0.08	1.92E-16		0.00E+00	0.00E+00		0.00E+00	0.00E+00		0.00E+00	0.00E+00
Standard: 0.006mg/L	0.1	1.64E-08		0.00E+00	0.00E+00		0.00E+00	0.00E+00		0.00E+00	0.00E+00
Depth: 5m	0.2	6.11E-04		0.00E+00	0.00E+00		0.00E+00	0.00E+00		0.00E+00	0.00E+00
	0.3	2.57E-02		9.42E-20	5.84E-21		9.90E-20	6.14E-21		1.36E-19	8.41E-21
	0.4	4.10E-01		9.76E-08	6.05E-09		1.19E-07	7.38E-09		3.89E-07	2.41E-08
	0.442	5.00E+00		4.21E-04	2.61E-05		6.78E-04	4.20E-05		8.37E-03	5.19E-04
Bis-2(ethylhexyl) phthalate	Soil Moisture	Unsat.HC		Ratio	Concentration		Ratio	Concentration		Ratio	Concentration
Concentration: 0.062mg/L	0.08	1.92E-16		0.00E+00	0.00E+00		0.00E+00	0.00E+00		0.00E+00	0.00E+00
Standard: 0.006mg/L	0.1	1.64E-08		0.00E+00	0.00E+00		0.00E+00	0.00E+00		0.00E+00	0.00E+00
Depth: 15m	0.2	6.11E-04		0.00E+00	0.00E+00		0.00E+00	0.00E+00		0.00E+00	0.00E+00
	0.3	2.57E-02		0.00E+00	0.00E+00		0.00E+00	0.00E+00		0.00E+00	0.00E+00
	0.4	4.10E-01		0.00E+00	0.00E+00		0.00E+00	0.00E+00		0.00E+00	0.00E+00
	0.442	5.00E+00		0.00E+00	0.00E+00		0.00E+00	0.00E+00		2.64E-06	1.63E-07

APPENDIX G: CONCENTRATIONS OF METHYLENE CHLORIDE IN WATER IN THREE SOIL TYPES

SILTY CLAY LOAM				Time: 1d			Time: 21d			Time: 150d	
Methylene chloride	Soil Moisture	Unsat.HC		Ratio	Concentration		Ratio	Concentration		Ratio	Concentration
Concentration: 0.015mg/L	0.091	4.58E-16		0.00E+00	0.00E+00		0.00E+00	0.00E+00		0.00E+00	0.00E+00
Standard: 0.005mg/L	0.1	2.24E-10		0.00E+00	0.00E+00		0.00E+00	0.00E+00		0.00E+00	0.00E+00
Depth: 20m	0.2	1.92E-04		0.00E+00	0.00E+00		0.00E+00	0.00E+00		0.00E+00	0.00E+00
	0.3	8.38E-03		0.00E+00	0.00E+00		0.00E+00	0.00E+00		0.00E+00	0.00E+00
	0.4	1.05E-01		0.00E+00	0.00E+00		0.00E+00	0.00E+00		1.47E-03	2.20E-05
	0.482	2.23E+00		4.28E-03	6.42E-05		5.57E-02	8.35E-04		2.81E-01	4.22E-03
SANDY LOAM				Time: 1d			Time: 21d			Time: 150d	
Methylene chloride	Soil Moisture	Unsat.HC		Ratio	Concentration		Ratio	Concentration		Ratio	Concentration
Concentration: 0.015mg/L	0.04	9.62E-15		0.00E+00	0.00E+00		0.00E+00	0.00E+00		0.00E+00	0.00E+00
Standard: 0.005mg/L	0.1	8.97E-05		0.00E+00	0.00E+00		0.00E+00	0.00E+00		0.00E+00	0.00E+00
Depth: 20m	0.2	2.14E-02		0.00E+00	0.00E+00		0.00E+00	0.00E+00		0.00E+00	0.00E+00
	0.3	4.16E-01		2.22E-06	3.33E-08		7.83E-05	1.17E-06		6.33E-02	9.50E-04
	0.387	1.55E+01		1.27E-01	1.91E-03		4.97E-01	7.46E-03		6.43E-01	9.64E-03
Methylene chloride	Soil Moisture	Unsat.HC		Ratio	Concentration		Ratio	Concentration		Ratio	Concentration
Concentration: 0.015mg/L	0.04	9.62E-15		0.00E+00	0.00E+00		0.00E+00	0.00E+00		0.00E+00	0.00E+00
Standard: 0.005mg/L	0.1	8.97E-05		0.00E+00	0.00E+00		0.00E+00	0.00E+00		0.00E+00	0.00E+00
Depth: 30m	0.2	2.14E-02		0.00E+00	0.00E+00		0.00E+00	0.00E+00		0.00E+00	0.00E+00
	0.3	4.16E-01		0.00E+00	0.00E+00		6.58E-06	9.87E-08		3.30E-02	4.95E-04
	0.387	1.55E+01		1.10E-01	1.64E-03		5.39E-01	8.08E-03		5.76E-01	8.64E-03

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Methylene chloride	Soil Moisture	Unsat.HC		Ratio	Concentration		Ratio	Concentration		Ratio	Concentration
Concentration: 0.015mg/L	0.04	9.62E-15		0.00E+00	0.00E+00		0.00E+00	0.00E+00		0.00E+00	0.00E+00
Standard: 0.005mg/L	0.1	8.97E-05		0.00E+00	0.00E+00		0.00E+00	0.00E+00		0.00E+00	0.00E+00
Depth: 40m	0.2	2.14E-02		0.00E+00	0.00E+00		0.00E+00	0.00E+00		0.00E+00	0.00E+00
	0.3	4.16E-01		0.00E+00	0.00E+00		1.09E-06	1.63E-08		1.76E-02	2.64E-04
	0.387	1.55E+01		1.40E-01	2.10E-03		2.80E-01	4.21E-03		5.25E-01	7.88E-03
CLAY LOAM				Time: 1d			Time: 21d			Time: 150d	
Methylene chloride	Soil Moisture	Unsat.HC		Ratio	Concentration		Ratio	Concentration		Ratio	Concentration
Concentration: 0.015mg/L	0.08	1.92E-16		0.00E+00	0.00E+00		0.00E+00	0.00E+00		0.00E+00	0.00E+00
Standard: 0.005mg/L	0.1	1.64E-08		0.00E+00	0.00E+00		0.00E+00	0.00E+00		0.00E+00	0.00E+00
Depth: 20m	0.2	6.11E-04		0.00E+00	0.00E+00		0.00E+00	0.00E+00		0.00E+00	0.00E+00
	0.3	2.57E-02		0.00E+00	0.00E+00		0.00E+00	0.00E+00		0.00E+00	0.00E+00
	0.4	4.10E-01		1.12E-06	1.69E-08		6.32E-05	9.48E-07		5.62E-02	8.43E-04
	0.442	5.00E+00		3.13E-02	4.69E-04		2.01E-01	3.02E-03		4.43E-01	6.64E-03
Methylene chloride	Soil Moisture	Unsat.HC		0.00E+00	0.00E+00		0.00E+00	0.00E+00		0.00E+00	0.00E+00
Concentration: 0.015mg/L	0.08	1.92E-16		0.00E+00	0.00E+00		0.00E+00	0.00E+00		0.00E+00	0.00E+00
Standard: 0.005mg/L	0.1	1.64E-08		0.00E+00	0.00E+00		0.00E+00	0.00E+00		0.00E+00	0.00E+00
Depth: 30m	0.2	6.11E-04		0.00E+00	0.00E+00		0.00E+00	0.00E+00		0.00E+00	0.00E+00
	0.3	2.57E-02		0.00E+00	0.00E+00		0.00E+00	0.00E+00		0.00E+00	0.00E+00
	0.4	4.10E-01		0.00E+00	0.00E+00		4.51E-06	6.76E-08		2.89E-02	4.34E-04
	0.442	5.00E+00		2.25E-02	3.37E-04		1.26E-01	1.89E-03		3.65E-01	5.47E-03

Methylene chloride	Soil Moisture	Unsat.HC		0.00E+00	0.00E+00		0.00E+00	0.00E+00		0.00E+00	0.00E+00
Concentration: 0.015mg/L	0.08	1.92E-16		0.00E+00	0.00E+00		0.00E+00	0.00E+00		0.00E+00	0.00E+00
Standard: 0.005mg/L	0.1	1.64E-08		0.00E+00	0.00E+00		0.00E+00	0.00E+00		0.00E+00	0.00E+00
Depth: 40m	0.2	6.11E-04		0.00E+00	0.00E+00		0.00E+00	0.00E+00		0.00E+00	0.00E+00
	0.3	2.57E-02		0.00E+00	0.00E+00		0.00E+00	0.00E+00		0.00E+00	0.00E+00
	0.4	4.10E-01		0.00E+00	0.00E+00		6.68E-07	1.00E-08		1.59E-02	2.39E-04
	0.442	5.00E+00		1.75E-02	2.63E-04		8.86E-02	1.33E-03		3.10E-01	4.65E-03

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USC Center for Sustainable Cities

Alternative Approaches to Stormwater Quality Control

Joseph S. Devinny
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Prepared for: The Los Angeles Regional Water Quality Control Board

Cover Photo: Catch Basin protection, Ventura, California. Storm Drain, Long Beach California. Permeable Parking Lot, Wales. Photos by Joseph S. Devinny

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EXECUTIVE SUMMARY

Background

A recent, widely debated study entitled *An Economic Impact Evaluation of Proposed Storm Water Treatment for Los Angeles County* projects extremely high costs for compliance with stormwater quality regulations (Gordon et al., 2002). These estimates followed from the study's fundamental assumption that the only way to comply with water quality regulations is to capture most or all of the flow and subject it to advanced treatment, and to do so at rates equal to peak runoff rates. *In contrast, this report shows that there are far less expensive approaches available that, should they be implemented, will achieve high levels of compliance with current federal water quality standards.*

Alternatives Considered

This report reviews present federal and state regulations and regulatory policy to determine whether advanced ultrafiltration treatment of the entire runoff flow is required to meet water quality standards, or whether compliance can be achieved through the widespread adoption of the various "best management practices" (BMPs) more commonly used for runoff quality control. The work identified and analyzed alternative measures that can be employed to meet present federal and state water quality standards. Particular attention was paid to strategies that concern ground water recharge, pollutant source control, and runoff detention, capture, and BMP treatment.

The report reviews possible approaches for controlling runoff water quality in the Los Angeles Region (the jurisdiction of the Los Angles Regional Water Quality Control Board) and presents a conceptual regional plan, including rough cost estimates. The study pursued a broad approach, providing an evaluation of total costs and benefits for the region, including those for municipalities, businesses, and individuals. The objective of the study was to outline a complete solution to stormwater quality problems, i.e., the plan is intended to meet the requirements of the stormwater permit and Total Maximum Daily Loads and provide acceptable water quality for the area. The alternatives of best management practices (BMPs) for control of individual pollutants (source control), and if necessary, a regional system of wetlands and infiltration facilities to provide final treatment and groundwater replenishment were chosen. These will be much cheaper than advanced treatment plants, and will provide benefits whose value exceeds costs.

Assumptions Made for Determining Costs

Following the review of possible remedial actions for stormwater pollution, a conceptual plan for the Los Angeles Region was developed. It was predicated on the following assumptions:

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Because source control is always cheaper than cleaning polluted water, efforts should begin with preventing the release of pollutants to runoff. This includes measures like litter control, improved street cleaning, improved industrial housekeeping and others. Such approaches may constitute sufficient control for runoff coming from residential areas, so that these areas will require no further action.

For new residential development, anecdotal information indicates that landscaping that captures and infiltrates the first-flush storm will be of comparable cost to traditional landscaping, and should therefore be used. For commercial construction, costs may be higher, and adequate regional facilities might be substituted.

Where non-structural BMPs will not be adequate, or where implementation is very expensive, efforts must expand to include regional wetlands and stormwater parks (multiple-use infiltration basins).

Large portions of the Los Angeles Region are already built out to various degrees, constraining available stormwater management solutions. This report assumes that 1000 square miles can be characterized as "low density", and that these regions can be served by a combination of source control, treatment wetlands, and infiltration systems. Another 1000 square miles is "high density" and can be served by source control and infiltration systems. About 50 square miles are "extremely high density" (such as downtown areas) and will require more sophisticated infiltration or treatment devices that occupy smaller areas.

Estimated Costs

Total costs for compliance with runoff water quality regulations were predicted to be between $2.8 billion (if non-structural systems are sufficient for the entire region) to between $5.7 billion and $7.4 billion (if regional treatment or infiltration systems must also be constructed throughout the entire area). It is likely that regional systems will be required for at least some, but not all, of the area, so that the final costs will be somewhere between these extremes.

- Enforcement of littering, pet waste, and chemical use ordinances is expected to cost about $9 million per year.

- Public education will cost about $5 million per year. A program to detect and prevent illicit discharges to the system will cost about $80 million per year at first, but can be reduced to much lower levels as compliance is achieved.

- Increased cleaning of storm drains will be needed if regional solutions are not used, and will cost about $27 million per year.

- Trash discharges to receiving waters can be controlled by installing screening devices on catch basins, enforcing litter laws, and improving street cleaning services. Estimates are that the immediate cost of instituting these measures will be about $600 million over the Los Angeles Region.

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- During periods of low flow, runoff water should be diverted to existing wastewater treatment plants. Construction costs for this effort will be about $28 million.

- Trash control and removal of particulates and their associated pollutants can be facilitated by improved street cleaning. It is expected that this will cost $7.5 million per year more than current street cleaning programs, with a present worth of $250 million.

- On-site BMPs required for individual firms might cost about $240 million. Costs associated with compliance with the ¾-inch rule for new construction will be a modest fraction of construction costs.

- With regard to structural BMPs, total costs (regional wetlands and infiltration systems) were first estimated by determining the costs per square mile of drainage area incurred at other sites, and multiplying by the area over which they will be applied. Wetlands for the "low density" areas were estimated to cost $420,000 per square mile of drainage area, for a total cost of $420 million. Infiltration systems for the "high density" areas were estimated to cost $3.7 million per square mile of drainage, for a total cost of $3.7 billion. More sophisticated treatment BMPs (such as sediment traps and oil adsorbers) for the "extremely dense" areas were estimated to cost $33 million per square mile of drainage, for a total of $1.7 billion. Thus total new facilities costs are $5.8 billion.

- A second method for estimating structural BMP costs utilized costs per acre-foot of retention capacity as determined by the Los Angeles County Department of Public Works Sun Valley Project. Presuming that runoff from a ¾-inch storm must be captured in the low-density, high density, and extremely high density areas with runoff coefficients of 0.4, 0.6, and 1.0, costs are $53,000, $98,000, and $470,000 per acre-foot, respectively. The overall facilities cost estimate using this method is $4.0 billion.

Estimated Benefits

There are substantial benefits to the examined approaches that extend beyond the value of stormwater quality control. Reductions in pollutant releases will improve public health and neighborhood livability. Restoration of the hydrologic cycle will replenish groundwater reservoirs, reduce flood risks, and provide greenspace for recreation and wildlife habitat. It was determined that the total value of benefits from the alternatives for runoff quality control described will exceed the costs. Total benefits for the non-structural stormwater quality control programs in the Los Angeles Region are estimated at $5.6 billion. Implementation of the non-structural and regional measures throughout the Los Angeles Region would have benefits worth $18 billion.

- Reduced need for flood control is expected to save about $400 million.

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- Property value increases from additional greenspace and bodies of water are expected to amount to $5 billion over the Los Angeles region.

- Additional groundwater supplies created by infiltration will have a current worth of about $7.2 billion.

- "Willingness to pay" surveys in similar circumstances suggest that the public amenity value of avoiding stormwater pollution of local bodies of water is about $2.5 billion.

- Cleaner streets are worth about $950 million.

- Improved beach tourism will bring in about $100 million.

- Preservation of the nature's services in the marine coastal zone, such as nutrient recycling and chemical maintenance of the atmosphere, is worth about $2 billion.

- Reduction of sedimentation in local harbors will save $330 million.

- Improvements in public health associated with reduced exposure to fine particles from streets are likely significant, but could not be quantified.

Recommendations for Immediate Action

Municipalities that have the responsibility for meeting runoff quality regulations should take some immediate steps.

- Outreach programs, explaining to citizens the need for runoff quality control and discouraging illegal discharges such as littering, should begin.

- Data should be collected on the stormwater discharges from subwatersheds to determine what BMPs are workable, and general plans should be updated to include policies that promote stormwater control.

- An administrative structure should be established which includes the relevant stakeholders and funding agencies for each watershed (such as watershed councils).

- Funding plans should be developed.

- Building codes that work against runoff quality control should be changed immediately—in particular, all parking lots built from now on should also be stormwater infiltration systems.

- All new street cleaning equipment should be high-quality vacuuming systems. Appropriate agencies should be encouraged to use the latest microbiological

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techniques to investigate sources of pathogenic organisms in runoff, so that mitigation efforts can be optimally designed.

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INTRODUCTION

This report identifies and analyzes alternatives for control of stormwater runoff in Los Angeles County. A recent, widely debated study entitled, *An Economic Impact Evaluation of Proposed Storm Water Treatment for Los Angeles County* projects extremely high costs for compliance with stormwater quality regulations (Gordon et al., 2002). These estimates followed from the study's fundamental assumption that the only way to comply with water quality regulations is to capture most or all of the flow and subject it to advanced treatment, and to do so at rates equal to peak runoff rates. As this report shows, however, there are far less expensive approaches that, if implemented, can achieve high levels of compliance with current federal water quality standards.

A broad approach was taken: an evaluation was made of total costs and benefits for the region, including those for municipalities, businesses, and individuals. A complete solution to stormwater quality problems was considered—that is, the plan is intended to meet the requirements of the stormwater permit and Total Maximum Daily Load and provide acceptable water quality for the area. The recommendations for steps to be taken are not limited to the Los Angeles Regional Water Quality Control Board (LA Regional Water Board). Action by other governmental agencies will also be required. The study begins with a brief description of runoff sources and contaminants. A review of present federal and state regulations and regulatory policy to was done to determine whether advanced ultrafiltration treatment of the entire runoff flow will be required, or whether compliance can be achieved through the widespread adoption of the various "best management practices" (BMPs) more commonly used for runoff quality control. The study then identifies and analyzes alternative measures that can be employed to meet present federal and state water quality standards. Particular attention is paid to strategies that facilitate ground water recharge, source control measures, storm water detention and capture, and BMP treatment. While prevailing uncertainties make an overall cost estimate only approximate at this time, costs of specific approaches are illustrated with examples. Financial benefits, such as those regarding groundwater replenishment, more appealing beach environments, improved public health, and the creation of additional urban green space, are also addressed in the report. Clearly, water is a scarce resource in this region of the country, and economic evaluations of different management techniques for stormwater runoff must also consider the benefits of improved water quality and water supply as well as flood control. Prior to reviewing federal and state water quality regulation and policy, this study provides an overview of more general policy and regulation theory.

Runoff

The bulk of urban runoff is generated during rainfall events, and can properly be termed stormwater. This flow is extremely irregular, especially in Southern California, where most days are dry, and measurable rain occurs on average of only 32 days per year. Total rainfall in the area is modest, averaging about 16 inches per year. A large storm in this area might drop as much as three inches of rainfall in 24 hours, but this is

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still much less intense than typical rainfall events in other states, such as those on the East Coast.

Even so, high flows and flooding do occur in Southern California because of the topography. Water from large watersheds drains into local rivers, and slopes are steep, so that rainfall is rapidly collected and concentrated.

Water also enters the storm drains from non-rainfall sources. Sprinklers left on overnight, car washing, and hoses used to clean sidewalks and driveways generate smaller streams sometimes called nuisance flows. These flow in the storm drain system all year, and with residual stream flows (and in a some areas, recycled wastewater), constitute dry-weather flow. The terms "stormwater" and "runoff" are often used interchangeably. However, it is important in some cases to recognize the difference—stormwater arrives suddenly in huge amounts, while nuisance flows are much smaller and run all year.

Urbanization of the landscape substantially changes the amount and composition of runoff. Because less water infiltrates (percolates) into soils, the total amount of runoff is increased. Because the water runs off pavement more rapidly, it is concentrated to make peak flows higher. Recharge of groundwater is reduced, and the shallow groundwater that feeds some streams dries up, so surface flows decrease in some areas. Surface flows may increase during dry weather in other areas because of nuisance flows from over-irrigation and car washing. In general, the storage and buffering effects of soils and groundwater reservoirs are reduced. Runoff flowing through vegetation, or entering and leaving shallow groundwater, is subject to the effects of filtration and biodegradation, which has a considerable purifying effect. Water runoff from pavement is not cleaned, and indeed is contaminated by whatever dirt and pollutants are on the pavement.

Pollutants

The cities of Southern California use "separate" systems, meaning stormwater is collected apart from the wastewater generated by toilets and showers. The wastewater enters a closed network of pipes and is carried to treatment plants. Stormwater may initially flow in underground conduits, but eventually passes to open flood control channels, rivers, and the ocean. This storm water drainage system is called a Municipal Separate Storm Sewer System (MS4). Runoff pollutants are different in nature from those in sewage. Pathogens are present, but in far smaller concentrations, as are nutrients such as phosphorus and nitrogen. There may be more petroleum hydrocarbons, dust, sediments, and settled air pollutants in runoff, but total organic content in runoff is usually much lower than in wastewater.

The pollutant load of stormwater varies greatly with location. The water contains pollutants that wash off rooftops, parking lots, industrial facilities, and the streets. Pollutants may also be discharged illegally, when individuals pour motor oil into the storm drains or industries release toxic pollutants.

Water flowing in the streets picks up trash, dust, dirt and other materials that have been deposited on the pavement. The dust includes fine particles of rubber from tire wear, settled air pollutants, trace metals from brake pads and other mechanical sources, and pet feces. Cars drip motor oil onto the pavement and the early flows of fall may carry a petroleum sheen.

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Stormwater quality protection measures may be placed in three general categories. Infiltration allows percolation of the water into the ground, relying on the soil to remove pollutants from the replenishing groundwater and eliminating the discharge to runoff. Source control measures prevent the release of pollutants, so that the water is never contaminated. Treatment systems remove the pollutants from the stormwater before it reaches the ocean.

Runoff Sources and Quality

Stormwater and runoff come from a great variety of sources and carry a varied suite of pollutants. There are many approaches to the task of protecting receiving waters, and the best choice depends on stormwater source and quality. Runoff from a residential area of single-family homes, for example, is unlikely to carry industrial pollutants, but may have small amounts of oil and grease from roads, microbiological contamination from pet feces., and dissolved nutrients from fertilizers. These are readily removed by filtration in soil, so groundwater recharge, with its additional benefit of replenishing aquifers, is a good choice. Runoff from construction sites is less likely to carry harmful microorganisms, but may have heavy loads of sediment. The best choice here is to use dikes, detention ponds, and other measures to allow the sediment to settle out of the water before it is percolated to groundwater or released to storm drains. The dispersed and difficult-to-control pollutants of urban commercial areas may best be dealt with by providing regional solutions, such as parkland designed to serve simultaneously as a flood control basin, a groundwater recharge site, and a sedimentation basin for large amounts of water.

Streets

Streets, particularly those in dense commercial areas, are the most difficult source of urban runoff to manage. They receive litter, dust and dirt, air pollutant particulates, pet feces, occasional human waste, trace metals and oil from cars, various illegal discharges, and other pollutants. Because they are the first part of the stormwater collection and transport system, they receive and pass on pollutants that are carried away from parking lots, commercial establishments, and industries.

Exposed Commercial Activity

Manufacturing and other commercial activities, even those dealing with hazardous materials, have no effect on stormwater quality if the work is carried out under cover. However, for some large-scale activities, such as oil refining, this is not practical. Rain falling on machinery, materials, or contaminated surfaces can pick up pollutants. Measures can be taken to cover individual activities, or treatment systems can be installed to clean the water before release.

Construction Sites

Frequently, the first step taken in construction of new facilities is to clear the land of vegetation and pavement. The exposed soil is highly vulnerable to erosion by rainfall, and the movement of trucks and machinery can “track” soil to the adjacent streets.

Residences

Single-family homes are a source of some pollutants. Roof runoff will contain dust, bird feces and settled air pollutants. Runoff from gardens may contain pesticides

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and fertilizers. Occasionally, homeowners will (illegally) dispose motor oil or paint waste into storm drains. For the most part, however, runoff from neighborhoods of single-family homes is relatively less polluted (if household toxics such as pesticides are properly used). Multiple-family residences produce many of the same pollutants, but typically have a higher ratio of rooftop and impervious surface to permeable landscaping, so that more water runs off.

Commercial Rooftops

Roof runoff from commercial facilities may be slightly polluted with air pollutant dusts, bird droppings, hydrocarbons from roof tar, and occasionally, some trace metals from rooftop machinery. The contaminants present may be very similar to those found on residential roofs, but handling the runoff may be more difficult because commercial areas have a high ratio of roof area to land area, and often have little landscaping.

Parking Lots and Landscaping

A significant fraction of urban land is devoted to parking lots. Parking lots are commonly polluted by litter, heavy metals from auto-parts and road wear, and by oil leaking from cars. Spilled food is present near establishments that sell food, and pet feces, bird droppings, and settled air pollutants will also be present, and all of these can be washed away in the runoff. Virtually all parking lots are designed for rapid drainage to the street or storm drain. Indeed, where grass or other plantings are present, these are commonly surrounded by curbs that prevent flow of the water from the lot into the soil. Many designs, in fact, promote runoff from the vegetation to the pavement.

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ASSESSMENT OF REGULATORY POLICY

Overview of Policy and Regulation Theory

This report, in identifying and assessing BMPs, takes a strategic regulatory planning approach to managing stormwater runoff in Los Angeles County. Strategic regulatory planning involves a close examination of the legislative goals concerning the given policy. The ultimate end of strategic regulatory planning is to control behavior through methods that agree with legislative goals and societal values regarding the issues at hand. Thus, a strategic approach demands careful consideration first of whether enforcement is appropriate; and second, if enforcement is appropriate, to what degree should the parties involved be pressured to comply; and third, how coercive should the regulatory devices be? Compliance with existing laws and regulations, in this case the provisions of the federal Clean Water Act and state law, is a major goal of the strategic regulatory planning process.

How compliance is defined can vary markedly depending upon the actors involved and the policymaking context. In this sense "compliance" means the degree to which members of a target group conform to the directives of an agency, court, legislative body, or some other governmental agency. One way to determine whether members of a target group are in compliance with an environmental law is to monitor levels of pollution on a regular basis. We assume that the greater the number of individuals and firms that are in compliance with rules, the more likely pollution will decrease in a given locality.

When legislators pass laws, they generally expect them to be vigorously enforced and fully obeyed. Only idealists, however, actually believe that this is possible or even necessary in all cases. Political and economic factors usually force policymakers to take a more realistic approach to enforcement by setting a desired and attainable level of compliance prior to program implementation. At this stage, policymakers must consider whether 100 percent compliance is necessary. If not, they must determine what degree of compliance is needed in order to meet environmental quality goals. While the desired degree of compliance is often only a rough estimate, several factors must be kept in mind. Policymakers must take into account, for example, the extent to which members of a target group are making a “reasonable” effort to change their behavior and follow the law.

If it is either unrealistic or undesirable to aim for total compliance on the part of the target population, a clear decision rule must be formulated concerning enforcement priorities. In a policy area where polluters vary a great deal in size and how much they pollute, for example, it is commonly most prudent to concentrate enforcement efforts on the largest polluters. If firms are roughly the same size and pollute about the same amount, however, alternative guidelines for identification and discrimination must be set. For example, will businesses be selected randomly for monitoring and inspection? Is systematic enforcement, perhaps based on location, possible? Or, is self-regulation the preferable approach? The decision rule should relate to the strategic goals, resources, and motivations of all those involved. Further considerations include the legal authority

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for enforcement, the resources of the enforcement agency, and the fragmentation of the enforcement agency (or agencies).

In the ex post review/revision stage, policymakers determine the effectiveness of the regulatory program after it has been implemented. Feedback and evaluation are used to assess program performance. Legislative goals are used as a guide in determining whether regulatory approaches are succeeding or failing.

If policymakers determine that the program goals are still desirable, they will continue the same course of action. If they determine that the goals are being met, they will either maintain present enforcement levels or perhaps decrease enforcement efforts. The latter decision should only be made if policymakers believe they can save time and money and feel reasonably certain that compliance rates will not suffer. Appropriate and immediate action is required, of course, if the objectives are no longer desirable or if the objectives are not being achieved. In nearly every case, the aim of policy revision will be improvement in compliance and environmental quality. According to Ingram, the implementation phase of a statutory program "should contribute toward policy improvement or the evolution toward more tractable problems for which there are more doable and agreeable responses." (1990:476) Realization of the statutory goal, therefore, is not the only way to gauge the success of program implementation.

The conceptual perspective for the selection of BMPs analyzed in this report relies on Lowi's (1964) policy classification scheme, with further elaboration by Salisbury (1968). Lowi classifies policies as distributive (non zero-sum policies in which nearly everyone benefits), redistributive (policies that approach zero-sum, in which some benefit and some lose), and regulatory (policies that also tend toward zero-sum, and in which government prescribes rules of behavior for particular groups). Salisbury added a critical dimension to Lowi's typology by identifying self-regulation policies as a fourth policy type. Self-regulation policies are frequently offered as a noncoercive alternative by sectors of society targeted for external regulation, and they are invariably non zero-sum. These policies also impose constraints upon a group, but are perceived only to increase, not decrease, the beneficial options to a particular segment of the population.

Under this classification scheme, policies are *either* self-regulatory *or* regulatory. Thus, the Lowi and Salisbury typologies suggest that regulatory policies are either noncoercive (through self-regulation) or coercive (through direct command-and-control regulation). In the real world, however, regulatory devices tend to fall at different points along a continuum of coerciveness. In other words, devices intended to control behavior tend to vary according to their restrictiveness. Non-coercive approaches (through self-regulation) occupy one end of the continuum while coercive approaches (through direct command-and-control regulation) occupy the other end.

Conceptualizing regulation in these terms provides water quality policymakers a flexible framework in which to assess alternative regulatory mechanisms. Water quality policymakers have a menu of regulatory approaches from which to choose, and careful thought must be given as to which regulatory devices are best suited to control stormwater runoff without being unnecessarily harsh. If members of the target population (e.g., citizens, small businesses, municipalities, etc.) unanimously believe that stormwater regulations and deadlines are too restrictive and unfair, they will likely ignore what they are being told to do. At the same time, if regulatory devices are too weak and not sufficiently coercive to lead to improvement in water quality, then efforts to control

stormwater runoff will fail. Water quality policymakers, therefore, must be familiar with the target population and possess considerable information before they select the most appropriate regulatory mechanisms that embody the level of coercion necessary to achieve an optimum degree of compliance.

Cost is a second dimension that characterizes regulatory mechanisms. Cost here refers to the amount of money government must spend to administer a particular regulatory approach (cost to the regulated community will be considered later). In general, the most coercive activities (e.g., imprisoning polluters) require the greatest government involvement and therefore are more expensive to administer than the least coercive activities (e.g., economic incentives). Limited government revenues obviously make this an important variable. This is especially the case in current government efforts to control stormwater pollution.

The total cost and coerciveness of the selected regulatory program represent the overall government effort necessary to attain compliance and control water pollution. Compliance can be achieved in varying degrees and is best conceptualized along a continuum ranging from avoidance to adherence. Under optimal conditions (e.g., a harmonious political environment), policymakers will be able to use the least coercive enforcement techniques (e.g., reporting by firms and municipalities and formal compliance tracking) at the least cost to achieve full compliance. The expectation is that least coercive mechanisms are always preferable to more coercive mechanisms if only because the former devices are more cost-effective. In contrast, extremely restrictive enforcement arrangements (e.g., court injunctions) will necessitate direct government involvement and thus require substantial cost. Under ideal conditions, therefore, policymakers will select regulatory devices that are the least coercive and least costly and that lead to compliant behavior.

Unfortunately for policymakers, optimal conditions are rare. Many times the conditions that do exist (e.g., a lack of agency funds or a small staff) tend to diminish the effectiveness of the least coercive approaches, often to the point where the outcomes are in danger of moving toward avoidance behavior. In order to prevent outcomes from moving in this direction, policymakers must select techniques, either singularly or in combination, that are affordable and sufficiently coercive to produce compliant behavior.

Naturally, policymaking is a dynamic process and circumstances tend to change over time. Decision makers are continuously gauging the potential impact of given conditions on regulatory mechanisms and making adjustments as they see fit. Eventually, they may be forced to adopt expensive and restrictive approaches that will result in compliant behavior in an attempt to prevent outcomes from moving toward avoidance behavior. When accurate information is available and incorporated into deliberations, policymakers usually will achieve the greatest level of compliance possible with the least effort and expense regardless of the conditions that exist at the time. This underscores the importance of obtaining the most accurate data available as changes occur over time.

In a pluralist, multi-level system like the United States, some communities may favor avoidance behavior in the face of unpopular regulations. While such situations may arise from time to time, in most cases policymakers will want their regulatory devices to achieve the highest level of compliance possible under given conditions.

Stormwater Regulation and Regulatory Intent

The federal Clean Water Act utilizes two approaches to managing water quality: technology-based requirements and national water quality standards. Section 303(d) of the Act integrates these two approaches by stipulating that states make a list of water bodies that are not attaining standards after the technology-based rules are implemented. For water bodies on this list, as well as where the U.S. Environmental Protection Agency (EPA) Administrator believes appropriate, the states are to formulate TMDLs which must account for all sources of the contaminants that forced the listing of the water bodies. Under federal law, TMDLs must account for contributions from point sources (federally permitted discharges) and pollution from nonpoint sources. The U.S. EPA must review and approve the list of contaminated waters and every TMDL. In the event that the U.S. EPA does not approve the list of impaired water bodies or a TMDL, the Agency must establish them for the state. (www.swrcb.ca.gov/tmdl/background.html, July 15, 2003)

The Clean Water Act does not specifically require the adoption of TMDLs. Instead, Section 303(d), Section 303(e), and their provisions stipulate TMDLs be included in water quality plans. The U.S. EPA has adopted rules (40 CFR 122) requiring that the National Pollutant Discharge Elimination System (NPDES) permits be modified to be consistent with all approved TMDLs. An NPDES permit outlines specific limits of pollution for a particular discharger. Nearly all the states, including California, are permitted to administer the NPDES permit program. (U.S. EPA administers the permit system in the remaining states.) Implementation plans are to be formulated along with the TMDLs.

California Law

California effectuates the provisions under the Clean Water Act principally through institutions and procedures set out in certain provisions of the California Water Code, including those of the California Porter-Cologne Water Quality Control Act. These provisions established the State Water Resources Control Board (SWRCB) within the California Environmental Protection Agency to develop and implement state policy for water quality control.

The Porter-Cologne Act also established nine California Regional Water Quality Control Boards that operate under the authority of the SWRCB. Each Regional Board is comprised of nine members and an executive officer appointed by the members of each board. The Regional Boards develop and adopt water quality control plans for all areas within their region. The SWRCB formulates, adopts, and revises general procedures for the development, adoption, and execution of water quality plans by the Regional Boards. It reviews these plans and either approves them or returns them for revision and resubmission. Water quality plans do not become effective until the SWRCB endorses the plans, followed by approval by the California Office of Administrative Law.

The Evolution of Water Pollution Control

During the 1970s, policymakers considered point source pollution to be the biggest threat to the water quality of the nation's inland lakes, rivers, and streams. (www.swrcb.ca.gov/tmdl/background.html, July 15, 2003) The Clean Water Act established a number of programs to address point sources of pollution, and most federal money went to formulate and implement point source controls. California pursued the same approach in its effort to improve the state's water quality. In addition, the State and

Regional Boards implement smaller scale corrective actions for nonpoint source pollution as permitted under the Porter-Cologne Act.

A major goal of the Clean Water Act was to expand treatment of wastewaters. According to Rosenbaum (2002), all treatment plants in operation before July 1, 1977 were required to have "secondary treatment" levels. All treatment facilities, regardless of age, were required to have "the best practicable treatment technology" by July 1, 1983. The Act also appropriated 18 billion dollars between 1973 and 1975 to assist local communities in building necessary wastewater treatment facilities. The federal government paid for 75 percent of the capital cost for building the new facilities. Programs focusing on treatment facilities resulted in significant improvements in water quality by the late 1980s.

Concerns over the nation's water quality arose again due to the growing impacts of nonpoint source pollution, and environmental groups looked to the TMDL requirements to ameliorate continuing water quality problems. A series of lawsuits ensued to force regulators to adopt an aggressive approach to TMDL development. Thus far, over 40 lawsuits have been filed throughout the nation, most of them by environmental groups. (www.swrcb.ca.gov/tmdl/background.html, July 15, 2003) The lawsuits are commonly filed against the U.S. EPA due to its responsibility to approve TMDLs. Several of them have led to negotiated settlements and consent decrees that are overseen by the courts. At present, California is operating under three consent decrees covering most of the North Coast Region, the entire Los Angeles Region, and Newport Bay and its tributaries in the Santa Ana Region.

TMDLs in California are established either by the Regional Boards or by the U.S. EPA. Those established by the Regional Boards are designed as Basin Plan amendments and include implementation rules. Those formulated by the U.S. EPA normally contain the total waste load allocations as required by Section 303(d), but do not include extensive implementation rules, primarily because U.S. EPA implementation of nonpoint source pollution control strategies are generally confined to education and outreach in accordance with CWA Section 319. (www.swrcb.ca.gov/tmdl/background.html, July 15, 2003) Presently, TMDLs are required for all waters and pollutants on the 303(d) list and must consider and include allocations to both point sources and nonpoint sources of contaminants. The limitations in a TMDL may be other than "daily load" limits. There also can be multiple TMDLs on a specific body of water, or there can be one TMDL that focuses on many contaminants. Current examples of TMDLs in the Los Angeles Region include the trash TMDLs for the Ballona Creek and Wetland, Los Angeles River Watershed, and East Fork San Gabriel River, and the wet-weather bacteria TMDL for the Santa Monica Bay Beaches. At this time the Section 303(d) list contains over 1,400 water body/pollutant combinations. Based on this list, the State Board estimates that about 800 TMDLs are needed. The Regional Boards are now developing over 120 TMDLs, with several addressing multiple pollutants.
(www.swrcb.ca.gov/tmdl/background.html, July 15, 2003)

Concerns over implementation have become a significant issue in the formulation of TMDLs. (www.swrcb.ca.gov/tmdl/background.html, July 15, 2003) Although these concerns generally fall outside the provisions of Section 303(d), they are nevertheless important to achieving water quality improvements as a result of the establishment of TMDLs. While it is possible to conduct technical assessments of total load without

considering implementation issues, one must address the possible mechanisms by which pollution can be reduced in determining allocations to various sources. Considering different implementation options can help analysts avoid adopting allocation schemes that are far more costly than necessary or, even worse, unachievable. The TMDL strategy in California seeks to engage the public and cultivate an understanding of watershed issues. It relies on an adaptive process that matches management capabilities with scientific knowledge and information.

The Stormwater Permit

The Los Angeles Regional Water Quality Control Board (LA Regional Water Board) has adopted a NPDES permit containing waste discharge requirements for MS4 discharges within the County of Los Angeles (with the City of Long Beach excluded because it is covered under a separate MS4 permit). The main intent of the Permit is to reduce significantly the amount of various pollutants contained in stormwater runoff. The County of Los Angeles has identified seven critical industrial and commercial sources of contamination: 1. wholesale trade (scrap recycling, automobile dismantling), 2. automotive repair/parking, 3. fabricated metal products, 4. motor freight, 5. chemical and allied products, 6. automotive dealers/gasoline stations, and 7. primary metal products. The priority industrial sectors and automobile repair facilities/ gas stations (two of the commercial sectors) on the list contribute substantial concentrations of heavy metals to stormwater. Overall, the Permit is intended to establish and implement a timely, comprehensive, cost-effective stormwater pollution control program to reduce the discharge of pollutants in stormwater to the Maximum Extent Practicable (MEP) from the permitted regions in the County of Los Angeles to the waters of the U.S. subject to the jurisdiction of the Permittees and also meet water quality standards. BMPs must be identified and implemented to reduce the discharge of pollutants in stormwater to the MEP and also meet water quality standards.

The Permit has established an iterative process that allows municipalities in Los Angeles County to measure noncompliance, test alternative BMPs, and consult County and regional water quality authorities. Thus, the Permit provides a mechanism to make adjustments to the required BMPs as necessary to ensure their adequate performance. According to the U.S. EPA, "Water quality-based effluent limits for NPDES-regulated stormwater discharges that implement wasteload allocations in TMDLs *may* be expressed in the form of BMPs under specified circumstances….If BMPs alone adequately implement wasteload allocations, then additional controls are not necessary." (U.S. EPA, Memorandum, November 22, 2002, p.2)

Regulatory Mechanisms

Pollution control regulations can range from programs that prescribe very specifically what the regulated community is to do, to programs that only set goals and leave the community to find the best methods to reach the goals. Programs of the first kind are often criticized by the regulated community for lack of flexibility—the standard complaint is "This approach does not work well for our particular case. We could do this in another way and accomplish the goals for a lower price". Programs of the second kind provide flexibility, but are often criticized for vagueness: "We don't know how to do this. We are not sure what we have to do to come into compliance".

The stormwater management program is clearly of the second type, and it should be so. Stormwater quality control is an extremely complex issue, influencing, if not everything under the sun, then everything under the rain. The best means of compliance will certainly differ from city to city, depending on land uses, land prices, and a host of physical characteristics of the landscape. It is likely that, as the nation engages the problem, new approaches will be developed. Entrepreneurs will develop new devices and methods as others are tried and discarded. Strict specification of methods at this time might well eliminate approaches that are more economical and effective, so a flexible approach is best.

However, an inevitable side effect of maintaining flexibility is that the regulated community faces an unsettling level of uncertainty. Mayors and city councils faced with planning future infrastructure and future budgets are understandably uncomfortable facing mandatory water quality goals without specified means of reaching those goals. This level of uncertainty will decline as plans are developed and experience with water quality control measures accumulates.

There is a historical precedent for this approach in the program for control of air pollution in Southern California. Like stormwater pollution, it is generated by a very large number of sources with varying compositions and emissions rates. Many of the sources are difficult to monitor and regulate. Implementation of pollution controls has been accompanied by intense political controversy. Even so, air pollution control efforts have been relatively successful—pollution levels and their associated health effects have declined. While costs have been high and some high-polluting marginally profitable businesses have closed or left the area, it is also clearly true that the economy of the area has not collapsed, as some predicted. Few people would suggest that we should return to days when taking a deep breath was literally painful.

Policy Implementation

Our research indicates that the LA Regional Water Board is strongly committed to abating pollution from stormwater runoff as effectively and inexpensively as possible. The U.S. EPA supports the LA Regional Water Board's efforts to require individual municipalities in Los Angeles County to adopt necessary BMPs to control stormwater runoff. Federal and state policymakers along with environmental group leaders believe that BMPs, if widely and strategically implemented, can significantly reduce stormwater pollution and improve water quality throughout Los Angeles County. Given the proven effectiveness of BMPs in different areas of the country (and the world), the LA Regional Water Board does not envision the need to build new advanced treatment plants throughout the region, and indeed has expressed the specific intent that such plants should not be required. Advanced treatment is viewed as an absolute last resort given the huge expense it would entail and the confidence policymakers and environmental leaders have in the ability of BMPs to reduce pollution significantly and allow the region to meet federal clean water standards. The authors of this report concur with this position. Some municipal leaders in Los Angeles County have asked why they should be forced to adopt BMPs when there is a possibility that advanced wastewater treatment plants will ultimately be required. Even if advanced treatment plants are necessary in the future, which is highly unlikely, the adoption of BMPs will dramatically reduce the amount of water and the mass of pollutants these plants will treat. This will reduce pollution

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treatment costs and improve the effectiveness and ability of plants to handle large volumes of water during heavy rain periods. That is, BMPs will be used as part of any program to build advanced treatment plants because the much cheaper BMPs will reduce the costs of the very expensive advanced treatment plants. Implementing BMPs now will be a good investment even in the unlikely event that an advanced treatment plant is required.

The LA Regional Water Board has focused some efforts on reducing trash in stormwater runoff, and it has adopted a "zero trash" rule to achieve this goal. The Board does not expect all communities to eliminate every single piece of trash from inclusion in stormwater runoff. Instead, the Board policy is that communities in Los Angeles County make reasonable efforts to prevent trash from entering storm drains. "Trash" is defined as materials larger than ½ cm, so municipalities can comply with this regulation by installing ½-cm screening devices on their catch basins, by enforcing litter laws already on the books and by conducting street sweeping in areas where trash tends to accumulate. Public education about littering and the installation and maintenance of catch basin devices can provide substantial progress in preventing garbage from entering storm drains.

In order to avoid a costly court battle with state water pollution policymakers, the County and City of Los Angeles have recently agreed to spend $168 million to reduce by half the amount of trash that collects in the 51-mile-long Los Angeles River (McGreevy and Weiss, 2003). In addition, the City of Los Angeles agreed to drop its lawsuit against state policymakers over the overall plan to abate polluted stormwater runoff. The agreement settles a lawsuit filed by the city and county that opposed the LA Regional Water Board's requirement to reduce trash entering the river 10 percent annually over the next 10 years. The LA Regional Water Board officials negotiated the deal, which requires the city and county to reduce rubbish going into the river and Ballona Creek 50 percent by September 2008, at which point state regulators will consider whether further rules are necessary. The agreement also provides local officials more flexibility in trying less-costly approaches of reducing trash. Environmental groups such as Heal the Bay, Santa Monica BayKeeper, and Friends of the L.A. River applauded the agreement. Rather than spend money on litigation, county and city officials will allocate funds to improve water quality.

Clearly, all communities in Los Angeles County will have to share the financial burden in helping to reduce contamination from stormwater runoff. This may require many communities to modify their budget priorities.

As long as communities make a reasonable, good faith effort to address stormwater pollution issues, it is unlikely that federal and state officials will take legal action. Thus far, this has been the case. Failure to make such an effort, however, will certainly result in legal action against violators. Moreover, environmental groups can choose to file lawsuits against federal and state officials if they do not continue to pursue polluters. Such action will lead to costly delays in meeting federal water quality standards and will likely lead to even more draconian measures given present federal and state law and previous judicial decisions.

Previous Actions by the LA Regional Water Board

The impacts on water quality and the heightened risks to public health from MS4 discharges that affect receiving waters across the U.S. and in Los Angeles County and its coastline have been well studied and documented. Accordingly, the LA Regional Water Board has taken a number of significant actions to control such discharges (LARWQCB, 2001)

In 1990, the LA Regional Water Board adopted Order No. 90-079, the Los Angeles County MS4 Permit. That permit required the Los Angeles County Flood Control District, the County of Los Angeles, and the incorporated municipalities in Los Angeles County to implement stormwater pollution controls including updating ordinances, optimizing existing pollutant controls such as street sweeping, construction site controls, and others. The Regional Board required all Permittees to adopt at least 13 specific BMPs for consistency across the County. The 1990 permit was executed on a system wide basis due to the highly interconnected storm drain system serving a population substantially larger than 100,000 residents. At this point, the region was committed to MEP standards—cleaning up stormwater to the maximum extent practicable.

On July 15, 1996 the LA Regional Water Board issued Order No. 96-054 that updated the 1990 permit. The 1996 Los Angeles County MS4 permit required model programs be formulated and implemented by the Permittees for Public Information and Public Participation, Industrial/Commercial Activities, Development Construction, Illicit Connections and Illicit Discharges, Public Agency Activities, and Development Planning. These model programs will change with time as more data on stormwater impacts are collected and become available.

On January 31, 2001 the Los Angeles County Department of Public Works formerly requested to renew their MS4 permit in the form of an ROWD for the County of Los Angeles and the incorporated cities, except the City of Long Beach. This request began the process of reissuance of the permit, which entered into its third permit term. On the same day the Los Angeles County Flood Control District submitted an ROWD. The Regional Board staff invested considerable time and effort in providing opportunities for public participation and comment. Over 30 meetings, two workshops, and many outreach activities were conducted to allow the public, Permittees, and other interested parties enough opportunity to participate in the development of permit requirements and language prior to consideration by the Regional Board for adoption. The reissued MS4 permit committed the region to meeting water quality standards based on the State Water Resources Control Board's precedential Orders.

Implementation of the MS4 permit requirements should reduce pollutants in stormwater in a cost-effective manner. The adoption of BMPs should also reduce pollutant discharges and enhance the quality of surface water.

The final steps of the regulatory process are now under way—TMDLs for the various impaired water bodies of the region are being promulgated.

Overall, it is clear that the LA Regional Water Board does not intend to require that municipalities build advanced treatment plants: indeed, they have publicly expressed the sentiment that they oppose this solution.

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Implementation of Regional Solutions

A regional infiltration and BMP treatment system, in combination with source control of trash, pesticides, and trace metals, can substitute for individual site controls on land parcels within the drainage area. This could take the form of "Local Equivalent Area Drainages", implementing regional solutions that would achieve better results than the application of new source controls, which, in built up areas, will have significant effects only over the long term during which existing structures are rebuilt.

Funding for regional solutions may pose a challenge because of Proposition 13 and other restrictions on tax policy. The challenge however is not insurmountable if property-owners and voters become adequately informed and educated. Nevertheless, regional solutions may significantly shift administrative and cost burdens for water quality protection from businesses and development firms to local government.

Trading Schemes

"Cap and trade" systems, in which regulatory agencies set a cap on the amount of pollution allowable and allow trading of discharge rights within the constraints of the cap, have been successful in several fields. A group of municipalities, for example, might assign discharge rights to landowners within a watershed such that total releases meet the constraints of the TMDLs. They could then allow trading in the discharge rights, so that those who can reduce discharges at least cost are the first to do so, and the overall cost of meeting the TMDL is minimized. Municipalities themselves, as owners of parks and open space, might be able to develop regional solutions and fund them through sales of discharge rights to others.

Stormwater pollution control may be particularly amenable to this approach because the costs of control are highly site-specific. In many cases, there may be considerable economy in applying regional solutions in the best possible sites rather than controlling every site individually.

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DESCRIPTION OF ALTERNATIVE APPROACHES

Infiltration

Before the City of Los Angeles was established, most of the rain that fell in the region evaporated or percolated into the soil. The groundwater was continually replenished and runoff flows were small. As population grew, impermeable surfaces such as paved roads, parking lots, and rooftops covered more and more of the land. Residences, commercial facilities, and roads were designed to shed water as rapidly as possible. Historical measurements of discharges to the Los Angeles River at Firestone Boulevard indicate that runoff has increased from 5% to 45% of rainfall. This change adversely affected stormwater quality in two ways. First it increased the amount of stormwater flow, magnifying the cost of any measures to control quality (and also requiring ever more costly flood control measures). Second, water that flowed directly to streams and the ocean no longer benefited from the purifying action of soil and vegetation, which can remove particulates through physical filtering, sequester some chemicals by adsorption, and destroy organic and biological contaminants by biodegradation.

Any program for remediation of stormwater contamination should reverse this trend, reducing the load of both water and pollutants on other parts of the system. At the same time, pollution of groundwater must be avoided. However, infiltration will benefit from the very considerable capacity of soils to filter particles, adsorb contaminants, and biodegrade organic materials. A relative estimate of the magnitude of the problem may be made by comparison with examples of leaking underground storage tanks at gasoline stations. In many cases, spills of tens or hundreds of gallons of gasoline are now being handled by "intrinsic remediation"—allowing natural biodegradation to degrade the hydrocarbons. The acceptability of this approach has been supported by extensive research. Hydrocarbon infiltration with stormwater will involve far lower concentrations of hydrocarbon, and will mostly be the higher-molecular-weight compounds that are much less mobile in soils than gasoline.

We can also compare stormwater infiltration to the effects of septic tanks. These systems infiltrate sewage that has received only a modest degree of treatment. Yet they are still in use in the Los Angeles Region, and indeed are the primary waste disposal method for 15% of households in the U.S. Groundwater contamination from septic tanks has occurred, but most are considered effective and safe waste disposal systems.

This comparison suggests that the relatively low concentrations of pollutants in common stormwater, with appropriate controls on sources of specific contaminants, will not pose a significant threat to groundwater quality.

The permeability of soils in the Los Angeles basin varies from place to place. Beneath the Whittier Narrows spreading basins, for example, sand and gravel deposits allow very high rates of infiltration. In other areas, clay-rich soils reduce rates of infiltration. However, the historically low rates of runoff indicate that infiltration is capable of handling the bulk of the rainfall in the Los Angeles Region. Many areas routinely considered as having poor infiltration rates will never the less be useful as multi-purpose infiltration systems. A soccer field, for example, can be used as an

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infiltration basin at little additional cost, and will make a valuable contribution even if infiltration rates are low in comparison to those in spreading basins.

Source Control

Industrial Releases

Industrial discharges can be controlled by a vigorous program of source identification and control. Businesses have a fundamental responsibility to do their work without contaminating their neighborhoods, and in the great majority of cases can do so without significant interference with their activities.

Trash Management

Many businesses and some homeowners contribute a disproportionate amount of trash to the urban burden. Paper waste often accumulates in the parking lots of fast food outlets and strip malls, where it can wash into the street during rainstorms. Inadequate dumpsters and garbage cans are overloaded so that trash spills into the streets. Poorly covered trucks can allow trash to fly out on the streets. In addition, citizens throw trash from their cars onto the streets (it has been estimated that as much as 60% of trash on freeways by weight is cigarette butts). All of these practices are illegal, but enforcement is currently rare and weak. While perfect compliance with anti-litter laws is not expected, there could certainly be major improvements through enforcement. Much of the cost of such efforts could be recovered through fines, with the satisfying result that those causing the problem would be paying for cleaning it up.

Municipalities are responsible for the trash deposited on their streets, and most will respond by installing screens on catch basins. These are sometimes referred to as catch basin "inserts". They will have half-centimeter openings and will be designed to collect trash during periods of low or modest flow, but to bypass the flow during heavy storms or if they are clogged. This will avoid local flooding that would be caused by clogging.

Street Cleaning

Trash that escapes enforcement efforts can be collected by street cleaning before it reaches the storm drains. Enhanced street cleaning is likely to be necessary as cities install half-centimeter screens on their catch basins. Trash that is now washed out of sight (at least until it reaches the beaches) will accumulate on the screens and possibly clog them. More effective and more frequent street cleaning will reduce this problem.

A major fraction of the pollutants in stormwater runoff are adsorbed on particles—this is particularly true of trace metals and pesticides, which are significant contributors to impairment of the receiving waters. Some of this particulate matter can be removed from streets by higher-quality street vacuuming equipment, which collects the dirt much as a vacuum cleaner does. This equipment is more expensive to purchase and operate, but it would make a significant contribution to reducing chemical pollutants in stormwater.

The Port of Seattle has tested high-quality street sweepers as a cleanup method in its container storage area (FHWA, 2003). The approach was successful, removing one-third to one-half of particulates and their associated pollutants. While the equipment is somewhat more expensive than simple sweepers to purchase, operations costs are about

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the same. The fine particles carry a significant portion of the pollutants, but they constitute only a small portion of the total mass of material on the streets, so their collection and disposal does not significantly increase costs. Such street cleaning may be more effective in Southern California, where the long dry season allows dust to accumulate for many months.

As explained in detail later, there would be substantial secondary benefits associated with improved street cleaning. Neighborhoods would look better, and residents would be exposed to less resuspended road dust, which dirties buildings and may have significant negative health effects.

Some investigators have also proposed street washing, using recycled water. If this were done during dry weather, and all of the dry-weather flow were being collected for treatment in wastewater treatment plants, street pollutants would be kept out of the rivers.

Pesticide Substitutions

Many of the receiving waters in the Los Angeles Region are impaired by pesticides, particularly Diazinon and Chlorpyrifos. The approach to this pollution should be the same as it has been historically for other pesticides that threatened environmental quality. None has ever been dealt with by treating contaminated waters. Those who use the pesticides should be responsible for ensuring that no water pollution results from that use. Pesticides that cannot be properly managed by appropriate use protocols such as labeling or use rules enforcement and which have an inherent tendency to persist in the environment should be banned. Pesticide controls are instituted by the state and federal governments, so additional political effort will be needed if a bans on specific compounds are required.

We presume that these pesticides are used in many cases because they are currently the most economical approach to insect control, and that substitution of another method would involve some cost. However, there are many possible alternatives, including use of more readily degraded pesticides, insect-resistant strains of plants, biological control with natural insect predators, and others. There are many examples of success with such integrated pest management (IPM), particularly at golf courses (NRDC, 1999). In some cases owners were pleased to find that costs actually declined when they switched from pesticide-dominated approaches to IPM.

Trace Metals

Trace metals enter stormwater as rain drains from industrial operations, transportation land uses, and other sources. Brake pad wear on cars produces a fine dust of copper. Zinc is released when galvanized equipment contacts the water. Trace metals in stormwater can be controlled by covering machinery and materials that release trace metals, by capturing and treating runoff from large industrial operations and transportation land uses, and by developing alternative materials for brake pads (research is currently under way on this objective).

Control of Automotive-Related Sources

Motor vehicles and related facilities are the source of many types of runoff pollutants, including hydrocarbons from oil and fuel leaks, and road wear. Vacuum street cleaning is effective in dealing with particle-bound hydrocarbons left on the street,

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and infiltration can effectively deal with hydrocarbons that are transported or deposited off the street surface.

Control of Bacteria

Bacterial contamination in stormwater is typically measured as counts of "coliform" bacteria, a category that contains many species of bacteria. While very few of the coliforms cause disease, some of these species are very abundant in human waste, and so detection of the group has long been used as a marker for sewage pollution. Efforts to interrupt the fecal-oral transmission of disease have commonly taken the elimination of coliforms from water as a surrogate for judging efforts to prevent the spread of the microorganisms that do cause disease. Where coliform counts in drinking water have been reduced (in much of the industrialized world) transmission of water-borne disease has indeed been largely eliminated. Thus the use of coliform counts as a marker for disease control has been remarkably successful. In some cases, a more specific test for "fecal coliforms" is used, because the test is an indicator of contamination by warm-blooded animals, including humans. While we have always counted coliforms, the real concern is pathogens—microorganisms that can cause disease. For sewage pollution, the association between the two has been strong, and controlling coliforms has been equivalent to controlling disease. The situation for stormwater, however, may be far more complex. Because there are many non-human sources of coliforms, it is possible that the test for their presence may be positive even when no human pathogens are present.

The sources of the coliforms found in stormwater remain uncertain. Pet wastes certainly include bacteria that test positive as coliforms, but the degree to which pet wastes constitute a disease threat is uncertain. Wild mammals, such as raccoons, possums, skunks and coyotes, may contribute when their wastes are left on paved surfaces. It has been proposed that fecal matter from homeless people denied access to restrooms may be a source, but there has been no study confirming this. In less developed areas with poor soil infiltration conditions, it is likely that poorly operated septic tanks and illegal disposal of gray water are contributing to the coliform counts detected in runoff. If septic tanks are the source, strict enforcement of waste control ordinances is appropriate. If homeless people are the source, provision of restroom facilities would be far cheaper than any imaginable stormwater treatment system (as well as being more humane). If pet feces are the source, the only approach is, through public outreach and enforcement, to press people to clean up after their pets. It must be expected, however, that such an approach will not be 100% effective. The contribution of wild animals seems uncontrollable.

Because the sources and significance of the coliform counts remain uncertain, it is important that research on the topic be pursued immediately. The recent development of genetic techniques for precise and rapid identification of bacterial species now provides the tool needed to provide the information needed to develop effective policies.

Coliforms, and presumably the associated human pathogens, are substantially reduced in treatment wetlands. Infiltration of course removes them from runoff flows, and adsorption on soils and biodegradation are effective at protecting groundwater. Water storage, because it holds coliforms in an environment for which they are not adapted, and because it allows settling of particles to which they may be attached, has

some beneficial effect. Disinfection, using chlorine, chloramines, or ultraviolet light is possible, but relatively expensive.

Water Quality Control Board Rules allow for 17 exceedences of the coliform limit per year. There are about 32 days per year of significant rainfall in the region, so it has been anticipated that exceedences during the heavy winter storms will be difficult to control, and will be allowed.

Improved Enforcement

It is important that source control efforts include genuine and credible enforcement. Rules that are widely ignored, of course, will not help clean up runoff water, and a considerable fraction of runoff contaminants come from illicit discharges or disposal. Trash is an obvious example—littering is already illegal, so 100% of the trash in stormwater represents illegal release.

The Environmental Protection agency describes an example in which improved enforcement of existing law was effective (USEPA, 1999):

"…during a 12-month period, the Houston, Texas, Public Utilities Department identified 132 sources of discharges leading to Buffalo Bayou, the local drinking water source, with estimated flow rates ranging from 0.3 to 31.5 liters per second. Houston's program involved monthly sampling from bridge crossings; analysis of samples for carbonaceous biochemical oxygen demand, ammonia and nitrate nitrogen, pH, TSS, DO, temperature, fecal coliform, and chlorine residual; comparison of samples to baseline flow concentrations; weekly sampling of temperature, dissolved oxygen (DO), and fecal coliform in stream reaches suspected of contamination; boat sampling to identify the contaminating outfalls along the reach; and, finally, a land-based search to pinpoint the source. Of the flows identified during the program, 85% were due to broken or clogged wastewater lines and 10% were due to illicit connections (Glanton et al., 1992). Eight months after an illicit discharge detection and elimination program began, fecal bacteria log mean concentration was reduced from 20,000 colonies/100mL to 2,000 colonies/100ml."

Thus, in this example, a 90% reduction in bacterial contamination resulted from a careful enforcement program alone.

Detention and BMP Treatment

Stormwater Detention Basins

Many of the problems of stormwater management are associated with its very irregular rate of flow. During dry periods runoff flow rates are so low that the water can be handled by existing sanitary wastewater treatment systems. During rainstorms, the water comes so fast that municipalities have had difficulty doing anything beyond avoiding floods.

The first step toward dealing with this problem is to increase infiltration—substantial reductions in the peak flow rates are possible. The second approach is to provide storage systems that will hold water back during the peak flow periods. Detention basins will reduce peak flows, collect trash, provide quiet water for settlement of particles and their associated pollutants, and promote infiltration. Analysis of the

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National BMP Database (Strecker et al., 2003) shows that detention basins infiltrate an average of 30% of the water they receive.

The primary difficulty with this approach is the shortage of available sites to construct large reservoirs. The topography of the Los Angeles area does not include any deep canyons in lower reaches of the rivers that could easily be made into reservoirs. Moreover, virtually all of the land is already occupied by other uses and would accordingly be very expensive to acquire.

This means that detention basins must be conceived as a distributed network of smaller systems, with each serving multiple uses. A useful model is the Sepulveda Dam Recreational Area, which retains water during storms to prevent downstream flooding. For the great majority of the days in the year, the basin is mostly empty, and serves as a park and a wildlife refuge.

A rough estimate of the general feasibility of a regional-park-based approach can be calculated. The City of Los Angeles currently has about 5% of its area in parks (Wolch et al., 2002) and it is reasonable to presume that at least a similar fraction is park throughout the LA Region. Thus, moving the rainfall from adjacent developed areas to the parks would constitute concentration of the flow by a factor of 20 (20 acres of land would drain to 1 acre of park). If the runoff coefficient for the developed areas is 0.5, a rainfall of ¾ inch would thus put 8 inches of water in the parks. This is less than the 24-inch depth of flooding assumed for the stormwater parks planned in the Sun Valley project, suggesting that this approach is feasible on the large scale in terms of the amount of land required.

This calculation is quite approximate: the runoff coefficient is uncertain, and several other factors are poorly known. Never the less, the calculation suggests that a joint program could simultaneously provide the region with needed parks and needed stormwater infiltration capacity.

Sanitary Treatment of Dry Weather Flows

During dry weather, small flows are present in the stormwater system as a result of overwatering of lawns, car washing, and other discharges. This modest amount of water can be collected and passed through existing wastewater treatment plants, which commonly have more than enough excess capacity for this purpose. Because the dry season in Southern California is very long, this would prevent runoff pollution of the oceans for much of the year.

Where this is done, street washing with recycled water would be possible. Collecting and treating the contaminants during dry periods would leave the streets clean for the rainstorms, when the water cannot be collected.

Treatment Wetlands

Wetlands remove many pollutants from the water that passes through them. The low flow velocities allow sediments to settle, removing particulates and any pollutants that are adsorbed on them. Algae and rooted plants absorb nitrate and phosphate as they grow. Vigorous microbiological activity degrades organic chemicals, as microbial predators consume disease organisms. These observations suggest that wetlands can be constructed to serve as treatment systems for stormwater and dry weather runoff. While this approach requires dedication of land, it has the considerable secondary benefit of providing riparian wildlife habitat and esthetic values.

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A system of treatment wetlands has been designed for the San Diego Creek Watershed that drains to Newport Bay, in Orange County, California. The system will serve an area of 120 square miles, and is expected to cost in the low tens of millions of dollars. It is expected to meet the low-flow nitrogen TMDL, the phosphorus TMDL during most years, and the fecal coliform TMDL during low flows.

A similar system has been constructed to provide stormwater quality protection for the Ballona Wetlands Watershed in the City of Los Angeles.

BMP Treatment of Flows from Problem Watersheds such as Industrial Areas

If source control is not successful for some industrial areas, it may be necessary to collect the runoff water and use more sophisticated BMP treatment. These might best be constructed as private facilities serving a consortium of local industries, and funded by them for the purpose. A public/private partnership could be created, perhaps with public loan guarantees. Past experience with business improvement districts could serve as a model.

Partial Treatment in Curbside Units

Many proprietary devices have been developed for treatment of runoff as it enters curbside catch basins. These generally remove trash from the flow, and may also collect sediments. Some include adsorbants to remove hydrocarbons and trace metals. They have the disadvantage that they are designed to bypass during higher volume wet-weather flows. All require some degree of maintenance, and some are expensive to install. Trash and sediment must be removed on a regular basis, and adsorbants must be replaced when they are exhausted. Never the less, they may be useful for treatment of problem dry weather flows in specific areas, such as industrial or commercial zones.

Public Outreach and Education

Much of the pollution in runoff water arises from actions of individuals—litter is discarded in the street, for example, or pesticides are used carelessly in a residential garden. This pollutant load can be reduced by educating citizens and urging them to behave in a way that protects water quality.

An effort in Oregon, conducted by the Tillamook Bay Rural Clean Water Project, was made to educate local farmers about the steps they could take to protect local streams. This involved personal visits, tours of successful BMPs, newsletters, and presentations (USEPA, 1999). Four years after the program began, bacterial concentrations dropped 40% to 60% in Tillamook Bay and 50% to 80% in local rivers. Thus in some cases significant progress can be made at very low cost through public education.

Good Housekeeping for Municipal Operations

While the behavior of individual citizens may be difficult to control, municipalities have far more control over their own operations. Efforts can be made to avoid careless use of pesticides and fertilizers on municipal facilities. Such steps have modest, but measurable impacts. An EPA report notes (USEPA, 1999):

> "…the City of Bellevue, Washington, found that street cleaning three times a week removed about only 10% of urban runoff pollutants; catch basin cleaning

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twice a year was estimated to be about 25% effective" (Pitt and Bissonnette, 1984).

Combined Approaches for Stormwater Quality Management

A general classification of rainfall receivers and appropriate methods for dealing with runoff they produce is shown in Figure 1. While the approach it describes is quite general, and other mixes of alternatives are possible, it shows one set of measures that can be used to control stormwater pollution.

Streets

The first step in reducing pollutants on streets is to restrict pollutant discharges from adjacent properties. Source control measures should prevent the release of industrial pollutants and construction sites should be managed to contain sediments. Litter laws and pet dropping collection laws should be enforced, although it must be acknowledged that it is not possible to prevent these inputs entirely. To stop litter from entering the storm drains, cities should install half-centimeter screens on their catch basins. The use of such screens will require diligent street cleaning, to ensure that the drains are not blocked during storms. In Southern California, rains mostly occur during a well-defined season, and frequently weather reports give two or three days warning of major storms. Cities should develop contingency plans for rapid-response street cleaning when storms are coming, to minimize stormwater contamination and the chances of flooding caused by clogged screens.

In some areas, where runoff water quality is relatively good, the streets themselves might be used as groundwater recharge facilities, by converting unused alleys to park/detention basins or by using permeable pavements.

It remains likely, however, that much street runoff will be of marginal quality. For the immediate future, it is also likely that a major portion of runoff from other sources will be initially discharged to streets, so that efforts to make use of stormwater as a water resource will require collection, and a degree of treatment before infiltration.

In most cases, this can be done with regional solutions. Water from storm drains can be collected in detention basins and wetlands, where sedimentation and biological activity will reduce pollutant load, and groundwater recharge can occur. The detention basins will serve as parks during the greater part of the year when water is not present, and the wetlands will double as much-needed wildlife habitat.

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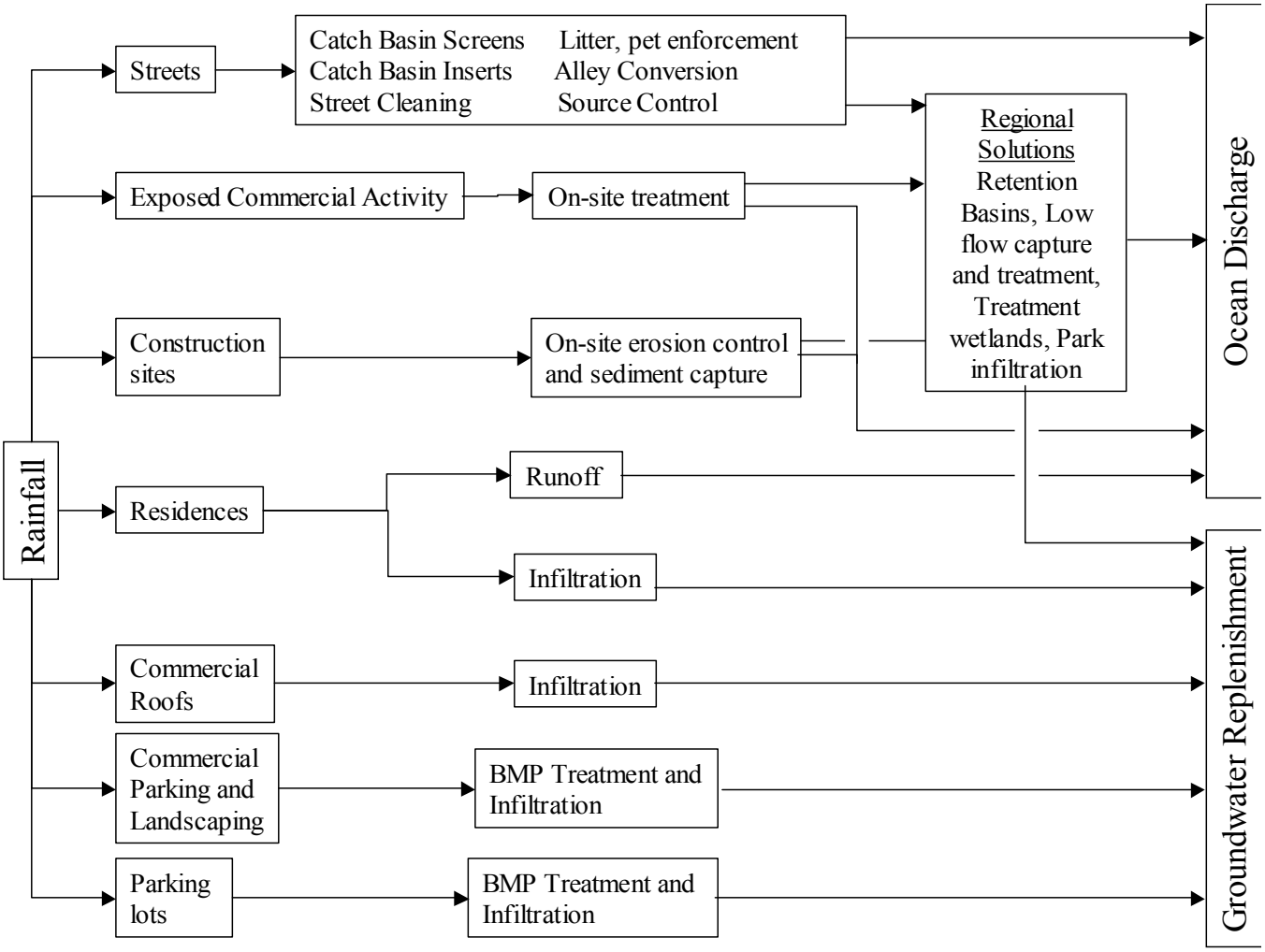

Figure 1. Stormwater quality control solutions for Southern California

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Alleys for Public Use and Infiltration

Some alleys in urban areas are no longer necessary for access purposes. Indeed, many have become nuisance areas because of illicit trash disposal and criminal activity. Many of these could be gated and converted to small parks, with keys provided for local residents. They could simultaneously serve as infiltration facilities or as bioswales. There are currently 2.3 square miles of alleys in Los Angeles, for example. While many must be retained for access purposes, the fraction that could be converted could constitute a significant stormwater retention and infiltration resource. Alleys maintained for access might be candidates for partial or permeable pavements.

Similar approaches could be used for power line rights-of-way.

Exposed Commercial Activity

Very often the cheapest approach to stormwater quality control for exposed commercial activities is simply to cover them. Stormwater will thereafter come in contact only with the rooftop, and runoff will be much less polluted and more easily dealt with. However, for some large-scale activities, such as oil refining, it is not physically possible to provide a roof. For others, such as auto dismantling, the large area needed and the relatively low value of the activity may mean that a roof is not financially possible. Such facilities must be required to collect and treat runoff from their facilities, and indeed this is already being done in many cases. While there certainly are costs involved, it has generally proven possible, through a combination of better housekeeping, substitution of non-polluting materials, and simple on-site treatment processes, to solve these problems. Requirements for on-site treatment are advantageous because the cost of such treatment is borne by the business that produces the pollutant, providing incentives for conversion to less-polluting products and methods. Consequently, green manufacturing will become increasingly common.

Construction Sites

Release of sediments from construction sites can be ameliorated if the construction crew provides erosion control measures, such as maintaining vegetation or spraying exposed soil with polymer stabilizers, and an adequate on-site retention pond for rainfall, along with dikes, silt fences, and appropriate vehicle entrance construction to prevent runoff. Detention allows the sediments to settle out and the exposed soils can function effectively for groundwater recharge. It is anticipated that the costs of these measures will be small in comparison to construction costs. A more detailed list of best management practices for construction sites appears in Appendix I.

Residences

In most cases, homes and the surrounding landscaping have been designed to facilitate rapid runoff. It is necessary that water not pool in depths sufficient to flood houses, and ponding is viewed with irritation, even if it is harmless and temporary. However, single-family homes typically are surrounded with a significant area of land that could serve well for infiltration. Commonly, the land is planted or covered with

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grass. The runoff from landscaping and residential rooftops typically contains only small amounts of pollutants that are readily removed by percolation through the root zone.

Landscaping for the typical single-family home could be arranged to infiltrate all of the rainfall that it receives (except, perhaps, in the most severe storms). Lawns a few inches below surrounding sidewalks could serve as infiltration ponds, gardens could receive roof runoff, and downspouts could conduct runoff to dry wells. Because the water would have had very little contact with pollutants, such infiltration would be an excellent addition to groundwater resources.

However, very few residences are arranged in this manner and, indeed, building codes often specify features that promote rapid runoff to the street. Building codes should be changed to utilize single-family homes as recharge sites. It is anticipated, however, that the effect on runoff will be seen only slowly in built-up areas as old homes are gradually replaced. Retrofit of existing homes will be expensive and politically difficult, but for new construction, single-family homes could be made to produce essentially zero discharge at little or no additional cost.

Xeriscaping—planting with native and other drought-tolerant plants—can also help to provide space for water infiltration, and it reduces watering and therefore the chance of irrigation runoff. Such landscaping also requires less fertilizer and pesticide, and so reduces incidental contamination.

In many cases, cities may be able to take interim steps to reduce runoff from homes. They have control over the "city strip" land that lies between the sidewalk and the gutter. It would be possible to institute a program of replacing the lawns after minor excavation, so that these areas would lie below the sidewalk and curb and serve as runoff detention and percolation basins.

Where infiltration is not possible, much residential runoff may be acceptable for direct discharge to the ocean, as long as it is not contaminated first by passing through polluted streets. More contaminated water can be conveyed to regional water cleanup and recharge facilities.

Low-flow Treatment in Wastewater Treatment Plants

Wastewater treatment plants are built with excess capacity in order to handle increased flow during rainy weather. While sanitary systems are designed to exclude stormwater, holes in manhole covers, leaks in piping, and illegal connections all allow the entry of some water during rainstorms. The flow is a very small portion of the rainwater, but can produce a significant increase in the much smaller sanitary flows—sometimes up to 50%. Treatment plants are designed with excess capacity to handle these peak loads.

This excess capacity can be used to treat dry weather runoff during periods when there is no rain. While these flows are not, by definition, stormwater, and indeed are governed by a separate set of regulations, dry weather runoff is often a significant contributor to impairment of receiving waters and its treatment would contribute to the objectives of stormwater control. It is also possible to use this capacity in concert with "street washing". In this approach, tank trucks filled with recycled water could be used to wash the streets, particularly in the months before the first rain of the fall. Contaminants removed from the streets and drains by the washing would be treated in the

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wastewater plants, leaving the streets far cleaner when the rains came. At present, municipal street cleaning is a prohibited activity where it results in flows to the storm drain system.

This treatment approach for dry weather runoff could also treat runoff from small rainstorms.

It is likely that all of dry weather runoff could be treated for much of the Los Angeles Region. Such a step would eliminate essentially all runoff pollutants in the areas where this is possible. Because this approach uses capacity that is already in place, the cost for this alternative is low.

This approach would be particularly significant for control of coliforms. Sanitary treatment of dry weather flows would eliminate coliforms through much of the year. Rain occurs during only 32 days of the year, on average (Some of these storms are so small that the runoff could still be treated. On the other hand, untreatably high levels of runoff typically continue for a few days after a major storm). The LA Regional Water Board allows variances for 17 days of wet weather flow during the year. Thus it seems likely that dry weather runoff treatment at wastewater treatment plants, plus some degree of source control, plus the variances, will be sufficient to bring most areas into compliance with the bacteria rules. Further study, including some basic research on the sources of coliforms, is necessary to confirm this.

In considering the acceptability of this approach, it is important to note that beach use declines during wet weather, so that closures during the variance days would have a small effect on overall beach use and public health.

Capture and Use of Rooftop Runoff

In many cases, the pollutants from commercial rooftops, like those from residential roofs, could be readily removed by soil infiltration. With appropriate controls to avoid specific pollutants from commercial activities, roof runoff could be used for groundwater recharge. Designs exist for infiltration planters, in which the planter has high sides that allow it to function as a reservoir, and an open bottom that allows infiltrating water to pass into the soil. Risks of groundwater pollution could be mitigated through the use of biologically active and adsorbant soils. Commercial rooftops are commonly associated with large parking areas, which could be adapted for infiltration. Such efforts will be more difficult than those for homes, because most commercial facilities have a higher ratio of roof area to land area. In some cases it may be possible to store runoff for future irrigation use.

The Washington State Department of Ecology (2001) has developed a decision tree for dealing with downspout discharges. For lots larger than 22,000 square feet, it specifies either dispersion or infiltration systems for runoff. For smaller lots on suitable soil, infiltration systems are required. Where soils do not readily accept infiltration, surface dispersion may be appropriate. If water quality is good and infiltration and dispersal are not possible, disposal to the storm drains is accepted.

Parking Lots and Landscaping

Parking areas occupy a very large amount of land in Southern California, and accordingly represent a significant opportunity for improvement in stormwater

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management. Construction costs for parking lots are far smaller per square foot than those for buildings, so that alterations are cheaper. They are reconstructed more frequently, so that requirements applying to new construction or reconstruction will propagate through the parking lot inventory much more rapidly than those for buildings.

In most cases, parking lots could serve as sites for rainwater infiltration. Trash can be collected on grates and be disposed of properly by the lot owners. The curbs around plantings (which are often necessary to avoid damage to the plants from cars) can be slotted so that water passes through them to infiltrate in the planter soils. Planted areas must be below grade, so that they collect and temporarily store water, and could be expanded, utilizing more space where cars don't actually park, such as the areas between and behind the parking bumpers. In some areas, permeable pavements could be used. Collected water could be passed to leach fields built under the parking lot.

An example of this sort of development is provided by the 6-acre parking lot of the Oregon Museum of Science and Industry (NRDC, 1999). It had originally been proposed as a traditional design, with water draining to catch basins, storm drains, and eventually the Willamette River. At the request of the Portland Bureau of Environmental Services, it was redesigned to use vegetated medians and landscaping as swales and linear wetlands. The parking lot is now able to infiltrate the water from a storm of 0.83 inches in 24 hours. Overall construction costs for the revised design were actually lower, because of the reduced costs for catch basins and drains.

Pervious pavements have also been developed so that even the space where cars are parked can be used for infiltration.

There is some concern over whether infiltration from parking lots will pollute underlying aquifers. Sediments, hydrocarbons, and trace metals are likely to be present in parking lot runoff from ordinary commercial establishments. But all of these are generally well retained on soils, particularly if the soils are selected to serve this purpose. Adsorbent materials might be added as a surface layer, to further retain hydrocarbons and trace metals.

It will be necessary to develop new guidelines for parking lots. The public and lot owners will not tolerate flooding that requires them to wade to their cars, so detention and infiltration systems will have to be carefully designed. Overflow will occur in extreme storms, and the lot and remediation areas should be designed so that the excess water flows to the street without impeding access to parked vehicles. Redesigned lots can be required for any new construction or for major renovations, but complete retrofit of all lots is likely to be too expensive for political acceptance.

This will require some additional maintenance. If adsorbants are included in the recharge areas to help control hydrocarbon infiltration, for example, these will have to be renewed from time to time. Regular trash collection will be required.

It is anticipated that most parking lots could become zero runoff areas, contributing substantially to water conservation and pollutant remediation. Further, very large parking lots, such as those at "big box" stores and shopping malls, could be reconstructed as stormwater infiltration facilities serving surrounding neighborhoods. In a cap and trade system, the lots would become financial opportunities for the retailers.

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River Greening

The Los Angeles Region has become infamous for its historical conversion of rivers to concrete-lined flood control channels. While these have served the purpose of moving water rapidly to the ocean and avoiding flooding, they have also prevented infiltration in the riverbed. For this and many other reasons, advocates have proposed "greening" the river. This would involve widening the river at some points and replacing the steep concrete walls with gently sloping vegetated shores. Parks and wildlife habitat could be developed alongside the river, designed such that they would flood when the river is high. This would allow infiltration to occur, and by providing temporary storage, would decrease peak flood flows. In many areas it may be possible to replace the concrete bottoms of rivers with permeable surfaces.

The Sepulveda Dam Recreation Area is an excellent example of such a facility. It stores water during heavy rains, but serves as a park and wildlife refuge during the greater part of the year when it is not flooded. It promotes infiltration of water during rain events.

Certainly, any such modifications of the rivers must be designed carefully so that flood risk is not increased. But this is clearly possible. Indeed, increased infiltration and storage capacity along the river will reduce peak flows and therefore the frequency of floods, and reduce the associated costs.

Infiltration in Residential Streets

Many areas in Southern California are primarily residential, and runoff from these areas is only moderately polluted—it could be used for direct infiltration without treatment. In newly developed areas, homes could be designed so the runoff is near zero. However, many areas are currently already built out. In these, preventing runoff to the street would be expensive. In many cases, it may be possible to install infiltration devices in the public streets.

Infiltration in Parks

Public parks, in most cases consisting predominantly of grassy areas, are already contributing to groundwater infiltration. However, some portions still contribute to runoff, and could be regraded to collect water rather than shedding it. Indeed, many could be rebuilt to serve as groundwater infiltration systems serving surrounding areas. Playgrounds could be sunk below surrounding areas in order to collect water during rainfall events. Designs would have to include provision for infiltration at acceptable rates—water left standing for days could become a nuisance. In some areas, soil conditions might preclude this approach.

During the few days after water is collected and before it percolates, that area of the park will be unavailable for other uses. However, parks are little used during rainy weather in any case, and detention will only occur on a few days each year, so the interference will be minimal.

Public Facilities

Runoff from public facilities could be reduced by many of the measures previously discussed. Parking lots could be used for infiltration and rooftop runoff could

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go to planters serving as infiltration systems. Retrofit of government facilities could begin more quickly than for individual homes, as part of the effort required to meet regulations.

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PRIMARY BENEFITS OF RUNOFF QUALITY CONTROL

The immediate purpose of runoff quality control is protection of the receiving waters. In the Los Angeles Region, this refers primarily to rivers, coastal wetlands, bays, and the ocean. Many benefits are definable.

Fishing

Pollutants in stormwater can adversely affect fishing. Commercial fishing is a small and declining industry in the waters local to Southern California, but sportfishing remains a significant activity, bringing income to coastal businesses and providing recreational opportunity for many people. Cleanup of stormwater will preserve and enhance this activity by ensuring that fish are safe for consumption and by preserving fish breeding grounds in estuaries.

Swimming

Ocean swimming, as part of a visit to the beach, is a recreational activity enjoyed by millions of people each year in Southern California. It attracts tourists who contribute substantially to coastal economies. It is discouraged if trash litters the beach or if fear of disease discourages water contact. It is prevented entirely in the event of beach closures, which are a common result of polluted stormwater runoff.

Boating

Powerboats and sailboats are widely used in Southern California and represent a substantial industry in manufacture, maintenance, provision of slips, and various associated shoreside activities. Polluted waters, particularly in the form of trash, can significantly degrade the quality of the boating experience.

Noncontact Recreation and Nonconsumptive Wildlife Uses

Some recreational activities involve bodies of water without contact: sitting or bicycle riding along rivers or lake shores are examples. These activities are seriously degraded if the water produces bad odors or is littered with trash. A stormwater quality program will protect and enhance these uses.

Observation of wildlife is often a valuable part of the outdoor experience. Continuation of this activity requires water quality sufficient to support birds and animals and the plants and insects that they eat. Many migratory birds are dependent on local bodies of water for their sustenance during their yearly movements.

Reduced Illness from Contaminated Seafood

Some illnesses are transmitted through consumption of contaminated seafood. Control of the microbiological quality of runoff waters will reduce the extent of such illnesses.

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Reduced Illness from Swimming in Contaminated Waters

Recent studies have indicated that people swimming near storm drains are more likely to contract waterborne diseases than those swimming far from storm drains. Microbiological control of runoff quality, particularly through sanitary treatment of dry weather flows, could reduce the incidence of these diseases.

Enhanced Esthetic Values

The trash cleanup associated with stormwater quality control will improve the appearance of our harbors, rivers, streets, and commercial establishments. Esthetic enjoyment of wildlife habitats such as wetlands, in particular, is hindered if trash is present.

Preservation of Natural Ecosystems

Polluted urban runoff damages natural ecosystems in many ways: toxic material can sicken or kill organisms, trash can choke marine mammals or birds, additional turbidity can prevent the penetration of light necessary for seaweed growth, sediment can bury habitats and prevent attachment of organisms to rocky surfaces, and nutrients can fertilize overgrowth of mosses and plankton. This damage can be prevented by stormwater quality control, and is one of the prime reasons for the program.

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SECONDARY BENEFITS OF STORMWATER QUALITY CONTROL

Urban runoff comes from a huge variety of sources and contacts much of the environment around us. The efforts made to clean up runoff, which have the primary purpose of preventing water pollution in receiving waters, will have many secondary benefits and these should be included in any cost-benefit analysis. Indeed, some of these benefits are so substantial that they suggest the agencies responsible for the resources in question should also be providing financial support for runoff quality control efforts.

Groundwater Restoration

Total rainfall in the Los Angeles basin in an average year is equal to about half of the amount used for drinking water supply. It is strange indeed that we pollute this water and discharge it to the ocean even as we import ecologically, politically, and financially expensive water from the Colorado River, Northern California, and the Owens Valley. The primary difficulty in making productive use of this water is the lack of storage capacity. Rainfalls are infrequent but intense: most of the time there is no rainfall available for use, but occasionally it is so abundant that it causes flooding. Surface water reservoirs are the traditional solution to this problem—water is stored during the rainy season to prevent floods and becomes available for valuable uses the weather is dry. But there are few workable sites for large, year-round surface water reservoirs in the Los Angeles area. Groundwater aquifers, however, can also serve as water reservoirs, being drawn down in the dry season and replenished during the wet season. Infiltration will constitute a use of this storage capacity, reducing future dependence on outside sources of water and avoiding expensive alternatives like desalination of seawater. Because environmental and political factors may make increasing water imports impossible at any price, better utilization of local rainfall through the use of the groundwater reservoirs may be necessary for future growth.

Improvement of groundwater supplies within Southern California would save money now spent on imported water, and would save the concomitant external costs of the environmental impact on source areas. It would also reduce political friction with source areas. Ultimately, it may be the only economically and politically feasible method by which the water supply in Southern California can be increased, and as such, it may be the key to continued development in the area.

Flood Control

As the fraction of the Los Angeles Region occupied by impermeable surface has increased, the amount of water runoff has also increased, putting an ever-growing load on the flood control system. A recent project improved flood control for the lower Los Angeles River by increasing the height of the dikes on the channels, at a cost of about $200 million. Future increases in channel capacity would be even more expensive—not only will the walls have to be made higher, several bridges will have to be raised. Increased infiltration will reduce runoff, reducing the maintenance costs on the system and eliminating the need for further capacity increases.

The possible magnitude of the impact can be judged by considering the case of the San Gabriel Valley. Runoff from the valley is mostly captured in spreading basins in

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the Whittier Narrows area and used for groundwater recharge. This makes the runoff coefficient for the valley overall 5%. In the urbanized areas of Los Angeles, the value is about 40%. Thus if the urbanized area were as well controlled as the San Gabriel Valley, runoff could decrease by a factor of eight. Flood risks would essentially disappear.

Increased Parkland and Wildlife Habitat

The regional alternatives for stormwater quality control include the development of parks and wetlands. The parks would serve as detention basins and infiltration facilities, but would be used for that purpose only during rainy periods, which comprise about 32 days per year in Southern California. During the rest of the year, these areas could serve the typical purposes for which parks are built, acting as recreational sites, playgrounds, soccer and baseball fields, and wildlife habitat. Because people are less likely to engage in these activities during rainstorms in any case, the conflict between the uses will be small. The Los Angeles area is notably short of public parks in comparison to other major cities, particularly in its poorer neighborhoods (Wolch et al., 2002). Because it is likely that residents will demand more park space in the future, the development of areas for dual use is particularly valuable. Ideally, the cost of development could be borne by both agencies intent on improving stormwater quality and by those responsible for parks and recreation. The planned redevelopment of the Corn Fields site in Los Angeles, for example, might provide a detention basin as well as the new park that is being planned.

Wetlands must be kept wet all year, but can withstand flooding during the rainy season. Thus reestablishment of these habitats, which have been largely lost in the Los Angeles Region, could simultaneously serve the purposes of wildlife restoration, flood control, and stormwater quality control. In many cases, it will be possible to develop wetlands within existing channels, reducing the need for additional land purchases.

Some of the parks and wetlands could be created as a part of river greening projects, and so would also serve the purposes of reestablishing esthetically appealing naturalistic rivers.

Improved Property Values from Trash Control

Often one of the most powerful visual cues that gives a visitor the perception of a "bad" neighborhood is the presence of trash on the streets. One approach to reducing pollutant discharge to storm drains will be improved enforcement of litter laws and additional street cleaning. These will have the secondary benefit of improving the appearance and livability of streets throughout the area. The "broken windows" campaigns of many police departments—indicating that improving the appearance of neighborhoods reduces crime—suggests that apparently cosmetic changes can have substantial benefits for neighborhoods. Certainly property values in a neighborhood with clean streets will be higher than they would if the streets are routinely littered with trash.

Reduction in Harbor Sedimentation

Sediments carried by runoff are moved because the water moves rapidly, and because small particles remain suspended in the low-salt-content chemical environment of fresh water. When runoff enters bays and harbors, however, the velocity of the water

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is slowed, allowing the particles to settle to the bottom. The higher salt content of marine waters promotes flocculation of the small particles, so that most of them will also settle to the bottom. The deposited sediment fills channels, blocking the passage of ships and recreational boats, and filling areas set aside for preservation of aquatic ecosystems. Ultimately, harbor dredging is required, and frequently the collected sediment has been contaminated, so that it requires special handling. Dredging associated with storm drains in Los Angeles Harbor, for example, costs between $1 million and $3 million per year. Sedimentation in Upper Newport Bay is considered a significant threat to its function as a wildlife refuge. Stormwater quality control measures would avoid sediments discharges or remove it from the runoff, ameliorating these problems for downstream communities.

Improved Public Health

A significant portion of exposure to particulate air pollutants arises when small particles are resuspended from roadways by traffic and wind. Tire dust, settled air pollutant particles, pet feces, particles with adsorbed trace metals and trash are pounded into fine powder and lifted into the air. Such resuspension includes an ultrafine particle fraction, which is most dangerous to human health. More frequent street cleaning, particularly using vacuum bag type cleaners, would reduce public exposure to fine materials carrying trace metals, hydrocarbons, and microorganisms. Some public health improvement is likely, but its magnitude cannot be estimated.

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REGIONAL PROGRAMS DESIGNED FOR STORMWATER QUALITY CONTROL

While there has been a substantial amount of work on individual facilities for runoff quality control, such as detention ponds and grassy swales, there have been only a few studies that have tried to determine the regional cost and effectiveness for a system of these "green solutions". It is important to ask whether it is possible to create an overall program within realistic constraints of land availability and costs that will bring the watershed into compliance with regulations.

We have sought descriptions of example projects that include overall costs and the area of land that drains to the facility, so that cost per square mile of area served can be calculated. In a few cases, these are area-wide systems that are the best evidence that an overall solution is possible. In others, they are single installations, for which we make the assumption that duplication is possible—ten facilities like the one described could be built to serve ten times the area. Because economies of scale are important in determining facility design and even regulatory policy, we have taken special interest in some sources that describe how the size of the drainage area (and the necessary BMP treatment facility) affects cost per square mile. Finally, we have included examples that have actually been built and tested, and others that have only been designed. While data for the latter may be less reliable, most systems perform as designed, and these designed-but-not-built systems provide some of the most useful results.

The chosen examples are described briefly below, and listed in Table 2. Results useful for determining the relationship between facility size and cost per square mile are plotted in Figures 2 and 3.

Area-Wide Systems

Sun Valley

The Sun Valley project was funded by Los Angeles County to develop an alternative approach for flood control and runoff quality management for the Sun Valley district. This is an urbanized area with considerable industrial development that currently does not have storm drains. It is consequently frequently plagued with flooding. The project was undertaken to determine whether there was an approach to flood control other than simply building storm drains.

Four alternative plans were produced, designed to maximize infiltration, to maximize water conservation and wildlife habitat, to maximize stormwater reuse by industry, and emphasizing conveyence to traditional storm drains. Notably, an alternative that maximized the use of onsite BMPs was rejected as too expensive. The components of the plans included industrial reuse, infiltration basins in parks, tree planting and mulching, infiltration in parking lots, and infiltration in vaults beneath the streets.

Because the emphasis of this project was flood control rather than water quality control, the hydraulic control objectives were quite stringent: the system was designed to collect and infiltrate all of the water produced by a 50-year, 96 hour storm. This means that the runoff from the area, if the project is built, will be reduced to near zero. Thus, this project, which includes flood control and water quality control, constitutes an "upper

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bound" estimate on the costs for water quality control. Achieving such complete collection and infiltration would certainly substantially exceed water quality goals, and costs for a stormwater quality control system in an area with storm drains already in place would certainly be lower.

San Diego Creek

A project supported by the Irvine Ranch Water District and Orange County and performed by Geosyntec Consultants has developed a plan for natural treatment systems—wetlands and stormwater detention ponds—for the San Diego Creek watershed. This watershed occupies 120 square miles of developed land that drains into Newport Bay. Newport Bay has been designated as impaired, requiring that stormwater discharges be cleaned up.

Geosyntec proposed a plan consisting of 44 facilities, including ponds and wetlands constructed within existing drainage channels or built outside. These are typically facilities with both deeper open water and shallow water supporting emergent vegetation (such as cattails).

Water quality improvements expected from the system are described in the report (Strecker et al., 2002): "The NTS Plan is estimated to achieve total nitrogen (TN) TMDL for base flows and reduce in-stream TN concentration below current standards at most locations. Total phosphorous TMDL targets would be met in all but the wettest years. The fecal coliform TMDL would be met during the dry season, but not all wet season base flow conditions, and not under storm conditions. The NTS Plan is not designed to meet the sediment TMDL, but would capture, on average, about 1,9000 tons/yr (1,724,000 kg/yr) of sediment from urban areas. The wetlands are estimated to remove 11% of the total copper and lead, and 18% of the total zinc in storm runoff. The NTS provides a cost-effective alternative to routing dry-weather flows to the sanitary treatment system."

While final budget numbers were not provided, it was anticipated that the first 13 treatment sites would be constructed for $12 million, and that the overall cost would be substantially less that the $60 million anticipated for low-flow sanitary treatment. This value is listed as the upper bound of cost in Table 2. For comparison of cost vs. unit drainage area size, it was presumed that the average area served by each of the 44 facilities was 120 $mi^2/44 = 2.7\ mi^2$.

Constructed wetlands will collect any trash that enters the storm drain, and should be effective at reducing concentrations of coliform organisms, hydrocarbons, particles, and the suite of pollutants associated with particles. They may constitute a complete control system if they are combined with vigorous source control for metals and pesticides and storm drain screens to minimize the trash loading.

Murray City, Utah, Golf Course and Wetlands

Officials in Murray City recognized an opportunity when the interstate highway I-215 was being built. They agreed to take soil from the excavation and runoff water from the freeway to make a golf course. The links, with an associated string of settling ponds, accept and treat all of the drain water from the eastbound lanes of 4.5 miles of the freeway (NRDC, 1999; Hill, 2003). The golf course has been a commercial success, and now produces $900,000 in revenue against $450,000 in operating and maintenance costs each year. The city has created other treatment wetlands for essentially all of the runoff

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from the City and from the westbound lanes of the freeway. The total cost of these wetlands has been less than $1,000,000. Overall, if the golf course infiltration system and the other wetlands are considered as a single stormwater control system, it pays for itself. Because this is an unusual circumstance, for calculation we ignored the income from the golf course, and presume the wetlands cost $1,000,000 and serve the area of Murray City, which is 9.5 mi^2.

Fresno Metropolitan Flood Control District

The Fresno Metropolitan Flood Control District serves the area including and surrounding the city of Fresno. It operates 130 infiltration basins that drain a region of about 120 square miles devoted to agriculture, residential areas, and urban landscape (NRDC, 1999; Pomaville, 2003). Some of the basins are turfed and serve as parks, while others are bare and serve seasonal infiltration needs. The basins succeed in infiltrating 80% to 90% of the stormwater in their drainage areas, and only 2% enters a receiving water without receiving some degree of treatment. To protect groundwater, the District also instituted a program of industrial inspections. While monitoring is still done to check for pollution of the San Joaquin River, the District anticipates no additional infrastructure will be necessary to meet water quality control regulations. For calculations, the unit area for each basin was assumed to be 1 mi^2.

Individual Systems

Long Lake Retrofit, Littleton, Massachusetts

Geosyntec Consultants also designed a low-impact-development program for Littleton, Massachusetts (Roy et al., 2003). The 1.5-square-mile watershed that contains the town drains into Long Lake, which has been subject to eutrophication and other water quality problems associated with urban runoff. The storm drain system collects water at 200 catch basins and releases it to the lake through 18 outfalls. The plan for mitigation of the problem includes a treatment wetland, grass and vegetated swales, bioretention cells (swales with underdrains), rain gardens, rain barrels, and an outreach program to promote source control for fertilizers.

The total budget for the project is estimated at $630,000, or $420,000 per square mile.

Tule Pond, Alameda, California

The Tule Ponds project is a group of three treatment wetlands that was constructed using information developed in the Demonstration Urban Storm Water Treatment Marsh in the early 1980s. It receives urban runoff, passing it through the three ponds in series and discharging it to an existing natural pond. It serves a drainage area of 0.8 square miles and cost $360,000, for a cost of $450,000 per square mile.

Treasure lsland, San Francisco Bay

Treasure Island is an artificial island of 403 acres in San Francisco Bay that was used for many years as a Navy base. It has recently been converted to residential use. A treatment wetland is planned as the means for stormwater quality control. It is anticipated that wetland construction will cost $800,000 to $ 1,100,000 (Bachand, 2003), or $1.2 million to $1.7 million per square mile. However, the island is a tourist destination, and it has been estimated that the increase in visitor spending associated with

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the wetland could be $4 million to $11 million (Fine, 2003). It was also estimated that the overall value of the project could be twice these values.

Herrerra Study of Stormwater Regulations Costs

As a part of the effort to determine the costs of complying with stormwater regulations in Western Washington, Herrerra Environmental Consultants (2001) prepared designs for typical projects needed to contain and treat stormwater on site in small projects of new construction. In both cases, the systems were planned for a 1.7-inch rainfall. The first hypothetical project was a ten-acre residential development with 40 individual home sites. It was presumed that runoff from the homes would be collected in a detention pond. Construction of the permanent facilities was determined to cost $240,000 to $230,000, depending on the quality of soils. This is about $15 million per square mile.

The second hypothetical site was a restaurant built on a one-acre site, with the area not occupied by the building used as a parking lot. Runoff was to be collected in subsurface infiltration vaults. Costs were determined to be $280,000 or $570,000, depending on the permeability of the soil, or $175 million to $356 million.

Dover Mall, Delaware

The Dover Mall has 30 acres of parking lot or otherwise impermeable surface. Runoff drains to a wetland that is sized to retain a 1-inch rainfall (NRDC, 1999). It includes a forebay that allows containment of exceptional spills. The total project cost was $171,000 (although much of this was defrayed by in-kind donations). The wetland is considered a considerable esthetic resource. The cost was $3.5 million per square mile.

Oakland Park Industrial Area, Florida

A BMP treatment system was developed for five acres of Oakland Park that included auto repair shops, paint shops and plating facilities. A short treatment train was developed, including a trash removal basin and absorbent media. The system cost $261,000, and was successful in removing 71% to 95% of oil and grease, along with all trash and most sediment. Costs were $33 million per square mile of drainage.

Clear Lake Packed Bed Wetland Filter System

Clear Lake, in Orlando, Florida, receives runoff water from 121 acres of nearby urban land and water quality in the lake has deteriorated significantly as a result of pollution. Packed beds, consisting of 10 filter beds composed of crushed concrete or granite media with growing aquatic plants, allow removal of sediments and nutrients. An initial wet detention pond is used to contain the first flush. The system cost $917,646. In calculations, the system was considered a single installation treating 121 acres of drainage. Costs were $4.6 million per square mile.

Sand Filters in Alexandria, Virginia

Two sand filters were built to treat runoff from an airport parking lot near National Airport in Alexandria, Virginia. The area drained was 1.95 acres, and the filters cost $40,000. While some initial problems with anaerobic conditions were encountered, the filters eventually achieved good treatment. The cost, calculated from the data reported by FHWA (2003), was $12.9 million per square mile.

Compost Filter Facility, Hillsboro, Oregon

A compost filter was constructed to decontaminate water upstream of a grassy swale. The treatment train received water from a five-lane highway, draining a total area of 74 acres. The 1200-square-foot filter contained 120 cubic yards of compost and was constructed and filled for $13,700. The cost, not including the swale, was thus $110,000 per square mile of drainage area.

Infiltration Trenches

The Federal Highway Administration (FHWA 2003) has estimated the costs for constructing infiltration trenches as $C_A = 1317 \times V^{(0.63)}$ where C is the cost in dollars and V is the volume in cubic meters. Calculations for this report are made assuming the need to provide detention for a ¾-inch storm. For one square mile (2.6×10^6 m^2), a ¾-in rainstorm will produce 5×10^4 m^3 of water. The cost per square mile is equal to the cost for each trench divided by the drainage area it serves, or $C_{mi2} = C_A/A = (1/A) \times 1317 \times V^{(0.63)} = 1.2 \times 10^6 \times A^{(-0.37)}$. The total cost for these systems thus declines as each system becomes larger—there are economies of scale. Costs for land are not included, but it is likely that trenches could be installed in land also used for other purposes. In some cases it might be necessary to collect more than ¾ inch of rain. On the other hand, the calculation assumes that no infiltration occurs in the trench during the storm. Also, this presumes that the runoff coefficient for the area served is 1.0—thus the typical systems described could treat a ¾-inch storm on totally impervious area or a 1.5-inch storm on an area with a runoff coefficient of 0.5, which is a commonly observed value. Thus the total seems a reasonable approximation.

Infiltration Basins

The Federal Highway Administration (FHWA 2003) has estimated costs for construction of open infiltration basins (dry basins) as $C = (V/0.02832)^{(0.69)}$, where C is the cost in dollars and V is the volume in cubic meters. As for the infiltration trenches, it is assumed the basins will be designed to treat a ¾-inch storm in an impervious drainage. Thus the cost per square mile is $C_{mi2} = C_A/A = (1/A) \times (V/0.02832)^{(0.69)} = 204{,}000 \times A^{(-0.31)}$. Costs for land are not included, and would be substantial. However, the basins could be used for other purposes for much of the year. Again, the systems assumed could treat a 1.5-inch storm in a drainage area with a runoff coefficient of 0.5.

Bioretention Areas

Stormwater can be collected in areas filled with highly permeable soils and planted with trees and other vegetation. Water that infiltrates is filtered by contact with the soils and may continue to move downward to replenish the groundwater. Much of it will also be taken up by the vegetation and returned to the atmosphere through evapotranspiration. The FHWA (2003) cost estimate for these bioretention areas is $10,000 per impervious acre, or $6.2 million per square mile of impervious watershed. Bioretention areas can readily serve multiple purposes as wildlife habitat and parks.

Detention and Retention Wetlands

The Federal Highway Commission Report (FHWA, 2003) has provided a general formula describing the cost of detention ponds as a function of size. Costs were estimated as $C_A = 168 \times V^{(0.699)}$, where C_A is the cost in dollars and V is the volume of the pond in cubic meters. The cost per square mile is $C_{mi2} = C_A/A = (1/A) \times 168 \times V^{(0.699)} =$

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$324{,}000 \times A^{(-0.301)}$. Land costs are not included, but these areas can serve other purposes during the larger part of the year when the weather is dry—they can be parks, wildlife areas, and playing fields.

Detention Vaults

In highly urbanized areas, water can be detained in underground vaults, which may be made of concrete or of corrugated steel pipe. Such systems primarily store water to avoid flooding or excessive hydraulic load on downstream systems, but some sedimentation may occur. This provides marginal treatment, but also requires that the vaults be cleaned out on a regular basis. The FHWA estimate for costs of such systems is $C = 38.1 \times (V/0.02832)^{(0.6816)}$. Cost per square mile of drainage area is $C_{mi2} = (1/A) \times 38.1 \times (V/0.02832)^{(0.6816)} = 690{,}000 \times A^{(-0.3184)}$.

Underground Sand Filters

Sand filters are quite effective at removing particulates from urban stormwater, and are commonly employed upstream of other systems in order to protect them from excessive sedimentation. They can be installed underground in densely urban areas, but are correspondingly expensive. The FHWA estimate for such systems is $10,000 to $14,000 per impervious acre served, or $8.7 million per square mile. Here we have chosen the upper estimate because costs are likely to be high in the Los Angeles area.

Surface Sand Filters

Sand filters may also be constructed at the surface, which reduces their cost. However, they occupy a relative large amount of land area, and cannot contribute to a secondary use. There are strong economies of scale. For facilities serving more than 5 impervious acres, the FHWA estimate of cost is $3,400 per acre or $2.1 million per square mile.

Dry Swales and Filter Strips

A vegetated dry swale is an area of land shaped so that stormwater flows through it in a broad, relative flat stream. Flow through the grass removes sediments from the water. At the same time, significant amounts of infiltration may occur. It may be necessary to prepare the soils to maximize infiltration before the grass is planted. Swales can be used for other purposes during the periods when it is not raining. The FHWA estimate of construction costs for swales is $1500 per impervious acre, or $930,000 per square mile.

Filter strips are similar installations, in which the water flows as a flat sheet. The FHWA estimate of constructions costs for filter strips is $2000 per acre or $1,240,000 per square mile.

Results from the ASCE-EPA BMP Database

A cooperative effort of the American Society of Civil Engineers and the U.S. Environmental Protection Agency has compiled data on the success of best management practices. Data were carefully vetted, put as much as possible in common format, and arranged so that they could be searched according to several parameters. Several searches of the database were done to gather data for this study.

A search for dry detention basins, serving watersheds of 0-100,000 acres, with 0-30 in annual rainfall, produced 17 responses, of which only four included cost data. All

of the four were associated with freeways and served small watersheds of 1-14 acres. This may be the reason why costs were exceptionally high.

A search for wetlands, serving watersheds of 0-100,000 acres, with 0-30 in annual rainfall, produced 10 responses, only one of which included cost data. Costs for this facility were exceptionally low. It was described as a "natural" wetland, perhaps implying that much of the system was already in place before construction was done.

A search for wetlands, draining 0-100,000 acres, with 0-30 in annual rainfall, produced 9 responses, including 6 with cost data. These also served very small watersheds, and costs per square mile were very high.

A search for hydrodynamic devices serving 0-100,000 acres, in areas of 0-30 in annual rainfall, produced 12 responses, including 8 with cost data. Costs ranged from $344,000 per square mile to $86 million per square mile, showing very strong economies of scale.

A search for grassy swales serving 0-100,000 acres, in areas of 0-30 in rainfall, produced 26 responses, including 7 with cost data. The cost per square mile ranged from $12 million to $341 million, and showed strong economies of scale. This was a surprising result—grassy swales are very simple and cheaply constructed systems—but it reflects the fact that each installation serves only very small areas.

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ESTIMATES OF COSTS AND RECOMMENDED APPROACH

Ultimately, stormwater pollution is a symptom of two anthropogenic changes: we are releasing pollutants into our local environment, and we have disrupted the hydrologic cycle of the Los Angeles Region by covering the soil with impervious surfaces. These changes have other symptoms as well. Local pollution impairs health, damages the esthetic quality of life, and reduces property values. Reducing infiltration increases runoff rates and the risk of flooding, and at the same time, reduces recharge of groundwater resources. Finally, impervious surfaces cannot support vegetation, and we suffer the loss of natural habitat, recreational areas, and aesthetic value of green space.

Cost Estimates

The solution proposed in the report by Gordon et al. (2002)—advanced treatment plants to clean up stormwater after it has entered the storm drains—constitutes treatment of a single symptom without correction of the fundamental problem. It is expensive, and has little benefit beyond the single objective of protecting receiving waters. A more fundamental approach—eliminating pollutant releases and restoring the hydrologic cycle—is cheaper. Further, because it will mitigate all of the effects of pollution and hydrologic disruption, it will have benefits whose value exceeds the costs.

While a rudimentary cost-benefit analysis is attempted here, the limitations of such an approach should be kept in mind. Many costs and benefits are difficult to evaluate—the psychological benefit to citizens who live on a clean street rather than a trashy one, for example, or the long term effects on local business of a general perception of regulatory burdens. In past cost-benefit analyses, it has been common that costs and benefits that are difficult to measure have been assumed to be zero, certainly producing misleading results. It remains true that two good-faith investigators can produce quite different cost-benefit results, especially for a complex problem like stormwater quality control. Assumptions may depend greatly on the value system of the investigators. A recent cost-benefit study was criticized, for example, because it put a lower value on the lives of elderly persons. This is reasonable in the sense that the death of and older person represents fewer years of life lost, and less loss of earnings, and it is a common presumption in cost-benefit studies. However, there was outrage among those who felt that this approach was offensive to the elderly and the general principle that we all have equal rights.

In this particular study, because the costs and expenditures are of many different kinds, it was necessary to use a variety of estimation methods. The results are necessarily approximate, and comparisons among them must be viewed with caution. To use technical terms, contingent valuation studies are included with benefits transfer estimates, and results from various investigators are combined. We anticipate that these steps may be criticized, but we hope that we can provide a framework approach that can be improved and refined as further research is done.

Finally, cost-benefit analysis frequently ignores the issues that arise because the costs and benefits are not borne by the same parties. One might suggest that pollution should not be cleaned up if the cost of doing so exceeds the benefits of relief from the pollution. But it is commonly the case that the polluter who is saving money is not the

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same person who is suffering from the effects of the pollution. Does your neighbor have the right to throw his trash in your yard if he can show that it saves him more money than it costs you? The principle of "polluter pays" has a satisfying moral aspect and it also puts the incentives right—the parties with the ability to reduce pollution are given the motivation to find a way to do so.

For these reasons, and because in this short study the numbers are particularly only estimates, we present our cost benefit analysis with the caution that more precise and detailed assessments are desperately needed.

Cost estimates have been prepared by examining case studies. Reports were chosen where information was available for both the total cost of the system described and the land area served, or the initial stormwater retention volume, in order to calculate the cost of stormwater management per square mile of watershed. Several assumptions and caveats must be observed:

1. In the cost-per-square-mile calculations, no attempt was made to adjust costs on the basis of the amount of rainfall in the watershed. Sufficient data were generally not available for this purpose. In most cases, data came from areas where annual rainfalls are greater than in Los Angeles, and this may cause the cost estimates to be high.
2. In the cost-per-square mile calculation, the cost data were not available in a uniform format. It was not possible to calculate an accurate "present worth" including operations and maintenance costs for each case. In some cases operations and maintenance data were included, while in others they were not. In most cases operations and maintenance costs are low in comparison to installation costs, and they would be further reduced by discounting to present worth. Never the less, this may cause the cost estimates to be low.
3. Installation costs may vary depending on the slope of the land, the nature of the soils, depth to water table, local labor costs, and a wide variety of other factors that change with locality. No attempt was made to adjust the costs for these factors, and this may make the estimates high or low.
4. It is presumed that the systems described will be sufficient, in conjunction with source control efforts, to comply with water quality regulations. There was no case reported in which the quality control efforts were described as failing, or for which regulators asked for additional measures after the systems were complete. However, few data were shown for after-construction water quality, and most of the systems have not been in place for enough time to allow long-term assessment. The degree of success for source control efforts, while likely to be substantial, cannot be guaranteed.
5. Several of the projects described have been designed, but not implemented. It is assumed that they will perform as designed. In the case of the Federal Highway Administration formulas, these are regression results rather than individual case results.
6. It is likely that implementation in the Los Angeles area would involve projects that are larger than most of those listed. There likely will be economies of scale. This may cause the cost estimates to be high.

Summary of Case Study Project Costs
"I or D" refer to Implemented or Designed

Project	I or D	Description	Unit Size, square miles	Cost, $M	Cost, $M per square mile
Infiltration Systems					
Fresno Metropolitan Flood Control District Regional Infiltration Basins (NRDC, 1999; Dave Pomaville, 2003)	I	130 turfed or unturfed infiltration basins serving residential areas. Treats or infiltrates 98% of runoff over area of 120 square miles	1		2.5 to 3.7
Study of Stormwater Regulations Cost (Herrerra Environmental Consultants, 2001)	D	Hypothetical calculation of costs for new residential development	0.016	.24	15
Study of Stormwater Regulations Cost (Herrerra Environmental Consultants, 2001)	D	Hypothetical calculation of costs for new commercial development	0.0016	0.28 to 0.57	175 to 356
Wetlands					
Tule Pond, Alameda (Wetzig, 1999)	I	Stormwater treatment pond for urban runoff	0.8	0.36	0.45
Treasure Island, San Francisco Bay (NRDC, 1999: Galvanis, 2003)	D	Wetland treatment system for local runoff	0.65	0.8 to 1.1	1.2 to 1.7
Long Lake Retrofit, Littleton, Mass. (Roy et al., 2003)	I	Swales, constructed wetlands, bioretention cells, outreach	1.5	0.63	0.42
San Diego Creek Natural Treatment System Master Plan (Strecker et al., 2003)	D	Network of open-water ponds and wetlands in Newport Bay drainage, 120 square mile area	2.7	<60	<0.5
Murray City, Utah (NRDC 1999: Hill,	I	Golf course and wetlands treat runoff from 4.5 miles of I-215	9.5	1.0	0.11

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2003)		and the city			
Dover Mall, Delaware, (NRDC 1999)	I	Wetland installed on mall grounds drains 30 acres of 100% impervious cover	0.048	0.17	3.5
Sun Valley Project, Los Angeles County	D	Combination of various measures for flood and quality control in L.A. Basin	4.4	172 to 297	39 to 68
BMP Treatment Processes					
Oakland Park, Fla, industrial area (NRDC 1999)	I	Oil, grease, sediment, and trash removal by sedimentation and absorbance	0.008	0.261	33
Clear Lake Packed Bed Wetland Filter System (NRDC 1999: FHWA, 2003)	I	Oil, grease, nutrients, trace metal removal for water entering Clear lake	0.2	0.92	4.6
Compost Filter Facility, Hillsboro, Or. (FHWA, 2003)	I	Oil, grease, removal and filtration for highway runoff	0.12	0.12	0.11
Alexandria, Va, airport parking lot	I	Sand filters installed along the borders of a 1.95-acre parking lot	0.003	0.04	12.9
Bioretention Areas, FHWA cost estimate	D	Areas of highly permeable soil planted with trees and other vegetation			6.2
Underground Sand Filters	D	Porous medium filters placed in underground vaults, appropriate for highly urban areas			8.7
Dry Swales	D	Broad, shallow vegetated drainways covered with vegetation, usually grass			0.93
Surface Sand Filters	D	Porous medium filters installed at the surface			2.1
Filter Strips	D	Flat vegetated drainways covered with vegetation, usually grass			1.2
Port of Seattle container area cleanup	I	High quality street sweeping with sediment trap catch basins			3.1
Cost:Area Formulas from FHWA					
Infiltration trenches, FHWA cost estimate	D	Gravel-filled trenches. Infiltration eliminates runoff discharge.	$C_{mi2} = C_A/A$ $= (1/A)\times 1317\times V^{(0.63)}$ $= 1.2\times 10^6\times A^{(-0.37)}$		

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Infiltration basins, FHWA cost estimate	D	Open basins, dry at most times, store and infiltrate runoff. Infiltration eliminates runoff discharge.	$C_{mi2} = C_A/A$ $= (1/A)\times(V/0.02832)^{(0.69)}$ $= 204{,}000\times A^{(-0.31)}$		
Detention and retention wetlands, FHWA cost estimate	D	Wetlands used for treating stormwater, with storage capacity available	$C_{mi2} = C_A/A$ $= (1/A)\times 168\times V^{(0.699)}$ $= 324{,}000\times A^{(-0.301)}$		
Detention vaults, FHWA cost estimate	D	Underground reservoirs for storage of runoff to reduce peak flows	$C_{mi2} =$ $(1/A)$ $\times 38.1\times(V/0.02832)^{(0.6816)}$ $= 690{,}000\times A^{(-0.3184)}$		
Results from ASCE-EPA BMP Database					
Dry Detention Basins					
I-605/SR-91 EDB	I		0.0013	0.077	60
I-5/Manchester (East)	I		0.0077	0.33	43
I-5 SR 6	I		0.0085	0.14	17
I-75/SR-78 EDB	I		0.022	0.82	38
Wetlands					
Swift Run Wetland	I		1.95	0.049	0.025
Sand Filters					
I-5/SR-78 P&R	I		0.0013	0.22	170
Escondido MS	I		0.0013	0.45	348
Eastern Eastern Regional MS	I		0.0024	0.34	141
Foothill MS (Sand Filter)	I		0.0029	0.48	164
Termination P&R	I		0.0045	0.46	102
LaCosta P&R	I		0.0045	0.23	49
Hydrodynamic Devices					
Jensen Precast (UVA)-Phase II	I		0.00045	0.039	86
I-210/Orcas Avenue	I		0.0018	0.04	22
Jensen Precast, (Sacramento)	I		0.0032	0.062	19
I-210/Filmore Street	I		0.0040	0.05	12
Charlottesville Stormceptor	I		0.0040	0.017	4.2
Sunset Park Baffle Box	I		0.040	0.023	0.57
Indian River Lagoon CDS Unit	I		0.098	0.055	0.56
Austin Rec Center	I		0.15	0.05	0.34

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OSTC					
Grassy Swales					
I-650/SR-91 Swale	I		0.00032	0.11	341
Cerrito MS	I		0.00065	0.06	93
1-605/DelAmo	I		0.0011	0.13	115
I5/I-605 Swale	I		0.0011	0.073	64
Monticello High School	I		0.0013	0.015	11
SR-78 Melrose Dr	I		0.0039	0.13	34
I-5 North of Palomar Airport Road	I		0.0074	0.14	18
I-650/SR-91 Swale	I		0.00032	0.11	341

Economies of Scale

The costs listed in Table 2 reflect the cost for an individual facility ("Cost, $M" and "Cost, $M/mi^2") and associate it with the drainage area served, referred to as the "Unit Size". The costs per square mile for the individual units can be plotted to determine the effects of unit size (Figures 1 and 2). While there is a great deal of scatter in the data, it is clear that there is considerable economy of scale. Units serving drainages of a half square mile are typically 30% more expensive that those serving 1 square mile. Those serving drainages of one-tenth square mile are twice as expensive and small installations are extremely expensive in dollars per square mile. The most notable example of this is grassy swales: while each unit is relatively inexpensive, their small service areas make them very expensive per square mile served.

For some of the BMPs there are not sufficient data to judge the economies of scale, and as described, all of the data must be taken as approximate. Never the less, it seems that there is a good case to suggest that regional systems for handling runoff water will be most economical. This is clearly true of wetlands and infiltration basins, which are likely to be the most widely used approaches in the Los Angeles Region as a whole. This supports the position that the best solution will be a wetland or an infiltration basin also serving as a park, playing filed, or wildlife habitat as the stormwater management unit for a neighborhood of a square mile or greater.

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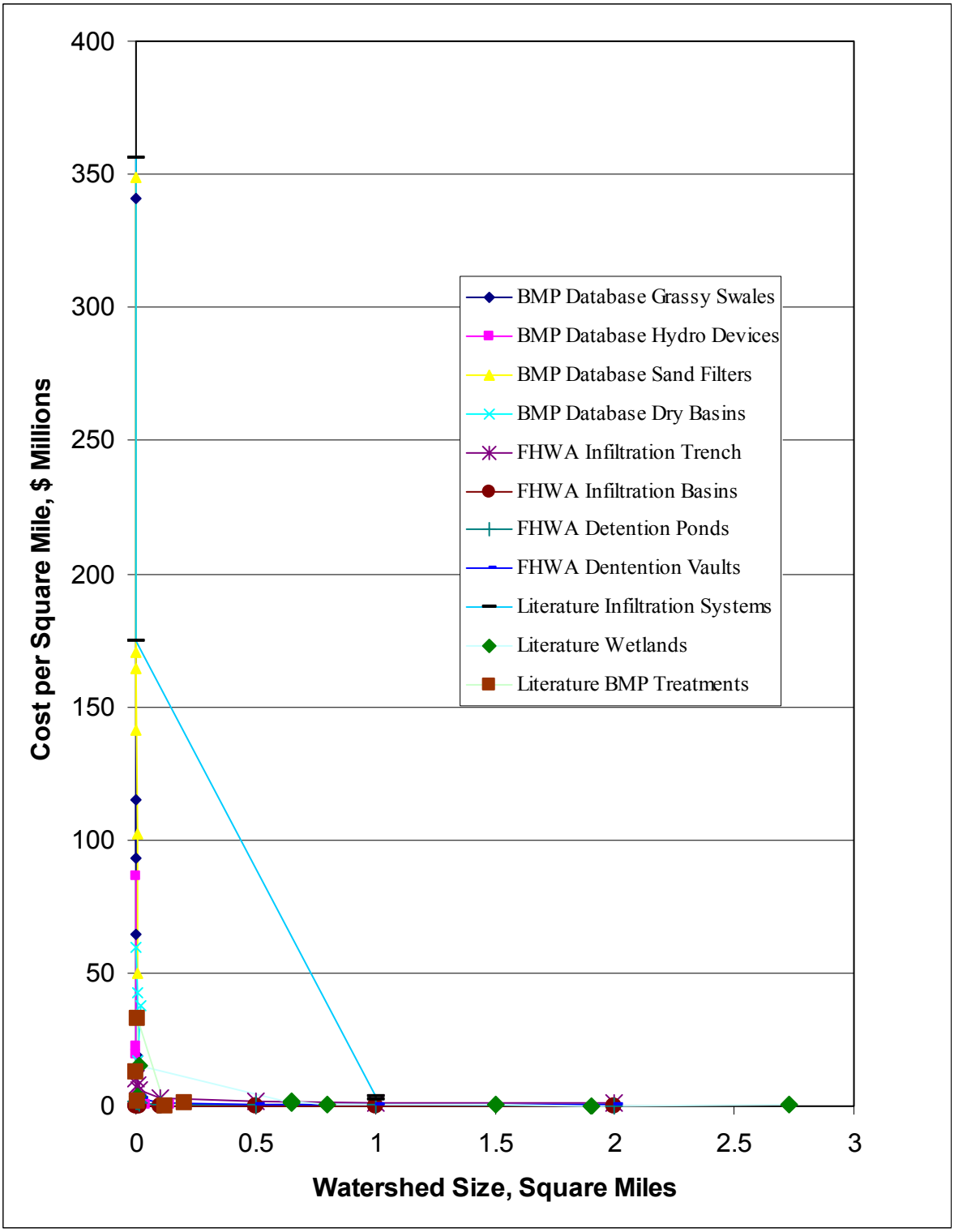

Figure 1. Plot of data for which costs per square mile and unit areas are known.

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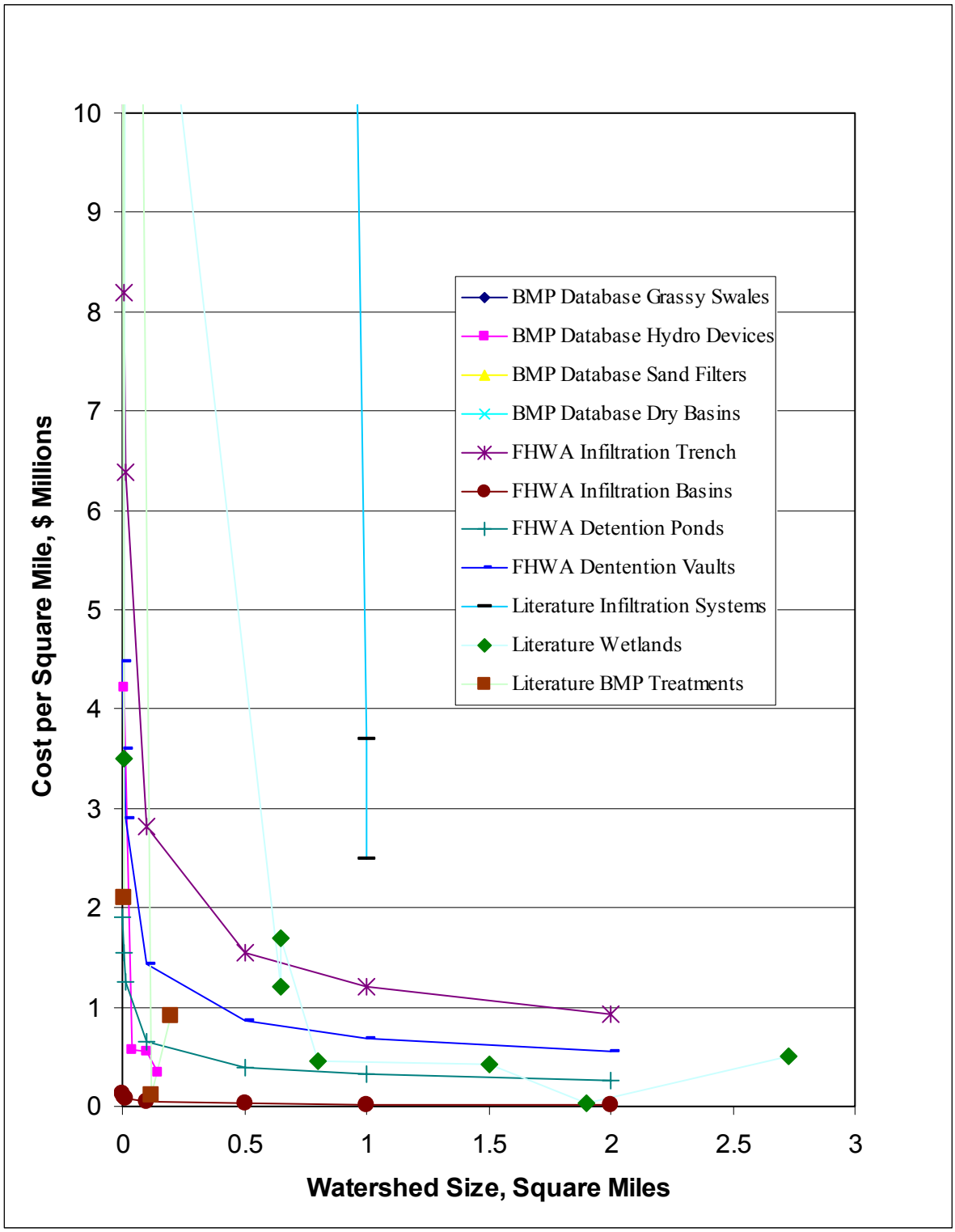

Figure 2. Cost per square mile versus unit size. Data are the same as those shown in Figure 1, but the axes have been magnified to show detail near the origin. Many data points fall outside of the plot.

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Overall Costs of Stormwater Quality Control

It remains very difficult to produce an estimate of the total costs for complying with regulations in the Los Angeles Region. While there is substantial information on individual units that have been designed or implemented elsewhere, local factors are likely to make costs different in the Region. In most cases, it seems likely that costs in the Los Angeles Region will be higher than those reported elsewhere because land and labor costs are higher. Therefore, where a range of values is given, we have chosen the higher numbers.

This difficulty is compounded by the great variability in the data reported. To give just one example, the Federal Highway Administration formula estimates the cost of an infiltration basin needed to serve one square mile as $200,000. At the other extreme, the Herrerra Consultants report said that a detention/infiltration system for a residential area would cost $15 million per square mile. In preparing our total estimate, we have avoided using data that seem like outliers in comparison to the general run of the data.

The results compiled suggest two possible scenarios for stormwater quality control. The first approach is to rely on non-structural BMPs, such as programs to reduce littering, control pet waste, collect trash, prevent release of pollutants, and clean existing drains. This approach is less expensive because it involves no construction. However, there remains considerable doubt whether it will be sufficient to meet stormwater quality goals expressed as TMDLs (Total Maximum Daily Loads). Control of pollutant release will be only partial—we cannot expect that everyone will comply with the rules—and the amount of runoff will be reduced only slightly.

The second scenario presumes implementation of non-structural BMPs (except storm drain cleaning) and construction of a network of wetlands and infiltration basins sufficient to capture the first three-quarters of an inch of rainfall, which typically carries the bulk of the pollutants. These relatively simple installations are not likely to be sufficient without complementary measures to reduce releases of coliforms, trace metals, fertilizers and toxic organics. Wetlands help to remove these, but will not be effective if inputs are too high. Infiltration avoids all pollutant discharge, because it prevents release of the water, but it is necessary to protect groundwater quality, so once again, inputs must be restricted. The wetlands and infiltration basins would be designed to have sufficient retention capacity to hold the first ¾ inch of rainfall—this "first flush" carries most of the pollutants, but pollutant discharges must be sufficiently reduced so that subsequent flows can be discharged directly to storm drains.

In combination with the non-structural BMPs, wetlands and infiltration basins (designed as "stormwater parks") are likely to bring stormwater quality into compliance. This system will be more expensive, but it also carries greater secondary benefits: the region will gain much-needed greenspace, property values will be improved, and most important, it will substantially increase the availability of groundwater.

It is our recommendation that the responsible municipalities and agencies in the region begin at once on assessing stormwater quality on a neighborhood basis and implementing the non-structural controls. As the success of these measures is measured, it will become apparent whether the structural BMPs are needed. It seems certain that they will be needed in some areas, but they may not be needed throughout the region. Thus our estimate of costs ranges from a minimum budget needed for the non-structural

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BMPs to a maximum representing the cost of an area-wide system of wetlands and infiltration basins. The following section provides the details of how the cost estimates were prepared.

Non-structural BMPs

An estimate of costs for non-structural BMPs has been prepared by the American Public Works Association (APWA, 1992). They defined five levels of BMPs that might be workable, with the appropriate level depending on the stringency of discharge requirements and the success of the individual measures. Their analysis included ten source control measures with cost data, and has been used as the starting point for the analysis here. Our treatment of each measure is described in the following paragraphs.

No littering ordinance. Litter laws are in place in the region, but there is a need for far more vigorous public education and enforcement. The APWA study determined that each municipality would spend $20,000 to put an enforcement program in place, and hire a half time person to manage the program ($30,000 per year). There are about a hundred municipalities in the Los Angeles Region, so this implies a startup cost of $200,000 and yearly costs of $3 million. Some officers will be necessary, but it is assumed that their pay will be covered by revenue from fines. Total costs are estimated to be $3 million plus the present worth of $3 million per year at 3%, or $103 million.

Pet waste ordinance. APWA predicted that the effort to control pet waste would be similar to that for litter, and estimated the same costs.

Chemical use and storage ordinance. APWA determined that a program to control the use and storage of chemicals would be similar is scope and cost to that for litter or pet waste. The same costs are estimated here. This would include the cost of programs to bring auto dismantlers and other local businesses into compliance.

Recycling programs. APWA predicted less trash would be discarded if convenient recycling programs were in place. Because these currently exist in most Los Angeles Region cities, and are justified by other concerns, no additional costs are estimated for this purpose.

Public education programs. Developing public support for stormwater quality control and explaining the need for citizen action will be vital to its success. The APWA determined a program costing $275,000 in each municipality would be necessary. However, it would be confusing and unnecessarily duplicative to have each of the one hundred municipalities in the Los Angeles Region conduct its own program. We instead assume a single program will be funded at the level of $5 million per year, which is approximately the current rate of expenditure. It also seems likely that education will not be needed indefinitely—to the degree that the message is successful, it will certainly become ingrained after perhaps ten years of advertising. We therefore estimate a total of $50 million for public education.

Vacant lot cleanup programs. This function will be part of the improved trash collection program, so funds are not separately allocated.

Spill prevention ordinance. APWA determined a separate program would be necessary to reduce the frequency of chemical spills and facilitate their rapid cleanup. This function has largely been overtaken by hazardous waste management regulations, and so is estimated to require no additional costs here.

Program to prevent illicit discharges. APWA determined that vigorous efforts would be needed to find and eliminate illicit discharges to the storm drain system. We agree that this will be necessary to avoid loads of non-biodegradable pollutants, such as trace metals, on treatment wetlands and infiltration basins, and to prevent excessive loading of organic contaminants and coliforms. APWA predicted a cost of $4 per acre of watershed to start, and $50 per acre per year thereafter in order to deploy and monitor sampling devices and to trace down points of discharge. For the 2,050 square miles in which stormwater protection is needed, this amounts to $6.5 million in capital expenses and $80 million per year in ongoing costs. We expect however, that many illicit connections will be found at first, and that after these are eliminated, only a small program will be needed to detect new illicit connections. We therefore estimate that the ongoing costs will continue for only five years, totaling $407 million.

Improved cleaning of storm drains. During dry periods, storm drains collect trash from illicit dumping and wind blown litter (we expect no trash will enter through the catch basins because screens will be installed). Sediments also accumulate in the channels. Releases to the rivers and ocean could be reduced by a summer program of storm drain cleaning. The APWA estimates such a program can be put in place for $21 per acre per year, or about $27 million per year over the area of concern. The present worth of $27 million per year is $900 million (assuming an interest rate of 3%). No storm drain cleaning is expected for the wetlands and infiltration scenarios, on the presumption that trash and sediments will be removed from the water before it enters the drains.

Trash control. Trash must be removed from the runoff. A settlement agreement on Trash TMDL between the LA Regional Water Board and the City of Los Angeles includes spending of $168 million to reduce trash releases by 50% in five years. Cleaning up the region required removing all of the trash from an urban area more than twice the size of the city. Thus the estimate of $600 million seems reasonable.

Low flow treatment. One of the best steps, in terms of water quality benefits per dollar, is to use excess capacity in the wastewater treatment plants for treatment of low flows. This will keep the rivers and oceans clean for most of the year at little additional cost. The City of Los Angeles estimates the cost of building the necessary diversion structures at $14 million (Kharaghani, 2003). The urban region is about twice the size of the city, so we have estimated a total cost of $28 million. This does not include operation costs. While there will be modest cost increases associated with the greater flows, the biggest costs are associated with the installed treatment capacity, which is already in place.

Improved street sweeping. The APWA report determined that sweeping should be improved by increasing its frequency. Research results developed since the APWA report suggest that more frequent sweeping with traditional brush machines produces only a modest improvement. However, changing to vacuum sweepers is effective, and can remove up to 50% of particulate pollutants.

The upgrade of street sweeping in the region will require purchasing new vacuum-type sweepers to replace those currently in use. There are about 400 street sweeping machines in use, which must be replaced once every four years, so 100 machines will be purchased each year. Vacuum machines cost about $150,000 rather than the $75,000 for standard machines. Thus the additional costs of higher quality

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sweeping are $75,000 per machine or about $7.5 million per year. Assuming an interest rate of 3%, this has a present worth of about $250 million.

Costs for on-site BMPs for private firms. It is anticipated that application of non-structural BMPS will include requirements that businesses make efforts to reduce pollution and runoff from their facilities. Efforts are likely to be highly variable: an accounting firm whose work is all done in offices might need to do no more that redirect its roof runoff to landscaping areas. A manufacturing facility might install sand filters and oil-water separators. Parking lots may be remodeled. It is difficult to provide an estimate for these efforts, but a general approximation for the total can be approached if firms are considered by size (Table 3). Data on the number of firms within chosen size ranges, measured by the number of employees, have been compiled for Los Angeles County by the California Employment Development Department (2001). Again, this area is not the same as the Los Angeles Region governed by LA Regional Water Board, but there is substantial overlap and the demographics are similar.

Table 3. Estimate of On-site BMP Costs for Los Angeles County Firms by Size Class

Number of Employees	Number of Firms	Average Cost per Firm	Total Costs
0-4	219,974	10	$2,199,740
5-9	37,125	500	18,562,500
10-19	25,366	1,000	25,366,000
20-49	19,682	2,000	39,364,000
50-99	7,745	5,000	38,725,000
100-249	4,239	10,000	42,390,000
250-499	1,138	25,000	28,450,000
500-999	408	50,000	20,400,000
1000+	260	100,000	26,000,000
Totals	315,937		241,457,240
		Average cost per firm	$764

Most small firms will not spend any money, so the average cost per firm is expected to be very low. A few might be required to improve trash disposal methods or reroute their rooftop drainage. At the other extreme, the largest companies might improve trash disposal and materials handling methods, build infiltration system planters, install oil-water separators, institute parking lot and work area sweeping. Companies that install new parking lots or reconstruct old ones may incur significant costs.

Costs for compliance with the "3/4-inch rule". The SUSMP regulations promulgated by the LA Regional Water Board require that new developments larger than one acre and redevelopment must provide for infiltration or minimal treatment of runoff from the first ¾-inch of rainfall from a storm event. It is difficult to determine how much this will cost. Proponents have suggested the costs will be minimal, while opponents

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have predicted high costs. Experts contacted during this study were of the general opinion that landscaping designed to infiltrate the runoff from a ¾-inch storm would be different, but not significantly more expensive, than traditional landscaping. On the other hand, engineers in the discipline believe that most builders are choosing treatment systems rather than infiltration. The stormwater control costs will likely be a small fraction of building costs. Ultimately, we have concluded that there are not sufficient data to make a numerical cost estimate. The costs are therefore described here only as "modest", and further study is recommended.

Wetlands and Infiltration Basins: Estimate Based on Cost per Square Mile of Watershed

The land within the Los Angeles Region varies from lightly settled areas, like the upper reaches of the Santa Clara River Watershed or the Santa Monica Mountains, through neighborhoods of single family homes with yards, to the extremely dense development of downtown Los Angeles or the Wilshire District. There are about 1,375 square miles of incorporated cities in Los Angeles County. The region of the LA Regional Water Board includes parts of Ventura County, and parts of both counties that are not incorporated are never the less populated. To evaluate the possible alternatives for runoff control, we have conceptually divided the 3,100-square-mile region that is under the jurisdiction of the Los Angeles Regional Water Quality Control Board into four parts 1000 square miles is estimated to be of "low density", requiring some runoff BMP treatment, but having sufficient land for development of treatment wetlands or infiltration systems. 1,000 square miles is estimated to be "high density" requiring infiltration systems but excluding wetlands. 50 square miles is estimated to be extremely dense downtown development, requiring some more sophisticated BMP treatment systems. The remainder of the region is considered rural, and we presume the only cost is for source control outreach and enforcement. These definitions and numbers are approximate, but there is also flexibility in the applicability of the various technologies.

For the low density urban areas, we assume some combination of infiltration systems and treatment wetlands will be constructed. The range of reported costs for treatment wetlands runs from $110,000 per square mile for Murray City, Utah, to $1.7 million per square mile for the Treasure Island wetland in San Francisco. The San Diego Creek wetland system seems an excellent example—it is designed for a populated region of Orange County that is quite similar to many areas in Los Angeles County. However, it is specifically designed to treat low flows only, and the total cost of the system has not been provided (except that it is less than $500,000 per square mile). The Long Lake retrofit also seems like an appropriate example. It uses a mix of wetland, infiltration and biological BMPs in an urban residential area, and has a well-established cost of $420,000 per square mile. We have therefore used this value in our total estimate of $420 million for the low density areas.

In areas of high density housing, where yards are small, or in industrial areas with large roof and parking areas, runoff coefficients are higher and there is less land available. Here it seems likely that infiltration systems will be necessary. The best example for comparison is the Fresno Metropolitan Flood Control District, which installed 130 basins over an area of 120 square miles, with many of the facilities dedicated to multiple uses as parks and playing fields. Cost estimates for the system range from $2.5 million to $3.7 million per square mile. While a similar system built in

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the Los Angeles Region could take advantage of existing parks, power line rights-of-way, parking lots, and other available land, it seems appropriate to use the higher number because land here will be more expensive. Thus we estimate cost in these areas to be $3.7 million per square mile for a total of $3.7 billion.

In extremely dense areas, neither wetlands nor infiltration systems will be possible. Pollutant loads, despite source control efforts, will be considerable in the near future. Underground sand filters, sediment traps, oil and grease adsorbants and other more elaborate treatment BMPs will be needed. The lowest-cost processes are filter strips, dry swales and bioretention areas, but these require space that is unlikely to be available (the Hillsboro, Oregon compost filter, at $110,000 per square mile is considered an outlier). Even the Alexandria, Virginia airport parking lot solution is unlikely to be workable because so much of the parking area is in multi-level structures in downtown areas. This combination of more pollutants and less space suggests that the Oakland Park, Florida system for treating industrial runoff is the best case example. Its cost was equivalent to $33 million per square mile, for a total of $1.65 billion over the extremely dense urban area.

Together, this approach estimates that the total BMP facilities cost will be about $5.7 billion.

Wetlands and Infiltration Basins: Estimate Based on Needed Retention Capacity

Investigators working on the Sun Valley Project (Los Angeles County Department of Public Works, 2003, Figure 4-3 of page 4-8) have designed several BMPs and provided carefully calculated cost estimates. These are recent figures, reduced to present worth, and reflecting the local conditions in the urban Los Angeles Region. They provide costs in terms of dollars per acre-foot of stormwater storage capacity for several BMPs. Three examples have been chosen for consideration here: Stonehurst Park and Wentworth Park (which simply lower the park level to two feet below the surrounding area so that they serve as infiltration basins, or "stormwater parks"), and storage in below-street infiltration vaults. A system that stores the runoff from a ¾-inch storm will comply with SUSMP requirements. In the low density areas, it is estimated that the runoff coefficient is 0.4. In the high density areas, it is estimated to be 0.6, and in the extremely dense areas it is estimated to be 1.0.

We estimate that the low-density areas can be served at the Stonehurst Park price, the high density areas can be served at the Wentworth Park price, and the extremely dense areas can be served by street infiltration vaults. This approach to estimating the total cost is completely independent of the first approach, but the final estimate of $4.0 billion for BMP facilities is reasonably similar.

Wetlands and Infiltration Basins: Estimation of Total Costs from the APWA Study

The APWA study produced total estimates for costs for the nation for five scenarios for stormwater quality control. One estimate was for a system of detention basins and wetlands, as is being proposed for the structural BMPs described here. They estimated that a national system would cost $91 billion. For 260 million people in the United States, this is about $350 per capita. For the 10 million people in the Los Angeles Region, this produces an estimate of $3.5 billion. The APWA anticipated maintenance costs for detention and retention basins at about 1% of the construction cost per year. Discounted to present worth, this increases the total cost by 33%, or $1.2 billion. APWA

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numbers thus indicate a total cost of $4.7 billion. This estimate is similar to those shown for the entries in Table 3 for facilities costs for alternatives B and C.

Wetlands and Infiltration Basins: An "Upper Bound" Provided by the Sun Valley Study

The Sun Valley study developed a detailed design for a 4.4 square mile watershed that currently has no storm drains. It was designed to contain the water from a 50-year, 3-day storm—14.8 inches of rain—using stormwater parks and below-street infiltration vaults. Because this approach will infiltrate essentially all of the rain that runs off from the area, and because the design criterion of 14.8 inches greatly exceeds the ¾ inch assumed here, it unquestionably constitutes a plan that would overcomply with the strictest imaginable stormwater quality control regulations. Further, because it is a complete and detailed design, it is essentially certain that it can be built for the cost estimated. Figures are recent, and reflect the costs of construction in the Southern California area.

The costs determined can therefore serve as an "upper bound" multiple benefit expenditure that a municipality could imaginable be required to incur—while there is every reason to suppose that the easier goal of stormwater quality control can be done for a much lower cost. The low cost alternative described was $171 million for 4.4 square miles, or $39 million per square mile. For the 1050 square miles of the high density and extremely dense urban Los Angeles Region, this would result in a cost of $41 billion. Wetlands for the low-density areas and trash control for the entire region would add about $1 billion more. Thus we can say with great certainty that no alternative more expensive than $42 billion will be needed.

Overall Benefits of Stormwater Quality Control

The Esthetic Value of a Clean Ocean

Much of the value of living near clean streams and a pollution-free ocean is difficult to quantify. People enjoy the view, they like watching wildlife, and they prefer vegetation and sand and water to pavement. Some efforts to place a dollar value on these benefits have been made by the EPA (1999) and others (Kramer, 2003; Soderqvist, 2000; Whitehead, et al., 2000).

Soderqvist asked residents in the area of the Stockholm archipelago how much they were willing to pay in order to reduce eutrophication of the nearby ocean. The effects of oceanic eutrophication are relatively subtle—less obvious than floating trash or debris washed up on the beach. He determined the willingness to pay to be between $54 and $90 per person.

Whitehead investigated resident willingness to pay for reduction of eutrophication of the Neuse River Basin in North Carolina. He found 44,000 landowners were willing to pay about $76 each for the water quality improvement.

Kramer surveyed people in the area of the Catawba River in North and South Carolina, asking about willingness to pay for improved water. The average result was $139 per taxpayer.

The EPA surveyed people across the U.S., asking about their willingness to pay for the various services associated with improvements in fresh water quality. They found people willing to pay $210 per household for improvement of water quality sufficient to support boating, $158 for the further improvement sufficient to support fishing, $177 for

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further improvement sufficient to allow swimming, and $158 for improvement sufficient to support natural aquatic life. Of the total of $703, however, only 67% was ascribed to local water quality improvement, while the rest was associated with improvement nationwide. Assuming 2.5 persons per household, this results in an estimate of $188 per person for willingness to pay for local freshwater improvements, similar to the estimate by Kramer for the Catawba River.

We have chosen the EPA estimate for freshwater improvements: the higher estimate seems reasonable because freshwater resources in the LA basin are generally in very poor condition, and because we have ignored the national effect (their results indicated that people throughout the nation were willing to pay for improvements throughout the nation—we are not counting the willingness of people outside the LA Region to pay for improvements here, and that number is not zero). Adding this to a mid-range value of the Soderqvist estimate for improvements in ocean water quality produces a result of $260 per person. This seems a quite reasonable value. 9.5 million people live in the Los Angeles Region, so this value indicates a total willingness to pay, based solely on the value of living in a region of clean waters, of about $2.5 billion.

Larsen and Kew (2003) have surveyed residents of California to determine their total willingness to pay for removing all impairments from bodies of water in the state. They determined that the average willingness to pay was $15.46 per month. Assuming 2.5 persons per household, this is $6.18 per person per month. For 9.5 million residents in the Los Angeles Region, this is $58.7 million per month, with a present worth of $23 billion. This represents the value of removing all impairments—including those caused by wastewater pollution, shoreside development, pollution from boats, and others. Our estimate for stormwater pollution alone is about one-tenth of this. Thus the Larsen and Kew results suggest our estimate is reasonable and conservative.

General support for these numbers was found in a survey done for the Packard Foundation performed by Mark Baldassare (Weisse, 2003). He determined that seven of ten Californians are concerned about the decline in coastal resources. Sixty-nine percent said the condition of the coastline is very important to their quality of life, and 75% visit the coast at least several times each year. Seventy-two percent favor reducing stormwater pollution, even if the cost leads to higher utility bills.

Ecosystem Services

A primary purpose of stormwater quality control is protection of nearshore marine ecosystems. These ecosystems provide humanity with a wide variety of services, ranging from educational opportunity to fish resources to chemical maintenance of the atmosphere. While the effort to value such ecosystem services is necessarily difficult and approximate, some studies have been made. Costanza, et al. (1997) in an article published in the respected journal *Nature*, assessed the value of coastal ecosystems at $12 trillion per year worldwide. The World Resources Institute estimates that there are 1.6 million kilometers of coastline (measured at a resolution of 1 kilometer). If we assume that stormwater discharges from the Los Angeles Region affect about 100 miles, or 160 kilometers of coastline, this is 0.01% of the world's total, suggesting that the value of local coastal resources is $1.2 billion per year. Assuming an interest rate of 3%, this income stream has a present worth of $40 billion. Finally, we can make the general

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approximation that stormwater pollution reduces the services provided by the local coastal ecosystem by 5%. This suggests that the value of lost services is $2 billion.

This number is quite approximate. It must secondly be interpreted thoughtfully because it includes services such as nutrient cycling and maintenance of the atmosphere, which are of undoubted value to the world, but which do not show up in the daily budgets of local citizens or local municipalities. The services are nevertheless quite real and quite valuable, and should be included in the accounting.

Additional Water Supply

Infiltration of stormwater will add to area groundwater reserves. These are a valuable resource that currently provides a substantial fraction of the Los Angeles Region water supply. Water that is infiltrated from the stormwater quality control system will add to local resources, reducing the need for imported water. We assumed that water will be collected from 2050 square miles. Rainfall ranges from 12 to 16 inches per year in the region, and infiltration is from 2 to 8 inches per year. It is conservative to assume that installation of a distributed system of infiltration basins will increase infiltration in this area by an average of 3 inches per year, corresponding to collection of four storms of ¾ inches (or a larger number of smaller storms). Thus total infiltration will be 300,000 acre-feet per year. Some of this may be unrecoverable, having entered contaminated or otherwise unusable aquifers. However, even this will contribute to reducing the problems of seawater intrusion. We estimate that about 90% or 270,000 acre-feet of the infiltrated water will be available.

Current importation costs are about $450 per acre-foot. However, current supply shortages are forcing serious consideration of desalination as an alternative source because political and environmental factors preclude significant increases in importation. We predict that continued growth in the Los Angeles Region will require that water be obtained from such high-cost sources, so we have used $800 per acre-foot as the value of the infiltrated ground water. Further, even if water is available for $450 per-acre foot, this is only the marginal financial cost of import—the true life cycle cost, including environmental impacts in source areas, is surely much higher. 270,000 acre-feet of water per year at $800 per acre-foot amounts to $216 million per year. The present worth of this income stream is $7.2 billion.

The appropriate number is highly dependent on assumptions: if conservation measures are effective and growth is slow, desalination might not be necessary. However if we include the costs of political friction with source areas, and the environmental impact of water transfers on those areas—that is, the full life-cycle cost of imported water, even the cost estimate of $800 per acre-foot may be low.

Flood Control

The flood control system in Los Angeles County is currently designed to cope with runoff from areas with a runoff coefficient on the order of 0.5. Stormwater quality control measures could substantially reduce this number—currently the coefficient for the San Gabriel Valley, measured below the spreading grounds at Whittier Narrows, is 0.05. Calculations suggest that the recent Army Corps of Engineers project that raised the embankments along the lower Los Angeles River have eliminated the 100-year flood plain for now, and property owners have correspondingly been relieved of flood insurance costs of $20 million or $30 million per year. However, if development

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continues to increase the runoff coefficient of the region, progressively more expensive projects will be required—it is likely that further protection would require rebuilding many bridges. Alternatively, flood insurance will once again be necessary, and uninsured properties will be at risk. It is perhaps reasonable to presume that infiltration systems will avoid the cost of the next embankment project, which could easily costs twice as much as the one just completed, or $400 million.

A second estimate can be developed this way: The National Flood Insurance Program says there are 25,620 policies held in Los Angeles County with an average premium of $550, for a total yearly cost of $14 million. The present worth at 3% is $466 million. Presumably, most but not all of this could be avoided with a complete stowmwater quality control system. Thus the estimate of $400 million seems reasonable.

Property Value Improvements from Greenspace and Water

Certainly additional parks and other greenspace would add to property values. Developers frequently add central lakes or greenspace to large developments, demonstrating their belief that the value of the land for additional housing is less than its value as an amenity. In a study compiled in 1995, the U.S. EPA said (U.S. EPA, 1995):

> "People have a strong emotional attachment to water, arising from its aesthetic qualities--tranquility, coolness, and beauty. As a result, most waterbodies within developments can be used as marketing tools to set the tone for entire projects (Tourbier and Westmacott, 1992). A recent study conducted by the National Association of Home Builders indicates that "whether a beach, pond, or stream, the proximity to water raises the value of a home by up to 28 percent." A 1991 American Housing Survey conducted by the Department of Housing and Urban Development and the Department of Commerce also concurs that "when all else is equal, the price of a home located within 300 feet from a body of water increases by up to 27.8 percent" (NAHB, 1993). Dick Dillingham, President of the National Association of Realtors' Residential Sales Council, declares, "Water makes a difference . . . there is such a very small supply of properties that can claim a water location and it is something you cannot add" (Lehman, 1994)."

Homes overlooking the new wetlands and greenspace will see the greatest increase in property values. Those farther away will appreciate less. A study reported by Fairfax County, Virginia, (Environmental Coordinating Committee, 2003) interpreted the EPA results and concluded that an aesthetically valuable pond raises the value of nearby houses by $10,000 each. In Los Angeles County, the median home is valued at about $400,000, so a $10,000 increase is about 2.5%, which seems a reasonable number. Demographic data for Los Angeles County (This is not the same as the Los Angeles Region governed by the Water Quality Control Board, but there is considerable overlap, and the demographics are quite similar) indicate there are 3.27 million homes, of which 47.9%, or 1.55 million, are owner-occupied. We expect that about one-third of these, or 500,000 homes, would benefit from additional greenspace in a complete stormwater control system (the others could be too remote, or might already have sufficient greenspace). Increasing the value of each home by $10,000 provides a total benefit of $5 billion.

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Improved Property Values from Trash Control

Enforcement of litter laws and improved street cleaning would improve the appearance of our neighborhoods. It is believed that the esthetic improvement would have a value to individuals at least equal to the esthetic benefits of a cleaner ocean, so we have valued this at $100 per person, for a total of $950 million.

Cost Savings from Reduced Dredging

Costs for sediment dredging and disposal in area harbors range from about $10 per ton, when the sediment is clean and a nearby disposal site is available, to $30 per ton when the sediment is contaminated or the disposal site is distant. Disposal of sediments classified as toxic may cost $100 per ton. Personnel at Los Angeles Harbor estimate that about 40% of currently dredged sediment is contaminated, and occasional loads are toxic. In general, acceptable disposal sites are becoming harder to find, so distant sites are likely to be the rule. Thus, an estimate for future sediment removal of $30 per ton is reasonable. The Environmental Protection Agency has estimated overall costs and effectiveness for sediment control at construction sites, and the results indicate that preventing the runoff of a ton of sediment costs from $69 to $86 (Appendix II). Therefore, the savings associated with alleviation of harbor sedimentation alone offset about a third of the costs of construction site measures. Savings for Los Angeles Harbor will be about $3 million per year. Regional savings will be about $10 million, with a present worth of $330 million.

To cite another example, it is estimated that the San Joaquin Marsh wetland preserve collects 50,000 tons of sediment per year. Assuming a removal cost of $30 per ton, the benefit for Newport Bay, which is just downstream, is $1.5 million per year.

Cost Savings from Improved Public Health

Sufficient data do not exist for estimating the value of benefits from reduced exposure to air pollutants. Certainly fine particles are an important part of the causes of health impairment, and experts agree that resuspension of road dust is an important contributor to fine particle exposure at street level where we live. They also contribute substantially to settlement of dust and dirt on buildings, requiring cleaning expenses. However, estimates of the magnitude of this effect are not currently possible.

Summary of predicted costs and benefits

Table 3 presents a summary of the estimated costs and benefits. Three estimates are included. In the first (A), non-structural BMPs are presumed to be the only measures employed. In the second (B), wetlands and infiltration basins are assumed, and the costs are estimated on a cost-per-square-mile basis. The third set of columns (C) again describes the wetlands and infiltration basins scenario, but makes cost estimates on a per-acre-foot-detention basis. The second and third estimates also presume implementation of the non-structural BMPs, except for storm drain cleaning.

Benefits differ because implementation on non-structural BMPs does not produce property increases associated with greenspace, does not significantly increase groundwater supply, and does not reduce harbor sedimentation.

The costs of stormwater quality control are significant. Non-structural BMPs alone will cost $2.6 billion. Structural systems, including wetlands and infiltration basins, will cost between $5.7 billion and $7.4 billion. However, it should be noted that these costs will be borne over a period of many years—probably ten years at least. More

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importantly, the benefits of these expenditures considerably exceed their costs. For the non-structural BMPs alone, the benefit-to-cost ratio is 1.9. For the structural approach the estimates are 2.5 and 3.3. Control of pollution and reestablishment of the hydrologic cycle will produce a greener city with higher property values, better esthetics, cleaner rivers and a cleaner ocean, and a larger and more stable water supply.

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Table 2. Overall Cost Estimate for Stormwater Quality Control in the Los Angeles Region

Sums are rounded to two significant figures

		A. Non-Structural BMPs, modified from APWA			B. Wetlands and Infiltration Basins, watershed area basis		C. Wetlands and Infiltration Basins, detention volume basis		
Regions and BMPs	**Area, sq. miles**	**Capi-tal Cost $M**	**O&M Costs $M**	**Total $M**	**Cost / square mile, $M**	**Cost or Bene-fit $M**	**Acre-feet initial flow**	**Cost per acre-foot**	**Cost or Bene-fit, $M**
Costs for Non-Structural BMPs									
No Littering Ordinance		2.5	3	103		103			103
Pet Waste Ordinance		2.5	3	103		103			103
Chemical Use and Storage		2.5	3	103		103			103
Public Education			5	50		50			50
Illicit Discharge Program		6.5	80	407		407			407
Increased Cleaning of Drains			27	900					
Trash Control				608		608			608
Low Flow Sanitary Treatment				28		28			28
Improved Street Cleaning	2050			250		250			250
Private On-site BMPs		241		241		241			241
New construction rules				Mod-est		Mod-est			Mod-est
Total N-S BMPs				2791		1891			1891
Costs for Structural BMPs									
Rural	1050					0			0
Low Density, Industrial (C=0.4)	1000				0.42	420	15,500	0.053	822
High Density (C=0.6)	1000				3.70	3,700	23,250	0.098	2,279
Extremely Dense (C=1.0)	50				33.00	1,650	1,938	0.470	911
Total Facilities Costs						5,770			4,011
Total Cost, LA Region				**2550**		**7420**			**5661**
Benefits									
Flood Control						400			400
Greenspace, Water Property Values						5,000			5,000
Clean Ocean Esthetics				2500		2,500			2,500
Clean Streets Esthetics				950		950			950
Groundwater Replenishment						7,200			7,200
Improved Beach Tourism				100		100			100
Preservation of Ocean Ecosystems				2000		2,000			2,000
Reduced Harbor Sedimentation						330			330
Improved Health, Cleaner Buildings, Reduced Exposure to Particulates						Sig-nifican t			Sig-nifican t
Total Benefits, LA Region				**5600**		**18,000**			**18,000**

Recommendations for Action

The results developed here indicate that a distributed approach to stormwater quality control, employing non-structural BMPS with a system of wetlands and infiltration basins will achieve stormwater quality compliance and will be far cheaper than advanced treatment plants. It is recommended that the responsible organizations begin immediately with the non-structural measures, analyze their effectiveness, and add wetlands and infiltration systems as necessary to achieve the goal of protecting the rivers and coastal zones of the Los Angeles Region. Our results indicate that the benefit-to-cost ratio for the non-structural BMPs is about two, and for the larger effort is about 3. Thus both the beginning effort and the full response represent good investments for the people of the region.

Outreach

Municipalities that are finding themselves responsible for stormwater cleanup should act immediately to lay the groundwork for comprehensive programs. Outreach programs should be developed to inform the public of the problems and of what they can do to help with the solution. Vigorous efforts to reduce littering, for example, will reduce costs in subsequent steps as programs develop. Current regulations controlling release of sediments from construction sites should be enforced and supplemented with contractor education efforts.

Data Collection and Planning

Municipalities should immediately begin the process of determining the extent and nature of their individual stormwater quality problems. Many may find, for example, that stormwater from neighborhoods of single-family homes can be discharged to rivers or infiltrated with little or no treatment. Early identification and elimination of problem sources might greatly reduce later expenditures on treatment systems—the programs of thorough data collection and vigorous enforcement described earlier were notably effective at reducing pollutant concentrations in discharges and cost very little. It will certainly be a tragedy if we build expensive treatment systems to solve a problem that can be eliminated with a citation.

Municipalities should also immediately assess their property holdings. Cities frequently own substantial amounts of land, and some of this will be appropriate for stormwater control facilities. Purchasing programs should be developed immediately, so that cities can take advantage of opportunities for economical land acquisition as they arise.

Administrative Structure

Adding to the daunting technical and financial problems, the distributed approach for stormwater control requires that problems be solved by a holistic effort for each sub-watershed. The boundaries of sub-watersheds do not correspond to political boundaries, and cities will be forced to cooperate in ways that have never been required before. Further, controlling local pollution releases and restoring the hydrologic cycle involve issues that have traditionally be dealt with by an astonishing variety of agencies. If we imagine controlling the runoff quality of a sub-watershed by installing a park/infiltration system with associated wetlands, for example, efforts should include the sanitation

districts for the cities overlapping the sub-watershed (because of stormwater quality control), the Water Replenishment District (because of groundwater infiltration), the County Flood Control District (because the park will contribute to flood control and reduce the cost of downstream facilities), parks departments (because a recreational area will result), and wildlife agencies (governing the habitat created). It is reasonable to expect, moreover, that each of these agencies will contribute to the funding necessary for construction and maintenance. It is likely that, with appropriate apportionment, such a facility will have a favorable cost/benefit ratio for each of the agencies involved. It is certain that gaining the cooperation and contributions of all of these agencies will be extremely difficult. It may be appropriate that legislation be passed at the state level to provide a means for bringing these agencies together.

Funding

While runoff quality can be controlled by methods significantly cheaper than the massive construction of advanced treatment plants, the cost remains significant, and comes at a time when state and local governments are desperately short of funds. It is reasonable to suggest that funding should come from those who contribute to the problem, so that the taxation system mimics a market—assigning costs to the activity that generates them. Hundreds of municipal stormwater utilities, for example, have instituted a tax that is proportional to the number of square feet of impermeable surface on the land. An extension to this approach is to give property-owners fee rebates for installing BMPs that lower runoff quantity or increase water quality. This approach, or others that encourage owners to reduce their runoff, could fund the solution even as they reduce the magnitude of the problem. Certainly fines for littering should be used to fund litter law enforcement in the way that parking fines fund parking enforcement. Efforts to control illegal discharges could be at least partially supported by fines of those making the discharges. All of these approaches would be consistent with the principle that the polluter should pay, and would provide incentives that would contribute to stormwater cleanup.

A "cap and trade" system would be one means of approaching the funding dilemma. If all landowners were given the choice of either purchasing tradable discharge allowances or cleaning up runoff, a free-market trading system would allow owners to trade these allowances and in the process assign stormwater runoff reduction to owners who are able to cheaply install BMPs. This system, or a combined stormwater utility fee with BMP credits, would tend to produce the lowest cost solution overall. A study under way in Cincinnati, Ohio, suggests that such systems could be successful (Thurston et al., 2003).

Changes in Building Codes

This study indicates that parking lots constitute a significant resource for promoting stormwater infiltration. Building codes should be amended immediately to require that all new or reconstructed parking lots be designed to infiltrate the water that they collect. While there will be costs associated with the infiltration systems, the work described above indicates that much—and often all—of these costs can be offset by reduced costs for curbs and drainage systems.

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Very large facilities, such as those for malls, should be considered sites for installation of subsurface infiltration vaults that could receive water from surrounding areas as well. These could be installed in sections, to minimize disruption to the commercial establishments. A mechanism could be established by which the site owners are compensated for the costs of handling the runoff.

Other building codes should be changed to encourage on-site infiltration of water rather than rapid drainage to the street. It may also be appropriate to consider limitations on the use of architectural copper sheeting, which can release copper ions to stormwater, and on the use of galvanized materials, which can release zinc.

Purchase of High-Efficiency Street Sweeping Equipment

Improved street sweeping seems very likely to be an important part of future stormwater programs. It can remove 30 to 50 percent of the particulate-associated pollutants, substantially reducing the load on downstream systems. It will have the secondary benefits of improving neighborhood appearance and reducing the exposure to air pollutants at street level. Municipalities should make the decision now to purchase only high-efficiency vacuum sweepers as they make routine replacements of their street cleaning machinery.

Investigation of Coliform Sources

Additional studies, particularly employing newly available methods for rapid identification of microorganisms, should be done to determine the sources of pathogenic organisms in stormwater.

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APPENDIX I.
BEST MANAGEMENT PRACTICES FOR CONSTRUCTION SITES

(Adapted from the Washington State Department of Ecology Water Quality Program, 2001).

The **12 Elements** of Storm Water Pollution Prevention Plan (SWPPP):

Mark Clearing Limits

Prior to beginning land disturbing activities all clearing limits, sensitive areas and their buffers, and trees that are to be preserved shall be clearly marked, both in the field and on the plans, to prevent damage and offsite impacts.

Preserving Natural Vegetation

The purpose of preserving natural vegetation is to reduce erosion wherever practicable. Limiting site disturbance is the single most effective method for reducing erosion.

Buffer Zones

An undisturbed area or strip of natural vegetation or an established suitable planting will provide a living filter to reduce soil erosion and runoff velocities.

High Visibility Plastic or Metal Fence, Stake and Wire Fence

Fencing is intended to: (1) restrict clearing to approved limits; (2) prevent disturbance of sensitive areas, their buffers; (3) limit construction traffic to designated construction entrances or roads; and, (4) protect areas where marking with survey tape may not provide adequate protection.

Establish Construction Access

To minimize the tracking of sediment onto public roads and into surface waters:

Stabilized Construction Entrance

Construction entrances are stabilized to reduce the amount of sediment transported onto paved roads by vehicles or equipment by constructing a stabilized pad of quarry spalls at entrances to construction sites.

Wheel Wash

Wheel washes reduce the amount of sediment transported onto paved roads by motor vehicles.

Construction Road/Parking Area Stabilization

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Stabilizing subdivision roads, parking areas, and other onsite vehicle transportation routes immediately after grading reduces erosion caused by construction traffic or runoff.

Control Flow Rates

Properties and waterways downstream from development sites shall be protected from erosion due to increases in the volume, velocity, and peak flow rate of stormwater runoff from the project site.

Sediment Trap

A sediment trap is a small temporary ponding area with a gravel outlet used to collect and store sediment from sites cleared and/or graded during construction.

Temporary Sediment Pond

Sediment ponds remove sediment from runoff originating from disturbed areas of the site. Sediment ponds are typically designed to remove sediment no smaller than medium silt (0.02 mm).

Install Sediment Controls

Straw Bale Barrier

To decrease the velocity of sheet flows and intercept and detain small amounts of sediment from disturbed areas of limited extent, preventing sediment from leaving the site.

Brush Barrier

The purpose of brush barriers is to reduce the transport of coarse sediment from a construction site by providing a temporary physical barrier to sediment and reducing the runoff velocities of overland flow.

Gravel Filter Berm

A gravel filter berm is constructed on rights-of-way or traffic areas within a construction site to retain sediment by using a filter berm of gravel or crushed rock.

Silt Fence

Use of a silt fence reduces the transport of coarse sediment from a construction site by providing a temporary physical barrier to sediment and reducing the runoff velocities of overland flow.

Vegetated Strip

Vegetated strips reduce the transport of coarse sediment from a construction site by providing a temporary physical barrier to sediment and reducing the runoff velocities of overland flow.

Straw Wattles

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Straw wattles are temporary erosion and sediment control barriers consisting of straw that is wrapped in biodegradable tubular plastic or similar encasing material. They reduce the velocity and can spread the flow of rill and sheet runoff, and can capture and retain sediment.

Sediment Trap

A sediment trap is a small temporary ponding area with a gravel outlet used to collect and store sediment from sites cleared and/or graded during construction.

Temporary Sediment Pond

Sediment ponds remove sediment from runoff originating from disturbed areas of the site. Sediment ponds are typically designed to remove sediment no smaller than medium silt (0.02 mm).

Construction Stormwater Chemical Treatment

Turbidity is difficult to control once fine particles are suspended in stormwater runoff from a construction site. Sedimentation ponds are effective at removing larger particulate matter by gravity settling, but are ineffective at removing smaller particulates such as clay and fine silt. Sediment ponds are typically designed to remove sediment no smaller than medium silt (0.02 mm). Chemical treatment may be used to reduce the turbidity of stormwater runoff.

Construction Stormwater Filtration

Filtration removes sediment from runoff originating from disturbed areas of the site.

Stabilize Soils

Exposed and unworked soils shall be stabilized by application of effective BMPs that protect the soil from the erosive forces of raindrops, flowing water, and wind.

Temporary and Permanent Seeding

Seeding is intended to reduce erosion by stabilizing exposed soils. A well-established vegetative cover is one of the most effective methods of reducing erosion.

Mulching

The purpose of mulching soils is to provide immediate temporary protection from erosion. Mulch also enhances plant establishment by conserving moisture, holding fertilizer, seed, and topsoil in place, and moderating soil temperatures.

Nets and Blankets

Erosion control nets and blankets are intended to prevent erosion and hold seed and mulch in place on steep slopes and in channels so that vegetation can become well established. In addition, some nets and blankets can be used to permanently reinforce turf to protect drainage ways during high flows.

Plastic Covering

Plastic covering provides immediate, short-term erosion protection to slopes and disturbed areas.

Sodding

The purpose of sodding is to establish permanent turf for immediate erosion protection and to stabilize drainage ways where concentrated overland flow will occur.

Topsoiling

Addition of topsoil will provide a suitable growth medium for final site stabilization with vegetation. While not a permanent cover practice in itself, topsoiling is an integral component of providing permanent cover in those areas where there is an unsuitable soil surface for plant growth. Native soils and disturbed soils that have been organically amended not only retain much more stormwater, but they also serve as effective biofilters for urban pollutants and, by supporting more vigorous plant growth, reduce the water, fertilizer and pesticides needed to support installed landscapes. Topsoil does not include any subsoils but only the material from the top several inches, including organic debris.

Polyacrylamide for Soil Erosion Protection

Polyacrylamide (PAM) is used on construction sites to prevent soil erosion. Applying PAM to bare soil in advance of a rain event significantly reduces erosion and controls sediment in two ways. First, PAM increases the soil's available pore volume, thus increasing infiltration through flocculation and reducing the quantity of stormwater runoff. Second, it increases flocculation of suspended particles and aids in their deposition, thus reducing stormwater runoff turbidity and improving water quality.

Surface Roughening

Surface roughening aids in the establishment of vegetative cover, reduces runoff velocity, increases infiltration, and provides for sediment trapping through the provision of a rough soil surface.

Gradient Terraces

Gradient terraces reduce erosion damage by intercepting surface runoff and conducting it to a stable outlet at a non-erosive velocity.

Dust Control

Dust control prevents wind transport of dust from disturbed soil surfaces onto roadways, drainage ways, and surface waters.

Small Project Construction Stormwater Pollution Prevention

To prevent the discharge of sediment and other pollutants to the maximum extent practicable from small construction projects.

Protect Slopes

Design, construct, and phase cut and fill slopes in a manner that will minimize erosion, considering soil type and its potential for erosion.

Temporary and Permanent Seeding

Seeding is intended to reduce erosion by stabilizing exposed soils. A well-established vegetative cover is one of the most effective methods of reducing erosion.

Surface Roughening

Surface roughening aids in the establishment of vegetative cover, reduces runoff velocity, increases infiltration, and provides for sediment trapping through the provision of a rough soil surface.

Gradient Terraces

Gradient terraces reduce erosion damage by intercepting surface runoff and conducting it to a stable outlet at a non-erosive velocity.

Interceptor Dike and Swale

Provide a ridge of compacted soil, or a ridge with an upslope swale, at the top or base of a disturbed slope or along the perimeter of a disturbed construction area to convey stormwater. Using the dike and/or swale to intercept the runoff from unprotected areas and direct it to areas where erosion can be controlled. This can prevent storm runoff from entering the work area or sediment-laden runoff from leaving the construction site.

Grass-Lined Channels

Channels lined with grass can convey runoff without erosion, and will provide some degree of treatment and infiltration.

Pipe Slope Drains

Piping can be used to convey stormwater anytime water needs to be diverted away from or over bare soil to prevent gullies, channel erosion, and saturation of slide-prone soils.

Subsurface Drains

Drains below the surface can intercept, collect, and convey ground water to a satisfactory outlet. These can be a perforated pipe or conduit below the ground surface. The perforated pipe provides a dewatering mechanism to drain excessively wet soils, provide a stable base for construction, improve stability of structures with shallow foundations, or to reduce hydrostatic pressure to improve slope stability.

Level Spreader

To provide a temporary outlet for dikes and diversions consisting of an excavated depression constructed at zero grade across a slope. To convert concentrated runoff to sheet flow and release it onto areas stabilized by existing vegetation or an engineered filter strip.

Check Dams

Construction of small dams across a swale or ditch reduces the velocity of concentrated flow and dissipates energy at the check dam.

Triangular Silt Dike (Geotextile-Encased Check Dam)

Triangular silt dikes may be used as check dams, for perimeter protection, for temporary soil stockpile protection, for drop inlet protection, or as a temporary interceptor dike.

Protect Drain Inlets

Storm drain inlets operable during construction shall be protected so that stormwater runoff does not enter the conveyance system without first being filtered or treated to remove sediment.

Storm Drain Inlet Protection

To prevent coarse sediment from entering drainage systems prior to permanent stabilization of the disturbed area:

Stabilize Channels And Outlets

Temporary on-site conveyance channels shall be designed, constructed, and stabilized to prevent erosion from the expected flow velocity of a 2-year, 24-hour frequency storm for the developed condition.

Channel Lining

Lining will protect erodible channels by providing a channel liner using either blankets or riprap.

Outlet Protection

Outlet protection prevents scour at conveyance outlets and minimizes the potential for downstream erosion by reducing the velocity of concentrated stormwater flows.

Control Pollutants

All pollutants, including waste materials and demolition debris, that occur on site during construction shall be handled and disposed of in a manner that does not cause contamination of stormwater.

Concrete Handling

Concrete work can generate process water and slurry that contain fine particles and high pH, both of which can violate water quality standards in the receiving water. Concrete handling is intended to minimize and eliminate concrete process water and slurry from entering waters of the state.

Sawcutting and Surfacing Pollution Prevention

Sawcutting and surfacing operations generate slurry and process water that contain fine particles and high pH (concrete cutting), both of which can violate the water quality standards in the receiving water. Collection of this water is intended to minimize and eliminate process water and slurry from entering waters of the State.

Control De-Watering

Foundation, vault, and trench de-watering water shall be discharged into a controlled conveyance system prior to discharge to a sediment pond.

Maintain BMPs

Temporary and permanent erosion and sediment control BMPs shall be maintained and repaired as needed to assure continued performance of their intended function. Maintenance and repair shall be conducted in accordance with BMPs.

Manage the Project

Development projects shall be phased where feasible in order to prevent, to the maximum extent practicable, the transport of sediment from the development site during construction. Revegetation of exposed areas and maintenance of that vegetation shall be an integral part of the clearing activities for any phase.

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APPENDIX II. ESTIMATION OF COSTS FOR CONTROLLING SEDIMENT RELEASES AT CONSTRUCTION SITES

EPA described the costs of the Phase II program in Chapter 4 of the economic analysis (U.S. EPA, 1995). This appendix is a summary of that description, and the figures presented come from that document. The costs were divided into 4 categories: municipal costs, construction costs, federal costs and state costs. Each of these was considered separately.

Construction costs:

Construction costs were described in parts 4-8 to 4-25. All the cost calculations are based on 1998 dollar value.

Because the Phase II program targets construction areas of 1 to 5 acres of land, the cost analysis are done for these land sizes. EPA divided the construction costs into two parts. The first part requires the owners and operators of construction sites disturbing one to five acres of land to plan and implement erosion and sediment control BMPs. The second part requires the implementation of post-construction stormwater runoff controls on construction sites located in Phase II municipalities.

Erosion and sediment control costs

EPA developed a national level cost estimate for implementing erosion and sediment controls on sites that disturb between one and 5 acres. EPA estimated a per site compliance cost for sites of one, three, and five acres and multiplied the cost by the total number of Phase II construction starts expected to incur incremental cost in these size categories to obtain a national cost estimate. EPA used construction start data from fourteen municipalities and 1994 Census Bureau construction permit data to estimate the number of construction starts disturbing between one and five acres of land. Of the estimated 129,675 construction starts likely to incur incremental costs, EPA expects that 110,223 (85%) will require erosion and sediment controls to comply with the regulation.

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Exhibit 4–4. Summary Characteristics of Municipalities Where Construction Start Data was Collected

Municipality	Population 1996 (Estimates)[1]	Population Growth 1990 to 1996	Median Household Income (1989)	Area (Sq. Mi.)
Austin, TX	541,278	+14.7%	$25,414	217.8
Baltimore County, MD	720,662	+4.1%	$38,837	599.0
Cary, NC	75,676	+70.5%	$46,259	31.2
Fort Collins, CO	104,196	+19.1%	$28,826	41.2
Lacey, WA	27,381	+42.0%	$29,726	10.1
Loudoun County, VA	133,493	+54.9%	$52,064	520.0
New Britain, CT	71,512	–5.3%	$30,121	13.3
Olympia, WA	39,006	+15.6%	$27,785	16.1
Prince George's County, MD	770,633	+5.6%	$43,127	486.0
Raleigh, NC	243,835	+15.0%	$32,451	88.1
South Bend, IN	102,100	–3.2%	$24,131	36.4
Tallahassee, FL	136,751	+9.6%	$34,764	63.3
Tucson, AZ	449,002	+9.1%	$21,748	156.3
Waukesha, WI	60,197	+5.8%	$36,192	17.3
United States	265 million	+6.6%	$35,225	

Source: US Department of Commerce, Bureau of the Census. [http://www.census.gov].
[1] US Census Bureau Data (1996).

Per-Site Compliance Costs: Installation and O&M.

EPA used standard cost estimates from R.S. Means (R.S. Means, 1997a and 1997b) and the WEF database to estimate construction BMP costs for 27 model sites of typical site conditions in the United States. The model sites included three different site sizes (one, three, and five acres), three slope variations (3%, 7%, and 12%), and three soil erosivity conditions (low, medium, and high). EPA used the WEF database to determine BMP combinations appropriate to the model site conditions. For example, sites with shallow slopes and a low erosivity require few BMPs, while larger, steeper, and more erosive sites required more BMPs. Detailed site plans, assumptions, and BMPs that could be used are presented in Appendices B–2 and B–3. Based on the assumption that any combination of site factors is equally likely to occur on a given site, EPA averaged the matrix of estimated costs to develop an average cost for one-, three-, and five-acre starts for all soil erodibilities and slopes.

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Exhibit 4–6. BMPs Used for the Model Sites

Site Size (acres)	Soil Erodibility	Slope		
		3%	7%	12%
1	low	a	a,b	a,c,e
	med	a,b	a,c,e	a,c,e
	high	a,c,e	a,c,e	c,e,f,g1
3	low	a,b	a,c,e	c,d,e,f,g2
	med	a,c,e	a,c,e	c,d,e,f,g2
	high	a,c,e	c,d,e,f,g2	c,d,e,f,g2
5	low	a,c,d,e	c,d,e,f,g3	c,d,e,f,g3
	med	a,c,d,e	c,d,e,f,g3	c,d,e,f,g3
	high	c,d,e,f,g3	c,d,e,f,g3	c,d,e,f,g3

a = silt fence
b = mulch
c = seed and mulch
d = stabilized construction entrance
e = stone check dam
f = earthen dike directing runoff to sediment trap
g = sediment trap (1=1,800 cf, 2=5,400 cf, 3=9,000 cf)

Costs related to each BMP and the description of the BMP were shown in Exhibit 4-7 of the original document.

Exhibit 4–8. Estimated Cost of BMPs for the Model Sites (1998 dollars)

Site Size (acres)	Soil Erodibility	Cost by Slope			Average Cost
		3%	7%	12%	
1	low	$317	$814	$1,422	$1,206
	med	$814	$1,422	$1,422	
	high	$1,422	$1,422	$1,799	
3	low	$1,978	$3,804	$6,047	$4,598
	med	$3,804	$3,804	$6,047	
	high	$3,804	$6,047	$6,047	
5	low	$6,245	$9,334	$9,519	$8,709
	med	$6,245	$9,334	$9,519	
	high	$9,334	$9,334	$9,519	

Per-Site Compliance Costs: Administrative.

EPA then estimated administrative costs per construction site for the following elements required under the Phase II rule: submittal of a notice of intent (application) for permit coverage; notification to municipalities; development of a stormwater pollution prevention plan (SWPPP); record retention; and submittal of a notice of termination. The average total administrative cost per site was estimated to be $937.

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Exhibit 4–10. Estimated Other Administrative Phase II Construction Costs Per Site (1998 Dollars)

Administrative Requirement	Cost
NOI	$126.50
Municipal Notification	$17.10
SWPPP	$772.25
Record Retention	$4.51
NOT	$17.10
Estimated Total Cost (per site)	$937.46

Summing the average BMP costs and the administrative costs yields a total compliance cost of $2,143 for sites disturbing between one and two acres of land, $5,535 for sites disturbing between two and four acres of land, and $9,646 for sites disturbing between four and five acres of land. To estimate national level incremental annual costs for Phase II construction starts, EPA multiplied the total costs of compliance for one to two acre, two to four acre, and four to five acre sites by the total number of Phase II construction starts within each of those size categories. This yielded an estimated annual compliance cost of approximately $499.8 million (based on 110,223 construction starts in 1998).

EPA anticipates that 19,452 (15%) of the estimated Phase II incremental construction universe will qualify for a waiver from program requirements by meeting one of two conditions. Construction sites can be waived if they are either located in areas with low rainfall potential or if water quality analyses show that there is no need for regulation. EPA estimates the incremental administrative cost associated with preparing and submitting a waiver to be approximately $665,000 (1998). Total costs (national compliance and waiver costs) resulting from implementation of the Phase II erosion and sediment control provision are estimated to be **$500.4 million**.

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Exhibit 4–11. Estimated National Phase II Construction Compliance Costs by Climatic Zones for Year 1998 (1998 Dollars)

Climatic Zone	Representative City	Number of Starts 1–2 Acres	Number of Starts 2–4 Acres	Number of Starts 4–5 Acres	Total Starts	Costs for Starts 1–2 Acres	Costs for Starts 2–4 Acres	Costs for Starts 4–5 Acres	Total Costs
A	Portland, OR	1,683	1,471	659	3,813	$3,608,528	$8,141,052	$6,360,054	$18,356,897
B	Boise, ID	1,508	1,345	576	3,429	$3,232,932	$7,443,548	$5,556,280	$16,455,088
C	Fresno, CA	2,388	2,018	974	5,380	$5,118,068	$11,171,812	$9,400,679	$26,039,422
D	Las Vegas, NV	7,154	6,256	3,035	16,445	$15,335,047	$34,628,344	$29,276,500	$80,306,157
E	Denver, CO	1,787	1,613	636	4,036	$3,829,714	$8,928,128	$6,135,764	$18,893,606
F	Bismarck, ND	560	469	156	1,185	$1,199,916	$2,595,370	$1,508,877	$5,304,163
G	Helena, MT	1,067	921	348	2,336	$2,287,796	$5,098,377	$3,354,650	$10,740,823
H	Amarillo, TX	3,295	2,838	1,152	7,285	$7,063,767	$15,708,383	$11,110,516	$33,882,666
I	San Antonio, TX	1,105	960	414	2,479	$2,368,045	$5,314,569	$3,997,033	$11,679,647
K	Duluth, MN	2,957	1,796	326	5,078	$6,339,106	$9,939,565	$3,141,089	$19,419,760
M	Des Moines, IA	9,335	7,599	2,695	19,629	$20,009,581	$42,063,182	$26,002,165	$88,074,928
N	Nashville, TN	5,801	4,707	1,705	12,212	$12,434,357	$26,052,990	$16,445,128	$54,932,475
P	Atlanta, GA	5,157	2,956	1,127	9,241	$11,054,430	$16,364,835	$10,875,252	$38,294,517
R	Hartford, CT	6,909	5,324	2,116	14,348	$14,808,848	$29,468,120	$20,412,901	$64,689,869
T	Charleston, SC	1,194	675	263	2,132	$2,560,342	$3,736,824	$2,535,496	$8,832,662
V	Hawaii	504	423	218	1,145	$1,080,648	$2,340,928	$2,099,447	$5,521,023
W,X,Y	Alaska	22	20	8	50	$47,885	$112,127	$72,563	$232,575
Total		52,426	41,389	16,408	110,223	$112,379,010	$229,108,154	$158,284,394	$499,771,558

Note: Number of sites include only those where storm water BMPs are not currently required by Federal or State programs. Totals may not add because of rounding.

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Exhibit 4–12. Phase II Erosion and Sediment Control Annual Costs

Construction Costs	Universe	Estimated Total National Annual Costs (1998 dollars)
Compliance Costs	110,223	$499,771,558
Waiver Costs*	19,452	$665,064
Total	129,675	$500,436,622

*Based on an engineering assistant's wage of $34.19 per hour. U.S. Department of Labor, 1996.

EPA also estimated incremental costs attributable to the post-construction runoff control measures. The Phase II municipal program requires municipalities to develop, implement, and enforce a program that addresses stormwater runoff from new development and redevelopment sites on which land disturbance is greater than one acre and that discharge into a regulated MS4. To develop a cost estimate associated with this measure, EPA estimated a per site BMP cost, including operation and maintenance, for 12 model sites of varying size (1, 3, 5, and 7 acres) and imperviousness (35%, 65%, and 85%). The per site BMP cost was then multiplied by the total number of multi-family, institutional, and commercial construction starts that are located in Phase II urbanized areas to obtain a national cost estimate. Using this total of 13,364 postconstruction starts, EPA estimated a range of national costs associated with this measure from $44.6 to $178.3 million (see Appendix B–4). EPA estimates total annual costs to construction operators, including implementation of erosion and sediment controls and post-construction controls, to be between **$545.0 – $678.7 million.**

Exhibit 4–15. Estimated Post-Construction Runoff Control Costs

Area	35% Impervious (Multi-Family Residential)	65% Impervious (Multi-Family/ Commercial/ Institutional)	85% Impervious (Commercial)	Total Cost (1998 dollars)
1 Acre	$503,163	$14,318,035	$25,530,478	$40,351,676
3 Acres	$1,486,961	$29,571,535	$29,588,931	$60,647,426
5 Acres	$2,001,641	$11,835,630	$9,151,038	$22,988,309
7 Acres	$3,863,272	$23,910,571	$26,494,414	$54,268,258
Total Cost	$7,855,037	$79,635,771	$90,764,861	$178,255,669

Summary of results of the total costs of the phase II program are shown below:

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Exhibit 4–21. Potential Annual Costs for Phase II Storm Water Regulation

Phase II Element	Universe	Estimated Total National Annual Costs (1998 dollars)
Municipal	32,458,000 Households	$297,318,623
Construction	129,675 Erosion & Sediment Control Starts and 13,364 Post-Construction Starts	$545,000,539 – $678,692,291
Federal and State	53 States and Territories	$5,318,668
Total		$847,637,830 – $981,329,582

Reduced Sediment Delivery From Construction Starts:

To estimate reduced sediment delivery from Phase II construction starts, the US ACE developed a model based on EPA's 27 model sites to estimate sediment loads from construction starts with and without Phase II controls (US ACE, 1998). The US ACE model uses the construction site version of the Revised Universal Soil Loss Equation (RUSLE) to generate sediment delivery estimates for 15 climatic regions with each of the following variations: three site sizes (one, three, and five acres), three soil erodibility levels (low, medium, and high), three slopes (3%, 7%, and 12%), and the BMP combinations from EPA's 27 model sites. The 15 climatic regions represent the various rainfall and temperature conditions throughout the United States. Sediment delivery represents the quantity of sediment that BMPs placed at the base of the hill slope are unable to capture. EPA estimated that the average reduction in soil loss from the model sites implementing BMPs would be 89.6 tons per site. (Calculations in Exhibit 4-24)

To determine the reduction in soil loss using the estimated 80% effectiveness rate, EPA multiplied the weighted average soil loss per start (89.6 tons) by 80%. This resulted in an estimated reduction in soil loss of 71.7 tons per site. Multiplying this reduction by the 110,223 construction starts expected to implement erosion and sediment controls for the year 1998, results in an estimated 7.9 million ton reduction in soil loss annually.

Exhibit 4–25. National Reduction Estimates for Municipalities and Construction Starts (tons/year)

Phase II Element	20% Reduction	80% Reduction
Municipal TSS Loading	639,115	4,062,815
Soil loss from Construction Sites	1,975,196	7,900,785

Summary

EPA has not presented the total cost of prevention of sediments leaving the site per ton of the sediment. ES.11 (in executive summary) describes only the costs effectiveness related to the Municipal TSS loading reduction. It seems that by a simple

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calculation from the two former exhibits (4-24 and 4-25) that the total cost assuming 80% reduction in the sediments would be between $69 - $86 per ton of sediment.

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BUILDING VALUATION DATA

The International Code Council® is pleased to provide the following Building Valuation Data (BVD) for its members. As indicated in the May 2003 issue of the *Building Safety Journal*™, ICC will now publish one data sheet in an effort to move toward complete consolidation and provide the most efficient set of information for jurisdictions to use. ICC strongly recommends that all jurisdictions and other interested parties actively evaluate and assess the impact of the new BVD table before utilizing it in their current code enforcement activities.

The BVD table provides two main functions. In addition to providing the "average" construction costs per square foot, the data can be used in determining permit fees for a jurisdiction as well as calculating the anticipated plan review fees charged by the ICC plan review service. Permit fee schedules are addressed in Section 108.2 of the *2003 International Building Code*® (IBC®) and Section 108.3 addresses building permit valuations. The permit fees can be established by using the BVD table and a Permit Fee Multiplier, which is based on the total construction value within the jurisdiction for the past year. The Square Foot Construction Cost table presents factors that reflect relative value of one construction classification/occupancy group to another so that more expensive construction is assessed higher permit fees than less expensive construction.

The resulting BVD table was compiled by ICC using the Marshall Valuation Service, as published by the Marshall and Swift Publication Company, Los Angeles, California. ICC has developed these data to aid jurisdictions in determining permit fees. It is important to note that while this BVD table does determine an estimated value of a building (i.e., gross area x square foot construction cost), the data are only intended to be used for determining permit fees for a jurisdiction. This data table is not intended to be used as an estimating guide because the data only reflect average costs and are not representative of specific construction.

The degree of precision is sufficient for the intended purpose, which is to establish permit fees so as to fund code compliance activities. The BVD table provides jurisdictions with a simplified way for determining the estimated value of a building that does not rely on the permit applicant to determine the cost of construction. Therefore, the bidding process for a particular job and other associated factors do not affect the value of a building for determining the permit fee. Whether a specific project is bid at a cost above or below the computed value of construction does not affect the permit fee because the cost of related code enforcement activities is not directly affected by the bid process and results.

BUILDING VALUATION

The building valuation data in Table 1 represent average valuations for most buildings. In conjunction with IBC Section 108.3, these data are offered as an aid for the building official for determining if the permit valuation is underestimated. Again it should be noted when using these data that these are "average" costs based on typical construction methods for each occupancy group and type of construction. The average costs include structural, electrical, plumbing, mechanical, interior finish, normal site preparation, architectural and design fees, overhead, and profit. The data represent a national average and must be modified using the appropriate regional cost modifier from Table 2.

Permit Fee Multiplier

Determine the Permit Fee Multiplier:

1. Based on historical records, determine the total annual construction value which has occurred within the jurisdiction in the previous year.
2. Determine the percentage (%) of the building department budget expected to be provided by building permit revenue.

$$\text{Permit Fee Multiplier} = \frac{\text{Bldg. Dept. Budget} \times (\%)}{\text{Total Annual Construction Value}}$$

Example

The building department operates on a $300,000 budget, and it expects to cover 75 percent of that with building permit fees. The total annual construction value which occurred within the jurisdiction in the previous year was $30,000,000.

$$\text{Permit Fee Multiplier} = \frac{\$300{,}000 \times 75\%}{\$30{,}000{,}000} = 0.0075$$

Permit Fee

The permit fee is determined using the building gross area, the Square Foot Construction Cost, the Regional Cost Modifier and the Permit Fee Multiplier.

$$\text{Permit Fee} = \text{Gross Area} \times \text{Square Foot Construction Cost} \times \text{Regional Cost Modifier} \times \text{Permit Fee Multiplier}$$

Example

Type of Construction: IIB

Group: B

Height: 2 stories

Area: 1st story = 8,000 sq. ft., 2nd story = 8,000 sq. ft.

Regional Cost Modifier (New York) = 1.03

Permit Fee Multiplier = 0.0075

1. Gross area: Business = 2 stories × 8,000 sq. ft. = 16,000 sq. ft.
2. Square Foot Construction Cost (see Table 1): B/IIB = $106.56/ft²
3. Permit Fee: Business = 16,000 ft² × $106.56/ft² × 1.03 × 0.0075 = $13,171

Important Points

- Tables 1 and 2 do not, in most cases, apply to additions, alterations or repairs to existing buildings. Because the scope of alterations or repairs to an existing building can vary so greatly, the Square Foot Construction Cost does not reflect accurate values for that purpose. However, the Square Foot Construction Cost can be used to determine the cost of an addition that is basically a stand-alone building which happens to be attached to an existing building. In the case of such additions, the only alterations to the existing building would involve the attachment of the addition to the existing building and the openings between the addition and the existing building.
- For purposes of establishing the Permit Fee Multiplier, the estimated total construction value for a given time period (1 year) is the sum of each building's value (gross area × Square Foot Construction Cost × Regional Cost Modifier) for that time period (e.g., 1 year).
- The Square Foot Construction Cost takes into account everything from site and foundation work to the roof structure and coverings, but does not include the price of the land on which the building is constructed. The price of the land does not affect the cost of related code-enforcement activities.

ICC PLAN REVIEW FEE SCHEDULE

The plan review fee is based on the estimated construction value calculated in accordance with the Square Foot Construction Costs in Table 1 (gross area × Square Foot Construction Cost). The Regional Cost Modifiers in Table 2 are not used when computing the estimated construction value for the purpose of determining plan review fees. For buildings with an estimated construction value up to $3,000,000, the building plan review fee is 0.0013 of the estimated value ($250 minimum). For buildings with an estimated construction value over $3,000,000 up to $6,000,000, the fee is $3,900 plus 0.0005 of the estimated value over $3,000,000. For buildings over $6,000,000, the fee is $5,400 plus 0.0004 of the valuation over $6,000,000.

BUILDING VALUATION DATA *(continued)*

Special consideration may be given in computing plan review fees for buildings such as large warehouses or indoor recreational facilities because of their plan review simplicity. Such considerations may also be given to buildings with repetitive floor plans such as high-rise buildings.

Structural reviews in areas of high seismic or wind risk will have an additional surcharge. Please contact your local ICC district office for more details.

The plan review fee for mechanical, plumbing and electrical reviews is computed at 25 percent of the building plan review fee for each discipline ($250 minimum).

The plan review fee for accessibility and energy reviews is also computed at 25 percent of the building plan review fee for each discipline ($250 minimum).

The sprinkler review fee is based on the number of sprinkler heads: 1–100, $275; 101–200, $325; 201–300, $350; 301–400, $375; 401–500, $425; over 500, $500 plus $0.33 per sprinkler over 500. For hydraulically designed systems, multiply the fee by 2.

Sample Plan Review Calculation

Type of Construction: IIIB — Group : B
Height: 3 stories, 35 feet — Area/Floor: 15,000 sq. ft.

Solution:

1. Gross square footage: 3 stories × 15,000 square feet = 45,000 sq. ft.
2. Compute estimated construction value:
   - Square Foot Construction Costs = $94.65/sq. ft.
   - Estimated Construction Value : 45,000 sq. ft. × $94.65/ft² = $4,259,250
3. Compute Plan Review fee:
   - Building: $3,000,000 × 0.0013 = $3,900
     $4,259,250 - $3,000,000 = $1,259,250
     $1,259,250 × 0.0005 = $630
   - Total Building Review Fee = $4,530
   - Mechanical, Plumbing, Electrical: (0.25)($4,530) = $1,132 each
   - Accessibility and Energy: (0.25)($4,530) = $1,132 each

Questions concerning the service should be directed to Christopher R. Reeves, P.E., Manager, Plan Review Services, (708) 799-2300 x309.

Table 1. Square Foot Construction Costs[a, b, c]

Group	(2003 International Building Code)	Type of Construction								
		IA	IB	IIA	IIB	IIIA	IIIB	IV	VA	VB
A-1	Assembly, theaters, with stage	160.69	153.29	149.76	143.55	133.59	132.90	138.98	123.75	119.25
	Assembly, theaters, without stage	148.41	141.02	137.48	131.28	121.31	120.63	126.71	111.47	106.98
A-2	Assembly, nightclubs	118.34	115.03	112.14	107.94	100.98	99.75	104.00	91.98	88.94
A-2	Assembly, restaurants, bars, banquet halls	117.34	114.03	110.14	106.94	98.98	98.75	103.00	89.98	87.94
A-3	Assembly, churches	149.66	142.27	138.73	132.52	122.51	121.82	127.96	112.67	108.17
A-3	Assembly, general, community halls, libraries, museums	119.71	111.78	107.24	102.03	91.08	91.39	97.46	81.24	77.74
A-4	Assembly, arenas	117.34	114.03	110.14	106.94	98.98	98.75	103.00	89.98	87.94
B	Business	119.85	115.54	111.79	106.56	95.15	94.65	102.31	84.79	81.61
E	Educational	128.37	124.05	120.50	115.17	106.24	103.73	111.36	94.92	91.38
F-1	Factory and industrial, moderate hazard	74.13	70.68	66.42	64.36	55.62	56.61	61.75	47.42	45.06
F-2	Factory and industrial, low hazard	73.13	69.68	66.42	63.36	55.62	55.61	60.75	47.42	44.06
H-1	High Hazard, explosives	69.75	66.29	63.04	59.97	52.43	52.42	57.36	44.23	N.P.
H234	High Hazard	69.75	66.29	63.04	59.97	52.43	52.42	57.36	44.23	40.88
H-5	HPM	119.85	115.54	111.79	106.56	95.15	94.65	102.31	84.79	81.61
I-1	Institutional, supervised environment	119.19	115.10	112.01	107.47	98.61	98.56	104.22	90.64	87.06
I-2	Institutional, incapacitated	200.36	196.04	192.30	187.07	175.32	N.P.	182.81	164.96	N.P.
I-3	Institutional, restrained	137.99	133.67	129.93	124.70	114.47	112.98	120.44	104.12	98.94
I-4	Institutional, day care facilities	119.19	115.10	112.01	107.47	98.61	98.56	104.22	90.64	87.06
M	Mercantile	88.15	84.83	80.95	77.74	70.26	70.02	73.81	61.26	59.22
R-1	Residential, hotels	120.33	116.24	113.15	108.61	99.80	99.75	105.41	91.83	88.25
R-2	Residential, multiple family	100.33	96.24	93.15	88.61	79.95	79.90	85.56	71.98	68.40
R-3	Residential, one- and two-family	96.19	93.52	91.22	88.71	84.51	84.30	87.22	80.46	74.68
R-4	Residential, care/assisted living facilities	119.19	115.10	112.01	107.47	98.61	98.56	104.22	90.64	87.06
S-1	Storage, moderate hazard	68.75	65.29	61.04	58.97	50.43	51.42	56.36	42.23	39.88
S-2	Storage, low hazard	67.75	64.29	61.04	57.97	50.43	50.42	55.36	42.23	38.88
U	Utility, miscellaneous	52.28	49.43	46.49	44.17	38.31	38.31	41.69	31.50	29.99

a. Private Garages use Utility, miscellaneous
b. Unfinished basements (all use group) = $15.00 per sq. ft.
c. N.P. = not permitted

Table 2. Regional Cost Modifiers

State	Cost Modifier	State	Cost Modifier	State	Cost Modifier	State	Cost Modifier	State	Cost Modifier
Alabama	0.86	Hawaii	1.41	Massachusetts	1.11	New Mexico	0.90	South Dakota	0.94
Alaska	1.39	Idaho	0.97	Michigan	1.01	New York	1.03	Tennessee	0.88
Arizona	0.97	Illinois	1.05	Minnesota	1.06	North Carolina	0.87	Texas	0.85
Arkansas	0.84	Indiana	0.99	Mississippi	0.84	North Dakota	0.97	Utah	0.93
California	1.12	Iowa	1.01	Missouri	0.95	Ohio	0.99	Vermont	1.01
Colorado	0.99	Kansas	0.92	Montana	0.94	Oklahoma	0.86	Virginia	0.89
Connecticut	1.10	Kentucky	0.95	Nebraska	0.94	Oregon	1.06	Washington	1.09
Delaware	1.07	Louisiana	0.87	Nevada	1.05	Pennsylvania	1.01	West Virginia	1.02
Dist. of Columbia	1.06	Maine	0.98	New Hampshire	0.98	Rhode Island	1.10	Wisconsin	1.05
Florida	0.91	Maryland	0.97	New Jersey	1.13	South Carolina	0.85	Wyoming	0.96
Georgia	0.88								

Water Rates and Charges

	Effective 1/1/2005	Effective 1/1/2006	Effective 1/1/2007
Tier 1 Supply Rate (dollars per acre-foot)	$73	$73	$73
Tier 2 Supply Rate (dollars per acre-foot)	$154	$169	$169
System Access Rate (dollars per acre-foot)	$152	$152	$143
Water Stewardship Rate (dollars per acre-foot)	$25	$25	$25
System Power Rate (dollars per acre-foot)	$81	$81	$90
Full Service Untreated Volumetric Cost ($/AF)			
Tier 1	$331	$331	$331
Tier 2	$412	$427	$427
Replenishment Water Rate: untreated (dollars per acre-foot)	$238	$238	$238
Interim Agricultural Water Program: untreated (dollars per acre-foot)	$241	$241	$241
Treatment Surcharge (dollars per acre-foot)	$112	$122	$147
Full Service Treated Volumetric Cost ($/AF)			
Tier 1	$443	$453	$478
Tier 2	$524	$549	$574
Treated Replenishment Water Rate (treated dollars per acre-foot)	$325	$335	$360
Treated Interim Agricultural Water Program (dollars per acre-foot	$329	$339	$364
Readiness-to-Serve Charge (millions of dollars)	$80	$80	$80
Capacity Charge (dollars per cubic foot second)	$6,800	$6,800	$6,800

Definitions

Tier 1 Supply Rate - recovers the of cost of maintaining a reliable amount of supply.

Tier 2 Supply Rate - set at Metropolitan's cost of developing additional supply to encourage efficient use of local resources.

System Access Rate – recovers a portion of the costs associated with the delivery of supplies.

System Power Rate – recovers Metropolitan's power costs for pumping supplies to Southern California.

Water Stewardship Rate – recovers the cost of Metropolitan's financial commitment to conservation, water recycling, groundwater clean-up and other local resource management programs.

Replenishment Water Rate – a discounted rate for surplus system supplies available for the purpose of replenishing local storage.

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Treated Replenishment Water Rate – a discounted rate for surplus system supplies available for the purpose of replenishing local storage.

Interim Agricultural Water Rate – discounted rate for surplus system supplies available for the purpose of growing agricultural, horticultural, or floricultural products.

Treated Interim Agricultural Water Program Rate – discounted rate for surplus system supplies available for the purpose of growing agricultural, horticultural, or floricultural products.

Treatment Surcharge – recovers the costs of treating imported water.

Readiness-to-Serve Charge - a fixed charge that recovers the cost of the portion of system capacity that is on standby to provide emergency service and operational flexibility.

Capacity Charge – the capacity charge recovers the cost of providing peak capacity within the distribution system.

Press Releases

Jan. 11, 2007

WATER TO BE LIMITED IN SOUTH VENTURA COUNTY WHILE REGIONAL TREATMENT PLANT, LARGE PIPELINE ARE SHUT DOWN, UPGRADED
Consumers asked to voluntarily reduce water use

Residents and businesses in south Ventura County are being called to voluntarily reduce their water use beginning Sunday, Jan. 14, while a regional water treatment plant is upgraded and a large-diameter pipeline is repaired during a 14-day shutdown.

The Metropolitan Water District of Southern California joined the Calleguas Municipal Water District in making the precautionary water-saving request as Metropolitan prepares for the planned shutdown of its Joseph Jensen Water Treatment Plant and Foothill Feeder pipeline. The outage is scheduled to last until Jan. 27.

The Jensen plant in Granada Hills—one of five such treatment facilities within Metropolitan's distributions system—is a significant source of drinking water for Ventura and Los Angeles counties. The 13-mile Foothill Feeder stretches from Castaic Lake to the Jensen plant, delivering state project supplies imported from Northern California through the California Aqueduct.

Although most local agencies affected by the shutdowns will have groundwater, reservoir supplies and other sources to meet retail demands during the outage, some pockets will need consumers to conserve water to stretch supplies, said Debra C. Man, Metropolitan's chief operating officer.

"As a precaution, we're asking consumers in the region to voluntarily conserve water whenever and wherever possible over the 14 days," Man said.

Consumers—particularly in the cities of Camarillo, Moorpark, Oxnard, Simi Valley, Thousand Oaks and Port Hueneme and communities of Camarillo Heights, Fairview, Las Posas Valley, Oak Park, Santa Rosa Valley, Lake Sherwood, Point Mugu, and Somis — are asked to contact their local water supplier to determine water-use restrictions for their area.

While Metropolitan will upgrade and test the Jensen plant's back-up emergency power generation systems during the shutdown, Foothill Feeder repairs are the primary reason for the outage, Man said. During the shutdown, Metropolitan plans to replace and repair sections of prestressed concrete pipe at three locations along the 21-foot-diameter pipeline.

"Maintaining and improving our ability to store, process and deliver drinking water throughout our Southern California service area requires periodic curtailments in deliveries while work is being done," Man said.

Metropolitan routinely schedules shutdowns of its facilities in winter months, when temperatures usually are cooler and demands are lower, to complete inspections and perform maintenance and upgrades with the least impact on consumers.

Don Kendall, Calleguas general manager, said voluntary water conservation by consumers, combined with activation of system interconnections between water agencies, will offer safeguards that residents and businesses have adequate water during the shutdown.

"We, however, stand prepared to intensify the conservation request in the unanticipated event that locally stored supplies dwindle during the outage," Kendall cautioned. "Residents who want to know more about how the shutdown will affect them should contact their local water provider directly."

Kendall added that the quality of tap water may be impacted to varying degrees within the Calleguas service area because the reduction in imported water deliveries may require increased use of groundwater within the region.

"As more local groundwater is pumped, some water users may notice a change in the aesthetics of their tap water," Kendall said.

The Metropolitan Water District of Southern California is a cooperative of 26 cities and water agencies serving 18 million people in six counties. The district imports water from the Colorado River and Northern California to supplement local supplies, and helps its members to develop increased water conservation, recycling, storage, and other resource-management programs.

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Rancho Cucamonga, CA

Rancho Cucamonga, CA News Forum Wire Classifieds

Water Quest Shifts Course

By Gary Polakovic
Los Angeles Times
June 10, 2006

A powerful thirst is building in Southern California as forecasters predict the addition of about 2 million new households in the region over the next 20 years.

In the past, finding water for all those extra showers, toilets and lawn sprinklers would have been easy: Look beyond a mountain range, find a wild river and divert it to Los Angeles.

But those days are over. The rivers are tapped, and there's more competition for their resources. So where will the water come from?

Part of the answer can be found at Loyola Marymount University, where a new cleaning process slashed the amount of water needed to flush giant cooling towers that regulate the campus' heating and air-conditioning system, saving 1.4 million gallons a year.

The university also switched to front-loading washing machines, turned to treated wastewater for landscaping and installed motion-sensing faucets and low-flow urinals that require one-fourth less water. 'We have more students and faculty, water rates are up, but our utility bills are down,' said Gerald Robinson, energy manager for the college near Marina del Rey. 'So we're actively pursuing more conservation measures.' Such steps may seem like drops in the bucket, but their widespread use add up to big savings. Water customers across the region - including vineyards, housing subdivisions, parks, restaurants and farms - are in the midst of an ambitious push to find more efficient ways to use the state's most precious natural resource.

Indeed, Southern California today gets half of its water from imported sources, compared with two-thirds a decade ago. Per capita water use in the region was 205 gallons a day 10 years ago; today it's about 175 gallons. Doing more with less has become the cornerstone of water management policy for one of the biggest and driest megalopolises on the continent. Unlike previous droughts, the last one - which ran from 1999 to 2003 and required no rationing in Southern California - went largely unnoticed because of the success of such programs, officials said.

'We've come to realize over the last decade that we're not building new dams, new aqueducts and moving more rivers to Southern California,' said Jeffrey Kightlinger, general manager for the Metropolitan Water District, which provides 60% of the region's water. 'We're creating the equivalent of a new river by conservation, water storage and paying transfer fees' to move water around the state.

Over the next two decades, Southern California's population is expected to grow by 6 million - equivalent to two Chicago-size cities. Most of that growth will take place in the deserts and canyons of Los Angeles, Riverside and San Bernardino counties. Roughly 1 million acre-feet of water will be needed annually to serve the newcomers, according to the MWD. An acre-foot is about 326,000 gallons, enough to cover an acre 1 foot deep or supply two households for a year.

Drought-reduced flows in the Colorado River and efforts to restore ecosystems in Northern California, including Mono Lake in the Owens Valley, also mean less water for thirsty cities in the south. Water supply disputes were a chief reason legislators earlier this year were unable to put Gov. Arnold Schwarzenegger's $49-billion public works bond measure on the June ballot. Republican lawmakers opposed attempts by Democrats to strip provisions from the spending package to build new reservoirs in Northern California. Rather than pursue resources they don't have, officials increasingly are searching for ways to maximize use of the water they do have. 'The water for Southern California growth is going to have to come from conservation, recycling and cleanup of groundwater basins,' said Jonas Minton, project manager for the Planning and Conservation League, a statewide environmental coalition. 'This is a new paradigm.'

The result is that the region's thirst-quenching quest has moved well beyond now-ubiquitous low-flow showerheads. New technologies and practices, such as those at Loyola Marymount, are spreading across the region. In the Inland Empire, newly installed pipes and 'spreading basins' along the Whitewater River near Palm Springs and Rancho Cucamonga helped capture more runoff during the drenching winter of 2004-05. The basins collected more than 20,000 acre-feet of water.

A new subdivision of about 400 houses in the hill country east of Murrieta features 'California friendly' landscaping that includes drought-tolerant deer grass, California lilac and coffeeberry.

The landscaping is moistened by drip irrigation run on a computerized timer that receives satellite information to calculate evaporation rates using temperature, barometric pressure and wind data. Other builders in San Diego, Riverside and San Bernardino counties are starting to use similar landscaping. About half of residential water use occurs outdoors.

'It's easy, it's low maintenance, I don't ever see the sprinklers come on,' said David Fafard, 34, who just bought a house in French Valley. 'It's so cheap, I don't even think about the water bill.' Even contaminated water in aquifers is being reclaimed.

In Chino, water agencies installed pumps and filters six years ago to remove nitrates from a sprawling 240-square-mile subterranean pool of tainted water in one of the fastest-growing areas in the nation. So far, about 27,000 acre-feet has been restored, said Martha Davis of the Inland Empire Utilities Agency. Similar projects are underway in Orange County and the San Gabriel Valley. 'This is the future of

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Los Angeles Times on Topix.net
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Los Angeles Times on Topix.net
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Southern California,' Davis said, 'figuring out how to take care of local water assets and maximize use.' This is why water agencies are also targeting the state's growers, who make up the largest consumers. Eight of every 10 gallons used in California goes to growing crops, irrigating orchards and watering livestock. The Bureau of Reclamation recently funded a project in the Temecula area to show wine growers how to improve efficiency. Vineyards that use drip irrigation based on weather conditions have cut water use by nearly a third. The MWD pays farmers in the Palo Verde Valley near Blythe to fallow land during dry spells - gaining about 100,000 acre-feet of water for cities - and has reached similar agreements with rice farmers in the Sacramento Valley. In addition, the district spent $200 million to line small, leaky irrigation canals in the Imperial Valley, yielding 105,000 acre-feet. Lining the dirt-bottom Coachella Canal should be completed by 2008 to yield 96,000 acre-feet for use in San Diego.

'The current practice of diversifying water supplies and building reserves allows us the flexibility we need to withstand changes in demand and supply to maintain a high degree of reliability,' the MWD's Kightlinger said. 'Based on current projections, we plan to have enough water for the future.'

But the region still faces many challenges. It must also contend with nature's unpredictability, including the potential effect of earthquakes on water delivery, as well as climate change. The Colorado River is prone to wide fluctuations in flow. Indeed, the river doesn't convey enough water to meet the allotments for seven Western states and Mexico, which own its water rights. Measurements made before 1922, when the water was divvied up, recorded an average annual flow of 16.5 million acre-feet, but that proved to be an unusually high-flow period. The long-term average flow in the river is about 15 million acre-feet. During the last drought, flows fell to about 5.4 million acre-feet.

Officials are confident that they have enough water reserves and flexibility in the delivery system to cope with short-term droughts of five to six years. But they acknowledge that they are not prepared for long droughts. Glen MacDonald, a geography professor at UCLA, gives Southern California water agencies high marks for more efficient use of water, but he warns that a 'mega-drought' spanning 10 to 15 years would push water supplies to the breaking point. Such events have occurred three times over the last 400 years in the Southwest. Concerned about the potential for long-term drought, a split Huntington Beach City Council approved plans in March to build a $250-million desalination plant.

'We live in a desert,' said Councilwoman Cathy Green. 'We need all the sources of fresh water that we can develop.'

Other threats persist. Schwarzenegger has unsuccessfully sought federal disaster aid to shore up aging levees in the Bay Delta, where nearly two-thirds of the state's water flows. A major quake or storm could potentially collapse levees and imperil much of the state's water supply. And environmentalists warn that, in the long-term, global warming could mean less snow in the Sierra and the Rockies, resulting in less water during summer months. Conservationists praise steps to use water more wisely but fault water agencies as well as state and local governments for not pursuing more conservation measures.

The most recent California Water Plan produced by the state Department of Water Resources shows that between 1.2 million and 3 million acre-feet of water could be saved just in the big cities through aggressive conservation.

The Pacific Institute, an Oakland-based think tank, has identified numerous strategies to slash water use by 20% over the next 25 years. They include retrofitting 7 million homes with low-flow toilets, requiring labels identifying water-efficient appliances and hardware, and setting rate structures so that customers that use the most water pay the most. 'California is a water-rich state,' said Peter Gleick, president of the organization. 'The problem is not with the quantity of water we have, the problem we have is how we use it.'

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■ **Original Los Angeles Times article:** Water Quest Shifts Course

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CLE International

California Wetlands Conference
January 27-28

San Diego, California

STORMWATER TREAMENT OPTIONS

A discussion by John Robertus

Executive Officer
California Regional Water Quality Control Board, San Diego Region

STORMWATER TREATMENT OPTIONS

FUNDAMENTALS AND EVALUATION OF EMERGING STORMWATER TREATMENT TECHNOLOGIES

The California Regional Water Quality Control Board, San Diego Region has provided regulatory programs for storm water discharges since 1991. The programs include regulation of industrial and construction sites utilizing statewide general permits, and regulation of municipal separate storm sewer system (MS4) discharges using regional permits adopted for countywide copermittees. Three such permits are currently in place for portions of San Diego, Riverside and Orange Counties that are within the jurisdiction of the San Diego Regional Board. MS4 permits are adopted for a 5-year period and require the copermittees to implement a comprehensive management plan to monitor and control pollutants that enter or are discharged from their MS4. The goal of the storm water program is to protect beneficial uses of receiving waters by controlling pollutants that are discharged from MS4s. Each copermittee must carefully select, implement and evaluate the effectiveness of stormwater treatment technologies to comply with the MS4 permit.

Receiving water quality objectives are determined by the beneficial uses that are designated for the receiving waters. Pollutants that can adversely impact water quality must be identified and reduced using an iterative application of best management practices (BMP), which include treatment technologies. Each copermittee must develop and implement a strategy to attain compliance with their MS4 permit by addressing both ends of the MS4: Efforts to abate pollutants at the upper portion of the MS4 must be measured with the success of attaining water quality objectives in the receiving waters at the lower end of the MS4. The MS4 is the means by which the pollutants are collected, conveyed and discharged, however, compliance with the permit must ultimately be established by attainment of the water quality objectives and the sustained protection of all beneficial uses of the receiving waters.

The challenge for each copermittee is to find a cost effective way to reduce the pollutants before they can reach receiving waters. The assimilation of pollutants or the treatment of wastewater to remove pollutants is not a beneficial use of waters of the state. Therefore, all treatment for pollutant reduction must occur upstream of the point of discharge. In many situations, improvement of the assimilative capacity can be accomplished by restoration, rehabilitation or expansion of wetland functions in receiving waters, however, BMPs intended to meet permit requirements for pollutant removal or treatment within the receiving waters are not allowed. Therefore, the strategy to reduce pollutants must focus on the source, the collection, the conveyance or the diversion of pollutants in the MS4 waste stream.

Pollutant Source Reduction

It may be possible to eliminate pollutants that are discharged to an area subject to runoff conditions entirely by taking an action that stops the discharge. The best possible outcome for pollutant reduction is to abate the pollutants at the source. This will prevent the need for treatment of the runoff to remove the pollutant. Pollutant reduction BMP technology must be coordinated with education and monitoring to ensure that all persons that live, work and recreate within the area impacting each MS4 know how to abate their pollutant sources. This strategy requires much emphasis on human behavior to motivate people to modify their actions that would

otherwise cause or contribute to pollutant discharges. Activities such as car washing, landscaping maintenance, automobile usage, pet waste removal, swimming pool maintenance, using power washing equipment, trash and solid waste management, hazardous chemical and waste handling and even smoking cigarettes can all have significant impacts as sources of pollutants. Enforcing a BMP that prohibits such activities is difficult and many elected officials are reluctant to take such steps. The decision to implement a pollutant source reduction BMP must be weighed with the alternative of allowing the pollutant discharge to continue and possibly remove or treat it downstream. This may be acceptable for bacteria sources but not acceptable for toxic pesticide sources. If a pollutant is known to cause or contribute to impairment of the receiving waters and it is difficult to remove downstream, it may be the best option to prevent its discharge at the source. Many pollutant discharges are so ubiquitous and difficult to prevent that they cannot be effectively reduced at the source, however they can be kept from entering the MS4.

Pollutant Treatment or Removal Upstream of the MS4

For pollutants that cannot be eliminated prior to their discharge to an area subject to runoff conditions, the next option is to remove them from the surface of the runoff area using BMPs such as sweeping, vacuuming, washing or otherwise cleaning up the pollutants. Well-disciplined house keeping or aggressive cleaning prior to rain events can be a very effective means of removing pollutants that would otherwise enter the MS4 system. Significant improvements in vacuum type street sweeping equipment in recent years can facilitate very effective removal of particulate pollutants from paved areas. Many municipalities target specific areas such as parks, schools, beaches and creeks for regular cleanup by civic and volunteer groups. Cities can provide services for pet waste collection and removal, non-discharging pavement cleaning and improved litter control. One of the most effective strategies to prevent pollutants from entering a MS4 inlet structure is to eliminate all non-storm water flows that can transport the pollutants. This may be a viable option in the San Diego Region due to infrequent rains and the need to conserve water.

Pollutants that are destined to enter the MS4 can be intercepted at the point of entry by filtration or other means. Many pollutants migrate into the MS4 without a rain event by the urban dynamics of traffic, urban runoff, wind and intentional discharges of waste into the storm drain inlet. These discharges can be prevented by filter sacks or by use of filtration technology that separates pollutants from the flow of water. The pollutants can then be removed by cleaning the filter sack or by cleaning out the capture portion of the filtration device. One Orange County city installed filter sacks in most of their MS4 inlets in 2001 and discovered a great deal about the sources, characteristics and solutions to reduce many pollutants entering their MS4. They have since made significant progress in improving their receiving waters. A common technique today for most new development is to install a grassy swale, detention basin or pollution filtration device such as a filter cartridge in a vault, circulating separator device or a filter medium just upstream of the point of entry into the MS4. This approach is very effective to keep pollutants from entering the MS4 if they are well maintained and do not become overwhelmed during rainstorms. The San Diego Regional Board has great concern for the long-term effectiveness of these numerous new treatment devices and facilities and prefers that each be maintained by the copermittee rather than by a neighborhood organization. There is a distinct advantage to low impact development or the use of natural filtration features such as grassy swales because these methods may not require intensive maintenance.

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Pollutant Treatment or Removal Within the MS4

Some pollutants will enter the MS4 and present another opportunity for capture, removal or treatment. However, will likely be multiple pollutants in the waste stream at this point and the dynamics of the flow through a typical MS4 is not conducive to capture, removal or treatment of pollutants. Capture of pollutants can be accomplished with weir dams, basins, sumps, nets, booms or bar screens and these methods usually work best in low flow conditions. Removal can be effective within the MS4 if there are features designed to facilitate the periodic removal of trash, debris and sediment between major runoff events. Typically, in debris basins or other locations where flow velocities are minimized, it is also feasible to remove such waste on a periodic basis. Treatment for pollutant removal within the MS4 is very difficult under normal circumstances unless the MS4 is designed to for this purpose.

Wastewater treatment is best accomplished in rectilinear ponds vs. linear flowing channels. A pond configuration can better control the appropriate depth, retention time, temperature and flow-through rate to optimize treatment processes. Since the design of most MS4s are intended to move wastewater with high velocity though narrow conduits, the MS4 configuration will not typically offer suitable treatment locations unless such treatment "ponds" are added later for this purpose. Since MS4 design also utilizes subsurface flow conduits or surface channels lined with concrete, it is very difficult to stimulate or support natural aquatic processes within the MS4 that can effectively reduce pollutants. The choice of using treatment to remove pollutants from a typical San Diego Regional MS4 will likely require the design and construction of new treatment facilities since most existing storm drains in the San Diego Region were intend to flow rapidly to the ocean. The City of Santa Monica has built such a facility that can clean and recycle millions of gallons of runoff every day. If there is no option to remove or reduce pollutants with treatment within the MS4 the last option prior to discharge to the receiving waters is to divert the flow to a treatment facility.

Pollutant Treatment or Removal by Diversion From the MS4

Within the San Diego Region there are currently about 100 sites that are designed and constructed to divert MS4 waste waters with known high levels of bacteria pollution from the MS4 to the sanitary sewer system. In some locations the entire flow of a creek or stream is diverted into the sanitary sewer system or into the treated effluent flow from a sewage treatment pant to an ocean outfall. In at least 2 locations, the diverted creek is completely treated and returned to the creek bed free of pollution. During high flow events from rainfall, these diversion facilities are bypassed allowing the entire flow to enter receiving waters via the MS4 or creek.

The low-flow diversion strategy is utilized with great success in Southern California coastal MS4 locations that discharge to popular swimming beaches. The primary objective is to protect the beneficial use of body-contact water recreation at the beaches and in some inland streams. The diversion consists of either a complete diversion to the nearest sanitary sewer system or a diversion to an on-site treatment facility that can remove the pollutants in the flow and return the treated effluent to a streambed or MS4. In either case, there in not an additional permit requirement for the diversion or discharge to the streambed since the Regional Board has considered such a discharge to be a BMP required by the MS4 permit. There have been isolated occurrences of sewage spills due to overflows caused by excessive inflow from MS4 diversion structures, however most diversion sites have performed as expected with few problems.

There may be potential future use of area wide diversion for urban runoff to protect some receiving waters such as Areas of Special Biological Significance (ASBS) or drinking water sources such as inland reservoirs. Sweetwater Reservoir in the San Diego Region utilizes an "urban runoff diversion system" or URDS to prevent urban runoff pollutants from flowing into the reservoir. This system effectively diverts all the collected runoff to a point below the reservoir dam. The diversion of urban runoff may also be used to protect two ASBS sites in the San Diego Region. Failing iterative efforts to abate, remove, treat or divert the pollution in their MS4, the copermittee is destined to deal with the consequences of impacts to the receiving waters and possible enforcement actions, third party lawsuits or the imposition of a Total Maximum Daily Limit (TMDL) requirement.

Summary Comments

The ultimate successful treatment technology for pollutant reduction should be both affordable and effective to protect water quality and beneficial uses. It must be based on accurate information about the pollutants entering the MS4 and the water quality standards and beneficial uses. The ease in identifying and reducing a plentiful pollutant that has little impact in the receiving waters must be balanced with the urgency to reduce another that can cause far greater damage to the environment even in small quantities. In some locations pollutant reduction may be required by implementing a Total Maximum Daily Limit (TMDL). Reducing pollutants at their source by challenging human behavioral norms that cause them may be viewed as much more difficult than treating or removing the pollutants far downstream. The strategy that is used to abate a pollutant at the source can probably be phased out in time, but a strategy that treats the pollutants by removal from the wastewater flow is perpetual. Pollutant abatement is an iterative process that can be constantly adapted and improved through the use of well planned monitoring and analysis of the MS4 operations. Pollution treatment and removal infrastructure must be properly operated and maintained if it is to perform its function. Urban runoff bacteria pollutants can be diverted to the sanitary sewer system in some cases to protect swimming areas.

SARB_004462

Water Quality Regulatory Dynamics of Development

CLE International California Wetlands Conference

January 26-27, 2006

San Diego, California

A Discussion by John H. Robertus

Executive Officer

California Regional Water Quality Control Board
San Diego Region

Water Quality Regulatory Dynamics of Development

This paper represents my observations and experiences serving as the Executive Officer for the California Regional Water Quality Control Board, San Diego Region for the past 10 years. It is not intended to represent the opinions of the Board Members.

The San Diego Regional Water Quality Control Board (Regional Board) regulates various water quality impacting discharges and activities in eleven coastal watersheds in Orange, Riverside and San Diego Counties. In the past 80 years these watersheds have been subject to extensive urban and agricultural development so that today large portions of these watersheds are considered "built out" or fully developed. However, in the remaining undeveloped areas, increasing pressure for development is focused on any remaining sites that might be suitable for construction. The high value of coastal real estate fits the well known "location, location, location" reputation and it is this high value that drives developers to build on any site that can be obtained, even when there are significant environmental impacts and inadequate infrastructure to support the new development. For every development project the Regional Board engages in an environmental review process that is expected to adequately consider and mitigate water quality resources impacts.

The Regional Board provides regulatory oversight of development through NPDES permits, Waste Discharge Requirements, 401 Water Quality Certifications and enforcement orders. The Regional Board however, has relatively limited resources to invest in avoiding or preventing water quality problems that are caused by development. Most water quality regulatory resources are dedicated to controlling wastes that are the result of development. The Regional Board does not have land use authority to control development, but it can review the process and impose requirements to protect water quality and beneficial uses. The Regional Board must assume that by reviewing each project there can be sufficient regulatory action identified to mitigate immediate and long-term impacts to water quality caused by each project. As development in the watershed reaches a higher and higher percentage, this assumption becomes questionable unless the Board is able to keep pace with the dynamic of the development within the watershed. For example, it is estimated that less than 5-10% of the original coastal wetlands and streams remain. How should this reality be integrated into the limited Regional Board regulatory oversight concerning development? This paper will examine the project review process in the context of the overall development within the watershed and discuss the water quality regulatory implications.

The MICRO versus the MACRO development process

The micro development or project-by-project level of the development process takes place within the context of a project site and the immediate surroundings. Micro development considers the individual development project and takes place within a larger scale of development within a watershed or region. Ideally, each project that takes place over time should be carefully considered in the context of the watershed or regional stage of development. This task can be challenging because the tools to objectively analyze the near and long-term impacts from a proposed development project can be extremely complex and difficult. The resources to plan and move a new development project through the approval process are usually plentiful, but the resources to track the cumulative environmental impacts of multiple projects in the watershed over time are sparse.

With very limited resources, the Regional Board must identify and evaluate water quality impacts for each development project and determine appropriate mitigation and regulatory oversight that will ensure that adverse impacts are adequately addressed. The Regional Board must rely on CEQA reports, developers, environmental consultants and other regulatory agencies to obtain needed information to thoroughly evaluate water quality impacts. Frequently, various aspects of the project are undecided and become negotiable as considerations for water quality impact mitigation. Projects are usually on a tight timeline with funding, permitting and scheduling pressures. Once the Regional Board acts on the 401Water Quality Certification, it does very limited review or follow-up action. The Regional Board has many water quality concerns to address for each development project which include the following:

1. Water supply source and sanitary sewage disposal
2. Loss of or impacts to wetlands caused by construction
3. Construction storm water discharges
4. Post construction waste discharges in urban runoff
5. Post construction storm water runoff flow rate and duration

Each of these concerns is related to each specific project in a unique way that is determined by many factors including the topography, geology, size, design and location of the project site. These project criteria are then analyzed in comparison to the relative status of development in the watershed as a whole. The Regional Board must decide how the water quality impacts caused by each project can best be reduced and mitigated within existing conditions in the watershed. The conditions in the watershed continuously change over time as new projects are constructed, the Regional Board must keep pace with this larger scale dynamic of macro-development.

The macro-development level of consideration includes the watershed and regional scope of development. The task is to reasonably determine the relative status of the water quality impacts from previous development within the watershed so that each new project can be accurately evaluated and adequately mitigated given the existing water quality conditions in the watershed. The macro-development water quality status for a watershed includes many factors including the following:

1. Impacts from water polluting discharges from existing development.
2. Impacts from hydromodification to the original creeks, streams, rivers, lagoons and bays
3. The amount and location of watershed area that has been covered with impervious surfaces
4. Successful planning and development efforts to protect water quality resources in the watershed

Each of these considerations represents different impacts that combine to define the condition of the water quality resources within the watershed. The Regional Board must evaluate this overall condition in the watershed for every new development project. Our current water quality regulations are expected to define and measure the additional impacts from a new development project and describe and quantify the appropriate mitigation. That mitigation must then be achieved in a watershed that has diminishing water quality resources due to development. The Regional Board must rely on mitigation, monitoring, waste discharge requirements and it acts on the assumption that these requirements will actually protect the beneficial uses of the waters in the watershed. The resources of the Regional Board are not sufficient to continuously and adequately evaluate the water quality impacts of most projects nor can it properly track the success or failure of the regulatory actions imposed as a condition of project certification. The remainder of this paper will more closely examine this challenge.

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The Challenges of Regulating the Micro-Development Process

1. Water Supply and Sanitary Sewage Wastewater Disposal.

Regional Board evaluation of new development projects will need to consider the water supply source and sanitary sewage disposal methods to be used. Although the Regional Board does not oversee water connections and delivery, it does oversee the protection of the beneficial uses that involve use of surface or ground water at the new development site. In the San Diego region most water use is supplied with imported water, but in some cases, the direct use of local water is required and must be evaluated. It may also require that water rights be evaluated to supply water to a new development.

Disposal of sanitary wastewater disposal requirements for new development projects in the San Diego region is usually satisfied by incorporating the discharges into existing sewage systems if feasible. About 85% of all sanitary sewage wastewater generated in the San Diego region is discharged into the ocean. The remaining is discharged to inland surface waters or ground water. New developments that will use a dedicated septic system or local community sewage treatment system may raise significant concerns for impacts to local ground water. Wastewater discharges with salt from imported water supplies is an increasing problem in some inland areas that also use local ground water for some supply needs. Fortunately, other planning and land use agencies have well established oversight of public health concerns for water supply and septic waste disposal that augment the efforts of the Regional Board. Extensive public health regulations have existed for many years as well. The Regional Board normally also has extensive experience and dedicated resources to address this concern.

2. Loss of or impacts to wetlands caused by construction.

Cumulative impacts to water quality resources in the San Diego Region from the loss of wetlands are significant and the regulatory programs to address this concern are relatively new and limited. Development projects that impact wetlands may require a USACOE 404 Permit and subsequently a 401 Water Quality Certification. Additionally, California requires additional oversight of some wetlands not regulated by the USACOE. No project may cause a net loss of wetlands. These regulatory requirements can be significant challenges for developers who wish to develop sites for projects that will impact wetlands. Projects in the San Diego region are increasingly designed or re-designed specifically to avoid this problem. Where impacts do occur, the resulting mitigation can be costly and cause scheduling and coordination difficulties that may delay projects for a considerable time.

Recent efforts to evaluate the success at mitigation sites required by the Regional Board indicates that many sites do not successfully mitigate the impacts as intended. However, in all cases the development and commensurate impacts to the wetlands do occur. In most cases where mitigation for wetlands impacts caused by development is required by the Regional Board, there are mitigation implementation, monitoring and reporting requirements imposed on the developer, but these requirements are not sufficient to ensure that the mitigation is successful. To fully assess the cumulative water quality impacts from a proposed development project, the Regional Board must do a thorough review of the project CEQA documents and other reports and information. Considering the few remaining wetlands in the San Diego region, and given the current severe limitations for the Regional Board to thoroughly track the cumulative impacts from development to California's wetlands, the regulatory process intended to protect these wetlands is insufficient to ensure that water quality will be protected.

3. Discharges of waste and storm water during construction

The construction phase of development projects involves grading of the site and an increase in the threat to water quality from discharges of waste. Waste discharges from construction sites in California are regulated by a general construction storm water permit that is required for graded sites of one acre or more. The permit requires the site to have a Storm Water Pollution Prevention Plan or SWPPP that will control pollution discharges through best management practices or BMPs that utilize the best current technology. The pollutant wastes that typically come from construction sites include sediments, trash, debris, paint, adhesives, concrete products, oils and fuels, nutrients, pesticides and other chemicals. Pollutants can be discharged to surface or ground waters and can have short or long term impacts. The Regional Board assessment to determine how to properly regulate construction sites includes consideration of the size, location, soils and topography, existing drainage, duration of construction and, receiving waters and other off-site considerations. The proximity of the site to a sensitive water body or other water resources may dictate strict requirements whereas some sites void of water resources may cause only minimal concern for the Regional Board.

The task of evaluating a new development project to determine the BMPs needed to prevent waste discharges during construction must be done by the developer and usually consists of the SWPPP. On some occasions the Regional Board may impose additional waste discharge requirements to supplement the construction storm water permit. Recent BMP compliance rates at most sites in the San Diego region are much improved, however construction storm water permit violations at some of these sites have resulted in significant fines in the past 2 years. Continued enforcement can be anticipated if violations persist. The water quality regulatory oversight of construction sites is well established and increasingly effective. Although there are insufficient resources for the Regional Board to inspect every site, local municipal and county oversight programs are assisting in these efforts. The regulation of the construction phase of development concludes when the Notice of Termination is completed and occupancy of the new tenant occurs. This begins the post construction phase of development.

4. Post construction waste discharges in urban runoff

Once the occupancy phase of development begins, the Regional Board relies on the Municipal Separate Storm Sewer System or MS4 permit to regulate waste discharges in urban runoff. The typical MS4 will collect, convey and discharge urban runoff in dry and wet weather with great efficiency. This will often ensure that pollutant wastes that are within the urban landscape will be discharged to receiving waters. The typical MS4 serving most urban areas in the San Diego region does not have any means to treat or remove wastes. Increasingly, the MS4 is connected to the sanitary sewage system to divert some dry weather urban runoff wastes to sewage treatment plants for treatment. These diversions do not function in the high flow conditions during rain events. The historical assumption for most development projects has been to simply incorporate each new project into the existing MS4 design and focus on the adequacy of flow capacity to take the runoff away from the new development. Pollutants in the runoff that might be collected or retained in the MS4 system would be whisked away downstream with the next rainstorm. This assumption is no longer valid in the San Diego region.

Upon occupancy at the site, pollutant discharges from all new developments must be reduced to the maximum extent practicable before discharge to waters of the state or entering the MS4. The Regional Board has implemented standard urban storm water mitigation plans or SUSMPs to ensure this is accomplished. These requirements are expected to be included in the design phase

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of the project or the Regional Board may add them during project certification. Oversight of post construction waste discharges is increasingly subject to public scrutiny. The growing list of 303d impaired water bodies and the imposition of total maximum daily loads for certain pollutants is causing some development projects to include significant post construction design features to limit some pollutant discharges. The Regional Board believes that over time the requirement for SUSMPs for all significant new development and re-development sites will gradually reduce waste loads of urban pollutants and better control unnaturally high storm water runoff rates. At some sites, the concern about increased runoff flow rates during storm events is very significant.

5. Post construction storm water runoff flow rate and duration

Development projects normally include construction of new impervious surfaces. These surfaces will modify the runoff characteristics of the site and will cause a cumulative effect of increasing rainfall runoff amounts. The runoff duration and hydraulic energy can cause significant impacts to receiving waters within a watershed. In the past, projects in the San Diego region did not always adequately consider the impacts of large impervious areas included in development projects. Today, all significant development projects must include design features that will control the runoff flow amounts and duration to emulate natural runoff conditions from the site. In several San Diego region watersheds, inland development has dramatically altered the landscape and caused one-year storms to exhibit downstream flows events previously considered as 5 or 10-year storm flows. At many locations in the region, downstream development is at greater risk due to increased runoff flows caused by additional impervious surfaces created by new development upstream. This problem is further aggravated by the reengineering of downstream creeks and streams to make them part of a flood control system that relies on high velocity in a narrow channel. These modified streams and rivers have been stripped of their natural capability to manage high flows by spreading and infiltrating into wetlands. When flooding does occur, the usual reaction is to increase the carrying capacity by "re-engineering" the stream even more. It may be more effective to take actions to remove the encroachments and restore the natural stream width and depth and to reduce the causes of the increased flows at upstream locations. One long-term solution to this dilemma is to require low impact development. This could dramatically improve the ability of the Regional Board to regulate water quality aspects for development in the San Diego region. For now, the reliance on SUSMPS will have to suffice for most sites.

The Challenges of Regulating the Macro-Development Process

The water quality considerations for each development project must be evaluated in the context of the existing conditions in the watershed and the region. The following discussion will consider several significant water quality considerations as watersheds are developed over time.

1. The cumulative impacts from water polluting discharges from existing development.

The impacts from discharges of waste to the soil, water and air in a developed watershed can be extensive. The impacts can be caused by past or ongoing discharges and they can impair beneficial uses of ground and surface waters. These water quality impacts from previous development can in fact limit additional new development. The USEPA Brownfield program exists for this reason. Pollution of ground water by inadequate sewage disposal systems, fuel tank leaks, solid waste dumpsites and dumping of toxic wastes are a few examples that can limit the use of ground water as a water supply source. Sediments accumulated in lakes, streams and

bays can be laden with pesticides, metals and nutrients that can significantly impact future beneficial uses of these areas. The reuse of contaminated soils from on-site excavation may be restricted due to pollutant levels that may threaten water quality. Cleanup of some sites may take decades and prevent their use for development. The Regional Board review of proposed development must include a thorough investigation to ensure that any impacts to soils and ground water within the watershed are considered.

Waste discharges to surface waters can likewise impair beneficial uses that can support new development. Excessive sediment discharges over time can cause flooding and trash and debris can fill in and spoil once attractive rivers and streams. Air emissions can cause polluting metals and chemicals to accumulate in water and soils. In locations where these pollutant discharges have exceeded the assimilative capacity of surface waters, total daily waste loads have been or may be imposed on all dischargers including new developments. Aesthetic and habitat impacts to water quality resources can add a complexity to urban or industrial blight that makes it too costly and difficult to cleanup. Restoration of water resources heavily impacted by pollutants must compete with resources to protect those waters that are not yet impacted. As new development takes place the Regional Board may elect to mitigate new impacts by requiring restoration of sites previously impacted by pollutant discharges. Although invasive species of plants and animals are not considered a pollutant, they can have a significant impact on the beneficial uses of waters in the region. They can dramatically alter the natural riparian ecosystem and impact existing and future development. Pollutant discharges are but one measure of the water quality impacts from development. The modification of natural water bodies as a result of development is another critical concern.

2. The impacts of hydromodification to the original creeks, streams, rivers, lagoons and bays

Hydromodification pertains to manmade impacts to natural wetland features in a watershed. It includes bridges, dams, deepening, narrowing, straightening, filling, culverting and sometimes even putting a stream underground. In several San Diego regional watersheds the impacts are severe and cause damaging floods, erosion and significant loss of the benefits of natural water bodies. The development process within a watershed can be carefully planned and regulated with full regard for hydraulics to ensure that flooding is minimized, but without also considering the hydrology of the watershed, it can be challenging to add new development into a watershed without causing even more impacts from hydromodification.

Engineering practices of building bridges with less expensive shorter spans may result in higher risks that bridges and abutments may be damaged in high flow conditions. Dams can pose a threat of flooding in the event of failure and culverts can restrict flows, especially when obstructed with debris or sediments. Roadways and sewer lines are frequently built along rivers and streams to take advantage of the natural grade. These locations can flood or be inaccessible during times of high flow. The bays and lagoons in the San Diego region have been systematically modified to accommodate development. They have been intentionally filled in for construction of residential and commercial developments and they all have road, railroad and other infrastructure constructed within them to the extent that these water bodies retain only a fraction of their original natural water quality resource value. San Diego Bay has been filled in to provide shore-side facilities for heavy industry and commercialization. It has been repeatedly dredged to maintain navigation channels. We all enjoy the economic benefits of these modifications, but we also bear the burden of maintaining them as natural hydrological forces constantly try to reclaim natural conditions.

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Wherever hydromodification for development has impacted watersheds, the Regional Board must include this concern in the evaluation of water quality impacts from new development. Another significant form of hydromodification can occur in the tributary areas that drain to rivers, creeks and streams. It is in the form of man made impervious surfaces that are abundantly present in almost all existing and new development projects. These impervious surfaces can dramatically alter the watershed.

3. The amount and location of watershed area that has been covered with impervious surfaces

Impervious surface areas resulting from development can dramatically alter the hydraulics and hydrology of a watershed. Knowledge of the actual characteristics and location of these impervious areas offers a measure of the impacts to water quality within the watershed. As new development projects are planned and constructed, it is extremely important to evaluate the impacts from the existing impervious surfaces and ensure that new development does not add to problems of increased runoff and pollution transport. Any roads, parking lots, walkways, rooftops and even some landscaping treatments within a watershed must be considered when water quality impacts from new development are assessed. In some cases, a small percentage increase in impervious areas can result in a tenfold increase in hydraulic energy in receiving streams. Additionally, reductions in natural erosion caused by this same impervious surface can cause the stream to be more vulnerable to in-stream erosion due to loss of the natural bed load of sand and gravel. Impervious surfaces will also prevent natural recharge of rainwater. Thus, impervious surfaces have multiple impacts on the receiving streams.

During dry weather, impervious surfaces cause increased runoff of urban wastes that are present on impervious surfaces. These wastes can be mobilized by intentional and unintentional use of water for irrigation and washing. Many San Diego streams are ephemeral and are naturally dry during summer months, however, the flows actually increase due to urban runoff from landscape irrigation. This has altered the aquatic ecosystem in the streams and caused high levels of pollution, such as bacteria and nutrients to be transported to the lower watershed and beaches. In considering new development it would be prudent to limit the impervious areas created for each project site. Re-development projects present the opportunity to remove previously constructed impervious surfaces or replace them with pervious materials.

4. Do planning and land use decisions in the watershed protect water quality resources?

When assessing the status of the watershed level of development it is essential to be aware of the model or pattern of development that has been used. In some cases this will reveal an extensive array of previous development decisions specifically intended to protect and preserve water quality related resources. It is not uncommon for cites to historically set aside areas for parks and green space and some include wetland areas as well. In San Diego there have been some efforts to set aside areas for river parks, nature preserves, conservancy areas and protected species habitat areas. This practice prevents or discourages future use of these areas for development. These same areas can offer mitigation sites for development in other locations. If a planning and development model that places a high value on water quality resources has been or is currently in use, new development projects will likely be more easily evaluated for water quality impacts within the watershed. If the "highest and best use" of wetlands are considered to be the natural functions that they offer, then this model will work in concert with the Regional Board purpose. If there is a pattern of relegating a low value to water quality resources however, it will be more difficult for the Board to succeed in protecting water quality and beneficial uses.

Development that has occurred without a high regard for water quality resources will create conditions that make it difficult to accommodate increased pressures for more development. In this case the highest and best use of wetlands may be to serve as a parking lot or a concrete lined storm drain. The needs to put more people, traffic, industry or agriculture into a watershed that has already lost most of its natural resources base due to development may support arguments to not change the pattern and assumptions of placing low value to wetlands. If the highest and best use of water resources such as creeks and streams is for floodwater conveyance, then the natural resource functions and value may be permanently lost. The mission of the Regional Board is to protect and preserve water quality resources for present and future generations. The existing beneficial uses of waters in many San Diego area watersheds are based on water resources that have been significantly impacted by existing development. It is never too late to begin the process of restoring water quality resources as land use decisions for development projects are considered. In some jurisdictions where water quality considerations have been a low priority in the past, recent decisions have emerged that indicate a desire to seek restoration and protection of water quality resources. As the pressure to create new development continues, the Regional Board will increasingly encourage developers, cities and environmental consultants to develop low impact projects that support sustainable natural conditions in the waters of the region.

Conclusions and Recommendations

1. The San Diego regional has a critical need to develop and implement a regional information system that collects, stores and processes information about urban development impacts on water quality resources in the San Diego region watersheds. This will enable the Regional Board to more reliably and efficiently protect those resources.
2. The Regional Board should strive to expand and improve its internal capabilities to evaluate and mitigate watershed impacts from urban development, pollutant sources and runoff, watershed hydromodification, and land use policies and planning that are used in the region. This will improve the assessment, assignment and tracking of mitigation needed to ensure that new development projects do not reduce or impair the water quality resources in the region.
3. Jurisdictions with planning and land use decision authority within the San Diego region should be encouraged to adopt policies and practices that protect and restore water quality resources. This can prevent and reduce adverse impacts to water quality resources caused by development or redevelopment. This will assist the Regional Board in its efforts to protect water quality and beneficial uses for present and future generations.

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The Role of Municipal Operators In Controlling the Discharge of Pollutants in Storm Water Runoff from Industrial/Commercial Facilities

A Case for Inspection Activities in the Large and Medium Municipal Separate Storm Sewer System Permits

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INTRODUCTION

A question that has been frequently asked during the process to renew the Los Angeles NPDES Municipal Stormwater Permit was if the storm water regulations require municipalities to conduct inspections at industrial or commercial facilities. This requirement establishes municipalities' responsibility to verify the effective implementation of best management practices to control the contribution of pollutants to the municipal storm drain system from industrial or commercial sites.

A second issue raised was the extent of responsibility municipalities have to control the contribution of pollutants from industrial or commercial sites and what is the relationship with the responsibilities that the Regional Board has over the same type of facilities.

This document attempts to answer to those specific questions raised by the Permittees and other stakeholders. The author adds emphases in the text.

I. Federal Mandate

The Federal Water Pollution Control Act Amendments (FWPCA) of 1972 created the framework for addressing critical pollution problems in the Nation's waters. Section 101, "Congressional Declaration of Goals and Policy", concisely summarized the new act. Section 101(a) stated, "The objective of this Act is to restore and maintain the chemical, physical, and biological integrity of the Nation's waters." This way a strong emphasis was put on the ecological and environmental aspects of protecting water quality. Elaborating on that position, the same section set down two "national goals": (1) eliminating the discharge of pollutants into navigable waters by 1985, and (2) achieving an interim water quality level that would protect fish, shellfish, and wildlife while providing for recreation in and on the water wherever attainable. The 1972 Amendments focused their attention on point sources such as municipal discharges through publicly owned treatment works and direct industrial discharges. The Act also focused the efforts on two categories of pollutants: conventional (BOD, SS, and pH), and what was classified as toxic.

Much of the effort following the enactment of FWPCA was to establish the United States Environmental Protection Agency (U.S. EPA) and the framework of the National **Pollutant Discharge Elimination** System (NPDES) permit program. Many other efforts were initiated in areas of construction of treatment plants, basin planning, treatment technologies development, establishment of effluent standards for toxic pollutants and the creation of appropriate regulations to implement the intent of the Act.

Under the provisions of the Act, the U.S. EPA could delegate NPDES permitting authority to the States. California is a delegated State and has full authority to issue NPDES permits with U.S. EPA's concurrence.

Between 1972 and 1987, the law has been subject to mid-course corrections and a change of name to the Clean Water Act (CWA).

The 1987 amendments, known as the Water Quality Act (WQA) of 1987, were aimed at addressing a number of issues on which progress was deemed to have been unsatisfactory. These issues included toxics, nonpoint sources, storm water, coastal

pollution, and others. States were required to identify waters not meeting designated uses because of toxic pollutants even after the application of technology based controls and to develop strategies for controlling them.

New provisions to permit discharges of storm water from separate storm sewers were also added. Section 402 phases in storm water permits. Originally, the 1972 Act required U.S. EPA to issue a NPDES permit for all point sources of pollution. The Agency interpreted that requirement so that it could issue areawide permits for separate storm sewers, rather than each storm water outfall.

The first phase of the program, commonly referred to as “Phase I", was promulgated on November 16, 1990 (55 FR 47990, 40 CFR 122). Phase I requires NPDES permits for storm water discharge from a large number of priority sources including municipal separate storm sewer systems (MS4s) generally serving populations of 100,000 or more and several categories of industrial activity, including construction sites that disturb five or more acres of land.

The second phase of the storm water program, recently promulgated on December 8, 1999 (64 FR 68722) expands the existing program to include discharges of storm water from smaller municipalities in urbanized areas and from construction sites that disturb between one and five acres of land. The new rule allows certain sources to be excluded from the national program based on a demonstrable lack of impact on water quality. The rule also allows other sources not automatically regulated on a national basis to be designated for inclusion based on increased likelihood for localized adverse impact on water quality.

II. Water Quality Concerns

After FWPCA was adopted in 1972, the implementation of end-of-pipe control methods from traditional point sources started to show improvement in the quality of the effluent discharged from Publicly Owned Treatment Works (POTW) and industrial wastewater treatment plants. However, it also become evident that receiving waters still did not attain designated uses, and water quality standards were frequently exceeded. That focused the attention to the other major component contributing to beneficial use impairments of the receiving water quality: pollution from diffuse sources, such as runoff from urban areas, construction sites, agricultural areas, land disposal and resource extraction. Early on, the Association of State and Interstate Water Pollution Control Administrators (ASIWPCA), along with U.S. EPA, conducted a comprehensive study of diffuse pollution sources that resulted in the 1985 report, “America’s Clean Water – The States Nonpoint Source Assessment.” This report indicated that 38 States reported urban runoff as a major cause of beneficial use impairment. In addition, 21 States reported construction site runoff as a major cause of impairment.

To provide a better understanding of the nature of urban runoff from commercial and residential areas, from 1978 through 1983, U.S. EPA provided funding and guidance to the Nationwide Urban Runoff Program (NURP)[1]. The NURP included 28 projects across the Nation. One focus of the NURP was to characterize the water quality of discharges from separate storm sewers that drain residential, commercial, and light industrial (industrial parks) sites. The majority of samples collected in the study were analyzed for

eight conventional pollutants and three metals. Data collected under the NURP indicated that on an annual loading basis, suspended solids in discharges from separate storm sewers draining runoff from residential, commercial and light industrial areas are around an order of magnitude greater than solids in discharges from municipal secondary sewage treatment plants. In addition the study indicated that the annual loading of chemical oxygen demand (COD) are comparable in magnitude to effluent from secondary sewage treatment plants. When analyzing annual loadings associated with urban runoff, it is important to recognize that discharges of urban runoff are highly intermittent and that the short-term loadings associated with individual events will be high and may have shockloading effects on receiving water, such as low dissolved oxygen levels. NURP data also showed that fecal coliform counts in urban runoff are typically in the tens to hundreds of thousands per 100 ml of runoff during warm weather conditions, (although the study suggested that fecal coliform may not be the most appropriate indicator organism for identifying potential health risks in storm water runoff), with the median for all sites being around 21,000/100 ml. This is generally consistent with studies that found that fecal coliform mean values range from 1,600 coliform fecal units (cfu)/100 ml to 250,000 cfu/100 ml[2]. Makepeace, et al., summarized ranges of contaminants from storm water, including physical contaminants such as total solids (76--36,200 mg/L) and copper (up to 1.41 mg/L); organic chemicals; organic compounds, such as oil and grease (up to 110 mg/L); and microorganisms.

Although NURP did not evaluate oil and grease other studies have demonstrated that urban runoff is an extremely important source of oil pollution to receiving waters, with hydrocarbon levels in urban runoff typically being reported at a range of 2 to 15 mg/l. These hydrocarbons tend to accumulate in bottom sediments where they may persist for long periods of time and exert adverse impacts on benthic organisms.

A portion of the NURP study involved monitoring 120 priority pollutants in storm water discharges from lands used for residential, commercial and light industrial activities. Seventy-seven priority pollutants were detected in samples of storm water discharges, from residential, commercial and light industrial lands taken during the NURP study, including 14 inorganic and 63 organic pollutants. The NURP data also showed a significant number of these samples exceeded various U.S. EPA freshwater water quality criteria. The NURP study provides insight on what can be considered background levels of pollutants for urban runoff, as the study focused primarily on monitoring runoff from residential, commercial and light industrial areas. However, NURP concluded that the quality of urban runoff can be adversely impacted by several sources of pollutants that were not directly evaluated in the study and are generally not reflected in the NURP data, including illicit connections, construction site runoff, **industrial site runoff** and illegal dumping. Other studies showed that storm water from industrial facilities might contain toxics and conventional pollutants when material management practices allow exposure to storm water.

Since the NURP study many other studies and programmatic assessments confirmed the magnitude of the diffuse pollution problem. Data from the NURP study were analyzed further in the U.S. Geological Survey (USGS) Urban Storm Water Data Base for 22 Metropolitan Areas Throughout the United States survey[3]. The USGS report summarized additional monitoring data compiled during the mid-1980s, covering 717 storm events at 99 sites in 22 metropolitan areas and documented problems associated with metals and sediment concentrations in urban storm water runoff. More recent reports have confirmed the pollutant concentration data collected in the NURP study[4].

Other recent studies have not found significantly different pollutant concentrations in urban runoff when compared to the original NURP data[5].

Storm water runoff from lands modified by human activities can harm surface water resources and, in turn, cause or contribute to an exceedance of water quality standards by changing natural hydrologic patterns, accelerating stream flows, destroying aquatic habitat, and elevating pollutant concentrations and loadings. Such runoff may contain or mobilize high levels of contaminants, such as sediment, suspended solids, nutrients (phosphorous and nitrogen), heavy metals and other toxic pollutants, pathogens, toxins, oxygen-demanding substances (organic material), and floatables[6]. After a rain, storm water runoff carries these pollutants into nearby streams, rivers, lakes, estuaries, wetlands, and oceans. The highest concentrations of these contaminants often are contained in “first flush" discharges, which occur during the first major storm after an extended dry period[7]. Individually and combined, these pollutants impair water quality, threatening designated beneficial uses and causing habitat alteration or destruction. Uncontrolled storm water discharges from areas of urban development and construction activity negatively impact receiving waters by changing the physical, biological, and chemical composition of the water, resulting in an unhealthy environment for aquatic organisms, wildlife, and humans.

Urbanization alters the natural infiltration capability of the land and generates a host of pollutants that are associated with the activities of dense populations, thus causing an increase in storm water runoff volumes and pollutant loadings in storm water discharged to receiving waterbodies[8]. Urban development increases the amount of impervious surface in a watershed as farmland, forests, and meadowlands with natural infiltration characteristics are converted into buildings with rooftops, driveways, sidewalks, roads, and parking lots with virtually no ability to absorb storm water. Storm water and snow-melt runoff wash over these impervious areas, picking up pollutants along the way while gaining speed and volume because of their inability to disperse and filter into the ground. What results are storm water flows that are higher in volume, pollutants, and temperature than the flows in less impervious areas, which have more natural vegetation and soil to filter the runoff[9].

Studies reveal that the level of imperviousness in an area strongly correlates with the quality of the nearby receiving waters. For example, a study in the Puget Sound lowland ecoregion found that when the level of basin development exceeded 5 percent of the total impervious area, the biological integrity and physical habitat conditions that are necessary to support natural biological diversity and complexity declined precipitously[10]. Research conducted in numerous geographical areas, concentrating on various variables and employing widely different methods, has revealed a similar conclusion: stream degradation occurs at relatively low levels of imperviousness, such as 10 to 20 percent (even as low as 5 to 10 percent according to the findings of the Washington study referenced above)[11]. Furthermore, research has indicated that few, if any, urban streams can support diverse benthic communities at imperviousness levels of 25 percent or more. An area of medium density single family homes can be anywhere from 25 percent to nearly 60 percent impervious, depending on the design of the streets and parking[12].

In addition to impervious areas, urban development creates new pollution sources as population density increases, and brings with it proportionately higher levels of car emissions, car maintenance wastes, pet waste, litter, pesticides, and household

hazardous wastes, which may be washed into receiving waters by storm water or dumped directly into storm drains designed to discharge to receiving waters. More people in less space results in a greater concentration of pollutants that can be mobilized by, or disposed into, storm water discharges from municipal separate storm sewer systems. A modeling system developed for the Chesapeake Bay indicated that contamination of the Bay and its tributaries from runoff is comparable to, if not greater than, contamination from industrial and sewage sources[13].

In addition, the 1996 305(b) Report, provides a national assessment of water quality based on biennial reports submitted by the States as required under CWA section 305(b)[14]. In the CWA 305(b) reports, States, Tribes, and Territories assess their individual water quality control programs by examining the attainment or nonattainment of the designated uses assigned to their rivers, lakes, estuaries, wetlands, and ocean shores. A designated use is the legally applicable use specified in a water quality standard for a watershed, waterbody, or segment of a waterbody. The designated use is the desirable use that the water quality should support. Examples of designated uses include drinking water supply, primary contact recreation (swimming), and aquatic life support. Each CWA 305(b) report indicates the assessed fraction of a State's waters that are fully supporting, partially supporting, or not supporting designated beneficial uses. In their reports, States, Tribes, and Territories first identified and then assigned the sources of water quality impairment for each impaired waterbody using the following categories: industrial, municipal sewage, combined sewer overflows, urban runoff/storm sewers, agricultural, silvicultural, construction, resource extraction, land disposal, hydrologic modification, and habitat modification.

The 1996 Inventory, based on a compilation of 60 individual 305(b) reports submitted by States, Tribes, and Territories, assessed the following percentages of total waters nationwide: 19 percent of river and stream miles; 40 percent of lake, pond, and reservoir acres; 72 percent of estuary square miles; and 6 percent of ocean shoreline waters. The 1996 Inventory indicated that approximately 40 percent of the Nation's assessed rivers, lakes, and estuaries are impaired. Waterbodies deemed as “impaired" are either partially supporting designated uses or not supporting designated uses. The 1996 Inventory also found urban runoff/discharges from storm sewers to be a major source of water quality impairment nationwide. Urban runoff/storm sewers were found to be a source of pollution in 13 percent of impaired rivers; 21 percent of impaired lakes, ponds, and reservoirs; and 45 percent of impaired estuaries (second only to industrial discharges). Additionally, urban runoff was found to be the leading cause of ocean impairment for those ocean miles surveyed.

In addition, a recent USGS study of urban watersheds across the United States has revealed a link between urban development and contamination of local waterbodies. The study found the highest levels of organic contaminants, known as polycyclic aromatic hydrocarbons (PAHs) (products of combustion of wood, grass, and fossil fuels), in the reservoirs of urbanized watersheds[15].

In addition to the large-scale nationwide studies and assessments, a number of local and watershed-based studies from across the country have documented the detrimental effects of urban storm water runoff on water quality. A study of urban streams in Milwaukee County, Wisconsin found local streams to be highly degraded due primarily to urban runoff, while three studies in the Atlanta, Georgia region were characterized as being, “the first documentation in the Southeast of the strong negative relationship

between urbanization and stream quality that has been observed in other ecoregions"[16]. Several other studies, including those performed in Arizona (*Maricopa County*), California (*San Jose's Coyote Creek*), Massachusetts (*Green River*), Virginia (*Tuckahoe Creek*), and Washington (*Puget Sound lowland ecoregion*), all had the same finding: runoff from urban areas greatly impair stream ecology and the health of aquatic life; the more heavily developed the area, the more detrimental the effects[17]. Pitt and others also described the receiving water effects on aquatic organisms associated with urban runoff[18]. In Wisconsin runoff samples were collected from streets, parking lots, roofs, driveways, and lawns. Source areas were broken up into residential, commercial, and industrial. Geometric mean concentration data for residential areas included total solids of about 500-800 mg/L from streets and 600 mg/L from lawns. Fecal coliform data from residential areas ranged from 34,000 to 92,000 cfu/100 mL for streets and driveways. Contaminant concentration data from commercial and industrial source areas were lower for total solids and fecal coliform, but higher for total zinc[19,20]. A number of other studies have indicated that urban roadways often contain significant quantities of metal elements and solids[21].

Automotive service stations have been characterized as potential "hot spots" for hydrocarbon pollutants and heavy metals in urban storm water discharges[22]. In an urban area, **industrial and commercial activities** can also be considered hot spots as sources of pollutants[23]. Urban storm water also can contribute significant amounts of toxicants to receiving waters. Pitt et. al., found heavy metal concentrations in the majority of samples analyzed. Industrial or commercial areas were likely to be the most significant pollutant source areas[24].

Wet weather flows have been recognized as the primary sources of estuarine pollution in coastal communities. Urban storm water runoff, sanitary sewer overflows, and combined sewer overflows have become the largest causes of beach closings in the United States in the past years. Storm water discharges from urban areas not only pose a threat to the ecological environment, they also can substantially affect human health. A survey of coastal and Great Lakes communities reports that in 1998, more than 1,500 beach closings and advisories were associated with storm water runoff[25]. Other reports also document public health, shellfish bed, and habitat impacts from storm water runoff, including more than 823 beach closings/advisories issued in 1995 and more than 407 beach closing/advisories issued in 1996 due to urban runoff[26].

The studies and research performed in the Southern California area, including Los Angeles County, show the similar impacts of polluted urban runoff on the local receiving waters, with significant impacts on the health of the environment and local economy. The "Epidemiological Study of Possible Adverse Health Effects of Swimming in Santa Monica Bay"**,** concluded that there is a 57 percent higher rate of illness in swimmers who swim adjacent to storm drains than in swimmers who swim more than 400 yards away from storm drains[27]. This and other studies document a relationship between gastrointestinal illness in swimmers and water quality, the latter of which can be heavily compromised by polluted storm water discharges. Other impacts on the Santa Monica Bay from the discharge of polluted storm water runoff have been documented[28].

In addition, the situation analysis of the "Los Angeles County Five-Year Public Education Overview" concluded:

Even after a generation of fighting water pollution, studies show the danger of illness to people swimming in waters near urban storm drain outfalls. The urban runoff that drains into the County's storm channels first litters and contaminates neighborhood streets and walks. Litter, fertilizers, pesticides, automobile soot and oil drippings, pet waste, and deteriorating leaves and plant debris not only make our communities unattractive, but also are swept untreated down the storm drains into our waterways…In total, the impacts of stormwater/urban runoff pollution encompass:

- losses to the County's $2 billion a year tourism economy
- health risks associated with swimming in areas near storm drain outfalls
- loss of recreational resources
- dramatic cost increases for cleaning up contaminated sediments
- impaired function and vitality of our natural resources
- losses to Southern California's commercial and sportfishing industry
- contamination to marine life[29].

III. Responsibility of Municipal Operators of Large and Medium Municipal Separate Storm Sewer Systems

The water quality impacts of urban runoff are well documented and identified as a leading cause of receiving water beneficial uses impairments. Many States and Municipalities in cooperation with U.S. EPA moved aggressively to control the sources of pollution within the framework of the NPDES permitting system and through other non-point source programs.

A. Role of Municipal Operator

As early as the promulgation of the 1990 Phase I storm water regulations, U.S. EPA clearly defined the roles and identified the responsibilities of all parties involved in the permitting process. Early on, the agency envisioned a partnership, a cooperative approach between U.S. EPA, States and Municipalities, recognizing that only through a coordinated effort will the difficult and complex issues of diffuse pollution be addressed appropriately. In the preamble to the 1990 Phase I storm water regulations, the agency stated that the:

> …EPA still believes that municipal operators of large and medium municipal systems have an important role in **source identification** and the **development of pollutant controls for industries** that discharge storm water through municipal separate storm sewer systems is appropriate. Under the CWA, large and medium municipalities are responsible for reducing pollutants in discharges from municipal separate storm sewers to the maximum extent practicable. Because **storm water from industrial facilities may be a major contributor of pollutants** to municipal separate storm sewer systems, **municipalities are obligated to develop controls for storm water discharges associated with industrial activity through their system in their storm water management program**… EPA believes that the permitting of municipal storm sewer systems and the industrial discharges through them will act in a complimentary manner to

fully control the pollutants in those sewer systems. This will fully implement the intent of Congress to control industrial as well as large and medium municipal storm water discharges as expeditiously and effectively as possible.

U.S. EPA continued to clarify its intent for:

> "…[t]he permit application requirements for large and medium municipal separate storm sewer systems, discussed in more detail later in today's preamble, **address the responsibilities of the municipal operators of these systems to identify and control pollutants in storm water discharges associated with industrial activity**. Permit applications for large and medium municipal separate storm sewer systems are to identify the location of facilities which discharge storm water associated with industrial activity to the municipal system… In addition, municipal applicants will provide a description of a proposed management program to reduce, to the maximum extent practicable, pollutants from storm water discharges associated with industrial activity which discharge to the municipal system… Controls developed in management plans for municipal permits may take a variety of forms. Where necessary, municipal permittees can pursue local remedies to develop **measures to reduce pollutants or halt** storm water discharges with high level of pollutants through municipal storm sewer systems. Some local entities have already implemented ordinances or laws that are designated to reduce the discharge of pollutants to municipal separate storm sewers, while other municipalities have developed a variety of techniques to control pollutants in storm water."

U.S. EPA reconfirmed its position in regard to the role of municipal operators of large and medium MS4s when it issued, in 1993 (58 FR 61146), the notice for the proposed multi-sector stormwater general permit for discharges of storm water associated with industrial activity (multi-sector permit).

In the Fact Sheet for the proposed multi-sector permit, U.S. EPA reiterated its position regarding the complimentary permit approach envisioned to address storm water discharges associated with industrial activity:

> "A second permit issued to the operator of the large or medium municipal storm sewer, establishes the **responsibilities** of the municipal operators in controlling pollutants from storm water associated with industrial activity which discharge through their system… The municipal storm water management programs that will be incorporated into NPDES permits for discharges from MS4s will generally address (in addition to other possible requirements) the following three major components:
>
> - Reducing pollutants in storm water discharges from municipal landfills; hazardous waste treatment, storage and disposal facilities; facilities subject to the Emergency Planning and Community Right-to-Know Act (EPCRA), section 313; and other priority industrial facilities through municipal separate storm sewers.
> - Reducing pollutants in construction site runoff through municipal separate storm sewers.
> - Identifying and controlling non-storm water discharges to municipal separate storm sewers…

> Municipal programs to reduce pollutants in industrial site runoff and construction site runoff through MS4s **specifically will address municipal responsibilities in controlling pollutants from industrial facilities**."

Recently, in its Storm Water Phase II Compliance Assistance Guide (Guide)[30], U.S. EPA restated and further clarified its intention regarding the integration of NPDES programs for storm water discharges: "…[t]he Phase I permits for MS4s mostly cover larger cities, and require them to develop a storm water management program, **track and oversee industrial facilities** regulated under the NPDES storm water program, conduct some monitoring, and submit periodic reports."

Furthermore, when referring to integration of NPDES program for construction (which is one of the eleven industrial categories addressed by the storm water program) with NPDES program for MS4s, the Guide specifies:

- "These are two **separate** and **distinct** construction programs.
- A construction operator is subject to requirements under **BOTH** programs if it is located in an NPDES-regulated MS4's jurisdiction."

In addition, the No Exposure Certification Form for Exclusion from NPDES Storm Water Permitting[31], includes in the certification section the following statements:

> "I understand that I am obligated to submit a no exposure certification form once every five years to the NPDES permitting authority and, if requested, to the operator of the local municipal separate storm sewer system (MS4) into which the facility discharges (where applicable). I understand that **I must allow the NPDES permitting authority, or MS4 operator where the discharge is into the local MS4, to perform inspections** to confirm the condition of no exposure and to make such inspection reports publicly available upon request."

Once more, U.S. EPA clearly states its standpoint that NPDES permitting authority responsibilities are intertwined with those of the local agency.

It can be reasonably inferred from the regulatory record and actions that U.S. EPA clearly envisioned a dual coverage and a strong role and clear responsibilities for the municipal operator in controlling pollutants from industrial sites as distinct from the activities required by the NPDES permitting agency. However, activities required by both entities should be coordinated and integrated as much as possible to achieve to common goal of effectively controlling and reducing the discharge of pollutants into the storm water runoff.

B. Legal Authority

40 CFR §122.26(d)(2)(i) ***Adequate legal authority****.* A demonstration that the applicant can operate pursuant to legal authority established by statute, ordinance or series of contracts which authorizes or enables the applicant at a minimum to:
(A) Control through ordinance, permit, contract, order or similar means, the **contribution of pollutants to the municipal storm sewer by storm water discharges associated**

with industrial activity and the quality of storm water discharged from sites of industrial activity;
(B) Prohibit through ordinance, order or similar means, illicit discharges to the municipal separate storm sewer;
(C) Control through ordinance, order or similar means the discharge to a municipal separate storm sewer of spills, dumping or disposal of materials other than storm water;
(D) Control through interagency agreements among coapplicants the contribution of pollutants from one portion of the municipal system to another portion of the municipal system;
(E) Require compliance with conditions in ordinances, permits, contracts or orders; and
(F) **Carry out all inspection**, **surveillance** and monitoring procedures necessary to determine compliance and noncompliance with permit conditions **including** the prohibition on illicit discharges to the municipal separate storm sewer.

40 CFR §122.26(d)(2)(iv)(A)(*5*) A description of a program to monitor pollutants in runoff from operating or closed municipal landfills or other treatment, storage or disposal facilities for municipal waste, which shall identify priorities and procedures for **inspections** and establishing and implementing control measures for such discharges (this program can be coordinated with the program developed under paragraph (d)(2)(iv)(C) of this section);

40 CFR §122.26(d)(2)(iv)(C) A description of a program to monitor and control pollutants in storm water discharges to municipal systems from municipal landfills, hazardous waste treatment, disposal and recovery facilities, industrial facilities that are subject to section 313 of title III of the Superfund Amendments and Reauthorization Act of 1986 (SARA), **and industrial facilities** that the municipal permit applicant determines are contributing a substantial pollutant loading to the municipal storm sewer system. The program shall:
(*1*) **Identify priorities and procedures for inspections and establishing and implementing control measures for such discharges**;…

In its Guidance Manual[32] U.S. EPA explicitly states on what the municipalities must achieve: “The municipality, as a permittee, is responsible for compliance with its permit and must have the authority to implement the conditions in its permit. To comply with its permit, a municipality must have the authority to **hold dischargers accountable for their contributions** to separate storm sewers.”

The Guidance Manual provides more clarification in regard to the extent of facilities that must be addressed and the link that must be made with the potential sources of pollutants: “However, a municipality, to satisfy its permit conditions, **may need to impose additional requirements** on **discharges from permitted industrial facilities**, **as well as discharges from industrial facilities** and construction sites ***not* required to obtain permits**… [t]he Source Identification component requires the applicant to provide **an inventory of pollutant sources**, organized by watershed. This inventory **identifies and describes the products and services** of each industrial facility that may discharge storm water to the MS4. The Source identification component suggests applicants to use standard industrial classification codes (SIC) codes for this description. EPA strongly recommends this information be used to identify priority waste handling sites and industrial facilities. A similar technique could be developed for sites ***that do not meet*** the ***regulatory definition of "storm water discharge associated with industrial activity"*** (i.e. not included in the Source Identification and Discharge Characterization

components), but ***are identified as a high priority*** under the proposed management program." It can be concluded that the scheme envisioned by the regulations do not only address industrial sites covered under the definition of storm water discharge associated with industrial activity, but depending on the identified significant sources contributing pollutants to the storm water runoff, other types of industrial facilities, such as commercial, must be addressed in the municipal program to inspect facilities contributing pollutants to the municipal separate storm drain system.

Many existing permits issued by U.S. EPA or authorized States, nationwide, already include these kind of requirements and municipalities are actively implementing them.[33] Regional Boards in California also issued MS4 permits requiring a program for inspections at industrial or commercial facilities.[34] Municipalities used a large spectrum of methods and innovative ways to implement the inspection program, and many local jurisdictions have the adequate required legal authority or have adopted ordinances giving them the necessary legal authority. Even smaller cities, to be covered under Phase II, not required to obtain the legal authorities for inspections as yet, decided to pass ordinances giving them the necessary authority for the implementation of the storm water program, including the authority to inspect industrial or commercial facilities and adopt and impose BMPs.[35]

As early as 1993, U.S. EPA Region 9, clarified the role of municipalities in addressing industrial sources.[36] More recently the same position was restated.[37] Regional Board's position, starting with the 1990 MS4 Permit was that an inspection program was required in the municipal storm water permit and was supported by the legal analysis provided by the State Board's Office of Chief Counsel[38].

C. Source Identification

40 CFR §122.26(d)(2)(ii). Source Identification… *Provide an inventory, organized by watershed of the name and address, and a description (such as SIC Codes) which best reflects the principal products or services provided by each facility which may discharge, to the municipal separate storm sewer, storm water associated with industrial activity.*

A very careful consideration was given to the issue of the pollutant sources in storm water discharges through MS4s and the control of those pollutant sources. The Agency continued to discuss and describe its intent of the elements needed to be addressed by a municipality through the application process in regards to the sources that contribute pollutants to the municipal storm sewers. Under the source identification heading in the preamble to the 1990 Phase I storm water regulations, U.S. EPA stated that, "…**the identification of sources which contribute pollutants** to municipal separate storm sewers is a **critical step** in characterizing **the nature and extent of pollutants in discharges** and in **developing appropriate control measures**." The agency expands the scope of the source identification concept leaving it general instead of focusing on any particular area, such as industrial, commercial, residential, roadways, etc., but linking it to the existing water quality problems. It is clear that the intent of the agency was to draw the attention of applicants to addressing, in a flexible way, the real issues and focus their limited resources on controlling the most problematic sources:

> "…**source identification** can be useful for providing **an analysis of pollutant source contribution** and for **identifying the relationship between pollutant**

> **sources and receiving water quality problems**. In cases where end-of-pipe controls alone are not practicable, it is essential to identify the source of pollutants into the municipal storm sewer system to support **a targeted approach to control pollutant sources**."

The agency continues to comment and clarify the provisions under the application requirements of the regulations:

> "…Part 1 of the application will also include: […]**the location of industrial facilities, open dumps, landfills or RCRA hazardous waste facilities** which discharge storm water to the municipal storm sewer system;…Part 2 of the application will supplement the information reported in part 1 of the application so that,[…]municipal or public entities responsible for and obtaining an NPDES permit will be required to **identify the location of an open dump, sanitary landfill, municipal incinerator or hazardous waste treatment, storage, and disposal facility under RCRA which may discharge storm water to the system as well as all facilities which discharge storm water with industrial activity into a large or medium municipal separate storm sewer system**. Requiring **these source identification measures is supported by the legislative history of section 405 of the WQA**, which instructs that '[i]n writing **any permit for a municipal separate storm sewer, EPA or the State should pay particular attention to the nature and uses of the drainage area and the location of any industrial facility, open dump, landfill, or hazardous waste treatment, storage, or disposal facility which may contribute pollutants to the discharge**.'[39]"

In answering some of the comments regarding the value of source identification information, the agency responded:

> [..]the **source identification** information serves several purposes. It is the first step for **identifying potential sources of pollutants** from which more in depth analysis can be accomplished…The **source identification component** of the municipal application also requires that **municipal applicants identify the industrial activity within the drainage area associated with each major outfall**…[A]pplicants identify the types of industrial facilities operating within the municipality, the municipality is free to use Standard Industrial Classification (SIC) or other systems which identify the principal products or services of the facility.

D. Los Angeles MS4 Permittees Compliance Efforts

The Permittees covered under the Los Angeles MS4 permit addressed the element of source identification and prioritization through compliance with the requirements of the 1996 permit (Board Order No. 96-054). The Critical Source Selection and Monitoring Report (Critical Source Report), identified 30 categories of industrial and commercial activities that may impact the quality of the stormwater runoff discharged to the MS4[40]. The study also ranked the critical sources on the basis of potential impact and proposed a Critical Source/BMP Monitoring program at the five highest ranked facility types: (i)

wholesale trade (scrap, auto dismantling), (ii) *automotive repair/parking*, (iii) fabricated metal products, (iv) motor freight (including trucking), (v) chemical and allied products.

At the same time, the Permittees, under the coordination of the Los Angeles County Department of Public Works, compiled, in 1997, a facilities database for the MS4 program identifying approximately 58,000 facilities that could have been potentially addressed by the public education site visit program. Out of the total universe of 58,000 facilities identified by their SIC Code, 21,000 were food or food related establishments. The 36,000 remaining facilities were in industrial/commercial sectors. An updated review of the potential number of facilities within the LA MS4 area, identified in the 30 industrial/commercial sectors Critical Source Report (not including food establishments), revealed that the number of facilities can be as high as 26,300 sites as of 2001. The survey was performed with the help of the Los Angeles City Stormwater Management Division staff. A significant portion of the total number of facilities, up to 60%, may be located within the City of Los Angeles boundaries. The SIC Code system proved to be inadequate in identifying the correct type of activity performed on-site, and also a significant number of facilities may not have activities or materials exposed to stormwater, which will make the actual number of sites potentially addressed through the municipal stormwater program much smaller than predicted.

The results of the Critical Source/BMP Monitoring program confirmed that the five highest ranking activities indeed contribute significant quantities of pollutants and source control BMPs alone were not effective in reducing the amount of pollutants into the stormwater runoff. The majority of the sampling results were in excess of the Criteria for Priority Toxic Pollutants for the State of California.[41] However, since the implementation of the source control BMPs was voluntary, the study could not determine with certainty that the apparent failure was due to the inefficacy of the BMPs or the lack of proper implementation.[42]

Furthermore, the Research Report on Issues, Pollutants and Materials[43](Research Report) accomplishes a comprehensive analysis of sources of pollutants, generation and receiving water impacts. The Research Report puts in a concise form and creates the link between typical pollutant sources, pollutants found in the County's waterbodies, pollutant of concerns for each Watershed Management Area and pollutants of concerns detected through previous monitoring. The Research Report clearly identifies the targeted pollutants: (i) heavy metals, (ii) oil and grease/PAHs, (iii) sediments, (iv) oxygen demanding substances, (v) litter/trash/debris, (vi) nutrients, (vii) other toxic materials, such as pesticides.[43] The Research Report confirms once again that the urban environment in the Los Angeles area is similar to the other urban areas in the nation when it comes to stormwater runoff characterization and receiving water impacts. The Los Angeles area is probably unique due to the highly industrialized and vast area served by an interconnected storm sewer system unlike any other in the nation. But that makes it even more imperative that significant efforts must be allocated in order to control the discharge of pollutants in the urban runoff.

CONCLUSION

From the record and all the studies referenced in this report it is evident that an inspection program at industrial and commercial facilities is not only required under the storm water

regulations but it is an essential component to control the contribution of pollutants from industrial or commercial facilities into storm water discharges through the municipal storm drain system. This inspection program is separate and in addition to the program administered by the Regional Board, and the municipalities have a clear responsibility to perform them.

The dual coverage is intended in the regulations, in order to maximize the use of limited resources at the State and local level, and assure through active coordination that significant sources of pollutants are not overlooked or missed due to lack of legal authority.

The Permittees under the Los Angeles MS4 Permit have made great strides in preparing the ground work for next phase of implementation: they performed a comprehensive source identification study confirmed by the monitoring results, the Regional Board approved the minimum menu of BMPs presented by the Permittees and they already put facilities on notice and performed the educational part through the site visits effort.

The introduction of the inspection program in the new MS4 permit is not capricious or arbitrary but based on facts. It utilizes tools already developed by Permittees and follows a widespread precedent in MS4 permits nationwide and in California.

Selected References

Requirement	Reference
"Today's rule also requires the municipal storm sewer permittee to describe **a program to address industrial discharges** that are covered under the municipal storm sewer permit. Today's rule requires the municipal applicant to identify such discharges…, provide a description of a program to monitor pollutants in runoff from certain industrial facilities that discharge to the municipal storm sewer system, **identify priorities and procedures for inspections**, and **establish and implement control measures for such discharges**."	Final Rule (Federal Register, Vol. 55, p. 48056)
Part 2 application requirement: [The applicant must demonstrate that it can control through] Adequate Legal Authority which authorizes or enables at a minimum to: **Control** through **ordinance, permit, contract, order or similar means**, the **contribution of pollutants** to the municipal storm sewer by **storm water discharges associated with industrial activity** and the quality of **storm water discharged from sites of industrial activity**;	40 CFR 122.26(d)(2)(i)(A)
Carry out all inspection, **surveillance** and **monitoring** procedures necessary to **determine compliance and noncompliance** with **permit conditions *including*** the prohibition on illicit discharges to the municipal separate storm sewer.	40 CFR 122.26(d)(2)(i)(F)
In part 2 of the application, municipal applicants **must demonstrate** that **they now possess adequate legal authority** to: • **Control** construction site and **other industrial discharges** to the MS4;… • **Control potential sources of pollutants from discharges to or from** coapplicants' MS4s, or MS4s that are interconnected or shared with other entities;… • **Carry out inspection, surveillance, and monitoring** procedures.	Guidance Manual for the Preparation of Part 2 of the NPDES Permit Applications for Discharges from Municipal Separate Storm Sewer Systems (Guidance Manual) USEPA 1992 Pag. 3-1
"Control"[…] means not only to require disclosure of information, but **also** to **limit, discourage, or terminate** a storm water discharge to the MS4.	Guidance Manual pag. 3-1
However, a municipality, to satisfy its permit conditions, **may need to impose additional requirements** on **discharges from permitted industrial facilities**, **as well as discharges from industrial facilities** and construction sites ***not* required to obtain permits**.	Guidance Manual pag. 3-1
In their part 2 applications, municipalities must propose programs to **control** the contributions of pollutants from industrial facilities **and prohibit** illicit discharges. For **both** of these activities, municipalities **must have the legal authority** to **carry out inspection, surveillance, and monitoring** procedures necessary to **determine compliance**.	Guidance Manual pag. 3-3
In their part 2 applications, municipalities should provide documentation of **their authority to enter, sample, inspect, review, and copy records,** etc. as well as demonstrate their authority to require regular reports.	Guidance Manual pag. 3-3
A description of **a program** to **monitor and control pollutants** in storm water discharges to municipal systems from **municipal landfills, hazardous waste treatment, disposal and recovery facilities, industrial facilities that are subject to section 313 of title III of the**	40 CFR 122.26(d)(2)(iv)(C)

Requirement	Reference
Superfund Amendments and Reauthorization Act of 1986 (SARA), and ***industrial facilities that the municipal permit applicant determines are contributing a substantial pollutant loading*** to the municipal storm sewer system. The program **shall**: (1) **Identify priorities and procedures for inspections** and **establishing and implementing control measures** for such discharges;	
NPDES permits for MS4s will establish *responsibilities* for municipal system operators to control pollutants from industrial storm water discharged through their system.	Guidance Manual pag. 6-16
Proposed storm water management programs must address the reduction of pollutants in storm water discharges from **municipal landfills, hazardous waste treatment, disposal and recovery facilities, facilities subject to SARA Title III;** and ***other priority industrial facilities***, as determined by the applicant. **Municipalities should consider** the information gathered for [..] the part 2 application (**particularly the Source Identification and Characterization Data** components) when prioritizing storm water discharges from these sites.	Guidance Manual pag. 6-16
In part 2 application, the Source Identification component requires the applicant to provide **an inventory of pollutant sources**, organized by watershed. This inventory **identifies and describes the products and services** of each industrial facility that may discharge storm water to the MS4. The Source identification component suggests applicants to use standard industrial classification codes (SIC) codes for this description. EPA strongly recommends this information be used to identify priority waste handling sites and industrial facilities. A similar technique could be developed for sites ***that do not meet*** the ***regulatory definition of "storm water discharge associated with industrial activity"*** (i.e. not included in the Source Identification and Discharge Characterization components), but ***are identified as a high priority*** under the proposed management program.	Guidance Manual pag. 6-16 [Commercial Sites]
The municipality is **ultimately responsible** for discharges from their MS4. Consequently, the proposed storm water management program should describe how **the municipality will help** EPA and authorized NPDES States: • **Identify priority industries** discharging to their systems; • **Review. and evaluate storm water pollution prevention plans and other procedures that industrial facilities must develop under general or individual permits;** • **Establish and implement BMPs to reduce pollutants from these industrial facilities (or require industry to implement them);** and • ***Inspect*** **and monitor industrial facilities *to verify* that the industries discharging storm water to the municipal systems *are in compliance with their NPDES storm water permit***, if required.	Guidance Manual pag. 6-17
At a minimum, priority facilities include: • Operating and closed municipal landfills; • Hazardous waste treatment, disposal or recovery facilities; and • Facilities subject to SARA Title lll.	Guidance Manual pag. 6-17

Requirement	Reference
Municipalities must identify these **and *other priority industrial facilities* and describe the criteria used to identify them**. For example, information from the Toxics Release Inventory is one source a municipality could use to identify industrial facilities subject to SARA Title III. **Other sources** may include CWA Section 205 or 208 use-attainability studies, other studies that **indicate a site-specific beneficial use impairment immediately downstream of a storm water outfall**, or **records of industrial pretreatment programs or other permit programs that identify facilities that may be the source of a use impairment or a major contribution of pollutants**. The program should also describe procedures for modifying the inventory of priority industries based on **additional evaluation** that occurs throughout the permit term.	
During the term of the permit, as additional information becomes available, **the municipality should target and set priorities for other program elements** that emerge.	Guidance Manual pag. 6-18
As noted above, when identifying priority sites, applicants must consider all the facilities listed in 122.26(d)(2)(iv)(C)(1). When municipalities develop criteria for **identifying additional priority industrial facilities**, they are advised to consider, **at a minimum:** • The **type of industrial activity** (SIC codes can help characterize the type of industrial activity); • The **use and management of chemicals or raw products** at the facility and **the likelihood** that storm water discharge from the site **will be contaminated**; and • The **size and location of the facility in relation to sensitive watersheds.**	Guidance Manual pag. 6-18
The proposed management program **must include procedures for inspecting priority industrial sites**. The results of inspection may be used as a basis for **requiring storm water management controls and enhanced pollution prevention measures**. It should also establish an **inspection schedule** for each priority facility at the time it is identified.	Guidance Manual pag. 6-18
Applicants also should describe a procedure for **conducting follow-up inspections**, where necessary, as part of this program component. For example, follow-up inspections **might be needed to verify the installation of a specific control or implementation of a practice specified** in a negotiated agreement between the municipality and the industrial site. A system-wide approach to establishing priorities for inspection procedures is recommended. The system-wide approach should begin with the evaluation of existing information, followed by the identification and evaluation of new information during the permit term. Therefore, applicants **should link** these procedures with information from the Source Identification and Discharge Characterization components.	Guidance Manual pag. 6-19
A municipality **must consider** if it **should place more stringent controls on discharges associated with industrial activity than are required in an industrial facility's existing NPDES storm water**	Guidance Manual pag. 6-19

Requirement	Reference
permit.	
Priority industrial facilities should focus on controlling activities such as the use, storage, and handling of toxic chemicals. Standard methods for implementing control measures at different types of facilities should be described. To facilitate this, municipalities **should obtain copies of the pollution prevention plans developed by industrial permittees**. **Control measures** that the municipality **may suggest include preventing exposure of pollutant sources to precipitation, on-site pretreatment, and oil/water separators.**	Guidance Manual pag. 6-19
The proposed management program **should describe the inspection procedures that will be followed**. **Storm water inspections can be coupled with inspections for other purposes** (e.g., pretreatment programs, fire and safety). Proposed management **programs should address minimum frequency for routine inspections**. For example, **how often, how much of the site, and how long an inspection may take** are appropriate to explain in this proposed management program component. Applicants should also describe **procedures for conducting inspections and provide an inspector's checklist**. In addition, these inspection procedures should identify the **minimum number of inspectors** that will be employed and **describe the programs to train them**.	Guidance Manual pag. 6-19
Municipalities are **urged to *evaluate* pollution prevention plans and discharge monitoring data collected by the industrial facility to *ensure* that the facility is *in compliance with its NPDES storm water permit*. *Site inspections* should include (1) *an evaluation of the pollution prevention plan*** and any other pertinent documents**, and (2) an *on-site visual inspection of the facility*** to ***evaluate the potential* for *discharges of contaminated storm water*** from the site and ***to assess the effectiveness of the pollution prevention plan.***	Guidance Manual pag. 6-20
On November 16, 1990 (55 FR 47990), EPA promulgated a permitting scheme where controls for storm water discharges associated with industrial activity through large and medium municipal separate storm sewer systems may be addressed by two permits issued in a coordinated manner. This complementary permit approach envisions cooperative efforts by the permit issuing agency and municipal operators of large and medium municipal separate storm sewer systems to develop programs that will result in controls on pollutants in storm water discharges associated with industrial activity which discharge through municipal systems.	Federal Register, Vol. 58, No. 222 pag. 61158
Under the complementary permit approach, storm water discharges associated with industrial activity which discharge through large and medium municipal separate storm sewer systems are required to obtain permit coverage. Permits for these discharges will establish requirements (such as controls or monitoring) for industrial operators of the discharge into the municipal system. In addition, these permits provide a basis for enforcement actions directly against the owner or operator of storm water discharges associated with industrial activity.	Federal Register, Vol. 58, No. 222 pag. 61158
A second permit, issued to the operator of the large or medium municipal separate storm sewer, establishes the responsibilities of the	Federal Register, Vol. 58, No. 222 pag. 61158

Requirement	Reference
municipal operators in controlling pollutants from storm water associated with industrial activity which discharges through their system. The framework for permits for discharges from large and medium municipal separate storm sewer systems has been developed to establish the responsibilities of the municipals systems.	
At the heart of the permit program for discharges from municipal separate storm sewer systems serving a population of 100,000 or more are requirements that municipal applicants develop and implement municipal storm water management programs.	Federal Register, Vol. 58, No. 222 pag. 61158
The municipal storm water management programs that will be incorporated into NPDES permits for discharges from municipal separate storm sewer systems will generally address (in addition to other possible requirements) the following three major components: • Reducing pollutants in storm water discharges from municipal landfills; hazardous waste treatment, storage, and disposal facilities; facilities subject to the Emergency Planning and Community Right-to-Know Act (EPCRA), section 313; and other priority industrial facilities through municipal separate storm sewers. • Reducing pollutants in construction site runoff through municipal separate storm sewers. • Identifying and controlling non-storm water discharges to municipal separate storm sewer systems. These components of a municipal program can initiate the role of the municipality in assisting EPA and authorized NPDES States in implementing controls to reduce pollutants in storm water discharges associated with industrial activity which discharge through large and medium municipal separate storm sewer systems.	Federal Register, Vol. 58, No. 222 pag. 61158
Municipal programs to reduce pollutants in industrial site runoff and construction site runoff through municipal separate storm sewer systems specifically will address municipal responsibilities in controlling pollutants from industrial facilities.	Federal Register, Vol. 58, No. 222 pag. 61158
EPA proposed a permitting scheme that would define the requirement to obtain coverage under an NPDES permit for a storm water discharge associated with industrial activity through a municipal separate storm sewer in terms of the classification of the municipal separate storm sewer. EPA proposed holding municipal operators of large or medium municipal separate storm sewer systems primarily responsible for applying for and obtaining an NPDES permit covering system discharges as well as storm water discharges (including storm water discharges associated with industrial activity) through the system.	Federal Register, Vol. 55, No. 222 pag. 47997-98
Under the proposed approach, operators of storm water discharges associated with industrial activity which discharge through a large or medium municipal separate storm sewer system would generally not be required to obtain permit coverage for their discharge (unless designated as a significant contributor of pollution pursuant to section 402(p)(2)(E)) provided the municipality was notified of: The name, location and type of facility and a certification that the discharge has been tested (if feasible) for non-storm water (including the results of any testing). The	Federal Register, Vol. 55, No. 222 pag. 47998

Requirement	Reference
notification procedure also required the operator of the storm water discharge associated with industrial activity to determine that: The discharge is composed entirely of storm water, the discharge does not contain hazardous substances in excess of reporting quantities; and the facility is in compliance with applicable provisions of the NPDES permit issued to the municipality for storm water.	
EPA also expressed its belief, based upon an analysis of ordinance controlling construction site runoff in places in certain cities, that municipalities generally possessed legal authority sufficient to control contributions of industrial storm water pollutants to their separate storm sewers to the degree necessary to implement the proposed rule.	Federal Register, Vol. 55, No. 222 pag. 47998
Based on consideration of the comments received on the notice, EPA has decided that it is appropriate to revise the approach in its proposed rule to require direct permit coverage for all storm water discharges associated with industrial activity, including those that discharge through municipal separate storm sewers.	Federal Register, Vol. 55, No. 222 pag. 47998
In response to all of these concerns, EPA has decided to require storm water discharges associated with industrial activity which discharge through municipal separate storm sewers to obtain separate individual or general NPDES permits.	Federal Register, Vol. 55, No. 222 pag. 48000
Although today's rule will require industrial discharges through municipal storm sewers to be covered by a separate permit, EPA still believes that municipal operators of large and medium municipal systems have an important role in source identification and the development of pollutant controls for industries that discharge storm water through municipal separate storm sewer systems is appropriate.	Federal Register, Vol. 55, No. 222 pag. 48000
Under the CWA, large and medium municipalities are responsible for reducing pollutants in discharges from municipal separate storm sewers to the maximum extent practicable. Because storm water from industrial facilities may be a major contributor of pollutants to municipal separate storm sewer systems, municipalities are obligated to develop controls for storm water discharges associated with industrial activity through their system in their storm water management program.	Federal Register, Vol. 55, No. 222 pag. 48000
The CWA provides that permits for municipal separate storm sewers shall require municipalities to reduce pollutants to the maximum extent practicable. Permits issued to municipalities for discharges from municipal separate storm sewers will reflect terms, specified controls, and programs that achieve that goal.	Federal Register, Vol. 55, No. 222 pag. 48000
As with all NPDES permits, responsibility and liability is determined by the discharger's compliance with the terms of the permit. A municipality's responsibility for industrial storm water discharged through their system is governed by the terms of the permit issued. If an industrial source discharges storm water through a municipal separate storm sewer in violation of requirements incorporated into a permit for the industrial facility's discharge, that industrial operator of the discharge may be subject to an enforcement action instituted by the Director of the NPDES program.	Federal Register, Vol. 55, No. 222 pag. 48000
Today's rule also requires operators of storm water discharges associated with industrial activity through large and medium municipal	Federal Register, Vol. 55, No. 222 pag. 48000

Requirement	Reference
systems to provide municipal entities of the name, location, and type of facility that is discharging to the municipal system. This information will provide municipalities with a base of information from which management plans can be devised and implemented. This requirement is in addition to any requirements contained in the industrial facility's permit. As in the proposal, the notification process will assist cities in development of their industrial control programs.	
EPA intends for the NPDES program, through requirements in permits for storm water discharges associated with industrial activity, to work in concert with municipalities in the industrial component of their storm water management program efforts. EPA believes that permitting of municipal storm sewer systems and the industrial discharges through them will act in a complementary manner to fully control the pollutants in those sewer systems.	Federal Register, Vol. 55, No. 222 pag. 48000
This will fully implement the intent of Congress to control industrial as well as large and medium municipal storm water discharges as expeditiously and effectively as possible. This approach will also address the concerns of municipalities that they lack sufficient authority and resources to control all industrial contributions to their storm sewers and will be liable for discharges outside of their control.	Federal Register, Vol. 55, No. 222 pag. 48000-01
In addition, municipal applicants will provide a description of a proposed management program to reduce, to the maximum extent practicable, pollutants from storm water discharges associated with industrial activity which discharge to the municipal system.	Federal Register, Vol. 55, No. 222 pag. 48001

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Ventura County
Waterworks
District No. 17
ANNUAL WATER
QUALITY REPORT
VENTURA COUNTY
WATERWORKS DISTRICTS
Water testing performed in 2004
PWS ID#: #: CA5610003

Continuing Our Commitment

Ventura County Waterworks District No. 17 (District) was created in 1977. The Water and Sanitation Department of the County of Ventura, Public Works Agency is responsible for the administration, operation, and maintenance of the water system. The Ventura County Board of Supervisors is the governing body of the District, and a Citizens' Advisory Committee provides input on policy and rate adjustment matters.

Once again we proudly present our annual water quality report. This edition covers all testing completed from January through December 2004. We are pleased to tell you that our compliance with all state and federal drinking water laws remains exemplary. As in the past, we are committed to delivering the best quality drinking water. To that end, we remain vigilant in meeting the challenges of source water protection, water conservation, and community education while continuing to serve the needs of all of our water users.

For more information about this report, or for any questions relating to your drinking water, please call Al Sexton, Laboratory Manager, at (805) 378-1168.

Important Health Information

Some people may be more vulnerable to contaminants in drinking water than the general population. Immunocompromised persons such as persons with cancer undergoing chemotherapy, persons who have undergone organ transplants, people with HIV/AIDS or other immune system disorders, some elderly, and infants can be particularly at risk from infections. These people should seek advice about drinking water from their health care providers. The U.S. EPA/CDC (Centers for Disease Control) guidelines on appropriate means to lessen the risk of infection by *Cryptosporidium* and other microbial contaminants are available from the Safe Drinking Water Hotline at (800) 426-4791.

Water Conservation Tips

Water conservation measures are an important first step in protecting our water supply. Here are a few suggestions:

Conservation measures you can use inside your home include:

- Fix leaking faucets and toilets; replace old fixtures with water-saving devices.
- Do not use the toilet for trash disposal.
- Turn water off while shaving or brushing teeth.
- Soak dishes before washing; run dishwasher only when full.

You can conserve outdoors as well:

- Water lawn and garden early morning or evening.
- Use mulch around plants and shrubs.
- Use water from a bucket to wash your car, and save the hose for rinsing.

Source Water Assessment

In December 2002, Metropolitan Water District of Southern California (MWD) completed its source water assessment of its State Water Project supplies. State Water Project supplies are considered to be most vulnerable to urban/storm water runoff, wildlife, agriculture, recreation, and wastewater. A copy of the Assessment can be obtained by contacting MWD by phone at (213) 217-6850.

Information on the Internet

The U.S. EPA Office of Water (www.epa.gov/watrhome) and the Centers for Disease Control and Prevention (www.cdc.gov) Web sites provide a substantial amount of information on many issues relating to water resources, water conservation, and public health. Also, the California Department of Health Services Division of Drinking Water and Environmental Management has a Web site (www.dhs.ca.gov/ps/ddwem) that provides complete and current information on water issues in our own state.

Community Participation

You are invited to participate in our public forum and voice your concerns about your drinking water. The Citizens' Advisory Committee meets bimonthly at the Bell Canyon Property Owners' Association Office located at 30 Hackamore Lane, Bell Canyon. If you wish to participate, please call (805) 584-4830 for the specific date and time.

Where does the District's Water come from?

Our water supply, which is imported from the State Water Project, originates in northern California. Water is captured in reservoirs north of Sacramento and released through natural rivers and streams into the delta of the Sacramento and San Joaquin rivers. The water is then transported to the Southland in the 444-mile California Aqueduct to State Water Project contractors, such as Metropolitan Water District of Southern California (MWD). The water the District eventually receives is filtered and disinfected by MWD at its Jensen Filtration Facility in Granada Hills. The water is then delivered by MWD to its 26 member public agencies, including Calleguas Municipal Water District (CMWD), Ventura County's regional wholesale purveyor.

CMWD delivers water to the Bell Canyon community with the help of Ventura County Waterworks District No. 8, operated by the City of Simi Valley. CMWD brings the water into Ventura County through its mile-long tunnel in the Santa Susana Mountains. The water then travels through Ventura County Waterworks District No. 8 to Bell Canyon.

The District provides water service through approximately 700 service connections to over 2,045 people in the Bell Canyon area. In 2004, the District supplied approximately 1,520 acre-feet of water for residential, industrial, commercial, agricultural, and fire protection needs. The District's distribution system consists of two reservoirs, one booster pump station, and approximately 15 miles of waterlines.

Substances that might be in Drinking Water

The sources of drinking water (both tap water and bottled water) include rivers, lakes, streams, ponds, reservoirs, springs, and wells. As water travels over the surface of the land or through the ground, it dissolves naturally occurring minerals and, in some cases, radioactive material, and can pick up substances resulting from the presence of animals or from human activity.

In order to ensure that tap water is safe to drink, U.S. EPA and the California Department of Health Services (CDHS) prescribe regulations that limit the amount of certain contaminants in water provided by public water systems. CDHS regulations also establish limits for contaminants in bottled water that must provide the same protection for public health. Drinking water, including bottled water, may reasonably be expected to contain at least small amounts of some contaminants. The presence of contaminants does not necessarily indicate that water poses a health risk.

Contaminants that may be present in source water include:

Microbial Contaminants, such as viruses and bacteria, which may come from sewage treatment plants, septic systems, agricultural livestock operations, and wildlife;

Inorganic Contaminants, such as salts and metals, which can be naturally occurring or result from urban storm water runoff, industrial or domestic wastewater discharges, oil and gas production, mining, or farming;

Pesticides and Herbicides, which may come from a variety of sources such as agriculture, urban storm water runoff, and residential uses;

Organic Chemical Contaminants, including synthetic and volatile organic chemicals, which are by-products of industrial processes and petroleum production, and can also come from gas stations, urban storm water runoff, and septic systems;

Radioactive Contaminants, which can be naturally occurring or be the result of oil and gas production and mining activities.

More information about contaminants and potential health effects can be obtained by calling the U.S. EPA's Safe Drinking Water Hotline at (800) 426-4791.

Sampling Results

During the past year we have taken hundreds of water samples in order to determine the presence of any radioactive, biological, inorganic, volatile organic, or synthetic organic contaminants. The table below shows only those contaminants that were detected in the water. Although all of the substances listed here are under the Maximum Contaminant Level (MCL), we feel it is important that you know exactly what was detected and how much of the substance was present in the water. The state requires us to monitor for certain substances less than once per year because the concentrations of these substances do not change frequently. In these cases, the most recent sample data are included, along with the year in which the sample was taken.

PRIMARY DRINKING WATER STANDARD (Regulated in order to protect against possible adverse health effects)

				District		MWD (Jensen)		CMWD (LBWFP)			
SUBSTANCE (UNITS)	YEAR SAMPLED	MCL [MRDL]	PHG (MCLG) [MRDLG]	AMOUNT DETECTED	RANGE LOW HIGH	AMOUNT DETECTED	RANGE LOW HIGH	AMOUNT DETECTED	RANGE LOW HIGH	VIOLATION	TYPICAL SOURCE
Aluminum (ppm)	2004	1	0.6	NA	NA	ND	ND-0.055	ND	ND	No	Erosion of natural deposits; residue from some surface water treatment processes
Chloramines (ppm)	2004	[4.0 (as Cl_2)]	[4 (as Cl_2)]	NA	NA	2.4	1.7-3.0	2.0	1.9-2.1	No	Drinking water disinfectant added for treatment
Fluoride (ppm)	2004	2	1	NA	NA	0.11	0.10-0.12	0.2	n/a	No	Erosion of natural deposits; water additive which promotes strong teeth; discharge from fertilizer and aluminum factories
Gross Beta Particle Activity (pCi/L)	2004	50	n/a	NA	NA	4.9 [1]	ND-6.2	ND	ND	No	Decay of natural and man-made deposits
Haloacetic Acids (ppb)	2004	60	n/a	8	4-13	27	10-63	14	6-24	No	By-product of drinking water disinfection
Nitrate (as nitrate, NO_3) (ppm)	2004	45	45	NA	NA	2.70	2.30-3.19	ND	ND	No	Runoff and leaching from fertilizer use; leaching from septic tanks, sewage; erosion of natural deposits
TTHMs [Total Trihalomethanes] (ppb)	2004	80	n/a	49.1	43.2-56.2	60	30-87	52	32-65	No	By-product of drinking water chlorination
Turbidity [2] (NTU)	2004	TT	n/a	NA	NA	0.07	n/a	0.03	n/a	No	Soil runoff

Tap water samples were collected for lead and copper analyses from 11 homes throughout the service area.

SUBSTANCE (UNITS)	YEAR SAMPLED	ACTION LEVEL	PHG (MCLG)	AMOUNT DETECTED (90TH%TILE)	HOMES ABOVE ACTION LEVEL	VIOLATION	TYPICAL SOURCE
Copper (ppm)	2003	1.3	0.17	0.22	0	No	Internal corrosion of household plumbing systems; erosion of natural deposits; leaching from wood preservatives
Lead (ppb)	2003	15	2	2.6	0	No	Internal corrosion of household water plumbing systems; discharges from industrial manufacturers; erosion of natural deposits

FOOTNOTES

[1] Sampled in 2002 & 2003

[2] Turbidity is a measure of the cloudiness of the water. MWD and CMWD monitor it because it is a good indicator of the effectiveness of their filtration systems. During the reporting year, 100% of all samples taken to measure turbidity met water quality standards.

[3] One grain per gallon is equal to 17.1 ppm.

SECONDARY DRINKING WATER STANDARD (Regulated in order to protect the odor, taste and appearance of drinking water)

SUBSTANCE (UNITS)	YEAR SAMPLED	SMCL	PHG (MCLG)	MWD Jensen AMOUNT DETECTED	MWD Jensen RANGE LOW HIGH	CMWD (LBWFP) AMOUNT DETECTED	CMWD (LBWFP) RANGE LOW HIGH	VIOLATION	TYPICAL SOURCE
Aluminum (ppb)	2004	200	600	ND	ND-55	ND	ND	No	Erosion of natural deposits; residual from some surface water treatment processes
Chloride (ppm)	2004	500	NS	71	65-77	96	n/a	No	Runoff/leaching from natural deposits; seawater influence
Corrosivity (Units)	2004	Non-corrosive	NS	0.1	n/a	0.2	n/a	No	Natural or industrially-corrosive influenced balance of hydrogen, carbon and oxygen in the water; affected by temperature and other factors
Odor--Threshold (Units)	2004	3	NS	3	n/a	ND	ND	No	Naturally-occurring organic materials
Specific Conductance (µmhos/cm)	2004	1,600	NS	500	479-512	623	622-624	No	Substances that form ions when in water; seawater influence
Sulfate (ppm)	2004	500	NS	46	39-56	54	n/a	No	Runoff/leaching from natural deposits; industrial wastes
Total Dissolved Solids [TDS] (ppm)	2004	1,000	NS	275	266-286	365	350-380	No	Runoff/leaching from natural deposits
Turbidity (NTU)	2004	5	NS	0.05	0.05-0.06	0.02	n/a	No	Soil runoff

UNREGULATED SUBSTANCES

SUBSTANCE (UNITS)	YEAR SAMPLED	MWD Jensen AMOUNT DETECTED	MWD Jensen RANGE LOW–HIGH	CMWD (LBWFP) AMOUNT DETECTED	CMWD (LBWFP) RANGE LOW–HIGH
Alkalinity (ppm)	2004	81	79-84	100	n/a
Boron (ppb)	2004	160	150-180	200	n/a
Calcium (ppm)	2004	23	22-24	29	n/a
Hardness[3] (ppm)	2004	110	106-116	138	n/a
Magnesium (ppm)	2004	13	n/a	16	n/a
N-Nitrosodimethylamine (ppt)	2004	2.6	ND-5.9	NA	NA
pH (Units)	2004	8.3	8.3-8.4	8.2	n/a
Potassium (ppm)	2004	3	n/a	3	n/a
Sodium (ppm)	2004	54	52-56	71	n/a
Total Organic Carbon (ppm)	2004	2.2	2.0-2.6	2.5	2.3-2.7
Vanadium (ppb)	2004	ND	ND-3.4	NA	NA

Table Definitions

Action Level (Regulatory Action Level): The concentration of a contaminant, which, if exceeded, triggers treatment or other requirements which a water system must follow.

CMWD (LBWFP): Calleguas Municipal Water District (Lake Bard Water Filtration Plant)

MCL (Maximum Contaminant Level): The highest level of a contaminant that is allowed in drinking water. Primary MCLs are set as close to the PHGs (or MCLGs) as is economically and technologically feasible. Secondary MCLs (SMCL) are set to protect the odor, taste and appearance of drinking water.

MCLG (Maximum Contaminant Level Goal): The level of a contaminant in drinking water below which there is no known or expected risk to health. MCLGs are set by the U.S. EPA.

MRDL (Maximum Residual Disinfectant Level): The level of a disinfectant added for water treatment that may not be exceeded at the consumer's tap.

MRDLG (Maximum Residual Disinfectant Level Goal): The level of a disinfectant added for water treatment below which there is no known or expected risk to health. MRDLGs are set by the U.S. EPA.

MWD (Jensen): Metropolitan Water District of Southern California (Jensen Filtration Facility)

n/a: not applicable

NA: Not Analyzed

ND: Not Detected

NS: No Standard

NTU (Nephelometric Turbidity Units): Measurement of the clarity, or turbidity, of water.

pCi/L (picocuries per liter): A measure of radioactivity.

PDWS (Primary Drinking Water Standard): MCLs and MRDLs for contaminants that affect health along with their monitoring and reporting requirements, and water treatment requirements.

PHG (Public Health Goal): The level of a contam-inant in drinking water below which there is no known or expected risk to health. PHGs are set by the California EPA.

ppb (parts per billion): One part substance per billion parts water (or micrograms per liter).

ppm (parts per million): One part substance per million parts water (or milligrams per liter).

ppt (parts per trillion): One part substance per trillion parts water (or nanograms per liter).

TT (Treatment Technique): A required process intended to reduce the level of a contaminant in drinking water.

µmhos/cm (micromhos per centimeter): A measure of electrical conductance.

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Case Studies

	Author/Agency/Organization	Title	Date	URL
Chicago, IL	City of Chicago	City Launches Green Roof Grants Program	11/02/05	http://egov.cityofchicago.org/city/webportal/portalContentItemAction.do?BV_SessionID=@@@@0664391742.1150324275@@@@&BV_EngineID=cccdaddidejikmgcefecelldffhdfgm.0&contentOID=536932287&contenTypeName=COC_EDITORIAL&topChannelName=HomePage
Davis, CA	Architecture Week	A Better Suburbia	01/05	http://www.architectureweek.com/2005/0119/building_1-1.html
	Rocky Mountain Institute	Village Homes, Davis, California		http://www.rmi.org/sitepages/pid209.php
	Rocky Mountain Institute			
Florida	EPA	Bioretention Applications: Inglewood Demonstration Project, Largo, Maryland and Florida Aquarium, Tampa, Florida	10/00	www.epa.gov/owow/nps/bioretention.pdf
Jordan Cove, CT	Clausen, J. et al.	Jordan Cove Urban Watershed Section 319 National Monitoring Program Project	02/06	http://www5.bae.ncsu.edu/programs/extension/wqg/issues/notes120.pdf
	Connecticut Department of Environmental Protection	After 10 Years – Officials Celebrate Results of Important Water Monitoring Project	10/19/05	http://dep.state.ct.us/whatshap/Press/2005/101905.htm
	Connecticut Department of Environmental Protection	Jordan Cove Urban Monitoring Project	10/02	http://dep.state.ct.us/wtr/nps/succstor/jordncve.pdf
	National Oceanographic and Atmospheric Administration / Coastal Services	Storm Water Management: Putting Real Life to the Test in Connecticut	01-02/04	http://www.csc.noaa.gov/magazine/2004/01/conn.html
Maryland	Maryland Department of the Environment	Controlling Stormwater: Some Lessons From The Maryland Experience	10/90	
Prince George's County, MD	Cheng, M., *et al*.	Hydrological Responses from Low Impact Development Comparing with Conventional Development	11/00	http://www.scdhec.net/water/lid/pdf/somerset.pdf
Michigan	PILGRIM Education Fund	Waterways at Risk: How Low-Impact Development Can Reduce Runoff Pollution in Michigan	2005	
Outer Banks, NC	Blue: Land, Water, Infrastructure	An Assessment of Outer Banks Coastal Environmental Conditions, Existing Stormwater Management Strategies, and the Local and State Regulatory Context to Help Local Communities Effectively Implement Low Impact Development	06/06	
Philadelphia, PA	Abrams, Glen J.	New Thinking in an Old City: Philadelphia's Movement Toward Low-Impact Development	02/04	http://www5.bae.ncsu.edu/programs/extension/wqg/issues/notes112.pdf
	EPA	Vegetated Roof Cover: Philadelphia, Pennsylvania	10/00	www.epa.gov/owow/nps/roofcover.pdf
Portland, OR	City of Portland Bureau of Environmental Services	Downspout Disconnection Program Hits the Billion Gallon Mark	06/14/05	http://www.portlandonline.com/bes/index.cfm?a=82190&c=37621#disco
Seattle, WA	Seattle Public Utilities	Natural Drainage Projects		http://www.seattle.gov/util/About_SPU/Drainage_&_Sewer_System/Natural_Drainage_Systems/Natural_Drainage_Overview/index.asp
	Levitt, J., and Bergan, L.	Using Nature's Plumbing to Restore Aquatic Ecosystems: The City of Seattle's Natural Drainage System	02/05	http://www5.bae.ncsu.edu/programs/extension/wqg/issues/notes116.pdf
	Horner, R., *et al*.	Hydrologic Monitoring of the Seattle Ultra-Urban Stormwater Management Projects: Summaray of the 2000-2003 Water Years	10/04	
Sun Prairie, WI	Dorava, J., Vierbicher Associates, Inc.	Enhancing Storm Water Infiltration to Reduce Water Temperature Downstream		http://www.epa.gov/owow/nps/natlstormwater03/08Dorava.pdf
Wilwaukee, WI	STORMWATER, The Journal for Surface Water Quality Professionals	Beyond Flood Control: From green roofs to pervious pavement to underground treatment, Milwaukee experiments with newer water-quality and flood control measures	03-04/04	http://www.forester.net/sw_0403_beyond.html
Vancouver	The City of Vancouver	Crown Street: Vancouver's First Environmentally Sustainable Street	03/30/05	http://www.tac-atc.ca/english/pdf/conf2005/s5/kauffman.pdf
Washington, DC	Natural Resources Defense Council	Out of the Gutter: Reducing Polluted Runoff in the District of Columbia	07/02	http://www.nrdc.org/water/pollution/gutter/gutter.pdf
	EPA	Stormwater Management at the EPA Headquarters Office Complex		http://www.epa.gov/owow/nps/lid/stormwater_hq/
Various	Sierra Club	Building Better: A Guide to America's Best New Development Projects	11/05	http://www.sierraclub.org/sprawl/report05/buildingbetter.pdf
	Sierra Club	Building Better II: A Guide to America's Best New Development Projects, *Clean Water Edition*	11/06	http://www.sierraclub.org/healthycommunities/buildingbetter/2006/report.pdf

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For Immediate Release
Contact: Larry Merritt (DOE)
Phone: (312) 744-5716
E-mail:
Wednesday, November 2, 2005

City Launches Green Roof Grants Program

City Launches Green Roof Grants Program
Residential and Small Commercial Building Owners can qualify for $5,000 for Green Roof Project

The City of Chicago has been recognized for its commitment to environmental issues. The City is furthering the cause of making Chicago the greenest city in the country with a new grant program for green roofs. Owners of residential and small commercial buildings will have an opportunity to get a $5,000 grant to help with the planning and installation of a green roof.

“Green roofs provide tremendous benefits to the environment, to building owners and to quality of life in the city. This is exemplified by the fact that more than 150 public and private green roof projects have been completed or are underway throughout the City” said Department of Environment Commissioner, Sadhu Johnston. “This new grant program will enable home owners and small businesses to install green roofs.”

A limited number of grants (20) will be awarded. In addition to supporting residential and small business owners with green roof costs, the City hopes that the grants will increase the public’s awareness of green roofs. A written commitment will be required to maintain the green roof project for at least 5 years. Small commercial buildings must be less than 10,000 square feet.

Green roofs have a number of benefits, both for an individual building owner and the City of Chicago community. The primary benefits include reducing storm water runoff. Green roofs hold rain like a sponge - moisture is then dissipated naturally thereby relieving pressure on an already taxed storm sewer system. A reduction in the urban heat island effect is another reason the City is encouraging both the public and private sector to get involved.

A reduction in the energy requirements for a building is another key benefit. Lowering the ambient temperature of the roof's surface, green roofs slow the transfer of heat into the building, making it easier to cool in the summer. Buildings require less energy to heat during the winter because of the additional insulation. Green roofs also create conditions for a longer-lasting roof system.

A free seminar will be held on Wednesday October 19, 2005 from 6:00pm - 7:00pm at the Chicago Center for Green Technology, 445 North Sacramento Avenue.

Application forms are available at www.cityofchicago.org/environment or from the Department of Environment, 30 North LaSalle Street, Suite 2500. Applications will be accepted starting Tuesday November 1, 2005 until Wednesday November 30, 2005. The grants will be awarded in January 2006. For more information please visit the Department of Environment’s Web site or call 312-744-7606.

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Greenhouse Gas Emissions

Household Greenhouse Gas Emissions and Savings Measures

Even when no one's home, your household quietly emits greenhouse gases. A refrigerator is keeping your food cold, a furnace and/or air conditioner is keeping things comfortable, and even the little black boxes powering telephone answering machines, DVD players, shavers, and Dustbusters are constantly soaking up a little juice.

Surprisingly, heating and cooling aren't responsible for the largest household climate impacts. Appliances, lighting, and water heating account for the biggest part of your utility bills, hence emit the most carbon dioxide (see table). Remember that you're not merely paying an electric bill — you're also plugging into the power plant, and the more power (and money) you can save at home the more carbon dioxide you avoid emitting to the atmosphere.

CO2 Emissions in an Average Single-Family Home

	Cost $/yr	Energy 10^6 Btu/yr	CO_2 lbs/yr	CO_2 percent
Space heating	$476	68.1	8,829	33.9%
Air conditioning	$105	13.6	1,882	7.2%
Water heating	$202	27.8	3,558	13.7%
Refrigerator, freezer	$146	18.9	2,607	10.0%
Cooking	$46	6.5	825	3.2%
Other appliances	$346	44.7	6,182	23.8%
Lighting	$120	15.5	2,145	8.2%
Total	**$1,441**	**195.1**	**26,028**	**100.0%**

Source: U.S. Energy Information Administration, *Household Energy Consumption and Expenditures 1993,* and RMI calculations (1999).

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Environmental Communities

The Sydney 2000 Olympic Village

Newington, the home of the Sydney 2000 Olympic Village, is located in next to Homebush Bay, 14.5 kilometers west of downtown Sydney, New South Wales (NSW). The site was an abandoned munitions depot that was restored to native savanna. Three neighborhoods were constructed, each within a five-minute walk to a village green and a 27,881-square-meter commercial center. The village housed 15,000 athletes and coaches during the Olympics; afterwards the village's houses were sold. The project has proven to be immensely popular. Houses originally priced at US$180,000 are now selling for more than double that. Great care went into energy-efficient design and the choice of building materials. Many of the homes have roof-integrated photovoltaic systems — financed by the NSW Sustainable Energy Development Authority — each generating 1 kilowatt of electricity. Overall, this is one of the largest building-integrated PV systems in the world, and it is being used to understand how a grid behaves with distributed electrical generation.

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Village Homes, Davis, California

Village Homes in Davis, California is a green, planned residential community of single-family detached homes and apartments built in 1981. The 70-acre development also includes 12 acres of greenbelts and open space, 12 acres of common agricultural land, and 4,000 square feet of commercial office space. Designed to take maximum advantage of the sun, the annual household bills are one-half to one-third lower than in surrounding neighborhoods. Natural drainage systems on site saved $800 per lot and proved more effective for handling stormwater. Narrow streets reduced the amount of pavement needed, lowered ambient air temperature by 15 degrees, increased pedestrian safety, and allowed for future reductions in the cost of repair and maintenance. Edible landscape, pedestrian walking paths, and bike trails have also proved popular with residents. The original investors of Village Homes have made a profit of 30 percent per year. In 1995, homes sold for $10–$25 per square foot higher than the market rate. They continually have a low turnover rate and sell faster than is typical for the region.

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BUILDING

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A Better Suburbia

by Mark Francis

Visiting "Village Homes" for the first time, one is struck by how different this 1970s-era community looks from typical California developments. Arriving by car, one notices narrower streets and less visually dominant parking, with access kept to the edges along long, narrow cul-de-sac streets.

A visitor arriving by bike or on foot is led through the neighborhood along a green network of continuous paths lined with native and edible vegetation. It quickly becomes apparent that it is easier to walk or bike here than to drive.

One encounters a diverse mix of open spaces including small common areas between groups of houses, larger greenways along main bike and pedestrian paths, turf areas for sports, and agricultural landscapes scattered throughout the neighborhood with orchards, vineyards, and community gardens.

Many of these spaces are not simply "look-at" spaces found in more manicured developments. There are people actually using these open spaces — walking, digging, or playing, for

At the Village Homes development, planners laid out bicycle and pedestrian paths to encourage residents not to drive.
Photo: Tom Lamb

Village Homes site plan.
Image: Judy Corbett

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example. When empty, there are physical traces of use such as garden furniture, tools, and children's toys. This activity communicates a sense of stewardship, of people caring for and feeling attached to where they live.

POPQUIZ

Also striking at Village Homes is the lack of some design elements promoted as essential in New Urbanist developments. There are no front porches, and front doors are often hidden at the side of houses. The developers could not decide if the front door should face the street or the common areas, so they compromised and placed them on the sides of houses.

>>>

Discuss this article in the Architecture Forum...

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A Better Suburbia

continued

The focus is on community space such as common areas, gardens, and green space rather than on the public spaces of formal parks and pedestrian streets found in neotraditional developments.

Design and Planning Concepts

Village Homes combines older design and planning principles with newer, more innovative ideas. Many of basic concepts, as the developers admit, are drawn directly from earlier greenbelt communities. The idea of a residential area organized around open space (instead of the street) is a longstanding and popular planning concept.

The physical planning principles grow directly from the larger social and environmental goals for the community. For instance, all streets run east-west and all lots are oriented north-south, making full use of the sun's energy.

The roads are all narrow, curving cul-de-sacs, less than 25 feet (7.6 meters) wide and generally are not bordered by sidewalks. Their narrow widths minimize the amount of pavement exposed to the sun in the long, hot

FREE TRIAL IMAGE

At the Village Homes development, designers provided a diversity of housing types, including these apartments on the southern edge. Photo: Tom Lamb

The focus of community life is in the common areas, each designed and built by the adjacent residents. Photo: Tom Lamb

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POPQUIZ

summers. The curving lines of the roads give them the look of village lanes, and the few cars that venture into the cul-de-sacs usually travel slowly.

The common areas contain an innovative natural drainage system, a network of creek beds, swales, and pond areas that allow rainwater to be absorbed into the ground rather than carried away through storm drains. Besides helping to store moisture in the soil, this system recharges the water table and provides a visually interesting backdrop for landscape design.

The ecological approach of open channel drainage (instead of catch basins and underground pipes) reportedly saved enough money to pay for most landscape improvements in the development, including walkways, gardens, and other landscape amenities.

Traffic-protected open areas form safe play spaces for children. Residents have built playgrounds for their children in some of these open spaces and modified them as the kids grew older. They have experienced some problems with nonresidents using the open spaces and picking fruit.

Edible Landscape

Much of the plant material in Village Homes is either edible or native. Residents can pick fruit right outside their houses in most common areas. The edible landscape includes oranges, almonds, apricots, pears, grapes, persimmons, peaches, cherries, and plums.

Cross section of a common area with open-channel drainage.
Image: Judy Corbett

Village Homes, aerial view.
Photo: Mark Francis

Passive solar design includes deciduous vegetation that shades the south side of houses in the summer.
Photo: Tom Lamb

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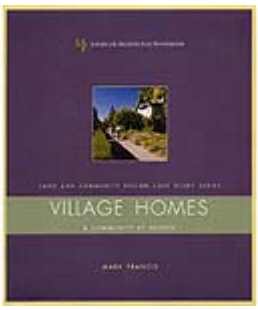
Community gardens located on the west side of the neighborhood provide organic produce, some of which is sold to local restaurants and markets. Annual harvest festivals bring residents together. This edible landscape has created a diverse and somewhat overgrown character to the neighborhood.

While common areas are unfenced, the fronts of houses along cul-de-sac streets are typically enclosed for privacy.

Photo: Tom Lamb

Some nonresidents have commented that the overall landscape is "an eyesore" and needs a great amount of maintenance. On the other hand, residents get pleasure in seeing the seasonal cycles of nature expressed in the Village's vegetation and open spaces.



Village Homes, written by Mark Francis.
Image: Island Press, photo by Tom Lamb

Circulation

Pedestrian and bicycle paths were laid out before the streets and receive higher emphasis. The greatest travel time within the neighborhood is five minutes, typically without ever crossing a road. The daycare center (located in the Community Center), the Plumshire Inn restaurant, and a dance studio are no more than a five-minute walk from any house.

Click on thumbnail images to view full-size pictures.

No other services are provided in the community. Grocery stores and other services are a short bicycle ride away, although most residents use cars to shop in neighborhood centers or in downtown Davis. Large purchases generally are made in Woodland, 10 miles to the north, or in Sacramento, 15 miles east.

The use of narrow and cul-de-sac streets in Village Homes appear to

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result in traffic-calming benefits. The long and narrow streets also accomplish this but lead to other problems, such as lack of visitor parking.

Energy Use and Conservation

A well-publicized aspect of Village Homes is its reported lower use of energy. This is a result of a combination of the passive solar house designs, south-facing site orientation, and south and west side shading. Natural heating and cooling are accomplished through both passive and active systems.

All houses can accommodate solar panels, and their orientation also allows south-facing windows to be shaded in the summer by overhangs and deciduous vegetation. Houses incorporate passive heating and cooling, are well insulated, and have a substantial thermal mass.

Solar hot water systems, when used, typically meet up to 100 percent of a household's hot water needs in the summer and above 50 percent in the winter. Street trees shade roads and reduce ambient air temperatures by as much as 10 degrees Fahrenheit (5.6 degrees Centigrade), which is significant on hot summer days.

Community Economics

The early vision was to develop, as much as possible, an economically self-sufficient community. Moneymaking ventures were envisioned through different types of agriculture, office developments, and an inn. Only some

of this has been realized.

Office space owned by the Village Homeowners Association is rented, as is the Community Center. The Community Center is very popular for weddings and family reunions and is often booked. Board-sponsored events as well as free classes, parties, and meetings are exempt from fees.

Most residents are employed by the University of California or in Sacramento, the state capital. There are a few employment opportunities in the village — at the office complex, restaurant, daycare center, or the Village Homeowners Association.

Although Village Homes has a 30-year history showing both successes and failures, it is a case study that remains of interest to modern planners interested in sustainable communities.

Discuss this article in the Architecture Forum...

Mark Francis, FASLA is professor of landscape architecture at the University of California, Davis, and senior design consultant with Moore Iacofano Goltsman.

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United States Environmental Protection Agency
Office of Water (4203) Washington, DC 20460
EPA-841-B-00-005A October 2000

Bioretention Applications

Inglewood Demonstration Project, Largo, Maryland
Florida Aquarium, Tampa, Florida

Key Concepts:

- Retrofits
- Structural Controls
- Source Controls

Project Benefits:

- Retrofit Opportunity
- Pollutant Removal
- Volume Reduction
- Cost-Effectiveness

LOW-IMPACT DEVELOPMENT CENTER

Introduction

Two case studies demonstrate the potential to use integrated management plans (IMPs) in the design of new parking facilities and as retrofits for existing parking facilities. The Inglewood study in Largo, Maryland, compared the pollutant removal efficiency of a bioretention cell in a laboratory setting to that of a comparable facility constructed in a parking lot. The Florida Aquarium study in Tampa, Florida, included monitoring of several storm events for volume and water quality control.

Inglewood Project Area

The project area is an existing 5-acre outdoor parking area located in a highly urbanized office park adjacent to Interstate 95. Runoff from adjacent areas does not flow across the lot. The slope of the parking area is approximately 3 percent. Parking stalls are aligned at 90-degree angles, and there are approximately 30 cars in each row of an aisle. At the end of each aisle are planting areas surrounded by curbs and gutters. Curb drainage inlets have been placed in some of the islands to intercept and collect runoff as sheet flow, which is piped to a downstream regional stormwater management facility.

Inglewood Project Description

The Inglewood project consisted of a laboratory segment and a field segment. The laboratory segment involved construction of a planter box filled with a typical bioretention facility soil mixture (50 percent construction sand, 20 to 30 percent topsoil, and 20 to 30 percent compost). This facility is approximately half the size in volume of the Inglewood facility. The box was planted with representative plants and mulched. A synthetic stormwater mixture was applied and the pollutant removal efficiency, temperature, and runoff volume rate were measured. The pollutant mix included metals (copper, lead, and zinc), phosphorus, organic nitrogen, and nitrate.

A landscaped island measuring approximately 38 feet by 12 feet was chosen as the retrofit area. The island contains a curb inlet that drains into the municipal storm drain system. Almost the entire drainage area is impervious. A 4-foot slot was cut into the curb immediately before the inlet. The landscaped island was then excavated to a depth of 4 feet. An underdrain was installed and tied into the bottom of the existing inlet to completely drain the planting soil to avoid oversaturation. The underdrain was covered with 8 inches of 1- to 2-inch gravel and backfilled with typical bioretention soil mix. The backfill extended to a depth of about 12 inches below the top of the curb, which allows for a ponding depth of approximately 6 inches of water in the island

Figure 1. Bioretention landscaping at the Inglewood demonstration project site.

Table 1. Summary of bioretention pollutant removal results for the Inglewood demonstration project.

Pollutant	Input mean ± standard deviation	Output mean ± standard deviation	Output range	Output percent removal mean ± standard deviation
Cu dissolved (µg/L)	120 ± 27	63 ± 6.5	55–75	48 ± 12
Cu total (µg/L)	120 ± 27	69 ± 9.4	55–85	43 ± 11
Pb dissolved (µg/L)	54 ± 9.4	11 ± 6	6.7–25	79 ± 26
Pb total (µg/L)	54 ± 9.4	16 ± 7	6.7–26	70 ± 23
Zn dissolved (mg/L)	1.1 ± 0.021	0.24 ± 0.44	0.11–0.56	78 ± 29
Zn total (mg/L)	1.1 ± 0.021	0.39 ± 0.44	0.12–1.4	64 ± 42
Ca (mg/L)	44 ± 6.4	32 ± 6.1	24–41	27 ± 14
Cl^- (mg/L)	5.1 ± 0.48	162 ± 80	74–228	3,000[a]
Na (mg/L)	3.1	359 ± 170	68–497	11,000[a]
P (mg/L)	0.83	0.11 ± 0.017	0.10–0.13	87 ± 2
TKN (mg/L as N)	6.9 ± 0.81	2.3 ± 0.64	1.7–3.0	67 ± 9
NO_3^- (mg/L as N)	1.3 ± 0.05	1.1 ± 0.15	0.94–1.2	15 ± 12

[a]Shows percent production.

before a backwater is created at the curb opening. Subsequently the area was planted and covered with 3 inches of shredded hardwood mulch. Figure 1 shows the bioretention area after vegetation was established.

The stormwater mixture was applied to a 50-square-foot area in the field facility at a rate of 1.6 inches per hour for 6 hours. The removal rates for several pollutants are shown in Table 1. In addition to pollutant removal, the runoff temperature was lowered approximately 12 °C as the runoff was processed and filtered through the soil mixture. Most of the pollutant removal process occurred in the mulch layer.

A similar field investigation was conducted on an 8-year-old facility, and the metals removal rate was much higher (Davis et al., 1998). This effect might be attributed to slower flow rates through the soil, which has higher clay content, as well as greater pollutant uptake by vegetation.

Inglewood Project Summary and Benefits

This study showed the feasibility of retrofitting an existing parking facility and demonstrated the consistency of laboratory and field pollutant removal performance. The retrofit cost approximately $4,500 to construct and treats approximately one-half acre of impervious surface. The bioretention retrofit was a more cost-effective way to filter pollutants than many proprietary devices designed to treat the same volume of runoff. These proprietary devices could cost $15,000 to $20,000, would be more expensive to maintain, and would not significantly decrease runoff volume or temperature. Also, bioretention areas offer the ancillary benefit of aesthetic enhancement. It is interesting to note that a drought occurred after the installation of the plants, and although many of the other plants in the parking lot died or experienced severe drought stress, the plants in the bioretention facility survived because of the retained water supply.

Florida Aquarium Project Area

The Florida Aquarium site is an 11.5-acre, asphalt and concrete parking area that serves approximately 700,000 visitors per year. Runoff was controlled using the following IMPs:

- End-of-island bioretention cells
- Bioretention swales located around the parking perimeter
- Permeable paving
- Bioretention strips between parking stalls
- A small pond to supplement storage and pollutant removal

Figure 2 is an illustration of the site that details the type and location of runoff controls.

Florida Aquarium Project Description

A total of 30 storm events were monitored for one year at the Florida Aquarium site during 1998-1999. The Southwest Florida Water Management

District measured rainfall and flow from eight of the subcatchments in the parking area and collected water quality samples on a flow-weighted basis. Comparisons between pavement areas controlled by IMPs and uncontrolled asphalt areas were made for peak runoff rate, runoff volume, runoff coefficients, and water quality. Sediment cores from swales also were collected and analyzed.

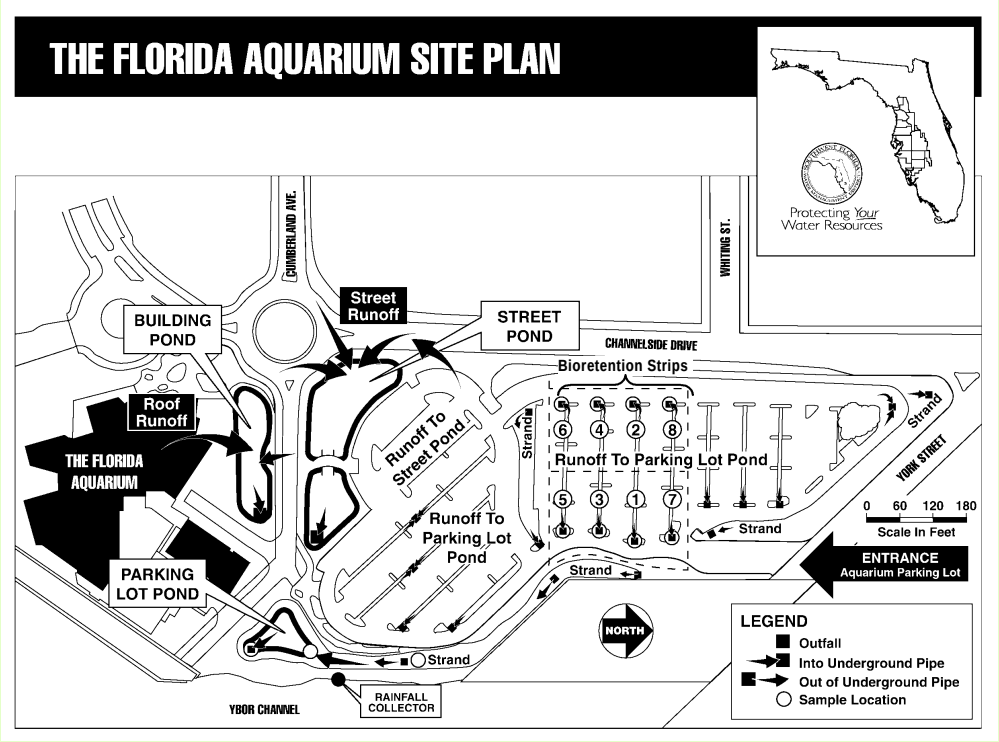

Figure 2. Layout of the Florida Aquarium site with IMPs. The eight basins outlined with dotted lines were evaluated in this part of the study.

Florida Aquarium Project Summary and Benefits

The parking areas controlled by IMPs showed a significant reduction in runoff volume and peak runoff rate. Table 2 shows pollutant load reductions for three pavement types; reduction is compared to pollutant loads in runoff from a basin without a swale. Much of the pollutant reduction is attributed to the reduced runoff in basins with swales. Because the swales are only the first element in the treatment train, even better removal efficiencies should be seen when data are analyzed for the entire system.

Table 2. Load efficiency of pollutants expressed as percent reduction for three types of pavement at the Florida Aquarium site.

	Percent pollutant reduction[a]		
Constituents	Asphalt w/swale	Cement w/swale	Porous w/swale
Ammonia	45	73	85
Nitrate	44	41	66
Total Nitrogen	9	16	42
Orthophosphorus	-180	-180	-74
Total Phosphorus	-94	-62	3
Suspended Solids	46	78	91
Copper	23	72	81
Iron	52	84	92
Lead	59	78	85
Manganese	40	68	92
Zinc	46	62	75

[a]The basins with swales were compared to a basin without a swale to determine the amount of reduction in pollutant loads possible using these small alterations. Notice that the efficiencies for phosphorus are negative, indicating an increase in phosphorus load in the basins with a swale.

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Coastal Services, January/February 2004

STORM WATER MANAGEMENT
PUTTING REAL LIFE TO THE TEST IN CONNECTICUT

"This will give managers more ammunition to help them sell low-impact development."

Bruce Morton,
Aqua Solutions

Resource managers know intuitively that by controlling water running off the land, sediment and pollutants ending up in coastal waters will be reduced. Thanks to an innovative experiment in Connecticut, managers are now getting proof.

"That's why we pursued this project. There weren't any studies out there done on a long-term basis that documented the fact that if you develop in a certain way and use BMPs [best management practices] you can reduce runoff and improve the quality of the runoff," says Mel Cote, manager of the Water Quality Unit of the U.S. Environmental Protection Agency's (EPA) New England Regional Office.

The Jordan Cove National Urban Watershed Monitoring project is a 10-year monitoring initiative comparing the quantity and quality of runoff between a traditionally developed residential subdivision and environmentally sensitive development.

Results from the Jordan Cove project may help provide the documentation communities around the country need to re-evaluate outdated storm water management regulations that often tie the hands of developers willing to change the way they do business.

"What we hope to do with the results," Cote says, "is show that the environmental

benefits of building this way outweigh the cost of going through the process of changing regulations."

The One and Only

Jordan Cove is the first storm water project in the country dealing with urban and suburban development, and is one of 23 national monitoring projects funded by the EPA's Nonpoint Source Management Program under section 319 of the federal Clean Water Act.

While 22 of the projects address agricultural runoff, Cote says most of the nitrogen in the Long Island Sound is coming from urban and suburban land use.

"We knew we needed to do a better job managing urban and suburban areas to control nitrogen," says Paul Stacey, supervising environmental analyst for Connecticut's Department of Environmental Protection, "but other than a few places in the Chesapeake Bay area, we really hadn't seen this consolidation of so many real-life BMPs in one residential development put to the test."

Managers from state and federal agencies and researchers from the University of Connecticut often discussed "conceptually, what we might do better," Stacey says. Eventually, talk turned to putting a number of BMPs to the test "all at once in a real neighborhood. That's when things got complicated."

Critical Pieces

Certain elements of the Jordan Cove project had to come together perfectly, or there would have been no project.

Needed was a soon-to-be-developed piece of coastal property with just the right topography in an environmentally aware community that would be willing to bend its zoning regulations. Key was a developer willing to put in the extra time and investment while working with local, state, and federal regulators, as well as academic researchers, all of whom had to be committed enough to the project to carry it through to fruition.

"The story is not the fact that we have all these engineering details; it's the fact that it actually happened at all," says Bruce Morton, co-owner of Aqua Solutions and the project's coordinator.

In 1995, after a year of searching, the project group found its site, an 18-acre parcel located in a small watershed that drains into Jordan Cove, an estuary connected to Long Island Sound.

The property had been a family farm, and the owner was willing to develop part of it in

an environmentally sound manner.

The parcel was located in the town of Waterford, which is known as an environmentally progressive community.

To conduct the paired watershed experiment, the property would be split roughly in half. On one half, a subdivision would be built using traditional building practices following the town's zoning requirements. On the other, a neighborhood would be built using practices that are more conducive to reducing runoff and protecting water quality. An existing subdivision nearby served as a control site.

Monitoring, led by University of Connecticut's Dr. Jack Clausen, was begun on all three sites and was conducted for nearly two years before construction began. Monitoring has continued through construction, which was completed in 2003, and will continue for the next two years.

Exceptions to the Rules

While baseline data were being collected, committee members completed the most challenging part of the project—getting the variances and approvals needed from all of the various town commissions and officials.

"A lot of our proposed measures in the BMP area are not standard building measures and did not fit into the confines that most towns have on the books," explains Cote.

What the town didn't allow in its regulations had to go through variance procedures.

"That in itself was one of the major obstacles," he says. "In most towns and cities, zoning regulations are pretty strict, and a lot of what they allow is not good for the environment."

Stacey notes that the response of Waterford officials was "very flexible and very interested. We made certain adjustments that you might expect along the way, but we were able to pretty much implement the project as we saw it."

More Equals Better

With the community's approvals in hand, construction of the traditional subdivision began in 1997, and ground was broken for the experimental neighborhood in March 2000. Construction on the BMP site was complete in 2002, and the traditional site was completed last year.

In the traditional neighborhood, curbs and catch basins collect runoff, which is then piped through a detention pond treatment system before entering a nearby stream and Jordan Cove. Houses were built in a "cookie-cutter" fashion, streets are impervious,

and vegetation is minimal.

Homeowners in this area, although aware of the monitoring project, are not part of the experiment, says project coordinator Morton. "We didn't want to interfere with their activity or give them special training because we wanted a real, actual neighborhood under traditional conditions."

In the experimental section, housing is clustered to minimize impervious coverage, permeable driveways are shared, and deed restrictions prohibit expansion of impervious surfaces. Rainwater from roofs is funneled into special "rain gardens," grass swales line the narrower, permeable road, and the center of the cul-de-sac is a vegetated infiltration basin. Lawns have areas designated as "low-mow" or "no-mow."

All of the experimental homes were sold before they were built, and educating those homeowners is an important part of the project, Stacey says. Education guidelines were written into the bylaws of the homeowners' association, presentations are made at association meetings, and graduate students conducting the monitoring answer homeowner questions.

A Question of Money

By the end of the 10-year project, Cote says, they will have spent $1 million in section 319 grant funds. He notes that 70 to 80 percent of those funds will have been used to pay for monitoring—equipment, graduate students, analysis, collection, and publishing.

The rest went to subsidize the developer for any BMP costs that went above and beyond what he would have had to pay for traditional approaches.

The experimental neighborhood took more time—and therefore money—than the traditional neighborhood, but much of that was due to the extra time it took to sell the town on the plan, and the learning curve of contractors unfamiliar with some of the practices.

"We learned that this type of development doesn't cost more and may cost less in the longer term, particularly as products become more accepted and there is a greater demand," Cote says. "By and large, we feel if BMPs were on a level playing field, a green neighborhood would be less expensive to build than a traditional one."

So Far, So Good

Not only may BMPs be cost effective, monitoring is showing that they also are working.

"The early results are, 'absolutely.' We've had a year now to monitor the BMP site and the results are extremely positive. We are seeing what we expected and maybe even a little better," Cote says.

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Preliminary results are showing that there is less runoff from the BMP area on a per unit basis and the quality of what does run off is improved.

"This will give managers more ammunition to help them sell low-impact development," Morton says. "If we're serious about dealing with water quality in the long term, this is something we are going to have to do to succeed."

Reaching Out

Managers, it seems, are interested in getting that ammunition. So far, 29 states and 3 countries have wanted more information on the Jordan Cove project.

"It's a bit of a showcase," says Morton, who regularly helps conduct tours of the neighborhood for regulators, design professionals, academics, and citizens. He notes that one of the project goals is to develop model guidelines that other towns can use to implement BMPs, and Washington State University is undertaking a similar project looking at their effectiveness in different soil types.

Cote adds, "What we've learned is that we can develop in a way that creates less pollution than how we've developed in the past. The practices exist, they are not expensive, and they are often aesthetically pleasing and attractive. It won't get us to 100 percent removal, but it will be worth the cost."

For more information on the Jordan Cove National Urban Watershed Monitoring project, point your browser to www.canr.uconn.edu/jordancove/. You may also contact Bruce Morton at (860) 295-1505 or aquasolutions@snet.net, Paul Stacey at (860) 424-3728 or paul.stacey@po.state.ct.us, and Mel Cote at (617) 918-1553 or cote.mel@epa.gov.

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Updated on June 13, 2006

Jordan Cove

Urban Monitoring Project

Background

Stormwater runoff from urban and urbanizing areas is widely recognized as a major cause of water pollution in the United States. Connecticut communities, like those in many urbanized states, are confronted with meeting nonpoint source management needs that often conflict with traditional subdivision regulations and construction standards. The challenge of meeting public safety and maintenance requirements in an environmentally sensitive manner is not currently being met, as evidenced by continued water quality impairments associated with new development. Can impervious surfaces be reduced, and curbing and storm drains be eliminated in a way that will not raise objections from municipal boards and commissions? Will homeowners accept cluster housing, natural landscaping, and "greener" home and yard maintenance practices? Most important, will those modifications make a difference in the quality and quantity of nonpoint source runoff under widespread application?

Project Purpose

The primary purpose of the Jordan Cove project is to measure differences in runoff quantity and quality emanating from traditional and "environmentally sensitive" development sites. The 18-acre "Glen Brook Green" subdivision, located in the southeastern Connecticut town of Waterford (Figure 1), is being constructed and monitored to make this comparison. The subdivision is split into two distinct "neighborhoods": one with building lots arranged in a traditional R-20 (half-acre) zoning pattern (Figure 2); the other, cluster housing with a variety of best management practices (BMPs) incorporated into the design (Figure 3).

Stormwater runoff from the traditional section is collected by curbs and catch basins, then piped through a stormwater treatment system before entering Nevins Brook, a tributary of Jordan Brook and, ultimately, Jordan Cove and Long Island Sound. Homeowners will not be subjected to any enhanced environmental education, or restrictions on how they manage their properties. The BMP neighborhood has grass swales(Figure 4); roof leader "rain gardens" (Figure 6); shared, permeable driveways; small building "footprints;" deed restrictions on increasing impervious surfaces; "low-mow," "no-mow," and

Figure 1. Project location

conservation zones; a narrower, permeable road surface (interlocking concrete pavement); and a vegetated infiltration basin, or bioretention area, located inside a "tear-drop" cul de sac. Several different driveway surfaces will be utilized, including interlocking concrete pavement, gravel, and asphalt, and monitored for their relative runoff rates. Homeowners and town road maintenance crews will be encouraged to adopt pollution prevention techniques, including controlled fertilizer and pesticide application, pet waste management, street sweeping/vacuuming, and reduced use of deicing agents.

The BMP neighborhood is expected to generate less stormwater runoff and pollution. Monitoring conducted before, during and after construction will document actual results. The Jordan Cove project team comprises a true public/private partnership, with researchers and educators from the University of Connecticut; federal, state, and local government officials; private consulting firms; and the developer.

Figure 2. Traditional design

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College of Agriculture
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Arthur J. Rocque, Jr., Commissioner

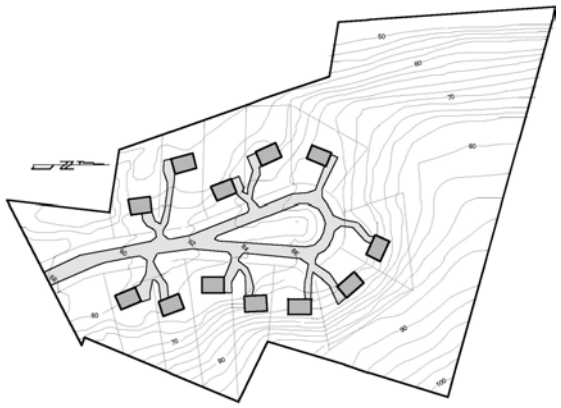

Figure 3. BMP design

The Jordan Cove Urban Watershed National Monitoring Project is funded, in part, through the Connecticut Department of Environmental Protection (CT DEP) by the U.S. Environmental Protection agency's (EPA) Section 319 National Monitoring Program (NMP).

It is one of 23 such projects nationwide. The Jordan Cove project is the only NMP project studying the effects of residential subdivision development on runoff quality and quantity, and of BMPs designed to mitigate those impacts.

Monitoring Design

This study is utilizing the "paired-watershed" monitoring design, which requires a minimum of two watersheds (control and treatment) and two periods of study (calibration and treatment). This approach assumes that there is a quantifiable relationship between paired water quality data for the two watersheds, and that this relationship is valid until a major change is made in one of the watersheds (e.g., construction, BMPs). It does not require that the quality and quantity of runoff be statistically the same for the two watersheds, but that the relationship between the paired observations of water quality and quantity remains the same over time — except for the influence of the land use changes in the treatment watershed.

Figure 4. Swale

For the Jordan Cove project, the treatment period will occur in two phases: (1) during construction of the traditional and BMP neighborhoods; and (2) after construction when the BMPs are in effect. The paired-watershed approach is being used to measure the differences in water quality and quantity between the treatment areas (traditional and BMP neighborhoods) and the control area (Figure 5), a nearby 10 year-old subdivision, caused by construction in the two treatment areas and the application of BMPs in the BMP neighborhood. Stormwater quality and quantity are measured at the outlets of each of the two treatment neighborhoods, and the control watershed. Water quality is measured by analyzing weekly flow-weighted composite samples for total suspended solids (TSS), total phosphorus (TP), total Kjeldahl nitrogen (TKN), ammonia nitrogen (NH_3-N), and nitrate+nitrite nitrogen (NO_3-N). Grab samples are analyzed for fecal coliform and BOD_5. Monthly analyses are conducted for copper (Cu), lead (Pb), and zinc (Zn).

Figure 5. Control Watershed

Figure 6. Rain Garden

The calibration period began in January 1996 to establish a baseline for future comparisons. Since the treatment period began in May 1998, runoff monitoring has focused on the effects of construction, and on the relative effectiveness of standard erosion and sediment control practices in the traditional neighborhood and enhanced controls in the BMP neighborhood. Post-construction monitoring began in July 2002 and will continue for three years.

Supplemental monitoring will be conducted on selected BMPs, including different driveway surfaces and enhanced turf management in the BMP neighborhood, and a "state-of-the-art" stormwater treatment device in the traditional neighborhood. This information will be used to evaluate the effectiveness of these specific practices.

Monitoring Results

Sampling during construction of the traditional neighborhood showed a significant increase in peak flow and flow volume. Total suspended solids concentrations did not change significantly during construction, indicating that erosion and sediment control was adequate. However, because the flow increased, mass export of total suspended solids, total phosphorus, nitrate, ammonia, total Kjeldahl nitrogen, copper, lead, and zinc also increased by over 90%.

During construction of the BMP neighborhood, a significant decrease in peak flow and flow volume was observed. However, total suspended solids concentrations increased 98%, and total phosphorus increased 99%. The mass export of solids and phosphorus also increased significantly.

These increases appear to be attributable to increased stormwater runoff volumes. The preliminary results from this study suggest that increased runoff, rather than erosion, is the cause of increased pollutant export from this construction site. Traditionally, erosion and sediment controls and stormwater management plans focus on the prevention of sediment and, occasionally, peak flow impacts on downstream areas. The preservation of pre-development hydrologic conditions within the watershed where construction is occurring is typically ignored.

Excess runoff, which is the driving force behind nonpoint source pollution, will transport pollutants into waterways and contribute to their degradation. Preliminary monitoring results demonstrate that erosion and sediment controls can reduce sediment and sediment-associated pollutants in construction site runoff. However, current erosion and sediment control practices do not address the increase in runoff from development sites. Consequently, these practices fail at reducing pollutant loads.

National Monitoring Program Section 319(l) of the federal Clean Water Act

(Nonpoint Source Management Programs Collection of Information) states that EPA shall collect and make available:
(1) Information concerning the costs and relative efficiencies of BMPs for reducing nonpoint source pollution.

(2) Data concerning the relationship between water quality and implementation of various management practices to control nonpoint sources of pollution.

The objectives of the Section 319 NMP are twofold:
(1) To scientifically evaluate the effectiveness of watershed technologies designed to control nonpoint source pollution.
(2) To improve our understanding of nonpoint source pollution.
To achieve these objectives, the NMP has selected watersheds across the country to be monitored over a 6- to 10-year period to evaluate how improved land management and the application of BMPs reduce water pollution. The results from these projects will be used to assist land use and natural resource managers by providing information on the relative effectiveness of BMPs to control nonpoint source pollution.

Next Steps

Construction of the BMP neighborhood was completed in June 2002, and the remaining three undeveloped lots in the traditional neighborhood will be completed in 2003. Monitoring of stormwater quality and quantity will be conducted for three years after build-out to determine the overall efficiency of the design. It should demonstrate that careful planning, landscaping, and use of vegetative BMPs can help protect and enhance the environment, while addressing other concerns that local planning and zoning commissions face. Lessons learned from this project have already been, and will continue to be, passed along to other communities through ongoing technical assistance and training programs administered by the CT DEP, the University of Connecticut Cooperative Extension System, and other agencies and organizations.

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http://www.epa.gov/owow/nps/education.html

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Section 319 of the Federal Clean Water act authorizes EPA to award grants to states and tribes to support their NPS management programs. The CT DEP passes through a portion of these funds to other state, regional and local government agencies and non-government organizations to implement programs and projects.

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October 19, 2005

After 10 Years – Officials Celebrate Results of Important Water Monitoring Project

Effective Stormwater Management in Residential Development Shown to Greatly Improve Water Quality

BOSTON – Federal, state and local officials celebrated the completion of a ten-year stormwater study in Waterford, Conn. today. The study concluded that effective stormwater management practices and design features, when implemented in a residential subdivision, greatly improved water quality of receiving waters when compared to a similar subdivision that did not implement the comprehensive stormwater measures.

The Jordan Cove Urban Watershed National Monitoring Project has generated national interest among water quality management professionals who have waited since 1995, to see if "best management practices" or "BMPs" that were used at the 18-acre Glen Brook Green subdivision significantly reduced the amount of pollution coming from the development through its stormwater discharges.

The one-of-a-kind project involved building two distinct neighborhoods – one with traditional design features built on conventional half-acre lots, the second with clustered housing and numerous BMPs installed to reduce stormwater pollution. Researchers then monitored runoff from the two neighborhoods to compare pollution levels.

Ten years after pre-construction monitoring began at the experimental subdivision and nearby "control" neighborhood and three years after completion of construction at the "green" neighborhood, the results are in. The data prove conclusively that reducing the amount of impervious surfaces such as road and driveway surfaces, and infiltrating the remaining runoff, significantly reduces the amount of polluted stormwater entering local streams and other waterways. In fact, monitoring of rain events after installing the BMPs indicate that the amount of stormwater runoff generated by the green neighborhood is similar to that generated by an undeveloped, forested parcel of land.

The study also examined relative costs of the two different development styles and found economic benefits associated with

the "green" development over the "control" neighborhood. The BMP neighborhood designed with less pavement, grass-lined ditches, and infiltration practices was significantly less expensive to construct than the traditional wide roads, curbs and storm drain systems found in the control neighborhood.

The project was funded with $980,000 in federal grants from the Environmental Protection Agency and was administered in coordination with the Connecticut Department of Environmental Protection. Monitoring and Research for the project was conducted by Professor John Clausen of the College of Agriculture and Natural Resources at the University of Connecticut. The project is one of 25 nationwide approved under EPA's Clean Water Act National Monitoring Program.

"By building two distinct neighborhoods and carefully evaluating pollution runoff from these sites, the Jordan Cove project has greatly improved our understanding of the impacts of new development on the environment and how we can reduce those impacts," said Ira Leighton, deputy regional administrator of EPA's New England Office, who attended the ceremony. "By showing that proper stormwater management practices can reduce water quality impacts to such an extent that the stormwater runoff generated by the green neighborhood is similar to that generated by an undeveloped, forested parcel of land, is a remarkable finding."

"The Jordan Cove monitoring project is a real life example of neighborhood-level environmental stewardship where innovative land use practices have been applied to reduce pollution and improve the quality of life of the residents who live in this urban subdivision," said DEP Commissioner Gina McCarthy. "Not only will the residents of this subdivision benefit from this national project, the ideas and practices utilized at Jordan Cove can be applied across Connecticut and the country to improve water quality, becoming the standard for the design and construction of residential neighborhoods nationwide."

Polluted runoff accounts for over fifty percent of the nation's remaining water quality problems. Runoff from both urban and agricultural land carries with it bacteria and pathogens that cause beach and shellfish bed closures, excess nutrients that cause eutrophication of streams, lakes, and estuaries – including Long Island Sound, and sediment that damage fish habitat and require more frequent dredging of our coastal ports and harbors.

To learn more about EPA's Water Quality Monitoring Programs visit: http://www.epa.gov/NE/lab/biology/watermicro.html

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Controlling Stormwater:

Some Lessons From The Maryland Experience

Prepared By:
Greg Lindsey
Molly Cannon

October, 1990

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INTRODUCTION

The State of Maryland has implemented a number of programs designed to control nonpoint source pollution. Maryland's Stormwater Management Program is the cornerstone of efforts to control urban nonpoint source pollution and has received national and international attention. This paper provides a synopsis of State efforts to control stormwater, a review of the strengths and weaknesses of the programs, and some observations about the implications of new federal programs and regulations for Maryland programs. Lessons from the Maryland experience are summarized.

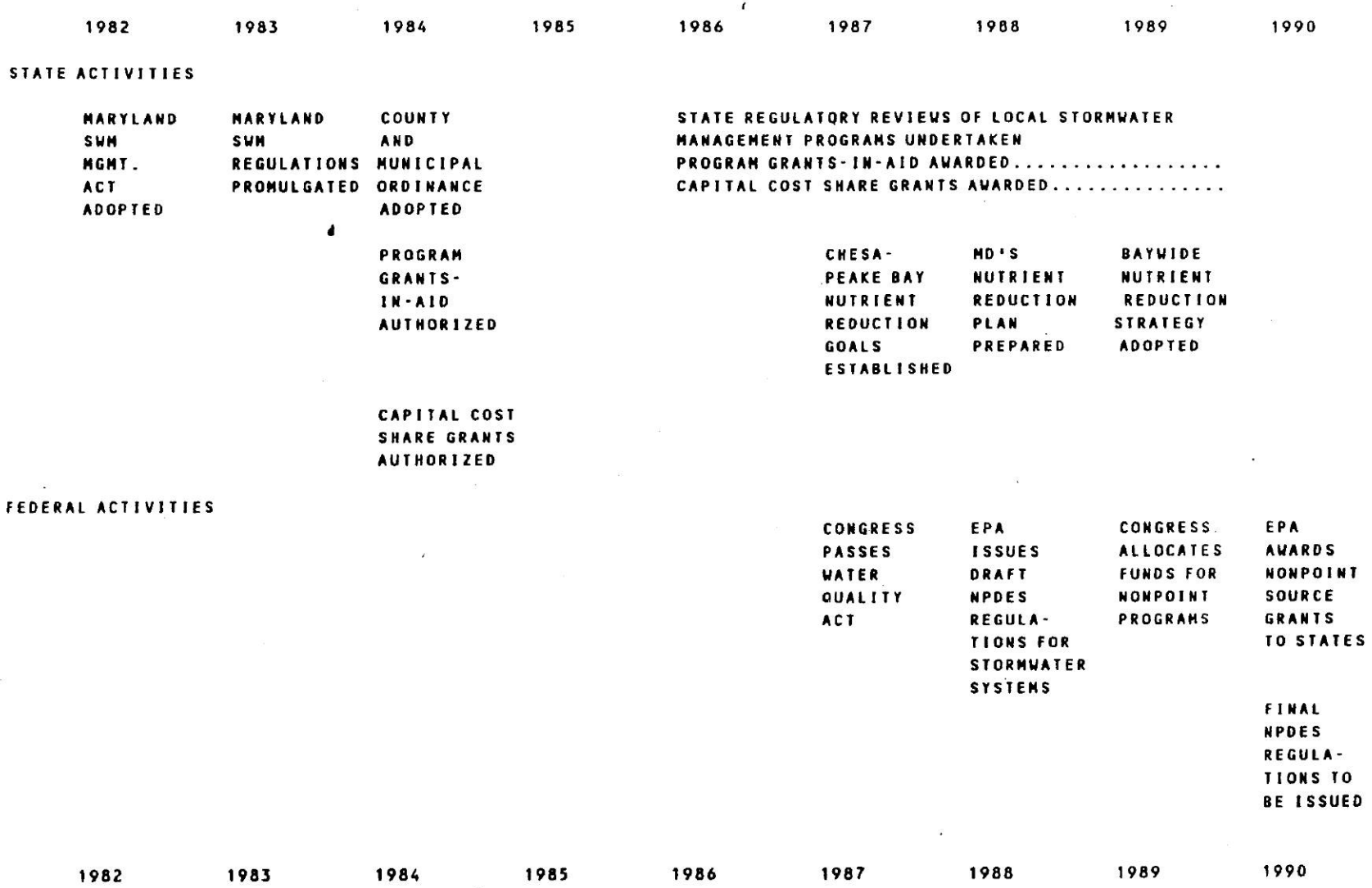
STORMWATER MANAGEMENT IN MARYLAND

The Stormwater Management Act

Programs to control urban stormwater in Maryland are a subset of a wide variety of programs aimed at controlling urban nonpoint source pollution. Related programs not reviewed here include, for example, a parallel, complementary Erosion and Sediment Control Program also administered by the Sediment and Stormwater Administration; the Department of Natural Resources' Chesapeake Bay Critical Areas Program; and the Department of the Environment's Water Quality Certification Program. Figure 1 is a timeline that includes significant events in the evolution of programs to manage stormwater in Maryland.

The Stormwater Management Act was passed by the Maryland General Assembly in 1982. The primary goal of State and local programs established by the Act is to "maintain after development, as nearly as possible, the predevelopment runoff characteristics." Regulations promulgated by the State in 1983 define this to mean, for quantity control for most of Maryland, on-site control of the 2 and 10 year storm events. In addition, for quality control, the Administration has established a list of preferred management practices. Pursuant to this list, local officials responsible for plan review are required to investigate the feasibility of infiltration of the first half inch of runoff -- the so-called first flush that contains most of the pollutants in runoff. If infiltration is not feasible, other practices may be used. These other practices, in order of preference, are vegetated swales, retention ponds, extended detention ponds, and detention facilities. The position of each practice on the list was determined primarily by its potential to provide pollutant removal. Infiltration is preferred because it offers the highest potential for reduction in pollutants such as sediment and phosphorus, has potential for groundwater recharge and maintenance of base flow, and mitigates thermal impacts. All incorporated counties and municipalities in Maryland were required to adopt ordinances, by 1984, that establish programs which, at minimum, provide these controls on every development that disturbs more than 5,000 square feet of land and significantly changes sit hydrology (waivers may be issued if the differences in pre- and post- two and ten year discharge are less than 10%).

FIGURE 1. MILESTONES IN THE EVOLUTION OF MARYLAND'S STORMWATER MANAGEMENT PROGRAM



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The Act is quite broad, and those who drafted it recognized that it would significantly change the way development occurs throughout the State. The authors also recognized that the mandates of the law would push technical knowledge in the area of stormwater management and that significant assistance would have to be provided to local governments to achieve successful implementation. The Act authorized local governments to establish fee systems to cover the cost of plan review and program implementation, mandated that State regulatory officials review local programs at least triennially, required that the State conduct research and provide technical assistance and training in the application of stormwater management technology and program implementation, and provided for civil and criminal penalties for violation of the law.

In addition to establishing minimum controls and preferred practices, the 1983 regulations established state responsibilities, criteria for exemptions and waivers, and requirements for construction and maintenance inspection and enforcement. State regulatory staff responsible for program review are required to determine whether local programs are "acceptable." To be acceptable, local programs must have (1) an approved ordinance, (2) adequate administrative procedures, (3) adequate plan review, (4) acceptable construction inspection and enforcement, and (5) acceptable maintenance inspection and enforcement.

Since 1982, the Administration has worked with Maryland's 23 counties and 151 municipalities to implement local programs. Forty-seven municipalities chose to implement programs; the remaining 104 adopted resolutions that gave the County governments the authority to implement programs within their respective jurisdictions. The Administration has conducted 25 local program reviews, completed a number of research studies, and held several training conferences and workshops to assist local officials. Details concerning implementation are summarized below.

Stormwater Program Grants-in-Aid

In 1984, as part of a legislative package known as the Chesapeake Bay Initiatives, the General Assembly authorized two additional programs related to stormwater management. One of these was the Stormwater Management Grants-in-Aid Program. This program, which became effective in 1985, has allocated approximately $1.5 Million annually to local governments to assist them with implementation. Grants-in-Aid may be used to fund personnel; to apply, local governments must have an Administration-approved program. Criteria used to evaluate funding requests are not rigorous and pertain mainly to the "reasonableness" of the request. In general, this refers to whether there appears to be sufficient work to justify the proposed positions. To assist local jurisdictions in estimating manpower requirements, the Administration provides productivity guidelines to local jurisdictions. Most funds are used to pay plan review staff and inspectors; some clerical and administrative positions also are funded. The grants program is competitive; some local governments choose not to seek support. The program is not an entitlement program.

Stormwater Pollution Control Cost-Share Program

The Stormwater Pollution Control Cost-Share Program, which also was authorized in 1984 and implemented in 1985, is a grant program that provides matches of up to 75% of the cost of stormwater management retrofits -- projects to serve areas developed without stormwater management. The objectives of the Cost-Share Program are to demonstrate best management practice (BMP) pollutant removal efficiency, cost effectiveness, social acceptability, and maintenance requirements. Grants are awarded competitively; funds for the projects are raised through the sale of state bonds. In total, between 1984 and 1990, the General Assembly authorized $5 Million for capital projects.

Chesapeake Bay Agreements

In 1987, the Governors of Maryland, Virginia, and Pennsylvania, the Mayor of Washington DC, the Chairman of the Chesapeake Bay Commission, and the Administrator of the USEPA signed an agreement calling for a 40% reduction in nutrient loadings to the Chesapeake Bay. In 1988, Maryland's Nutrient Reduction Plan was completed. This Plan outlines a strategy for implementation of the nutrient reduction objectives. In general, the Plan calls for a 40% reduction in all point and nonpoint sources, including urban stormwater. To control urban runoff, three programs are identified: (1) the continuation of the existing cost share program; (2) a massive new retrofit program

to be funded by stormwater utilities; and (3) a redevelopment program aimed at "explicit management of development intensity. No complete cost estimates for implementing these programs are available. Although direct construction costs for retrofits have been estimated at $71,000,000, this estimate is extremely low and does not include any ancillary costs such as planning, modeling, or design.

EPA Nonpoint Source Control Programs

In 1987 Congress passed the Water Quality Act, a comprehensive overhaul of the Clean Water Act. In Section 319, the Act required that all states develop assessment and management reports that identify and categorize sources of nonpoint pollution and outline coordinated strategies for implementation of programs to control them. The primary goal of Maryland's Assessment and Management Reports is to implement the Nutrient Reduction Plan. State officials made nutrient reduction the focus of the nonpoint source program because significant effort had been put into developing the Nutrient Reduction Plan, quantitative goals already were in place (i.e., the 40% reductions), and steps towards implementation already were underway. Maryland's Assessment and Management Reports were approved in August and December, 1989, respectively. In 1989, Congress authorized $40 Million for implementation of nonpoint source management plans, and in March, 1990, EPA awarded to Maryland a grant for FY 1990 for $447,771.

NPDES Permits for Stormwater Discharges

The 1987 Water Quality Act also directed EPA to promulgate regulations to require National Pollutant Discharge Elimination System (NPDES) Permits for stormwater discharges. It appears that numerous industries and at least five major jurisdictions in Maryland will be required to apply for permits. To receive permits, local jurisdictions must have in place, among other items, programs to control pollutants from urban runoff from both existing and new development. Final regulations are to be issued in July 1990. Like existing NPDES programs for wastewater treatment facilities and hazardous waste management operations, the program is designed to be administered by the States.

Observations

To summarize, Maryland requires by statute and regulation that local governments manage both the quantity and quality of runoff from new development; the State assists local governments in implementation with both program grants and technical assistance. The State also has established a grants program for capital projects to address pollution problems in older areas developed without stormwater controls. Since creation of these programs, the State has established an extremely ambitious objective: a 40% reduction of nitrogen and phosphorus loadings from urban runoff from existing areas. More recently, the USEPA has required that the State develop nonpoint source management plans to address urban stormwater runoff. Finally, EPA will soon begin regulating some stormwater systems and facilities. Thus, the government apparatus to manage stormwater in Maryland includes the State's regulatory program, two grant programs, and the nutrient reduction program, all of which now are overlain by two federal programs, one of which is regulatory. This may seem complicated, but readers should keep in mind that this is only a partial picture. We have not described at all, for example, the State's Erosion and Sediment Control Program, which in certain ways is more complex than the regulatory program required under the Stormwater Management Act. In addition, the Maryland's Critical Areas Law establishes special stormwater-related requirements for projects in the Critical Area (the strip of land 1000 feet wide that surrounds the high tide area of the Chesapeake Bay). The Department of Environment's Water Quality Certification Group has issued special guidance and requirements for stormwater discharges into wetlands. Though incomplete, these brief summaries provide a good snapshot of some of the major state and federal activities that impact the stormwater management component of nonpoint source management program.

IMPLEMENTATION

We provide here some results -- an overview of the status of implementation of each of the programs summarized above. We conclude this section with a subjective evaluation of progress. When possible, we make judgements of both technical progress (i.e., an assessment of progress towards objectives) and administrative performance.

The Stormwater Management Act and Implementation of Local Programs

Local jurisdictions implemented stormwater management programs in 1984 following approval of local ordinances by the Administration. In late 1984 and early 1985, the State completed a cursory review to determine whether the local jurisdictions had begun implementation. The data that were collected were used to set priorities for the first round of triennial field reviews. To date, the Administration has reviewed all the counties but one and Baltimore City (a total of 23 jurisdictions have been reviewed). None of the 47 smaller municipalities that opted to implement their own programs has been reviewed. Using the five criteria noted above, the Administration determined that 13 of the programs were acceptable; 10 were found to be unacceptable. Since the initial review, two programs have been brought into compliance and are now acceptable. Presently, according to the most recent data available, 15 of the major programs in the State are acceptable, while 8 are unacceptable (Table 1).

These findings require some interpretation. Per the regulations (COMAR 26.09.01), programs can be unacceptable if they are deficient in any of the categories. In general, programs found to be deficient had inadequate administrative procedures or documentation in files, were failing to provide adequate plan review, were issuing waivers for too many projects, or were failing to provide adequate construction inspection. Reviewers during the first round of reviews essentially ignored the issue of maintenance: the program was too new for local officials to establish a performance record in this area. While a about a third of the counties apparently are operating unacceptable programs, these data may be misleading. Many of the findings were made four to five years ago when programs were new and few data were available for evaluation. During the early reviews, programs were judged to be acceptable if all programs elements were in place; track records for performance evaluations were not available. The findings of program evaluations are summarized by year in Table 2. We conclude from these data that the Administration has become more stringent in its review of local programs. This makes sense; as local officials gain experience, it seems reasonable to expect more of them. However, given that almost a third of the programs were last reviewed in 1985 and 1986 when reviews were less rigorous, it may be that more than eight of the major jurisdictions are not operating acceptably.

Although a number of programs may be unacceptable, it is difficult to judge what this means in terms of environmental impact. For example, a finding of unacceptable for failure to provide adequate documentation in plan review files may be nothing more than a paper deficiency. On the other hand, it may be a clue that local officials are issuing waivers in situations in which stormwater management, at least quality controls, ought be required. In and of itself, issuance of a waiver may not be significant, either in terms or runoff quantity or quality. However, the cumulative effects of waiving projects are precisely those that the regulations are intended to prevent.

Several problems emerged consistently during the reviews. These include the issuance of waivers for development of agricultural land in row crops because hydrologic models show that runoff volumes will decrease following development, failure to adhere to the preference list for facilities, no construction inspections, failures to require submittal of as-built plans, no maintenance of facilities (including failure to maintain inventories), and the failure to notify homeowners' associations that responsibility for maintenance had been transferred to them. While some of these problems can and have been corrected during the review process, others will require changes in regulations.

Table 1. Most Recent Sediment and Stormwater Administration Stormwater Reviews.

County/ City	Date of Review	Finding
Allegany	2/87	Acceptable
Anne Arundel	6/89	Acceptable
Baltimore County	4/86	Acceptable
Baltimore City	4/87	Acceptable
Calvert	10/85	Acceptable
Caroline	4/87	Unacceptable
Carroll	4/86	Acceptable
Cecil	3/90	Acceptable
Charles	11/85	Acceptable
Dorchester	4/87	Acceptable
Frederick	5/89	Unacceptable
Garrett	7/97	Acceptable
Harford	8/87	Unacceptable
Howard	10/88	Unacceptable
Kent	3/87	Unacceptable
Montgomery	1/88	Acceptable
Prince George's	11/86	Acceptable
Queen Anne's	4/90	Acceptable
Somerset	9/89	Unacceptable
St. Mary's	3/86	Unacceptable
Talbot	9/89	Unacceptable
Washington	Ongoing	
Wicomico	4/86	Acceptable
Worcester	11/85	Acceptable

Current Status: 15 Acceptable (65%)
8 Unacceptable (35%)

(Note: Programs in Cecil and Anne Arundel Counties initially were found unacceptable but in rereviews were found to be acceptable.)

Table 2. Findings of Program Reviews by Year.

Year	Jurisdictions found Acceptable	Jurisdictions found Unacceptable	Reviews
1985	3	0	3
1986	4	1	5
1987	4	3	7
1988	1	2	3
1989*	1	4	5
1990*	2	0	2
Total	15	10	25

* Includes one re-review in which one county was upgraded from unacceptable to acceptable.

In assessing the review process, we also examined our own performance. First, reviews have not been completed as frequently as required by the Stormwater Management Act. Not only have the major jurisdictions not been reviewed triennially (in 1990 a second round of reviews should be completed), but only one of the 47 municipalities (Baltimore City) which elected to implement their own programs has been reviewed. The failure to achieve timely reviews is attributable primarily to staff shortages; only two to three individuals have been available at any one time to undertake reviews, and these individuals also have had other responsibilities.

The 23 reviews completed initially have been conducted by nine individuals, including several engineers, a geographer, and a planner. Despite general guidance in the regulations, reviewers have emphasized different criteria, and the reviews reflect this. We examined each of the reviews in detail to determine if the reviewers addressed the same program elements. We established seventeen items pertinent to the review and noted whether reviewers commented on that program aspect. For example, we found that each review included a summary comment on the quality of plan review, but that comments about the quality of hydrologic and hydraulic calculations were included in only 15 of the 23 reviews. Seventeen of the reviews included the number of inspectors on staff, but only eight noted the types of enforcement tools available to the inspectors, and nine reviewers included findings relative to enforcement activity and the use of enforcement tools. Of the 17 program elements that were included in the review, the only single program element that was mentioned explicitly in each of the 23 initial reviews was the quality of plan review and design. Staff responsible for program review have used the assessment of past reviews to develop new procedures for conducting triennial reviews to ensure consistency in administration. These include a requirement for annual administrative reviews based on data supplied by each local jurisdiction in a detailed 20 page data form.

Stormwater Program Grants-in-Aid

Data on the program grants-in-aid awarded by the Administration are presented in Table 3. Between 1985 and 1988, the State of Maryland has awarded almost $9 Million in grants-in-aid. Twenty-one of Maryland's 23 Counties have requested and received funds; nine of the 47 municipalities have requested and received funds. Slightly over 82% of the total funds have been awarded to counties; almost 18% has been awarded to municipalities. Of the counties that have received funds, 14 of the programs at the last review were acceptable; seven were unacceptable. One of the two counties that has not requested funds was unacceptable; a review has not been completed for the other. The City of Baltimore is the only municipality to receive funds that has been reviewed. In sum, 65% of the grants has gone to counties with acceptable programs; just over 17% has gone to counties with unacceptable programs. Just over 6% of the total grants has been given to Baltimore City, which operates an acceptable program. Program reviews have not been completed for the other eight municipalities that have received almost 12% of the total awards.

It is difficult to assess the effect that the grants have had on jurisdictions responsible for implementing stormwater programs, let alone the effects of the grants on mitigating adverse effects of development on water resources. We do not even know, for example, the percentage of each local stormwater budget that is comprised of state funds. Thus, we cannot assess the extent to which state funds have helped local jurisdictions to establish successful program. We noted above that just over 17% of the grants ($1.56 Million) has been allocated to seven counties that operate unacceptable programs; we do believe that the number of unacceptable programs would be higher if state funds were not available.

With respect to impact on the environment, enough data are available for us to make a general assessment of whether the funds are being allocated to the "right" jurisdictions. Intuitively, we would hope to grant funds to those jurisdictions where the greatest impact on the environment is occurring, which is, in this case, where the most amount of development is occurring. We present in Table 4 the total funds granted to each major jurisdiction between 1985 and 1990 along with the total number of housing starts between 1985 and 1988. Although the grants are not tied directly to development levels, we would expect to see the funds track the development. This generally seems to be the case: the difference between the percentage of total funds received and the percentage of total housing starts in most cases is very small. We conclude the following: for those smaller jurisdictions, the percentage of funds received generally corresponds to the percentage of housing starts. However, among the larger jurisdictions, there is greater variation. For example, Prince George's County has received more than 22% of the total grants, although only [illegible] percent of the total housing starts have

Table 4.Stormwater Grants-in-Aid and Housing Starts

COUNTIES	Program Grants TOTAL FY 1985 FY 1990	PERCENT OF TOTAL GRANTS	HOUSING STARTS 1985-1988	PERCENT OF TOTAL
Allegany	219,542	2.4%	877	0.5%
Anne Arundel	798,304	8.9%	15,429	9.3%
Baltimore	695,750	7.8%	21,222	12.8%
Calvert	197,451	2.2%	3,515	2.1%
Caroline	0	0.0%	954	0.6%
Carroll	165,049	1.8%	6,698	4.0%
Cecil	108,707	1.2%	3,252	2.0%
Charles	344,645	3.8%	6,242	3.8%
Dorchester	127,409	1.4%	721	0.4%
Frederick	75,234	0.8%	7,844	4.7%
Harford	442,359	4.9%	11,338	6.8%
Howard	309,855	3.5%	15,805	9.5%
Garrett	134,840	1.5%	1,200	0.7%
Kent	128,917	1.4%	399	0.2%
Montgomery	622,146	6.9%	30,342	18.3%
Prince George's	2010,816	22.4%	20,121	12.2%
Queen Anne	173,204	1.9%	2,182	1.3%
Somerset	8,790	0.1%	674	0.4%
St. Mary's	533,382	6.0%	3,327	2.0%
Talbot	65,751	0.7%	1,426	0.9%
Washington	0	0.0%	2,955	1.8%
Wicomico	203,862	2.3%	2,829	1.7%
Worcester	13,477	0.2%	3,730	2.3%

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occurred within the County. For Baltimore, Howard, and Montgomery Counties and Baltimore City, the percentage of housing starts that have occurred in the jurisdiction is higher than the percentage of total program grants that have been awarded to the jurisdiction. Howard County is the only one of these five major jurisdictions that had an unacceptable program at the time of review. It appears that local officials in Prince George's County have been more aggressive in seeking funds than other local jurisdictions. One other program that stands out in this crude analysis is St. Mary's County. St. Mary's County has received approximately 6% of the total grants awarded, although the number of housing starts in the area comprises just two percent of the total. Despite receiving funds disproportionate to development activity, St. Mary's program was unacceptable at the time of the last review.

Stormwater Pollution Control Cost-Share Grants

Since 1984, the General Assembly has authorized approximately $5 Million for stormwater pollution control grants. The Sediment and Stormwater Administration has obligated 47 grants totalling $4.97 Million. The funds have been used to support a variety of projects, including seven infiltration facilities, 19 extended detention facilities with wetlands, two extended detention dry ponds, eight wetlands, one sand filter, and 10 other practices. The projects are at various stages of implementation.

Overall, 14 jurisdictions have received cost-share grants (11 counties and three municipalities). Of the counties that received grants, four had unacceptable stormwater programs at the time of the last review. Two of the municipalities that received grants never have been reviewed. Prince George's County has received a disproportionate share of funds (21.7%); Baltimore County has received an unexpectedly small share (3%; Table 5). Like the grants-in-aid, the cost share program is not an entitlement program. Since retrofits are not required by state law or regulation, the effort put forth at the local level to identify and rectify stormwater pollution problems varies greatly. To a significant degree, the allocation of cost-share funds to local jurisdictions reflects the sophistication of local programs.

Table 5. Stormwater Pollution Control Cost Share Grants by County.

County City	Number of Projects	Total Funds ($)	Percent of Funds
Allegany	1	65,000	1.3%
Anne Arundel	5	777,000	15.6%
Baltimore	2	147,000	3.0%
Calvert	1	24,578	0.5%
Caroline	1	25,000	0.5%
Dorchester	2	320,908	6.5%
Harford	4	416,750	8.4%
Howard	1	37,500	0.8%
Kent	1	45,000	0.9%
Montgomery	9	826,000	16.6%
Prince George's	12	1,080,000	21.7%
Baltimore City	3	628,508	12.6%
Crisfield	1	303,750	6.1%
Ocean City	4	272,400	5.5%
Total	47	4,969,394	100%

Chesapeake Bay Agreements

Regionally, implementation of the Chesapeake Bay Agreements is being coordinated through an Interstate Implementation Committee. In Maryland, The Sediment and Stormwater Administration has been designated as the lead agency for nonpoint source pollution controls. An Interagency Steering Committee has been established to coordinate all state-wide efforts to control all types of nonpoint source pollution, including nutrients, conventional pollutants, and toxics. The Committee presently is updating Maryland's Nutrient Reduction Plan, which is the best developed statement of the State's overall efforts to control pollution in the Bay. Sections of the Nutrient Reduction Plan concerning nonpoint pollution have been extracted and used to develop Maryland's nonpoint source management plan for USEPA pursuant to Section 319 of the Water Quality Act. Specific implementation activities have included extensive retrofit efforts in selected or targeted watersheds.

EPA Nonpoint Source Control Programs

While the State of Maryland has been active in stormwater management, direct federal support for implementation of related nonpoint source management programs has evolved more recently. The State of Maryland has redefined existing programs to control nonpoint pollution in the Bay, particularly the Chesapeake Bay nutrient reduction plan, to fit into the framework outlined by EPA pursuant to Section 319 of the Clean Water Act. In March, 1990, the State of Maryland received its first nonpoint source implementation grant. Projects, activities, and items funded include:

1. One staff position to coordinate nonpoint source programs;
2. Two staff positions to implement stormwater utilities;
3. One stormwater retrofit project manager;
4. Four agricultural soil conservation planners;
5. Groundwater modeling study;
6. Demonstration wetlands joint use project;
7. Cooperative Extension Service nonpoint source conference.

These projects were identified by a statewide, interagency task force that was created to guide implementation of projects funded by EPA. As is evident from the projects, about half of the programs are for projects related to urban nonpoint source programs. The coordinator position will be based in the Sediment and Stormwater Administration to strengthen existing programs. The staff to assist with utilities will build on ongoing technical assistance activities to help local jurisdictions identify adequate financing for programs, and the stormwater retrofit project manager will improve the existing cost-share program by strengthening management capabilities, including capabilities for project evaluation. At this time, we anticipate that funds will be available under Section 319 for the next three or four years and that in years hence funds will be used increasingly for implementation of capital and educational projects.

NPDES Permits for Stormwater Discharges

EPA expects to issue final regulations for implementation of the permit system in late July or August of 1990. The State of Maryland has determined that municipal permits will be issued by the Sediment and Stormwater Administration; industrial permits will be issued by the Hazardous and Solid Waste Management Administration. While details of the permitting program have not been developed, it is clear that implementation of the program will require substantial effort and resources not presently available to the Administration.

Administration

Primary responsibility for implementation of the Stormwater Management Act initially was delegated to the Sediment and Stormwater Division within the Maryland Department of Natural Resources (DNR). In 1984, the Division included only three staff members. In 1987, a new Department of the Environment (MDE) was created, and programs were transferred from DNR to

LESSONS LEARNED

To sum up, the State has made significant investments in managing stormwater. Since 1984, the State has awarded $9 Million in program grants-in-aid and about $5 Million for pollution control cost share projects. We estimate that the annual costs to administer these programs (including stormwater regulatory reviews) is about $1 Million annually. We believe these investments have resulted in significant progress. All the counties have implemented programs. Literally thousands of best management practices (BMPs) have been built in Maryland. Most of these are functioning, though perhaps not as designed. With respect to existing programs, we need to improve in a number of areas, both at the local and state levels. The pending stormwater regulations have the potential to significantly impact the Administration's current operations and budget. We are not optimistic that implementation of new federal permit requirements will proceed smoothly. For example, the draft regulations specify that, to obtain a permit, local governments must have water quality monitoring and modeling programs as well as stormwater management programs, sediment and erosion control programs, retrofit programs similar to those already in place in Maryland. These will require significant new resources. We would like to share the following observations.

* State law and regulations are making a difference. On-site controls are helping to mitigate the effects of urbanization. With respect to pollution control, however, these controls simply slow the rate of pollution. BMPs are not 100% effective. Regulators and stormwater managers should be emphatic about the limitations of the practices that are being used.

* Effective stormwater management requires a commitment by elected decision makers at the local level. Despite the existence of state regulations and technical assistance activities, a number of programs at the local level in Maryland are not acceptable. We believe that this results, in large part, from the failure of local officials to allocate adequate resources to the programs. This is particularly a problem in moderately populated jurisdictions that now are experiencing significant growth.

* Given that BMPs have limitations in their ability to control pollutants, growth management must be viewed as a key element of nonpoint source control efforts. Planning at the watershed scale to mitigate against nonpoint source pollution will be required for efficient allocation of scarce resources. For example, major, yet-to-be defined elements of Maryland's Nutrient Reduction Plan involve definition of growth management objectives through watershed planning processes.

* The State's plans for implementation of the federal NPDES program are not well developed. We do not know at this time exactly what the regulations will require or the number of people that will be required to administer the permit system -- even though, according to timetables set forth by EPA, implementation should be occurring.

* Finally, the Maryland experience suggests that evolution of programs will be required to control urban nonpoint source pollution effectively. Despite the existence of path breaking regulations and significant financial and technical assistance, there have been problems with implementation. Recognition of the pervasiveness of the nonpoint source problem and the limitations of even innovative structural approaches leads to the conclusion that growth management approaches are essential; Maryland's program must evolve to incorporate these. Responding to federal regulatory requirements will require additional new elements in the State's stormwater programs. Continual evaluation and reevaluation will be essential to achievement of objectives.

MDE. The Division was elevated to the Sediment and Stormwater Administration (SSA), an organizational leap of two steps. The Administration now includes three programs: (1) the Policy and Evaluation Program, which is responsible for local program reviews, (2) the Construction Management Program, which administers the two State grant programs, and (3) the Compliance Program, which is responsible for sediment and erosion control inspection and enforcement and is the largest program. Table 6 includes a summary of the Administration budget and number of staff for Fiscal Years 1987 through 1991. The budget remained relatively constant between FY 1987 and FY 1989, but increased significantly between FY 1989 and FY 1991. The growth primarily has been for more inspectors to strengthen the erosion and sediment control inspection and enforcement. The Compliance Program is by far the largest in the Administration, accounting for over two-thirds of the staff (in FY 1990), very few of whom have any involvement with stormwater management. The Construction Management Program is the second largest in terms of budget and personnel. The FY 1991 budget figures for this program include, however, about $1.6 Million for the Stormwater Program Grants-in-Aid, about 89% of the Program budget. The Policy and Evaluation Program, which has primary responsibility for review of local stormwater programs, is the smallest of the three Program, accounts for fewer than 10% of the Administration employees and about 12% of the Administration Budget. The Division responsible for review of local programs presently includes only three staff members.

Excluding administrative and clerical staff, approximately five to six technical staff (planners and engineers) actually work to administer stormwater regulations and grant programs. No new positions have been authorized to the Administration specifically for development of programs to achieve the 40% reductions in nutrients in urban nonpoint source loadings to the Bay, although the sediment and erosion control initiatives work towards this goal. The Sediment and Stormwater Administration has been designated the lead agency in Maryland to administer EPA's nonpoint source programs; the 319 grant will fund four additional staff people in the SSA. The SSA also has been assigned responsibility for development and administration of the NPDES system; however, no positions have been authorized to assist with development of the program.

Table 6. Sediment and Stormwater Administration, Staff and Budget.

Fiscal Year	1987	1988	1989	1990	1991
Budget (Million $)					
Policy and Evaluation					0.6
Construction Management					1.8
Compliance					1.4
Other Grants and Administration					1.1
Total Budget	3.3	3.2	3.4	4.1	4.9
Permanent Positions					
Policy and Evaluation					5
Construction Management					8
Compliance					39
Other Grants and Administration					6
Permanent Positions	46	44	43	58	58

Waterways at Risk

How Low-Impact Development Can Reduce Runoff Pollution in Michigan

Travis Madsen
Mike Shriberg

PIRGIM Education Fund

October 2005

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Executive Summary

Many communities in Michigan are developing in ways that create water quality problems in the Great Lakes and inland waterways.

Runoff from developed land contaminates waterways with pollution after rainstorms. Construction of roads and buildings replaces natural surfaces that store and clean rainwater with hard, impervious surfaces (like pavement) that divert water and pollution directly into creeks or into sewers. As a result, community growth can lead to higher levels of contaminated runoff, impaired drinking water quality, degraded wildlife habitat and uncontrolled sewage overflows.

One quarter of Michigan watersheds are impacted by or vulnerable to contaminated runoff from developed land.

- 5 percent of Michigan watersheds are impacted, with more than 15 percent of their land area covered by pavement and other impervious surfaces.
- Another 4 percent are moderately impacted, with between 10 and 15 percent impervious cover; and
- 15 percent of Michigan's watersheds are vulnerable to developing significant water quality problems as a result of expanded development, with between 5 and 10 percent impervious cover as of 2001. (See Figure ES-1.)
- According to a 2001 forecast, Michigan will add over 4 million acres of new development by 2040, nearly tripling the amount of built land. Development on this scale threatens to pollute inland waterways and increase downstream impacts in the Great Lakes.

Watersheds in rapidly developing communities are most at risk, including areas surrounding Detroit and Grand Rapids, plus smaller areas near Kalamazoo, Lansing and Traverse City.

Municipalities that issued more than 200 building permits for single family homes in 2004 and occupy watersheds vulnerable to water quality decline include:

- **Southwest Detroit Metro Area:** Ann Arbor, Ypsilanti, Superior, Canton, Van Buren, Romulus, Huron, Brownstown and Bedford;
- **Northwest Detroit Metro Area:** Clinton, Sterling Heights, Troy, Chesterfield, Macomb, Shelby,

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Figure ES-1: Impervious Cover in Michigan Watersheds

Impacted
(>15 Percent impervious)

Moderately Impacted
(Between 10 and 15 percent impervious)

Vulnerable
(Between 5 and 10 percent impervious)

Rochester Hills, Washington, Oxford, Independence, White Lake, Commerce, Novi, Northville, Davison, Grand Blanc, Holly, Mundy, Brighton and unincorporated Livingston County;

- **Grand Rapids Area:** Lowell, Plainfield, Gaines, Byron, Wyoming, Georgetown and Holland;
- **Additional Areas:** Portage, Delhi, Union, and Grand Traverse County. (See Figure ES-2.)

Poorly designed development can cause water pollution, but development using innovative low-impact development and smart growth principles can greatly reduce runoff and prevent harm.

- Poorly designed developments treat stormwater runoff as a waste product, creating more runoff at a given site by using gutters and drains to dispose of runoff in ponds, creeks and sewers. The problem is aggravated by sprawling growth patterns that create larger amounts of runoff for a given number of residents. For example, a community of low-density development with a large network of roadways along a river will impact a larger area and cause greater amounts of runoff than a high-density, low-impact development, while disrupting the natural water cleaning ability of the land around the waterway.
- In contrast, low-impact development techniques replicate the natural functions of the environment on-site, using green spaces, native landscaping, and a variety of other simple, cost-effective and low-tech methods to capture and treat stormwater close to where it falls. In addition, smart growth practices reduce the area of impact and protect critical parts of

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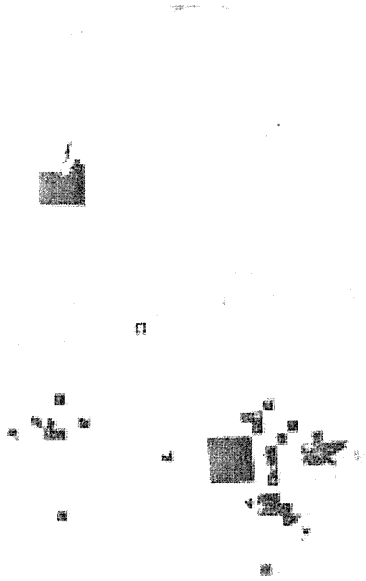
Figure ES-2: Rapidly Developing Areas At Risk of Water Quality Decline



the ecosystem by using strategic open spaces, infill development and redevelopment, and clustered, higher-density design—minimizing runoff in the aggregate.

Local governments have the power to promote smart growth and low-impact development.

Local governments can protect and restore local waterways by establishing riparian buffer zones, requiring no net runoff from new developments and implementing smart growth strategies. These policies can be included in community master plans and stormwater management plans, and included as legal requirements in zoning ordinances. Local governments should:

- Establish a natural buffer zone around creeks, streams or rivers. The state of New Jersey applies a 150- to 300-foot buffer zone to protect valuable drinking water supplies and their upstream headwaters.
- Change zoning policy in areas outside the urban core to require no net runoff from new developments. On-site measures should be capable of replicating pre-development runoff rates during a 2-year, 24-hour storm.
- Allow more flexibility in zoning policy to accommodate low-impact development principles. For example, zoning rules with strict requirements for wide streets or traditional stormwater infrastructure should be modified to allow equally effective low-impact strategies.
- Initiate low-impact retrofit programs in urban core areas like Detroit, Grand Rapids, Flint, Saginaw and Lansing to mitigate the impact of existing development.
- Couple riparian buffers, "no net runoff" and retrofit policies with broader smart growth strategies, including incentives for clustered development around town centers, infill development and redevelopment, strategic open land preservation and coordinated planning across local and regional boundaries. A comprehensive approach to growth will magnify the benefit of individual policies—leading to cleaner water locally and in the Great Lakes.

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Introduction: Restoring the Great Lakes Through Local Government

The Great Lakes and urban waterways in Michigan have suffered serious abuse since the first days of settlement. First forests were cleared, causing runoff and erosion. Then factories were built along rivers and lakeshore, complete with waste pipes leading directly to the water. Industrial pollution caused serious toxic contamination and declines in water quality, and a corresponding loss of plant and animal life. These trends continued unchecked until the environmental regulations of the late 1960s and early 1970s—especially the Clean Water Act of 1972—established limits on direct pollution of Michigan waters.

However, it has become increasingly clear that simply controlling industrial pollution is not enough to restore and protect Michigan waterways and the Great Lakes. The progress achieved in the last 15 years has stalled, and some positive trends have reversed. As stated in *The Great Lakes Green Book:* "We are going in the wrong direction."[1]

Irresponsible land use is now one of the most important threats facing the Great Lakes and inland waterways. Sprawling development and highway expansion create contaminated runoff. The pace and intensity of development increases the volume of water running through municipal systems. Impervious surfaces prevent the soil from absorbing waste accumulated in stormwater, and instead serve as a swift conduit to transmit that waste into the Lakes and connected waterways. In addition to causing direct runoff into the Lakes, these practices strain the capacity of municipal water treatment, resulting in sewage overflows, drinking water contamination and beach closings. Moreover, development is overtaking wetlands and other crucial habitats.

In contrast to industrial pollution, land use does not have defined discharge points that can be easily identified and regulated. To restore and protect the Great Lakes, Michigan needs to restore and protect the health of inland waterways. Since the source of the pollution is diffuse, the response must be distributed as well.

More than 70 organizations representing millions of residents in the region have joined a new coalition to restore and protect the Great Lakes. The Healing Our Waters-Great Lakes Coalition seeks to secure a sustainable restoration plan—including a plan to stop stormwater pollution—and the billions of dollars of state and federal funding needed to implement it.

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The coalition is currently working to develop a consensus Great Lakes restoration plan through the Great Lakes Regional Collaboration, led by the U.S. Environmental Protection Agency. The draft *Action Plan to Restore and Protect the Great Lakes* released in July 2005 calls for nearly $14 billion in new funding to help municipalities across the region plan and implement effective stormwater programs, with emphasis on comprehensive stormwater management, including low-impact development and other "soft-path" controls. The plan also sets a goal of virtually eliminating sewage overflows, primarily caused by stormwater infiltration of sewage systems, by 2020.

Implementing the plan will require action by Congress and the Great Lakes states. However, if done right, local governments will be doing most of the real work to stop runoff pollution—making individual development decisions, promoting smart growth patterns and encouraging innovative measures to prevent contaminated runoff at the source. Innovative low-impact development techniques can allow a community to grow while reducing the impact of development on inland water resources. They can also restore natural functions to existing urban areas and encourage revitalization, reducing pollution.

This report documents where development is occurring in Michigan and identifies areas of the state vulnerable to water quality decline. It also suggests policy ideas for local government to use in protecting water resources from new development or in restoring impaired waterways in urban areas. Taking advantage of these policies, local government in Michigan can play a central role in restoring and protecting local water resources and the Great Lakes.

For More Information

For more information on the Healing Our Waters-Great Lakes Coalition, visit www.restorethelakes.org.

Lake Michigan from Empire, MI.

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Sprawling Development Is Polluting Michigan's Water

Despite progress in controlling industrial water pollution over the last 30 years, water quality problems in Michigan persist. Most urban and suburban watersheds, and the near-shore areas of Great Lake cities, still do not have water that:[2]

- is safe for swimming;
- contains fish that are safe to eat; or
- supports diverse communities of plants and wildlife.

The Michigan Department of Environmental Quality (DEQ) monitors the status of lakes and rivers across the state. In the latest water quality report, the DEQ found that:[3]

- 80 miles of Michigan's Great Lakes shoreline is too polluted for use as a public water supply.
- More than a quarter of Michigan's inland lakes have high nutrient levels, which contribute to algae blooms, low oxygen levels and poor conditions for wildlife.
- At least 25 percent of the stream miles in Michigan tested between 1997 and 2003 did not fully support wildlife, swimming, drinking or fish consumption.
- Many impaired waterways are located in the southern half of the Lower Peninsula, near the majority of Michigan's population.

Irresponsible land use is one of the primary factors behind water pollution.[4] In particular, paving land increases the amount of runoff after rainstorms and seeds the runoff with contamination.

After heavy rainfall, water flows down rooftops, sidewalks, parking lots and streets, carrying everything from sediment to pesticides into waterways. In some areas, runoff overwhelms outdated sewage infrastructure, spilling raw or partially-treated sewage into waterways.

As a result, Michigan's streams, rivers and lakes become less suitable for drinking and less able to support a diverse community of wildlife. Areas downstream become more prone to flooding and sewage overflows. And the pollution ends up in the Great Lakes.

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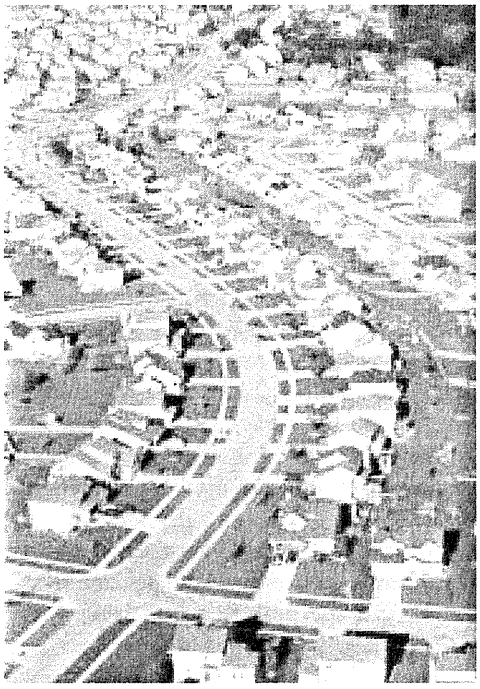
Development Is Increasing Faster Than Population Growth

Michigan is developing in ways that aggravate water quality problems. Between 1982 and 1997, developed land in the state increased by more than 30 percent.[5] New homes, shopping centers and businesses continued to move away from city centers into once-rural areas.

Land use grew much faster than population across much of the state. In some places, such as the Detroit and Saginaw metro areas, land use increased more than ten times faster than population.[6]

The trend toward this type of sprawling growth is readily apparent in Southeast Michigan:[7]

- Between 1990 and 2000, developed land increased by 17 percent, while population only increased by 5 percent.
- Almost half of the growth in land use was due to decreasing density of new residential areas.



- People leaving urban Detroit for the suburbs aggravated the trend. During the decade, over 7 square miles of land in urban Detroit became vacant.
- Most of the land available for future development is in outlying parts of the region, where plans and zoning specify low-density development typified by larger homes on larger lots.

This type of growth increases dependence on the automobile and requires more roads and paved land to serve a smaller number of people. Paving natural areas can have serious consequences for water quality, both locally and in areas downstream.

Development Causes Contaminated Runoff

Paving land with hard surfaces causes increased levels of stormwater runoff, which carries pollutants from roads, rooftops and parking lots into creeks and rivers.

When rain falls on natural, undeveloped land, water is captured by leaves, branches, ground cover, roots or soil. At Michigan's latitude and with its climate, much of the rain eventually evaporates back into the air. The remaining water either flows into a stream or filters underground into the water table.[8] In the process, vegetation and soils filter and clean the water of sediment and pollution.[9]

However, when natural landscape is replaced with a road, a driveway or a building, the ground becomes less able to capture water. Concrete, asphalt and rooftops do not absorb water. Instead, these impervious surfaces create runoff, directing large volumes of rainfall into gutters, trenches, canals and storm sewers.

High volumes of this runoff quickly reach nearby creeks, rivers and lakes:[10]

- Replacing a meadow with a parking lot increases runoff by about 16 times.[11]

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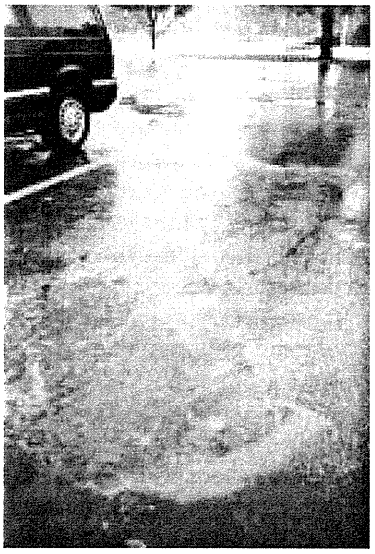
- In developed areas, up to 50 percent of rainwater or snowmelt becomes surface runoff.[12]
- In downtown areas, 90 percent or more of precipitation becomes runoff.[13]

This effect is apparent in Michigan:

- From 1964 to 1995, development-caused runoff in the Rouge River watershed increased the frequency of peak flooding levels by four times.[14] Development caused more water to flow immediately downstream as opposed to evaporate or filter into the water table.
- Sprawling development in the Detroit metro area built between 1982 and 1997 diverts over 8 billion gallons of water from the underground water table annually.[15]



Patricial Pennell, www.raingardens.org

Runoff from paved areas can carry pollutants (like the oil in this parking lot) into rivers.

Runoff Pollutes Drinking Water and Degrades Wildlife Habitat

Pollution from runoff causes significant problems for communities across the state. Contaminated drinking water must be filtered and treated before public use—which is harder and more expensive to do with more polluted water. Runoff also damages wildlife habitat and makes waterways less suitable for recreation.

Polluting Drinking Water

A source of clean drinking water is one of the most important requirements for a healthy community. Natural areas filter pollutants out of runoff and keep drinking water sources clean, making them a valuable part of the natural infrastructure that supports communities across the state.[16] Because natural areas provide clean water for free, their value often goes unrecognized and unincorporated into planning decisions.

In Michigan, public water supply systems use over 1.2 billion gallons of water per day. Close to 80 percent of that water comes from surface sources, including the Great Lakes and nearby rivers.[17] When this water is not clean, public water supply agencies have to spend money building and operating water treatment plants to remove contaminants, or risk making people sick.[18]

Runoff can make water supplies more polluted and increase water treatment costs for local governments. For example, New York City estimated that expanded development in the Catskill Mountains would pollute the city's water supply reservoirs, requiring up to $8 billion for a new treatment plant. The city determined that preserving natural areas to protect the reservoirs would ensure clean water for $5 billion to $7 billion less.[19]

Runoff can contain a variety of harmful contaminants that impair drinking water quality and threaten public health, including fallen air pollution, pesticides, and pollution from roads, like oil, salt, sediment and bits of rubber. Some of these chemicals are toxic, such as lawn care pesticides

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and diesel exhaust particles that fall back to the ground.

Other contaminants can become toxic during the drinking water treatment process. Drinking water treatment plants often use chlorine to kill the bacteria in the water before pumping it into homes and businesses. While this step protects the public from bacterial infections, chlorine treatment can produce byproducts when it reacts with organic pollutants and sediments that are also in the water. These chlorinated byproducts, such as trihalomethanes and haloacetic acids, are suspected to cause birth defects, miscarriages, and cancer.[20] Chlorination tends to be the treatment of choice in the Great Lakes region.[21]

Degrading Wildlife Habitat

Runoff can also reduce the ability of a waterway to support a full, diverse and healthy range of wildlife—reducing the capacity of the ecosystem to absorb and filter pollution, or to support activities like recreational fishing.

Runoff comes in large amounts after rainstorms, eroding stream channels and destabilizing stream banks, increasing the amount of sediment in the water.[22] These changes disrupt habitat for aquatic organisms and pollute the water.

Runoff also carries nutrients like phosphorus and nitrate compounds. These chemicals promote excessive growth of harmful aquatic vegetation like algae. As this vegetation dies and decays, it removes oxygen from the water, which can kill local species of aquatic plants and fish. This process is known as eutrophication, and it makes waterways less able to support fishing, recreation, industry and drinking.[23]

Increased pollution and degraded habitat kill sensitive species and lead to a shift toward more pollution-tolerant insects and weeds. Waterways surrounded by urban areas and with high levels of treated sewage discharge tend to have an impaired aquatic community, with a narrow range of pollution-tolerant species.[24] Waterways fed by land with a large amount of forest and wetlands are more likely to have a full and healthy aquatic community. Forests and wetlands provide a buffer from runoff pollution and help to maintain a healthy supply of water, food and habitat for sensitive species.[25]

Runoff Causes Flooding and Sewer Overflows

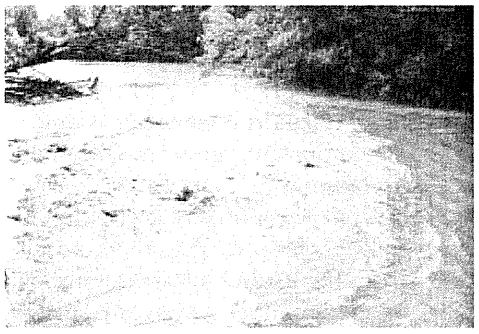
Runoff causes flooding in downstream areas by increasing the levels of water in a stream immediately after a storm. In some areas, flooding overwhelms outdated sewage infrastructure, spilling raw or partially-treated sewage into rivers and the Great Lakes.

Increasing Flooding

Runoff increases the amount of water reaching a waterway after a storm and raises the elevation of the flood plain, leading to higher flood vulnerability in downstream areas.

With 30 to 60 days of thunderstorms per year, Michigan can experience serious flooding.[26]

- Approximately six percent of Michigan's land is flood-prone, threatening about 200,000 buildings.[27]
- Flooding is the leading cause of disaster declarations by the governor or the president.[28]



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Runoff carrying sediment and pollution into Emmons Creek, in Caledonia, MI.

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- Michigan's annual flood-related damages are estimated to be between $60 and $100 million.[29]
- After flooding in May 2004, almost 34,000 people filed disaster claims with the Federal Emergency Management Agency, requesting more than $50 million in assistance.[30]

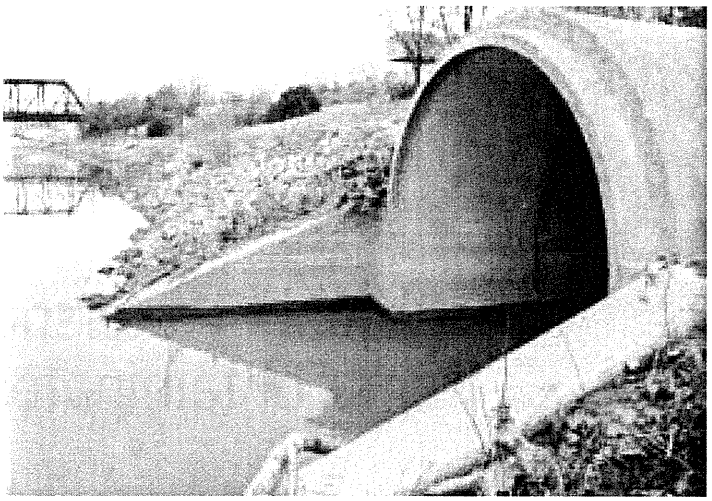
The experience of New Brunswick, New Jersey illustrates the connection between increased runoff and intensified flood damage. After Hurricane Floyd dropped 11 inches of rain on the New Brunswick area in 1999, the Raritan River escaped its banks and inundated part of the city, causing extensive damage. Upstream, development had added more than 2,700 acres of impervious surface (an 18.8% increase) in the previous 15 years.[31] The extra water diverted into the Raritan River by runoff from this development undoubtedly made the flooding damage in New Brunswick more extensive.

Sewage Overflows

Some storm drains are combined with sewage systems, which deliver contaminated water to a treatment plant. After heavy rainfall, these systems can overflow, dumping raw or partially-treated sewage into waterways. The U.S. EPA estimates that every year, trillions of gallons of untreated human sewage are discharged from such overflows.

In 2004, stormwater runoff led to the discharge of more than 27 billion gallons of sewage into Michigan waterways, and ultimately to the Great Lakes.[32]

Sewage discharge can contaminate waterways with fecal bacteria from human waste, making rivers and lakes unsafe for swimming or drinking.[33] In 2004, Michigan officials closed a swimming beach or



A stormwater outfall discharging directly into a waterway.

issued a bacterial contamination advisory for a total of 255 days (by county).[34]

For Additional Information

For further background on the causes and effects of stormwater pollution, see:

- *Urbanization Impacts on Aquatic Resources*, Public Sector Consultants for the Michigan Land Use Leadership Council. Available at www.michiganlanduse.org/resources/councilresources.htm
- *Stormwater Strategies: Community Responses to Runoff Pollution*, Natural Resources Defense Council. Available at www.nrdc.org/water/pollution/storm/stoinx.asp
- *Site Planning for Urban Stream Protection, Chapter 2: The Importance of Imperviousness*, The Center for Watershed Protection. Available at www.cwp.org/SPSP/TOC.htm

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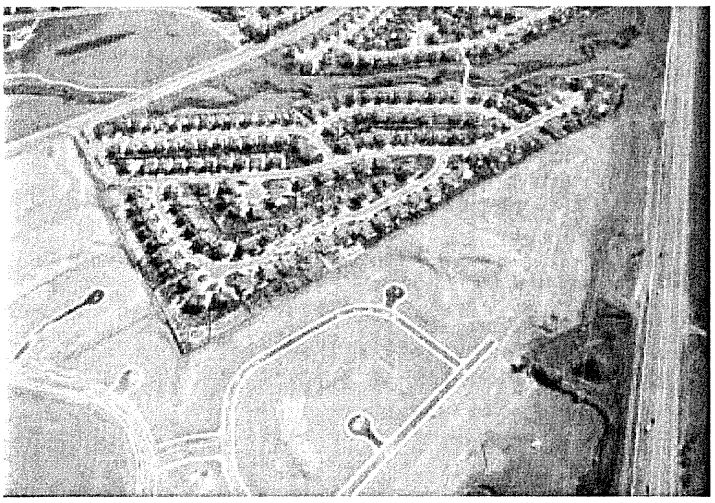
Michigan Watersheds at Risk from Contaminated Runoff

Watersheds in Michigan with intermediate levels of impervious surface cover and high levels of growth are at risk of developing water quality problems caused by runoff from new development. As future development expands into these areas, more contaminated runoff is likely to enter local waterways and flow downstream to the Great Lakes.



Development near rivers harms water quality.

Impervious Surface and Watershed Health

The amount and location of impervious surface in watersheds is closely connected to the health of downstream waterways.

- Pollution problems grow as urbanization increases, as forest cover decreases, and as riparian buffers between development and waterways decrease.[35]
- Watersheds with a large amount of forested cover, a large riparian buffer, and low levels of impervious surface tend to have better water quality. When a watershed is developed to the point where 25 percent or more of the land is impervious, severe water quality degradation results.[36]
- Water quality problems tend to become apparent when 5 to 10 percent of a watershed is covered with impervious surfaces. Adding more impervious surface leads to more serious water quality problems.[37]

A significant number of watersheds in Michigan are vulnerable to development-

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Figure 1: Impervious Cover in Michigan Watersheds

Impacted
(>15 Percent impervious)

Moderately Impacted
(Between 10 and 15 percent impervious)

Vulnerable
(Between 5 and 10 percent impervious)]

caused runoff and water quality problems. Based on analysis of 2001 land use data obtained from the Michigan Department of Environmental Quality, areas in the urban cores of major cities in Southern Michigan have the highest levels of impervious surface. Watersheds surrounding these areas have intermediate levels of impervious surface coverage and still retain significant natural areas that mitigate water pollution. (See Methodology for analysis description.)

As shown in Figure 1, of Michigan's roughly 1,650 sub-watersheds:

- 15 percent have between 5 and 10 percent impervious cover and are vulnerable to developing significant water quality problems with increased development.
- Another 4 percent have between 10 and 15 percent impervious cover and are moderately impacted.
- 5 percent have more than 15 percent impervious surface and are impacted.

Watersheds in heavily urbanized areas tend to have the most severe water quality problems in the state. Some watersheds in central Detroit have up to 40 percent of their land area covered by impervious surface. Waterways in these areas receive heavy loads of pollution from stormwater runoff, in addition to industrial discharge and sewage treatment plant discharge.

Vulnerable watersheds tend to be in the same locations that are under increasing pressure from development—the outlying areas of major population centers.

In 2001, the Michigan Land Resource Project, an initiative of the Frey Foundation and the W.K. Kellogg Foundation on behalf of the Michigan Economic and Environmental Roundtable, projected what the state would look like in 40 years if business as usual continued. They concluded that Michigan would add over 4 million acres (6,250 square miles) of new development by 2040, nearly tripling the amount of built land.[38]

In Southeast Michigan, local governments forecast a 36 percent increase in

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developed land from 2000 to 2030. The addition of a half-million more people (a 12 percent increase in population), coupled with more households and land zoned for low-density development, could drive land use to increase at least as fast as recent trends.[39]

If recent development patterns continue, in addition to growing amounts of built land, many more Michigan waterways will succumb to the effects of stormwater runoff pollution.

Rapidly Growing Municipalities

Southeast Michigan is the center of development activity in the state, followed by Southwestern Michigan near Grand Rapids.

Nearly 23,000 permits for single-family residences—a proxy measure for residential development characteristic of "sprawl"—were issued in Southeast Michigan in 2004, 55 percent of all such permits issued in the state. Over 5,500 permits were issued in the area surrounding Grand Rapids, accounting for 15 percent of the statewide total.

Figure 2 shows the number of building permits issued by municipality or unincorporated county across the Lower Peninsula.

Figure 3 shows the municipalities that issued more than 200 building permits in 2004, plus counties that issued over 500 building permits in unincorporated areas. These areas make up the 43 most rapidly developing municipalities in the state.

Figure 2: Building Permits Issued for Single-Family Residences in 2004

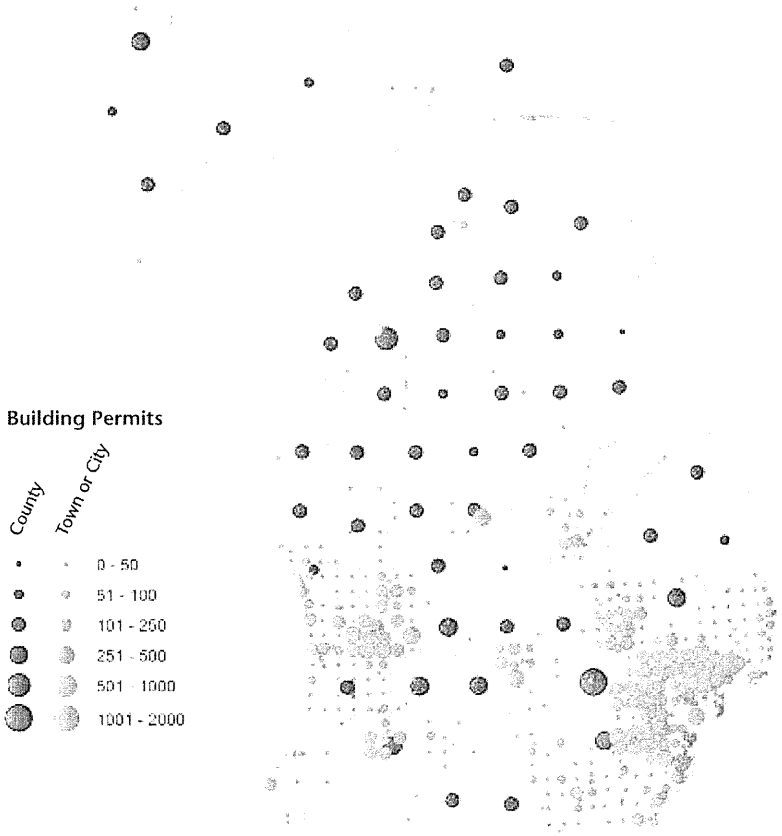

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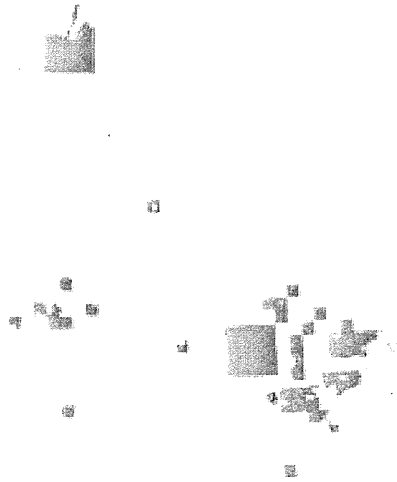
Figure 3: The Most Rapidly Developing Municipalities and Counties in Michigan



Watersheds in Areas of Rapid Growth Are Most at Risk

Watersheds in rapidly developing communities are most at risk for water quality degradation caused by runoff from new development. We define the most at-risk communities as areas that issued more than 200 building permits for single family homes in 2004 and occupy watersheds vulnerable to water quality decline (between 5 and 15 percent impervious surface).

These areas are primarily surrounding Detroit and Grand Rapids, with other important areas near Kalamazoo, Lansing and Traverse City, including:

- **Southwest Detroit Metro Area:** Ann Arbor, Ypsilanti, Superior, Canton, Van Buren, Romulus, Huron, Brownstown and Bedford;
- **Northwest Detroit Metro Area:** Clinton, Sterling Heights, Troy, Chesterfield, Macomb, Shelby, Rochester Hills, Washington, Oxford, Independence, White Lake, Commerce, Novi, Northville, Davison, Grand Blanc, Holly, Mundy, Brighton and unincorporated Livingston County;
- **Grand Rapids Area:** Lowell, Plainfield, Gaines, Byron, Wyoming, Georgetown and Holland;
- **Additional Areas:** Portage, Delhi and Union, and Grand Traverse County.

These areas are shown in Figure 4. Table 1 lists the number of building permits in each area in 2004. Figure 5 shows a close-up view of vulnerable watersheds and rapidly developing communities in Southeast Michigan.

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Figure 4: Communities Most at Risk of Water Quality Degradation Caused by Runoff from New Development

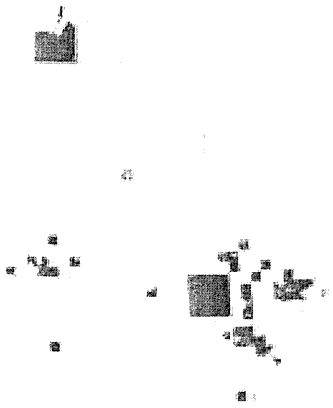

Figure 5: Rapidly Developing Towns and Vulnerable Watersheds in Southeast Michigan

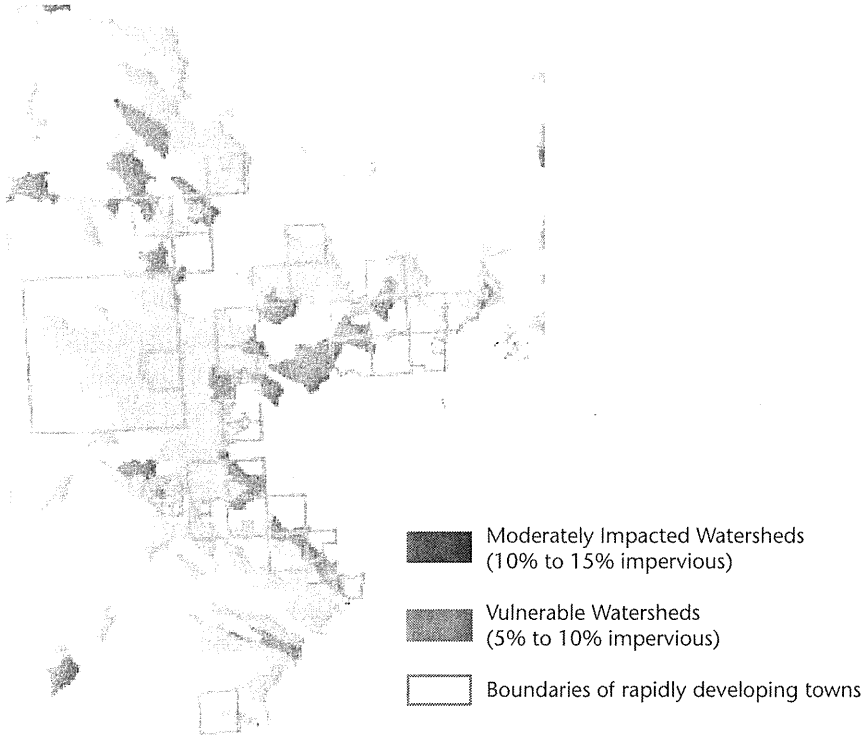

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Table 1: Number of Single-Family Home Building Permits Issued in 2004 in At-Risk Municipalities

	Town	County	Permits Issued for Single-Family Homes in 2004
1	Livingston County	(Unincorporated)	1,563
2	Macomb Township	Macomb	1,087
3	Shelby Township	Macomb	755
4	Chesterfield Township	Macomb	663
5	Sterling Heights	Macomb	621
6	Grand Traverse County	(Unincorporated)	581
7	Novi	Oakland	505
8	Ypsilanti Township	Washtenaw	495
9	Northville Township	Wayne	488
10	Van Buren Township	Wayne	469
11	Huron Township	Wayne	465
12	Lowell Township	Kent	399
13	Canton Township	Wayne	396
14	Washington Township	Macomb	369
15	Georgetown Township	Ottawa	353
16	Brownstown Township	Wayne	343
17	White Lake Township	Oakland	339
18	Union Township	Isabella	328
19	Commerce Township	Oakland	326
20	Grand Blanc Township	Genesee	316
21	Byron Township	Kent	314
22	Troy	Oakland	311
23	Rochester Hills	Oakland	302
24	Ann Arbor	Washtenaw	283
25	Delhi Township	Ingham	266
26	Gaines Township	Kent	252
27	Independence Township	Oakland	246
28	Romulus	Wayne	245
29	Mundy Township	Genesee	244
30	Oxford Township	Oakland	242
31	Bedford Township	Monroe	241
32	Holly Township	Oakland	236
33	Brighton Township	Livingston	227
34	Clinton Township	Macomb	219
35	Wyoming	Kent	217
36	Plainfield Township	Kent	214
37	Superior Township	Washtenaw	211
38	Portage	Kalamazoo	209
39	Davison Township	Genesee	207
40	Holland Township	Ottawa	201

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Low-Impact Development and Smart Growth Can Prevent Water Pollution

Irresponsible land use creates contaminated runoff at two separate levels. At the level of the individual development, traditional stormwater management practices treat stormwater runoff as a waste product, creating more runoff at a given site by using gutters and drains to dispose of runoff in ponds, creeks and sewers. These practices at best fail to take advantage of natural features of the landscape that could minimize pollution—and at worst, reduce the ability of the landscape to filter pollution out of the water.

At the aggregate, community-wide level, sprawling growth patterns create larger amounts of runoff for a given number of residents and can encroach into critical areas of the ecosystem. For example, a community of low-density development with a large network of roadways along a river will impact a larger area and cause greater amounts of runoff than a high-density, low-impact development, while disrupting the natural water cleaning ability of the land around the waterway. Together, sprawling development and traditional stormwater management pollute waterways.

Two approaches are necessary to solve the problem—low impact development and smart growth. At the site level, low-impact development techniques aim to make the built environment function more like the natural environment. By customizing the approach to natural features of the landscape, incorporating green spaces, planting native landscaping, using absorbent surfaces, and implementing other simple, cost-effective and low-tech methods, low-impact development manages stormwater close to where it falls. Low-impact practices capture and treat stormwater on-site, allowing runoff to soak into the ground, evaporate or be stored for later use in irrigation.

At the community-wide level, smart growth practices reduce the area of impact and protect critical parts of the ecosystem. Smart growth uses strategic open spaces, infill development, town center redevelopment and clustered, higher-density design to minimize runoff in the aggregate.

Combining these two approaches in a comprehensive plan to manage growth will magnify the benefit of individual policies and lead to cleaner water locally and in the Great Lakes. There are a variety of additional benefits as well, including more beautiful and desirable urban areas; reduced costs for municipalities; increased developer profits and improved quality of life.

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Principles of Low-Impact Development

Underlying low-impact development is a set of principles that focus on creating a built landscape with the function of a natural landscape—or retrofitting an urban area to restore ecological function. Low-impact principles include:[40]

1) Focus on prevention of runoff rather than mitigation;
2) Conserve natural landscape features and processes to retain stormwater and filter pollution;
3) Emphasize simple, non-structural, low-tech and low-cost methods;
4) Manage runoff as close to the source as possible;
5) Minimize effective impervious surface area by directing runoff to "rain gardens" and other natural infrastructure;
6) Encourage private landowner stewardship to reduce stormwater runoff;
7) Take a "fix-it-first" approach to public infrastructure, prioritizing the updating and separating of stormwater and sewer systems; and
8) Customize the approach to the land under consideration.

A "rain garden" designed to absorb and treat runoff from a parking lot.

Permeable pavement.

For Additional Information

For more information on low-impact development, see:

- *Catching the Rain: A Great Lakes Resource Guide for Natural Stormwater Management*, American Rivers. Available at www.americanrivers.org.
- "Low-Impact Development," Chapter 12 of *Stormwater Strategies: Community Responses to Runoff Pollution.* Natural Resources Defense Council. Available at www.nrdc.org.
- *Low-impact Development: Urban Design Tools*, a web page addressed to watershed managers, created by the U.S. EPA and the Low-Impact Development Center. Available at www.lid-stormwater.net
- *Low-Impact Development Design Strategies: An Integrated Design Approach*, Prince George's County, Maryland and U.S. EPA. Available at www.epa.gov/owow/nps/lid.
- The Green Roof Research Program at Michigan State University: www.hrt.msu.edu/greenroof.

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Principles of Smart Growth

Low-impact development principles work equally well in a variety of situations—from urban retrofits to new sprawl-style developments in rural areas. Thus, a broader approach to creating sustainable communities is also necessary to maximize the impact of low-impact development.

Low-density developments tend to have large amounts of impervious surface serving a smaller number of people. As a result, communities zoned for low-density development impact a much larger area. According to research at the U.S. EPA, low-density development (1 unit per acre and 20 percent impervious cover) creates almost three times as much runoff as high-density development (8 units per acre and 65 percent impervious cover).[41]

Several additional studies document the benefits of higher-density development in reducing runoff:

- Researchers in Connecticut found that low-density sites produce 95 percent more runoff during construction than high-density sites.[42]
- The Chesapeake Bay Foundation found that high density developments convert 75 percent less land area, create 42 percent less impervious surface and produce 41 percent less runoff than low-density development.[43]
- The New Jersey *State Plan* calls for higher-density development around town centers and infill development in areas with existing infrastructure. Researchers at Rutgers University found that this plan would reduce runoff by 30 percent versus business as usual.[44]

Accordingly, low-impact development techniques should be used in conjunction with a broader approach to creating healthy, sustainable communities following the principles of smart growth. Ideally, a smart growth community will:[45]

- Mix land uses;
- Use compact building and community design, built around vital town centers;
- Create a range of housing opportunities;
- Create walkable neighborhoods;
- Foster distinctive, attractive communities;
- Preserve open space, farmland, natural beauty and critical environmental areas;
- Invest in and maintain existing communities;
- Restore and redevelop abandoned buildings and sites;
- Provide a variety of transportation choices;
- Make development decisions predictable, fair and cost-effective;
- Encourage community involvement in planning and development decisions; and
- Coordinate planning across town and regional boundaries.

For Additional Information

For additional detail on the core principles of smart growth, a brief history of the issue, and a detailed list of policies associated with smart growth, please see the American Planning Association's *Policy Guide on Smart Growth*, available at www.planning.org.[46] See also *Smart Growth for Clean Water: Innovative Strategies for NPDES Phase II Stormwater Management in Michigan*, a report by the Michigan Environmental Council, available at www.mecprotects.org.

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Local Governments Should Promote Low-Impact Development and Smart Growth

Local governments are the center of land-use decision-making in Michigan. Villages, townships, cities and counties all play a role in how development proceeds within their boundaries.

Local governments regulate development using two main tools: master growth plans and zoning ordinances. The master planning process represents a long-term vision for how, where and when growth is intended to occur—and what natural features or resources deserve preservation. Zoning ordinances are the nuts and bolts of the master plan, identifying areas where residential, commercial or industrial development is allowed and setting rules for design and construction. Both of these forums offer opportunities to protect water quality by promoting low-impact development and smart growth.

A comprehensive approach to policy reform will have the greatest effect, combining the best features of on-site low-impact development techniques and community-wide smart growth strategy.

Policies that will protect waterways from new sources of stormwater runoff include establishing buffer zones around waterways (in both the master plan and the zoning ordinance) and legally establishing a no net runoff standard as a part of the zoning code. In addition, communities in more heavily urbanized areas can set up retrofit programs to mitigate the effects of pre-existing development. These changes need to be coupled with broader smart growth strategies, including incentives for clustered development around town-centers, infill development and redevelopment, strategic open land preservation and coordinated planning across local and regional boundaries.

For Additional Information

For a guide to local government and land use planning in Michigan, see:

- Citizen's Guide to Land Use Planning, *Huron River Watershed Council, available at www.hrwc.org/program/land.htm.*
- Better Site Design: A Handbook for Changing Development Rules in Your Community, *Center for Watershed Protection. Available for purchase, with associated free resources available at: www.cwp.org/bfb_better_site_design.htm*

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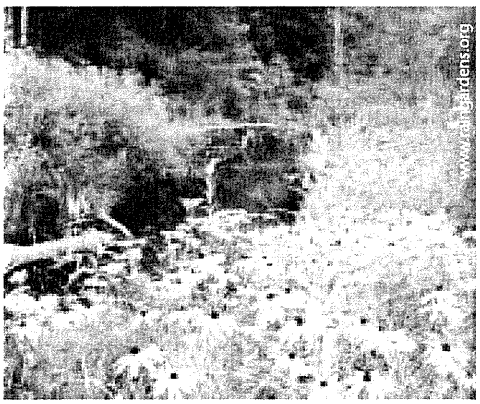
Creating Buffer Zones Around Waterways

Waterways with healthy riparian areas are much less vulnerable to runoff pollution. Preserving these areas is an important way local governments can prevent water quality problems, while also offering beautiful natural areas for citizens to enjoy.

Community master plans should identify riparian areas as a critical natural resource and source of clean drinking water. Accordingly, the plan should establish the intent of preserving a natural buffer zone along and around waterways. The state of New Jersey uses a 150 to 300-foot buffer to protect creeks, streams, rivers, reservoirs and headwaters that are important sources of drinking water or have other important values.[47]

However, master planning documents are not legally binding—rather, they indicate the vision for how the community will grow and develop over time. To legally require preservation of a buffer zone around a waterway within a locality, a buffer zone ordinance would be required. The ordinance would establish specific rules for the establishment, protection and maintenance of riparian areas along stream corridors.

A model buffer zone ordinance establishing a 200 foot buffer can be found at the Center for Watershed Protection's Stormwater Manager's Resource Center, online at www.stormwatercenter.net. Additional information about stream buffer design can be found in *The Architecture of Urban Stream Buffers*, a publication of the Center for Watershed Protection available at www.cwp.org.



Establishing a "No Net Runoff" Standard for New Development in Areas Outside the Urban Core

A community zoning ordinance establishes rules that govern the design and construction of all types of development, from residential areas to commercial shopping areas and office complexes to industrial sites.

Zoning regulations offer an opportunity to require new development to prevent stormwater runoff. The key features of a low-impact stormwater ordinance should include:

1) A standard of no net runoff from new development. An appropriate standard would be replication of pre-development runoff characteristics during a 2-year, 24-hour storm event. This level of performance would offer significant benefits in terms of detaining runoff and treating runoff contamination. In addition, research has shown that this level of performance protects downstream areas from flooding even during a 100-year storm.[48]

2) Flexibility for developers to use a wide range of non-structural low-impact development practices to achieve that standard.

3) Revision of outdated requirements that interfere with low-impact development practices or promote greater levels of impervious surface, including requirements for excessively wide streets, large setbacks or traditional stormwater infrastructure.

The zoning ordinance should specifically endorse and encourage low-impact

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development features that residents and local leaders find desirable, while revising older parts of the ordinance that prohibit effective stormwater management. For example, the town of Lacey in Washington State has adopted rules eliminating legal barriers to the use of zero-impact principles. The goal of the ordinance is to allow developments to achieve near-zero effective impervious surface. However, the ordinance is voluntary and no incentives or requirements to use low-impact techniques yet exist. To date, two separate developmers have taken advantage of the ordinance. The Villages at Hicks Lake and the Long Lake Retirement Community plan to incorporate a range of low impact techniques to achieve zero impact, including narrower roads, forest conservation, bioretention swales and permeable pavement.[49]

In 1996, the Center for Watershed Protection gathered experts together in a site-planning roundtable and produced a list of 22 model development principles.[50] These principles, plus a codes and ordinances worksheet, can help community groups evaluate local zoning policy and identify areas where changes to reduce impervious cover, conserve natural features and prevent stormwater pollution are necessary.

For Additional Information

For further information on model development principles, see:

- *Site Planning Model Development Principles*, Center for Watershed Protection. Available at www.cwp.org/22_principles.htm.
- The "Codes and Ordinances" worksheet at the same site offers tools to evaluate your own community.
- A technical support manual with greater detail on each design principle and how to incorporate them into municipal code is available for purchase: *Better Site Design: A Handbook for Changing Development Rules in Your Community*, Center for Watershed Protection, www.cwp.org. Associated presentations and other free resources are available at www.cwp.org/bfb_better_site_design.htm.

Retrofit Programs in the Urban Core

Policies that reduce runoff from new development won't be as effective in more heavily urbanized areas of Michigan. Community organizations located in these areas can instead work with their local governments to establish retrofit programs to reduce the impact of existing development on water quality. Low-impact development principles are effective for retrofit projects as well as for new development.

For example, Chicago has established a requirement that all new or refurbished roofs in the city either use living material or a reflective surface. The intent of the rule is focused on the heat gain from so many black roofs and to promote energy efficiency. However, green roofs, such as the rooftop meadow atop Chicago City Hall, will also significantly reduce stormwater runoff.[51]

Seattle has established a retrofit program to address runoff from roadways called "SEA Streets." The program seeks to retrofit the ditch and culvert drainage system in the northern part of the city with innovative natural approaches to manage runoff. The first demonstration project included installation of vegetated swales, gardens, tree preservation and planting, and street improvements that reduce impervious surface cover.[52]

Local governments in Michigan should follow these examples and create their own retrofit programs. Low-impact development principles can help restore natural functions in these areas while improving natural beauty, energy efficiency, and quality of life.

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Funding Retrofit Projects

Funding will likely be a major challenge facing any new retrofit project to improve urban stormwater infrastructure with low-impact techniques. The U.S. Environmental Protection Agency recommends the following resources to assist communities seeking funding for stormwater management:[53]

- **An Internet Guide to Financing Stormwater Management** - This site was designed to help communities find ways to fund stormwater management projects. http://stormwaterfinance.urbancenter.iupui.edu/
- **Catalog of Federal Funding Sources for Watershed Protection** - The Catalog of Federal Funding Sources for Watershed Protection Web site is a searchable database of financial assistance sources (grants, loans, cost-sharing) available to fund a variety of watershed protection projects. http://cfpub.epa.gov/fedfund/
- **State Revolving Fund** - State Revolving Fund programs in each state and Puerto Rico are funded by EPA and operated like banks. Assets are used to make low- or no-interest loans. www.epa.gov/owm/cwfinance/cwsrf/index.htm

In addition, if Congress and state governments act on the recommendations of the Great Lakes Regional Collaborative (see Introduction), new programs and funding sources will be created.

Promote Broader Smart Growth Strategies

Low-impact development reforms will be most effective when coupled with a broader strategy to create healthy, sustainable communities.

There are a variety of reasons to adopt a smart growth strategy to guide long-term development. In terms of water quality, smart growth reduces the overall potential for runoff. Smart growth has a variety of additional benefits, including:

- Cost savings for municipalities;
- Enhanced tourism and other business opportunities;
- Vital neighborhoods;
- Community quality of life;
- Recreation, parks and open space; and
- Improved transportation options.

Smart growth strategies have to be implemented at the local, county, regional and state level. Locally, governments can promote clustered development around town centers, infill development and redevelopment, and strategic open land preservation.

Because local governments can control their own growth decisions, but not those of neighboring areas, they should engage in coordinated planning across local and regional boundaries to create a plan for the future that is consistent across a wide area, and takes into account natural resources in a regional context. Local governments should also encourage leaders at the county and state level to facilitate the inclusion of smart growth principles in policies regulating growth and development.

Local governments in Michigan have the resources and tools to minimize the effect of development on water quality. By coupling low-impact development strategies with smart-growth principles in a comprehensive approach, communities can maximize the benefit of individual policies and create new patterns of land use. The rewards will include cleaner streams and rivers, fewer sewage spills, and healthier Great Lakes.

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Patricia Pennell, www.raingardens.org

Patricia Pennell, www.raingardens.org

Low-impact development and smart growth techniques can prevent streams like Basset Creek (top) from turning into Whiskey Creek (bottom), and protect the Great Lakes from pollution.

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Methodology

Impervious Surface Calculation

To calculate the levels of impervious surface in Michigan, we used two main data sources:

- 2001 land use data for Michigan's Lower Peninsula at 30 meters square resolution, obtained from the Michigan Geographic Data Library;[54] and
- U.S. Geological Survey watershed boundaries at the Hydrologic Unit Code-14 (HUC 14) level, obtained from the Michigan Geographic Data Library.[55]

After obtaining the data, we used Geographic Information Systems software to analyze land use and calculate the levels of impervious surface in each watershed.

1) Using ArcView GIS software, we cut the land use file into pieces representing each HUC 14 watershed in the Lower Peninsula.
2) We analyzed each individual watershed land-use file to determine the area of each type of land, listed in Table 2.
3) We calculated the percentage of the watershed covered by impervious surface, using the percentage of each land use type estimated to be impervious, as interpreted from work done by the Rouge Program Office to measure impervious surface coverage on various land uses in Southeast Michigan from aerial photographs, supplemented by similar studies of impervious cover from other locations.[56]

Identifying At-Risk Watersheds

To identify at-risk watersheds, we looked at municipalities that issued more than 200 building permits for single-family residences in 2004 (or unincorporated areas of counties that issued more than 500 building permits) that contained a watershed with more than 5 percent but less than 15 percent impervious surface.

Building permit information for 2004 was compiled by the U.S. Census bureau.[57] We linked permit data to a GIS file representing Michigan villages, townships, cities and counties to produce the building permit maps in the report and calculate overlap with specific watershed areas.

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Table 2: Estimated Percentage Impervious Cover by Land Use

Land Use Code	Land Use Category	Percent Impervious Surface
0	Background	EXCLUDED
1	Low-Intensity Urban	19%
2	High-Intensity Urban	51%
3	Airports	53%
4	Roads and Parking Lots	53%
5	Non-Vegetated Farmland	2%
6	Row Crops	2%
7	Forage Crops	2%
9	Orchards	2%
10	Herbaceous Openland	2%
12	Low-Density Trees and Shrubs	2%
13	Golf Courses and Parks	11%
14	Northern Hardwood	2%
15	Oaks	2%
16	Aspens	2%
17	Other Upland Deciduous	2%
18	Mixed Upland Deciduous	2%
19	Pines	2%
20	Other Upland Conifers	2%
21	Mixed Upland Conifers	2%
22	Upland Mixed Forest	2%
23	Water	EXCLUDED
24	Lowland Deciduous Forest	2%
25	Lowland Coniferous Forest	2%
26	Lowland Mixed Forest	2%
27	Floating Aquatic	2%
28	Lowland Shrubs	2%
29	Emergent Wetland	2%
30	Mixed Non-Forest Wetland	2%
31	Sand and Soil	3%
32	Bare Rock	50%
33	Mud Flats	2%
35	Other Bare / Sparsely Vegetated	5%

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Harriet Eckstein Graphic Design

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NRDC

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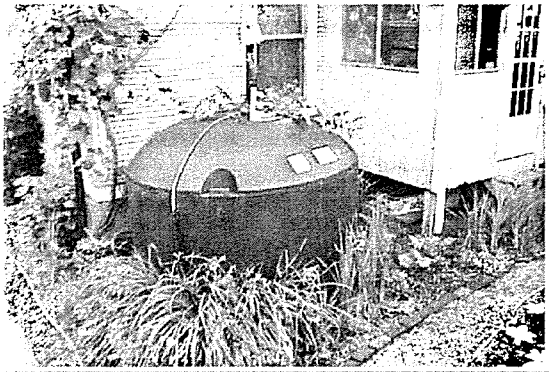
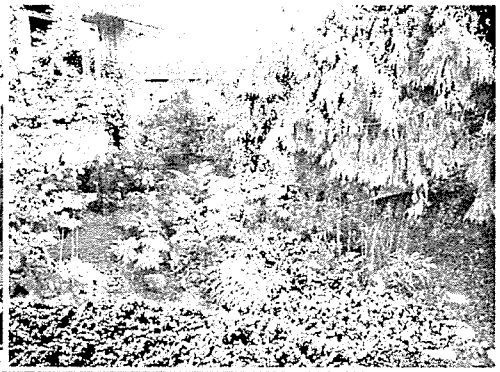
An Assessment of:

Outer Banks Coastal Environmental Conditions, Existing Stormwater Management Strategies, and the Local and State Regulatory Context to Help Local Communities Effectively Implement Low Impact Development

Outer Banks, North Carolina





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An Assessment of Outer Banks Coastal Environmental Conditions, Existing Stormwater Management Strategies, and the Local and State Regulatory Context to Help Local Communities Effectively Implement Low Impact Development – Outer Banks, NC

Completed for the Outer Banks Hydrology Management Committee With UNC-CSI

Funding for this work was provided by the National Oceanic and Atmospheric Administration through the NC Department of Environment and Natural Resources' Coastal Nonpoint Source Program (Grant Award #NA03NOS41900094).

FINAL REPORT

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Executive Summary

This study provides an overall assessment of the feasibility of using LID methods as part of a regional integrated stormwater management program on the Outer Banks.

Based on a review existing stormwater policies for communities within the Outer Banks LID Study Area, limited impediments to LID were identified in existing ordinances. Several recommendations are made to modify general ordinances to facilitate the use of LID. To embrace LID, a shift from the current philosophy (of conveying stormwater from a site) will be required to eliminate stormwater runoff from the site, maximizing retention and treatment within each lot. A *Model Ordinance for Stormwater Management in the Outer Banks* was developed and is intended to serve as a framework for all communities within the study area.

The majority of potentially developable properties along the Outer Banks have been subdivided and platted for residential housing and associated real estate development. In Dare County, approximately 22% of potentially developable parcels have not been constructed upon; in Currituck County, approximately 54% of developable parcels have not been constructed upon.

Two major factors impede the implementation of LID in the Outer Banks. The first, the presence of a high water table, is a physical constraint. The second, property boundaries, is a legal constraint. For LID techniques to have significant positive benefits, these must be undertaken through retrofit projects within existing residential developments and associated areas. Both LID Site planning techniques and structural stormwater measures may be applied in the Outer Banks. Site planning techniques include clustering of structures, reducing impervious surfaces and grading to conform to natural topography. Structural measures which are recommended in the Outer Banks include bioretention areas, vegetated filter strips, cisterns, vegetated open channels, permeable pavement.

Several organizational options exist for developing and implementing LID strategies for storm water management. It is recommended that LID be promoted through a two pronged approach whereby:

1. Existing municipal and county stormwater programs and ordinances be revised to provide incentives, remove impediments and strongly encourage LID practices for new development and redevelopment; and

2. In cooperation with the Dare and Currituck County Soil and Water Conservation District (SWCD) s and UNC-CSI, communities work to (a) develop pilot projects for educational purposes, (b) facilitate LID workshops and (c) seek state and federal support to retrofit existing properties.

Public workshops and pilot projects illustrating the benefits and use of LID will be instrumental in achieving public support and implementation. UNC-CSI and SWCD should continue to facilitate workshops which provide a platform for the public and site developers to learn more about LID practices.

1.0 Introduction

In 2005, the Outer Banks Hydrology Management Committee was convened to review issues related to flooding and stormwater problems facing Dare and Currituck counties. The Committee identified problems linked to stormwater management in the Outer Banks including flooding, closing of shellfish beds, property damage and threatened water quality of the receiving waters. Based on stakeholder input, the committee outlined a number of action items to address stormwater and water quality issues in the Outer Banks. Recommendations by the Committee were outlined in a Report of Findings (University of North Carolina Coastal Studies Institute (UNC-CSI), 2005).

A key recommendation by the Committee was to remove barriers and develop incentives for the use of Low Impact Development (LID) in the Outer Banks. LID's goal is to mimic a site's predevelopment hydrology by using techniques that infiltrate, filter, store, evaporate and detain runoff close to its source.

This study is a follow-up to the efforts by the Outer Banks Hydrology Management Committee, conducted for UNC-CSI in partnership with Dare and Currituck Counties. This study was undertaken to assess the feasibility of using LID methodologies as part of a regional integrated stormwater management program in the Outer Banks. Specific study objectives are to:

(a) Review existing stormwater policies for communities within the Outer Banks LID Study Area and identify impediments to LID;
(b) Provide a review of existing land use and soil conditions and planned development and identify what LID strategies may be applied in the Outer Banks;
(c) Develop a model stormwater ordinance which may be used as the framework for all communities in the Outer Banks & identify appropriate performance ordinances (hydro curve numbers) and
(d) Review organizational options for regional stormwater management and identify a strategy for implementation of LID practices.

The LID Study Area encompasses all of the Outer Banks portions of Dare and Currituck Counties (Exhibit 1).

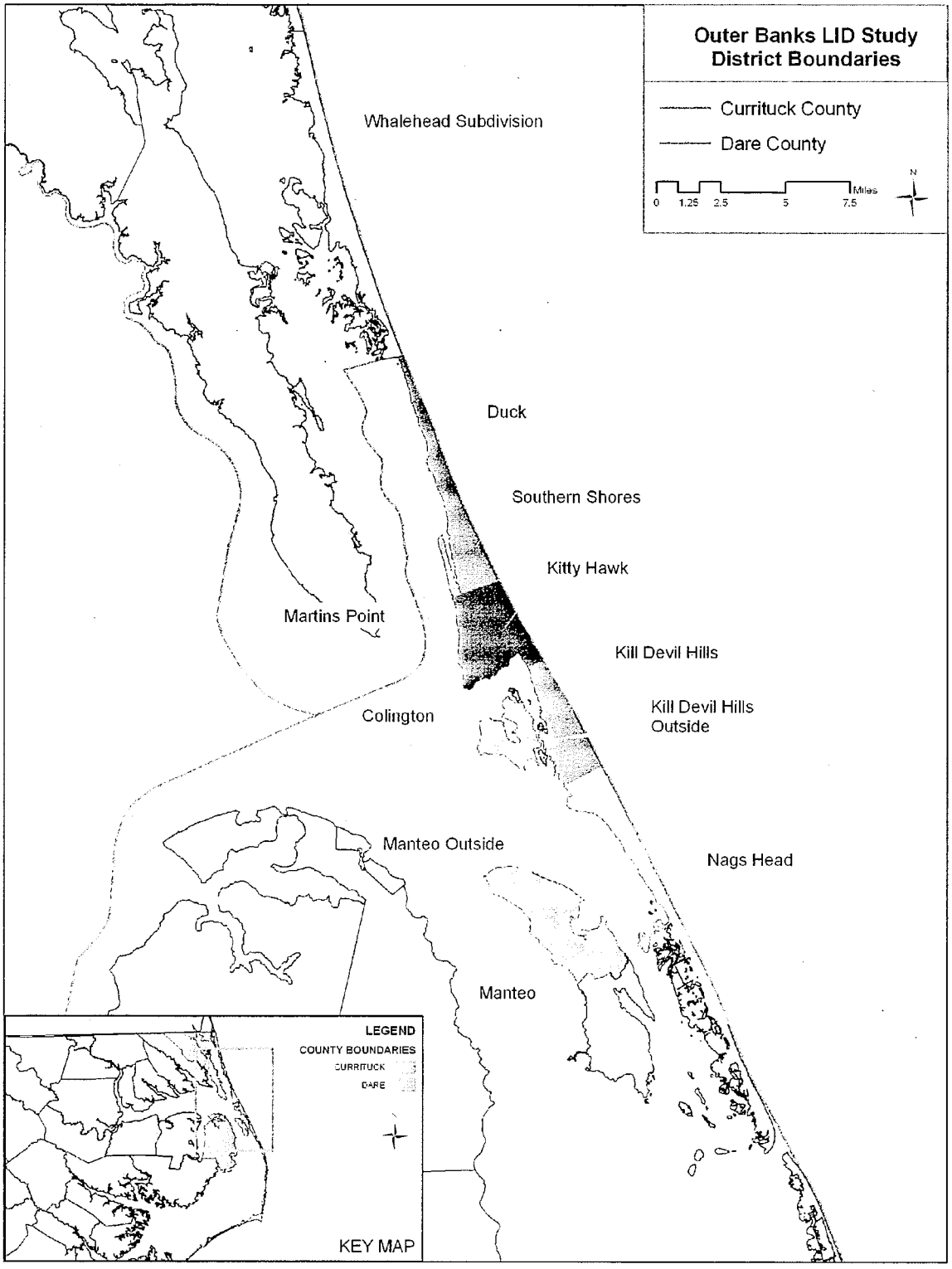

Exhibit 1. Outer Banks LID Study Area

2.0 Overview of LID

2.1. Definition

Low Impact Development (LID) is the implementation of real estate development in such a manner that the postdevelopment hydrologic response mimics the predevelopment hydrologic response (quantity, character, and constituents). Other components such as landscape aesthetics, wildlife habitats, and temperature buffers are sometimes included.

2.2. Outer Banks Real Estate Development and Stormwater Management

Prior to real estate development along the Outer Banks, most precipitation reaching the ground surface outside wetland areas would infiltrate into the soil. Surface waters (creeks, streams, sounds, and ocean) were well buffered by wetlands and high infiltration potential soils. These areas provided natural treatment of stormwater constituents which can negatively affect the surface waters. Prior to real estate development along the Outer Banks, such constituents were generally limited to fecal coliform from birds and mammals. Other common stormwater constituents which can negatively affect surface waters include nutrients (nitrogen, phosphorous, etc), petroleum products (greases, oils, etc), heavy metals (lead, copper, mercury, chromium, cadmium, zinc, etc), and biological control agents (herbicides, pesticides). Significant sources of these stormwater constituents were not present along the Outer Banks prior to real estate development.

As real estate development has increased along the North Carolina Outer Banks, significant loadings of stormwater constituents which can negatively affect surface waters have also increased. Nitrogen loadings have significantly increased from landscape fertilizer use and automobile exhaust. Phosphorus loadings have significantly increased from landscape fertilizer use and vehicle washing. Petroleum product loadings have significantly increased from automobile fluid leaks, automobile fluid dumping, and automobile fuel pump discharges. Heavy metal loadings have increased from automobile tire wear, automobile part deterioration, automobile brake pad wear, automobile exhaust, and asphalt pavement deterioration. Other sources of these stormwater constituents also exist.

Real estate development increases the amount of impervious surfaces and compacts soils. When rainwater reaches ground surfaces of impervious cover and compacted soils, the amount of stormwater which infiltrates into the soil is reduced. Stormwater does not infiltrate impervious surfaces and infiltrates slower into compacted soils. This produces more stormwater runoff.

Stormwater runoff comes in contact with various pollutants (bacteria, viruses, nitrogen, phosphorous, greases, oils, lead, copper, mercury, chromium, cadmium, zinc, herbicides, pesticides, etc). The polluted stormwater flows along various paths until reaching a receiving water body. Unless the polluted stormwater is managed such that the undesirable constituents are adequately treated (bound, removed, or transformed), the stormwater runoff can negatively affect the surface waters to which it flows. Real estate development also results in a reduction in the

extent and size of natural areas, including areas which buffer surface waters. These areas provided natural treatment of stormwater constituents which can negatively affect the surface waters.

In addition to increased pollutant loadings, the stormwater runoff also increases in terms of volume and rate. This increased stormwater runoff can produce undesirable erosion and flooding unless the stormwater is managed such that the quantity and rate are adequately restrained.

Post World War II real estate development stormwater approaches have focused on collection of stormwater at the project site and conveyance of the stormwater from the site to the nearest discharge location. Facilitating rapid surface drainage was the primary goal, usually without consideration of off-site affects. Most requirements for managing stormwater have been limited to preventing direct capital damage and loss-of-life. Largely beginning in the mid-1970s, efforts have been undertaken to address pollution from stormwater runoff. More recently, these efforts have begun to be applied in a more widespread manner, including throughout the 20 coastal counties of North Carolina (see Section 4, Summary of Existing Ordinances).

Common current "high-density" real estate development techniques for addressing stormwater management requirements focus on an "end of pipe" approach, employing hardened components (channels and pipes) to direct stormwater runoff into detention basins. Common current "low-density" real estate development techniques for addressing stormwater management requirements focus on limiting impervious area below a maximum limit (generally a percentage of the total project area) and employing vegetated open channels to convey stormwater runoff from the site. Such efforts have produced limited success and have failed to prevent significant degradation of water resources, including economically important fisheries.

There is a significant need for an approach to real estate development stormwater management which protects water resources as well as public health, safety, and welfare while maintaining and improving life quality and economic development. LID is such an approach.

2.3. The LID Approach

LID offers real estate developers a cost effective means to address stormwater management. The approach involves five key elements: Natural Area Conservation, Stormwater Management Measures, Site Specific Design, Stormwater Treatment Train, and Beneficiary Involvement. These elements provide tools to ensure the postdevelopment hydrologic response mimics the predevelopment hydrologic response (quantity, character, and constituents). Including all of these elements is not required to implement a LID project, but all of these elements must be considered and addressed when undertaking a LID approach.

As opposed to common stormwater management practices which focus on "end-of-pipe" solutions, the LID approach emphasizes infiltration and treatment of stormwater as close to the location of precipitation reaching the ground as possible as well as along the various stormwater runoff pathways. LID affords a way to mesh aesthetically pleasing landscape features with stormwater management. Employing the LID approach can significantly reduce stormwater infrastructure costs while meeting or exceeding regulatory requirements.

2.4. The Five Key LID Elements

(a) **Natural Area Conservation** - Conserving natural areas includes locating important natural areas to be preserved, siting features to reduce natural area negative impacts, and minimizing disturbance to natural areas. Natural area conservation should receive particular attention during the planning stages of a real estate development project.

(b) **Stormwater Management Measures** - Stormwater management measures may be either: 1) structural (comprised of various physical, biological, and chemical components); or 2) behavioral (comprised of various activities, manners, and methods). Structural measures directly restrain or treat stormwater. These include implementation of bioretention areas, detention ponds, vegetated swales, and others. Behavioral measures prevent or reduce pollution of stormwater. These include approaches to fertilizer application, oil dumping, vehicle washing, automobile maintenance, groundcover selection, and others. Each is important to stormwater management, though behavioral measures are much more difficult to successfully implement.

(c) **Site Specific Design** - Each real estate development project site is different. Site soil conditions (ecology, texture, etc), vegetation characteristics (native/nonnative, survival, etc), hydrologic/hydraulic inputs, and pollutant inputs (spills, nutrients, etc), as well as the proposed built features affect the hydrologic response of a site. As each site is unique, the manner in which stormwater is managed must be specific to each site and each project.

(d) **Stormwater Treatment Train** - A treatment train is a series of management measures along a stormwater flow path which address various aspects of hydrologic response. The treatment train approach is a standard aspect of water and wastewater treatment facilities. By providing several types of stormwater management measures across the site, particular components of stormwater are more effectively addressed. Additionally, by including several stormwater management measures, the potential for system failure is reduced as failure of individual measures does not result in overall system failure.

(e) **Beneficiary Involvement** – Stormwater management is not a "fire and forget" operation. System maintenance and pollution prevention as well as awareness and education are important to ensure stormwater management is adequate over the project lifetime, which may extend for many decades.

2.5. LID Site Planning Techniques

An integral part of LID is site planning. Once a conceptual site plan has been developed, it guides the remaining process. Below are basic concepts which should be employed for LID.

(a) **Clustering Structures** - Increasing density of structures on a parcel and across a region improves the efficiency of the space. This reduces the magnitude of required basic infrastructure; not only stormwater, but also wastewater collection, water supply, and transportation facilities. Such clustering of structures also allows preservation of open space. This open space can be utilized for active and passive recreation; sound, sight,

wind, and temperature buffers; as well as wildlife habitat. The combination of clustering and open space facilitates contact between neighbors and provides marketable amenities.

(b) **Reducing Impervious Surfaces** - Impervious surfaces are the largest contributors to stormwater runoff. Less impervious surface directly reduces the amount of stormwater runoff, reducing the degree of structural stormwater management measures which must be employed. Reducing the width and maximizing the efficiency of vehicular and pedestrian transportation routes is often a key aspect of impervious surface reduction. Utilizing shared driveways, flag lots, and open cul-de-sacs are other common methods for reducing impervious surfaces.

(c) **Landform Conformance** - Modifying natural landforms often increases the amount of runoff. Working with the natural landforms of a site directly reduces the cost of project earthwork, the extents of land disturbance, and removal of topsoil. Berms and channels can be utilized to transform natural areas into effective stormwater runoff retention and detention components.

(d) **Disconnected Impervious Surfaces** - Connected impervious surfaces convey stormwater runoff without the potential for treatment while increasing the magnitude of stormwater which must be treated once the runoff reaches a structural stormwater management measure. By disconnecting impervious surfaces, structural stormwater management measures may be employed along the path of stormwater runoff. Disconnecting impervious surfaces can also reduce the velocity of stormwater runoff, which reduces the cost of conveyance measures.

2.6. Structural Stormwater Management Measures

A key LID element is implementation of structural stormwater management measures. Such measures are central components of site specific design and an overall stormwater management system. Stormwater management measures are the foundation of a treatment train. Stormwater management measures readily included in LID are indicated below. A summary regarding the application, potential conflicts and opportunities for each of the structural stormwater management measures is included in Appendix A.

(a) **Bioretention Areas** – These are vegetated depressions which retain stormwater, allowing the water to infiltrate and evapotranspirate (Exhibit 2). Bioretention areas are generally 12 inches to 36 inches deep, with 18 inches being a common depth. Appropriate native herbaceous and woody vegetation is preferred and typically utilized, though suitable turf grasses can be employed. Bioretention areas do not maintain standing water. Water in bioretention areas should remain above the surface no more than about 3 days, allowing volume recovery for subsequent storms and preventing mosquito breeding. Highly concentrated infiltration may require soil water mounding analysis.

(b) **Vegetated Filter Strips** - These are narrow measures generally placed at the edges of impervious surfaces with relatively nonconcentrated flow, such as parking lots, to provide an area for stormwater treatment by infiltration, filtering, sedimentation, and sorption (Exhibit 3). These are often employed as the first component of a treatment train.

(c) **Cisterns** - Cisterns have been used for thousands of years to collect and store rainwater (Exhibit 4). The primary function of cisterns relative to LID is detention, retaining direct runoff from impervious surfaces during and following precipitation events. Cisterns are typically connected to roof drains. The water is often utilized for irrigation and sometimes for drinking (though treatment prior to such use is generally needed). These are high maintenance systems and should only be implemented where proper regular maintenance will be undertaken.

(d) **Vegetated Open Channels** - Wherever stormwater must be conveyed on a site, it is generally preferred that such occurs along a vegetated open channel (Exhibit 5). These allow treatment of stormwater by infiltration, filtering, sedimentation, and sorption. These are often placed along roadways and innervating through sites.

(e) **Permeable Pavement** - Surfaces intended for vehicular and pedestrian traffic can be constructed from a variety of materials. Such surfaces are almost always impermeable and usually constructed of asphalt or concrete. These surfaces can be pervious (allowing stormwater to infiltrate) and constructed of pavers or other materials (Exhibit 6). These are high maintenance systems which are expensive to patch and repair compared to asphalt and concrete. These should only be implemented where proper regular maintenance will be undertaken. These should not be implemented in areas of high vehicular traffic or other areas where fine particles and other clogging pollutants could degrade performance.

(f) **Vegetated Roof** - This is a measure intended to reduce or eliminate runoff from roofs. The roof is generally covered with a planting matrix and vegetation installed densely across the surface (Exhibit 7). A high density polyethylene membrane or similar material serves as moisture barrier over the base roof structure.

Exhibit 2. Bioretention Area (Photo from website www.bioretention.com)

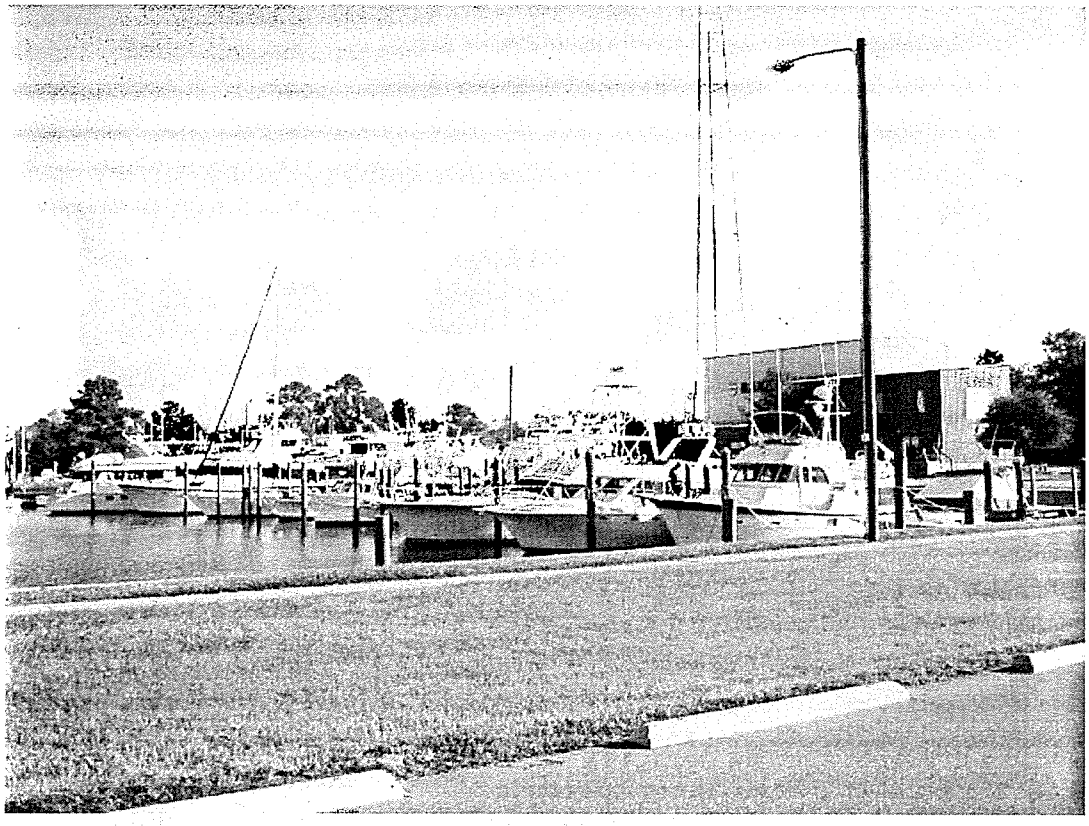

Exhibit 3. Vegetated Filter Strip (Photo from website http://www.psat.wa.gov/)

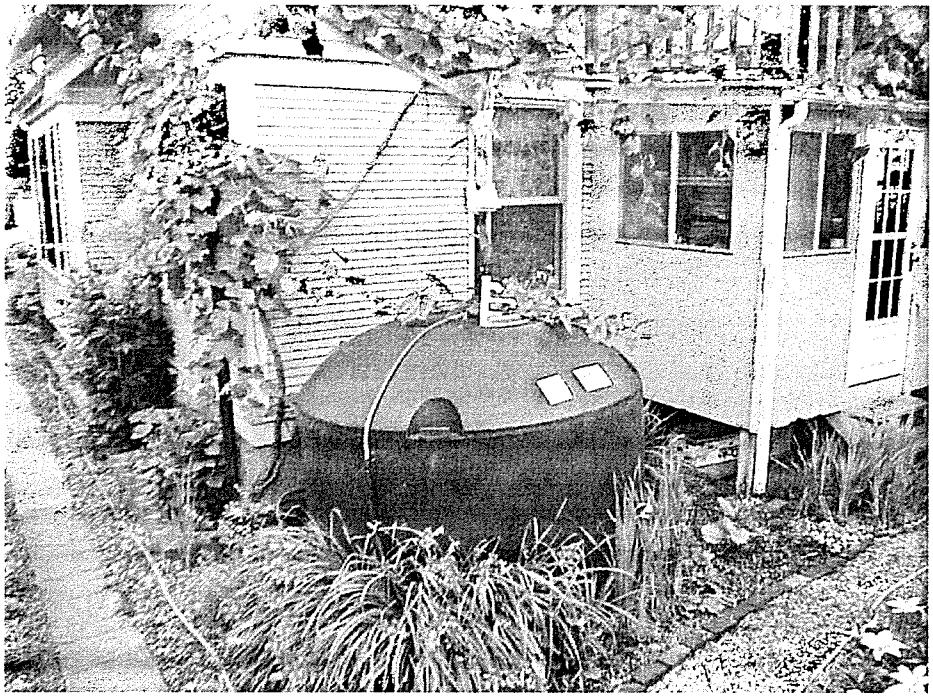

Exhibit 4. Cistern (Photo from website http://www.harvestingwater.com/)

Exhibit 5. Vegetated Open Channel (turf cover) (Photo from website http://www.psat.wa.gov/)

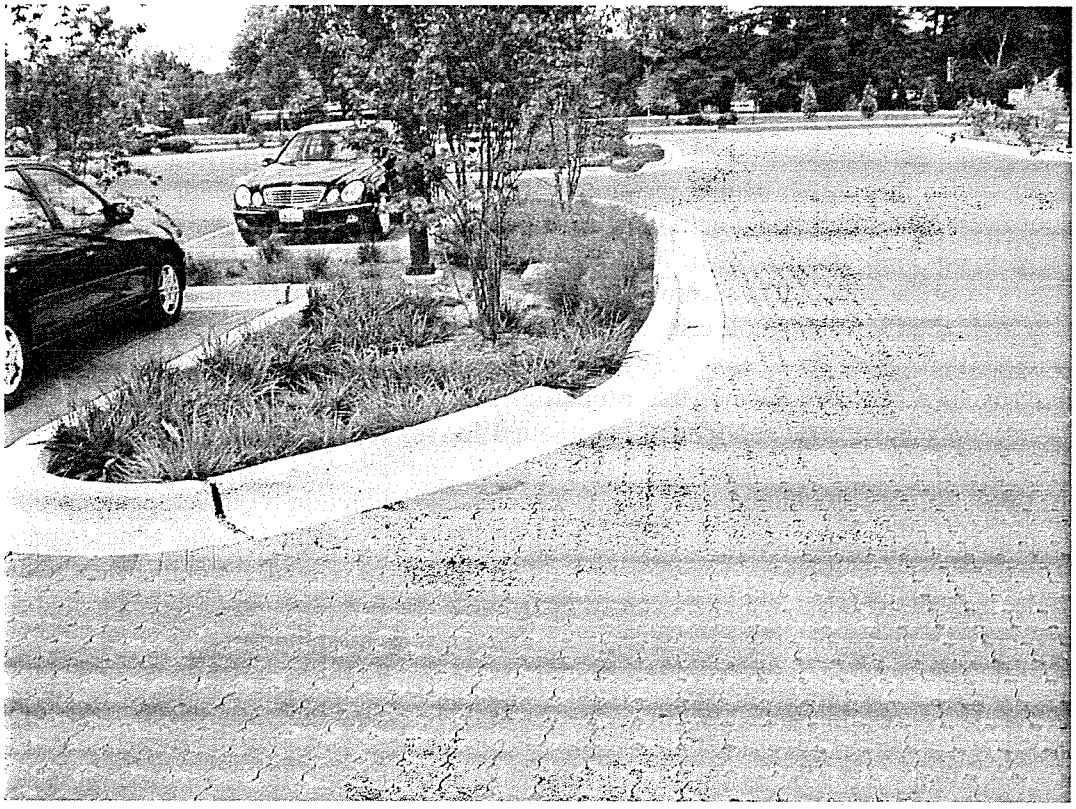

Exhibit 6. Permeable Pavement (Photo from website www.bioretention.com)

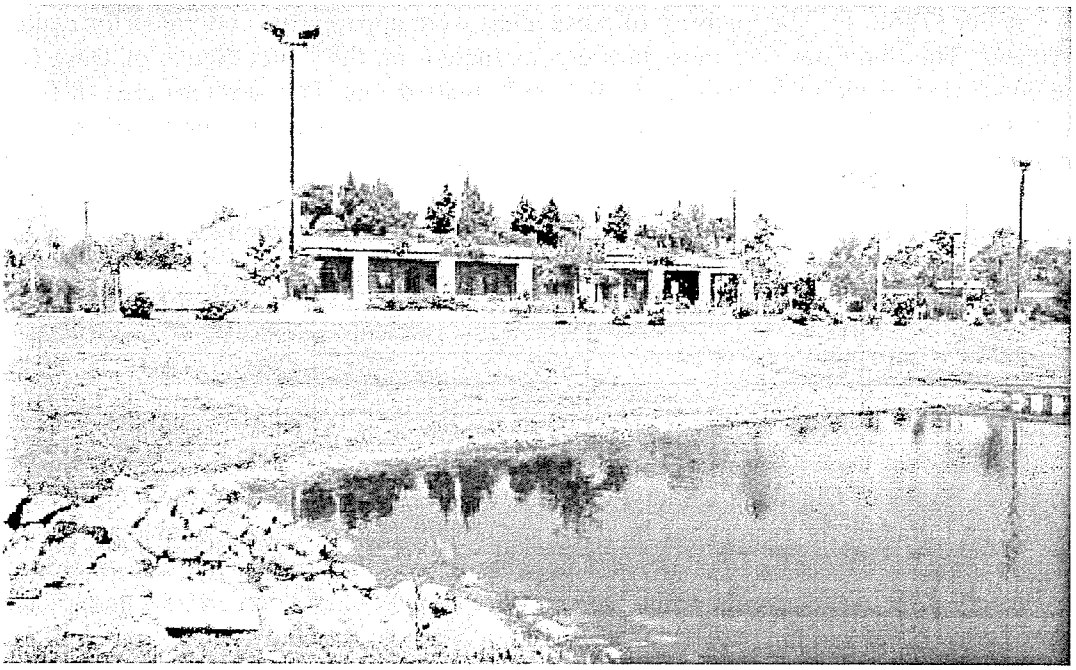

Exhibit 7. Vegetative Roof (Photo from website http://www.bae.ncsu.edu/workshops/ashevillegreenroof/greenroof.html)

3.0 Review of Real Estate Development and Application of LID

3.1. Real Estate Development on the Outer Banks

The Outer Banks has drawn people to the area for beautiful beaches, excellent fishing, and a variety of other water dependent activities. The economy of the North Carolina Outer Banks is dependent upon high quality water resources. The character and economy of the area is inseparable from the waters that surround the Outer Banks. Proper management of stormwater is central to high quality water resources.

The majority of potentially developable properties along the Outer Banks of Currituck County and Dare County have been subdivided and platted for residential housing and associated real estate development. Land owned by government entities and environmental nonprofit organizations is not considered potentially developable. Potentially developable properties include any privately held land, regardless of jurisdictional wetlands, flood zones, and other typical real estate development impediments on the property. Given the high property value relative to mitigation costs for such constraints, these are not seen as preventing real estate development (though associated regulations may limit such development).

On the Outer Banks of Dare County, construction has occurred on the majority of land subdivided and platted for residential housing and associated real estate development. In this area, approximately 22% of potentially developable parcels have not been constructed upon. Approximately 87% of the parcels which have not been constructed upon are one acre or smaller; approximately 72% of the parcels which have not been constructed upon are one-half acre or smaller (Table 1). The majority of these areas were apparently subdivided for residential development. This indicates that most future construction on the Outer Banks of Dare County will be comprised of individual houses on currently platted lots. The northern area of the Dare County Outer Banks is more developed than the southern area in terms of real estate construction.

Table 1. Approximate Development of Potentially Developable Properties.

County	Percent of Parcels Not Constructed Upon		
	Total	Less Than 1.0 Acre	Less Than 0.5 Acre
Dare	22%	87%	72%
Currituck	54%	92%	81%

On the Outer Banks of Currituck County, construction has not occurred on the majority of land subdivided and platted for residential housing and associated real estate development. In this area, approximately 54% of potentially developable parcels have not been constructed upon. Approximately 92% of the parcels which have not been constructed upon are one acre or smaller and approximately 81% of the parcels which have not been constructed upon are one-half acre or smaller. The majority of these areas were apparently subdivided for residential development. This indicates that most future construction on the Outer Banks of Currituck County will be comprised of individual houses on currently platted lots. The southern area of the Currituck

County Outer Banks is more developed than the northern area in terms of real estate construction.

3.2. LID on the Outer Banks

The naturally high infiltration potential of soils on the Outer Banks provides an excellent opportunity for LID. Two major factors impede the implementation of LID techniques in areas of the Outer Banks of Currituck County and Dare County. The first, high water table, is a physical constraint. The second, property boundaries, is a legal constraint. Each of these can be successfully addressed.

Much of the higher areas have been utilized (or will likely be utilized) for construction of vertical structures (housing, in particular). On-site wastewater systems (septic tanks, nitrification leachfields, and associated components) are also sited (or will likely be sited) in higher areas of properties. The sandy nature of the area allows a high infiltration potential for stormwater. The proximity of water table to the surface in some areas limits, however, the volume of stormwater which can be infiltrated. The high water table also hinders various biological and chemical treatment processes for stormwater. Ditches and canals constructed to manage the water table present short circuiting issues for stormwater that has been infiltrated. Stormwater management must be assessed and addressed on a site-by-site basis relative to water table. Such site specific design, however, is a key element of LID.

Though many areas of the Outer Banks contain relatively high dunes, many other areas of the Outer Banks are within a two or three feet of mean sea level. Approximately 19% of the undeveloped area along the Outer Banks of Currituck County and Dare County has water table depths of at least 6 feet below the ground surface throughout the year. Approximately an additional 3% (21% total) of the undeveloped area on potentially developable parcels, along the Outer Banks of Currituck County and Dare County, maintain water table depths of at least 5 feet below the ground surface throughout the year. Approximately 13% of the undeveloped area on potentially developable parcels has water table depths of between 1.5 feet and 3.0 feet generally during wetter portions of the year. Approximately 8% of the undeveloped area on potentially developable parcels has a slightly shallower water table, from about 1 foot to 2 feet below the ground surface. The remaining 57% of undeveloped area on potentially developable parcels along the Outer Banks of Currituck County and Dare County has water table depths of less than 1 foot during wetter portions of the year.

Table 2. Approximate Water Table Depths on Potentially Developable Properties.

Status	High Water Table Location (Depth Below the Surface)				
	at Least 6 Feet	5 to 6 Feet	1.5 Feet and 3.0 Feet	1 Feet and 2 Feet	Less than 1 Foot
Developed	68%	1%	10%	9%	13%
Undeveloped	19%	3%	13%	8%	57%

Approximately 68% of the real estate developed area along the Outer Banks of Currituck County and Dare County has water table depths of at least 6 feet below the ground surface throughout

the year. Approximately an additional 1% (69% total) of the real estate developed area along the Outer Banks of Currituck County and Dare County water table depths of at least 5 feet below the ground surface throughout the year. Approximately 10% of the real estate developed area has water table depths of between 1.5 feet and 3.0 feet generally during wetter portions of the year. Approximately 9% of the real estate developed area has a slightly shallower water table, from about 1 foot to 2 feet below the ground surface. The remaining 13% of real estate developed area along the Outer Banks of Currituck County and Dare County has water table depths of less than 1 foot during wetter portions of the year.

Nearly all of the undeveloped area with water table depths of less than 1 foot during wetter portions of the year would be classified as jurisdictional wetlands. Approximately 68% of the potentially developable area is comprised of hydric (wet) soils. Approximately 46% of the real estate developed area contains hydric (wet) soils. Most of these wetlands would be directly regulated by both the US Army Corps of Engineers (USACE) and the NC Division of Coastal Management (NCDCM). The Army Corps of Engineers regulates primarily through the Federal Water Pollution Control Act (commonly known as the Clean Water Act) as an agent of the US Environmental Protection Agency (USEPA). The Division of Coastal Management regulates through the North Carolina Coastal Area Management Act (CAMA). Though such regulation is not necessarily an impediment to the implementation of LID techniques on the Outer Banks of Currituck County and Dare County, such regulation does directly affect the magnitude and character of real estate development in these areas.

Ground infiltration potential is an important component of stormwater management. In natural areas of the Outer Banks where the ground is not saturated, rainfall can often enter the ground where the raindrops hit the surface. Most of the soils in these natural areas have about 40% of their volume available for this rainfall.

A 2-year 24-hour storm over most of the Outer Banks of Currituck County and Dare County produces approximately 3.8 inches of rain. If this rainfall infiltrates into the ground without runoff (common on the Outer Banks in natural areas where the ground is not saturated), the rainwater would require about 10 inches of ground above the water table in a typical natural Outer Banks sandy soil. The maximum allowable impervious surface along the Outer Banks of Currituck County and Dare County is 30%. If the rainfall from a 2-year 24-hour precipitation event (3.8 inches total) is to be infiltrated with 30% impervious surface on a site, at least 14 inches of ground would be required above the water table in a typical natural Outer Banks sandy soil. Some additional soil depth would also be required as the natural soil volume available for rainwater is reduced from compaction during construction operations. To retain stormwater on-site for infiltration, a depression of some type must generally be formed. This depression reduces the available depth for stormwater in the soil. Additional depth is also often required to treat pollutants in the stormwater before reaching the water table.

Soils outside mucky wetland areas along the North Carolina Outer Banks are very sandy. The dominant limiting factor for stormwater infiltration potential in these sandy areas is the high water table. This limitation is significantly reduced as the area of stormwater infiltration increases. At existing elevations, approximately 21% of the undeveloped area is generally highly favorable for infiltrating large volumes of stormwater and approximately 69% of the real estate

developed area is generally highly favorable for infiltrating large volumes of stormwater. This indicates that most areas of existing real estate development are highly favorable for stormwater infiltration retrofits. Future real estate development has less opportunity for high stormwater infiltration at existing elevations.

At existing elevations, approximately 13% of the undeveloped area is moderately favorable to unfavorable for infiltrating stormwater and approximately 10% of the real estate developed area is moderately favorable to unfavorable for infiltrating stormwater. Unfavorable stormwater infiltration potential due to high water table can be addressed in areas of future real estate development through the proper use of fill material at the site. Importing off-site fill material has become a common component of most construction along the Outer Banks of Currituck County and Dare County. Importing fill along with appropriate siting of structures and associated earthwork (grading, soil preparation) can provide significant additional depth between ground surface and the high water table. This would, in essence, create an area highly favorable for infiltrating large volumes of stormwater. Properly employed, the use of off-site fill can provide significant benefits without causing stormwater problems for adjacent property owners. Builders, designers, and property owners should employ a combination of detention and retention to manage site stormwater. Several potential management measures are outlined in this document.

Two locations which illustrate the range of terrain that exists within the study area are depicted in Exhibits 8 & 9. Exhibit 8 is a photo taken at the Tuckahoe Ridge Subdivision in the Town of Duck. Adjacent to the Tuckahoe Ridge subdivision, North Carolina State Road 12, has a history of frequent flooding problems (VHB, 2006). The subdivision is located in an area with significant topography and excess groundwater storage available (also present at First Flight Ridge). This is good an example where retrofit of existing lots with structural best management practices (such as bioretention) could be performed at a low cost to reduce flooding. Exhibit 9 taken in the Martins Point subdivision, illustrates the high water table and limited storage capacity (also present at Frisco, Whalehead) which exists in approximately 57% of the remaining undeveloped lots. These areas will be more problematic for bioretention, but larger surface area, shallower systems may be viable. In areas where the population is permanent, cisterns may be another good option.

As nearly all potentially developable properties along the Outer Banks of Currituck County and Dare County have been platted for residential housing and associated real estate development, property boundaries of the subdivided parcels and associated structures control the location, magnitude, and type of stormwater management measures. Roadways, houses, driveways, and utilities (including on-site wastewater) have been constructed relative to property boundaries. Stormwater management must be assessed and addressed on a site-by-site basis relative to each of these as well as required legal easements.

For LID techniques to have significant positive benefits along the Outer Banks of Currituck County and Dare County, these must be undertaken through retrofit projects within existing residential developments and associated areas.

Exhibit 8. Photo taken at Tuckahoe Ridge Subdivision, Town of Duck (5/24/06)

Exhibit 9. Photo at Martin's Point Subdivision (5/24/2006)

4.0 Review of Existing Ordinances

The Moffatt & Nichol project team reviewed existing stormwater policies and ordinances for the following communities in the LID Study Area: Dare County, Manteo, Town of Nags Head, Town of Kill Devil Hills, Town of Kitty Hawk, Southern Shores, Duck, Currituck County and various subdivisions (Colington Harbor, Martin's Point and Whalehead). The policies were reviewed to identify (a) potential impediments to LID within the existing rules and (b) opportunities to augment the use of LID. A detailed summary of the existing policies and ordinances was compiled and is included in Appendix B. A discussion of key points regarding LID implementation and preliminary recommendations are identified below.

4.1. General Stormwater Requirements

The overarching objective of several of the stormwater ordinances is to facilitate stormwater drainage from the site. For example, pursuant to Currituck County ordinances, "All developments shall be provided with a drainage system that is adequate to prevent undue retention of surface water on the development site." The Town of Kill Devil Hills requires that "Surface water leaving the site shall be channeled to points of approved discharge...." Dare County ordinance states "where feasible the subdividers shall connect to an existing storm drainage system."

The conceptual basis of LID is to eliminate stormwater runoff from the site, maximizing retention and treatment within each lot. Underlying goals of an LID program would be to:

- Minimize increase in stormwater runoff from development or redevelopment
- Minimize increase in sources of non-point pollution caused by stormwater runoff by treating on-site
- Minimize total volume of surface water runoff that flows from a specific site in order to replicate, to maximum extent possible, predevelopment hydrology
- Maintain stormwater on-site controls

The more LID techniques that are applied, the closer to natural hydrologic function a site becomes. Where there are known flooding problems, however, a hybrid approach may be needed to reduce liability and provide a sense of safety. LID does not demand isolation from conventional technology.

In keeping with LID, the Town of Manteo requires "Appropriate stormwater management facilities shall be used for all new developments and redevelopments in order that stormwater runoff on one parcel of land must enter adjacent property with the same characteristics of predevelopment hydrology".

Preliminary Recommendation:

- ***Develop general stormwater goals consistent with LID practice.***

4.2. Applicable Property/Exemptions

Storm water rules and regulations are applied, in most communities, to multi-family and commercial lots. Exemptions are often made to single family dwellings and other properties. For example, in Dare County, "Stormwater regulations are for subdivisions only which are defined as any division or tract or parcel of land into two or more lots, building sites."

Land use within the project area is predominantly single family residential. It is also anticipated that much of the redevelopment which will occur in the Study Area will be single family residential structures. Please refer to Section 3.0 for a more detailed description. It should also be noted that current "typical" lot values range from $200,000 to $1,000,000 depending on lot size and location.

A few sets of ordinances specifically identify that storm water rules are applicable to both redevelopment as well as new development. For example, the Town of Nags Head identifies "Regulations apply to all new development and/or redevelopment within the town jurisdiction."

Preliminary Recommendations:

- ***Consider tightening the regulations to reduce exemptions and extending stormwater regulations to explicitly include single family residential lots with a minimum square footage.***
- ***Explicitly require compliance of stormwater regulations for both new development and redevelopment plots.***

4.3. Stormwater Management Requirements & Methods

In Currituck County, "unsubdivided developments utilize curb and gutter and storm drains to provide adequate drainage…". This is an impediment to LID practices because it precludes design and construction of rain gardens or filter strips adjacent to the road. One set of ordinances (Manteo) explicitly encourages use of LID stormwater devices. The use of "rain barrels, cisterns, porous pavement systems, vegetated swales, level spreader, filter strips, and bioretention" is recommended. Although encouraged, there are no incentives provided for implementation of LID practices.

Drainage requirements differ widely among the varying ordinances. Several communities require retention of runoff from 4.3 inches of rainfall whereas, in Manteo, the first 1.5 inches of a storm is required for retention. A performance based retention requirement should be established for residential and commercial lots that would be consistent for all communities.

Based on prior experience, three performance based methods are suggested for estimating stormwater runoff which will provide for protection of natural resources. Further research is required to evaluate the suggested methods. Methods are described in the model stormwater ordinance (refer to Section 4 of Appendix C), and identified as follows:

(a) Simple Method - Storage of a 2-Year 24-Hour (4.15 inches) precipitation event; applicable to lots less than 1 acre or minor modifications to existing homes.
(b) Standard Method – Post-development runoff for 10-Year 24-Hour precipitation event (6.38 inches) shall be equivalent to the pre-development runoff for the same event; applicable to lots not eligible for simple method and not employing the advanced method.
(c) Advanced Method – Post-development runoff for 5-Year 24-Hour runoff event shall be equivalent to the pre-development runoff for the same event; applicable to lots not eligible for simple method and not employing the standard method.

A follow up study to assess proposed design criteria is recommended. Multiple sites which are representative of the variability in land cover (e.g. residential, commercial) and physical terrain (e.g. elevated lot on sand dune, low lying terrain, soil characteristics) in the Outer Banks are recommended for evaluation. Temporary wells would be constructed at each of the sites to evaluate infiltration rates for the in situ soils. Stormwater design criteria will be applied to estimate storage required for representative sites. The practicality and effectiveness of the draft performance based ordinances will be assessed.

Preliminary Recommendations:

- ***Conduct a follow-up study to verify stormwater design criteria are appropriate for commercial and residential development in the Outer Banks.***
- ***Consider developing water quality in conjunction with quantity performance based criteria (e.g. TSS removal, minimum drawdown time for water quality purposes).***
- ***Remove any requirements for curb and gutter system.***
- ***Identify appropriate LID practices and consider development of incentives based program for implementation of LID.***

4.4. Fill Practices

Several ordinances are established regarding fill placement. Ordinances limit height, location of placement with respect to property lines, placement within floodplains and within road right of way. However, most of the regulations allow for loose interpretation on a lot by lot basis. There is no consistency among the ordinances.

A maximum height of fill is explicitly identified only within the subdivision under one ordinance. For the Colington Harbor development, it is limited to 18 inches. Within Currituck County and the Town of Duck, fill is not allowed to be placed within 10 feet and 5 feet of any property line, respectively.

There are not any ordinances which explicitly preclude filling a new lot to an elevation greater than that of adjacent properties. In practice new homeowners are filling in lots, in some areas by constructing bulkheads, to elevation greater than existing properties and grading the site such that surface water drains to adjacent properties.

The Town of Nags Head has an ordinance which allows for fill placement up to the base flood elevation in flood hazard zones; in non flood hazard areas fill is allowed to be placed to construct a septic field. The Town recently adopted an ordinance in an effort to limit the amount of fill brought on site be restricting the use of structures. The fill ordinance was amended to include the following:

The construction and use of bulkheads, walls, and other structural controls to retain the placement of fill on property shall only be permitted (1) in the immediate area of the on-site sewage disposal system as approved by the Dare County Health Department for the installation of such system, and (2) in only those areas of the property where the naturally occurring slope is 3:1 or greater in steepness.

In the Town of Kill Devil Hills, filling of stormwater natural lakes, ponds, ditches and drainage systems is permitted so long as "the project will not diminish the town's ability to manage stormwater."

Preliminary Recommendation:

- ***Consider developing one consistent set of regulations regarding fill placement which may be easily enforced on a site by site basis. Consider onsite fill grades within and away from the lots and fill grades relative to adjacent lot elevations.***

4.5. Land Disturbing Setbacks, Minimum Building Setbacks and Lot Coverage

Setback requirements for land disturbing activities are established in several ordinances. Within Dare County, a 30 foot setback between all road improvements and defined surface waters of Dare County is required. Similarly, in Currituck County a setback of 10 feet is required from any property line with the exception of drainage and stormwater improvements. Manteo requires that a 100 foot buffer be maintained, allowing for development within the buffer "as long as stormwater is managed on site".

Building setbacks are established in conjunction with maximum lot coverage as identified in Table 1. A more detailed summary is included in Appendix A. As noted in the table several communities reduce lot coverage requirements for use of Turfstone™ or equivalent.

Currituck County allows total coverage to increase by 15% if 50% of allowable coverage is in Turfstone™ or equivalent, or if the development is served by a functional stormwater management plan.

Preliminary Recommendations:

- ***Modify land disturbance setback requirements to explicitly allow for LID improvements within the setback area.***
- ***Consider providing incentives for implementing on-site stormwater practices by reducing the setbacks with adjacent properties.***

Table 3. Summary of Building Setback Requirements

	Building Setback			Lot Coverage	
Organization	Front (feet)	Side (feet)	Rear (feet)	Residential	Commercial
Dare County	25	10	20% depth or 20 ft		
Manteo	15	10	20% depth or 20 ft	30% +8% detached	55%
Town of Nags Head	30 res./15 comm.	8-12	20% depth or 30 ft	33%; 45% with TurfstoneTM	55%; 65% openface paving
Town of Kill Devil Hills	15-30	6-10	20% depth or 30 ft	40-50%, f(wetland soils)	
Kitty Hawk	25 res./15 comm.	10	20% depth or 20 ft	30%	60%
Southern Shores	25	15	25	30%	60%
Duck	25 res./15 comm.	10	20	30%	60%
Currituck County	20	15	20	35%	60%
Colington Harbor	25	8	20% depth		
Martin's Point	40	12.5	25		
Whalehead Subdivision	20	15	30		
Note: Setbacks identified are for "typical" for commercial and residential lots.					

4.6. Parking Requirements and Materials

Ordinances related to parking lot design requirements do not preclude the use of LID practices. Several ordinances encourage the use of permeable blocks and Turfstone™. Incentives are in place for the use of permeable pavement. Southern Shores excludes the porous parking areas from lot coverage calculations.

Permeable pavement requires regular maintenance in order to perform as designed. While permeable pavements have the potential to significantly reduce runoff, they are susceptible to surface sealing and pore clogging. It is generally recommended for use in low traffic use areas and dedicated pedestrian pathways.

Generally, permeable pavements are not recommended for high traffic areas or areas susceptible to clogging. Where regular traffic loading exceeds 10 vehicles per day (irrespective of vehicular weight) and areas exposed to heavy loadings of fine sediment (clay, silt, dust), permeable paving is not recommended for use. It is not recommended for areas where there is significant potential for surface sealing or clogging or dedicated maintenance.

Preliminary Recommendations:

- ***Clearly identify consistent specifications to encourage porous pavement materials in applicable locations and discourage use in non-applicable locations.***

4.7. Landscaping Buffers and Natural Buffers

Landscaping

In neither Dare County nor Currituck County do specific landscaping/buffer ordinances exist. Zoning regulations require a visual buffer where a commercial use or zone abuts a residential use or zone. However, regulations do not specify that the buffer be planted with native plants or drought tolerant vegetation.

Several ordinances within communities are more explicit in the location and extent of buffer types. For example in the Town of Nags Head, all large residential dwellings shall comply with one of the following requirements:

(a) The preservation of a minimum of ten percent of the lot's total area with existing natural vegetation and/or dune elevations or
(b) The planting of a minimum of 15 percent of the lot's total area. The minimum lot area for large residential dwellings shall be 16,000 square feet. At minimum 50 percent of the required landscaping shall consist of locally adapted live evergreen tree species. The remainder of the buffer may be live forbs and shrubs.

In other communities, native species are encouraged.

Natural Water Bodies

Within Dare County, buffers are established around existing water bodies. No structure, paved area, or any part of a ground absorption wastewater treatment system shall be located within 50 feet of any marsh, stream, pond, or wetland.

Preliminary Recommendations

- ***Develop consistent set of ordinances requiring preservation and use of native vegetation.***
- ***Consider establishing buffers around all natural water bodies and drainage ditches to enhance water quality.***

4.8. North Carolina State Regulations

In addition to the above ordinances, the State of North Carolina regulates stormwater runoff and sediment and erosion control.

Sediment and Erosion Control

Statewide regulation of sediment and erosion control is performed in compliance with 1973 North Carolina Sediment and Erosion Control Act. The law covers all land-disturbing activities, regardless of the size of the disturbance, except those involving agriculture, forestry, and mining, which are addressed in other legislation. The law and the rules do not specify a rigid set of practices; rather, they require the land developer to prepare an erosion and sedimentation control plan and employ appropriate measures to meet the performance standards.

The law requires installation and maintenance of sufficient erosion control devices and practices to retain sediment within the boundaries of the site. Under the law, compliance is determined by assessing performance. It prohibits visible off-site sedimentation from construction sites but permits the owner and developer to determine the most economical, effective methods for controlling erosion and sedimentation.

Several communities in the Outer Banks, including the Towns of Nags Head, Kill Devil Hills, and Kitty Hawk have developed their own ordinances and enforcement programs in compliance with the State sediment and erosion control program. In the remainder of the Outer Banks study area, State staff is responsible for permitting and enforcement of the sediment and erosion control regulations.

Water Quality

Development located in the 20 coastal counties must comply with North Carolina Administrative Code (NCAC) 02H. Projects subject to permitting are either classified as low or high density management alternatives. For low density sites, development is permitted where (a) the built-upon area is limited to 30% or less (25% or less within one half mile of and draining to SA waters), (b) stormwater is conveyed by vegetated conveyances and (c) there is a 30 ft wide vegetative buffer. High density areas require the use of stormwater controls to meet specific performance requirements for stormwater runoff. Infiltration practices are mandated for areas draining to SA waters.

The following state Division of Water Quality (DWQ) regulations apply within 30 feet of the normal high water line along public trust waters, 75 feet of the normal high water line along estuarine waters. Along Outstanding Resource Waters, the rules apply within 575 feet of the normal high water line.

- Hard surfaces, such as buildings, paved parking lots and roads, must cover no more than 30 percent of the project area within the Area of Environmental Concern, unless you can show that the design of your project limits runoff equally well. All projects should limit hard surfaces to the smallest area necessary.

- Redevelopment of areas exceeding the 30 percent limit may be permitted if hard surface areas are not increased and the project meets the rule to the maximum extent feasible.

- If your project is located on the shoreline of an Outstanding Resource Water (ORW), you may build on only 12 percent of the project area located within the AEC, and you may not use a stormwater collection system.

Universal Stormwater Management Program

The initial draft set of modifications to State stormwater rules, the Universal Stormwater Management Program (USMP), has been developed and is currently under review. The USMP would be a voluntary program which local communities can chose to adopt to replace existing state stormwater regulations. Similar to existing State regulations, local communities can elect to defer to the Division of Water Quality in whole or in part for enforcement.

The following are excerpts from the current draft rules which are planned to be submitted for review by the Environmental Management Commission, July 2006:

All development activities located in one of the twenty (20) Coastal Counties that disturb 10,000 square feet or more of land shall control the runoff from the first one and one half inch of rainfall to the level specified in Paragraph (f) of this Rule. In addition, all impervious surfaces, except for roads, paths, and water dependent structures, shall be located at least 30 feet landward of all perennial and intermittent surface waters. Redevelopment activities that meet the provisions of 15A NCAC 02H .1002(14) shall not be required to comply with the requirements of this Paragraph.

Structural stormwater controls required under Paragraphs shall meet the following criteria:
(1) Remove an 85% average annual amount of Total Suspended Solids.
(2) For wet detention ponds draw down the treatment volume no faster than 48 hours, but no slower than 120 hours.
(3) Discharge the storage volume at a rate equal or less than the pre-development discharge rate for the 1-year, 24-hour storm.
(4) Meet the General Engineering Design Criteria set forth in 15A NCAC 02H .1008(c).

In coastal communities where there are currently low density and high density management options, under the USMP there would be one consistent set of State regulations. A key change from the existing management of stormwater in shellfish waters is that the cap for impervious area which is currently at 25% (without stormwater controls) in low density would increase to 35% with stormwater controls required as identified above.

There is some concern regarding the effectiveness of the proposed rules as compared to existing regulations for watersheds in Shellfish Waters. Further assessment of the draft rules in relation to the potential effectiveness in the Outer Banks is recommended.

5.0 Model Stormwater Management Ordinance

Based on a review of the existing ordinances and assessment of geographic constraints, a draft *Model Ordinance for Stormwater Management in the Outer Banks* was developed and is included in Appendix B. It is intended that this ordinance will provide flexibility to builders, designers, planners, and regulators and facilitate the implementation of LID (LID) and similar approaches to real estate development of the Outer Banks.

The model ordinance is intended to serve as a framework for all communities within the study area. Upon refinement, it would replace existing local stormwater ordinances. The model ordinance is designed to compliment and be used in conjunction with the State stormwater regulations.

The model ordinance addresses several of the key points identified in Section 2.0 of this report. Consistent with the recommendations outlined in Section 2.0, further effort will be required to modify general ordinances to address issues of design storm criteria, fill placement, setback requirements, and use of native vegetation and buffers.

6.0 Management & Implementation

6.1. Organizational Options for Stormwater Management

Several organizational options exist for developing and implementing LID strategies for storm water management and water quality improvement in the Outer Banks. Options range from working within existing governmental organizations to creating a new entity for water resource management.

The legal authority for organizations to manage stormwater and water quality is established under N.C.G.S. 160A-311 (10). Programs are defined as a public enterprise including "Stormwater management programs designed to protect water quality by controlling the level of pollutants in, and the quantity and flow of, stormwater and structural and natural stormwater and drainage systems of all types."

Based on correspondence with the University of North Carolina, Chapel Hill (UNC-CH) Institute of Government, (Hughes, 2006), the authority and structure of stormwater management alternatives is similar to that for water and sewer services. The institutional options for stormwater management in the Outer Banks (and supporting North Carolina General Statutes (G.S.)) are identified as follows:

- Municipality (G.S. 160A, Art. 16)
- Counties (G.S. 153A, Art. 15)
- Water Authority (G.S. 162A, Art. 1)
- Interlocal Agreement (G.S. 160A, Art. 29, Part 1)
- Joint Management Agency (G.S. 160A, Art. 20, Part 1)
- Water Districts

Individual municipalities and counties have the authority to establish ordinances and manage separate LID programs. Alternatively, a regional institutional approach could be undertaken to establish a consistent set of LID ordinances and a management strategy throughout the Outer Banks. Such an approach could be undertaken via interlocal agreement, or by creating a new regional authority or water district. Table 2 summarizes the range of options and authority which may be granted under the various organizational strategies.

Table 4. Power/Authority Which May Be Designated to Specific Organization

	Type of Organization/Structure			
Power/Authority	**City/County Utility**	**Interlocal Contract**	**County Service District**	**Management District/Authority**
Corporate Powers	Yes	yes	No	yes
System Ownership	Yes	yes	Yes	yes
Construct Systems	Yes	Under contract	County	yes
Establish Rates & Charges	Yes	by unit	County	yes
Levee Property Taxes	Yes	City/county	County	no
Zoning	Yes	City/county	County	no

Considerations for selecting a LID implementation & management strategy include:

- Clear, consistent goals & objectives
- Political support
- Financing & funding
- Inspection/permit fees
- Construction maintenance
- Integration with existing organizational bodies/utilities

A key advantage of a new regional stormwater district or authority would be the establishment of a clear and consistent set of policies and ordinances, applicable to the entire watershed area. A regional organization could work with the existing planning and engineering utilities to implement a LID program.

Local political support is a prerequisite to establishing a new governing organization. Based on initial input from the technical advisory committee, there appears to be neither political support for development of a regional planning body, nor support for an interlocal agreement of stormwater management in the Outer Banks.

Given the local political environment, it is recommended that LID be promoted through a two pronged approach whereby:

1. Existing municipal and county stormwater programs and ordinances be revised to provide incentives, remove impediments and strongly encourage LID practices for new development and redevelopment; and

2. In cooperation with the Dare and Currituck County Soil and Water Conservation District (SWCD) s and UNC-CSI, communities work to (a) develop pilot projects for educational purposes, (b) facilitate LID workshops and (c) seek state and federal support to retrofit existing properties.

The County SWCDs are state agencies with an elected Board of Supervisors. Current responsibilities include promoting conservation and carrying out North Carolina Agricultural cost share program (set up in 1985) to address non-point source pollution. The SWCD partners with federal, state and local agencies to assist and educate the land users (farmers, homeowners, developers) in care of and use of land as it relates to soil and water conservation. In June 2006, the Dare County filled a full-time staff position; that staff member will be responsible for water resources and water quality education programs. Based on initial discussion with Dare County SWCD staff, it is anticipated that they will support the education and implementation of LID.

6.2. Implementation of LID

Key elements for successful stormwater management and implementation of LID practices in the Outer Banks are identified below.

1. Public Education - Public workshops and pilot projects illustrating the benefits and use of LID will be instrumental in achieving public support and implementation. UNC-CSI and SWCD should continue to facilitate workshops which provide a platform for the public and site developers to learn more about LID practices.

   It is recommended that multiple sites which are representative of the varying physical conditions and political jurisdictions be selected for LID retrofit pilot projects. Each of the sites should be sited in locations of high visibility with easy public access. A variety of sites should be considered including (a) residential retrofit (bioretention), (b) commercial retrofit (several small structural measures), and educational awareness (signage) at existing sites.

2. Ordinances – A general stormwater management ordinance has been developed for the Outer Banks to facilitate LID practices (Appendix B). The stormwater management ordinance serves as a framework which may be tailored to meet the specific objectives of individual communities in the Outer Banks.

3. Administrative Structure – The county and municipalities currently administer stormwater policies through planning and engineering departments. Roles and

responsibilities of the respective departments can be expanded to include LID implementation as outlined in the model stormwater program. Additional staff and training may be required to develop an in-house expertise to promote LID and implement the stormwater management program.

Several references are available or in development which serve as good resources for developers and regulators to review and apply LID practices. The LID Manual for Prince George's County (Prince George's County MD, 1999) provides a comprehensive review of the general design practices of LID. The existing *Stormwater BMP Manual* (NC Division of Water Quality, Draft July 2005) and the *LID Manual* (currently being developed by NCDWQ) may be used as guidance for LID design practices.

4. Financing – Responsibility for construction and implementation will be delegated to the developer. Additional administrative costs may be financed through stormwater permit application fees, as identified in the model ordinance.

   Additional financing for retrofit of existing lots and development of pilot projects may be obtained through alternative funding sources. It is recommended that UNC-CSI and SWCD submit applications for Clean Water Management Trust Fund and United States Environmental Protection Agency (EPA) 319 grants as the primary source of funding to establish LID pilot projects including the design, construction, maintenance and monitoring. Once the initial projects are in place, secondary sources for grant funding should be pursued including but not limited to:

   - United States Department of Commerce (USDoC) (National Oceanic and Atmospheric Administration (NOAA))
   - United States Department of Interior (USDoI) (US Fish and Wildlife Service)
   - United States Department of Defense (USDoD) (United States Army Corps of Engineers (USACE))

   It is anticipated that successful pilot projects will serve as a seed to initiate the public and development community's interest in LID practices.

5. Mechanisms for Implementation

(a) Regulatory Enforcement - Currently, several communities (Kitty Hawk, Nags Head, and Kill Devil Hills) have a mechanism in place for reviewing land disturbing activity and sediment and erosion control practices. There is also a procedure in place for review of commercial and multifamily residential stormwater plans.

It is recommended that a stormwater inspection review process be established to review new development and redevelopment of all lots. The framework for permit review, inspection, monitoring and enforcement is identified in the *Model Ordinance for Stormwater Management*. This process will be independent of sediment and erosion control permitting.

(b) Voluntary Programs – Implementation of LID retrofits on lots may be initiated by the individual lot owners. Assistance for planning and design may be provided through Master's gardeners, NC SWDC and NC Cooperative extension.

(c) Incentives Program - LID may be promoted through community awards and increased enhanced public relations for participants. Additional consideration may be provided by modifying ordinances to implement LID practice (e.g. modification of percent imperviousness requirement).

7.0 Summary and Recommendations

This study provides an overall assessment of the feasibility of using LID methods as part of a regional integrated stormwater management program in the Outer Banks.

Based on a review existing stormwater policies for communities within the Outer Banks LID Study Area, limited impediments to LID were identified in existing ordinances. Several recommendations are made to modify general ordinances to facilitate the use of LID. To embrace LID, a shift from the current philosophy (of conveying stormwater from a site) will be required to eliminate stormwater runoff from the site, maximizing retention and treatment within each lot.

A *Model Ordinance for Stormwater Management in the Outer Banks* was developed and is included in Appendix B. It is intended that this ordinance will provide flexibility to builders, designers, planners, and regulators and facilitate the implementation of LID and similar approaches to real estate development of the Outer Banks. The model ordinance is intended to serve as a framework for all communities within the study area.

Based on prior experience, three performance based methods are suggested for estimating stormwater runoff which will provide for protection of natural resources. A follow up study to assess proposed design criteria (hydro curves) is recommended.

The majority of potentially developable properties along the Outer Banks have been subdivided and platted for residential housing and associated real estate development. In Dare County, approximately 22% of potentially developable parcels have not been constructed upon; in Currituck County, approximately 54% of developable parcels have not been constructed upon.

Two major factors impede the implementation of LID in the Outer Banks. The first, high water table, is a physical constraint. The second, property boundaries, is a legal constraint. For LID techniques to have significant positive benefits, these must be undertaken through retrofit projects within existing residential developments and associated areas.

Both LID Site Planning techniques and structural stormwater measures may be applied in the Outer Banks. Site Planning techniques include clustering of structures, reducing impervious surfaces and grading to conform to natural topography. Structural measures which are recommended in the Outer Banks include bioretention areas, vegetated filter strips, cisterns, vegetated open channels, permeable pavement.

Several organizational options exist for developing and implementing LID strategies for storm water management. Given the local political environment, it is recommended that LID be promoted through a two pronged approach whereby:

3. Existing municipal and county stormwater programs and ordinances be revised to provide incentives, remove impediments and strongly encourage LID practices for new development and redevelopment; and

4. In cooperation with the Dare and Currituck County Soil and Water Conservation District (SWCD) s and UNC-CSI, communities work to (a) develop pilot projects for educational purposes, (b) facilitate LID workshops and (c) seek state and federal support to retrofit existing properties.

Public workshops and pilot projects illustrating the benefits and use of LID will be instrumental in achieving public support and implementation. UNC-CSI and SWCD should continue to facilitate workshops which provide a platform for the public and site developers to learn more about LID practices.

It is recommended that UNC-CSI and the SWCD submit applications for Clean Water Management Trust Fund and EPA 319 grants as the primary source of funding to establish LID pilot projects including the design, construction, maintenance and monitoring. Once the initial projects are in place, secondary sources for grant funding should be pursued.

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Appendix A

Summary of Structural LID Stormwater Management Measures

Structural LID Stormwater Management Measures

Name

Bioretention Area

Description

Bioretention Areas are vegetated depressions which retain stormwater, allowing the water to infiltrate and evapotranspirate. Bioretention areas are generally 12 inches to 36 inches deep, with 18 inches being a common depth. Appropriate native herbaceous and woody vegetation is preferred and typically utilized, though suitable turf grasses can be employed. Bioretention areas do not maintain standing water. Water in bioretention areas should remain above the surface no more than about 3 days, allowing volume recovery for subsequent storms and preventing mosquito breeding. Highly concentrated infiltration may require soil water mounding analysis.

Potential Solutions

Erosion - reduce the velocity of stormwater runoff from a site and can decrease downslope erosion.
Drainage - provide landscape depressions to which stormwater runoff can be directed.
Flooding - reduce the amount of stormwater runoff from a site and decrease associated flooding potential.
Irrigation - can be incorporated into vegetated landscape features, reducing or eliminating the need for irrigation of such.

Potential Conflicts

On-site wastewater (septic systems) - bioretention areas can reduce the depth to water table near the infiltration area, conflicting with requirements for on-site wastewater disposal.
Water table - bioretention areas are not feasible when adequate depth to water table is not available.
Utilities - bioretention areas may reduce the required ground cover over water supply, sanitary sewer, and other utilities, requiring ductile iron or other conduit to be utilized for these utilities.

Potential Opportunities

Shared Bioretention Areas - bioretention areas can be implemented along property boundaries to serve two or more adjoining parcels.
Residential gardens - Residential gardens, especially for wildflowers and showy shrubbery are excellent opportunities for bioretention areas which can provide an aesthetically pleasing amenity.
Landscape buffers - Areas of required landscape buffers can readily include bioretention areas.
Site fill - bioretention areas can be employed to take advantage of additional ground water storage volume and depth to water table afforded by site filling and associated grading operations

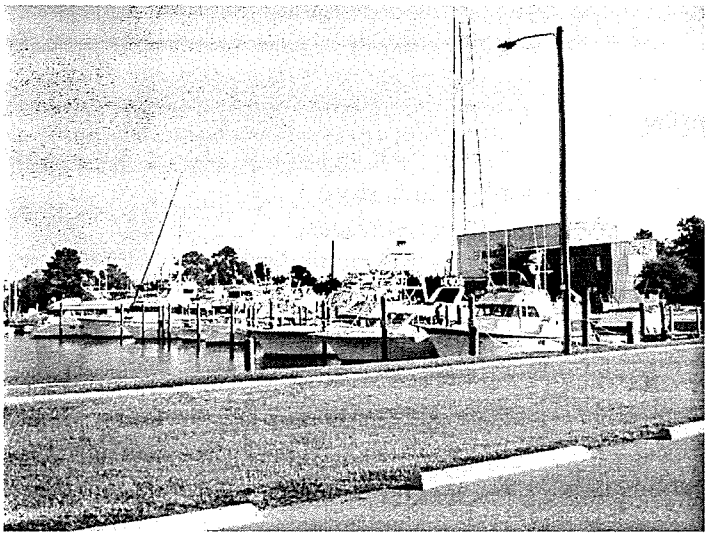
Potential Locations

Bioretention areas are readily located throughout a site. In most all areas where vegetation can be planted, a bioretention area can be implemented. Bioretention areas can be large or small.

Structural LID Stormwater Management Measures

Name

Vegetated Filter Strip



Description

Vegetated Filter Strips are narrow measures generally placed at the edges of impervious surfaces with relatively non-concentrated flow to provide an area for stormwater treatment by infiltration, filtering, sedimentation, and sorption. Appropriate native herbaceous and woody vegetation is preferred, though suitable turf grasses can be employed. These are often employed as the first component of a treatment train.

Potential Solutions

Erosion - reduce the velocity of stormwater runoff from a site and can decrease downslope erosion.
Irrigation - can be incorporated into vegetated landscape features, reducing or eliminating the need for irrigation of such.

Potential Conflicts

No typical conflicts.

Potential Opportunities

Pathways - Ingress and egress areas to parking lots can be can be combined with vegetated filter strips if wear resistant turf (such as zoysia grass) or other suitable land cover is employed.
Landscape buffers - Areas of required landscape buffers can readily include vegetated filter strips.

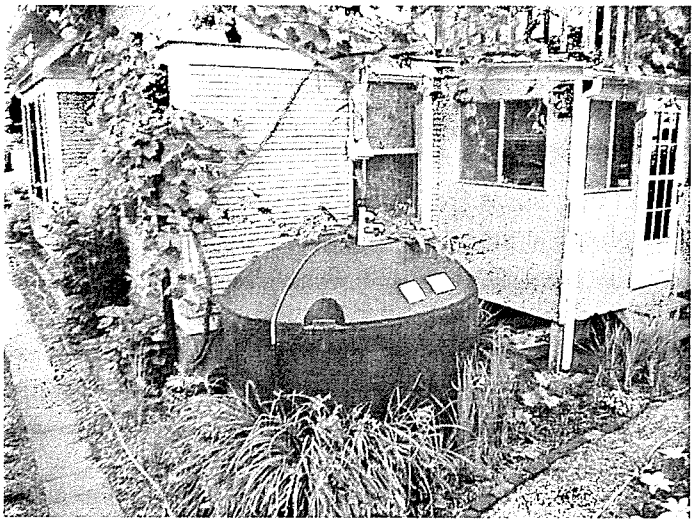
Potential Locations

Vegetated Filter Strips are readily located at the edge of walkways, driveways, parking lots, and similar surfaces. Vegetated Filter Strips are often comprised of turf, but can consist of other suitable dense, low growing, leaf retaining vegetation (such as *Vaccinium crassifolium* - Creeping Blueberry or *Gaultheria procumbens* - Teaberry).

Structural LID Stormwater Management Measures

Name

Cistern



Description

Cisterns are storage tanks which store precipitation from impervious surfaces, generally roofs. These structures retain direct runoff from impervious surfaces during and following precipitation events. Cisterns are often located underground, but may be placed at ground level or on elevated platforms. Cisterns can be located within buildings or in the landscape. Cisterns may be constructed of many materials, with polyethylene (PE), polyvinyl chloride (PVC), and concrete being the most common. These are high maintenance systems and should only be implemented where proper regular maintenance will be undertaken.

Potential Solutions

Erosion - reduce the velocity of stormwater runoff from a site and can decrease downslope erosion.
Flooding - reduce the amount of stormwater runoff from a site and decrease associated flooding potential.

Potential Conflicts

Water table - Cisterns placement below the ground surface may not be feasible when adequate depth to water table is not available.
Utilities - Cistern placement may interfere with routing and maintenance of cablevision, telephone, water supply, sanitary sewer, and other utilities.

Potential Opportunities

Irrigation - Cisterns are an excellent source of water for garden and yard irrigation.
Potable water - Though treatment prior to such use is generally needed, cisterns are readily adapted as a source of drinking water.
Vehicle washing - Cisterns can be utilized as a source of water for vehicle washing, especially when the storage tank is elevated to increase available pressure.
Water gardens - Cisterns can be employed to supply water for small ponds in the landscape, especially when the storage tank is elevated to increase available pressure.

Potential Locations

Cisterns are most easily located directly adjacent to buildings with roof drains that can direct water to the storage tank.

Structural LID Stormwater Management Measures

Name

Vegetated Open Channel

Description

Vegetated Open Channels convey stormwater runoff. It is generally the preferred measure for directing stormwater flow through the landscape. These allow treatment of stormwater by infiltration, filtering, sedimentation, and sorption. Appropriate native herbaceous and woody vegetation is preferred, though suitable turf grasses can be employed. Vegetated Open Channels are usually relatively wide and shallow.

Potential Solutions

Drainage - provide landscape depressions to which stormwater runoff can be directed and can include underdrains to increase drainage.
Irrigation - can be incorporated into vegetated landscape features, reducing or eliminating the need for irrigation of such.

Potential Conflicts

On-site wastewater (septic systems) - Vegetated Open Channels generally need to be located away from on-site wastewater disposal systems.
Utilities - Vegetated Open Channels may reduce the required ground cover over water supply, sanitary sewer, and other utilities, requiring ductile iron or other conduit to be utilized for these utilities.

Potential Opportunities

Shared Vegetated Open Channels - Vegetated Open Channels can be implemented along property boundaries to serve two or more adjoining parcels.
Landscape buffers - Areas of required landscape buffers can readily include Vegetated Open Channels.

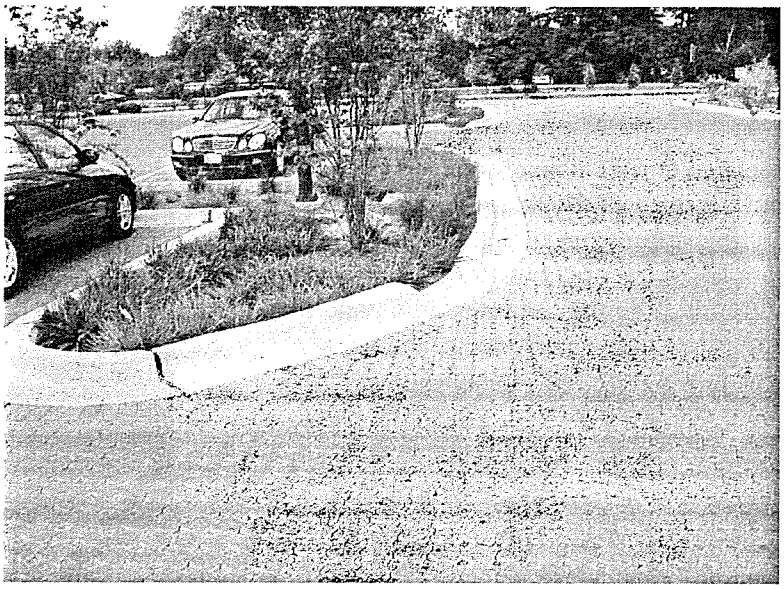
Potential Locations

These are often placed along roadways and innervating through sites.

Structural LID Stormwater Management Measures

Name

Permeable Pavement



Description

Permeable Pavements are employed for vehicular and pedestrian traffic. These are pervious surfaces (allowing stormwater to infiltrate) and constructed of pavers or other materials. These are high maintenance systems. These should only be implemented where proper regular maintenance will be undertaken. These should not be implemented in areas of high vehicular traffic or other areas where fine particles and other clogging pollutants could degrade performance.

Potential Solutions

Flooding - Permeable Pavements reduce the amount of stormwater runoff from a site and decrease associated flooding potential.

Potential Conflicts

Utilities - Permeable Pavements require special construction which makes standard compaction above subsurface utilities problematic. Permeable Pavements are also expensive to patch and replace when repairing utilities (compared to asphalt and concrete).

Potential Opportunities

Pedestrian walkways - Permeable pavements are well suited for low to moderate traffic pedestrian walkways.
Overflow parking - Permeable pavements can be utilized in areas where overflow parking is needed.

Potential Locations

Permeable pavements are utilized where alternatives to traditional impervious pavements are desired.

Structural LID Stormwater Management Measures

Name

Vegetated Roof

Description

Vegetated Roofs are measures which reduce or eliminate runoff from roofs. A high density polyethylene membrane or similar material serves as moisture barrier over the base roof structure. The roof is generally covered with a planting matrix and vegetation installed densely across the surface. Water is retained or detained in the planting matrix and evapotranspirated by the vegetation. Appropriate native herbaceous and woody vegetation is preferred, though suitable turf grasses can be employed and specialized vegetation is sometimes necessary.

Potential Solutions

Erosion - reduce the velocity of stormwater runoff from a site and can decrease downslope erosion.
Flooding - reduce the amount of stormwater runoff from a site and decrease associated flooding potential.

Potential Conflicts

Utilities - Vegetated Roofs may interfere with routing and maintenance of building mechanical components, including heating, venting, cooling, and plumbing.

Potential Opportunities

Insulation - Vegetated Roofs provide significant additional building insulation, moderating temperature changes and reducing energy costs.
Roof gardens - Vegetated Roofs can be combined with other roof top features to provide space for dining, recreation, or relaxation.

Potential Locations

Vegetated Roofs are, as the name indicates, located on roofs. Flat roofs or slightly inclined roofs are most suitable as Vegetated Roofs.

Appendix B

Summary of Existing Stormwater Ordinances

	General Stormwater Requirements	Applicable Property/Exemptions	Stormwater Control Design Requirements
Dare County	Where feasible, the subdivider shall connect to an existing storm drainage system.	Stormwater regulations are for Subdivisions only which is defined as any division of a tract or parcel of land into 2 or more lots, building sites, or other divisions.	
Manteo	Appropriate stormwater management facilities shall be used for all new developments and redevelopments in order that storm water runoff on one parcel of land must enter adjacent property with the same characteristics of the predevelopment hydrology.	Regulations apply to all new development requiring a Site Plan Review within the Town's Planning Jurisdiction. Exemptions include a development disturbing less than 5,000 square feet and single family residence with customary accessory dwelling units.	Recommend LID stormwater management. A list of recommended stormwater devices including rain barrels and Cisterns, Porous Pavement Systems, Vegetated Swales, Level Spreader, Filter Strips, Bioretention, etc. is provided. Design criteria is first 1.5 inches of total rainfall depth.
Town of Nags Head	Runoff shall be infiltrated on-site, or shall be disposed of on-site by a means acceptable to and approved by the town, and such other regulatory agencies having jurisdiction, in accordance with appropriate design, disposal and construction practice. Development in ocean overwash drainage districts shall provide swales, culverts, and other features to allow for drainage of ocean overwash flooding.	Regulations apply to all new development and/or redevelopment within town jurisdiction. Exemptions include detached single-family and duplex residential structures, which are not part of commercial or multifamily development or redevelopment of existing land uses which were lawful at the time of adoption of the ordinance from which this chapter derives.	All stormwater runoff resulting from the first 1 ½ - inch, two-hour rainfall shall be retained on any public or private commercial, group development or multifamily site, or commercial or residential subdivision. Either infiltrated or disposed of on-site. For new construction of single-family and duplex structures where the natural elevation has been increased by more than 3 feet by the deposit of fill material, on-site stormwater management facilities shall be designed and constructed to retain and infiltrate runoff from the first 2 inches of a storm event.
Town of Kill Devil Hills	Surface water leaving the site shall be channeled to points of approved discharge, including but not limited to, a natural or man-made watercourse, a lake, pond, ditch, stormwater drainage system, or other approved points of discharge. In all cases, including one- and two-family dwellings, the developer shall be required to provide culvert pipes, swales, any improvements in the right-of-way and other drainage improvements approved by the Public Works Division.	Regulations are applicable for all zoning districts as defined in the town code. Separate but similar storm drainage regulations existing within the code for subdivisions.	Systems shall be designed to retain, as a minimum, runoff expected from a ten-year, two-hour storm (4.3 inches of rainfall). Some situations may warrant a different requirement due to the size of the system.
Town of Kitty Hawk	No specific stormwater management regulations, however, various rules are defined for different development districts (e.g. low density residential). For existing streets and roads, all storm drainage shall be adequate to prevent flooding on private property from storm runoff of the design frequency	No specific stormwater management regulations, however, various rules are defined for different development districts (e.g. low density residential). These design criteria are for existing streets and roads.	Minimum design frequency for cross drainage is 25 years.
Southern Shores	No specific stormwater management regulations provided.		For all uses other than one and two family dwelling units, Town Council stormwater policy requires drainage for 10-yr, 2-hr, 4.3 inch rainfall event.
Duck	Drainage improvements and/or stormwater measures such as infiltration basins, swales or ditches my be placed within 5 feet of any side or rear property line.	Regulations apply to any land-disturbing activity.	
Currituck County	All developments shall be provided with a drainage system that is adequate to prevent undue retention of surface water on the development site.	Regulations apply to all Special Flood Hazard Areas, as defined by FEMA or through a Cooperating Technical State (CTS) agreement between the State and FEMA in its Flood Hazard Boundary Map or Flood Insurance Study and its accompanying flood maps such as the FIRM and/or Flood Boundary Floodway Maps, within the jurisdiction of Currituck County.	Private roads and access ways within unsubdivided developments shall utilize curb and gutter and storm drains to provide adequate drainage if the grade of such roads or access ways is too steep to provide drainage in another manner or if other sufficient reasons exist to require such construction.
Colington Harbor	Stormwater needs to be retained as much as possible on each individual property and not just dumped onto the roads or individual parcels. Lots that have poor percolation may be required to remove the bad material and get below the peat layer and install a curtain drain to eliminate standing water. A swale must be included on each side line to help drainage and to minimize dumping water onto abutting lots.		
Martin's Point	No specific stormwater regulations. Emphasize that development shall not impede roadside drainage.		
Whalehead Subdivision	No specific stormwater regulations.		

	Fill Allowances	Drainage Slope Requirements	Setback/Buffers/Easements
Dare County	No homeowner/lot owner/developer/contractor shall be allowed to fill in, alter, or pipe any roadside swales shown on the drainage plan approved in conjunction with the final subdivision plat.	Surface drainage course shall have side slopes of at least 3H:1V in feet	Subdivisions must maintain a minimum 30-foot wide setback between all road improvements and defined surface waters of Dare County
Manteo			If any portion of any lot proposed for development that includes a traditionally established drainage ditch, the developer shall dedicate for public use an area 10 feet wide of both sides of the centerline of the drainage ditch for pedestrian greenways. A contiguous 100 foot buffer must be maintained with a maximum slope of no more than two percent. Development may occur within this buffer as long as storm water is managed on site.
Town of Nags Head	Fill shall not be permitted to exceed base flood elevation and in areas in which there is no base flood, fill shall not exceed the amount required for wastewater permits required by the Dare County Health Dept. or two feet above natural elevation, whichever is higher.		
Town of Kill Devil Hills	Filling of a man-made watercourse, lake, pond, ditch, stormwater drainage system is permitted if it demonstrates that the project will not diminish the town's ability to manage stormwater.	For subdivisions, surface drainage courses shall have side slopes of at least three feet of horizontal distance for each one foot of vertical distance, and courses shall be of sufficient size to accommodate the drainage area without flooding, and designed to comply with the standards and specifications for erosion control of the North Carolina Sedimentation Pollution Control Act.	
Town of Kitty Hawk	In defined floodways, no encroachments, including fill, new construction, substantial improvements and other developments, shall be permitted unless it has been demonstrated through hydrologic and hydraulic analyses performed in accordance with standard engineering practice that the proposed encroachment would not result in any increase in flood levels during the occurrence of the base flood.		Where a subdivision is traversed by a watercourse, drainageway, channel, or stream, there shall be provided a stormwater easement or drainage right-of-way conforming substantially with the lines of such watercourse, and such further width of construction, or both, as will be adequate for the purpose. Parallel streets or parkways may be required in connection therewith.
Southern Shores	No grading, filling, or other alteration of the topography or elevation of any unimproved lot shall be undertaken prior to granting of a permit by the Building Inspector.		
Duck	For land development, fill shall not be allowed within 5 feet of any side or rear property line except to directly match the grade at the street and to accommodate driveway improvements as approved by the Planning Director or Board of Adjustment.	Fill shall be established at a slope not to exceed 3H:1V. The toe of the slope shall meet the 5 feet property setback line.	Land disturbing activities, excluding necessary clearing and grubbing shall not be permitted within 5 feet from any property line with the exception of drainage and stormwater improvements and underground utilities.
Currituck County	No fill of any kind shall be allowed within 10 feet of any property line except as associated with a driveway improvements located within 10 feet of the front property line and/or a bulkhead for shoreline protection with the exception of lots within Planned Unit Developments.	All fill shall be established at a slope not to exceed 3H:1V. The toe of the slope shall meet the 10 foot setback requirement from all property lines.	Land disturbing activities excluding clearing, grubbing and vegetable gardens shall not be permitted within 10 feet from any property line with the exception of drainage and stormwater improvements and underground utilities.
Colington Harbor	Any build-up of material placed on a lot, other than the septic field, is hereby limited to a maximum 18 inches before the concrete pad is poured, and then graded accordingly to taper or slope to each side line. Lots may not be filled beyond the individual property lines, i.e. road right of way, without first getting approval from the ACC.		Easements are reserved unto the Developer for the purpose of conveying to public utility companies the necessary easements for utilities along and within 10 feet of the front, rear, and side lines of all original lots in the subdivision for the construction and perpetual maintenance of conduits, poles, wires and fixtures for electrical lights, telephones and other public and quasi public utilities and drainage.
Martin's Point	No fill material may be placed in the swale or any part of the Common Area other than that which is necessary under the driveway and then only after written approval by the Committee. No fill material may be placed on a Lot in the side setback areas unless the fill lies under a line with a vertical to horizontal slope of 1 to 3 or less.	Fill, where allowed must be established at a slope not to exceed 3H:1V.	The Association reserves unto itself a fifteen (15) foot easement surrounding all ponds and wet areas for the purpose of protection of said areas from erosion and the implementation of adequate draining and circulation of said ponds and wet areas.
Whalehead Subdivision			

	Driveway Crossings	Minimum Building Setbacks [1,2,3,4]	Exceptions to Building Setbacks
Dare County	Driveway improvements may be sloped to retain the shape of the retention basins in lieu of driveway culverts if approved by the Dare County Engineer. A culvert pipe shall be installed where any proposed driveway, roadway, walkway, or other improvement crosses an established drainage feature (e.g. roadside ditches, swales, streams, etc.). Minimum requirements for culverts are given.	For unzoned areas, minimum building setback must be 25 feet from the front property line, 10 feet from the side property lines, 20% of lot depth, not to exceed 20 feet from the rear property lines.	In those zoning districts that permit multifamily structures, an increase in the permitted dwelling density may be authorized according to the following table
Manteo		Varies by zoning district type. For most residential districts, setback must be 15 feet from the front property line, 10 feet from the side property lines, 20% of the lot depth, not to exceed 20 feet from the rear property lines. Maximum allowable lot coverage is 30% except that the lot may be increased by 8% for detached structures. Commercial uses allow for increased lot coverage, typically 55%.	
Town of Nags Head	A culvert shall be installed in any existing town ditch or swale prior to constructing a driveway over such ditch or swale. Culvert requirements are given.	Varies by zoning district type. For most residential districts, setback must be 30 feet from the front property line, 8-12 feet from the side property lines, 20% of the lot depth, not to exceed 30 feet from the rear property lines. Maximum allowable lot coverage is 30% plus 300 sq feet or 33%, whichever is greater. Coverage may be increased to a maximum of 40%-45% if open-face paving block or Turfstone us use in place of concrete or asphalt. Commercial uses are less stringent on front setback (15 feet) and allow for increased lot coverage, typically 55% or up to 65% with open-face paving.	
Town of Kill Devil Hills	A culvert shall be installed in any existing town ditch or swale prior to constructing a driveway over such ditch or swale.	Varies by zoning district type. For most residential districts, setback must be 15 or 30 feet from the front property line, 6-10 feet from the side property lines, 20% of the lot depth, not to exceed 30 feet from the rear property lines. Maximum allowable lot coverage varies by lot size but ranges between 40-55%. Allowable coverage is dependent on wetland soils on site. Commercial uses have similar setbacks but allow for 65% maximum allowable lot coverage.	
Town of Kitty Hawk		Kitty Hawk Zoning broken up into Kitty Hawk Woods, Kitty Hawk Village, and Kitty Hawk Beach. Kitty Hawk Woods district encourages low impact development, to preserve natural state. Other districts are subdivided into various residential/commercial zones. For most residential districts, setback must be 25 feet from front property line, 10 feet from side property line, 20% of lot depth, not to exceed 20 feet from the rear property lines. Maximum allowable lot coverage is 30%. Commercial uses have reduced front setbacks of 15 feet and allow for 60% lot coverage.	No yard or lot existing on August 18, 1986 shall be reduced in dimension or area below the minimum requirements. Yards or lots created after August 18, 1986 shall meet at least the minimum requirements established by this chapter.
Southern Shores		Varies by zoning district type. For most residential districts, setback must be 25 feet from front property line, 15 feet from side property lines, and 25 feet from rear property lines. Maximum allowable lot coverage is typically 30%. Commercial uses have slightly reduced setbacks and allow for 60% maximum lot coverage.	
Duck		Varies by zoning distinct type. For most residential districts, setback must be 25 feet from front property line, 10 feet from side property lines, and 20 feet from rear property line. Maximum allowable lot coverage is typically 30%. Commercial uses reduce the front setback to 15 feet and allow for 60% maximum lot coverage.	Allow for reductions in minimum yard requirements in residential districts, if approved by the zoning administrator for structures such as driveways, patios, swimming pools, etc. It was noted that the Town is looking at ordinance changes to include all driveways/parking areas in lot coverage regardless of composition to avoid conversion of driveways to pervious surfaces and transfer of the resulting extra lot coverage square footage into addn'l pool concrete or house footprint.
Currituck County		Setbacks defined for all residential structures: Street setback is 20 feet, side line setback is 15 feet, rear line setback is 25 feet. Maximum allowable lot coverage is 30% for general residential districts, 35% for residential lots between 10,000 to 19,000 sq feet, and 45% for lots less than 10,000 sq feet in area.	Total lot coverage may be increased by 15% if 50% of the maximum allowable coverage is in Turfstone or equivalent porosity, or if the development is served by an approved and functional stormwater management plan.
Colington Harbor		No resident structure shall be located nearer than 25 feet to front property line, 8 feet to any side lot line, and 20% of the depth of the lot for the rear setback. Colington Harbour was zoned single-family residential (R-4) in 1985 by Dare County and is subject to that designation under the Zoning Ordinances of Dare County.	
Martin's Point	Permanent driveways shall incorporate an asphalt, brick or concrete apron extending from the roadway edge to the lot line and a culvert, placed under the apron in the existing roadside swale.	No building, including porches, shall be located on any lot within 40 feet of the front lot line, closer than 12.5 feet to the sidelines, or 25 feet to the rear lot line.	
Whalehead Subdivision		For residential lots, no building or structure, including porches, shall be nearer than 20 feet to the front or side street line, 15 feet to any interior side line, or 30 feet to the rear lot line.	

Additional Notes:

[1] Setbacks defined above represent typical or average for residential and commercial uses.

[2] Side setbacks typically higher (typically +5 feet) when lot abuts a street.

[3] There are typically conditional uses/regulations for various zoning differences which may allow different setbacks.

[4] Frontage setback typically increased for lots on major roadways.

SARB_004622

	Off-Street Parking Requirements	Materials For Parking	Drive Aisle Requirements
Dare County	Parking requirements are given for various uses.	Requirements typically specify that at least a percentage of the parking shall be an impervious surface. For example: One parking space for each authorized bedroom or bedroom equivalent shall be provided with 50% of the required parking spaces of an impervious surface. The remainder may be of a pervious surface. Concrete, asphalt, turf-stone and /or paving block installed over a clay sub-base are considered impervious surfaces. Gravel, stone, grassed or sodded areas, or turf-stone and/or paving block installed over a sand sub-base shall be considered pervious surfaces.	A drive aisle, minimum width of 10', shall be provided to facilitate emergency vehicle access and vehicle maneuvering. This drive aisle shall be constructed of an impervious surface.
Manteo	Parking requirements are given for 30 different uses. Parking lots shall not drain onto or across public sidewalks or into adjacent property, except into a natural watercourse or a drainage easement.	Parking lots shall be constructed with a surface which will permit safe and convenient passage of vehicles in all weather conditions. Suggested materials include porous asphalt, oyster shells, paving block similar to turf stone, or other materials approved by the Planning Board.	
Town of Nags Head	Parking requirements vary for different uses. Accessory buildings shall be included with principal buildings in measurement of gross floor area for determining parking requirements.	Required parking spaces shall be graded and paved with asphalt, concrete, gravel, porous paving as approved by the town engineer or an open-face paving block over sand and filter-cloth base, provided that the open-face paving block is equivalent to TurfstoneTM with regards to compressive strength, density, absorption and durability.	Residential drive aisles, minimum of 12 feet in width shall be provided.
Town of Kill Devil Hills	Parking requirements vary for different uses. In all zones, parking space dimensions will be 200 square feet, 10 feet by 20 feet. However, for commercial and multi-family residential, only 18 feet of the length need to be paved or constructed of turfstone. The remaining two feet of length shall remain pervious, and a concrete curb stop shall be placed at the front end of each space to accommodate vehicle overhang on the remaining two feet of length.	Commercial driveways, parking areas and turn-around areas shall be made of asphalt, concrete or permeable blocks. Single-family and duplex residential driveway and parking areas can utilize approved commercial materials above or a minimum of four inches of compacted Aggregate Base Course (ABC) with one inch of pea gravel as an approved surface.	Vehicle accommodation areas of all development shall be designed so that sanitation, emergency, and other public service vehicles can serve such developments without the necessity of backing unreasonable distances or making other dangerous or hazardous turning movements.
Town of Kitty Hawk	Parking requirements vary for different uses. Each parking space shall have a minimum length of 18 feet and width of 9.5 feet with the addition of an unpaved open area 2 feet in length beyond the concrete.	Required parking spaces and driveways, other than for single-family or two-family uses, shall be graded and improved with approved surfaces, such as concrete, asphalt, or turfstone. Grass, however, may be used as a parking surface if the town council approves it as a conditional use. Driveways shall be constructed of concrete, asphalt, or turfstone.	
Southern Shores	Parking requirements vary for different zoning uses. Each parking space shall have a minimum length of 20 feet and a minimum width of 10 feet. When a parking space abuts an open space, then 2 feet at the end of the space shall be left unpaved to allow for drainage. No parking spaces for residential use, except for single-family and two-family use, shall be located in the required front yard.	Required parking spaces and driveways, for other than single-family and two-family uses shall be graded, improved with concrete or I-2 asphalt. For large residential dwellings, the drive-aisle and one-half of the required parking spaces shall have an improved surface of concrete or asphalt. Other required and additional spaces may be either gravel, perforated paving blocks, or polymer open-cell soil stabilization systems. Such porous parking areas shall be excluded from lot coverage calculations.	For residential uses, a 10 foot wide drive aisle shall be provided.
Duck	Parking requirements vary for different zoning uses. Each parking space shall have a minimum length of 20 feet and minimum width of 10 feet. Accessory buildings shall be included with principal buildings in measurement of gross floor area for determining parking requirements. All space requirements which are based in part or in whole upon employment shall be computed on the basis of the greatest number of persons on duty at any one period during the day or night in the peak season.	Required parking shall be graded and improved with asphalt, concrete, gravel, or porous paving as approved by the zoning administrator or an open-face paving block (equivalent to Turfstone) over a pervious base.	Drive aisles shall be a minimum 12 feet in width and have same surface requirements as parking.
Currituck County	Parking requirements vary for different zoning uses. Each parking space shall contain a rectangular area at least 20 feet long and 10 feet wide. For single-family and two-family residences located in RO1 and RO2 district, minimum parking space shall be 8 feet in width and 15 feet in length.	Vehicle accommodation areas shall be graded and surfaced with asphalt, concrete, crushed stone, gravel, or other suitable material that will provide protection against potholes, erosion, and dust.	Drive aisles for residential use shall be a minimum of 15 feet in width.
Colington Harbor	A concrete or asphalt paved driveway or a parking pad for a minimum of two cars must be included for all residential structures. Paving must be continuous with the roadway.	Concrete or asphalt.	
Martin's Point	There are no specific parking requirements in the covenants. Driveway requirements include an asphalt, brick, or concrete apron extending from roadway edge to the lot line.		
Whalehead Subdivision	There are no specific parking requirements in the covenants, except that private garages are limited to two cars.		

	Erosion & Sedimentation	Landscaping	Landscaping Buffers
Dare County	No specific regulations for soil erosion and sedimentation control. Under subdivision regulations, state that stream banks and channels upstream from any land disturbing activity shall be protected in accordance with the NC Sedimentation Pollution Control Act.	There are no specific landscaping/buffer ordinances. The Zoning regulations require a visual buffer where a commercial use or zone abuts a residential use or zone. However, regulations do not specify that the buffer be planted with native plants. The Planning Board may recommend the use of a buffer strip adjacent to major roads and to commercial or industrial development which would be part of the platted lots but have the following restriction on the face of the plat: This strip reserved for the planting of trees or shrubs by the owner; the building of structures prohibited	Wetland buffer. Existing natural wetlands, ponds, and wetland swales shall not be dredged, filled or otherwise altered from their natural state. No structure, paved area, or any part of a ground absorption wastewater treatment system shall be located within 50 feet of any marsh, stream, pond, or wetland. Minor road crossing fill for property access shall be allowed only as authorized under the jurisdiction of the Army Corps of Engineers specifications for access roads.
Manteo	Require prior approval of an erosion and sedimentation control plan for any development that would cause land disturbing activity. Land disturbing activity means any use of the land by any person in residential, industrial, educational, institutional, or commercial development, highway and road construction and maintenance that results in a change in the natural cover or topography and that may cause or contribute to sedimentation except exempt activities.	Each development shall provide sufficient screening so that neighboring properties are shielded from any adverse external effects, the development is shielded from negative impacts of adjacent uses such as streets or parking lots.	Three buffer types are established: Parking/Traffic Buffer, Opaque Screen Buffer (req'd between commercial/residential use), and Setback Buffer (req'd between commercial uses). Recommended trees are given for different buffer types, based on hardiness, longevity, ease of maintenance, and long-term cost-effectiveness.
Town of Nags Head	Land disturbance above which sedimentation and erosion control devices are required is 5,000 square feet. Sediment must be retained within the boundaries of the tract during construction upon and development of said tract and plantings or otherwise permanent ground cover is required to restrain erosion after completion of construction.	All large residential dwellings shall comply with one of the following requirements: A) The preservation of a minimum of ten percent of the lot's total area with existing natural vegetation and/or dune elevations. Or B) The planting of a minimum of 15 percent of the lot's total area. The minimum lot area for large residential dwellings shall be 16,000 square feet. At minimum 50 percent of the required landscaping shall consist of locally adapted live evergreen tree species. The remainder of the buffer may be live forbs and shrubs. The above landscaping requirements may be altered due to unique and unusual physical conditions or characteristics of the property, including the reduction of landscaping requirements for oceanfront properties and other lots containing significant dune features that will be preserved in equal proportion.	Any new use of land shall provide a buffer yard if required under the pertinent zoning regulations. 10 buffer yard types are defined. Required type(s) is given for each zoning district.
Town of Kill Devil Hills	Land disturbance above which sedimentation and erosion control devices are required is 1/2 acre. Sediment must be retained within the boundaries of the tract during construction upon and development of said tract and plantings or otherwise permanent ground cover is required to restrain erosion after completion of construction.	A perimeter landscaped area, with a minimum depth of five feet may be required along property lines. Along property lines abutting any street, the minimum depth will be ten feet. Driveways, sidewalks and similar facilities may traverse perimeter landscaped areas. No more than 20% of a required perimeter landscaped area may be utilized for sidewalks, walkways, or private roads. Landscaping standards may be satisfied within required setbacks. The planting of drought-tolerant vegetation common to the immediate natural coastal environment is encouraged to ensure proper plant life development and maturation.	
Town of Kitty Hawk	Land disturbance above which sedimentation and erosion control devices are required is 1 acre. Sediment must be retained within the boundaries of the tract during construction upon and development of said tract and plantings or otherwise permanent ground cover is required to restrain erosion after completion of construction.	Buffer details including vegetation type and size, and fence details shall be submitted for planning board review and for approval by the town council. Plants shall be selected for their hardiness, growth potential and suitability to the particular site. Plants should be indigenous or drought and salt tolerant.	Three buffer types are established. Required type(s) is given for each zoning district.
Southern Shores	No specific regulations for soil erosion and sedimentation control.	Landscaping plans of the intended development shall be submitted and approved prior to the preliminary landscaping plan. Suitable plant types shall be those recommended for the coastal area by the U.S. Department of Agriculture which can be expected to reach a mature growth of eight (8) to ten (10) feet. The vegetation plan shall be approved by the Town Council. Buffers to be permitted in the town shall consist of berms, fencing and/or vegetation.	Where a commercial use abuts a residential zone, or where a conditional use is planned in a residential zone, a buffer of dense vegetative planting or natural vegetation is required. Three buffer types are defined.
Duck	Any lot requiring a land disturbance permit shall install erosion and sediment control measures to prevent sediment from leaving the site. A land disturbance permit shall be required for filling and/or grading a lot, any lot clearance, filling or grading activity prior to issuance of a building permit, any installation of gravel or pavers or accessory structures and similar site features whether or not subject to building permit requirements, and any removal or installation of site features such as septic systems, wells, and drainage systems that disturb the land.	Native species and related cultivars are encouraged.	Buffers are required as described for each zoning district. In general, landscape buffers shall measure no less than ten feet in width. Only landscaping and approved fences and walls shall be permitted within a required buffer or street yard area, except that sidewalks and other pedestrian walkways, bicycle paths, aboveground utilities, drainageways, and approved signs shall be permitted where they do not comprise more than 20 percent of the total area of the required buffer or street yard.
Currituck County	Any lot requiring a land disturbance permit shall install erosion and sediment control measures to prevent sediment from leaving the site. Land disturbing activity means any use of the land by any person in residential, industrial, educational, institutional or commercial development, highway and road construction and maintenance that results in a change in the natural may cause or contribute to sedimentation except activities that are exempt.	Each development shall provide sufficient screening so that neighboring properties are shielded from any adverse external effects, the development is shielded from negative impacts of adjacent uses such as streets or parking lots. When undeveloped land is subdivided and undeveloped lots only are sold, the subdivider shall not be required to install any landscaping. Screening shall be required, if at all, only when the lots are developed. There are no specific requirements to use native or drought-tolerant vegetation.	Four buffer types are established. Required type(s) is based on land use type (zoning district).
Colington Harbor			
Martin's Point			
Whalebead Subdivision			

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Other Applicable Regulations

Standard For Most Towns & Counties Having Soil Erosion & Sedimentation Control Regulations:
No land-disturbing activity shall be permitted in proximity to a lake or natural watercourse unless a buffer zone is provided along the margin of the watercourse of sufficient width to confine visible siltation within the 25% of the buffer zone nearer the land-disturbing activity, provided that this subsection not apply to a land-disturbing activity in connection with the construction of facilities to be located on, over or under a lake or natural watercourse.

Town of Manteo From Pedestrian Greenways and Drainage Ditches Section of Zoning Ordinance:
Every multifamily residential development of 12 or more units or mixed use of 12 or more units shall be developed so that at least 5 % of the total area of the development remains permanently as public pedestrian greenways. Greenways mean areas which are not encumbered with a substantial structure, not devoted to use as a roadway or parking area, are left in natural undisturbed state except for cutting of trails or landscaping.

Appendix C

Draft Model Ordinance for Stormwater Management (Post-Construction) in the Outer Banks

Model Ordinance

for

Stormwater Management

(Post-Construction)

along the

North Carolina Outer Banks

2006 June 19
v1.0

SARB_004627

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SARB_004628

Introduction

As this ordinance addresses a topic which is technical in nature, some portions of this document may appear complex relative to ordinances for signage, subdivisions, grading, zoning, and other aspects of real estate development. Effort has been put forth to present this ordinance in relatively non-technical terms understandable and necessary for individuals building, reviewing, and administering real estate development projects (typically home builders, infrastructure contractors, landscape installers, home buyers, government regulators, elected officials, and local citizens), while presenting key technical information in terms understandable and necessary for individuals planning, analyzing, designing, and certifying real estate development projects (typically civil engineers, land surveyors, and landscape architects). The purpose of this ordinance is to protect natural resources; to protect public health, safety, and welfare; and to maintain and improve life quality and economic development. It is intended that this ordinance will provide flexibility to builders, designers, planners, and regulators and facilitate the implementation of Low Impact Development (LID) and similar approaches to real estate development.

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Section 1. General Provisions

1. Authority

In accordance with the provisions of Sections XXXX-XXX to XXXX-XXX and of Article XX of Chapter XXXX of the General Statutes of North Carolina, the [local government entity] hereby adopts this ordinance.

2. Background

The following is hereby acknowledged.

1. Real estate development projects and associated modifications to the natural landscape directly alter the hydrologic response (quantity, constituents, and character) of sites being developed, the watersheds containing sites being developed, and (to a lesser degree) areas outside the watersheds containing the sites being developed;

2. Real estate development without appropriate stormwater management increases stormwater runoff rates, volumes, flooding, stream pollutants, and infrastructure costs; and decreases stormwater infiltration, aquifer recharge, stream flow, surface water quality, and aquatic resources;

3. Appropriate stormwater management can be implemented to minimize the negative aspects of real estate development on hydrologic response (quantity, constituents, and character) through regulatory mechanisms.

Therefore, the [local government entity] establishes this set of policies to provide reasonable guidance for real estate development stormwater management with the purpose of protecting natural resources; protecting public health, safety, and welfare; and maintaining and improving life quality and economic development.

3. Purpose

The provisions of this ordinance have been prepared with regards to the hydrologic and real estate development character of the North Carolina Outer Banks. The purpose of this ordinance is to protect natural resources; to protect public health, safety, and welfare; and to maintain and improve life quality and economic development.

This ordinance seeks to meet that purpose through the following objective: The postdevelopment hydrologic response (quantity, constituents, and character) of each site having undergone real estate development construction shall mimic the predevelopment hydrologic response of each site (quantity, constituents, and character). This ordinance applies to new construction and redevelopment projects.

The primary aspects of hydrologic response which are of concern, include, but are not necessarily limited to:

1. Quantity. The postdevelopment total quantity (mass, volume) of stormwater infiltrating the soil surface at the site, evapotranspirating from the site, and flowing from the site by way of surface runoff (eg, open channel flow, sheet flow, pipe flow) shall mimic the predevelopment total quantity (mass, volume) of stormwater infiltrating the soil surface at the site, evapotranspirating from the site, and flowing from the site by way of surface runoff (eg, open channel flow, sheet flow, pipe flow).

2. Constituents. The postdevelopment instantaneous, event, and total mass of constituents transported from the site by surface flow (stormwater runoff) and subsurface flow (soil water) shall mimic the predevelopment instantaneous, event, and total mass of constituents transported from the site by surface flow (stormwater runoff) and subsurface flow (soil water).

3. Character. The postdevelopment character (instantaneous flow rates, site hydrograph shape) of stormwater runoff from the site shall mimic the predevelopment character (instantaneous flow rates, site hydrograph shape) of stormwater runoff from the site.

4. Applicability

This ordinance shall be applicable to all construction (residential, commercial, institutional, and others) of $10,000 or greater estimated total cost (material supplies, installation labor, government fees, professional fees, and other costs), unless granted a waiver by the [local government entity] under the specifications of Section 4 of this ordinance or eligible for an exemption as indicated below. The total cost is based upon the average value of the US Dollar during 2005 and shall be adjusted to the current value based on the US Federal Consumer Price Index (CPI) at the date on which the first construction permit application (subdivision, zoning, building, or other) was received by the [local government entity].

This ordinance applies to construction activities that are less than $10,000 total cost (as defined above) if such activities are part of a larger construction project, even though multiple separate and distinct construction activities may take place at different times and on different schedules.

The entire parcel (lot, tract, etc) or parcels (lots, tracts, etc) on which the construction is proposed to occur is subject to implementation of stormwater management as per the requirements of this ordinance. Stormwater management shall be undertaken either as a part of the proposed construction or as a separate retrofit, whether or not the proposed construction was proposed to include stormwater management for the entire parcel or portions thereof. All construction (residential, commercial, institutional, and others) of any type (parking expansion, room addition, interior remodeling, landscape improvement, and others) is subject to this ordinance.

All plans must be reviewed and approved by the [local government entity].

The following activities may be exempt from the requirements of this ordinance:

1. Logging and agricultural activities which are regulated by the State of North Carolina, have an approved soil conservation plan and/or timber management plan (as appropriate) prepared or approved by the appropriate agency (or agencies), and are in compliance with such plan(s).

2. Maintenance and repairs to stormwater management measures deemed necessary by the [local government entity].

Additions or modifications to existing structures (single family buildings and others), including such activities resulting from storm damage and other natural disasters, are not exempt from this ordinance.

5. Compatibility

This ordinance is not intended to interfere with, abrogate, or annul any ordinance, rule, regulation, statute, or other provision of law. The requirements of this ordinance should be considered minimum requirements, and where any provision of this ordinance imposes restrictions different from those imposed by any other ordinance, rule, regulation, statute, or other provision of law, whichever provisions are more restrictive shall be considered to take precedence.

6. Severability

If the provisions of any article, section, subsection, paragraph, subdivision or clause of this ordinance shall be judged invalid by a court of competent jurisdiction, such order of judgment shall not affect or invalidate the remainder of any article, section, subsection, paragraph, subdivision, or clause of this ordinance.

7. Guidance

The [local government entity] may furnish additional policy, criteria, and information including specifications and standards, for the proper implementation of the requirements of this ordinance. This may be provided in the form of a Stormwater Management Manual or other documents. Technical guidance provided in such a Manual and associated documents shall not supplant the judgement of appropriately licensed professionals with suitable background in stormwater management. Development of plans by licensed professionals without suitable background in stormwater management shall be subject to referral to the appropriate NC Licensing Boards. Not all stormwater management activities require professional licensure, however, unlicensed individuals undertaking analysis and design of stormwater management components which require licensure for such work shall be subject to referral to the appropriate NC Licensing Boards.

Section 2. Definitions

"Accelerated Erosion" means erosion caused by real estate development activities that exceeds the natural processes by which the surface of the land is worn away by the action of water, wind, or chemical action.
"Applicant" means a property owner or agent of a property owner who has filed an application for a stormwater management permit.
"Channel" means a natural or artificial watercourse with a definite bed and banks that conducts continuously or periodically flowing water.

"Dedication" (dedicate) means the deliberate appropriation of property by its owner for general public use.
"Detain" (detention) means the temporary storage of stormwater prior to controlled release as runoff. (Contrast with retention.)
"Developer" means a person who undertakes real estate development activities.
"Fee-in-Lieu" means a payment of money in place of meeting all or part of the stormwater performance standards required by this ordinance.
"Hydrologic Soil Group" (HSG) means a Natural Resource Conservation Service (NRCS) classification system in which soils are categorized into four groups of infiltration potential. The groups range from A soils, with high permeability and little runoff production, to D soils, which have low permeability and produce much more runoff.
"Impervious Cover" means those surfaces that cannot effectively infiltrate rainfall (e.g., building rooftops, pavement, sidewalks, driveways, etc).
"Infiltration Facility" means any structure or device designed to infiltrate retained water to the subsurface. These facilities may be above grade or below grade.
"Infiltration" means the process of water moving into the soil matrix from the soil surface.
"Jurisdictional Water" means a surface water under regulatory control of the local, state, or federal governments.
"Landowner" means the legal or beneficial owner of land, including those holding the right to purchase or lease the land, or any other person holding proprietary rights in the land.
"Maintenance Agreement" means a legally recorded document that acts as a property deed restriction, and which provides for long-term maintenance of stormwater management practices.
"Mimic" means significantly equivalent in nature.
"Nonpoint Source Pollution" (NPS) means pollution from any source other than from any discernible, confined, and discrete conveyances, and shall include, but not be limited to, pollutants from agricultural, silvicultural, mining, construction, subsurface disposal and urban runoff sources.
"Off-Site Facility" means a stormwater management measure located outside the subject property boundary described in the permit application for real estate development activity.
"On-Site Facility" means a stormwater management measure located within the subject property boundary described in the permit application for real estate development activity.
"Open Space" means a vegetated, unoccupied, space open to the sky, without vertical structures or surfaces covered with pavements or other relatively impervious materials.
"Recharge" means generally downward movement of water through the soil matrix to below the limits of active evapotranspiration effects.
"Retain" (retention) means to facilitate full infiltration and/or evapotranspiration of stormwater, not allowing runoff. (Contrast with detention.)
"Stop Work Order" means an order issued which requires that all construction activity on a site be stopped.
"Stormwater Management Measures" (SMMs) means components, either structural or nonstructural, that function to manage one or more components of hydrologic response (quantity, constituents, and character) from stormwater inputs.
"Stormwater Management" means the use of structural or nonstructural practices to manage one or more components of hydrologic response (quantity, constituents, and character) from stormwater inputs.

"Stormwater Retrofit" means stormwater management for an existing site that previously had no stormwater management measures in place, measures inadequate to meet the stormwater management requirements of the this ordinance, or measures inadequate to meet other stormwater management goals or requirements.
"Stormwater Runoff" means water flow across ground surface, resulting from precipitation.
"Stream" (Creek, River) means an open water system which carries sediment from higher elevation areas to lower elevations.
"Watercourse" means a permanent or intermittent stream or other body of water, either natural or man-made, which gathers or carries surface water.
"Wetland" means an area that is inundated or saturated by surface water or groundwater at a frequency and duration sufficient to support a prevalence of vegetation typically adapted for life in saturated soil conditions, commonly known as hydrophytic vegetation.

Section 3. Stormwater Management Permit Procedures and Requirements

1. Permit Required

No land owner, land operator, or equivalent entity shall receive any signage, subdivision, grading, zoning, and other real estate development permits required by the [local government entity] without first meeting the requirements of this ordinance prior to commencing the proposed activity.

2. Application Requirements

Unless specifically excluded by this ordinance, any land owner, land operator, or equivalent entity desiring a permit for a real estate development activity shall submit to the [local government entity] a permit application on a form provided for that purpose.

Unless specifically excluded by this ordinance, a full stormwater management permit application package must include the following in order that the permit application be considered.

1. A completed stormwater management permit application form

2. A stormwater management plan (with associated supporting calculations and data, as appropriate)

3. A stormwater management maintenance agreement

4. A stormwater management performance bond (as required)

5. A nonrefundable stormwater management permit application review fee

The stormwater management plan shall be prepared to meet the requirements of Section 5 of this ordinance, the maintenance agreement shall be prepared to meet the requirements of Section 9 of this ordinance, and fees shall be those established by the [local government entity].

Prior to submission of a full permit application package, the requesting entity (land owner, land operator, or equivalent) may submit a stormwater management concept plan for review and comment by the [local government entity] prior to submission of a full stormwater permit application package. The stormwater management concept plan shall be prepared at a standard engineering scale and include, at a minimum: property boundaries, legal easements, existing landform and vegetation features, proposed landform and vegetation features, and proposed stormwater management features; each of which must be appropriately indicated by labels or a legend.

3. Application Review Fees

The fee for review of any real estate development application shall be based on: 1) the amount of land proposed to be disturbed at the site; and 2) the total estimated project cost. The fee structure shall be established by the [local government entity] and updated annually. All fees shall be credited to a [local government entity] account to support [local government entity] plan review, inspection, enforcement, and program administration, and shall be made prior to the issuance of any signage, subdivision, grading, zoning, and other real estate development permits.

4. Application Procedure

1. A full stormwater management permit application package shall be submitted to the [local government entity] on standard [local government entity] business days during regular business hours.

2. Three print copies of all documents shall be submitted.

3. One electronic copy of all documents shall be submitted in Portable Document Format (PDF). This may be emailed or submitted on appropriate media (compact disc, digital video disc, magnetic tape, other) as deemed appropriate by the [local government entity].

4. Within [XX] business days of receiving a full stormwater management permit application package, the [local government entity] shall inform the applicant of approval or disapproval of the stormwater management application components (completed application form, plan, supporting calculations and data (as appropriate), maintenance agreement, performance bond (as required), nonrefundable permit application review fee).

5. If any of the stormwater management application components are disapproved, the applicant may revise and resubmit the disapproved component without revising and resubmitting other components except as deemed necessary by the [local government entity]. No additional fee is required for the first resubmittal. An additional fee of 25% of the initial application fee is required for each subsequent resubmittal.

6. If stormwater management application components are resubmitted, the [local government entity] shall inform the applicant of approval or disapproval of the resubmitted stormwater management application components within [XX] business days of receiving the resubmitted components.

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7. The stormwater management permit shall be issued upon approval of all stormwater management application components.

5. Permit Duration

Stormwater management permits shall be valid from the date of issuance through the date the [local government entity] notifies the permit holder that all stormwater management measures have passed the final inspection required under the permit conditions.

Section 4. Waivers to Stormwater Management Requirements

1. Minimum Conditions

Every applicant shall provide for stormwater management as required by this ordinance, unless a written request is filed to waive this requirement. Requests to waive the stormwater management plan requirements shall be submitted to the [local government entity] for approval. The minimum requirements for stormwater management may be waived in whole or in part upon written request of the applicant, provided that at least one of the following conditions applies:

1. It can be demonstrated that the proposed development is not likely to impair attainment of the objectives of this ordinance.

2. Provisions are made to manage stormwater by an off-site facility. The off-site facility is required to be in place, to be designed and adequately sized to provide a level of stormwater management that is equal to or greater than that which would be afforded by on-site stormwater management measures, or set forth in this ordinance, and there is a legally obligated entity responsible for long-term operation and maintenance of the stormwater management facility.

3. The [local government entity] finds that meeting the minimum on-site management requirements is not feasible due to legal or physical characteristics of the site.

2. Evaluation Criteria

In instances where one of the conditions above applies, the [local government entity] may grant a waiver from strict compliance with these stormwater management provisions, as long as acceptable mitigation measures are provided. However, to be eligible for a variance, the applicant must demonstrate to the satisfaction of the [local government entity] that the variance will not result in the following.

1. Deterioration of existing canals, culverts, ditches, bridges, dams, and other structures.

2. Degradation of local aquatic or terrestrial flora and fauna.

3. Impairment of downstream water quality.

4. Accelerated erosion or sedimentation.

5. Increased health risk, property damage, or community nuisance from flooding.

3. Mitigative Measures

Furthermore, where compliance with minimum requirements for stormwater management is waived, the applicant will satisfy the minimum requirements by meeting one of the mitigation measures selected by the [local government entity]. Mitigation measures may include, but are not limited to, the following:

1. The purchase and donation of privately owned lands; the grant of an easement to be dedicated for preservation, enhancement or rehabilitation; or similarly regarded activity which will directly offset impacts from existing stormwater runoff. In lieu of a monetary contribution, an applicant may obtain a waiver of the required stormwater management by entering into an agreement with the [local government entity] for the granting of an easement or the dedication of land by the applicant, to be used for the construction of an off-site stormwater management facility. The agreement shall be entered into by the applicant and the [local government entity] prior to the recording of plats or, if no record plat is required, prior to the issuance of the building permit.

2. The development and implementation of a stormwater management facility or other stormwater improvements on previously developed properties, public or private, that currently lack stormwater management facilities designed and constructed in accordance with the purposes and standards of this ordinance.

3. Monetary contributions (Fee-in-Lieu) to fund stormwater management activities such as research and studies (e.g., water quality and quantity monitoring, flora and fauna studies, hydrologic analysis, stormwater management monitoring, and others). The applicant shall be required to pay a fee in an amount as determined by the [local government entity]. All of the monetary contributions shall be credited to an appropriate capital improvements program project, and shall be made by the developer prior to the issuance of any building permit for the development. The fee shall be credited to a [local government entity] account to support [local government entity] plan review, inspection, enforcement, and program administration, and shall be received by made prior to the issuance of any signage, subdivision, grading, zoning, and other real estate development permits.

Section 5. Minimum Stormwater Management Hydrologic Performance Criteria

Unless judged by the [local government entity] to be exempt or granted a waiver, the following performance criteria shall be addressed for stormwater management at all sites.

1. Option A: Simplified Method

The Simplified Method may be employed for a project if either of the two conditions are met.

1. The total area of land to be disturbed is less than one acre.

2. The estimated total cost (material supplies, installation labor, government fees, professional fees, and other costs) of the project is $50,000 or less. The total cost is based upon the average value of the US Dollar during 2005 and shall be adjusted to the current value based on the US Federal Consumer Price Index (CPI) at the date on which the first construction permit application (subdivision, zoning, building, or other) was received by the [local government entity].

The Simplified Method is solely volume based, without consideration for stormwater infiltration or evapotranspiration during the precipitation event. The Simplified Method has one requirement: the total 2-year 24-hour precipitation event volume shall be retained on the project site and infiltrated and/or evapotranspirated within 48 hours of the precipitation event end.

2. Option B: Standard Method

The Standard Method shall be employed for any project not eligible for the Simplified Method and not employing the Advanced Method. The Standard Method may also be employed for any project eligible for the Simplified Method.

The Standard Method is event response based. The Standard Method has the following three requirements.

1. The site postdevelopment total volume of stormwater runoff from the 10-year 24-hour precipitation NRCS Type III design event shall not exceed the predevelopment total volume from the same design event.

2. The site postdevelopment total mass of nitrogen, phosphorous, sediment, and fecal coliform from the 10-year 24-hour precipitation NRCS Type III design event shall not exceed the predevelopment total quantity from the same design event.

3. The site postdevelopment character of stormwater runoff from the 10-year 24-hour precipitation NRCS Type III design event shall mimic the predevelopment character from the same design event relative to the Normalized Maximum Flow Residual (NMFR). The NMFR is the maximum difference between a specific postdevelopment hydrograph flow value and the predevelopment hydrograph flow value during the corresponding time interval over the range of time intervals divided by the maximum predevelopment flow value. NMFR = ((Maximum ($Qpost_i$ - $Qpre_i$))/$Qpre_{max}$). NMFR shall not exceed 5% (NMFR <= 0.05).

For the above parameter criteria, predevelopment and post development site response hydrographs shall be developed for 10-year 24-hour precipitation NRCS Type III design event. These hydrographs shall consist of at least 100 data pairs (time, flow) and shall have a temporal range extending from the beginning of the precipitation event to the time at which the flow rate decreases (on the falling limb of the hydrograph) to within 10% of the flow rate prior to the precipitation event.

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3. Option C: Advanced Method

The Advanced Method may be employed for any project. The Advanced Method is continuous simulation based.

The Advanced Method has the following three requirements.

1. The site postdevelopment total volume of stormwater runoff from the 5-year 24-hour runoff event (volume basis) shall not exceed the predevelopment total volume from the same event.

2. The site postdevelopment total mass of nitrogen, phosphorous, sediment, and fecal coliform from the 5-year 24-hour runoff event (volume basis) shall not exceed the predevelopment total quantity from the same event.

3. The site postdevelopment character of stormwater runoff from the 5-year 24-hour runoff event (volume basis) shall mimic the predevelopment character from the same event relative to the Normalized Maximum Flow Residual (NMFR). The NMFR is the maximum difference between a specific postdevelopment hydrograph flow value and the predevelopment hydrograph flow value during the corresponding time interval over the range of time intervals divided by the maximum predevelopment flow value. NMFR = ((Maximum ($Qpost_i$ - $Qpre_i$))/$Qpre_{max}$). NMFR shall not exceed 5% (NMFR <= 0.05).

For the above parameter criteria, predevelopment and post development site response hydrographs shall be developed for at least a 15 year span. Historical precipitation data from the closest gaging station along the NC Outer Banks with 15 minute resolution data shall be employed for the simulation. The temporal resolution of the hydrograph during the 5-year 24-hour runoff event (volume basis) shall be 5 minutes or finer.

Section 6. Requirements for Stormwater Management Permit Application Package Approval

1. Preparer

The plan and supporting technical documents must be prepared by an individual with adequate knowledge and appropriate licensure to undertake the stormwater management planning, analysis, and design. In general, development of a stormwater plan employing Option A (as specified in Section 5) may not necessitate the preparer to be a licensed professional. Development of a stormwater plan employing Option B (as specified in Section 5) or Option C (as specified in Section 5) requires the preparer to be an appropriately licensed professional with suitable background in stormwater management. Unlicensed individuals undertaking analysis and design of stormwater management components which require licensure for such work shall be subject to referral to the appropriate NC Licensing Boards.

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2. Stormwater Management Permit Application Form

A stormwater management permit application form shall be completed and included in the submittal package. This form shall be notarized by a Notary Public.

3. Stormwater Management Plan Minimum Requirements

A stormwater management plan shall be required with all permit applications. The plan shall include sufficient information (eg, calculations, maps, data, etc) to evaluate the characteristics of the project site; the potential impacts of all proposed construction (present and future) on water resources; and the effectiveness and acceptability of the measures proposed for managing stormwater at the project site. To accomplish this goal the following information shall be included in the stormwater management plan (which may be incorporated into other design/construction plan documents such as those for roadways, sanitary sewer collection, potable water supply, erosion/sedimentation control, landscaping, and others).

1. Introduction. The name and physical address of the project. The name, address, and telephone number of all entities having a legal interest in the project property (including utility providers) with associated legal references (deed, plat, etc). The parcel identification numbers of the project properties. A vicinity map indicating (at least) the project location, adjacent roads, and the nearest public road intersection.

2. Existing Conditions. Sheets or maps indicating the location of existing topographic features: buildings, elevations, landforms, parking areas, roadways, structures, subsurface utilities, surface utilities, surface waters, vegetation, and other significant elements. Elevation contours shall be depicted at 0.5 foot intervals for areas with slopes of less than 1%. Elevation contours shall be depicted at 1.0 foot intervals for areas with slopes of 1% to 5%. Elevation contours shall be depicted at 2.0 foot intervals for areas with slopes of more than 5%. Spot elevations shall depict depressions and peaks. Contours shall extend 15 feet beyond the property boundaries (if possible). All elevations shall be at North American Vertical Datum 1988 (NAVD88). A permanent benchmark which will not be damaged during construction shall be indicated. The project construction boundary shall be clearly depicted and labeled.

3. Proposed Conditions. Sheets or maps indicating location of proposed topographic features: buildings, elevations, pavement, structures, subsurface utilities, surface utilities, shrubs, trees, herbs, turf, and other significant elements. Stormwater management measures will be clearly depicted and labeled. Erosion/sedimentation control measures for stormwater management implementation will also be clearly depicted and labeled. Elevation contours shall be depicted at 0.5 foot intervals for areas with slopes of less than 1%. Elevation contours shall be depicted at 1.0 foot intervals for areas with slopes of 1% to 5%. Elevation contours shall be depicted at 2.0 foot intervals for areas with slopes of more than 5%. Spot elevations shall be sufficient to facilitate tracing the path of all surface water runoff on the site. All elevations shall be at North American Vertical Datum 1988 (NAVD88). The project construction boundary shall be clearly depicted and labeled.

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4. Design Details. Plan sheets or shop drawings indicating finer resolution construction/installation information than can be clearly depicted on proposed conditions sheets or maps. Information level should be sufficient to construct/install all components in concert with proposed conditions sheets/maps.

5. Performance Conditions. A detailed written description of the maintenance, inspection, reporting, and repair requirements for all stormwater management measures. Information should relate routine and special operations for normal and long-term proper functioning on stormwater management measures. Any specific equipment and skills or training necessary for these operations shall be described. It is preferable that the performance conditions be submitted as a separate document from plan sheets and maps.

6. Design Calculations/Data. Sufficient analysis to relate the adequacy of proposed stormwater management measures relative to the requirements of this ordinance. Calculations and supporting data (with maps and other information as appropriate) for the predevelopment and postdevelopment site conditions/response. At a minimum, such shall include: 1) indication of minimum stormwater management hydrologic performance criteria option chosen (A, B, or C); 2) parameters (constants and variables) employed in the analysis (with appropriate British Imperial System units indicated), with references to the information sources; 3) results of the analysis; and 4) references for standard analysis methodologies employed and detailed description (with justification) of nonstandard analysis methodologies.

3. Stormwater Management Maintenance Agreement

The applicant shall execute a stormwater management maintenance agreement with an associated stormwater management easement binding on all subsequent owners of land served by an on-site stormwater management measure in accordance with the specifications of this ordinance. The beneficiary of the maintenance agreement and associated easement will be the [local government entity].

The applicant shall ensure access by the [local government entity] and its agents (consultants, contractors, others retained or employed by the [local government entity]) to all stormwater management measures at the site for the purposes of inspection, maintenance, reporting, and repair operations. The legal instruments conveying such rights to the [local government entity] shall be recorded in the [Dare/Currituck] County Registry and shall transfer with property interest to subsequent title holders.

The maintenance agreement shall specify when inspection, maintenance, reporting, and repair operations will occur, either on a periodic basis or as a result of particular conditions (severe storms, citizen complaints, other) to ensure proper function of the stormwater management measures. The property owner shall grant to the [local government entity] the right to enter the property at reasonable times and in a reasonable manner for the purpose of inspection. This includes the right to enter a property when there is a reasonable basis to believe that a violation of this ordinance is occurring or has occurred, to enter when necessary for abatement of a public nuisance, and for correction of a violation of this ordinance. The maintenance agreement shall contain a provision for increased inspection, maintenance, reporting, and repair operations if

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deemed necessary by the [local government entity] to ensure proper functioning of the stormwater management measures.

The [local government entity] may, at its discretion, accept responsibility for inspection, maintenance, reporting, and repair operations of any existing or future stormwater management measures. Regardless of such provision, the maintenance agreement shall convey adequate and perpetual access as well as sufficient area, by easement or otherwise, for inspection, maintenance, reporting, and repair operations.

4. Stormwater Management Performance Bond

The [local government entity] may, at its discretion, require the submittal of a performance bond or similar security prior to issuance of a permit in order to insure that the stormwater management plan is implemented as required. The amount of the performance bond or similar security shall be the total estimated cost of implementing the stormwater management plan, plus 25%. The performance bond or similar security shall contain forfeiture provisions for failure to complete work specified in the stormwater management plan.

The performance bond or similar security shall be released in full only upon submission of final as-built maps and associated written certification by appropriately licensed professionals that the stormwater management plan has been properly implemented as per all permit requirements. The [local government entity] will make a final inspection of the site after receipt of the as-built maps and associated written certification. The [local government entity] will certify the stormwater management plan construction completion only after any outstanding items have been addressed. Provisions for partial pro-rata releases of the performance bond or similar security based on the completion of various development stages may be undertaken at the discretion of the [local government entity]. The additional 25% portion of the performance bond or similar security shall be retained by the [local government entity] until 18 months after the [local government entity] certifies the stormwater management plan construction completion. This portion of the performance bond or similar security shall be utilized as necessary by the [local government entity] to repair stormwater management measures functioning in an unsatisfactory manner.

5. Stormwater Management Permit Application Review Fee

The stormwater management permit application fee shall be tendered in the form of cash, check, or money order. Checks must be drawn on an account in a bank, credit union, or similar financial institution with primary offices registered in the United States.

Section 7. Construction Inspection

1. Notice of Construction Commencement

The stormwater management permit applicant must notify the [local government entity] no less than [XX] standard work days prior to the intended commencement of construction. Inspections of the stormwater management system construction on a regular or random basis may be conducted by the [local government entity] or its agents (consultants, contractors, others retained or

employed by the [local government entity]). Inspections shall be documented and written reports shall be prepared that contain the following information.

1. The date and location of the inspection

2. Whether construction appears in compliance with the approved stormwater management plan

3. Variations from the approved stormwater management plan

4. Any violations that exist

If any violations are found, the property owner shall be notified in writing of the nature of the violation and the required corrective actions. No added work shall proceed until any violations are corrected and all work previously completed has received approval by the [local government entity].

2. As-Built Map and Written Certification

All stormwater management permit holders shall submit as-built maps for any stormwater management measures on-site after final construction has been completed. The as-built maps should be prepared from a full topographic survey of the construction area by a board certified land surveyor licensed to practice in North Carolina. The as-built survey and associated map should include all elements indicated on the construction/design plans as well as other prominent physical surface features, subsurface utilities, vegetation (including all planted stock as well as dense vegetation groupings), drainage features, above ground utilities, as well as legal and regulatory boundaries (lots, zoning, easements, setbacks, wetlands, hazards, etc). The maps should include contours at the same interval as depicted on the stormwater management plan. Spot elevations should be indicated in areas depicted on the proposed conditions sheet or map. Contours shall extend 15 feet beyond the property boundaries (if possible). All elevations shall be at North American Vertical Datum 1988 (NAVD88). A permanent benchmark shall be indicated. The map shall contain a written certification by an appropriately licensed professional that the stormwater management plan has been properly implemented as per all permit requirements. It is preferable that the certifying licensed professional be the same entity that prepared the stormwater management plan if Option B or Option C of the minimum stormwater management hydrologic performance criteria were employed for the plan.

Three print copies of the as-built maps shall be submitted to the [local government entity]. One electronic copy of the as-built map shall be submitted in Portable Document Format (PDF). This may be emailed or submitted on appropriate media (compact disc, digital video disc, magnetic tape, other) as deemed appropriate by the [local government entity].

Section 8. Performance, Maintenance, Repair, Inspection, and Reporting

1. Performance of Stormwater Management Measures

Stormwater management measures should consistently function at (or above) the minimum stormwater management hydrologic performance criteria specified in this ordinance and employed for the project (Option A, B, or C).

2. Maintenance and Repair of Stormwater Management Measures

Maintenance may include, but is not limited to, the following.

1. Removal of sediment, litter, and debris

2. Replanting or reseeding vegetation

3. Trimming of vegetation

4. Removal of undesirable vegetation

5. Aerating or amending topsoil

6. Patching or sealing boxes, pipes, and other structures

7. Replacing soil and other porous media

Depending upon the type of stormwater management measures and the specific stormwater management maintenance agreement requirements, maintenance operations may be undertaken by the property owner, the [local government entity], or agents of the [local government entity] (consultants, contractors, others retained or employed by the [local government entity]). Relatively frequent maintenance operations may be required for some stormwater management measures, while other stormwater management measures may require little to no maintenance.

3. Inspecting and Reporting on Stormwater Management Measures

Inspecting and reporting may include, but are not limited to, the following.

1. Reviewing maintenance and repair records

2. Sampling discharges, surface water, groundwater, and material or water

3. Evaluating the condition of stormwater management measures and contributing watersheds

4. Photographing stormwater management measures and upslope areas

Depending upon the type of stormwater management measures and the specific stormwater management maintenance agreement requirements, inspections may be undertaken by the property owner, the [local government entity], or agents of the [local government entity] (consultants, contractors, others retained or employed by the [local government entity]). Entities responsible for inspecting and reporting on stormwater management measures shall prepare records of all inspection, maintenance and repair activities. These records shall be maintained for at least 5 years and shall be made available to the [local government entity] and its agents (consultants, contractors, others retained or employed by the [local government entity]) during inspection and at other reasonable times upon request.

Section 9. Enforcement, Violations, and Penalties

1. Violations

Any development activity that is commenced or is conducted contrary to this ordinance, may be restrained by injunction or otherwise abated in a manner provided by law.

If a responsible entity fails or refuses to meet the requirements of the this ordinance, the [local government entity], after reasonable notice, may correct a violation by performing all necessary work to place the stormwater management measures in proper working condition. In the event that a stormwater management measure becomes a danger to the health, safety, or welfare of the public, the [local government entity] shall notify the party responsible for maintenance of the stormwater management measures in writing. Upon receipt of that notice, the responsible entity shall have [XX] standard work days to effect necessary maintenance and repair operations for the stormwater management measures to function at (or above) the minimum stormwater management hydrologic performance criteria specified in this ordinance and employed for the project (Option A, B, or C). After proper notice, the [local government entity] may assess the owners of the property for all costs incurred during such maintenance and repair operations and levy penalties against the owners for the incident. The cost of the maintenance and repair operations shall be a lien on the property, or prorated against the beneficial users of the property, and may be placed on the tax bill and collected as ordinary taxes by the County in which the property is located.

2. Notice of Violation

When the [local government entity] determines that an activity is not being undertaken in accordance with the requirements of this ordinance, it shall issue a written Notice of Violation (NoV) to the owner of the property. The Notice of Violation shall contain, at a minimum, the following information.

1. A statement referencing this ordinance and indicating the [local government entity] has authority in the matter

2. The name and address of the property owner

3. The address of the property

4. A general or legal description of the property upon which the violation is occurring

5. A statement specifying the nature of the violation

6. A description of the management and repair operations required to bring the stormwater management measures into compliance with this ordinance

7. A time schedule for the completion of required management and repair operations

8. A statement of the penalties that may be assessed against the entity to whom the Notice of Violation is directed

9. A statement that the determination of violation may be appealed to the [local government entity] by filing a written notice of appeal within [XX] days of being served with the Notice of Violation.

3. Stop Work Orders

Entities receiving a Notice of Violation shall be required to halt all construction activities on the property on which the violation has been determined to be occurring immediately upon receipt of Notice of Violation. The Stop Work Order will be in effect until the [local government entity] determines that the stormwater management measures are in compliance with is ordinance and the violation has been satisfactorily addressed. Failure to address a Notice of Violation in a timely manner may result in civil, criminal, or monetary penalties in accordance with the enforcement measures authorized in this ordinance.

4. Civil and Criminal Penalties

In addition to, or as an alternative to, any penalty provided herein or by law, any entity which violates the provisions of this ordinance shall be levied a fine of not less than ($1,000) based upon the average value of the US Dollar during 2005 and shall be adjusted to the current value based on the US Federal Consumer Price Index (CPI) at the date on which the first Notice of Violation was served to the violating entity. Such entity shall be guilty of a separate offense for each day during which the violation occurs or continues.

5. Restoration of Lands

Any violator may be required to restore land to its undisturbed condition. In the event that restoration is not undertaken within a reasonable time after notice, the [local government entity] may take necessary corrective action, the cost of which shall become a lien upon the property until paid.

6. Holds on Certificates of Occupancy

Certificates of Occupancy shall not be granted until required management and repair operations required to bring the stormwater management measures into compliance with this ordinance have been completed and accepted by the [local government entity].

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http://www.bioretention.com

Center for Watershed Protection
http://www.cwp.org

Cooperative Research Centre for Catchment Hydrology
http://www.toolkit.net.au

Design: Low Impact Development Manual
http://www.wbdg.org/ccb/DOD/UFC/ufc_3_210_10.pdf

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http://www.ces.ncsu.edu/depts/hort/consumer/masgar

International Stormwater Best Management Practices (BMP) Database
http://www.bmpdatabase.org

Low Impact Development Center
http://www.lowimpactdevelopment.org

Low Impact Development Urban Design Tools
http://www.lid-stormwater.net

Minimum Impact Development
http://www.nhmid.org

National Association of Home Builders Research Center
http://www.toolbase.org

NC Cooperative Extension Service

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http://www.ces.ncsu.edu

NC Cooperative Extension Service County Centers
http://www.ces.ncsu.edu/index.php?page=countycenters

NC Soil & Water Conservation District Offices
http://www.enr.state.nc.us/dswc/pages/district%20offices.html

NC Home Assessment System
http://www.soil.ncsu.edu/assist

NC State University Biological and Agricultural Engineering Department Stormwater Group
http://www.bae.ncsu.edu/stormwater

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http://www.ces.ncsu.edu/depts/hort/consumer/factsheets

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http://www.stormwatercenter.org

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WDMutil (Aqua Terra, EPA) - Hydrologic Data Manipulation
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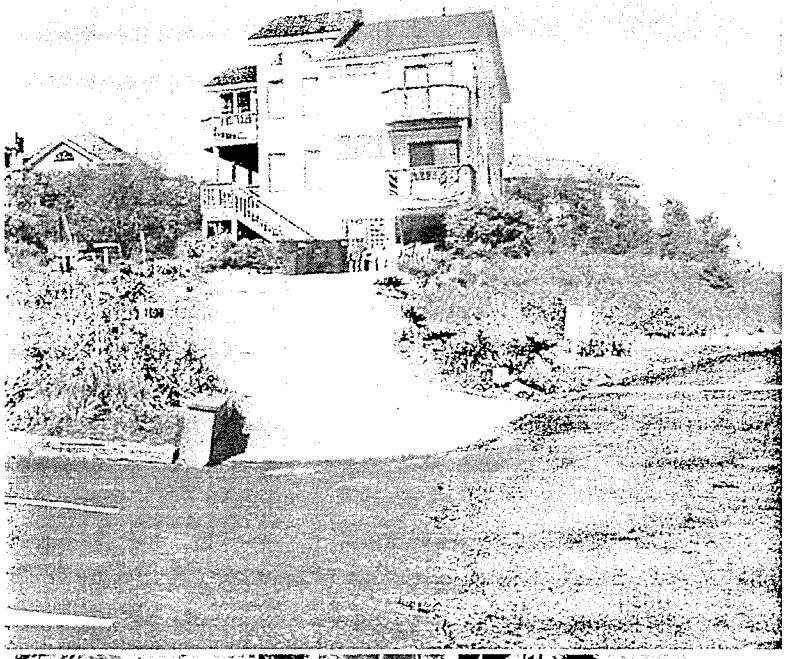

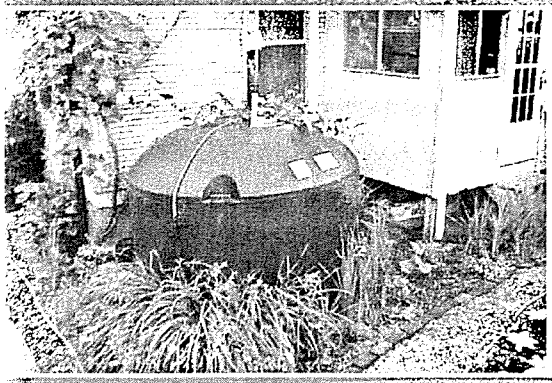

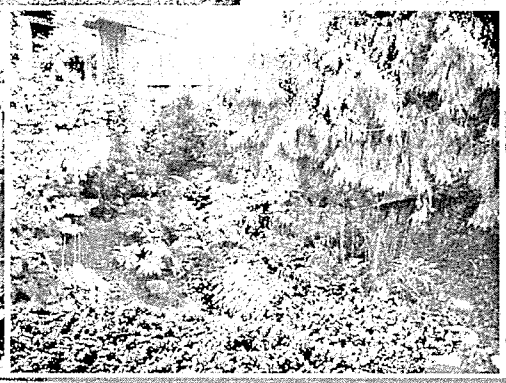

NWQEP NOTES

The NCSU Water Quality Group Newsletter

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PROJECT SPOTLIGHT

New Thinking in an Old City: Philadelphia's Movement Towards Low-Impact Development

Glen J. Abrams, AICP
Philadelphia Water Department

Introduction

The Philadelphia Water Department (PWD), the oldest municipal water department in the United States, is an integrated drinking water, wastewater, and stormwater utility that serves the nation's fifth largest city, with a population of over 1.4 million. Its massive sewer system network includes 1,600 miles of combined sewers, 1,200 miles of separate sanitary and storm sewer lines, 150 miles of intercepting sewers, 169 combined sewer regulating chambers, 85,600 manholes, and 75,000 stormwater inlets.

In 1844, Philadelphia embarked on an ambitious land preservation program to protect drinking water supply by prioritizing acquisition of riparian corridors. Roughly ten percent of the City's land area was dedicated to stream and river valley parks and prevented from development. Nevertheless, industrialization and other development upstream fouled the water that flowed into the City. While water quality in the City's rivers and streams has vastly improved over the past thirty years due to Clean Water Act regulations on "point sources" of pollution, Philadelphia's waterways still do not meet designated use standards. Today, the most significant remaining impacts to the health of the City's rivers and streams result from stormwater runoff, or "nonpoint source pollution," and combined sewer overflows.

To address these remaining challenges, PWD has embraced a comprehensive watershed management program that fosters regional cooperation and looks beyond traditional infrastructure projects as a

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solution to stormwater management and combined sewer overflow mitigation. The program strives to minimize water pollution from all sources in a manner that is based on good science and achieves a sensible balance between ratepayer costs and environmental benefit. To that end, PWD has integrated the department's "wet weather" programs – combined sewer overflow and stormwater management – with a new drinking water source protection program under the umbrella of the Office of Watersheds (OOW).

EDITOR'S NOTE

It is well documented that land clearing and traditional development adversely impact water quality by altering the hydrologic cycle. Plant uptake, evapotranspiration and infiltration are all decreased, leading to increased site runoff. Conventional stormwater management is designed to collect this runoff and convey it off site as quickly as possible, further disrupting the local watershed hydrology. While this approach may prevent local flooding, it often leads to increased streambank erosion, sediment deposition, downstream flooding and wildlife habitat degradation.

Low impact development (LID) is gaining recognition as an environmentally friendly approach to land development and stormwater management. Its objective is to maintain the natural, pre-developed site hydrology through the creation of a hydrologically functional landscape that provides for stormwater source control and treatment. Specifically, LID practices are intended to reduce runoff volume, velocity and pollutant loads by promoting on-site stormwater capture, detention and infiltration. LID can help communities meet Phase II requirements for post construction runoff control.

This issue of *NWQEP NOTES* highlights the innovative programs and projects of the Philadelphia Water Department's Office of Watersheds. Driven by the need to reduce combined sewer overflows, the City uses LID in concert with neighborhood transformation programs to bring about improvements in both water quality and quality of life for its communities. It is inspiring to learn how this city is successfully turning great challenges into even greater opportunities.

As always, please feel free to contact me regarding your ideas, suggestions, and possible contributions to this newsletter.

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The Office of Watersheds

PWD established the Office of Watersheds in 1999 by combining staff from the department's planning and research, collector systems, laboratory services, and other key function groups, and charged the new organization with the goal of watershed protection. PWD realized that the daunting task of addressing nonpoint source pollution and combined sewer overflows would require innovation and a much more collaborative, multi-disciplinary approach. Therefore, additional OOW personnel have training and experience in environmental education, urban planning, environmental engineering, and landscape architecture.

OOW has begun establishing *Watershed Partnerships* for each of the City's waterways (see Figure 1). Watersheds do not conform to municipal and county jurisdictional boundaries, so the need for multi-jurisdictional partnerships is critical. These partnerships provide a forum for regional stakeholders to work together to develop strategies that embrace the dual focus of improving water quality while improving the quality of life in Philadelphia's communities. Similarly, the *Drinking Water Source Protection Program* also recognizes that regional cooperation is the key to success. This award-winning program has identified thousands of potential sites of contamination to the Schuylkill and Delaware Rivers and has assessed their impacts on 50 drinking water facilities throughout Southeastern Pennsylvania. A model Source Water Protection Program, including a first-of-its-kind early warning system for contamination events, is now under development, partially funded through $1.3 million in State and Federal grants.

The *Stream-Based Programs* include extensive monitoring and modeling for water quality and the physical attributes of waterways, both inside and outside the City. Fluvial geomorphology studies and an ongoing wetland inventory allow OOW

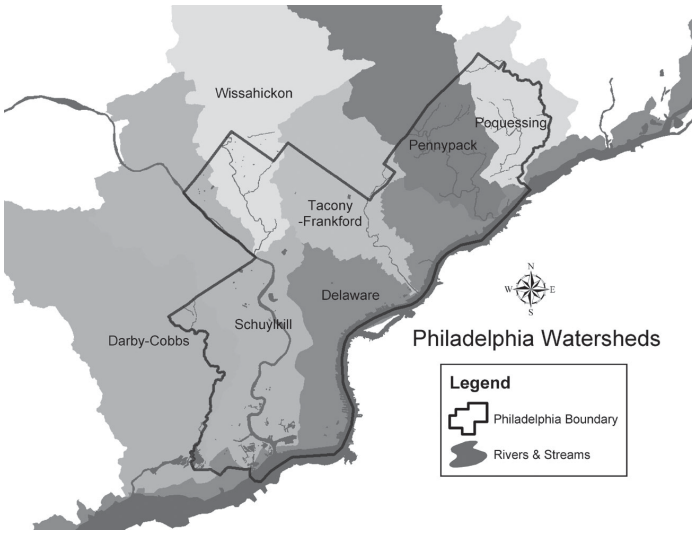

Figure 1: Philadelphia watersheds.

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to plan for and implement major stabilization projects along the City's creeks and define opportunities for wetland protection and enhancement. OOW is also leading the implementation of a $48 million, five-year *Capital Improvement Program* to upgrade infrastructure and improve the capture and treatment of sewage and stormwater in the combined sewer system. One example project is the largest installation of "inflatable dam technology" in the world to more efficiently utilize existing infrastructure for in-pipe storage.

The *Clean Water Act Programs*, specifically the Stormwater Management Program and Combined Sewer Overflow (CSO) Program, are making progress through the implementation of both traditional infrastructure and non-traditional low impact development (LID) projects. OOW has been a proponent of advocating for better urban and suburban design that views stormwater as an asset and not a liability.

Vacant Land and Neighborhood Transformation

The City of Philadelphia is at a crossroads. At its height, over 2 million people lived within the City. However, over the last 50 years population has been steadily declining due to rapid development of the suburbs, decline of the City's manufacturing sector, and a number of other factors. The result has been widespread vacancy and abandonment. A recent survey conducted by the City identified 30,730 vacant lots and 25,992 vacant buildings within the City, equaling about 2,600 acres. While the extent of disinvestment is daunting, the City has chosen to view vacant land as an opportunity to build new neighborhoods that meet the needs of 21st century residents. The presence of vacant land is also an opportunity for PWD to work with other City agencies and local developers to radically change the City's approach to stormwater management.

Low-impact development (LID) is a design approach that attempts to minimize the adverse environmental impacts typically associated with development. A combination of LID site design techniques and stormwater best management practices can help attain the three major goals of stormwater management: reduction of peak flow, reduction of total volume, and reduction of pollutants in runoff. Design features such as rain gardens, green roofs, permeable paving, and infiltration areas are fully integrated into and distributed throughout the landscape and built environment.

The majority of vacant land and buildings in the City is located within areas served by combined sewers (see Figure 2). By incorporating LID and site-specific infrastructure projects that detain stormwater runoff during storm events, or keep it out of the combined sewers entirely, PWD hopes to alleviate combined sewer overflows and minimize the scale of future large infrastructure projects. PWD recognizes that LID and other site-specific projects will not solve the City's CSO problem on their own, but views LID as one valuable tool for CSO mitigation. Furthermore, PWD believes that LID designs can effectively balance development costs and water pollution controls with projects that enhance community aesthetics, quality of life, sustainability, and environmental education.

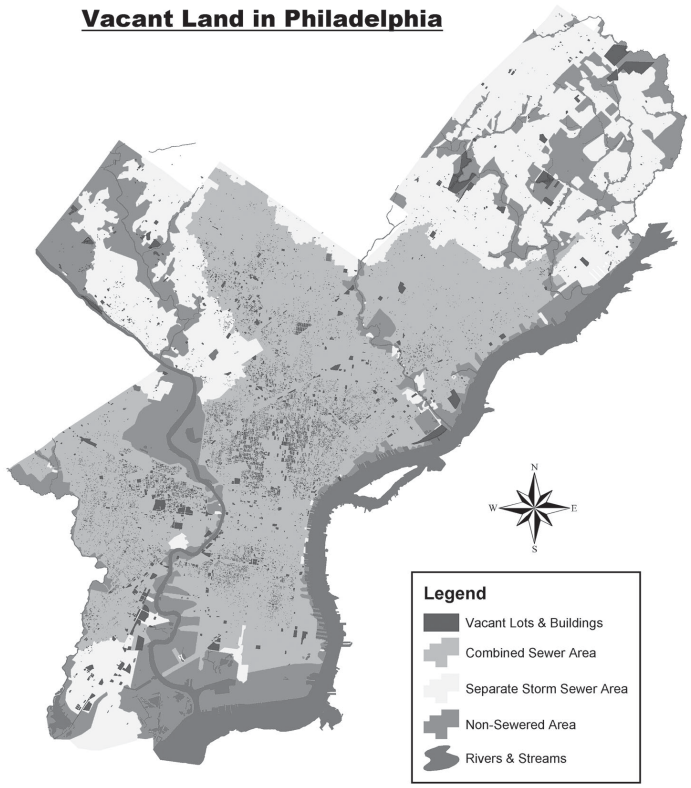

Figure 2: Vacant land in Philadelphia, mostly located in areas served by combined sewers.

Technical Assistance and Demonstration Projects

Recognizing that LID design strategies are new to most people in the Philadelphia area, OOW has taken the lead in providing technical assistance and implementing demonstration projects. Through financial assistance from the Pennsylvania Department of Environmental Protection (DEP), OOW has been able to provide conceptual design services to many institutional and nonprofit partners, such as the Philadelphia School District and community development corporations. Furthermore, OOW has been designing and implementing projects on its own, again through support from PA DEP.

Technical assistance and demonstration projects in the Philadelphia area can be divided into six broad categories:

1) Vacant lot stabilization and transformation
2) School yard projects
3) Parking lot projects
4) Recreation courts

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5) Rooftops, and
6) Large scale redevelopment projects

Vacant Lot Stabilization and Transformation

The first demonstration project designed and implemented by OOW was the conversion of an overgrown, trash-strewn vacant lot into an outdoor classroom for Sulzburger Middle School in West Philadelphia. The site was designed to mimic the transformation of a watershed from "natural" to "man-made," with the back planted with trees and understory plantings and the front paved with concrete (see Figure 3). Stormwater reaches the site as direct rainfall and from the downspout of a neighboring property. A rain barrel collects the initial roof runoff to provide a watering source for the onsite vegetation and the overflow is allowed to flow across the site. The sub-surface stormwater management feature is an infiltration trench excavated to an approximate depth of four feet and backfilled with layers of gravel and sand (see Figure 4). Because of the close proximity of the houses on either side of the lot, the trench was lined with an impervious liner and slowly underdrained by a perforated PVC pipe. The surface of the lot is gently graded to the middle, and the lot is sloped from back to front to emulate a watershed's topography. Three small check dams were installed on the surface above the trench to allow water flowing down the site to puddle and infiltrate down through the mulch, soil, sand, and gravel. Finally, the City's Mural Arts Program was engaged to paint a mural that represents the Schuylkill River as it flows through rural and urban areas. Because this site was built in a combined sewer area, the primary design emphasis was on delaying the time it takes for stormwater from the site to reach the sewer in the street.

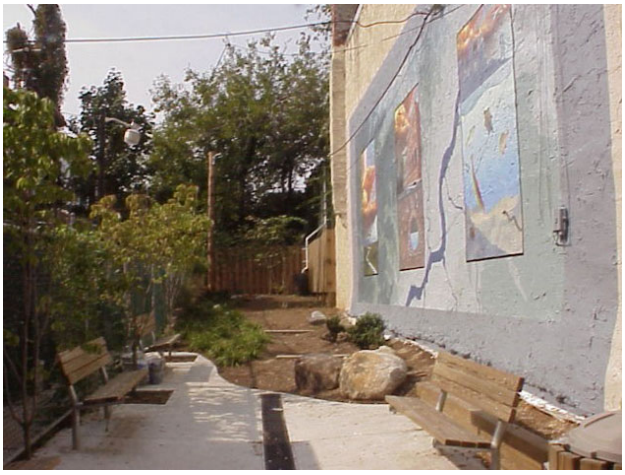

Figure 3: Outdoor demonstration for Sulzburger Middle School in West Philadelphia, mimicking transformation of a watershed from natural to man-made.

While the project above transformed a vacant lot into a productive use, the intensity of the project is not appropriate for most vacant lot stabilization projects. Since the City of Philadelphia is pursuing an aggressive policy of demolishing derelict vacant properties, OOW felt it was necessary to demonstrate rather simple grading techniques to ensure that stormwater stays on site and does not unnecessarily drain into the sewers. The demonstration site, with an approximate area of 14,250 square feet, was re-graded to direct runoff to the middle of the site, planted with a few trees and a flowering ground-cover border for aesthetic appeal, and fenced to prevent short dumping. As such, in the interim while properties such as this site are land-banked and awaiting development, most runoff is directed into small depressions and swales and allowed to infiltrate, easing the burden especially on the City's combined sewer system.

Figure 4: Construction of infiltration trench at Sulzburger Middle School demonstration site.

A more permanent vacant lot strategy involves identifying lots that are appropriate for long-term open space, often as community pocket parks or gardens. OOW's demonstration of this kind of project targeted a small corner lot at the end of a block. Although this parcel had been developed as a community pocket park several decades ago, deferred maintenance had essentially rendered the park unusable, except for the most unsavory of activities. Given the location of this lot at the downward slope of the block, it was a logical choice for demonstrating how bioretention and sub-surface storage can be easily incorporated into a neighborhood. The site was cleared and graded toward a small bioretention garden along the perimeter of the site, with gravel storage below the soil (see Figure 5). Furthermore, a new porous walkway, benches, and trees were installed. Currently only runoff from the parcel itself is managed by the bioretention garden, but it is hoped that future funding can be used to retrofit the design to manage roof runoff from many of the block's properties. In this scenario, property rain leaders would be connected to a storm line installed under the rear alleyway and runoff would be directed into the subsurface storage. Because of the small rear yards on this particular block, on-property bioretention is not feasible.

School Yard Projects

One of the largest institutional landholders in the City is the School District of Philadelphia, with 276 schools serving nearly 215,000 students. Unfortunately, over the years many school campuses have become nearly entirely paved, which results in schools that are completely divorced from the natural environment. The School District recognized the value in restoring green space to schoolyards and has established the Campus Park Ini-

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Figure 5: Vacant lot demonstration site under construction.

tiative. OOW has been closely collaborating with the District and individual schools on their updated campus plans to ensure that stormwater management is included as an integral component, both of site plans and environmental education.

The first school project to include LID in the schoolyard design was at the newly constructed Penn Alexander School. Three key elements of the site design manage much of the site runoff: (1) Play field with subsurface stormwater storage/infiltration area; (2) Bioretention "rain garden;" and (3) porous asphalt play yard with subsurface storage (see Figures 6 and 7). Runoff from about 40% of the school's roof area is collected and piped under the play field into an 18-inch gravel bed, where it is allowed to freely infiltrate. The gravel itself provides storage volume for runoff from about 1.5 inches of rainfall. A pipe from the infiltration bed daylights onto the lawn and allows overflow to flow overland to street inlets. Runoff from another section of roof (about 20%) is collected and conveyed to the rain garden. The roughly 1,400 square foot garden

Figure 6: Planting vegetation at Penn Alexander School raingarden.

area is designed for a maximum ponding depth of about 3 inches, providing about 170 cubic feet of surface storage. This surface storage manages runoff from the first ½-inch of rainfall from the contributing roof area. However, additional water volume control is provided via storage in the mulch and soil layers as well as infiltration. The infiltration bed beneath the porous play yard receives overflow from the rain garden in addition to the rainfall that falls directly on the play yard. The porous portion of the play yard is almost 5,000 square feet, with the gravel infiltration bed beneath the playground providing approximately 400–500 cubic feet of storage. Overflow from the infiltration bed flows directly to the combined sewer in the street.

Figure 7: Penn Alexander School porous asphalt play yard under construction.

Two other schoolyard projects have been designed with assistance from OOW, with construction anticipated in 2004. Turner Middle School will be converting over 60,000 square feet of pavement area to a garden and outdoor classroom/learning lab that will rely on overland flow to collect and infiltrate stormwater runoff from the surrounding schoolyard. Wissahickon Charter School, an elementary school with an environmental education focus, will construct a similar project at the front of their school. The design will "daylight" surface runoff and a portion of roof runoff into a naturalized watercourse that terminates in a bioretention basin located at the lowest site elevation. This school is located within an area served by separate storm sewers that outfall upstream of a drinking water intake, so the design is especially attuned to improving the quality of site runoff, via careful attention to subsurface filtering media and plant selection, in addition to reducing/delaying the quantity of runoff.

Parking Lot Projects

Within all urbanized areas, a significant proportion of land area is devoted to parking. Thus, OOW sees great value in offering alternatives to traditional parking lot designs that collect and convey stormwater offsite as quickly as possible. Low-impact parking lots often use simple and relatively inexpensive features, such as utilizing medians or landscaped buffers as

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bioretention or infiltration areas, to manage stormwater. The City's new Police Forensics Laboratory, converted from a long-vacant school building, directs parking lot runoff into landscaped medians through several curb cuts (see Figure 8). The medians were designed as slightly depressed planting areas, and storm inlets within the medians were raised to allow some ponding and encourage infiltration. Another project to be constructed this year will retrofit an oversized teachers' parking lot by removing pavement around the existing inlet, amending the soil, planting the area as a bioretention garden, and raising the inlet to allow ponding to provide some surface storage and encourage infiltration. A new parking lot to be constructed adjacent to the Schuylkill River will also rely on bioretention/infiltration to manage and treat, at a minimum, the most polluted "first-flush" of runoff before it is discharged into the river upstream of one of the City's drinking water intakes. The garden will also be designed as a gateway feature for the East Falls neighborhood.

Figure 8: Low impact parking lot with landscaped median at Philadelphia's new Police Forensic Laboratory.

Recreation Courts

Another significant proportion of City land area is devoted to recreation courts, such as basketball and tennis courts. OOW is working with the City's Recreation Department on a demonstration of porous pavement for court surfaces. The two basketball courts at the Mill Creek Playground will be replaced, one with a standard asphalt covering and the other with a porous paving above a gravel storage basin. The impervious court will drain onto the pervious, and runoff from other portions of the site will be conveyed into the gravel storage via modified storm inlets. Nearly two feet of gravel will be necessary to provide the necessary storage volume. Due to poor soil conditions, the design will not rely on infiltration. A perforated riser within the gravel basin will slowly drain the detained runoff, and in times of particularly heavy rainfall the riser will provide direct overflow to the sewer system. Because this project is located within a combined sewer area, the primary design objective is to increase the time of concentration for site runoff. After construction this fall, the project will be monitored to measure the efficacy of the stormwater management design and also to determine how basketball players react to the different surface material.

Rooftops

Rooftops are another impervious surface that can be readily converted to a stormwater management feature. Following the recent lead of Chicago, Portland, and Toronto and many years of implementation in Germany, Philadelphia is beginning to construct vegetated roofs. The first "green roof" constructed in Philadelphia was a 3,000 square foot demonstration project at the Philadelphia Fencing Academy completed in 1998. Currently, two nonprofit agencies in Philadelphia are in the process of implementing green roof designs for their facilities. Norris Square Civic Association, a community development corporation serving a growing Hispanic community in North Philadelphia, has renovated a former industrial building into a community marketplace and will install a green roof on the building as part of the project. Although the roof area is quite small (5,440 square feet), the location adjacent to the City's elevated rail line with a daily average ridership of 50,000 ensures that the project will have high visibility and educational benefit. The Enterprise Center CDC has also proposed a green roof for their new building, Enterprise Heights, which will provide office space for start-up businesses. This will be the first new construction project in Philadelphia to incorporate a green roof, and will include other green building features. Finally, OOW has begun collaborating with the City's Capital Program Office to begin incorporating green roofs, where feasible, when facilities are scheduled for roof replacement or when new facilities are constructed.

Large Scale Redevelopment Projects

The small-scale projects designed and implemented to date are meant to demonstrate the effectiveness of various stormwater best management practices within a very dense urban context. However, pursuing LID techniques is most effective when incorporated from the onset of project planning and design. Early participation in the design process ensures that every surface in a design is considered in the hydrologic context and that stormwater management features are integrated into every element of the development project. Too often, stormwater management is viewed as a requirement that can be squeezed onto the "leftover" land at the end of the design process. The greatest challenge and opportunity of LID is to design stormwater management facilities that provide multiple benefits, including improved aesthetic appeal, recreational opportunities, wildlife habitat, and a positive environmental message.

To date, OOW has had the opportunity to participate in one large-scale redevelopment project. In 2001, the Philadelphia

Continued on p. 9

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NCSU Water Quality Group Publications List and Order Form (February 2004)

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WQ-131*	Stream Restoration: A Natural Channel Design Handbook (2003) (129p) *http://www.ncsu.edu/sri/stream_rest_guidebook/guidebook.html*	35.00	_____	_____
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WQ-96	Goal-Oriented Agricultural Water Quality Legislation (Water Resources Bulletin) (1996) (14p)	Free	_____	
WQ-92	The Rural Clean Water Program: A Voluntary, Experimental Nonpoint Source Pollution Control Program and its Relevance to Developing Countries (1995) (18p)	Free	_____	
WQ-83	Effective Monitoring Strategies for Demonstrating Water Quality Changes from Nonpoint Source Controls on a Watershed Scale (Wat. Sci. Tech.) (1993) (6p)	Free	_____	
WQ-21	Setting Priorities: The Key to Nonpoint Source Control (EPA 841-B-87-110) (1987) (50p)	Free	_____	
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WQ-60	Selecting Priority Nonpoint Source Projects: You Better Shop Around (EPA/506/2-89/003) (1989) (39p)	5.00	_____	_____
WQ-24	Selecting Critical Areas for NPS Pollution Control (J. Soil & Water Conservation) (1985) (4p)	Free	_____	
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WQ-07	Best Management Practices for Ag. Nonpoint Source Pollution Cntrl: II. Commercial Fertilizer (1982) (55p).	6.00	_____	_____
WQ-08	Best Management Practices for Agric. Nonpoint Source Pollution Cntrl: III. Sediment (1982) (47p)	5.00	_____	_____
WQ-09	Best Management Practices for Agric. Nonpoint Source Pollution Cntrl: IV. Pesticide (1984) (87p)	8.00	_____	_____
WQ-98	Farm*A*Syst Fact Sheets (7 fact sheets) (1997) (*http://h2osparc.wq.ncsu.edu/info/farmassit/index.html*)	Free	_____	
WQ-99	Home*A*Syst Fact Sheets (5 fact sheets) (1997) (*http://h2osparc.wq.ncsu.edu/info/farmassit/homeindx.html*)			
WQ-89	Rural Clean Water Program Technology Transfer Fact Sheets (10 fact sheets) (1995) (*http://h2osparc.wq.ncsu.edu/info/concepts.html*)	Free	_____	
WQ-91	Watershed Management: Planning and Managing a Successful Project to Control Nonpoint Source Pollution (contains a list of resources specific to North Carolina) (1995) (8p) (*http://www.bae.ncsu.edu/bae/programs/extension/publicat/wqwm/ag522.html*)	Free	_____	
WQ-86	Paired Watershed Study Design (EPA 841-F-93-009) (1993)	Free	_____	
WQ-48	Pesticide Fact Sheets (10 fact sheets) (1988)	4.00	_____	_____
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- NCSU Water Quality Group home page: http://www.ncsu.edu/waterquality/
- U.S. Environmental Protection Agency's Office of Water publications list: http://www.epa.gov/OW/info
- WATERSHEDSS — Water, Soil, Hydro-Environmental Decision Support System, Internet-based management tool: http://www.water.ncsu.edu/watershedss/
- Understanding the Role of Agricultural Landscape Feature Function and Position in Achieving Environmental Endpoints: Final Project Report (to the U.S. Environmental Protection Agency) (1996) (118p) (*abstract and instructions for downloading the report available at: ftp://ftp.epa.gov/epa_ceam/wwwhtml/software.htm*

Housing Authority (PHA) was awarded a $35 million HOPE VI grant from the U.S. Department of Housing and Urban Development to demolish and rebuild the Mill Creek housing development and invest in the surrounding areas. In the grant application, PHA committed to working with the Philadelphia Water Department (PWD) to create an innovative stormwater management design. This demonstrated a significant departure from the typical redevelopment approach in the older sections of Philadelphia, in which housing infrastructure and street inlets are connected to the existing combined sewer system.

The initial design for the development included LID design features such as vegetated swales, disconnected roof leaders, and distributed infiltration of stormwater. However, as design concepts were more clearly developed, PHA became concerned about site maintenance and liability issues that it perceived would result from accepting the LID concepts. Because these designs were new to Philadelphia's densely populated urban setting, the City Planning Commission and some units within the Water Department also expressed reservations about many of the proposed LID elements for similar reasons. Furthermore, much of what was proposed was in direct conflict with existing City codes and ordinances.

As a result, most of the innovative "softscape" design features were replaced with more traditional infrastructure. For instance, instead of using vegetated swales to convey runoff to a detention/infiltration area, the parties involved opted to construct two dedicated stormwater lines. All detention and infiltration of site runoff is subsurface and is therefore not visible to community residents. Furthermore, infiltration zones are not distributed throughout the site, but instead are concentrated in one area. Therefore, at the surface, very little separates this development from other past developments. However, despite the design challenges faced during the course of the project, the ultimate goal was realized: this final design separates a sizable portion of the site runoff from the existing combined sewer system.

The Future of Stormwater Management and Watershed Planning in Philadelphia

Philadelphia is in the very beginning stages of implementing a better approach to stormwater management. However, the experience with the PHA project described above clearly indicates that many challenges still remain. The City's existing stormwater ordinance must be overhauled to reflect the most current practices in watershed sciences and encourage watershed-wide planning. The City's land development codes also must be updated to ensure that they are not an impediment to implementing LID designs. Economic incentives need to be created to reward those that carry out truly innovative designs that exceed minimum requirements. And most importantly, OOW must continue to educate others on the merits of LID and its important role in ensuring the long-term health of the region's watersheds.

For More Information

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Information

Decision Support System for NPS Control Available on the Web

The North Carolina State University Water Quality Group has developed a watershed-level, web-based decision support system called WATERSHEDSS (WATER, Soil, and Hydrologic Decision Support System), which allows users to conduct a preliminary watershed evaluation in order to determine appropriate best management practices (BMPs). WATERSHEDSS is available at: **http://www.water.ncsu.edu/watershedss/**

The site's two primary objectives are to:

1. Transfer water quality and land treatment information to watershed managers in order to assist them in making appropriate land management decisions to achieve water quality goals.
2. Assess and evaluate sources, impacts, and potential management options for control of nonpoint source pollution in a watershed based on user-supplied information and decisions.

The site provides educational information covering diverse topics on water quality, monitoring, land treatment, watershed management, and watershed projects. The site also provides a searchable database of over 6,000 annotated articles on NPS pollution control developed by the NCSU Water Quality Group over the past 20 years.

Getting to Smart Growth: 100 Policies for Implementation, Volume 2

EPA and ICMA recently released *Getting to Smart Growth II: 100 More Policies for Implementation*. Free copies are available for a limited time. This document provides states and communities with 100 policy options that can be mixed and matched to fit local circumstances, visions, and values, and highlights steps that the private sector can take to encourage more livable communities. It follows on the heels of the extremely popular first volume of Getting to Smart Growth. The publica-

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tion serves as a road map for states and communities that have recognized the need for smart growth but are unclear on how to achieve it.

Like the first volume, Getting to Smart Growth II provides 10 policy options to achieve each of the 10 Smart Growth Principles. These policies are supported with *Practice Tips* that offer additional resources or brief case studies of communities that have applied the approach to achieve smart growth. Features of the new volume include

- An entirely new list of 100 policies for implementation
- More case studies and examples in each chapter
- An appendix listing funding resources for smart growth projects.

To get a free hard copy of this publication from the Smart Growth Network and EPA, call EPA's Development, Community, and Environment Division at 202-566-2878.

To download an electronic copy of the publication in PDF format, go to: **http://www.smartgrowth.org/library/articles.asp?art=870**

For information on joining the Smart Growth Network, visit **http://www.smartgrowth.org/sgn/join.asp.**

2003 Summary Report of Section 319 National Monitoring Program Projects

The annual report of the Section 319 National Nonpoint Source Monitoring Program (NMP) is available on-line at **http://www.ncsu.edu/waterquality/**. This report provides profiles for 24 watershed projects selected under the NMP that are being monitored over a 6- to 10-year period to evaluate effectiveness of best management practices in reducing nonpoint source water pollution. Printed copies are available by contacting Cathy Smith at 919-515-3723 or cathy_scache@ncsu.edu.

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Meetings

Meeting Announcements — 2004

April

STORMWATER: Emerging Issues for Local Communities, 2004 Southeast Regional Conf: April 19-21, 2004, Raleigh, NC. Contact Dr. Bill Hunt at bill_hunt@ncsu.edu. Website: www.soil.ncsu.edu/swetc/stormwaterconf/main.htm.

17th Annual Nat'l Conf: Enhancing The States' Lake Management Programs: Effective Monitoring Programs for Lakes & Reservoirs: April 20-23, 2004, Chicago, IL. Contact Bob Kirschner, Chicago Botanic Garden, 1000 Lake Cook Road, Glencoe, IL 60022; Email: bkirschn@chicagobotanic.org; Web site: http://www.nalms.org/symposia/chicago/index.htm

May

4th Nat'l Monitoring Conf: Building & Sustaining Successful Monitoring Programs: May 17-20, 2004, Chattanooga, TN. Contact the conference coordinator at nwqmc2004@tetratech-ffx.com or 410-356-8993. Web site: www.nwqmc.org

Stormwater Program Mgmt & BMPs: Pollutants, Selection & Maintenance Workshops & Exposition: May 19, 2004, Myrtle Beach, SC. Contact Steve Di Giorgi, Program Director. Tel: 805-682-1300 x129; Email: stevedg@forester.net

June

Environmental Statistics Short Course: June 7-9, 2004, Colorado State University. E-mail: loftis@engr.colostate.edu; Website: www.engr.colostate.edu/~loftis/

Southeastern Regional Conf on Stream Restoration: June 21-24, 2004, Winston-Salem, NC. NC Stream Restoration Institute. Web site: http://www.bae.ncsu.edu/programs/extension/wqg/sri/2004_conference/index.html

Riparian Ecosystems & Buffers: Multi-scale Structure, Function & Mgmt: June 28-30, 2004, Olympic Valley, CA. American Water Resources Association. Web site: http://www.awra.org/meetings/Olympic2004/index.html

July

Soil & Water Conservation Society 2004 Annual Conf: July 24-28, 2004, St. Paul, MN. Contact Nancy Herselius, SWCS meetings coordinator. Tel: 515-289-2331, ext. 17; Email: nancy.herselius@swcs.org; Website: www.swcs.org/t_what_callforpapers04.htm.

StormCon 2004, the North American Surface Water Quality Conference & Exposition: July 26-29, 2004, Palm Desert, CA. Website: www. StormCon.com.

September

Self-Sustaining Solutions for Streams, Wetlands, & Watersheds: Sept 12-15, 2004, St. Paul, MN. ASAE. Contact Andy Ward, Conference Chair, The Ohio State University, Tel: 614-292-9354; Email: ward.2@osu.edu; Web site: http://www.asae.org/meetings/streams2004/Index.html

Second Nat'l Conf on Coastal & Estuarine Habitat Restoration: Sept 12-15, 2004, Seattle, WA. Contact Nicole Maylett at nmaylett@estuaries.org; Web site: http://www.estuaries.org/2ndnationalconference.php

12th Nat'l Nonpoint Source Monitoring Workshop: Sept 26-30, 2004, Ocean City, MD. Contact Tammy Taylor at 765-494-1814; Email: taylor@ctic.purdue.edu; Web site: http://www.ctic.purdue.edu/NPSWorkshop/NPSWorkshop.html (see Call for Abstracts on p. 11).

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Call For Abstracts

12th National Nonpoint Source Monitoring Workshop: Managing Nutrient Inputs and Exports in the Rural Landscape

September 27-30, 2004
Ocean City, Maryland

About the Conference: The 12th year of this workshop will once again bring together land managers and water quality specialists to share information on the effectiveness of best management practices in improving water quality, effective monitoring techniques, and statistical analysis of watershed data. The workshop will focus on the successes of Section 319 National Monitoring Program projects and other innovative projects from throughout the U.S. The agenda will include three days of sessions, posters presentations and a field trip. Plus, two half-day workshops will focus on Project Evaluation and Nonpoint Source Modeling.

Session Topics:

- Detecting change in water quality from agricultural BMP implementation
- Modeling applications for NPS pollution
- Integrating monitoring into management activities
- Innovative management strategies in the agriculture landscape
- Agricultural nonpoint source pollution TMDLs
- Volunteer monitoring in 319 projects
- Innovative monitoring in the agricultural landscape
- Riparian area and stream protection/restoration in the agricultural landscape
- Programs and approaches for animal operations and nutrient management

Presentations will be 20 minutes, followed by 10 minutes for discussion. Poster presentations are also encouraged. Proposals can be submitted two ways. Pick **one** of the following:

1. Submit online at: http://www.ctic.purdue.edu/NPSWorkshop/Abstracts.html.
2. Email or mail a proposal with the following information included: (MS Word or Text file)
   a) Author name, affiliation, session topic the presentation will address, and preferred presentation format (oral or poster). Also include mailing address, phone, fax and email.
   b) The circumstances creating the need for the project.
   c) The measurable objectives of the project.
   d) The project design and methods employed in: designing the project, enlisting cooperators, developing implementation programs or approaches, measuring implementation, monitoring the effectiveness of the implementation, and developing TMDLs or models.
   e) Partnerships (public and private) supported and/or created by this project, including partner role and contribution to the project.
   f) A description of how the project integrated monitoring and implementation.
   g) A discussion of results:
      - Did the monitoring indicate the project goals were accomplished?
      - What changes in land treatment/land uses occurred?
      - How did these changes relate to water quality monitoring results?
      - How was the model used in conjunction with the implementation?
      - How was the TMDL implemented?

Mail to: Nonpoint Source Workshop
1220 Potter Drive, Suite 170
West Lafayette, IN 47906
Phone (765) 494-9555; Fax (765) 494-5969
Email: taylor@ctic.purdue.edu
Conference Website: http://www.ctic.purdue.edu/NPSWorkshop/NPSWorkshop.html

Deadline for submission of abstracts is **March 15, 2004.**

Authors will be notified by April 15, 2004 regarding the status of their abstract.

If you have questions, contact Tammy Taylor at taylor@ctic.purdue.edu

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United States
Environmental Protection Agency

Office of Water (4203)
Washington, DC 20460

EPA-841-B-00-005D
October 2000

Vegetated Roof Cover

Philadelphia, Pennsylvania

Key Concepts:

- Structural Control
- Retrofit Opportunity
- Volume Reduction
- Life Cycle Costs

LOW-IMPACT DEVELOPMENT CENTER

Project Benefits:

- Runoff Reduction
- Air & Water Quality Improvement
- Aesthetics
- Energy Conservation

Introduction

Vegetated roof covers on industrial and office buildings have been used in Europe for more than 25 years to control runoff volume, improve air and water quality, and promote energy conservation. These systems, known as "green roofs" or "extensive roof gardens," also have aesthetic benefits. They typically include layers of drainage material and planting media on a high-quality waterproof membrane. These systems use foliage and a lightweight soil mixture to absorb, filter, and detain rainfall. Some of the conditions responsible for the promotion and acceptance of green roofs in Europe, which many American cities face as well, are

- Widespread implementation of stormwater-related fees or taxes
- Laws requiring mitigation or compensation for the elimination of open space
- Densely populated areas with high real estate values
- Requirements to reduce loads on combined sewer systems (CSSs)

Project Area

The demonstration project was installed on the roof of the Fencing Academy of Philadelphia (Figure 1). Like many urban areas on the East Coast, Philadelphia experiences frequent, small, high-intensity storm events. These short-duration events frequently overload and surcharge sewer systems. In the Philadelphia region, storms with 24-hour volumes of 2 inches or less contribute 90 percent of all rainfall. Vegetated roof covers are designed to control these high-intensity storms by intercepting and retaining water until the rainfall peak has passed, while also allowing larger storm events to be safely conveyed away from the building.

Vegetated roofs are complex structures that require consideration of the load-bearing capacity of roof decks, the moisture and root penetration resistance of the roof membrane, hydraulics, and wind shear.

The plants help recreate the hydrologic function of open space in the following ways:

- Capturing and holding precipitation in the plant foliage
- Absorbing water in the root zone

Figure 1. Fencing Academy of Philadelphia vegetated roof cover.

- Slowing the velocity of direct runoff by extending the flow path through the vegetation
- Cooling the temperature of the air and runoff. (Green roofs can be very effective measures for reducing the "thermal shock" caused by flash runoff from hot roof surfaces.)

Project Description

The vegetated rooftop project at the Fencing Academy of Philadelphia is a 3,000-square-foot vegetated cover installed and monitored by Roofscapes, Inc., on top of an existing structure (Figure 1). The roof system was intended to mimic the natural hydrologic processes of interception, storage, and detention to control the 2-year, 24-hour storm event. The distinguishing features of this system include

- Synthetic under-drain layer that promotes rapid drainage of water from the surface of the roof deck
- Thin, lightweight growth media that permits installation on existing conventional roofs without the need for structural reinforcement
- Meadow-like setting of perennial *Sedum* varieties that have been selected to withstand the range of seasonal conditions typical of the Mid-Atlantic region without the need for irrigation or regular maintenance

The installed vegetated roof cover is only 2.74 inches thick including the drainage layer. The system weighs less than 5 pounds per square foot when dry and less than 17 pounds per square foot when saturated. The saturated moisture content of the media is 45 percent by volume. The saturated infiltration capacity is 3.5 inches per hour. Figure 2 shows the components of the roof system.

The runoff characteristics of the roof were simulated using rainfall records for 1994 from eastern Pennsylvania. The model predicted a 54 percent reduction in annual runoff volume. The model also predicted attenuation of 54 percent of the 24-hour, 2-year Type II storm event and 38 percent of the 24-hour, 10-year Type II storm event. Additionally, monitoring at a pilot-sized project for real and synthetic storm events was conducted for a period of 9 months at 14- and 28-square-foot trays. The most intense storm monitored was a 0.4-inch, 20-minute thunderstorm. The storm event occurred after an extended period of rainfall had fully saturated the system. Figure 3 shows the runoff attenuation effectiveness for this event. Although 44 inches of rainfall was recorded during this period, only 15.5 inches of runoff was generated from the trays. Runoff was negligible for storm events with less than 0.6 inch of rainfall.

Project Summary and Benefits

This project showed that vegetated rooftop covers can help to reduce peak runoff rates for a wide range of storm events. The project also demonstrated that existing structures can be successfully retrofitted to help prevent CSS surcharging in urban areas. Significant energy

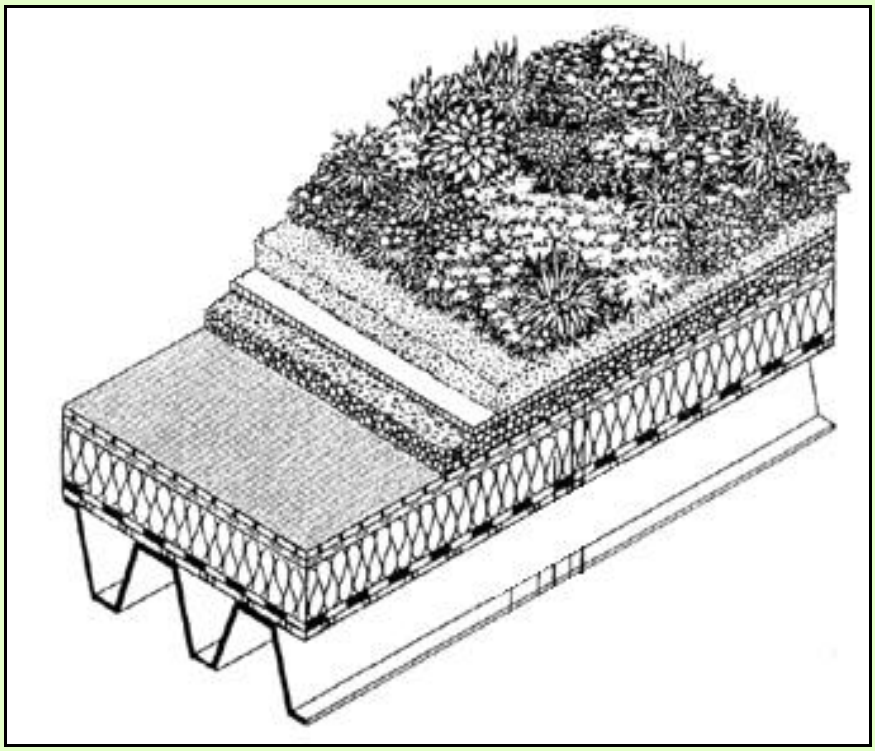

Figure 2. Components of the vegetated roof cover.

conservation benefits also are associated with vegetated rooftop covers. During the spring and summer, temperatures on a neighboring black tar roof varied by as much as 90 °F, while the variation under the 2.74-inch vegetated cover was only 18 °F. The vegetated cover also insulates the roof in winter, and the vegetation protects the roof membrane from the elements. Vegetated rooftop covers can potentially extend the life of a roof by 20 years or more.

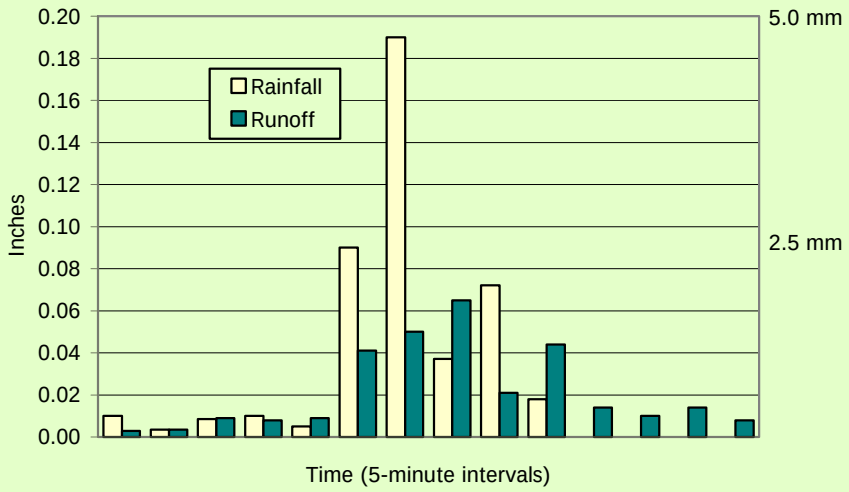

Figure 3. Runoff attenuation efficiency for a 0.4-inch rainfall event with saturated media.

References

Miller, C. 1998. *Vegetated Roof Covers: A New Method for Controlling Runoff in Urbanized Areas*. Pennsylvania Stormwater Management Symposium, October 21-22, 1998, Villanova University, Villanova, Pennsylvania.

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June 2005 - Printable Version

City recommends caution for recreational river use - 6/5/05
Lane closures begin next week on West Burnside Street - 6/9/05
Daytime road closure on SE 162nd Avenue - 6/10/05
Downspout Disconnection Program hits the billion gallon mark - 6/14/05
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Chinese delegation will tour West Side Big Pipe Project - 6/29/05

Questions & Comments

If you have any questions or comments on our site, please contact our site administrator.

City recommends caution for recreational river use

June 5, 2005

Due to the most recent rainstorm, Portland's combined sewers have overflowed. Portland's Environmental Services advises the public against any recreational activity in the Willamette River during which water could be swallowed.

The public should avoid the Willamette River for 48 hours after the rain has stopped. It is especially important to avoid recreational activities–

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such as water skiing, jet skiing or swimming–during which water could be swallowed. While health risks from combined sewer overflows are unknown, these precautions are taken to protect the public health.

People who fish should wash their hands following contact with the water. Those who choose to eat fish caught in the Willamette River should cook them thoroughly to kill bacteria.

In many areas of Portland, sewage mixes with stormwater runoff in what is called a combined sewer system. When the combined sewer system receives too much runoff, it overflows into the Willamette River. These combined sewer overflows (CSOs) are contaminated with bacteria from untreated sewage.

Portland is in the 14th year of a 20-year program to improve the city's sewer system. Until the program is complete, overflows of untreated sewage and stormwater will occur during rain storms, although as the program progresses, the frequency of overflows and number of outfalls are diminishing.

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Lane closures begin next week on West Burnside Street

June 9, 2005

Next Tuesday, June 14, sewer work will close both eastbound lanes of West Burnside Street between SW 21st and SW 18th avenues. Beginning at about 3:00 a.m. next Tuesday, eastbound traffic on West Burnside will detour to Morrison at SW 21st and can return to Burnside at SW 18th. The City's contractor will temporarily convert SW Morrison to a one-way eastbound street between SW 21st and SW 18th.

Westbound traffic on Burnside will not be affected. The eastbound detour will be in effect 24 hours a day until construction is complete, which could take up to two weeks.

A private firm is redeveloping the Civic Apartments next to PGE Park. The lane closures will allow workers to install a pipe liner to rehabilitate the 30-inch sewer that will serve the redeveloped apartments. Crews will work extended hours to shorten the duration of the project and the detour.

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Daytime road closure on SE 162nd Avenue

June 10, 2005

A section of SE 162nd Avenue in the Pleasant Valley area will be closed for sewer construction during the day until about June 20. The project area is on SE 162nd between SE Clatsop Street and SE Henderson Way. Work hours are 9:00 a.m. to 3:30 p.m. Monday through Saturday. The street is open to through traffic after work hours and on Sunday.

Eastbound traffic on SE Foster Road can take SE Barbara Welch Road south to Clatsop Street during construction hours. Westbound Foster Road traffic can use SE 172nd Avenue to reach SE Clatsop.

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Downspout Disconnection Program hits the billion gallon mark

June 14, 2005

When Environmental Services launched the Downspout Disconnection Program in 1995, it was hard to imagine it would be responsible for removing a billion gallons of stormwater a year from Portland's combined sewer system. But entering its tenth season this year, the program has exceeded that goal.

"The more than 45,000 homeowners who have disconnected downspouts get the credit for this success," says Environmental Services Director Dean Marriott. "This is a way for citizens to participate directly in our efforts to control combined sewer overflows and their help is crucial," Marriott says. Canvassers are going door to door in east Portland this summer signing up new homeowners.

Disconnecting downspouts keeps stormwater runoff from flowing into Portland's combined sewer system. Combined sewers carry both stormwater and sewage in the same pipe. Thousands of residential downspouts are connected directly to the combined sewers. When it rains, combined sewers fill up and overflow to the Willamette River. Downspout disconnection redirects roof drainage to yards or gardens where the water can soak into the earth instead of spilling into the river.

The program is a partnership between Environmental Services, the Office of Neighborhood Involvement, homeowners and community groups. For each downspout they disconnect, community volunteers earn $13 to spend on neighborhood projects. More than 5,300 volunteers have disconnected downspouts and community groups have earned nearly $220,000.

Homeowners who do the work themselves earn $53 per downspout, or the City will do the work for free. It's not too late to help The Downspout Disconnection Program can always use more community volunteers. Call 503-823-5858 to learn how to get involved.

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City recommends caution for recreational river use

June 17, 2005

Due to the most recent rainstorm, Portland's combined sewers have overflowed. Portland's Environmental Services advises the public against any recreational activity in the Willamette River during which water could be swallowed.

The public should avoid the Willamette River for 48 hours after the rain has stopped. It is especially important to avoid recreational activities–such as water skiing, jet skiing or swimming–during which water could be swallowed. While health risks from combined sewer overflows are unknown, these precautions are taken to protect the public health.

People who fish should wash their hands following contact with the water. Those who choose to eat fish caught in the Willamette River should cook them thoroughly to kill bacteria.

In many areas of Portland, sewage mixes with stormwater runoff in

what is called a combined sewer system. When the combined sewer system receives too much runoff, it overflows into the Willamette River. These combined sewer overflows (CSOs) are contaminated with bacteria from untreated sewage.

Portland is in the 14th year of a 20-year program to improve the city's sewer system. Until the program is complete, overflows of untreated sewage and stormwater will occur during rain storms, although as the program progresses, the frequency of overflows and number of outfalls are diminishing.

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City recommends caution for recreational river use

June 20, 2005

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City recommends caution for recreational river use

June 22, 2005

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The public should avoid the Willamette River for 48 hours after the rain has stopped. It is especially important to avoid recreational activities–such as water skiing, jet skiing or swimming–during which water could be swallowed. While health risks from combined sewer overflows are unknown, these precautions are taken to protect the public health.

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Eastbound lanes of West Burnside are open again

June 23, 2005

The sewer project that closed both eastbound lanes of West Burnside at SW 21st is complete and both lanes have reopened. The detour to SW Morrison Street was removed overnight and traffic was restored to normal on both Burnside and Morrison.

The sewer rehabilitation project began on June 14 and was expected to take up to two weeks. The project went smoothly and the City's contractor was able to complete work ahead of schedule.

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Nighttime sewer work scheduled on Capitol Highway

June 24, 2005

This Sunday night, June 26, work starts on a sewer repair project that will restrict nighttime traffic on SW Capitol Highway in Hillsdale. The work area is on the north side of Capitol between SW Sunset Boulevard and SW Bertha Court.

The project will reduce two-way traffic to one lane in each direction from 8:00 p.m. to 6:00 a.m. Sunday evening through early Saturday morning. The project will take about four weeks.

All lanes will be restored each day after 6:00 a.m. Trenches will be covered with steel plates or temporary asphalt.

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City recommends caution for recreational river use

June 27, 2005

Due to the most recent rainstorm, Portland's combined sewers have overflowed. Portland's Environmental Services advises the public against any recreational activity in the Willamette River during which water could be swallowed.

The public should avoid the Willamette River for 48 hours after the rain has stopped. It is especially important to avoid recreational activities–such as water skiing, jet skiing or swimming–during which water could be swallowed. While health risks from combined sewer overflows are unknown, these precautions are taken to protect the public health.

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Chinese delegation will tour West Side Big Pipe Project

June 29, 2005

A delegation from China’s Ministry of Construction will tour the largest public infrastructure project in Portland’s history. On Friday, July 1, the 25 delegates will visit the West Side Combined Sewer Overflow (CSO) Project office for a project presentation and an elevator trip down the 120-foot deep Nicolai Tunnel Shaft to view completed portions of the 14-foot diameter tunnel. Reporters and photographers are welcome to join the tour.

The West Side Big Pipe is part of Portland’s 20-year program to control combined sewer overflows. The Chinese delegation arrives in Portland June 25 for an

eight-day training on sustainable development practices.

Who: China Ministry of Construction officials
Environmental Services Director Dean Marriott

What: Tour of the West Side Big Pipe Project

When: Friday, July 1, 11:00 a.m.

Where: West Side CSO Project Office, 2730 NW Front

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For information about Environmental Services programs, contact Linc Mann, 503-823-5328, or Joan Saroka, 503-823-5021.

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SARB_004674

Hydrological Responses from Low Impact Development comparing with Conventional Development

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Yanping Zhang[3] and Z. John Licsko[4]

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ABSTRACT

In November of 2000, Prince George's County, Maryland initiated a field monitoring program to compare the stormwater hydrologic and water quality responses between a Low Impact Development (LID) design and the conventional development design at Somerset Heights Subdivision. In the Subdivision, two small watersheds are located side-by side: one was developed using a few LID concepts (grassed swales, bioretention areas, etc) with drainage area of 11.84 acres and another was developed entirely using a conventional stormwater conveyance system (a curb, gutter and pipe stormwater conveyance system) with drain area of 8.43 acres. The monitoring program, including one rain gage, two stream gages and two water quality automatic samplers, is capable of collecting continuous data in a 2-minute time interval. So far, more than two years of continuous flow and water quality data have been collected at both sites. The program is now moving into the third year of operation. This paper presents a data summary and analysis for the first two years of the monitoring program.

Although there are only two years of data, analysis of this data seems to reach a few general conclusions. When compared to the conventional site, the LID site had considerably lower event runoff volumes and peak flow rates as well as lower annual flow. In addition, most event runoff hydrographs started later, including peak time, in the LID site. The LID site showed a higher frequency of smaller flow rates while the conventional site showed a higher frequency of larger flow rates. As expected, the peak flow rate or runoff volume reduction at the LID site decrease as the event rainfall depth increased because the ground is saturated after certain rainfall depth. The annual pollutant loads for the LID site were lower for most constituents measured but not significant. The major reason is that the LID site is just recently completed and the soil conditions are still not stabilized yet. It is expected that, after the site is stabilized, the better water quality benefits will show-up.

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Keywords: Stormwater, Runoff, Bioretention, BMP, Low Impact Development (LID)

INTRODUCTION

Urban stormwater runoff has been identified as a significant source of pollution for many water bodies. Washing off road surfaces, parking areas, vehicles, and building materials, this precipitation and surface runoff contain a broad spectrum of pollutants. Proper control and management of runoff from impervious urban sources can provide for significant improvements to the quality of water entering local waterways. Concern for urban water quality improvements has spawned interest in natural-based treatment processes, such as bioretention and vegetated swales. These practices are part of an integrated paradigm known as Low Impact Development (LID—Department of Environmental Resources, 1999), which employs vegetated techniques to hold and treat run off water at the source, maximize infiltration, and reduce both quality and quantity impacts on local ecology.

Bioretention facilities are an integral part of stormwater management in the Prince George's County (Maryland) low-impact development program. Several systems have been designed and constructed in the county. However, not much performance data has been collected on their treatment efficiency, especially their advantage comparing to the conventional piping system; this paper represents the work in this regard. Detailed monitoring of the characteristics and performance of bioretention systems have been performed. The removals of several heavy metals and nutrients from both LID development and conventional development were evaluated.

The Somerset Heights monitoring program was developed to quantify the storm water hydrology and water quality benefits of LID. This evaluation is based on a comparison of the hydrologic and water quality differences between a watershed developed using LID practices and another watershed developed entirely using a conventional stormwater conveyance system. The two watersheds selected for the study are completely developed small, urban watersheds with uniform land uses and stormwater conveyance systems. Construction in the LID watershed was completed during 1999-2000. The stormwater management system for the LID watershed consists of grassed swales, Bioretention areas and disconnected impervious areas. Only a few LID techniques were used since the site was designed three years prior to the release of the County's LID design manual and very early in the County's development of the technologies. The conventional watershed was developed in 1990 and uses a curb, gutter and pipe stormwater conveyance system. The monitoring program was started in November of 2000 when the LID site was just completed and has been in continuous operation since that time.

It should be noted that the LID site is not developed in a typical and full-scale LID manner and is County's first attempt of using non-conventional approaches to reduce stormwater flows. This LID-like development includes grass swales, disconnection

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of impervious areas, and non-typical bioretention facilities. Although the site did not follow the LID sizing and design criteria and was not stabilized during the monitoring period, the sampling results are very encouraging because it works better than what was expected.

METHODOLOGY

Watershed Characteristics

Landscape features for the two watersheds, while not identical, are in almost all respects similar. Land use within each watershed is comprised entirely of single family detached housing (1/4 acre lot size). The watersheds are geographically located adjacent to each other and drain approximately the same area. Housing and road density are different slightly (Table 1). Figure 1 shows the geographic location of the two sites.

Figure 1. Project site

Table 1. Watershed Features

Watershed	Drainage Area (acres)	Number of Houses	Houses/acre	Road Length (ft/acre)	Road Width (ft)	Percent Impervious
Low Impact Development (S2 LID)	11.84	40	3.37 houses per acre	187	36	36 %
Conventional Development (S3 CONV)	8.43	28	3.33 houses per acre	189	24	30 %

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The conventional site's stormwater conveyance system consists entirely of a curb, gutter and pipe system. The LID site consists of a curb-less road drained by a grassed swale network; but did not follow today's LID sizing and design criteria. It was County's first attempt of using non-conventional approaches to reduce stormwater flow. Bioretention areas are located both on individual lots and along grassed swales. Typically, pipes are used only to convey stormwater under driveways and roads, however, when flows become too concentrated drop inlet structures and pipes are used to convey stormwater flows to an outfall point. In some cases, inverts for the drop inlets are slightly higher then the inverts for the bioretention area or swale and provide additional stormwater flow attenuation (see Figure 2).

Figure 2. Drop Inlet Structure Located in Bioretention Area

Monitoring Program

In addition to the careful selection of the two watersheds, a well-designed monitored program is also essential to the evaluation of differences in hydrology and water quality. Each watershed's outfall was instrumented with automated level and water quality sampling equipment. A rain gage was also located at the outfall point for the conventional watershed. A second rain gage, located about 0.5 miles from the monitored watersheds and maintained as part of county's flood warning system, was used as a data quality check.

A 2-foot H flume is used at each site to determine the flow rate and volume at each watershed's outfall point (Figure 3). The water levels in each flume are continuously monitored using an ISCO water level sensor, with level data recorded every two minutes. Conversion of water levels to flow rate is based on standard rating curves for H type flumes. Rainfall data are also collected using a two-minute interval.

Water quality sampling at each site is based on volume-weighted composite sampling procedure. This sampling method results in a 250-ml storm water sample being collected for each 250 cf (cubic feet) of runoff for small storms (less than 1.0 inches).

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While for larger storms, the programming is changed to collect a water sample for each 500 cf. of runoff. These 250-ml samples are combined into a single water quality sample that is then sub-sampled and submitted to a laboratory for chemical analyses. This sample represents a volume-weighted event mean concentration for each sampled storm. The chemical analyses completed include measurements for lead, zinc, copper, total nitrogen, total phosphorus and total suspended solids. The sampling equipment is also illustrated graphically in Figure 3.

Figure 3. Flow and Water Quality Sampling Equipment at the Project sites

RESULTS AND DISCUSSIONS

General Climate

The results of any monitoring program are always affected by the large-scale weather patterns that occur during the course of monitoring. On an annual basis, rainfalls during the first and the second years of monitoring were slightly less than the long-term average of 42.3 inches reported by National Resources Conservation Service for Upper Marlboro (NRCS, 1995). Using a combined rainfall data set based from the Somerset monitoring station and County's rain gage, a rainfall total of 35.5 inches was measured from November 1, 2000 to October 31, 2001. For the period from November 1, 2001 to October 31, 2002, the total rainfall was 26.4 inches which is only 75% of the first year's value and only about 63% of the long term average. Figure 4 shows a comparison of monthly rainfall for these two years.

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Hydrology

The flow sampling devices used in this project automatically record information at a two-minute interval. When measured on an annual basis, significant differences between the two watersheds were observed in the number of runoff events, the total runoff volumes and in peak event flow rates (Table 2). For the period, the LID watershed had 20% fewer runoff events. The LID watershed also had 20% less runoff volume per acre than did the conventional watershed. Peak flow rates during the period also had a tremendous reduction in flow rates on a per acre basis of about 44%. A change in the distribution of peak event flow rates was also observed and is illustrated in Figure 5. As shown in Figure 5 the event peak flow rates are generally lower and less frequent for LID sites than those observed at the conventional site. These results appear very encouraging. Even better, because of the location of the LID outfall (about 30 feet below the ground surface), the measured flow volume include both surface runoff and groundwater. Therefore, the actual annual surface runoff volume is even much smaller than the sampling results show.

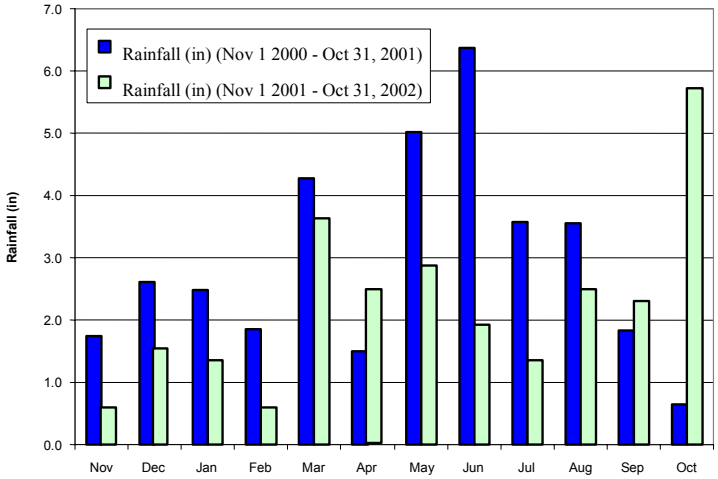

Figure 4. Month Rainfall Totals Nov 2000 to Oct 2002

Table 2. 2-Year Hydrologic Summary

Measurement	Watershed	
	Conventional	LID
Number of Events with Measurable Runoff > 100 cubic feet*	104	83
Total Runoff Volume (cubic feet/acre)*	41,403	33,391
Percent of Rainfall converted to Total Runoff*	19.0%	15.3%

* Difference is significant at the 95% confidence interval

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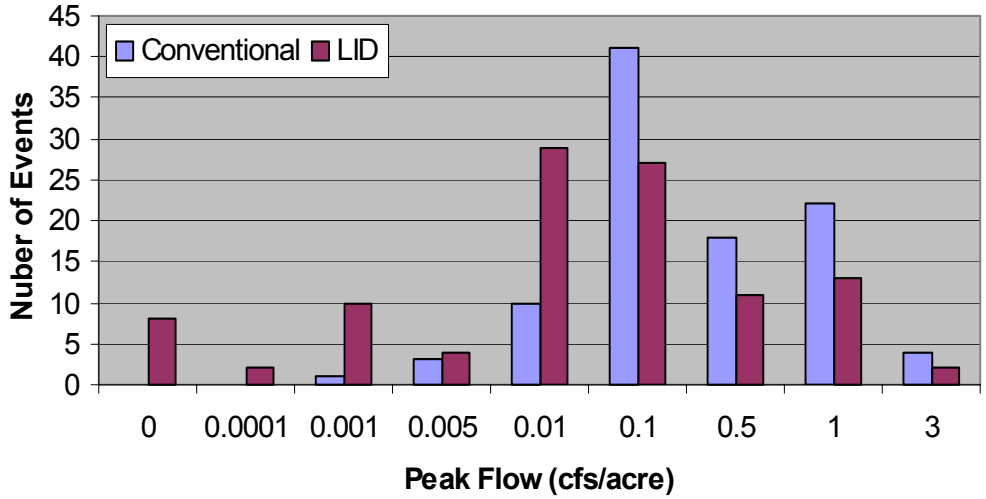

Figure 5. Comparison of Peak Event Flows at Conventional and LID Sites (November 2000 – October 2002)

On an event basis, reductions in an event's peak flow rate were also observed to increase in proportion to the inter-event time period between storms. Conversely, for very short inter-event time periods, a much smaller reduction in event peak flow rates was observed. A minimum inter-event period of about 24 hours appeared to be sufficient for the recovery of the LID watershed's storage and infiltration capacity. This recovery period is longer in duration during the non-growing season or nonexistent in the case of frozen soils. The responses of the LID and conventional site to a short event time period are illustrated in Figure 6. While the LID site effectively reduces the peak flow rate and volume for the first event, the following storm is not as effectively managed. In total thirty-six percent or 1/3 of the storms monitored at Somerset had a prior storm event that occurred within the previous 24- hour period. The main reason for this result is because of the location of the storm drain outfalls. For the conventional site, the storm drain outfall is located only a couple feet from the ground surface; while the outfall for the LID site is approximately 30 feet below the ground surface. Consequently, the measured peak and flow volume at LID site includes not only the surface runoff but also the ground water flow. This situation is very obvious because the outfall at LID site still releases flows even days after the storm events.

This annual groundwater volume needs to be estimated. A similar monitoring station, with a drainage area of 50 acres, is located a few miles away from this site. 38% of the total flow volume is measured to be groundwater. By carefully examining the flow data, the groundwater contribution is estimated at 25.5%. This separation between surface runoff and groundwater is estimated based on the storm hydrograph at a point which the flow is 150% of the pre-storm event.

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It is also difficult to accurately measure runoff volume from short and intense storms at the conventional site. These storms produced rapid changes in flow that, even with the use of a 2-minute interval sampling, from which it was difficult to get accurate runoff volume estimates. Conversely, the slow and more gradual response of the LID site resulted in more accurate volume estimates for these types of storms.

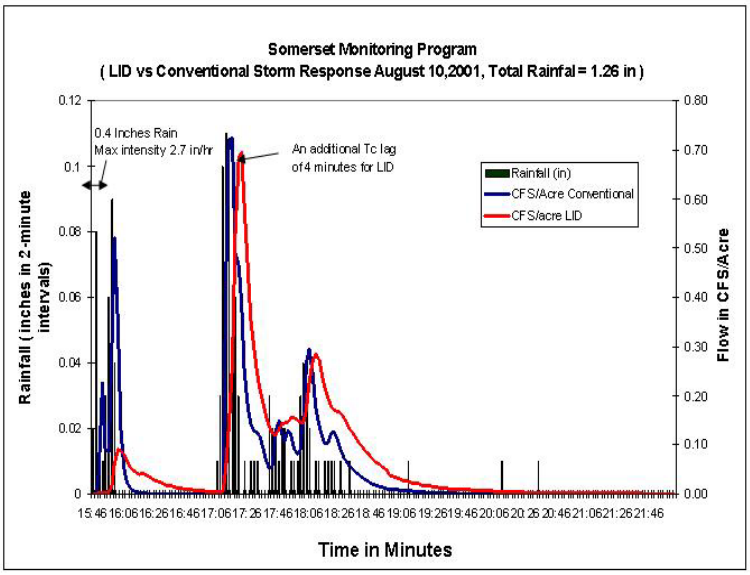

Figure 6. Peak flows comparison for Consecutive Storm Events

Even with these two disadvantages, the overall hydrological performance at the LID is still very impressive. The average peak flow rate for the two-year period at LID site is only 56% of the conventional site. The total flow volume, including groundwater / interflow volume at LID site is approximately 80 % of the conventional site. Since groundwater / interflow is 25.5% of the measured flow volume, the surface runoff volume at LID site is only approximately 60% of the conventional site. (see Figure 7).

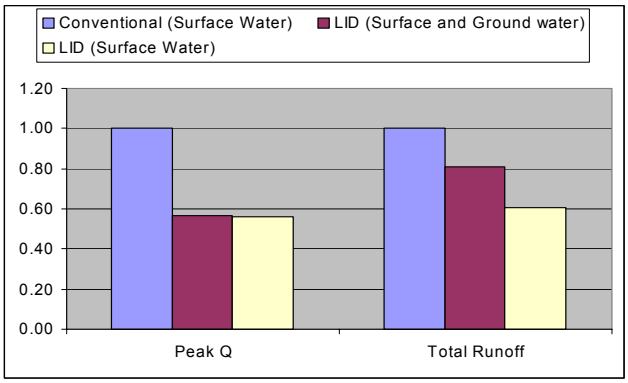

Figure 7. Two Years Hydrologic Performance Chart

Water Quality

The sampling program to compare the water quality benefits of the two stormwater conveyance systems consisted of a monthly sampling program for subset of the parameters normally monitored as part of the County's NPDES permit (Table 3). All the samples collected were volume-weighted composite samples. A total of ten storms were monitored every year.

Table 3. Water Quality Sampling Parameters

Parameters	Method	Reporting Limit (mg/L)
Nitrate/Nitrite	EPA 353.2	0.05
Total Kjeldahl Nitrogen	EPA 351.3	1.00
Total Phosphorus	SM 4500 P B+E	0.01
Total Suspended Solids	EPA 160.2	2.5
Total Copper	EPA 200.8	0.002
Total Lead	EPA 200.8	0.005
Total Zinc	EPA 200.8	0.020

For comparative purposes, water quality samples were required from both sites for the same storm. Since runoff from the LID watershed occurred less frequently then at the conventional site, the sizes of storms from which water quality samples were submitted were mostly larger storms (>0.5 inches). Overall, this resulted in a large percent of the total annual runoff volume from both sites being sampled for water quality (Table 3). For the conventional site, 66% of the annual runoff volume was sampled for water quality while 69% of the annual runoff volume was sampled for water quality measured at the LID site.

Event mean concentrations (EMC) and loading values were measured for both watersheds. The annual EMCs are calculated based on the total measured load for all ten storms divided by the total runoff for these storms. From the two-year average annual EMC values the LID site had lower loading rates for nitrate, total suspended solids (TSS) and zinc, and slightly higher loading rates for total Kjeldahl nitrogen and total phosphorus (see Table 4 and Figure 8).

This is a very in-consistent sampling result. After a careful reviewing of the site conditions, it is concluded that the major reason for this in-consistency is that the LID site is just recently completed and the vegetation and soil conditions are still not stabilized yet; while the conventional site was constructed in early 1990's. It is therefore expected that, after the site is stabilized, the better water quality benefits will show-up.

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Table 4. Two-Year Average Loading

Parameter	Conventional Loading (lb./acre)	LID Loading (lb./acre)	% Difference
Total N	6.57	6.39	2.74%
Nitrate/Nitrite	1.64	1.07	34.76%
TKN	4.92	5.33	-8.33%
Total P	1.11	1.55	-39.64%
TSS	121.86	104.45	14.29%
Copper	0.0184	0.0117	36.41%
Lead	0.0057	0.0045	21.05%
Zinc	0.0682	0.0433	36.51%

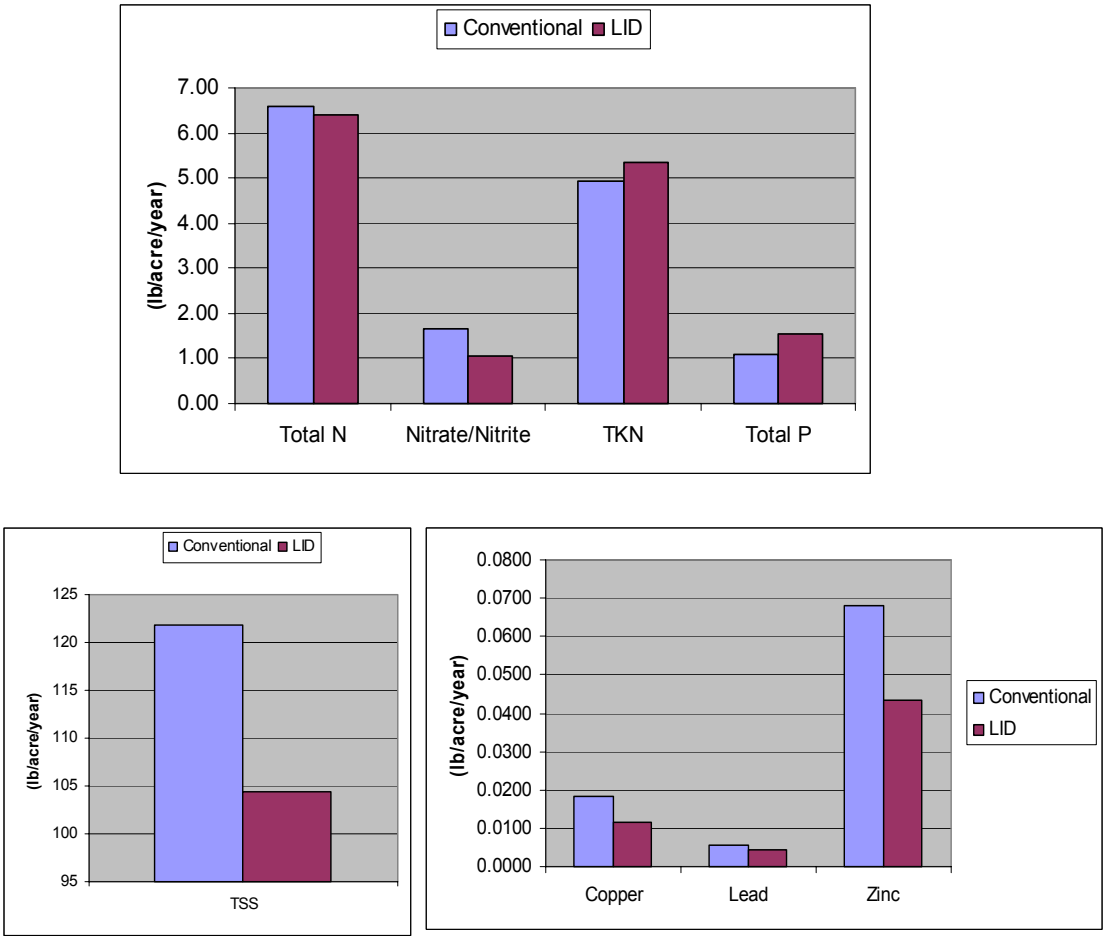

Figure 8. Comparison of Annual Pollutant Loadings between Two Sites.

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SUMMARY AND CONCLUSIONS

Although the LID site did not utilize the typical and full-scaled LID approaches and was simply a first attempt of using non-conventional approaches to reduce stormwater flows, when compared to the conventional site, the LID site had considerably lower runoff volumes and event peak flow rates per unit area. The LID site also had fewer runoff producing events. Over the two years, percent of rainfall converted to runoff was 19% for the conventional site and 15% for the LID site. Accordingly, the average annual runoff volume per unit area was smaller at the LID site by 20%. Event runoff hydrographs started later in the LID site. The LID site showed a higher frequency of smaller flow rates (including no runoff events) while the conventional site showed a higher frequency of larger flow rates.

LID site also had a smaller peak flow per unit area. The ratio of the LID to Conventional peak flow per unit areas showed a general positive trend with event rainfall depth. Any peak flow rate or runoff volume saving of the LID practices seem to decrease as the event rainfall depth increases. The magnitude of the differences between the two sites did not appear to be affected by seasonal differences in rainfall intensity and infiltration rates. However, it is impacted by the time period between rainfall events.

The Total Nitrogen loading per unit area was similar at the two sites while the Total Phosphorus loadings were higher by about 40% at the LID site. The average annual loading per unit area for suspended sediment was lower at the LID site by 14.3%. For copper, lead, and zinc, the LID site had lower EMCs and annual loadings. The annual loadings per unit area were 36%, 21%, and 37% lower for Copper, Lead, and Zinc respectively at the LID site than the conventional site. This difference is a result of removal mechanisms in the grassed channels and/or bioretention areas. Another factor to remember is that the LID site is just recently completed and the site and soil conditions are still not stabilized yet. It is expected that, after the site is stabilized, the better water quality benefits will show-up.

It is beneficial to keep in mind that this monitoring period was a rather dry period when the annual rainfall was only about 84% of the long-term average for the first year, and 63% for the second year. Data from dry years may not be a good representative of normal or average years. Two other issues are also important to remember. For a drainage area as small as 10 acres, two-minute sampling time interval may not short enough for a conventional development site. One-minute time interval is more appropriate. To address the issue of consecutive storm events, more storage for the LID measures is recommended.

Finally, because the LID site was not developed according to today's LID sizing and design criteria, an EPA 319 grant was provided to the County to retrofit this residential development. When the project is completed, a better performance is expected.

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PROJECT SPOTLIGHT

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Using Nature's Plumbing to Restore Aquatic Ecosystems: The City of Seattle's Natural Drainage System

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Salmon, steelhead trout and their cousins that make the epic journey from freshwater streams to the ocean and back again, are charismatic symbols of America's Pacific Northwest. These fish, known by the scientific community as anadromous species, are iconic reminders of the region's spectacular natural abundance. Salmon and other natural aquatic communities in and around Seattle's Puget Sound are, however, in trouble. After years of public debate, several species of Pacific salmon now appear on the federal threatened and endangered species lists. In part in response to the listing, urban, suburban and rural communities in the Puget Sound watershed have engaged in various efforts aimed at bringing back healthy salmon populations, including stream and estuary restoration projects and community education programs. These restoration and education programs alone, unfortunately, have not gone far enough.

In contrast to salmon and the streams in which they live, the region's stormwater management systems are decidedly uncharismatic. Historically, local voters generally have not given much thought to stormwater management, unless they or their neighbors have flooded basements after a heavy rainfall.

Employment and program opportunities are offered to all people regardless of race, color, national origin, sex, age, or disability.
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Despite the prosaic nature of stormwater drainage systems, Denise Andrews, an employee of Seattle Public Utilities (SPU), recognized an opportunity to innovate at the intersection of stormwater management and salmon habitat restoration.

When the city announced in 1998 that it would fund a series of small, innovative projects as a way to celebrate the coming Millennium, Andrews and other stormwater planners with SPU proposed a scheme for installing natural drainage systems in northwest Seattle neighborhoods that had inadequate stormwater management systems. Such natural drainage systems utilize soil and plants—nature's drainpipes—to substantially decrease surface runoff from impervious surfaces such as city streets, thereby encouraging the absorption of rainwater into the natural subsurface hydrologic systems, changing stream flow conditions and reducing pollutant loads in aquatic ecosystems. In effect, Andrews and her colleagues (see Figure 1) had envisioned a way to integrate an existing gray infrastructure with a novel green infrastructure in a major metropolitan area. The city approved an initial planning grant, thus launching the effort, now known as the SPU Natural Drainage Systems (NDS) program.

Figure 1. NDS Team (left to right): Miranda Maupin, Jim Johnson, Denise Andrews, Darla Inglis. Tracy Tackett not shown.

With a team of civil engineers, landscape architects, fire and police department representatives, Seattle Public Utilities managers and local elected officials, Andrews set out to demonstrate that low-impact development (LID) strategies for stormwater management could be both technically effective in improving aquatic ecosystem health, and economically efficient at getting the job done. By 2004, the team has succeeded well beyond their expectations, developing five natural drainage projects, including the recently completed Broadview Green Grid, a project covering 15 city blocks in northwest Seattle's Piper's Creek watershed.[1]

For their efforts, the NDS team has received wide recognition. Visitors from as far away as New Zealand have come to inspect and consider replication of the novel and measurably effective stormwater system design. The team has also successfully engaged in a rigorous competitive process to win one of five 2004 Innovations in American Government Awards presented by the Ash Institute for Democratic Governance and Innovation at Harvard University's Kennedy School of Government.

The Stormwater Management Challenge

Stormwater management is a challenge to existing and emerging urban, suburban and rural settlements across the United States and around the world. In conventional stormwater

EDITOR'S NOTE

In past issues of *NWQEP NOTES*, we featured innovative stormwater management programs of cities such as Philadelphia, PA and Greensboro, NC. In this issue, we highlight the City of Seattle's award-winning *Natural Drainage Systems* program, established with the ultimate goal of helping reduce impacts of development on Pacific salmon and other important aquatic communities of Puget Sound. The practices employed include *Street Edge Alternative* (SEA Street) design, in which existing streets are reconstructed to be narrower and drain to beautifully landscaped vegetated swales, and *Cascades*, a stair-stepped system of swales and pools, which replace existing concrete drainage ditches. Monitoring of pilot projects indicates that both of these stormwater control strategies are highly successful at reducing runoff volume, peak flow, and increasing infiltration. They have also shown to be cost effective and desirable by the public. Based on these positive results, Seattle is expanding its application of *Natural Drainage Systems* into other areas of the City, including a high-density redevelopment project, which will provide a wonderful opportunity for showcasing the implementation of low impact development in an urban retrofit setting.

As always, please feel free to contact me regarding your ideas, suggestions, and possible contributions to this newsletter.

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systems engineered in the twentieth century, a network of impervious troughs, tanks and pipes fit together to literally drain an area. Such conventional stormwater systems send irregular, high velocity flows of storm runoff into natural bodies of water, including streams, ponds, lakes and bays. Such flows result in unnatural erosion and the subsequent deposition of sediment. These factors alone can seriously disrupt habitat for aquatic species. In addition, in conventional systems the runoff from storms washes pollutants such as pesticides, motor oil, and bacteria from animal waste off of streets and other impervious surfaces into the piped system. By sending such contaminants down the drain, and then swiftly into local streams, lakes and estuaries, traditional stormwater management systems can further harm local freshwater and marine ecosystems.

A More Efficient, Effective Alternative

The natural drainage systems (NDS) approach to these problems is simple in concept: restore and utilize the environment to do the work it was intended to do. Generally, the NDS approach does so by: 1) increasing along the edges of city streets the amount of soil and plants in an interlinked network of vegetated swales and cascades; 2) reducing the area of impervious surfaces on the street itself by adopting new, multi-functional street designs; and 3) using these landscape features to allow stormwater to be absorbed into the ground, rather than sending polluted water, at unnaturally high velocities, to rush into local streams, lakes, and bays.

The NDS techniques employed in various SPU pilot projects are described further below.

SEA Street:

Street Edge Alternative (SEA) street design consists of a series of shallow, generally flat-bottomed, heavily vegetated swales placed along a gently curving street (see Figures 2 through 5). This type of system is considered to be a *source control* strategy because it manages the stormwater runoff from the immediate surrounding area. The system infiltrates and detains stormwater to maximize the water quality and flow control benefits. The bottom widths of the swales will vary depending on the amount of room available, but at least a 2-foot bottom width is recommended and not more that 4-feet in depth. Side-slopes are graded at 3:1 along the road, but may be slightly steeper on the property side. Generally, these systems attempt to treat all runoff in the immediate basin from the 6-month, 24-hr storm by filtering the stormwater through vegetation and infiltrating the water through the soil media. The stormwater flow control goals are to maximize retention, infiltrating at a minimum all flow generated by a ½-inch storm event, and maximize detention, ideally detaining the developed 1-2 year storm event for the adjacent drainage area to pre-developed forested conditions.

Figure 2: Street before conversion to Street Edge Alternative (SEA) design.

Figure 3: Street after conversion to SEA design.

Cascade:

A cascade refers to a stair-stepped system of wide, flat-bottomed, heavily vegetated swales or pools (see Figures 6 and 7). The system treats an area of runoff larger than just its street and is considered more of an *end-of-pipe* strategy. The system slows stormwater flows, allowing maximum opportunity for deposition of solids, infiltration of runoff, and bioremediation of chemical pollutants. The primary objective of this type of system is to reduce the peak flows to the receiving downstream creek system and achieve some level of water quality treatment. Generally, these systems attempt to detain the flows generated by the full drainage basin to reduce the 2-yr, 24-hr storm to pre-developed forested conditions or provide maximum volume detention for this event. In addition, conveyance of the 25-yr, 24-hr storm through the full length of the project must be achieved. Water quality goals for these systems are generally undefined, but whatever is achievable is characterized as an added benefit.

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Soil Mixes:

There are two types of soils typically used within the NDS – bioretention soil and engineered soil. Swales should be overexcavated and the native soil replaced with the appropriate amended soil mix. Swale soil depth should be a minimum of 1 foot, with a 2-foot preferred depth. When using the engineered soil, a 2-foot depth is often necessary to provide sufficient storage volume to hold the water while it infiltrates into the native soil. Both of these mixes should have approximately 20-30% available void volume and between 8 and 12% organic content.

Figure 4. An aerial view of SEA street design showing narrow, curvilinear streets with sidewalks and street-edge gardens.

The *bioretention* soil has infiltration rates of 0.5 to 1 inch per hour at 85% compaction and is most typically used on the SEA street systems, except in areas where higher rates are needed, and along the banks of the Cascade systems. Native soil on site can be amended with 30% compost if it is an outwash or weathered till material, otherwise imported material can be used.

The *engineered* soil has infiltration rates between 1.5 to 2 inches per hour at 85% compaction and is most typically used in the Cascade systems. It is generally composed of 50-60% sandy material, 25-30% compost, and 15-20% sandy loam topsoil.

Figure 5. Swale as part of SEA street design.

Project Results

Initial tests of the pilot projects to date have been so successful that SPU has made a commitment to utilize NDS as its primary stormwater management approach in all areas that drain directly to creeks. Based on early results, the city is recognizing that three types of benefits are most notable: environmental benefits, cost effectiveness, and public appeal.

Environmental Benefits

Studies of SPU's pilot projects reveal that they are extremely successful at capturing water flow and reintroducing it to the natural groundwater system. SPU constructed two drainage projects in the northwestern part of the city to decrease stormwater quantities discharged to Piper's Creek, with the goal of reducing channel erosion and water pollutant loadings to the stream. The first project, the Viewlands Cascade Drainage System, replaced a narrow, partially concreted ditch with a wide series of stepped pools. The second project was the very first application of the Street Edge Alternative (SEA Street) design, at 2nd Avenue NW, and involved the complete reconstruction of the street and its drainage system. Both of these projects have been monitored, under the direction of Richard Horner and Stephen Burges at the University of Washington,[2] for flow in relation to precipitation to evaluate their effectiveness in controlling stormwater runoff. Flow was measured with shaft encoder floats and pressure transducers that recorded water depths behind V-notch weirs. Precipitation was recorded using tipping bucket gauges. The record extends for more than four water years beginning on October 1, 2000. Some earlier baseline data were also collected from the street preceding the SEA Street project.

Upstream and downstream monitoring has demonstrated that the Viewlands Cascade, which drains a 26-acre basin, is capable of reducing the mean influent peak flow rate by approximately 60% and total runoff volume by more than half, although little or no reduction of either peak flow rate or volume occurred in relatively large storms. There was no discharge

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from the end of the channel in 27% of the events monitored. It can completely infiltrate the catchment response to about 0.13 inch (3.3mm) of precipitation and 1750 ft^3 (50 m^3) of influent regardless of the season or conditions. Based on the estimates for the ditch that preceded the Viewlands Cascade project, the new channel reduces runoff discharged directly to Piper's Creek in the wet months by a factor of three relative to the old ditch.

Figure 6. Construction of swale at 110th Street cascade pilot project, Seattle, Fall 2003.

Monitoring results for the 2nd Avenue SEA Streets project indicate the prevention of discharge of all dry season flow and 99% of the wet season runoff. This project's performance has advanced since its installation, to the point that it has not discharged since December 2002, even during large rainfalls in the autumn of 2003. The preceding street discharged flow in all 35 rainfall events for which baseline data are available. An increase in infiltration and evapotranspiration is attributed to maturing vegetation. It was estimated that a conventional City of Seattle street drainage system design in the same location would have discharged almost 100 times as much runoff to Piper's Creek as the SEA Streets alternative.

Despite serving a catchment less than 10% as large as the Viewlands Cascade, the 2nd Avenue NW project retains one-quarter to one-third as much runoff volume in the wet season as Viewlands, and thus has higher efficiency on a unit area basis. However, when normalized in terms of the cost per unit catchment area served, the SEA Streets project is considerably less cost-effective than the Cascade channel.

The Viewlands Cascade and SEA Streets projects represent different strategies for controlling the quantity of urban runoff. The SEA Street is a source control strategy that can manage a large proportion of the precipitation falling on its catchment, while the Cascade is an end-of-pipe approach that can attenuate a large quantity of already flowing runoff, although not nearly as high a percentage as the source control option. These two urban stormwater management strategies can be used in concert where appropriate to increase the overall effectiveness of the total system.

The environmental benefits of the Cascade and SEA Streets projects are significant to improving urban stream quality and reducing the amount of pollution entering Puget Sound. While this work in itself does not generate pristine salmon habitat, experts, such as Dr. Derek Booth, a professor at the University of Washington, suggest that addressing hydrologic conditions is an essential element of stream restoration.[3] That is, without the installation of distributed stormwater systems, it is doubtful that the urban creeks in Seattle could ever support a sustainable, healthy population of salmon.

Cost Effectiveness

The city of Seattle is finding that in addition to providing significant environmental protection, the implementation of natural drainage systems is more cost effective to implement than traditional systems. The reduction of runoff at its source has reduced the need to build and maintain costly infrastructure, such as pipes and holding tanks. It also mitigates the pollution of local waterways, thus lowering costs to the city in

Figure 7. A cascade in full flood at Broadview Green Grid, Seattle, Washington.

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the long run. In addition, the tools of natural drainage systems – plants and trees – maintain themselves and increase their benefit with time as they grow bigger and provide more surface area to slow runoff. SPU estimates that natural drainage systems cost 25% less than traditional roadside development. This cost reduction does not factor in environmental services such as increased carbon sequestration through the planting of trees, cleaner waterways, and replenished groundwater—when these benefits are considered, the actual benefit to society is likely much greater.

Public Appeal

Public support for natural drainage systems has been very enthusiastic. Neighborhood residents and community activists alike are supportive of the concept and the implementation. SPU has been working diligently to involve residents in all stages of planning and implementation. The residents are supportive of the programs because they are planting trees and public gardens along the streets, making their neighborhoods more livable and aesthetically appealing. Redesign of old streets has added sidewalks to areas where there were none. The curvilinear streets are slowing the speed of traffic, in effect creating a pedestrian-friendly environment. Many residents attribute a recent rise in property values to the installation of NDS systems along their streets; additional market data will need to be collected to prove this. Finally, many residents are proud to be associated with the NDS initiative because of the environmental benefits it is beginning to yield.

Together these benefits go beyond the initial SPU aim of improving salmon habitat; the project appears to be improving the entire ecosystem, using government funds efficiently, and enhancing the quality of life of Seattle residents. This culmination of improvements has increased the visibility of the NDS program, and has drawn to SPU's door municipal officials and stormwater engineers from far and near seeking more information.

Building on Earlier Initiatives

Utilizing the idea that biological systems can effectively retain rainwater and provide environmental and economic benefits is not new in the United States. Part of the rationale for creating the Adirondack Preserve in New York State and National Forests across the country was that these public forests would absorb rain where it fell and replenish groundwater supplies that feed major navigable rivers. Heightened awareness of the pollution-related damages caused by stormwater runoff in the mid-1980s inspired creative initiatives to mitigate such impacts. Prince George's County, Maryland in metropolitan Washington, D.C. actively sought new methods to reduce runoff into its local estuary, Chesapeake Bay, and implemented a variety of low impact development (LID) designs for stormwater control. Such LID designs included bio-swales and rain gardens. In 1998, the U.S. Environmental Protection Agency awarded Prince George's County a first place national award for the Outstanding Municipal Stormwater Program, setting it as an example for the rest of the country.

Denise Andrews and her colleagues picked up on the LID ideas then gaining currency to propose a novel approach to retrofitting city streets in northwest Seattle. Previously, LID had only been applied to small areas, such as parking lots or individual buildings, or in new suburban developments. Seattle was the first major city in America to apply these techniques to existing city streets and neighborhoods.

The number of jurisdictions interested in learning more about NDS indicates the success of the Seattle program. Since its implementation, SPU has given over 50 tours to representatives from local communities, across the United States, and around the world. Almost any local government challenged to comply with EPA stormwater management regulations could benefit from learning more about the NDS program in Seattle. The lessons are applicable both for jurisdictions that are redeveloping traditionally built infrastructure and for those permitting new subdivisions and developments.

Things to Look Out For

As SPU has moved forward in developing its initiative they have come up against challenges. Initial obstacles to implementing the low-impact development approaches came from within the city government. City traffic engineers were at first opposed to the redesigned street plans that reduced the total paved surface area. According to SPU, the redesigned streets are gradually gaining favor with this group of individuals. Emergency response professionals were also concerned that narrower streets might impair the delivery of public safety services. Once the pilot project was completed, the alternative street designs gradually gained acceptance among public safety officials, as they found that their ambulances and fire trucks could navigate the curvilinear street without exceptional difficulty.

With continued development of SEA and cascade projects some risks remain. From an engineering perspective, there are two main concerns. One is that if the infiltration of a redesigned soil bed or vegetated swale does not work properly, the result could be standing water in the neighborhoods. Recognizing that standing water provides a breeding ground for mosquitoes and other insects, the swales have been designed to drain completely within three to five days; mosquitoes require six days of standing water to breed. Another potential engineering problem is the risk that repeated infiltration might cause slope instability. To reduce this risk, the city is remaining cautious in implementing the LID techniques in steep, densely populated areas and adhering to strict engineering standards.

Continued on p. 9

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WQ-89	Rural Clean Water Program Technology Transfer Fact Sheets (10 fact sheets) (1995) (*http://h2osparc.wq.ncsu.edu/info/concepts.html*)	Free	_____	
WQ-91	Watershed Management: Planning and Managing a Successful Project to Control Nonpoint Source Pollution (contains a list of resources specific to North Carolina) (1995) (8p) (*http://www.bae.ncsu.edu/bae/programs/extension/publicat/wqwm/ag522.html*)	Free	_____	
WQ-86	Paired Watershed Study Design (EPA 841-F-93-009) (1993)	Free	_____	
WQ-48	Pesticide Fact Sheets (10 fact sheets) (1988)	4.00	_____	_____
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WQ-121	Nonpoint Sources (Review of 1998 Literature) (Water Environment Research) (1999) (16p)	Free		
WQ-118	Nonpoint Sources (Review of 1997 Literature) (Water Environment Research) (1998) (17p)	Free	_____	
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- U.S. Environmental Protection Agency's Office of Water publications list: http://www.epa.gov/OW/info
- WATERSHEDSS — Water, Soil, Hydro-Environmental Decision Support System, Internet-based management tool: http://www.water.ncsu.edu/watershedss/
- Understanding the Role of Agricultural Landscape Feature Function and Position in Achieving Environmental Endpoints: Final Project Report (to the U.S. Environmental Protection Agency) (1996) (118p) (*abstract and instructions for downloading the report available at: ftp://ftp.epa.gov/epa_ceam/wwwhtml/software.htm*

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In an effort to encourage citizen involvement and reduce costs, SPU has enlisted homeowners to contribute to the maintenance of their street-side gardens. Initial response to this request by residents has been quite positive. However, if the gardens are not maintained there will be an increased cost to the government to manage these areas.

Inspiring Innovation

In applying for an Innovations in American Government Award, the City of Seattle demonstrated that its effort met each of the four key criteria considered by site visitors and competition judges: *novelty, significance, effectiveness, and transferability*. A fifth criteria—*the ability to endure* as an innovation—was also met. Seattle's Deputy Mayor, Tim Ceis, and SPU Director, Chuck Clarke, explained that the NDS program is likely to have a long life for several reasons. First, all reports to date indicate that it achieves its stated objectives in a cost-effective manner.[4] Second, as it is currently structured, the revenues that support the program come from SPU stormwater fees, which by law the City of Seattle cannot use for any purpose other than stormwater-related efforts. Third, the program enjoys widespread support not only from elected officials and experienced city managers, but also from local political advocates.

With this significant political and financial support behind them, Denise Andrews and her team are actively expanding the NDS program. Having successfully completed the 32-acre Broadview Green Grid, a SEA Streets project, in September 2004, they are planning another 15-block SEA, called the Pinehurst Green Grid, to be installed in Seattle's Thornton Creek watershed. In the most ambitious initiative to date, SPU is working with the Seattle Housing Authority to apply NDS methods to a 34-block high-density housing redevelopment called High Point. The redevelopment project will cover 129 acres and encompass 10 percent of the Longfellow Creek watershed. High Point is challenging SPU to achieve significant stormwater absorption while maintaining traditionally designed curbs, gutters and sidewalks.[5] Once completed, High Point should provide a significant test case for the use of LID methods in a high-density urban area. As SPU continues to evolve its NDS program, widely distributed groups of stormwater management officials, as well as citizens striving to improve local water quality conditions, are likely to notice.

For More Information

Visit the Seattle Public Utilities web site at http://www.ci.seattle.wa.us/util/About_SPU/Drainage_&_Sewer_System/Natural_Drainage_Systems/index.asp.

Endnotes

[1] Seattle Public Utilities Press Release, "Natural Drainage Systems Receive $100,000 Award: Harvard Recognizes Innovative City Program," July 28, 2004. City of Seattle: Seattle, WA. See http://www.ci.seattle.wa.us/util/About_SPU/News/News_Releases/COS_003041.asp.

[2] Horner, Richard R., Heungkook Lim, and Stephen J. Burges. "Hydrologic Monitoring of the Seattle Ultra-Urban Stormwater Management Projects: Summary for the 2000-2003 Water Years." Water Resources Series: Technical Report No. 181, Department of Civil and Environmental Engineering, University of Washington, Seattle, Washington, October 2004.

[3] Field interview of Dr. Derek Booth by James N. Levitt, February 12, 2004, Seattle, Washington.

[4] Field interview of Tim Ceis and Chuck Clark by James N. Levitt, February 12, 2004, Seattle, Washington.

[5] See "High Point Project" on the Seattle Public Utilities website: http://www.ci.seattle.wa.us/util/About_SPU/Drainage_&_Sewer_System/Natural_Drainage_Systems/High_Point_Project/index.asp, as of September 2004.

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INFORMATION

2004 Summary Report of Section 319 National Monitoring Program Projects

The annual report of the Section 319 National Nonpoint Source Monitoring Program (NMP) Projects is available online at **http://www.ncsu.edu/waterquality/319index.htm**. This report provides profiles for 25 watershed projects selected under the NMP that are being monitored over a 6-10 year period to evaluate effectiveness of best management practices in reducing nonpoint source water pollution. Printed copies are available by contacting Cathy Smith at 919-515-3723 or waterquality@ncsu.edu.

EPA Joins With Organizations to Reduce Water Pollution from Septic Systems

In January, 2005, EPA along with other organizations that focus on septic systems, formalized an agreement to improve wastewater treatment for 25 million homes nation-wide. The memorandum of understanding is a first step in implementing EPA's program that works cooperatively with national organizations that represent septic system practitioners and the public. These systems are used in nearly 25 percent of homes across the country and used in about one-third of all new housing and commercial development. When properly sited, designed and maintained, these systems are capable of producing high quality wastewater. However, decentralized systems are the second greatest threat to groundwater qual-

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ity, second only to leakage from underground storage tanks. It is estimated that nation-wide, 10 to 20 percent of decentralized systems are not adequately treating wastewater due to inadequate site location, design and maintenance.

The program strategy identifies EPA's vision, mission and actions to improve the performance of decentralized wastewater treatment systems. The MOU and the strategy are intended to upgrade the management of these systems and facilitate collaboration between EPA headquarters, EPA regions, state and local governments and national organizations representing practitioners and assistance providers. Improved performance of decentralized systems will provide better protection of public health and water resources.

For more information about the effort or the decentralized wastewater treatment system program, visit EPA's website at **http://epa.gov/owm/septic.**

■

MEETINGS

Call for Abstracts

13th National Nonpoint Source Monitoring Workshop: Sept 19-25, 2005, Raleigh, NC. See Call For Abstracts on Page 11. **Abstracts due March 24, 2005.**

Clean Water, Healthy Streams, Strong Communities: Joint Southeastern Stormwater Mgmt & Erosion & Sediment Control Conf: Oct 2-6, 2005, Peachtree City, GA. Contact Rose Mary Seymour – Conference Chair, Bio & Ag Eng, 1109 Experiment St, Griffin, GA 30223. Tel: (770) 229-3214; Fax: (770) 228-7218; email: rseymour@griffin.uga.edu. **Abstracts due March 30, 2005**.

National Water Research Symp – Balancing Water Law & Science: Oct 10-12, 2005, Blacksburg, VA. Contact Tamim Younos at tyounos@vt.edu. Web site: www.vwrrc.vt.edu. **Abstracts due March 31, 2005**.

Workshops

Watershed Academy, Mar 29-31, 2005, Clemson, SC. Watershed Academy participants will learn how to apply water quality and watershed management principles to understand and solve complex water resource problems. Instructors will use case studies, field trips, and group assignments to teach about water quality assessment and watershed management approaches, including conservation, protection, and restoration. For additional information, see website: www.bae.ncsu.edu/workshops, or the Clemson University website at http://www.aces.edu/waterquality/streams/academy3.htm.

Stormwater Funding & Utility Development & BMPs: Pollutants, Selection & Maintenance Full Day Workshops & Exposition, May 13, 2005, Irvine, CA. Register online at www.StormCon.com/events.

Meeting Announcements — 2005

April

Environmental Banking & Beyond: The 8th National Mitigation & Conservation Banking Conf: April 18-21, 2005, Charlotte, NC. Web site: www.mitigationbankingconference.com; Tel: 703-548-5473.

18th Annual National Conf, Enhancing the States' Lake Mgmt Programs: Protecting Lakes & Reservoirs in Urbanizing Areas: April 26-29, 2005, Chicago, IL. Contact Bob Kirschner, Chicago Botanic Garden, 1000 Lake Cook Road, Glencoe, IL 60022. Email: bkirschn@chicagobotanic.org. Web site: http://www.nalms.org/symposia/chicago/index.htm.

9th Biennial Conf on Stormwater Research & Watershed Mgmt: April 27-29, 2005, Tampa, FL. For more information, contact Ms. Tammy Smith at Tel: 850-906-0099; email: Tammy@mcraeco.com; web site: www. mcraeco.com/stormwater_conf.html.

May

16th Annual Nonpoint Source Pollution Conf: Our Watersheds: Working Together to Achieve Results: May 24-26, 2005, Bretton Woods, NH. Web site: www.neiwpcc.org/npsannualmeeting.htm.

June

Design of Water Quality Monitoring Networks Short Course: June 6-10, 2005. Colorado State Univ, Fort Collins, CO. Contact Tom Sanders at tgs@engr.colostate.edu.

Environmental Statisics Short Course: June 8-10, 2005. Colorado State Univ, Fort Collins, CO. Contact Jim Loftis at loftis@engr.colostate.edu.

TMDL 2005: June 26-29, 2005, Philadelphia, PA. Web site: www.wef.org/Conferences/.

July

StormCon '05, the North American Surface Water Quality Conference & Exposition: July 18-21, 2005, Orlando, FL. Web site: www.StormCon.com.

September

13th National Nonpoint Source Monitoring Workshop: Sept 19-25, 2005, Raleigh, NC. See the highlighted workshop announcement on Page 11.

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Call For Abstracts

13th National Nonpoint Source Monitoring Workshop

September 19-25, 2005
Sheraton Capital Center Hotel
Raleigh, NC
http://www.ncsu.edu/waterquality/nmp_conf/

You are invited to submit proposals for oral and poster presentations. Presentations will be 20 minutes, followed by 10 minutes for discussion. Posters are also encouraged.

Presentations should focus on one of the following **session topics:**

- Enhancing States' nonpoint source management programs
- Impact of NPS project monitoring results and lessons learned on States' NPS programs
- Detecting change in water quality from agricultural or urban BMP implementation
- Modeling applications for NPS pollution
- TMDLs
- Education and Outreach on NPS pollution control
- Riparian area and stream protection/restoration
- Monitoring Low Impact Development

INSTRUCTIONS FOR SUBMITTING PROPOSALS

1. Submit online at: http://www.ncsu.edu/waterquality/nmp_conf/abstracts.html.
2. Email or mail a proposal with the following information included: (MS Word or Text file)
   - Author name, affiliation, session topic the presentation will address, and preferred presentation format (oral or poster). Also include mailing address, phone, fax and email.
   - The circumstances creating the need for the project/program.
   - The measurable objectives of the project/program.
   - Impact on NPS programs from project monitoring results and lessons learned.
   - Partnerships (public and private) supported and/or created by this project/program, including partner role and contribution to the project.
   - A description of how the project/program integrated monitoring and implementation.
   - A discussion of results:
     - Did the monitoring indicate that project goals were accomplished?
     - What changes in land treatment/land uses occurred?
     - How did these changes relate to water quality monitoring results?
     - How was modeling used in conjunction with BMP implementation?
     - How was the TMDL implemented?
3. Submit a short bio-sketch of yourself to appear in the printed program.
4. Submit a short statement regarding the following question: If you were king or queen, what one program change would you make to your state's NPS program to improve water quality (does not have to be related to your submittal paper, and it will not be printed in the workshop program)?
5. Below the short statement in item # 4, also let us know if you do **not** want to give us permission to post your presentation on our website after the conference. We plan to post a low-resolution pdf file of your presentation with the accessibility disabled so that there can be no content copying or extraction and no changing. If you do not indicate anything on the statement, we will assume you are giving permission.

Mail to:

NCSU Water Quality Group
Dr. Jean Spooner, Conference Chair
Campus Box 7637
Raleigh, NC 27695-7637
Phone (919) 515-3723; Fax (919) 515-7448
Email: waterquality@ncsu.edu

Deadline for submission of abstracts is **March 24, 2005**.

Review and Notification

Authors will be notified of receipt of their abstract. The workshop program committee will review abstracts. Authors will be notified by May 2, 2005 regarding the status of their abstract. An update of accepted abstracts may be submitted by Sept 1 (optional), which will be published in the workshop program.

Contact person: Jean Spooner at jean_spooner@ncsu.edu.

Production of NWQEP NOTES is funded through U.S. Environmental Protection Agency (EPA) Grant No. X825012. Project Officer: Tom Davenport, Office of Wetlands, Oceans, and Watersheds, EPA. 77 W. Jackson St., Chicago, IL 60604. Website: http://www.epa.gov/OWOW/NPS

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Natural Drainage Systems Overview

Natural drainage systems (NDS) are an innovative alternative to traditional stormwater management systems. The pipes and ditches of traditional drainage systems carry runoff with traces of everyday contaminants such as oil, paint, fertilizer, and heavy metals directly into creeks, lakes, and Puget Sound. The speed and volume of water coming out of pipes erodes stream channels. These problems decrease water quality, disrupt marine food chains, and negatively impact wildlife habitat.

Natural drainage systems limit the negative impacts of stormwater runoff by redesigning residential streets to take advantage of plants, trees, and soils to clean runoff and manage stormwater flows. Vegetated swales, stormwater cascades, and small wetland ponds allow soils to absorb water, slowing flows and filtering out many contaminants.

Natural Drainage Projects

Street Edge Alternatives (SEA Streets)
This natural drainage pilot project was the first natural drainage system constructed by the City of Seattle. It was completed in the spring of 2001.

110th Cascade
110th Cascade was completed in the spring of 2003. It is a series of stair-stepped natural pools that slow the flow of stormwater, reduce flooding, and filter pollutants before they reach Pipers Creek.

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Broadview Green Grid

This ambitious natural drainage system project provides stormwater improvements to almost the entire sub-basin of Piper's Creek watershed. Broadview Green Grid was completed in the spring of 2005.

High Point

High Point is one of the largest redevelopment projects in Seattle's recent history. The High Point NDS is the largest the City has undertaken and is the first natural drainage system to be used in a high density urban setting. The first phase of the High Point NDS was completed in the fall of 2005.

Pinehurst Green Grid

This project covers 12 city blocks and combines neighborhood enhancements with a new stormwater system that improves the quality of runoff to Thornton Creek. Landscaping was completed in the spring of 2007.

More Information

If you have questions after viewing this site, contact Drena Donofrio at drena.donofrio@seattle.gov.

Links to other sites

Low Impact Development - Learn how Puget Sound planners, developers, engineers and others are transitioning to an innovative approach to land development and stormwater management

Portions of this website were made possible by a grant from the Innovations in American Government Award, a program of the Ash Institute for Democratic Governance and Innovation at Harvard University's Kennedy School of Government and administered in partnership with the Council for Excellence in Government.

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Program Information

Natural drainage systems (NDS) are an innovative approach to street design in the United States. Learn more about:

• The Story of the Natural Drainage Systems Program
Learn about the problems threatening our waterways and how NDS have proved an effective part of the solution.

• Goals and Objectives
Natural drainage systems are designed to meet certain goals and objectives.

• Benefits and Challenges
Natural drainage systems offer many benefits to homeowners, municipalities, and the environment. There are also a few risks and challenges.

• Frequently Asked Questions
How are NDS sites selected? How are projects funded? How much do NDS cost? These and other questions are answered on the Frequently Asked Questions page.

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The Story of Natural Drainage Systems

The Problem

Prior to development, present-day Seattle was covered by forests and grasslands that acted like a sponge, absorbing rainfall into the ground and letting it seep into creeks and rivers. Today, the rooftops, streets, and parking lots that cover much of the land in Seattle prevent rain from moving through the soil. Instead, water is carried away from these hard surfaces through pipes and ditches to our waterways.

This can lead to two problems:

- Runoff carries everyday contaminants, such as oil, paint, fertilizer, and heavy metals directly into creeks, lakes, and Puget sound, impacting the food chain that supports fish and other wildlife
- The speed and volume of stormwater coming out of pipes erodes stream channels, impacting wildlife habitat

Toxic runoff in Puget Sound waterways has likely caused high numbers of mortalities of the endangered Coho salmon. Chinook salmon, which are listed as threatened under the Endangered Species Act, are also in dramatic decline.

An Innovative Solution

In response to the threats to habitat, Seattle Public Utilities began programs such as the Urban Creeks Legacy projects to actively promote citizen stewardship and restoration of local creek habitat.

However, in-stream restorations alone are not enough. In 1999, SPU initiated the natural drainage systems (NDS) program, an innovative approach to stormwater management that protects the fragile ecosystems in Seattle's water bodies.

In pristine forest conditions, creeks maintain a dynamic equilibrium with storm cycles, allowing for aquatic

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organisms to adjust to changing creek conditions. NDS mimics natural forested conditions to limit the impacts of urban development on Seattle's water bodies.

SPU redesigns residential streets to include vegetated swales, stormwater cascades, and small wetland ponds. These features slow stormwater flows and allow soils to absorb water and filter out many contaminants. The system relies on plants, trees, and the deep, healthy soils that support them. If maintained properly, the plants and soils combine to form a living infrastructure that, unlike pipes and vaults, improves in function over time.

Achieving Positive Results

The first natural drainage project, Street Edge Alternatives (SEA Streets), was implemented in a single residential block in a low-density neighborhood in Piper's Creek watershed in northwest Seattle. The project combined swales with traditional drainage infrastructure (such as catch basins and culverts) and decreased the watertight surface area of the site's streets by 11 percent.

Two years of monitoring show that SEA Streets reduced the total volume of wet season runoff by 99 percent.

Natural Drainage System Evolution

The success of SEA Streets enabled the NDS projects to grow and diversify. The High Point project features the largest natural drainage project that the City has undertaken and protects 10 percent of the Longfellow Creek watershed. The Capitol Hill Water Quality Improvement project will redesign the drainage system in one of Seattle's densest neighborhoods.

For more information about specific natural drainage projects, visit the Natural Drainage Systems Program Overview page.

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Goals and Objectives

The natural drainage systems (NDS) program has two goals:

1. Slow the flow and reduce the volume of stormwater runoff. Retrofit and redevelop public right-of-ways to improve water quality and imitate hydrologic processes that existed before development
2. Use a state-of-the-science approach to apply existing and new data in adjusting technical stormwater management design objectives.

NDS has three objectives for management of urban stormwater in areas of the city draining into creeks:

1. Protect Aquatic Organisms: Minimize the fluctuation of stream levels and disturbance of creek beds during storms that account for up to 90 percent of the total volume of rainfall in a given year.

Why? Creeks within urban areas receive too much stormwater flow too often, completely altering the sensitive equilibrium between storms and creek organisms.

How? Stormwater volumes entering our creeks as surface water will decrease by letting stormwater infiltrate into soils. Stormwater turns into ground water that seeps into creeks and keeps water at a level that is habitable for fish and other aquatic organisms.

2. Protect Creek Channels: Where possible, NDS will be used to reduce the disturbance of creek channels to pre-development levels.

Why? Prior to development, large rainstorms significantly changed the physical form of creek channels only once a year or less. The use of traditional drainage systems in developed areas increases the speed and volume of stormwater flows. Subsequently, the physical form of creek channels

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changes more frequently. This leads to the damage of wildlife habitat.

How? By infiltrating into soils, stormwater flows and volumes entering our creeks will decrease and the physical form of creek channels will change less frequently.

3. Improve Water Quality: Reduce pollutants reaching water bodies.

Why? Urban environments generate pollutants that are transported to creek systems by stormwater, impacting creek life and the food chain that includes humans.

How? Soils and vegetation absorb water and filter out or chemically break down many contaminants.

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Benefits and Challenges

Benefits

Natural drainage systems (NDS) offer a number of benefits to homeowners, municipalities, and the environment:

- Reduce stormwater volumes, and thereby decrease flooding.
- Improve water quality because plants and other natural organisms remove or neutralize contaminants.
- Reduce peak flow volumes and provide more stability for our creek flows.
- Incorporate more trees and green space into our neighborhoods.
- Involve neighbors in planning and implementation.
- Increase pedestrian and traffic safety by reducing average auto speeds.
- Rather than deteriorating over time like piped systems, NDS become more effective as plants and trees grow.
- NDS can easily integrated into the landscape and appear more natural than traditional drainage systems.
- One or more of the swales, cascades, or other components of the system can fail without undermining the integrity of the system as a whole.
- Controlling runoff at the source eliminates the need for more costly conveyance systems, regional detention facilities, and mitigation for toxic buildups in water bodies.
- The reduction of impervious surfaces (such as roadways and sidewalks) and use of aboveground

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swales rather than underground vaults significantly reduce costs of new street and drainage improvements in residential areas of low to medium density.

Challenges

In addition to the benefits associated with NDS, there are also risks and uncertainties:

- The possible failure of infiltration, resulting in standing water within the swale. Mosquitoes require at least six days of standing water to breed. Therefore, all swales are designed to drain completely within three to five days.

- The possibility of infiltration causing slope instability. SPU has a policy of not placing infiltration facilities within one block of a steep slope at minimum and further if a geotechnical survey shows higher risk.

- Uncertainty regarding long-term impact on aquatic species in Seattle's creeks, lakes, and bays.

- Safety of car traffic on non-standard design streets.

- The reduction of available parking.

For municipalities, NDS may be difficult to implement due to institutional barriers:

- Traditional land use code standards may impede implementation of NDS. Traditional land use codes require wide street widths, curb and gutter, and piped stormwater infrastructure.

- Street design mangers often prefer to uphold existing national street standards they feel are necessary for car mobility and pedestrian safety.

- Fire response officials often assume the need for wider streets for emergency vehicle access.The High Point project required a city executive directive to secure street widths that were less than redevelopment code required. Once built, the established rules of standard street design can more easily be questioned as emergency vehicles navigate the new street without difficulty.

Although there can be significant hurdles to overcome, SPU found that the impact on our region's receiving waters is too high to forgo the study and implementation of natural

drainage systems.

Seattle develops at a slow rate (less than one percent per year); therefore new regulatory requirements in the state stormwater manual will take hundreds of years to be fully implemented. Taking a proactive retrofitting approach to improving receiving waters' health is a priority for the City.

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Frequently Asked Questions

Why is Seattle doing this program?
Urban activities such as landscaping, transportation, and business generate pollutants which are carried through creeks into nearby lakes and Puget Sound – impacting our local marine life food chain.

Traditional stormwater management, focusing on pipes to move stormwater from one area to another, serves worthy goals of flood reduction and public safety. Unfortunately, this type of management negatively impacts our creeks and the larger receiving water ecosystems they flow into.

Natural drainage systems (NDS) are a response to the public call to develop drainage projects that sustain high quality water bodies and species diversity. In addition, emerging federal and state environmental regulations clearly indicate that efforts to protect and enhance the state's receiving waters will be mandatory.

How are these projects funded?
Seattle property owners pay a drainage fee based on impervious surface coverage. The drainage fee supports many different drainage projects and programs at Seattle Public Utilities.

What are the benefits of using natural drainage systems?
Natural drainage systems

- Improve water quality through filtering out or chemically breaking down pollutants
- Slow the flow and reduce the volume of stormwater
- Incorporate more trees and green space into our neighborhoods
- Involve neighbors in planning, implementation, and maintenance
- Increase pedestrian and traffic safety by reducing average auto speeds
- Become more effective as plants and trees grow

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What are the drawbacks?
Because of the participatory and comprehensive nature of the projects, NDS can take more time than traditional systems in the planning and design phase. It may also be necessary, and difficult, to change street standards.

How much more do they cost than "traditional" systems?
NDS cost about 10 to 20 percent less than traditional street redevelopment with curb, gutter, catch basins, asphalt, and sidewalks.

How do they relate to work done in support of compliance with the Endangered Species Act?
NDS are an important element of Seattle's Endangered Species Act response. They are a key strategy to protect water bodies with all types of salmon and other aquatic life.

How do these systems perform over time?
From October of 2000 through September of 2003, the University of Washington monitored the stormwater flow of the SEA Streets project and found that the project prevented 99 percent of the wet season runoff from flowing directly into Piper's Creek.

SPU is monitoring the flow and water quality of the Broadview Green Grid and High Point.

How are sites selected?
Streets are selected based on the following criteria:

- The proposed project streets are residential streets.
- Each project street has or could have (by diverting flow from an adjacent ditch) a minimum of five acres of upstream drainage area directed to it.
- The majority of the project streets have no existing local drainage infrastructure.
- The potential project blocks have no existing formal street improvements, such as sidewalks and asphalt or concrete streets.
- All potential project streets are a minimum of 300 feet from a critical slope area (as defined by the Department of Planning and Development) so that infiltration technologies can be used.
- Existing soil maps do not indicate clay in the area.
- The longitudinal slope of project streets is less than eight percent. Larger longitudinal slopes may limit infiltration capacity or drive up project costs by requiring earth stabilization walls and fences.
- Potential project streets do not have a bus route on

them.

If any potential funding partnering is desired from Seattle Public Utilities, the proposed project streets must be in an area prioritized for one of our business area needs. These areas include creek basins, combined sewer overflow problem areas, and prioritized water quality basin areas. No funding mechanism is currently in place for partnering on these types of projects; this process will be initiated in 2008. Due to intensive time commitment for City staff to evaluate and develop a partnering strategy, the minimum project area that SPU can consider for partnership is a 600-foot project length.

Related links
Be a Creek Steward
Creek Restoration Projects
Charting Common Ground for Salmon and Buildings

Links to other sites
Low Impact Development - Learn how Puget Sound planners, developers, engineers and others are transitioning to an innovative approach to land development and stormwater management

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Technical Resources

Seattle Public Utilities offers an array of technical resources for other municipalities that have an interest in implementing natural drainage systems (NDS). Learn more about:

Measuring the Success of Natural Drainage Systems
The NDS program monitors water quality and surface runoff volumes at some NDS sites.

Cost Analysis (PDF)
A cost comparison of SPU's natural drainage system program and traditional street and drainage improvements.

Plant Palette, 2000-2006 (PDF)
Compilation of planting lists from SEA Streets and Broadview Green Grid.

Soil Specifications (PDF)
Soil mix requirements for High Point Phase I.

High Point Landscape Maintenance Guidelines (PDF)
Written to guide maintenance professionals at High Point, this manual is a good example of a landscape maintenance plan for any project. It has many practical methods and resources for landscapers and project managers.

Seattle Natural Drainage Systems Program Presentation (PDF)
Overview of NDS presented at the Second National Low Impact Development Conference.

Stormwater Design Seminars
2006 professional seminars highlighting design and construction lessons learned from NDS and Low Impact Development projects around the Northwest.

Practically Easy Landscape Manual: A Care Manual for Natural Drainage Systems, Fall 2006 Edition (PDF)
This manual outlines the responsibilities of the City and of residents in maintaining natural drainage systems. It also

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includes helpful tips for major landscape maintenance tasks needed to establish and nurture NDS plantings, or to maintain any residential yard.

Plant Identification (PDF) - Provides color photos, special needs, and environmental requirements of NDS plants.

Learn more about Project specific technical resources:

- Street Edge Alternatives (SEA Streets)
- Broadview Green Grid
- Pinehurst Green Grid
- 110th Cascade Project
- High Point Project

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Measuring Success of Natural Drainage Systems

From October of 2000 through September of 2003, the University of Washington's Department of Civil and Environmental Engineering monitored the stormwater flow of the Street Edge Alternatives project (SEA Streets). The Hydrologic Monitoring Report (pdf) was produced and found that the SEA Streets project:

- Prevented 99 percent of the wet season runoff from flowing directly into Pipers Creek between 2000 and 2003.
- Discharges much less runoff to Pipers Creek than a traditional system. A drainage system that adheres to City of Seattle conventions would have discharged almost 100 times more runoff to Pipers Creek as the SEA Streets system.
- Prevents more runoff from flowing directly into Pipe's Creek as time passes. As vegetation matures, more water is absorbed through the soil.

Seattle Public Utilities is monitoring the water quality of Broadview Green Grid. A report will be available at the end of 2007.

Seattle Public Utilities began monitoring the first phase of the High Point natural drainage system in January of 2007. Data will be available in three years.

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Seattle Public Utilities – Natural Drainage System Program

Problem Statement: Seattle's receiving waters and aquatic life have been significantly impaired by the negative impacts of urban stormwater runoff. Increasing volumes of runoff also cause flooding of roadways and property. Traditional methods of stormwater management and street design have proven to be ineffective at countering the impacts of current and future development on receiving waters.

Natural Drainage Systems (NDS) is an alternative stormwater management approach that delivers higher levels of environmental protection for receiving waters at a lower cost than traditional street and drainage improvements.

- NDS targets areas of the city draining to creek watersheds that do not currently have formal drainage or street improvements.
- NDS design is based on technology that emphasizes infiltration and decentralized treatment of stormwater to reduce the total volume of runoff reaching creek systems.
- The goal of NDS is to more closely match the hydrologic function of natural forests that existed prior to development, thereby creating stable creek systems and clean water.
- NDS designs cost less than traditional drainage and street designs.

Cost Analysis of Natural vs. Traditional Drainage Systems Meeting NDS Stormwater Goals

Street Type	***Local street*** **SEA Street**	***Local street*** **Traditional**	***Collector street*** **Cascade**	***Collector street*** **Traditional**	**Broadview Green Grid** 15 block area
Community Benefits	▪ one sidewalk per block ▪ new street paving ▪ traffic calming ▪ high neighborhood aesthetic	▪ two sidewalks per block ▪ new street paving ▪ no traffic calming ▪ no neighborhood aesthetic	▪ no street improvement ▪ moderate neighborhood aesthetic	▪ no street improvement ▪ no neighborhood aesthetic	▪ both 'SEA Street' and 'Cascade' types ▪ one sidewalk per block ▪ new paving ▪ high neighborhood aesthetic
Ecological Benefits	▪ high protection for aquatic biota ▪ mimics natural process ▪ bio-remediate pollutants	▪ high protection from flooding ▪ some water quality	▪ high water quality protection ▪ some flood protection	▪ high protection from flooding ▪ some water quality	▪ high water quality & aquatic biota protection ▪ some flood protection ▪ excellent monitoring opportunity
% impervious area	35%	35%	35%	35%	35%
Cost per block (330 linear feet)	$325,000	$425,000	$285,000	$520,400	Average per block: $280,000

SPU Natural Drainage Systems Plant Palette 2000-2006

A DRAFT compilation of planting lists from SEA Streets and the Broadview Green Grid.

Scientific Name	Common Name	Sun	Shade	Water	Native Notes
Emergent/Wetland Plants					
Carex obnupta	slough sedge	●		wet-moist	Y
Carex rostrata	beaked sedge	●		wet-moist	Y
Sagittaria latifolia	broadleaf arrowhead	●		wet-moist	Y
Scirpus acutus	hard stem bulrush	●		wet-moist	Y
Scirpus microcarpus	small fruit bulrush	●		wet-moist	Y
Evergreen Groundcover					
Arctostaphylos uva-ursi	kinnikinnick	●		dry	Y
Rubus calycinoides	creeping bramble	●		moist-dry	N
Ferns/Perennials/Herbs					
Athyrium filix-femina	lady fern	●	●	moist	Y
Asarum caudatum	wild ginger		●	moist	Y
Cornus canadensis	bunchberry		●	wet-moist	Y
Epimedium	epimedium		●	moist-dry	N
Gaura	gaura	●		moist-dry	N
Geranium sanguinium	cranesbill geranium	●	●	moist-dry	N
Helianthemum nummularium	sunrose	●		moist-dry	N
Hemerocallis spp.	day lily	●		moist-dry	N
Heuchera micrantha	purple palace heuchera		●	moist	N
Heuchera sanguinea	coral bells		●	moist	N
Iris douglasiana	Pacific coast iris	●		wet-moist	Y
Iris foetidissima	Gladwin iris	●	●	wet-moist	N
Lavandula spp.	lavender	●		dry	N
Lupinus spp.	lupine	●		dry	N/Y
Maianthemum dilatatum	false lily of the valley	●	●	wet-moist	Y
Polystichum munitum	sword fern		●	moist	Y
Smilacina racemosa	false solomon's seal		●	wet-moist	Y
Tolmiea menziesii	youth-on-age		●	wet-moist	Y
Evergreen Small Shrubs (12-30" Height)					
Gaultheria shallon	salal		●	moist-dry	Y
Mahonia nervosa	longleaf mahonia		●	moist-dry	Y
Mahonia repens	creeping mahonia	●		moist-dry	Y

Scientific Name	Common Name	Sun	Shade	Water	Native Notes
Deciduous Small Shrubs (12-30" Height)					
Cornus stolonifera 'Kelseyi'	dwarf redtwig dogwood	●	●	wet-moist	N
Potentilla fruticosa	bush cinquefoil	●		wet-moist	Y
Rosa spp.	dwarf wild rose	●		moist-dry	N
Symphoricarpos albus	snowberry	●	●	moist-dry	Y
Evergreen Shrubs (>48" Height)					
Arbutus unedo 'compacta'	compact strawberry tree	●		moist-dry	N
Myrica californica	California myrtle	●		wet-moist	Y
Vaccinium ovatum	evergreen huckleberry		●	moist-dry	Y
Deciduous Shrubs (>48" Height)					
Cornus stolonifera (& cultivars)	redtwig dogwood	●	●	wet-moist	Y
Hydrangea quercifolia	oak-leaf hydrangea	●	●	moist	N
Lonicera involucrata	twinberry	●	●	wet-moist	Y
Philadelphus lewisii	mock-orange	●		moist	N
Ribes sanguineum	red flowering currant	●		moist-dry	Y
Rosa nutkana	nootka rose	●		moist-dry	Y
Rosa rugosa	rugosa rose	●		moist-dry	N
Rosa woodsii	woods rose	●		moist-dry	Y
Rubus parviflora	thimbleberry	●	●	moist-dry	Y
Rubus spectabilis	salmonberry	●	●	moist-dry	Y
Vaccinium spp.	blueberry		●	moist-dry	Y/N
Evergreen Small Trees (16-20' Height)					
Arbutus unedo	strawberry tree	●		dry	N
Deciduous Small Trees (16-20' Height)					
Acer circinatum	vine maple		●	wet-moist	Y
Amelanchier alnifolia	Western serviceberry	●	●	dry	Y
Corylus cornuta	Western hazelnut	●	●	moist-dry	Y
Evergreen Medium Trees (20-30' Height)					
Chamaecyparis obtusa	Hinoki cypress	●		moist-dry	N
Pinus contorta	shore pine	●		wet-dry	Y
Deciduous Medium Trees (20-30' Height)					
Acer campestre	hedge maple	●		moist-dry	N
Cornus nuttallii	Western dogwood		●	moist-dry	Y
Crataegus spp.	hawthorn	●		wet-moist	Y/N
Magnolia 'Ballerina'	ballerina magnolia	●		moist-dry	N
Magnolia 'Galaxy'	galaxy magnolia	●		moist-dry	N
Sorbus spp.	mountain-ash	●		moist-dry	N

Scientific Name	Common Name	Sun	Shade	Water	Native Notes
Evergreen Large Trees (>30' Height)					
Pinus nigra	Austrian pine	●		moist-dry	N
Pinus thunbergii	Japanese black pine	●		moist-dry	N
Pseudotsuga menziesii	Douglas-fir	●		moist-dry	Y
Thuja plicata	Western redcedar		●	moist-wet	Y
Tsuga heterophylla	Western hemlock		●	moist-wet	Y
Deciduous Large Trees (>30' Height)					
Acer 'Norwegian sunset'	Norwegian sunset maple	●		moist-dry	N
Acer 'Pacific sunset'	Pacific sunset maple	●		moist-dry	N
Betula jacquemontii	Jackmonti birch	●	●	moist-dry	N
Cercidiphyllum japonicum	katsura tree			moist-dry	N
Fraxinus latifolia	oregon ash	●		wet-moist	Y
Fraxinus ornus	flowering ash	●		wet-moist	N
Fraxinus oxicarpa	flame ash	●		wet-moist	N

HIGH POINT PHASE I – GRADING AND INFRASTRUCTURE
SEATTLE, WASHINGTON
SECTION 02310
NATURAL DRAINAGE SYSTEM SOIL MIX

PART 1 – GENERAL

1.1 SECTION INCLUDES

A. Work includes but is not limited to the following:
   1. Natural Drainage System (NDS) soil mixes.

1.2 SUBMITTALS

A. Submit the following in accordance with Section 01300 – Submittals:
   1. Manufacturer certification that the organic compost material meets the specifications in Part 2.1, including certified laboratory test results dated within 60 days of placement of material.
   2. As construction progresses, resubmit every 60 days manufacturer certification that the organic compost material meets the specifications in Part 2.1, including certified laboratory test results dated within 60 days of placement of material.
   3. A grain-size analysis per ASTM Designation D 422 (Standard Test Method for Particle-Size Analysis of Soils) from a representative sample of the gravelly sand material, demonstrating that it meets the specifications in Part 2.2.
   4. Organic content and permeability test results demonstrating the organic soil mixture meets the requirements specified in Parts 3.1.A.1 and 3.1.A.2.

B. Submit the following test results prior to mixing of compost with other specified materials in accordance with Section 01300 – Submittals:
   1. Solvita Compost Maturity Test of Organic Compost: Test results of Organic Compost shall be submitted one (1) working day prior to mixing Organic Compost with other NDS soil materials specified in Part 2. Organic Compost material that does not meet specifications noted in Part 2 shall not be mixed as NDS soil nor delivered to the site. Organic Compost material to be used in following day mixing operation shall be tested each day prior to mixing operation (i.e. this will be a continuous, at times daily, submittal process).

PART 2 – PRODUCTS

2.1 MATERIALS

A. Organic Compost: derive from a Type 1 feedstock and produced by a facility in compliance with WAC Chapter 173-350 (Solid Waste Handling Standards), Section 220 (Composting Facilities).
   1. Meet Grade AA Compost as defined by the Washington State Department of Ecology's Interim Guidelines for Compost Quality (Publication #94-38, Revised November 1994).
   2. Meet Grading Criteria: 100 percent passing a ½-inch screen.
   3. Decomposed Organic Compost shall be mature as US Composting Council stability test ratings referred to in the WAC 173-350.
   4. Meet Sovita Compost Maturity Test Score: 6 or above. Solvita Compost Maturity Test is available from Woods End Research Laboratory, phone (207) 293-2457 or 1(800) 451-0337, or website address: www.woodsend.org .

B. Gravelly sand: conform to the following gradation:

U.S. Sieve Size	Percent Passing
2-inch	100
¾-inch	70-100
¼-inch	50-80
No. 40	15-40
No. 200	0-3

C. Crushed Rock: use 5/8-inch clear crushed rock with no more than a trace of sand and silt.

D. Fill Sand: use slightly gravelly sand that meets the following gradation:

U.S. Sieve Size	Percent Passing
No. 4	95
No. 10	70-75
No. 20	58-62
No. 40	38-42
No. 60	12-16
No. 200	< 3

E. Provide gravelly sand free of organic material, contaminants, and hazardous materials.

PART 3– EXECUTION

3.1 MIXING

A. NDS Soil Mix #1:
1. Mix 30 to 35 percent by volume organic compost with the remaining volume being gravelly sand to provide an organic soil mix with the following properties.
   a. Organic content between 4 and 8 percent by dry weight per ASTM D 2974.
   b. Minimum hydraulic conductivity rate of 4 inches per hour per ASTM Designation D 2434 when compacted to 80 percent of maximum dry density per ASTM Designation D 1557.

B. NDS Soil Mix #2:
1. Mix three parts organic compost with one part fill sand by volume. Mix shall have an average organic content of 5 percent and be within a range of 4 to 8 percent as measured by ASTM D 2974.
2. Mix 78 percent crushed rock to 22 percent organic mix by dry weight.

C. Mix each NDS Soil Mix uniformly to a homogeneous consistency.
1. Do not mix in the rain or wet conditions.

3.2 STORAGE

A. Store stockpiles of organic soil mix in a manner that prevents them from becoming wet from rain, stormwater runoff, or other sources of water or contaminated by fine soil or other undesirable materials.

B. All stockpiles of mixed and pre-mixed NDS soil material shall be protected and covered in accordance with Contract Documents.

3.3 PLACEMENT

A. Moisture condition the organic soil mixes as needed for suitable placement and compaction and at the locations shown on the Drawings.

B. Place in lifts not exceeding 6 inches in loose thickness.

C. Compaction
1. NDS Soil Mix #1: compact lightly organic soil mixes to not less than 70 percent and not more than 80 percent of the maximum dry density per ASTM Designation D 1557.
2. NDS Soil Mix #2: compact to 95%.

D. Do not drive or park equipment on the NDS soil mix once placed.

E. Coordinate construction scheduling so that sediment laden water does not enter NDS soil mix once placed.

END OF SECTION 02310

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Project Photos

These photos can be used by government agencies, educational groups and individuals. Please reference Seattle Public Utilities as the source.

SEA Street before

SEA Street after

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SEA Street aerial view

SEA Street swale detail

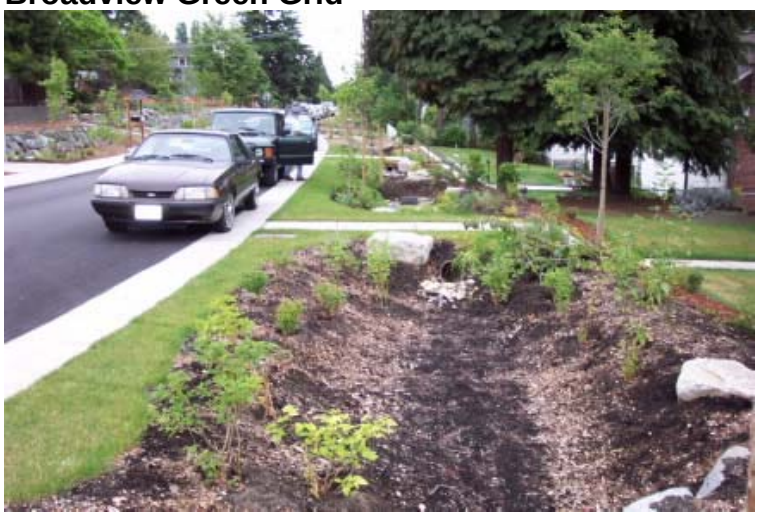
Planted swales on SEA Street

110th Street excavation, Summer 2003

110th Street planting, Winter 2003

Cascade in a storm, Broadview Green Grid

New grass, plants and swales on the street edge, Broadview Green Grid



New pavement in rain, Broadview Green Grid

New swale in rain, Broadview Green Grid

New curvy streets and sidewalks, Broadview Green

Grid

Pinehurst Swale

Pinehurst Street View

High Point Swales

Related links

Street Edge Alternatives (SEA Streets)
Broadview Green Grid Project
High Point Project
110th Cascade Project

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HYDROLOGIC MONITORING OF THE SEATTLE ULTRA-URBAN STORMWATER MANAGEMENT PROJECTS: SUMMARY OF THE 2000-2003 WATER YEARS

by

Richard R. Horner
Heungkook Lim
Stephen J. Burges

Water Resources Series
Technical Report No. 181

October 2004

SARB_004733

ABSTRACT

Seattle Public Utilities constructed two drainage projects in the northwestern part of the city to decrease stormwater quantities discharged to Pipers Creek, with the goal of reducing channel erosion there and water pollutant loadings to the stream. One project, the Viewlands Cascade Drainage System, replaced a narrow, partially concreted ditch with a wide series of stepped pools. The second installation, at 2nd Avenue NW and known as a Street Edge Alternatives (SEA Streets) project, involved the complete reconstruction of the street and its drainage system to reduce impervious area and install stormwater detention ponds. These projects have been monitored over three water years beginning on 1 October 2000 for flow in relation to precipitation to determine their actual benefits. Flow was sensed with shaft encoder floats and pressure transducers that recorded water depths behind V-notch weirs. Precipitation was recorded using tipping bucket gauges.

Monitoring has demonstrated that the Viewlands Cascade is capable of reducing the mean influent peak flow rate by approximately 60 percent and total runoff volume by more than half, although little or no reduction of either peak flow rate or volume occurs in relatively large storms. Based on estimates for the ditch that preceded the Viewlands Cascade project, the new channel reduces runoff discharged directly to Pipers Creek in the wet months by a factor of three relative to the old ditch.

The 2nd Avenue SEA Streets project has prevented the discharge of all dry season flow and 99 percent of the wet season runoff. This project's performance has advanced since its installation, to the point that it has not discharged since December of 2002, even during large rainfalls in the autumn of 2003. Maturing vegetation is likely assisting both soil infiltration and evapotranspiration. It was estimated that a street drainage system design according to City of Seattle conventions in the same place would have discharged almost 100 times as much runoff to Pipers Creek as the SEA Streets alternative. Despite serving a catchment less than 10 percent as large as the Viewlands Cascade, the 2nd Avenue NW project retains one-quarter to one-third as much runoff volume in the wet season as Viewlands, and thus has higher efficiency on a unit area basis. However, when normalized in terms of the cost per unit catchment area served, the SEA Streets project is considerably less cost-effective than the Cascade channel.

The two projects represent two contrasting urban stormwater management options. The SEA Streets project is at the drainage source, where rainfall is converted to surface runoff. It is capable of preventing almost all of the conversion. The large Viewlands Cascade is in an end-of-pipe location and can attenuate large amounts of already flowing runoff, although not at nearly the proportional efficiency of the SEA Streets alternative. Together, using the two strategies where the best opportunities for each exist can significantly advance the ability to manage urban runoff peak flow rates and volumes.

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CHAPTER 1 - INTRODUCTION

1.1. Background and Objectives

The City of Seattle has launched a program to protect and improve the health of the City's freshwater ecosystems. Creative approaches are necessary to manage stormwater in urban areas, since impacts from the developed watershed significantly influence the health of the stream. As such, the National Marine Fisheries Service (NMFS) requires quantitative relationships between stormwater management activities implemented in the watershed and benefits to the associated stream ecosystem. The Washington Department of Ecology (WDOE) is moving in the same direction under the City's stormwater National Pollutant Discharge Elimination System (NPDES) permit.

In the summer of 1999, Seattle Public Utilities (SPU) established a memorandum of understanding with the University of Washington's Center for Urban Water Resources Management to assist in the evaluation of various stormwater management Capital Improvement Projects (CIPs). The work under the agreement involves testing a variety of innovative "ultra-urban" stormwater management techniques and documenting their benefits with quantitative data. In this context "ultra-urban" is defined as any built environment within the City of Seattle, including a variety of industrial, commercial, residential, and mixed land use types. The first stormwater management projects proposed for testing apply mainly to single-family residential and neighborhood commercial areas.

The broad objectives of the series of ultra-urban studies are to:

Determine how effective the selected projects are in reducing peak rates and volumes of runoff;

Evaluate receiving water ecosystem benefits that could be achieved with widespread application of these project types; and

3 Develop a long-term, systematic approach to ultra-urban stormwater management in Seattle.

The first two ultra-urban stormwater management projects to be evaluated are the Viewlands Cascades Drainage System and the 2nd Avenue NW Street Edge Alternative (SEA) Streets Millennium Project. The projects were designed to reduce stormwater quantities discharged to Pipers Creek. A related goal in the case of Viewlands was to decrease the high velocities often occurring in the previous drainage ditch to prevent bypass of the drain inlet at its end, and the consequent erosion of the adjacent slope. Both projects were also expected to provide water quality benefits through enhanced pollutant capture by vegetation and soils and reduced pollutant mass loadings associated with lower flow volumes.

The Viewlands Cascade receives drainage from a catchment thought during project design to be approximately 26 acres (10.5 ha) in area. Subsequently, it was established that an additional area of approximately 46 acres (18.6 ha) discharges via the Dayton Avenue swale to the Cascade

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during relatively large storms and prolonged events when soils are largely saturated. The full contributing catchment has approximately 29 percent impervious land cover. Slopes range from about 0 to 6 percent, with average slopes north to south being 1.8 percent and east to west 5.7 percent.

Collected runoff is piped to the Cascade, where it flows through 16 stepped cells formed by log weirs to the downstream drain inlet and onward to Pipers Creek via another pipe. Construction cost was approximately $225,000.

The 2nd Avenue NW SEA Streets project represents a full street right-of-way redesign. The width of the 660-ft (201-m) long roadway between NW 117th and NW 120th Streets was reduced from 25 ft (7.6 m) to 14 ft (4.3 m), paved parking slots were provided at angles to the street, and sidewalks were added. The remainder of the 60-ft (18-m) right of way was devoted to runoff detention ponds planted with native vegetation. The original right of way covered approximately 0.91 acre (0.37 ha), about 0.38 acre (0.15 ha) paved with asphalt and the remainder in vegetation on the edges. Hard surface was reduced slightly to 0.31 acre (0.13 ha) in the redesign, with the remainder given to ponds. The construction cost was initially bid at $244,000. There were substantial additional costs for this first-of-its-type project in reaching community consensus, change orders to satisfy community concerns, etc.

The catchment area draining to the 2nd Avenue NW pond system includes properties on the east side of 2nd Avenue NW, as well as the streetscape, and totals approximately 2.3 acres (0.93 ha). Slopes are slight toward the west and south. The catchment discharges to a ditch flowing along NW 117th Street at the southwest corner of the project.

Precipitation at the Viewlands Cascade has been monitored since January 2000. Post-construction flow monitoring began in July 2000 and has continued since then. Both inflow and outflow were monitored through April 30, 2002, at which time the outflow station was decommissioned. The inflow station remains in place to support upcoming catchment hydrologic model development. Baseline (pre-construction) monitoring was not possible at this site, because construction began shortly after establishment of the memorandum of understanding.

The construction schedule at 2nd Avenue NW allowed some baseline monitoring of the pre-existing street, from March 11 to July 11, 2000. At that point monitoring was suspended during construction, which lasted until the following January. Post-construction monitoring started soon thereafter and has continued since then.

A graduate thesis (Miller 2001) and two technical reports in this series (Miller, Burges, and Horner 2001; Horner, Lim, and Burges 2002) document all events in the ultra-urban stormwater management studies through April 2002. These references provide more extensive background to the projects, a review of relevant literature, descriptions of the monitoring equipment and methods at both sites, data management and analysis procedures, results for the period of coverage, discussion of findings, and what conclusions could be drawn at that time.

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This report summarizes all meteorological data collected from the outset of monitoring in January 2000 through the conclusion of the water year on September 30, 2003. It profiles all flow data collected during the three water years commencing on October 1, 2000 and ending on September 30, 2003. This water-year organization was adopted for this and future reports in the series to offer the clearest portrayal of year-to-year trends in relation to stochastic meteorological cycles. This report therefore reiterates some data presented in previous reports, while also omitting a small amount of data from the early flow monitoring. Miller (2001) and Miller, Burges, and Horner (2001) are sources of these data. This report also covers two large rainfall events that occurred shortly after the close of the most recent water year. This coverage is provided because of the high interest in project performance with much greater daily (or longer duration) rainfall than previously experienced.

1.2. Brief Description of Instrumentation

This subsection provides a basic description of the monitoring systems established at both projects. Refer to Miller (2001) and Miller, Burges, and Horner (2001) for full details.

The log weirs at the ends of cells 1 and 15 of the Viewlands Cascades Drainage System were outfitted with V-notch weirs to serve as controls for comparative flow monitoring near the entrance and exit of the channel. Weir water levels, from which flow rates were computed, were sensed at each point with both float/shaft encoders and submersible pressure transducers.

The Viewlands site has a full meteorology station on the adjacent elementary school property. The station has three precipitation gauges, two tipping-bucket recording gauges and a non-recording collector. Mounted on a tripod are temperature and relative humidity probes, a wind anemometer, a net radiometer, a short-wave pyranometer, and a solar panel for power supply. The station also includes an evaporation pan with an anemometer and a net radiometer mounted just above the water surface. Data from all flow and meteorological instruments are logged at one of three data loggers at the station for computer downloading.

With the collection of sufficient data, the downstream Viewlands flow monitoring station was decommissioned in May 2002. The upstream station will continue in operation for at least several more years to serve as the check point for rainfall-runoff mathematical modeling of the catchment now getting underway. All meteorological instruments will also continue to function to support the same purpose. The goal of this enterprise is to develop a calibrated, verified hydrologic model that can be used for future stormwater management decision making relative to small catchments in the Pipers Creek watershed.

With no runoff entering from outside its catchment, the 2nd Avenue NW SEA Streets site was equipped only with a flow monitoring station at the point where runoff exits the project. This station has a float/shaft encoder with a stilling basin and V-notch weir flow control. In an adjacent yard were a tipping-bucket recording precipitation gauge and a non-recording collector. These gauges were removed in September 2003, after the relationship between precipitation here and at the nearby Viewlands station was well established. This site has one data logger. The 2nd Avenue NW monitoring system will continue to operate for an undetermined period of time to collect more post-construction data.

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1.3. Viewlands Leakage Testing and Calibration

1.3.1. Summary of Early Work

It has been observed since the beginning of monitoring that water levels in Viewlands cells 1 and 15, ahead of the upstream and downstream V-notch weirs, respectively, continue dropping after flow into the cells and over the weirs stops. This water loss is positive from a performance standpoint, since much of this water infiltrates, although some leakage can be seen under the logs. However, the loss complicates monitoring and the upstream versus downstream flow comparison. Various efforts, described by Miller (2001) and Miller, Burges, and Horner (2001), were attempted to stop water loss, without much success. These references also discuss early tests to attempt to quantify losses. They concluded that water loss is a major factor at relatively low flow rates but that flow measurements are likely to be accurate above 0.25 cfs (7.1 L/s). Measured loss rates were mostly in the range 0.03-0.04 cfs (0.85-1.1 L/s). The measurements were considered to be too limited for conclusive correction of low flow rates.

Horner, Lim, and Burges (2002) reported on additional water loss tests performed during 2001 in the first cell using an adjacent fire hydrant as a water source. Testing was precluded at the downstream end by the danger of discharging chlorinated water to Pipers Creek. The results proved insufficient for conclusively correcting inflows. Companion upstream weir calibration, also using the fire hydrant for source water, indicated that water losses represent a greater monitoring problem than non-ideal weir conditions at low flow rates. Additional tests were scheduled for the summer of 2002 using refined methods.

1.3.2. 2002 Leakage Test Methods

The purpose of the 2002 tests was to quantify leakage over a range of flow rates in a way considered to be reliable enough to correct influent records by adding estimated losses. Leakage is defined as any water loss through the bed and banks of the first channel cell and around and under the weir and its mounting. These losses register as falling head without any discharge over the weir. The 2002 leakage test series consisted of three procedures appropriate for different phases of operation: (1) filling of the first cell up to the weir notch, (2) flow over the weir at relatively low rates, and (3) flow over the weir at relatively high rates.

The initial step in estimating leakage during filling was an engineering survey of the first cell of the Cascade. The survey permitted computation of volumes contained in the cell in relation to water levels. The cell was filled from the fire hydrant to a series of water levels up to the notch invert. After reaching each filling level, the data logger record was used to determine level fall over measured time intervals (15 minutes in this test). Volumes computed from the survey record for the stages at the beginning and end of the interval were then used to estimate the leakage rate at each filling level:

$$\text{Leakage rate} = (V_0 - V_i)/\Delta t$$

where, V_0 = Cell volume associated with stage at the beginning of the time interval;

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V_i = Cell volume associated with stage at the end of the time interval; and
Δt = Length of time interval.

The test for flow over the weir at relatively low rates used two wooden flumes constructed to collect water flowing into and out of the first channel cell and direct it to collection containers. Collection chamber volumes were calibrated by weighing full containers and converting to volume, considering the effect of temperature at the time of calibration on density. See Appendix A for photographs of the test procedure in progress.

The low-flow test procedure was:

1. Tightly attach one flume to the inlet section (Appendix A-1) and the other flume to the outlet side of the weir (Appendix A-2) to catch all flow without loss.

2. Extend a fire hose from the hydrant to deliver flow into the inlet pipe, from where it flows to the inlet flume (see Appendix A-1; hose is held in pipe with a rock).

3. Fill up the cell to the notch invert.

4. Fill the container at the discharge of the inlet flume at a steady set flow rate, while measuring by stopwatch the time required to fill the container (Appendix A-1). Calculate the flow rate before leakage as the known volume divided by the time to fill the container. Replicate this procedure several times.

5. Fill the container at the discharge of the outlet flume at a steady set flow rate, while measuring by stopwatch the time required to fill the container (Appendix A-2). Calculate the flow rate after leakage as the known volume divided by the time to fill the container. Replicate this procedure several times.

6. Calculate the leakage rate as the difference in the two flow rates measured in steps 4 and 5.

7. Repeat the tests at both locations at other set flow rates.

Because the maximum hydrant flow rate was only 0.21 cfs (6 L/s), it was necessary to devise another test for leakage at relatively high flow rates. On a rainy day producing a flow rate well above the hydrant capacity, the water level in the first cell was measured at a time when it was holding steady (i.e., inflow was invariable). Plywood was then attached to cover the entire V-notch, so that weir overflow could not occur. If the level appeared to stay steady, it was measured and the plywood was removed. If the level still appeared to stay steady, it was measured and compared to the initial reading (before installation of the plywood). If the two readings agreed, the existing flow rate was the leakage rate at the steady stage. If the level did not remain steady, and the readings diverged, the test was repeated until a steady period occurred.

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1.3.3. 2002 Leakage Test Results and Their Use

Figure 1-1 presents the results of all three test series and the flow rates prevailing during tests both corrected and uncorrected for leakage. The leakage rate tends asymptotically toward zero at a stage of around 1.2 ft (37 cm). Therefore, the leakage rate was taken as zero at this stage and below. While the leakage rate is low at small stages, it is a substantial proportion of the measured flow rate; i.e., the error is relatively large if leakage is ignored. The leakage rate grows as a function of the static head of higher stages, but becomes increasingly less instrumental at the high flow rates associated with these stages. The leakage rate was less than 5 percent of the flow rate in the high flow test and tends asymptotically toward 0.2 cfs (5.7 L/s) in that region. The flow during this test was near the maximum yet measured in the Viewlands Cascade.

Figure 1-2 shows the leakage rate in expanded scale. Between a stage of 1.2 ft (37 cm) and 1.85 ft (56 cm, the height of the V-notch invert), the leakage rate follows a nearly linear relationship with stage. A second-order polynomial regression equation gave a better fit than simple linear regression to compute a leakage correction in this range. At higher stages, up to the maximum tested, the relationship deviates considerably from linear and is better expressed as another function. Table 1-1 summarizes the leakage corrections used in each stage range.

The appropriate correction was applied to each stage reading in the entire record assembled since the beginning of monitoring. Storm peak flow rates, discharge volumes and other variables related to them were then calculated both with and without leakage correction and carried through the analysis presented in this report.

It was only possible to perform tests to quantify leakage at the inlet end of the Viewlands Cascade and not at its outlet because of concern with discharging chlorinated water to Pipers Creek. Correcting the entering but not the exiting flow overestimates the system's performance in reducing discharge to the creek, because the quantity of water remaining at the end of the channel was actually greater than measured. On the other hand not using the correction on the influent underestimates performance overall. The underestimation occurs because the flow at the downstream end was sometimes zero or relatively low, while the uncorrected inflow was actually higher than used in the comparison. Therefore, performing the analysis with and without inflow leakage correction gives a range in performance estimation.

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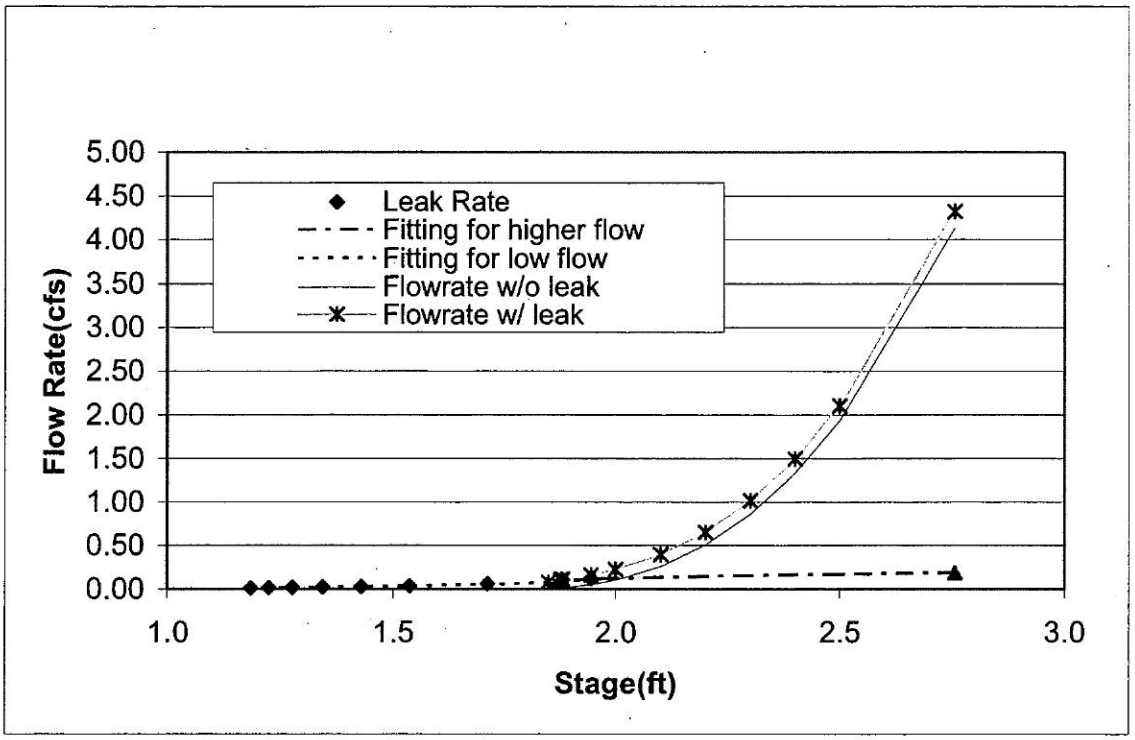

Figure 1-1. Viewlands Cell 1 Leakage Rates and Test Flow Rates Versus Stage

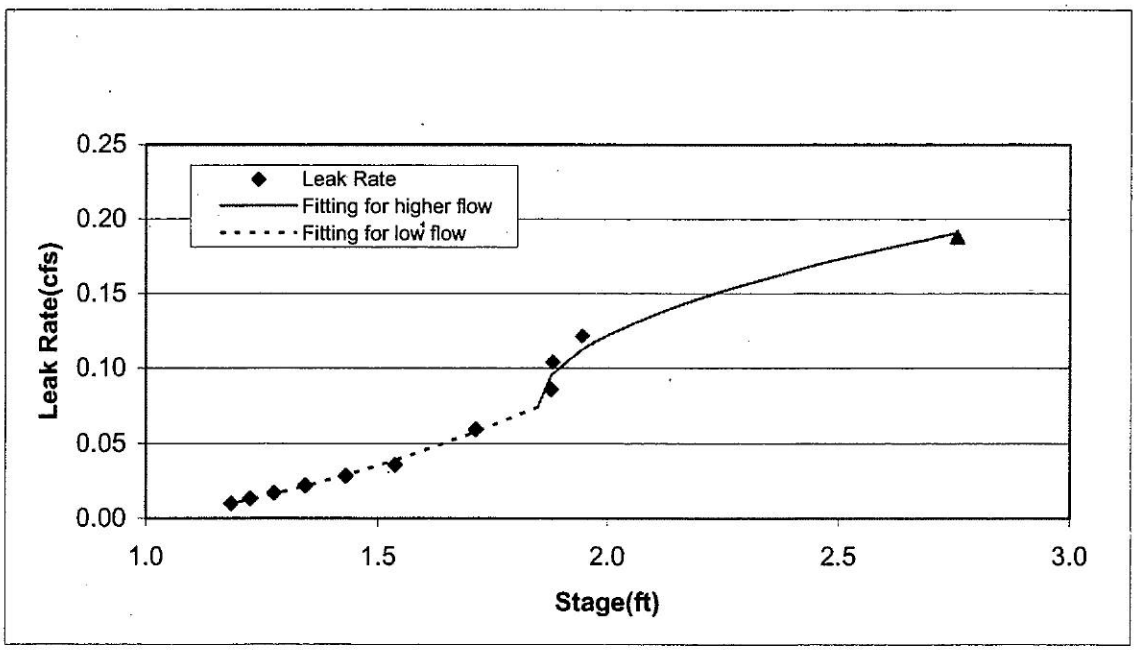

Figure 1-2. Viewlands Cell 1 Leakage Rates Versus Stage

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Table 1-1. Leakage Rate Corrections Applied at Different Viewlands Cell 1 Stages

Stage	Leakage Correction (cfs)[a]
≤ 1.2 ft (37 cm)	None
1.2 ft (37 cm) – 1.85 ft (56 cm)	$0.048\ h^2 - 0.049$
> 1.85 ft (56 cm)	$0.12\ (h^2 - 1.85)^{0.5} + 0.075$

[a] h = stage (ft); correction is added to measured flow rate.

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CHAPTER 2 – SUMMARY OF METEOROLOGICAL MEASUREMENTS

2.1. Precipitation Summary

Table 2-1 presents monthly and yearly precipitation totals from the onset of monitoring in January 2000 through September 2003 at the project stations and Seattle-Tacoma International Airport (SeaTac), as well as the antecedent 1999 year at the airport. Comparing calendar-year precipitation, 2001 was close to the long-term mean, while 1999 was above average and 2000 and 2002 were 25 and 16 percent below, respectively.

Comparing wet season (October-March) precipitation based on the airport station, totals were:

53-year mean—28.9 inches (734 mm);
1999-2000—17.4 inches (442 mm), 60 percent of 53-year mean;
2000-2001—16.3 inches (414 mm), 56 percent of 53-year mean;
2001-2002—31.3 inches (794 mm), 108 percent of 53-year mean; and
2002-2003—26.7 inches (678 mm), 92 percent of 53-year mean.

Initial monitoring occurred during relatively dry winters. The two most recent winters overall approximate typical conditions in the region, and thus provide a better opportunity to assess performance capabilities of the drainage projects.

The October 2000 to March 2001 wet season had two storms approximating the 6-month, 24-hour rainfall event for the region (1.2 inch, 30 mm) and one that exceeded 24 hours duration and the precipitation total associated with the 1-year, 24-hour event (1.9 inch, 48 mm). In contrast, the following winter period had three storms exceeding 24 hours with rainfall between the 6-month, 24-hour and 1-year, 24-hour totals, plus three additional events lasting over 24 hours and exceeding the 1-year, 24-hour total. Furthermore, August 2001 had an unusually large summer storm also longer than 24 hours and with more rain than the 1-year, 24-hour rainfall. The October 2002 to March 2003 wet season exhibited one event with rainfall total slightly over the 6-month, 24-hour amount, two approximating the 1-year, 24-hour quantity, and one event measuring somewhat more, at 2.29 inches (58 mm) of precipitation. All of these events considerably exceeded 24 hours duration, however.

While the maximum rainfall in any event during the water years summarized in this report was 2.95 inches (75 mm), two much larger episodes occurred just after the beginning of the subsequent water year. The Viewlands station recorded 4.22 inches (107 mm) of rain from late on October 19, 2003 to the morning of October 21 (a period of 32.5 hours). The SeaTac Airport gauge registered its highest ever 24-hour rainfall total during this event. A quantity of 3.86 inches (98 mm) fell at Viewlands over a 51.25-hour period from November 17 to 19, 2003. Average rainfall intensities during these two storms were 0.13 and 0.075 inches/hour (3.3 and 1.9 mm/h), respectively.

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Table 2-1. Precipitation Summary for Full Monitoring Period Through September 30, 2003

Millimeters													
Location	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	**Total**
Viewlands 2000[a]	62	115	73	33	68	31	12	11	33	81	83	67	**669**
Viewlands 2001[a]	90	56	74	63	32	90	20	59	10	89	229	144	**957**
Viewlands 2002[a]	153	105	72	66	33	27	18	1	7	12	63	139	**697**
Viewlands 2003[a]	174	40	135	67	35	13	0	7	26				
2nd Ave. NW 2000[b]			77	33	54	27	11						
2nd Ave. NW 2001	86	52	66	54	28	81	22	53	10	87	231	141	**911**
2nd Ave. NW 2002	156	101	78	64	40	26	18	1	9	15	71	160	**738**
2nd Ave. NW 2003[c]	183	40	137	66	30	11	0	8					
SeaTac 1999	174	177	93	35	54	47	30	24	4	57	244	129	**1067**
SeaTac 2000	96	133	72	39	83	40	6	8	26	74	83	64	**723**
SeaTac 2001	69	53	69	80	35	77	26	59	21	79	235	150	**954**
SeaTac 2002	165	106	72	109	28	44	16	1	11	17	94	152	**815**
SeaTac 2003	202	46	165	70	29	13	2	8	23				
SeaTac 53-yr mean	141	107	94	64	42	38	20	27	47	89	149	149	**967**
Inches													
Location	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	**Total**
Viewlands 2000[a]	2.4	4.5	2.9	1.3	2.7	1.2	0.5	0.4	1.3	3.2	3.3	2.6	**26.3**
Viewlands 2001[a]	3.5	2.2	2.9	2.5	1.3	3.5	0.8	2.3	0.4	3.5	9.0	5.7	**37.7**
Viewlands 2002[a]	6.0	4.1	2.8	2.6	1.3	1.1	0.7	0.1	0.3	0.5	2.5	5.5	**27.4**
Viewlands 2003[a]	6.9	1.6	5.3	2.6	1.4	0.5	0.0	0.3	1.0				
2nd Ave. NW 2000[b]			3.0	1.3	2.1	1.1	0.4						
2nd Ave. NW 2001	3.4	2.0	2.6	2.1	1.1	3.2	0.9	2.1	0.4	3.4	9.1	5.6	**35.9**
2nd Ave. NW 2002	6.1	4.0	3.1	2.5	1.6	1.0	0.7	0.0	0.3	0.6	2.8	6.3	**29.1**
2nd Ave. NW 2003[c]	7.2	1.6	5.4	2.6	1.2	0.4	0.0	0.3					
SeaTac 1999	6.8	7.0	3.7	1.4	2.1	1.9	1.2	0.9	0.2	2.3	9.6	5.1	**42.0**
SeaTac 2000	3.8	5.3	2.8	1.5	3.3	1.6	0.2	0.3	1.0	2.9	3.3	2.5	**28.5**
SeaTac 2001	2.7	2.1	2.7	3.2	1.4	3.1	1.0	2.3	0.8	3.1	9.3	5.9	**37.5**
SeaTac 2002	6.5	4.2	2.8	4.3	1.1	1.7	0.6	0.0	0.4	0.7	3.7	6.0	**31.4**
SeaTac 2003	8.0	1.8	6.5	2.7	1.2	0.5	0.1	0.3	0.9				
SeaTac 53-yr mean	5.7	4.1	3.8	2.6	1.7	1.5	0.8	1.1	1.7	3.4	6.0	5.9	**38.1**

[a] All Viewlands readings are from the trench recording gauge, except for February 2001, when the standing recording gauge reading was used because of snow melt that produced an inaccurate trench gauge total.

[b] Monitoring performed only from March through July.

[c] Gauges removed in September 2003.

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Monthly precipitation totals were generally consistent among measuring stations. Comparing mean and maximum monthly differences for all months in the record:

SeaTac averaged 0.2 inch (5.0 mm) more than Viewlands, with a maximum difference in any month of 1.7 inch (43 mm) more;
SeaTac averaged 0.2 inch (5.0 mm) more than 2nd Avenue NW, with a maximum difference in any month of 1.8 inch (46 mm) more; and
Viewlands averaged the same as 2nd Avenue NW, located 13 city blocks away, with a maximum difference in any month of 0.5 inch (14 mm) more.

The trench gauge should collect more precipitation than the standing device, because of lesser wind effects at the lower elevation. These expectations held overall. Although the trench gauge collection exceeded the quantity in the standing gauge during only 19 of the 36 months between October 1, 2000 and September 30, 2003, trench gauge deficits relative to the standing gauge were generally small. Excesses, however, were frequently substantially larger. The trench gauge collection averaged 0.2 inch (5.0 mm) per month higher in the three-year period and totaled 16.3 percent more than the standing gauge contents during this time. The greatest positive and negative disparities in any month for the trench versus standing gauges were 0.4 inch (9.5 mm) more and 0.2 inch (5.7 mm) less.

2.2. Evaporation Summary

Table 2-2 gives monthly evaporation totals from the beginning of monitoring in July 2000 through September 2003. Directly measured pan evaporation averaged 0.30 inch (8 mm) higher than potential evaporation, calculated using the Penman-Monteith method (Mansell 2004) and data from instruments at the Viewlands station, in the 34 months for which data comparison was possible. However, deviation was substantial in some months, with a maximum of 2.10 inches (53 mm) in July 2003. The pan measurement exceeded the potential estimate in 20 of the 34 months. In the single year thus far having sufficient measurements of all quantities to make a comparison (2002), the total annual evaporation by pan measurement, 29.84 inches (758 mm) was 5.31 inches (135 mm) higher than the potential. Shallow lake evaporation, a surrogate for potential evaporation, is approximately 70 percent of pan evaporation. On that basis, the pan calculated potential evaporation is 0.7 x 29.84 = 20.9 inches (531 mm).

Table 2-3 presents monthly pan and potential evaporation averaged over the available months in the record, along with reported averages from Washington State University's Puyallup evaporation station. Averaging by month reveals the clear tendency of pan readings to exceed potential evaporation estimates in the warmer, drier months starting in April, with deviations of about 1.25 inch (32 mm) in each of the three summer months. On the other hand, potential evaporation averaged higher in the months November to March, but by much smaller margins. Annually, about 4 inches (102 mm) more pan evaporation was measured than would be expected through the potential estimate.

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Table 2-2. Monthly Evaporation at the Viewlands Meteorological Station

	Millimeters[a]												
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	**Total**
Pan evaporation 2000	NA	NA	NA	NA	NA	NA	126	107	68	32	8	1	
Pan evaporation 2001	5	10	40	77	97	NA	NA	NA	64	33	13	2	
Pan evaporation 2002	6	19	22	60	85	132	146	146	86	34	8	12	**758**
Pan evaporation 2003	5	5	28	61	107	142	183	140	77				
Potential evaporation 2000[b]	NA	NA	NA	NA	NA	NA	NA	NA	61	33	12	9	
Potential evaporation 2001[b]	11	23	38	62	91	94	116	100	60	31	14	11	**651**
Potential evaporation 2002[b]	9	22	32	55	74	100	110	100	65	30	15	10	**623**
Potential evaporation 2003[b]	12	19	37	57	87	116	130	102	66				
Puyallup pan evaporation[c]	NM	18	40	62	101	118	142	126	74	33	15	NM	**730**
	Inches[a]												
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	**Total**
Pan evaporation 2000	NA	NA	NA	NA	NA	NA	4.96	4.21	2.67	1.28	0.33	0.05	
Pan evaporation 2001	0.19	0.41	1.58	3.04	3.83	NA	NA	NA	2.53	1.28	0.52	0.09	
Pan evaporation 2002	0.25	0.77	0.87	2.38	3.33	5.21	5.74	5.77	3.39	1.33	0.33	0.48	**29.84**
Pan evaporation 2003	0.18	0.19	1.09	2.40	4.20	5.58	7.20	5.52	3.02				
Potential evaporation 2000[b]	NA	NA	NA	NA	NA	NA	NA	NA	2.42	1.28	0.48	0.35	
Potential evaporation 2001[b]	0.45	0.92	1.50	2.44	3.59	3.69	4.56	3.92	2.38	1.21	0.53	0.45	**25.64**
Potential evaporation 2002[b]	0.34	0.87	1.27	2.16	2.93	3.93	4.34	3.95	2.54	1.20	0.59	0.41	**24.53**
Potential evaporation 2003[b]	0.46	0.73	1.47	2.24	3.42	4.56	5.10	4.01	2.58				
Puyallup pan evaporation[c]	NM	0.71	1.58	2.46	3.97	4.63	5.61	4.97	2.92	1.28	0.61	NM	**28.74**

[a] NA indicates data are not available.

[b] Potential evaporation was calculated by the Penman-Monteith method (Mansell 2004) and readings from other Viewlands instruments.

[c] Puyallup pan evaporation quantities are averages from 1931 through 1995. NM indicates no measurements in the month.

Table 2-3. Average Monthly Evaporation at the Viewlands and Puyallup Stations

	Millimeters												
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	**Total**
Pan evaporation	5	12	30	66	96	137	152	131	74	33	10	5	**751**
Potential evaporation[a]	11	21	36	58	84	103	119	101	63	31	13	10	**650**
Puyallup pan evaporation[b]	NM	18	40	62	101	118	142	126	74	33	15	NM	**730**
	Inches												
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	**Total**
Pan evaporation	0.21	0.46	1.18	2.60	3.79	5.40	5.97	5.17	2.90	1.30	0.39	0.21	**29.58**
Potential evaporation[a]	0.42	0.84	1.41	2.28	3.31	4.06	4.67	3.96	2.48	1.23	0.53	0.40	**25.59**
Puyallup pan evaporation[b]	NM	0.71	1.58	2.46	3.97	4.63	5.61	4.97	2.92	1.28	0.61	NM	**28.74**

[a] Potential evaporation was calculated by the Penman-Monteith method (Mansell 2004) and readings from Viewlands instruments.

[b] Puyallup pan evaporation quantities are averages from 1931 through 1995. NM indicates no measurements in the month.

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The Viewlands pan figures exceeded the long-term Puyallup averages in half of the months (Puyallup does not measure in December and January). The greatest differences were in the three summer months, when Viewlands evaporation exhibited higher average evaporation in each month. The few years of record at Viewlands are probably not typical of the many years in the Puyallup database, with the 2003 summer being exceptionally clear, warm, and dry. The Puyallup average annual evaporation is 0.84 inch (21 mm) less than the Viewlands average, half of which is accounted for by the practice of not measuring at Puyallup in December and January.

2.3. Summary of Other Meteorological Data

Tables 2-4 to 2-7 provide statistics on temperature, relative humidity, wind speed, and net radiation, respectively, for the full record available at Viewlands. The tables give credence to the observation above about the effect of the 2003 summer on evaporation, showing higher temperatures, lower relative humidities, and generally higher net radiation than in earlier years.

Table 2-8 presents monthly averages over the available years of record for each meteorological variable. Temperature, relative humidity, and net radiation exhibit the expected seasonal variations. Average wind speed varies relatively little month to month, with September and October being the calmest months and March and April the windiest.

Table 2-4. Monthly and Annual Temperature (^{0}C) Statistics

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
2000[a]--Mean	NA	NA	NA	NA	NA	NA	NA	16.0	14.6	10.8	5.8	4.9	
Maximum	NA	NA	NA	NA	NA	NA	NA	27.7	27.0	25.5	14.8	13.3	
Minimum	NA	NA	NA	NA	NA	NA	NA	8.9	4.5	3.9	-2.3	-3.0	
Standard deviation	NA	NA	NA	NA	NA	NA	NA	3.5	3.4	2.9	3.1	2.7	
2001--Mean	5.7	4.6	7.3	8.7	11.9	13.3	15.6	16.9	14.2	9.9	8.2	5.0	10.1
Maximum	13.7	11.6	19.5	21.8	25.8	23.3	24.7	29.7	22.7	20.2	16.2	12.1	29.7
Minimum	-1.4	-3.7	0.0	1.8	3.5	6.1	9.0	10.0	6.2	1.7	1.5	-1.4	-3.7
Standard deviation	2.7	2.7	2.6	3.7	4.0	3.3	3.4	3.5	3.0	2.8	2.8	2.3	5.1
2002--Mean	5.3	5.7	5.1	8.9	10.8	15.3	16.7	16.8	14.6	9.8	8.2	6.3	10.3
Maximum	14.1	14.4	13.6	18.3	25.4	29.9	29.4	29.8	25.1	17.7	16.4	12.6	29.9
Minimum	-1.5	-1.8	-2.4	1.7	1.2	7.0	8.6	9.7	6.2	-1.6	-2.2	-1.0	-2.4
Standard deviation	3.1	2.7	3.2	2.9	3.8	4.0	3.8	4.0	3.4	3.2	3.3	2.3	5.5
2003--Mean	7.5	5.3	8.1	9.1	11.8	15.9	18.2	17.3	15.5				
Maximum	14.0	12.0	18.7	17.3	22.0	29.3	31.5	27.2	28.0				
Minimum	0.8	-2.5	0.9	1.8	4.2	7.7	8.9	8.1	7.5				
Standard deviation	2.6	2.7	3.0	3.0	3.8	4.4	4.3	3.6	3.7				

[a] NA indicates data are not available.

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Table 2-5. Monthly and Annual Relative Humidity (%) Statistics

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	**Annual**
2000[a]--Mean	NA	NA	NA	NA	NA	NA	NA	74.7	76.8	82.4	81.1	83.4	
Standard deviation	NA	NA	NA	NA	NA	NA	NA	15.2	16.9	14.5	13.0	12.2	
2001--Mean	83.5	79.5	79.3	74.8	70.4	74.0	73.8	74.7	79.5	83.0	84.9	82.7	**78.3**
Standard deviation	13.9	14.0	11.7	15.4	15.2	13.2	14.5	16.0	13.4	13.6	9.4	11.6	**14.3**
2002--Mean	86.5	77.4	77.9	75.3	74.2	71.0	71.3	70.1	74.0	81.4	83.7	83.5	**77.2**
Standard deviation	7.6	14.9	13.9	14.7	15.1	14.8	15.2	16.6	13.6	15.9	13.0	12.8	**15.1**
2003--Mean	85.0	82.0	79.4	74.8	72.0	65.2	63.9	67.2	72.6				
Standard deviation	12.3	14.8	12.4	14.9	14.6	17.2	16.3	16.4	15.9				

[a] NA indicates data are not available.

Table 2-6. Monthly and Annual Wind Speed [at 2.7 m Height] (m/s) Statistics

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	**Annual**
2000[a]--Mean	NA	1.27	1.36	1.44	1.39	1.35	1.36	1.20	1.15	1.11	1.06	1.17	
Maximum	NA	3.89	4.25	3.97	3.62	3.56	3.55	3.26	3.37	3.38	3.49	4.26	
Standard deviation	NA	0.66	0.73	0.74	0.62	0.65	0.67	0.64	0.69	0.61	0.55	0.64	
2001--Mean	1.14	1.32	1.50	1.50	1.30	1.26	1.21	1.23	1.06	1.27	1.31	1.44	**1.30**
Maximum	4.25	5.00	4.06	4.21	3.58	3.13	3.52	3.56	3.00	4.89	4.60	4.91	**5.00**
Standard deviation	0.64	0.79	0.72	0.74	0.68	0.60	0.63	0.67	0.66	0.74	0.69	0.89	**0.72**
2002--Mean	1.41	1.45	1.65	1.54	1.34	1.33	1.27	1.13	1.13	0.92	1.13	1.36	**1.30**
Maximum	4.02	4.17	4.75	4.09	3.30	3.93	4.02	3.54	3.51	3.16	3.97	5.70	**5.70**
Standard deviation	0.79	0.79	0.90	0.82	0.68	0.70	0.71	0.73	0.70	0.58	0.74	0.90	**0.78**
2003[a]--Mean	1.18	1.15	1.60	1.47	1.29	1.47	NA	NA	NA				
Maximum	4.13	3.74	4.21	3.84	3.85	3.34	NA	NA	NA				
Standard deviation	0.81	0.64	0.79	0.70	0.69	0.67	NA	NA	NA				

[a] NA indicates data are not available; data are again available from October 2003 forward.

Table 2-7. Monthly and Annual Net Radiation (W/m^2) Statistics

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	**Annual**
2000[b]--Mean	NA	NA	NA	NA	NA	NA	NA	NA	80.8	42.5	10.1	4.2	
Maximum	NA	NA	NA	NA	NA	NA	NA	NA	645.5	489.1	339.8	325.1	
Standard deviation	NA	NA	NA	NA	NA	NA	NA	NA	161.0	108.6	55.4	40.1	
2001--Mean	8.8	36.9	57.6	96.3	129.3	138.7	158.5	127.9	84.3	39.3	12.3	6.4	**74.9**
Maximum	255.9	456.2	652.8	655.8	670.8	751.0	706.0	666.1	632.3	448.4	311	233.6	**751.0**
Standard deviation	44.6	104.9	126.9	172.0	198.3	204.5	221.9	195.6	155.0	99.9	48.2	36.7	**157.9**
2002--Mean	4.9	30.6	46.7	85.7	108.2	136.9	144.3	125.5	84.5	41.9	15.8	3.0	**69.2**
Maximum	205.3	474.4	566.5	619.2	688.0	716.0	745.0	605.3	525.8	443.1	349	168.8	**745.0**
Standard deviation	28.4	100.2	116.8	169.1	186.1	209.4	218.9	199.6	165.5	106.7	64.7	34.9	**156.5**
2003--Mean	9.1	29.4	51.3	87.2	126.4	150.4	155.6	122.4	84.3				
Maximum	252.3	389.5	602.2	669.8	726.0	691.7	684.7	619.1	606.9				
Standard deviation	46.7	87.8	117.0	160.4	193.4	214.5	223.1	201.8	165.3				

[a] The maximum value per month is based on the largest 15-minute recorded value. The means and standard deviations are calculated from the 15-minute data.

[b] NA indicates data are not available.

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Table 2-8. Mean Monthly and Annual Temperature, Relative Humidity, Wind Speed, and Net Radiation at the Viewlands Meteorological Station

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	**Annual**
Temperature (^{0}C)	6.2	5.2	6.8	8.9	16.5	14.8	16.8	16.8	14.7	10.2	7.4	5.4	**10.8**
Relative humidity (%)	85.0	79.6	78.9	75.0	72.2	70.1	69.7	71.7	75.7	82.3	83.2	83.2	**77.2**
Wind speed (m/s)	1.24	1.30	1.53	1.49	1.33	1.35	1.28	1.19	1.11	1.10	1.17	1.32	**1.28**
Net radiation (W/m^2)	7.6	32.3	51.9	89.7	121.3	142.0	152.8	125.3	83.5	41.2	12.7	4.5	**72.1**

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CHAPTER 3 – RAINFALL-RUNOFF ANALYSIS

3.1. Viewlands Cascade Drainage System

3.1.1. Rainfall and Runoff Event Summary

Table 3-1 summarizes Viewlands drainage system rainfall and runoff statistics for 210 events for the three water years beginning on 1 October 2000 and concluding on 30 September 2003. Downstream monitoring stopped at the end of April 2002. Flow rate and volume statistics for the upstream station, and in comparison with the downstream monitoring point, are given both with and without the correction for leakage at the upstream weir. It was not possible to determine a correction at the downstream station, although leakage was evident there too. The correction has a proportionately greater effect on relatively small compared to larger values. Over the three years the mean corrected upstream flow rate estimate was 21 percent larger than the uncorrected measure, whereas the maximum corrected rate was only 5 percent larger.

Seven precipitation events during April, June, and July 2001 are missing from the Viewlands flow record because of flow instrumentation malfunction. These storms ranged from 0.05 to 1.25 inch (1.4 to 35.4 mm) of rain. This range was covered by the 11 events recorded during the dry season, and it is not likely that overall statistics would be heavily influenced if the missing data were available, although recording of total runoff volumes is incomplete for that season.

The rainfall statistics demonstrate the distinctions between the wet and dry seasons (e.g., a mean antecedent dry period three times as long in the dry compared to the wet season). They also indicate the different characteristics of the three wet seasons represented. As discussed earlier, the 2001-2002 and 2002-2003 winters were wetter overall than the first two years of the program. However, their mean precipitation intensities were less, and rain was spread over a longer average storm duration.

The Viewlands Cascade did not experience a large rain event of infrequent occurrence until October and again in November 2003, just after the start of the present water year. The 19-21 October 2003 storm produced the highest maximum inflow rate in the record thus far, 4.51 cfs (128 L/s). The inflow rate during the 17-19 November 2003 event was 3.86 cfs (109 L/s). Interestingly, much smaller rainfall totals in earlier years produced comparable peak rates, 4.26 cfs (121 L/s) in December 2001 and 3.97 cfs (112 L/s) in August 2001. The explanation is probably that the Fall 2003 storms followed an especially dry summer and early autumn. Higher peaks could be expected should such precipitation quantities fall on an already relatively saturated catchment. However, measurements thus far give no indication that, without an exceptional event of extreme infrequency, the inflow rate would ever approach the 25 cfs (708 L/s) estimated for the 25-year, 24-hour rainfall event and used to design the project.

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Table 3-1. Viewlands Rainfall and Runoff Event Summary, 1 October 2000-30 September 2003

Period (No. events)	Statistic	Antecedent Dry Period (Hours)	Rainfall (Inch)	Duration (Hours)	Average Intensity (Inch/Hour)	Storm Response Time (Hours)	Maximum Upstream Flow Rate[a] (cfs)	Maximum Downstr. Flow Rate[b] (cfs)	Flow Rate Decrease[a,b] (%)	Upstream Flow Volume[a] (ft3)	Downstr. Flow Volume[b] (ft3)	Flow Volume Decrease[a,b] (%)	Average Velocity[a,b] (ft/sec)	Minimum Residence Time[a,b] (Minutes)
10/1/00-3/31/01	Mean	78.2	0.40	13.9	0.033	3.0	0.76/0.62	0.42	62.8/52.5	11078/5654	2990	84.7/70.2	1.3	3.7
Wet	Std. Dev.	68.5	0.45	11.9	0.019	3.0	0.68/0.66	0.65	31.1/37.8	11015/7460	5570	16.8/27.3	0.4	1.2
(47)	Maximum	336.3	2.76	61.5	0.094	14.3	4.07/3.88	3.80	100/100	48304/35457	26941	100/100	2.7	7.9
	Minimum	5.8	0.04	1.0	0.009	0.5	0.08/0.00	0.00	6.6/0	1021/0	0	44.2/16.2	0.6	1.6
4/1/01-9/30/01	Mean	223.6	0.48	11.8	0.048	3.2	1.24/1.08	0.74	64.9/59.9	11060/6689	3141	85.1/76.5	1.6	3.0
Dry	Std. Dev.	240.5	0.56	9.5	0.040	2.1	1.13/1.11	1.17	36.9/39.5	16835/11657	6973	16.5/23.9	0.5	0.8
(11)	Maximum	826.0	2.15	37.0	0.138	6.3	4.16/3.97	3.66	100/100	60999/41086	23699	100/100	2.8	3.9
	Minimum	8.3	0.15	3.0	0.019	0.8	0.43/0.28	0.00	-6.0/-16.4	2195/1054	0	59.2/38.2	1.1	1.6
10/1/00-9/30/01	Mean	105.8	0.42	13.5	0.035	3.0	0.86/0.71	0.48	63.2/53.9	11075/5850	3018	84.8/71.4	1.4	3.5
Water Year	Std. Dev.	131.3	0.47	11.4	0.025	2.8	0.79/0.78	0.77	31.9/37.9	12151/8302	5794	16.6/26.6	0.4	1.1
(58)	Maximum	826.0	2.76	61.5	0.138	14.3	4.16/3.97	3.80	100/100	60999/41086	26941	100/100	2.8	7.9
	Minimum	5.8	0.04	1.0	0.009	0.5	0.08/0.00	0.00	-6.02/-16.4	1021/0	0	44.2/16.2	0.6	1.6
10/1/01-3/31/02	Mean	59.6	0.48	18.1	0.024	2.4	0.88/0.73	0.53	62.1/54.5	23628/15140	10068	82.0/68.9	1.4	3.7
Wet	Std. Dev.	69.8	0.66	18.0	0.014	1.7	0.82/0.81	0.71	36.7/43.2	36260/27064	20567	19.9/29.5	0.5	1.3
(58)	Maximum	341.5	2.95	97.8	0.063	8.5	4.26/4.06	3.11	100/100	142035/108691	82862	100/100	2.8	6.8
	Minimum	5.5	0.01	2.0	0.001	0.5	0.11/0.01	0.00	-71.7/-121.9	991/14	0	39.1/17.2	0.7	1.6
4/1/02-9/30/02	Mean	220.5	0.27	9.9	0.031	2.4	0.53/0.41			5593/2618			1.1	5.4
Dry	Std. Dev.	436.3	0.22	7.0	0.016	1.9	0.49/0.45			6891/4452			0.5	3.3
(19)	Maximum	1986.8	0.90	27.8	0.071	8.0	1.87/1.70			27145/18519			2.0	14.1
	Minimum	10.3	0.05	0.8	0.013	1.0	0.02/0.00			199/0			0.3	2.2
10/1/01-9/30/02	Mean	99.3	0.43	16.1	0.026	2.4	0.79/0.65			19178/12050			1.3	4.1
Water Year	Std. Dev.	231.5	0.59	16.3	0.014	1.8	0.77/0.74			32536/24157			0.5	2.1
(77)	Maximum	1986.8	2.95	97.8	0.071	8.5	4.26/4.06			142035/108691			2.8	14.1
	Minimum	5.5	0.01	0.8	0.001	0.5	0.02/0.00			199/0			0.3	1.6

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10/1/02-3/31/03	Mean	68.2	0.38	14.5	0.027	3.0	0.81/0.68			13298/8228			1.3	4.6
Wet	Std. Dev.	118.8	0.48	13.8	0.018	2.4	0.91/0.88			21836/5900			0.6	2.8
(53)	Maximum	770.0	2.29	66.8	0.086	12.0	3.66/3.47			99807/71125			2.6	15.4
	Minimum	5.5	0.01	0.5	0.001	0.5	0.01/0.00			73/0			0.3	1.6
						Storm	Maximum	Maximum	Flow	Upstream	Downstr.	Flow		Minimum
		Antecedent			Average	Response	Upstream	Downstr.	Rate	Flow	Flow	Volume	Average	Residence
Period		Dry Period	Rainfall	Duration	Intensity	Time	Flow Rate[a]	Flow Rate[b]	Decrease[a,b]	Volume[a]	Volume[b]	Decrease[a,b]	Velocity[a,b]	Time[a,b]
(No. events)	**Statistic**	(Hours)	(Inch)	(Hours)	(Inch/Hour)	(Hours)	(cfs)	(cfs)	(%)	(ft3)	(ft3)	(%)	(ft/sec)	(Minutes)
4/1/03-9/30/03	Mean	178.8	0.22	9.4	0.039	6.2	0.29/0.19			2321/732			0.9	6.7
Dry	Std. Dev.	282.8	0.18	8.7	0.040	6.8	0.26/0.22			2311/927			0.4	3.5
(22)	Maximum	1141.3	0.67	31.3	0.161	24.8	0.80/0.65			7732/2602			1.5	14.7
	Minimum	6.8	0.04	0.8	0.010	0.5	0.02/0.00			96/0			0.3	3.1
10/1/02-9/30/03	Mean	100.6	0.33	13.0	0.030	3.8	0.66/0.53			10078/6029			1.2	5.2
Water Year	Std. Dev.	187.6	0.42	12.7	0.027	4.1	0.81/0.78			19024/13773			0.6	3.2
(75)	Maximum	1141.3	2.29	66.8	0.161	24.8	3.66/3.47			99807/71125			2.6	15.4
	Minimum	6.5	0.03	0.5	0.006	0.5	0.01/0.00			73/0			0.3	1.7
Oct.-Mar.	Mean	68.0	0.42	15.6	0.028	2.7	0.82/0.68			16430/10000			1.3	4.0
2000-2003	Std. Dev.	88.7	0.54	15.0	0.017	2.4	0.81/0.79			26493/19556			0.5	2.0
3 Wet Seasons	Maximum	770.0	2.95	97.8	0.094	14.3	4.26/4.06			142035/108691			2.8	15.4
(158)	Minimum	5.5	0.01	0.5	0.001	0.5	0.01/0.00			73/0			0.3	1.6
Apr-Sep.	Mean	203.5	0.29	10.1	0.038	4.1	0.58/0.46			5365/2681			1.1	5.4
2000-2003	Std. Dev.	334.5	0.32	8.2	0.033	4.7	0.70/0.67			9249/6253			0.5	3.3
3 Dry Seasons	Maximum	1986.8	2.15	37.0	0.161	24.8	4.16/3.97			60999/41086			2.8	14.7
(52)	Minimum	6.8	0.04	0.8	0.010	0.5	0.02/0.00			96/0			0.3	1.6
10/1/00-9/30/03	Mean	101.6	0.39	14.3	0.030	3.0	0.76/0.63			13690/8187			1.3	4.3
3 Water Years	Std. Dev.	191.5	0.50	13.8	0.022	3.0	0.79/0.77			23896/17517			0.5	2.4
(210)	Maximum	1986.8	2.95	97.8	0.161	24.8	4.26/4.06			142035/108691			2.8	15.4
	Minimum	5.5	0.01	0.5	0.001	0.5	0.01/0.00			73/0			0.3	1.6

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The paired upstream and downstream stations operated through all of two wet seasons and one dry season, permitting comparison in flow rates and volumes at the two points. Notwithstanding seasonal and annual distinctions in rainfall and rainfall-runoff relations, channel hydrology and hydraulics did not differ much from wet to dry seasons and between divergent winters.

The mean peak flow rate decrease from upstream to downstream was approximately 62-65 percent in all periods of observation, based on upstream readings corrected for leakage, or 53-60 percent based on uncorrected readings. As pointed out earlier the higher number is probably an overestimate, while the lower one is likely to be an underestimate. Therefore, it can be concluded that the Viewlands Cascade is capable of reliably reducing peak flow rate by an average of about 60 percent over a period of a number of storms. However, the reduction for any individual storm is highly dependent on the event's characteristics and was seen to be nil in the larger events observed.

The mean event total discharge volume decreased from upstream to downstream by 82-85 percent based on corrected readings, or 69-77 percent based on uncorrected values. Taking the first as an overestimate and the second as an underestimate, it can be concluded that the channel can reliably decrease individual event runoff volume by an average of about 75-80 percent over a period of time. As with peak flow rate, there was little volume reduction in the largest storms.

One of the key objectives of the Viewlands project was to reduce formerly high velocity flows that bypassed the downstream drain inlet and eroded the steep adjacent slope. The estimated mean velocity was generally in the range 1.0-1.5 ft/s (0.3 – 0.46 m/s) regardless of season or year. It typically rose to about 2.8 ft/s (0.85 m/s) during the largest storms. The channel was estimated to provide a mean hydraulic residence time of around 4-5 minutes most of the time, although the average increased in relatively dry conditions and dropped in wetter ones. These residence times apply to the occasions when flow would reach all the way to the end of the channel. With full attenuation, of course, the surface flow residence time is infinite.

Of the 128 events with both upstream and downstream measurements, 34 (27 percent) had no surface discharge to Pipers Creek. The highest reductions in flow volume were coupled with the greatest decreases in peak flow rate from channel entrance to exit, consistent with previous observations. Earlier analysis concluded that up to approximately 1000 ft^3 (28.3 m^3) of influent could be fully attenuated through the channel, based on data uncorrected for leakage (Miller 2001; Miller, Burges, and Horner 2001; Horner, Lim, and Burges 2002). Examination of the data set for all 128 events confirms that judgment. Applying the correction would increase the estimate to approximately 2500 ft^3 (71 m^3). Again on the philosophy that under- and overestimates bracket the likely true value, it is reasonable to conclude that the Viewlands channel can prevent surface runoff of up to about 1750 ft^3 (50 m^3) of incoming water. The initial analysis also found that an average precipitation depth of 0.13 inch (3.3 mm) could be fully attenuated during wet conditions (Miller 2001; Miller, Burges, and Horner 2001). This conclusion was also confirmed with the larger data set now available.

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3.1.2. Total Discharge Summary

Inflow volume varied noticeably in the different winters. The 2001-2002 wet season registered 79 percent more precipitation than the preceding winter and, more than 2.6 times as much total inflow to the Viewlands Cascade (based on leakage-corrected values). On average, antecedent dry periods were shorter, storm durations were longer, and rainfall quantities were larger in the wetter winter. Even though the latter winter had slightly lower precipitation intensity, the combination of other factors accentuated the effect of overall rainfall on runoff hydrology. The third winter in the period was intermediate in terms of influent quantity.

As averages from all events, the high mean flow volume decreases shown in Table 3-1 are misleading. Most events have relatively small rainfall quantities, and infiltration is generally more complete with small volumes. Averaged in this way, therefore, the relatively more numerous small events influence the statistics more than the fewer large rainfalls. Furthermore, whether or not the leakage correction is applied has a major bearing on the flow volume decrease from upstream to downstream averaged over all events. Leakage is a much greater factor in relatively small compared to large events, again giving undue influence to the small storms in the Table 3.1 statistics. More indicative of overall recharge from the drainage channel are the total seasonal and annual flow volume decreases (given corrected and uncorrected for leakage):

10/1/00-3/31/01 (wet season)—73.2 % corrected, 47.1% uncorrected;
4/1/01-9/30/01 (dry season)—71.6 % corrected, 53.0% uncorrected;
10/1/00-9/30/01 (water year)—72.9 % corrected, 48.4% uncorrected; and
10/1/01-3/31/02 (wet season)—57.4 % corrected, 33.5% uncorrected.

It thus appears that the Viewlands Cascade can prevent surface discharge to Pipers Creek of about 50-70 percent of the inflow in relatively dry or moderately wet conditions and about 35-55 percent in relatively wet periods. The first number in each case is probably an underestimate and the second likely an overestimate. What is safe to say is that it can prevent surface discharge of over half of the entering flow, unless conditions are quite wet, in which case attenuation slips a bit under half. The total inflow in the three water years was estimated at approximately 2,870,000 ft^3 (81,300 m^3). Assuming roughly half of that quantity did not exit the channel, its presence kept roughly 1.5 million ft^3 (43,000 m^3) from directly discharging to Pipers Creek.

The Viewlands catchment exhibited runoff coefficients differing greatly between seasons and years. Based on a catchment area of 26 acres (10.5 ha), 17.7 inches (450 mm) of precipitation during the 2000-2001 wet season, and 31.1 inches (790 mm) in the following winter, the runoff coefficient (inflow/rainfall volume) was 16 percent in the first case and 30 percent in the second. Dry period runoff coefficient in the first two years of monitoring was only 8 percent. These results demonstrate the large effect of specific conditions on runoff coefficients and the unreliability of characterizing hydrology with their use.

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3.1.3. Comparison with Preceding Ditch

Table 3-2 compares key performance aspects of the Viewlands Cascade Drainage System with the ditch that preceded it based on the estimation procedure for the ditch described earlier. With equivalent meteorology, the ditch is estimated to attenuate through infiltration and evapotranspiration only about one-third as much flow volume, during both dry and wet seasons, under average and maximum conditions, and in total. This uniformity in prediction is an artifact of the simple model used to estimate infiltration from the old ditch but is generally indicative of the different potential recharge in the two cases. If the Cascade prevented the release of roughly half (1.5 million ft^3, 43000 m^3) of the influent surface runoff to Pipers Creek over three water years, then, the preceding ditch would have held back only about 0.5 million ft^3 (14000 m^3) if it were still in place, or approximately one-sixth of the total produced by the catchment.

Average velocities were estimated to be approximately 20 percent higher in the old ditch. Minimum hydraulic residence times were computed to be about a factor of three longer in the new system compared to the old ditch.

Table 3-2. Comparison of Viewlands Cascade Drainage System Performance with Estimates for Preceding Ditch

		Viewlands Cascade[a]			Preceding Ditch[a]					
Period	Statistic	Flow Volume Decrease (ft^3)	Average Velocity (ft/sec)	Minimum Residence Time (Minutes)	Flow Volume Decrease ft^3)	Ratio Ditch/ Cascade	Average Velocity (ft/sec)	Ratio Ditch/ Cascade	Minimum Residence Time (Minutes)	Ratio Ditch/ Cascade
10/1/00-3/31/01 Wet	Mean	8104/ 2664	1.3	3.7	2694/ 882	0.33/ 0.33	1.7	1.31	1.4	0.38
	Maximum	35246/ 12326	2.7	7.9	11082/ 3779	0.31/ 0.31	3.2	1.19	2.8	0.35
4/1/01-9/30/01 Dry	Mean	7920/ 3548	1.6	3.0	2896/ 1291	0.37/ 0.37	2.0	1.25	1.1	0.37
	Maximum	37300/ 17387	2.8	3.9	15238/ 7047	0.41/ 0.41	3.2	1.14	1.5	0.38
10/1/00-9/30/01 Water Year	Mean	8069/ 2832	1.4	3.5	2733/ 959	0.34/ 0.34	1.7	1.21	1.3	0.37
	Maximum	37300/ 17387	2.8	7.9	15238/ 7047	0.41/ 0.41	3.2	1.14	2.8	0.35
10/1/01-3/31/02 Wet	Mean	13560/ 5072	1.4	3.7	4766/ 1784	0.35/ 0.35	1.7	1.21	1.4	0.38
	Maximum	64943/ 31901	2.8	6.8	24515/ 12979	0.38/ 0.38	3.2	1.14	2.4	0.35

[a] Given with the leakage correction applied to the upstream measurement; except where there are two values, the first number is with the correction and the second is uncorrected.

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3.2. 2nd Avenue NW SEA Streets

3.2.1. Rainfall and Runoff Event Summary

Table 3-3 summarizes rainfall and 2nd Avenue NW runoff statistics for 183 events over the period beginning just after completion of construction (20 January 2001) and concluding on 30 September 2003. As to be expected because of the proximity of the two sites, the rainfall statistics demonstrate the same tendencies as described for Viewlands.

Undetected shaft encoder slippage produced unreliable readings from 10 March 2001 until 7 April 2002. Reliable manual stage measurements were available to determine discharge from 1 May to 20 October 2001 and 3 January to 30 March 2002. For the remaining intervals the antecedent dry periods, rainfall totals, storm durations, average intensities, and estimated precipitation volumes were examined in relation to the same measurements for events when discharge was measured. There was never any measured discharge when the estimated precipitation volume was less than 2300 ft^3 (65.2 m^3), representing substantial ranges of the meteorological variables. Thus, it was safe to assume that there was no discharge associated with any unmeasured events below that rainfall volume total. This volume is associated with a rainfall total of about 0.75 inch (19 mm), the runoff from which can apparently be completely attenuated by the storage ponds.

Three storms with measured discharges were available to make estimates for the seven unmeasured events having larger estimated volumes. Discharge during these three events ranged from 3.1 to 6.8 percent of the rainfall volume, averaging 4.9 percent. The seven missing discharges were accordingly estimated as 5 percent of the respective precipitation volumes. This factor may overestimate some cases and underestimate others, depending on meteorological and soil moisture conditions. The misestimate is probably no more than about 2 percent, with approximate compensation of low and high estimates.

After the SEA Streets project was in place, discharge was measured or estimated for only 11 of the 183 events (6 percent). Seven of these occurrences were during the period of shaft encoder slippage, when it was necessary to estimate. Therefore, it is possible that outflow did not actually occur in all of these cases. In strong contrast, flow over the weir occurred during all 35 events measured before project construction, even though most were in the drier months. With the new street design there was no dry-season release, even during the large August 2001 storm, an event when the shaft encoder was functioning well, allowing direct discharge measurement. Moreover, the project did not discharge at any time following the period fully documented in this report up the the present time, even during or after the large October and November 2003 storms. In fact, the last recorded outflow was on 14 December 2002. On the few discharge occasions there was a lag of more than 15 hours on average before the onset of flow.

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Table 3-3. 2nd Avenue NW Rainfall and Runoff Event Summary, 20 January 2001-30 September 2003

Period (No. events) [No. discharging]	Statistic	Antecedent Dry Period (Hours)	Rainfall Duration (Inch)	(Hours)	Average Intensity (Inch/Hour)	Precipitation Volume (ft3)	Flow Volume (ft3)	Flow Volume Decrease (%)
1/20/01-3/31/01	Mean	79.6	0.32	12.5	0.034	925	8	99.6
Partial Wet	Std. Dev.	59.6	0.20	10.2	0.025	594	36	1.6
(19)	Maximum	182.3	0.79	37.3	0.118	2301	157	100
[1]	Minimum	13.3	0.04	1.3	0.011	112	0	93.2
4/1/01-9/30/01	Mean	216.8	0.43	17.1	0.026	1244	0	100
Dry	Std. Dev.	255.3	0.45	13.0	0.015	1318	0	0
(18)	Maximum	815.8	1.86	50.5	0.060	5428	0	100
[0]	Minimum	10.0	0.05	5.0	0.003	134	0	100
1/20/01-9/30/01	Mean	146.3	0.37	14.7	0.030	1080	4	99.8
Partial Water Year	Std. Dev.	193.4	0.35	11.7	0.021	1012	26	1.1
(37)	Maximum	815.8	1.86	50.5	0.118	5428	157	100
[1]	Minimum	10.0	0.04	1.3	0.003	112	0	93.2
10/1/01-3/31/02	Mean	99.7	0.61	21.2	0.027	1777	42	99.2
Wet	Std. Dev.	170.9	0.73	19.1	0.015	2121	106	1.8
(53)	Maximum	815.8	3.05	99.5	0.068	8891	445	100
[9]	Minimum	7.3	0.05	2.3	0.006	134	0	95.0
4/1/02-9/30/02	Mean	219.3	0.29	12.7	0.024	831	0	100
Dry	Std. Dev.	436.9	0.24	10.5	0.010	703	0	0
(19)	Maximum	1987.5	0.97	40.8	0.047	2837	0	100
[0]	Minimum	10.8	0.02	2.0	0.008	70	0	100
10/1/01-9/30/02	Mean	103.4	0.48	17.7	0.026	1401	25	99.5
Water Year	Std. Dev.	237.7	0.63	17.1	0.014	1831	85	1.5
(72)	Maximum	1987.5	3.05	99.5	0.068	8891	445	100
[9]	Minimum	7.3	0.02	2.0	0.006	70	0	95.0
10/1/02-3/31/03	Mean	68.0	0.44	14.8	0.029	1275	0	100
Wet	Std. Dev.	119.3	0.52	12.8	0.017	1520	2	0
(53)	Maximum	770.5	2.45	53.5	0.095	7154	15	100
[1]	Minimum	4.8	0.03	1.0	0.007	93	0	99.8
4/1/03-9/30/03	Mean	186.3	0.23	10.8	0.040	667	0	100
Dry	Std. Dev.	298.1	0.17	9.4	0.051	488	0	0
(21)	Maximum	1141.3	0.67	33.8	0.223	1941	0	100
[0]	Minimum	6.5	0.03	0.8	0.008	93	0	100
10/1/02-9/30/03	Mean	101.6	0.38	13.7	0.032	1102	0	100
Water Year	Std. Dev.	193.3	0.46	12.0	0.031	1337	2	0
(74)	Maximum	1141.3	2.45	53.5	0.223	7154	15	100
[1]	Minimum	4.8	0.03	0.8	0.007	93	0	99.8

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Table 3-3 continued

Period (No. events) [No. discharging]	Statistic	Antecedent Dry Period (Hours)	Rainfall (Inch)	Duration (Hours)	Average Intensity (Inch/Hour)	Precipitation Volume (ft3)	Flow Volume (ft3)	Flow Volume Decrease (%)
Oct.-Mar. 2001-03	Mean	67.1	0.47	16.4	0.029	1362	15	99.7
2^+ Wet Seasons	Std. Dev.	91.4	0.58	15.4	0.018	1690	66	1.2
(125)	Maximum	770.5	3.05	99.5	0.118	8891	445	100
[11]	Minimum	4.8	0.03	1.0	0.006	93	0	95.0
Apr.-Sep. 2001-03	Mean	206.6	0.31	13.4	0.030	900	0	100
3 Dry Seasons	Std. Dev.	333.4	0.31	11.1	0.033	904	0	0
(58)	Maximum	1987.5	1.86	50.5	0.223	5428	0	100
[0]	Minimum	6.5	0.02	0.8	0.003	70	0	100
1/20/01-9/30/03	Mean	111.3	0.42	15.5	0.029	1215	10	99.8
2+ Water Years	Std. Dev.	211.5	0.51	14.2	0.023	1500	55	1.0
(183)	Maximum	1987.5	3.05	99.5	0.223	8891	445	100
[11]	Minimum	4.8	0.02	0.75	0.003	70	0	95.0

The SEA Streets project has never attenuated less than 93.2 percent of the potential event runoff volume nor released more than 157 ft^3 (4.4 m^3), measured, or 445 ft^3 (12.6 m^3), estimated during the period of equipment malfunction. With so few events yielding any discharge, attenuation was so close to complete that the mean flow volume decreases shown in Table 3-3 are quite indicative of recharge over the full seasonal, water-year, and multi-year periods. Over the wet seasons and water years of record, the project reduced the total potential surface runoff by 99 percent.

The 2nd Avenue NW SEA Streets site is demonstrating a clear tendency to store and prevent surface runoff from even more rainfall than during its early years. The previous estimate that the complex can fully attenuate up to 0.75 inch (19 mm) of precipitation no longer applies, and the quantity now seems to be much larger. The reason for this development can only be speculation, but it is likely that the maturing vegetation both takes up more water and assists its passage into the soil. What fractions leave the system through infiltration versus evapotranspiration is unknown. Analyzing the water's fate is a subject being taken up in connection with hydrologic modeling being performed in ongoing work.

Even though the project has now experienced some large, low-frequency storms, monitoring continues because these events occurred after one of the driest summers on record. The ultimate test will come when it receives a similar quantity of rainfall following wet antecedent conditions.

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3.2.2. Comparison with Preceding Street and Conventional Street Design

The SEA Streets design thoroughly out-stripped the prediction made during the initial study period that it would reduce total discharge from the pre-existing street for equivalent conditions by 42 percent and from a conventional Seattle street with curb and gutter drainage by 66 percent (Miller 2001; Miller, Burges, and Horner 2001). The model used in these earlier estimates predicts that, if a conventional street had been the place of the SEA Streets project during the almost three water years reported on here, it would have released 75 times as much surface runoff during the wet seasons and 98 times as much overall.

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CHAPTER 4 – DESIGN COMPARISON

This chapter compares the relative amounts of flow volume reduction achieved with the various drainage system designs covered in this report, including: (1) the Viewlands Cascade Drainage System versus the ditch that preceded it, (2) the 2nd Avenue NW SEA Streets project versus a conventional street drainage system design, and (3) the 2nd Avenue NW SEA Streets project versus the Viewlands Cascade Drainage System. Horner, Lim, and Burges (2002) compared the 2nd Avenue NW SEA 1Streets project versus the original street drainage system as well. That comparison is omitted now because of the great disparity in data availability from SEA Streets versus the brief baseline monitoring opportunity. The designs are compared as ratios for dry and wet seasons by normalizing in terms of the runoff volume retained per month. In addition, the Viewlands Cascade and SEA Streets projects are compared in relation to: (1) the runoff volume retained per unit area of contributing catchment, and (2) the runoff volume retained per month and per dollar of unit area construction cost. A month is the normalization basis because runoff was sometimes measured or estimated for the various designs during different periods, not always a full season in length. The exercise uses the data from the three water years for Viewlands and the almost three water years for SEA Streets.

Comparisons of the Viewlands and SEA Streets projects used the full 2.3-acre (0.93 ha) contributing catchment area for SEA Streets and the 26-acre (10.5 ha) subcatchment that generally contributes runoff to Viewlands, omitting for this purpose the additional area that sometimes drains to the Cascade. The rationale for this choice is that these areas were the basis for the designs and capital expenditures made by the City of Seattle. Tables 4-1 and 4-2 present the comparisons.

The benefit ratios for Viewlands Cascade/preceding ditch and SEA Streets/conventional street in Table 4-1 reiterate the points made in Sections 3.1 and 3.2: the improved drainage systems retain several times as much runoff volume as the predecessor ditch at Viewlands or, in the case of SEA Streets, the alternative of designing according to the City of Seattle's current convention. The project benefit ratios range from about 3 to 5.

The tables show ratios both with and without weir measurement leakage correction applied to the Viewlands influent. As discussed earlier correcting is thought to overestimate the Cascade's benefit and not correcting to underestimate it. Therefore, mean values of the ratios are also reported in the tables and are probably better indicators than either of the ratios with and without correction.

On this basis the SEA Streets/Viewlands Cascade ratios in Table 4-1 show that the 2nd Avenue NW project is estimated to attenuate about one-quarter to one-third as much runoff as the new Viewlands channel, even though the SEA Streets project serves less than one-tenth as much contributing catchment area. When placed on an areal basis (Table 4-2, second column), that advantage multiplies. However, calculating according to unit area cost (Table 4-2, third column) puts a different light on the comparison. Costing roughly the same as Viewlands but serving a much smaller catchment, the 2nd Avenue NW project has a fractional cost-benefit compared to Viewlands. These financial comparisons take no account of potential savings that might be realized with experience and economies of scale in future construction of both project types.

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Table 4-1. Monthly Benefit Comparisons of Ultra-urban Drainage System Designs

Comparison	Period	Retained Volume/Month[a]
Viewlands Cascade/Preceding ditch	Drier months[b]	2.7
	Wetter months[c]	2.9
SEA Streets/Conventional street	Drier months[b]	5.1
	Wetter months[c]	5.1
SEA Streets/Viewlands Cascade	Drier months[b]	0.20 (0.45) [0.33][d]
	Wetter months[c]	0.12 (0.33) [0.23][d]

[a] Expressed as the ratio of the volume retained per month by the first site divided by the volume retained per month by the second site in the comparison; in ft^3/month (divide by 35.3 for m^3/month)
[b] April-September
[c] October-March
[d] The first number is with the leakage correction applied to the upstream Viewlands measurements; the second number in parentheses is without the correction; the third number in brackets is the mean value.

Table 4-2. Benefit and Cost-Benefit Comparisons of 2nd Avenue NW SEA Streets and Viewlands Cascade Projects

Period	Retained Volume/(Month-Unit Contributing Area)[a]	Retained Volume/(Month-Unit Area-Cost)[b]
Drier months[c]	2.3 (5.1) [3.7][d]	0.016 (0.037) [0.27][d]
Wetter months[e]	1.4 (3.7) [2.6][d]	0.010 (0.027) [0.19][d]

[a] Expressed as the ratio of SEA Streets/Viewlands Cascade, both in ft^3/month-acre (divide by 14.3 for m^3/month-ha)
[b] Expressed as the ratio of SEA Streets/Viewlands Cascade, both in ft^3/(month-$/acre) (multiply by 0.011 for m^3/month-$/ha), using costs of construction alone of $225,000 and $244,000 for Viewlands and 2nd Avenue NW, respectively
[c] April-September
[d] The first number is with the leakage correction applied to the upstream Viewlands measurements; the second number in parentheses is without the correction the third number in brackets is the mean value.
[e] October-March

With its position at the discharge of its subbasin, the Viewlands Cascade might be termed a "downstream" solution. Managing runoff at or near its source, the 2nd Avenue NW project site is an "upstream" solution. Its relatively greater effectiveness on an areal basis is a demonstration of the common observation in stormwater management that acting closer to the source on smaller

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quantities of water yields better results than downstream intervention. In this case, the unit cost of the upstream project was much higher because of its nature, not its catchment position. Thus, lower cost effectiveness is not a general drawback of upstream projects.

There is another factor not represented in these numbers that should be considered in interpreting and applying them in project planning. The Viewlands Cascade's downstream position makes it the last opportunity to attenuate runoff before discharge to Pipers Creek. The 2nd Avenue NW project site is more distant from the stream, both geographically and hydrologically. There would be a subsequent chance for attenuation, for example by channeling drainage from this subbasin and others into a cascade-type channel. The strategy in any situation should be guided by the opportunities and constraints posed by the case, the benefits that can accrue from different options, and the cost of achieving them.

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CHAPTER 5 – SUMMARY AND CONCLUSIONS

1. Flow has been monitored at the Viewlands Cascade Drainage System over three full water years between 1 October 2000 and 30 September 2003, representing 210 precipitation events. Both upstream and downstream monitoring occurred for the first 128 of these events, to quantify flow attenuation in the channel. The 2nd Avenue NW SEA Streets project has received flow monitoring for nearly as long, since it went into service in late January 2001, over 183 events. The wet seasons represented have differed in meteorological characteristics. The 1999-2000 and 2000-2001 winters had little more than half of the long-term average rainfall, while the following two wet seasons were above or close to average. There were no especially large storms in those winters, but the early weeks of the present water year had the largest 24-hour rainfall in the region's history and another event almost as large. However, this precipitation occurred after an exceptionally dry summer and early fall. Therefore, the projects have still not experienced the most challenging conditions.

2. The Viewlands channel has had considerable attention to try to prevent water losses in the cells where monitoring occurs, which are not recorded as flow. When losses could not be prevented fully, attention turned to quantifying them at the upstream station using metered city water flows. The same technique could not be used at the downstream station, which could discharge chlorinated city water to Pipers Creek. Correction factors were derived for the inflow station. Using a correction upstream and not downstream tends to overestimate the flow reduction in the channel. On the other hand, not using the correction tends to underestimate the decrease. Therefore, using both corrected and uncorrected upstream values is thought to bracket estimates of flow decrease.

3. The Viewlands meteorological station has assembled several years of record on temperature, relative humidity, wind speed, net radiation, and pan evaporation data, which will be invaluable in developing a hydrologic model for the Pipers Creek watershed. From the record to date, pan evaporation totals about 30 inches (76 cm) per annum, about 4 inches (10 cm) higher than potential evaporation from a standard model.

4. According to the best estimates, the Viewlands Cascade can cut the average peak flow rate of entering runoff by about 60 percent and the total influent volume over a period of time by over half. However, little or no reduction of either peak flow rate or volume occurs during relatively large storms. There was no discharge from the end of the channel in 27 percent of the events monitored. It can completely infiltrate the catchment response to about 0.13 inch (3.3 mm) of precipitation and 1750 ft^3 (50 m^3) of influent regardless of the season or conditions.

5. Based on estimates for the ditch that preceded the Viewlands Cascade project, the new channel reduces runoff discharged to Pipers Creek in the wet months by a factor of three relative to the old ditch and cuts flow velocities by approximately 20 percent, both under identical conditions. Reducing velocities and associated erosiveness was a major goal of the project.

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6. During the three water years the new Viewlands channel retained roughly 1.5 million ft^3 (43000 m^3) of runoff that entered it, preventing its direct release to Pipers Creek and the elevation of erosive flows there. This quantity is about three times the amount of retention estimated were the preceding narrow, partially concreted ditch still been in place.

7. During monitoring thus far the 2nd Avenue SEA Streets project has prevented the discharge of all dry season flow and 99 percent of the wet season and overall runoff. Whereas all events in the baseline monitoring period, which occurred mostly in the dry season, created a discharge, only 6 percent have since the project's construction.

8. It was estimated that over the nearly three water years of record a street drainage system design according to City of Seattle conventions would have discharged almost 100 times as much runoff to Pipers Creek.

9. The 2nd Avenue NW SEA Streets drainage system has been withholding more water from discharge as time goes on. Apparently, vegetation is both intercepting and taking up more water for evapotranspiration and assisting infiltration.

10. Despite serving a catchment less than 10 percent as large as the Viewlands Cascade, the 2nd Avenue NW project retains one-quarter to one-third as much runoff volume in as Viewlands. On the basis of unit runoff contributing area, the SEA Streets project is around three times as effective as Viewlands. However, when normalized in terms of the cost per unit catchment area served, the 2nd Avenue NW reconstruction is much less cost-effective than the Viewlands Cascade.

11. The Viewlands and 2nd Avenue NW projects represent different strategies for controlling the quantity of urban runoff. The latter is a source control strategy that can manage a large proportion of the precipitation falling on its catchment. The former is an "end-of-pipe" solution that can attenuate a large quantity of runoff, although not nearly as a high a percentage as the source control option. Used in concert as opportunities arise, the two alternatives can work together to bring significant change to the effectiveness of urban stormwater management.

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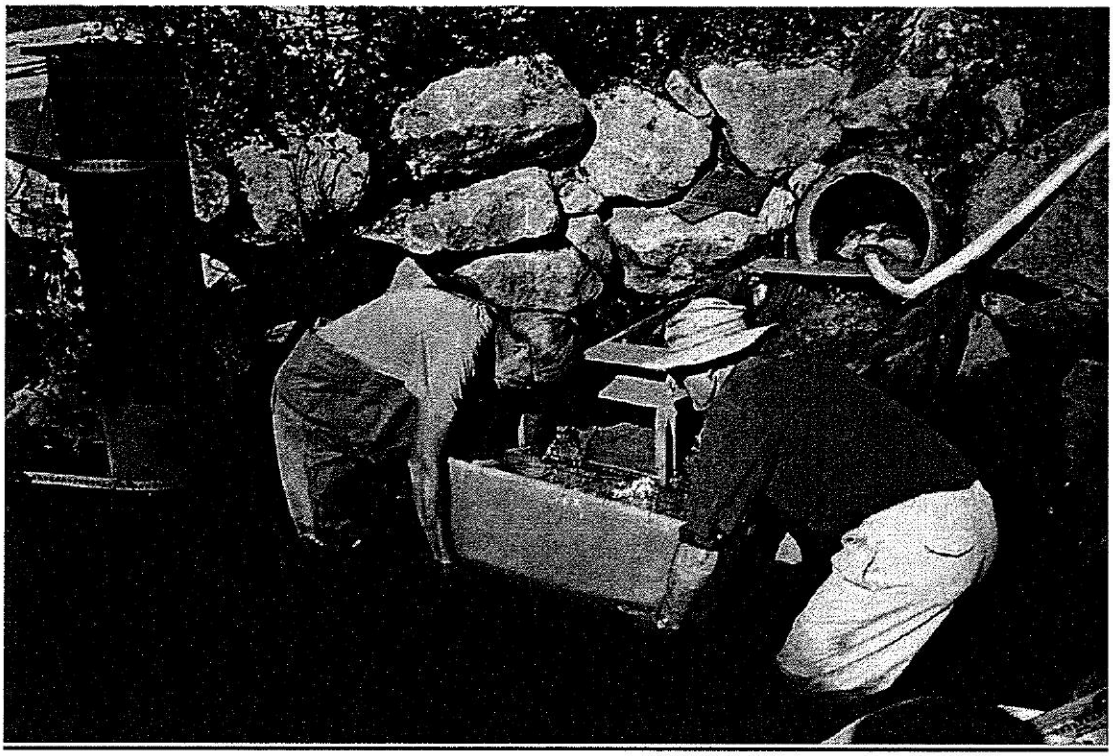
APPENDIX A

LEAKAGE TEST PHOTOGRAPHS

A-1. Flume at Viewlands Cascade Inlet



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A-2. Flume at Viewlands Cascade Cell 1 Outlet

SARB_004770

Crown Street

Vancouver's First Environmentally Sustainable Street

Prepared For: TAC's Environment Council
Prepared By: The City of Vancouver
Date: March 30, 2005

Crown Street – Vancouver's First Environmentally Sustainable Street

INTRODUCTION

The City of Vancouver has undertaken an exciting new approach to residential street design and storm water management. Vancouver's Crown Street has recently become the City's first environmentally sustainable street. The design uses innovative ideas to integrate transportation into an environmentally sensitive setting. The City of Vancouver wishes to nominate this project for the TAC Environmental Achievement Award.

SCOPE & HISTORY

In 2001, residents of the 6200 block of Crown Street petitioned to have their badly deteriorated street reconstructed and the chronic run off problems addressed. The residents expected a standard curb and gutter treatment to replace the existing soft shoulder conditions. However, the Official Community Plan for the area aimed to maintain a rural aesthetic and disallowed such treatment. The City responded by suggesting a new and innovative design that would fit the overall character of the area, beautify the street, and nurture the salmon habitat that existed just south of the street.

Modelled after a design in Seattle called SEA Street (Street Edge Alternatives), which used vegetated swales and retention ponds to facilitate storm runoff, the Crown Street design aimed to address historic drainage issues, water quality in the nearby salmon streams, pedestrian safety, parking, and of course the deteriorated road surface. After a thorough consultation process with the residents and a few modifications to suit their needs, the proposal gained the support of the residents and design began.

The main goals of the design were to provide an adequate surface for vehicle travel, force speeding traffic to slow down, facilitate pedestrians safely, provide ample resident and visitor parking, and address a wide range of drainage issues.

The drainage issues were of particular consideration for the design. Crown Street is a tributary to the Musqueam Watershed which contains the last two salmon bearing creeks in Vancouver. There have been significant efforts in the past by The Musqueam Indian Band, The David Suzuki Foundation and other interest groups to preserve and restore the Musqueam Watershed. Thus, the City wished to support these efforts by applying a unique environmentally friendly design. The design aimed to minimize impervious surfaces and facilitate runoff through a network of swales and retention ponds. This would allow water to infiltrate the ground and be filtered by natural vegetation before reaching the creeks. In addition, it would reduce volume extremes entering the creeks in periods of heavy rain.

Upon further analysis, it became clear that if anything was to be done to better the salmon habitat in the creeks, the culverts that facilitated them under Crown needed to be replaced in conjunction. This drove the cost of the project up too high and it was put on hold until the finances could be worked out. In April 2003, The Federation of Canadian Municipalities, Green Municipal Funds, awarded the City a grant of $563, 000, almost half of the projected costs. This funding made the project possible and in October 2004 construction of Vancouver's First Environmentally Sustainable Street began.

INNOVATIVE TECHNOLOGIES

In order to achieve the design goals, Crown Street showcases a number of innovative technologies and recycled products. When one looks upon Crown, it's obvious that it is a special street. Upon closer inspection, it is the innovative ideas that make it so special, they are as follows.

Structural Grass Road Edges

This is one of the most interesting features of the project. Flanking the road are 0.6m wide strips of structural grass. This structural grass was created by using a product called Golpla. Golpla is basically plastic matting with honeycomb shaped voids on the surface. It is laid down on a structural base and filled with topsoil. The base and Golpla can support the load of a car while the topsoil allows for grass growth. So grass actually becomes part of the driving surface. The picture below shows Golpla on a structural soil base.

Figure 1: Golpla on Structural Soil

As shown in Figure 1, the Golpla is honeycomb in shape and sits upon a structural soil base. Once the voids are filled with topsoil it provides a medium for grass growth and can support the load of a car.

Structural Soil

One of the hidden treasures on Crown, structural soil is a product innovated by the City of Vancouver. It is basically structural fill with some organic material mixed in. It provides support while allowing the grass to root itself beyond the topsoil that fills the Golpla.

Swales and Retention Ponds

A network of swales and retention ponds was built to facilitate storm runoff. Swales are basically ditches but shallower and broader so they're not so obtrusive. This network is designed to handle a 10 year storm with overflow directed into the adjacent park land. The system allows water to infiltrate the ground while being filtered by natural vegetation before entering the salmon habitat south of the project. The swales and ponds were decorated with over 3000 native plants. These plants will help filter contaminants from the water as well as reduce erosion.

Crown Street exists at about a 5% grade. As a result drop structures made from recycled granite curbs were used in the swales as weirs and drop structures.

Figure 2: Swale

As illustrated in Figure 2, the swales are shallow and unobtrusive. Once planted and hydroseeded they add green space to the streetscape.

Recycled Concrete Sidewalks and Granite Curbs

Consistent with the environmental theme of the project, recycled concrete walks were provided from the road to the residents' properties. They are made up of old sidewalks that have been removed from other areas of the City and salvaged for applications such as this. Additionally, granite curbs that were installed during Vancouver's formative years then removed for street upgrades have also been salvaged and applied as drop structures in the swales. Some of these granite curbs are nearly a century old; the residents of Crown were thrilled to have a piece of the City's history used on their new street. Both applications of recycled materials add an architectural finish and reduce waste.

Figure 3: Recycled Concrete Walks and Recycled Granite Drop Structure

As shown in Figure 3, the use of recycled materials adds an architectural finish.

Narrowed Meandering Road Alignment

To minimize impervious surfaces further, the road width was narrowed to 6.7m rather than the City's usual standard of 8.5m. A narrow asphalt surface of 3.5m is bordered by 1m strips of concrete that are designed to visually narrow the road. Then there is an additional 0.6m on each side of structural grass, bringing the total road width to 6.7m.
Also, the alignment meanders gently which breaks up long sightlines and forces traffic to slow down.
The picture below is of a one way section where the road forks around a vegetated island which can be seen in the left of the picture. This one way section is only 3.0m wide, made up of 2.2m of asphalt and bordered by .4m of concrete, as shown in Figure 4.

Figure 4: Narrowed Meandering Road Alignment – One Way Section

As illustrated in Figure 4, the narrowed, meandering alignment forces traffic to slow down to safely manoeuvre the gentle curves.

COSTS AND FUNDING

Phase I of Crown, including consulting fees, cost $875K. A traditional curb and gutter treatment has been estimated at approximately $450K. However, being the showcase

project that it is, Crown had many special features that won't be included on a more standard version of the project. If we consider making the following changes, we see the cost begin to come down dramatically. The following table illustrates the potential savings for similar projects in the future.

Table 1: Cost Savings For Future Sustainable Streets Projects

Item	Scope	Approximate Savings
Eliminate meandering Alignment	Savings occur on survey, factor of difficulty for construction and reduction in material quantities.	$35 000
Eliminate Golpla	Although an attractive item on the project, elimination of the Golpla offers large savings.	$50 000
Pathways	There were two pathways constructed for Crown. These likely would not be on future projects.	$20 000
Street Lighting	New street lighting was included on Crown, however normally it is a separate local improvement option.	$40 000
Reduce Landscaping	On future projects the landscaping should be reduced.	$20 000
Consultant Fees	As part of the Grant Agreement it was necessary to hire an outside Consultant. This will not be necessary on future projects	$100 000
Contractor's Profit	Also part of the Grant Agreement, it was necessary to contract out the construction. City crews will perform future projects eliminating profit margins.	$120 000
	Total Savings	**$385 000**

As shown in Table 1, if we eliminate costs that won't be applicable to future projects as well as reduce the level of detail, the price becomes comparable to a standard curb and gutter treatment. By making these changes we maintain the environmental benefits of a swale/pond system and can still include significant landscaping; two benefits that a curb and gutter option can't offer at a similar price.

An additional and very significant benefit of the Crown Street project is the degree of community building and participation. The project, through its consultation process, has brought the residents together with themselves and the City. City staff reflect fondly of the general buzz that the neighbourhood was feeling when construction was

ongoing. With the residents playing an active role in the planning of the street, they take pride in its success and maintenance.

THE FUTURE OF CROWN

Crown Street is currently being monitored in partnership with the University of British Columbia, Institute for Resources Environment and Sustainability. Dr. Ken Hall has started the monitoring period with a group of students and it is intended to continue over the next 5 years. Also, there are preliminary plans to establish some permanent monitoring equipment so long term data can be collected and compared to similar data that is collected throughout the city. Crowns success will be based on

- The quality of sediments that accumulate in the ponds
- The ground water quality collected from piezometers
- Trace metals in discharge storm runoff
- Total hydrocarbon fraction
- Temperature, conductivity, turbidity

All this data will be compared to a street just east of Crown, Holland Street, which uses a traditional curb and gutter system. We will be able to compare the water quality leaving both streets to determine how well Crown Street is performing. Finally, the number of the salmon spawning season each year will also reflect Crown's success. Once the success of Crown has been determined, the City hopes to make it a local improvement option for residents petitioning to have work done to their street.

CONCLUSION

Crown Street is an exciting new face to residential street design in Vancouver. Utilizing innovative ideas it pushes forward the City of Vancouver's initiatives to provide residents with functional streets while minimizing impact to the environment. The efforts shall no doubt have a positive impact on the creek habitat as well as the residents' day to day use of the new street. Based on the monitoring period and overall success of the project, the treatment could become a local improvement option for residents petitioning to have their street reconstructed. The City of Vancouver wishes to thank The Federation of Canadian Municipalities for their contribution as well as The TAC Environmental Council for their consideration towards Crown Street for the Urban Environmental Achievement Award.

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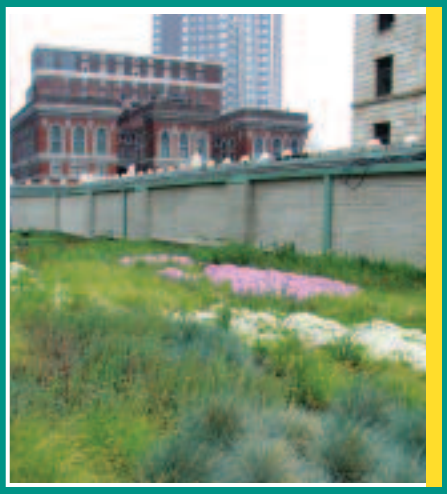

Building Better II

A Guide to America's Best New Development Projects

CLEAN WATER EDITION

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Cover photos (clockwise from top left): Alberici Constructors headquarters, Overland, Missouri; Heinz 57 Center's green roof, Pittsburgh, Pennsylvania; Brays Bayou restored wetland, Mason Park, Houston, Texas; Street Edge Alternatives natural drainage system, Seattle, Washington.

Thank you to all who contributed to this report.

Building Better II: A Guide to America's Best New Development Projects can be found on the Sierra Club's website at: *www.sierraclub.org/buildingbetter*

The Sierra Club's members are 750,000 of your friends and neighbors. Inspired by nature, we work together to protect our communities and the planet. The Sierra Club is America's oldest, largest and most influential grassroots environmental organization.

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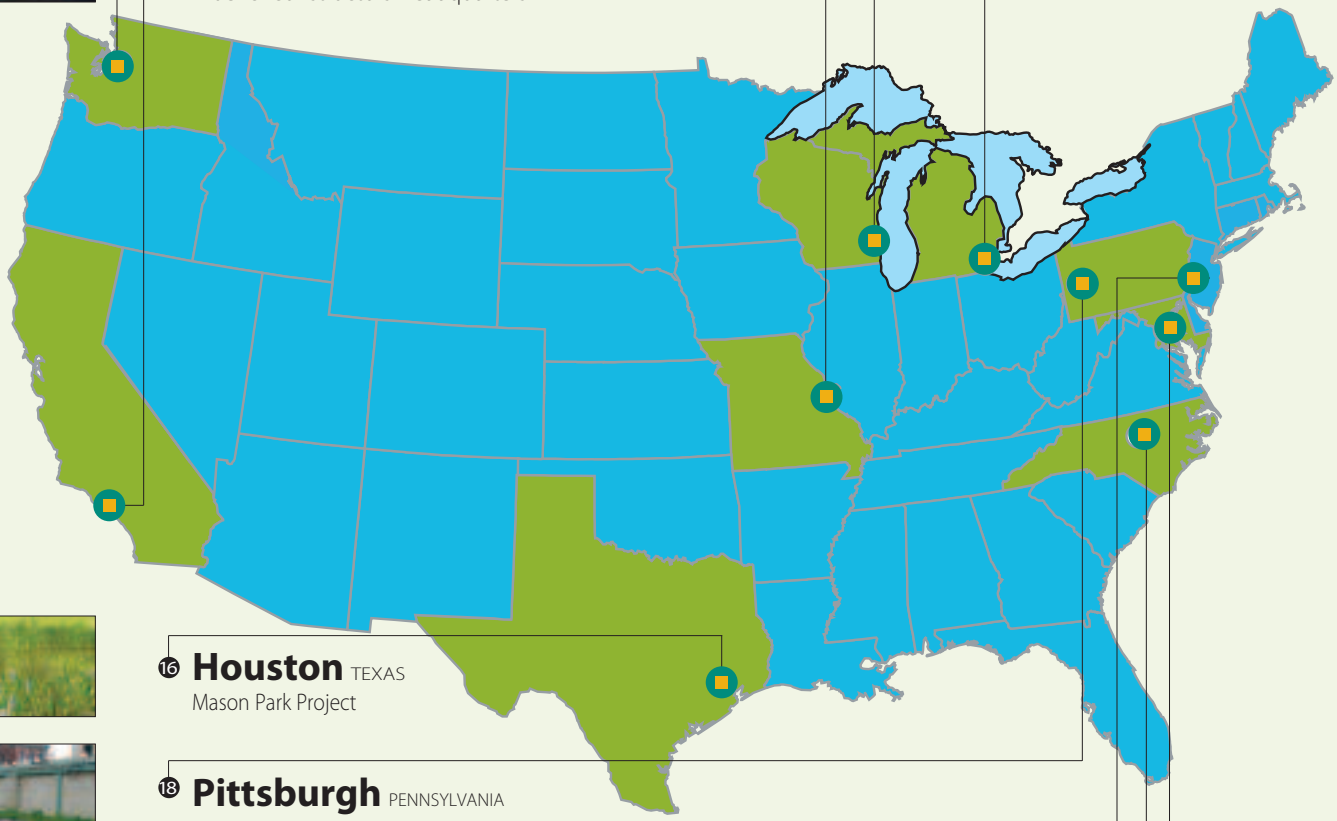

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Building Better II

A Guide to America's Best New Development Projects

CLEAN WATER EDITION

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Melinda Kelley, TreePeople

Above: Seattle "SEA Streets" natural drainage system. See page 6.

Right: Children look into cistern at Open Charter Magnet Elementary School, Westchester, California. See page 8.

Stormwater runoff and sewage overflows are growing threats to the health of our water. Across the country sprawling developments are generating huge amounts of sewage and stormwater runoff. Land that used to absorb rain is being paved over, creating more runoff than treatment systems can handle. The end result is that more untreated or poorly treated sewage and urban runoff is polluting the sources of our drinking water.

Fortunately, there are simple solutions that can make a big difference. The key is to think of stormwater as a resource, not a waste product. By changing this perspective, we can reap a host of benefits from recycling stormwater. This report highlights ten outstanding projects using innovative design to protect clean water and recognizes developers, institutions and communities who are leading the way toward combining a respect for nature with development and redevelopment.

Stormwater's Toll on the Environment

Almost 35 years after passage of the Clean Water Act, many of our nation's waterways are still polluted. When Congress enacted the law, industrial dumping and other "point source" contamination was the major cause of polluted rivers, streams, lakes and bays. Today the largest source of water pollution comes from two areas: (1) stormwater runoff washing contaminants into the water from parking lots and roads; and (2) combined sewer overflows, which occur when stormwater overwhelms the sanitary sewer system. An explanation of both methods of contamination follows.

Pollutant Runoff

The pollutants that wash into our waterways during storms are an ugly toxic soup. They range from auto-related fluids from roads and parking lots—including oil, grease, gasoline and hydrocarbons—to metals and other contaminants like copper, zinc, lead, cadmium, chloride, and nitrate. Runoff can also contain bacteria and other pathogens, pesticides, fertilizers, nutrients, sediment, debris, and much more. Each of these pollutants and toxins threatens water quality and aquatic life in their own way. Sediment clouds the water, killing plants and destroying habitat,[1] while nutrients contribute to algae blooms that can deplete oxygen, creating "dead zones" in water.[2] Bacteria can cause human illness, and heavy metals and chemicals can be harmful or deadly to both animals and humans.[3]

Sewer Overflows

In many of our older urban areas, the storm drain system and the sewer system are connected. This normally poses little problem during dry weather, but when rainstorms occur, runoff can overwhelm the sewers, causing both stormwater and raw sewage to overflow into streams and rivers without ever receiving treatment at a sewage treatment facility. The EPA estimates that an astounding 1.2 trillion gallons of untreated sewage combined with stormwater and industrial waste are dumped into our waterways each year due to combined sewer overflows, contaminating our waters.[4] According to the EPA, sewer overflows "pose major health concerns to the general public, and are responsible for gastrointestinal diseases, many beach closings, shellfishing restrictions, and limitations on other recreational activities."[5]

Development's Role in Stormwater Runoff

Runoff is produced largely through conventional development which creates swaths of impermeable surfaces—roofs, roads, and parking lots that rain falls on and drains off into waterways, picking up trash and toxins along the way.

The volume of stormwater runoff from developed sites is staggering. Twenty-five thousand gallons of water run off a single acre of impermeable surface, as opposed to only 2,700 gallons that run off an undeveloped acre during a one-inch storm.[6] With development occurring at a rapid rate across our nation, the runoff of harmful pollutants entering our waterways has far surpassed acceptable levels. According to the EPA, over 10 trillion gallons of urban stormwater runoff flows into the nation's rivers, streams and other waterways each year.[7]

Historically, as is noted by an engineer in one of our stories in the following pages, stormwater has been treated as a waste product—to be disposed of as quickly and efficiently as possible. This approach has led to expensive projects involving large volumes of concrete, elaborate piping, and other mechanisms to channel runoff —and its pollutants—from streets, parking lots and rooftops out to our natural waterways.

However, by viewing stormwater as a resource, not a waste product, we can create a host of benefits. Retaining natural features and vegetation slows and filters stormwater before it reaches waterways. Capturing and re-using stormwater from our roofs and other surfaces will not only help prevent pollutants from entering waterways, but will also conserve water, replenish groundwater and reduce flooding. These methods of managing stormwater are better for our environment, and in many cases they are less expensive than conventional approaches.

Debbie Franke

Alberici Constructors Headquarters, in Overland, Missouri, keeps 100 percent of runoff on site. See page 14.

Redevelopment and Revitalization Help Water Quality

In addition to the particular stormwater management practices outlined in these stories, communities can continue to advocate for redevelopment of existing urbanized areas, which reduces the amount of sprawl and creates more opportunities for people to live, work and shop within walking distance. It can help reduce both impermeable surfaces like parking lots and roads, and the need to drive—which helps cut down on the pollutants that get washed into streams during wet weather. The Sierra Club has long advocated for these approaches to development, since they disturb less land, use less energy, promote more walking and less driving, and produce less polluted runoff.

Charting a Course for the Future

While vast acres of poorly planned development continue to contribute to sprawl and polluted stormwater runoff, many developers, institutions and communities, are recognizing the environmental benefits and long-term savings of easily implemented, more natural stormwater management practices. In the following pages, we offer ten outstanding examples of environmentally responsible stormwater runoff management projects, with the hope that the leadership shown by the proponents of these projects will become

Charriss York

Restored wetland at Houston's Mason Park. See page 16.

Innovative Stormwater Solutions

Re-creating wetlands: Over 120 million wetland acres have been destroyed in the nation's history to make way for development and other uses.[8] Creating new and restored wetlands that hold and filter stormwater runoff is a key to controlling flooding and cleansing the water.

Rain gardens and swales: These are depressed, landscaped areas that catch and hold rain water and runoff, allowing it to slowly seep into the ground. Plants in these rain gardens and swales also absorb the stormwater.

Stormwater parks, bio-retention ponds: Like rain gardens and swales, these depressed areas hold excess stormwater so that it does not simply run off into waterways. These areas help prevent flooding, while also helping filter the stormwater. Stormwater parks and bioretention ponds are generally larger areas, and temporarily hold water only during wet weather.

Green roofs: Unlike conventional roofs, these have a thin layer of soil with native plantings which absorb rainfall. They also provide good insulation, which saves energy, and they have twice the lifetime of a conventional roof.

Cisterns and rain barrels: These storage tanks hold stormwater runoff for re-use. The runoff can be used to water plants and athletic fields, and for non-potable indoor uses like toilets.

Cascades: In steeper areas, these "mini-waterfalls" and pools help to slow the flow of water. This prevents erosion and sedimentation, while also holding water in pools and helping filter the water through vegetation.

Urban "greening" and natural plantings: Planting trees, native vegetation, and breaking up impervious surfaces all help absorb stormwater and prevent it from running off into streams and rivers.

commonplace in communities throughout the country in the years to come. Carried out on a watershed-wide basis, these relatively easy-to-implement types of projects could make a large-scale, lasting improvement in cleaning up our polluted rivers and bays. Government agencies—from the local and state level up to federal government—should provide incentives for more of these low impact development projects rather than throwing money into ineffective methods of stormwater management.

When citizens and local officials demand better development projects and more environmentally sound stormwater management practices, we help protect our drinking water sources and make our rivers, lakes and beaches safe for recreation and wildlife.

Nancy Aten

Milwaukee's new Menomonee Valley Park after a two-inch rainstorm, holding stormwater. See page 12.

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Seattle WASHINGTON

SEA Streets Project

In response to the high mortality of the endangered Coho salmon in Puget Sound estuaries, likely caused by toxic stormwater runoff, Seattle and Seattle Public Utilities (SPU) have developed an innovative plan requiring any new development or street to incorporate better stormwater management when redevelopment occurs. Consideration must be given to expansion of basic drainage systems, flood protection, protecting ditch drainage systems, coordination of landslide mitigation and expanding water quality monitoring.

Street Edge Alternatives (SEA Streets) Project

SPU initiated Street Edge Alternative (SEA Streets), its first Natural Drainage System project, with the goal of catching, detaining and filtering runoff from a 2.3-acre area near Pipers Creek.

Instead of installing a "traditional" stormwater system exclusively involving culverts, drains and pipes, SPU created a drainage system along streets and sidewalks which incorporated native plantings and swales with soils that catch, hold and filter water. In the process of creating more natural drainage systems, SEA Streets reduced the impervious surface area of city streets by 11 percent, helping to rein in the pavement that contributes to high velocity, toxic rainwater runoff.[1]

The impressive results of the SEA Streets project – a decrease in the volume of stormwater runoff by 98 percent for a 2-year storm event—have led the way for other Natural Drainage System projects, such as the 110th Street Cascade project.[2]

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110th Street Cascade Project

The Cascade project contains and filters runoff from a steeply sloped, 21-acre area by employing a system of pools that step down through a series of mini-waterfalls that mimic nature,[3] slowing the velocity of the water. Vegetation and swales that form part of the system help to filter out and break down polluted runoff, before the water reaches Pipers Creek.

An example of one of Seattle's "Street Edge Alternative" projects—a natural drainage system.

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Seattle's Green Future

As the Natural Drainage System project continues to grow, areas like the Broadview Green Grid, a 32-acre, 15 square block area are incorporating techniques from both the SEA Streets and Cascade projects, using vegetated swales and tiered water pools to control stormwater. Ambitious projects are planned for the Thornton Creek watershed and are underway for the 129-acre High Point Housing project, where SPU is partnering with the Seattle Public Housing Authority to improve stormwater management in this project that comprises 10 percent of the Longfellow Creek watershed.[4]

Working in conjunction with the Seattle Department of Transportation, Seattle Public Utilities has started a path toward a cleaner, better way of building residential streets. Already, university researchers and other local government officials have made Seattle's streets a destination to learn about these good models of stormwater stewardship.

Used with permission © 2005, Seattle Public Utilities, City of Seattle, Washington

A cascade helps slow the downhill flow of runoff, protecting land from erosion while helping filter stormwater.

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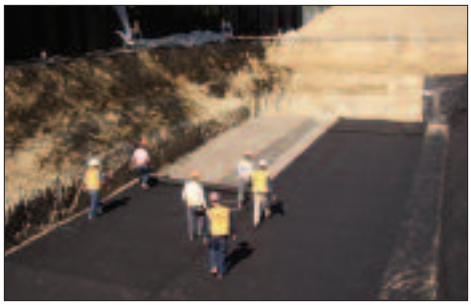
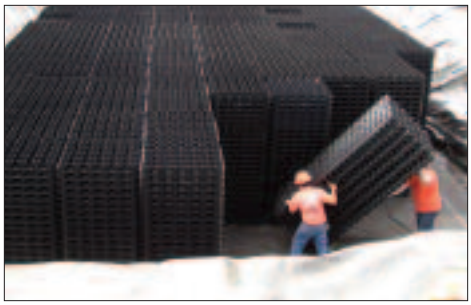
CALIFORNIA

Westchester





Small photos by Rebecca Drayse, TreePeople

Melinda Kelley, TreePeople

Open Charter Magnet Elementary School

Photos at top show before and during construction of the cistern project, which is now beneath the grassy field in the larger picture.

Los Angeles and Santa Monica Bay have faced their share of water quality problems. The loss of 98 percent of L.A.'s wetlands has jeopardized the health of its waterways. The health of the Bay has improved from horribly poor water quality several decades ago, but challenges still remain. Following the heavy rains of 2004-2005, Heal the Bay wrote, "Wet weather water quality trends look fairly dismal…exceedingly heavy rainfall magnifies a continuing problem in Los Angeles, the lack of significant progress on wet weather water quality and lack of appropriate funding to clean up wet weather water quality. In the near future, wet weather water quality, it appears, will only improve with less rain."[1]

Parents, Teachers and Children Working Together

In a watershed that can empty more than 80 billion gallons of runoff into the Santa Monica Bay in a year, one school is leading the way toward a more innovative future.[2] The Open Charter Magnet Elementary School in Westchester, California made a

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number of improvements to its grounds to capture and re-use stormwater under the leadership of Andy Lipkis, an Open Charter parent and founder of Tree People, an environmental non-profit best known for its work planting over two million trees in the Los Angeles area.

Starting in 1999, Tree People worked with the school's staff, students, and parents to create a more environmentally friendly site, by planting trees and other vegetation on school grounds and breaking up impervious parking lot surfaces to help prevent polluted stormwater runoff. However, the largest, most significant stormwater improvement to the school grounds was a 110,000 gallon cistern buried beneath the campus's playing fields. This underground tank collects, holds, and cleans runoff from the property, enabling the school to use the recycled water for watering the vegetation on the site instead of letting wasted water gather pollution and flow into the Bay.

Melinda Kelley, TreePeople

Children get an education in stormwater pollution as they look into the school's cistern.

Stormwater: A Resource, Not a Waste Product

The system created for the Open Charter cistern project varies from the traditional engineering approach, which is to treat stormwater as a waste product to be disposed of as quickly as possible. One of the engineers for the project, Michael Drennan, P.E. explains, "As we look at how the system evolved over time we realize that the way we designed the (stormwater) system was reactionary and single purpose in its approach … if you think about multiple objectives like flooding, pollution reduction, and water supply, then you might design a system like we did at Open Charter, which manages stormwater as a resource rather than a waste."[3]

Los Angeles: A Look Ahead

The Open Charter project is helping lead the way for more positive stormwater solutions in Los Angeles. Los Angeles voters recently passed a $500 million bond to underwrite projects to meet the goals of the new Integrated Resources Plan (IRP) which seeks to capture, clean and reuse water, while also creating open space and wildlife habitat where possible. The State's Regional Water Quality Control Board has come to recognize the value of natural treatment systems for cleaning polluted stormwater, including swales, treatment wetlands and vegetated buffers. Sierra Club activists have proposed a treatment wetland just down the hill from Open Charter Elementary on more than 100 acres in the Ballona Valley floodplain where the Los Angeles River historically converged with Centinela Creek. These treatment wetlands will not only capture stormwater, but also cleanse pollutants before the waters empty into the Santa Monica Bay. Bringing back more of the natural landscape throughout the watershed, rather than pouring more concrete, can best help L.A. improve its water quality.

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MICHIGAN
Monroe

Both photos by Holly Knight

Sisters, Servants of the Immaculate Heart of Mary Motherhouse Renovation

Dedicated to the Earth

For the Sisters, Servants of the Immaculate Heart of Mary (IHM), good stewardship of their corner of the environment is part of their larger social and economic justice mission. So when their Motherhouse began showing its age after 70 years of wear, the home's 250 Sisters set about the updates with an eye toward preserving the natural environment, creating a building and grounds that tread lightly on the earth.

The Sisters preserved much of the landscaping during construction, including all of the trees on the 280-acre site, while also restoring portions of the campus grounds to wetlands and meadows which help hold and filter water. The creation of these natural sponges keeps and cleans water, preventing polluted runoff from flowing into the River Raisin where *E. coli* and pollution levels are already elevated.

The wetlands also collect greywater from the facility's sinks and showers, recycling it to be treated and re-used in the building's toilets instead of going into the sewer system. Recycling reduces the Sisters' water usage by 55 percent, diverting 7,000 gallons per day to wetlands and recycling 4,500 per day to flush toilets.[1]

To further reduce stormwater runoff, the parking lots have been retrofitted with vegetated swales that break up the large impervious surface and create natural drainage systems.

Building Renovation

In addition to recycling wastewater, there are hosts of energy, resource, and water conservation features built into the project, which has received the bronze level Leadership in Energy and Environmental Design (LEED) certification. The renovation maximizes the use of natural daylight, uses low-flow shower spigots and uses environmentally sustainable products like fast-growing cork in the flooring. It also employs an innovative geothermal heating and cooling system, as well as a heat recovery system to reclaim heat from ductwork exhaust. The geothermal system sends water deep into the ground where it taps into the earth's natural temperature instead of relying on other energy sources to heat and cool the building.

People Making the Difference

The Sisters, who studied and became experts in ecological design, were aided in their renovation endeavor by Philadelphia firm Susan Maxman & Partners, national leaders in ecological design and sustainability. Viridian Landscape Studio created the ecologically sound site plan with civil engineering input from the Mannik and Smith Group. The Christman Company managed construction, and the H.F. Lenz Company handled engineering and design, while the Middleton Corporation and Jackson & Sons Drilling Company were responsible for the geothermal drilling.

A swale of native planting helps absorb parking lot runoff.

Both photos by Shirley Mathus

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WISCONSIN

Milwaukee

All Milwaukee photos by Nancy Aten

Menomonee Valley Industrial Site

Menomonee Valley's stormwater park.

A Wasteland Made Green

The former rail yard and manufacturing center in the Menomonee Valley had long been an environmental wasteland until a $20 million cleanup project of this Brownfield site was completed in 2004.[1] It took nearly two dozen state and federal Brownfield grants to address the environmental hazards—from free petroleum to arsenic, asbestos and other contaminants on the site. Now that the site is clean, portions of the 1,200-acre space in the heart of Milwaukee, are slated for light industrial redevelopment and a business park.

Already on the site, Harley-Davidson, Inc. is building a $95 million motorcycle museum, and Palermo Villa, Inc., a frozen pizza company, is currently developing a 14-acre site.[2] Caleffi North America, a division of an Italian company manufacturing hydronic systems, plans to build a 35,000-square-foot plant, while Badger Railing, which makes ornamental iron products, is planning an 18,400-square-foot building to house 41 employees.[3]

Water Woes

Worries over stormwater management heavily influenced the Menomonee Valley development after heavy rains overwhelmed the Milwaukee sewer system in 2004, dumping 1.7 billion gallons of raw sewage into Lake Michigan.[4] During the same period, surrounding communities released another 5.1 million gallons of sewage into the lake, which is a drinking water source for more than 10 million people.[5,6] The relatively small drainage area of the lower Menomonee and Milwaukee Rivers contributes disproportionately large amounts of pollutants associated with urban runoff and are designated as "areas of concern," meaning that the water quality impairments affect recreation, fish consumption and drinking water.[7]

Stormwater Park

In an effort to better stormwater management practices, a stormwater park has been created on 70 acres of the Menomonee Valley site, which runs along the Menomonee River. The park which will feature natural areas, open space, playing fields, and the Hank Aaron State Trail, is expected to capture every drop of rain that falls on the business park.[8] The native plants, woodlands and new topography will serve to detain flood water and will clean water contaminants from the new commercial and industrial area that would otherwise drain into the river. Two large smokestacks from the original rail yard on the site have been left standing, and serve as a visual contrast to link Milwaukee's future to its industrial past. The site plan for the park has been recognized for excellence by the American Society of Landscape Architects.

City Leadership Combating Stormwater Runoff

The city is answering the wake up call of tragic floods which overwhelmed Milwaukee in 1997 and 1998, costing several lives and $35 million in damages. The stormwater park is only one part of Milwaukee's Mayor Tom Barrett's initiative to control flooding and implement better stormwater management practices. Among other strategies, he plans to reduce stormwater runoff from city properties through the use of green roofs, rain gardens, and native plantings along roadways and public green spaces.

---

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All Milwaukee photos by Nancy Aten

Milwaukee's stormwater park and the Menomonee River.

MISSOURI
Overland

Debbie Franke

Alberici Constructors Headquarters

Alberici's headquarters keeps 100 percent of runoff on site.

Building Greener

As one of the largest general contracting construction companies in the nation, Alberici Constructors has been building large-scale projects since 1918.[1] Yet, their experience building green began much later, in 2003, when the company decided to build a new headquarters in Overland, Missouri. The goal was to construct an example of the very best in environmental design and construction and receive a platinum-rated Leadership in Energy and Environmental Design (LEED) building. Alberici was successful and their headquarters is one of only six buildings worldwide to achieve this top rating of environmental excellence.

Protecting Water Quality—Zero Runoff

While the building has many remarkable energy saving and environmental features, perhaps the most notable is that the building and surrounding property produce zero stormwater runoff.

Rainwater from the one-acre roof is captured by a 38,000 gallon, underground cistern.[2] The captured water is then used in the building's urinals and toilets, saving an estimated 300,000 gallons of water annually and saving it from running off the site.[3] According to Thomas Taylor, Alberici Constructors' Vice President of Special Projects, water-saving measures like using recycled water and low-flow faucets result in a 67 percent reduction in water use over a comparable, conventional building.

Alberici removed an unneeded 60,000 square foot building from the site and reduced the impermeable surface by removing large surface parking and replacing both the building and the parking lot with landscaping made up exclusively of native plants. Six acres of prairie and wetlands were constructed to filter out pollutants and help keep 100 percent of the water on site as it runs slowly into the vegetation where it is absorbed.

A Better Building for People and Nature

The platinum-rated LEED building has a number of other environmentally-friendly features. A significant portion of the building was constructed using recycled materials. Alberici saved 93 percent of potential construction waste

from going to the landfill[4] and approximately 30 percent of the new building materials were recycled.

Through the use of energy recovery—which extracts heat from the air without the need to re-circulate stale air—and a number of other features like operable windows, under-floor air distribution, a passive solar preheat system for heating the building's water, and a 65kW refurbished wind turbine, which supplies 20 percent of the energy for the building,[5] the building is "60 percent more energy efficient than a conventional building."[6] The building is designed to take advantage of natural daylight, which minimizes the need for indoor lighting and reduces the stress of employees.

Alberici encourages employees to carpool by giving parking preference to carpoolers, and they provide bike racks inside the parking garage protected from the elements. They also provide showers and locker rooms for employees who bike to work. While it is a suburban location, with limited public transportation options, there is a bus stop a short distance from the building.[7]

Industry Inspiration

Alberici Constructors has used their headquarters to create a real-life example of innovative, cost-effective green building. Through their attention to environmental excellence Alberici is leading the construction industry in green building and stormwater management. Alberici hosts tours of the facility, and encourages others to learn from their work.

Alberici Constructors

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TEXAS Houston

Diane Humes

Mason Park Project and Better Bayou Protection

Correcting Mistakes of the Past

In the race for urbanization, Houston's Harris County lost many of its estimated 800 miles of bayous to artificial, concrete gulches that moved water—and the pollution in it—quickly to Galveston Bay, destroying water quality. High concentrations of fecal coliform and increased nitrate nitrogen levels have forced the closing of about one-half of the Bay's shellfish harvesting areas.[1] However, an array of local partners including the City of Houston and Harris County are now taking action to address polluted stormwater runoff, the top water quality problem facing the Bay, by creating new wetlands at Mason Park in southeast Houston and in other locations.

Mason Park Project

Constructed through a partnership between the Harris County Flood Control District, the Army Corps of Engineers, the Houston Parks Department, and the Texas Parks and Wildlife Department, a new 3.5-acre wetland area at Houston's Mason Park serves as a filter for runoff from a 30-acre urban residential watershed. Where a stormwater culvert once dumped polluted runoff directly into the bayou, now three terraced ponds with native plantings seek to re-create a freshwater marsh that existed in the area nearly 50 years ago.[2] This marsh, which helps hold and cleanse water before it makes its way on to the Bay, is part of a pilot project that will eventually lead to the creation of a series of wetlands along the length of Brays Bayou. The Mason Park project is one of several efforts that began after recent severe floods to address flooding along Brays Bayou by using re-created wetlands as an effective means of slowing and cleaning large volumes of stormwater.

Improving Habitat

Not only will the project help control stormwater pollution, it will also provide habitat for fish and wildlife. Birds such as ibis, white pelicans, osprey, heron and egrets that are found in the area will flock to

Diane Humes

The re-created wetland at Mason Park controls stormwater and provides wildlife habitat.

the restored marsh and fish will use the natural freshwater marsh as a nursery.[3]

Community Involvement and Partnerships

Students from Chavez and Austin High Schools spent months planting natural vegetation on the Mason Park site,[4] which will serve as a laboratory they will use to see natural science in action. Eventually the project will even include an outdoor education area for classes.[5] In 2006, the Harris County Flood Control District was honored for a Brave Bayou Tidal Marsh Project by the nonprofit Park People. Park People is "dedicated to promoting the importance of park and green space" in Houston.[6]

Innovative Work in Harris County

In addition to the 3.5-acre wetland at Mason Park, significant work in and around Houston to protect its bayous is being done by the Harris County Flood Control District. These significant projects include a multiple use detention basin called the Hill at Sims Greenway, where existing dirt has been sculpted into hills, and where a trail system and recreational facility is being established.[7] This project—and the overall 19-mile work on the Sims Bayou Main Channel—is a tremendous move away from the typical "concrete ditch" system. The Main Channel work, which was started in 1992, includes no concrete and instead has a gentler, more natural and sloping channel. Thousands of trees were planted along the bayou and the work preserved existing trees. Other innovative detention facilities have been constructed in the White Oak Bayou watershed and on the northwest side of Houston.

Promise for a Cleaner Watershed

The pioneering work that occurred in Harris County to advocate for, and construct, the Mason Park wetland, the Hill at Sims Greenway, and other projects, is a step toward reducing the threat of flooding as well as cleaning up polluted runoff into Galveston Bay's tributaries. With more marshland restoration planned in the regional watershed, there is positive movement toward reversing some of the past environmental damage that was done to the waterways. Managing urban watersheds and creating more natural stormwater filters is a key to improving overall water quality in Houston.

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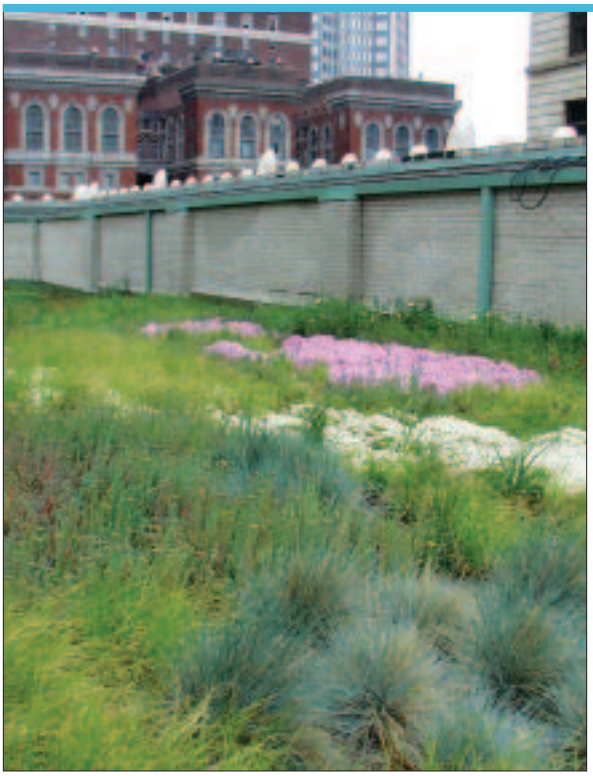
PENNSYLVANIA

Pittsburgh

Pittsburgh's Sewer Problems

Pittsburgh, which sits at the juncture of the Monongohela, Allegheny, and Ohio Rivers, has serious problems with combined sewer overflows in the Three Rivers. "I would not go swimming in the Three Rivers after it rains," said Noel Hefele, who has worked on a Carnegie Mellon University project studying pollution in Allegheny County's rivers and streams over the last five years. "One-tenth of an inch of rainfall can lead to a sewage overflow."[1] However, the average rainfall in Pittsburgh is one-quarter of an inch.[2] Each year an estimated 16 billion gallons of raw sewage are discharged from hundreds of outfalls in the region's sewage collection system to local waterways in the Pittsburgh area.[3]

Capturing rainwater before it makes its way into the storm system, however, can be an affordable key to preventing an overload of the system that contributes to these sewer overflows.



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Heinz 57 Center

Heinz 57 Center's green roof and plantings absorb rainfall.

An Environmental Renovation: Saving Runoff, Energy, Reducing Heat

In 2001, the Heinz Corporation moved its North American headquarters into a renovated, 14-story, historic Gimbels Department Store building in downtown Pittsburgh. Heinz worked with McKnight Development Partners to add an atrium to the top seven floors of the building, which lets in light, reducing energy use and creating a more comfortable environment.

The most impressive environmental feature of the building is its 12,000-square-foot green roof, completed in 2001. No outside irrigation is needed for the plants in the five inch thick roof, which absorb rainfall that would otherwise make its way into the stormwater system and contribute to sewage overflows. The roof is estimated to have a 55 percent annual rainfall retention rate and since green roofs last twice as long as traditional roofs, the Heinz building will continue to reduce stormwater for years to come.

As an added bonus the green roof helps bring down energy costs by providing insulation, and reducing the rooftop heat generated in the summer. By absorbing the sun's warmth, the roof will

help mitigate the "heat island effect," caused by a lack of vegetation and the presence of dark roofs and pavement in cities. Summer heat is about eight degrees hotter in cities due to the heat island effect.[4]

The Heinz 57 Center's roof was constructed by Philadelphia's Roofscapes, Incorporated, in cooperation with the architects Burt, Hill, Kozar, Rittlemann Associates.

Pittsburgh's Past Becomes its Future

Thanks to the environmentally sound decision to renovate a historical and until recently vacant building, the Heinz 57 Center reflects a strong sense of Pittsburgh's history and architecture. Originally constructed in 1914, the Heinz building has now become an example of using revitalization and green construction to minimize the environmental footprint of growth.

Conveniently located in a pedestrian friendly mixed-use area, with shops, restaurants and businesses, the Heinz Center is worker friendly as well as eco-friendly. The location and the transportation options it provides help the more than 800 employees who work in the building avoid having to drive. The building that once stood during Pittsburgh's industrial past now helps point to a cleaner future.

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A closeup of the Heinz 57 Center's green roof.

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PENNSYLVANIA

Philadelphia

Pennsylvania Horticultural Society

Philadelphia has a significant problem with sewage overflows, which means that the local sewer systems are overwhelmed during periods of heavy rain and untreated sewage overflows into the surrounding rivers and streams. At 165 locations around the city sewage routinely overflows into the Delaware and Schuylkill Rivers and other waterways during rainstorms.[1] The Schulkill supplies drinking water to 1.5 million people in Philadelphia[2] and both are important centers of commerce and recreation in the region. Experts agree that the main contributor to the poor water quality of these rivers is stormwater runoff.

Philadelphia Green: Cleaning Philadelphia's Stormwater

Philadelphia Green—a program of the Pennsylvania Horticultural Society and the City of Philadelphia—has initiated projects across the city to clean up vacant lots, green the city, and improve stormwater management.

Teaming up with the Philadelphia Water Department in 2003, and with grant support from the Pennsylvania Department of Environmental Protection's Growing Greener Program, Philadelphia Green has transformed five plots of land into models of good stormwater management by installing shallow trenches and berms that harness the rainfall and allow it to seep slowly into the ground over a 24- to 36-hour period.[3] "We hope to create a whole series of 'natural sponges' in the city that reconnect the urban land to the natural water cycle," said Gerry Abrams, an urban watershed planner at the Philadelphia Water Department.[4] These natural sponges help reduce the volume of water contributing to sewer overflows and purify the water before it reaches the rivers.

'Philadelphia Green' Urban Greening and Stormwater Projects

One of many re-created "natural" drainage areas in Philadelphia that absorb stormwater.

Greening Schools, Reducing Impervious Surface

In 2005, Philadelphia Green, in conjunction with the Philadelphia Water Department (PWD), started work on a project with seven

Philadelphia schools to address stormwater runoff, while promoting environmental education.[5] At S. Weir Mitchell Elementary School, one of the seven schools participating in the project, children created a raised bed vegetable garden in a paved parking lot, which will help to reduce the "heat island effect" and absorb stormwater instead of contributing to runoff.

Mitchell Elementary is also slated for a stormwater retrofit project by Philadelphia Green and the PWD in the near future, which calls for the addition of vegetation, infiltration trenches, bio-swales and a rain garden on the 3-acre impervious site.[6] According to the designers of the plan, "the stormwater management and planting plan at the Mitchell School is designed to capture a significant portion of this [stormwater] volume by mitigating runoff generated by all storms less than or equal to the 1 inch rainfall."[7]

A Greener Future

Philadelphia, like many older American cities, faces severe stormwater challenges due to its massive combined sewer system and the large, paved surface area of the metropolitan area. But Philadelphia is making strides toward a greener city and cleaner water since the city and the Philadelphia Horticultural Society have teamed up to take on the problem. With more projects on the horizon to green vacant lots and school grounds, Philadelphia Green continues to make strides to improve water quality in and around Philadelphia.

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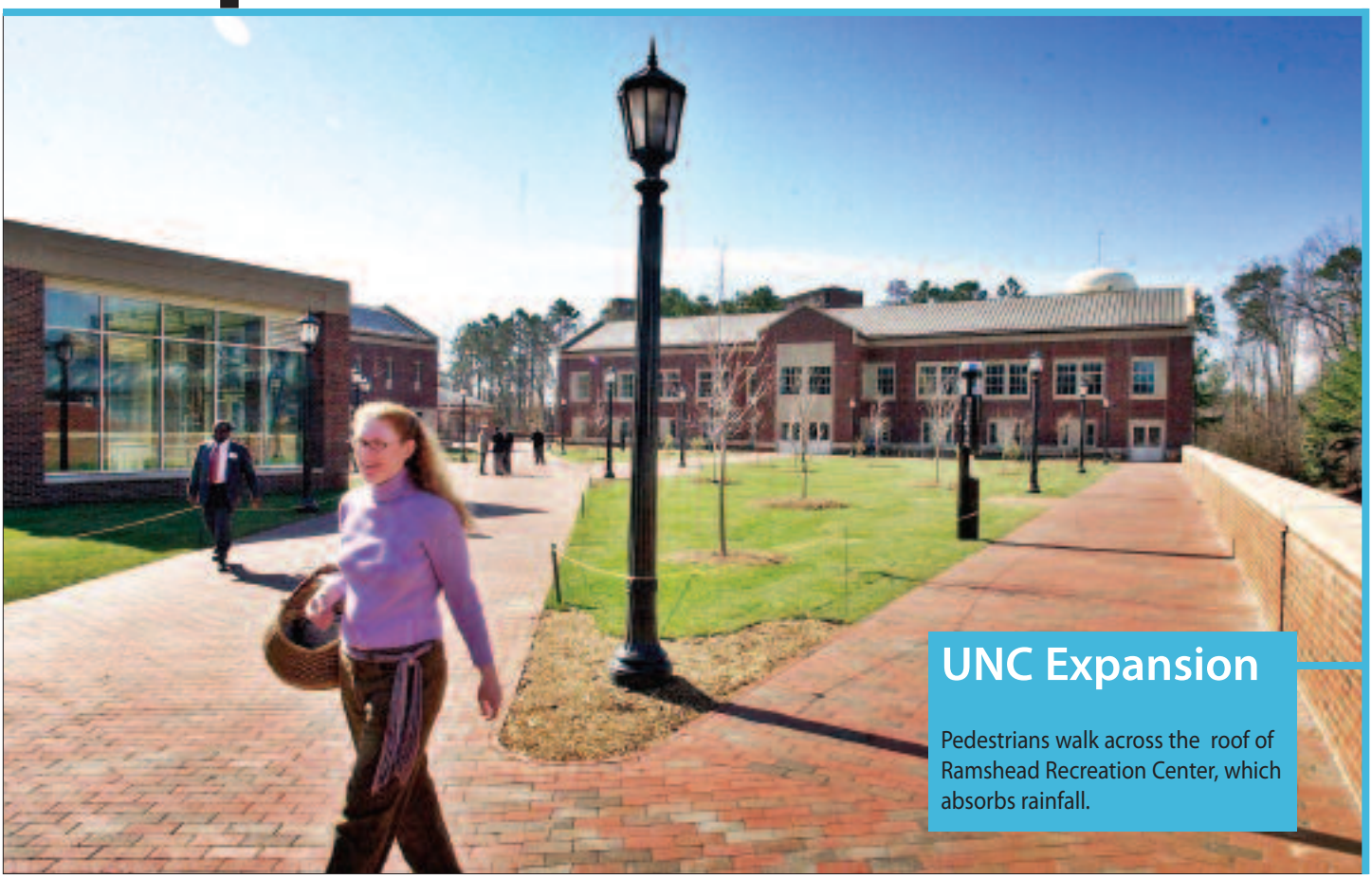
Chapel Hill NORTH CAROLINA



Dan Sears

UNC Expansion

Pedestrians walk across the roof of Ramshead Recreation Center, which absorbs rainfall.

UNC Environmental Sustainability

Impaired biological integrity for aquatic life, including several endangered species, in "Meeting of the Waters Creek," shellfish harvesting closures in the Cape Fear River, and impaired water quality in Jordan Lake – a major source of drinking water – emphasized the need for water quality improvement in North Carolina. "There is no doubt [the Cape Fear River] is impaired, and no doubt stormwater has a large part to do with it," says Bill Murray of Cape Fear River Watch, Inc.[1] To address water quality problems such as these North Carolina established "Project Green" in 1998 to promote environmental sustainability in state government.

As part of this project, the University of North Carolina, Chapel Hill is pursuing a billion-dollar construction plan to meet the needs of its growing programs. The 5.9 million square feet of new buildings on campus will be constructed using methods that accommodate new development without adding to stormwater runoff, something conventional development could never accomplish.[2,3]

The UNC Plan

While the development plan for the University will take a decade, much of it is being implemented now and several projects are already complete. The newly finished Ram's Head recreation center and 750-space parking garage, and the Carrington Hall addition both feature green roofs that catch and clean stormwater to prevent polluted water from entering the waters nearby. The reduction of 20 acres of impermeable surface, and replacement of traditional parking lots with porous pavement and 10 acres of green space also aids in controlling stormwater pollution by reducing the amount of oil, grease and other auto-related pollutants running into waterways.

One of the most enterprising of UNC's stormwater management improvements is the installation of a 70,000 gallon underground cis-

tern beneath Carmichael athletic field. Rainwater gathered from the roofs of nearby buildings, including the School of Government and the Ram's Head recreation center, is stored in the cistern and then used to irrigate the playing fields and landscaping.

Making the Grade

As development continues, UNC has plans to replace lawn areas with mulch beds, which will improve the infiltration of stormwater, and create additional rain gardens on the campus to absorb runoff from paved surfaces. Both during and after construction, streams will be monitored to ensure that water quality is upheld and two streams that were piped through campus will be opened up to restore oxygen and sunlight to the water. With more stormwater solutions in the works UNC is on the leading edge of sustainable development among universities and other large institutions.

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Cindy Shea

Carrington Hall's roof captures rainwater.

Mt. Rainier MARYLAND

The small community of Mt. Rainier, Maryland is taking action to help protect the Chesapeake Bay. About 5 percent of the Bay has been classified as a dead zone because of excessive nutrients from sewage discharges, urban stormwater and fertilizer runoff, and other pollution sources.[1] Gutter filters and bioinlets installed along Route 1 as part of Mt. Rainier's pilot program are making real improvements in preventing polluted stormwater runoff that contributes to poor water quality of the Bay.

What are Bioinlets and Gutter Filters?

These methods of addressing stormwater runoff are uniquely suited to urban areas where there is little land available for other methods of filtering runoff.

"Gutter filters are similar to sand filters which work on the principle of sedimentation and filtration," says Ameya Ulhas Pradhan, who studied these stormwater management methods in a Master's Thesis at the University of Maryland. "They are constructed below grade …. [and] the filtered runoff is discharged to a storm drain or natural channel."[2] In other words, the stormwater runoff flows into the gutter filter where the water is filtered through sand, which catches many of the chemicals, metals and other pollutants before the water flows into the Bay. In Mt. Rainier, these are constructed along the roadside, in the place of a traditional storm drain.

Bioinlets include vegetation to help break down pollutants and provide sedimentation, filtration, soil absorption, microbial decay processes and uptake of pollutants by plants.[3] These act like bio-retention areas, which collect and hold water while it is filtered through soil and into plants. Like the gutter filter, bioinlets fit into the small area of a traditional storm drain.

Results for a Cleaner Watershed

A variety of tests and studies conducted confirm the effectiveness of bioinlets and gutter filters. Gutter filters were found to eliminate Total Suspended Solids by 75 percent, Total Kjeldahl Nitrogen by 50 percent, zinc by 71 percent, copper by 40 percent, lead by 69 percent, and cadmium by 43 percent. However, there was no effect on nitrate or total phosphorus.[4]

With the installation of both the bioinlets and gutter filters, there was generally an even greater reduction in these pollutants. Total Suspended Solids were reduced by 83 percent, cadmium by 86-89 percent, lead by 84 percent, and zinc by 58 percent. Nitrogen was reduced by 42 percent, Total Kjeldahl Nitrogen by 12 percent, and copper by 29 percent. Nitrogen and phosphorus contribute to the growth of algae, which can deplete water of life-sustaining oxygen when it decomposes, and metals can be harmful or toxic to human health and aquatic life.

Urban Roadside Project

A bioinlet absorbs water, and its vegetation helps break down pollutants.

Ameya Pradhan, University of Maryland

An Effective Stormwater Management Practice

These small steps have an effect, and they can make a big difference in water quality if done on a large scale. They can be replicated across the region efficiently, without a lot of retrofitting, and without a huge price tag.

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Ameya Pradhan, University of Maryland

A gutter filter cleanses runoff before sending water to the stormdrain.

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Building Better: A Guide to America's Best New Development Projects can be found on the Sierra Club's Web site at *www.sierraclub.org/sprawl/report05*.

The Sierra Club's members are 750,000 of your friends and neighbors. Inspired by nature, we work together to protect our communities and the planet. The Sierra Club is America's oldest, largest and most influential grassroots environmental organization.

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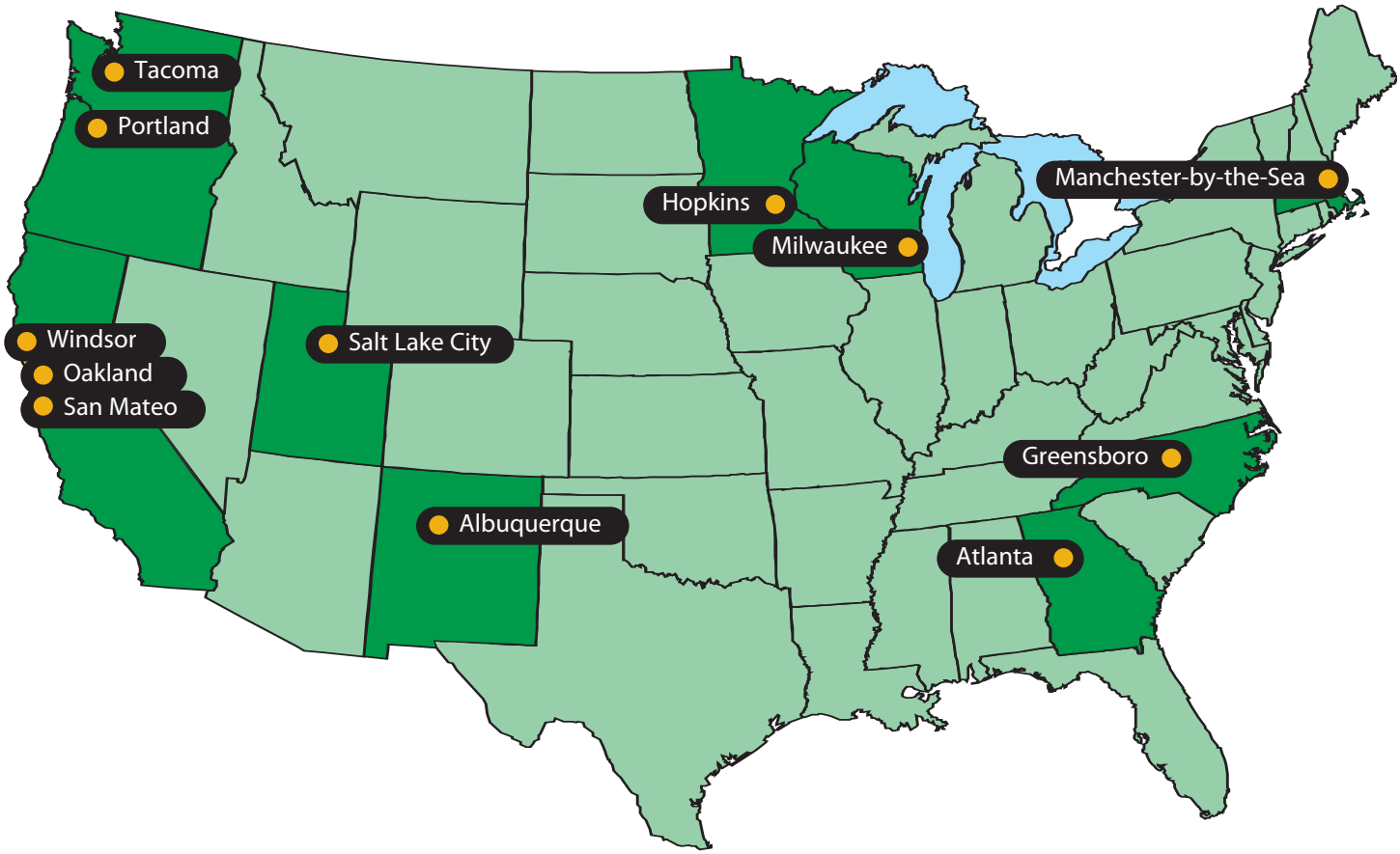

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Building Better

A Guide to America's Best New Development Projects

This report highlights America's best new development projects, based on their ability to offer transportation choices, revitalize neighborhoods, and preserve local values. It also spotlights some of the movers and shakers—developers, architects, local officials, activists—responsible for making these innovative projects a reality.

Curbing Sprawl, Building Healthy Communities

Much of the development in the United States today is sprawling, low density, car-dependent "big-box" or "strip-mall" construction, which produces more and more traffic and harms our land, air, and water. The Sierra Club believes there is a better way to build, and in doing so, to produce healthy neighborhoods, and livable communities.

While the Sierra Club opposes poorly planned, sprawling development, built on natural areas and farmland, we support quality investment in areas that already have a history of development to enhance communities and the environment. By reinvesting in existing neighborhoods and creating more walkable, transit accessible places to live and work, a select subset of the nation's development leaders are raising the bar for neighborhood design. By embracing conservation, green building techniques, and affordable housing, and by building on the assets we already have, these developments offer a path to a more sustainable future.

"Good Development" Criteria

We had several criteria for selecting America's best new development projects. Top candidates had to:

- Offer a range of transportation choices, including walking, biking, and public transportation;
- Redevelop existing areas, rather than developing natural areas, working farmland, or wetlands;
- Locate homes, retail shops, and offices close to each other;
- Preserve existing community assets, by re-using older buildings and protecting rivers, woodlands, and farms;
- Minimize stormwater pollution and handle runoff in an environmentally responsible manner; and,
- Be the product of meaningful input by local citizens and reflect a broad set of local values.

We also considered the use of "green building" design and housing affordability in compiling our list of the best new development.

Building Large and Small

We arrived at a diverse list of successful projects, from cities large and small, to suburbs, to small towns in each corner of the nation. They involve economically challenged areas like Fruitvale in Oakland and Highland Park in Milwaukee, as well as well-off areas like Manchester-by-the-Sea, Massachusetts.

We included massive projects like Atlantic Station in Atlanta, which encompasses 138 acres and includes 12 million square feet of retail, office, residential and hotel, and by contrast, smaller scale projects like 66 residential homes and an industrial building in Hopkins, Minnesota.

BAY MEADOWS LAND COMPANY

The layout of Bay Meadows in San Mateo, California. More on page 12.

ERIC OLSON

A light-rail stop in Tacoma, Washington. More on page 4.

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These model development projects include all manner of housing: single-family homes, condominiums, apartments, and live-work units. They supply low and moderate income housing, public housing, and high-end market rate housing. Retail offerings include large, established department stores, restaurants, and shops, as well as local, independent boutiques and eateries.

With leadership and commitment, as well as neighborhood support, quality redevelopment can be successful in our towns, cities, and our older suburban areas.

The Players

None of these innovative projects would have happened without the vision and determination of key individuals and organizations. In some cases, the champions were developers like Orrin Thiessen in Windsor, California; Rob Dickson in Albuquerque; and Robert "Nate" Bowman in Greensboro, North Carolina. Each of these developers decided to buck the trend of sprawl. In other cases, the champions of redevelopment were non-profit or public sector advocates like the Unity Council in Oakland, the Housing Authority, City of Milwaukee, and the Salt Lake City Redevelopment Agency. Yet others who made these projects happen include the architects, local business leaders, and political leaders. While we have tried to highlight key individuals or organizations for each case study, in each of these examples, it took a host of people working together to make the projects succeed.

We hope these projects and their champions will inspire other communities, developers, citizens and public officials across the country.

BREWERY BLOCKS

Portland, Oregon's Pearl District is a former industrial area that has been redeveloped into a thriving neighborhood.

BECKY GILLETTE

A Mississippi resident stands on the front steps of a house swept away by Hurricane Katrina in Biloxi's D'Iberville neighborhood.

Lessons for the Gulf Coast

Restoring the communities devastated by Hurricane Katrina will require the largest rebuilding effort in our nation's history. The winning projects in this report hold valuable lessons for the Gulf Coast as well. New Orleans, where the storm exposed the fact that thousands of people do not have cars, offers the perfect chance to design neighborhoods to provide many transportation choices. Good design can also make it possible to house people and businesses without destroying the wetlands that are vital for flood protection. Probably the most important lesson is that the best new development projects consistently require strong input from local citizens and are designed to enhance community values, whether that means ensuring affordability or preserving the historic character of the neighborhood.

While plans for rebuilding are still unfolding, there is some good news. In October, Mississippi Governor Haley Barbour invited over 100 of the nation's top architects, designers, and planners—led by "new urbanism" visionary Andres Duany —to brainstorm with local officials and citizens about options for rebuilding ravaged towns. They offered ideas for downsizing big-box stores, designing walkable communities, and developing high quality and affordable housing. Hopefully, their ideas will inspire state and community leaders to not just rebuild, but to rebuild smarter and better.

WASHINGTON
Tacoma

University of Washington, Tacoma

UNIVERSITY OF WASHINGTON, TACOMA

Downtown Tacoma is booming, in large part due to the University of Washington system investing in this historic area for its new campus rather than choosing a suburban location. In 1997, the University of Washington, Tacoma, opened at 1900 Commerce Street in a former warehouse. Now, in 2005, the growing campus boasts 2,000 students studying in a part of Tacoma that had only twenty years before been an empty, blighted, and abandoned former warehouse district.

History and Historic Preservation

This section of Tacoma, the "Warehouse District," had been built at the turn of the 20th Century. Located along Commencement Bay of the Puget Sound and served by the Northern Pacific Railroad, Tacoma became a thriving commercial center.

Large, sturdy brick warehouses were constructed along the rail line and close to the Bay. Tacoma's passenger rail station—an architectural gem—Union Station, was built in 1911 in the same area as the warehouses, at the terminus of the Northern Pacific Railroad.

By the late 20th century, the area had become dilapidated and devoid of people or economic activity. Some proposed leveling the area, but local businesspeople and Pierce County's Director of Economic Development in 1986, Ryan Petty, began promoting the idea of a university in Tacoma.[1] While many in the community thought it would be too much trouble and expense to renovate, this visionary group—especially the downtown businesses—teamed up with state legislators and other leaders to promote the idea of re-using the warehouses for a new state university.

In the meantime, Union Station, which had fallen into disrepair, was purchased by the city for $1, and renovated to become part of the federal courthouse. A new state history museum was also approved to be constructed adjacent to the train depot. As an incentive to the state to locate a campus downtown, the business community put up $1 million toward redevelopment at the same time they started buying options on the warehouse properties to protect them for a campus.

The campus core consists of four renovated warehouses and the former Snoqualmie Falls Power Company's transformer house, which has been converted into the campus library. The campus plan and the renovations of the Power Company house and warehouses, designed by LMN Architects of Seattle, and architect Charles Moore, earned awards

from the American Institute of Architects.[2]

These historic buildings have kept the old timbers and brick exposed, while newer buildings are being constructed in brick, with attention toward blending in with the historic warehouses that anchor the campus' architecture.

Bringing in the Bustle—Good Planning, Walking, and Light Rail

Good planning and design can have a tremendous effect on the success or failure of a neighborhood. In the case of the University of Washington, Tacoma, the design has contributed toward a thriving area of activity in the streets around campus. There is a seamless transition between campus and the city, and the university even leases out commercial space from the warehouses along Pacific Avenue, which faces Union Station, the State History Museum, and the light rail stop.

Locating retail, coffee shops, eateries and the University bookstore in this corridor has livened up the street considerably with pedestrians. Several other restaurants and pubs are located on the campus, with one restaurant renovating a historic building on campus on its own.

With the University bringing 2,000 students, plus new faculty and staff to the campus, and up to 10,000 students in 10 years, it is adding a large customer base to Tacoma.[3] New condos have been constructed in recent years in close proximity to the school, and several arts and cultural attractions, including Dale Chihuly's Museum of Glass, have opened in this district.

The campus and surrounding areas have become a bustling addition to Tacoma, which only adds to the demand for retail, hotels, housing, and further redevelopment. It is unrecognizable from the empty, crime-filled, and blighted district of twenty years ago.

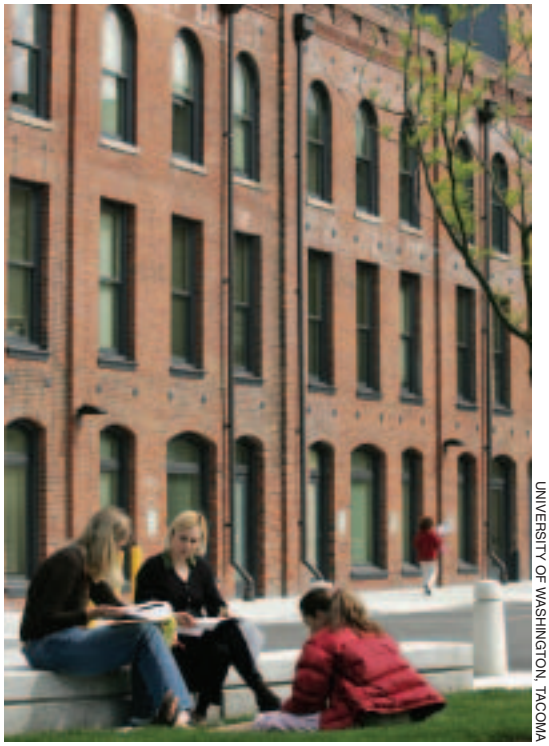
In 2003, Sound Transit's 1.6 mile Light Rail line opened. It travels in front of the campus, through the warehouse district, and connects with Sound Transit's commuter rail line. Already, it is exceeding the ridership that was projected in 2010.[4] Significant pedestrian improvements were made during the process, such as landscaping medians, utility relocation, new sidewalks, benches, trees, lighting, and shelters. This transit connection makes the University easily accessible from commuter rail as well as from other parts of downtown Tacoma.

Taking A Chance

Establishing a new campus in downtown Tacoma was an example of local leaders—primarily businesspeople—getting fed up with an eyesore at the city's gateway, and taking initiative to create a vision, put their own resources into that idea, and then working relentlessly to sell the idea to state and local officials and university administrators.

As Bliss Moore, Chair of the Sierra Club's Tacoma area (Tatoosh) Group explains: "The revitalization of downtown Tacoma over the last 15 years shows how a city can turn itself around. The visionary leadership from public officials, the business community and community at-large have made the proverbial silk purse out of a sow's ear. The transportation system touts the first modern light rail system in the region, carrying employers, employees, visitors, and students to the heart of Tacoma from a well-planned major transportation hub on the edge of town just off the I-5 Interstate. This hub accommodates interstate, regional, and local trains and buses with free public parking."[5]

Public institutions like universities have, in the past, often contributed to sprawl, but increasingly, public entities are beginning to see the multiple benefits of reinvesting in existing urban areas. The partnership between businesses, local and state government, and the University of Washington has created a better Tacoma, reduced crime, increased economic activity, protected historically significant buildings, and created an area where it is easy to walk and use public transportation.



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OREGON
Portland

The Pearl District

SCOTT CHAPMAN

The Pearl District has historically been an industrial area of Portland, Oregon. Today, through redevelopment efforts, this district has been converted into a thriving mixed-use neighborhood with a variety of housing units, shops, and businesses. Many of the buildings are renovated warehouses and factories that long went abandoned until two decades ago. During the 1980s, the Pearl District slowly became a popular destination for artists who were attracted to the abundance of loft space and affordable rent, and proximity to downtown. By the 1990s, private investors were expressing interest in the older warehouses, and soon restaurants and other entertainment venues were moving into the area.

In urban planning circles, Portland has emerged as a model city, at the forefront of creating a vibrant, quality urban environment, and the Pearl District only bolsters its reputation. Jill Fuglister, Executive Director of the Coalition for a Livable Future describes the area: "The Pearl District is a great example of how we can create a marketable, compact, green neighborhood in an already developed area, preserving greenfields and preventing sprawl in other parts of the metro region. Going forward, we will need to make sure that middle and lower income families will always have a place in the Pearl District."[1]

Attractive Housing Options

Currently there is a mix of more than 1,700 condominiums, townhouses, and apartments built since redevelopment efforts began in the area in the 1990s and over 1,500 new housing units planned for the district in the coming years.[2] Importantly, the developments include a mix of incomes, with public investment from the Portland Development Council contributing to a stock of affordable housing units. Over six multi-story apartment buildings, with over 800 affordable units, have been constructed to maintain affordability in the District as well as to balance out the rapid redevelopment underway with a focus on market rate housing.[3]

For now, the demographics of the Pearl District are mostly adults and young couples, however, slowly families are settling into the area, with a few area schools nearby. There is housing designated for seniors, too, contributing to a more diverse neighborhood. For example, REACH Community Development, a local affordable housing provider recently completed building Station Place, a "green" tower of 176 one and two bedroom apartment units for 55-plus individuals, all with incomes at or 30, 50, or 80 percent below median income.[4]

Creating a Pedestrian Environment

The first major redevelopment project within the Pearl District began in 1997 when Hoyt Street Properties bought a former 34-acre rail yard, encompassing 30 blocks.[5] Hoyt Street Developers collaborated with the Portland Development

Commission to relocate a highway ramp that would have divided the neighborhood. Relocation of the ramp also helped to encourage transportation options other than cars in the area, making it a more walkable neighborhood. The rail yard has been transformed into a mixed-use neighborhood with nine different apartment and condominium buildings, some with retail space on the ground level.

Multiple transportation options exist for individuals traveling to or within the Pearl District. TriMet, the regional transit authority, offers free fares to ride light rail or bus within a designated downtown boundary, called "fareless square." This applies to public transportation within some areas of the Pearl District, since part of it overlaps with the downtown zone. In addition, the City of Portland runs a modern streetcar line through the fareless square component of the Pearl District. The District is also extremely conducive to pedestrians, and free walking maps of the neighborhood are available at most shops within the area.

The Pearl District is also home to parks. Jamison Square Park is popular for both residents and those who live elsewhere. Tanner Springs Park celebrated its grand opening in August 2005, and blends the industrial character of the area with natural features. Designed with community input, the park has a wall made of railroad steel, cobblestone paths, and will have a stream running through it. Two additional parks are planned for construction in the Pearl District. Recreational space along the Willamette River is easily accessible from the District as well, with a bridge connecting the Pearl District to the other side of the river in the planning phase.

Saving History, Saving Energy

In 2000, another large-scale redevelopment project in the Pearl District began on the site of a former five-block brewery, called the Brewery Blocks. Gerding/Edlen Development Company bought the historic brew houses, which are being converted into approximately 1.7 million square feet of retail and office space, and new residential buildings that are under construction nearby. Homeownership opportunities in the Brewery Blocks range from approximately $200,000 to over $1 million. Both the historic and new buildings are incorporating environmentally friendly techniques that will provide long-term savings as well as conserve energy. For instance, during the construction phase of the Brewery Blocks, a recycling program diverted 96 percent of construction waste from going to landfills.[6] The latest green energy technology, including windows, lighting, insulation, and solar power are projected to save between 20 and 30 percent of energy costs per year. It is projected that after three years, the extra expenses to buy the "green" materials will be offset by the savings in energy.

Other historic buildings have been rehabilitated in the Pearl District using green building technology. The Jean Vollum Natural Capital Center, which is an office building located in the Pearl District, is a gold-level certified Leadership in Energy and Environmental Design (LEED) building.[7] Its ecoroof will reduce storm water runoff by filtering and absorbing rainwater, and also reduce the urban heat island effect.

SCOTT CHAPMAN

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CALIFORNIA
Windsor

Town Green Village Project

TOWN GREEN VILLAGE, LLP

Guided by concepts of Smart Growth and New Urbanism, the Town of Windsor, in collaboration with a private developer, Orrin Thiessen and Town Green Enterprises, has engaged in a $120 million redevelopment project on 10 acres of property to create a new downtown. The new downtown community, called "Town Green Village Project," began in 2001, and is now in the last phases of development. Phases 1 through 6 of the redevelopment are either complete or nearly complete. The final, seventh, phase in still in the planning stage. A four-acre plaza, serving as a town green for public use, is the focal point for the multiple projects that are taking place in the area.

A New "Old Downtown"

This development is also referred to as "Old Downtown" because, like other new urbanism projects, its premise is a new community design based on traditional neighborhoods and town centers of the past.

Thiessen's buildings are clustered around the focal point of a town green and present a mix of uses, primarily residential, retail, and commercial. The building exteriors are designed based on historic photos of the region.[1] Most buildings are three stories, and offer retail and commercial space on the ground floors, with condominiums and apartments on the top floors. One building is designed for disabled and senior residents. As of April 2004, Thiessen's condos range from $190,000 to $439,000 depending on their size and location, however, most are selling in the $300s. The project includes 250 new residences and 80 to 90 businesses surrounding the plaza.[2] Additionally, the City of Windsor has worked with non-profit developers, Workforce Housing Associates, and Burbank Housing Development Corporation, to build affordable housing units throughout Windsor, many near the green.[3] To enhance the small-town feel of old downtown Windsor, Thiessen has excluded chain stores from moving into any of the retail space. A number of restaurants, clothing, specialty food, music, book stores, and services occupy the store fronts, and—echoing an earlier era—some of the owners live above their businesses.[4]

Transportation Alternatives

Old Downtown is located on an existing rail line. A referendum in 2006 will determine whether commuter rail will come to Windsor and the region. If passed, commuter rail would use the tracks that follow Route 101, and run through Sonoma County into the San Francisco Bay area. A future intermodal center could be built in Windsor to serve commuter rail, and include a regional bus station, a park and ride facility, and that would enhance carpooling opportunities. Today, local and regional buses serve as the public transportation mode for Windsor.

Town Leadership and Developer Collaboration

Town officials in Windsor have clearly expressed their desire to preserve natural areas, which was a key reason they turned toward this project's Smart Growth and New Urbanist design concepts. Thiessen specializes in mixed-use projects and downtown redevelopment. He claims, "I can build on 10 acres what would probably require 50 acres if you developed it using a traditional sprawl model with tract homes and shopping centers."[5] This is Thiessen's focus because he notices the popular trend for people who want to live in places that have real downtowns, not "impersonal subdivisions" where "nobody knows their neighbors and you have to get into your car to do anything at all."[6] This is integral to the Village Green as well as the Town of Windsor's overall vision for their community, which contributed partial funding to build and improve infrastructure and construct the green. Windsor's ability to fund the improvements was made possible using open space monies.[7] The Green also helps bring the natural and built environment together. A linear park will serve as a buffer between the freeway and the town, and create recreational opportunities.

Creating a Better Environment

At the final city council hearing for the seventh phase of the project, the Sierra Club Sonoma Group urged the council to approve the project and countered claims that the project should be reduced in size. The seventh phase, which is located just off downtown, will provide local residents with much needed retail, and will create a mixed-use feel. This is one of the only times the Sierra Club has endorsed a development project like this in Sonoma County.[8]

"I can build on 10 acres what would probably require 50 acres if you developed it using a traditional sprawl model..."

—Orrin Thiessen, developer

TOWN GREEN VILLAGE, LLP

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CALIFORNIA
Oakland

Fruitvale Transit Village Project

BART

Located in the Fruitvale neighborhood in Oakland, California, this redevelopment—which opened in March 2005—sits on a nine acre parcel that was previously a parking lot serving the Fruitvale Bay Area Rapid Transit (BART) station.

A Community Demands Better

Plans to improve this area initially began in 1991, after BART proposed to increase auto capacity to Fruitvale Station by converting the parking lot into a multiple-level parking structure. Fruitvale community members—led by activists from the nonprofit Unity Council local development corporation—opposed the proposal as it would have exacerbated traffic and pollution problems in the neighborhood, as well as create a greater barrier between residents and the transit station. Recognizing that the local BART station was an asset to revitalize and that there was an opportunity to redevelop the neighborhood and economy, the Unity Council took the lead engaging local residents, businesses, and other stakeholders to work toward a better plan. The Unity Council is an organization that for four decades has advocated for the Fruitvale neighborhood and its largely Latino, low-income population on economic and environmental justice issues. In this case, the Unity Council worked with BART and the City of Oakland to facilitate community meetings; the local bus system (AC—or Alameda/Contra Costa—Transit) also became a partner in the discussions, since bus is the essential mode of public transportation for many of the local residents. These meetings led to the creation of a community plan for redevelopment that addresses the needs and concerns of the Fruitvale community in a successful example of Environmental Justice.

Before and After

In stark contrast to the acres of parking lot that existed, the result of the community- based planning process is an award winning, mixed-use, transit-oriented development (TOD). The Fruitvale Transit Village consists of 47 housing units, 40,000

square feet of retail and restaurant space, plus a library, a child care facility, and a health clinic, 114,510 square feet of office space, and two parking garages.[1] An important consideration was given to making the area unique and local, which is reflected in its retail. Only twenty percent of Fruitvale Transit Village's retail is open to national chains, in contrast to so many new developments that offer the same retail fare across the nation.

The 47 housing units help address a shortage of quality housing in the Fruitvale neighborhood area. Ten of the 47 units are designated affordable, while the others are rented at market rate.[2] Some are loft units, however, many have been designed specifically for families. The housing is maintained and managed by the Unity Council, which has a long history and strong track record of housing successes.

Innovative Bicycle and Pedestrian Leadership

Emphasis on pedestrian activity is central to the village, with the community all within walking distance of the BART station. A pedestrian plaza, named Independence Boulevard, runs through the neighborhood, bringing the BART Station and nearby business district together. Restaurants, retail stores, and public art contribute to an attractive streetscape that lines Independence Boulevard. This pedestrian plaza also serves as a public space that hosts a market, neighborhood festivals, and other community-wide events. The Fruitvale community is also served by a dozen AC Transit bus routes, and plans for a Bus Rapid Transit (BRT) service on nearby International Boulevard are underway.

Although there are two parking garages on the outskirts of the village, the City of Oakland passed a zoning ordinance to ban construction of additional automobile parking within the boundaries of the Village in order to "maintain the pedestrian-oriented character of the Transit Village."[3] Over 6,000 passengers use the Fruitvale BART station everyday,[4] and the addition of the Fruitvale Bike Station has encouraged bicycling as an attractive way for commuters and local residents to travel into and within the Transit Village. The bike station is a free, indoor bike storage facility for over 230 bikes, which is supervised during commuter hours. Additionally, the bike station, run by an area bike shop, has on-site retail and repair facilities and stresses local youth employment. The Fruitvale BART station is the second largest bike station in the nation,[5] and the only BART station in the system that offers such bike services.

As the Oakland City Council President, Ignacio De La Fuente noted, "The Fruitvale Transit Village was designed to be on the cutting edge of smart growth projects that get people out of their cars and onto alternative forms of transportation. With the completion of the bike station, the last piece will be in place."[6]

A Model for Others to Follow

This redevelopment at Fruitvale demonstrates the value of community advocacy in local transportation and land use planning. Instead of large scale parking garages surrounding the BART station, the community now enjoys a lively town center that serves residents and encourages bike, pedestrian, and public transportation use. It should be a model for multi-modal development and redevelopment around transit in existing neighborhoods throughout the nation.

BART

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San Mateo CALIFORNIA

Bay Meadows

BAY MEADOWS LAND COMPANY

Bay Meadows is an ambitious two-part development that contains housing, office, and retail in San Mateo, California—a city of 96,000 between San Jose and San Francisco. The plan for Phase I was adopted in 1997, and the project was built several years later. Now, in 2005, the second phase is going through the local planning process. These sites are convenient to rail and reflect "New Urbanist" design in a region that is experiencing significant growth.

Bay Meadows I

The first phase of construction—built on a practice horseracing track adjacent to the actual racetrack which is slated for redevelopment as part of Phase II—is a thriving residential, office, and retail community.

This mixed-use redevelopment includes 734 housing units: 579 condominiums, 98 townhomes, 28 single-family homes, and 27 small lot single-family homes. Ten percent of the housing is moderately priced. The retail component is 98,000 square feet and includes a Whole Foods grocery store, two restaurants, several other eateries and coffee shops, a health club, and small stores. The nearly 750,000 square feet of office space is almost all the headquarters of Franklin Templeton, a mutual fund company that employs 1,247 people at this location.[1] There is still room for the office component to expand by another 340,000 square feet, and a site originally designated for a hotel is likely to instead become a multifamily housing use. The last remaining space in Bay Meadows I, which was slated for a restaurant, is expected instead to become a public use as the site of the City's new police station.

Commuter Rail

All of Bay Meadows I is approximately within a half mile walking distance of the Hillsdale commuter rail station, although due to the configuration of the site, some of the areas are a longer walk, 15 to 20 minutes, rather than the typical 8 to 10 minutes to walk to the station. While the development is close to rail, there is recognition that walking routes to the station could have been done more conveniently. There is hope that even better walking and bike paths will be incorporated into

the development in the future.

The Caltrain "Baby Bullet" commuter rail line, which runs between San Jose and San Francisco, stops at both the Hillsdale station and the Hayward Park station. The proposed Bay Meadows II will be located within the 600 acres that lies between the two stations. In fact, the Hillsdale station will be relocated, which will serve the redevelopment even better, and will help improve rail service by adding sidetracks to help express trains bypass slower trains. The "Baby Bullet" service began its commute hour express service in 2004, and now includes 11 morning and 11 evening weekday trips. The trains travel up to 79 miles per hour, and make the trip between San Jose and San Francisco in less than an hour.

This train service makes housing at Bay Meadows extremely popular, as residents can commute easily and efficiently to either major city—indeed it is an ideal commute for couples who each work in one of the cities. Stephanie Schaaf and Rafael Reyes are one such San Mateo couple. Stephanie explains their situation: "With the Baby Bullet train service, San Mateo is convenient for us. In the morning, I head off to San Jose, while Rafael commutes to San Francisco. We can only imagine that couples like us will find Bay Meadows II, with its proposed stores, and its short walk to the train, to be an ideal place to live in the future."[2]

Bay Meadows II

In order to meet the Transportation Demand Management requirements, this project depends upon commuter rail. If this proposed development were auto oriented rather than transit oriented, it would fail to meet the planning and zoning regulations.

Bay Meadows II will be built upon 83 acres that is currently a horseracing track. This site is next to Bay Meadows I, and located between the Hillsdale and Hayward Park commuter rail stations.

There will be between 1,000 and 1,500 housing units, including a mix of condominiums, townhomes and single family. Ten percent of these housing units will be affordable, moderately priced dwelling units.

Like Phase I, this project will be a "New Urbanist" design with a mix of uses and an emphasis on creating a sense of place and community, rather than a generic development. The walkability of Bay Meadows II to the train station is exceptional, with eighty percent of the site within a quarter mile of the station, and all of it within a half mile.

The office portion of the project will include between a million and 1.5 million square feet, while retail at the site is slated at 150,000 square feet. This retail space will be located on a three-block Main Street area, with traditional design of stores at ground-level and housing above. The plan also includes significant green space with 15 acres of parkland.

As of this report's press time, Bay Meadows II has not yet been formally approved, but it is anticipated. Some of the details that—from an environmental, smart growth perspective—are important for local officials to approve include: building the full 1,500 housing units, ensuring that the parkland will remain at 15 acres, creating more and better pedestrian and bicycle connections (especially those linking Phase I and Phase II of the development), and incorporating more sustainable development methods and efforts to protect water quality.

Forward-looking Design and Planning by Peter Calthorpe

Bay Meadows I and II reflect the design of Peter Calthorpe, one of the nation's leading New Urbanist architects. Calthorpe is a founder and the first Board President of the Congress for New Urbanism, which promotes walkability, mixed uses, and traditional neighborhood design for new development projects. Calthorpe has written and lectured extensively on the subject of urban design, and creating more sustainable communities.

Peter Calthorpe has led the way to better community design among architects in the last quarter century, and is leading the way on the Bay Meadows project.

BAY MEADOWS LAND COMPANY

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Salt Lake City UTAH

Central Business District Extension Project and Gateway Area

MARC HELLESON

Salt Lake City has enjoyed—and continues to enjoy—significant revitalization. Part of the City's redevelopment efforts were sparked by the anticipation of the 2002 Winter Olympics, but now, three years later, Salt Lake City continues on a path of smarter growth.

Two areas that have undergone a transformation, and continue to redevelop, are the Central Business District—which is getting extended—and the Gateway area.

Visionary Leadership

Within the last decade, Salt Lake City has become a leader at creating a vibrant, transit-oriented, livable city. The City opened TRAX, its light rail system, in December 1999, and ridership surpassed all expectations. The Federal Transit Administration estimated that ridership would be 14,000 per day in 2020, but in 1999, there were already 20,000 daily riders on the North-South light rail line.[1] TRAX has been so popular that in 2000, voters approved a tax increase to extend light rail. The City's leadership, non-profit community, business leaders, and environmentalists have promoted redevelopment within Salt Lake City, and a strong public transportation network in order to create a more thriving city.

Several players at the local and state level have made this transformation possible. Envision Utah is a group of business and political leaders, formed in large part by Bob Grow, a local businessman, in 1998. Envision Utah promoted a transparent planning process for the greater Salt Lake City area that looked at different patterns of urban growth, and brought key leaders into the process. Ultimately, the plans that received the most consensus were: 1) those that promoted light rail and commuter rail over roads; 2) those that concentrated development around transit; and 3) those that would redevelop existing urban areas. This process helped establish a blueprint for how the region could best chart a course for the future.

Mayor Rocky Anderson and the Salt Lake City Redevelopment Agency also provided strong leadership and helped focus efforts on revitalizing and contributing toward Salt Lake City's renaissance. The Church of Latter Day Saints is also investing in the city's downtown to the tune of at least $500 million to redevelop a blighted mall in the Central Business District.

Central Business District: An Improved Downtown

Many players, including the Salt Lake City Redevelopment Agency, sought an expansion of the Central Business District (CBD). This area, consid-

ered the "downtown" of Salt Lake City, is home to many of the arts and cultural centers of the region, it is where many office buildings are located, and it is home to the convention center and hotels. The Central Business District is also an area that is home to the Church of Latter Day Saints, and the downtown also has retail and department stores.

Traditionally, however, the CBD has not included housing. To remedy this, the Redevelopment Agency, among others, has been working to add housing to the downtown mix. These efforts are leading to new housing construction as well as warehouse conversions downtown, and it is helping create a more lively area in Salt Lake City. Adding housing in the CBD means that residents can live, work, and play all within a short radius that is easily accessible by walking or light rail. In this decade, over 2,000 new housing units are expected to be added to downtown—that's on top of 960 units that were added in the 1990s.[2] Over 10,000 residents will be living in the Central Business District by 2010.[3] The Redevelopment Agency of Salt Lake City has been focusing low-interest loans on the CBD for housing, and has a specific program for converting warehouses to housing. The arrival of housing in the CBD creates more business for local restaurants and retailers, and reduces the need of residents to drive, lessening traffic and air pollution.

Gateway Area: From Warehouses to Urban, Transit Community

A few blocks from the Central Business District is the 650 acre Gateway Project Area. The Gateway Area is becoming a dense, transit-oriented community, anchored by the new Multimodal Hub. This transit station is on the south side of the Gateway district. Today it serves as a station for buses and Amtrak trains, but it will soon also be a station on the TRAX light rail system, as well as for the new commuter rail line, which broke ground in August 2005. The Multimodal Hub was once the site of the "Am-shack"—a storage facility for Amtrak trains, but now the new facility has many transportation functions, connecting commuters to bus, light rail, inter-city rail, and commuter rail.

For generations, the Gateway area, which is adjacent to Salt Lake City's downtown, was a railyard, warehouse, and industrial area. In recent years, however, the area has been in significant decline. The area was considered a "brownfield" site, with contaminants from oil, gas, and creosote, and including pollutants like barium, lead, chromium, selenium and arsenic. The Salt Lake City Redevelopment Agency worked with the federal Environmental Protection Agency and developers to alleviate these contaminants and redevelop the site.

After receiving federal Economic Development Administration grants, and federal Housing and Urban Development grants, the local Redevelopment Agency was able to help assemble properties for redevelopment.

Today, the redevelopment includes a refurbished, historic Union Pacific Train Depot, which includes retail; a public plaza celebrating the 2002 Olympics; restaurants, culture and entertainment venues—including an IMAX theater and a 12-screen movie multiplex—and a significant mix of uses. There are 650,000 square feet of office and 650,000 square feet of retail space in the Gateway development. It includes 350 apartments and 150 condominiums. Among these residential units, 135 are affordable housing. Other investments in the district include new curbs, gutters, and sidewalks and improvements to create an attractive streetscape.

During the course of the project, concerns were raised about the project potentially drawing department stores away from Main Street. In response to these concerns, several disincentives were built into the leasing of the Gateway's retail space to discourage leasing to Main Street stores.

A Bright Future

Salt Lake City has established priorities and invested in initiatives to create a strong, transit-oriented urban core and a healthy mix of offices, retail, and housing. The City has shown real leadership by making Salt Lake City a livable place.

MARC HELLESON

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NEW MEXICO

Albuquerque

MOULE & POLYZOIDES ARCHITECTS & URBANISTS

East Downtown (EDO) Redevelopment Project

A New, Lively Corridor Again

Many decades ago, the area around Broadway and Central Avenues in Albuquerque was a bustling district, adjacent to the railyard and teeming with activity. Central Avenue, the legendary Route 66, was the main road to California before the interstates came through. Those days had long ago passed this corner of Albuquerque by, and the district had fallen into a strip of budget hotels, odd shops and the vacant buildings of the Old Albuquerque High School campus. But now, Broadway and Central are roaring back, thanks to some visionary leadership and exciting redevelopment.

The redevelopment of the Old Albuquerque High School campus is at the heart of this ambitious project. This area is a short walk from Albuquerque's downtown and only two blocks from the Alvarado Transportation Center. The historic Old Albuquerque High School buildings have been converted to loft-style apartments, condos, and live-work spaces. The original high school building dates to 1914, and several other buildings on its campus were constructed during the New Deal. The school closed in 1974, and historic preservationists are pleased with the adaptation of these grand, brick buildings into productive use.

Transit-oriented

The Alvarado Transportation Center is a hub of transit activity with the "Rail Runner"—New Mexico's new commuter rail line—opening in the fall of 2005, and Albuquerque's planned new light rail system on its way. The light rail will intersect with the Rail Runner Commuter Rail at Alvarado Center, where a new Amtrak station and Greyhound bus depot are being built. Alvarado Center is the hub for ABQRide, Albuquerque's bus system. Service along Central Avenue, through EDO, includes "Rapid Ride" buses, articulated and diesel-electric hybrid powered, that are equipped with red-light signal changing equipment to give priority and shorten bus rides by 25 percent.

Urban Redevelopment

There is significant underused urban space throughout the Broadway and Central corridor, making it ideal for redevelopment. For years, these empty streets have seen only limited economic activity, and there have been very few housing opportunities. Now, with infill development including housing, retail and other economic uses, the area is coming alive. Its proximity to downtown Albuquerque creates a strong pedestrian environment. In addition to more expensive loft housing, there will be mixed-income and affordable housing. More new retail and office space will soon be available as well.

Vision and Community Involvement

In September 2003, Albuquerque put together a five-day planning process for community members and other stakeholders to weigh in with their ideas for the future of the East Downtown area. Several of these meetings were attended by more than 100 to 150 citizens. This process resulted in a common vision for the district, which the Broadway and Central Corridors Association then incorporated into a Master Plan for the area. This was used to develop an Urban Conservation Overlay Zone for the area to enable developers to plan new development that would be what the city and community desired. Part of the strength in redeveloping the East Downtown area has been the involvement and shared vision of stakeholders, making the EDO project as much a product of the community as that of developers.

City Councilor, Eric Griego, discussed the plan for East Downtown: "I think the master plan will promote a dynamic corridor and really encourage redevelopment citywide. I think we will hear from people saying this area is really friendly to pedestrians and local transit ... it's going to bring people back to live in the heart of the city."[1]

Historic Preservation

The East Downtown area is surrounded by the Huning-Highland historic district. Its redevelopment is occurring with a strong effort toward preserving and reusing buildings in a way that enhances the streetscape and creates a welcoming pedestrian environment. Coupled with the conversion of the Old Albuquerque High School into housing as described above, the overall EDO project is a model of historic preservation and revitalization efforts coinciding to make an economically stronger, better, and more vibrant neighborhood.

Making it Happen

These transformations would not have taken place, however, without the support and vision of the Albuquerque City leadership, citizens, business leaders, and developers. Rob Dickson is the owner of Paradigm & Co., the Albuquerque redevelopment firm that is responsible for the conversion of the Old Albuquerque High School. Dickson saw the future in the high school campus and stuck with it for many years. He is in large part responsible for bringing together the public planning process and helping rezone the entire area, rather than pursuing redevelopment on a piecemeal basis. Other leaders in the effort to create a vision for the area included Terry Keane, owner of Artichoke Café, and New Urbanist architect, Stefanos Polyzoides, who led the design team for the EDO redevelopment.

These leaders chose to make the right decisions by reinvesting in existing communities, where buildings, infrastructure and transportation choices are already present. Many developers and other local governments choose to instead make the long-term mistake of growing ever farther outward, increasing traffic congestion, the need for new roads, and the consumption of land. Developer Dickson, architect Polyzoides, business owner Keane, and the City of Albuquerque are helping to create a better, more livable community through their efforts on the East Downtown project; it is clear that the neighborhood will thrive well into the future.

MOULE & POLYZOIDES ARCHITECTS & URBANISTS

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Hopkins MINNESOTA

Excelsior Tech Center Redevelopment and Regency Project

THE BEARD GROUP, INC.

Located 13 miles from the Twin Cities, the City of Hopkins is set apart from its sprawling suburban neighbors through extensive redevelopment efforts that began in the mid-1990s. Many of these efforts are a model of smart growth.

Innovative Land Use

With 98 percent of the town already developed, there is little open space, limiting the options for growth from a "traditional" developer's standpoint. However, making the best use of the already-developed land has been a priority of the City of Hopkins for many years. What has resulted are numerous award-winning redevelopment projects that ensure community design at a human scale, and individual projects that reinforce the rich historic character of the town, making Hopkins a sought-after, desirable place to live.

One developer, the Beard Group, Inc., has engaged in redevelopment efforts that its founder, Bill Beard, considers "oddball stuff." Beard says this because he utilizes land that many others might pass by, since it is not considered prime for development.[1] Most recently, the Beard Group transformed a blighted torpedo factory, the Excelsior Tech Center, into a mixed-use business/industrial center, which consists of a storage warehouse, a juice bottling factory, and office space. All materials in the redevelopment of this building were recycled, which reduced construction costs. In 2004, the redevelopment project was completed and the Excelsior Tech Center was leased at 70 percent. The entire building is 380,000 square feet.

Financing Redevelopment Through Infill

The financing for the Excelsior Tech Center project was unique because it did not require public subsidies, a request typical of developers when they take on projects to transform a blighted property. Abutting the former defense factory were large parking lots, not necessary to support the new businesses in the center. Making the most of this extra property, the Beard Group partnered with Ryland Homes to develop the old lots to accommodate 66

new homes. The revenues from these townhouses, which were built in the first phase of the project, were then used to finance the renovations of the torpedo factory. The only public funding was used to clean up asbestos floor tiles.

Creating a Better Environment and a Short Commute

The new town homes were an immediate success, and each unit sold out quickly. The homes were built based on the existing street grid, which helped create a neighborhood of single-family homes and row houses. Local rain gardens in the neighborhood help manage storm water on the site.

Unlike typical subdivisions, the neighborhood, called Regency, is adjacent to the Excelsior Tech Center, and is connected by a well-landscaped street with adequate sidewalks for pedestrians. Many of the offices in the Excelsior Tech Center are staffed by residents of Regency, making for a short commute and reducing the need for a car. With the infill housing occupying the former parking lot, this redevelopment has taken advantage of a great location and created a community of housing and jobs. Additionally, a trail connects the Regency neighborhood to an extensive trail system through Hopkins, which continues throughout the region, the county, and into Minneapolis. It is important to note, however, that the homes sold at an average of $320,000, so while the homes may be within reach for the tech sector workers, this is not considered affordable housing.

The Hopkins redevelopment is a model for creating new, vibrant neighborhoods from industrial areas of bygone days. The City of Hopkins' Mayor, Eugene Maxwell, aptly observes, "When a developer and the community come together, the smart growth and environmental rewards are enormous."[2]

"When a developer and the community come together, the smart growth and environmental rewards are enormous."

—Hopkins Mayor Eugene Maxwell

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THE BEARD GROUP, INC.

SARB_004830

Milwaukee WISCONSIN

HOUSING AUTHORITY—CITY OF MILWAUKEE

Highland Park: Highland Gardens and Highland Homes

Highland Park—a neighborhood in Milwaukee—is located just northwest of downtown near the corner of West Vliet Street and North 17th Street. Two major projects are taking place in this neighborhood, mainly the dismantling of older housing authority buildings and replacing those dwelling units with better designed Highland Gardens and Highland Homes. Aside from providing better homes for local residents, the revitalization of Highland Park is viewed as an investment aimed at stimulating economic improvements in the city, particularly the commercial district near Highland Park just a few blocks away on West Vliet Street between 11th and 13th Streets.[1] Additionally, 2 blocks south of the neighborhood is Marquette University, which is undergoing a $100 million renovation.[2] Surrounding Highland Park are revitalization projects that will improve the conditions of the entire neighborhood.

Highland Gardens

In November 2004, the City of Milwaukee unveiled the city's first "green" public housing facility, Highland Gardens. This 114-unit building has transformed the property of two derelict high-rise apartment buildings, owned by the Housing Authority, City of Milwaukee (HACM), which previously inhabited the 1.2 acre property. The towers, which were built in 1967 were in poor condition, expensive to maintain, and densely crowded, among other problems. After assessing the property, HACM initiated the Highland Gardens project with the goal of replacing the old units in the high-rises since it was determined it would be more cost effective then renovation. This decision was met with strong community support. The towers, which were built for elderly and disabled residents, have been replaced by the completed four story building, which is 120,000 square feet. There are also a number of family units included in the building. The entire building is accessible for residents with disabilities.

Highland Homes

On the same lot behind the two high-rise towers sat 54 "barracks-style" apartments for large families. Under the same redevelopment scheme as Highland Gardens, Highland Homes are 4 to 5 bedroom homes being built as infill on abandoned and blighted lots donated to HACM by the city. To prevent displacement of the residents living in the "barracks-style" housing, HACM will be constructing 16 low-income rental townhouses and 30 market rate single family homes which have been built on-site, and 40 low-income single family homes within a 3 to 4 mile radius of Highland Park. Of those 40 homes, 18 have been completed and the rest will be finished when the old towers are demolished, so as not to leave anyone without a home.[3] All the new homes will be built for the former residents of the "barracks" and they will have a choice of which plots they would like to live in for the scattered site housing. Additionally, rents will remain at 30 percent of their monthly income, the same as previous rents. Relocation costs

are covered by the federal Department of Housing and Urban Development (HUD).

Environmental Justice

Highland Gardens and Highland Homes are replacing what has been described as a "Superblock" because of its isolation from the rest of the community. Rather than having all dwelling units concentrated within a "superblock," a popular model during Urban Renewal development of four decades ago, one of the overall goals of Highland Park is to create a residential neighborhood by creating streets to reconnect the neighborhood to the city's grid system. This helps develop more community interaction, plus it provides more travel options and provides better pedestrian access. Previously there were only two entrance points into the development from the rest of the city,[4] exacerbating social and economic isolation of residents. The new streets serve as connecting points to downtown and a nearby shopping district. Alderman Willie Hines, chairman of HACM, says the new street plan "will do wonders for the neighborhood. It's a tremendous development opportunity that will integrate public housing into the surrounding community. Before it was an island unto itself."[5] This development provides a mix of public housing—rental and homeownership opportunities throughout Highland Park.

Incorporating Environmental Design and Materials

Highland Gardens is one of the first efforts in an environmental initiative the City of Milwaukee is taking to make it a "greener, cleaner" place to live.[6] The windows, cement, wooden gym floors, and other materials from the two high rises were recycled and used in the construction of Highland Gardens. The most prominent environmental feature of Highland Gardens is the 20,032 square foot, modular green roof, "believed to be the largest vegetated roof on any residential development in the nation."[7] Green roofs are composed of tiles/modules that have plants growing in them to absorb and eliminate the storm water runoff that would otherwise overload the storm and sanitary sewers that eventually drain into Lake Michigan.[8] Other benefits include lower energy consumption since the roof provides strong insulation for the building, and a longer roof life. The green roof is also designed to reduce the amount of heat given off, which helps mitigate poor air quality in the summer months. Two rain gardens that landscape Highland Gardens will also help to deter water runoff.

Highland Homes have also been designed to be more environmental, with energy efficiency an important component of their construction. Some of the features in Highland Homes include energy efficient heating, ventilation and cooling, and windows; soy-based insulation, rain gardens, and rain water that empties to grade rather than into the storm sewer.[9]

Good Planning and Design

HACM is implementing good design practices in the remodeling of the Highland Park neighborhood to improve quality of life by strengthening access to other parts of the city. Local residents were encouraged to participate in planning for Highland Homes and Highland Gardens at a series of public meetings. Many ideas from these meetings were incorporated into neighborhood design.[10] Using New Urbanism principles, Highland Park has been designed to blend in with the surrounding neighborhoods.[11] Entrances enter to sidewalks rather then to parking areas, and the neighborhood is developing with Highland Gardens serving as a recognizable center.[12] Additionally, a local bus hub abuts Highland Park at 17th Street with four major bus lines serving the area.

Developing a neighborhood in this fashion contributes toward making the community a better, more attractive place to live, makes public transportation an efficient option, and reduces the pressure on sprawling outside the city.

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MASSACHUSETTS

Manchester-by-the-Sea

10 and 12 Summer Street

AFFIRMATIVE INVESTMENTS, INC.

Located approximately 30 miles north of Boston, and along the Atlantic Ocean, Manchester-by-the-Sea is an affluent residential community in Massachusetts. On 2.2 acres in the center of town, just a stone's throw from a commuter rail station that travels along the North Shore into Boston, the local housing authority pursued a smart growth project to provide a mixed-income, mixed-use infill project. The affordable housing development is one of the largest ever for Manchester-by-the-Sea, which is among the region's priciest communities.

Affordable Housing, Ideal Location

The two-phase project began with a $2 million renovation of a rundown 21 unit apartment building at 12 Summer Street. Eighteen, or 80 percent of those apartments, have been set aside as long-term affordable rental units. The cost for these units is roughly $962/month for two bedrooms, while the remaining apartments are rented at the market rate of $1375/month.[1] This is significantly less than a private one or two bedroom apartment in the area which rents for $1,500-2,000 per month, not including heat.[2]

Residents of the 12 Summer Street building have been able to move back into the renovated units. These apartment units were completed in the fall of 2003. The second phase of the development which was completed in 2004, is comprised of 18 newly constructed owner-occupied condominiums at 10 Summer Street. Five of these units are set aside for income-qualified first-time homebuyers—the 2-bedroom condos priced and sold for $145,000, and the 3-bedroom condos at $155,000.[3] The remaining units are priced from $325,000 to $450,000.[4] Resale of the condos by these homeowners must be to other income-qualified first-time homebuyers, which will ensure an availability of affordable housing in the area. Previously, this property was solely commercial, now residential units exist above the commercial space.

The People Behind the Development

This project was initiated in 2002 by the Manchester Housing Authority, a public housing

entity chartered by the town of Manchester-by-the-Sea. The housing authority bought the two acre site and then gave the land to the newly established Manchester Affordable Housing Corporation as a non-profit to develop and oversee the project. They worked with Mosture & Associates Architects, Inc., and Affirmative Investment, a Boston based development group.

Traditional Community, Transportation

Like many older New England communities, the village center of Manchester-by-the-Sea is already built on a human scale and is pedestrian friendly. This makes it an ideal setting for a transit-oriented development project. Homes and businesses at 10 and 12 Summer Street are walking distance from the local stores and town services, 1000 yards from the harbor, a mile from a beach, and minutes from public transportation. Though there is adequate parking for the dwelling units, bike riding throughout Manchester-by-the–Sea is a popular mode of transportation. It is also highly encouraged, and there are two volunteer town committees committed to improving the streetscape downtown and to making it more bike and pedestrian friendly.

This project breathed new life into a corner of the town while addressing some of the affordable housing needs in the community. Just as good urban planning is critical to our environment, so is affordable housing. If our workforce cannot afford to live near work, or near public transportation, a whole class of people is essentially pushed into housing farther out, creating more traffic and more sprawl. This redevelopment project in Manchester-by-the-Sea was accomplished while providing an attractive development within an existing community.

"The whole project is really quite ambitious and needed in town" said Regina Villa, President of Manchester Affordable Housing, "It's a great location, across from the train station and grocery store. It's very accessible for people."[5]

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AFFIRMATIVE INVESTMENTS, INC.

SARB_004834

Greensboro NORTH CAROLINA

Southside Neighborhood

CITY OF GREENSBORO, NORTH CAROLINA

Located minutes walking distance from the central business district, one of Greensboro's most historically affluent neighborhoods—Southside—experienced increasing disinvestment and decay after World War II. Starting in the late 1980s, the Greensboro City Council addressed the possibility of redeveloping the Southside neighborhood, which was then considered blighted. At the time it was uncharted territory, but the City of Greensboro foresaw the full potential this neighborhood would have if redeveloped using Smart Growth principles. The City's Community Development Director, Andy Scott, said: "We are using the principles of smart growth to protect and enhance our natural environment. By reusing previously developed land; providing more housing and transportation choices; preserving critical natural areas; and developing vibrant places throughout Greensboro, we are protecting our air, water, and land for future generations to enjoy."[1] Targeting many historic homes and abandoned properties for preservation and renovation, rezoning the district for mixed-use development, and creating a master plan for the district has all resulted in the first mixed-use infill development project in the state, which has received wide recognition, including a Smart Growth award by the federal Environmental Protection Agency.

Location, Location, Location

The location of the Southside neighborhood enhances the redevelopment. In the southern part of downtown, the neighborhood is short distance from the city's historic downtown. Two major bus lines run through the 10-acre neighborhood, and it is walking distance from a multi-modal transportation center that has been recently renovated, bringing together the city buses, intercity buses, coaches, taxis, and intercity rail services.[2] Future plans for the hub include light rail, high-speed rail, a farmers market, and occupied restaurant space.[3] The completion of the transportation center renovation in 2001 was a landmark since it is the first multi-modal transit center in North Carolina, and it marks the city's effort to promote multiple transportation options for Greensboro residents while addressing traffic congestion. A proposed "Rail Yard Park," will run for a mile between the Southside neighborhood and the transportation terminal, creating an easy, safe corridor for pedestrians to travel between public transportation and their residences and work.

New Residences and Stores in a Historic Neighborhood

Following traditional neighborhood design concepts, the redevelopment of Southside is mixed-use and centered around a new town square which serves as a neighborhood park and host to a rotating schedule of public art and community events. Ten historic residences have been restored, while the new buildings, including 30 new single family homes, 10 two-family homes, 50 townhouses, and 20 live/work units with retail space on the ground floor have been constructed with historic facades to blend in with existing homes and enhance the historic character of the neighborhood. These residences sold out completely upon the development's completion,[4] with residents including a mix of young professionals, young couples, retired adults, and a small but growing number of families.[5]

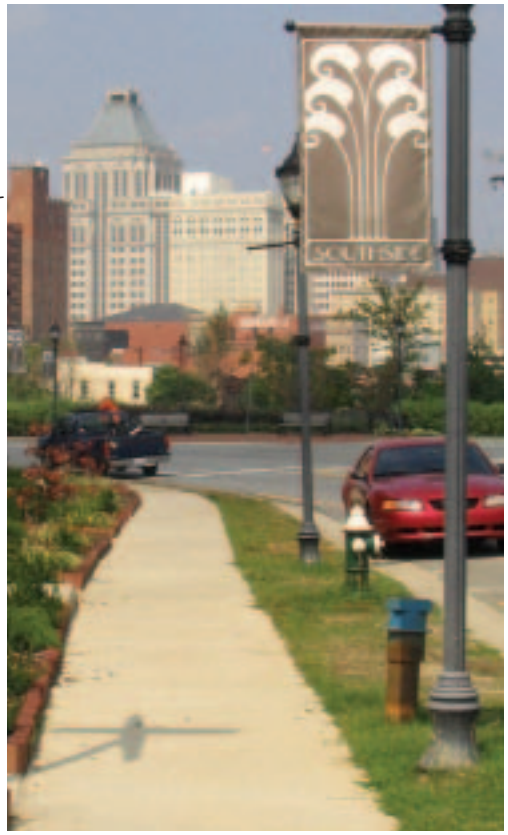
Neighborhood streetscape improvements, such as the addition of trees, sidewalk improvements, and landscaping have contributed to a pedestrian friendly environment, which makes for a better business environment for local retail shops. Southside is a short, 10-minute walk to downtown attractions, including the Children's Museum, Central Library, Carolina Theatre and City Hall.

One resident comments on her neighborhood saying, "Southside was the type of neighborhood we had been searching for—it provides us with the sense of community we crave within walking distance of all the services and amenities downtown has to offer. When we built our house two years ago we felt like urban pioneers, but now, with the neighborhood nearly complete we know we made the right choice."[6]

A Vision for Southside

Revitalization of Southside has been close to twenty years in the making. Discussion began in the 1980s about the potential for the area, and the lack of housing in downtown Greensboro. In 1990, a local redevelopment bond passed to start pursuing work on the neighborhood. A two-year planning process brought together stakeholders including residents of Southside, businesses, historic preservationists, and others. The planning process was completed in 1995, and helped create a blueprint for sensible redevelopment that was acceptable to the community. Construction began in 2000, and today in 2005, the houses have all been sold.

Robert "Nate" Bowman, founder of the Bowman Development Group, based in Huntersville, North Carolina, was the only developer to respond to the City of Greensboro's request for proposals to redevelop Southside. Bowman notes a growing trend "toward moving back downtown even in smaller cities like Greensboro. There have been restaurants and bars built, a new ball park, and a new library. Our urban housing project both supports and takes advantage of that."[7] To create this neighborhood, Bowman teamed up with land-use planner Thomas Low, director of the Charlotte, North Carolina office of Duany Plater-Zyberk & Company Architects and Town Planners, a leading New Urbanist firm. Low specializes in neo-traditional neighborhood design and used his expertise to design the new Southside. From an environmental standpoint there are many benefits to this approach of development. Bowman claims that ensuring walkability for residents is key to a project's success and that "if you design a better place for humans to live, usually by default you're protecting the environment."[8] Bowman has developed other award-winning neighborhood projects, and has been recognized by the Environmental Protection Agency and the Sierra Club for his work in the Vermillion neighborhood in Huntersville, North Carolina.



CITY OF GREENSBORO, NORTH CAROLINA

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GEORGIA Atlanta

Atlantic Station

EDELMAN

Smarter Development in a Sprawling Metropolis

The Atlanta metro region is one of the fastest growing areas in the country. Over 55 acres of open space is bulldozed for development each day in this region, adding to a sprawling metropolis and making Atlanta the least compact metropolitan area in the country.[1] According to a 2002 US Census survey, Atlanta is in the top twenty cities with the longest commutes to work,[2] at an average of 34 miles per day.[3]

While sprawl unfortunately continues, there are also a number of positive development projects taking place within Atlanta's city boundaries. One such project is Atlantic Station, the redevelopment of the former Atlantic Steel Company mill, once the largest employer in Georgia. After almost a century of producing steel on this industrial site, the Atlantic Steel Mill is considered the largest urban brownfield redevelopment in the country, spanning 138 urban acres.

With government encouragement, the master developers of Atlantic Station, Jacoby Development, bought the property in 1997. Since then, efforts have been underway to redevelop the mill into an environmentally sustainable, mixed-use community. Jacoby Development recognized the site of the mill, located in midtown Atlanta near the junctions of Interstates 75 and 85 would be prime for reuse. Observing that desirable urban locations are becoming harder to find, Jacoby has shifted their focus from projects once constructed solely on open space to almost entirely on brownfield redevelopment. The developers have had to undertake extensive remediation efforts in order to clean up the site for redevelopment. While some have criticized the clean up of the old mill, the developer, EPA, and local environmental groups supported the decision to deal with the lowest level toxic residue onsite, rather than ship it to someone else's backyard.

Connecting Atlanta by Foot and by Transit

The east and west parts of midtown Atlanta have long been divided from each other, due to interstates 75 and 85 slicing through the city. With the advent of Atlantic Station, however, the developers quite literally bridged this divide. The 17th Street Bridge, which is 130-feet wide, was constructed and is equipped with bike lanes, sidewalks, two High Occupancy Vehicle lanes (HOV), and four single-occupancy vehicle lanes. This bridge is a vital and convenient pedestrian link from Atlantic Station to the nearby Arts Center

Station of the city's subway system known as the Metropolitan Atlanta Rapid Transit Authority (MARTA). The bridge itself was constructed with flexible funding made possible due to the project's "smart growth" location. Atlantic Station's developers, Jacoby, collaborated with the federal Environmental Protection Agency (EPA) on the bridge project. Because Atlanta failed to meet federal air pollution standards, this bridge was deemed an important link to public transportation which would take cars off the road and reduce air pollution. Making bridge funding available, the EPA noted that the Atlantic Station development would "produce less air pollution than an equivalent amount of development at other likely sites in the region."[4] A fleet of electric shuttles will also serve Atlantic Station and run a free service between the development and the MARTA station.[5] In the spirit of making this development truly transit dependent, parking is limited and priority for parking spaces is made for vans and shared carpool vehicles. Atlantic Station is among the largest scale transit-oriented development project in the nation.

A Place to Live, Work and Shop

Calling itself a "live-work-play community," a large portion of Atlantic Station will be composed of residential units. Currently, 56 townhomes, 347 condominiums, and 231 one- and two-bedroom apartments have been completed, and are almost all occupied. The additional six buildings are under construction and are all set open their doors for occupancy throughout 2006.[6] When the project is fully completed, there will be between 3,000 to 5,000 residential units available and it is expected to have a population of 10,000 residents. There are a number of homeownership and rental options, with a variety of condominiums, townhouses, and apartments on the market. Rental units start at $675/month; some of the ownership condos range from $100,000 to $300,000; lofts begin in the $300,000s, and townhomes range from $385,000 to $700,000. There is a waiting list for the many of the new homes that are available now or in the construction phase, illustrating the high demand for urban living in close proximity to other amenities. Residential properties and rentals are varied, and the people moving to Atlantic Station are diverse: families, young professionals, executives, college students, and married couples all live in Atlantic Station.

There is also a retail component to Atlantic Station, which opened in 2004. Approximately thirty national retailers have stores in Atlantic Station, as well as a dozen or more restaurants. A movie theater is also coming for a total of 1.5 million square feet of retail. Though already functioning, the grand opening for the completion of the retail and entertainment district is set for October 2005. A hotel with 1,000 rooms is expected to open in the winter of 2006. The first commercial tower, 171 17th Street, has been completed, with a 90 percent occupancy rate as of May 2005.[7] It was constructed using LEED standards as a guideline for sustainable design, with a special heat-reflecting roof, water-saving bathrooms, and natural landscaping to conserve water.[8] More office towers are in the planning phase and will similarly be built according to LEED standards,[9] and once completed, Atlantic Station will have 6 million square feet of office space. Additionally, over 2,500 trees have been planted throughout the community, and when the Station is finished there will be 11 acres of green space.

A Smarter Atlanta

Atlantic Station is not perfect, but it is creating good steps in the right direction that will influence the future of Atlanta. Since the high-density residential units have been wildly successful, it shows the demand for urban living. This sets a precedent that can guide future development to provide more housing units in the city. Additionally, city transportation has improved because of Atlantic Station, at little cost to the taxpayer. Jacoby Development made a commitment to pay for the shuttle that will service Atlantic Station and the closest MARTA station, and has connected different points in the city with a choice of transportation options that were previously not easily accessible. This project started dialogue about transportation access in Atlanta and has influenced changes in the way the Georgia Department of Transportation operates.

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7. Atlantic Station Fact Sheet: Retail, Office Commitments. July 2005.
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University of Washington, Tacoma

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UNIVERSITY OF WASHINGTON, TACOMA

Town Green Village Project

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TOWN GREEN VILLAGE, LLP

Highland Park

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HOUSING AUTHORITY—CITY OF MILWAUKEE

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SCOTT CHAPMAN

Salt Lake City

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MARC HEILESON

Atlantic Station

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U.S. Environmental Protection Agency

Polluted Runoff (Nonpoint Source Pollution)

What is NPS Pollution
NPS Categories
Publications & Info Resources
Education Resources
Funding
Outreach
CWA Section 319
CZARA Section 6217
State-EPA NPS Partnership
Training/Meetings

Stormwater Management at EPA Headquarters

The Ariel Rios South Building Courtyard project is part of a larger effort to beautify the EPA Headquarters complex and also demonstrate more environmentally sound building and landscaping techniques. The Facilities Management Division, the Office of Water and the General Services Administration have been working on a plan to exhibit stormwater management techniques, sustainable design and low impact development (LID) at the Federal Triangle complex. We hope that this plan will serve as a model for the federal community and will demonstrate many of the practices that can be employed to mitigate the effects of stormwater runoff and reduce combined sewer overflows into our rivers, streams and coastal waters. It will also demonstrate that sustainable design and LID can be utilized in high profile, urban sites that must pass through rigorous aesthetic design reviews. Some of the techniques that we are demonstrating include:

- low maintenance/native plants
- cisterns to collect and reuse runoff
- bioretention cells (PDF) (134K, About PDFs)
- permeable pavers (PDF) (66K, About PDFs)
- permeable concrete

On this Page

- EPA Stormwater Management
- Project Details
- For More Information
- Project Partners
- Viewing the Project

Quick Links

- Fact Sheet (PDF) — Stormwater Management at EPA Headquarters (4pp, 2MB, About PDFs)
- Questions and Answers (PDF)—EPA Headquarters Low Impact Development Demonstration Project (5pp, 37K, About PDFs)

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Demonstration Project Details

EPA Headquarters is located as part of the larger Federal Triangle Complex (PDF) (135K, About PDFs) in downtown Washington. The demonstration project involves three sites:

Click for PDF version of large map of Federal Triangle Complex

Ariel Rios South Courtyard

At the Federal Triangle Complex's eastern end, the Ariel Rios South Courtyard (PDF) (135K, About PDFs) features two biofilters (often called rain gardens) and permeable concrete and permeable pavers, which allow stormwater to filter into the ground rather than wash off the surface and into storm drains and combined sewers. In addition, the South Courtyard has a cistern to recycle stormwater for irrigation. Sustainable planting is also included in the courtyard landscape. Plants take up stormwater and provide valuable wildlife habitat. Other sustainable best

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management practices include reuse of an historic granite curb as a bench, recycled farm tool plant signs, and recycled glass in the cistern cover and artwork.

Constitution Avenue

The south end of the Federal Triangle Complex is bordered by Constitution Avenue, 12th Street, and 14th Street. Four additional rain gardens are located here (PDF). (135K, About PDFs)

West Building Parking Garage (Planned)
Near the EPA West Building along 14th Street, stormwater runoff will be diverted from the building roof into six 1000 gallon cisterns located in the below grade parking garage (PDF). (45K, About PDFs) Cistern water will be used to irrigate the West Building´s Constitution Avenue planting beds and grass.

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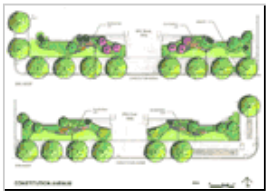
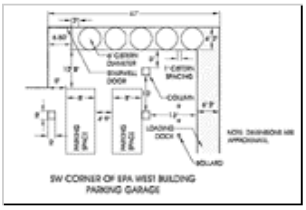
Click for PDF version of larger view of Ariel Rios South Courtyard



Click for PDF version of larger view of Constitution Avenue diagram



Click for PDF version of larger view of West Building Parking Garage Cisterns

More Information

- Fact Sheet (PDF)—Stormwater Management at EPA Headquarters (4pp, 1.6MB, About PDFs)
- Questions and Answers (PDF)—EPA Headquarters Low Impact Development Demonstration Project (5pp, 37K, About PDFs)
- EPA Facilities—Greening EPA
- EPA Office of Water—Low Impact Development
- EPA Office of Water—Green Infrastructure
- National Pollutant Discharge Elimination System (NPDES) LID and Other Green Design Strategies
- Low Impact Development Center EXIT Disclaimer

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Project Partners

This demonstration project is a collaborative effort involving EPA´s Office of Water, the Facilities Management Division of EPA´s Office of Administration and Resources Management, and the General Services Administration. Other partners joined as this project evolved, including the U.S. Commission of Fine Arts, the National Capital Planning Commission, the DC Water and Sewer Authority, and a variety of contractors.

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Viewing the Demonstration Project

If you are interested in more information on the demonstration project or a tour, please contact LIDHQ@epa.gov.

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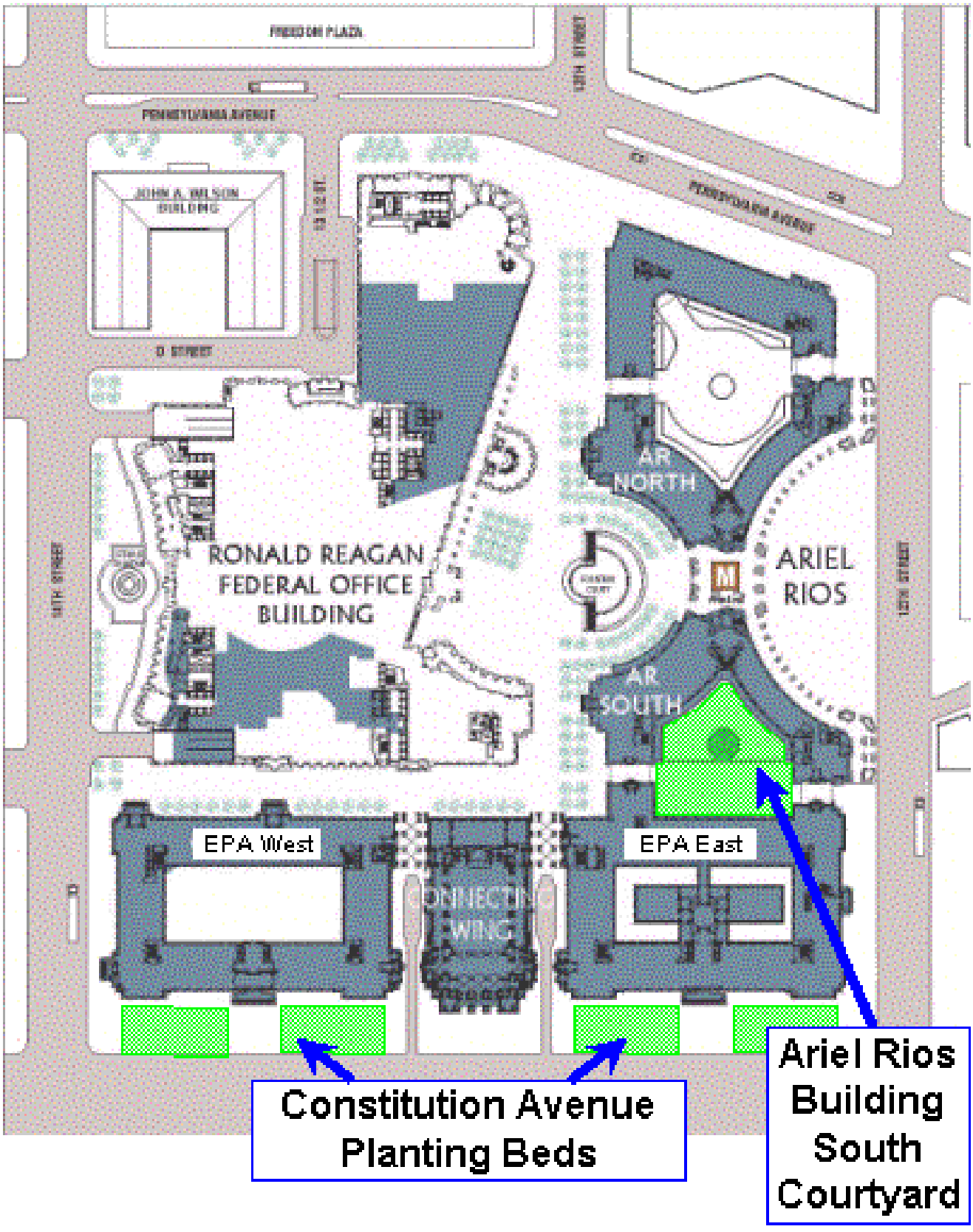
FREEDOM PLAZA
PENNSYLVANIA AVENUE
JOHN A. WILSON BUILDING
D STREET
12TH STREET
13TH STREET
14TH STREET
15TH STREET
RONALD REAGAN FEDERAL OFFICE BUILDING
AR NORTH
ARIEL RIOS
AR SOUTH
EPA West
EPA East
CONNECTING WING
Constitution Avenue Planting Beds
Ariel Rios Building South Courtyard

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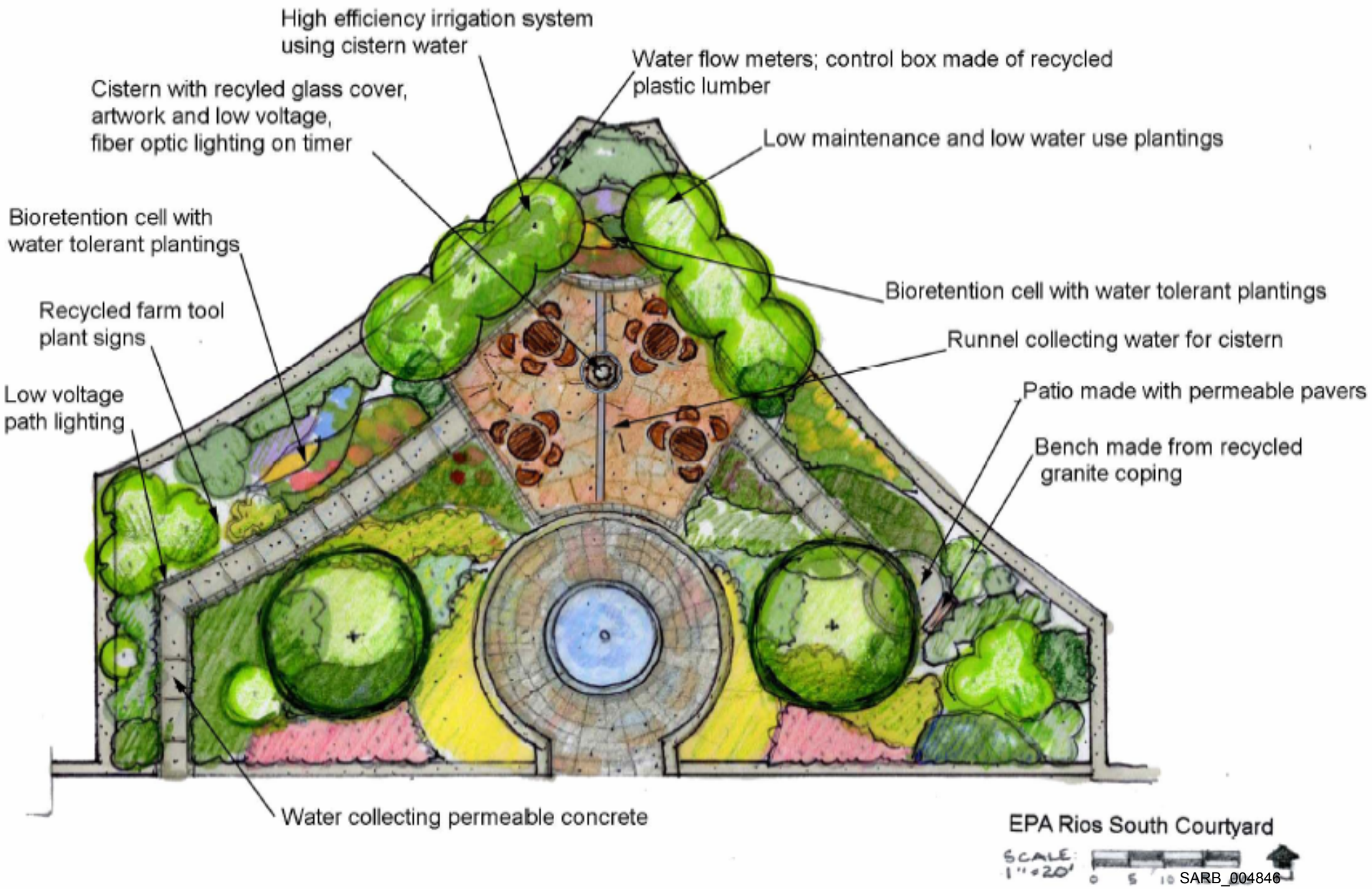
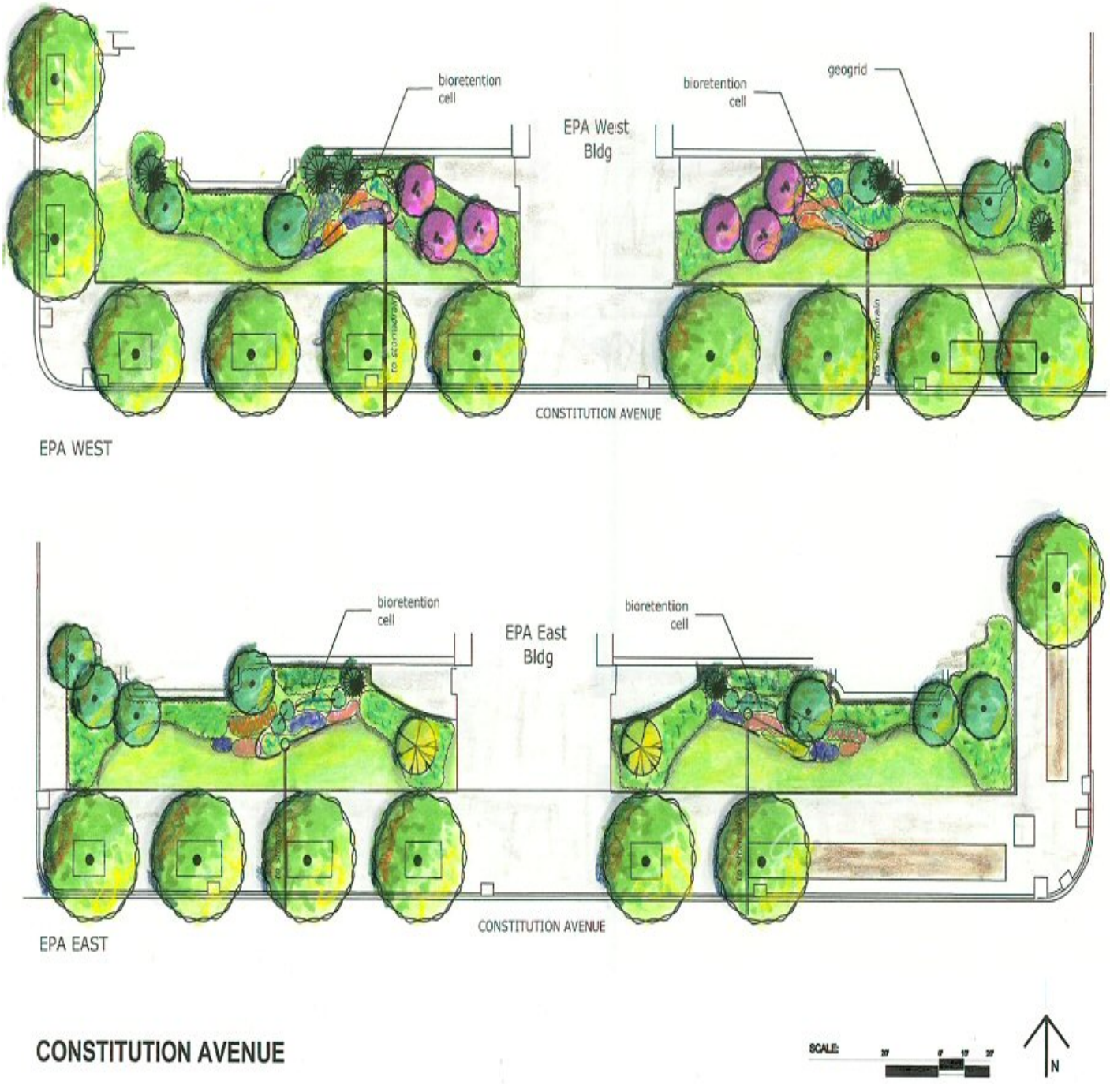
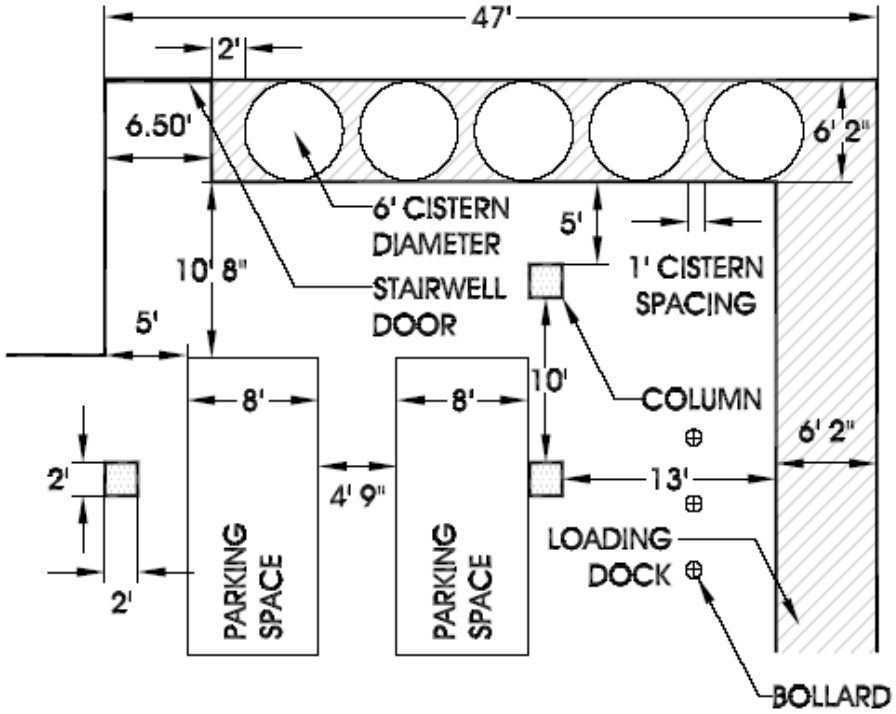
Ariel Rios South Courtyard





Constitution Avenue Bioretention Sites

STORMWATER COLLECTION CISTERNS



NOTE: DIMENSIONS ARE APPROXIMATE.

SW CORNER OF EPA WEST BUILDING
PARKING GARAGE

SCALE 1" = 10'

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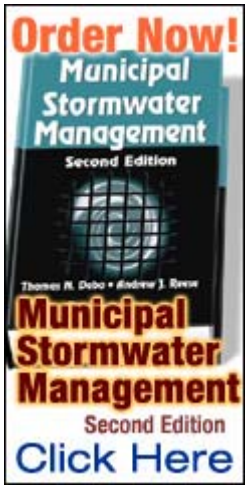

The Journal for Surface Water Quality Professionals
Stormwater

FEATURES

PHOTO:BOB KUEHN, MMSD

From green roofs to pervious pavement to underground treatment, Milwaukee experiments with newer water-quality and flood control measures.

By Mark L. Kass

The Milwaukee Metropolitan Sewerage District (MMSD) and municipalities throughout southeastern Wisconsin have spent more than $300 million in recent years building flood control projects to deal with the aftermath of floods that ravaged the area in 1997 and 1998.

But MMSD and the communities are not stopping there. To help prevent flooding that could occur from future growth, they are implementing several tools to capture stormwater during heavy rains and to prevent it from causing extensive flooding and sewer overflows

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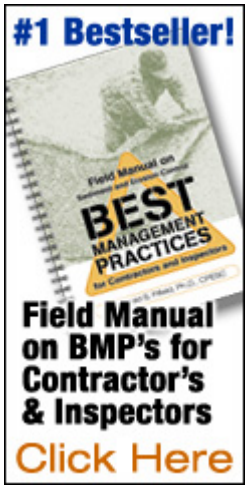

similar to those the area has experienced in the past few years.

"We know we have to do more than just build flood control facilities," explains Kevin Shafer, MMSD executive director, who previously headed the agency's Technical Services Division. "We wanted to be creative and find innovative ways to handle stormwater that have not been tried in Milwaukee in the past. If they work, we are confident others will use them too, and that will help us all."

Demonstrating Underground Treatment Methods

MMSD itself has undertaken several techniques to try and showcase stormwater control methods. The first—and most visible—was the installation of an underground stormwater treatment system at a coffee shop and education center MMSD opened along the Milwaukee side of Lake Michigan in 2002. This system effectively is reducing a broad range of pollutants that drain from the parking lot, including bacteria, petroleum hydrocarbons, metals, and nutrients.

SAVE THIS

The coffee shop is located along the heavily traveled Lake Drive and has hosted several meetings of community and municipal officials to view the system, a StormTreat device purchased through Eco-Cycle Inc. of Manchester, ME. "We are trying to use it as a model to show communities how they can do stormwater management as part of smaller developments," Shafer says. "We've had a lot of interest from the communities we serve who are looking for innovative stormwater control methods to show to developers who come to them and say they can't do stormwater control with their new project."

Comment
On This

The system is centered within a small wetland fringed with plants designed to filter runoff from the property's parking lot. It is intended to capture and treat all runoff from small storms and first-flush runoff from large storms.

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The system uses a multistage total suspended solids removal system to treat the runoff before infiltration. A

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grit filter bag is used to trap the larger floatables that find their way past the catch basin preceding the unit. The system also includes a series of sedimentation chambers fitted with skimmers and a gravel filter that serves as a substrate for constructed wetlands.

Treated stormwater is infiltrated into the 0.75-in. stone used for backfill in the excavation around and under the StormTreat tanks. The stone is highly permeable and transmits the treated water downward until it encounters the parent soils. During heavy rains, the infiltration rate exceeds the permeability of the parent soils, and the stone backfill area serves as a temporary storage reservoir.

"It is the hope of all involved that this project will be a model for what's possible," says Sheila Charnon, MMSD's project manager. "Few public sites exist in greater Milwaukee that clearly demonstrate the values of what [effects] good ‘green' building practices can have on the water environment. The goal in going green on the [project] was to show citizens how to reduce the impact of construction on the environment while still being able to maintain a building's beauty and highlighting its historic features."

Green Roofs

MMSD has also installed a green roof on its four-story headquarters building near downtown Milwaukee. One of the first green roofs in southeastern Wisconsin, it consists of 435 containers holding manmade growing material and dry prairie plant species native to the region. The containers, which measure 2 x 4 ft. and are 4 in. deep, cover about one-third of the building's 11,000-ft.^{2} roof. Each holds about eight plants that will grow to between 12 and 16 in. The green roof also features a walkway built of recycled materials.

Steve McCarthy, MMSD's project manager, notes that the district's project is mainly designed to demonstrate how much rainwater and polluted runoff it can keep out of the sewer system and the rivers. By mimicking natural drainage processes, green roofs can achieve

runoff characteristics similar to open-space conditions and can reduce runoff volumes by 15–90%. Other benefits of green roofs include aesthetics and reduced energy costs and urban temperatures.

"What makes the district's green roof unique is the native species of grasses and flowering plants we've selected and that they're growing in only 4 inches of material," McCarthy says. Other green-roof systems involve installation of a waterproof membrane followed by layers of insulation, drainage filter, soil, and plantings.

The district selected what's known as a "Green Grid" container system because of its easy installation, use of recycled plastics, and ability to be rearranged as needed. Roy F. Weston Inc. of Chicago, IL, performed the installation. The green-roof project cost just more than $69,000.

McCarthy is adding native, dry prairie seeds to the containers to see how well they grow over a period of time. Plants growing on dry bluffs along the Mississippi River in southwestern Wisconsin served as a natural model for species selection, he says. Plantings indigenous to Wisconsin were selected for their ability to withstand the hot and dry summer conditions and other seasonal variations typical of roof installations.

McCarthy says the plantings are expected to provide other advantages:

- A waterproof sheet between the roof and the planters should reduce the wear and tear on the roof, resulting in fewer costly roof repairs.
- Because the plants are in modular containers, they can be moved if there is a need to repair a leak.
- If the green roof catches on in the area, it could lower nearby temperatures with its cooling effect. Because of the urban heat island effect, cities are generally several degrees warmer than areas that have foliage.
- The plants might scare off seagulls, which

generally don't like grassy areas because predators might be lurking there.

Common in Europe for the past several decades, the green roof has been taking off slowly in the United States. Chicago City Hall got considerable kudos for its green roof installed in 2001, but there are other examples, including the Oaklyn Branch Library in Evansville, IN, and the Yorktown Square condominium project in Fairfax, VA, McCarthy notes. In addition, Ford Motor Company is building a 500,000-ft.^{2} green roof at its Rouge River assembly plant in Dearborn, MI, billed as the largest living roof in the world.

One reason building owners are reluctant to build green roofs is a fear that the weight could prove to be too much for the structures. McCarthy says the MMSD project adds only 15 lb./ft.^{2}, well below what most buildings can hold. Even at Chicago City Hall, where the "soil" depth ranges from a few inches to a couple of feet and the plants range from grasses to trees, the maximum weight is only 30 lb./ft.^{2}

The green-roof project is part of the district's Best Management Practices initiative. Shafer launched the initiative as a way to help communities prevent future flooding. The program looks at various methods to reduce or delay the volume of stormwater that can overwhelm the sewer system during periods of heavy rain and contribute to sewer overflows and flooding.

Under the initiative, MMSD provided $454,000 to eight businesses and governments to undertake demonstration projects in the Milwaukee area to highlight the benefits of stormwater best management practices (BMPs) that manage volume, rate, and quality of stormwater runoff.

Two additional green roofs are being undertaken as part of the initiative. The University of Wisconsin-Milwaukee's Great Lakes Water Institute is converting about 10,000 ft.^{2} of its first-floor roof to a vegetated

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green roof, with an accompanying graywater irrigation system. The agency received $110,000 from MMSD for its project.

"We believe that the only limitation for the use of green roofs in our urban areas is education: few people are aware that green roofs are a feasible roofing option," the agency states in its proposal. "The green roof will serve as an educational demonstration both during construction and when completed in order to establish a local base of knowledge for green roof implementation."

The agency will monitor the green roof and an adjacent unconverted roof for temperature, precipitation, runoff volume, and bacterial water-quality indicators, comparing the results to five asphalt roofs in downtown Milwaukee.

In addition, the Urban Ecology Center, a Milwaukee community center, is installing a green roof as part of its new accessible garage roof. The garage is part of a new sustainable, or green, building the group is constructing. The center is receiving $40,000 from MMSD.

Pervious Concrete

The most watched BMP project, however, was the first implementation in the Milwaukee area of pervious concrete, which MMSD did at the coffee shop site. In mid-2003, MMSD installed pervious concrete in a portion of the parking lot to see how it would work in a winter climate.

Shafer says the biggest problem with standard pavement is it doesn't allow water to soak into the ground naturally, where it is cleaned and purified. Instead massive amounts of rainwater and melting snow flow over paved surfaces, collecting everything from engine oil, transmission fluid, and metals to bacteria, garbage, and more.

Porous pavement reduces and slows runoff. Made from concrete, with solid areas that surround smaller

open areas, it allows water to infiltrate the ground. Asphalt porous pavement appears to be one solid surface, but it acts like a sponge. It uses less tar and fewer small particles to create tiny holes in the pavement for draining water.

The first commercial use of the pervious concrete in the Milwaukee area is part of the development of an ice cream and donut shop in Oak Creek, a southern suburb of Milwaukee. Zabest Commercial Group Inc. is including the 0.54-ac. pervious parking lot as part of its 1.23-ac. Dunkin' Donuts and Baskin-Robbins development.

To help fund the project, Zabest and the City of Oak Creek received $79,900 from MMSD. As part of the grant, Zabest has agreed to monitor the effectiveness of the concrete for one year and prepare a final report, fact sheet, and PowerPoint presentation on its effectiveness.

Steve Nikolas, president of Zabest, says the use of the pavement was much more cost-effective than purchasing the land necessary for stormwater detention ponds and then building them. "The incremental cost to acquire additional land to accommodate the above grade stormwater retention, or the costs associated with the underground storage of stormwater, may make such development economically unfeasible," Zabest wrote in its grant proposal to MMSD. "Unlike large parcels where these costs can be spread across the development and pass through to many end users to defray the financial impact, the smaller parcel developments are unable to do so and face a difficult financial obstacle. In many cases, it will preclude development."

In fact, Nikolas estimates that the cost to accommodate underground storage for a 1- to 5-ac. development could be as high as $400,000. Similarly, he says, the cost to purchase an adjacent parcel to accommodate a stormwater detention pond could range from $85,000 to $350,000. "These small parcel developments often do not provide the income to

support these incremental costs," he notes.

Nikolas says Zabest agreed to include the pervious pavement in the development because of frustrations with other stormwater management techniques. As part of its recent 35,000-ft.^{2} retail development on East Capitol Drive in Milwaukee, the developer had to include 2,100 lin. ft. of 12-in. pipe under the parking lot to collect and store runoff. "We decided there had to be a better and more cost-effective way to deal with stormwater," he says.

Although pervious pavement has been used frequently in Florida, Texas, and California, there have been concerns about its uses in cold-weather climates, such as Wisconsin. But Nikolas found that its use in the early 1990s in several developments in Sweden, which he says has a climate similar to Wisconsin, proved to engineers that it could handle freezing temperatures and freeze/thaw cycles. The pavement used in this case is developed by Ecocreto of Texas Inc.

The developer will incorporate several features to deal with cold-weather concerns:

- Installation is in a low-traffic area that will be used only for parking and access.
- Special care will be taken during construction to avoid clogging the pavement, and stormwater runoff will be diverted away from the planned pavement area to further prevent clogging. The pavement will be immediately covered after construction, and no vehicular traffic will be allowed on it for at least seven days after installation.
- The installation will include design features in the subgrade to prevent frost heave.
- Regular maintenance of the pavement, including regular vacuum sweeping and high-pressure washing, will be used to remove any particles.
- A snow removal plan will be implemented but will not include sand, which can clog the porous

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spaces. A designated snow management area on the property will eliminate the need to store snow piles on the pavement.

"The research has shown it should be effective in this climate, and we are confident it will work," states Nikolas. At peak efficiency, the concrete can handle rain up to 4 in./min., he says, adding that even at 60% efficiency, it can handle rain up to 4 in./hr., or the equivalent of a 100-year storm.

City officials will be closely monitoring the project to see if it works and thus can be used by future developments in Oak Creek. "This is not typical stormwater practice, but if it works, I think it has great merit," says Doug Seymour, director of community development for Oak Creek.

The project will also include three rooftop rain gardens, with a combined area of 775 ft.^{2}, or one-third of the contributing rooftop area.

StormTreat System near Lake Michigan

Other Demonstration Projects

Additional BMPs and demonstration projects are being undertaken in Milwaukee. A project to install rain gardens at 17 local automotive recycling facilities received $60,500 from MMSD. The project will demonstrate the application and benefits of installing rain gardens in industrial and commercial settings. The rain gardens will be installed at roof downspouts and engineered to promote

infiltration and plants' uptake of relatively clean rooftop runoff.

"Together with existing best management practices implemented by auto recyclers, rain gardens will become part of an integrated stormwater management approach that addresses both water quantity and water quality," the Automotive Recyclers Cooperative Compliance Program states in its proposal. "These innovative landscape features will help reduce stormwater flow to MMSD's conveyance and treatment systems and to Milwaukee's waterways, create industrial sites that are more attractive places to work, and contribute to improved urban ecological health."

Adds Roger Bannerman of the Wisconsin Department of Natural Resources, "Rain gardens are something you can do to reduce runoff and replenish groundwater—they not only help solve the environmental problems, but they improve the aesthetics of your yard, they can attract wildlife, and they're fun."

Another demonstration project is the incorporation of low-impact development techniques in the site design of the proposed $10 million African American World Culture Center being built in central Milwaukee. The project, which received $44,610 from MMSD, will include a rain garden, grassed swales, a wetlands system, and pavement management techniques to reduce runoff.

Low-impact development design seeks to mimic the natural hydrologic response of undeveloped landscape, using a variety of strategies that integrate natural green spaces with onsite storage. "[The] facility will serve as a living environmental science laboratory that can be used to develop lesson plans and teach children and adults about the benefits of using innovative water-resource practices," William Farmer, a Milwaukee engineer, states in the group's proposal.

The restoration and enlargement of degraded wetlands along Trinity Creek in Mequon, WI, is

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another ongoing project. The wetland system is designed to provide additional floodwater storage, improve water quality, and provide a northern pike spawning habitat. This project received $27,462 from MMSD.

In a rain barrel demonstration project, the Milwaukee Community Service Corps will assemble rain barrels, educate property owners about their use, and conduct demonstration installations in 16 family developments of the Housing Authority of the City of Milwaukee. Rain barrels collect and store rainwater from rooftops to use later for lawn and garden watering. Within the combined sewer area of the City of Milwaukee, water collected in the rain barrels normally would flow through the downspout, onto a paved surface, and into a combined sewer.

And finally, the City of Milwaukee, through its Redevelopment Authority, received $60,061 from MMSD to develop site plans for a stormwater park as part of its redevelopment of Menomonee Valley, an old industrial area near downtown Milwaukee. The park will manage stormwater to improve water quality as well as volume of runoff. The project includes funding for the planning and design phase and for developing and implementing an educational and outreach component.

"We are excited about these projects because we are confident the results will show that they can be used in the Milwaukee area," Shafer says. "We are also very pleased with the enthusiasm shown to try new things for Milwaukee to benefit the residents of this area and reduce the risk of future flooding. The purpose of all of this is also to show the individual property owners that they can help reduce flooding and basement backups by just doing some common sense improvements."

Guest author Mark L. Kass is the former head of media relations for the Milwaukee Metropolitan Sewerage District.

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Appendix B.2

Construction Specifications for Infiltration Practices

B.2.A Infiltration Trench General Notes and Specifications

An infiltration trench may not receive run-off until the entire contributing drainage area to the infiltration trench has received final stabilization.

1. Heavy equipment and traffic shall be restricted from traveling over the proposed location of the infiltration trench to minimize compaction of the soil.

2. Excavate the infiltration trench to the design dimensions. Excavated materials shall be placed away from the trench sides to enhance trench wall stability. Large tree roots must be trimmed flush with the trench sides in order to prevent fabric puncturing or tearing of the filter fabric during subsequent installation procedures. The side walls of the trench shall be roughened where sheared and sealed by heavy equipment.

3. A Class "C" geotextile or better (see Section 24.0, Material Specifications, 1994 Standards and Specifications for Soil Erosion and Sediment Control, MDE, 1994) shall interface between the trench side walls and between the stone reservoir and gravel filter layers. A partial list of non-woven filter fabrics that meet the Class "C" criteria follows. Any alternative filter fabric must be approved by the plan approval authority.

Amoco 4552	Carthage FX-80S
GEOLON N70	Mirafi 180-N
WEBTEC N07	

   The width of the geotextile must include sufficient material to conform to trench perimeter irregularities and for a 6-inch minimum top overlap. The filter fabric shall be tucked under the sand layer on the bottom of the infiltration trench for a distance of 6 to 12 inches. Stones or other anchoring objects should be placed on the fabric at the edge of the trench to keep the trench open during windy periods. When overlaps are required between rolls, the uphill roll should lap a minimum of 2 feet over the downhill roll in order to provide a shingled effect.

4. If a 6 inch sand filter layer is placed on the bottom of the infiltration trench, the sand for the infiltration trench shall be washed and meet AASHTO-M-43, Size No. 9 or No. 10. Any alternative sand gradation must be approved by the plan approval authority.

5. The stone aggregate should be placed in a maximum loose lift thickness of 12 inches. The gravel (rounded "bank run" gravel is preferred) for the infiltration trench shall be washed and meet one of the following AASHTO-M-43, Size No. 2 or No. 3.

6. Following the stone aggregate placement, the filter fabric shall be folded over the stone aggregate to form a 6-inch minimum longitudinal lap. The desired fill soil or stone

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aggregate shall be placed over the lap at sufficient intervals to maintain the lap during subsequent backfilling.

7. Care shall be exercised to prevent natural or fill soils from intermixing with the stone aggregate. All contaminated stone aggregate shall be removed and replaced with uncontaminated stone aggregate.

8. Voids may occur between the fabric and the excavation sides shall be avoided. Removing boulders or other obstacles from the trench walls is one source of such voids. Therefore, natural soils should be placed in these voids at the most convenient time during construction to ensure fabric conformity to the excavation sides.

9. Vertically excavated walls may be difficult to maintain in areas where soil moisture is high or where soft cohesive or cohesionless soils are dominant. These conditions may require laying back of the side slopes to maintain stability.

10. PVC distribution pipes shall be Schedule 40 and meet ASTM-D-1785. All fittings shall meet ASTM-D-2729. Perforations shall be 3/8 inch in diameter. A perforated pipe shall be provided only within the infiltration trench and shall terminate 1 foot short of the infiltration trench wall. The end of the PVC pipe shall be capped. **Note:** PVC pipe with a wall thickness classification of SDR-35 meeting ASTM-D-3034 is an acceptable substitute for the Schedule 40 pipe.

11. The observation well is to consist of 6-inch diameter perforated PVC Schedule 40 pipe (M 278 OR F758, Type PS 28) with a cap set 6 inches above ground level and is to be located near the longitudinal center of the infiltration trench. The pipe shall have a plastic collar with ribs to prevent rotation when removing the cap. The screw top lid shall be a cleanout with a locking mechanism or special bolt to discourage vandalism. The depth to the invert shall be marked on the lid. The pipe shall be placed vertically within the gravel portion of the infiltration trench and a cap provided at the bottom of the pipe. The bottom of the cap shall rest on the infiltration trench bottom.

12. Corrugated metal distribution pipes shall conform to AASHTO-M-36, and shall be aluminized in accordance with AASHTO-M-274. Aluminized pipe in contact with concrete shall be coated with an inert compound capable of preventing the deleterious effect of the aluminum on the concrete. Perforated distribution pipes shall conform to AASHTO-M-36, Class 2 and shall be provided only within the infiltration trench and shall terminate 1 foot short of the infiltration trench wall. An aluminized metal plate shall be welded to the end of the pipe.

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13. If a distribution structure with a wet well is used, a 4-inch drain pipe shall be provided at opposite ends of the infiltration trench distribution structure. Two (2) cubic feet of porous backfill meeting AASHTO-M-43, Size No. 57 shall be provided at each drain.

14. If a distribution structure is used, the manhole cover shall be bolted to the frame.

B.2.B Infiltration Basins Notes and Specifications

An infiltration basin may not receive run-off until the entire contributing drainage area to the basin has received final stabilization.

1. The sequence of various phases of basin construction shall be coordinated with the overall project construction schedule. A program should schedule rough excavation of the basin with the rough grading phase of the project to permit use of the material as fill in earthwork areas. The partially excavated basin, however, **cannot** serve as a sedimentation basin.

   Specifications for basin construction should state: (1) the earliest point in progress when storm drainage may be directed to the basin, and (2) the means by which this delay in use is to be accomplished. Due to the wide variety of conditions encountered among projects, each should be separately evaluated in order to postpone use as long as is reasonably possible.

2. Initial basin excavation should be carried to within 2 feet of the final elevation of the basin floor. Final excavation to the finished grade should be deferred until all disturbed areas on the watershed have been stabilized or protected. The final phase excavation should remove all accumulated sediment. Relatively light tracked equipment is recommended for this operation to avoid compaction of the basin floor. After the final grading is completed, the basin should provide a well-aerated, highly porous surface texture.

3. Infiltration basins may be lined with a 6- to 12-inch layer of filter material such as coarse sand (AASHTO-M-43, Sizes 9 or 10) to help prevent the buildup of impervious deposits on the soil surface. The filter layer can be replaced or cleaned when it becomes clogged. When a 6-inch layer of coarse organic material is specified for discing (such as hulls, leaves, stems, etc.) or spading into the basin floor to increase the permeability of the soils, the basin floor should be soaked or inundated for a brief period, then allowed to dry subsequent to this operation. This induces the organic material to decay rapidly, loosening the upper soil layer.

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4. Establishing dense vegetation on the basin side slopes and floor is recommended. A dense vegetative stand will not only prevent erosion and sloughing, but will also provide a natural means of maintaining relatively high infiltration rates. Erosion protection of inflow points to the basin shall also be provided.

5. Selection of suitable vegetative materials for the side slope and all other areas to be stabilized with vegetation and application of soil amendments (e.g., lime, fertilizer, etc.) shall be done in accordance with the NRCS Standards and Specifications for Critical Area Planting (MD-342) or the 1994 Maryland Standards and Specifications for Soil Erosion and Sediment Control.

6. Grasses of the fescue family are recommended for seeding primarily due to their adaptability to dry sandy soils, drought resistance, hardiness, and ability to withstand brief inundations. The use of fescues will also permit long intervals between mowings. This is important due to the relatively steep slopes which make mowing difficult. Mowing twice a year, once in June and again in September, is generally satisfactory. Refertilization with 10-6-4 ratio fertilizer at a rate of 500 lb per acre (11 lb per 1000 sq ft) may be required the second year after seeding.

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Appendix B.3

Construction Specifications for Sand Filters, Bioretention and Open Channels

B.3.A Sand Filter Specifications

1. Material Specifications for Sand Filters

The allowable materials for sand filter construction are detailed in Table B.3.1.

2. Sand Filter Testing Specifications

Underground sand filters, facilities within sensitive groundwater aquifers, and filters designed to serve urban hot spots are to be tested for water tightness prior to placement of filter media. Entrances and exits should be plugged and the system completely filled with water to demonstrate water tightness. Water tightness means no leakage for a period of 8 hours.

All overflow weirs, multiple orifices and flow distribution slots are to be field-tested to verify adequate distribution of flows.

3. Sand Filter Construction Specifications

Provide sufficient maintenance access (i.e., 12-foot-wide road with legally recorded easement). Vegetated access slopes are to be a maximum of 10%; gravel slopes to 15%; paved slopes to 25%.

Absolutely no runoff is to enter the filter until all contributing drainage areas have been stabilized.

Surface of filter bed is to be level.

All underground sand filters should be clearly delineated with signs so that they may be located when maintenance is due.

Surface sand filters may be planted with appropriate grasses; see Appendix A.

"Pocket" sand filters (and residential bioretention facilities treating areas larger than an acre) shall be sized with a stone "window" that covers approximately 10% of the filter area. This "window" shall be filled pea gravel (3/4 inch stone).

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4. Specifications Pertaining to Underground Sand Filters (F-2)

Provide manhole and/or grates to all underground and below grade structures. Manholes shall be in compliance with standard specifications for each county but diameters should be 30" minimum (to comply with OSHA confined space requirements). Aluminum and steel louvered doors are also acceptable. Ten inch wide (minimum) manhole steps (12" o.c.) shall be cast in place or drilled and mortared into the wall below each manhole. A 5' minimum height clearance (from the top of the sand layer to the bottom of the upper/surface slab) is required for all permanent underground structures. Lift rings are to be supplied to remove/replace top slabs on pre-fabricated structures. Manhole covers should allow for proper ventilation.

Underground sand filters should be constructed with a gate valve located just above the top of the filter bed for dewatering in the event that clogging occurs.

Underground sand beds shall be protected from trash accumulation by a wide mesh geotextile screen to be placed on the surface of the sand bed; screen is to be rolled up, removed, cleaned and re-installed during maintenance operations.

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Table B.3.1 Material Specifications for Sand Filters

Material	Specification/Test Method	Size	Notes
sand	clean AASHTO-M-6 or ASTM-C-33 concrete sand	0.02" to 0.04"	Sand substitutions such as Diabase and Graystone #10 are not acceptable. No calcium carbonated or dolomitic sand substitutions are acceptable. No "rock dust" can be used for sand.
peat	ash content: < 15% pH range: 5.2 to 4.9 loose bulk density 0.12 to 0.15 g/cc	n/a	The material must be reed-sedge hemic peat, shredded, uncompacted, uniform, and clean.
leaf compost		n/a	
underdrain gravel	AASHTO-M-43	0.375" to 0.75"	
geotextile fabric (if required)	ASTM-D-4833 (puncture strength - 125 lb.) ASTM-D-4632 (Tensile Strength - 300 lb.)	**0.08"** thick equivalent opening size of #80 sieve	Must maintain 125 gpm per sq. ft. flow rate. Note: a 4" pea gravel layer may be substituted for geotextiles meant to "separate" sand filter layers.
impermeable liner (if required)	ASTM-D-4833 (thickness) ASTM-D-412 (tensile strength 1,100 lb., elongation 200%) ASTM-D-624 (Tear resistance - 150 lb./in) ASTM-D-471 (water adsorption: +8 to -2% mass)	30 mil thickness	Liner to be ultraviolet resistant. A geotextile fabric should be used to protect the liner from puncture.
underdrain piping	F 758, Type PS 28 or AASHTO-M-278	4" - 6" rigid schedule 40 PVC or SDR35	3/8" perf. @ 6" on center, 4 holes per row; minimum of 3" of gravel over pipes; not necessary underneath pipes
concrete (cast-in-place)	MSHA Standards and Specs. Section 902, Mix No. 3, f'_c = 3500 psi, normal weight, air-entrained; re-inforcing to meet ASTM-615-60	n/a	on-site testing of poured-in-place concrete required: 28 day strength and slump test; all concrete design (cast-in-place or pre-cast) *not using previously approved State or local standards* requires design drawings sealed and approved by a professional structural engineer licensed in the State of Maryland
concrete (pre-cast)	per pre-cast manufacturer	n/a	SEE ABOVE NOTE
non-rebar steel	ASTM A-36	n/a	structural steel to be hot-dipped galvanized ASTM-A-123

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B.3.B Specifications for Bioretention

1. Material Specifications

The allowable materials to be used in bioretention area are detailed in Table B.3.2.

2. Planting Soil

The soil shall be a uniform mix, free of stones, stumps, roots or other similar objects larger than two inches. No other materials or substances shall be mixed or dumped within the bioretention area that may be harmful to plant growth, or prove a hindrance to the planting or maintenance operations. The planting soil shall be free of Bermuda grass, Quackgrass, Johnson grass, or other noxious weeds as specified under COMAR 15.08.01.05.

The planting soil shall be tested and shall meet the following criteria:

pH range	5.2 - 7.0
organic matter	1.5 - 4% (by weight)
magnesium	35 lb./ac
phosphorus (phosphate - P_2O_5)	75 lb./ac
potassium (potash - K_2O)	85 lb./ac
soluble salts	not to exceed 500 ppm

All bioretention areas shall have a minimum of one test. Each test shall consist of both the standard soil test for pH, phosphorus, and potassium and additional tests of organic matter, and soluble salts. A textural analysis is required from the site stockpiled topsoil. If topsoil is imported, then a texture analysis shall be performed for each location where the top soil was excavated.

Since different labs calibrate their testing equipment differently, all testing results shall come from the same testing facility.

Should the pH fall out of the acceptable range, it may be modified (higher) with lime or (lower) with iron sulfate plus sulfur.

3. Compaction

It is very important to minimize compaction of both the base of the bioretention area and the required backfill. When possible, use excavation hoes to remove original soil. If bioretention

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areas are excavated using a loader, the contractor should use wide track or marsh track equipment, or light equipment with turf type tires. Use of equipment with narrow tracks or narrow tires, rubber tires with large lugs, or high pressure tires will cause excessive compaction resulting in reduced infiltration rates and is not acceptable. Compaction will significantly contribute to design failure.

Compaction can be alleviated at the base of the bioretention facility by using a primary tilling operation such as a chisel plow, ripper, or subsoiler. These tilling operations are to refracture the soil profile through the 12 inch compaction zone. Substitute methods must be approved by the engineer. Rototillers typically do not till deep enough to reduce the effects of compaction from heavy equipment.

Rototill 2 to 3 inches of sand into the base of the bioretention facility before backfilling the optional sand layer. Pump any ponded water before preparing (rototilling) base.

When backfilling the topsoil over the sand layer, first place 3 to 4 inches of topsoil over the sand, then rototill the sand/topsoil to create a gradation zone. Backfill the remainder of the topsoil to final grade.

When backfilling the bioretention facility, place soil in lifts 12" to 18". Do not use heavy equipment within the bioretention basin. Heavy equipment can be used around the perimeter of the basin to supply soils and sand. Grade bioretention materials with light equipment such as a compact loader or a dozer/loader with marsh tracks.

4. Plant Material

Recommended plant material for bioretention areas can be found in Appendix A, Section A.2.3.

5. Plant Installation

Mulch should be placed to a uniform thickness of 2" to 3". Shredded hardwood mulch is the only accepted mulch. Pine mulch and wood chips will float and move to the perimeter of the bioretention area during a storm event and are not acceptable. Shredded mulch must be well aged (6 to 12 months) for acceptance.

Root stock of the plant material shall be kept moist during transport and on-site storage. The plant root ball should be planted so $1/8^{th}$ of the ball is above final grade surface. The diameter of the planting pit shall be at least six inches larger than the diameter of the planting ball. Set and maintain the plant straight during the entire planting process. Thoroughly water ground bed cover after installation.

Trees shall be braced using 2" by 2" stakes only as necessary and for the first growing season only. Stakes are to be equally spaced on the outside of the tree ball.

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Grasses and legume seed should be drilled into the soil to a depth of at least one inch. Grass and legume plugs shall be planted following the non-grass ground cover planting specifications.

The topsoil specifications provide enough organic material to adequately supply nutrients from natural cycling. The primary function of the bioretention structure is to improve water quality. Adding fertilizers defeats, or at a minimum, impedes this goal. Only add fertilizer if wood chips or mulch are used to amend the soil. Rototill urea fertilizer at a rate of 2 pounds per 1000 square feet.

6. Underdrains

Underdrains are to be placed on a 3'-0" wide section of filter cloth. Pipe is placed next, followed by the gravel bedding. The ends of underdrain pipes not terminating in an observation well shall be capped.

The main collector pipe for underdrain systems shall be constructed at a minimum slope of 0.5%. Observation wells and/or clean-out pipes must be provided (one minimum per every 1000 square feet of surface area).

7. Miscellaneous

The bioretention facility may not be constructed until all contributing drainage area has been stabilized.

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Table B.3.2 Materials Specifications for Bioretention

Material	Specification	Size	Notes
Plantings	see Appendix A, Table A.4	n/a	plantings are site-specific
planting soil [2.5' to 4' deep]	sand 35 - 60% silt 30 - 55% clay 10 - 25%	n/a	USDA soil types loamy sand, sandy loam or loam
mulch	shredded hardwood		aged 6 months, minimum
pea gravel diaphragm and curtain drain	pea gravel: ASTM-D-448 ornamental stone: washed cobbles	pea gravel: No. 6 stone: 2" to 5"	
geotextile	Class "C" - apparent opening size (ASTM-D-4751), grab tensile strength (ASTM-D-4632), puncture resistance (ASTM-D-4833)	n/a	for use as necessary beneath underdrains only
underdrain gravel	AASHTO M-43	0.375" to 0.75"	
underdrain piping	F 758, Type PS 28 or AASHTO M-278	4" to 6" rigid schedule 40 PVC or SDR35	3/8" perf. @ 6" on center, 4 holes per row; minimum of 3" of gravel over pipes; not necessary underneath pipes
poured in place concrete (if required)	MSHA Mix No. 3; f'_c = 3500 psi @ 28 days, normal weight, air-entrained; reinforcing to meet ASTM-615-60	n/a	on-site testing of poured-in-place concrete required: 28 day strength and slump test; all concrete design (cast-in-place or pre-cast) *not using previously approved State or local standards* requires design drawings sealed and approved by a professional structural engineer licensed in the State of Maryland - design to include meeting ACI Code 350.R/89; vertical loading [H-10 or H-20]; allowable horizontal loading (based on soil pressures); and analysis of potential cracking
sand [1' deep]	AASHTO-M-6 or ASTM-C-33	0.02" to 0.04"	Sand substitutions such as Diabase and Graystone #10 are not acceptable. No calcium carbonated or dolomitic sand substitutions are acceptable. No "rock dust" can be used for sand.

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B.3.C Specifications for Open Channels and Filter Strips

1. Material Specifications

The recommended construction materials for open channels and filter strips are detailed in Table B.3.3.

2. Dry Swales

Permeable soil mixture (20" to 30" deep) should meet the bioretention "planting" soil specifications.

Check dams, if required, shall be placed as specified.

System to have 6" of freeboard, minimum above 2 year water surface elevation.

Side slopes to be 3:1 maximum; (4:1 or flatter is preferred).

No gravel or perforated pipe is to be placed under driveways.

Bottom of facility to be above the seasonally high water table per Table 2 of Appendix D.1.

Seed with flood/drought resistant grasses; see Appendix A, Section 2.4.

Longitudinal slope to be 4%, maximum.

Bottom width to be 8' maximum to avoid braiding; larger widths may be used if proper berming is supplied. Width to be 2' minimum.

3. Wet Swales

Follow above information for dry swales, with the following exceptions: the seasonally high water table may inundate the swale; but not above the design bottom of the channel [NOTE: if the water table is stable within the channel, the WQ_v storage may start at this point – see Figure 3.19]

Excavate into undisturbed soils; do not use an underdrain system.

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4. Filter Strips

Construct pea gravel diaphragms 12" wide, minimum, and 24" deep minimum.

Pervious berms to be a sand/gravel mix [sand (35-60%), silt (30-55%), and gravel (10-25%)]. Berms to have overflow weirs with 6 inch minimum head.

Slope range to be 2% minimum to 6% maximum.

5. Plant Selection

Recommended grass species for use in establishing permanent ground cover are provided in Section 2.4 of Appendix A.

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Table B.3.3 Open Channel Systems and Filter Strip Materials Specifications

Material	Specification	Size	Notes
dry swale soil	USCS; ML, SM, SC	n/a	soil with a higher percent organic content is preferred
dry swale sand	ASTM C-33 fine aggregate concrete sand	0.02” to 0.04”	
check dam (pressure treated)	AWPA Standard C6	6” by 6” or 8” by 8”	do not coat with creosote; embed at least 3’ into side slopes
check dam (natural wood)	Black Locust, Red Mulberry, Cedars, Catalpa, White Oak, Chestnut Oak, Black Walnut	6” to 12” diameter; notch as necessary	do not use the following, as these species have a predisposition towards rot: Ash, Beech, Birch, Elm, Hackberry, hemlock, Hickories, Maples, Red and Black Oak, Pines, Poplar, Spruce, Sweetgum, Willow
filter strip sand/gravel pervious berm	sand: per dry swale sand gravel; AASHTO M-43	sand: 0.02” to 0.04” gravel: ½” to 1”	mix with approximately 25% loam soil to support grass cover crop; sand (35-60%), silt (30-55%), and gravel (10-25%) see Bioretention planting soil notes for more detail.
pea gravel diaphragm and curtain drain	ASTM D 448	varies (No. 6) or (1/8” to 3/8”)	use clean bank-run gravel
underdrain gravel	AASHTO M-43	0.25” to 0.75”	
underdrain	F 758 Type PS 28 or AASHTO M-278	4” to 6” rigid schedule 40 PVC or SDR35	3/8” perf. @ 6” on center, 4 holes per row; minimum of 3” of gravel over pipes; not necessary underneath pipes
geotextile	Class “C” - apparent opening size (ASTM-D-4751), grab tensile strength (ASTM-D-4632), puncture resistance (ASTM-D-4833)	n/a	
rip rap	per county criteria; if none given, use MSHA Standards and Specs Section 905	size per county DOT requirements based on 10-year design flows	

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Appendix C.1

Design Example 1 – Shallow Wetland (W-1)

Design Example 1 – Shallow Wetland (W-1)

The following example demonstrates the process for the design of a shallow wetland (W-1) BMP.

Site Specific Data

Clevenger Community Center is a recreational center located in Charles County, Maryland. The site area and drainage area to the proposed stormwater management facility is 5.3 acres. The project consists of constructing the community center and parking for a total impervious area of 1.94 acres. Existing ground at the outlet of the facility is 44.5' above mean sea level (MSL). Soil borings indicate that the seasonally high water table is at elevation 41'. The underlying soils are loams. TR-55 calculations for the existing and developed hydrologic conditions are shown in Figures C.1.2 and C.1.3.

Confirm Design Criteria

The site is within the Eastern Rainfall Zone and located on the Western Shore of the Chesapeake Bay (see Volume I, Chapter 2, Figures 2.1 and 2.4). Additionally, the site is located within a USE I watershed. Therefore, the following criteria apply:

1. WQ_v treatment is required. In the Eastern Rainfall Zone, P = 1".
2. Re_v treatment is required.
3. Cp_v treatment is required.
4. Q_{p10} may be required by the local jurisdiction. For this example, Q_{p10} will be required.
5. Q_f may be required by the local jurisdiction. For this example, Q_f will not be required. However, safe conveyance of the 100-year design storm is required through the proposed stormwater management facility.

Preliminary Design

Step 1. Compute WQ_v

Step 1a. Compute Volumetric Runoff Coefficient (R_v)

R_v = 0.05 + (0.009)(I); I = 1.94 acres / 5.3 acres = 0.366 or 36.6%
= 0.05 + (0.009)(36.6) = 0.379

Step 1b. Compute WQ_v

WQ_v = [(P)(R_v)(A)]/12
= [(1")(0.379)(5.3 ac)]/12
= 0.167 ac-ft (7,292 cf.)

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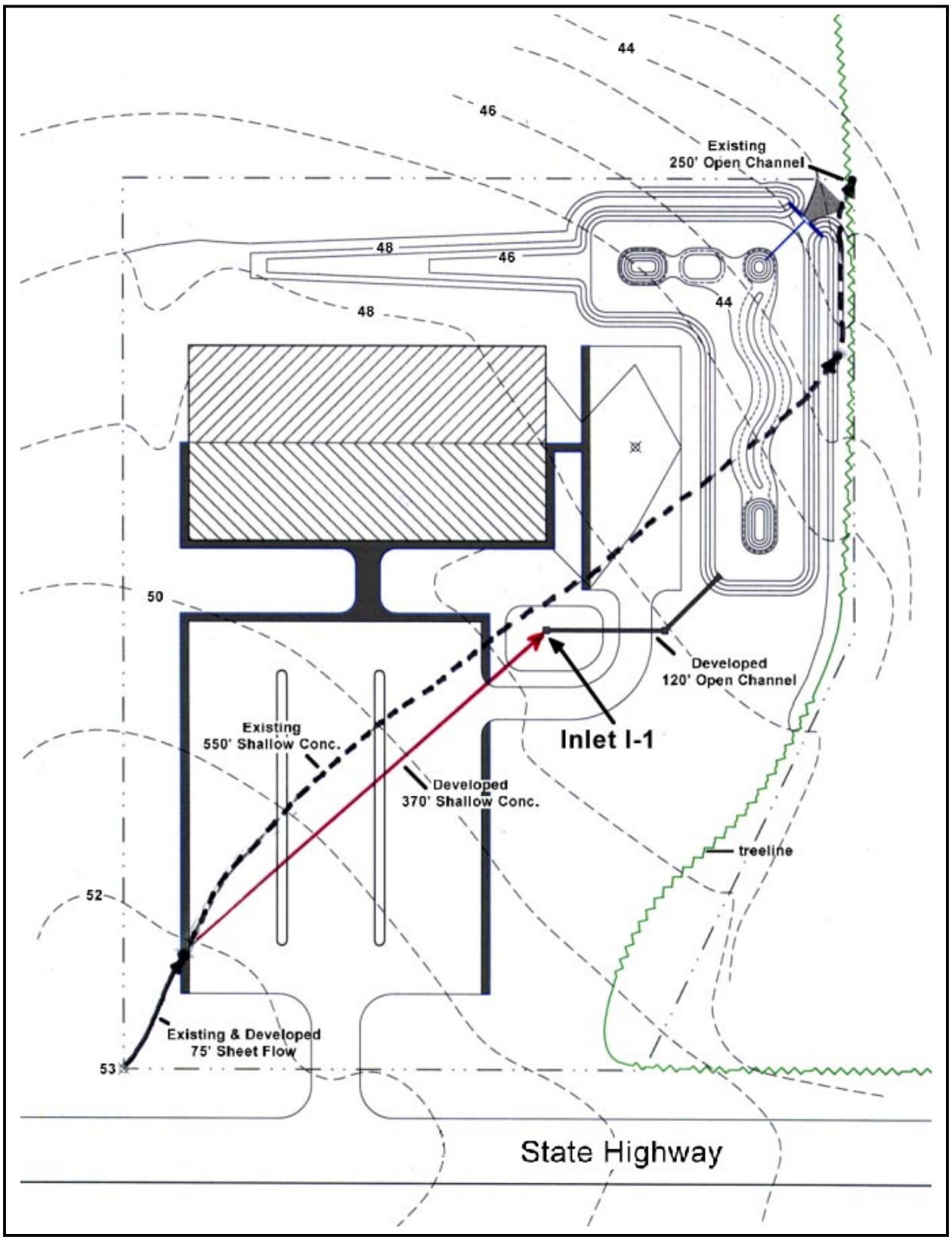
Figure C.1.1 Clevenger Community Center Site Plan



SARB_004881

Figure C.1.2 Clevenger Community Center – Existing Conditions
(source: TR-55 computer printouts)

```
RUNOFF CURVE NUMBER COMPUTATION            Version 2.00
Project : CLEVENGER COMMUNITY CENTER             User: SRC      Date: 06-18-99
County  : CHARLES              State: MD      Checked: ____     Date: ________
Subtitle: EXISTING
--------------------------------------------------------------------------------
Hydrologic Soil Group
COVER DESCRIPTION                              A        B        C        D
Acres (CN)
--------------------------------------------------------------------------------
OTHER AGRICULTURAL LANDS
Meadow -cont. grass (non grazed) ----           -   5.0(58)       -        -
Woods                             good          -   0.3(55)       -        -
Total Area (by Hydrologic Soil Group)              5.3
--------------------------------------------------------------------------------
TOTAL DRAINAGE AREA: 5.3 Acres       WEIGHTED CURVE NUMBER: 58*
--------------------------------------------------------------------------------
* - Generated for use by GRAPHIC method

TIME OF CONCENTRATION AND TRAVEL TIME        Version 2.00
--------------------------------------------------------------------------------
Flow Type   2 year   Length   Slope  Surface   n   Area     Wp   Velocity  Time
rain     (ft)   (ft/ft)   code       (sq/ft)  (ft)  (ft/sec)  (hr)
--------------------------------------------------------------------------------
Sheet        3.3      75       0.013    F                                  0.221
Shallow Concent'd     550      0.016    U                                  0.075
Open Channel          250                                          4.0     0.017
                                                 Time of Concentration = 0.31*
--- Sheet Flow Surface Codes ---
A Smooth Surface           F Grass, Dense     --- Shallow Concentrated ---
B Fallow (No Res.)         G Grass, Burmuda   ---     Surface Codes    ---
C Cultivated < 20 % Res.   H Woods, Light              P Paved
D Cultivated > 20 % Res.   I Woods, Dense              U Unpaved
E Grass-Range, Short       J Range, Natural
* - Generated for use by GRAPHIC method

GRAPHICAL PEAK DISCHARGE METHOD            Version 2.00
Data: Drainage Area        :  5.3 * Acres
Runoff Curve Number  :  58 *
Time of Concentration:  0.31 * Hours
Rainfall Type        :  II
Pond and Swamp Area  :  NONE
================================================================================
| Storm Number          |   1   |   2   |   3   |   4   |   5   |   6   |   7   |
|-----------------------|-------|-------|-------|-------|-------|-------|-------|
| Frequency  (yrs)      |   1   |   2   |   5   |  10   |  25   |  50   |  100  |
| 24-Hr Rainfall (in)   |  2.7  |  3.3  |  4.4  |  5.3  |   6   |  6.6  |  7.5  |
| Ia/P Ratio            | 0.54  | 0.44  | 0.33  | 0.27  | 0.24  | 0.22  | 0.19  |
|            Used      | 0.50  | 0.44  | 0.33  | 0.27  | 0.24  | 0.22  | 0.19  |
| Runoff (in)           | 0.18  | 0.38  | 0.85  | 1.34  | 1.76  | 2.14  | 2.76  |
| Unit Peak Discharge   |0.460  |0.615  |0.835  |0.904  |0.929  |0.946  |0.967  |
|    (cfs/acre/in)      |       |       |       |       |       |       |       |
| Pond and Swamp Factor| 1.00  | 1.00  | 1.00  | 1.00  | 1.00  | 1.00  | 1.00  |
|    0.0% Ponds Used    |       |       |       |       |       |       |       |
|-----------------------|-------|-------|-------|-------|-------|-------|-------|
| Peak Discharge (cfs)  |    0  |    1  |    4  |    6  |    9  |   11  |   14  |
================================================================================
* - Value(s) provided from TR-55 system routines
```


SARB_004882

Figure C.1.3 Clevenger Community Center – Developed Conditions (source: TR-55 computer printouts)

```
                        RUNOFF CURVE NUMBER COMPUTATION            Version 2.00
Project : CLEVENGER COMMUNITY CENTER            User: SRC      Date: 06-18-99
County  : CHARLES              State: MD      Checked: ____     Date: ________
Subtitle: DEVELOPED
--------------------------------------------------------------------------------
                                                      Hydrologic Soil Group
COVER DESCRIPTION                                   A        B        C        D
Acres (CN)
--------------------------------------------------------------------------------
FULLY DEVELOPED URBAN AREAS (Veg Estab.)
Open space (Lawns,parks etc.)
  Good condition; grass cover > 75%               -  3.06(61)       -        -
Impervious Areas
  Paved parking lots, roofs, driveways            -  1.94(98)       -        -
OTHER AGRICULTURAL LANDS
Woods                              good           -   0.3(55)       -        -

Total Area (by Hydrologic Soil Group)                 5.3
--------------------------------------------------------------------------------
                TOTAL DRAINAGE AREA: 5.3 Acres       WEIGHTED CURVE NUMBER: 74*
--------------------------------------------------------------------------------
* - Generated for use by GRAPHIC method

                     TIME OF CONCENTRATION AND TRAVEL TIME        Version 2.00
--------------------------------------------------------------------------------
Flow Type   2 year   Length   Slope  Surface   n   Area     Wp   Velocity  Time
             rain     (ft)   (ft/ft)   code       (sq/ft)  (ft)  (ft/sec)  (hr)
--------------------------------------------------------------------------------
Sheet        3.3      70       0.013    F                                  0.209
Shallow Concent'd     310      0.013    P                                  0.037
Open Channel                                                      5.0      0.007
                                                  Time of Concentration = 0.26*
           --- Sheet Flow Surface Codes ---
    A Smooth Surface           F Grass, Dense     --- Shallow Concentrated ---
    B Fallow (No Res.)         G Grass, Burmuda   ---     Surface Codes    ---
    C Cultivated < 20 % Res.   H Woods, Light              P Paved
    D Cultivated > 20 % Res.   I Woods, Dense              U Unpaved
    E Grass-Range, Short       J Range, Natural
* - Generated for use by GRAPHIC method
                    GRAPHICAL PEAK DISCHARGE METHOD            Version 2.00
  Data: Drainage Area        :  5.3 * Acres
        Runoff Curve Number  :  74 *
        Time of Concentration:  0.26 * Hours
        Rainfall Type        :  II
        Pond and Swamp Area  :  NONE
=================================================================
| Storm Number          |   1   |   2   |   3   |   4   |   5   |   6   |   7   |
|-----------------------|-------|-------|-------|-------|-------|-------|-------|
| Frequency  (yrs)      |   1   |   2   |   5   |  10   |  25   |  50   |  100  |
| 24-Hr Rainfall (in)   |  2.7  |  3.3  |  4.4  |  5.3  |   6   |  6.6  |  7.5  |
| Ia/P Ratio            | 0.26  | 0.21  | 0.16  | 0.13  | 0.12  | 0.11  | 0.09  |
|            Used      | 0.26  | 0.21  | 0.16  | 0.13  | 0.12  | 0.11  | 0.10  |
| Runoff (in)           | 0.72  | 1.10  | 1.90  | 2.61  | 3.18  | 3.70  | 4.48  |
| Unit Peak Discharge   |0.995  |1.033  |1.076  |1.098  |1.110  |1.119  |1.124  |
|    (cfs/acre/in)      |       |       |       |       |       |       |       |
| Pond and Swamp Factor| 1.00  | 1.00  | 1.00  | 1.00  | 1.00  | 1.00  | 1.00  |
|    0.0% Ponds Used    |       |       |       |       |       |       |       |
|-----------------------|-------|-------|-------|-------|-------|-------|-------|
| Peak Discharge (cfs)  |   4   |   6   |  11   |  15   |  19   |  22   |  27   |
=================================================================
* - Value(s) provided from TR-55 system routines
```


SARB_004883

Step 2. Compute Re_v

Step 2a. Determine Soil Specific Recharge Factor (S) Based on Hydrologic Soil Group

Soils found throughout the site are loams and silt loams therefore $S = 0.26$

Step 2b. Compute Re_v Using Percent Volume Method

$$\begin{aligned} Re_v &= [(S)(R_v)(A)]/12 \\ &= [(0.26)(0.379)(5.3)]/12 \\ &= \underline{0.0456 \text{ ac-ft.}} \ (1{,}986 \text{ cf}) \end{aligned}$$

Step 2c. Compute Re_v Using Percent Area Method

$$\begin{aligned} Re_v &= (S)(A_i) \\ &= (0.26)(1.94 \text{ ac.}) \\ &= 0.50 \text{ acres} \end{aligned}$$

The Re_v requirement may be met by: a) treating 1,986 cf using structural methods, b) treating 0.50 acres using non-structural methods, or c) a combination of both (e.g. 994 cf structurally and 0.25 acres non-structurally).

Step 3. Compute Cp_v

The proposed community center is located within a USE I watershed, therefore an extended detention time (T) of 24 hours for the one-year storm event. The time of concentration (t_c) and one-year runoff (Q_a) are 0.26 hours and 0.72" respectively (see Fig. C.1.3).

Use the MDE Method to Compute Storage Volume (Appendix D.11):

Initial abstraction (I_a) for CN of 74 is 0.703: (TR-55) [$I_a = (200/CN)-2$]

$I_a/P = (0.703)/2.7" = 0.26$
$t_c = 0.26$ hours

$q_u = 625$ csm/in. (Figure D.11.1, Appendix D.11)

$q_i = q_u A Q_a$ where A is the drainage area in square miles
$= (625 \text{ csm})(0.0083 \text{ square miles})(0.72")$
$= 3.7$ cfs; $q_i > 2.0$ cfs $\therefore$ Cp_v is required.

Knowing q_u and T (extended detention time), find q_o/q_i from Figure D.11.2, "Detention Time Versus Discharge Ratios."

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Peak outflow discharge / peak inflow discharge (q_o/q_i) = 0.030

With q_o/q_i, compute V_s/V_r for a Type II rainfall distribution,

$V_s/V_r = 0.683 - 1.43(q_o/q_i) + 1.64(q_o/q_i)^2 - 0.804(q_o/q_i)^3$; (Appendix D.11)
$V_s/V_r = 0.64$

Therefore, V_s = $[(V_s/V_r)(Q_a)(A)] / 12$
= [(0.64)(0.72")(5.3 ac.)] / 12
= 0.204 ac-ft (8,886 cf.)

With q_o/q_i, compute the Cp_v release rate,

$q_o = (q_o/q_i)(q_i)$; q_i = 4.0 cfs
= (0.030)(4.0 cfs)
= 0.12 cfs

With q_o, determine the required orifice area (A_o) for extended detention design:

$$A_o = \frac{q_o}{C\sqrt{2gh_o}} = \frac{q_o}{4.81\sqrt{h_o}}$$

"h_o" is the maximum storage depth associated with V_s. For this example, assume h_o to be no more than 3.0 ft.

$\therefore A_o$ = (0.12 cfs) / (4.81√3.0 ft)
= (0.12 cfs) / (8.33 ft)
= 0.014 sf.

With A_o, determine the required orifice diameter (d_o):

$$d_o = \sqrt{4A_o/\pi} = \sqrt{4 \times 0.014 sf/\pi} = 0.134\ ft \qquad (1.6") \text{ USE } 1.5"$$

"d_o's" of less than 3" are subject to local jurisdictional approval, and are not recommended unless an internal control for orifice protection is used. For this example, use a d_o of 3".

Step 4. Compute Q_{p10} Storage Volume

Per TR-55, Figure 6-1 (Page 6-2 of TR-55) for an inflow (Q_{in}) of 15 cfs and an allowable outflow (Q_{out}) of 6 cfs, the volume of storage (V_s) necessary for control is 0.37 ac-ft, with a developed CN of 74 (see TR-55 Worksheet 6a, Page 6-5 of TR-55). Note that there is 5.3 inches of rainfall during this event with 2.6 inches of runoff.

SARB_004885

Step 5. Compute Q_f

For this example, management of Q_f is not required. However, the 100-year storm event must be conveyed safely through the stormwater management practice.

Table C.1.1 Summary of General Storage Requirements for Clevenger Community Center

Step	Requirement	Volume Required (acre-feet)	Notes
1.	WQ_v	0.167	
2.	Re_v	0.0456 (or 0.50 acres)	volume is included within the WQ_v storage
3.	Cp_v	0.204	Cp_v release rate is 0.10 cfs
4.	Q_{p10}	0.36	10-year release rate is 6.0 cfs
5.	Q_f	N/A	provide safe passage for the 100-year event in final design

Final Design

Step 1. BMP Selection Process

While the stormwater management BMP's listed in Chapter 2.7 (Volume I) are equivalent in meeting the established pollutant removal goals, site characteristics are an important consideration in selecting the most appropriate BMP for a specific design. The process outlined in Chapter 4 (Volume I) provides guidance for screening BMP's as part of the selection process.

❶ **Watershed Factors: Is the project located in a watershed that has special design objectives or constraints that must be met?** This project is located in a USE I watershed and there are no other special objectives or constraints that must be considered.

❷ **Terrain Factors: Is the project located in a portion of the State that has particular design constraints imposed by local terrain and or underlying geology?** The project is located in a region of the State that has no constraints imposed by local terrain or underlying geology

❸ **Stormwater Treatment Suitability: Can the BMP meet all five stormwater criteria at the site or are a combination of BMPs needed?** For this project, a single BMP will not satisfy all of the required criteria (see Table 4.3 BMP Selection Matrix No. 3). Therefore, one BMP will treat WQ_v, Cp_v, and Q_{p10} while a separate BMP will treat Re_v.

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❹ **Physical Feasibility Factors: Are there any physical constraints at the project site that may restrict or preclude the use of a particular BMP?** Although the soils encountered are infiltratable, the depth to the existing water table is less than 4.0'. Therefore infiltration is not feasible for treating WQ_v. Additionally, the soils indicate that wet pond designs may require a liner. Sand filters will require substantial pretreatment as the proposed imperviousness is near 37%. The drainage area, 5.3 acres, is marginally low to support either ponds or wetlands. However, the groundwater table may be sufficient to support a shallow wetland.

❺ **Community and Environmental Factors: Do the remaining BMPs have any important community or environmental benefits or drawbacks that might influence the selection process?** The projected use of the site as a community center may require that BMPs possess a greater acceptance by the community. Additionally, habitat quality is important if environmental education is provided at the center. Finally, ease of maintenance and costs relative to drainage area are important considerations as the sources of future funding may be limited.

❻ **Location and Permitting Factors: What environmental features must be avoided or considered when locating the BMP system at a site to fully comply with local, State and federal regulations?** There are no wetlands, stream buffers, floodplains or forest conservation areas located on the site although the area of existing woods should be preserved if possible.

After considering all factors and the site layout, use a shallow wetland (W-1) for treating WQ_v. Cp_v and Q_{p10} will be treated by providing sufficient storage above the shallow wetland. Finally, Re_v will be treated prior to the wetland by providing storage around the inlet, I-1.

Step 2. Shallow Wetland (W-1) Design

Using the information developed in Preliminary Design Steps 1 and 2, design a shallow wetland to treat WQ_v (see Figure C.1.4).

A. Calculate Design Volume

Because Re_v will be treated prior to the shallow wetland, Re_v may be subtracted from the WQ_v for the design of this BMP:

$$WQ_v' = WQ_v - Re_v$$
$$= 7{,}292 \text{ cf.} - 1{,}986 \text{ cf.}$$
$$= 5{,}306 \text{ cf.}$$

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B. Calculate Pretreatment (Forebay) Volume

Forebays shall be sized to capture 10% of the design runoff volume (in this case WQ_v') at each inflow point; assume that inflow is divided equally between the two inflow points for this design.

forebay volume = (10%)(5,306 cf./ 2)
= 265.3 cf. at each inflow point

forebay volume provided = 800 cf. and 700 cf. respectively

B. Determine Shallow Wetland Size Criteria

Using the design criteria set forth in Chapter 3 for the design of shallow wetland systems, the configuration shown in Figure C.1.4, and the information in Table C.1.2, design a shallow wetland to treat WQ_v'. Specific criteria that govern the configuration of the shallow wetland design are as follows.

1. Surface area ≥ 1.5% × drainage area
≥ 1.5% × 5.3 acres
≥ 0.0795 acres (3,463 sf.)

Surface area of shallow wetland at elevation 44.0 = 0.1366 acres (5,950 sf.) -OKAY

2. Deepwater (depth ≥ 4') zones ≥ 25% × WQ_v'
≥ 25% × 5,306 cf.
≥ 1,326.5 cf.

Deepwater zones provided = 1,950 cf. (forebays and micropool)

3. High marsh (depth ≤ 6") zones ≥ 35% × total surface area
≥ 35% × 3,463 sf.
≥ 1,212.1 sf.

High marsh area provided = 2,160 sf.

4. Total marsh area (depth ≤ 18") zones ≥ 65% × total surface area
≥ 65% × 3,463 sf.
≥ 2,251 sf.

Total marsh area provided = 4,200 sf.

5. Check for water balance (see Appendix D.3) for maintenance of wet pool:

SARB_004888

a. Calculate maximum drawdown:

Inflow Runoff Volume = P x E where P = Precipitation & E = Runoff Efficiency
- for a CN of 74, Volume of runoff (2 year storm) = 1.10"
- for Charles County, P (2 year rainfall) = 3.3" (0.275')
- E = 1.1"/3.3" = 0.33
∴ Inflow = P x E = 0.275' x 0.33 x 5.3 acres = 0.48 ac-ft

Outflow = surface area x evaporation losses
= 0.137 acres x 0.54 ft (see Table D.3.2)
= 0.074 ac-ft

Inflow (0.48 ac-ft) is greater than Outflow (0.074 ac-ft) –OKAY

b. Check for drawdown over an extended period without rainfall:

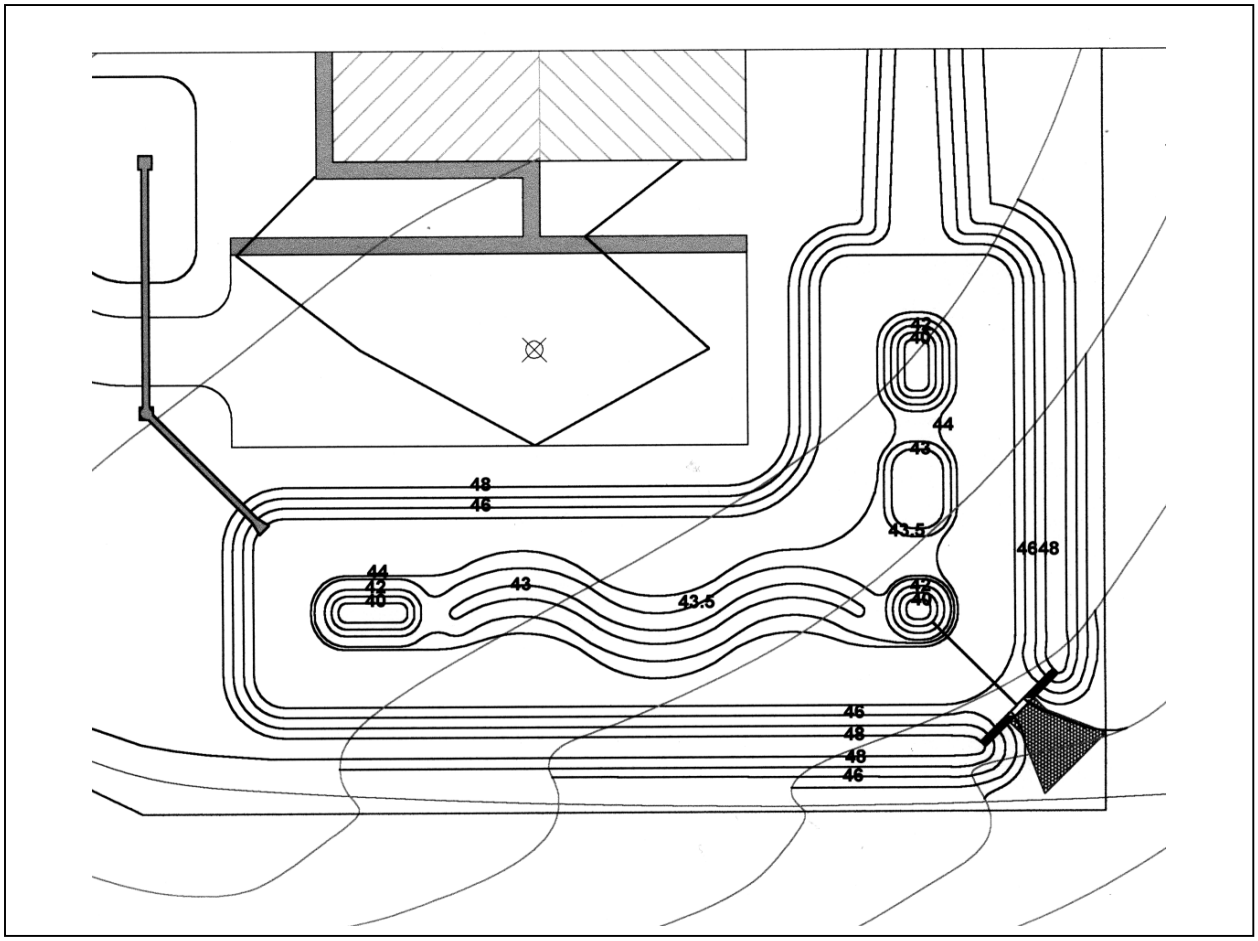
Using 45 day "worst case" drought conditions
- highest evaporation occurs in July – 0.54 ft per month
- average evaporation per day = 0.54/31 days = 0.017 ft/day
- over 45 day interval, evaporation loss = 45 x 0.017 ft/day = 0.78 ft.
- assume surface of wetland may drop up to 0.78 ft. over this interval -OKAY

SARB_004889

Table C.1.2 Stage – Storage Data for Stormwater Management Design

Stage - Storage Data				
Elevation	Δ Storage	Storage (cubic feet)	Storage (acre-feet)	Storage Above WQ_v (acre-feet)
40.0	0.0	0.0	0.0	
41.0	372.0	372.0	0.0085	
42.0	665.0	1,037.0	0.0238	
43.0	1,428.0	2,465.0	0.0566	
44.0	3,990.0	6,455.0	0.1482	0.0
45.0	11,200.0	17,665.0	0.4055	0.2573
45.5	8,478.0	26,133.0	0.5999	0.4517
46.0	8,987.0	35,120.0	0.8062	0.6581
47.0	19,530.0	54,650.0	1.2546	1.1064
48.0	21,646.0	76,296.0	1.7515	1.6033

Figure C.1.4 Plan View of Shallow Wetland Design



Step 3. Cp_v Design

Using the information from Preliminary Design Step 3, the stage–storage data from Table C.1.2, and the stage-discharge data for the 3" orifice in Table C.1.3, design an extended-detention basin to treat Cp_v.

Table C.1.3 Stage – Discharge Data for Clevenger Community Center

Stage - Discharge Data							
Elevation	3" Orifice[1] centerline – 44.125'		5.2' Weir[2] crest @ 45.00'		10.0' Weir[3] crest @ 45.50'		Total Discharge
	Head (h)	Discharge	Head (h)	Discharge	Head (h)	Discharge	
44.00	0.0	0.00					0.00
44.25	0.1	0.085					0.085
44.50	0.4	0.150					0.150
44.75	0.6	0.194					0.194
45.00	0.9	0.229	0.0	0.0			0.229
45.50	1.4	0.287	0.5	5.70	0.0	0.0	5.70
46.00	1.9	0.335	1.0	16.12	0.5	10.96	27.08
47.00	2.9	0.415	2.0	45.59	1.5	56.95	102.54
48.00	3.9	0.482	3.0	83.76	2.5	122.53	206.29

1. Using orifice equation $Q = ca\sqrt{2gh}$ where c=0.61, a=0.05 sf., and g= 32.2 ft/sec^2
2. Using weir equation $Q = clh^{3/2}$ where c= 3.1 & l =5.2'
3. Using weir equation $Q = clh^{3/2}$ where c= 3.1 & l =10.0'

From Preliminary Step 3, the storage volume (V_s) for Cp_v is 0.204 ac-ft and the required orifice diameter (d_o) is 3". Using Table C.1.2 and starting at elevation 44.0, the storage volume of the proposed stormwater management structure is 0.2573 ac-ft at elevation 45.0'. Therefore, Cp_v treatment will be provided between elevations 44.0' and 45.0'.

Step 4. Q_{p10} Treatment

From Preliminary Step 5, the estimated storage volume (V_s) for treating Q_{p10} is 0.36 ac-ft and the allowable discharge rate is 6.0 cfs. Using Table C.1.2 and starting at elevation 44.0', the storage volume of the proposed stormwater management structure is 0.4517 ac-ft at elevation 45.5'. Therefore, design a control structure that will produce a discharge rate of 6.0 cfs at storage elevation 45.5'. This will be a conservative design since the volume provided (0.4517 ac-ft) is greater than the 0.36 ac-ft required. Using a weir with crest at elevation 45.0' and including flow from the 3" orifice, the ten-year discharge (q_{10}) may be computed as follows:

$$q_{10} = c_w l h_w^{3/2} + c_o a\sqrt{2gh_o}$$

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where: q_{10} = 10 yr. discharge = 6.0 cfs
c_w = weir coefficient = 3.1
l = length of weir
h_w = head on weir; at elevation 45.5, h_w = 0.5'
c_o = orifice coefficient = 0.61
a = area of 3" orifice = 0.05
g = gravitational acceleration = 32 ft/sec^2
h_o = head on orifice; at elevation 45.5, h_o = 1.375

therefore: $q_{10} = (3.1)(l)(0.5)^{3/2} + (0.61)(0.05)[(2)(32.2)(1.375)]^{1/2}$
6.0 cfs = 1.1l cfs + 0.29 cfs
by rearranging this equation and solving for l; l = 5.2'

use a 5.2' weir with crest at elevation 45.0 –OKAY

Step 5. Q_f Treatment

From Preliminary Step 5, the 100-year storm event must be conveyed safely through the stormwater management facility. From Figure C.1.3, 100-year discharge rate (q_{100}) is 27 cfs and from Figure C.1.4, the top of the proposed stormwater management facility is at elevation 48.0'. Allowing for 2.0' of freeboard, design a control structure that will discharge 27 cfs at elevation 46.0'. Using a weir with crest at elevation 45.5', including flow from the 5.5' weir and assuming that the 3" orifice is clogged, q_{100} may be computed as follows:

$$q_{100} = cl_{100}h_{100}^{3/2} + cl_{10}h_{10}^{3/2}$$

where: q_{100} = 100 yr. discharge = 27 cfs.
c = weir coefficient = 3.1
l_{100} = length of 100 yr. weir
h_{100} = head on 100 yr. weir; at elev. 46.0', h_{100} = 0.5'
l_{10} = length of 10 yr. weir = 5.2'
h_{10}= head on 10 yr. weir; at elev. 46.0', h_{10} = 1.0'

therefore: $q_{100} = (3.1)(l_{100})(0.5)^{3/2} + (3.1)(5.2')(1.0)^{3/2}$
27 cfs = 1.1l_{100} cfs + 16.1 cfs
by rearranging this equation and solving for l_{100}; l_{100} = 9.89'

use a 10.0' weir with crest at elevation 45.5' –OKAY

See Figure C.1.5 for a schematic of the control structure and Figure C.1.6 for a profile through the centerline of the dam and control structure. See Figures C.1.7 and C.1.8 for the TR-20 input and summary tables.

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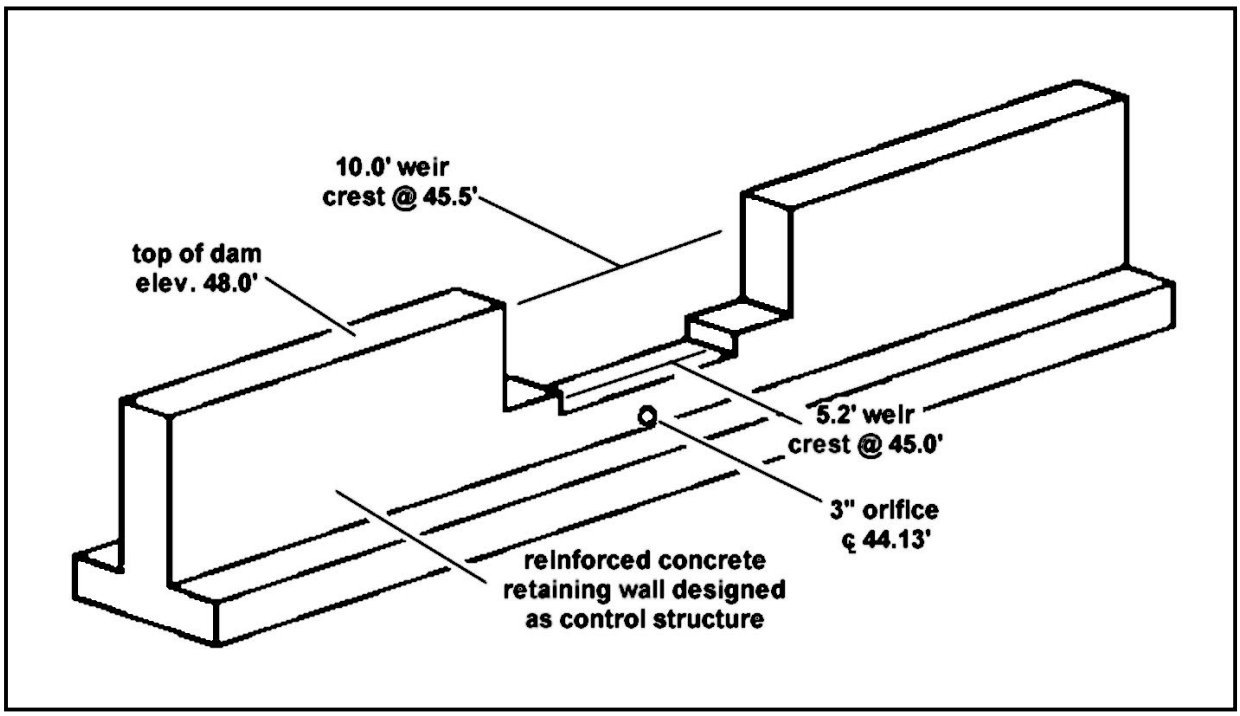
Figure C.1.5 Schematic of Control Structure



Step 6. Investigate Potential Pond Hazard Classification

Using NRCS-MD Code No. 378 Pond Standards/Specifications (Appendix B.1), review downstream conditions and compute a preliminary Breach Peak Discharge (Q_{max}) to determine pond hazard classification.

$$Q_{\max} = (3.2)(H_w^{5/2})$$

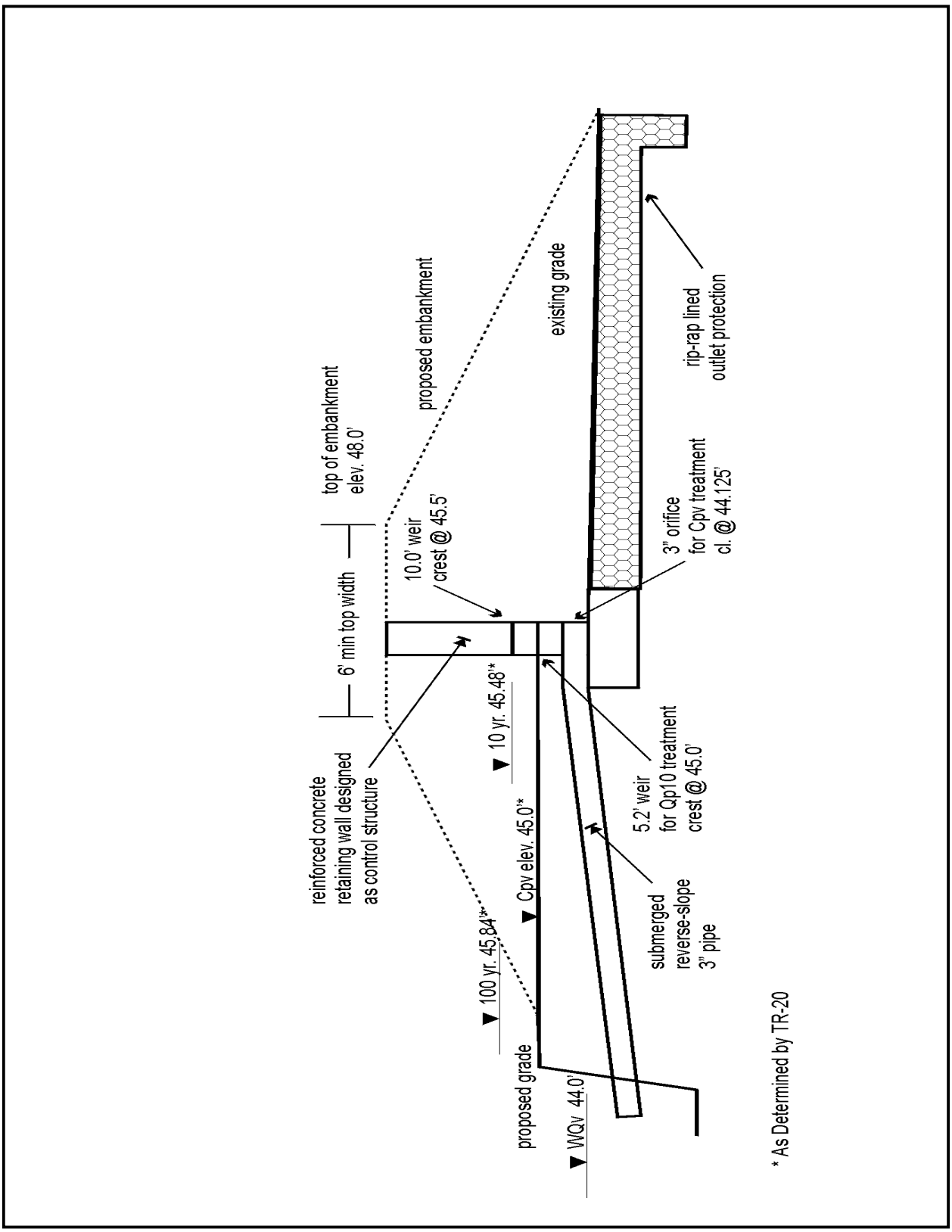
where: Q_{max} = Breach Peak Discharge
H_w = depth of water at the dam at time of failure, in feet, and is measured from the design high water to the lowest point in the original cross section at the centerline of the dam; H_w = 46.0' – 44.0' = 2.0'

$Q_{max} = (3.2)(2.0)^{5/2} = 18.1$ cfs

Q_{max} will not overtop downstream roads or infrastructure, therefore the stormwater management facility may be considered as a Class "a" low hazard structure per the NRCS-MD 378 standards.

SARB_004893

Figure C.1.6 Profile of Principle Spillway



SARB_004894

Figure C.1.7 TR-20 Computer Program Input File

```
JOB TR-20 EXAMPLE1  ECON      FULLPRINT PASS=001  SUMMARY   GRAPHICS
TITLE     DESIGN EXAMPLE 1  CLEVENGER COMMUNITY CENTER
 3 STRUCT      01
 8                      44.0        0.0         0.0
 8                      44.25       0.12        0.060
 8                      44.5        0.17        0.128
 8                      44.75       0.21        0.180
 8                      45.0        0.24        0.2573
 8                      45.5        5.70        0.4517
 8                      46.0        27.08       0.6581
 8                      47.0        102.54      1.1064
 8                      48.0        206.29      1.6033
 9 ENDTBL
 6 RUNOFF 1 001       1 .00828      74.         0.26        1 1   1 1 1
 6 RESVOR 2    01 1   2 44.0                                1 1 1 1 1 1
 6 RUNOFF 1 003       3 .00828      58.         0.31        1 1   1 1 1
   ENDATA
 7 INCREM 6             0.10
 7 COMPUT 7 001   003   0.0         2.7         1.0         2 2  01  01
   ENDCMP 1
 7 INCREM 6             0.10
 7 COMPUT 7 001   003   0.0         3.3         1.0         2 2  01  02
   ENDCMP 1
 7 INCREM 6             0.10
 7 COMPUT 7 001   003   0.0         5.3         1.0         2 2  01  10
   ENDCMP 1
 7 INCREM 6             0.10
 7 COMPUT 7 001   003   0.0         7.5         1.0         2 2  01  99
   ENDCMP 1
   ENDJOB 2
```


SARB_004895

Figure C.1.8 TR-20 Computer Program Output Summary Table

SUMMARY TABLE 1

SELECTED RESULTS OF STANDARD AND EXECUTIVE CONTROL IN ORDER PERFORMED.
A CHARACTER FOLLOWING THE PEAK DISCHARGE TIME AND RATE (CFS) INDICATES:
F-FLAT TOP HYDROGRAPH T-TRUNCATED HYDROGRAPH R-RISING TRUNCATED HYDROGRAPH

XSECTION/ STRUCTURE ID	STANDARD CONTROL OPERATION		DRAINAGE AREA (SQ MI)	RUNOFF AMOUNT (IN)	PEAK DISCHARGE ELEVATION (FT)	TIME (HR)	RATE (CFS)	RATE (CSM)
RAINFALL OF 2.70 inches AND 24.00 hr DURATION, BEGINS AT .0 hrs.								
RAINTABLE NUMBER 2, ARC 2								
MAIN TIME INCREMENT .100 HOURS								
ALTERNATE 1 STORM 1								
XSECTION	1	RUNOFF	.01	.72	---	12.07T	4T	400.0
STRUCTURE	1	RESVOR	.01	.71	---	.00	0	.0
XSECTION	3	RUNOFF	.01	.71	---	.00	0	.0
XSECTION	3	RUNOFF	.01	.71	---	.00	0	.0
RAINFALL OF 3.30 inches AND 24.00 hr DURATION, BEGINS AT .0 hrs.								
ALTERNATE 1 STORM 2								
XSECTION	1	RUNOFF	.01	1.10	---	12.06	7	700.0
STRUCTURE	1	RESVOR	.01	1.09	---	.00	0	.0
XSECTION	3	RUNOFF	.01	.38	---	12.14T	1T	100.0
RAINFALL OF 5.30 inches AND 24.00 hr DURATION, BEGINS AT .0 hrs.								
MAIN TIME INCREMENT .100 HOURS								
ALTERNATE 1 STORM 10								
XSECTION	1	RUNOFF	.01	2.60	---	12.05	16	1600.0
STRUCTURE	1	RESVOR	.01	2.59	45.50	12.32	6	600.0
XSECTION	3	RUNOFF	.01	1.34	---	12.10	7	700.0
RAINFALL OF 7.50 inches AND 24.00 hr DURATION, BEGINS AT .0 hrs.								
ALTERNATE 1 STORM 99								
XSECTION	1	RUNOFF	.01	4.48	---	12.04	28	2800.0
STRUCTURE	1	RESVOR	.01	4.43	45.84	12.18	20	2000.0
XSECTION	3	RUNOFF	.01	2.75	---	12.09	16	1600.0

Step 7. Re_v Treatment

Using the information developed n Preliminary Step 2, design a structural practice to treat Re_v. Non-structural practices will not be utilized therefore the entire Re_v (1,986 cf) must be treated. For this example, design an infiltration area around inlet I-1 (see Figure C.1.9) that will treat the entire Re_v. Because of its high visibility and the communal nature of the project, this infiltration area will be designed and planted similar to a bioretention area.

The surface area around I-1 that is available for this practice has an area (*A*) of 2,250 sf. Using a porosity (*n*) of 0.30* for the sand and planting soil mixture, the required depth (*d*) to treat the entire Re_v is equal to:

$$[(Re_v)/(A)] / n$$
$$= [(1{,}986 \text{ cf.})/(2{,}250 \text{ sf.})] / 0.30$$
$$= 0.883 / 0.30$$
$$= 2.94 \text{ ft. } \textit{Use } d = 3.0 \textit{ ft.}$$

*Note: The porosity of mixed-grained sand varies from 0.30 (dense) to 0.40 (loose). Using the minimum value, 0.30, results in a more conservative design.

Using a depth of 3.0', a surface area of 2,250 sf. and a *n* of 0.3, storage for Re_v treatment is equal to:

$$(A \times d) \times n$$
$$= (2{,}250 \text{ sf. } \times 3.0 \text{ ft.}) \times 0.3$$
$$= 2{,}025 \text{ cf. -OKAY}$$

Using the dimensions above, a cross section of the infiltration area is shown in Figure C.1.10.

Step 8. Landscaping

The BMP's for both WQ_v and Re_v treatment have specific landscaping requirements for proper implementation. Therefore, landscaping plans developed in accordance with Chapter 3 and using the guidelines provided in Appendix A will be required with submittal of the final design.

SARB_004897

Figure C.1.9 Location of Re_v Treatment

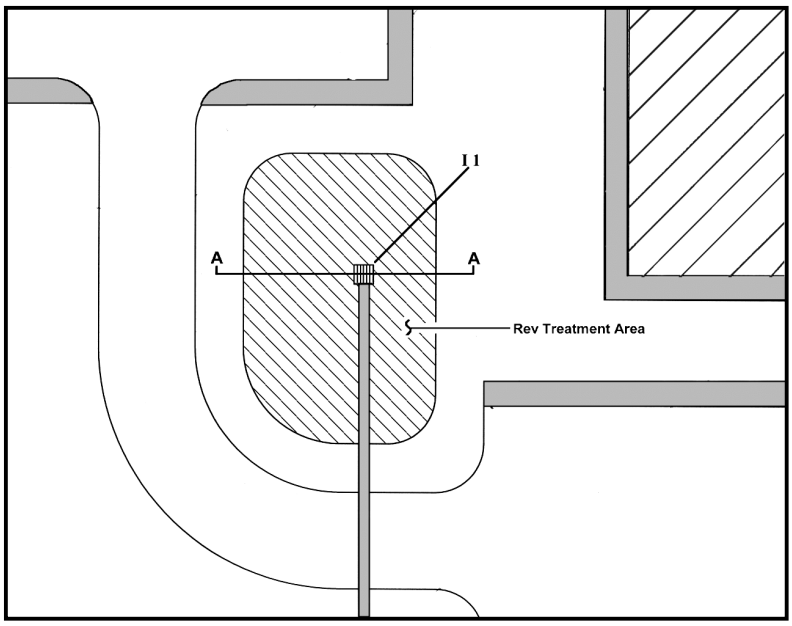
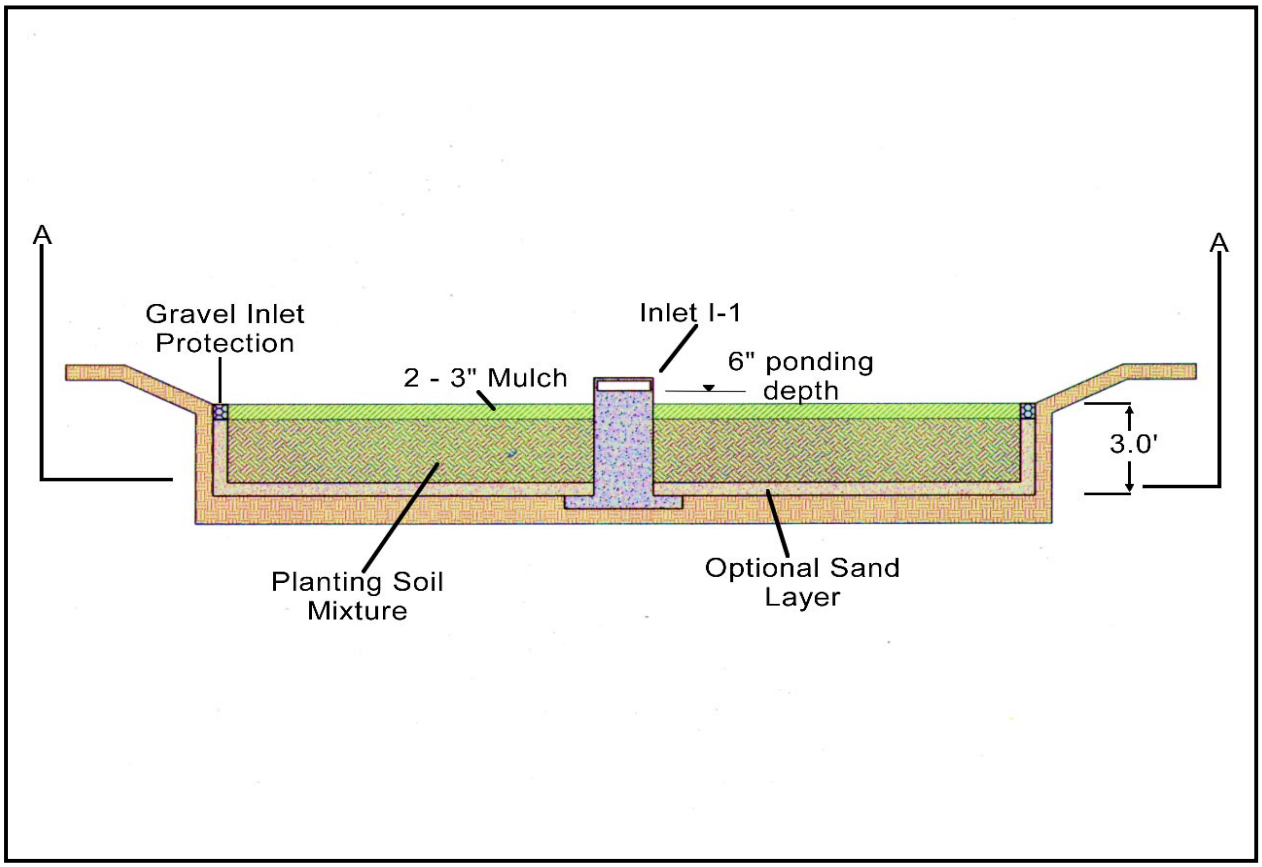


Figure C.1.10 Cross Section "A-A"



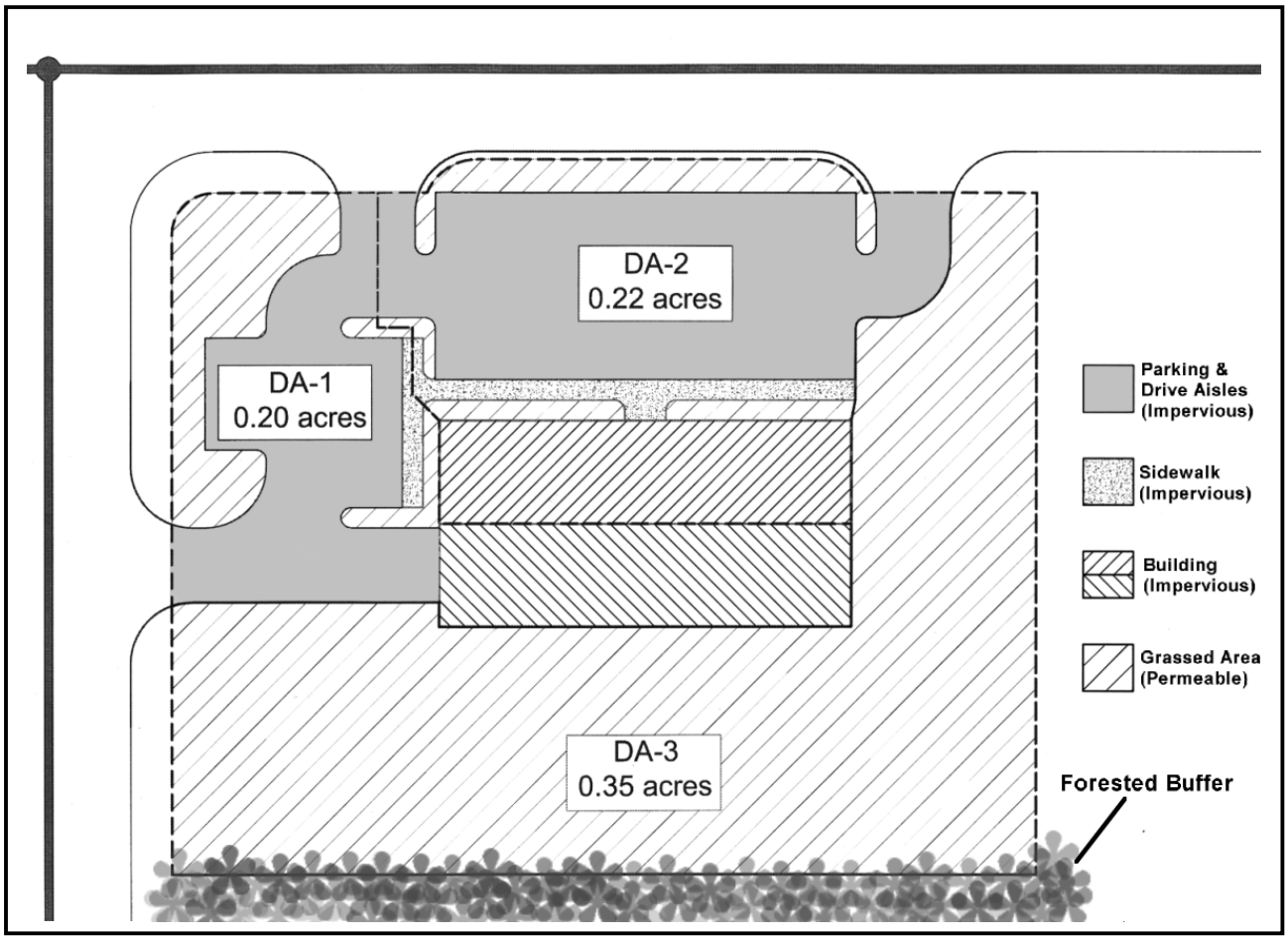
Appendix C.2

Design Example 2 – Water Quality BMPs

Design Example 2 – Water Quality BMPs

The following example demonstrates the design of several different BMPs for WQ_v and Re_v treatment including filtering, infiltration, and open channel practices.

Figure C.2.1 Comstock Commercial Center Site Plan



Site Specifc Data

Comstock Commercial Center is a 0.77 acre retail store located in Howard County, Maryland. The developed area of the site may be divided into two drainage areas of 0.20 and 0.22 acres respectively with a remaining drainage area of 0.35 acres. Total impervious area for the development is 0.36 acres; 0.16 acres in DA-1 and 0.20 acres in DA-2. Existing and proposed topography are not given for this exercise; it may be assumed that these conditions are amenable for each specific design. Likewise, the seasonally high water table will not be a factor in infiltration designs. The underlying soils are loams (HSG B). TR-55 calculations for the developed hydrologic conditions are shown in Figures C.2.2, C.2.3 and C.2.4.

SARB_004901

C.2.1 Design Criteria

The site is within the Eastern Rainfall Zone and located on the Western Shore of the Chesapeake Bay (see Volume I, Chapter 2, Figures 2.1 and 2.4). Additionally, the site is located within a USE I watershed. Therefore, the following criteria apply:

1. WQ_v treatment is required. In the Eastern Rainfall Zone, P = 1".
2. Re_v treatment is required.
3. Cp_v treatment is required.
4. Q_{p10} may be required by the local jurisdiction. For this example, Q_{p10} will not be required.
5. Q_f may be required by the local jurisdiction. For this example, Q_f will not be required. However, safe conveyance of the 100-year design storm is required through the proposed stormwater management facility.

C.2.2 Preliminary Design

Step 1. Compute WQ_v

Step 1a. Compute Volumetric Runoff Coefficient (R_v)

R_v = 0.05 + (0.009)(I); I = (0.36 acres / 0.77 acres) = 0.468or 46.8%
= 0.05 + (0.009)(46.8) = 0.471

Step 1b. Compute WQ_v

WQ_v = [(P)(R_v)(A)]/12
= [(1")(0.471)(0.77 ac)]/12
= 0.0302 ac-ft (1,316.5 cf.)

SARB_004902

Figure C.2.2 Comstock Commercial Center – Developed Conditions
(source: TR-55 computer printouts)

```
              RUNOFF CURVE NUMBER COMPUTATION             Version 2.10
Project : COMSTOCK COMMERCIAL                    User: SRC      Date: 09-17-1999
County  : HOWARD               State: MD      Checked: ____     Date: ________
Subtitle: DEVELOPED CONDITIONS
--------------------------------------------------------------------------------
                                                    Hydrologic Soil Group
         COVER DESCRIPTION                        A        B        C        D
                                                          Acres (CN)
--------------------------------------------------------------------------------
FULLY DEVELOPED URBAN AREAS (Veg Estab.)
Open space (Lawns,parks etc.)
  Good condition; grass cover > 75%              -  0.41(61)       -        -
Impervious Areas
  Paved parking lots, roofs, driveways           -  0.36(98)       -        -

Total Area (by Hydrologic Soil Group)                .77
--------------------------------------------------------------------------------
                TOTAL DRAINAGE AREA: .77 Acres       WEIGHTED CURVE NUMBER: 78*

                       GRAPHICAL PEAK DISCHARGE METHOD            Version 2.10


Project : COMSTOCK COMMERCIAL CENTER             User: SRC      Date: 12-07-1999
County  : HOWARD               State: MD      Checked: ____     Date: ________
Subtitle: DEVELOPED CONDITIONS

  Data: Drainage Area        :  .77   Acres
        Runoff Curve Number  :  78
        Time of Concentration:  0.10   Hours (MINIMUM VALUE)
        Rainfall Type        :  II
        Pond and Swamp Area  :  NONE

================================================================================
| Storm Number          |   1  |   2  |   3  |   4  |   5  |   6  |   7  |
|-----------------------|------|------|------|------|------|------|------|
| Frequency  (yrs)      |   1  |   2  |   5  |  10  |  25  |  50  |  100 |
| 24-Hr Rainfall (in)   |  2.6 |  3.2 |  4.2 |  5.1 |  5.6 |  6.3 |  7.2 |
| Ia/P Ratio            | 0.22 | 0.18 | 0.13 | 0.11 | 0.10 | 0.09 | 0.08 |
|            Used       | 0.22 | 0.18 | 0.13 | 0.11 | 0.10 | 0.10 | 0.10 |
| Runoff (in)           | 0.85 | 1.27 | 2.05 | 2.80 | 3.23 | 3.85 | 4.66 |
| Unit Peak Discharge   |1.511 |1.534 |1.558 |1.572 |1.578 |1.578 |1.578 |
|    (cfs/acre/in)      |      |      |      |      |      |      |      |
| Pond and Swamp Factor| 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
|    0.0% Ponds Used    |      |      |      |      |      |      |      |
|-----------------------|------|------|------|------|------|------|------|
| Peak Discharge (cfs)  |    1 |    2 |    2 |    3 |    4 |    5 |    6 |
================================================================================

* - Value(s) provided from TR-55 system routines
```

Figure C.2.3 Comstock Commercial Center – Drainage Area (DA) 1
(source: TR-55 computer printouts)

```
              RUNOFF CURVE NUMBER COMPUTATION            Version 2.10
Project : COMSTOCK COMMERCIAL                    User: SRC      Date: 09-27-1999
County  : HOWARD              State: MD      Checked: ____     Date: ________
Subtitle: DRAINAGE AREA DA-1
--------------------------------------------------------------------------------
                                                    Hydrologic Soil Group
         COVER DESCRIPTION                        A        B        C        D
                                                        Acres (CN)
--------------------------------------------------------------------------------
FULLY DEVELOPED URBAN AREAS (Veg Estab.)
Open space (Lawns,parks etc.)
  Good condition; grass cover > 75%              -  .04 (61)       -        -

Impervious Areas
  Paved parking lots, roofs, driveways           -  0.16(98)       -        -

Total Area (by Hydrologic Soil Group)               .20
                                                    ====
--------------------------------------------------------------------------------
                TOTAL DRAINAGE AREA: .20 Acres      WEIGHTED CURVE NUMBER: 91*
--------------------------------------------------------------------------------
* - Generated for use by GRAPHIC method

                       GRAPHICAL PEAK DISCHARGE METHOD            Version 2.10


Project : COMSTOCK COMMERCIAL CENTER              User: SRC      Date: 12-07-1999
County  : HOWARD               State: MD      Checked: ____     Date: ________
Subtitle: DEVELOPED CONDITIONS DA-1

  Data: Drainage Area        :  .2   Acres
        Runoff Curve Number  :  91
        Time of Concentration:  0.10   Hours
        Rainfall Type        :  II
        Pond and Swamp Area  :  NONE

=================================================================================
| Storm Number          |   1   |   2   |   3   |   4   |   5   |   6   |   7   |
|-----------------------|-------|-------|-------|-------|-------|-------|-------|
| Frequency  (yrs)      |   1   |   2   |   5   |  10   |  25   |  50   |  100  |
| 24-Hr Rainfall (in)   |  2.6  |  3.2  |  4.2  |  5.1  |  5.6  |  6.3  |  7.2  |
| Ia/P Ratio            | 0.08  | 0.06  | 0.05  | 0.04  | 0.04  | 0.03  | 0.03  |
|            Used      | 0.10  | 0.10  | 0.10  | 0.10  | 0.10  | 0.10  | 0.10  |
| Runoff (in)           | 1.70  | 2.26  | 3.21  | 4.08  | 4.57  | 5.25  | 6.14  |
| Unit Peak Discharge   |1.578  |1.578  |1.578  |1.578  |1.578  |1.578  |1.578  |
|    (cfs/acre/in)      |       |       |       |       |       |       |       |
| Pond and Swamp Factor | 1.00  | 1.00  | 1.00  | 1.00  | 1.00  | 1.00  | 1.00  |
|    0.0% Ponds Used    |       |       |       |       |       |       |       |
|-----------------------|-------|-------|-------|-------|-------|-------|-------|
| Peak Discharge (cfs)  |    1  |    1  |    1  |    1  |    1  |    2  |    2  |
=================================================================================
```

Figure C.2.4 Comstock Commercial Center – Drainage Area (DA) 2
(source: TR-55 computer printouts)

```
               RUNOFF CURVE NUMBER COMPUTATION            Version 2.10
Project : COMSTOCK COMMERCIAL CENTER             User: SRC      Date: 09-21-1999
County  : HOWARD               State: MD      Checked: ____     Date: ________
Subtitle: DRAINAGE AREA DA-2 DEVELOPED
--------------------------------------------------------------------------------
                                                    Hydrologic Soil Group
         COVER DESCRIPTION                        A        B        C        D
                                                        Acres (CN)
--------------------------------------------------------------------------------
FULLY DEVELOPED URBAN AREAS (Veg Estab.)
Open space (Lawns,parks etc.)
  Good condition; grass cover > 75%              -  0.02(61)       -        -

Impervious Areas
  Paved parking lots, roofs, driveways           -  0.20(98)       -        -

Total Area (by Hydrologic Soil Group)               .22
                                                   ====
--------------------------------------------------------------------------------
                TOTAL DRAINAGE AREA: .22 Acres       WEIGHTED CURVE NUMBER: 95*
--------------------------------------------------------------------------------
* - Generated for use by GRAPHIC method

                        GRAPHICAL PEAK DISCHARGE METHOD            Version 2.10
  Data: Drainage Area        :  .22 * Acres
        Runoff Curve Number  :  95 *
        Time of Concentration:  0.10   Hours (MINIMUM VALUE)
        Rainfall Type        :  II
        Pond and Swamp Area  :  NONE

=================================================================================
| Storm Number          |   1   |   2   |   3   |   4   |   5   |   6   |   7   |
|-----------------------|-------|-------|-------|-------|-------|-------|-------|
| Frequency  (yrs)      |   1   |   2   |   5   |  10   |  25   |  50   |  100  |
| 24-Hr Rainfall (in)   |  2.6  |  3.2  |  4.2  |  5.1  |  5.6  |  6.3  |  7.2  |
| Ia/P Ratio            | 0.04  | 0.03  | 0.03  | 0.02  | 0.02  | 0.02  | 0.01  |
|            Used      | 0.10  | 0.10  | 0.10  | 0.10  | 0.10  | 0.10  | 0.10  |
| Runoff (in)           | 2.06  | 2.64  | 3.63  | 4.52  | 5.01  | 5.71  | 6.60  |
| Unit Peak Discharge   |1.578  |1.578  |1.578  |1.578  |1.578  |1.578  |1.578  |
|    (cfs/acre/in)      |       |       |       |       |       |       |       |
| Pond and Swamp Factor| 1.00  | 1.00  | 1.00  | 1.00  | 1.00  | 1.00  | 1.00  |
|    0.0% Ponds Used    |       |       |       |       |       |       |       |
|-----------------------|-------|-------|-------|-------|-------|-------|-------|
| Peak Discharge (cfs)  |    1  |    1  |    1  |    2  |    2  |    2  |    2  |
=================================================================================

* - Value(s) provided from TR-55 system routines
```


SARB_004905

Step 2. Compute Re_v

Step 2a. Determine Soil Specific Recharge Factor (S) Based on Hydrologic Soil Group

Soils found throughout the site are loams (HSG B) therefore $S = 0.26$

Step 2b. Compute Re_v Using Percent Volume Method

$$Re_v = [(S)(R_v)(A)]/12$$
$$= [(0.26)(0.471)(0.77)]/12$$
$$= \underline{0.0078 \text{ ac-ft.}} \text{ (342.3 cf)}$$

Step 2c. Compute Re_v Using Percent Area Method

$$Re_v = (S)(A_i)$$
$$= (0.26)(0.36 \text{ ac.})$$
$$= 0.094 \text{ acres (4,095 sf.)}$$

The Re_v requirement may be met by: a) treating 342.3 cubic feet using structural methods, b) treating 4,095 square feet using non-structural methods, or c) a combination of both.

Step 3. Compute Cp_v

The proposed community center is located within a USE I watershed, therefore use an extended detention time (T) of 24 hours for the one-year storm event. The time of concentration (t_c) and one-year runoff (Q_a) are 0.10 hours and 0.85" respectively.

Use the MDE Method to Compute Storage Volume (Appendix D.11):

Initial abstraction (I_a) for CN of 78 is 0.564: (TR-55) [$I_a = (200/CN)-2$]

$I_a/P = (0.564)/2.6" = 0.22$
$t_c = 0.10$ hours

$q_u = 975$ csm/in. (Figure D.11.1, Appendix D.11)

$q_i = q_u A Q_a$ where A is the drainage area in square miles
$= (975 \text{ csm})(0.0012 \text{ square miles})(0.85")$
$= 1.0$ cfs; $q_i < 2.0$ cfs $\therefore$ Cp_v is not required.

SARB_004906

Step 4. Compute Requirements for Sub-Drainage Areas DA-1, DA-2 and DA-3

DA-1: $R_v = 0.05 + (0.009)(I)$; $I = 0.16$ acres / 0.20 acres = 0.80 or 80%
$= 0.05 + (0.009)(80.0) = 0.77$

$WQ_v = [(P)(R_v)(A)]/12$
$= [(1")(0.77)(0.20\ ac)]/12$
$=$ 0.0128 ac-ft (557.5 cf.)

$Re_v = [(S)(R_v)(A)]/12$
$= [(0.26)(0.77)(0.20\ ac)]/12$
$=$ 0.0033 ac-ft (145 cf.)

DA-2: $R_v = 0.05 + (0.009)(I)$; $I = 0.20$ acres / 0.22 acres = 0.91 or 91%
$= 0.05 + (0.009)(91) = 0.87$

$WQ_v = [(P)(R_v)(A)]/12$
$= [(1")(0.87)(0.22\ ac.)]/12$
$=$ 0.0160 ac-ft (694.8 cf.)

$Re_v = [(S)(R_v)(A)]/12$
$= [(0.26)(0.87)(0.22\ ac.)]/12$
$=$ 0.0041 ac-ft (180.6 cf.)

DA-3: $R_v = 0.05 + (0.009)(I)$; $I = 0.0$ acres / 0.35 acres = 0.0 or 0%
$= 0.05 + (0.009)(0.0) = 0.05$

Because $I < 15\%$, $WQ_v = 0.2"$/acre
$WQ_v = [(0.2")(0.35\ ac.)]/12$
$=$ 0.0058 ac-ft (254.1 cf.)

$Re_v = [(S)(R_v)(A)]/12$
$= [(0.26)(0.05)(0.35\ ac.)]/12$
$=$ 0.0004 ac-ft (16.5 cf.)

NOTE: Although DA-3 has no proposed impervious surfaces, portions of DA-3 will be disturbed to construct structural BMPs for DA-1 and DA-2. As a result, WQ_v and Re_v must be addressed for DA-3. For this example, the portion of DA-3 not disturbed for BMP construction shall be treated by promoting sheet flow into the adjacent forested buffer (see Chapter 5.4, "Sheetflow to Buffer Credit").

SARB_004907

Table C.2.1 Summary of General Storage Requirements for Comstock Commercial Center

Requirement	Drainage Area	Volume Required (cubic feet)	Notes
WQ_v*	Total	1,316.5	The sum of treatment volumes for DA-1, DA-2 and DA-3 is greater than that calculated for the entire site.
	DA-1	557.5	
	DA-2	694.8	
	DA-3	254.1	
Re_v*	Total	342.3 (or 4,095 sf.)	volume is included within the WQ_v storage
	DA-1	145.6 (or 1,812 sf.)	
	DA-2	180.6 (or 2,265 sf.)	
	DA-3	16.1	
Cp_v		N/A	Cp_v inflow rate is < 2.0 cfs
Q_{p10}		N/A	not required
Q_f		N/A	provide safe passage for the 100-year event in final design

SARB_004908

C.2.3 BMP Design Option 1

The first option consists of the design of a perimeter sand filter (F-3) for DA-1 and a pocket sand filter (F-5) for DA-2. In both designs, Re_v storage will be provided below the filter's underdrain system. As a result, the entire WQ_v must be considered in the design of each filter system. A plan view for Option 1 is shown in Figure C.2.5

C.2.3.1 Perimeter Sand Filter (F-3) for DA-1

Pretreatment

The pretreatment requirements for a perimeter sand filter are as follows:

The pretreatment volume (*Vp*) for the perimeter sand filter shall be at least 25% of the computed WQ_v:

$$V_p = (0.25)(WQ_v)$$
$$= (0.25)(557.5 \text{ cf.})$$
$$= 139.4 \text{ cf.}$$

The minimum required surface area as computed by the Camp-Hazen equation:

$$A_s = \frac{Q_o}{W} \times E' \qquad \text{(see Section 3.4.3 for terms)}$$

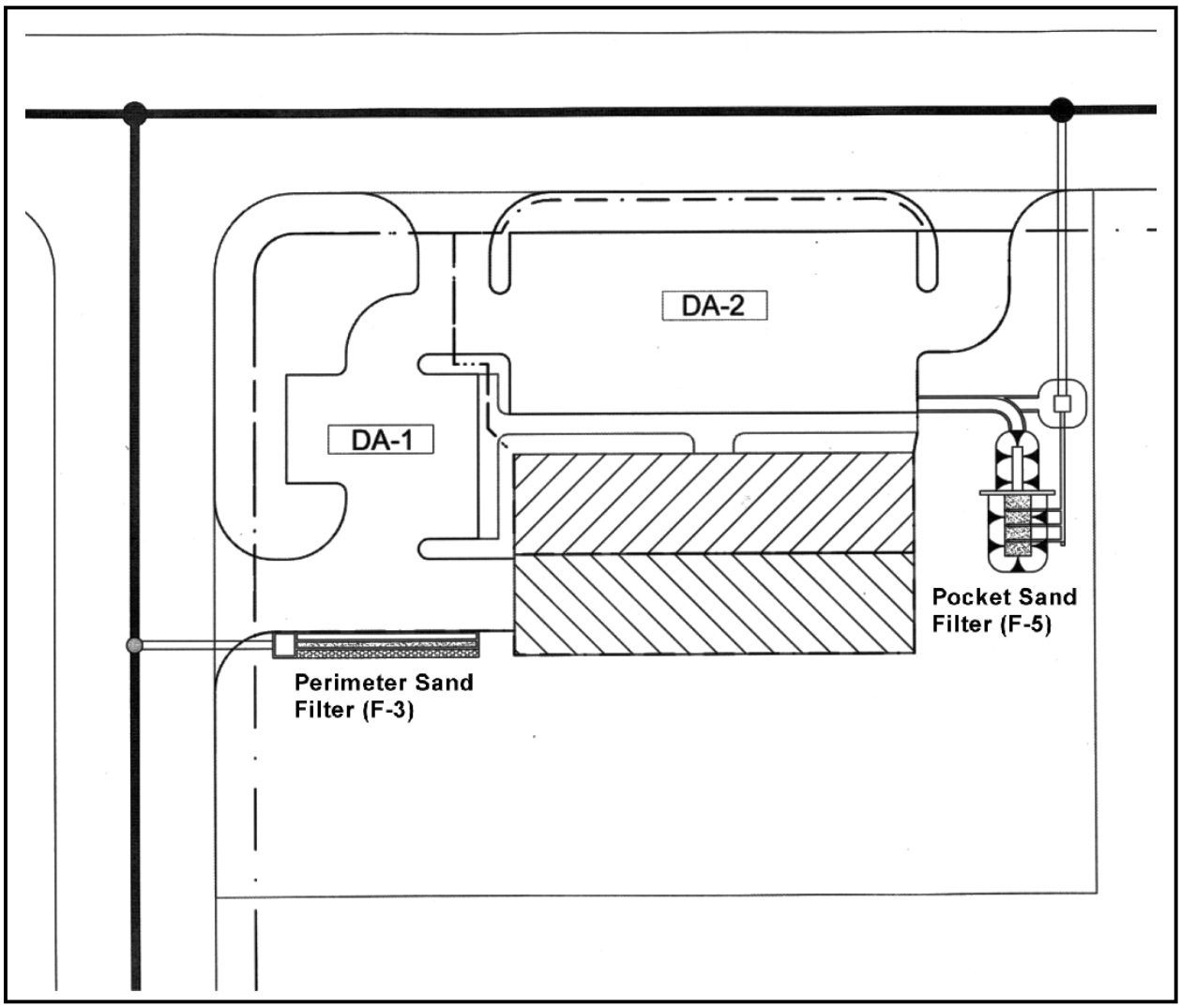
For imperviousness (I) > 75%, this equation reduces to:

$$A_{sp} = (0.0081)(WQ_v)$$
$$= (0.0081)(557.5 \text{ cf.})$$
$$= 4.52 \text{ sf.}$$

Using a width (w) =1.5 ft. and length (l) = 45 ft., the required depth for the sedimentation chamber = 139.4 cf. / (1.5 ft.)(45 ft.) = 2.06 ft.; **Use a sedimentation chamber 1.5 ft. by 45 ft. by 2.1 ft.**

SARB_004909

Figure C.2.5 Design Option 1 - Plan View



Treatment

The treatment requirements for the perimeter sand filter are as follows:

The entire treatment system (including pretreatment) shall temporarily hold at least 75% of the WQ_v prior to filtration:

$$V_{temp} = (0.75)(WQ_v)$$
$$= (0.75)(557.5 \text{ cf.})$$
$$= 418.1 \text{ cf.}$$

The required filter bed area (A_f) is computed using the following equation:

$$A_f = \frac{(WQ_v)(d_f)}{[k \times (h_f + d_f) \times t_f)]} \qquad \text{(see Section 3.4.4)}$$

Minimum filter bed depth (d_f) = 12"; for this design use d_f = 12" (1.0 ft)

The coefficient of permeability (k) for sand filters = 3.5 ft./day

The average height of water above the filter bed (h_f) = (0.5)(design ponding depth). For this design, the ponding depth =1.0 ft. ∴ hf = 0.5 ft.

The design filter bed drain time (t_f) = 1.67 days

Therefore: $A_f = \dfrac{(557.5\ cf.)(1.0\ ft.)}{[(3.5\ ^{ft}/_{day})(0.5\ ft. + 1.0\ ft.)(1.67\ days)]} = 63.6$ sf.

Setting the filter chamber width (w) to 1.5 ft., the length (l) of the filter chamber = 63.6 sf./1.5 ft. = 42.4 ft; **Use a filter chamber 1.5 ft. by 45 ft.**

Check V_{temp}: $V_{temp} = V_p + V_{treatment}$

$= 139.4 + [(1.0)(1.5)(45) + (1.0)(1.5)(45)(0.4)] = 236.5$ cf.

note: 0.4 is the porosity of the filter media

Approximately 182 cf. of additional storage is needed to meet this requirement. Either increase the storage in one or both chambers or design parking area to provide additional storage. For this design, the pretreatment chamber width will be increased to 3.5 ft.

$V_{temp} = V_p + V_{treatment}$

$= (3.5)(45.0)(2.1) + [(1.0)(1.5)(45) + (1.0)(1.5)(45)(0.4)] = 425.25$ cf.

Groundwater Recharge (Re_v)

Re_v storage will be provided within a stone-filled trench adjacent to the perimeter sand filter. Setting the trench length (l) = 45 ft., and the width (w) = 2.0 ft, the trench depth (d) needed to store the Re_v volume (V =145.6 cf.) is:

$$d = \frac{V}{l \times w \times n}$$ where n is the porosity of stone; use n = 0.4

Therefore, d = 145.6 cf./(45.0 ft. × 2.0 ft. × 0.4) = 4.04 ft.; **use a stone-filled trench 45.0 ft. by 2.0 ft. by 4.1 ft.**

Overflow

Flow splitters and overflow devices may be designed using volume or flow rate. For this example, a weir discharging from the sedimentation chamber into the clear well

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will provide volume overflow for the ten-year storm. For DA-1, the ten-year flow (Q_{10}) = 1.0 cfs. Using a weir length of 1.5 ft., the head required to safely convey Q_{10} may be calculated using the weir equation: $Q=Clh^{3/2}$ where C = 3.1, l = weir length (1.5 ft.), and h = head. By rearranging the weir equation and solving for h; $h=[Q/(C\times l)]^{2/3}$ = 0.40 ft. **Design perimeter sand filter with at least 0.4 ft. freeboard to safely convey Q_{10}.**

Design details for the perimeter sand filter are shown in Figures C.2.6.

C.2.3.2 Pocket Sand Filter (F-5) for DA-2

Pretreatment

The pretreatment requirements for a pocket sand filter are as follows:

V_p for the pocket sand filter shall be at least 25% of the computed WQ_v:

$$V_p = (0.25)(WQ_v)$$
$$= (0.25)(694.8 \text{ cf.})$$
$$= 173.7 \text{ cf.}$$

The minimum required surface area as computed by the Camp-Hazen equation:

$$A_s = \frac{Q_o}{W} \times E'$$

For $I > 75\%$, this equation reduces to:

$$A_{sp} = (0.0081)(WQ_v)$$
$$= (0.0081)(694.8 \text{ cf.})$$
$$= 5.62 \text{ sf.}$$

Maintaining at least a 2:1 ratio (l:w); set w = 6.5 ft. and l = 13.0 ft. The required d for the sedimentation area = 173.7 cf. /(6.5 ft.)(13.0 ft.)= 2.0 ft.; **Use a sedimentation chamber 6.5 ft. by 13.0 ft. by 2.0 ft.**

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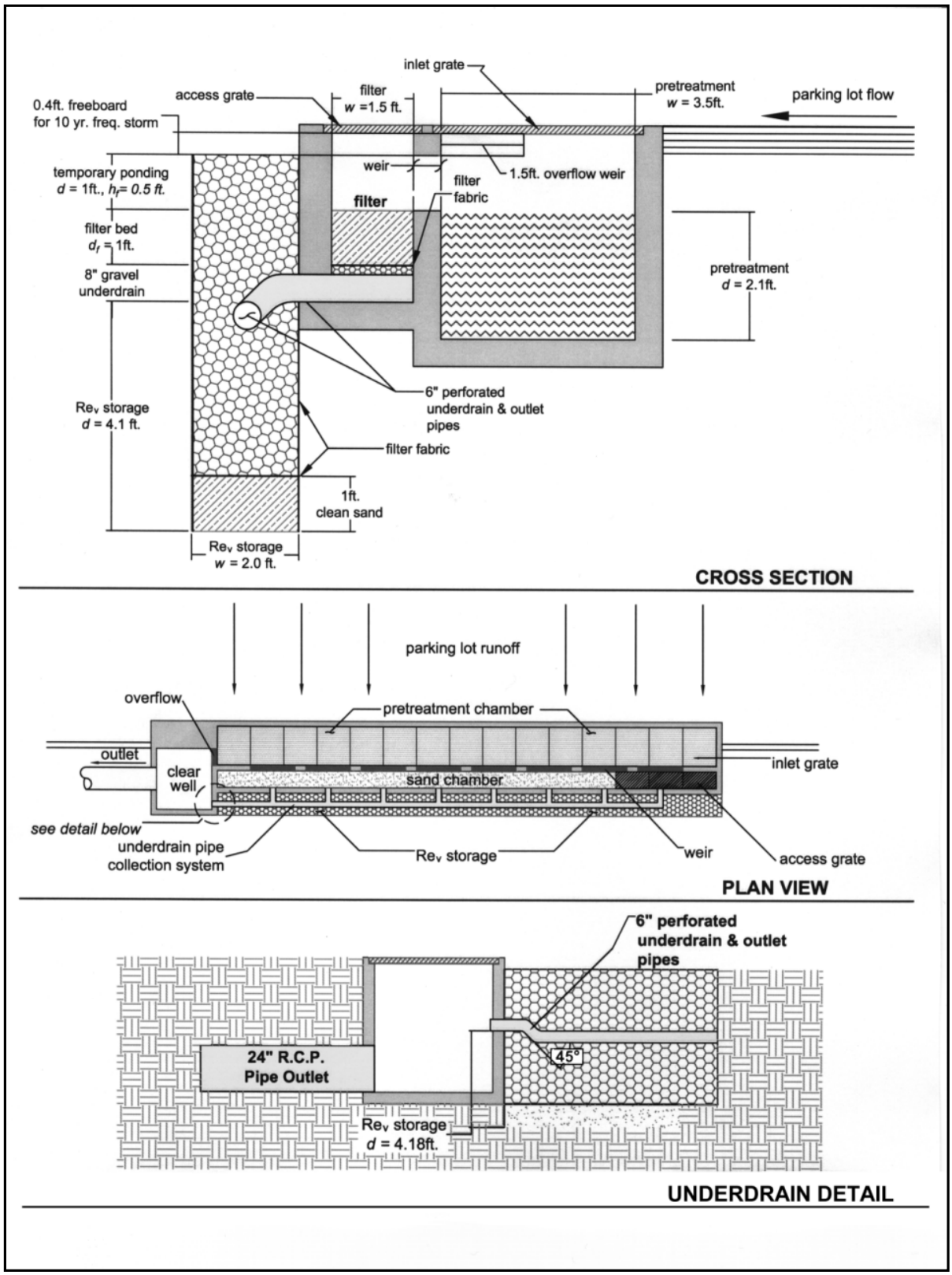
Figure C.2.6 Perimeter Sand Filter Design Details



Treatment

The treatment requirements for the pocket sand filter are as follows:

The entire treatment system (including pretreatment) shall temporarily hold at least 75% of the WQv prior to filtration:

$$V_{temp} = (0.75(\text{WQv}) = (0.75)(694.8 \text{ cf.}) = 521.1 \text{ cf.}$$

The required filter bed area is computed using the following equation:

The minimum d_f for a pocket sand filter = 18"; for this design use d_f = 18" (1.5').

$$A_f = (WQ_v)(d_f) \Big/ [k \times (h_f + d_f) \times t_f)]$$

The coefficient of permeability (k) for sand filters = 3.5 ft/day

The average height of water (h_f) above the filter bed for this design = 0.5 ft.

The design filter bed drain time (t_f) = 1.67 days.

Therefore: $A_f = \dfrac{(694.8\ cf.)(1.5\ ft.)}{[(3.5\ ^{ft}/_{day})(0.5\ ft. + 1.5\ ft.)(1.67\ days)]} = 89.2\ sf.$

Setting the filter chamber width (w) to 6.5 ft. l = 89.2 ft./6.5 ft. =13.7 ft.; **Use a filter chamber 6.5 ft. by 13.7 ft.**

Check V_{temp}: $V_{temp} = V_p + V_{treatment}$

$= 173.7 + [(1.0)(6.5)(13.7) + (1.5)(6.5)(13.7)(0.4)] = 316.1$ cf.

note: 0.4 is the porosity of the filter media

Approximately 205 cf. of additional storage is needed to meet this requirement. Either increase the storage in one or both chambers or design parking area to provide additional storage. For this design, the pretreatment chamber width will be increased to 9.0 ft. and the depth increased to 3.0 ft.

$V_{temp} = V_p + V_{treatment}$

$= (9.0)(13.0)(3.0) + [(1.5)(6.5)(13.7) + (1.5)(6.5)(13.7)(0.4)] = 538.0$ cf

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Groundwater Recharge (Re_v)

Re_v storage will be provided within a stone-filled reservoir directly below the filter chamber's underdrain system. Using w = 6.5 ft. and l = 13.7 ft., the depth needed to store the Re_v volume (V = 180.6 cf.) is:

$$d = \frac{V}{l \times w \times n}$$ where n is the porosity of stone; use n = 0.4

Therefore, d = 180.6/(13.7 ft. × 6.5 ft. × 0.4)=5.1 ft.; **Use a stone-filled reservoir 6.5 ft. by 13.7 ft. by 5.1 ft.**

Overflow/Bypass

As the pocket sand filter will be located "off-line" from the main conveyance system, a flow splitter will be required to divert the WQv into the filter. Flow splitters may be designed using volume or flow rate. For this example, use a concrete flume with a bottom width of 4.0 ft designed to divert the flow associated with the WQ_v. The head required to divert the WQv flow may be calculated using the weir equation: $Q=Clh^{3/2}$ where Q is flow associated with WQv (using Appendix D.10, Q= 0.3 cfs), C = 3.1, l = 4.0 ft., and h=head. By rearranging the equation and solving for h; $h=[Q/(C \times l)]^{2/3}=0.084$ ft. **Design flow splitter with a 1 inch high diversion.** NOTE: With this type of flow splitter, runoff in excess of the WQ_v may continue to flow into the sand filter.

Design details for the pocket sand filter are shown in Figures C.2.7 and C.2.8.

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Figure C.2.7 Pocket Sand Filter – Plan View

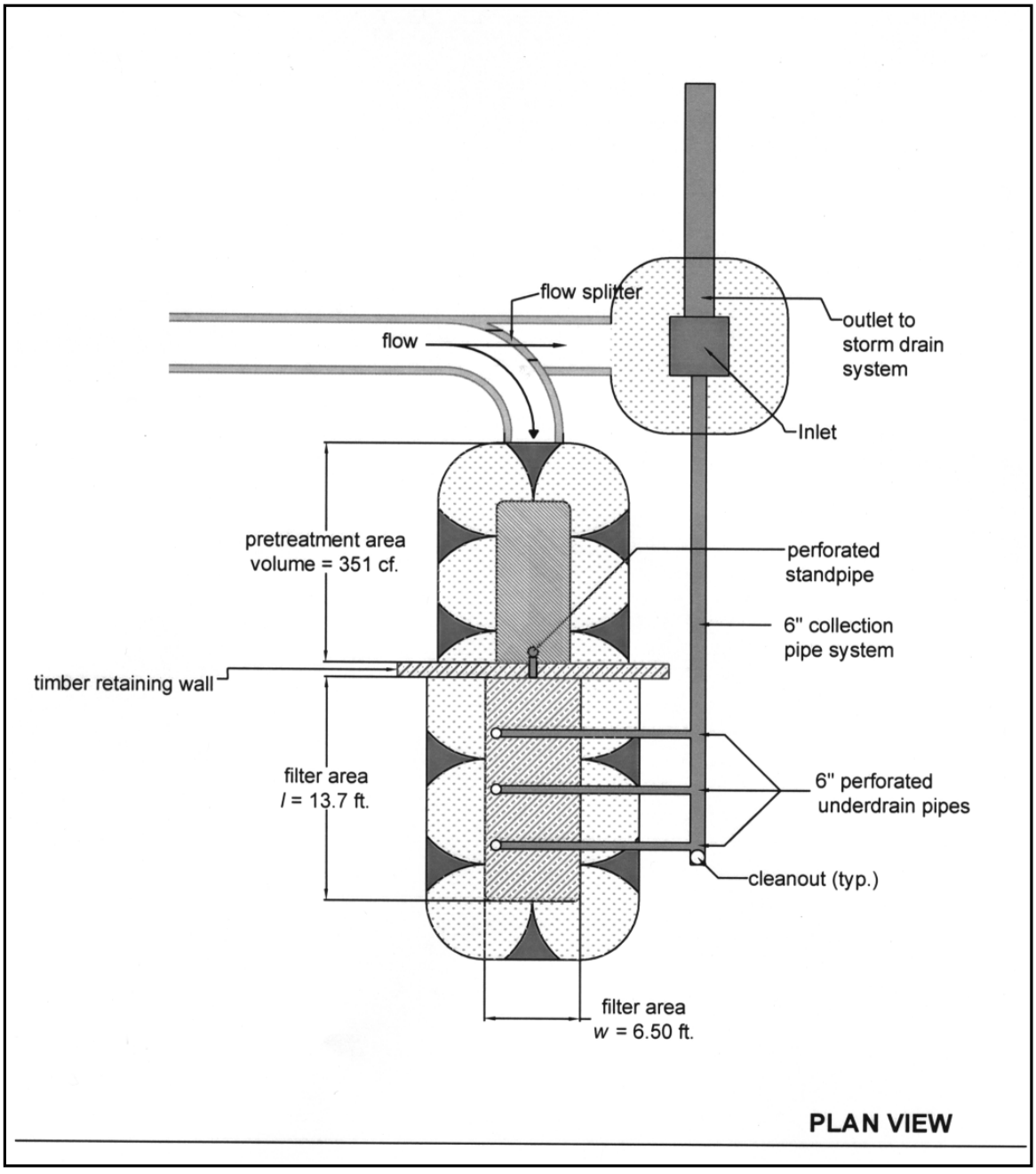

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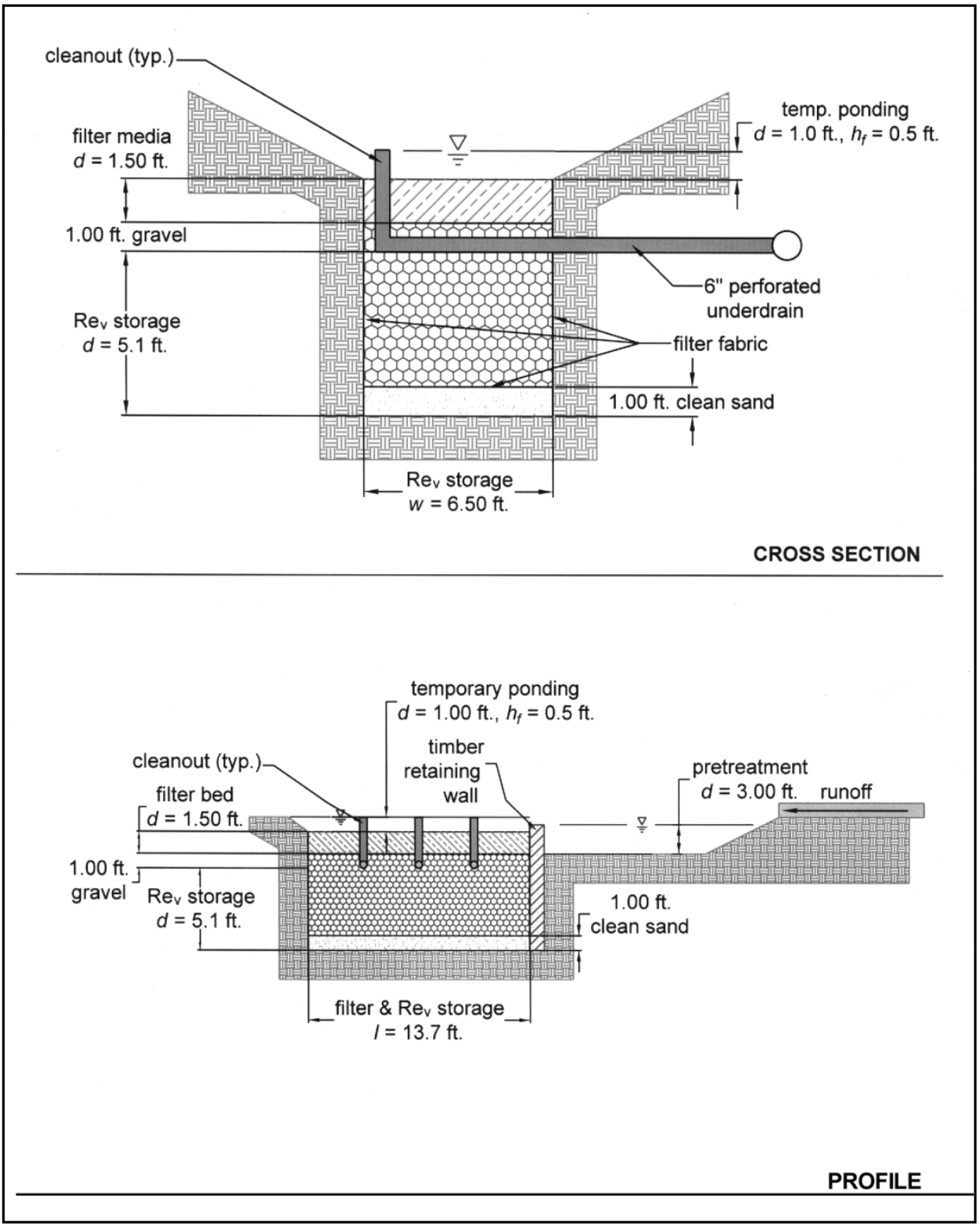
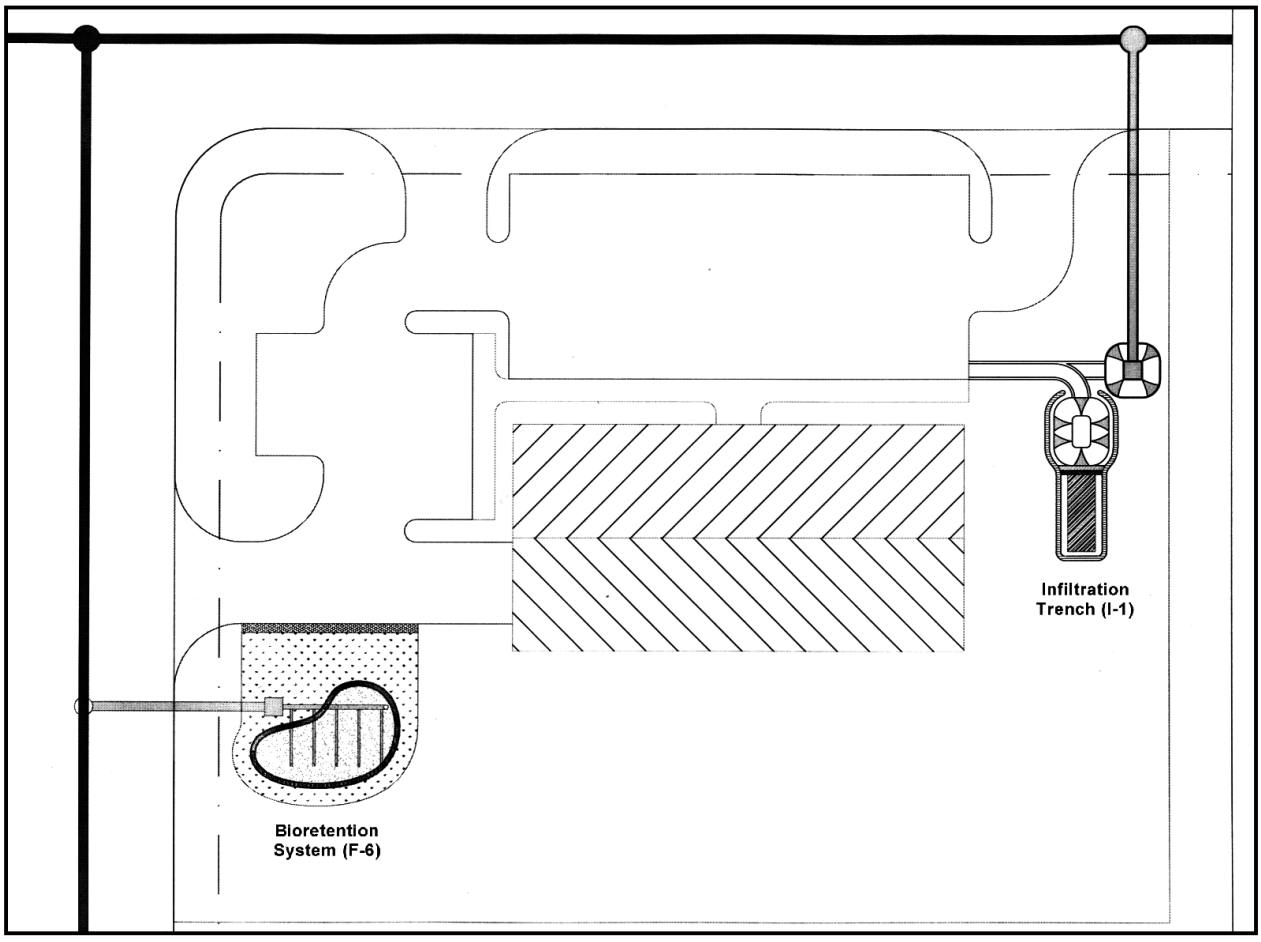
Figure C.2.8 Pocket Sand Filter Design Details



C.2.4 BMP Design Option 2.

The second option consists of the design of a bioretention area (F-6) for DA-1 and an infiltration trench (I-1) for DA-2. For the bioretention system, Re_v storage will be provided below the underdrain system, and as a result, the entire WQ_v will be used as the design. The infiltration trench automatically meets the Re_v requirement. A plan view of Option 2 is shown in Figure C.2.9.

Figure C.2.9 Design Option 2 – Plan View



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C.2.4.1 Bioretention System (F-6) for DA-1

Pretreatment

Adequate pretreatment for a bioretention system is provided when all of the following are provided:

1. 20 ft. grass filter strip below a level spreader or an optional sand filter layer;
2. gravel diaphragm; and
3. 2" to 3" mulch layer.

Treatment

The treatment requirements for the bioretention system are as follows (Section 3.4.3 & 4):

The entire treatment system (including pretreatment) shall temporarily hold at least 75% of the WQv prior to filtration:

$$V_{temp} = (0.75)(WQ_v)$$
$$= (0.75)(557.5 \text{ cf.})$$
$$= 418.1 \text{ cf.}$$

The required filter bed area (A_f) is computed using the following equation:

$$A_f = \frac{(WQ_v)(d_f)}{[k \times (h_f + d_f) \times t_f)]}$$

Recommended filter bed depth (d_f) for a bioretention system is 2.5 to 4.0 ft. For this design, use $d_f = 3.0$ ft.

The coefficient of permeability (k) for bioretention systems = 0.5 ft./day

The average height of water above the filter bed (h_f) = 0.5 ft. (Note: The maximum ponding depth for a bioretention system is 1.0 ft.)

The design filter bed drain time (t_f) = 2.0 days

Therefore: $A_f = \frac{(557.5\ cf.)(3.0\ ft.)}{[(0.5\ ^{ft.}/_{day})(0.5\ ft. + 3.0\ ft.)(2.00\ days)]} = 477.9\ sf.$

Use a bioretention system with minimum surface area =478 sf.

Check V_{temp}: $V_{temp} = V_{treatment} = (1.0)(478\ sf) + (3.0)(478\ sf)(0.4) = 1051.6$ cf.

note: 0.4 is the porosity of the filter media

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Groundwater Recharge (Re_v)

Re_v storage will be provided in a stone-filled reservoir directly below the underdrain system. Setting the reservoir area (A_r) = 478 sf., the depth (d) needed to store the Re_v volume (V=145.6 cf.) is:

$$d = \frac{V}{A_r \times n}$$ where n is the porosity of stone; use $n = 0.4$

Therefore; d =145.6 cf./(478.0ft. $\times$ 0.4)=0.76 ft.; **Use a stone-filled reservoir 478 sf. by 0.76 ft.**

Overflow

Overflow for the ten-year storm shall be provided to a non-erosive outlet. For this design, a standard inlet will be used to bypass the volume in excess of the WQ_v by setting the inlet invert at the elevation corresponding to the WQ_v treatment volume (1.0 ft. above the bioretention system filter bed).

Design details and a planting plan for the bioretention system are shown in Figures C.2.10 and C.2.11.

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Figure C.2.10 Bioretention System Details

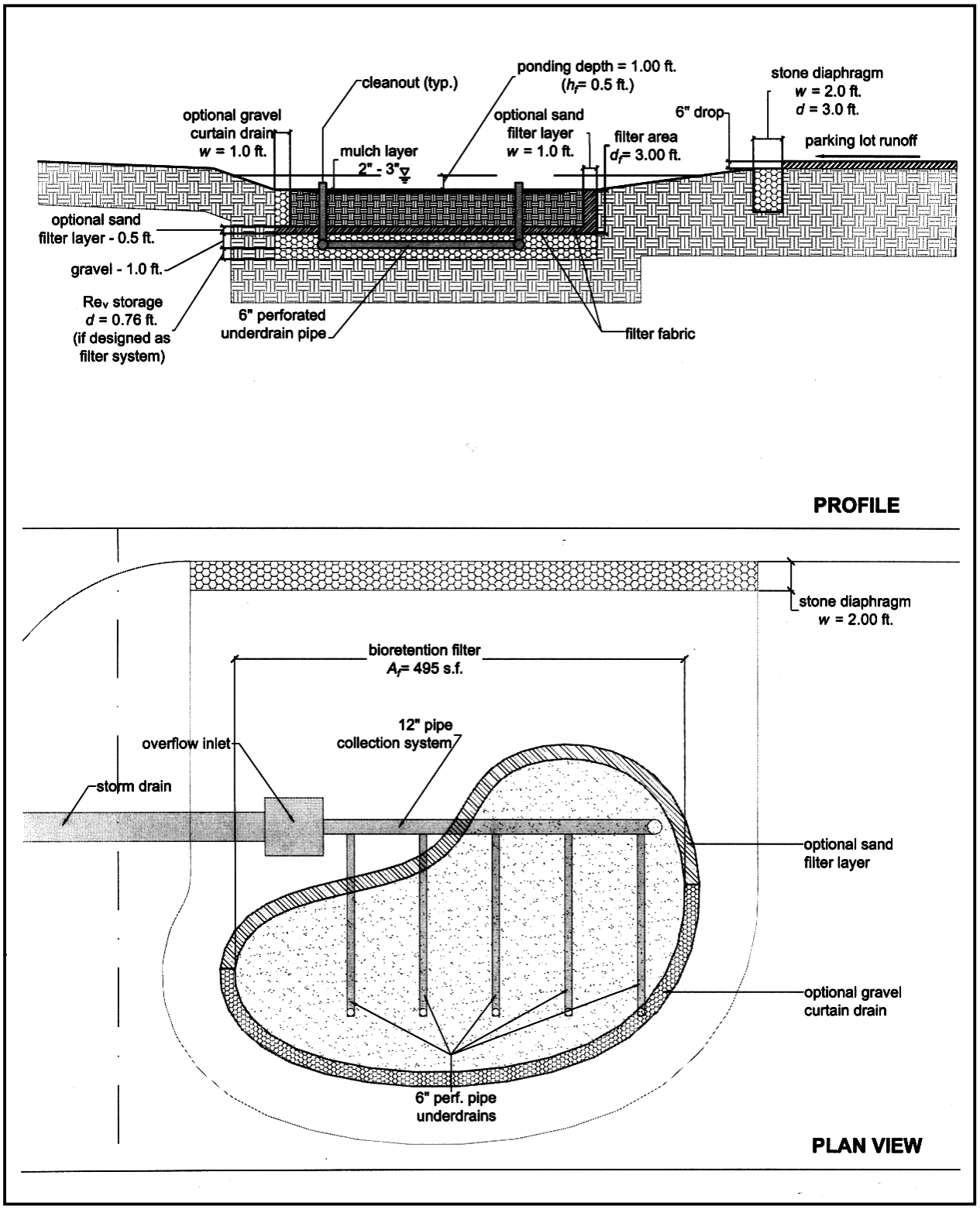

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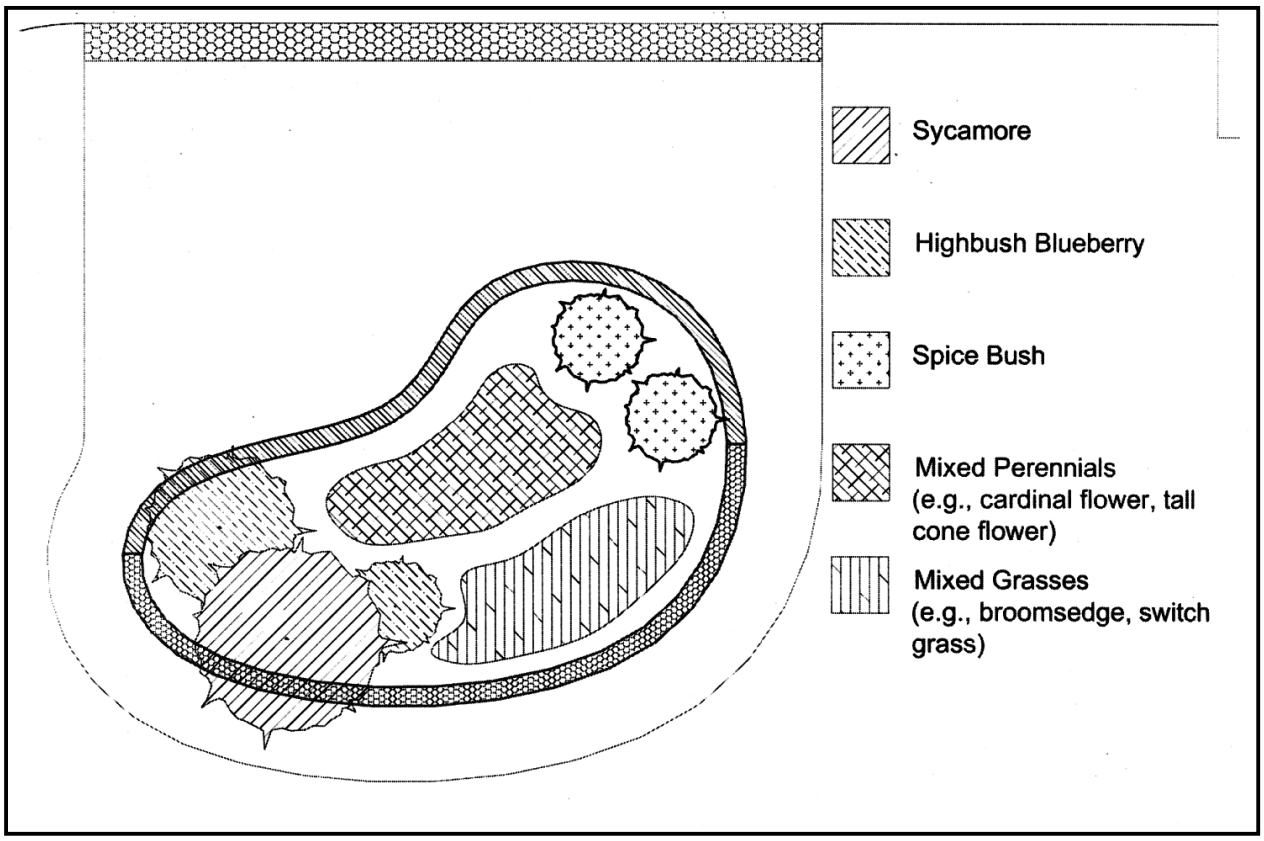
Figure C.2.11 Bioretention Planting Plan



C.2.4.2 Infiltration Trench (I-1) for DA-2

Pretreatment

The pretreatment requirements for an infiltration trench are as follows:

The pretreatment volume (*Vp*) for the infiltration trench shall be at least 25% of the computed WQ_v:

$$V_p = (0.25)(WQ_v)$$
$$= (0.25)(694.8 \text{ cf.})$$
$$= 173.7 \text{ cf.}$$

Using a width (*w*) of 8.0 ft. and a length (*l*) of 11.0 ft., the required depth for the sedimentation chamber = 173.7 cf. /(8.0 ft.)(11.0 ft.) = 1.97 ft.; **Use a sedimentation chamber 8.0 ft by 11.0 ft. by 2.0 ft.**

Additionally, each infiltration trench shall have at least three of the following measures to prevent clogging and maintain the long-term integrity of the trench:

1. grass channel;
2. grass filter strip (minimum 20 ft.);

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3. bottom sand layer
4. upper sand layer (minimum 6") with filter fabric at sand/gravel interface; and
5. use washed bank run gravel as aggregate.

This design will use a bottom sand layer, upper sand layer, and washed bank run gravel.

Treatment

The treatment requirements for an infiltration trench are as follows:

The practice shall be designed to exfiltrate the entire WQv less the pretreatment volume through the floor of the practice. The design volume (V_w) = WQv-V_p = 521.1 cf.

Infiltration practices are designed using the methodology in Appendix D.13.

The maximum allowable depth (d_{max}) of an infiltration trench is

$$d_{\max} = f \times \frac{T_s}{n}$$

where:

f is the infiltration rate, for this design $f = 0.52$ $^{\text{inches}}/_{\text{hour}}$
T_s is the maximum allowable storage of 48 hours
n is the porosity of the stone reservoir, use 0.4

Therefore, d_{max} = $0.52^{\text{inches}}/_{\text{hour}} \times (48 \text{ hours}/0.4) = 62.4$ inches (5.2 ft). **Use a trench depth (d_t) = 5.0 ft.**

Using equation D.13.3, the area of the infiltration trench (A_t) is:

$$A_t = \frac{V_w}{nd_t + fT}$$ where the time to fill the trench (T) is 2.0 hours.

$$A_t = \frac{521.1\ cf.}{(0.4 \times 5.0) + (0.52^{\,inches/hour} \times 2.0\ hours \times {}^{1\ ft}/_{12\ in})} = 249.7\ sf.$$

Use an infiltration trench 7.5 ft. by 35.0 ft. by 5.0 ft.

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Groundwater Recharge (Re_v)

Infiltration trenches automatically meet the Re_v storage requirement; no additional storage is required.

Overflow

As the infiltration trench will be located "off-line" from the main conveyance system, a flow splitter will be required to divert the WQv into the filter. Use the flow splitter design from the pocket sand filter above.

Design details for the infiltration trench are shown in Figures C.2.12.

C.2.5 BMP Design Option 3

The third option consists of the bioretention area (F-6) previously designed for DA-1 and a dry swale (O-1) for DA-2. In the dry swale design, Re_v storage will be provided below the swale's underdrain system. As a result, the entire WQv must be considered in the design of the dry swale. A plan view of Option 3 is shown in Figure C.2.13.

C.2.5.1 Dry Swale (O-1) for DA-2

Pretreatment

The pretreatment requirements for a dry swale are as follows:

> Pretreatment storage of 0.1 inch of runoff from impervious area shall be provided. This is equivalent to 10% of WQv. Therefore, $V_p = (10\%)(\text{WQv}) = 69.5$ cf. **Use a forebay or sedimentation chamber sized to store 62.5 cf.**

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Figure C.2.12 Infiltration Trench Details

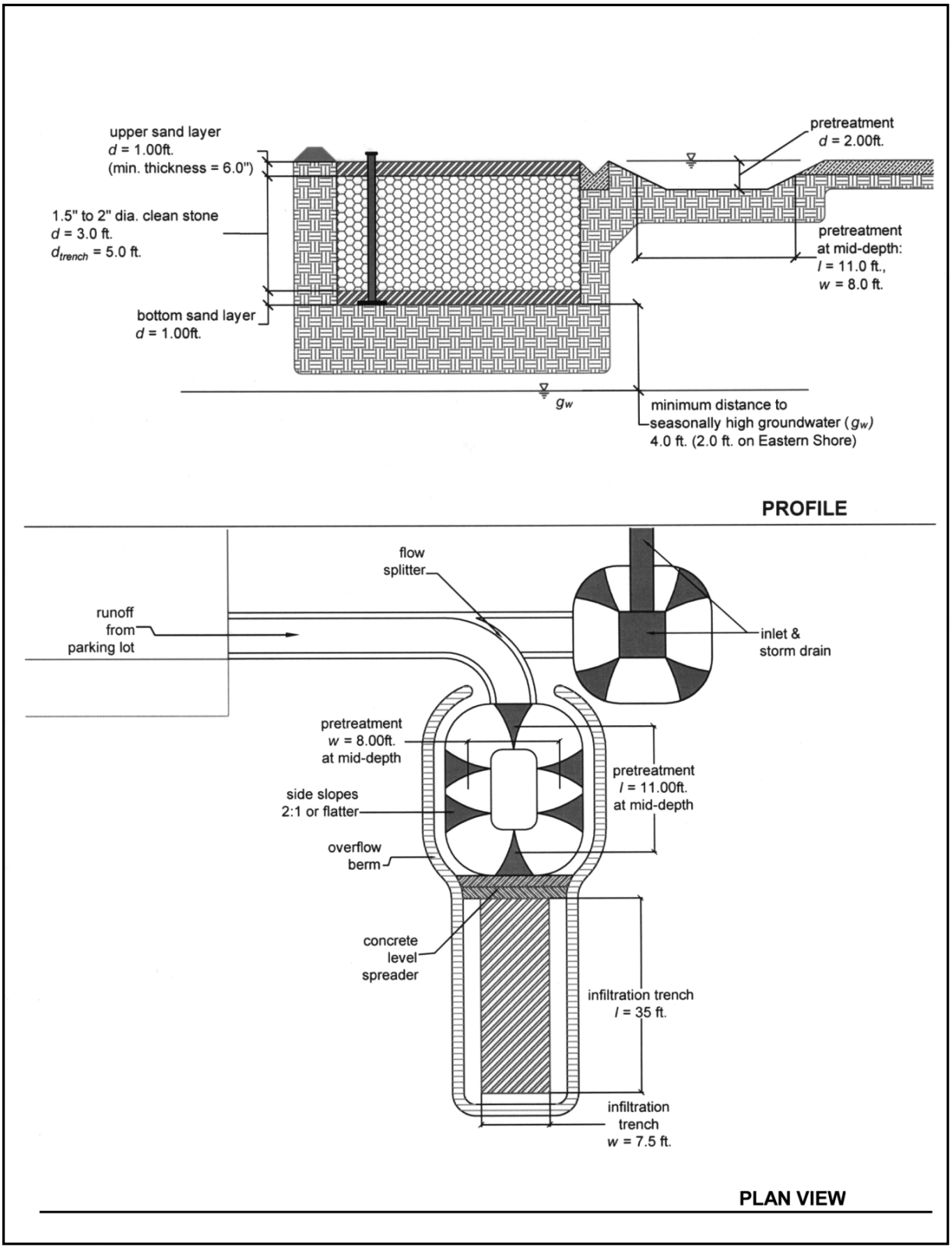
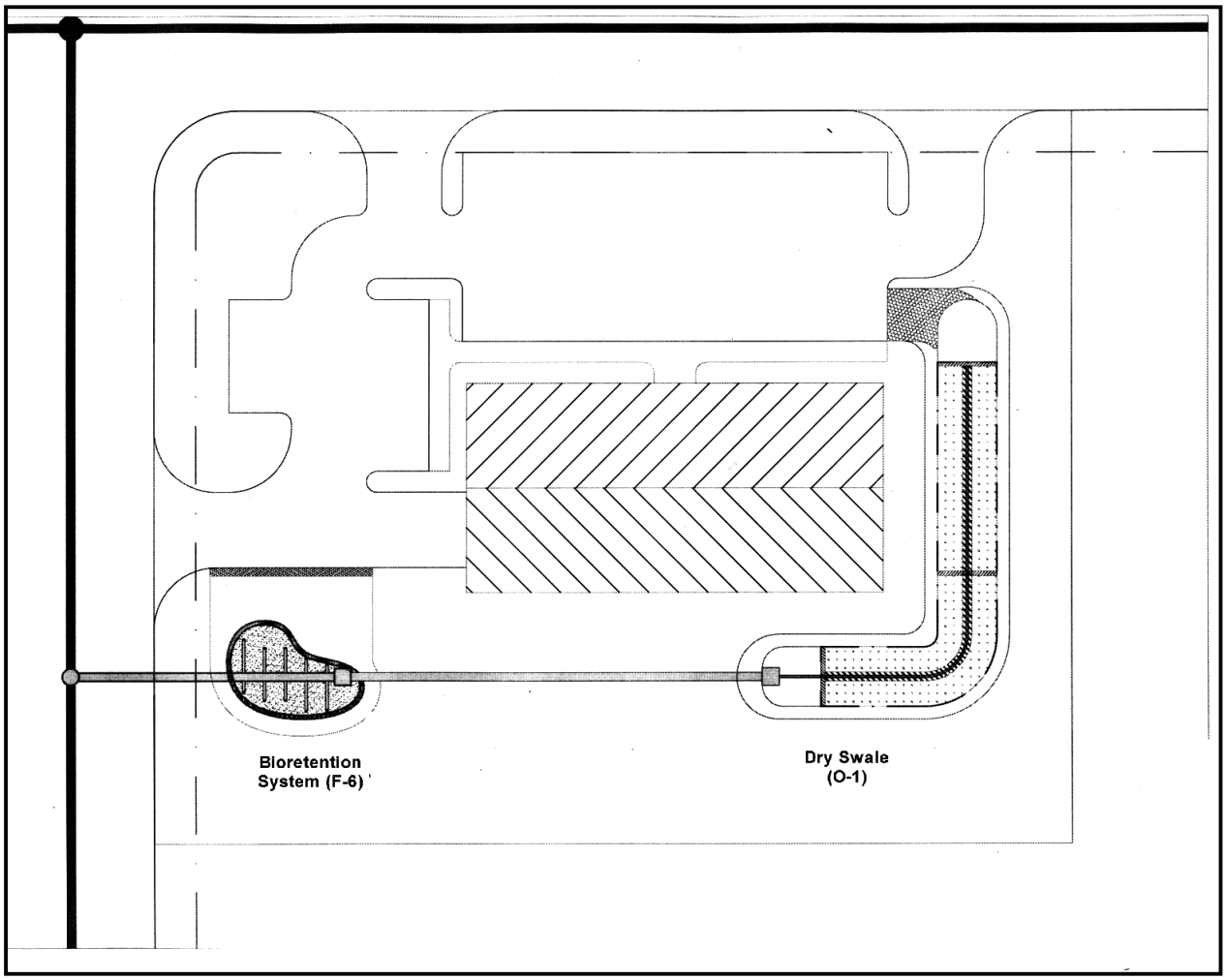


Figure C.2.13 Design Option 3 – Plan View



Treatment

The treatment requirements for the dry swale are as follows:

Dry swales shall be designed to temporarily store the WQv for a maximum 48-hour period. An underdrain system shall provided to ensure the maximum ponding time is not exceeded.

Dry swales shall have a maximum longitudinal slope (*s*) of 4.0%. **For this design, s= 3.0%.**

Channel side slopes (*z*:1) should be no steeper than 2:1. **For this design, side slopes shall be 4:1 (z=4).**

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Dry swales shall have a bottom width (w_b) no narrower than 2.0 ft. and no wider than 8.0 ft. (if wider than 8.0 ft., a meandering drainage pattern shall be established).

Maximum ponding depths (d_{mid}, d_{end}) of 1.0 ft. at the channel mid-point and 1.5 ft. at the downstream end shall be maintained. *Use d_{mid} = 0.75 ft. and d_{max} = 1.5 ft.*

Due to the length (100 ft.) and grade (3.0%) of the channel, the channel will be divided into two contiguous channels separated by a check dam to achieve d_{mid} and d_{end} requirements. *Use three check dams located at the entrance, mid-point and end of the swale.*

With three check dams, there will be two ponding areas of equal storage. Using d_{mid}=0.75', and setting the total length of the swale to 100 ft., the treatment volume of the swale is:

$$WQ_v - V_p = w \times l \times d_{mid}$$

By rearranging this equation and solving for the width of storage surface (w):

$$w = \frac{WQ_v - V_p}{l \times d_{mid}} = \frac{694.8\ cf. - 69.5\ cf.}{100\ ft. \times 0.75\ ft.} = 8.3\ ft.$$

Using w =8.3 ft. and 4:1 side slopes, $w_b = w\text{-}(2 \times z \times d_{mid}) = 8.3\text{-}(2 \times 4 \times 0.75) = 2.3$ ft. **Use a dry swale with bottom dimensions of 2.3 ft. by 100 ft. with 4:1 side slopes.**

Groundwater Recharge (Re_v)

Re_v storage will be provided within a stone-filled reservoir below the dry swale underdrain system. Using the swale dimensions (2.3 ft by 100 ft.), the reservoir depth (d) needed to store the Re_v volume (V=180.6 cf.) is:

$$d = \frac{V}{l \times w \times n}$$ where n is the porosity of stone; use n=0.4

Therefore, d=180.6 cf./(100 ft. × 2.3 ft. × 0.4)=1.96 ft. **Use a stone-filled reservoir 2.3 ft. by 100.0 ft. by 2.0 ft.**

Overflow (Q_{10} Conveyance)

A dry swale is required to safely convey the 10-year design storm with minimum freeboard of 3 inches. Check the design to ensure that the 10-year storm is conveyed non-erosively and that the minimum freeboard is provided. For DA-2, the 10-year peak flow (Q_{10}) =2.0 cfs. At d_{max}, the width (w_{max})=w+(2 × z × d_{mid})=14.3 ft. Using a trapezoidal channel with a bottom width =14.3 ft., 4:1 side slopes, and a longitudinal

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slope (s) $=3.0\%$, the depth (d) and velocity (v) of flow can be calculated using the Manning equation:

$$v = \frac{1.49}{n} r^{2/3} s^{1/2}$$

where: n is the roughness coefficient of the channel lining, use 0.025
r is the hydraulic radius of the channel; at d = 0.10 ft., r is very nearly 0.10

Therefore, at d=0.1 ft.:

$$v = \frac{1.49}{0.025}(0.10)^{2/3}(0.03)^{1/2} = 2.2 \ fps$$

The cross-sectional area of the channel (A) needed to safely pass Q_{10} can be calculated using $A = Q_{10}/v$ =2.0 cfs / 2.2 fps =0.91 sf. At d = 0.1 ft., A =1.4 sf. **The proposed design will safely convey the 10-year storm.**

The minimum depth of the channel (d_c) may be determined by adding the required depths:

$d_c = d_{max} + d_{10\ yr.\ storm} + d_{freeboard}$
= 1.5 ft. + 0.1 ft. + 0.25 ft.
= 1.85 ft. **Use channel depth (d_c) = 2.0 ft.**

Design details for the dry swale are shown in Figures C.2.14.

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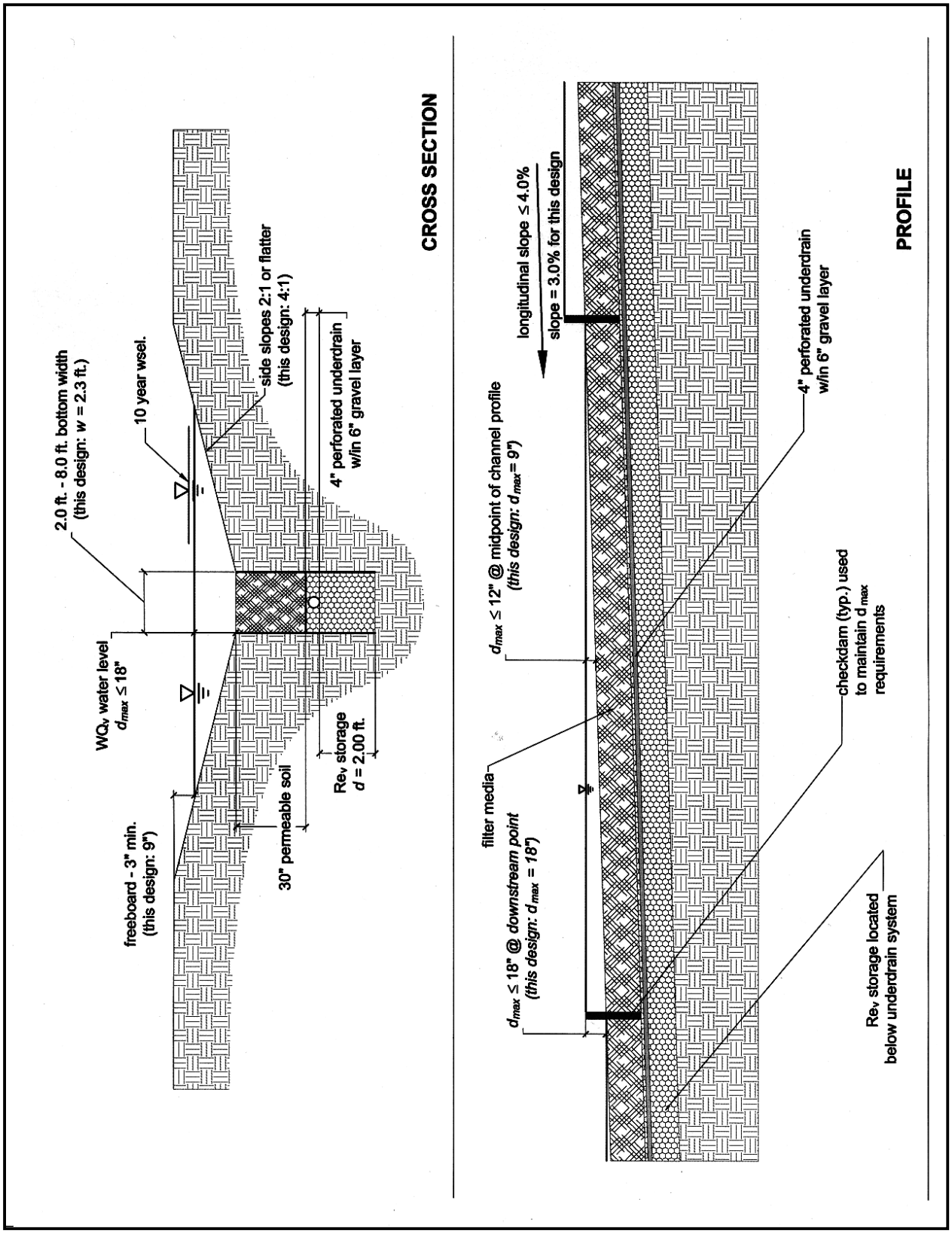
C.2.14 Dry Swale Design Details



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Appendix

D.1

Testing Requirements for Infiltration, Bioretention and Sand Filter Subsoils

General Notes Pertinent to All Testing

1. For infiltration trench (I-1) and basin (I-2) practices, a minimum field infiltration rate (f_c) of 0.52 inches per hour is required; lower rates preclude the use of these practices. For surface sand filter (F-1) and bioretention (F-6) practices, no minimum infiltration rate is required if these facilities are designed with a "day-lighting" underdrain system; otherwise these facilities require a 0.52 inch per hour rate.

2. Number of required borings is based on the size of the proposed facility. Testing is done in two phases, (1) Initial Feasibility, and (2) Concept Design.

3. Testing is to be conducted by a qualified professional. This professional shall either be a registered professional engineer, soils scientist or geologist and must be licensed in the State of Maryland.

Initial Feasibility Testing

Feasibility testing is conducted to determine whether full-scale testing is necessary, screen unsuitable sites, and reduce testing costs. A soil boring is not required at this stage. However, a designer or landowner may opt to engage Concept Design Borings per Table D.1.1 at his or her discretion, without feasibility testing.

Initial testing involves either one field test per facility, regardless of type or size, or previous testing data, such as the following:

* on-site septic percolation testing, within 200 feet of the proposed BMP location, and on the same contour which can establish initial rate, water table and/or depth to bedrock,
* geotechnical report on the site prepared by a qualified geotechnical consultant, or
* Natural Resources Conservation Service (NRCS) County Soil Mapping showing an unsuitable soil group such as a hydrologic group "D" soil in a low-lying area or a Marlboro Clay.

If the results of initial feasibility testing as determined by a qualified professional show that an infiltration rate of greater than 0.52 inches per hour is probable, then the number of concept design test pits shall be per the following table. An encased soil boring may be substituted for a test pit, if desired.

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Table D.1.1 Infiltration Testing Summary Table

Type of Facility	Initial Feasibility Testing	Concept Design Testing (initial testing yields a rate greater than 0.52"/hr)	Concept Design Testing (initial testing yields a rate lower than 0.52"/hr)
I-1 (trench)	1 field percolation test, test pit not required	1infiltration test and 1 test pit per 50' of trench	not acceptable practice
I-2 (basin)	1 field percolation test, test pit not required	1 infiltration test and 1 test pit per 200 square feet of basin area	not acceptable practice
F-1 (surface sand filter)	1 field percolation test, test pit not required	1 infiltration test and 1 test pit per 200 square feet of filter area (no underdrains required*)	underdrains required
F-6 (bioretention)	1 field percolation test, test pit not required	1 infiltration test and 1 test pit per 200 square feet of filter area (no underdrains required*)	underdrains required

* underdrain installation is still strongly recommended

Documentation

Infiltration testing data shall be documented, and include a description of the infiltration testing method. This is to ensure that the tester understands the procedure.

Test Pit/Boring Requirements

a. Excavate a test pit or dig a standard soil boring to a depth of 4 feet below the proposed facility bottom;

b. Determine depth to groundwater table (if within 4 feet of proposed bottom) upon initial digging or drilling, and again 24 hours later;

c. Conduct Standard Penetration Testing (SPT) every 2' to a depth of 4 feet below the facility bottom;

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d. Determine United States Department of Agriculture (USDA) or Unified Soil Classification (USC) System textures at the proposed bottom and 4 feet below the bottom of the best management practice (BMP);

e. Determine depth to bedrock (if within 4 feet of proposed bottom);

f. The soil description should include all soil horizons; and

g. The location of the test pit or boring shall correspond to the BMP location; test pit/soil boring stakes are to be left in the field for inspection purposes and shall be clearly labeled as such.

Infiltration Testing Requirements (field testing required)

a. Install casing (solid 5 inch diameter, 30" length) to 24" below proposed BMP bottom (see Figure D.1.1).

b. Remove any smeared soiled surfaces and provide a natural soil interface into which water may percolate. Remove all loose material from the casing. Upon the tester's discretion, a two (2) inch layer of coarse sand or fine gravel may be placed to protect the bottom from scouring and sediment. Fill casing with *clean* water to a depth of 24" and allow to pre-soak for twenty-four hours.

c. Twenty-four hours later, refill casing with another 24" of clean water and monitor water level (measured drop from the top of the casing) for 1 hour. Repeat this procedure (filling the casing each time) three additional times, for a total of four observations. Upon the tester's discretion, the final field rate may either be the average of the four observations, or the value of the last observation. The final rate shall be reported in inches per hour.

d. May be done through a boring or open excavation.

e. The location of the test shall correspond to the BMP location.

f. Upon completion of the testing, the casings shall be immediately pulled, and the test pit shall be back-filled.

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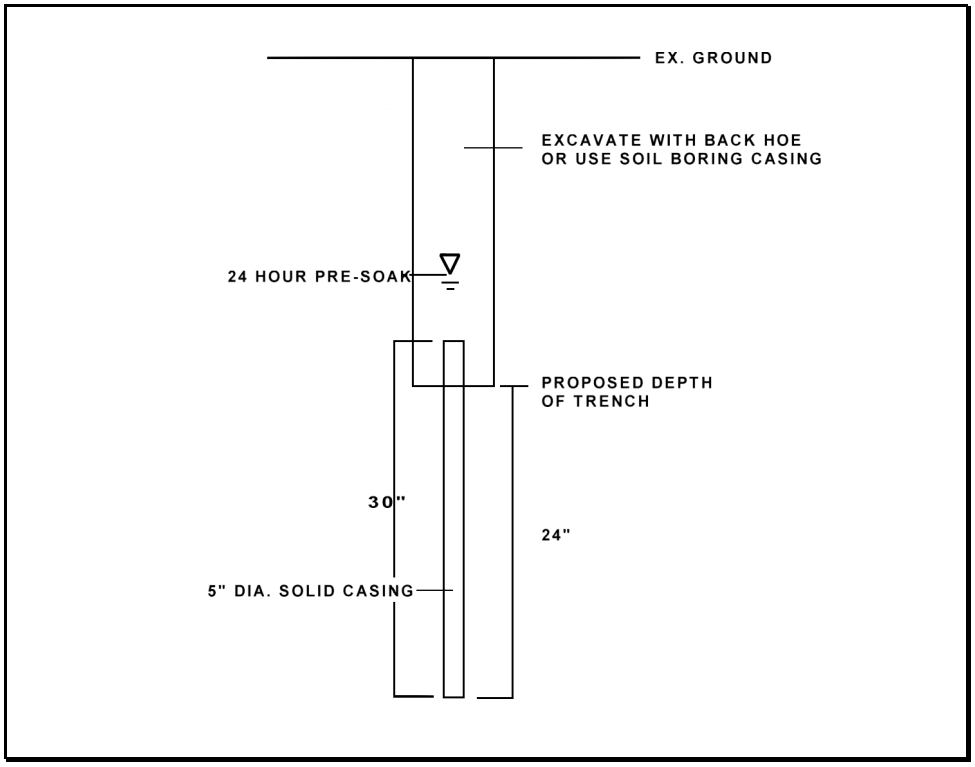
Figure D.1.1 Infiltration Testing Requirements



Laboratory Testing

Use grain-size sieve analysis and hydrometer tests (where appropriate) to determine USDA soils classification and textural analysis. Visual field inspection by a qualified professional may also be used, provided it is documented. The use of lab testing to establish infiltration rates is prohibited.

Bioretention Testing

All areas tested for application of F-6 facilities shall be back-filled with a suitable sandy loam planting media. The borrow source of this media, which may be the same or different from the bioretention area location itself, must be tested as follows:

If the borrow area is undisturbed soil one test is required per 200 square feet of borrow area. The test consists of "grab" samples at one foot depth intervals to the bottom of the borrow area. All samples at the testing location are then mixed, and the resulting sample is then lab-tested to meet the following criteria:

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a) USDA minimum textural analysis requirements: A textural analysis is required from the site stockpiled topsoil. If topsoil is imported, then a texture analysis shall be performed for each location where the topsoil was excavated.

Minimum requirements:
sand 35 - 60%
silt 30 - 55%
clay 10 - 25%

b) The soil shall be a uniform mix, free of stones, stumps, roots or other similar objects larger than one inch.

c) Consult the bioretention construction specifications (Appendix B.3.8) for further guidance on preparing the soil for a bioretention area.

Table D.1.2 Minimum Depth to Seasonably High Water Table

Region	Depth to water table for infiltration	Depth to water table for encased or lined facilities such as an underground concrete sand filter
Lower Eastern Shore	2	0*
Remainder of State	4	0*

*may need professional structural design

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Appendix A

Landscaping Guidance for Stormwater BMPs

Introduction

Landscaping is a critical element to improve both the function and appearance of stormwater best management practices (BMPs). This Appendix provides landscaping criteria and plant selection guidance for effective stormwater BMPs. It is organized as follows:

The first section, A.1, outlines general guidance that should be considered when landscaping any stormwater practice. Section A.2 then presents more specific guidance on landscaping criteria and plant selection for individual BMP designs. These include:

- Stormwater ponds and wetlands
- Infiltration and sand filter practices
- Bioretention
- Open Channels
- Filter Strips and Buffers

In Section A.3, key factors in selecting plant material for stormwater landscaping are reviewed, including hardiness zones, physiographic regions, hydrologic zones, and cultural factors. Section A.4 contains a detailed plant list of native woody and herbaceous species that can be used when preparing a stormwater planting plan.

Native Species

This manual encourages the use of native plants in stormwater management facilities. Native plants are defined as those species which evolved naturally to live in this region. Practically speaking, this refers to those species which lived in Maryland before Europeans explored and settled in America. Many introduced species were weeds brought in by accident; others were intentionally introduced and cultivated for use as medicinal herbs, spices, dyes, fiber plants, and ornamentals.

Introduced species can often escape cultivation and begin reproducing in the wild. This is significant ecologically because many introduced species out-compete indigenous species and begin to replace them in the wild. Some introduced species like kudzu, phragmites, and dandelions are invasive, have few predators, and can take over naturally occurring species at an alarming rate. By planting native species in stormwater management facilities, we can protect Maryland's natural heritage and provide a legacy for future generations.

Native species also have distinct genetic advantages over non-native species for planting in Maryland. Because they have evolved to live here naturally, indigenous plants are best suited for our local climate. This translates into greater survivorship when planted and less replacement and maintenance during the life of a stormwater management facility. Both of these attributes provide cost savings for the facility owner.

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Finally, people often plant exotic species for their ornamental value. While it is important to have aesthetic stormwater management facilities for public acceptance and the maintenance of property value, it is not necessary to introduce foreign species for this purpose. Many native species are aesthetically pleasing and can be used as ornamentals. For example, the following species are part of Maryland's natural heritage and provide high aesthetic value throughout the year: rhododendron, pink azalea, red maple, pin oak, sycamore, flowering dogwood, mountain laurel, willow, hemlock, white pine, bald cypress, atlantic cedar, american holly, black-eyed susan, sunflower, lobelia, pickerel weed, marsh hibiscus, and yellow pond lily. When selecting ornamentals for stormwater management facilities, planting preference should be given to native ornamentals. Please refer to the plant list in Section A.4 for a comprehensive list of native species available for stormwater management facility planting.

A.1 General Landscaping Guidance for All Stormwater BMPs

- Trees, shrubs, and/or any type of woody vegetation are not allowed on the embankment.
- Plant trees and shrubs at least 15 feet away from the toe of slope of a dam.
- Trees or shrubs known to have long taproots should not be within the vicinity of the earth dam or subsurface drainage facilities.
- Plant trees and shrubs at least 25 feet away from perforated pipes.
- Plant trees and shrubs at least 25 feet away from a principal spillway structures.
- Provide 15 foot clearance from a non-clogging, low flow orifice.
- Herbaceous embankment plantings should be limited to 10 inches in height.
- Use erosion control mats and fabrics in channels to reduce the potential for erosion.
- Stabilize all emergency spillways with plant material that can withstand strong flows. Root material should be fibrous and substantial but lacking a taproot.
- Sod channels that are not stabilized with erosion control mats.
- Divert flows temporarily from seeded areas until stabilized.
- Check water tolerances of existing plant materials prior to inundation of area.
- Stabilize aquatic and safety benches with emergent wetland plants and wet seed mixes.
- Do not block maintenance access to structures with trees or shrubs.
- To reduce thermal warming, shade inflow and outflow channels as well as southern exposures of ponds.
- Avoid plantings that will require routine or intensive chemical applications (i.e. turf area).
- Have soil tested to determine if there is a need for amendments.
- Native plant species should be specified over exotic or foreign species because they are well adapted to local on-site soil conditions and require little or no additional amendments.
- Decrease the areas where turf is used. Use low maintenance ground cover to absorb run-off.

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- Plant stream and water buffers with trees, shrubs, ornamental grasses, and herbaceous materials where possible, to stabilize banks and provide shade.
- Maintain and frame desirable views. Be careful not to block views at entrances, exits, or difficult road curves. Screen unattractive views into the site. Aesthetics and visual characteristics should be a prime consideration.
- Use plants to prohibit pedestrian access to pools or steeper slopes.
- The designer should carefully consider the long-term vegetation management strategy for the BMP, keeping in mind the "maintenance" legacy for the future owners. Provide a planting surface that can withstand the compaction of vehicles using maintenance access roads. Make sure the facility maintenance agreement includes requirements to ensure vegetation cover in perpetuity.
- If a BMP is likely to receive excessive amounts of deicing salt, salt tolerant plants should be used.
- Provide signage for:
  - Stormwater Management Areas to help educate the public.
  - Wildflower areas, when possible, to designate limits of mowing.
- Avoid the overuse of any plant materials.
- Preserve existing natural vegetation when possible.

It is necessary to test the soil in which you are about to plant in order to determine the following:

- pH; whether acid, neutral, or alkaline
- major soil nutrients; Nitrogen, Phosphorus, Potassium
- minerals; such as chelated iron, lime

Have soil samples analyzed by experienced and qualified individuals, such as those at the Agricultural Extension Office, who will explain in writing the results, what they mean, as well as what soil amendments would be required. Certain soil conditions, such as marine clays, can present serious constraints to the growth of plant materials and may require the guidance of qualified professionals. When poor soils can not be amended, seed mixes and plant material must be selected to establish ground cover as quickly as possible.

Areas that recently have been involved in construction can become compacted so that plant roots cannot penetrate the soil. Also seeds will lie on the surface of compacted soils and are often washed away or eaten by birds. For planting success, soils should be loosened to a depth of three to five inches. Hard soils may require disking to a deeper depth. The soil should be loosened regardless of the ground cover. This will improve seed contact with the soil, increase germination rates, and allow the roots to penetrate the soil. For areas to be sodded, disking is necessary so that the roots can penetrate the soil. Providing good growing conditions can prevent poor vegetative cover. This saves money because vegetation will not need to be replanted.

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Whenever possible, topsoil should be spread to a depth of four to eight inches and lightly compacted to minimum thickness of four inches. This provides organic matter and important nutrients for the plant material. The use of topsoil allows vegetation to become established faster and roots to penetrate deeper. This ensures quicker and more complete stabilization, making it less likely that the plants will wash out during a heavy storm.

If topsoil has been stockpiled in deep mounds for a long period of time, it is necessary to test the soil for pH as well as microbial activity. If the microbial activity has been destroyed, it is necessary to inoculate the soil after application.

Remember that newly installed plant material requires water in order to recover from the shock of being transplanted. Be sure that some source of water is provided, especially during dry periods. This will reduce plant loss and provide the new plant materials with a chance to establish root growth.

A.2 Specific Landscaping Criteria for BMP Groups

A.2.1 Ponds and Wetlands

For planting within a stormwater management facility, it is necessary to determine what hydrologic zones will be created. Hydrologic zones describe the degree to which an area is inundated by water. Plants have differing tolerances to inundation and the six zones described in this section will dictate which plants will survive where. Every facility does not necessarily exhibit all of these zones.

Table A.1 Hydrologic Zones

Zone #	Zone Description	Hydrologic Conditions
Zone 1	Deep Water Pool	1-6 foot deep permanent pool
Zone 2	Shallow Water Bench (low marsh)	6 inches to 1 foot deep
Zone 3	Shoreline Fringe (high marsh)	Regularly inundated
Zone 4	Riparian Fringe	Periodically inundated
Zone 5	Floodplain Terrace	Infrequently inundated
Zone 6	Upland Slopes	Seldom or never inundated

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Zone 1: Deep Water Area ***(1 to 6 feet)***

Ponds and wetlands both have deep pool areas that comprise Zone 1. These pools range from one to six feet in depth, and are best colonized by submergent plants, if at all. This pondscaping zone has not been routinely planted for several reasons. First, the availability of plant materials that can survive and grow in this zone is limited, and it is also feared that plants could clog the stormwater facility outlet structure. In many cases, these plants will gradually become established through natural recolonization (e.g., transport of plant fragments from other ponds by waterfowl). If submerged plant material becomes more commercially available and clogging concerns are addressed, this area can be planted. The function of the planting is to reduce sedimentation and improve oxidation while creating a greater aquatic habitat.

- Plant material must be able to withstand constant inundation of water of one foot or greater in depth.
- Plants may be submerged partially or entirely.
- Plants should be able to enhance pollutant uptake.
- Plants may provide food and cover for waterfowl, desirable insects, and other aquatic life.

Some suggested emergent or submergent species include, but are not limited to lotus, wild celery, and redhead grass.

Zone 2: Shallow Water Bench/Low Marsh ***(6 inches to 1 foot)***

Zone 2 includes all areas that are inundated below the normal pool to a depth of one foot, and is the primary area where emergent plants will grow in stormwater wetlands. Zone 2 also coincides with the aquatic bench found in stormwater ponds. This zone offers ideal conditions for the growth of many emergent wetland species. These areas may be located at the edge of the pond or on low mounds of earth located below the surface of the water within the pond. When planted, Zone 2 can be an important habitat for many aquatic and nonaquatic animals, creating a diverse food chain. This food chain includes predators, allowing a natural regulation of mosquito populations, thereby reducing the need for insecticide applications.

- Plant material must be able to withstand constant inundation of water to depths between six inches and one foot deep.
- Plants will be partially submerged.
- Plants should be able to enhance pollutant uptake.
- Plants may provide food and cover for waterfowl, desirable insects and other aquatic life.

Plants will stabilize the bottom of the pond, as well as the edge of the pond, absorbing wave impacts and reducing erosion, when water level fluctuates. In addition to slowing water velocities and increasing sediment deposition rates, plants can also reduce resuspension of sediments caused

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by the wind. Plants can also soften the engineered contours of the pond, and can conceal drawdowns during dry weather.

Some suggested species for Zone 2 include lobelia, bayberry, many asters, turtlehead, pond cypress, iris, and blue flag. It is important to recognize that a plant typically found in wetlands may be cultivated in nonwetland conditions. Hence the importance of obtaining plant stock which is cultivated in similar hydrologic and soil conditions as those present in the stormwater management facility. A plant typically found in wetlands, but cultivated in nonwetland conditions, may not survive if installed in wetland conditions. A nonwetland plant cultivated in wetland conditions should thrive when introduced to wetland conditions.

Table A.2 Common Emergent Wetland Plant Species Used for Stormwater Wetlands and on Aquatic Benches of Stormwater Ponds

Common Name	Scientific Name	Inundation Tolerance
Arrow Arum	*Peltandra virginica*	up to 12 inches
Arrowhead/Duck Potato	*Saggitaria latifolia*	up to 12 inches
Broomsedge	*Andropogon virginicus*	up to 3 inches
Broad Water Weed	*Elodea canadensis*	at least 12 inches
Bushy Beardgrass	*Andropogon glomeratus*	up to 12 inches
Common Three-square	*Scirpus pungens*	up to 6 inches
Marsh Hibiscus	*Hibiscus moscheutos*	up to 3 inches
Spatterdock	*Nuphar luteum*	up to 3 inches
Rice Cutgrass	*Leersia oryzoides*	up to 3 inches
Sedges	*Carex spp.*	up to 3 inches
Soft Rush	*Juncus effusus*	up to 3 inches
Switchgrass	*Panicum virgatum*	up to 3 inches
Note 1: Inundation tolerance is maximum inches below the normal pool; most plants prefer shallower depths than the maximum indicated.		
Note 2: for additional plant options, consult the stormwater planting list at the end of this appendix. Other good sources include the 1994 Maryland Standards and Specifications for Soil Erosion and Sediment Control (MDE, 1994), Design of Stormwater Wetland Systems (Schueler, 1992) and Planting Guide for the Northeastern United States (Environmental Concern, 1993).		

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Zone 3: Shoreline Fringe/High Marsh ***(regularly inundated)***

Zone 3 encompasses the shoreline of a pond or wetland, and extends vertically about one foot in elevation from the normal pool. This zone includes the safety bench of a pond, and may also be periodically inundated if storm events are subject to extended detention. This zone occurs in a wet pond or shallow marsh and can be the most difficult to establish since plants must be able to withstand inundation of water during storms, when wind might blow water into the area, or the occasional drought during the summer. In order to stabilize the soil in this zone, Zone 3 must have a vigorous cover.

- Plants should stabilize the shoreline to minimize erosion caused by wave and wind action or water fluctuation.
- Plant material must be able to withstand occasional inundation of water. Plants will be partially submerged at this time.
- Plant material should, whenever possible, shade the shoreline, especially the southern exposure. This will help to reduce water temperature.
- Plants should enhance pollutant uptake.
- Plants may provide food and cover for waterfowl, songbirds, and wildlife. Large plants could also be selected and located to control overpopulation of waterfowl.
- Plants should be located to reduce human access where there are potential hazards, but should not block the maintenance access.
- Plants should have very low maintenance requirements, because they may be difficult or impossible to reach.
- Plants should be resistant to disease and other problems which require chemical applications (since chemical application is not advised in stormwater ponds).
- Native plants are preferred because they are low maintenance and disease resistant.

Many of the emergent wetlands plants outline in Table A.2 also thrive in Zone 3. Some other species that do well include bentgrass, foxtail, panic grass, and hawthorn. If shading is needed along the shoreline, the following tree species are suggested— river birch, ash, willow, red maple and willow oak.

Zone 4: Riparian Fringe ***(periodically inundated)***

Zone 4 extends from one to four feet in elevation above the normal pool. Plants in this zone are subject to periodic inundation after storms, and may experience saturated or partly saturated soil. Nearly all of the temporary ED area is included within this zone.

- Plants must be able to withstand periodic inundation of water after storms, as well as occasional drought during the warm summer months.
- Plants should stabilize the ground from erosion caused by run-off.

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- Plants should shade the low flow channel to reduce pool warming whenever possible.
- Plants should enhance pollutant uptake.
- Plant material should have very low maintenance, since they may be difficult or impossible to access.
- Plants may provide food and cover for waterfowl, songbirds and wildlife. Plants may also be selected and located to control overpopulation of waterfowl.
- Plants should be located to reduce pedestrian access to the deeper pools.
- Native plants are preferred because they are low maintenance and disease resistant.

Some frequently used plant species in Zone 4 include coneflower, violets, primrose, milkwort, nannyberry, lespedeza, lilies, flatsedge, hollies, horsythia, lovegrass, hawthorn, spiraea, birch, and sugar maple.

Zone 5: Floodplain Terrace ***(infrequently inundated)***

Zone 5 is periodically inundated by floodwaters that quickly recede in a day or less. Operationally, Zone 5 extends from the maximum two year or Cp_v water surface elevation up to the 10 or 100 year maximum water surface elevation. Key landscaping objectives for Zone 5 are to stabilize the steep slopes characteristic of this zone and establish low maintenance natural vegetation.

- Plant material should be able to withstand occasional but brief inundation during storms. In between storms, typical moisture conditions may be moist, slightly wet, or even swing entirely to drought conditions during the dry weather periods.
- Plants should stabilize the basin slopes from erosion.
- Ground cover should be very low maintenance, since they may be difficult to access on steep slopes or if frequency of mowing is limited. A dense tree cover may help reduce maintenance and discourage resident geese.
- Plants may provide food and cover for waterfowl, songbirds, and wildlife.
- Placement of plant material in Zone 5 is often critical, as it often creates a visual focal point and provides structure and shade for a greater variety of plants.

Some commonly planted species in Zone 5 include solomon's seal, nannyberry, many fescues, many viburnums, cherries, chestnut oak, post oak, and phlox.

Zone 6: Upland Slopes/Pond Buffer ***(seldom or never inundated)***

The last zone extends above the maximum 100 year water surface elevation, and often includes the outer buffer of a pond or wetland. Unlike other zones, this upland area may have sidewalks, bike paths, retaining walls, and maintenance access roads. Care should be taken to locate plants so they will not overgrow these routes or create hiding places that might make the area unsafe.

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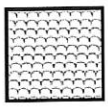
- Plant selections should be made based on soil condition, light, and function within the landscape because little or no water inundation will occur.
- Ground covers should require infrequent mowing to reduce the cost of maintaining this landscape.
- Placement of plants in Zone 6 is important since they are often used to create a visual focal point, frame a desirable view, screen undesirable views, serve as a buffer, or provide shade to allow a greater variety of plant materials. Particular attention should be paid to seasonal color and texture of these plantings.

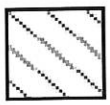
Some frequently used plant species in Zone 6 include eastern cottonwood, american yew, linden, bald cypress, magnolia, and mountain ash.

Figure A.1 Hydrologic Zones Around Stormwater Facilities – Legend

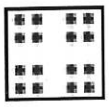


12"-36" depth below normal pool elevation
Water Lily, Deep Water Duck Potato, Sago Pond Plant, Wild Celery, Redhead Grass

0"-12" depth below normal pool elevation
Blue Flag Iris, Duck Potato, Flowering Bulrush, Softrush, Sedges, Lobelia, Pond Cypress, various asters

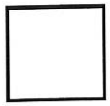


0" to 12" elevation above normal pool elevation
New England Aster, Marsh Aster, Marsh Marigold (Appalachian Plateau), Tussock Sedge, Spotted Joe Pye Weed, Forget Me Nots, Inkberry, Purple Osier Dogwood, Pin Oak, River Birch, Sycamore, Swamp White Oak (Coastal Plain), Weeping Willow, Dawn Redwood



1' to 4' elevation above normal pool elevation
Purple Cone Flower, Birds Foot Trefoil, Slender Rush, Deer Tongue Grass, Lespedeza, Switch Grass, Serviceberry, Gray Birch, Hackberry, Sweet Pepper Bush (Coastal Plain, Gray stem Dogwood, Red Osier Dogwood, Green Ash,

Qp_2 or Cp_v to Qp_{10} or Q_f water surface elevation
(Many Wildflowers and native grasses) American Holly, Witch Hazel, Ninebark, Red Oak, American Elderberry, American Hemlock, Lowbush Blueberry, Maple Leaf Viburnum, Nannyberry, Blackhaw Viburnum



Q_f water surface elevation and above (Floodplain)
Mostly ornamentals as long as soils drains well. Many natives. All species must be able to tolerate flood plain conditions. Hackberry, Pitch Pine, Sheep Fescue, Wildflowers, many Native Grasses.

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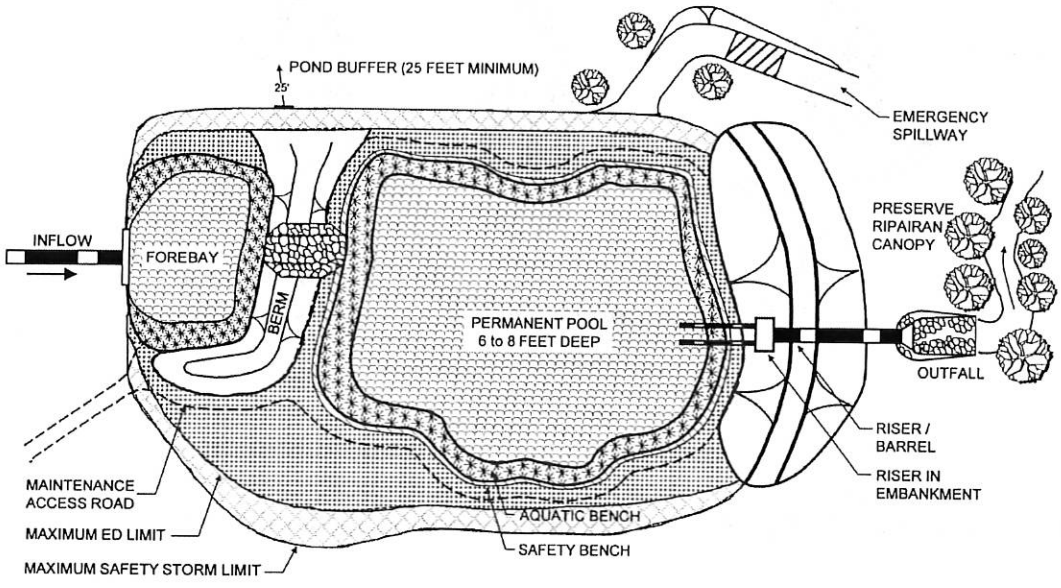
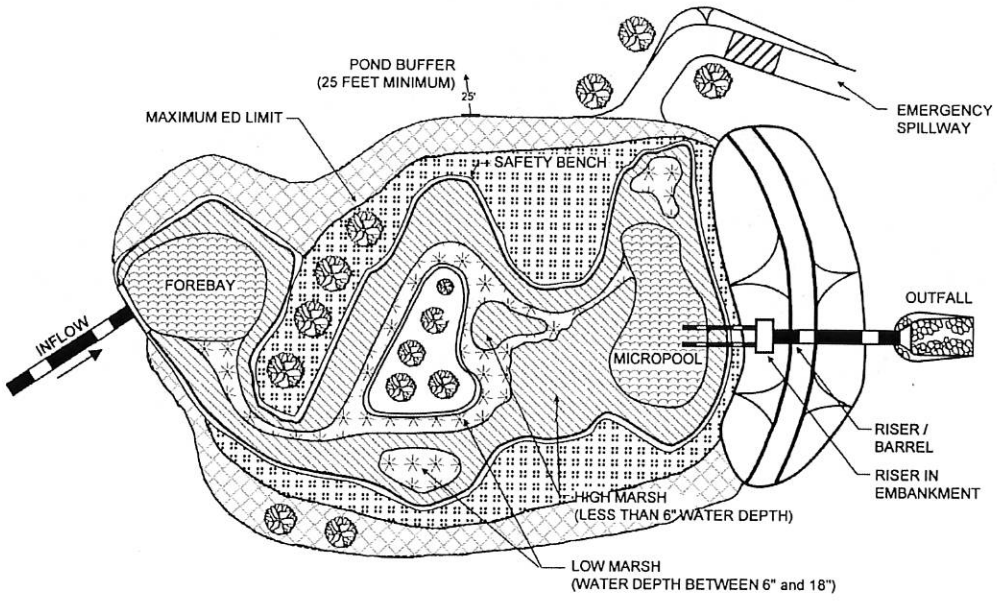
Figure A.2 Hydrologic Zones Around Stormwater Facilities



WET ED POND (P-3)



ED SHALLOW WETLAND (W-2)

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Figure A.3 Section of Typical Stormwater Management Detention Pond

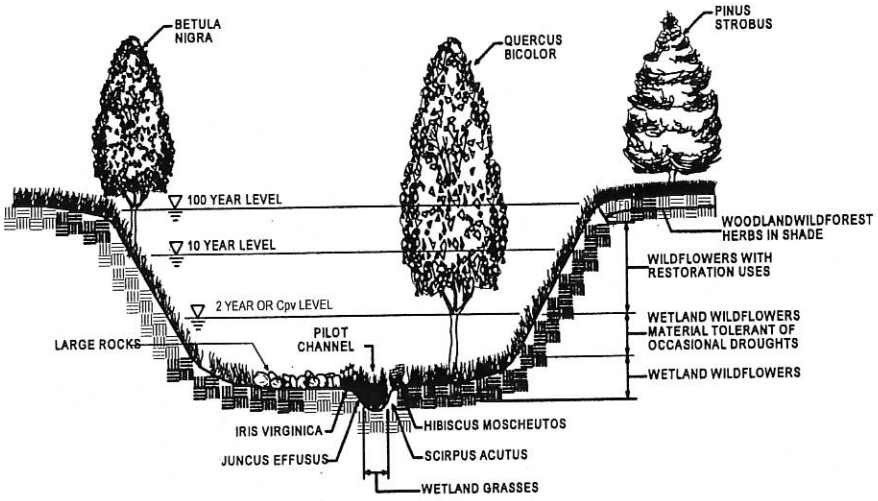
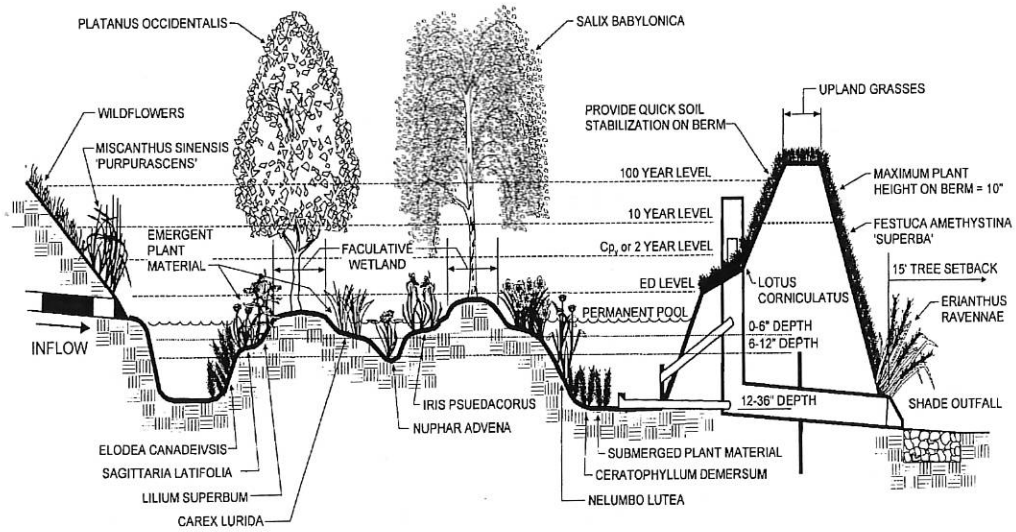


Figure A.4 Section of Typical Shallow Extended Detention Wetland System



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A.2.2 Infiltration and Filter Systems

Infiltration and filter systems either take advantage of existing permeable soils or create a permeable medium such as sand for WQ_v and Re_v. In some instances where permeability is great, these facilities may be used for Q_p as well. The most common systems include infiltration trenches, infiltration basins, sand filters, and organic filters.

When properly planted, vegetation will thrive and enhance the functioning of these systems. For example, pre-treatment buffers will trap sediments that often are bound with phosphorous and metals. Vegetation planted in the facility will aid in nutrient uptake and water storage. Additionally, plant roots will provide arteries for stormwater to permeate soil for groundwater recharge. Finally, successful plantings provide aesthetic value and wildlife habitat making these facilities more desirable to the public.

Design Constraints:

- Planting buffer strips of at least 20 feet will cause sediments to settle out before reaching the facility, thereby reducing the possibility of clogging.
- Determine areas that will be saturated with water and water table depth so that appropriate plants may be selected (hydrology will be similar to bioretention facilities, see figure A.5 and Table A.4 for planting material guidance).
- Plants known to send down deep taproots should be avoided in systems where filter fabric is used as part of facility design.
- Test soil conditions to determine if soil amendments are necessary.
- Plants shall be located so that access is possible for structure maintenance.
- Stabilize heavy flow areas with erosion control mats or sod.
- Temporarily divert flows from seeded areas until vegetation is established.
- See Table A.5 for additional design considerations.

A.2.3 Bioretention

Soil Bed Characteristics

The characteristics of the soil for the bioretention facility are perhaps as important as the facility location, size, and treatment volume. The soil must be permeable enough to allow runoff to filter through the media, while having characteristics suitable to promote and sustain a robust vegetative cover crop. In addition, much of the nutrient pollutant uptake (nitrogen and phosphorus) is accomplished through absorption and microbial activity within the soil profile. Therefore, soils must balance their chemical and physical properties to support biotic communities above and below ground.

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The planting soil should be a sandy loam, loamy sand, loam (USDA), or a loam/sand mix (should contain a minimum 35 to 60% sand, by volume). The clay content for these soils should be less than 25% by volume [Environmental Quality Resources (EQR), 1996; Engineering Technology Inc. and Biohabitats, Inc. (ETAB), 1993]. Soils should fall within the SM, ML, SC classifications or the Unified Soil Classification System (USCS). A permeability of at least 1.0 feet per day (0.5"/hr) is required (a conservative value of 0.5 feet per day is used for design). The soil should be free of stones, stumps, roots, or other woody material over 1" in diameter. Brush or seeds from noxious weeds (e.g., Johnson Grass, Mugwort, Nutsedge, and Canada Thistle or other noxious weeds as specified under COMAR 15.08.01.05.) should not be present in the soils. Placement of the planting soil should be in 12" to 18" lifts that are loosely compacted (tamped lightly with a backhoe bucket or traversed by dozer tracks). The specific characteristics are presented in Table A.3.

Table A.3 Planting Soil Characteristics
(Adapted from EQR, 1996; ETAB, 1993)

Parameter	Value
pH range	5.2 to 7.00
Organic matter	1.5 to 4.0% (by weight)
Magnesium	35 lbs. per acre, minimum
Phosphorus (phosphate - P_2O_5)	75 lbs. per acre, minimum
Potassium (potash - K_2O)	85 lbs. per acre, minimum
Soluble salts	□ 500 ppm
Clay	10 to 25%
Silt	30 to 55%
Sand	35 to 60%

Mulch Layer

The mulch layer plays an important role in the performance of the bioretention system. The mulch layer helps maintain soil moisture and avoids surface sealing which reduces permeability. Mulch helps prevent erosion, and provides a microenvironment suitable for soil biota at the mulch/soil interface. It also serves as a pretreatment layer, trapping the finer sediments which remain suspended after the primary pretreatment.

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The mulch layer should be standard landscape style, single or double shredded hardwood mulch or chips. The mulch layer should be well aged (stockpiled or stored for at least 12 months), uniform in color, and free of other materials, such as weed seeds, soil, roots, etc. The mulch should be applied to a maximum depth of three inches. Grass clippings should not be used as a mulch material.

Planting Guidance

Plant material selection should be based on the goal of simulating a terrestrial forested community of native species. Bioretention simulates an upland-species ecosystem. The community should be dominated by trees, but have a distinct community of understory trees, shrubs and herbaceous materials. By creating a diverse, dense plant cover, a bioretention facility will be able to treat stormwater runoff and withstand urban stresses from insects, disease, drought, temperature, wind, and exposure.

The proper selection and installation of plant materials is key to a successful system. There are essentially three zones within a bioretention facility (Figure A.5). The lowest elevation supports plant species adapted to standing and fluctuating water levels. The middle elevation supports plants that like drier soil conditions, but can still tolerate occasional inundation by water. The outer edge is the highest elevation and generally supports plants adapted to dryer conditions. A sample of appropriate plant materials for bioretention facilities are included in Table A.4. The layout of plant material should be flexible, but should follow the general principals described in Table A.5. The objective is to have a system which resembles a random and natural plant layout, while maintaining optimal conditions for plant establishment and growth. For a more extensive bioretention plan, consult ETA&B, 1993 or Claytor and Schueler, 1997.

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Figure A.5 Planting Zones for a Bioretention Facilities

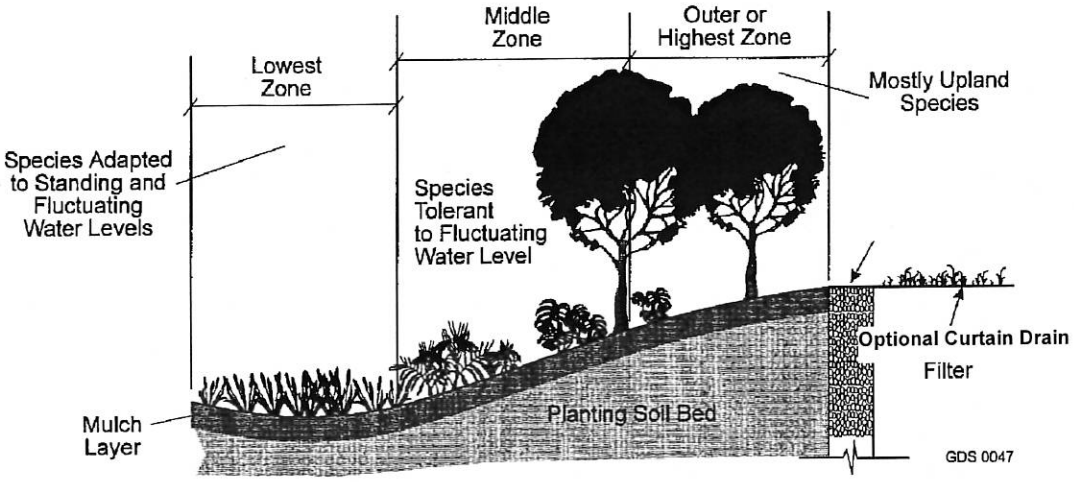

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Table A.4 Commonly Used Species for Bioretention Areas

Trees	Shrubs	Herbaceous Species
Acer rubrum Red Maple	*Aesculus pariviflora* Bottlebrush Buckeye	*Andropogon virginicus* Broomsedge
Betula nigra River Birch	*Cephalanthus occidentalis* Buttonbush	*Eupatorium perpurea* Joe Pye Weed
Juniperus virginiana Eastern Red Cedar	*Hamemelis virginiana* Witch Hazel	*Scirpus pungens* Three Square Bulrush
Chionanthus virginicus Fringe-tree	*Vaccinium corymbosum* Highbush Blueberry	*Iris versicolor* Blue Flag
Nyssa sylvatica Black Gum	*Ilex glabra* Inkberry	*Lobelia cardinalis* Cardinal Flower
Diospyros virginiana Persimmon	*Ilex verticillata* Winterberry	*Panicum virgatum* Switchgrass
Platanus occidentalis Sycamore	*Viburnum dentatum* Arrowwood	*Dichanthelium scoparium* Broom Panic Grass
Quercus palustris Pin Oak	*Lindera benzoin* Spicebush	*Rudbeckia laciniata* Tall Coneflower
Quercus phellos Willow Oak	*Myrica pennsylvanica* Bayberry	*Scirpus cyperinus* Woolgrass
Salix nigra Black willow		*Vernonia noveboracensis* New York Ironweed
Note 1: For more options on plant selection for bioretention, consult Bioretention Manual (ETAB, 1993) or the Design of Stormwater Filtering Systems (Claytor and Schueler, 1997).		

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Table A.5 Planting Plan Design Considerations

- Native plant species should be specified over exotic or foreign species.
- Appropriate vegetation should be selected based on the zone of hydric tolerance.
- Species layout should generally be random and natural.
- A canopy should be established with an understory of shrubs and herbaceous materials.
- Woody vegetation should not be specified in the vicinity of inflow locations.
- Trees should be planted primarily along the perimeter of the bioretention area.
- Stressors (e.g., wind, sun, exposure, insect and disease infestation, and drought) should be considered when laying out the planting plan.
- Noxious weeds shall not be specified or used.
- Aesthetics and visual characteristics should be a prime consideration.
- Traffic and safety issues must be considered.
- Existing and proposed utilities must be identified and considered.

Plant Material Guidance

Plant materials should conform to the American Association of Nurserymen's publication, the American Standard Nursery Stock. The planting plan shall include a sequence of construction; a description of the contractor's responsibilities; a planting schedule and installation specifications; initial maintenance requirements; and a warranty period stipulating requirements for plant survival. Table A.6 presents some typical issues for planting specifications.

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Table A.6 Planting Specification Issues

Specification Element	Elements
Sequence of Construction	Describe site preparation activities, soil amendments, etc.; address erosion and sediment control procedures; specify step-by-step procedure for plant installation through site clean-up.
Contractor's Responsibilities	Specify the contractor's responsibilities, such as watering, care of plant material during transport, timeliness of installation, repairs due to vandalism, etc.
Planting Schedule and Specifications	Specify the plants to be installed, the type of materials (e.g., balled and burlap, bare root, containerized); time of year of installations, sequence of installation of types of plants; fertilization, stabilization seeding, if required; watering and general care.
Maintenance	Specify inspection periods; mulching frequency (annual mulching is most common); removal and replacement of dead and diseased vegetation; treatment of diseased trees; watering schedule after initial installation (once per day for 14 days is common); repair and replacement of staking and wires.
Warranty	Specify the warranty period, the required survival rate, and expected condition of plant species at the end of the warranty period.

A.2.4 Open Channels

Consult Table A.7 for grass species that perform well in the stressful environment of an open channel. For more detailed information, please consult the 1994 Maryland Standards and Specifications for Soil Erosion and Sediment Control. If a BMP is likely to receive excessive amounts of deicing salt, salt tolerant plants should be used.

A.2.5 Filter Strips and Stream Buffer

For design and plant selection of filter strips and stream buffers, please consult the USDA Natural Resources Conservation Service Maryland Conservation Practice Standard No. 391 "Riparian Stream Buffers."

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Table A.7 Common Grass Species for Open Channels

Common Name	Scientific Name	Notes
Big Bluestem	*Andropogon gerardii*	Warm, not for Wet Swale
Creeping Bentgrass	*Agrostis palustris*	Cool,
Red Fescue	*Festuca rubra*	Cool, not for Wet Swale
Reed Canary grass	*Phalaris arundinacea*	Cool, Wet Swale
Redtop	*Agrostis alba*	Cool,
Smooth Brome	*Bromus inermis*	Cool, not for Wet Swale
Switch grass	*Panicum virgatum*	Warm

Note 1: These grasses are sod-forming and can withstand frequent inundation, and are thus ideal for the swale or grass channel environment. Most are salt-tolerant, as well. Cool refers to cool season grasses that do well in the western part of the State, Warm refers to warm season grasses that work well in the eastern part of the State (see Table A.8).

Note 2: Where possible, one or more of these grasses should be in the seed mixes. For a more thorough listing of seed mixes, consult the 1994 Maryland Standard and Specifications for Soil Erosion and Sediment Control (MDE, 1994) or the MD NRCS Code 391 Riparian Forest Buffer Standard, Table 2 (Zone 3).

A.3 Plant Selection for Stormwater Facilities

A.3.1 Hardiness Zones

Hardiness zones are based on historical annual minimum temperatures recorded in an area. A BMPs location in relation to plant hardiness zones is important to consider first because plants differ in their ability to withstand very cold winters. This does not imply that plants are not affected by summer temperatures. Given that Maryland summers can be very hot, heat tolerance is also a characteristic that should be considered in plant selection.

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Table A.8 Average Annual Minimum Temperature

Zone		USDA Minimum Temperature (°F)
Temperate Zone 1		below -50°
Temperate Zone 2		-50° to -40°
Temperate Zone 3		-40° to -30°
Temperate Zone 4		-30° to -20°
Temperate Zone 5	a	-20° to -15°
	b	-15° to -10°
Temperate Zone 6	a	-10° to -5°
	b	-5° to 0°
Temperate Zone 7	a	0° to 5°
	b	5° to 10°
Temperate Zone 8		10° to 20°

It is best to recommend plants known to thrive in specific hardiness zones. The plant list included at the end of this appendix identifies the hardiness zones for each species listed as a general planting guide. It should be noted, however, that certain site factors can create microclimates or environmental conditions which permit the growth of plants not listed as hardy for that zone. By investigating numerous references and based on personal experience, a designer should be able to confidently recommend plants that will survive in microclimates.

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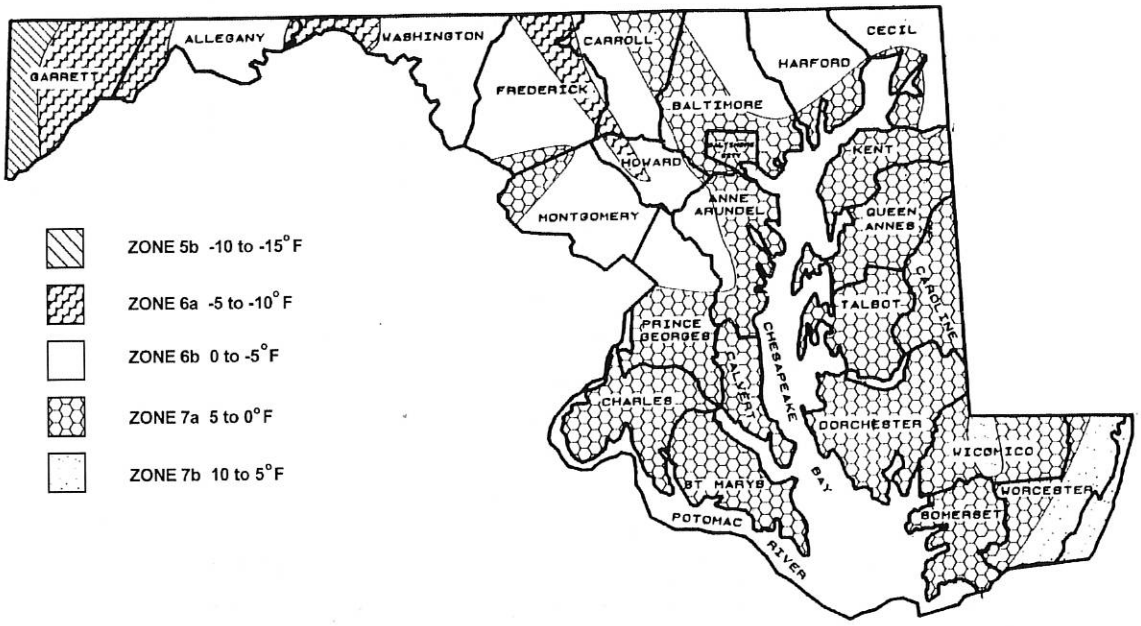
Figure A.6 USDA Plant Hardiness Zones in Maryland



A.3.2 Physiographic Provinces

There are five physiographic provinces in Maryland that describe distinct geographic regions in the State with similar physical and environmental conditions (Figure A.7). These physiographic provinces include, from west to east, the Appalachian Plateau, Valley and Ridge, Blue Ridge, Piedmont, and Coastal Plain. Each physiographic region is defined by unique geological strata, soil type, drainage patterns, moisture content, temperature and degree of slope which often dictate the predominant vegetation. Because the predominant vegetation has evolved to live in these specific conditions, a successful stormwater management facility planting design can be achieved through mimicking these natural associations. The five physiographic regions are described below with associated vegetation listed as general planting guidance. For more detailed information and plant listings please refer to *Woody Plants of Maryland* (Brown and Brown, 1992).

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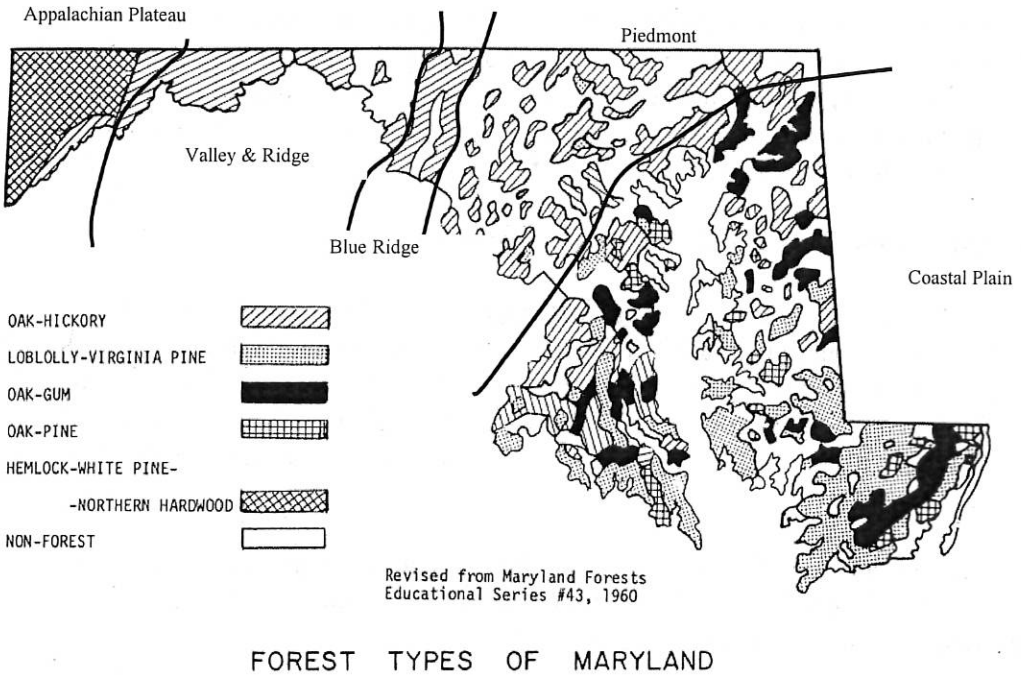
Figure A.7 Physiographic Provinces and Forest Types of Maryland



Appalachian Plateau Province

The Appalachian Plateau Province is where Maryland's highest elevations occur with Backbone Mountain being the greatest at 3,360 feet above sea level. In the higher elevations of the Appalachian Plateau, the climate becomes similar to that of the northern states and Canada. Slopes in the Appalachian Plateau are often steep and deeply carved by winding streams. This province has mountainous soils composed of clay and clay loams. The predominant forest types in this province are the Northern Hardwood and Oak-Hickory.

Common Species of the Appalachian Plateau Province	
Tree Species	**Understory**
eastern hemlock, white pine, mountain pine, pitch pine, red spruce, sugar maple, white basswood, american basswood, beech, yellow birch, sweet birch, cucumber tree, tulip tree, white oak, chestnut oak, scarlet oak, red oak, white ash, black walnut, and white walnut	hydrangea, flowering dogwood, pink azaleas, greenbriers, witch hazel, iron wood, hazelnut, blueberries, huckleberries, dewberries, dockmackie, deerberry, great laurel, hobble bush, mountain maple, striped maple, red-berried elder, bush honeysuckle, canadian yew, mountain holly, red raspberry, allegheny menziesia, and dwarf cornel

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Within the Appalachian Plateau are bog and swamp areas which support unique vegetation. For stormwater management facilities that will remain wet year-round, many species found in these bog and swamp areas will likely do well. Around the edges of these bogs, red spruce, white pine, hemlock, black gum, red maple, large and small toothed aspen, and pussy willow are common. Interior bog species include tamarack or larch, alders, swamp rose, winter berry, wild raisin, arrowwood, mountain holly, great laurel, smooth service berry, high bush blueberry, swamp dewberries, and cranberries.

Valley and Ridge, Blue Ridge, and Piedmont Provinces

The Valley and Ridge Province is where parallel ridges and valleys of the Appalachian Mountains create an alternating pattern. This province has mountainous soils composed of clay and clay loams, as well as sandy or stony loams. Often, the soils are shallow, and shale barrens may be found. The climate is dry. Most of the precipitation from the west is blocked by the Allegheny Mountain range, and precipitation from the east is blocked by the Blue Ridge Mountains.

The Blue Ridge Province is on the eastern edge of the Appalachian Mountains. This province has mountainous soils composed of sandy or stony loams. The climate is similar to that in the Piedmont Province, but somewhat cooler and moister.

The Piedmont Province is an area of rolling uplands with elevations ranging from 100 to 500 feet above sea level. Soils of the Piedmont are derived from granite rock and consist of loams and clays with rock fragments and gravel. The climate is moderate throughout this central Maryland province.

Common Species of the Valley and Ridge, Blue Ridge. and Piedmont Provinces	
Tree Species	**Understory**
hickory, chestnut oak, scarlet oak, scrub oak, white oak, red oak, black oak, scrub pine, pitch pine, short leaf pine, white pine, hemlocks, beech, black jack oak, shingle oak, fringe tree, and chinquapin	Sweet fern, flowering dogwood, black haw, chinquapin, sassafras, redbud, mountain laurel, blueberry, fringe tree, pink azalea, hydrangea, spicebush, and maple-leaved arrowwood

In the Hagerstown region of the Ridge and Valley Province, limestone outcrops produce alkaline soils which are conducive to red cedar communities. Other common species include oaks, black locust, redbud, fragrant sumac, hop hornbeam, hackberry, and slippery elm. Between Cumberland and Flintstone a series of shale barrens occur. These areas have a low water holding capacity and surfaces can get hot on sunny days. Common species associated with the shale barrens include scrub pine, scrub oak, post oak, yellow oak, fragrant sumac, dwarf sumac, single-flowered hawthorn, dwarf hackberry, New Jersey tea, Allegheny plum and pasture rose.

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Coastal Plain Province

The Coastal Plain Province is recognized by flat or gently rolling topography and elevations rising from sea level to about 100 feet. Coastal Plain marshes and swampy tidal flats surround the Chesapeake Bay. Sands, sandy loams, and silt loams make up the soils of the Coastal Plain. The climate is mild and sometimes rainy, similar to that found further south.

Common Species of the Coastal Plain Province	
Forest Species	**Understory**
loblolly pine, virginia pine, pitch pine, pond pine, sweet gum, willow oak, water oak, basket oak, pin oak, post oak, spanish oak, black cottonwood, pale hickory, bitternut hickory, sweet bay, american holly, beech, tulip tree, and river birch	blueberry, huckleberry, greenbier, sand blackberry, beach plum, beach heather, bay berry, sweet pepper bush, azalea, maleberry, stagger bush, fetter bush, inkberry, and alder

Because of low topographic relief and proximity to sea level, extensive swamp areas are common to the Coastal Plain Province. Most notable are the cypress swamps found on both the Eastern and Western Shores. As with the bogs of the Appalachian Province, species common to Coastal Plain swamps will grow well in wet stormwater management facilities because of the similar hydrology. In addition to bald cypress, other common species to these swamps are southern white cedar, black gum, red maple, and swamp bay. Common understory include evergreen laurel-leaved greenbrier, red-berried greenbrier, red choke berry, swamp haw, smooth winterberry, virginia willow, bay berry, inkberry, and swamp rose.

Floodplain Regions in Maryland

Floodplains occur across Maryland's physiographic provinces as low-lying areas adjacent to streams and rivers. Floodplain plant communities are similar across most of the State because of common soil characteristics governed by occasional flooding and high groundwater. Because stormwater management facilities are often located in floodplains, plant associations in these areas can provide valuable information for successful BMP plantings.

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Common Species of Floodplain Regions	
Forest Species	**Understory**
river birch, willows, silver maple, sweet gum, sycamore, box elder, green ash, american elm, swamp white oak, bur oak, honeylocust, and hackberry	shrub willows, ninebark, silkey cornel, buttonbush, spicebush, black alder, winterberry, black elderberry, and alders

A.3.3 Hydrologic Zones

For planting within a stormwater management facility, it is necessary to determine what hydrologic zones will be created. Hydrologic zones describe the degree to which an area is inundated by water. Plants have differing tolerances to inundation and as an aid to landscape designers, these tolerance levels have been divided into six zones and corresponding plant species have been identified.

Section A.4 includes a native plant list with appropriate hydrologic zones designated for each species. The hydrologic zones which are bracketed [ ] are where the plants tend to occur. There may be other zones listed outside of these brackets. The plants may occur in these zones, but are not typically found in them. Just as plants may, on occasion, be found outside of their hardiness zone, they may also be found outside of their hydrologic zone. They tend to grow where they can compete and survive. Additionally, hydrologic conditions in a stormwater management facility may fluctuate in unpredictable ways; thus the use of plants capable of tolerating wide varieties of hydrologic conditions greatly increases a successful planting. Conversely, plants suited for specific hydrologic conditions may perish when hydrologic conditions fluctuate, expose the soil, and increase the chance for erosion.

Table A.9 Hydrologic Zones

Zone #	Zone Description	Hydrologic Conditions
Zone 1	Deep Water Pool	1-6 foot deep permanent pool
Zone 2	Shallow Water Bench (low marsh)	6 inches to 1 foot deep
Zone 3	Shoreline Fringe (high marsh)	Regularly inundated
Zone 4	Riparian Fringe	Periodically inundated
Zone 5	Floodplain Terrace	Infrequently inundated
Zone 6	Upland Slopes	Seldom or never inundated

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A.3.4 Other Considerations in Stormwater BMP Landscaping

Use or Function

In selecting plants, consider their desired function in the landscape. Is the plant needed as ground cover, soil stabilizer, or a source of shade? Will the plant be placed to frame a view, create focus, or provide an accent? Does the location require that you provide seasonal interest to neighboring properties? Does the adjacent use provide conflicts or potential problems and require a barrier, screen, or buffer? Nearly every plant and plant location should be provided to serve some function in addition to any aesthetic appeal.

Plant Characteristics

Certain plant characteristics are so obvious, they may actually be overlooked in the plant selection. These are:

- Size
- Shape

For example, tree limbs, after several years, can grow into power lines. A wide growing shrub may block an important line of sight to oncoming vehicular traffic. A small tree, when full grown, could block the view from a second story window. Consider how these characteristics can work for you or against you, today and in the future.

Other plant characteristics must be considered to determine how the plant provides seasonal interest and whether the plant will fit with the landscape today and through the seasons and years to come. Some of these characteristics are:

- Color
- Texture
- Seasonal Interest (e.g., flowers, fruit, leaves, stems/bark)
- Growth Rate

If shade is required in large amounts, quickly, a sycamore might be chosen over an oak. In urban or suburban settings, a plant's seasonal interest may be of greater importance. Residents living next to a stormwater system may desire that the facility be appealing or interesting to look at throughout the year. For example, willows are usually the first trees to grow leaves signaling the coming of spring. Pink and white dogwoods bloom in mid-spring to early summer, while witch hazel has a yellow bloom every fall which can be contrasted with the red fall foliage of a sugar maple. Careful attention to the design and planting of a facility can result in greater public acceptance and increased property value.

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Availability and Cost

Often overlooked in plant selection is the availability from wholesalers and the cost of the plant material. There are many plants listed in landscape books that are not readily available from local nurseries. Without knowledge of what is available, time spent researching and finding the one plant that meets all the needs will be wasted. It may require shipping, therefore, making it more costly than the budget may allow. Some planting requirements may require a special effort to find the specific plant that fulfills the needs of the site and the function of the plant in the landscape.

In some cases, it may be cost effective to investigate nursery suppliers for the availability of wetland seed mixtures. Specifications of the seed mix shall include wetland seed types and the relative proportion of each species. Some suppliers provide seed mixtures suitable for specific wetland, upland, or riparian habitat conditions. This option may best be employed in small stormwater facilities such as pocket wetlands and open swales, or to complement woody vegetation plantings in larger facilities.

A.4 Stormwater Plant List

The pages at the end of this appendix present a list of herbaceous, tree and shrub plants native to Maryland and suitable for planting in stormwater management facilities. The list is intended as a guide for general planting purposes and planning considerations. Knowledgeable landscape designers and nursery suppliers may provide additional information for considering specific conditions for successful plant establishment and accounting for the variable nature of stormwater hydrology.

The planting list is in alphabetical order according to the common name, with the scientific name also provided. Life forms indicate whether a plant species is an "annual," "perennial," "grass," "fern," "shrub," or "tree".

Each plant species has a corresponding hydrologic zone provided to indicate the most suitable planting location for successful establishment. While the most common zones for planting are listed in parenthesis, the listing of additional zones indicates that a plant may survive over a broad range of hydrologic conditions.

The wetland indicator status (from Region 1, Reed, 1988) has been included to show "the estimated probability of a species occurring in wetlands versus nonwetlands" (Reed, 1988). Reed defines the indicator categories as follows:

> Obligate wetland (OBL): Plants, which nearly always (more than 99% of the time) occur in wetlands under natural conditions.

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Facultative Wetland (FACW): Plants, which usually occur in wetlands (from 67 to 99% of the time), but occasionally found in non wetlands.

Facultative (FAC): Plants, which are equally likely to occur in wetlands and non wetlands and are found in wetlands from 34 to 66% of the time.

Facultative Upland (FACU): Plants, which usually occur in non wetlands (from 67 to 99% of the time), but occasionally found in wetlands (from 1 to 33% of the time).

Upland (UPL): Plants, which almost always (more than 99% of the time) under natural conditions occur in non wetlands.

A given indicator status shown with a "+" or a "-" means that the species is more (+) or less (-) often found in wetlands than other plants with the same indicator status without the "+" or "-" designation.

Since the wetland indicator status alone does not provide an indication of the depth or duration of flooding that a plant will tolerate, the "Inundation Tolerance" section is designed to provide further guidance. Where a plant species is capable of surviving in standing water, a "yes" is designated in this column. Additional information is provided for depth of inundation for aquatic vegetation and tolerance for seasonal inundation or saturated soil conditions. Because individual plants often have unique life requirements difficult to convey in a general listing, it will be necessary to research specific information on the plant species proposed in order to ensure successful plant establishment.

Pollution tolerance and salt tolerance information are indicated to identify plantings that would be most appropriate in pollution hot spots.

Hardiness zones are provided for the U.S.D.A. hardiness zones. The herbaceous plant list identifies the range of zones the plant may survive in, while the tree and shrub list shows the coldest zone where the plant may naturally occur.

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Table A.4.1 Stormwater Plant List - Woody Vegetation

COMMON	SCIENTIFIC	FORM	ZONE	INDICATOR	TOLERANCE			HARDINESS
					INUNDATION	POLLUTION	SALT	
ALDER,BROOK-SIDE	*Alnus serrulata*	Tree	[1,2],3	OBL	0-3"	☐	☐	
ALDER,SEASIDE	*Alnus maritima*	Tree	[1,2],3	OBL	YES	☐	☐	
ALDER,SPECKLED	*Alnus rugosa*	Tree	1[2,3]	FACW+	YES	☐	☐	2
ARROW-WOOD	*Viburnum dentatum*	Shrub	[3,4],5	FAC	SEASONAL	☐	☑	2
ASH,BLACK	*Fraxinus nigra*	Tree	[2,3],4	FACW	SATURATED	☐	☐	2
ASH,GREEN	*Fraxinus pennsylvanica*	Tree	[2,3],4	FACW	SEASONAL	☐	☑	2
ASH,WHITE	*Fraxinus americana*	Tree	[4,5],6	FACU	NO	☐	☐	3
ASPEN,BIG-TOOTH	*Populus grandidentata*	Tree	[4,5,6]	FACU	NO	☐	☐	3
ASPEN,QUAKING	*Populus tremuloides*	Tree	[4,5],6	FACU	YES	☐	☐	1
AZALEA,DWARF	*Rhododendron atlanticum*	Shrub	[2,3,4],5	FAC,FAC+	YES	☐	☐	
AZALEA,EARLY	*Rhododendron prinophyllum*	Shrub	[2,3,4],5	FAC,FAC+	YES	☐	☐	3
AZALEA,HOARY	*Rhododendron canescens*	Shrub	[2,3],4	FACW	YES	☐	☐	
AZALEA,PINK	*Rhododendron periclymenoides*	Shrub	2,[3,4],5	FAC	SEASONAL	☐	☐	3
AZALEA,SMOOTH	*Rhododendron arborescens*	Shrub	[3,4],5	FAC	YES	☐	☐	4
AZALEA,SWAMP	*Rhododendron viscosum*	Shrub	[1,2,3],4	FACW+,OBL	SEASONAL	☐	☐	3
BASSWOOD,AMERICAN	*Tilia americana*	Tree	3,[4,5],6	FACU	NO	☐	☐	2
BAYBERRY,NORTHERN	*Myrica pennsylvanica*	Shrub	[3,4],5	FAC	SEASONAL	☐	☑	2
BAYBERRY,SOUTHERN	*Myrica cerifera*	Shrub	[2,3,4],5	FAC,FAC+	REG.INUNDA	☐	☐	
BEECH,AMERICAN	*Fagus grandifolia*	Tree	[4,5],6	FACU	NO	☐	☐	3
BIRCH,GRAY	*Betula populifolia*	Tree	[3,4],5	FAC	SEASONAL	☐	☐	5
BIRCH,RIVER	*Betula nigra*	Tree	[2,3],4	FACW	SEASONAL	☐	☐	4
BIRCH,YELLOW	*Betula alleghaniensis*	Tree	[3,4],5	FAC	YES	☐	☐	3
BLACK GUM, SWAMP TUPELO	*Nyssa sylvatica*	Tree	1,[2,3]	FACW+	SEASONAL	☐	☐	4

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COMMON	SCIENTIFIC	FORM	ZONE	INDICATOR	TOLERANCE			HARDINESS
					INUNDATION	POLLUTION	SALT	
BLACK-HAW	*Viburnum prunifolium*	Shrub	[3,4,5],6	FACU,FACU+	YES	☐	☐	3
BLACK-HAW,RUSTY	*Viburnum rufidulum*	Shrub	3,[4,5,6]	UPL,FACU	NO	☐	☐	5
BLADDERNUT, AMERICAN	*Staphylea trifolia*	Shrub-Tree	[3,4],5	FAC	YES	☐	☐	3
BLUEBERRY,BOG	*Vaccinium uliginosum*	Shrub	2,3,4,5,6	FACU+,FACW+	YES	☐	☐	
BLUEBERRY,CREEPING	*Vaccinium crassifolium*	Shrub	[2,3,4],5	FAC,FAC+	YES	☐	☐	
BLUEBERRY,HIGHBUSH	*Vaccinium atrococcum*	Shrub	[2,3]	FACW	SEASONAL	☐	☐	3
BLUEBERRY,LOWBUSH	*Vaccinium angustifolium*	Shrub	3,[4,5,6]	FACU-,FACU	NO	☐	☐	2
BLUEBERRY,VELVET-LEAF	*Vaccinium myrtilloides*	Shrub	1,2,[3,4,5],	FACU,FACW-	YES	☐	☐	2
BOX-ELDER	*Acer negundo*	Tree	2,[3,4]	FAC+	SEASONAL	☐	☐	2
BUCKTHORN,CAROLINA	*Rhamnus caroliniana*	Shrub	2,[3,4,5,6]	FACU-,FAC	YES	☐	☐	5-6
BUCKTHORN,LANCE-LEAF	*Rhamnus lanceolata*	Shrub	6	NI	NO	☐	☐	5
BUFFALO-BERRY,CANADA	*Shepherdia canadensis*	Shrub	6	NI	NO	☐	☑	
BURNING-BUSH,EASTERN	*Euonymus atropurpureus*	Shrub	[2,3,4,5],6	FACU,FAC+	YES	☐	☐	4
BUTTERNUT	*Juglans cinerea*	Tree	[3,4,5,6]	FACU-,FACU+	YES	☐	☐	3
BUTTONBUSH,COMMON	*Cephalanthus occidentalis*	Shrub	[1,2],3	OBL	0-3'	☐	☐	
CEDAR,ATLANTIC WHITE	*Chamaecyparis thyoides*	Tree	[1,2],3	OBL	SATURATE	☐	☐	3
CEDAR,EASTERN RED	*Juniperus virginiana*	Shrub	4,5,6	FACU	NO	☑	☐	2
CEDAR,NORTHERN WHITE	*Thuja occidentalis*	Tree	[2,3],4	FACW	SEASONAL	☐	☐	2
CHERRY,BLACK	*Prunus serotina*	Tree	[4,5],6	FACU	NO	☐	☐	3
CHERRY,CHOKE	*Prunus virginiana*	Tree	4,5,6	FACU	YES	☐	☐	5,6
CHERRY,FIRE	*Prunus pensylvanica*	Tree	4,5,6	FACU	NO	☐	☐	2
COTTON-WOOD,EASTERN	*Populus deltoides*	Tree	[3,4],5	FAC	SEASONAL	☑	☑	2
COTTON-WOOD,SWAMP	*Populus heterophylla*	Tree	[2,3]	FACW+	YES	☐	☐	
CRANBERRY,MOUNTAIN	*Vaccinium vitis-idaea*	Shrub	2,[3,4],5	FAC	YES	☐	☐	2
CRANBERRY,SMALL	*Vaccinium oxycoccos*	Shrub	[1,2],3	OBL	YES	☐	☐	2

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COMMON	SCIENTIFIC	FORM	ZONE	INDICATOR	TOLERANCE			HARDINESS
					INUNDATION	POLLUTION	SALT	
CRANBERRY,SOUTHERN MOUNTAIN	*Vaccinium erythrocarpum*	Shrub	2,[3,4],5	FAC	YES	☐	☐	5
CYPRESS,BALD	*Taxodium distichum*	Tree	[1,2],3	OBL	SATURATED	☐	☐	4
DANGLE-BERRY	*Gaylussacia frondosa*	Shrub	2,[3,4],5	FAC	YES	☐	☐	
DEERBERRY	*Vaccinium stamineum*	Shrub	[3,4,5,6]	FACU-,FACU+	YES	☐	☐	5
DOG-HOBBLE,COASTAL	*Leucothoe axillaris*	Shrub	[1,2,3,4],5	FACW,FACW+	YES	☐	☐	6
DOG-HOBBLE,RED-TWIG	*Leucothoe recurva*	Shrub	3,[4,5],6	FACU	NO	☐	☐	5
DOGWOOD, GRAY	*Cornus racemosa*	Shrub	2[3,4]	FAC+	SEASONAL	☐	☐	
DOGWOOD,FLOWERING	*Cornus florida*	Shrub-Tree	4,5,6	FACU-	NO	☐	☐	4
DOGWOOD,ROUGH-LEAF	*Cornus asperifolia*	Shrub	1,2,[3,4,5]	FAC-,FACW-	YES	☐	☐	
DOGWOOD,ROUGH-LEAF	*Cornus drummondii*	Shrub	2,[3,4],5	FAC	YES	☐	☐	4
DOGWOOD,SILKY	*Cornus amomum*	Shrub	[2,3],4	FACW	SEASONAL	☐	☐	5
ELDER,EUROPEAN RED	*Sambucus racemosa*	Shrub	[3,4,5],6	FACU,FACU+	YES	☐	☐	4
ELM,SLIPPERY	*Ulmus rubra*	Tree	[3,4],5	FAC	YES	☐	☐	3
FALSE-WILLOW,EASTERN	*Baccharis halimifolia*	Shrub	1,[2,3,4],5	FAC,FACW	0-6"	☐	☐	
FARKLEBERRY	*Vaccinium arboreum*	Shrub	3,[4,5],6	FACU	NO	☐	☐	7
FETTER-BUSH	*Leucothoe racemosa*	Shrub	1,[2,3,4],5	FACW	SEASONAL	☐	☐	5
FETTER-BUSH	*Lyonia lucida*	Shrub	1,[2,3,4],5	FACW	YES	☐	☐	
GERMANDER,AMERICAN	*Teucrium canadense*	Shrub	1,[2,3,4],5	FAC+,FACW	YES	☐	☐	
GROUNDSEL TREE	*Baccheris halimifolia*	Shrub	[2,3]4	FACW		☐	☐	
GUM,SWEET	*Liquidambar styraciflua*	Tree	[3,4],5	FAC	YES	☐	☐	4
HACKBERRY,COMMON	*Celtis occidentalis*	Shrub-Tree	4,5,6	FACU	SEASONAL	☑	☐	5
HAWTHORN,BEAUTIFUL	*Crataegus pulcherrima*	Tree	2,[3,4],5	FAC	YES	☐	☐	4
HAWTHORN,COCKSPUR	*Crataegus crus-galli*	Tree	2,[3,4,5],6	FACU,FAC	YES	☑	☐	4
HAWTHORN,DOWNY	*Crataegus mollis*	Tree	1,2,[3,4,5],	FACU,FACW-	YES	☐	☐	4
HAWTHORN,GREEN	*Crataegus viridis*	Tree	1,[2,3,4],5	FAC,FACW	YES	☐	☐	4

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COMMON	SCIENTIFIC	FORM	ZONE	INDICATOR	TOLERANCE			HARDINESS
					INUNDATION	POLLUTION	SALT	
HAWTHORN,LITTLE-HIP	*Crataegus spathulata*	Tree	1,[2,3,4],5	FAC,FACW	YES	☐	☐	4
HAWTHORN,PARSLEY	*Crataegus marshallii*	Tree	[1,2,3,4],5,	FACU+,FACW	YES	☐	☐	4
HAWTHORN,WASHINGTON	*Crataegus phaenopyrum*	Tree	2,[3,4,5]	FAC-,FAC	YES	☐	☐	4
HAZEL-NUT,AMERICAN	*Corylus americana*	Shrub	3,[4,5,6]	UPL,FACU	NO	☐	☐	4
HAZEL-NUT,BEAKED	*Corylus cornuta*	Shrub	3,[4,5,6]	UPL,FACU	NO	☐	☐	4
HEATHER	*Calluna vulgaris*	Shrub	2,[3,4],5	FAC	YES	☐	☐	4
HEMLOCK,EASTERN	*Tsuga canadensis*	Tree	4,5,6	FACU	NO	☐	☐	3
HICKORY,BIG SHELLBARK	*Carya laciniosa*	Tree	1,[2,3,4],5	FAC,FACW	YES	☐	☐	5
HICKORY,BITTER-NUT	*Carya cordiformis*	Tree	4,5,6	FACU+	NO	☐	☐	4
HICKORY,PECAN	*Carya illinoensis*	Tree	1,[2,3,4,5],	FACU,FACW	YES	☐	☐	5
HICKORY,RED	*Carya ovalis*	Tree	3,[4,5,6]	UPL,FACU	NO	☐	☐	4
HICKORY,SHAG-BARK	*Carya ovata*	Tree	[3,4,5,6]	FACU-,FACU+	YES	☐	☐	4
HICKORY,SWEET PIGNUT	*Carya glabra*	Tree	3,[4,5,6]	FACU-,FACU	NO	☐	☐	4
HOLLY, WINTERBERRY	*Ilex laevigata*	Shrub	[1,2],3	OBL	YES	☐	☐	4
HOLLY,AMERICAN	*Ilex opaca*	Shrub	4,5,6	FACU	LIMITED	☑	☐	5
HOLLY,BAY-GALL	*Ilex coriacea*	Shrub	1,[2,3,4],5	FACW	YES	☐	☐	
HOLLY,DECIDUOUS	*Ilex decidua*	Shrub	1,[2,3,4,5]	FACW-,FACW	SEASONAL	☐	☐	
HOLLY,GEORGIA	*Ilex longipes*	Shrub	1,[2,3,4],5	FAC,FACW	YES	☐	☐	
HOLLY,SARVIS	*Ilex amelanchier*	Shrub	[1,2],3	OBL	YES	☐	☐	
HOP-HORNBEAM,EASTERN	*Ostrya virginiana*	Shrub-Tree	[3,4,5,6]	FACU-,FACU+	YES	☐	☐	4
HORNBEAM,AMERICAN	*Carpinus caroliniana*	Tree	[3,4],5	FAC	SOME	☐	☐	2
HUCKLEBERRY,BLACK	*Gaylussacia baccata*	Shrub	3,[4,5],6	FACU	NO	☐	☐	2
HUCKLEBERRY,DWARF	*Gaylussacia dumosa*	Shrub	2,[3,4],5	FAC	YES	☐	☐	2
HYDRANGEA,PANICLE	*Hydrangea paniculata*	Shrub	2,[3,4],5	FAC	YES	☐	☐	4
HYDRANGEA,WILD	*Hydrangea arborescens*	Shrub	3,[4,5,6]	UPL,FACU	NO	☐	☐	4

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COMMON	SCIENTIFIC	FORM	ZONE	INDICATOR	TOLERANCE			HARDINESS
					INUNDATION	POLLUTION	SALT	
INK-BERRY	*Ilex glabra*	Shrub	[2,3],4	FACW-	SEASONAL	☐	☐	3
LAUREL,MOUNTAIN	*Kalmia latifolia*	Shrub	4,5,6	FACU	NO	☐	☐	4
LOCUST,BLACK	*Robinia pseudoacacia*	Tree	4,5,6	FACU	YES	☐	☑	5
MAGNOLIA,UMBRELLA	*Magnolia tripetala*	Tree	2,[3,4,5],6	FACU,FAC	YES	☐	☐	4
MALEBERRY	*Lyonia ligustrina*	Shrub	1,[2,3,4],5	FACW	YES	☐	☐	3
MAPLE,MOUNTAIN	*Acer spicatum*	Tree	4,5,6	FACU	NO	☐	☐	2
MAPLE,RED	*Acer rubrum*	Tree	[3,4],5	FAC	SEASONAL	☐	☐	3
MAPLE,SILVER	*Acer saccharinum*	Tree	[2,3],4	FACW	SEASONAL	☐	☐	3
MAPLE,STRIPED	*Acer pensylvanicum*	Shrub-Tree	3,[4,5,6]	FACU-,FACU	NO	☐	☐	3
MARSH ELDER	*Iva frutescens*	Shrub	1[2,3]	FACW+		☐	☑	
MEADOW-SWEET,BROAD-LEAF	*Spiraea latifolia*	Shrub	[2,3,4]	FAC+,FACW	YES	☐	☐	2
MEADOW-SWEET,NARROW-LEAF	*Spiraea alba*	Shrub	[1,2,3,4],5	FACW,FACW+	YES	☐	☐	4
MEADOW-SWEET,VIRGINIA	*Spiraea virginiana*	Shrub	1,[2,3,4,5],	FACU,FACW	YES	☐	☐	5
MEADOW-SWEET,WILLOW-LEAF	*Spiraea salicifolia*	Shrub	1,[2,3]	FACW+	YES	☐	☐	4
NANNYBERRY	*Viburnum lentago*	Shrub	[3,4],5	FAC	SEASONAL	☐	☐	2
NINEBARK,EASTERN	*Physocarpus opulifolius*	Shrub	[2,3],4	FACW-	YES	☐	☐	2
OAK, PIN	*Quercus palustris*	Tree	[2,3],4	FACW	SEASONAL	☑	☐	4
OAK, SCARLET	*Quercus coccinea*	Tree	6		NO	☐	☐	
OAK,BUR	*Quercus macrocarpa*	Tree	3,[4,5],6	FAC-	YES	☑	☐	2
OAK,CHERRY-BARK	*Quercus falcata var. pagodafolia*	Tree	1,[2,3,4],5	FAC+,FACW	YES	☐	☐	5-6
OAK,CHESTNUT	*Quercus prinus*	Tree	4,5,6	FACU	NO	☐	☐	5,6
OAK,CHINKAPIN	*Quercus muhlenbergii*	Tree	[3,4],5	FAC	YES	☐	☐	5
OAK,LAUREL	*Quercus laurifolia*	Tree	1,[2,3,4,5]	FACW-,FACW	YES	☐	☐	
OAK,LIVE	*Quercus virginiana*	Tree	4,5,6	FACU	YES	☐	☑	7
OAK,OVERCUP	*Quercus lyrata*	Tree	[1,2],3	OBL	YES	☐	☐	5

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COMMON	SCIENTIFIC	FORM	ZONE	INDICATOR	TOLERANCE			HARDINESS
					INUNDATION	POLLUTION	SALT	
OAK,POST	*Quercus stellata*	Tree	3,[4,5,6]	UPL,FACU	NO	☐	☐	5
OAK,RED	*Quercus rubra*	Tree	6		NO	☑	☐	
OAK,SHINGLE	*Quercus imbricaria*	Tree	[3,4],5	FAC	YES	☑	☐	5
OAK,SHUMARD	*Quercus shumardii*	Tree	2,[3,4]	FAC+	YES	☐	☐	5
OAK,SWAMP CHESTNUT	*Quercus michauxii*	Tree	1,[2,3,4,5]	FACW-,FACW	YES	☐	☐	
OAK,SWAMP WHITE	*Quercus bicolor*	Tree	1,[2,3]	FACW+	SEASONAL	☐	☐	3
OAK,WATER	*Quercus nigra*	Tree	[3,4],5	FAC	SEASONAL	☐	☐	6
OAK,WHITE	*Quercus alba*	Tree	[4,5,6]	FACU	YES	☐	☐	4
OAK,WILLOW	*Quercus phellos*	Tree	2,[3,4]	FAC+	SEASONAL	☐	☐	5
PEPPER-BUSH,SWEET	*Clethra alnifolia*	Shrub	2,[3,4]	FAC+	SEASONAL	☐	☑	3
PINE,EASTERN WHITE	*Pinus strobus*	Tree	4,5,6	FACU	NO	☑	☑	3
PINE,JERSEY	*Pinus viginiana*	Tree	6		NO	☐	☑	
PINE,LOBLOLLY	*Pinus taeda*	Tree	3,[4,5],6	FAC-	SEASONAL	☐	☐	
PINE,PITCH	*Pinus rigida*	Tree	4,5,6	FACU	SEASONAL	☐	☑	4
PINE,POND	*Pinus serotina*	Tree	[1,2],3	OBL	YES	☐	☐	
REDBUD,EASTERN	*Cercis canadensis*	Shrub-Tree	3,[4,5,6]	UPL,FACU	NO	☐	☐	4
RHODODENDRON	*Rhododendron canadense*	Shrub	1,[2,3,4],5	FACW	YES	☐	☐	2
RHODODENDRON,ROSEBAY	*Rhododendron maximum*	Shrub	[3,4],5	FAC	YES	☐	☐	3
ROSEMARY,BOG	*Andromeda polifolia*	Shrub	[1,2],3	OBL	YES	☐	☐	
SAND-MYRTLE	*Leiophyllum buxifolium*	Shrub	3,4,[5,6]	FACU-	NO	☐	☐	
SASSAFRAS	*Sassafras albidum*	Tree	3,[4,5,6]	FACU-,FACU	NO	☐	☐	4
SERVICE-BERRY,DOWNY	*Amelanchier arborea*	Shrub-Tree	2,[3,4,5],6	FAC-	YES	☐	☐	
SHEEP-LAUREL	*Kalmia angustifolia*	Shrub	3,[4,5],6	FAC	YES	☐	☐	2
SILVER-BERRY,AMERICAN	*Elaeagnus commutata*	Shrub	[6]	UPL	NO	☐	☐	
SNOWBELL,BIG-LEAF	*Styrax grandifolia*	Shrub	3,[4,5,6]	FACU-,FACU	NO	☐	☐	5

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COMMON	SCIENTIFIC	FORM	ZONE	INDICATOR	TOLERANCE			HARDINESS
					INUNDATION	POLLUTION	SALT	
SPICEBUSH,NORTHERN	*Lindera benzoin*	Shrub	[2,3],4	FACW-	SEASONAL	☐	☐	3-5
STAGGER-BUSH,PIEDMONT	*Lyonia mariana*	Shrub	2,[3,4,5,6]	FACU-,FAC	YES	☐	☐	5
STEEPLE-BUSH	*Spiraea tomentosa*	Shrub	1,[2,3,4],5	FACW	YES	☐	☐	4
STRAWBERRY-BUSH,AMERICAN	*Euonymus americanus*	Shrub	1,[2,3,4,5],	FACU,FACW	YES	☐	☐	5
SUGAR-BERRY	*Celtis laevigata*	Shrub	1,[2,3,4,5,6	UPL,FACW	YES	☐	☐	
SWEETSHRUB	*Calycanthus fertilis*	Shrub	[3,4,5],6	FACU,FACU+	YES	☐	☐	5
SYCAMORE,AMERICAN	*Platanus occidentalis*	Tree	[2,3],4	FACW-	SATURATED	☐	☐	
TEABERRY	*Gaultheria procumbens*	Shrub	3,[4,5],6	FACU	NO	☐	☐	3
TREE,TULIP	*Liriodendron tulipifera*	Tree	2,[3,4,5],6	FACU,FAC	YES	☐	☐	4
VIBURNUM,MAPLE-LEAF	*Viburnum acerifolium*	Shrub	3,[4,5,6]	UPL,FACU	NO	☐	☐	3
VIBURNUM,POSSUM-HAW	*Viburnum nudum*	Shrub	[1,2],3	OBL	YES	☐	☐	6
WILLOW,BLACK	*Salix nigra*	Tree	[2,3]	FACW+	SEASONAL	☐	☐	3
WILLOW,HEART-LEAF	*Salix cordata*	Shrub	1,[2,3,4],5	FAC,FACW	YES	☐	☐	3
WILLOW,SILKY	*Salix sericea*	Shrub	[1,2],3	OBL	YES	☐	☐	3
WILLOW,TALL PRAIRIE	*Salix humilis*	Shrub	3,[4,5],6	FACU	NO	☐	☐	3
WILLOW,VIRGINIA	*Itea virginica*	Shrub	[1,2],3	OBL	0-6"	☐	☐	5
WINTERBERRY,COMMON	*Ilex verticillata*	Shrub	1,[2,3]	FACW+	SEASONAL	☐	☐	3
WITCH-ALDER,DWARF	*Fothergilla gardenii*	Shrub	1,[2,3,4],5	FACW	YES	☐	☐	
WITCH-HAZEL, AMERICAN	*Hamamelis virginiana*	Shrub-Tree	3,[4,5],6	FAC-	NO	☑	☐	4
WITCH-HAZEL,AMERICAN	*Hamamelis virginiana*	Shrub-Tree	2,3,[4,5],6	FACU,FAC-	NO	☑	☐	4
WITHE-ROD	*Viburnum cassinoides*	Shrub	1,[2,3,4],5	FACW	YES	☐	☐	3
YAUPON	*Ilex vomitoria*	Shrub	3,[4,5],6	FAC-	YES	☐	☑	
YEW,AMERICAN	*Taxus canadensis*	Shrub	2,[3,4,5],6	FACU,FAC	YES	☐	☐	2

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Appendix A.4.2 Stormwater Plant List - Herbaceous Vegetation

COMMON	SCIENTIFIC	FORM	ZONE	INDICATOR	TOLERANCE			HARDINESS
					INUNDATION	POLLUTION	SALT	
ARROW-GRASS,MARSH	*Triglochin palustre*	Grass	[1,2],3	OBL	YES	☐	☐	
ARROW-HEAD,BROAD-LEAF	*Sagittaria latifolia*	Perennial	[1,2],3	OBL	0-2'	☐	☐	
ARROW-HEAD,COASTAL	*Sagittaria falcata*	Perennial	[1,2],3	OBL	YES	☐	☐	
ARROW-HEAD,GRASS-LEAF	*Sagittaria graminea*	Perennial	[1,2],3	OBL	0-1'	☐	☐	
ARROW-HEAD,NORTHERN	*Sagittaria cuneata*	Perennial	[1,2],3	OBL	YES	☐	☐	
ARROW-HEAD,SHORT-BEAK	*Sagittaria brevirostra*	Perennial	[1,2],3	OBL	YES	☐	☐	
ARROW-HEAD,WAPATO DUCK POTATO	*Sagittaria latifolia*	Perennial	[1,2],3	OBL	0-2'	☐	☐	3-8
ASTER,ANNUAL SALTMARSH	*Aster subulatus*	Annual	[1,2],4	OBL	YES	☐	☑	
ASTER,BOG	*Aster nemoralis*	Perennial	[2,3],4	FACW+	YES	☐	☐	
ASTER,BUSH	*Aster dumosus*	Perennial	[3,4],5	FAC	NO	☐	☐	
ASTER,CALICO	*Aster lateriflorus*	Perennial	[2,3,4]	FACW-	SEASONAL	☐	☐	
ASTER,CROOKED-STEM	*Aster prenanthoides*	Perennial	[3,4],5	FAC	NO	☐	☐	
ASTER,FLAT-TOP WHITE	*Aster umbellatus*	Perennial	[2,3],4	FACW	YES	☐	☐	
ASTER,NEW ENGLAND	*Aster novae-angliae*	Perennial	[2,3],4	FACW	YES	☐	☐	
ASTER,NEW YORK	*Aster novi-belgii*	Perennial	[2,3],4	FACW+	YES	☐	☐	
ASTER,ONTARIO	*Aster ontarionis*	Perennial	[3,4],5	FAC	NO	☐	☐	
ASTER,PANICLED	*Aster simplex*	Perennial	[2,3],4	FACW	YES	☐	☐	
ASTER,PERENNIAL SALTMARSH	*Aster tenuifolius*	Perennial	1,[2,3]	OBL	YES	☐	☑	
ASTER,SMALL WHITE	*Aster vimineus*	Perennial	[3,4,5]	FAC	NO	☐	☐	
ASTER,SWAMP	*Aster puniceus*	Perennial	1,[2,3]	OBL	YES	☐	☐	

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COMMON	SCIENTIFIC	FORM	ZONE	INDICATOR	TOLERANCE			HARDINESS
					INUNDATION	POLLUTION	SALT	
ASTER,TRADESCANT	*Aster tradescanti*	Perennial	[2,3],4	FACW	YES	☐	☐	
ASTER,WHITE HEATH	*Aster ericoides*	Perennial	3,[4,5,6]	FACU	NO	☐	☐	
ASTER,WILLOW-LEAF	*Aster praealtus*	Perennial	[2,3],4	FACW	YES	☐	☐	
BABY-BLUE-EYES,SMALL-FLOWER	*Nemophila aphylla*	Annual	[2,3],4	FACW	YES	☐	☐	
BEACHGRASS,AMERICAN	*Ammophila breviligulata*	Grass	4,[5,6]	FACU-	NO	☐	☐	
BEAKRUSH,FASCICULATE	*Rhynchospora fascicularis*	Grass	[1,2],3	OBL	YES	☐	☐	
BEAKRUSH,GRAY'S	*Rhynchospora grayi*	Grass	2,3,4,5,6	FAC	NO	☐	☐	
BEAKRUSH,PINELAND	*Rhynchospora perplexa*	Grass	[2,3],4	FACW+	YES	☐	☐	
BEAKRUSH,TALL	*Rhynchospora macrostachya*	Grass	[1,2],3	OBL	YES	☐	☐	
BEARDTONGUE	*Penstemon digitalis*	Perennial	3,4,5	FAC	NO	☐	☐	3-8
BEARDTONGUE,LONG-SEPAL	*Penstemon calycosus*	Perennial	[4,5,6]	UPL,FACU	NO	☐	☐	
BEARDTONGUE,LOWLAND	*Penstemon alluviorum*	Perennial	[2,3,4]	FACW	YES	☐	☐	
BEEBALM	*Monarda didyma*	Perennial	3,4,5	FAC+	SATURATED	☐	☐	4-8
BENTGRASS,BROWN	*Agrostis canina*	Grass	[4,5,6]	FACU	NO	☐	☐	
BENTGRASS,PERENNIAL	*Agrostis perennans*	Grass	[4,5],6	FACU	YES	☐	☐	
BENTGRASS,SPREADING	*Agrostis stolonifera*	Grass	[2,3],4	FACW	YES	☐	☐	
BENTGRASS,WINTER	*Agrostis hyemalis*	Grass	[3,4],5	FAC	NO	☐	☐	
BERGAMOT,WILD	*Monarda fistulosa*	Perennial	[4,5,6]	UPL	NO	☐	☐	
BLACK-EYED SUSAN	*Rudbeckia hirta (yellow)*	Perennial	4,5,6	FACU-	NO	☐	☐	3-7
BLADDERWORT,COMMON	*Utricularia macrorhiza*	Perennial	[1,2],3	OBL	YES	☐	☐	
BLOODROOT	*Sanguinaria canadensis*	Perennial	4,[5,6]	UPL,FACU-	NO	☐	☐	
BLUEBELLS,VIRGINIA	*Mertensia virginica*	Perennial	[2,3],4	FACW	YES	☐	☐	

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COMMON	SCIENTIFIC	FORM	ZONE	INDICATOR	TOLERANCE			HARDINESS
					INUNDATION	POLLUTION	SALT	
BLUE-EYE-GRASS	*Sisyrinchium capillare*	Grass	[2,3]4	FACW+	YES	☐	☐	
BLUEFLAG,SOUTHERN	*Iris shrevei*	Perennial	1,[2],3	OBL	YES	☐	☐	
BLUEFLAG,VIRGINIA	*Iris virginica*	Perennial	1,[2],3	OBL	YES	☐	☐	
BLUEGRASS,BOG	*Poa paludigena*	Grass	[2,3],4	FACW+	YES	☐	☐	
BLUEGRASS,GROVE	*Poa alsodes*	Grass	2,[3,4],5	FACW-	SEASONAL	☐	☐	
BLUEGRASS,LOW	*Poa alpigena*	Grass	2,[3,4],5	FACW-	SEASONAL	☐	☐	
BLUESTEM,BIG	*Andropogon gerardii*	Grass	[4,5],6	FAC	NO	☐	☐	
BLUESTEM,BUSHY	*Andropogon glomeratus*	Grass	[2,3],4	FACW+	YES	☐	☐	
BROOM-SEDGE	*Andropogon virginicus*	Grass	[4,5],6	FACU	NO	☐	☐	
BULRUSH, HARDSTEMMED	*Scirpus acutus*	Perennial	[1,2],3	OBL	0-3'	☐	☐	8
BULRUSH, SOFTSTEM	*Scirpus validus*	Perennial	[1,2,],3	OBL	0-1'	☐	☐	8
BULRUSH,ALKALI	*Scirpus robustus*	Grass	1,[2],3	OBL	SALT, EDGE	☐	☑	
BULRUSH,CLINTON'S	*Scirpus clintonii*	Grass	[4,5,6]	FACU	NO	☐	☐	
BULRUSH,OLNEY'S	*Scirpus americanus*	Grass	[1,2],3	OBL	0-6"	☐	☐	
BULRUSH,RIVER	*Scirpus fluviatilis*	Grass	[1,2],3	OBL	0-1'	☐	☐	
BULRUSH,SPREADING	*Scirpus divaricatus*	Grass	[1,2],3	OBL	YES	☐	☐	
BULRUSH,THREE-SQUARE	*Scirpus pungens*	Grass	[2,3],4	FACW+	0-6"	☐	☐	
BURREED,AMERICAN	*Sparganium americanum*	Grass	[1,2],3	OBL	0-1'	☐	☐	
BURREED,GIANT	*Sparganium eurycarpum*	Grass	[1,2],3	OBL	YES	☐	☐	
BUSHCLOVER,NARROW-LEAF	*Lespedeza angustifolia*	Groundcover	4,5,6	FACU	NO	☐	☐	
BUTTER-CUP,ALLEGHENY MOUNTAIN	*Ranunculus allegheniensis*	Perennial	[3,4],5	FAC	NO	☐	☐	
BUTTER-CUP,POND	*Ranunculus subrigidus*	Perennial	[1,2],3	OBL	YES	☐	☐	

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COMMON	SCIENTIFIC	FORM	ZONE	INDICATOR	TOLERANCE			HARDINESS
					INUNDATION	POLLUTION	SALT	
BUTTER-CUP,SEASIDE	*Ranunculus cymbalaria*	Perennial	[1,2],3	OBL	YES	☐	☐	
CAMPION, SNOWY	*Silene nivea*	Perennial	[3,4],5	FAC	NO	☐	☐	4-8
CARDINAL FLOWER	*Lobelia cardinalis*	Perennial	1,[2,3],4	FACW+	YES	☐	☐	2-8
CHICORY	*Cichorium intybus*	Perennial	5,6	UPL	NO	☐	☐	3-8
CLUB,GOLDEN	*Orontium aquaticum*	Perennial	[1,2],3	OBL	YES	☐	☐	
COLTSFOOT,SWEET	*Petasites palmatus*	Perennial	1,[2,3],4	FACW+	YES	☐	☐	
COLUMBINE,WILD	*Aquilegia canadensis*	Perennial	[3,4],5	FAC	NO	☐	☐	
CONEFLOWER,CUT-LEAF	*Rudbeckia laciniata*	Perennial	[2,3],4	FACW	YES	☐	☐	
CONEFLOWER,ORANGE	*Rudbeckia fulgida*	Perennial	[3,4],5	FAC	NO	☐	☐	
CONEFLOWER,SWEET	*Rudbeckia subtomentosa*	Perennial	[3,4],5	FAC	NO	☐	☐	
CORDGRASS,BIG	*Spartina cynosuroides*	Grass	[1,2],3	OBL	SALT, EDGE	☐	☑	
CORDGRASS,PRAIRIE	*Spartina pectinata*	Grass	[1,2],3	OBL	SALT, EDGE	☐	☑	
CORDGRASS,SALTMARSH	*Spartina alterniflora*	Grass	[1,2],3	OBL	SALT, EDGE	☐	☑	
CORDGRASS,SALTMEADOW	*Spartina patens*	Grass	1,[2,3],4	FACW+	SALT, EDGE	☐	☑	
CORNFLOWER	*Centaurea cyanus*	Perennial	5,6	UPL	NO	☐	☐	
CUTGRASS,RICE	*Leersia oryzoides*	Grass	[1,2],3	OBL	0-6"	☐	☐	
DAISY, OXEYE	*Chrysanthemum levcanthemu*	Perennial	5,6	UPL	NO	☐	☐	
DRAGON-HEAD,FALSE	*Physostegia virginiana*	Perennial	2,[3,4],5	FAC+	SATURATED	☐	☐	
DRAGON-HEAD,PURPLE	*Physostegia purpurea*	Perennial	[2,3],4	FACW	YES	☐	☐	
DRAGON-HEAD,SLENDER	*Physostegia intermedia*	Perennial	[2,[3,4]	FACW-	SEASONAL	☐	☐	
DRAGON-HEAD,SLENDER-LEAF	*Physostegia leptophylla*	Perennial	[1,2],3	OBL	YES	☐	☐	
DROPSEED,SEASHORE	*Sporobolus virginicus*	Grass	1,[2,3],4	FACW+	YES	☐	☐	

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COMMON	SCIENTIFIC	FORM	ZONE	INDICATOR	TOLERANCE			HARDINESS
					INUNDATION	POLLUTION	SALT	
DUCKWEED	*Lemna trinervis*	Perennial	[1,2],3	OBL	Fre Float	☐	☐	
DUCKWEED,LEAST	*Lemna minima*	Perennial	[1,2],3	OBL	Free Float	☐	☐	
DUCKWEED,LESSER	*Lemna minor*	Perennial	[1,2],3	OBL	Free Float	☐	☐	
DUCKWEED,MINUTE	*Lemna perpusilla*	Perennial	[1,2],3	OBL	Free Float	☐	☐	
DUCKWEED,PALE	*Lemna valdiviana*	Perennial	[1,2],3	OBL	Free Float	☐	☐	
DWARF PLAINS COREOPSIS	*Coreopsis tinctoria (dwarf)*	Annual	3,[4,5],6	FAC-	NO	☐	☐	
EELGRASS	*Zostera marina*	Perennial	[1,2],3	OBL	2-6'	☐	☑	3-8
FALSE-HELLEBORE,AMERICAN	*Veratrum viride*	Perennial	[2,3,4]	FACW+	YES	☐	☐	
FALSE-SOLOMON'S-SEAL,FEATHER	*Smilacina racemosa*	Perennial	[4,5],6	FACU-	NO	☐	☐	
FERN,CINNAMON	*Osmunda cinnamomea*	Fern	[2,3],4	FACW	SATURATE	☐	☐	
FERN,NEW YORK	*Thelypteris noveboracensis*	Fern	[3,4],5	FAC	SATURATE	☐	☐	
FERN,ROYAL	*Osmunda regalis*	Fern	[1,2],3	OBL	SATURATE	☐	☐	
FERN,SENSITIVE	*Onoclea sensibilis*	Fern	[2,3],4	FACW	SATURATE	☐	☐	
FESCUE,MEADOW	*Festuca pratensis*	Grass	[3,4,5,6]	FACU-	NO	☐	☐	
FESCUE,NODDING	*Festuca obtusa*	Grass	[4,5],6	FACU	NO	☐	☐	
FESCUE,RED	*Festuca rubra*	Groundcover	[4,5]	FACU	NO	☐	☐	
FLATSEDGE,MARSH	*Cyperus pseudovegetus*	Grass	[2,3],4	FACW	YES	☐	☐	
FLATSEDGE,POORLAND	*Cyperus compressus*	Grass	[3,4],5	FAC+	SATURATE	☐	☐	
FLATSEDGE,RUSTY	*Cyperus odoratus*	Grass	[2,3],4	FACW	YES	☐	☐	
FLATSEDGE,SHORT-LEAF	*Cyperus brevifolius*	Grass	[1,2],3	OBL	YES	☐	☐	
FLATSEDGE,SLENDER	*Cyperus filicinus*	Grass	2,[3,4,5,6]	UPL,FAC	YES	☐	☐	
FLAX, VIRGINIA	*Linum virginianum*	Perennial	5,6	FACU	NO	☐	☐	1-8

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COMMON	SCIENTIFIC	FORM	ZONE	INDICATOR	TOLERANCE			HARDINESS
					INUNDATION	POLLUTION	SALT	
FLOATING-HEART,YELLOW	*Nymphoides peltata*	Perennial	[1,2],3	OBL	YES	☐	☐	
FORGET-ME-NOT,FIELD	*Myosotis arvensis*	Perennial	[3,4,5,6]	UPL	NO	☐	☐	
FOUR-O'CLOCK,HEART-LEAF	*Mirabilis nyctaginea*	Perennial	[4,5,6]	FACU	NO	☐	☐	
FOXTAIL,MEADOW	*Alopecurus geniculatus*	Grass	[1,2],3	OBL	YES	☐	☐	
FOXTAIL,MEADOW	*Alopecurus pratensis*	Grass	[2,3],4	FACW	YES	☐	☐	
FOXTAIL,MOUSE	*Alopecurus myosuroides*	Grass	[2,3],4	FACW	YES	☐	☐	
FOXTAIL,SHORT-AWN	*Alopecurus aequalis*	Grass	[1,2],3	OBL	YES	☐	☐	
FOXTAIL,TUFTED	*Alopecurus carolinianus*	Grass	[2,3],4	FACW	YES	☐	☐	
GLASSWORT,VIRGINIA	*Salicornia virginica*	Perennial	[1,2],3	OBL	SALT,EDGE	☐	☐	
GOLDEN-ROD	*Solidago austrina*	Perennial	[1,2],3	OBL	YES	☐	☐	
GOLDEN-ROD,COAST	*Solidago spathulata*	Perennial	4,[5,6]	FACU-	NO	☐	☐	
GOLDEN-ROD,SEASIDE	*Solidago sempervirens*	Perennial	[2,3],4	FACW	YES	☐	☐	
GOLDEN-ROD,STIFF	*Solidago rigida*	Perennial	1,2,3	OBL	NO	☐	☐	
GRASS,BROOM PANIC	*Dichanthelium scoparium*	Grass	[2,3],4	FACW	YES	☐	☐	
GRASS,CANADA MANNA	*Glyceria canadensis*	Grass	[1,2],3	OBL	0-1'	☐	☐	
GRASS,EASTERN MANNA	*Glyceria septentrionalis*	Grass	[1,2],3	OBL	0-1'	☐	☐	
GRASS,FOWL MANNA	*Glyceria striata*	Grass	[1,2],3	OBL	SEASONAL	☐	☐	
GRASS,PANIC	*Dichanthelium acuminatum*	Grass	[2,3],4	FAC	NO	☐	☐	
GRASS,PANIC	*Panicum longifolium*	Grass	[1,2],3	OBL	YES	☐	☐	
GRASS,ROUGH BARNYARD	*Echinochloa muricata*	Grass	[2,3],4	FACW+	YES	☐	☐	
GRASS,SALTMARSH ALKALI	*Puccinellia fasciculata*	Grass	[1,2],3	OBL	YES	☐	☐	
GRASS,SALTMEADOW	*Spartina caespitosa*	Grass	[1,2],3	OBL	YES	☐	☐	

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COMMON	SCIENTIFIC	FORM	ZONE	INDICATOR	TOLERANCE			HARDINESS
					INUNDATION	POLLUTION	SALT	
HORNWORT,COMMON	*Ceratophyllum demersum*	Perennial	[1,2],3	OBL	1-5'	☐	☐	
HORSETAIL,ROUGH	*Equisetum hyemale*	Grass	[2,3],4	FACW	YES	☐	☐	
INDIAN-TOBACCO	*Lobelia inflata*	Perennial	[4,5,6]	FACU	NO	☐	☐	
IRIS, BLUE WATER	*Iris versicolor*	Perennial	[1,2],3	OBL	0-6"	☐	☐	2-7
IRIS,BEACH-HEAD	*Iris hookeri*	Perennial	4,[5,6]	FACU-	NO	☐	☐	
IRIS,BEACH-HEAD	*Iris setosa*	Perennial	[3,4],5	FAC	NO	☐	☐	
IRIS,COPPER	*Iris fulva*	Perennial	[1,2],3	OBL	YES	☐	☐	
IRIS,LAMANCE	*Iris brevicaulis*	Perennial	[1,2],3	OBL	YES	☐	☐	
JACK-IN-THE-PULPIT,SWAMP	*Arisaema triphyllum*	Perennial	[2,3],4	FACW	SEASONAL	☐	☐	
JACOB'S LADDER	*Polemonium reptans*	Perennial	[4,5],6	FACU	NO	☐	☐	3-8
JACOB'S-LADDER,BOG	*Polemonium van-bruntiae*	Perennial	[3,4],5	FAC+	SATURATED	☐	☐	
LILY,CANADA	*Lilium canadense*	Perennial	2,[3,4]	FAC+	YES	☐	☐	
LILY,CAROLINA	*Lilium michauxii*	Perennial	[3,4,5]	FAC	NO	☐	☐	
LILY,GRAY'S	*Lilium grayi*	Perennial	3,[4,5],6	FACU	NO	☐	☐	
LILY,SOUTHERN RED	*Lilium catesbaei*	Perennial	[2,3,4]	FACW	YES	☐	☐	
LILY,TURK'S-CAP	*Lilium superbum*	Perennial	[2,3,4]	FACW+	YES	☐	☐	
LIZARDS TAIL	*Saururus cemuus*	Perennial	2,3,4	OBL	0-1'	☐	☐	2-8
LOBELIA,BOYKIN'S	*Lobelia boykinii*	Perennial	[1,2],3	OBL	YES	☐	☐	
LOBELIA,BROOK	*Lobelia kalmii*	Perennial	[1,2],3	OBL	YES	☐	☐	
LOBELIA,DOWNY	*Lobelia puberula*	Perennial	[2,3,4]	FACW-	SEASONAL	☐	☐	
LOBELIA,ELONGATED	*Lobelia elongata*	Perennial	[1,2],3	OBL	YES	☐	☐	
LOBELIA,GEORGIA	*Lobelia georgiana*	Perennial	[2,3,4]	FACW	YES	☐	☐	

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COMMON	SCIENTIFIC	FORM	ZONE	INDICATOR	TOLERANCE			HARDINESS
					INUNDATION	POLLUTION	SALT	
LOBELIA,GREAT BLUE	*Lobelia siphilitica*	Perennial	[2,3],4	FACW+	YES	☐	☐	
LOBELIA,NUTTALL'S	*Lobelia nuttallii*	Perennial	[2,3,4]	FACW	YES	☐	☐	
LOBELIA,PALE-SPIKE	*Lobelia spicata*	Perennial	[3,4,5]	FAC-	NO	☐	☐	
LOBELIA,SOUTHERN	*Lobelia amoena*	Perennial	[1,2],3	OBL	YES	☐	☐	
LOBELIA,WATER	*Lobelia dortmanna*	Perennial	[1,2],3	OBL	YES	☐	☐	
LOTUS,AMERICAN	*Nelumbo lutea*	Perennial	[1,2],3	OBL	1-5'	☐	☐	
LOTUS,SACRED	*Nelumbo nucifera*	Perennial	[1,2],3	OBL	1-5'	☐	☐	
LOVEGRASS,MEADOW	*Eragrostis refracta*	Grass	[2,3,]4	FACW	YES	☐	☐	
LOVEGRASS,PURPLE	*Eragrostis pectinacea*	Grass	[4,5],6	FAC	NO	☐	☐	
MALLOW,VIRGINIA SEASHORE	*Kosteletzkya virginica*	Perennial	[1,2],3	OBL	SALT, EDGE	☐	☑	
MARSH MARIGOLD	*Caltha palustris*	Perennial	3,4	OBL	6"SATURATE	☐	☐	3-8
MARSH SMARTWEED	*Polygonum hydropiperoides*	Perennial	2,3	OBL	0-1'	☐	☐	2-8
MARSH SMARTWEED	*Polygonum puntatum*	Perennial	2,3	OBL	SATURATE	☐	☐	2-8
MARSH-MALLOW,COMMON	*Althaea officinalis*	Perennial	[1,2,3]	FACW+	YES	☐	☐	
MEADOW-RUE,PIEDMONT	*Thalictrum macrostylum*	Perennial	[2,3,4]	FACW	YES	☐	☐	
MILKWORT,MARYLAND	*Polygala mariana*	Annual	[2,3,4]	FACW	YES	☐	☐	
MONKEY-FLOWER	*Mimulus ringens*	Perennial	[1,2],3	OBL	YES	☐	☐	3-8
MONKEY-FLOWER,COMMON LARGE	*Mimulus guttatus*	Annual	[1,2],3	OBL	YES	☐	☐	
MOUNTAIN-MINT,NARROW-LEAF	*Pycnanthemum flexuosum*	Perennial	[2,3,4]	FACW	YES	☐	☐	
MUHLY,MARSH	*Muhlenbergia glomerata*	Grass	[2,3],4	FACW	YES	☐	☐	
NIMBLE-WILL	*Muhlenbergia schreberi*	Grass	[3,4,5]	FAC	NO	☐	☐	
NUTRUSH	*Scleria flaccida*	Grass	[2,3],4	FACW	YES	☐	☐	

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COMMON	SCIENTIFIC	FORM	ZONE	INDICATOR	TOLERANCE			HARDINESS
					INUNDATION	POLLUTION	SALT	
PANSY,FIELD	*Viola bicolor*	Annual	[4,5,6]	FACU	NO	☐	☐	
PARTRIDGE-BERRY	*Mitchella repens*	Groundcover	[4,5],6	FACU	NO	☐	☐	
PENNSYLVANIA SMARTWEED	*Polygonum pensylvanicum*	Annual	[2,3]	FACW	0-6"	☐	☐	2-8
PENNY-WORT,MANY-FLOWER	*Hydrocotyle umbellata*	Perennial	[1,2],3	OBL	0-1'	☐	☐	
PHLOX,FALL	*Phlox paniculata*	Perennial	[4,5],6	FACU	NO	☐	☐	
PHLOX,MEADOW	*Phlox maculata*	Perennial	[2,3,4]	FACW	YES	☐	☐	
PHLOX,WOODLAND	*Phlox divaricata*	Perennial	[4,5,6]	FACU	NO	☐	☐	
PICKERELWEED	*Pontederia cordata*	Perennial	2,3	OBL	0-1'	☐	☐	2-8
PLANTAIN,SEASIDE	*Plantago maritima*	Perennial	1,2,3,4	FACW	YES	☐	☐	
PLUMEGRASS,SUGARCANE	*Erianthus giganteus*	Grass	[2,3]	FACW+	YES	☐	☐	
PONDWEED,CLASPING-LEAF	*Potamogeton perfoliatus*	Perennial	[1,2],3	OBL	1' MIN-6'	☐	☐	
PONDWEED,LONG-LEAF	*Potamogeton nodosus*	Perennial	[1,2]	OBL	1' MIN-6'	☐	☐	
PONDWEED,SAGO	*Potamogeton pectinatus*	Perennial	[1,2]	OBL	1' MIN-24'	☐	☐	
PRIMROSE,BIRDSEYE	*Primula laurentiana*	Perennial	[4],5	FAC	NO	☐	☐	
REED, MEADOWGRASS	*Glyceria maxima*	Grass	[1,2],3	OBL	YES	☐	☐	
REEDGRASS,BLUE-JOINT	*Calamagrostis canadensis*	Grass	[1,2],3	FACW+	6"SATURATE	☐	☐	
ROCKCRESS,ALPINE	*Arabis alpina*	Perennial	[3,4,5]	FAC+	SATURATE	☐	☐	
ROSE-GENTIAN,NARROW-LEAF	*Sabatia brachiata*	Annual	[4,5,6]	FACU	NO	☐	☐	
RUSH,ARCTIC	*Juncus arcticus*	Grass	[1,2],3	OBL	YES	☐	☐	
RUSH,GRASS-LEAF	*Juncus marginatus*	Grass	[2,3],4	FACW	YES	☐	☐	
RUSH,NARROW-PANICLE	*Juncus brevicaudatus*	Grass	[1,2],3	OBL	YES	☐	☐	
RUSH,NEEDLEGRASS	*Juncus roemeranus*	Grass	[1,2],3	OBL	SALT, EDGE	☐	☑	

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COMMON	SCIENTIFIC	FORM	ZONE	INDICATOR	TOLERANCE			HARDINESS
					INUNDATION	POLLUTION	SALT	
RUSH,SALTMEADOW	*Juncus gerardii*	Grass	[2,3],4	FACW+	YES	☐	☐	
RUSH,SLIM-POD	*Juncus diffusissimus*	Grass	[2,3],4	FACW	YES	☐	☐	
RUSH,SOFT	*Juncus effusus*	Grass	[2,3],4	FACW+	0-1'	☐	☐	4-8
RUSH,TURNFLOWER	*Juncus biflorus*	Grass	[2,3],4	FACW	YES	☐	☐	
RYEGRASS,PERENNIAL	*Lolium perenne*	Groundcover	[4,5,6]	FACU-	NO	☐	☐	
SALTGRASS,SEASHORE	*Distichlis spicata*	Grass	[2,3,]4	FACW+	SALT, EDGE	☐	☑	
SAWGRASS,SMOOTH	*Cladium mariscoides*	Grass	[1,2],3	OBL	YES	☐	☐	
SAXIFRAGE,SWAMP	*Saxifraga pensylvanica*	Perennial	[1,2],3	OBL	YES	☐	☐	
SAXIFRAGE,VIRGINIA	*Saxifraga virginiensis*	Perennial	[4,5]	FAC-	NO	☐	☐	
SEA-LAVENDER,CAROLINA	*Limonium carolinianum*	Perennial	[1,2],3	OBL	YES	☐	☐	
SEA-LAVENDER,NORTHERN	*Limonium nashii*	Perennial	[1,2],3	OBL	YES	☐	☐	
SEA-OATS	*Uniola paniculata*	Grass	[4,5,6]	FACU-	NO	☐	☐	
SEDGE,BEARDED	*Carex comosa*	Grass	[1,2],3	OBL	6"SATURATE	☐	☐	
SEDGE,BENT	*Carex styloflexa*	Grass	2,[3,4]	FACW-	YES	☐	☐	7-8
SEDGE,CAT-TAIL	*Carex typhina*	Grass	[2,3],4	FACW+	YES	☐	☐	5-8
SEDGE,CRESTED	*Carex cristatella*	Grass	[1,2],3,4	FACW	YES	☐	☐	
SEDGE,FESCUE	*Carex festucacea*	Grass	[3,4,5]	FAC	NO	☐	☐	4-6
SEDGE,FOX	*Carex vulpinoidea*	Grass	[1,2],3	OBL	SAT. 0-6"	☐	☐	
SEDGE,FRINGED	*Carex crinita*	Grass	[1,2],3	OBL	YES	☐	☐	
SEDGE,GRACEFUL	*Carex gracillima*	Grass	[4,5],6	FACU	NO	☐	☐	7
SEDGE,HOARY	*Carex canescens*	Grass	[1,2],3	OBL	YES	☐	☐	
SEDGE,INLAND	*Carex interior*	Grass	1,[2,3]	OBL	YES	☐	☐	5-8

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COMMON	SCIENTIFIC	FORM	ZONE	INDICATOR	TOLERANCE			HARDINESS
					INUNDATION	POLLUTION	SALT	
SEDGE,LAKEBANK	*Carex lacustris*	Grass	[1,2],3	OBL	SAT. 0-2'	☐	☐	
SEDGE,LOOSE-FLOWERED	*Carex laxiflora*	Grass	[4,5,6]	FACU	NO	☐	☐	5-8
SEDGE,RETRORSE	*Carex retrorsa*	Grass	[2,3],4	FACW+	SAT. 0-6"	☐	☐	
SEDGE,SHALLOW	*Carex lurida*	Grass	[1,2],3	OBL	YES	☐	☐	5-8
SEDGE,SWAN'S	*Carex swanii*	Grass	[4,5,6]	FACU	NO	☐	☐	5-8
SEDGE,UPTIGHT	*Carex stricta*	Grass	[1,2],3	OBL	SAT.0-6"	☐	☐	
SEDGE,WOOLY	*Carex lanuginosa*	Grass	[1,2],3	OBL	SAT.0-6"	☐	☐	
SEDGE,YELLOW-FRUIT	*Carex annectens*	Grass	[2,3,]4	FACW+	YES	☐	☐	
SEEDBOX	*Ludwigia x lacustris*	Annual	[1,2],3	OBL	YES	☐	☐	
SENNA,MARYLAND	*Cassia marilandica*	Groundcover	3,[4,5]	FAC+	SATURATED	☐	☐	
SKULLCAP	*Scutellaria churchilliana*	Perennial	[2,3],4	FACW	YES	☐	☐	
SOLOMON'S-SEAL,GREAT	*Polygonatum commutatum*	Perennial	[4,5,6]	FACU	NO	☐	☐	
SOLOMON'S-SEAL,SMALL	*Polygonatum biflorum*	Perennial	[4,5,6]	FACU	NO	☐	☐	
SPIKERUSH,BLUNT	*Eleocharis obtusa*	Grass	[1,2],3	OBL	0-6"	☐	☐	
SPIKERUSH,CREEPING	*Eleocharis palustris*	Grass	[1,2],3	OBL	SEASONAL	☐	☐	
SPIKERUSH,ENGELMANN'S	*Eleocharis engelmannii*	Grass	[2,3],4	FACW+	YES	☐	☐	
SPIKERUSH,SQUARE-STEM	*Eleocharis quadrangulata*	Grass	[1,2],3	OBL	0-1'	☐	☐	
SPRING BLUE EYE, MARY	*Collinsia verna*	Perennial	4,5,6	FAC-	NO	☐	☐	1-8
ST. JOHN'S-WORT,MARSH	*Triadenum fraseri*	Perennial	[1,2],3	OBL	YES	☐	☐	
STARWORT,MARSH	*Stellaria palustris*	Perennial	[5],6	FACU	NO	☐	☐	
STONECROP,ROCK	*Sedum pulchellum*	Perennial	[4,5,6]	FACU	NO	☐	☐	
STONECROP,ROSEROOT	*Sedum rosea*	Perennial	3,4,5,6	FACU	NO	☐	☐	

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COMMON	SCIENTIFIC	FORM	ZONE	INDICATOR	TOLERANCE			HARDINESS
					INUNDATION	POLLUTION	SALT	
SWAMP MILKWEED	*Asclepias incarnata*	Perennial	2,3	OBL	SATURATED	☐	☐	3-8
SWAMP ROSE MALLOW	*Hibiscus moscheutos*	Perennial	2,3	OBL	0-3"	☐	☐	4-8
SWAMP SMARTWEED	*Polygonum coccineum*	Perennial	2,3,4	OBL	0-3'	☐	☐	2-8
SWAMP-LOOSESTRIFE,HAIRY	*Decodon verticillatus*	Perennial	[1,2],3	OBL	YES	☐	☐	
SWITCHGRASS	*Panicum virgatum*	Grass	2,[3,4],5	FAC	SEASONAL	☐	☐	
TREFOIL, BIRD'S-FOOT	*Lotus corniculatus*	Perennial	4,5,6	FACU-	NO	☐	☐	2-8
TURTLEHEAD,RED	*Chelone obliqua*	Perennial	[1,2],3	OBL	YES	☐	☐	
TURTLEHEAD,WHITE	*Chelone glabra*	Perennial	[1,2],3	OBL	YES	☐	☐	
VALERIAN,EDIBLE	*Valeriana edulis*	Perennial	[1,2],3	OBL	YES	☐	☐	
VERVAIN,BLUE	*Verbena hastata*	Perennial	2,3,4	FACW+	YES	☐	☐	
VIOLET,APPALACHIAN BLUE	*Viola appalachiensis*	Perennial	[4,5],6	FACU	NO	☐	☐	
VIOLET,COASTAL	*Viola brittoniana*	Perennial	[3,4],5	FAC	NO	☐	☐	
VIOLET,COMMON BLUE	*Viola papilionacea*	Perennial	[3,4,5]	FAC	NO	☐	☐	
VIRGINIA WILD RYE	*Elymus virginicus*	Grass	2,[3,4]	FACW-	YES	☐	☐	
WATER SMARTWEED	*Polygonum amphibium*	Perennial	2,3	OBL	6"-Sat	☐	☐	2-8
WATER-CRESS,TRUE	*Nasturtium officinale*	Annual	[1,2],3	OBL	2"-1'	☐	☐	
WATER-LILY,PYGMY	*Nymphaea tetragona*	Perennial	[1,2],3	OBL	1-3'	☐	☐	
WATER-LILY,WHITE	*Nymphaea odorata*	Perennial	[1,2],3	OBL	1-3'	☐	☐	
WATER-LILY,WHITE	*Nymphaea tuberosa*	Perennial	[1,2],3	OBL	1-3'	☐	☐	
WATER-LILY,YELLOW/ SPATTERDOCK	*Nuphar advena/luteum*	Perennial	[1,2],3	OBL	1-3'	☐	☐	
WHORLED COREOPSIS	*Coreopsis verticillata*	Perennial	[2,3],4	FACW	YES	☐	☐	3-8
WIDGEON-GRASS	*Ruppia maritima*	Grass	[1,2],3	OBL	1' MIN	☐	☑	

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COMMON	SCIENTIFIC	FORM	ZONE	INDICATOR	TOLERANCE			HARDINESS
					INUNDATION	POLLUTION	SALT	
WILD-LILY-OF-THE-VALLEY	*Maianthemum canadense*	Perennial	[4,5],6	FAC-	NO	☐	☐	
WITCHGRASS,HELLER'S	*Dichanthelium oligosanthes*	Grass	[4,5,6]	FACU	NO	☐	☐	
WITCHGRASS,NEEDLE-LEAF	*Dichanthelium aciculare*	Grass	[4,5,6]	FACU	NO	☐	☐	
WOOD-REEDGRASS,SLENDER	*Cinna latifolia*	Grass	[2,3,4]	FACW	YES	☐	☐	
WOODRUSH,COMMON	*Luzula multiflora*	Grass	[4,5,6]	FACU	NO	☐	☐	
WOOL-GRASS	*Scirpus cyperinus*	Grass	[2,3],4	FACW+	SEASONAL	☐	☐	

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Section A.5 References

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Appendix B.1

NRCS-MD Code No. 378 Pond Standards/Specifications

USDA
NATURAL RESOURCES
CONSERVATION SERVICE
MARYLAND

CONSERVATION PRACTICE
STANDARD

POND

CODE 378
(Reported in No.)

DEFINITION

A water impoundment made by constructing a dam or an embankment or by excavating a pit or dugout.

In this standard, ponds constructed by the first method are referred to as embankment ponds, and those constructed by the second method are referred to as excavated ponds. Ponds constructed by both excavation and the embankment methods are classified as embankment ponds if the depth of water impounded against the embankment at the principal spillway storm design high water elevation is 3 feet or more (See Table 1).

This 3 feet shall be measured from the low point on the upstream toe of the embankment to the design high water.

PURPOSE

To provide water for livestock, fish and wildlife, recreation, fire control, crop and orchard spraying, and other related uses, and to maintain or improve water quality. This standard also applies to stormwater management ponds.

CONDITIONS WHERE PRACTICE APPLIES

General - This practice applies where it is determined that stormwater management, water supply, or temporary storage is justified and it is feasible and practicable to build a pond which will meet local and state law requirements.

This standard establishes the minimum acceptable quality for the design and construction of ponds if:

1. Failure of the dam will not result in loss of life; in damage to homes, commercial or industrial buildings, main highways, or railroads; or interruption of the use or service of public utilities.

2. The product of the storage times the effective height of the dam is less than 3,000. Storage is the volume, in acre-feet, in the reservoir below the elevation of the crest of the emergency spillway.

   The effective height of the dam is the difference in elevation, in feet, between the emergency spillway crest and the lowest point on a profile taken along the centerline of the dam, excluding the cutoff trench. If there is no emergency spillway, the top of the dam becomes the upper limit for determining the storage and the effective height.

3. For dams in rural areas, the effective height of the dam (as defined above) is 35 feet or less and the dam is hazard class "a". For dams in urban areas, the effective height of the dam is 20 feet or less and the dam is hazard class "a".

Ponds exceeding any of the above conditions shall be designed and constructed according to the requirements of Technical Release 60.

Exemptions - Soil Conservation District small pond approval is not required for small class "a" structures where the following exists:

1. Ponds or other structures have less than four (4) feet of embankment, or

2. The storage at emergency spillway design high water elevation according to Table 1 does not exceed 40,000 cubic feet, and the

Conservation practice standards are reviewed periodically, and updated if needed. To obtain the current version of this standard, contact the Natural Resources Conservation Service

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height of the embankment is 6 feet or less.

The height of the embankment shall be measured from the top of the dam to the lowest point of excavation, excluding the cutoff trench, along the centerline of the dam.

In addition, an embankment pond that meets the criteria below shall be considered an excavated pond and is also exempt from small pond approval.

1. The calculation of 10H+20=L, where H=height from the pond bottom to the top of the dam, is provided, and

2. The projection of L horizontally downstream from the pond bottom is below the existing or proposed ground, and

3. The existing or proposed downstream ground slope within the projection of L is less than 10% at any point.

The review and design of such class "a" structures shall be based on sound engineering judgment assuring a stable outfall for the ten (10) year, 24-hour storm event.

Site Conditions - Site Conditions shall be such that runoff from the design storm can be safely passed through (1) a natural or constructed emergency spillway, (2) a combination of a principal spillway and an emergency spillway, or (3) a principal spillway.

Drainage Area - The drainage area above the pond must be protected against erosion to the extent that expected sedimentation will not shorten the planned effective life of the structure.

For ponds whose primary purpose is to trap sediment for water quality, adequate storage should be provided to trap the projected sediment delivery from the drainage area for the life of the pond.

If the intent is to maintain a permanent pool, the drainage area should be at least 4 acres for each acre-foot of permanent storage. These recommendations may be reduced if a dependable source of ground water or diverted surface water contributes to the pond. The water quality shall be suitable for its intended use.

Soils Investigation - A soils investigation is required on all ponds. As a minimum it shall include information along the centerline of the proposed dam, in the emergency spillway location, and the planned borrow area. The type of equipment used and the extent of the investigation will vary from site to site. All investigations shall be logged using the Unified Soil Classification System.

Road Embankments - Where road embankments are being designed to impound a specific volume of water, either as a permanent pool or temporary stormwater storage, special design and evaluation criteria may be required as determined by Appendix B.

CONSIDERATIONS

Water Quantity - The following items should be considered for water quantity:

1. Effects upon components of the water budget, especially effects on volumes and rates of runoff, infiltration, evaporation, transpiration, deep percolation, and ground water recharge.

2. Variability of effects caused by seasonal or climatic changes.

3. Effects on the downstream flows or aquifers that could affect other water uses or users.

4. Potential for multiple use.

5. Effects on the volume of downstream flow to prohibit undesirable environmental, social or economic effects.

Water Quality - The following items should be considered for water quality:

1. Effects on erosion and the movement of sediment, pathogens, and soluble and sediment attached substances that are carried by runoff.

2. Effects on the visual quality of on-site and downstream water resources.

3. Short-term and construction-related effects of this practice on the quality of downstream water courses.

4. Effects of water level control on the temperatures of downstream waters to prevent undesired effects on aquatic and wildlife communities.

5. Effects on wetlands and water-related wildlife habitats.

6. Effects of water levels on soil nutrient processes such as plant nitrogen use or denitrification.

7. Effects of soil water level control on the soil chemistry, soil water, or downstream water.

8. Potential for earth moving to uncover or redistribute sulfidic bearing soils.

CRITERIA

Embankment Ponds

Structure Hazard Classification - Documentation of the classification of dams is required. Documentation is to include but is not limited to location and description of dam, configuration of the valley, description of existing development (houses, utilities, highways, railroads, farm or commercial buildings, and other pertinent improvements), potential for future development, and recommended classification. It is also to include results obtained from breach routings, if breach routings are used as part of the classification process. The class ("a", "b", and "c") as contained in this document is related to the potential hazard to life and property that might result from a sudden major breach of the earth embankment. Structure classification and land use for runoff determination must take into consideration the anticipated changes in land use throughout the expected life of the structure. The classification of a dam is the responsibility of the designer, and subject to review and concurrence of the approving authority.

The classification of a dam is determined only by the potential hazard from failure, not by the criteria. Classification factors in the National Engineering Manual, as supplemented, are given below:

Class "a" - Structures located in rural, agricultural or urban areas dedicated to remain in flood tolerant usage where failure may damage non-inhabited buildings, agricultural land, floodplains or county roads.

Class "b" - Structures located in rural, agricultural, or urban areas where failure may damage isolated homes, main highways or minor railroads or cause interruption of use or service of relatively important public utilities.

Class "c" - Structures located where failure may cause loss of life or serious damage to homes, industrial and commercial buildings, important public utilities, main highways, or railroads.

"Rural areas" is defined as those areas in which residents live on farms, in unincorporated settlements, or in incorporated villages or small towns. It is where agriculture, including woodland activities, and extractive industries, including seafood harvesting, provides the primary employment base for residents and where such enterprises are dependent on local residents for labor.

Non-rural areas shall be classified as urban.

Peak Breach Discharge Criteria - Breach routings are used to help delineate the area potentially impacted by inundation should a dam fail and can be used to aid dam classification. The breach hydrograph is the outflow hydrograph attributed to the sudden release of water in reservoir storage. This is due to a dam breach during non-storm conditions.

Stream routings made of the breach hydrograph are to be based upon topographic data and hydraulic methodologies mutually consistent in their accuracy and commensurate with the risk being evaluated.

The minimum peak discharge of the breach hydrograph, regardless of the techniques used to analyze the downstream inundation area, is as follows:

$Q_{max} = 3.2\ H_w^{2.5}$ where,

Q_{max} = the peak breach discharge, cfs.

H_w = depth of water at the dam at the time of failure, feet. This is measured to the crest of the emergency spill-

way or to design high water, if no emergency spillway exists. Use "nonstorm" conditions downstream of the dam.

Where breach analysis has indicated that only overtopping of downstream roads will occur, the following guidelines will be used:

Class	Depth of Flow (d) ft.
"a"	$d \leq 1.5$
"b" & "c"	$d > 1.5$

Use and importance of the roadway shall be considered when making a classification.

Hydrology - Principal and emergency spillways will be designed within the limitations shown on TABLE 1. The storm duration used shall be 24 hours except where TR-60 is specified. The pond shall be designed to safely pass the base flow along with volume and peak rates of runoff from design storms, specified in Table 1. All storm water management ponds shall be designed using urban criteria. This can be done by using principal and emergency spillways. The following shall be used to determine runoff rates and volumes:

1. NRCS "Engineering Field Handbook, Part 650" or;
2. NRCS, NEH, Section 4, Hydrology" or;
3. NRCS, TR-55, "Urban Hydrology for Small Watersheds" or;
4. NRCS, TR-20, "Computer Program for Project Formulation" or,
5. Computer programs using NRCS hydrology methods with identifiable inputs and outputs as approved by the reviewing agency.

Earth Embankment

Top Width - The minimum top width of the dam is shown in Table 2. When the embankment top is to be used as a public road, the minimum width is to be 16 feet for one-way and 26 feet for two-way traffic. If the embankment is to be used for infrequent vehicle crossings, the minimum top width shall be 10 feet. Guardrails or other safety measures are to be used where necessary and are to meet the requirements of the responsible road authority.

Side Slopes - The combined upstream and downstream side slopes of the settled embankment shall not be less than five horizontal to one vertical (5:1) with neither slope steeper than 2:1. If the dam is used as a road crossing with a top width greater than 26 feet, then the combined side slopes of the settled embankment shall not be less than 4 horizontal to one vertical (4:1) with neither slope steeper than 2:1. Slopes must be designed to be stable in all cases, even if flatter side slopes are required.

Earth Cuts - If cuts in an existing fill or in natural ground are required for the rehabilitation of an existing pond spillway or the construction of a new pond, the slope of the bonding surfaces between the existing material in place and the fill to be placed shall not be steeper than a ratio of two horizontal to one vertical (2:1).

Foundation Cutoff - A cutoff trench of relatively impervious material shall be provided under the entire length of the dam and shall be located at or upstream from the centerline of the dam. The cutoff trench shall have a bottom width adequate to accommodate the equipment used for excavation, backfill and compaction operations, with the minimum width being 4 feet, and shall have side slopes no steeper than one horizontal to one vertical. Minimum depth shall be 4 feet.

Impervious Core - Any impervious core within the embankment shall be located at or upstream from the centerline of the dam, and shall extend up the abutments to the 10-year water surface elevation. The impervious core shall extend vertically from the cutoff trench up to the 10-year water surface elevation throughout the embankment.

Seepage Control - Seepage control is to be included: (1) if pervious layers are not intercepted by the cutoff; (2) if seepage from the abutments may create a wet embankment; (3) if the phreatic line intersects the downstream slope; or (4) if special conditions require drainage to insure a stable dam. The phreatic line shall be drawn on a 4:1 slope starting on the inside slope at the

normal pool elevation. For stormwater management ponds, normal pool shall be considered as the 10-year water surface elevation.

Seepage may be controlled by (1) foundation abutment or embankment drains; (2) reservoir blanketing; or (3) a combination of these measures. Foundation drains may control seepage encountered in the cutoff trench during construction. These drains must be located downstream of the dam centerline and outside the limits of the proposed cutoff trench. All drains must be designed according to the section Principal Spillway, *Conduit Piping and Seepage Control*.

Wave Erosion Protection - Where needed to protect the face of the dam, special wave protection measures such as a bench, rock riprap, sand-gravel, soil cement or special vegetation shall be provided. (Reference NRCS Technical Releases 56 & 69)

Freeboard - The top elevation of the settled embankment shall be determined in accordance with minimum criteria established in Table 1

Allowance for Settlement - The design height of the dam shall be increased by the amount needed to insure that the design top of fill elevation will be maintained after all settlement has taken place. This increase shall not be less than 5 percent, except where detailed soil testing and lab analyses indicate a lesser amount is adequate.

Principal Spillway

Capacity - A conduit, with needed appurtenances, shall be placed under or through the dam, except where a weir type structure is used. The minimum capacity of the principal spillway shall be that required in Table 1.

Crest Elevation of Inlet - The crest elevation of the principal spillway shall be no less than 1.0 foot below the crest of the emergency spillway. The crest elevation is the invert elevation of the lowest opening 6 inches or larger in any direction.

The inlet or riser size for the pipe drops shall be such that the flow through the structure goes from weir-flow control to pipe-flow control without going into orifice-flow control in the riser. The inlets and outlets shall be designed and analyzed to function satisfactorily for the full range of flow and hydraulic head anticipated.

The riser shall be analyzed for flotation assuming all orifices and pipes are plugged. The factor of safety against flotation shall be 1.2 or greater.

Pipe Conduits - Pipe conduits under or through the dam shall meet the following requirements:

1. All pipes shall be circular in cross section except for cast-in-place reinforced concrete box culverts.

2. Pipe shall be capable of withstanding the external loading without yielding, buckling, or cracking.

3. Pipe strength shall be not less than those shown on Tables 3, 4 and 5 for corrugated steel, aluminum, and plastic pipes and applicable ASTM's for other materials.

4. Where inlet or outlet flared sections are used, they shall be made from materials compatible with the pipe.

5. All pipe joints shall be made watertight by the use of flanges with gaskets, coupling bands with gaskets, bell and spigot ends with gaskets, or by welding. See Construction Specifications for details.

6. The joints between sections of pipe shall be designed to remain watertight after joint rotation and elongation caused by foundation consolidation.

The capacity of the pipe conduit shall be adequate to discharge long duration, continuous or frequent flows without flow through the emergency spillway. The diameter of the pipe shall be not less than 6 inches.

For dams 20 feet or less in effective height, the following pipe materials are acceptable: cast-iron, ductile iron, steel, corrugated steel or aluminum, concrete with rubber gaskets, plastic, and cast-in-place reinforced concrete box culverts. Plastic pipe that will be exposed to direct sunlight should be made of ultraviolet resistant materials and protected by coating or shielding. Connections of pipe to less flexible pipe or struc-

tures must be designed to avoid stress concentrations that could rupture the pipe.

For dams over 20 feet in effective height, conduits are to be reinforced concrete pipe, cast-in-place reinforced concrete box culverts, corrugated steel, ductile iron, welded steel or aluminum pipe. The maximum height of fill over any principal spillway steel, aluminum, or plastic pipe must not exceed 25 feet.

Concrete pipe shall have a concrete cradle extending up the sides of the pipe at least 50% of its outside diameter with minimum thickness of 6 inches. Where a concrete cradle is not needed for structural reasons, flowable fill may be used as described in the CONSTRUCTION SPECIFICATIONS section of this standard. Gravel bedding is not permitted. Cantilever outlet sections, if used, shall be designed to withstand the cantilever load. Pipe supports shall be provided when needed. Other suitable devices such as plunge basin, stilling basin, impact basin, or rock riprap spreader should be used to provide a safe outlet. Cathodic protection is to be provided for welded steel and corrugated steel pipe where the need and importance of the structure warrant. Cathodic protection should normally be provided for corrugated steel pipe where the saturated soil resistivity is less than 4,000 ohms-cm or the pH is lower than 5. The National Handbook of Conservation Practices, Irrigation Water Conveyance, Steel Pipeline Standard (430-FF), provides criteria for cathodic protection of welded steel pipes.

Multiple Conduits - Where multiple conduits are used, there shall be sufficient space between the conduits and the installed anti-seep collars to allow for backfill material to be placed between the conduits by the earth moving equipment and for easy access by hand operated compaction equipment. This distance between conduits shall be equal to or greater than half the pipe diameter but not less than 2 feet.

Conduit Piping and Seepage Control - Seepage along pipe conduit spillways extending through the embankment shall be controlled by use of (1) anti-seep collars, or (2) filter and drainage diaphragm. Seepage control will not be required on pipes 6 inches in diameter or less.

Anti-seep collars shall be installed around all conduits through earth fills according to the following criteria:

1. Sufficient collars shall be placed to increase the seepage length along the conduit by a minimum of 15 percent of the pipe length located within the saturation zone.

2. The assumed normal saturation zone shall be determined by projecting a line at a slope (4) horizontal to (1) vertical from the point where the normal water elevation meets the upstream slope to a point where this line intersects the invert of the pipe conduit or bottom of the cradle, whichever is lower. For Stormwater Management ponds, the phreatic line starting elevation shall be the 10-year water elevation.

3. Maximum collar spacing shall be 14 times the required projection above the pipe. The minimum collar spacing shall be 5 times the required minimum projection.

4. Anti-seep collars should be placed within the saturated zone. In cases where the spacing limit will not allow this, at least one collar will be in the saturated zone.

5. All anti-seep collars and their connections to the conduit shall be watertight and made of material compatible with the conduit.

6. Collar dimensions shall extend a minimum of 2 feet in all directions around the pipe.

7. Anti-seep collars shall be placed a minimum of two feet from pipe joints except where flanged joints are used.

8. For pipes with concrete cradles, the projection shall be measured from the cradle.

Filter and drainage diaphragms are always recommended, but are required when the following conditions are encountered:

1. The pond requires design according to TR-60.

2. Embankment soils with high piping potential such as Unified Classes GM, SM, and ML.

Filter and drainage diaphragms shall be designed in accordance with procedures from NRCS TR-60, Earth Dams and Reservoirs, Section 6, Principal Spillways, as described below.

The drainage diaphragm shall usually consist of sand, meeting the fine concrete aggregate requirements (ASTM C-33). A design analysis shall be made using Part 633 of the National Engineering Manual, Chapter 26, Gradation Design of Sand and Gravel Filters.

The drainage diaphragm shall be a minimum of 3 ft thick and extend vertically upward and horizontally at least three times the conduit outside diameter or the width of the cradle, whichever is greater except that:

1. The vertical extension need be no higher than the maximum potential reservoir water level, and

2. The horizontal extension need be no further than 5 feet beyond the sides and slopes of any excavation made to install the conduit.

3. The minimum soil cover over any portion of the filter-drainage diaphragm measured normal to the nearest embankment surface shall be at least 2 feet.

It shall extend vertically downward at least 2 ft beneath the conduit outside diameter or bottom of the cradle, whichever is greater. The drainage diaphragm shall be located immediately downstream of the cutoff trench, approximately parallel to the centerline of the dam but no further upstream than the centerline of the dam.

The drainage diaphragm shall outlet at the embankment downstream toe, preferably using a drain backfill envelope continuously along the pipe to where it exits the embankment. Protecting drain fill from surface erosion will be necessary.

It is required that the outlet for the filter diaphragm is sized to safely discharge the design flow. Where a drain backfill envelope is used as the outlet, it is recommended that it be designed so the hydraulic head does not exceed the depth of the drain outlet. The exposed area of the drain outlet must also be protected from external attack such as surface erosion and slope instability due to horizontal seepage pressures. A weighted toe cover such as riprap can be effective if protected with a properly designed filter between the sand drain material and the riprap cover.

If pipe drain outlets are used, consideration must be given to the structural design of the conduit in resisting external loading and the design life of the pipe must be consistent with the design life of the dam and physical conditions of the site. Also, the pipe must be designed for capacity and size of perforations as outlined in NEH Part 633, Chapter 26 and Soil Mechanics Note 3. If the pipe corrodes, is crushed by exterior loading, or is otherwise damaged, the outlet of the filter diaphragm is lost and a piping failure may occur.

The design quantity (Q) used to size the outlet can be calculated by Darcy's Law, $Q = kiA$ where:

k = permeability of the embankment or drain outlet material (ft/day)

i = hydraulic gradient where $i = h/l$

h = head differential (ft)

l = seepage path (ft)

A = area of flow (diaphragm or outlet) (ft^2)

Anti-vortex Devices - Drop inlet spillways are to have adequate anti-vortex devices. Splitter type anti-vortex devices shall be placed in line with the barrel. An anti-vortex device is not required if weir control is maintained in the riser through all flow stages.

Trash Racks - All pipe and inlet structures shall have a trash rack. Openings for trash racks shall be no larger than 1/2 of the barrel conduit diameter, but in no case less than 6 inches.

Flush grates for trash racks are not acceptable. Inlet structures that have flow over the top shall have a non-clogging trash rack such as a hood-type inlet extending a minimum of 8 inches below the weir openings, which allows passage of water from underneath the trash rack into the riser.

For inlet structures with solid covered tops, the bottom of the cover slab must be set at an eleva-

tion to prevent orifice flow control before pipe flow control governs.

Low stage releases, where the opening is larger than 6 inches, shall have a non-clogging trash rack with openings no larger than half the low flow dimension.

For all low stage releases 6 inches or smaller in any direction, the emergency spillway design storm shall be routed assuming the release has failed, using storage and discharge only above the elevation of the next opening larger than 6 inches in all directions. This design storm routing shall not overtop the dam.

Drain Pipe - A pipe with a suitable valve shall be provided to drain the pool area, where needed for proper pond management. The principal spillway conduit may serve as a pond drain, when so located, to accomplish this function.

Water Supply Pipes or Utilities - All pipes through the dam shall have an inside diameter of not less than 1 1/4 inches. Pipes / utilities not parallel to the axis of the dam shall meet all principal spillway requirements (i.e. filter diaphragm, embankment soils, etc.). Pipes / utilities parallel to the axis of the dam shall be constructed with no granular bedding.

Earth Emergency Spillways

Emergency spillways are provided to convey large flood flows safely past earth embankments. An emergency spillway must be provided for each dam, unless the principal spillway is large enough to pass the routed design hydrograph peak discharge and any trash without overtopping the dam. The only design that may be utilized without an emergency spillway is: a principal spillway with a cross-sectional area of 3 square feet or more and an inlet that will not clog, such as a hood-type inlet which allows passage of water from underneath the trash rack into the riser.

Capacity - The minimum capacity of emergency spillways shall be that required to pass the peak flow expected from a design storm of the frequency and duration shown in Table 1 less any reduction creditable to conduit discharge and detention storage.

The emergency spillway shall (1) safely pass the storm design peak or (2) the storm runoff shall be routed through the reservoir. The routing shall start with the water surface at the elevation of the crest of the principal spillway, or at the water surface after 10 days drawdown, whichever is higher. The 10-day drawdown shall be computed from the crest of the emergency spillway or from the elevation that would be attained had the entire design storm been impounded, whichever is lower. Emergency spillways are to provide for passage of the design flow at a non-erosive velocity to a point downstream where the dam will not be endangered.

Component Parts - Earth spillways are open channels and usually consist of an inlet channel, level section, and an exit channel. The minimum difference in elevation between the crest of the emergency spillway and the settled top of dam shall be 2.0 feet.

Cross-Section - Earth spillways shall be trapezoidal and shall be located in undisturbed earth. The side slopes shall be stable for the material in which the spillway is to be constructed, but not steeper than 2:1. The emergency spillway shall have a bottom width of not less than 8 feet.

The inlet channel may be curved to fit existing topography; however, it should be flared to allow unrestricted flow to the level section. The level section should be located as near the centerline of dam as possible. The level section shall be 25 feet in length, and shall be rectangular or square.

Exit channel centerline shall be perpendicular to the level section downstream edge and must be straight for a distance beyond the downstream toe, so that discharges will not reach the earth embankment. The grade of the exit channel shall fall within the range established by discharge requirement and permissible velocities.

The crest of any "token" spillway will be located at or above the 100-year storm elevation in undisturbed earth and have a minimum depth of one foot and bottom width of 8 feet.

Permissible Velocities - Earth spillways shall be designed for non-erosive velocities through the control section and to a point downstream where the dam will not be endangered. The maximum permissible velocity for the grass and grass mix-

ture to be used shall be selected from Table 6. Velocities exceeding these values will require use of linings other than vegetation.

Infiltration / Water Quality Basins – Ponds, either excavated or embankment, that are designed solely for infiltration or as water quality basins will have an emergency spillway. The capacity of the spillway will be determined by the following procedure:

Pass the routed 100-Year Storm with 1 foot of freeboard to the top of dam elevation. Routing will begin at the emergency spillway crest.

Structural Emergency Spillways

Chutes or drops, when used for principal spillways or principal-emergency or emergency spillways, shall be designed in accordance with the principals set forth in the National Engineering Handbook, Section 5 "Hydraulics"; Section 11 "Drop Spillways"; and Section 14 "Chute Spillways". The minimum capacity of a structural spillway shall be that required to pass the peak flow expected from a design storm of the frequency and duration shown in Table 1 less any reduction creditable to conduit discharge and detention storage.

Visual Resource Design

The visual design of ponds shall be carefully considered in areas of high public visibility and those associated with recreation. The underlying criterion for all visual design is appropriateness. The shape and form of ponds, excavated material, and plantings are to relate visually to their surroundings and to their functions.

The embankment may be shaped to blend with the natural topography. The edge of the pond should be shaped so that it is generally curvilinear rather than rectangular. Excavated material shall be shaped so that the final form is smooth, flowing, and fitting to the adjacent landscape rather than angular geometric mounds. If feasible, islands may be added for visual interest and to attract wildlife.

Trees and Shrubs

Non-Roadway Embankments - Trees and/or shrubs will not be allowed on any embankment, will not be allowed within the buffer zone (15 feet from the toe of the dam), and will not be allowed within a 25-foot radius around the inlet structure.

Roadway Embankments - Trees and/or shrubs will not be allowed on any embankment, except for dry stormwater management structures that will be utilized as a roadway under all the following conditions:

1. Plantings may only be on top of the dam along the roadway and/or sidewalks.
2. The top of the dam shall have a minimum of 50-foot top width.
3. Plantings will not be allowed on the side slopes of the embankment.
4. Plantings will not be allowed within the buffer zone (15 feet from the toe of the dam).
5. Plantings will only be shallow rooted (roots less than 3' deep) trees or shrubs.
6. The pond is a "dry" structure (normal pool not exceeding 18 inches).
7. A landscape plan showing type and location of planting must be prepared by a Landscape Architect certifying shallow rooted plants (roots less than 3' deep) under mature conditions.
8. A minimum of 3 feet freeboard above the 100-year water surface elevation must be maintained.
9. The structure is a low hazard (Class "a") pond.

Safety

Special considerations should be made for safety and access during the design of a pond. Measures to be considered may include fencing, slope benching, access roads, flattened side slopes, etc. When fencing a structure, the fence will be located so it will not interfere with the operation of the emergency spillway.

Excavated Ponds

General - Excavated ponds that create a failure potential through a constructed or created embankment will be designed as embankment ponds. Excavated ponds that include a pipe or weir outlet control system for urban stormwater management shall be designed using the principal and emergency spillway hydrologic criteria for Embankment Ponds, Table 1.

Side Slopes - Side slopes of excavated ponds shall be such that they will be stable and shall not be steeper than 1 horizontal to 1 vertical. Flatter slopes are to be utilized where safety for children, livestock watering, etc. is a design factor.

Perimeter Form - Where the structures are used for recreation or are located in high public view, the perimeter or edge should be shaped to a curvilinear form.

Inlet Protection - When the excavated pond is a bypass type and water is being diverted from a stream, the minimum size inlet line shall be a 4-inch diameter pipe. All state laws concerning water use and downstream rights shall be strictly adhered to.

Where surface water enters the pond in a natural or excavated channel, the side slope of the pond shall be protected against erosion.

Outlet Protection – An excavated pond with a low embankment (combination excavation / embankment pond) shall be designed to ensure a stable outfall for the 10-year, 24-hour frequency storm.

Placement of Excavated Material - The material excavated from the pond shall be placed in one of the following ways so that its weight will not endanger the stability of the pond side slopes and where it will not be washed back into the pond by rainfall:

1. Uniformly spread to a height not exceeding 3 feet with the top graded to a continuous slope away from the pond;

2. Uniformly placed or shaped reasonably well with side slopes no steeper than 2 to 1. The excavated material will be placed at a distance equal to the depth of the pond, but not less than 12 feet from the edge of the pond;

3. Shaped to a designed form that blends visually with the landscape;

4. Used for low embankment and leveling; or

5. Hauled away.

Reservoir Area for Wet Ponds

For most ponds, the topography of the site shall permit storage of water at a depth and volume that ensures a dependable supply, considering beneficial use, sedimentation, season of use, and evaporation and seepage losses. Soils in the reservoir shall be impervious enough to minimize seepage losses or shall be of a type that sealing is practical.

Excavation and shaping required to permit the reservoir area to suitably serve the planned purpose shall be included in the construction plans.

Reservoirs designed specifically for fish production or wildlife management shall follow design criteria in the standards and specifications for Fish Pond Management (MD-399) and Wildlife Wetland Habitat Management (MD-644), as appropriate.

TABLE 1

HYDROLOGIC CRITERIA FOR PONDS

Structure Class	Storage Height Product[1]	Watershed Area (Acres)	Height To Emergency Spwy Crest (Feet)	Normal Surface Area (Acres)	Spillway Capacity[5]				Freeboard[6] Rural & Urban
					Principal[2]		Emergency[3, 4]		
					Rural	Urban	Rural	Urban	
"c" & "b"	Any	Any	Any	Any	TR 60	TR 60	TR 60	TR 60	TR 60
"a"	3,000 or more	Any	Any	Any	TR 60	TR 60	TR 60	TR 60	TR 60
"a"	Less than 3,000	320 and Larger	>20 - 35	≥12	25 YR	TR 60	100 YR	100 YR	2.0' above E.S. Design Storm
			≤20	≥12	10 YR	25 YR	100 YR	100 YR	
			<15	<12	5 YR	10 YR	50 YR	100 YR	
		100 to 320	>20 - 35	≥12	10 YR	TR 60	100 YR	100 YR	2.0' above E.S. Design Storm
			≤20	≥12	5 YR	10 YR	50 YR	100 YR	1.0' above E.S. Design Storm
			<15	<12	2 YR	5 YR	25 YR	100 YR	1.0' above E.S. Design Storm
		Less Than 100	>20 - 35	≥12	5 YR	TR 60	50 YR	100 YR	1.0' above E.S. Design Storm
			≤20	≥12	2 YR	5 YR	25 YR	100 YR	
			<15	<12	10% of 25 YR Peak	5 YR	25 YR	100 YR	

NOTES

1) The storage is defined as the original capacity of the reservoir in acre-feet at the elevation of the crest of the emergency spillway. The effective height is the difference in elevation in feet between the emergency spillway crest and the lowest point on a profile taken along the centerline of the dam, excluding the cutoff trench. If there is no emergency spillway, this height shall be to the top of the dam.

2) Principal - minimum storm to be contained below the crest of the emergency spillway including any combination of temporary storage and principal spillway discharge.

3) Emergency - minimum storm used to proportion the emergency spillway to meet the limitations for shape, size, velocity and exit channel. This storm can be handled by any combination of principal spillway discharge, emergency spillway discharge and storage.

4) For ponds without a separate emergency spillway, the principal spillway functions as the emergency spillway. In this situation, the principal spillway must comply with the emergency spillway hydrologic criteria.

5) All ponds, which are being designed to meet local stormwater requirements, will be required to use the urban criteria. Storm duration used shall be 24 hours except where TR-60 is specified.

6) For ponds without a functioning open channel emergency spillway, minimum freeboard will be 2 feet.

TABLE 2

Total Height Of Embankment (Feet)	Minimum Top Width (Feet)
10 or less	6
11 - 14	8
15 - 19	10
20 - 24	12
25 - 34	14
35 or more	15

TABLE 3[1,2]

MINIMUM GAGES

CORRUGATED STEEL PIPE
2 - 2/3 inches x 1/2 inch Corrugations

Fill Height Over Pipe (Feet)	Pipe Diameter in Inches				
	24 & Less	30	36	42	48
1 - 15	16	16	14	10	10
15 - 20	16	12	10	*	*
20 - 25	16	10	*	*	*

CORRUGATED STEEL PIPE
3 inches x 1 inch or 5 inch x 1 inch Corrugations

Fill Height Over Pipe (Feet)	Pipe Diameter (Inches)						
				Flowable Fill			
	36	42	48	54[3]	60[3]	66[3]	72[3]
1 - 15	16	16	16	14	14	14	14
15 - 20	16	16	12	14	14	14	14
20 - 25	14	14	10	14	14	14	14

* Not Permitted.

TABLE 4[1,2]

MINIMUM GAGES

CORRUGATED ALUMINUM PIPE
2 - 2/3 inches x 1/2 inch Corrugations

Fill Height Over Pipe (Feet)	Pipe Diameter in Inches		
	21 & Less	24	30
1 - 15	16	14	10
15 - 20	12	10	*
20 - 25	10	*	*

CORRUGATED ALUMINUM PIPE
3 inches x 1 inch Corrugations

Fill Height Over Pipe (Feet)	Pipe Diameter in Inches				
	30	36	42	48	54[3]
1 - 15	16	16	14	10	14
15 - 20	16	12	*	*	*
20 - 25	12	*	*	*	*

* Not Permitted.

[1] Coatings for corrugated metal shall be as specified by the MD-378 Construction Specifications.
[2] Tables 3 and 4 were developed using the modified Spangler equation. Sizes other than those shown above are not permitted.
[3] Must use flowable backfill as specified by the MD-378 Construction Specifications and the pipe must be bituminous coated.

TABLE 5

ACCEPTABLE PLASTIC PIPE FOR USE IN EARTH DAM[1, 2]

Nominal Pipe Size (inches)	Schedule or Standard Dimension Ratio (SDR)	Maximum Depth of Fill Over [3]
6 - 24	PVC Schedule 40	10
6 - 24	PVC Schedule 80	15
6 – 24	PVC SDR 26	10
6 - 24	Corrugated HDPE	10

[1] See Specifications, Plastic Pipe

[2] All designs based on Technical Release 77, Reference 20. Other diameters and / or fill heights may be used that meet all the requirements of TR-77.

[3] larger fill heights may be permitted when using flowable fill.

TABLE 6

Permissible Velocities (Ft/Sec)
For Emergency Spillways Lined with Vegetation

	Slope Of Exit Channel	
Type of Cover	0 - 5%	5 - 10%
Bermudagrass	6	5
Reed Canarygrass	5	4
Tall Fescue	5	4
Kentucky Bluegrass	5	4
Grass-legume mixture	4	3

CONSTRUCTION SPECIFICATIONS

These specifications are appropriate to all ponds within the scope of the Standard for practice MD-378. All references to ASTM and AASHTO specifications apply to the most recent version.

Site Preparation

Areas designated for borrow areas, embankment, and structural works shall be cleared, grubbed and stripped of topsoil. All trees, vegetation, roots and other objectionable material shall be removed. Channel banks and sharp breaks shall be sloped to no steeper than 1:1. All trees shall be cleared and grubbed within 15 feet of the toe of the embankment.

Areas to be covered by the reservoir will be cleared of all trees, brush, logs, fences, rubbish and other objectionable material unless otherwise designated on the plans. Trees, brush, and stumps shall be cut approximately level with the ground surface. For dry stormwater management ponds, a minimum of a 25-foot radius around the inlet structure shall be cleared.

All cleared and grubbed material shall be disposed of outside and below the limits of the dam and reservoir as directed by the owner or his representative. When specified, a sufficient quantity of topsoil will be stockpiled in a suitable location for use on the embankment and other designated areas.

Earth Fill

Material - The fill material shall be taken from approved designated borrow areas. It shall be free of roots, stumps, wood, rubbish, stones greater than 6", frozen or other objectionable materials. Fill material for the center of the embankment, and cut off trench shall conform to Unified Soil Classification GC, SC, CH, or CL and must have at least 30% passing the #200 sieve. Consideration may be given to the use of other materials in the embankment if designed by a geotechnical engineer. Such special designs must have construction supervised by a geotechnical engineer.

Materials used in the outer shell of the embankment must have the capability to support vegetation of the quality required to prevent erosion of the embankment.

Placement - Areas on which fill is to be placed shall be scarified prior to placement of fill. Fill materials shall be placed in maximum 8 inch thick (before compaction) layers which are to be continuous over the entire length of the fill. The most permeable borrow material shall be placed in the downstream portions of the embankment. The principal spillway must be installed concurrently with fill placement and not excavated into the embankment.

Compaction - The movement of the hauling and spreading equipment over the fill shall be controlled so that the entire surface of each lift shall be traversed by not less than one tread track of heavy equipment or compaction shall be achieved by a minimum of four complete passes of a sheepsfoot, rubber tired or vibratory roller. Fill material shall contain sufficient moisture such that the required degree of compaction will be obtained with the equipment used. The fill material shall contain sufficient moisture so that if formed into a ball it will not crumble, yet not be so wet that water can be squeezed out.

When required by the reviewing agency the minimum required density shall not be less than 95% of maximum dry density with a moisture content within ±2% of the optimum. Each layer of fill shall be compacted as necessary to obtain that density, and is to be certified by the Engineer at the time of construction. All compaction is to be determined by AASHTO Method T-99 (Standard Proctor).

Cut Off Trench - The cutoff trench shall be excavated into impervious material along or parallel to the centerline of the embankment as shown on the plans. The bottom width of the trench shall be governed by the equipment used for excavation, with the minimum width being four feet. The depth shall be at least four feet below existing grade or as shown on the plans. The side slopes of the trench shall be 1 to 1 or flatter. The backfill shall be compacted with construction equipment, roll-

ers, or hand tampers to assure maximum density and minimum permeability.

Embankment Core - The core shall be parallel to the centerline of the embankment as shown on the plans. The top width of the core shall be a minimum of four feet. The height shall extend up to at least the 10 year water elevation or as shown on the plans. The side slopes shall be 1 to 1 or flatter. The core shall be compacted with construction equipment, rollers, or hand tampers to assure maximum density and minimum permeability. In addition, the core shall be placed concurrently with the outer shell of the embankment.

Structure Backfill

Backfill adjacent to pipes or structures shall be of the type and quality conforming to that specified for the adjoining fill material. The fill shall be placed in horizontal layers not to exceed four inches in thickness and compacted by hand tampers or other manually directed compaction equipment. The material needs to fill completely all spaces under and adjacent to the pipe. At no time during the backfilling operation shall driven equipment be allowed to operate closer than four feet, measured horizontally, to any part of a structure. Under no circumstances shall equipment be driven over any part of a concrete structure or pipe, unless there is a compacted fill of 24" or greater over the structure or pipe.

Structure backfill may be flowable fill meeting the requirements of Maryland Department of Transportation, State Highway Administration Standard Specifications for Construction and Materials, Section 313 as modified. The mixture shall have a 100-200 psi; 28 day unconfined compressive strength. The flowable fill shall have a minimum pH of 4.0 and a minimum resistivity of 2,000 ohm-cm. Material shall be placed such that a minimum of 6" (measured perpendicular to the outside of the pipe) of flowable fill shall be under (bedding), over and, on the sides of the pipe. It only needs to extend up to the spring line for rigid conduits. Average slump of the fill shall be 7" to assure flowability of the material. Adequate measures shall be taken (sand bags, etc.) to prevent floating the pipe. When using flowable fill, all metal pipe shall be bituminous coated. Any adjoining soil fill shall be placed in horizontal layers not to exceed four inches in thickness and compacted by hand tampers or other manually directed compaction equipment. The material shall completely fill all voids adjacent to the flowable fill zone. At no time during the backfilling operation shall driven equipment be allowed to operate closer than four feet, measured horizontally, to any part of a structure. Under no circumstances shall equipment be driven over any part of a structure or pipe unless there is a compacted fill of 24" or greater over the structure or pipe. Backfill material outside the structural backfill (flowable fill) zone shall be of the type and quality conforming to that specified for the core of the embankment or other embankment materials.

Pipe Conduits

All pipes shall be circular in cross section.

Corrugated Metal Pipe - All of the following criteria shall apply for corrugated metal pipe:

1. Materials - (Polymer Coated steel pipe) - Steel pipes with polymeric coatings shall have a minimum coating thickness of 0.01 inch (10 mil) on both sides of the pipe. This pipe and its appurtenances shall conform to the requirements of AASHTO Specifications M-245 & M-246 with watertight coupling bands or flanges.

   Materials - (Aluminum Coated Steel Pipe) - This pipe and its appurtenances shall conform to the requirements of AASHTO Specification M-274 with watertight coupling bands or flanges. Aluminum Coated Steel Pipe, when used with flowable fill or when soil and/or water conditions warrant the need for increased durability, shall be fully bituminous coated per requirements of AASHTO Specification M-190 Type A. Any aluminum coating damaged or otherwise removed shall be replaced with cold applied bituminous coating compound. Aluminum surfaces that are to be in contact with concrete shall be painted

with one coat of zinc chromate primer or two coats of asphalt.

Materials - (Aluminum Pipe) - This pipe and its appurtenances shall conform to the requirements of AASHTO Specification M-196 or M-211 with watertight coupling bands or flanges. Aluminum Pipe, when used with flowable fill or when soil and/or water conditions warrant for increased durability, shall be fully bituminous coated per requirements of AASHTO Specification M-190 Type A. Aluminum surfaces that are to be in contact with concrete shall be painted with one coat of zinc chromate primer or two coats of asphalt. Hot dip galvanized bolts may be used for connections. The pH of the surrounding soils shall be between 4 and 9.

2. Coupling bands, anti-seep collars, end sections, etc., must be composed of the same material and coatings as the pipe. Metals must be insulated from dissimilar materials with use of rubber or plastic insulating materials at least 24 mils in thickness.

3. Connections - All connections with pipes must be completely watertight. The drain pipe or barrel connection to the riser shall be welded all around when the pipe and riser are metal. Anti-seep collars shall be connected to the pipe in such a manner as to be completely watertight. Dimple bands are not considered to be watertight.

   All connections shall use a rubber or neoprene gasket when joining pipe sections. The end of each pipe shall be re-rolled an adequate number of corrugations to accommodate the bandwidth. The following type connections are acceptable for pipes less than 24 inches in diameter: flanges on both ends of the pipe with a circular 3/8 inch closed cell neoprene gasket, pre-punched to the flange bolt circle, sandwiched between adjacent flanges; a 12-inch wide standard lap type band with 12-inch wide by 3/8-inch thick closed cell circular neoprene gasket; and a 12-inch wide hugger type band with o-ring gaskets having a minimum diameter of 1/2 inch greater than the corrugation depth. Pipes 24 inches in diameter and larger shall be connected by a 24 inch long annular corrugated band using a minimum of 4 (four) rods and lugs, 2 on each connecting pipe end. A 24-inch wide by 3/8-inch thick closed cell circular neoprene gasket will be installed with 12 inches on the end of each pipe. Flanged joints with 3/8 inch closed cell gaskets the full width of the flange is also acceptable.

   Helically corrugated pipe shall have either continuously welded seams or have lock seams with internal caulking or a neoprene bead.

4. Bedding - The pipe shall be firmly and uniformly bedded throughout its entire length. Where rock or soft, spongy or other unstable soil is encountered, all such material shall be removed and replaced with suitable earth compacted to provide adequate support.

5. Backfilling shall conform to "**Structure Backfill**".

6. Other details (anti-seep collars, valves, etc.) shall be as shown on the drawings.

Reinforced Concrete Pipe - All of the following criteria shall apply for reinforced concrete pipe:

1. Materials - Reinforced concrete pipe shall have bell and spigot joints with rubber gaskets and shall equal or exceed ASTM C-361.

2. Bedding - Reinforced concrete pipe conduits shall be laid in a concrete bedding / cradle for their entire length. This bedding / cradle shall consist of high slump concrete placed under the pipe and up the sides of the pipe at least 50% of its outside diameter with a minimum thickness of 6 inches. Where a concrete cradle is not needed for structural reasons, flowable fill may be used as described in the "Structure Backfill" section of this standard. Gravel bedding is not permitted.

3. Laying pipe - Bell and spigot pipe shall be placed with the bell end upstream. Joints shall be made in accordance with recommendations of the manufacturer of the material. After the joints are sealed for the entire line, the bedding shall be placed so that all spaces under the pipe are filled. Care shall be exercised to prevent any deviation from the original line and grade of the pipe. The first joint must be located within 4 feet from the riser.

4. Backfilling shall conform to "**Structure Backfill**".

5. Other details (anti-seep collars, valves, etc.) shall be as shown on the drawings.

Plastic Pipe - The following criteria shall apply for plastic pipe:

1. Materials - PVC pipe shall be PVC-1120 or PVC-1220 conforming to ASTM D-1785 or ASTM D-2241. Corrugated High Density Polyethylene (HDPE) pipe, couplings and fittings shall conform to the following: 4" – 10" inch pipe shall meet the requirements of AASHTO M252 Type S, and 12" through 24" inch shall meet the requirements of AASHTO M294 Type S.

2. Joints and connections to anti-seep collars shall be completely watertight.

3. Bedding -The pipe shall be firmly and uniformly bedded throughout its entire length. Where rock or soft, spongy or other unstable soil is encountered, all such material shall be removed and replaced with suitable earth compacted to provide adequate support.

4. Backfilling shall conform to "**Structure Backfill**".

5. Other details (anti-seep collars, valves, etc.) shall be as shown on the drawings.

Drainage Diaphragms - When a drainage diaphragm is used, a registered professional engineer will supervise the design and construction inspection.

Concrete

Concrete shall meet the requirements of Maryland Department of Transportation, State Highway Administration Standard Specifications for Construction and Materials, Section 414, Mix No. 3.

Rock Riprap

Rock riprap shall meet the requirements of Maryland Department of Transportation, State Highway Administration Standard Specifications for Construction and Materials, Section 311.

Geotextile shall be placed under all riprap and shall meet the requirements of Maryland Department of Transportation, State Highway Administration Standard Specifications for Construction and Materials, Section 921.09, Class C.

Care of Water during Construction

All work on permanent structures shall be carried out in areas free from water. The Contractor shall construct and maintain all temporary dikes, levees, cofferdams, drainage channels, and stream diversions necessary to protect the areas to be occupied by the permanent works. The contractor shall also furnish, install, operate, and maintain all necessary pumping and other equipment required for removal of water from various parts of the work and for maintaining the excavations, foundation, and other parts of the work free from water as required or directed by the engineer for constructing each part of the work. After having served their purpose, all temporary protective works shall be removed or leveled and graded to the extent required to prevent obstruction in any degree whatsoever of the flow of water to the spillway or outlet works and so as not to interfere in any way with the operation or maintenance of the structure. Stream diversions shall be maintained until the full flow can be passed through the permanent works. The removal of water from the required excavation and the foundation shall be accomplished in a manner and to the extent that will maintain stability of the excavated slopes and bottom required excavations and will allow satisfactory per-

formance of all construction operations. During the placing and compacting of material in required excavations, the water level at the locations being refilled shall be maintained below the bottom of the excavation at such locations which may require draining the water sumps from which the water shall be pumped.

Stabilization

All borrow areas shall be graded to provide proper drainage and left in a sightly condition. All exposed surfaces of the embankment, spillway, spoil and borrow areas, and berms shall be stabilized by seeding, liming, fertilizing and mulching in accordance with the Natural Resources Conservation Service Standards and Specifications for Critical Area Planting (MD-342) or as shown on the accompanying drawings.

Erosion and Sediment Control

Construction operations will be carried out in such a manner that erosion will be controlled and water and air pollution minimized. State and local laws concerning pollution abatement will be followed. Construction plans shall detail erosion and sediment control measures.

OPERATION AND MAINTENANCE

An operation and maintenance plan in accordance with Local or State Regulations will be prepared for all ponds. As a minimum, the dam inspection checklist located in Appendix A shall be included as part of the operation and maintenance plan and performed at least annually. Written records of maintenance and major repairs needs to be retained in a file. The issuance of a Maintenance and Repair Permit for any repairs or maintenance that involves the modification of the dam or spillway from its original design and specifications is required. A permit is also required for any repairs or reconstruction that involve a substantial portion of the structure. All indicated repairs are to be made as soon as practical.

SUPPORTING DATA AND DOCUMENTATION

Field Data and Survey Notes

The following is a list of the minimum data needed:

1. Profile along centerline of structure.
2. Profile along centerline of principal spillway.
3. Profile along centerline of emergency spillway.
4. Survey of storage area to develop topography and storage volumes.
5. Soil investigation logs and notes.

Design Data

Record on appropriate engineering paper. The following is a list of the minimum required design data:

1. Determine pond class and list appropriate spillway design criteria, including map.
2. Determine peak runoff from the contributing area for the design storms selected, including topo map.
3. Develop a stage-storage/discharge curve for the site.
4. Determine the pipe spillway by storm routing using the procedure in the SWM Pond Design Manual; Chapter 11, EFH; Chapter 6, TR-55; or TR-20.
5. Design emergency spillway using EFH 11-61.
6. Drawings should show the following as a minimum: profile along centerline of dam; profile along centerline of emergency spillway; cross section through dam at principal spillway; cross section through emergency spillway; plan view; and construction details & notes and soil logs.
7. Compute earth fill (if needed).
8. Special design feature details; watering, fire hydrants, fish management, irrigation, outfall stabilization, etc.; structural details with design loadings, if applicable, should be shown on the drawings.
9. Complete data required on MD-ENG-14.
10. Record seeding plan on drawings or MD-CONS-10.
11. A written Operation and Maintenance Plan.

Construction Check Data/As-built

Record on survey note paper, SCS-ENG-28. Survey data for ponds will be plotted in red. All construction inspection visits shall be recorded on the CPA-6 or appropriate documentation paper. The documentation shall include the date, who performed the inspection, specifics as to what was inspected, all alternatives discussed, and decisions made and by whom. The following is a list of the minimum data needed for As-Builts:

1. A profile of the top of the dam.
2. A cross-section of the emergency spillway at the control section.
3. A profile along the centerline of the emergency spillway.
4. A profile along the centerline of the principal spillway extending at least 100 feet downstream of the fill.
5. The elevation of the principal spillway crest.
6. The elevation of the principal spillway conduit invert (inlet and outlet).
7. The diameter, length, thickness and type of material for the riser.
8. The diameter, length, and type of material for the conduit.

9. The size and type of anti-vortex and trash rack device and its elevations in relation to the principal spillway crest.

10. The number, size and location of the anti-seep collars.

11. The diameter and size of any low stage orifices or drain pipes.

12. Show the length, width, and depth of contours of the pool area so that design volume can be verified.

13. Notes and measurements to show that any special design features were met.

14. Statement on seeding and fencing.

15. Notes on site clean up and disposal.

16. Sign and date check notes to include statement that practice meets or exceeds plans and specifications.

REFERENCES

1. *AWWA Standards*, American Water Works Association, Denver, Colorado.

2. *ASTM Standards*, American Society for Testing and Materials, Philadelphia, Pennsylvania.

3. *Engineering Field Handbook, Part 650*, USDA, Soil Conservation Service.

4. *Handbook of PVC Pipe Design and Construction*, First Edition, Uni-Bell Plastic Pipe Association, Dallas, Texas, 1980.

5. *Handbook of Steel Drainage and Highway Construction Products*, Third Edition, American Iron and Steel Institute, Washington, D.C., 1983.

6. *Maryland Dam Safety Manual*, Maryland Department of Natural Resources, Water Resources Administration, Annapolis, Maryland, June 1993.

7. *Maryland Technical Guide, Section IV, Standards and Specifications,* USDA, Natural Resources Conservation Service.

8. *National Engineering Handbook, Section 4, Hydrology*, USDA, Natural Resources Conservation Service, March 1985.

9. *National Engineering Handbook, Section 5, Hydraulics*, USDA, Natural Resources Conservation Service, August 1956.

10. *National Engineering Handbook, Section 11, Drop Spillways*, USDA, Natural Resources Conservation Service, April 1968.

11. *National Engineering Handbook, Section 14, Chute Spillways*, USDA, Natural Resources Conservation Service, October 1977.

12. *National Handbook of Conservation Practices*, USDA, Natural Resources Conservation Service.

13. *Standard Specifications for Materials and Methods of Sampling and Testing*, Nineteenth Edition, American Association of State Highway and Transportation Officials, Washington D.C., 1998.

14. *Standard Specifications for Construction and Materials*, Maryland Department of Transportation, State Highway Administration, Baltimore, Maryland, October 1993.

15. Technical Release No. 20, *Computer Programs for Project Formulation Hydrology*, USDA, Natural Resources Conservation Service, 1992.

16. Technical Release No. 55, *Urban Hydrology for Small Watersheds*, USDA, Natural Resources Conservation Service, 1986.

17. Technical Release No. 56, *A Guide for Design and Layout of Vegetative Wave Protection for Earth Dam Embankments*, USDA, Natural Resources Conservation Service, 1974.

18. Technical Release No. 60, *Earth Dams and Reservoirs*, USDA, Natural Resources Conservation Service, 1985.

19. Technical Release 69, *Riprap for Slope Protection Against Wave Action*, USDA, Natural Resources Conservation Service, 1983.

20. Technical Release No. 77, *Design and Installation of Flexible Conduits*, USDA, Natural Resources Conservation Service, 1990.

21. *National Engineering Handbook, Part 633, Chapter 26, Gradation Design of Sand and Gravel Filters*, USDA, Natural Resources Conservation Service, October 1994.

APPENDIX A

DAM INSPECTION CHECKLIST

To help the dam owner perform periodic safety inspections of the structure, a checklist is provided. Each item of the checklist should be completed. **Repair** is required when obvious problems are observed. **Monitoring** is recommended if there is potential for a problem to occur in the future. **Investigation** is necessary if the reason for the observed problem is not obvious.

A brief description should be made of any noted irregularities, needed maintenance, or problems. Abbreviations and short descriptions are recommended. Space at the bottom of the form should be used for any items not listed.

DAM _____ **DATE** _____ **OWNER** _____ **WEATHER** _____ **INSPECTED BY** _____ **POOL LEVEL** _____		Y/N	MONITOR	REPAIR	INVESTIGATE
Item	Comments				
1. CREST					
a. Visual settlement?					
b. Misalignment?					
c. Cracking?					
2. UPSTREAM SLOPE					
a. Erosion?					
b. Ground cover in good condition?					
c. Trees, shrubs, or other woody vegetation?					
d. Longitudinal/Vertical cracks?					
e. Adequate riprap protection?					
f. Stone deterioration?					
g. Settlements, depressions, or bulges?					
3. DOWNSTREAM SLOPE					
a. Erosion?					
b. Ground cover in good condition?					
c. Trees, shrubs, or other woody vegetation?					
d. Longitudinal/Vertical cracks?					
e. Riprap protection adequate?					
f. Settlements, depressions, or bulges?					
g. Soft spots or boggy areas?					
h. Movement at or beyond toe?					
i. Boils at toe?					
4. DRAINAGE-SEEPAGE CONTROL					
a. Internal drains flowing?	Est. Left _____ gpm Est. Right _____ gpm				
b. Seepage at toe?	Estimated _____ gpm				
c. Does seepage contain fines?					

INSPECTION CHECKLIST - PAGE 2

INSPECTED BY _____ **DATE** _____

Item	Comments	Y/N	MONITOR	REPAIR	INVESTIGATE
5. ABUTMENT CONTACTS					
a. Erosion?					
b. Differential movement?					
c. Cracks?					
d. Seepage?	Estimated _____ gpm				
e. Adequate erosion protection for ditches?					
6. INLET STRUCTURE	Concrete or Metal Pipe (circle one)				
a. Seepage into structure?					
b. Debris or obstructions?					
c. If concrete, do surfaces show:					
1. Spalling?					
2. Cracking?					
3. Erosion?					
4. Scaling?					
5. Exposed reinforcement?					
6. Other?					
d. If metal, do surfaces show:					
1. Corrosion?					
2. Protective Coating deficient?					
3. Misalignment or split seams?					
e. Do the joints show:					
1. Displacement or offset?					
2. Loss of joint material?					
3. Leakage?					
f. Are the trash racks:					
1. Broken or bent?					
2. Corroded or rusted?					
3. Obstructed?					
4. Operational?					
g. Sluice/Drain gates:					
1. Broken or bent?					
2. Corroded or rusted?					
3. Leaking?					
4. Not seated correctly?					
4. Periodically maintained?					
5. Operational?					

INSPECTION CHECKLIST - PAGE 3

INSPECTED BY _____ **DATE** _____

Item	Comments	Y/N	MONITOR	REPAIR	INVESTIGATE
7. PRINCIPAL SPILLWAY PIPE	Concrete or Metal Pipe (circle one)				
a. Seepage into conduit?					
b. Debris present?					
c. Do concrete surfaces show:					
1. Spalling?					
2. Cracking?					
3. Erosion?					
4. Scaling?					
5. Exposed reinforcement?					
6. Other?					
d. Do the joints show:					
1. Displacement or offset?					
2. Loss of joint material?					
3. Leakage?					
8. STILLING BASIN/POOL	Riprap or Concrete (circle one)				
a. If concrete, condition of surfaces?					
b. Deterioration or displacement of joints?					
c. Outlet channel obstructed?					
d. Is released water:					
1. Undercutting the outlet?					
2. Eroding the embankment?					
3. Displacing riprap?					
4. Scouring the plunge pool?					
e. Tailwater elevation and flow condition:					
9. EMERGENCY SPILLWAY					
a. Is the channel:					
1. Eroding or backcutting?					
2. Obstructed?					
b. Trees or shrubs in the channel?					
c. Seepage present?					
d. Soft spots or boggy areas?					
e. Channel slopes eroding or sloughing?					
10. RESERVOIR					
a. High water marks?					
b. Erosion/Slides into pool area?					
c. Sediment accumulation?					
d. Floating debris present?					
e. Adequate riprap protection for ditches?					

APPENDIX B

ROADWAY EMBANKMENT DESIGN CRITERIA

HW - TW > 10'* AND HW/D > 2, OR PERMANENT POOL > 3' OR PROPOSED RISER

No → **NO SPECIAL DESIGN**

Yes ↓

MEETS SMALL POND CRITERIA, AND CLASS "A"

No → **MDE DAM SAFETY REVIEW**

Yes ↓

8:1 PROJECTION LINE INTERSECTS DOWNSTREAM SLOPE OF THE EMBANKMENT

No → **SPECIAL EMBANKMENT DESIGN**

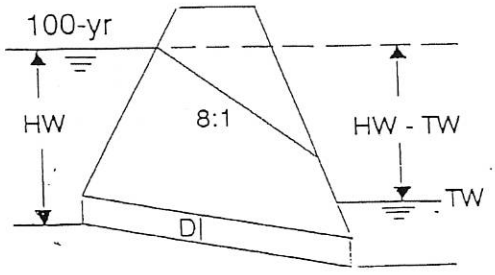
Yes ↓

MD 378 Design

Use any nonorganic soils for the embankment, elimination of the cut-off trench and core based on approval of geotechnical engineer and acceptable to local jurisdictions.

Filter diaphragm is required.

All other MD 378 criteria apply.



* Use HW when TW is below the inlet invert elevation.

Appendix

B.1.1

Supplemental Pond and Wetland Specifications (Non-378)

Supplemental Stormwater Pond and Wetland Specifications (Non-378)

These notes and specifications are in addition to the MD-378 Specifications. If there is any question as to their applicability, the MD-378 Specifications supercede.

1. It is preferred to use the same material in the embankment as is being installed for the core trench. If this is not possible because the appropriate material is not available, a dam core with a shell may be used. The cross-section of the stormwater facility should show the limits of the dam core (up to the 10-year water surface elevation) as well as the acceptable materials for the shell. The shape of the dam core and the material to be used in the shell should be provided by the geotechnical engineer.

2. If the compaction tests for site improvements is using a Modified Proctor (AASHTO T-180), then to maintain on-site consistency, the Modified Proctor may be used in lieu of a Standard Proctor (AASHTO T-99). The minimum required density using the Modified Proctor test method shall be at least 92% of maximum dry density with a moisture content of $\pm 2\%$ of the optimum. The minimum required density using the Standard Proctor test method shall be at least 95% of the maximum dry density with a moisture content of $\pm 2\%$ of the optimum.

3. For all stormwater management facilities, a geotechnical engineer or their representative must be present to verify compaction in accordance with the selected test method. This information needs to be provided in a report to the design engineer, so that certification of the construction of the facility, in accordance with MD-378 specifications, can be made.

4. A 4-inch layer of topsoil shall be placed on all disturbed areas of the dam embankment. Seeding, liming, fertilizing, mulching, etc. shall be in accordance with Maryland Soil Conservation Service MD-342 or the 1994 Maryland Standards and Specifications for Soil Erosion and Sediment Control "Permanent Seeding," Section in Chapter 20. The purpose of the topsoil is to establish a good growth of grass which is not always possible with some of the materials that may be placed for the embankment fill.

5. Geotextile placed beneath rip-rap shall be Class "C" geotextile or better (see Section 24.0, Material Specifications, 1994 Standards and Specifications for Soil Erosion and Sediment Control (MDE, 1994). Some acceptable geotextiles that meet the Class "C" criteria include:

Amoco 4552	Carthage FX-70S
GEOLON N70	Mirafi 180-N
WEBTEC N07	

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This is only a partial listing of available geotextiles based on information provided by the manufacturers to the 1997 Specifier's Guide dated December 1996. It is the responsibility of the engineer to verify the adequacy of the material, as there are changes in the manufacturing process and the type of fabric used, which may affect the continued acceptance.

6. A rule of thumb to determine when an excavated pond may need to be considered an embankment pond is as follows:

   - Provide calculation of 10H + 20 feet = L, where H equals height from pond bottom to top of dam. If the projection of L, downstream in a horizontal line from the upstream toe of slope is below existing ground, the pond can be considered an excavated pond. In addition, the existing ground slope, downstream of the toe, must be less than 10%.

7. The design engineer and geotechnical engineer should make the determination that the settlement of the pond will not cause excessive joint extension. For further information on joint extension analysis, see NRCS Publication TR-18.

8. Fill placement **shall not** exceed a maximum 8-inch. Each lift shall be continuous for the entire length of the embankment.

9. The embankment fill **shall not** be placed higher than the centerline of the principal spillway until after the principal spillway has been installed. If the embankment needs to be excavated to install the principal spillway, the side slope shall be no less than 2:1.

10. The side slopes of a cut to repair a dam, install a principal spillway for an excavated pond, or other repair work, shall be no less than 2:1.

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Appendix B.1.2

MDE Dam Safety Division Small Pond Review Criteria

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MDE Dam Safety Division Small Pond Review and Approval Criteria

The following criteria are established for the MDE Dam Safety Division small pond review and approval:

1) If any of the following apply, a permit is required from the MDE Dam Safety Division:
   a) Drainage area of the pond is greater than 640 acres.
   b) Dam embankment height is greater than 20 feet (top of dam to lowest point on the upstream toe).
   c) Pond is an intermediate or high hazard structure the failure of which is likely to cause damage to homes, public transportation, loss of life or property (NRCS Class b & c).

2) If the pond is in a USE III watershed, a permit is required if the pond will be:
   a) Capturing a flowing stream (stream with a base flow*),
   b) Capturing any spring, or
   c) A wet pond, or
   d) Located within 100 feet of a flowing stream, or
   e) Proposes extended detention for the one year storm longer than 12 hours.

3) If the pond is located within the drainage of the Gwynns Falls, Jones Falls, or Herring Run streams situated in or adjacent to Baltimore City, approval is required in accordance with the provisions of the Maryland Environment Article 5-503.

4) If the pond is to be constructed across a stream, excluding USE III waters, **SCD** may approve the pond with verification that the 100 year pool based on ultimate development with current zoning does not increase flooding on adjacent properties or is in a floodplain easement. The in-stream closure period must be noted on the plans.

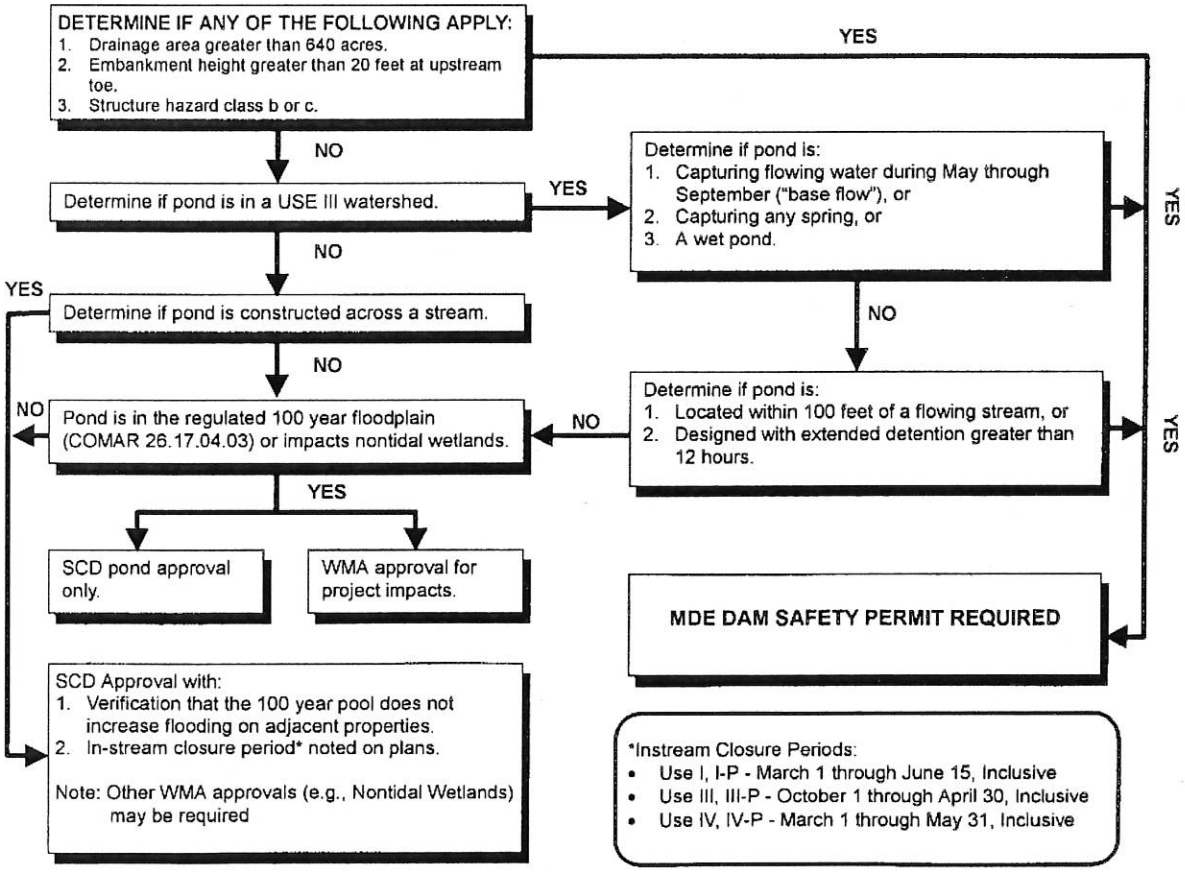
5) If the pond is in the floodplain, an MDE Nontidal Wetlands and Waterways Permit may be required. The pond will be evaluated for potential impacts in the floodplain and to nontidal wetlands. However, the pond construction plans may be approved by the **SCD**.

* "Base Flow" or "Dry Weather Flow" - Stream flows originating from groundwater or spring contributions that are not influenced by storm events. Base flow measurements should not be made within two days of a storm event.

Appendix B.1.2. Small Pond Approval Criteria

Figure B.1.2.1 Small Pond Review Flow Chart

This flow chart is intended to determine whether MDE or the local SCD will review construction plans. SCD pond approval does not relieve the applicant from obtaining other necessary approvals associated with pond construction such as impacts to nontidal wetlands.



Appendix

D.2

Geotechnical Methods for Karst Feasibility Testing

The following information on BMP design and SWM geotechnical testing in Karst areas has been adapted from the *Carroll County Water Resource Management Manual and Ordinance* (CCWRM) dated July 2, 1996. For a complete discussion of these items, please refer to the Carroll County document.

Section 1: Stormwater Management in Karst Areas

In general, stormwater runoff should not be concentrated and should be conveyed through vegetated areas; in addition, the facilities should be designed in accordance with the following standards:

(1) Detention/retention ponds should be designed and constructed with a synthetic or clay liner approved by the local plan approval authority.

(2) Discharges from SWM facilities or directly from impervious surfaces should not be routed within 1000 feet of the edge of any existing unremediated sinkhole. The flow should then be directed to an area not underlain by carbonate rock. Alternatively, these discharges may be routed to a stable watercourse via a pipe or lined channel.

(3) Sinkholes occurring within stormwater management structures should be repaired within 72 hours of first observation of occurrence.

(4) Liners: Where natural soil permeabilities are greater than 10^{-6} cm/sec or 1.4×10^{-3} inches per hour for the two-foot interval below the depth of the proposed facility, a stable, low permeability liner shall be installed as follows:

(a) One foot of clay with a permeability less than 10^{-7} cm/sec, or;

(b) Two feet of clay with a permeability less than 10^{-6} cm/sec, or;

(c) Two feet of compacted soil with a permeability less than 10^{-5} cm/sec with a 30 mil thick artificial liner with a permeability less than 10^{-7} cm/sec, or;

(d) A very low permeability base constructed of concrete.

Section 2: Soils Investigation for Karst Areas

The purpose of a karst investigation is to identify subsurface voids, cavities, fractures, or other discontinuities which could pose an environmental concern or a construction hazard to an

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existing or proposed SWM facility. By definition, karst investigations are required only in areas suspected of containing carbonate rocks. The requirements outlined below should not be interpreted as all-inclusive. The design of any subsurface investigation should reflect the size and complexity of the proposed project.

The investigation should determine the nature and thickness of subsurface materials, including depth to bedrock and to the water table. Subsurface data may be acquired by backhoe excavation and/or soil boring. These field data should be supplemented by geophysical investigation techniques, deemed appropriate by a qualified professional. The data listed herein should be acquired under the direct supervision of a qualified geologist, geotechnical engineer, or soil scientist who is experienced in conducting such studies. Pertinent site information shall be collected which should include the following:

1. Bedrock characteristics (type, geologic contacts, faults, geologic structure, rock surface configuration).

2. Soil characteristics (type, thickness, mapped unit).

3. Photogeologic fracture traces.

4. Bedrock outcrop areas.

5. Sinkholes and/or other closed depressions.

6. Perennial and/or intermittent streams.

Section 3: Location of Borings

Borings should be located to provide representative area coverage of the proposed facilities. The exact location of borings will be based on the following conditions or features:

1. In each geologic unit present, as mapped by the Maryland and U.S. Geological Surveys (USGS) and local county records.

2. Placed near on-site geologic or geomorphic indications of the presence of carbonate rock.

3. On photogeologic fracture traces.

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4. Next to bedrock outcrop areas (i.e., ten feet from).

5. As near to identified sinkholes and/or closed depressions as possible.

6. Near the edges and center of the proposed facility, and spaced at equal distances from one another.

7. Near any areas identified as anomalies from any geophysical studies.

Section 4: Number of Borings

The density shall be dependent upon the type and size of the proposed facility such that a representative sampling is obtained, as follows:

1. Ponds/wetlands - a minimum of three per facility, or three per acre, whichever is greater with at least one along the centerline of the proposed embankment and the remainder within the proposed impoundment area.

2. Infiltration trenches - a minimum of 2 per facility.

3. Additional borings - to define lateral extent of limiting horizons, or site specific conditions, where applicable.

Section 5: Depth of Borings

Borings shall be extended to depths dependent upon bedrock type as follows:

1. Non-carbonate rocks - a minimum depth of 5 feet below the lowest proposed grade, within the facility unless auger/backhoe refusal is encountered.

2. Carbonate rocks - a minimum of 20 feet below ground surface or proposed grade; where refusal is encountered the boring may either be extended by rock coring or moving to an adjacent location within 10 linear feet of the original site, in order that the 20-foot minimum depth be reached.

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Section 6: Identification of Material

All material penetrated by the boring shall be identified, as follows:

1. Description, logging, and sampling for the entire depth of the boring.

2. Any stains, odors, or other indications of environmental degradation.

3. A minimum laboratory analysis of two soil samples, representative of the material penetrated including potential limiting horizons, with the results compared to the field descriptions.

4. Identified characteristics shall include, as a minimum: color; mineral composition; grain size, shape, and sorting; and saturation.

5. Any indications of water saturation shall be carefully logged, to include both perched and groundwater table levels, and descriptions of soils that are mottled or gleyed should be provided. Water levels in all borings shall be taken at the time of completion and again 24 hours after completion. The boring must remain fully open to total depth of these measurements.

6. When conducting a standard penetration test (SPT), estimation of soil engineering characteristics, including "N" or estimated unconfined compressive strength.

Section 7: Geophysical Investigation

An electromagnetic terrain conductivity survey may be conducted over the entire area of the facility and extending outward to 200 feet beyond the boundaries of the proposed facility. This survey may be performed to provide a qualitative evaluation of the area to be utilized. The survey results may be used to identify "suspect areas" which will be further evaluated using borings. The use of this technique may reduce the total number of borings for a site by better defining "suspect areas." This survey shall include appropriate techniques such that representative data are collected from a minimum depth of 20 feet below ground surface or the final proposed grade, whichever is deeper. These data shall then be correlated with boring data in the site area.

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Section 8: Evaluation

At least one subsurface cross section shall be provided. It should extend through a central portion of the proposed facility, using the actual or projected boring data and the geophysical data. In addition, an iso-conductivity map should be constructed. Finally, a bedrock contour map should be developed to include all of the geophysical and boring data. A sketch map or formal construction plan indicating the location and dimension of the proposed facility and line of cross section should be included for reference, or as a base map for presentation of subsurface data.

Section 9: Sinkhole Remediation

Proper sinkhole remediation involves investigation, stabilization and final grading. For more information, please see the CCWRM, Section 4.2.

Section 10: Sinkhole Stabilization

Sinkholes should be repaired by (1) reverse-graded backfilling, (2) concrete plugging, or (3) an engineered subsurface structure. For more information on these methodologies, see the CCWRM, Section 4.2.2.

Section 11: Monitoring of BMPs in Karst Regions

A water quality monitoring system installed, operated and maintained by the owner/operator may be required in a karst region. For areas requiring monitoring, at least one monitoring well shall be placed at a point hydraulically up gradient from the BMP and two (2) down gradient monitoring wells shall be provided within 200' of the facility. The wells shall be fitted with locking caps. Bi-annual sampling should take place, and an annual report should be filed with the plan approval authority.

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Appendix

D.3

Short Cut Method for Wetland Drawdown Assessment

This section presents a simple method for calculating whether a stormwater pond or wetland has an appropriate water balance to maintain a wet pool over a 30-day period without rainfall. When conducting this analysis, the following should be considered:

1. Calculate maximum drawdown during periods of high evaporation and during an extended period of no appreciable rainfall.
2. The change in storage within a pond (ΔV) = Inflows - Outflows
3. Potential inflows: runoff, baseflow and rainfall
4. Potential outflows: infiltration, surface overflow and evaporation (and evapotranspiration)
5. Assume no inflow from baseflow, no losses for infiltration and because only the permanent pool volume is being evaluated, no losses for surface overflows.
6. Therefore, ΔV = runoff - evaporation

Using Design Example No. 1 - Reker Meadows (see Chapter 2.6) as an example and given the conditions in Table D.3.1 and table D.3.2, a wetland drawdown assessment may be determined as follows:

Table D.3.1 Site Data from Design Example 1 for Sample Water Balance Analysis

Drainage Area	38.0 ac
Post Developed Conditions CN	78
2-yr. Design Rainfall Event	3.1"
2-yr. Design Storm Runoff	1.2"
Water Quality Volume (WQ_v)	1.08 ac-ft
Groundwater Recharge Volume (Re_v)	0.25 ac-ft
Surface Area of Wetland (minimum 1.5% of drainage area to BMP)	0.58 acres

A shallow wetland (W-1) will be designed to treat the water quality volume (WQ_v) minus the groundwater recharge volume (Re_v). Therefore, the permanent pool volume = 0.83 ac-ft.

Table D.3.2 Evaporation Rates for Maryland Ponds
(from Ferguson and Debo, "On-Site Stormwater Management", 1990)

	April	May	June	July	August	September
Precipitation (ft.)	0.30	0.35	0.32	0.36	0.38	0.31
Evaporation (ft.)	0.36	0.44	0.52	0.54	0.46	0.35

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Calculate maximum drawdown during periods of high evaporation:

- Period of greatest evaporation occurs during the month of July (see Table D.3.2)
- Runoff Volume = P x E

  where P = Precipitation
  E = Runoff Efficiency (ratio of NRCS 2 year storm runoff to rainfall depths)
- For CN = 78, Volume of Runoff (2 year storm) = 1.2"
- For Frederick County, 2 year storm rainfall = 3.1"
- E = 1.2"/3.1" = 0.39
- Inflow = $P \times E$
  = .36 ft ×.39 = 0.14 ft
  over entire site area: (0.14 ft) (38 acres) = 5.32 ac-ft
- Outflow = surface area × evaporation losses
  = 0.58 ac × 0.54 ft (see Table D.3.2)
  = 0.31 ac-ft
- Inflow (5.32 ac-ft) is greater than Outflow (0.31 ac-ft) therefore, drainage area is adequate to support wet pond during normal conditions.

Check for drawdown over an extended period without rainfall:

- Use a 45 day interval using worst case conditions
- Highest evaporation occurs during July - 0.54 ft per month (see Table D.3.2)
- Calculate average evaporation per day = 0.54 ft / 31 days = 0.017 ft/day
- Over 45 day interval, evaporation loss = 45 × .017 ft/day = 0.78 ft
- Assume surface of the permanent pool may drop up to 0.78 ft (9.4") over this interval. Therefore, to be safe, specify vegetation for the aquatic shelves (to 10") that can tolerate periods of drawdowns.

Reference

Ferguson, B. and T.N. Debo. 1990. On-Site Stormwater Management - Applications for Landscape and Engineering. Van Nodstrandt, Reinhold, New York.

SARB_005033

Appendix

D.4

Stormwater Criteria for Maryland Critical Area IDA Zone

This Appendix has been adapted from the document

Urban Stormwater Quality Guidance for the
Maryland Chesapeake Bay Critical Area
in Intensely Developed Areas

Prepared by:
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Additional Information on the 10% Rate, including an applicants guide, can be obtained from the:

Chesapeake Bay Critical Area Commission
45 Calvert Street
Annapolis, MD 21401
(410) 974-2426

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Background

What is the Critical Area?

The Chesapeake Bay Critical Area Act, passed by the Maryland General Assembly in 1984, is designed to help protect the Chesapeake Bay and its tributaries from resource degradation primarily resulting from development activity. In 1986, the more specific and comprehensive Critical Area Criteria were adopted to implement the law. **The "Critical Area" is defined as all water and submerged lands of the Chesapeake Bay to the head of tide, and all land and water within 1000 feet of Mean High Water or from the edge of tidal wetlands.** The Criteria mandate certain restrictions on the use of land within this area. However, the responsibility for implementing the Criteria is delegated to local governments, where zoning and other land use controls have traditionally been carried out.

What is an IDA?

In writing the Criteria, the Chesapeake Bay Critical Area Commission was cognizant of the fact that development already existed within the Critical Area. The Criteria also written with an implicit acceptance of a limited and controlled level of additional development or redevelopment. One particular class of land use, termed **"Intensely Developed Areas,"** or **IDAs**, was identified as areas where continued growth could be accommodated through redevelopment and/or new development. Local governments desiring to permit or promote such projects within the Critical Area have been encouraged to direct such efforts within the IDA.

What does the 10% Rule mean?

IDAs are designated to each local jurisdiction and are characterized as intensely developed areas that are predominately commercial, residential or industrial in nature. The Critical Area Criteria require that any development within the IDA be accompanied by urban **"best management practices (BMPs)"** to help mitigate potential water quality impacts associated with stormwater runoff. The Criteria further specify that these practices should be capable of removing pollutant loads generated from the development site to a level at least 10% below the load generated at the site prior to development. This requirement is commonly referred to as the **"10% Rule."**

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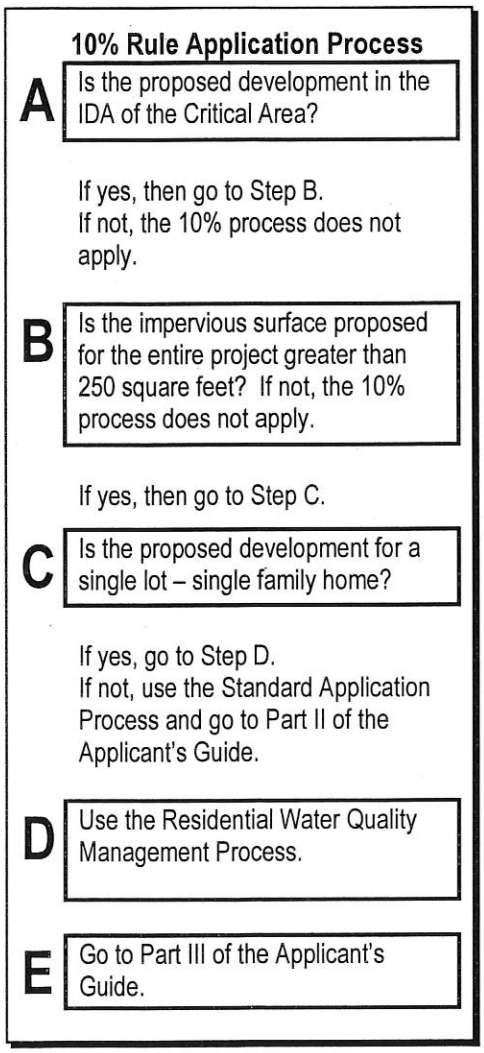
Introduction

The requirements set forth in this document relate only to the requirements of the Chesapeake Bay Critical Area Act passed by the Maryland General Assembly in 1984 as well as the associated criteria passed in 1986. Under this act, development and redevelopment activities shall be required to use stormwater management practices appropriate to site development which achieves a ten (10%) percent reduction of pre-development pollutant loadings.



This section details a step-by-step approach for compliance with the 10% Rule. It is important to note that these requirements are designed to provide water quality treatment of urban runoff and that other site environmental features cannot be substituted towards compliance. For example, environment requirements for waste water treatment plants cannot be substituted for urban runoff BMPs— the Six Step Standard Application process or Standard Procedure.

Two application processes have been developed for 10% Rule compliance in recognition of the broad scale of development that occurs within the Critical Area.

- In the Standard Procedure, computations of pre- and post-development pollutant loadings and pollutant removal efficiencies of BMPs are used to determine compliance with the 10% Rule.

- The second procedure provides a streamlined process for individual, residential lot development. If the proposed development is eligible, the applicant must submit a Residential Water Quality Management Plan for approval.

The 10% Rule provides three different approaches for compliance:

1) A reduction in impervious surface may lower post-development levels; therefore, I_{post} is lower, and hence, I_{post} (post-development load) is lower;

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2) A stormwater management BMP may remove pollutants from the Critical Area portion of the site equal to the 10% reduction;
3) A stormwater management BMP may remove pollutants from the Critical Area portion of the site and portions outside of the Critical Area equal to the 10% reduction.

Who must comply?

An individual planning development or re-development of land in the Critical Area District zoned as an Intensely Developed Area (IDA) must comply with the 10% Rule. As mentioned above, IDA refers to the land-use management classification as determined by the Chesapeake Bay Critical Area Commission and incorporated into a local government's Critical Area program. IDAs are areas where residential, commercial, institutional, and/or industrial developed land uses predominate, and where relatively little natural habitat occurs. IDAs also have at least one of the following characteristics:

- A density of development equal to or greater than four dwellings per acre;
- Presence of public water and sewer systems with a density of greater than three units per acre; or,
- Concentration of industrial, commercial, or institutional uses. In addition, these features are concentrated in an area of at least 30 adjacent acres.

What must be submitted?

For persons proposing development or re-development in areas designated as an IDA on a local Critical Area map, the specific submittal requirements vary from jurisdiction to jurisdiction. Applicants should refer to their local Critical Area Program guidelines for preliminary and final site plan or subdivision plan submittal requirements. As mentioned earlier, this Applicant's Guide contains the minimum recommended submittal requirements for two separate 10% Rule application processes. Schedules for submittal of either document may vary among Critical Area jurisdictions.

What if my project is small?

Check to see if the project meets the criteria for the Residential Water Quality Management Plan. This program is designed to ease the application process for individual lot residential development or improvements that involve disturbances of 250 square feet or greater. Projects smaller than 250 square feet of disturbance are exempted from the requirements of 10% Rule.

What if my project will be completed in phases?

Applicants anticipating that their development will occur in phases are required to submit a conceptual plan indicating the entire scope of work for preliminary review and approval. This will ensure that the impacts of the project are evaluated in their entirety.

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Who do I submit it to?

Before commencement of construction, all plans indicating proposed development, (e.g. site plans, building permits, subdivision plans), shall be submitted to the county or municipality department which is generally responsible for the administration and enforcement of Chesapeake Bay Critical Area Program regulations. In most jurisdictions, there is a zoning department that handles Critical Area projects.

How does this program relate to other stormwater management programs?

Other local or state stormwater regulations may require additional stormwater requirements or submittal information. For example, the state stormwater requirements require that stormwater designs be assessed according to the state priorities, (for example: infiltration of runoff as top priority, followed by wet ponds, etc.). State or local stormwater requirements may also specify control of larger storms for quantity or flood safety control purposes. It is possible to meet various design requirements within one facility, but local and state programs must be addressed in addition to the requirements outlined within this document.

When must the application be submitted?

Any application process for the 10% Rule should parallel the plan review process, for example: a conceptual 10% Rule Application should be submitted as part of the preliminary review followed by a final 10% application at the final plan review stage. Upon receipt of the site plan, the local reviewing agency may conduct a review soliciting technical comments from other departments, agencies, and officials. Although the process varies between jurisdictions, the site plan shall be preliminarily approved, subject to final approval, assuming it meets all requirements.

The Standard Application Process provides a six-step method for comparing pollutant loads before and after development, and assessing the appropriate BMP for a given site. The pollutant loading methodology is based on relationships between surface imperviousness and concentrations of pollutants found in urban runoff (Schueler 1987).

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Table D.4.1 Six Step Method of the Standard Application Process

Worksheet A	
STEP #1	Calculate Site Imperviousness
STEP #2	Calculate Pre-Development Pollutant Load
STEP #3	Calculate Post-Development Pollutant Load
STEP #4	Calculate Pollutant Removal Requirement
STEP #5	Identify Feasible Urban BMP
Worksheet B	
STEP #6	Define Off-Site Compliance
then..	Submit Application to Critical Area Plan Reviewer

STEP 1: Calculate Site Imperviousness

In this step, the applicant will describe imperviousness of pre- and post- development site conditions. In general, impervious surfaces are human-made surfaces that are devoid of vegetation. Refer to Table D.4.2 for detailed definitions of imperviousness.

Impervious Measurement

- Imperviousness must be measured directly from the most recent site plan.
- A table of measured values (planimeter, preferred) listed specifically for each impervious surface type (roads, rooftops, etc.) must be submitted.
- Estimates of imperviousness based on land use types by computer generated surface runoff programs (e.g. TR-55), are not appropriate for submission.
- If land is subdivided prior to construction, it is recommended that a 10% Application is submitted at the time of initial subdivision, with imperviousness calculated using maximum building envelopes and proposed road layouts. This submittal process is recommended so that the entire project may be assessed as a whole.

Define Development Category

Using existing site imperviousness data, the proposed development must be categorized as 1) new development, 2) redevelopment, or 3) single lot residential.

1) New Development: pre-development imperviousness < 15%

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2) Re-development: pre-development imperviousness > 15%

3) Single Lot Residential: projects involving an individual lot of residential development which exceed 250 square feet in site disturbance.

Table D.4.2 Definition of Imperviousness

Impervious Surfaces are those that:

1) impede the natural infiltration of rainfall into underlying soils; and,

2) result in an increased volume of surface runoff to adjacent soils. As a simple rule, human-made surfaces that are not vegetated will be considered impervious (BMPs will be exempted from this definition).

Surface	Impervious	Design Suggestions
Roads		
paved/concrete	yes	• minimize road width
gravel	yes	• avoid curb and gutters; use grassed swales
dirt	yes	
Driveways		
paved/concrete	yes	• minimize surface area
gravel	yes	• use gridded pavers or porous pavement in areas of low usage
dirt	yes	
grid pavers	no	
porous pavement	yes	
Sidewalks/paths		
paved	yes	• minimize surface area
gravel	yes	• disconnect imperviousness; combine with vegetation
grid pavers	no	
porous pavement	no	
wood chip	no	
Rooftops	yes	• use sheet-flow spouting, dry wells or french drains
Decks	yes	• treat runoff under deck area
Swimming pools/ponds	yes	

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STEP 2: Calculate Pre-Development Pollutant Load

In this step the applicant calculates the storm loadings of phosphorous from the site prior to development (see Technical Guide "Simple Method for Calculating Phosphorous Export"). The equation shown in Table D.4.3 is a simplification of the equations presented in the 1987 10% Document. Two loading formulas are used based on the development category (redevelopment or new development) and site imperviousness. The information needed for these calculations include:

- the area of the site within the IDA of the Critical Area
- pre-development site imperviousness.

Table D.4.3 Method for Calculating Pre-Development Phosphorous Loading

Pre-development Phosphorous Loading: $L_{pre} = (R_v)(C)(A)\ 8.16$

$R_v = 0.05 + 0.009(I)$

where:

L_{pre}	=	average annual load of total phosphorous exported from the site in pounds per year
R_v	=	runoff coefficient, which expresses the fraction of rainfall which is converted into runoff
C	=	flow-weighted mean concentration of phosphorous in urban runoff (mg/l)
		C = 0.26 if pre-development I < 20%
		C = 1.08 if pre-development I ≥ 20%
A	=	area of the site within the IDA Critical Area (acres)
8.16	=	includes regional constants and unit conversion factors
I	=	site imperviousness (I = 75 if site is 75% impervious)

New Development Phosphorous Loading: $L_{pre} = 0.5\ (A)$

where:

L_{pre}	=	average annual load of total phosphorous exported from the site in pounds per year
A	=	area of the site within the IDA Critical Area (acres)

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STEP 3: Calculate Post-Development Pollutant Load

The next step involves computing the post-development pollutant load from the site. Again, an abbreviated version of the Simple Method (Schueler, 1987), described in Step 2 is used for the calculations. The equations to be used to determined post-development pollutant loads follows below.

Table D.4.4 Method for Computing Post-Development Pollutant Loadings

Post-Development Pollutant Loading:		$L_{post} = (R_v)(C)(A)(8.16)$ $R_v = 0.05 + 0.009(I)$
where:		
L_{post}	=	average annual load of total phosphorous exported from the site through storm runoff in pounds per year
R_v	=	runoff coefficient, which expresses the fraction of rainfall which is converted into runoff
I	=	site imperviousness (I = 75 if site is 75% impervious)
C	=	flow-weighted mean concentration of the pollutant in urban runoff (mg/l) C = 0.26 if new development activity C = 1.08 if redevelopment activity
A	=	area of the development site (acres)
8.16	=	includes regional constants and unit conversion factors

STEP 4: Calculate the Pollutant Removal Requirement

Phosphorous pollutant loads generated from the site must be reduced so that they are 90% or less of the load that is generated prior to development. The amount of phosphorous that must be removed though the use of stormwater BMPs is called the Pollutant Removal Requirement. The equation in Table D.4.5 expresses this term numerically.

Table D.4.5 Computing Pollutant Removal Requirements

Removal Requirement	=	Post-development phosphorous load - (0.9) Pre-development phosphorous load $RR = L_{post} - 0.9\ (L_{pre})$

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STEP 5: Identify Feasible Urban Best Management Practices (BMP)

Urban BMP options must be shown to be feasible for the site both in terms of physical suitability and pollutant removal capabilities (see Volume 1, Chapter 4). It should be noted that the BMPs which survive the screening procedure still need to undergo more detailed design checks and field tests to confirm that they are actually feasible. Evidence of site feasibility will be required as part of the final submittal package.

Table D.4.6 Estimate of Pollutant Load Removed by Each BMP

Load Removed	=	(Post-development Load)(Removal Rate)
		$LR = L_{post}$ (RR)(% Drainage Area Served)

If the Load Removed is equal to or greater than the Pollutant Removal Requirement computed in STEP 4, then the on-site BMP complies with the 10% Rule. If not, the designer must evaluate alternative BMP designs to achieve higher removal efficiencies.

Tables D.4.7 and D.4.8 provide updated phosphorous removal rates for stormwater BMPs used in this manual, based on a comprehensive national survey of pollutant removal performance monitoring data (Brown and Schueler, 1997).

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Table D.4.7 Updated Critical Area Keystone Phosphorous Removal Rates

CODE	BMP LIST	TP%
P-1	Micropool ED	40
P-2	Wet Pond	50
P-3	Wet ED Pond	60
P-4	Multiple Pond	65
P-5	Pocket Pond	50
W-1	Shallow Wetland	40
W-2	ED Wetland	40
W-3	Pond/Wetland	55
W-4	Pocket Wetland	40
I-1	Infiltration Trench	65
I-2	Infiltration Basin	65
F-1	Surface Sand Filter	50
F-2	Underground Sand Filter	50
F-3	Perimeter Sand Filter	50
F-4	Organic Filter	50
F-5	Pocket Sand Filter	40
F-6	Bioretention	50
O-1	Dry Swale	65
O-2	Wet Swale	40

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Table D.4.8 TP Removal Rates for BMPs Not on the List

BMP LIST	TP%
Detention Facility - 2	10
Dry ED Pond - 7	20
Open Channels - 7	-15
Biofilter - 2	25
Dry Well	Nd
Catchbasin - 1	5
Filterstrip - 1	7
Water Quality Inlets - 1	0

Source: Brown and Schueler, 1997, National Pollutant Removal Database for Stormwater BMPs

STEP 6: Define Off-Site Compliance

In the event that on-site BMPs cannot fully meet the pollutant removal requirement and on-site design cannot be changed, an option exists for off-site mediation, otherwise known as an Offset Project. Of primary concern is that the project be associated with pollutant removal or water quality protection for water bodies within the same sub-watershed as the development project. Similarly, off-site projects should be designed to minimize maintenance requirements. In such cases where this is not feasilbe, a maintenance agreement should be established so as to insure long-term water quality protection. Table D.4.9 provides a prioritized list of potential offset projects.

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Table D.4.9 Prioritized List of Potential Offsite Projects

Having shown that on-site compliance is not feasible, the applicant may choose from the following Offset options in order of preference.

1. Construction and operation of an off-site BMP, sized to meet the removal requirements.

2. Retrofit an existing BMP or pond structure.

3. Retrofit an existing storm drain system to encourage infiltration.

4. Reduce the imperviousness of an existing property through reforestation.

5. Implement a riparian reforestation project (0.5 acres of tree planting per lb of removal requirement). Planting plan must meet local Critical Area reforestation standards, or Maryland Forest Conservation Manual, if no local standards exist.

6. In rural jurisdictions where retrofit options are limited, finance the installation of a structural agricultural BMP for a farm with a NRCS approved conservation plan.

7. Other innovative options: restore a degraded tidal or non-tidal wetland that has been disturbed by previous urban or agricultural drainage activity. This may be accomplished through removal of fill, restoration of original water circulation patterns, and wetland plantings.

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Appendix

D.5

Documentation of BMP Ability to Meet the 80% TSS Removal Requirement

BMPs employed at new development in the State of Maryland are now required to meet a performance standard under the recently issued CZARA Coastal Zone 6217(g) management measures guidance (US EPA, 1993). The specific management measures read "After construction is completed and the site is permanently stabilized, reduce the average annual total suspended solid (TSS) loadings by 80% percent...on an average annual basis."

Based on the 90% capture sizing criteria and published pollutant removal performance data, it may be presumed that the BMPs contained on the Acceptable BMP List outlined in Chapter 2 can meet the 80% TSS removal performance standard, if they are designed in accordance with the BMP performance criteria outlined in Chapter 3. The Acceptable BMP List will be periodically updated as new monitoring research is conducted and new stormwater treatment technologies are tested.

Table 1 shows the median sediment removal rate measured or projected for the nineteen stormwater BMPs currently on the approved list. The Table was developed as part of a national assessment of stormwater BMP monitoring research by the Center for Watershed Protection (Brown and Schueler, 1997).

It should be clearly noted that the median values were obtained from a range of research studies that varied widely in respect to geography, climate, design, treatment volume, sampling intensity, and removal efficiency calculation method. In particular, the averages for some pond and wetland designs reflect facilities that were under-sized or poorly designed, which tends to skew averages lower than they would otherwise be. Consequently, the numbers in Table 1 should be considered only as an indicator of expected pollutant removal performance in the State of Maryland.

As can be seen from Table 1, many BMPs on the list are capable of meeting the 80% TSS removal requirement. Nine of the BMPs, however, had median removal rates that ranged from 60% and 79%. As noted earlier, these slightly lower removal rates may have been caused by the fact that datasets include some under-sized or poorly designed practices that reduce the overall median.

In addition, performance monitoring data was not available to assess five practices, and their sediment removal rate had to be projected based on the performance of similar systems. They are:

P-5 Pocket Pond	(presumed to be similar to P-2)
I -2 Infiltration Basin	(published rate based on land application studies [Schueler, 1987])
F-2 Underground Sand Filter	(presumed to be similar to F-1)
F-5 Pocket Sand Filter	(presumed to be similar to F-1)
F-6 Bioretention	(presumed to be similar to O-1)

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Table D.5.1 TSS Removal Performance List

ACCEPTABLE BMPs	N	TSS	80% ?
P-1 Micropool ED	6 (a)	61	yes (b)
P-2 Wet Pond	30	77	yes
P-3 Wet ED Pond	6	60	yes (b)
P-4 Multiple Pond	pr- W-3	72	yes
P-5 Pocket Pond	pr- W-4	nd	yes
W-1 Shallow Wetland	14	84	yes
W-2 ED Wetland	5	62	yes (b)
W-3 Pond/Wetland	11	72	yes (b)
W-4 Pocket Wetland	1	76	yes (b)
I-1 Infiltration Trench	2	89	yes
I-2 Infiltration Basin	0	nd	yes
F-1 Surface Sand Filter	6	83	yes
F-2 Underground Sand Filter	see F-1	nd	yes
F-3 Perimeter Sand Filter	3	79	yes
F-4 Organic Filter	2	81	yes
F-5 Pocket Sand Filter	0	nd	yes
F-6 Bioretention	0	nd	yes (pr)
O-1 Dry Swale	4	93	yes
O-2 Wet Swale	5	74	yes

Notes:
N = number of BMPs sampled
nd = No data
pr = projected removal , based on similar facilities
(a) data from dry ED ponds without micropools
(b) 80% removal can be achieved under proposed design criteria, current database is biased by under-sized or poorly designed facilities

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References

Brown, W. and T. Schueler. 1997. National Pollutant Removal Performance Database for Stormwater BMPs. Center for Watershed Protection. Chesapeake Research Consortium. 220 pp.

U.S. EPA. 1993. Guidance Specifying Management Measures for Sources of Nonpoint Pollution in Coastal Waters. Issued under authority of Section 6217(g) of the Coastal Zone Act Reauthorization Amendments of 1990. No. 840-B-92-002. EPA Office of Water. Washington, D.C.

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Appendix

D.6

Industrial Stormwater NPDES Permit Requirements

Section D.6.1 **Standard Industrial Classification (SIC) Code Identified by EPA in 40 CFR 122.26(b)(14)(i through xi):**

(i) Facilities subject to stormwater effluent limitations...
No specific SIC codes cited. [Contact MDE/WMA for SIC number if not identified previously on another NPDES permit; 410-631-3543 or 410-631-3323.]

(ii)
- 24 (except 2434) Lumber and Wood Products, Except Furniture
  - 2434 - Wood Kitchen Cabinets
- 26 (except 265 and 267) Paper and Allied Products
  - 265 - Paperboard Containers and Boxes
  - 267 - Converted Paper and Paperboard Products, Except Containers and Boxes
- 28 (except 283) Chemicals and Allied Products
  - 283 - Drugs
- 29 Petroleum Refining and Related Industries
- 31 Leather and Leather Products
- 32 (except 323) Stone, Clay, Glass, and Concrete Products
  - 323 - Glass Products made of Purchased Glass
- 33 Primary Metal Industries
- 344 Fabricated Structural Metal Products
- 373 Ship and Boat Building and Repairing

(iii)
- 10 Metal Mining
- 12 Coal Mining
- 13 Oil and Gas Extraction (including facilities where stormwater comes into contact with overburden or raw materials)
- 14 Mining and Quarrying of Nonmetallic Minerals, Except Fuels

(iv) Hazardous waste treatment, storage or disposal facilities.
No specific SIC codes cited. [Contact MDE/WMA for SIC number if not identified previously on another NPDES permit; 410-631-3543 or 410-631-3323.]

(v) Landfills, land application sites, and open dumps...
No specific SIC codes cited. [Contact MDE/WMA for SIC number if not identified previously on another NPDES permit; 410-631-3543 or 410-631-3323.]

(vi) Facilities involved in the recycling of materials...
including, but not limited to;
- 5015 Motor Vehicle Parts, Used
- 5093 Scrap and Waste Materials

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(vii) Steam electric power general facilities...
No specific SIC codes cited. [Contact MDE/WMA for SIC number if not identified previously on another NPDES permit; 410-631-3543 or 410-631-3323.]

(viii) Transportation facilities classified as:
- 40 Railroad Transportation
- 41 Local and Suburban Transit and Interurban Highway Passenger Transportation
- 42 (except 4221-4225) Motor Freight Transportation and Warehousing
  - 4221 - Farm Product Warehousing and Storage
  - 4222 - Refrigerated Warehousing and Storage
  - 4225 - General Warehousing and Storage
- 43 United States Postal Service
- 44 Water Transportation
- 45 Transportation by Air
- 5171 Petroleum Bulk Stations and Terminals

(ix) Treatment works treating domestic sewage...
No specific SIC codes cited. [Contact MDE/WMA for SIC number if not identified previously on another NPDES permit; 410-631-3543 or 410-631-3323.]

(x) Construction Activity
See attached SIC code list for construction activity [Major Group Number 15].

(xi)
- 20 Food and Kindred Products
- 21 Tobacco Products
- 22 Textile Mill Products
- 23 Apparel and other Finished Products made from Fabrics and Similar Materials
- 2434 Wood Kitchen Cabinets
- 25 Furniture and Fixtures
- 265 Paperboard Containers and Boxes
- 267 Converted Paper and Paperboard Products, Except Containers and Boxes
- 27 Printing, Publishing, and Allied Industries
- 283 Drugs
- 285 Paints, Varnishes, Lacquers, Enamels, and Allied Products
- 30 Rubber and Miscellaneous Plastics Products
- 31 (except 311) Leather and Leather Products
  - 311 - Leather Tanning and Finishing
- 323 Glass Products, made of Purchased Glass
- 34 (except 3441) Fabricated Metal Products, Except Machinery and Transportation Equipment
  - 3441 - Fabricated Structural Metal
- 35 Industrial and Commercial Machinery and Computer Equipment
- 36 Electronic and other Electrical Equipment and Components, Except Computer Equipment

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37 (except 373) Transportation Equipment
373 - Ship and Boat Building and Repairing
38 Measuring, Analyzing, and Controlling Instruments; Photographic, Medical and Optical Goods; Watches and Clocks
39 Miscellaneous Manufacturing Industries
4221 Farm Product Warehousing and Storage
4222 Refrigerated Warehousing and Storage
4225 General Warehousing and Storage

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Section D.6.2 General Discharge Permit - Sample

GENERAL DISCHARGE PERMIT FOR STORM WATER ASSOCIATED WITH INDUSTRIAL ACTIVITIES

GENERAL DISCHARGE PERMIT NO. 97-SW-

GENERAL NPDES PERMIT NO. MDR_____

Effective Date: _____

Expiration Date: _____

Part I. APPLICABILITY.

A. Geographic Coverage. This permit covers all areas of the State of Maryland.

B. Eligible Discharges. This permit may cover all storm water discharges associated with industrial activity, as defined in 40 CFR 122.26, that discharge to surface waters of the State. Such discharges may be commingled with wastewater or water discharges not regulated by this permit. This permit also covers storm water discharges not included in 40 CFR 122.26 that the Department determines would, if not regulated by a permit, be likely to contribute to a violation of a water quality standard or be a significant contributor of pollutants to waters of the State, either surface or ground.

C. Ineligible Discharges. The following discharges are not covered under this general permit.

1. Storm water discharges from any construction activity, as defined in 40 CFR 122.26, except for construction activity associated with an industrial facility that is or will be covered by this permit;

2. Storm water discharges that are regulated by effluent limitation guidelines. All or part of the storm water from the following industries are covered by effluent limitation guidelines: cement manufacturing (40 CFR 411), feedlots (40 CFR 412), fertilizer manufacturing (40 CFR 418), petroleum refining (40 CFR 419), phosphate manufacturing (40 CFR 422), steam electric generating (40 CFR 423), coal mining (40 CFR 434), mineral mining and processing (40 CFR 436), ore mining and dressing (40 CFR 440), and asphalt emulsion (40 CFR 443);

3. Storm water discharges associated with industrial activity from inactive mining or inactive oil and gas operations occurring on federal lands; and

4. Storm water discharges whose NPDES permit has been terminated (other

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than at the request of the permittee) or denied, or those for which the Department requires an individual permit or an alternative general permit.

D. Individual Permit or Another General Permit Required.

1. Any person who conducts activities which are covered by this General Permit and does not have a valid individual discharge permit is required to apply for coverage under this General Permit within 60 days of the issuance of the permit.

2. The Department may require any person authorized by this permit to apply for and obtain an individual State or State/NPDES discharge permit or to obtain coverage under another general permit. If an owner or operator fails to submit, in a timely manner, an application for an individual State or State/NPDES discharge permit or a Notice of Intent (NOI) for another general permit as required by the Department under this condition, the applicability of this permit to the owner or operator is automatically terminated at the end of the day specified by the Department for the application or NOI submittal.

3. Any person authorized by this permit may request to be excluded from coverage under this permit by applying for an individual State or State/NPDES discharge permit or requesting coverage under another general permit. The Department may grant this request by issuing an individual State or a State/NPDES discharge permit or by granting coverage under another general permit, if the reasons cited by the owner or operator are adequate to support the request.

4. When an individual State or State/NPDES discharge permit is issued to a person otherwise subject to this permit, the applicability of this permit to the permittee is automatically terminated on the effective date of the individual State or State/NPDES discharge permit.

5. If there is evidence indicating potential or realized impacts on water quality due to any activity covered by this permit, the owner or operator of such discharge may be required to obtain an individual State or a State/NPDES discharge permit or coverage under another general permit.

6. If a person otherwise covered under this permit is denied coverage under an individual State or a State/NPDES discharge permit, or another general permit, the denial automatically terminates, on the date of the denial, the person's coverage under this general permit, unless otherwise specified by the Department.

7. The Department may terminate coverage under this general permit for an existing permittee if the Department finds that:

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a. The NOI contained false or inaccurate information;

b. Conditions or requirements of the discharge permit have been or are about to be violated;

c. Substantial deviation from plans, specifications, or requirements has occurred;

d. The Department has been refused entry to the premises for the purpose of inspecting to insure compliance with the conditions of the discharge permit;

e. A change in conditions exists that requires temporary or permanent reduction or elimination of the permitted discharge;

f. Any State or federal water quality stream standard or effluent standard has been or is likely to be violated; or

g. Any other good cause exists for denying coverage under this permit.

E. Authorization. To be authorized to discharge under this general permit, a person is required to submit an NOI in accordance with the requirements of Part III of this permit, to pay the required fee, and to comply with the terms and conditions of this permit. Coverage under this permit is effective on the date that the NOI is acknowledged by the Department and the NOI fee is paid to the Department in accordance with the terms stipulated in Part III below. A person who submits such an NOI is notified of its acceptance by the Department, complies with the terms and conditions of this permit, and pays the required fee is authorized to discharge under the terms and conditions of this permit.

If the NOI fee is paid by a check which does not clear for any reason, the person will be given 30 calendar days to make proper payment including any interest and other charges that are due. If payment is not made within this time, coverage under this permit shall be considered void from the outset. The permittee should save the cancelled check, a copy of the completed NOI, and related documents. These documents shall be provided to the Department upon request.

F. Transfer of Authorization.

1. The authorization under this permit is not transferable to any person except in accordance with this section.

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2. Authorization to discharge under this permit may be transferred to another person if:

a. The current permittee notifies the Department (Industrial Discharge Permits Division with copy sent to Inspection and Compliance Program) in writing of the proposed transfer;

b. A written agreement, indicating the specific date of the proposed transfer of permit coverage and acknowledging the responsibilities of the current and new permittee for compliance with the terms and conditions of this permit, is submitted to the Department;

c. The new permittee either confirms in writing that the type of discharge, number of outfalls, and other information given on the original NOI remain correct or updates this information;

d. The new permittee confirms in writing that either they will follow the existing storm water pollution prevention plan or that they have developed a new plan; and

e. Neither the current permittee nor the new permittee receives notification from the Department, within 30 days of receipt of items I.F.2.a through d above, of intent to terminate coverage under this permit.

3. The Department may continue coverage for the new permittee under this permit or may require the new permittee to apply for and obtain an individual State or State/NPDES discharge permit or obtain coverage under another general permit.

4. A new owner of a facility is responsible for any fees unpaid by the former owner.

G. Continuation of an Expired General Permit. An expired general permit continues in force and effect until a new general permit is issued; for the next 60 days provided the permittee submits a new NOI and fee within that period; or until the general permit is revoked or withdrawn. Only those permittees authorized to discharge prior to the expiration of the general permit are covered by the continued permit.

Part II. Definitions.

A. "Best management practices (BMP)" means schedules of activities, prohibitions of practices, maintenance procedures, and other management practices to prevent or reduce the pollution of waters of this State. BMP also include treatment requirements, operating procedures, and practices to control plant site runoff, spillage or leaks, sludge or waste disposal, or drainage from raw materials storage.

B. "CFR" means Code of Federal Regulations.

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C. "COMAR" means Code of Maryland Regulations.

D. "Construction activity" means clearing, grading, and excavation activities except: operations that result in the disturbance of less than five acres (or whatever threshold is currently specified in 40 CFR 122.26) of total land area which are not a part of a larger common plan of development or sale.

E. "Department" means the Maryland Department of the Environment. Unless stated otherwise, all submissions to the Department shall be directed to the attention of the Industrial Discharge Permits Division.

F. "Federal Clean Water Act" means the federal Water Pollution Control Act Amendments of 1972, its amendments and all rules and regulations adopted thereunder.

G. "General permit" means a discharge permit issued for a class of dischargers.

H. "Ground water" means underground water in a zone of saturation.

I. "Includes" or "including" means includes or including by way of illustration and not by way of limitation.

J. "NPDES permit" means a National Pollutant Discharge Elimination System permit issued under the federal Clean Water Act.

K. "NOI" means Notice of Intent to be covered by this permit (see Part III of this permit).

L. "Operator" means that person or those persons with responsibility for the management and performance of each facility.

M. "Permittee" means the person holding a permit issued by the Department.

N. "Person" means an individual, receiver, trustee, guardian, personal representative, fiduciary, or representative of any kind, and any partnership, firm, association, corporation, or other entity. Person includes the federal government, this State, any county, municipal corporation or other political subdivision of this State or any of their units.

O. "Project" means the total area upon which construction activity will occur through stages or phases over time.

P. "Section 313 water priority chemical" means a chemical or chemical categories which: 1) are listed at 40 CFR 372.65 pursuant to Section 313 of Title III of the Superfund Amendments and Reauthorization Act (SARA) of 1986, also titled the Emergency Planning and Community Right-to-Know Act of 1986; 2) are present at or above threshold levels at a facility subject to

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SARA Title III, Section 313 reporting requirements; and 3) that meet at least one of the following criteria: (i) are listed in Appendix D of 40 CFR 122 on either Table II (organic priority pollutants), Table III (certain metals, cyanides, and phenols) or Table V (certain toxic pollutants and hazardous substances); (ii) are listed as a hazardous substance pursuant to Section 311(b)(2)(A) of the Clean Water Act at 40 CFR 116.4; or (iii) are pollutants for which EPA has published acute or chronic water quality criteria.

Q. "Significant materials" includes, but is not limited to: raw materials; fuels; materials such as solvents, detergents, and plastic pellets; finished materials, such as metallic products; raw materials used in food processing or production; hazardous substances designated under Section 101(14) of CERCLA; any chemical the facility is required to report pursuant to Section 313 of Title III of SARA; fertilizers; pesticides; and waste products, such as ashes, slag and sludge that have the potential to be released with storm water discharges.

R. "Significant spills" includes, but is not limited to: releases of oil or hazardous substances in excess of reportable quantities under Section 311 of the Clean Water Act (40 CFR 110.10 and 40 CFR 117.21) or Section 102 of CERCLA (40 CFR 302.4).

S. "State discharge permit" means a discharge permit issued pursuant to the Environment Article, Title 9, Subtitle 3, Annotated Code of Maryland.

T. "Storm water associated with construction activity" means the discharge from any conveyance which is used for collecting and conveying storm water and which is directly related to clearing, grading, and excavation activities. For this permit, groundwater that seeps into construction excavations shall be considered and regulated as storm water.

U. "Storm water associated with industrial activity" means storm water as defined in 40 CFR 122.26(b)(14).

V. "Surface waters" means all waters of this State which are not ground waters.

W. "Wastewater" means any:

1. Liquid waste substance derived from industrial, commercial, municipal, residential, agricultural, recreational, or other operations or establishments; and

2. Other liquid waste substance containing liquid, gaseous or solid matter and having characteristics which will pollute any waters of this State.

X. "Waters of this State" includes:

1. Both surface and underground waters within the boundaries of this State subject to its jurisdiction, including that part of the Atlantic Ocean within the boundaries of this State,

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the Chesapeake Bay and its tributaries, and all ponds, lakes, rivers, streams, tidal and nontidal wetlands, public ditches, tax ditches, and public drainage systems within this State, other than those designed and used to collect, convey, or dispose of sanitary sewage; and

2. The flood plain of free-flowing waters determined by the Department of the Environment on the basis of the 100-year flood frequency.

PART III. Notice of Intent Requirements.

A. Deadlines for Notification. Any person who has an existing individual State or State/NPDES discharge permit for activities covered under this general permit is not obligated to obtain coverage under this general permit until the individual State or State/NPDES discharge permit expires. At least 180 days prior to the expiration date of the individual State or State/NPDES discharge permit for activities covered under this general permit, a person shall submit an NOI requesting coverage under this general permit. However, a person currently covered under an individual State or State/NPDES discharge permit may choose to request coverage under this general permit by submitting an NOI and a fee in accordance with the requirements of this Part following issuance of this general permit. At least 30 days prior to the commencement of any new storm water discharge covered under this general permit, a person shall request coverage by submitting an NOI in accordance with the requirements of this Part. Any person who is covered under 92-GP-0001 shall submit a new NOI and fee within 60 days of issuance to continue coverage. A person planning construction activity (disturbing five or more acres) at an industrial facility must submit an NOI or updated NOI at least 48 hours prior to any land disturbing activities. The Department may bring an enforcement action for failure to submit an NOI in a timely manner, or for any unauthorized discharges that occurred prior to obtaining coverage under this permit.

B. Notice of Intent. A person shall obtain the appropriate NOI form from the Department, and shall provide the following information:

1. County, name and address (location) of the facility;
2. Name and telephone number of the facility contact;
3. Written description of industrial activity taking place;
4. One four-digit SIC code that best represent the principal products or activities provided by the facility;
5. Watershed basin code;
6. The latitude and longitude of the approximate center of the facility to the nearest 15 seconds;
7. The name of the receiving water(s), or if the discharge is to a municipal separate storm sewer, the name of the municipal operator of the storm sewer and the ultimate receiving water(s);
8. Permit number of any other NPDES permit issued for the facility;
9. Area of industrial activity at facility in acres;
10. Status of owner/operator (private, Federal, etc);
11. Federal tax ID number;

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12. Name and mailing address of applicant (company that operates the permitted facility;
13. Name and telephone number of operator contact;
14. A summary of all existing quantitative data, if any, describing the concentration of pollutants in storm water discharges;
15. Where construction is involved, a brief project description, including existing and proposed land uses;
16. Where construction is involved, the total site area, the total proposed disturbed area, the type(s) of storm water management best management practice(s) (BMP) proposed, and the total drainage area to be controlled by each type of BMP; and
17. Signiture of applicant.

If a person operates multiple facilities, an NOI is required for each noncontiguous site.

C. Discharge Permit Fee

Persons who intend to obtain coverage under this general permit shall submit to the Department a fee of $550 with the NOI application. Local and state governments are not required to pay a fee.

As an alternative to a single fee, a person may submit five annual $120 payments beginning with the submission of the NOI application and every July 1 thereafter.

For facilities which did not begin operating until after September 29, 1995 and which were previously registered under permit 92-GP-0001, the total fee shall be discounted by 100 dollars for each full calendar year between January 1, 1993 and the month which operations began.

The discharge fee for new facilities that have commenced operating after July 1 of any year shall be prorated on a monthly basis.

D. Required Signatures.

1. Certification. Any person signing an NOI shall make the following certification as part of the NOI.

"I certify under penalty of law that this document and all attachments were prepared under my direction or supervision in accordance with a system designed to assure that qualified personnel properly gather and evaluate the information submitted. Based on my inquiry of the person or persons who manage the system, or those persons directly responsible for gathering the information, the information submitted is, to the best of my knowledge and belief, true, accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine and imprisonment for knowing violations."

2. Signatories. The NOI shall be signed as follows:

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a. For a corporation: by a responsible corporate officer. For the purpose of this section, a responsible corporate officer means:

(i) A president, secretary, treasurer, or vice-president of the corporation in charge of a principal business function, or any other person who performs similar policy or decision-making functions for the corporation; or

(ii) The manager of one or more manufacturing, production, or operating facilities employing more than 250 persons or having gross annual sales or expenditures exceeding $25 million (in second-quarter 1980 dollars), if authority to sign documents has been assigned or delegated to the manager in accordance with corporate procedures.

b. For a partnership or sole proprietorship: by a general partner or the proprietor, respectively; or

c. For a municipal, State, federal, or other public agency: by either a principal executive officer or ranking elected official. For purposes of this section, a principal executive officer of a federal agency includes:

(i) The chief executive officer of the agency; or

(ii) A senior executive officer having responsibility for the overall operations of a principal geographic unit of the agency (e.g., Regional Administrators of EPA).

3. Report Submission.

a. All reports required by permits, and other information requested by the Department shall be signed by a person described in Part III E.2 or by a duly authorized representative of that person. A person is a duly authorized representative only if:

(i) The authorization is made in writing by a person described in Part III E.2;

(ii) The authorization specifies either an individual or a position having responsibility for the overall operation of the regulated facility or activity such as the position of plant manager, operator of a well or a well field, superintendent, position of equivalent responsibility or an individual or position having overall responsibility for environmental matters for the company; and

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(iii) The written authorization is submitted to the Department.

b. If an authorization under this subsection is no longer accurate because a different individual or position has responsibility for the overall operation of the facility, a new authorization satisfying the requirements of Part III E.3(a) must be submitted to the Department prior to or together with any reports, information or applications to be signed by the new authorized representative.

E. Where to Submit. A person shall submit a signed copy of the NOI and the required fee, made payable to the Maryland Department of the Environment, to the following address:

Maryland Department of the Environment
P.O. Box 2057
Baltimore MD 21203-2057

F. Failure to Notify. Persons who discharge storm water associated with industrial activity, who fail to notify the Department of their intent to be covered under this permit, and who discharge to waters of this State without an individual State or State/NPDES discharge permit, are in violation of the federal Clean Water Act and the Environment Article, Annotated Code of Maryland, and may be subject to penalties.

G. Additional Notification.

Facilities which discharge storm water associated with industrial activity to the municipal separate storm sewer system of Anne Arundel County, Baltimore (City), Baltimore County, Carroll County, Charles County, Frederick County, Harford County, Howard County, Montgomery County, Prince George's County, or the State Highways Administration shall, in addition to filing copies of the NOI in accordance with condition III.B., submit, concurrently, signed copies of the NOI to the operator of the municipal separate storm sewer to which they discharge (see NOI form for addresses).

H. Permit Expiration and Renewal. Within 60 days after the reissuance of this general permit with new effective and expiration dates, the permittee is required to submit to the Department either:

1. A notice that the discharge or industrial activity (including the exposure of residual pollutants from concluded industrial activity) will cease by the expiration date of this permit; or

2. A new NOI and any fee in accordance with the requirements of the reissued general permit in order to be covered under the reissued general permit.

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Part IV. Special Conditions.

A. Releases In Excess Of Reportable Quantities

1. The discharge of hazardous substances or oil in the storm water discharge(s) from a facility shall be prevented or minimized in accordance with the applicable storm water pollution prevention plan for the facility. This permit does not relieve the permittee of the reporting requirements of 40 CFR part 117 and 40 CFR part 302. Except as provided in condition IV.A.2 (multiple anticipated discharges) of this permit, where a release containing a hazardous substance in an amount equal to or in excess of a reporting quantity established under either 40 CFR 117 or 40 CFR 302, occurs during a 24-hour period:

a. The discharger is required to notify the Department of any oil spill or discharge of oil by calling its Emergency Response Division at (410) 974-3551 and notify the National Response Center (NRC) at (800) 424-8802 or, in the Washington, DC metropolitan area, at (202) 426-2675 in accordance with the requirements of COMAR 26.10.01.03, 40 CFR 117 and 40 CFR 302 respectively as soon as he or she has knowledge of the discharge;

b. The permittee shall submit to the Department within 10 working days of knowledge of the release a written description of: the release (including the type and estimate of the amount of material released), the date that such release occurred, the circumstances leading to the release, and steps to be taken in accordance with condition IV.A.1.c (below) of this permit, and any other information as required by COMAR 26.10.01.03; and

c. The storm water pollution prevention plan required under condition IV.B (storm water pollution prevention plans) of this permit must be modified within 14 calendar days of knowledge of the release to: provide a description of the release, the circumstances leading to the release, and the date of the release. In addition, the plan must be reviewed to identify measures to prevent the reoccurrence of such releases and to respond to such releases, and the plan must be modified where appropriate.

2. Multiple Anticipated Discharges - Facilities which have more than one anticipated discharge per year containing the same hazardous substance in an amount equal to or in excess of a reportable quantity established under either 40 CFR 117 or 40 CFR 302, which occurs during a 24-hour period, where the discharge is caused by events occurring within the scope of the relevant operating system shall comply with conditions IV.A.1.a,b, and c above, but must submit notifications only for the first such release that occurs during a calendar year (or for the first year of this permit, after submittal of an NOI).

3. Spills. This permit does not authorize the discharge of hazardous substances or oil resulting from an on-site spill.

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B. Storm Water Pollution Prevention Plans - General

The permittee shall develop a storm water pollution prevention plan for each facility covered by this permit. The storm water pollution prevention plan shall be prepared in accordance with sound engineering practices. The plan shall identify potential sources of pollution which may reasonably be expected to affect the quality of storm water discharges associated with industrial activity from the facility. In addition, the plan shall describe and ensure the implementation of practices which are to be used to reduce the pollutants in storm water discharges associated with industrial activity at the facility and to assure compliance with the terms and conditions of this permit.

1. In developing this plan, the permittee shall use as a reference "Storm Water Management for Industrial Activities: Developing Pollution Prevention Plans and Best Management Practices" (EPA Document #EPA832-R-92-006) or, when it is available, an EPA-published summary document on the same subject. These documents can be obtained from the National Technical Information Service, 5285 Port Royal Road, Springfield, Virginia 22161 (phone: 703-487-4600).

2. The plan shall be signed in accordance with Part III, Section E.2 of this permit, and be retained on site in accordance with Part VI, Section A.2 of this permit. Plans for facilities in existence at the time of the issuance of this permit shall be completed within one year of obtaining coverage under this general permit or within one year of notification by the Department of the need for obtaining a storm water discharge permit, whichever occurs first. Plans shall provide for compliance with the terms of the plan within 18 months of obtaining coverage under this general permit or within 18 months of notification by the Department of the need for obtaining a storm water discharge permit, whichever occurs first. In the case of new facilities, the plan shall be completed and implemented prior to submitting an NOI to be covered under this permit. The permittee shall make plans available upon request to the Department, and in the case of a storm water discharge associated with industrial activity which discharges to a municipal separate storm sewer system with an NPDES permit, to the municipal operator of the system (those systems are listed in Condition III. G, addresses are on NOI).

3. If the plan is reviewed by the Department, the Department may notify the permittee, at any time, that the plan does not meet one or more of the minimum requirements of this Part. After such notification from the Department, the permittee shall make changes to the plan to meet the objections of the Department and shall submit to the Department a written certification that the requested changes have been made and implemented. Unless otherwise provided by the Department, the permittee shall have 90 days after such notification to make the necessary changes.

4. The permittee shall amend the plan whenever there is a change in design, construction, operation, or maintenance which has a significant effect on the potential for the discharge of pollutants to the waters of the State or if the storm water pollution prevention plan proves to be

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ineffective in achieving the general objectives of controlling pollutants in storm water discharges associated with industrial activity. Amendments to the plan may be reviewed by the Department as described above.

C. Storm Water Pollution Prevention Plan - Contents

The plan shall include, at a minimum, the following items:

1. **Description of Potential Pollutant Sources**

Each plan shall provide a description of potential sources which may be reasonably expected to add significant amounts of pollutants to storm water discharges. Each plan shall identify all activities and significant materials which may potentially be significant pollutant sources. Each plan shall include:

a. A site map indicating an outline of the drainage area of each storm water outfall; each existing structural control measure to reduce pollutants in storm water runoff; and surface water bodies, including drainage ditches and wetlands.

b. A topographic map (or other map, if a topographic map is unavailable), extending one-quarter of a mile beyond the property boundaries of the facility. The requirements of this condition may be included in the site map required under Part IV, Section C.1.a. above, if appropriate.

c. A narrative description of significant materials that have been treated, stored, or disposed in a manner which allowed exposure to storm water at anytime from three years prior to obtaining coverage under this permit until the time the present method of on-site storage or disposal was initiated; materials management practices employed to minimize contact of these materials with storm water runoff; materials loading and access areas; the location and a description of existing structural and non-structural control measures to reduce pollutants in storm water runoff; and a description of any treatment the storm water receives.

d. For each area of the facility that generates storm water discharges associated with industrial activity with a reasonable potential for containing significant amounts of pollutants, a prediction of the direction of flow, and an estimate of the types of pollutants which are likely to be present in storm water discharges associated with industrial activity; and

e. A summary of all existing sampling data describing pollutants in storm water discharges.

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2. **Storm Water Management Controls**

Each facility covered by this permit shall develop a description of storm water management controls appropriate for the facility, and implement such controls. The appropriateness and priorities of controls in a plan shall reflect identified potential sources of pollutants at the facility. The description of storm water management controls shall address the following minimum components, including a schedule for implementing such controls:

a. **Preventive Maintenance.** A preventive maintenance program that involves timely inspection and maintenance of storm water management devices (cleaning oil/water separators, catch basins) as well as inspecting and testing plant equipment and systems to uncover conditions that could cause breakdowns or failures resulting in discharges of pollutants to surface waters.

b. **Good Housekeeping.** Good housekeeping that requires the maintenance of a clean, orderly facility.

c. **Spill Prevention and Response Procedures.** If spills have a potential to occur, procedures for cleaning up spills shall be identified in the plan and made known to the appropriate personnel. The necessary equipment to implement a cleanup shall be available to the appropriate personnel.

d. **Sediment and Erosion Prevention.** The plan shall identify areas which, due to topography, activities, or other factors, have a high potential for significant soil erosion, and identify measures to limit erosion.

e. **Management of Runoff.** The plan shall contain a narrative consideration of the appropriateness of traditional storm water management practices (practices other than those which control the generation or source(s) of pollutants) used to divert, infiltrate, reuse, or otherwise manage storm water runoff in a manner that reduces pollutants in storm water discharges from the site. The plan shall provide that measures determined to be reasonable and appropriate shall be implemented and maintained. The potential of various sources at the facility to contribute pollutants to storm water discharges associated with industrial activity (see Part IV, Section C.1. - description of potential pollutant sources) shall be considered when determining reasonable and appropriate measures. Appropriate measures may include: vegetative swales and practices, reuse of collected storm water (such as for a process or as an irrigation source), inlet controls (such as oil/water separators), snow management activities, infiltration devices, and wet detention/retention devices.

f. **Visual Inspections.** Qualified plant personnel shall be identified to inspect designated equipment and plant areas. A site inspection shall be conducted annually by such personnel to verify that the description of potential pollutant sources required under Part IV, Section C.1. is accurate, the drainage map has been updated to reflect current conditions, and the controls to reduce pollutants identified in the storm water pollution prevention plan are being

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implemented and are adequate. In particular, material handling areas shall be inspected for evidence of, or the potential for, pollutants entering the drainage system. A tracking or follow-up procedure shall be used to ensure that each inspection results in an appropriate response.

g. **Recordkeeping and Internal Reporting Procedures.** Spills or other discharge incidents, and information describing the quality and quantity of storm water discharges shall be in the facility records. Maintenance activities shall be documented and recorded with inspection and discharge records. All records shall be maintained at the facility, for a minimum of three years. This period shall be automatically extended during the course of litigation, or when requested by the Department.

3. **Consistency with Other Plans**

Storm water management programs may include requirements for Spill Prevention Control and Countermeasure (SPCC) plans under Section 311 of the Clean Water Act or Best Management Practices (BMPs) programs otherwise required by an NPDES permit and may incorporate any part of such plans into the storm water pollution prevention plan by reference.

4. **Special Requirements for Storm Water Discharges Associated with Industrial Activity to Municipal Separate Storm Sewer Systems Serving a Population of 100,000 or More**

Facilities covered by this permit shall comply with applicable requirements in municipal storm water management programs developed under State/NPDES permits issued for the discharge of the municipal separate storm sewer system that receives the facility's discharge, provided the municipal operator has notified the discharger of such conditions. These facilities shall make storm water pollution prevention plans available to the municipal operator of the system upon request.

5. **Salt Storage**

Storage piles of salt used for deicing or other commercial or industrial purposes shall be enclosed or covered to prevent exposure to precipitation.

6. **Pollution Prevention Committee**

The description of the storm water Pollution Prevention Committee shall identify specific individuals within the plant organization who are responsible for developing the storm water pollution prevention plan and assisting the plant manager in its implementation, maintenance, and revision. The activities and responsibilities of the committee should address all aspects of the facility's storm water pollution prevention plan.

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7. **Employee Training**

Employee training programs shall inform personnel at all levels of responsibility of the components and goals of the storm water pollution prevention plan. Training should address topics, such as spill response, good housekeeping and material management practices. A pollution prevention plan shall identify periodic dates for such training.

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D. STORM WATER POLLUTION PREVENTION PLAN - ADDITIONAL REQUIREMENTS FOR FACILITIES SUBJECT TO SARA TITLE III, Section 313 REQUIREMENTS

Storm water pollution prevention plans for facilities subject to reporting requirements under SARA Title III, Section 313 (42 U.S.C.§11023) are required to include, in addition to the information listed in Part IV, Section C., a discussion of the facility's conformance with the following (appropriate) guidelines:

1. In areas where Section 313 water priority chemicals are stored, processed or otherwise handled, appropriate containment, drainage control and/or diversionary structures shall be provided. At a minimum, one of the following preventive systems or its equivalent shall be used:

a. Curbing, culverting, gutters, sewers or other forms of drainage control to prevent or minimize the potential for storm water runoff to come into contact with significant sources of pollutants; or

b. Roofs, covers, liners, or other forms of appropriate protection to prevent storage piles from leaching or exposure to storm water and wind.

2. The storm water pollution prevention plan shall include a complete discussion of measures taken to conform with the following applicable guidelines, other effective storm water pollution prevention procedures, and applicable State rules, regulations and guidelines.

a. **Liquid storage areas where storm water comes into contact with any equipment, tank, container, or other vessel used for Section 313 water priority chemicals.** No tank or container shall be used for the storage of a Section 313 water priority chemical unless its material and construction are compatible with the material stored and conditions of storage, such as pressure and temperature, etc. Liquid storage areas for Section 313 water priority chemicals shall be operated to minimize discharges of Section 313 chemicals by means such as secondary containment for at least the entire contents of the largest single tank plus sufficient freeboard to allow for precipitation, a strong spill contingency and integrity testing plan, and/or other equivalent measures.

b. **Truck and rail car loading and unloading areas for liquid Section 313 water priority chemicals**. These areas shall be operated to minimize discharges of Section 313 water priority chemicals by means such as the placement and maintenance of drip pans (including the proper disposal of materials collected in the drip pans) where spillage may occur (such as hose connections, hose reels and filler nozzles) for use when making and breaking hose connections; a strong spill contingency and integrity testing plan; and/or other equivalent measures.

c. **In plant areas where Section 313 water priority chemicals are transferred, processed or otherwise handled.** Piping, processing equipment and materials handling

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equipment shall be designed and operated so as to prevent discharges of Section 313 chemicals, and be composed of materials that are compatible with the substances handled. Additional protection, such as covers or guards to prevent wind blowing, spraying or releases from pressure relief vents from causing a discharge of Section 313 water priority chemicals to the drainage system shall be provided, as appropriate, to control the releases.

d. **Discharges from secondary containment areas.**

(1) Drainage from secondary containment shall be restrained by valves or other positive means to prevent a spill or other excessive leakage of Section 313 water priority chemicals into the drainage system. After a visual inspection of the storm water and determination that no product is present, containment areas may be emptied by pumps or ejectors; however, these shall be manually activated.

(2) Flapper-type drain valves shall not be used to drain containment areas. Valves used for the drainage of containment areas shall be of manual, open-and-close design.

(3) Records of the frequency and estimated volume (in gallons) of discharges from containment areas shall be kept at the facility for a minimum of three years.

(4) In lieu of facility drainage engineered as described above, the final discharge of all in-facility storm sewers shall be equipped with a diversion system that could, in the event of an uncontrolled spill of Section 313 water priority chemicals, return the spilled material to the facility.

(5) **Facility site runoff other than from areas covered by (a), (b), (c) or (d).** Other areas of the facility [those not addressed in paragraphs (a), (b), (c) or (d)], from which runoff which may contain Section 313 water priority chemicals or spills of Section 313 water priority chemicals and which could cause a discharge shall incorporate the necessary drainage or other control features to prevent discharge of spilled or improperly disposed material and ensure the mitigation of pollutants in runoff or leachate.

3. **Facility Security**

Facilities shall have the necessary security systems to prevent accidental or intentional entry which could cause a discharge. Security systems shall be described in the plan and address fencing, lighting, vehicular traffic control, and securing of equipment and buildings.

4. **Risk Identification and Assessment/Material Inventory**

The storm water pollution prevention plan shall assess the potential of various sources at the plant to contribute pollutants to storm water discharges associated with industrial activity. The plan shall include an inventory of the types of materials handled. Facilities shall include in

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the plan a description of releases to land or water of SARA Title III water priority chemicals that have occurred at any time after July 1, 1989. Each of the following shall be evaluated for the reasonable potential for contributing pollutants to runoff: loading and unloading operations; outdoor storage activities; outdoor manufacturing or processing activities; significant dust or particulate generating processes; and on-site waste disposal practices. Factors to consider include the toxicity of chemicals; quantity of chemicals used, produced, or discharged: the likelihood of contact with storm water; and history of significant leaks or spills of toxic or hazardous pollutants.

E. STORM WATER POLLUTION PREVENTION PLAN - ADDITIONAL REQUIREMENTS FOR CONSTRUCTION ACTIVITY

1. **Plans and Approvals**

Prior to commencing construction, the permittee shall obtain approved erosion and sediment control plans in accordance with the requirements established in Title 4, Subtitle 1 of the Environment Article, Annotated Code of Maryland (Sediment Control); and in Code of Maryland Regulations (COMAR) 26.09.01 (Erosion and Sediment Control); and shall obtain approved storm water management plans in accordance with the requirements established in Title 4, Subtitle 2 of the Environment Article, Annotated Code of Maryland (Storm Water Management); and in COMAR 26.09.02 (Storm Water Management).

2. **Monitoring and Records**

For the purposes of monitoring, permittees must do all of the following:

a. During construction, maintain at the site the approved erosion and sediment control plan.

b. Conduct the following inspections:

(1) weekly inspections of implemented erosion and sediment controls; and
(2) inspections of erosion and sediment controls the next business day after a rainfall event resulting in runoff.

c. During construction, maintain at the site written reports of all inspections conducted by the permittee that include:

(1) the date and time of the inspection;
(2) the name(s) of the individual(s) who performed the inspection;
(3) an assessment of the condition of erosion and sediment controls;
(4) a description of any erosion and sediment control implementation and maintenance performed; and

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(5) a description of the site's present phase of construction.

d. Maintain all inspection reports and enforcement actions issued to the permittee by the appropriate enforcement authority.

e. Permittees must retain the records described in Part IV. E. 2. a., c., and d. and records of all data used to complete the NOI to be covered by this permit for a period of three (3) years from the date that the site is finally stabilized.

3. Duty to Comply With Plans

It is a condition of this permit that the permittee comply with erosion and sediment control and storm water management plans approved in accordance with the laws and regulations cited in Part IV. E. 1 above, and with all conditions of this general permit

4. Continuation of Coverage Under This Permit

Once construction has commenced, it is a condition of this permit that erosion and sediment control and storm water management plan approvals be kept in effect. Construction activity may not continue if these plans have expired, but may resume once plans are renewed without payment of an additional fee.

V. Violation of Permit Conditions.

A. Compliance With This General Permit and Water Pollution Abatement Statutes. The permittee shall comply at all times with the terms and conditions of this permit, the provisions of the Title 7, Subtitle 2, Title 9, Subtitles 2 and 3 of the Environment Article, Annotated Code of Maryland, and the Federal Act.

B. Civil and Criminal Liability. In issuing or reissuing this permit, the Department does not waive or surrender any right to proceed in an administrative, civil, or criminal action for any violations of State law or regulations occurring before the issuance or reissuance of this permit. Nothing in this permit shall be construed to preclude the institution of any legal action or relieve the permittee from any civil or criminal responsibilities, liabilities, or penalties for noncompliance with Title 9 of the Environment Article, Annotated Code of Maryland or any federal, local or other state law or regulation.

C. Civil Penalties for Violations of Permit Conditions. In addition to civil penalties for violations of State water pollution control laws set forth in Section 9-342 of the Environment Article, Annotated Code of Maryland, the Federal Act provides that any person who violates Section 301, 302, 306, 307, 308, 318, or 405 of the Act, or any permit condition or limitation implementing any of such sections in a permit issued under Section 402 of the Act or in a permit issued under Section 404 of the Act, is subject to a civil penalty not to exceed $25,000 per day for each violation.

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D. Criminal Penalties for Violations of Permit Conditions. In addition to criminal penalties for violations of State water pollution control laws set forth in Section 9-343 of the Environment Article, Annotated Code of Maryland, the Federal Act provides that:

1. Any person who negligently violates Section 301, 302, 306, 307, 308, 318, or 405 of the Act, or any permit condition or limitation implementing any of such sections in a permit issued under Section 402 of the Act, or in a permit issued under Section 404 of the Act, is subject to a fine of not less than $2,500 nor more than $25,000 per day of violation, or by imprisonment for not more than one (1) year, or by both.

2. Any person who knowingly violates Section 301, 302, 306, 307, 308, 318, or 405 of the Act, or any permit condition or limitation implementing any of such sections in a permit issued under Section 402 of the Act, or in a permit issued under Section 404 of the Act, is subject to a fine of not less than $5,000 nor more than $50,000 per day of violation, or by imprisonment for not more than three (3) years, or by both.

3. Any person who knowingly violates Section 301, 302, 306, 307, 308, 318, or 405 of the Act, or any permit condition or limitation implementing any of such sections in a permit issued under Section 402 of the Act, or in a permit issued under Section 404 of the Act, and who knows at that time that he thereby places another person in imminent danger of death or serious bodily injury, is subject to a fine of not more than $250,000 or imprisonment of not more than fifteen (15) years, or both. A person which is a corporation, shall, upon conviction, be subject to a penalty of not more than $1,000,000.

E. Penalties for Falsification and Tampering. The Environment Article, §9-343, Annotated Code of Maryland provides that any person who knowingly makes any false material statement, representation, or certification in any application, record, report, plan, or other document filed or required to be maintained under this permit, including monitoring reports or reports of compliance or noncompliance, or who knowingly falsifies, tampers with or renders inaccurate any monitoring device or method required to be maintained under this permit shall, upon conviction, be punished by a fine of not more than $10,000 per violation, or by imprisonment for not more than 6 months per violation, or by both. The federal Clean Water Act provides that any person who knowingly falsifies, tampers with, or renders inaccurate any monitoring device or method required to be maintained under the Act, or who knowingly makes any false statement, representation, or certification in any records or other documents submitted or required to be maintained under this permit, including monitoring reports or reports of compliance or noncompliance shall, upon conviction, be punished by a fine of not more than $10,000, or by imprisonment for not more than two years, or by both.

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Part VI. General Conditions.

A. Right of Entry. The permittee shall permit the Secretary of the Department, the Regional Administrator for the EPA, or their authorized representatives, upon the presentation of credentials:

1. To enter upon the permittee's premises where an effluent source is located or where any records are required to be kept under the terms and conditions of this permit;

2. To access and copy, at reasonable times, any records required to be kept under the terms and conditions of this permit;

3. To inspect, at reasonable times, any monitoring equipment or monitoring method required in this permit;

4. To inspect, at reasonable times, any collection, treatment, pollution management, or discharge facilities required under this permit;

5. To sample, at reasonable times, any discharge of pollutants;

6. To install ground water monitoring wells; and

7. To take photographs.

B. Property Rights/Compliance with Other Requirements. The issuance of this permit does not convey any property rights in either real or personal property, or any exclusive privileges, nor does it authorize any injury to private property or any invasion of personal rights, nor does it authorize any infringement of federal, State or local laws or regulations.

C. Duty to Provide Information. The permittee shall furnish to the Department, within the time frame stipulated by the Department, any information which the Department may request to determine compliance with this permit. The permittee shall also furnish to the Department, upon request, copies of records required to be kept by this permit.

D. Other Information. If the permittee becomes aware that incorrect information has been included in the NOI or any other report submitted to the Department, or relevant facts have been omitted from the NOI or any other report to the Department, the permittee shall submit the correct information or facts to the Department with 30 calendar days of becoming aware.

E. Availability of Reports. Except for data determined to be confidential under the Maryland Public Information Act, and Section 308 of the federal Clean Water Act, all submitted data shall be available for public inspection at the Department.

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F. Toxic Pollutants. The permittee shall comply with effluent standards or prohibitions for toxic pollutants established under the federal Clean Water Act, or under Section 9-314 and Sections 9-322 through 9-328 of the Environment Article, Annotated Code of Maryland. Compliance shall be achieved within the time provided in the regulations that establish these standards or prohibitions, even if this permit has not yet been modified to incorporate the requirement.

G. Oil and Hazardous Substances Prohibited. Nothing in this permit shall be construed to preclude the institution of any legal action or relieve the permittee from any responsibility, liability, or penalties to which the permittee may be subject under the federal Clean Water Act or under the Annotated Code of Maryland.

H. Water Construction and Obstruction. This permit does not authorize the construction or placing of physical structures, facilities, or debris or the undertaking of related activities in any waters of the State.

I. Severability. The provisions of this permit are severable. If any provisions of this permit shall be held invalid for any reason, the remaining provisions shall remain in full force and effect. If the application of any provision of this permit to any circumstances is held invalid, its application to other circumstances shall not be affected.

Part VII. Authority to Issue General NPDES Permits.

On September 5, 1974, the Administrator of the EPA approved the proposal submitted by the State of Maryland for the operation of a permit program for discharges into navigable waters under Section 402 of the federal Clean Water Act, 33 U.S.C. Section 1342.

On September 30, 1990, the Administrator of the EPA approved the proposal submitted by the State of Maryland for the operation of a general permit program.

Under the approvals described above, this general discharge permit is both a State of Maryland general discharge permit and an NPDES general discharge permit.

J. L. Hearn, Director
Water Management Administration

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Appendix

D.7

MDE/WMA Overview of the NPDES Stormwater Program

Background

The United States Environmental Protection Agency (EPA) issued final regulations in November 1990 that require National Pollutant Discharge Elimination System (NPDES) Permits for stormwater discharges associated with industrial activity. These regulations require permits for stormwater discharges associated with eleven categories of industrial activities and municipal separate storm sewer systems. Within the Maryland Department of the Environment (MDE), these permits are being administered by the Water Management Administration (WMA). Ten of these industrial activities are being permitted by one general permit, the General Industrial Discharge Permit, implemented by WMA's Wastewater Discharge Permit Program. However, industry-specific general permits are currently being drafted.

Examples of these activities are hazardous waste treatment facilities; landfills; open dumps receiving industrial waste; steam electric power generating facilities; mass transit, school bus, and trucking facilities; hazardous waste storage facilities; land application sites; recycling facilities (junk yards, etc.); vehicle maintenance facilities; and treatment works for domestic sewage. The eleventh industrial activity subject to the stormwater discharge permit requirements is construction activity with a planned total disturbance of five acres* or more. Construction activity, along with municipal separate storm sewer systems, are permitted by MDE/WMA's Compliance Program. Construction activity is being permitted by a general permit that covers only construction, the General Permit for Construction Activity. *** Area of disturbance subject to NPDES regulatory changes.**

Regulatory Requirements for Construction Activity in Maryland

EPA's regulations [40 CFR (Code of Federal Regulations) 122.26] provide for three types of applications for industrial stormwater discharge permits: an individual application, a group application, and a Notice of Intent (NOI) to comply with a general permit. 40 CFR 122.26(b)(14) identifies construction activity, including clearing, grading, and excavating, as one of the categories of "industrial activity." 40 CFR 122.26(c)(1)(ii) requires that the following information be provided on the NPDES permit application for construction activity:

(A) The location and the nature of the construction;
(B) The total area of the site;
(C) Proposed measures, including best management practices, to control pollutants in stormwater discharges during construction;
(D) Proposed measures to control pollutants in stormwater discharges that will occur after construction has been completed;
(E) An estimate of the runoff coefficient of the site and the increase in impervious area after construction; and
(F) The name of the receiving water.

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Because Maryland presently has programs in place to control erosion, sediment and stormwater for new development activities, MDE/WMA has composed its NPDES General Permit in such a way so as not to change current erosion and sediment control and stormwater management requirements. Through the review and approval and subsequent inspection and enforcement processes for erosion and sediment control and stormwater management, the majority of information required to be submitted under 40 CFR 122.26(c)(1)(ii) will have already been supplied to agencies responsible for construction site evaluation according to Maryland's current laws and regulations (Environment Article Title 4. Subtitle 1; Subtitle 2; COMAR 26.17.01; and COMAR 26.17.02). For this reason, MDE/WMA Simply, operators of construction activity will be complying with 40 CFR 122.26 if they comply with current Maryland law.

The General Permit

Construction activity in Maryland with a planned total disturbance of five acres* or more will be required to be covered by the General Permit for Construction Activity. Coverage under this Permit mandates that the permittee be held accountable for complying with the terms of the General Permit. Compliance with the terms of the General Permit shall be in compliance with EPA's stormwater regulations.

While Maryland law requires erosion and sediment control and stormwater management plan approval prior to the commencement of construction for any earth disturbance of 5,000 square feet or more, General Permit coverage will be required only for construction activity with a planned total disturbance of five acres* or more. Plans must still be approved and remain active during the construction phase, as per existing Maryland law.

Permittees are encouraged to submit only one NOI for the entire project, even if plans are not approved for subsequent phases/stages of development. The completed NOI form is considered an application for coverage under the General Permit. The NOI is to be completed by the permittee and will require that general information describing the construction activity be provided. The completed NOI form must be submitted at least 48 hours prior to any earth disturbing activity and the appropriate application fee must accompany the submitted NOI.

Who Is Covered by the General Permit?

It is intended that the General Permit cover construction activity in Maryland with a planned total disturbance of five acres* or more. This includes phased/staged construction projects, even if individual phases will disturb less than five acres. Current Maryland law requiring approved erosion and sediment control and stormwater management plans for earth disturbances exceeding 5,000 square feet remains unchanged.

The permittee who applies for coverage under the terms of the General Permit shall be held

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accountable for complying with all of the terms of the General Permit. A person who has submitted a Notice of Intent (NOI) and does not intend to be responsible for controlling the permitted activities on site must transfer authorization under the General Permit to a duly authorized person. Upon transfer, this duly authorized person shall be held accountable for compliance under the terms stated in the General Permit.

How is Coverage Obtained?

Coverage under the General Permit is obtained by filing a completed Notice of Intent (NOI) form with the Maryland Department of the Environment, Water Management Administration (MDE/WMA). The completed NOI form is considered a formal application for coverage and intent to comply with the terms of the General Permit.

What is the Procedure for Application?

For construction activity with a planned total disturbance of five acres* or more, General Permit coverage is required. NOI forms are available at local plan review offices and at MDE. NOI forms must be complete and include the signature of the permittee in order to be processed. Completed NOI forms must be submitted with the appropriate application fee (see below) to the Maryland Department of the Environment, Water Management Administration, P.O. Box 1417, Baltimore, Maryland 21203-1417. Receipt by MDE/WMA of the completed NOI form will authorize coverage under the terms of the General Permit. Upon receipt of the completed NOI form. MDE will mail a verification letter and a copy of the General Permit to the permittee. Once the construction activity is completed, including final stabilization and the elimination of all stormwater discharges authorized by the General Permit, the permittee must submit a Notice of Termination form to MDE/WMA. Forms are available at local plan review offices and at MDE.

The application fee schedule for stormwater discharges associated with construction activity is as follows:

Total Disturbed Area (acres)	NOI Fee (dollars)
less than 5	Exempt
5 to less than 10	$100
10 to less than 15	$500
15 to less than 20	$1,500
20 and up	$2,500

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What Information is Required on the NOI Form?

Information required on the NOI Form is general information describing the construction activity. Much of this information can be provided directly by the permittee from prepared site plans and any other necessary information should be available at the local plan review offices. The omponent parts of the NOI form are outlined below:

I. Site Name and Location including name and general location of the site; MD Grid Coordinates; latitude and longitude; watershed basin code;

II. Project Description including stormwater management BMPs to be implemented and drainage area for each type of BMP; brief project description; total site area/disturbed area; runoff curve numbers; estimate of total impervious surface area; the project types, as a county/municipal or private entity and its eventual use as residential, commercial or industrial; Standard Industrial Classification (SIC) code; any other NPDES permit number; name of eventual receiving waters/ storm sewer system receiving the site's runoff;

III. Permittee Identification including name/company and address of permittee and name and phone number of the principal contact person for the site;

IV. Certification including a certification statement to be signed by the permittee;

V. Fees including the fee amount to be paid with the NOI submission.

MDE issued a new Notices of Intent form for use beginning in 1994. This form is a scanner compatible "bubble" form, replacing the original single page handwritten form. This form is the one currently being accepted by MDE and it is available at local plan review offices and at MDE.

Additionally, MDE has developed a new State and Federal NOI form, to be used for all state and federal construction projects. This is a separate NOI form, labeled "For State and Federal Government Project Only," but it is not significantly different from the standard NOI form.

When Must the NOI Form be Submitted?

The completed NOI must be submitted to the Water Management Administration at least 48 hours prior to the commencement of construction activities. This is applicable to all construction activity with a planned total disturbance of five acres* or more that is active as of October 1, 1992 and any such construction activity beginning on or after October 1, 1992. Such construction will need to be permitted under the General Permit. The application fee is due at the time of NOI submission. Checks and money orders only will be accepted and should be made payable to MDE.

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MDE has supplied local plan review offices with NOI forms. Forms and information may also be obtained at MDE. It is the responsibility of the permittee to accurately complete the form and submit it to MDE/WMA.

Miscellaneous

Coverage under the General Permit is effective until MDE is notified by the permittee that construction is complete. Submission of a Notice of Termination form to MDE will indicate that construction activity is complete, areas are stabilized, and authorized stormwater discharges have been eliminated (the address is given at the end of the Appendix).

No effluent limitations have been established for stormwater discharges from construction sites. However, the General Permit requires Permittees to visually inspect erosion and sediment controls on a weekly basis and the next work day after a storm event. Permittees are required to maintain, on site during construction, written documentation of the findings and any subsequent maintenance that is performed. These records must be kept for a period of three years following final stabilization of the site and must be made available upon request.

The permittee shall be held accountable for compliance under the term of the General Permit. A person who has submitted an NOI and does not intend to control the permitted activities on the site must transfer authorization under the General Permit to a duly authorized person. Upon transfer, the duly authorized person shall be held accountable for compliance under the terms stated in the General Permit.

Although coverage under the General Permit does not involve additional regulations, it should be noted that because construction activity now falls under the Clean Water Act (CWA), federal penalties will apply to violations. Both state and federal civil and criminal penalties will apply to violations occurring under General Permit coverage.

Further information regarding the General Permit and the NOI form can be obtained by contacting:

The Maryland Department of the Environment
Water Management Administration
Compliance Program
2500 Broening Highway
Baltimore, Maryland 21224
(410) 631-3510

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Appendix

D.8

Miscellaneous Details for Compliance with Performance Criteria

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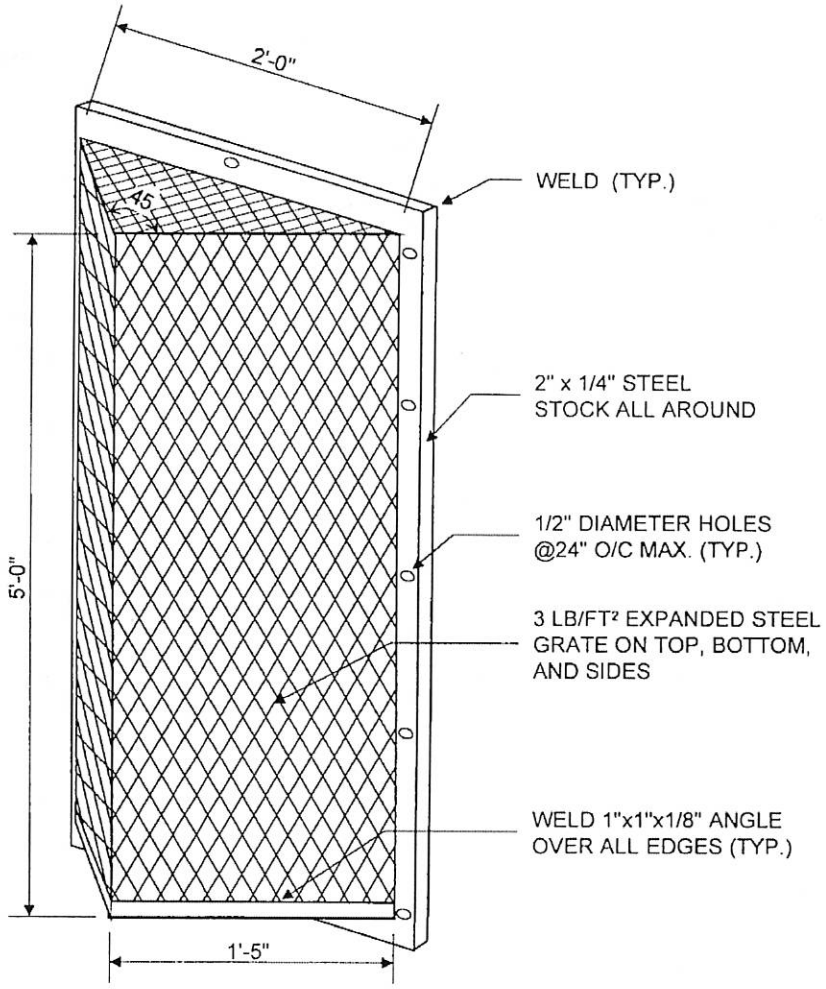
Appendix D.8 ..... Miscellaneous Details for Compliance with Performance Criteria

Detail 1: Trash Rack for Low Flow Orifice
Detail 2: Expanded Trash Rack Protection for Low Flow Orifice
Detail 3: Internal Control for Orifice Protection
Detail 4: Observation Well for Infiltration Practices
Detail 5: Off-line Versus On-line Schematic
Detail 6: Isolation/Diversion Structure
Detail 7: Half Round CMP Hood
Detail 8: Half Round CMP Weir
Detail 9: Concrete Level Spreader

SARB_005088

Detail 1 Trash Rack Protection for Low Flow Orifice



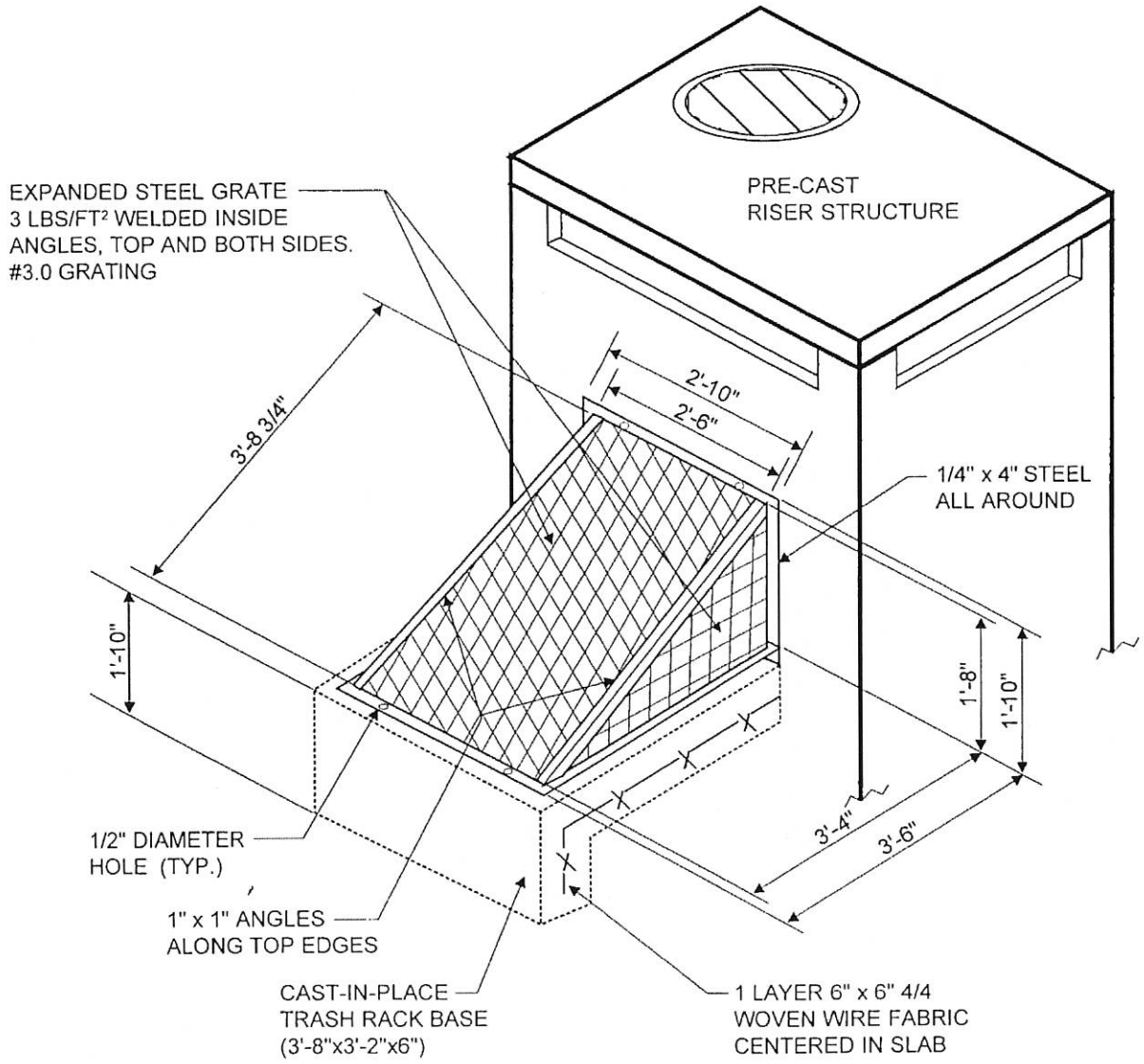
NOTES FOR TRASH RACK

1. TRASH RACK TO BE CENTERED OVER OPENING.
2. STEEL TO CONFORM TO ASTM A-36.
3. ALL SURFACES TO BE COATED WITH ZRC COLD GALVANIZING COMPOUND AFTER WELDING.
4. TRASH RACK TO BE FASTENED TO THE WALL WITH 1/2" MASONRY ANCHORS. TRASH RACK TO BE REMOVABLE.

TRASH RACK DETAIL (NTS)

SARB_005089

Detail 2 Expanded Trash Rack Protection for Low Flow Orifice



EXPANDED METAL TRASH RACK (NTS)

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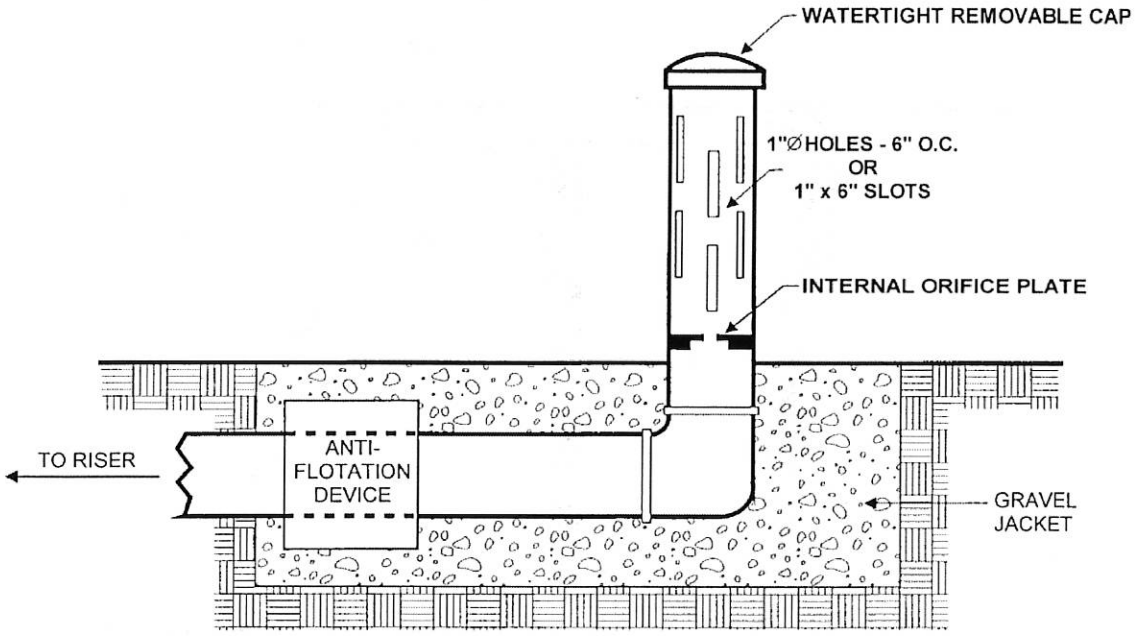
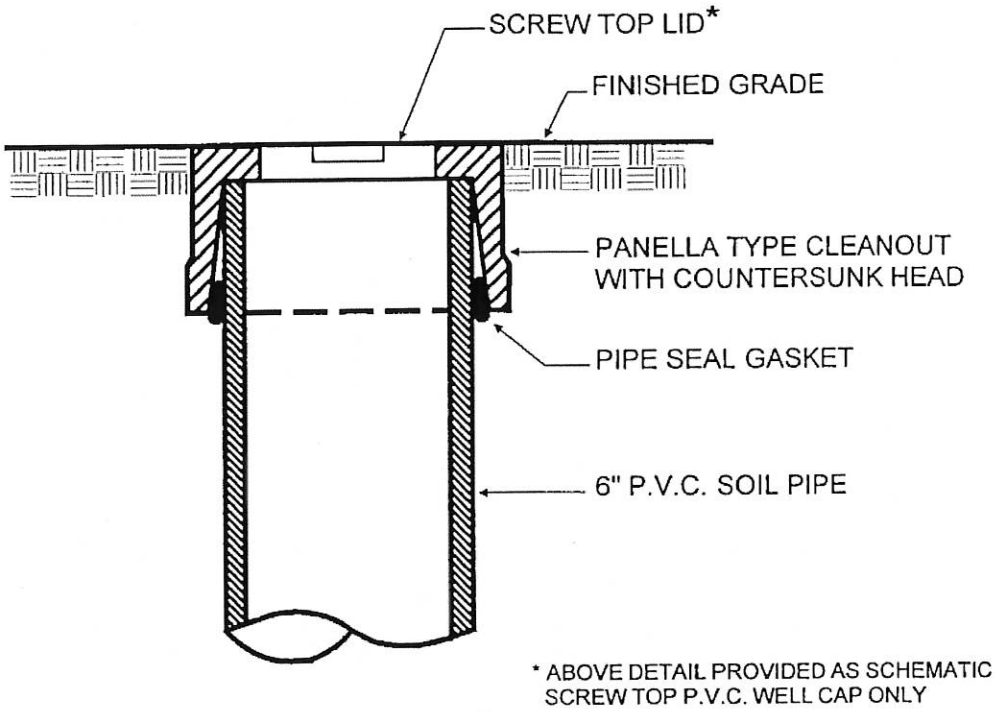
Detail 3 Internal Control for Orifice Protection



INTERNALLY CONTROLLED ORIFICE (NTS)

SARB_005091

Detail 4 Observation Well for Infiltration Practices



EACH OBSERVATION WELL / CLEANOUT SHALL INCLUDE THE FOLLOWING:

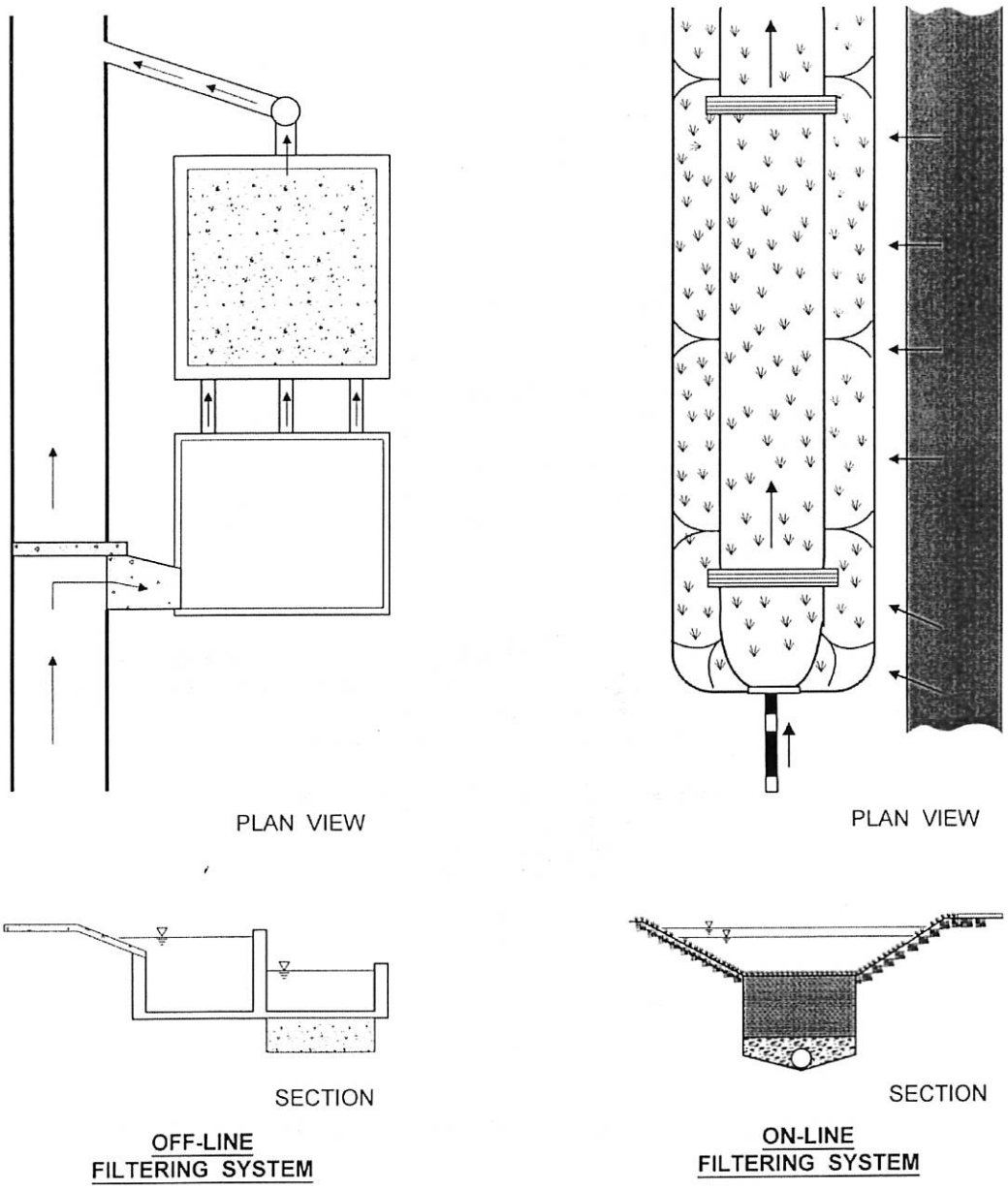
1. FOR AN UNDERGROUND FLUSH MOUNTED OBSERVATION WELL / CLEANOUT, PROVIDE A TUBE MADE OF NON-CORROSIVE MATERIAL, SCHEDULE 40 OR EQUAL, AT LEAST THREE FEET LONG WITH AN INSIDE DIAMETER OF AT LEAST 6 INCHES.

2. THE TUBE SHALL HAVE A FACTORY ATTACHED CAST IRON OR HIGH IMPACT PLASTIC COLLAR WITH RIBS TO PREVENT ROTATION WHEN REMOVING SCREW TOP LID. THE SCREW TOP LID SHALL BE CAST IRON OR HIGH IMPACT PLASTIC THAT WILL WITHSTAND ULTRA-VIOLET RAYS.

OBSERVATION WELL DETAIL

SARB_005092

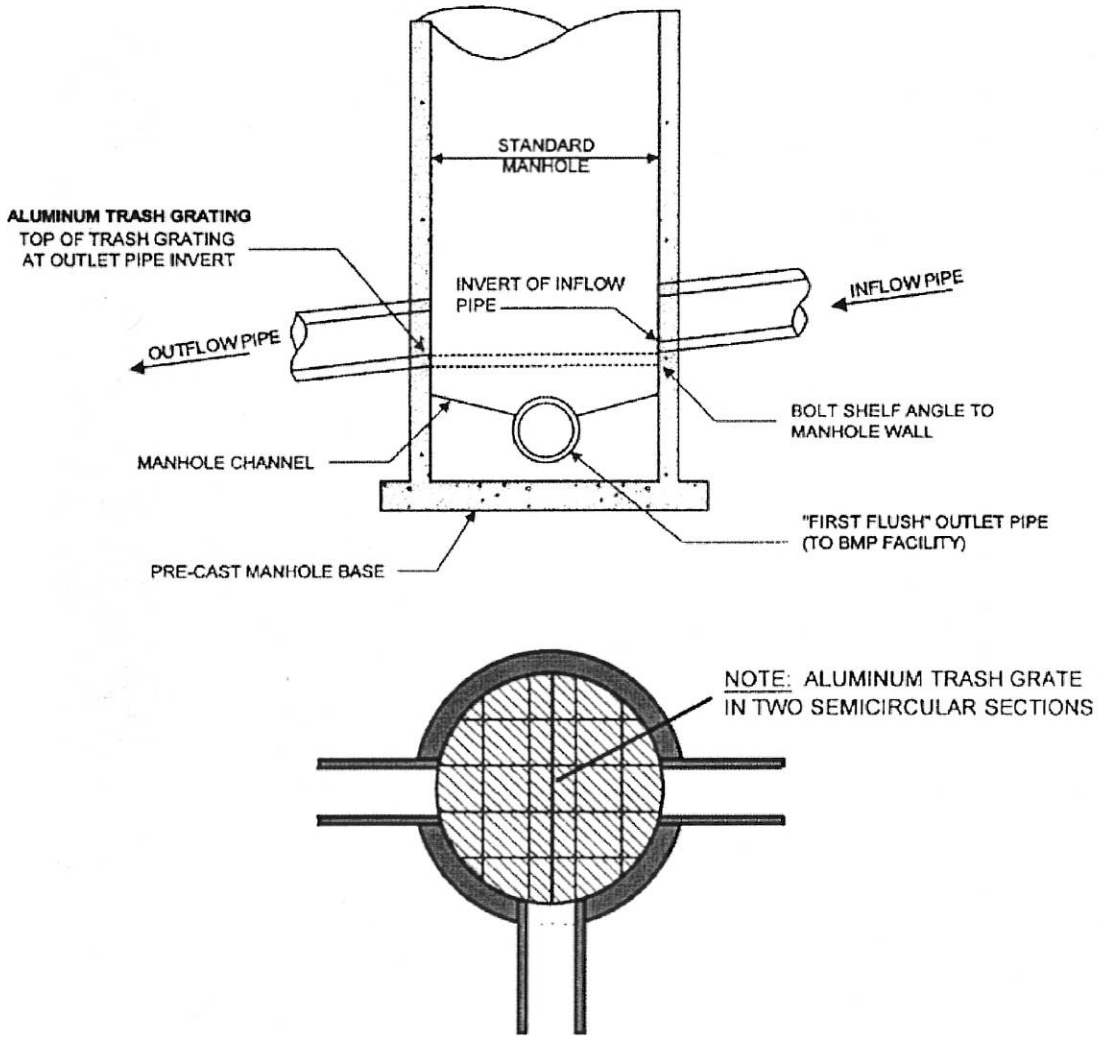
Detail 5 Off-Line Versus On-Line Schematic



SCHEMATIC: ON-LINE vs OFF-LINE

SARB_005093

Detail 6 Isolation Diversion Structure

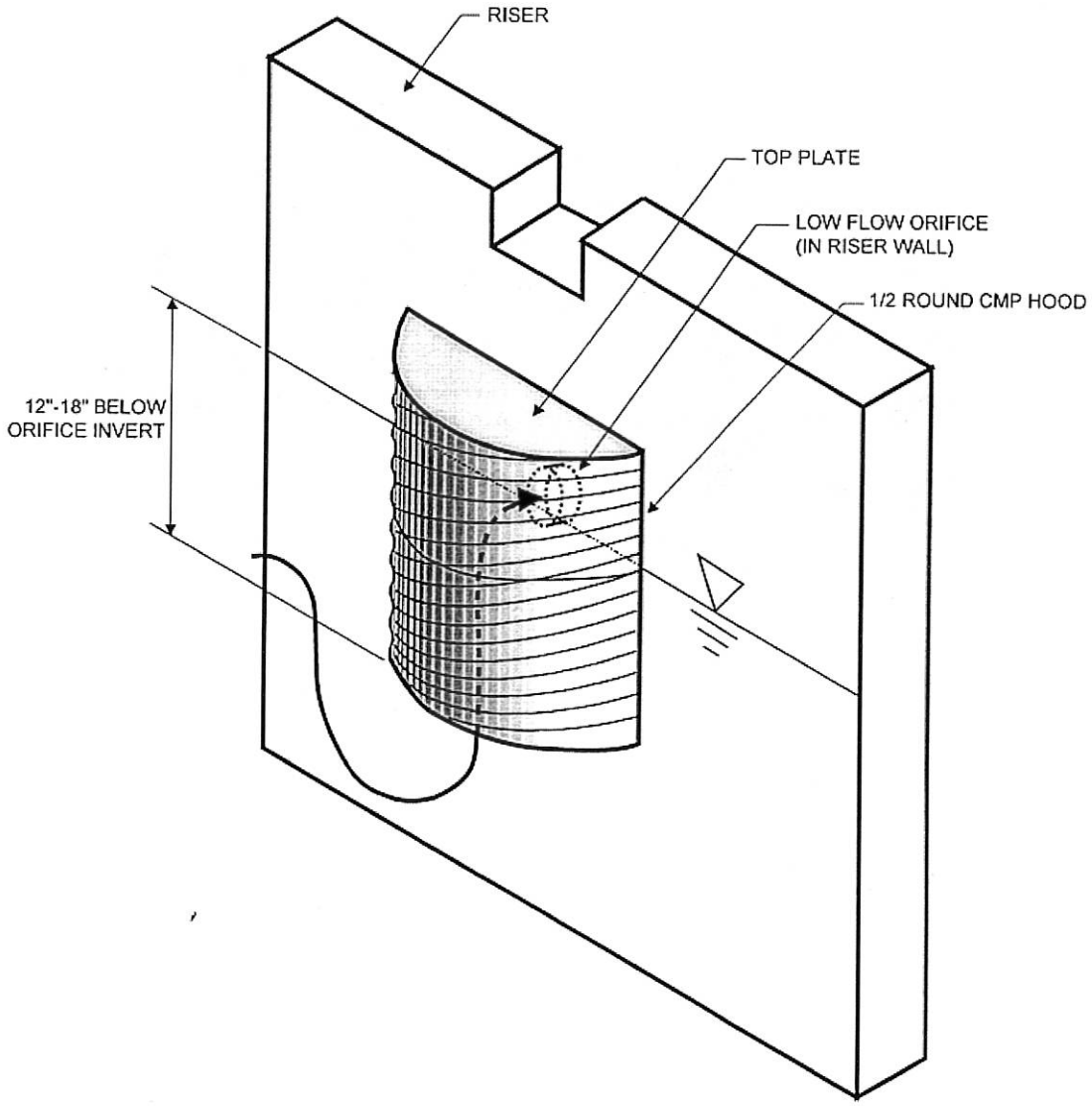


TYPICAL ISOLATION / DIVERSION MANHOLE

(Source: Bell, 1996)

SARB_005094

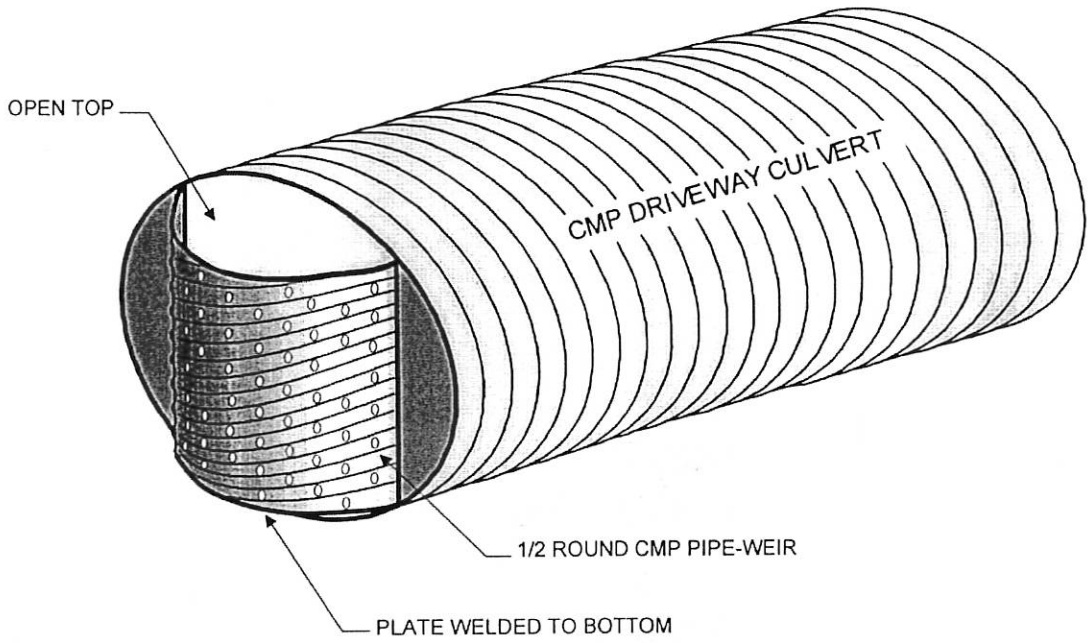
Detail 7 Half Round CMP Hood



1/2 ROUND CMP PIPE-HOOD
(FOR PROTECTION OF LOW FLOW ORIFICE)

SARB_005095

Detail 8 Half Round CMP Weir

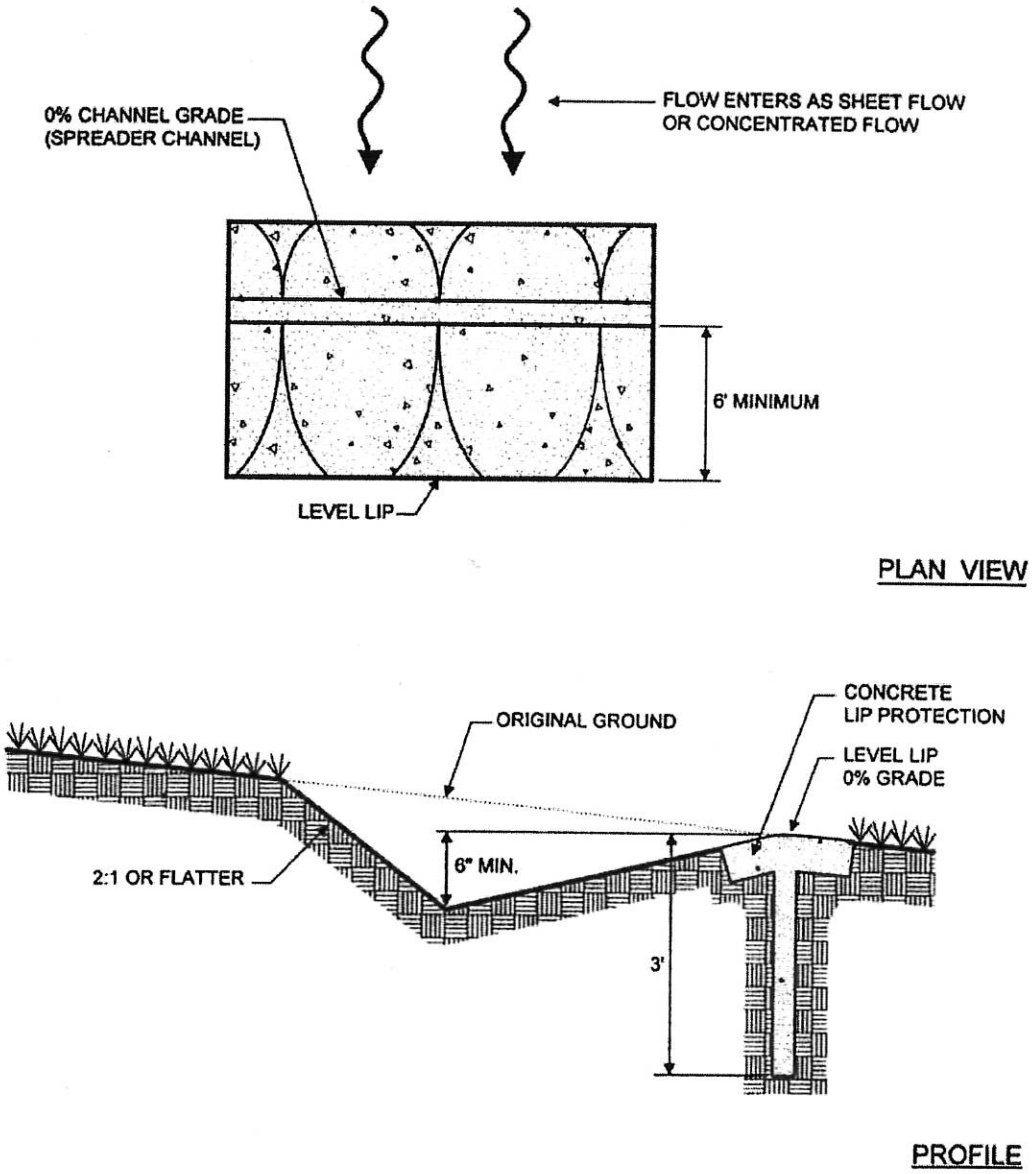


1/2 ROUND CMP PIPE-WEIR

(FOR USE WITH DRY SWALE)

SARB_005096

Detail 9 Concrete Level Spreader



LEVEL SPREADER

Source: Virginia Erosion and Sediment Control Handbook, Virginia Soil and Water Conservation Commission, 1980

SARB_005097

Appendix

D.8

Miscellaneous Details for Compliance with Performance Criteria

Appendix D.8 ..... Miscellaneous Details for Compliance with Performance Criteria

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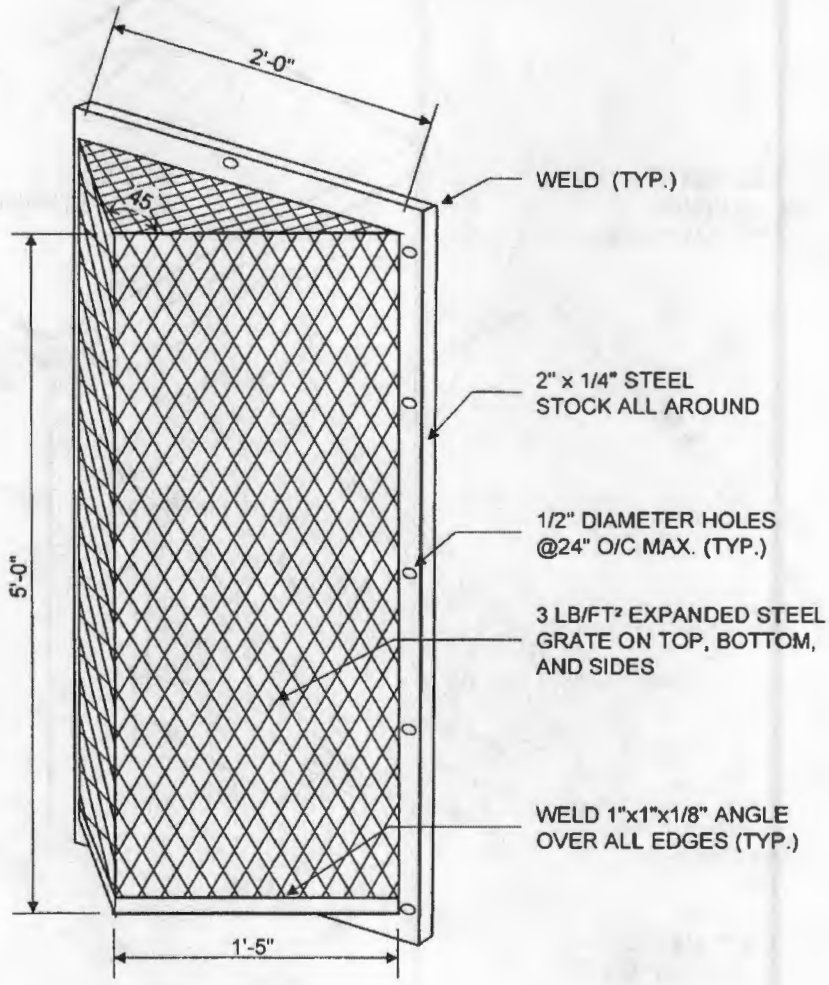
Detail 7: Half Round CMP Hood
Detail 8: Half Round CMP Weir
Detail 9: Concrete Level Spreader

SARB_005100

Detail 1 Trash Rack Protection for Low Flow Orifice



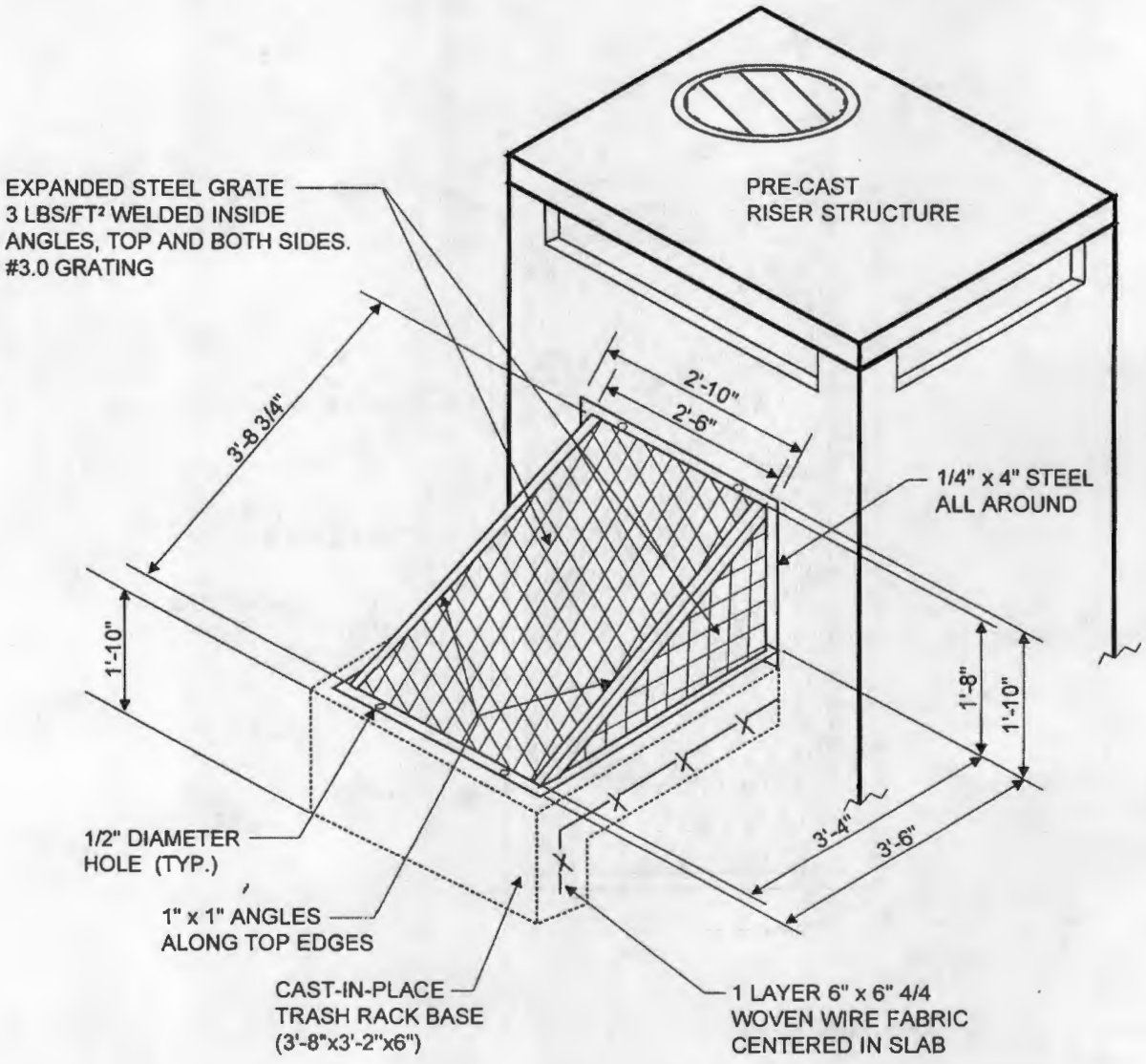
NOTES FOR TRASH RACK

1. TRASH RACK TO BE CENTERED OVER OPENING.
2. STEEL TO CONFORM TO ASTM A-36.
3. ALL SURFACES TO BE COATED WITH ZRC COLD GALVANIZING COMPOUND AFTER WELDING.
4. TRASH RACK TO BE FASTENED TO THE WALL WITH 1/2" MASONRY ANCHORS. TRASH RACK TO BE REMOVABLE.

TRASH RACK DETAIL (NTS)

SARB_005101

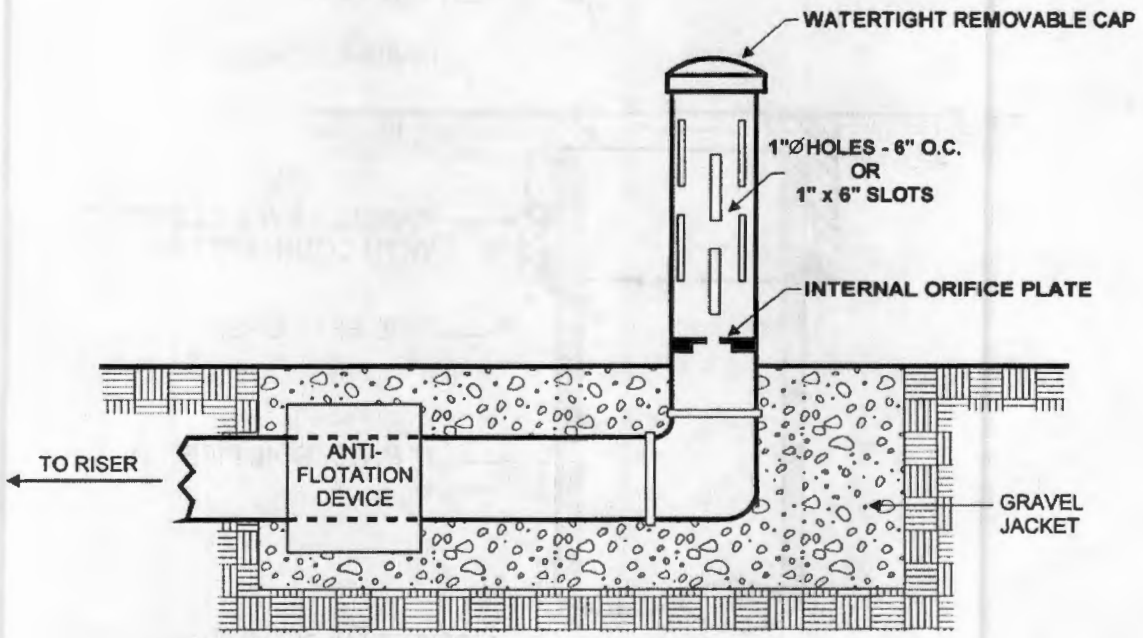
Detail 2 Expanded Trash Rack Protection for Low Flow Orifice



EXPANDED METAL TRASH RACK (NTS)

SARB_005102

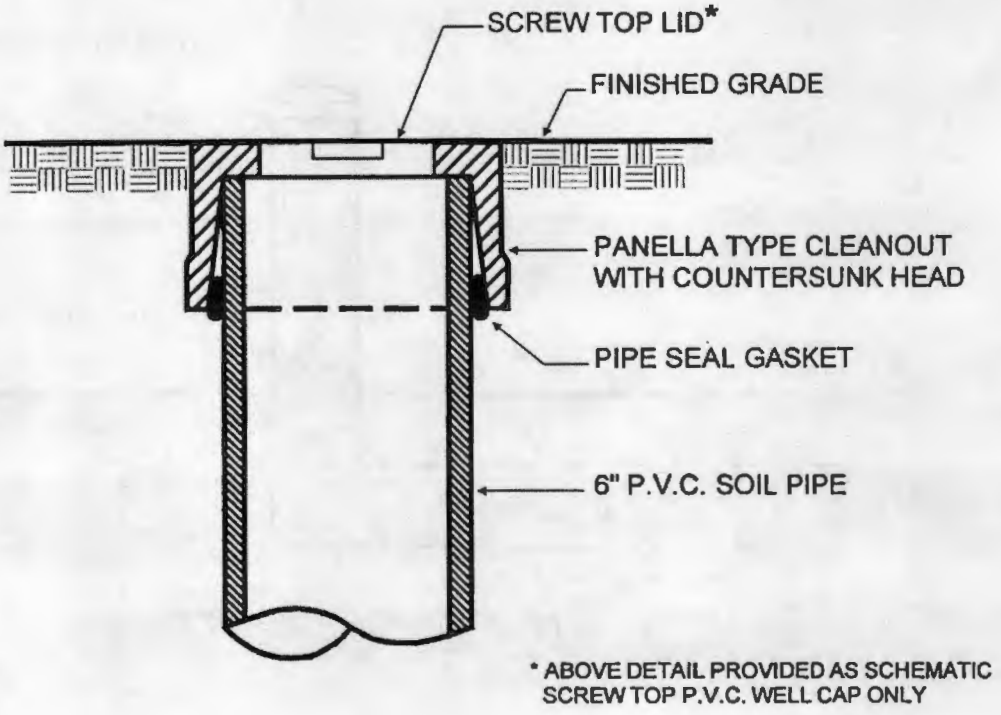
Detail 3 Internal Control for Orifice Protection



INTERNALLY CONTROLLED ORIFICE (NTS)

SARB_005103

Detail 4 Observation Well for Infiltration Practices



EACH OBSERVATION WELL / CLEANOUT SHALL INCLUDE THE FOLLOWING:

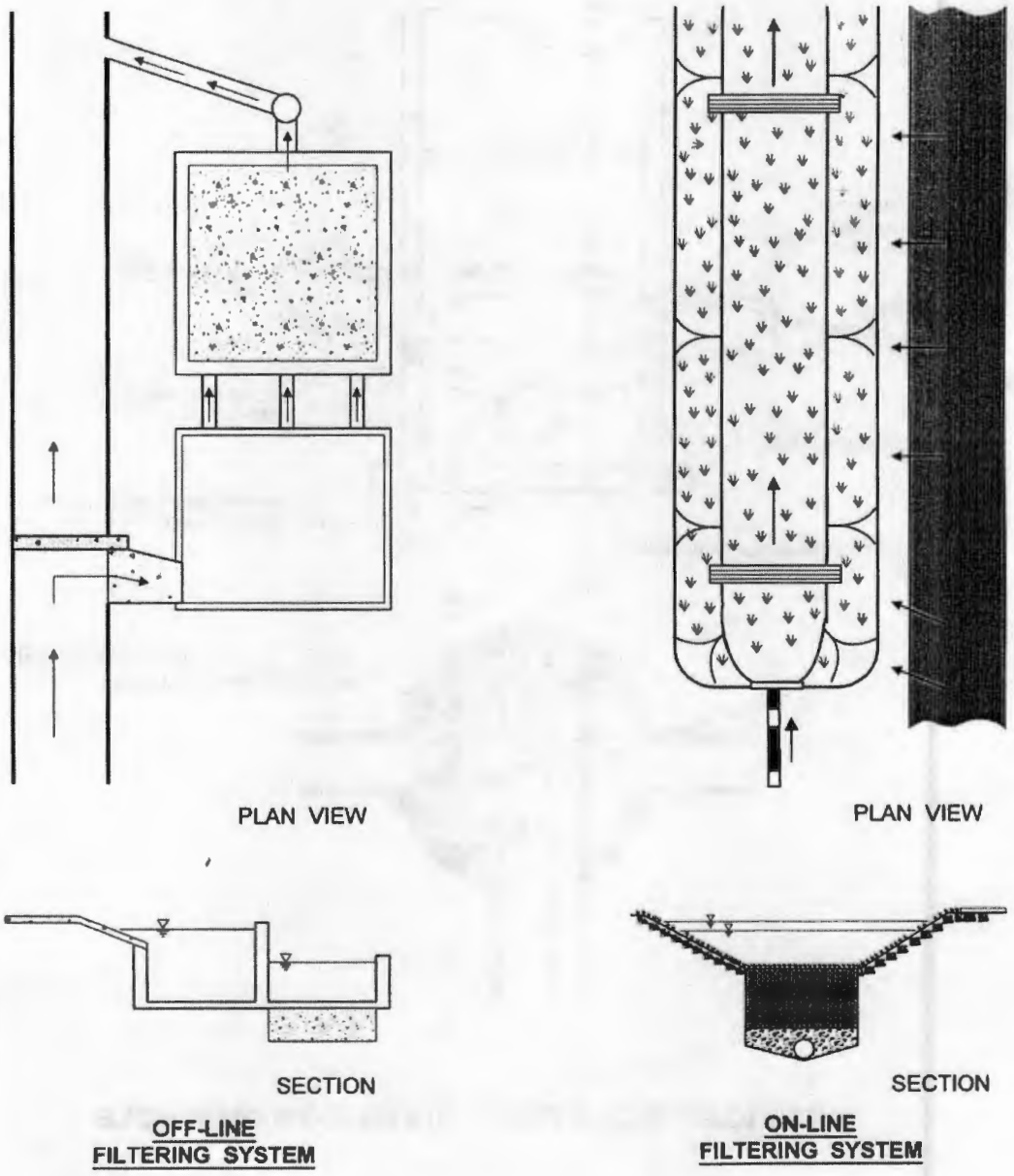
1. FOR AN UNDERGROUND FLUSH MOUNTED OBSERVATION WELL / CLEANOUT, PROVIDE A TUBE MADE OF NON-CORROSIVE MATERIAL, SCHEDULE 40 OR EQUAL, AT LEAST THREE FEET LONG WITH AN INSIDE DIAMETER OF AT LEAST 6 INCHES.

2. THE TUBE SHALL HAVE A FACTORY ATTACHED CAST IRON OR HIGH IMPACT PLASTIC COLLAR WITH RIBS TO PREVENT ROTATION WHEN REMOVING SCREW TOP LID. THE SCREW TOP LID SHALL BE CAST IRON OR HIGH IMPACT PLASTIC THAT WILL WITHSTAND ULTRA-VIOLET RAYS.

OBSERVATION WELL DETAIL

SARB_005104

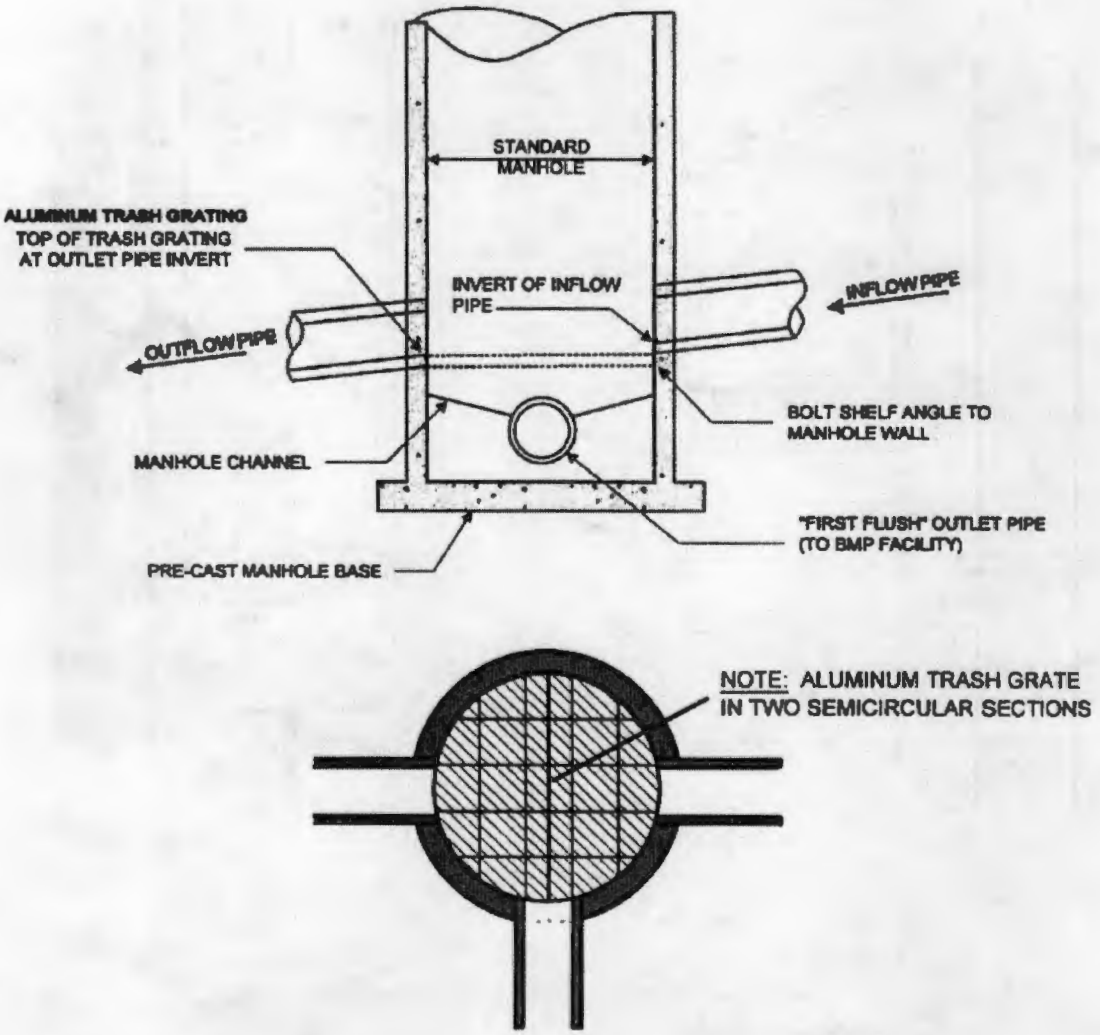
Detail 5 Off-Line Versus On-Line Schematic



SCHEMATIC: ON-LINE vs OFF-LINE

SARB_005105

Detail 6 Isolation Diversion Structure

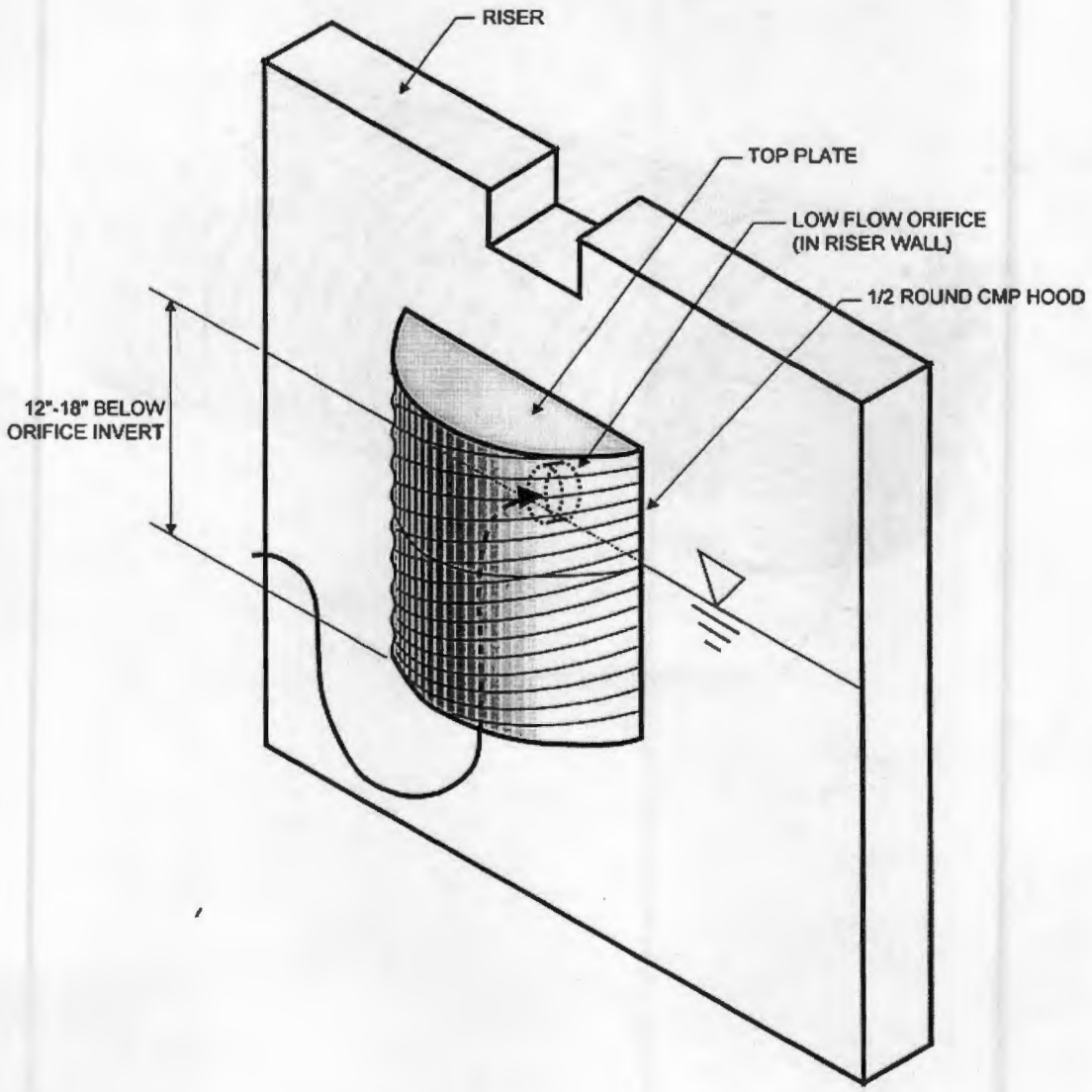


TYPICAL ISOLATION / DIVERSION MANHOLE

(Source: Bell, 1996)

SARB_005106

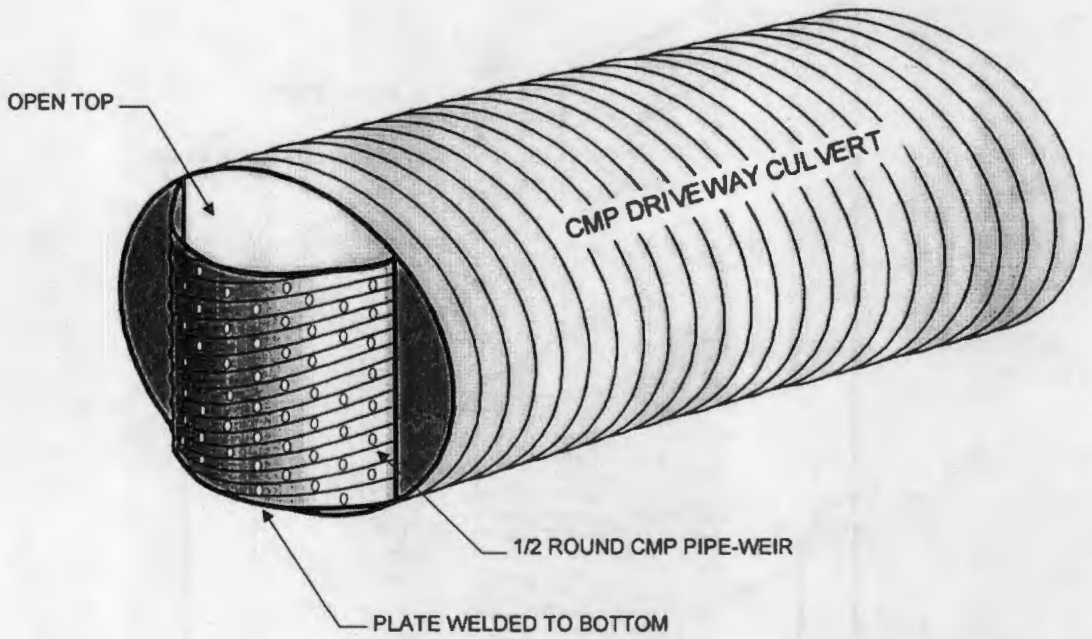
Detail 7 Half Round CMP Hood



1/2 ROUND CMP PIPE-HOOD
(FOR PROTECTION OF LOW FLOW ORIFICE)

SARB_005107

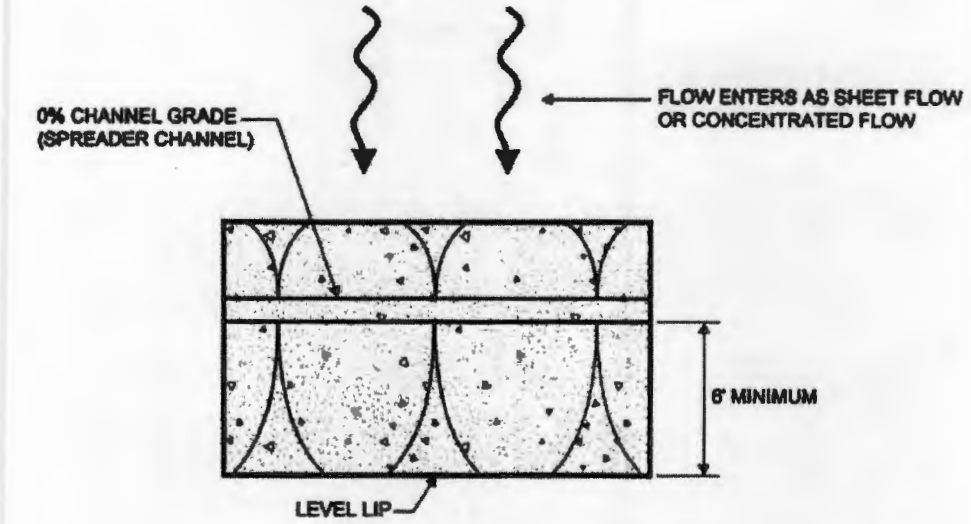
Detail 8 Half Round CMP Weir



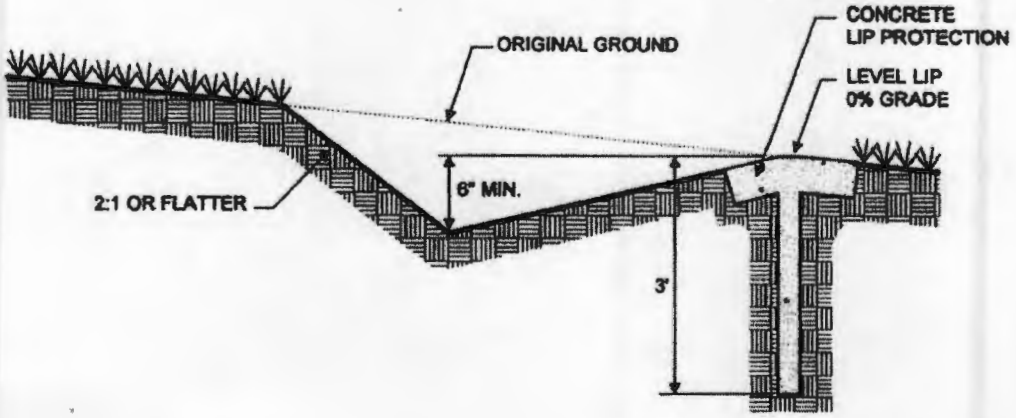
1/2 ROUND CMP PIPE-WEIR
(FOR USE WITH DRY SWALE)

SARB_005108

Detail 9 Concrete Level Spreader



PLAN VIEW



PROFILE

LEVEL SPREADER

Source: Virginia Erosion and Sediment Control Handbook, Virginia Soil and Water Conservation Commission, 1980

SARB_005109

Appendix

D.9

MD Stream Use Designations

Introduction

This Appendix, adapted from the Code of Maryland Regulations (COMAR) 26.08.02.08 "Stream Segment Designations", is reprinted here for informational purposes only. Please use the Code of Maryland Regulations for the Official Version and for any updates to these designations.

The stream segments are listed in tabular form according to Use designations as follows:

- Water Contact Recreation, and Protection of Aquatic Life (Use I and Use I-P waters)
- Shell Fish Harvesting Waters (Use II waters);
- Natural Trout Waters (Use III and Use III-P waters);
- Recreational Trout Waters (Use IV and Use IV-P waters); and
- Public Water Supply (Use I-P, III-P, and IV-P waters).

For each sub-basin, information is arranged under the following headings:

1) Use – Refers to water classification;
2) Waters – Exact name of stream segment or segments;
3) MCGS – Most downstream point or line for each stream segment using the Maryland Coordinate Grid System (East/North);
4) Limits – Written description of boundary of stream segment established by MCGS; and
5) Any stream segment not listed may be considered Use I waters.

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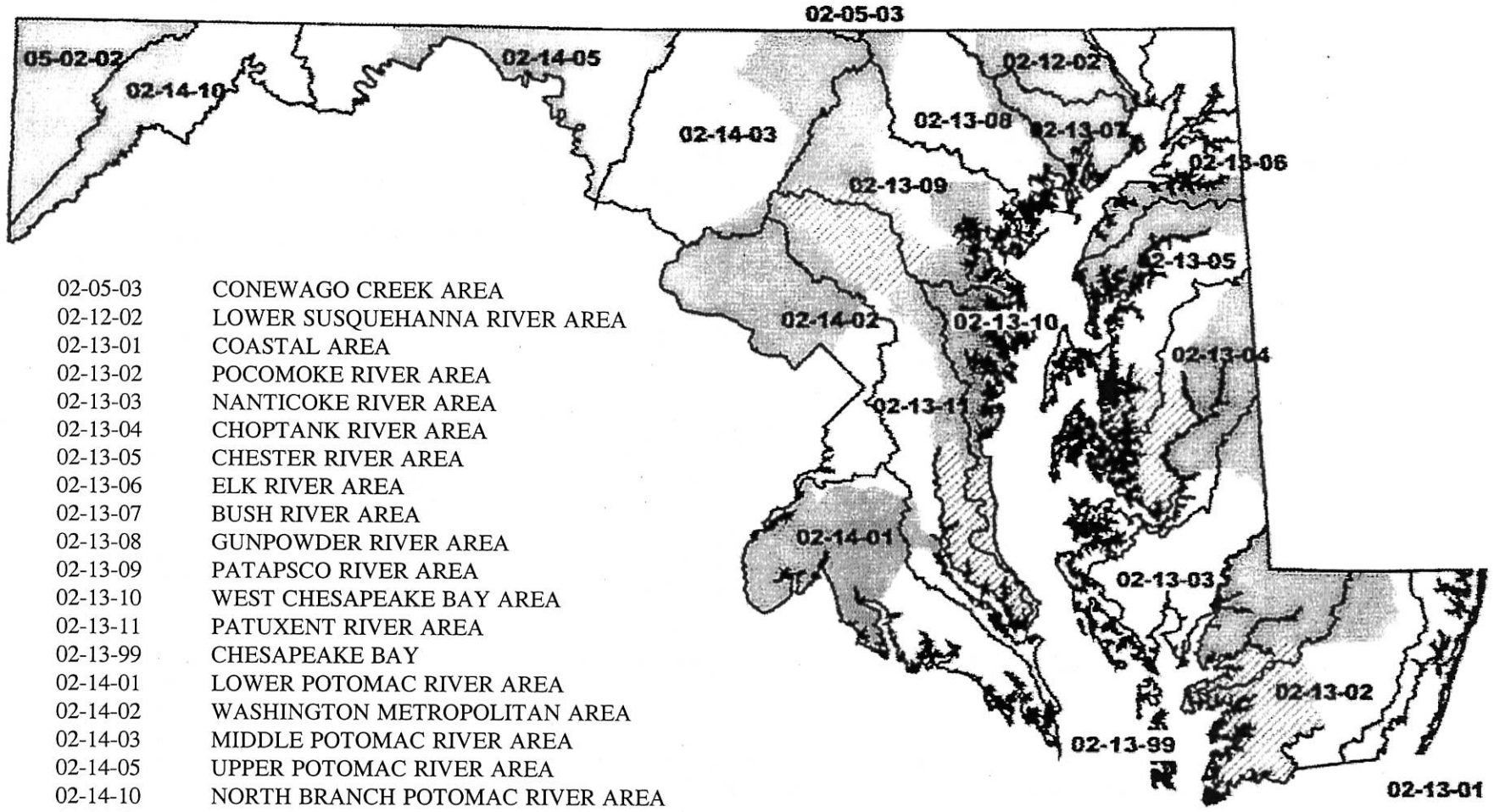
Figure D.9.1 Maryland 6 Digit Sub-Basins



02-05-03	CONEWAGO CREEK AREA
02-12-02	LOWER SUSQUEHANNA RIVER AREA
02-13-01	COASTAL AREA
02-13-02	POCOMOKE RIVER AREA
02-13-03	NANTICOKE RIVER AREA
02-13-04	CHOPTANK RIVER AREA
02-13-05	CHESTER RIVER AREA
02-13-06	ELK RIVER AREA
02-13-07	BUSH RIVER AREA
02-13-08	GUNPOWDER RIVER AREA
02-13-09	PATAPSCO RIVER AREA
02-13-10	WEST CHESAPEAKE BAY AREA
02-13-11	PATUXENT RIVER AREA
02-13-99	CHESAPEAKE BAY
02-14-01	LOWER POTOMAC RIVER AREA
02-14-02	WASHINGTON METROPOLITAN AREA
02-14-03	MIDDLE POTOMAC RIVER AREA
02-14-05	UPPER POTOMAC RIVER AREA
02-14-10	NORTH BRANCH POTOMAC RIVER AREA
05-02-02	YOUGHIOGHENY RIVER AREA

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Stream Segment Designations

Use	*Waters*	*MCGS**	*Limits*
A. SUB-BASIN 02-12-02: LOWER SUSQUEHANNA RIVER AREA			
(1)	Use I-P: Susquehanna River and all tributaries except those designated below as Use III-P or Use-IV-P	From 1068.8/625.5 to1056.8/621.3	Mainstem from mouth to MD/PA line
(2)	Use II: None		
(3)	Use III: None		
(4)	Use-III-P:		
	(a) Deer Creek and all tributaries	956/671	Above Eden Mill Dam
	(b) Basin Run and all tributaries	1040/667	
	(c) Kellogg Branch and all tributaries	966/655.5	
	(d) North Stirrup Run and all tributaries	969/650.2	
	(e) South Stirrup Run and all tributaries	968.3/649	
	(f) Deep Run and all tributaries	1008.2/677.8	
	(g) Gladden Branch and all tributaries	967/658	
	(h) Rock Hollow branch and all tributaries	958/663	
	(i) Love Run and all tributaries	1046/678	
	(j) Stone Run and all tributaries	1050.5/682.5	
(5)	Use IV: None		
(6)	Use IV-P:		
	(a) Deer Creek and all tributaries	1040/649.3	From mouth to Eden Mill Dam
	(b) Octoraro Creek	1036.7/665	Mainstem only
B. SUB-BASIN 02-13-01: COASTAL AREA			
(1)	Use I-P: None		
(2)	Use II: All portions of the territorial seas and estuarine portions of bays and tributaries except:		
	(a) Bishopville Prong and tributaries	1321.7/216.4	Above confluence with St. Martins River
	(b) Shingle Landing Prong and its tributaries	1323/214	Above confluence with St. Martins River at Piney Island
	(c) Herring Creek and its tributaries	1336.4/189.9	Above Rt. 50
	(d) Ocean City Harbor	1345/185.5	Above entrance to West Ocean City Harbor
(3)	Use III: None		
(4)	Use IIII-P: None		
(5)	Use IV: None		
(6)	Use IV-P: None		

* Most downstream point or line for the segment using the Maryland Coordinate Grid System (MCGS) (East/North)

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C. SUB-BASIN 02-13-02: POCOMOKE RIVER AREA

(1) Use I-P: None		
(2) Use II: All estuarine portions of tributaries except:		
(a) Manokin River and tributaries	1165/125.3	Above confluence of Manokin River & Kings Creek
(b) Big Annemessex River and tributaries	1160.8/95.2	Above River Road
(c) Jenkins Creek	From 1127/48 to 1127.3/45.7	Above mouth
(d) Fair Island Canal	From1177.6/51 to 1187.7/50.1	
(e) Pocomoke River	1196/62	Above MD/VA line
(3) Use III: None		
(4) Use III-P: None		
(5) Use IV: None		
(6) Use IV-P: None		

D. SUB-BASIN 02-13-03: NANTICOKE RIVER AREA

(1) Use I-P: None		
(2) Use II; All estuarine portions of tributaries except:		
(a) Blackwater River and tributaries	From 1083.1/92 to 1084.2/191.6	Above mouth
(b) Transquaking River and tributaries	From 1085.2/196.3 to 1088/197	Above mouth
(c) Nanticoke River and tributaries	From 1126/194 to 1128.2/191.2	Above line from Runaway Pt. to Long Pt.
(d) Wicomico River and tributaries	1147.9/160.5	Above ferry crossing at White Haven
(e) Monie Creek	1138.7/146.7	Above mouth
(3) Use III: None		
(4) Use III-P: None		
(5) Use IV: None		
(6) Use IV-P: None		

E. SUB-BASIN 02-13-04: CHOPTANK RIVER AREA

(1) Use I-P: None		
(2) Use II: All estuarine portions of tributaries except:		
(a) Choptank River and tributaries	From 1099.3/308 to 1101/306.5	Above line from Bow Knee Pt. to Wright Wharf
(b) Tred Avon River and tributaries	1057.6/341.6	Above Easton Pt.
(3) Use III: None		
(4) Use III-P: None		
(5) Use IV: None		
(6) Use IV-P: None		

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F. SUB-BASIN 02-13-05: CHESTER RIVER AREA

(1) Use I-P: None		
(2) Use II: All estuarine portions of tributaries except:		
(a) Chester River and tributaries	1066.5/502	Above Rt. 213
(b) Corsica River	1060.4/448.4	Above Earl Cove
(c) Piney Creek	From 1010.7/419.9 to 1012/418.8	Above Rt. 50
(d) Winchester Creek	1026.5/416.1	Above mouth
(e) St. Michaels Harbor	1023/348.7	
(3) Use III: None		
(4) Use III-P: None		
(5) Use IV: None		
(6) Use IV-P: None		

G. SUB-BASIN 02-13-06: ELK RIVER

(1) Use I-P:		
(a) Big Elk Creek and all tributaries	1129.3/647.5	Above Md Rt. 213
(b) Northeast Creek and all tributaries	1096.6/643.1	Above confluence with Stoney Run
(c) Mill Creek and all tributaries	1065.9/636	Above US Rt. 40
(2) Use II: All estuarine portions of tributaries except		
(a) Elk River and tributaries	From 1112.8/617 to 1114.8/613.9	Above line from Bull Minnow Pt. to Courthouse Pt.
(b) Bohemia River and tributaries	From 1108/603.7 to 1109/600	Above line from Rich Pt. to Baltery Pt.
(c) Sassafras River and tributaries	1088.6/561.5	Above Ordinary Pt.
(d) Stillpond Creek and tributaries (Still Pond)	1044/547	Above Kinnaird Pt.
(e) Worton Creek	From 1031.4/532 to 1032.5/534.7	Above mouth
(f) Fairlee Creek	From 1023.6/524 to 1026/527.5	Above mouth
(g) Northeast River	From 1081.3/623.3 to 1087.6/619.1	
(3) Use III: Principio Creek and all tributaries	1073/634.5	
(4) Use III-P: None		
(5) Use IV: None		
(6) Use IV-P: None		

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H. SUB-BASIN 02-13-07: BUSH RIVER AREA

(1) Use I-P: Winters Run and all tributaries, including Atkisson Reservoir	995.5/585.5	From Otter Point Creek to upstream boundary of Atkisson Reservoir
(2) Use II: All estuarine portions of tributaries except:		
(a) Bush River and tributaries	From 1010.5/576 to 1014.1/574.1	Above line from Fairview Pt. to Chillbury Pt.
(b) Romney Creek	1022.3/567.5	Above Briar Pt.
(c) Swan Creek and tributaries	From 1050/603.5 to 1047.5/604.2	Above mouth
(3) Use III: Bynum Run and all tributaries	1008.9/597.4	
(4) Use III-P: None		
(5) Use IV: None		
(6) Use IV-P: Winters Run and all tributaries	982.2/604.8	Above Atkisson Reservoir

I. SUB-BASIN 02-13-08: GUNPOWDER RIVER AREA

(1) Use I-P: None		
(2) Use II: All estuarine portions of tributaries except:		
(a) Gunpowder River and all tributaries	From 987/561.5 to 991.2/555.5 From 972/536.1 to 970/532.5	Above line from Oliver Pt. to Maxwell Pt.
(b) Middle River		Above line from Log Pt. to Turkey Pt.
(3) Use III:		
(a) Little Gunpowder Falls and all tributaries	976.8/5788.8	Above B&O railroad bridge ¾ mile south of Rt. 7 (Old Philadelphia Road)
(b) Long Green Run and all tributaries	950/584	
(c) Sweathouse Branch and all tributaries	950/584	
(4) Use III-P: Gunpowder Falls and all tributaries	930.8/578.9	Above Loch Raven
(5) Use IV: Whitemarsh Run and all tributaries	964/564	
(6) Use IV-P: None		

J. SUB-BASIN 02-13-09: PATAPSCO RIVER AREA

(1) Use I-P:		
(a) Liberty Reservoir	830.9/562.1	Above Liberty Dam
(b) All tributaries to West Branch Patapsco River	828.8/621.4	
(c) All tributaries to North Branch Patapsco River except those designated below as Use III-P or Use IV-P	835.8/604.8	Above Liberty Reservoir
(2) Use II: None		
(3) Use III:		
(a) Brice Run and all tributaries	850/540	
(b) Piney Run and all tributaries	From 828/554 to 815.8/563.6	From mouth to Slacks Road (on Springfield State Hospital Grounds)

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(c) Jones Falls and all tributaries	897.7/567.6	Above Lake Roland
(d) Red Run and all tributaries	863/572.4	
(e) Gwynns Falls and all tributaries	861.5/578.5	Above Reistertown Road
(f) Gillis Falls and all tributaries	782/557	
(g) South Branch Patapsco River and all tributaries	782/557	Above confluence with Gillis Falls tributaries
(h) Unnamed tributary to the South Branch Patapsco River at Henryton and all tributaries to this unnamed tributary	823.9/552.9	
(4) Use III-P:		Above Slacks Road (on Springfield State Hospital Grounds)
(a) Piney Run and all tributaries	815.8/563.6	
(b) Morgan Run and all tributaries	813.8/589.6	
(c) Norris Run and all tributaries	835.1/592.6	
(d) Cooks Branch and all tributaries	836.2/584.4	
(e) Keysers Run and all tributaries	833.8/596.8	
(f) Beaver Run and all tributaries	828.3/602.1	
(g) Snowdens Run and all tributaries	825/572	
(h) Stillwater Creek and all tributaries	824.8/570.9	
(i) Carroll Highlands Run and all tributaries	825.5/567.4	
(j) Autumn Run and all tributaries	825.7/567	
(k) Locst Run and all tributaries	839.1/572.9	
(l) Glen Falls Run and all tributaries	837.4/605.1	
(m) East Branch Patapsco River and all tributaries	830.1/620.4	
(5) Use IV:		
(a) South Branch Patapsco River	833.4/552.5	Mainstem only
(b) Jones Falls	From 908/538.5 to 901/563	From North Ave. to Lake Roland Dam
(c) Herring Run and all tributaries	929.5/537	Above I-95
(d) Stony Run and all tributaries	905/541	
(e) Dead Run and all tributaries	888/536.5	
(f) Stemmers Run and all tributaries	941.4/553.8	Above I-95
(6) Use IV-P:		
(a) North Branch Patapsco River	833.4/552.2	Mainstem only above Liberty Reservoir
(b) West Branch Patapsco River	830.1/620.3	Mainstem only
(c) Cranberry Branch and all tributaries	888.1/637.3	Above Md Rt. 852 (Old Manchester Rd)
K. SUB-BASIN 02-13-10: WEST CHESAPEAKE BAY AREA		
(1) Use I-P: None		
(2) Use II: All estuarine portions of tributaries except:		
(a) Magothy River and tributaries	936.9/455	Above Henderson Pt
(b) Severn River and tributaries	920.6/451	Above mouth of Forked Creek
(c) South River and tributaries	918.8/410.1	Above Porter Pt.
(d) Rockhold Creek and tributaries	925.7/315.8	Above Mason Beach Road

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(e) Tracys Creek	924.5/344.2	
(3) Use III: Jabez Branch and all tributaries	905/455	
(4) Use III-P: None		
(5) Use IV: Severn Run and all tributaries	907.3/454.1	Above Rt.3
(6) Use IV-P: None		
L. SUB-BASIN 02-13-11: PATUXENT RIVER AREA		
(1) Use I-P:		
(a) Little Patuxent River and all tributaries	866.5/453.8	Above Old Forge Bridge (1 mile south of MD Route 198)
(b) Patuxent River and all tributaries except those designated below aas Use III-P or IV-P	845.8/467.4	Above Rocky Gorge Dam
(2) Use II: All estuarine portions of tributaries except Patuxent River and tributaries	886.8/316.3	Above Ferry Landing
(3) Use III: None		
(4) Use III-P: Patuxent River and tributaries	787.2/510.7	Above Triadelphia Reservoir
(5) Use IV: None		
(6) Use IV-P: Patuxent River and tributaries	813.2/476.8	Between Rocky Gorge Reservoir and Triadelphia Reservoir, and including Triadelphia Reservoir
M. SUB-BASIN 02-14-01: LOWER POTOMAC RIVER AREA		
(1) Use I-P: Tilghman Lake Reservoir	817/260	
(2) Use II: All estuarine portions of tributaries except Potomac River and tributaries	From 723.8/211.8 to 710.9/205.3	Above line from Smith Pt. to Simms Pt.
(3) Use III: None		
(4) Use III-P: None		
(5) Use IV: None		
(6) Use IV-P: None		
N. SUB-BASIN 02-14-02: WASHINGTON METROPOLITAN AREA		
(1) Use I-P: Potomac River and all tributaries except those designated below as Use III, Use III-P, Use IV or Use IV-P	766/401	From MD/DC line to Frederick/Montgomery County line
(2) Use II: None		
(3) Use III:		
(a) Paint Branch and all tributaries	815.2/433.2	Above Capital Beltway (I-495)
(b) Rock Creek and all tributaries	764/475	Above Muncaster Mill Road
(c) North Branch Rock Creek and all tributaries	771.5/468	Above Muncaster Mill Road
(4) Use III-P:		
(a) Little Seneca Creek and all tributaries	From 704/477.4 to 716/491.3	From the stream's confluence with Bucklodge Branch to the Baltimore and Ohio railroad bridge (see Regulation 26.08.02.03-3E(1) of this chapter)
(b) Wildcat Branch and all tributaries	740.5/504	

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(5) Use IV:		
(a) Rock Creek and all tributaries	From 766.7/459.3 to 763.5/475 809/413	From Rt. 28 to Muncaster Mill Road
(b) Northwest Branch and all tributaries		Above east-West Highway (Rt. 410)
(6) Use IV-P: Little Seneca Creek and all tributaries	719.2/497.4	
O. SUB-BASIN 02-14-03: MIDDLE POTOMAC RIVER AREA		
(1) Use I-P: Potomac River and all tributaries except those designated below as Use III-P or Use IV-P	671/505.9	From Frederick/Montgomery County Line to confluence with Shenandoah River
(2) Use II: None		
(3) Use III: None		
(4) Use III-P:		
(a) Tuscarora Creek and all tributaries	694/592	
(b) Carroll Creek and all tributaries	678.5/579.5	Above U.S. Rt. 15
(c) Rocky Fountain Run and all tributaries	681/546	
(d) Fishing Creek and all tributaries	689.2/609.2	
(e) Hunting Creek and all tributaries	698.5/625.5	
(f) Owens Creek and all tributaries	705.9/635.9	
(g) Friends Creek and all tributaries	697.2/689.1	
(h) Catoctin Creek and all tributaries	640.6/589.8	Above Alternate U.S. Rt. 40
(i) Little Bennett Creek and all tributaries	711/527	Above Md. Rt. 355
(j) Furnace Branch and all tributaries	675/514	
(k) Ballenger Creek and all tributaries	557/683	
(l) Bear Branch and all tributaries	685.2/531.9	From confluence with Bennett Creek
(5) Use IV: None		
(6) Use IV-P:		
(a) Monacacy River and all tributaries except those designated above as Use III-P	696/570	Above U.S. Rt. 40
(b) Catoctin Creek	640.6/538	Mainstem only, below Alternate U.S. Route 40
(c) Israel Creek and all tributaries	607/545	
P. SUB-BASIN 02-14-05: UPPER POTOMAC RIVER AREA		
(1) Use I-P: Potomac River and all Maryland tributaries except those designated below as Use III-P or Use IV-P	543.3/594.4	From confluence of Shenandoah River to the confluence of the North and South Branches of the Potomac River
(2) Use II: None		
(3) Use III: None		
(4) Use III-P:		
(a) Town Creek tributaries	365/618.8	
(b) Beaver Creek and all tributaries	599.9/620.3	In Antietam Creek Watershed
(c) Marsh Run and all tributaries	605.7/662.1	In Antietam Creek Watershed

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(d) Little Antietam Creek and all tributaries	620/674	
(e) Camp Spring Run and all tributaries	536/653	
(5) Use IV: None		
(6) Use IV-P:		
(a) Town Creek	365/618.8	
(b) Fifteen Mile Creek and all tributaries	410.1/655	
(c) Sideling Hill Creek and all tributaries	424.5/660	
(d) Tonoloway Creek and all tributaries	474.8/679.8	
(e) Licking Creek and all tributaries	504/663.5	
(f) Conococheague Creek and all tributaries	566.3/645.4	
(g) Antietam Creek and all tributaries except those designated above as Use III-P	58901/577.8	

Q. SUB-BASIN 02-14-10: NORTH BRANCH POTOMAC RIVER AREA

(1) Use I-P:		
(a) North Branch Potomac River mainstem	352.3/621.1	From the confluence of the North and South Branches of the Potomac River to the MD/WVA State line
(b) Georges Creek mainstem	222.8/607.4	From the confluence with N. Branch
(c) Mill Run and its tributaries in Allegany County	272.2/625.8	From the confluence with N. Branch (near Rawlings and Rawlings Heights)
(d) an unnamed tributary near Pinto	281.7/636.5	Confluence of the unnamed tributary with the North Branch of the Potomac River
(2) Use II: None		
(3) Use III: None		
(4) Use III-P: All Maryland tributaries to the North Branch Potomac River except for:	From 352.3/621.1 to MD/WVA State line	From confluence of North and South Branches of the Potomac River to MD/WVA State line
(a) Those designated below as Use IV-P waters		
(b) Those designated above as Use I-P waters		
(5) Use IV: None		
(6) Use IV-P:		
(a) Wills Creek	303.3/655.5	Mainstem only
(b) Evitts Creek	310.2/656.8	Mainstem only

R. SUB-BASIN 05-02-02: YOUGHIOGHENY RIVER AREA

(1) Use I-P:		
(a) Broad Ford Run and all tributaries	130/579	Above Dam
(b) Piney Creek and all tributaries in Maryland	232/687	Upstream from confluence with Church Creek
(2) Use II: None		
(3) Use III:		
(a) South Branch, Casselman River	187.7/674.0	Confluence of North and South Branches

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(b) Piney Creek and all tributaries in Maryland, including Church Creek	223.9/693.9	From MD/PA State line to confluence of Church Creek
(4) Use III-P: Youghiogheny River and all tributaries	126.8/696.2	Upstream of MD/PA State line joining mainstem of the Youghiogheny River in Maryland
(5) Use-IV: Casselman River	205.5/694.8	Mainstem only, confluence of South Branch & North Branch to PA line
(6) Use IV-P: None		

S. SUB-BASIN 02-05-03: CONEWAGO CREEK

(1) Use I-P: None
(2) Use II: None
(3) Use III: None
(4) Use III-P: None
(5) Use IV: None
(6) Use IV-P: None

T. SUB-BASIN 02-13-99: CHESAPEAKE BAY (PROPER)

(1) Use I-P: None
(2) Use II: All waters of the Chesapeake Bay Proper — From the Susquehanna River mouth to the Virginia State line, including the tidal waters of the Chesapeake Bay bounded generally by the shoreline of the Bay and by "zero river mile" lines of estuaries and tributaries to the Bay, as designated by the Department of the Environment, and any peripheral waters designated as part of the Chesapeake Bay Proper by the Department of the Environment after consultation with the Tidewater Administration and the Forest, Park and Wildlife Service
(3) Use III: None
(4) Use III-P: None
(5) Use IV: None
(6) Use IV-P: None

SARB_005122

Designator	Sub-Basin
02-12-02	Lower Susquehanna River Area
02-13-01	Coastal Area
02-13-02	Pocomoke River Area
02-13-03	Nanticoke River Area
02-13-04	Choptank River Area
02-13-05	Chester River Area
02-13-06	Elk River Area
02-13-07	Bush River Area
02-13-08	Gunpowder River Area
02-13-09	Patapsco River Area
02-13-10	West Chesapeake Bay Area
02-13-11	Patuxent River Area
02-14-01	Lower Potomac River Area
02-14-02	Washington Metropolitan Area
02-14-03	Middle Potomac River Area
02-14-05	Upper Potomac River Area
02-14-10	North Branch Potomac River Area
05-02-02	Youghiogheny River Area
02-05-03	Conewago Creek Area
02-13-99	Chesapeake Bay

SARB_005123

Appendix D.10

Method for Computing Peak Discharge for Water Quality Storm

METHOD FOR COMPUTING PEAK DISCHARGE FOR WATER QUALITY STORM

(Adapted from Claytor and Schueler, 1996)

The peak rate of discharge is needed for the sizing of off-line diversion structures and to design grass channels. Conventional SCS methods underestimate the volume and rate of runoff for rainfall events less than 2". This discrepancy in estimating runoff and discharge rates can lead to situations where a significant amount of runoff by-passes the filtering treatment practice due to an inadequately sized diversion structure or leads to the design of undersized grass channels.

The following procedure can be used to estimate peak discharges for small storm events. It relies on the volume of runoff computed using the Small Storm Hydrology Method (Pitt, 1994) and utilizes the NRCS, TR-55 Graphical Peak Discharge Method (USDA, 1986).

- Using the WQ_v methodology, a corresponding Curve Number (CN) is computed utilizing the following equation:

$$CN = \frac{1000}{[10 + 5P + 10Q_a - 10\sqrt{Q_a^2 + 1.25Q_aP}]}$$

where: P = rainfall, in inches (use 1.0" or 0.9" for the Water Quality Storm)
Q_a = runoff volume, in inches (equal to $P \times R_v$)

Note: The above equation is derived from the SCS Runoff Curve Number method described in detail in NEH-4, Hydrology (SCS 1985) and SCS TR-55 Chapter 2: Estimating Runoff. The CN can also be obtained graphically using Figure D.10.1 or from TR-55.

- Once a CN is computed, the time of concentration (t_c) is computed (based on the methods identified in TR-55, Chapter 3: "Time Of Concentration And Travel Time").

- Using the computed CN, t_c and drainage area (A), in acres; the peak discharge (Q_p) for the Water Quality Storm is computed (based on the procedures identified in TR-55, Chapter 4: "Graphical Peak Discharge Method"). Use Rainfall distribution type II.

  - Read initial abstraction (I_a), compute I_a/P
  - Read the unit peak discharge (q_u) from Exhibit 4-II for appropriate t_c
  - Using the runoff volume (Q_a), compute the peak discharge (Q_p); $Q_p = q_u \times A \times Q_a$

where: Q_p = the peak discharge, in cfs
q_u = the unit peak discharge, in cfs/mi²/inch
A = drainage area, in square miles
Q_a = runoff volume, in watershed inches

SARB_005126

Example Calculation of Peak Discharge for Water Quality Storm

Using a 3.0 acre small shopping center having a 1.0 acre flat roof, 1.6 acres of parking, and 0.4 acres of open space, and using $P = 1.0"$; the weighted volumetric runoff coefficient (R_v) is:

$$R_v = 0.05 + 0.009(I);\ I = 2.6 \text{ acres}/3.0 \text{ acres} = 0.867\ (86.7\%)$$
$$= 0.05 + 0.009(86.7\%)$$
$$= 0.83$$

The runoff volume, Q_a is:

$$Q_a = P \times R_v$$
$$= 1.0" \times 0.83$$
$$= 0.83 \text{ watershed inches}$$

and WQ_v is:

$$WQ_v = \frac{[(1.0")(0.83)(3.0\ acres)]}{12} \times \frac{43{,}560\ ft^2}{acre} = 9{,}039\ ft^3$$

Using $Q_a = 0.83$ watershed inches and $P = 1.0"$; CN for the water quality storm is:

$$CN = \frac{1000}{[10 + (5)(1.0") + (10)(0.83) - 10\sqrt{(0.83)^2 + 1.25(0.83)(1.0")}]} = 98$$

Using: $t_c = 10$ minutes (0.17 hour);
$I_a = (200/CN) - 2 = 0.041$;
$I_a/P = (0.041/1.0") = 0.041$;
$q_u = 950$ csm/in. (from TR-55 Exhibit 4-II); and
$A = 3.0$ acres $\times$ 1/640 mi^2 per acre $= 0.0047$ mi^2

$$Q_p = (950 \text{ csm/in.})(0.0047 \text{ mi}^2)(0.83") = 3.7 \text{ cfs}$$

For computing runoff volume and peak rate for storms larger than the Water Quality Storm (i.e., 2, 10 and 100 year storms), use the published CN's from TR-55 and follow the prescribed procedure in TR-55.

In some cases the Rational Formula may be used to compute peak discharges associated with the Water Quality Storm. The designer must have available reliable intensity, duration, frequency (IDF) tables or curves for the storm and region of interest. This information may not be available for many locations and therefore the TR-55 method described above is recommended.

SARB_005127

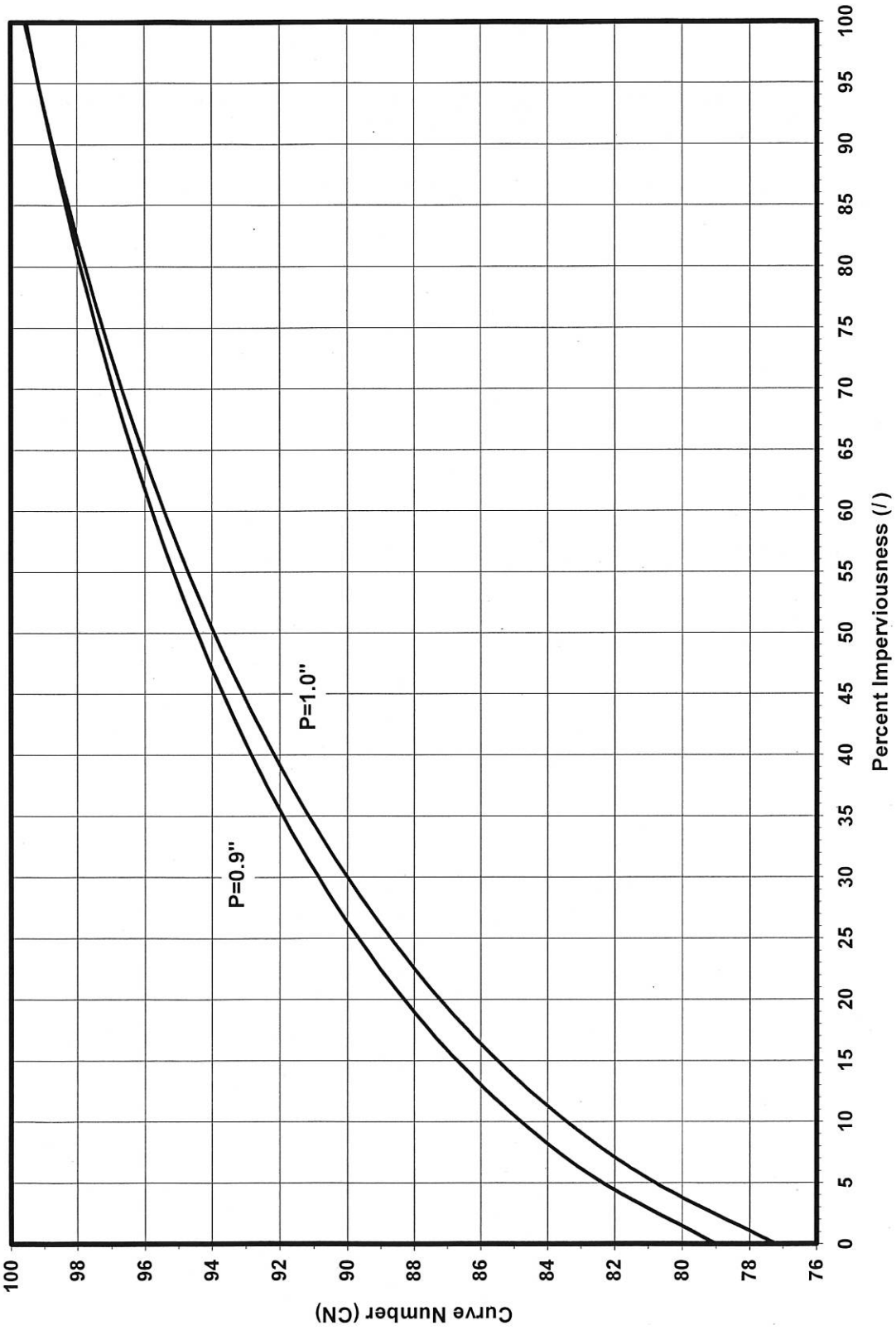


Figure D-10.1 Curve Number (CN) for Water Quality Storm
- Rainfall (P) =1.0" & 0.9"

SARB_005128

References

Pitt, R., 1994, Small Storm Hydrology. University of Alabama - Birmingham. Unpublished manuscript. Presented at design of stormwater quality management practices. Madison, WI, May 17-19 1994.

Schueler, T.R. and R.A. Claytor, 1996, Design of Stormwater Filter Systems. Center for Watershed Protection, Silver Spring, MD.

United States Department of Agriculture (USDA), 1986. Urban Hydrology for Small Watersheds. Soil Conservation Service, Engineering Division. Technical Release 55 (TR-55).

SARB_005129

Appendix D.11

Method for Computing the Channel Protection Storage Volume (Cp_v)

SARB_005132

The following procedure shall be used to design the channel protection storage volume (Cp_v). The method is based on the Design Procedures for Stormwater Management Extended Detention Structures (MDE, 1987) and utilizes the NRCS, TR-55 Graphical Peak Discharge Method (USDA, 1986).

- Compute the time of concentration (t_c) and the one-year post-development runoff depth (Q_a) in inches.

- Compute the initial abstraction (I_a) [$I_a = 200/CN - 2$] and the ratio I_a/P where P is the one-year rainfall depth (see Table 2-2).

- With t_c and I_a/P, find the unit peak factor (q_u) from Figure D.11.1 and compute the one year post-development peak discharge $q_i = q_u A Q_a$ where A is the drainage in square miles.

- If $q_i \leq 2.0$ cfs, Cp_v is not required. Provide for water quality (WQ_v) and groundwater recharge (Re_v) as necessary.

- With q_u, find the ratio of outflow to inflow (q_o/q_i) for T = 24 hours from Figure D.11.2 (use T=12 hours in USE III/IV waters).

- Compute the peak outflow discharge $q_o = \frac{q_o}{q_i} \times q_i$

- With q_o/q_i, compute the ratio of storage to runoff volume (V_s/V_r).

$$\frac{V_s}{V_r} = 0.683 - 1.43\left(\frac{q_o}{q_i}\right) + 1.64\left(\frac{q_o}{q_i}\right)^2 - 0.804\left(\frac{q_o}{q_i}\right)^3$$

- Compute the extended detention storage volume $V_s = \left(\frac{V_s}{V_r}\right) \times V_r$ (note: $V_r = Q_a$);

  Convert V_s to acre-feet by $\frac{V_s}{12} \times A$, where V_s is in inches and A is in acres.

- Compute the required orifice area (A_o) for extended detention design:

$$A_o = \frac{q_o}{C\sqrt{2gh_o}} = \frac{q_o}{4.81\sqrt{h_o}}$$

  where h_o is the maximum storage depth associated with V_s.

- Determine the required maximum orifice diameter (d_o) $d_o = \sqrt{4A_o/\pi}$.

  A d_o of less than 3.0" is subject to local jurisdictional approval, and is not recommended unless an internal control for orifice protection is used (App. D.8).

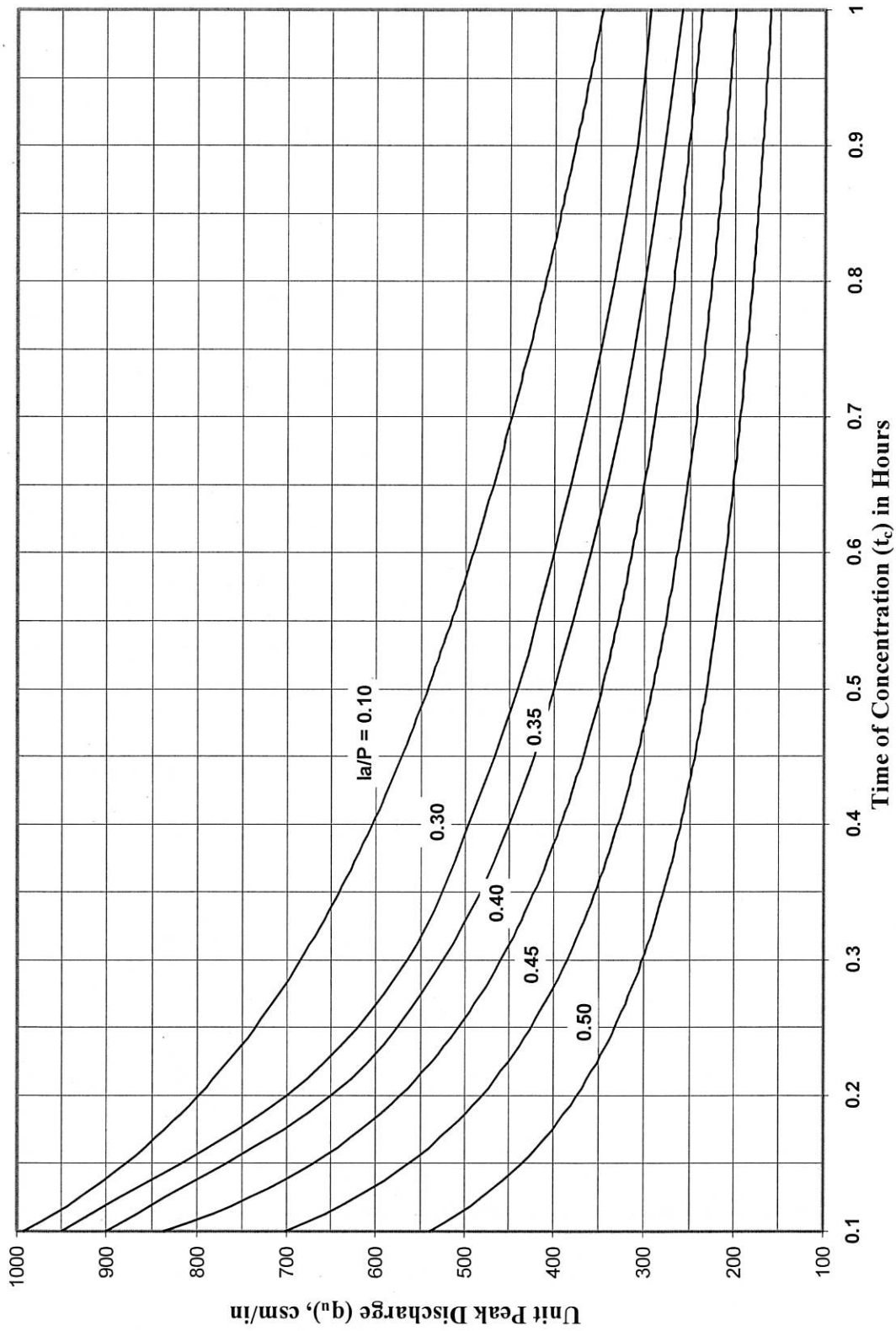
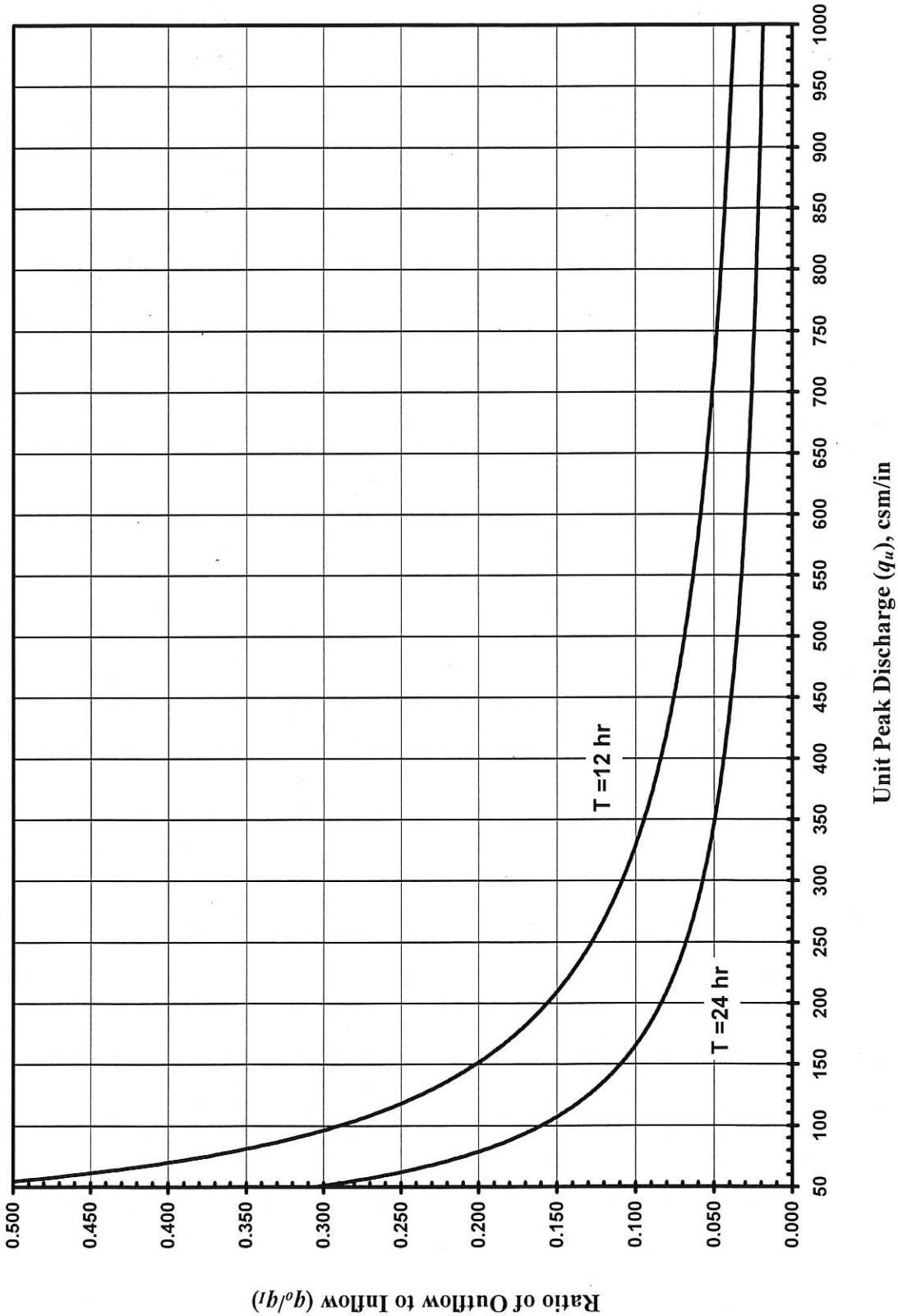


Figure D.11.1 SCS Graphical Method of Determining Peak Discharge (q_u) in csm/in for 24-Hour Type II Storm Distribution

Figure D.11.2 Detention Time Versus Discharge Ratios (q_o/q_i)



Appendix D.12

Critical Erosive Velocity for Grass and Soil

Velocity

Maximum permissible velocities of flow shall not exceed the values shown on the following table:

Table D.12.1 Permissible Velocities for Channels Lined with Vegetation

Channel Slope	Lining	Permissible Velocity[1] (ft/sec)
0-5%	Reed canarygrass Tall fescue Kentucky bluegrass	5
	Grass-legume mixture	4
	Red fescue Redtop Sericea lespedeza Annual lespedeza Small grains	2.5
5-10%	Reed canarygrass Tall fescue Kentucky bluegrass	4
	Grass-legume mixture	3
Greater than 10%	Reed canarygrass Tall fescue Kentucky bluegrass	3

[1] For highly erodible soils, permissible velocities should be decreased 25%. An erodibility factor (K) greater than 0.35 would indicate a highly erodible soil. Erodibility factors (K-factors) for Maryland soils are listed either in the Soil Survey or on the Soils-5 forms available in each Soil Conservation District or local NRCS office.

Source: Soil and Water Conservation Engineering, Schwab, *et al.*

SARB_005136

Appendix D.13

Method for Designing Infiltration Structures

SARB_005138

Introduction

The following procedures shall be used for designing infiltration trenches (I-1) and basins (I-2) to meet the water quality (WQ_v), the channel protection (Cp_v), and the overbank flood protection (Qp) volume requirements. These methods are based on the 1984 Maryland Standards and Specifications for Infiltration Practices (MDE, 1984) and Modelling Infiltration Practices Using TR-20 (MDE, 1983).

The use of infiltration practices depends on careful site investigation. The feasibility conditions listed in Chapter 3.3 and in Appendix D.1 are to be investigated and are equally important in ensuring the proper function of an infiltration practice. Should a site investigation reveal that any one of the feasibility tests is not adequate, the implementation of infiltration practices should not be pursued. Alternate feasibility criteria may be permitted only in those conditions where the local jurisdictions can justify and ensure proper application.

D.13.1 Soil Textures

The hydrologic design methods presented in this appendix are based on the utilization of two hydrologic soil properties, the effective water capacity (C_w) and the minimum infiltration rate (f) of the specific soil textural groups, as shown in Table D.13.1. The effective water capacity of a soil is the fraction of the void spaces available for water storage, measured in inches per inch. The minimum infiltration rate is the final rate that water passes through the soil profile during saturated conditions, measured in terms of inches per hour. The hydrologic soil properties are obtained by identifying the soil textures by a gradation test for each change in soil profile. The soil textures presented in Table D.13.1 correspond to the soil textures of the U.S. Department of Agriculture (USDA) Textural Triangle presented in Figure D.13.1.

The data presented in Table D.13.1 are based on the analysis of over 5,000 soil samples by the USDA under carefully controlled procedures. The use of the soil properties established in Table D.13.1 for design and review procedures will offer two advantages. First, it provides for consistency of results in the design procedures. Second, it eliminates the need for the laborious and costly process of conducting field and laboratory infiltration and permeability tests.

SARB_005139

Table D.13.1 Hydrologic Soil Properties Classified by Soil Texture*

Texture Class	Effective Water Capacity (C_w) (inch per inch)	Minimum Infiltration Rate (f) (inches per hour)	Hydrologic Soil Grouping
Sand	**0.35**	**8.27**	**A**
Loamy Sand	**0.31**	**2.41**	**A**
Sandy Loam	**0.25**	**1.02**	**A**
Loam	**0.19**	**0.52**	**B**
Silt Loam	**0.17**	**0.27**	**B**
Sandy Clay Loam	**0.14**	**0.17**	**C**
Clay Loam	**0.14**	**0.09**	**D**
Silty Clay Loam	**0.11**	**0.06**	**D**
Sandy Clay	**0.09**	**0.05**	**D**
Silty Clay	**0.09**	**0.04**	**D**
Clay	**0.08**	**0.02**	**D**

* Source: Rawls, Brakensiek and Saxton, 1982

Based on the soil textural classes and the corresponding minimum infiltration rates, a restriction is established to eliminate unsuitable soil conditions. Soil textures with minimum infiltration rates less than 0.52 inches per hour are not suitable for usage of infiltration practices. These include soils that have a 30 percent clay content, making these soils susceptible to frost heaving and structurally unstable, in addition to having a poor capacity to percolate runoff. Soil textures that are recommended for infiltration systems include those soils with infiltration rates of 0.52 inches per hour or greater, which include loam, sandy loam, loamy sand, and sand.

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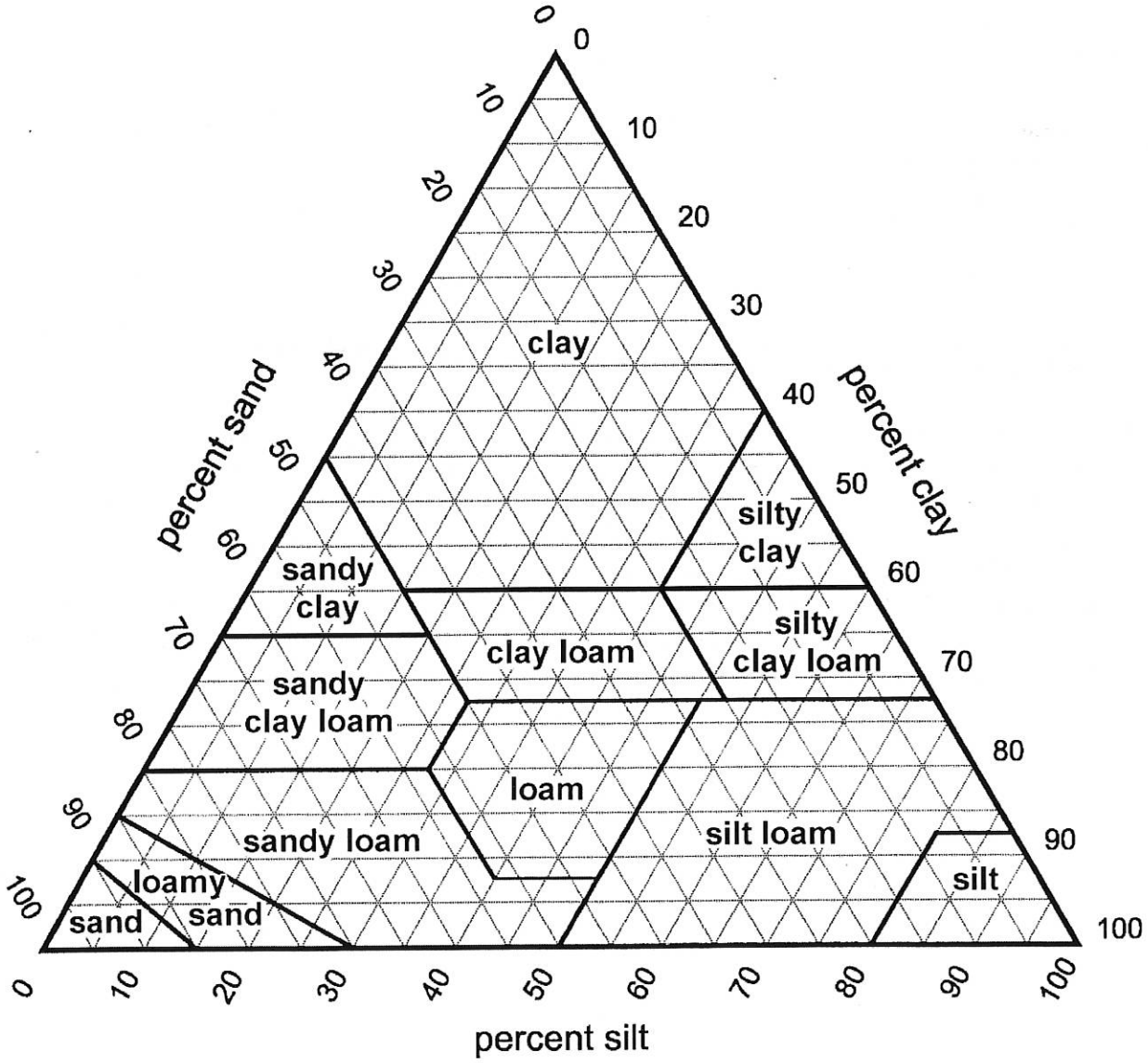
Figure D.13.1 USDA Soils Textural Triangle



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D.13.2 Hydrologic Design Methods

D.13.2.1 General Design Situations

There are two general types of situations where infiltration practices may be used. First , one may be interested in the dimensions of an infiltration device that is required to provide storage of the WQ_v, and/or the Cp_v or Q_p. Second, site conditions may dictate the layout and capacity of infiltration measures and one might be interested in determining the level of control provided by such a layout. In the latter case, control may not be sufficient and additional control, possibly using other acceptable Best Management Practices (BMPs), may be required. It is important to emphasize that the same principles of design apply to both cases.

Design methodologies are presented for two infiltration practices: infiltration trenches (I-1) and infiltration basins (I-2). The design procedures are based on either intercepting the WQ_v from the area contributing runoff or using the truncated hydrograph method for control of the runoff from an area for either Cp_v or Q_p. The design equations may be defined for either case of stormwater quality or quantity control because the volume of water (V_w) stored in the individual infiltration practice may be determined from the methods described in Chapter 2 (for WQ_v) and in Appendix D.13.3 for Cp_v and/or Q_p.

D.13.2.2 Design of Infiltration Trenches (I-1)

The design of an infiltration trench is based on the textural class of the soils underlying the trench such that a feasible design is possible. The design of an infiltration trench is also based on the maximum allowable depth of the trench (d_{max}). The maximum allowable depth should meet the following criteria:

$$d_{\max} = \frac{fT_s}{n}$$

Where f is the final infiltration rate of the trench area in inches per hour, T_s is the maximum allowable storage time in hours, and n is the porosity (V_v/V_t) of the stone reservoir.

An infiltration trench is sized to accept the design volume that enters the trench (V_w) plus the volume of rain that falls on the surface of the trench (PA_t) minus the exfiltration volume (fTA_t) out of the bottom of the trench. Based on the SCS hydrograph analysis, the effective filling time for most infiltration trenches (T) will generally be less than two hours. The volume of water that must be stored in the trench (V) is defined as:

SARB_005142

$$V = V_w + PA_t - fTA_t \quad \text{(Equation D - 13.1)}$$

where P is the design rainfall event (ft), and A_t is the trench surface area (ft^2). For most design storm events, the volume of water due to rainfall on the surface area of the trench (PA_t) is small when compared to the design volume (V_w) of the trench and may be ignored with little loss in accuracy to the final design.

The volume of rainfall and runoff entering the trench can be defined in terms of trench geometry. The gross volume of the trench (V_t) is equal to the ratio of the volume of water that must be stored (V) to the porosity (n) of the stone reservoir in the trench; V_t is also equal to the product of the depth (d_t) and the surface area (A_t):

$$V_t = V/n = d_t A_t n \quad \text{(Equation D - 13.2)}$$

Combining equations D.13.1 and D.13.2 yields the following relationship:

$$d_t A_t n = V_w - fTA_t \quad \text{(Equation D - 13.3)}$$

Because both dimensions of the trench are unknown, this equation may be rearranged to determine the area of the trench (A_t) if the value of d_t were set based on either the location of the water table or the maximum allowable depth of the trench (d_{max}):

$$A_t = \frac{V_w}{nd_t + fT}$$

Procedures for Infiltration Trench Design

1. Determine the volume of water for storage using the methods for WQ_v, Cp_v, or Q_p found in Chapter 2 and/or Appendix D.13.3.

2. Compute the maximum allowable trench depth (d_{max}) from the feasibility equation, $d_{max} = fT_s/n$. Select the trench design depth (d_t) based on the depth that is the required depth above the seasonal groundwater table, or a depth less than or equal to d_{max}, whichever results in the smaller depth.

3. Compute the trench surface area (A_t) for the particular soil type using Equation D.13.3.

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In the event that the sidewalls of the trench must be sloped for stability during construction, the surface dimensions of the trench should be based on the following equation:

$$A_t = (L - Zd_t)(W - Zd_t)$$

where L and W are the top length and width, and Z:1 is the trench side slope ratio. The design procedure would begin by selecting a top width (W) that is greater than $2 \times Zd_t$ for a specified slope (Z). The side slope ratio value will depend on the soil type and the depth of the trench. The top length (L) may then be determined as:

$$L = Zd_t + \frac{A_t}{W - Zd_t}$$

D.13.2.3 Design of Infiltration Basins (I-2)

The design of an infiltration basin is based on the same soil textural properties and maximum allowable depth as the infiltration trench such that a feasible design is possible. However, because the infiltration basin uses an open area or shallow depression for storage, the maximum allowable depth (d_{max}) should meet the following criteria:

$$d_{\max} = f \times T_p$$

where f is the final infiltration rate of the trench area in inches per hour and T_p is the maximum allowable ponding time in hours.

An infiltration basin is sized to accept the design volume that enters the basin (V_w) plus the volume of rain that falls on the surface of the basin (PA_b) minus the exfiltration volume (fTA_b) out of the bottom of the basin. Based on the SCS hydrograph analysis, the effective filling time for most infiltration basins will generally be less than two hours therefore use $T = 2$ hours. The volume of water that must be stored in the trench (V) is defined as

$$V = V_w + PA_b - fTA_b \quad \text{(Equation D - 13.4)}$$

where P is the design rainfall event (ft), and A_b is the basin surface area (ft^2). For most design storm events, the volume of water due to rainfall on the surface area of the basin (PA_b) is small when compared to the design volume (V_w) of the basin and may be ignored with little loss in accuracy to the final design.

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The volume of rainfall and runoff entering the basin can be defined in terms of basin geometry. The geometry of a basin will generally be in the shape of an excavated trapezoid with specified side slopes. The volume of a trapezoidal shaped basin may be approximated by:

$$V = \frac{(A_t + A_b)d_b}{2} \quad \text{(Equation D - 13.5)}$$

where A_t is the top surface area of the basin (ft^2), A_b is the bottom surface area of the basin (ft^2), and d_b is the basin depth (ft). By setting Equations D.13.4 and D.13.5 equal the following equation may be used to define the bottom area (A_b):

$$A_b = \frac{2V_w - A_t d_b}{(d_b - 2P + 2fT)} \quad \text{(Equation D - 13.6)}$$

If a rectilinear shape is used, the bottom length and width of the basin may be defined in terms of the top length and width as:

$$L_b = L_t - 2Zd_b$$

$$W_b = W_t - 2Zd_b$$

where Z is a specified side slope ratio (Z:1). By substituting the above relationships for L_b and W_b, into Equation D.13.6, the following equation is derived for the basin top length:

$$L_t = \frac{V_w + Zd_b(W_t - 2Zd_b)}{W_t(d_b - P) - Zd_b^2} \quad \text{(Equation D - 13.7)}$$

Procedures for Infiltration Basin Design

1. Determine the volume of water for storage using the methods for WQ_v, Cp_v, or Q_p found in Chapter 2 and/or Appendix D.13.3.

2. Compute the maximum allowable basin depth (d_{max}) from the feasibility equation, $d_{max} = fT_p$. Select the basin design depth (d_b) based on the depth that is the required depth above the seasonal groundwater table, or a depth less than or equal to d_{max}, whichever results in the smaller depth.

3. Compute the basin surface area dimensions for the particular soil type using Equation D.13.6.

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Note: If a rectilinear shape is used, the basin top length (L_t) and width (W_t) must be greater than $2Zd_b$ for a feasible solution. If L_t and W_t are not greater than $2Zd_b$ the bottom dimensions would be less than or equal to zero. In this case, the basin depth (d_b) shall be reduced for a feasible solution.

D.13.3 The Truncated Hydrograph Method for Stormwater Quantity Management

Most stormwater polices require that the peak discharge from the post-developed hydrograph for a selected return period(s) not exceed the peak discharge from the pre-developed hydrograph after development for stream channel erosion control and/or flood control purposes. In previous stormwater quantity management infiltration design methods, the difference between the pre-development and post-development runoff volumes was stored in the proposed infiltration structure. In most cases, this volume of runoff occurs prior to the actual hydrograph peak (see Figure D.13.2) and therefore actual peak discharge control is not provided. Therefore, when considering infiltration practices for peak discharge or stormwater quantity control, the truncated hydrograph method should be used to determine the necessary infiltration storage volumes.

The pre-development and post-development peak discharges can be computed using standard SCS methodology (TR-55 Tabular or TR-20). The time (T_2) at which the allowable discharge occurs on the receding limb of the post-development hydrography, as shown in Figure D.13.1 is determined from the SCS methods. The volume of runoff under the post-development hydrograph and to the left of the allowable discharge at T_2 is the design storage volume (V).

The computed infiltration storage volume, V, may be adjusted to account for the volume of water which exfiltrates from the infiltration structure during the period of time required to fill the structure. The exfiltration volume (V_e) is the product of the minimum soil infiltration rate (ft/hr), the filling time (hrs), and the surface area of the infiltration practice. The filling time (T_f) of the infiltration practice may be determined directly from the post-development hydrograph as shown in Figure D.13.1. T_f is the difference between T_2, where the allowable discharge occurs on the recession limb and the time T_1 where the discharge value on the rising of the hydrograph is equal to the minimum infiltration discharge. The minimum discharge is equal to the minimum soil infiltration rate (ft/sec) times the surface area (ft^2) of the infiltration practice.

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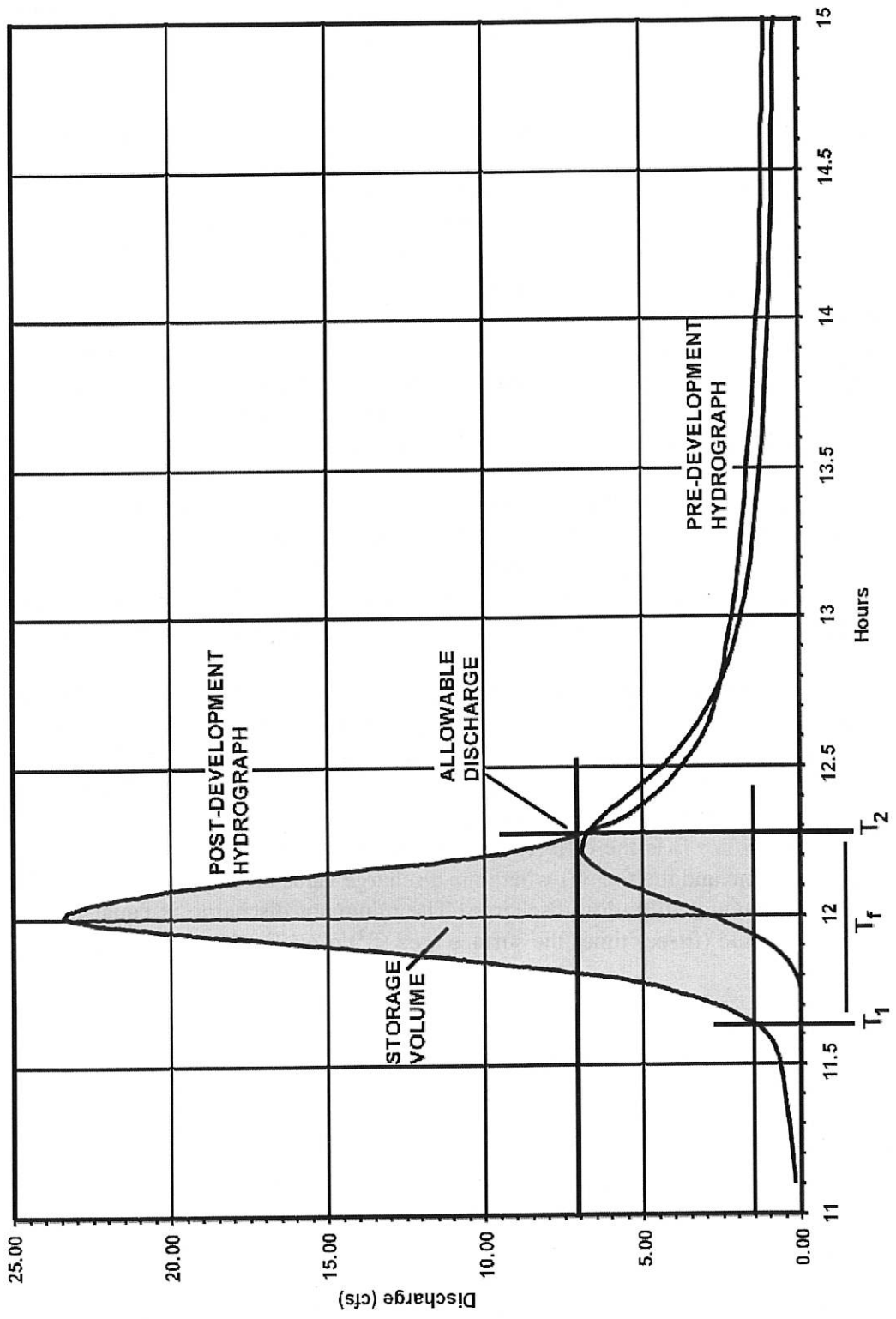

Figure D.13.2 Truncated Hydrograph Method

Appendix

D.14

Eastern Shore (Delmarva) Dimensionless Hydrograph

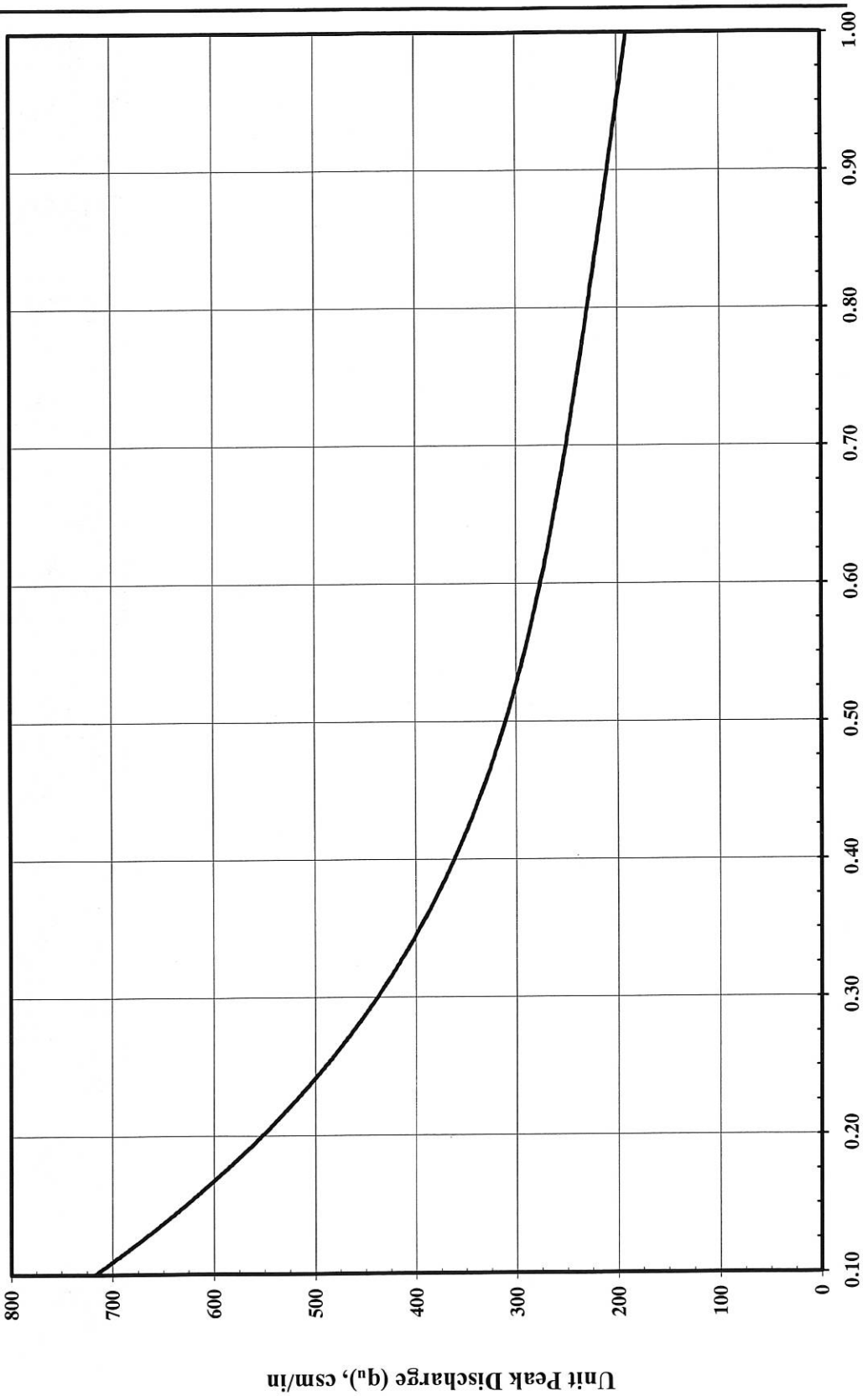

Figure D.14.1 SCS Graphical Method of Determining Peak Discharge (q_u) in csm/in For Delmarva Peninsula

SARB_005148

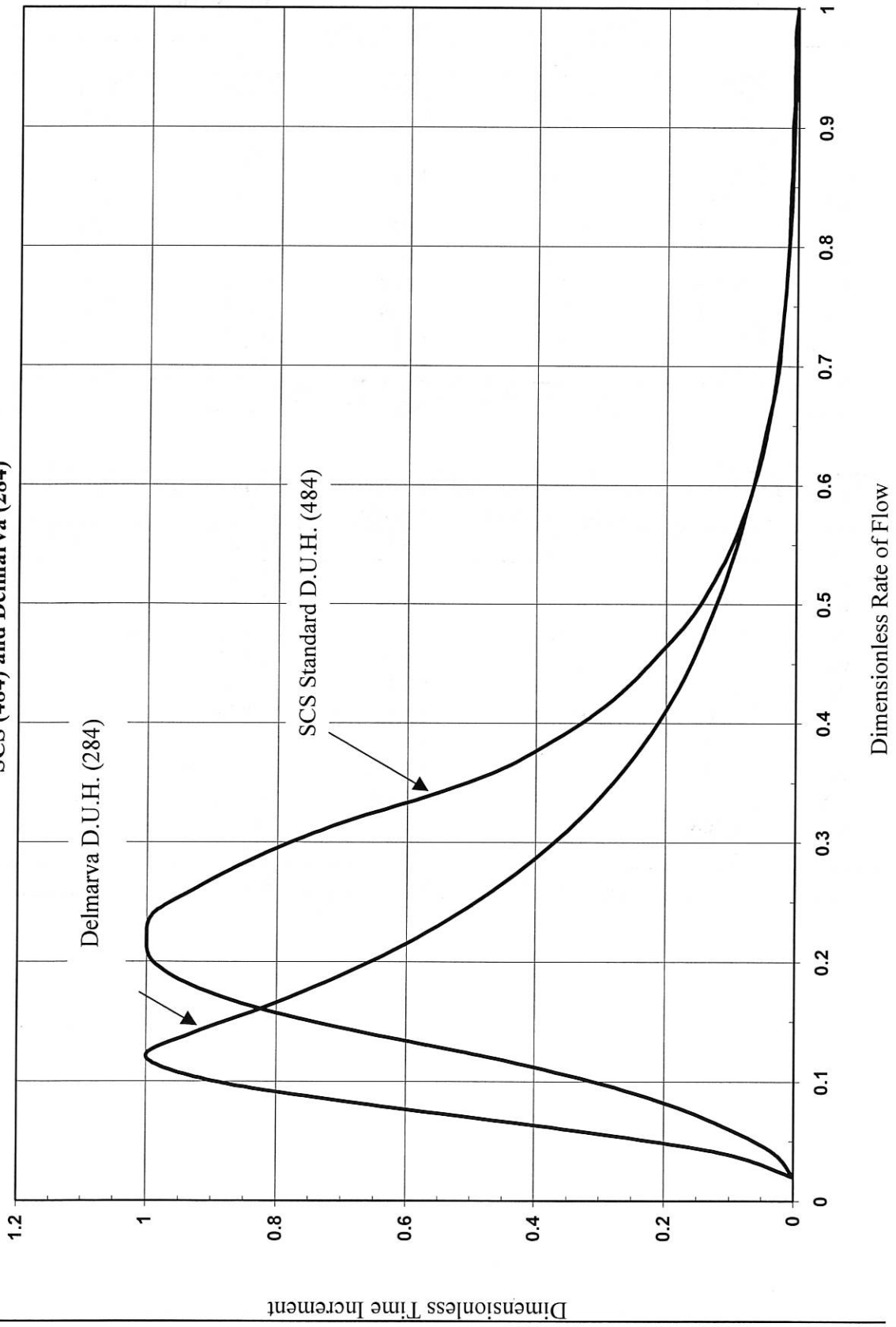

Figure D.14.2

SARB_005149

Table D.14.1 Standard 24-Hour Dimensionless Unit Hydrograph Dimensionless Time Increment = 0.02					
Δt	x.x0	x.x2	x.x4	x.x6	x.x8
0.0	0.0	0.0300	0.100	0.1900	0.31
0.1	0.47	0.66	0.82	0.93	0.99
0.2	1.00	0.99	0.93	0.86	0.78
0.3	0.68	0.56	0.46	0.39	0.33
0.4	0.28	0.241	0.207	0.174	0.147
0.5	0.126	0.107	0.091	0.077	0.066
0.6	0.055	0.047	0.04	0.034	0.029
0.7	0.025	0.021	0.018	0.015	0.013
0.8	0.011	0.009	0.008	0.007	0.006
0.9	0.005	0.004	0.003	0.002	0.001
1.0	0.0	0.0	0.0	0.0	0.0
Computed Peak Rate Factor = 484.00					

Table D.14.2 24-Hour Dimensionless Unit Hydrograph for Use in the Delmarva Peninsula Dimensionless Time Increment = 0.02					
Δt	x.x0	x.x2	x.x4	x.x6	x.x8
0.0	0.0	0.111	0.356	0.655	0.896
0.1	1.000	0.929	0.828	0.737	0.656
0.2	0.584	0.521	0.465	0.415	0.371
0.3	0.331	0.296	0.265	0.237	0.212
0.4	0.190	0.170	0.153	0.138	0.123
0.5	0.109	0.097	0.086	0.076	0.066
0.6	0.057	0.049	0.041	0.033	0.027
0.7	0.024	0.021	0.018	0.015	0.013
0.8	0.012	0.011	0.009	0.008	0.008
0.9	0.006	0.006	0.005	0.005	0.0
1.0	0.0	0.0	0.0	0.0	0.0
Computed Peak Rate Factor = 284.00					

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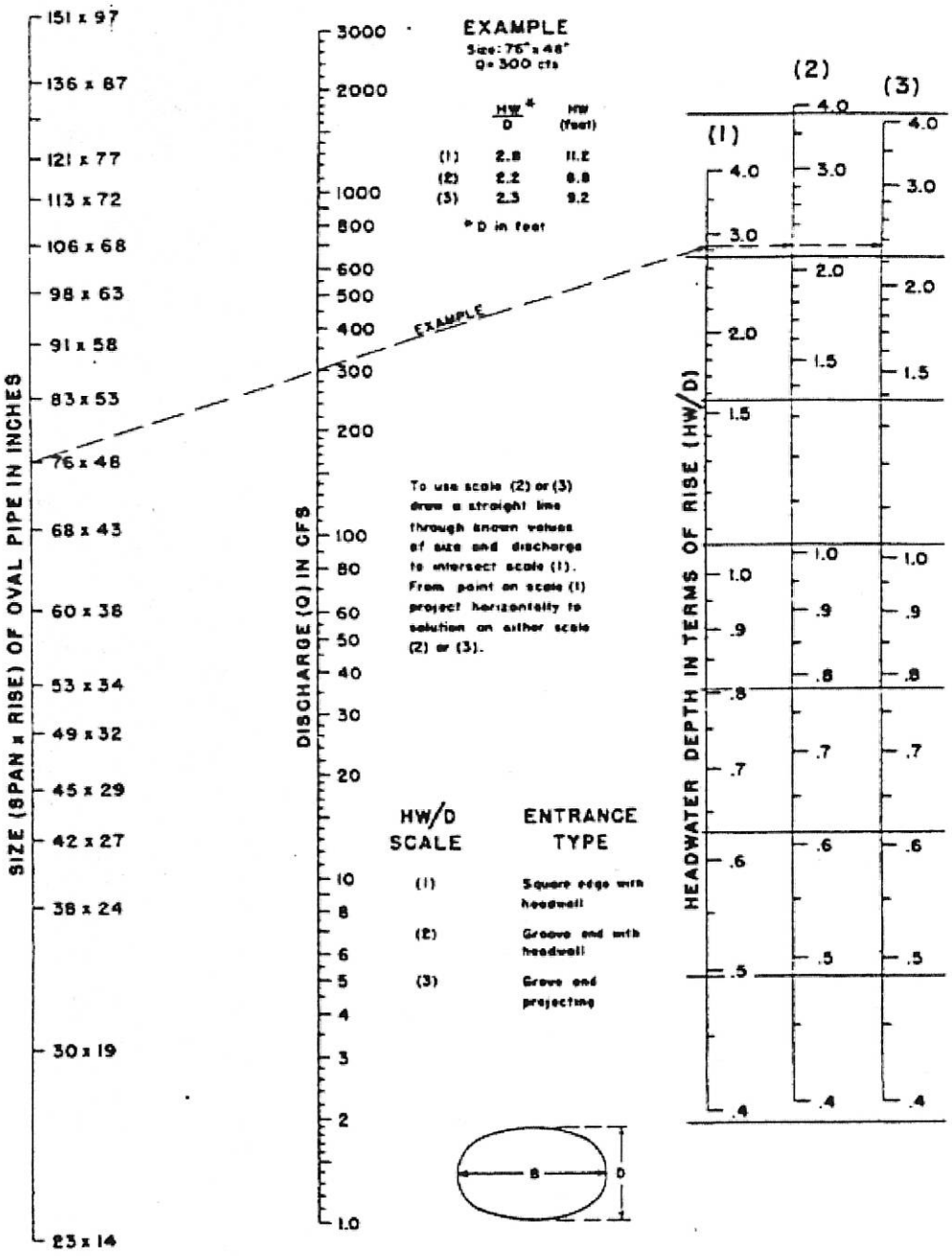
Appendix

D.15

Miscellaneous MD SHA Design Charts for Determining Pipe Inlet Control

FIGURE D.15.1 HEADWATER DEPTH FOR OVAL CONCRETE PIPE CULVERTS

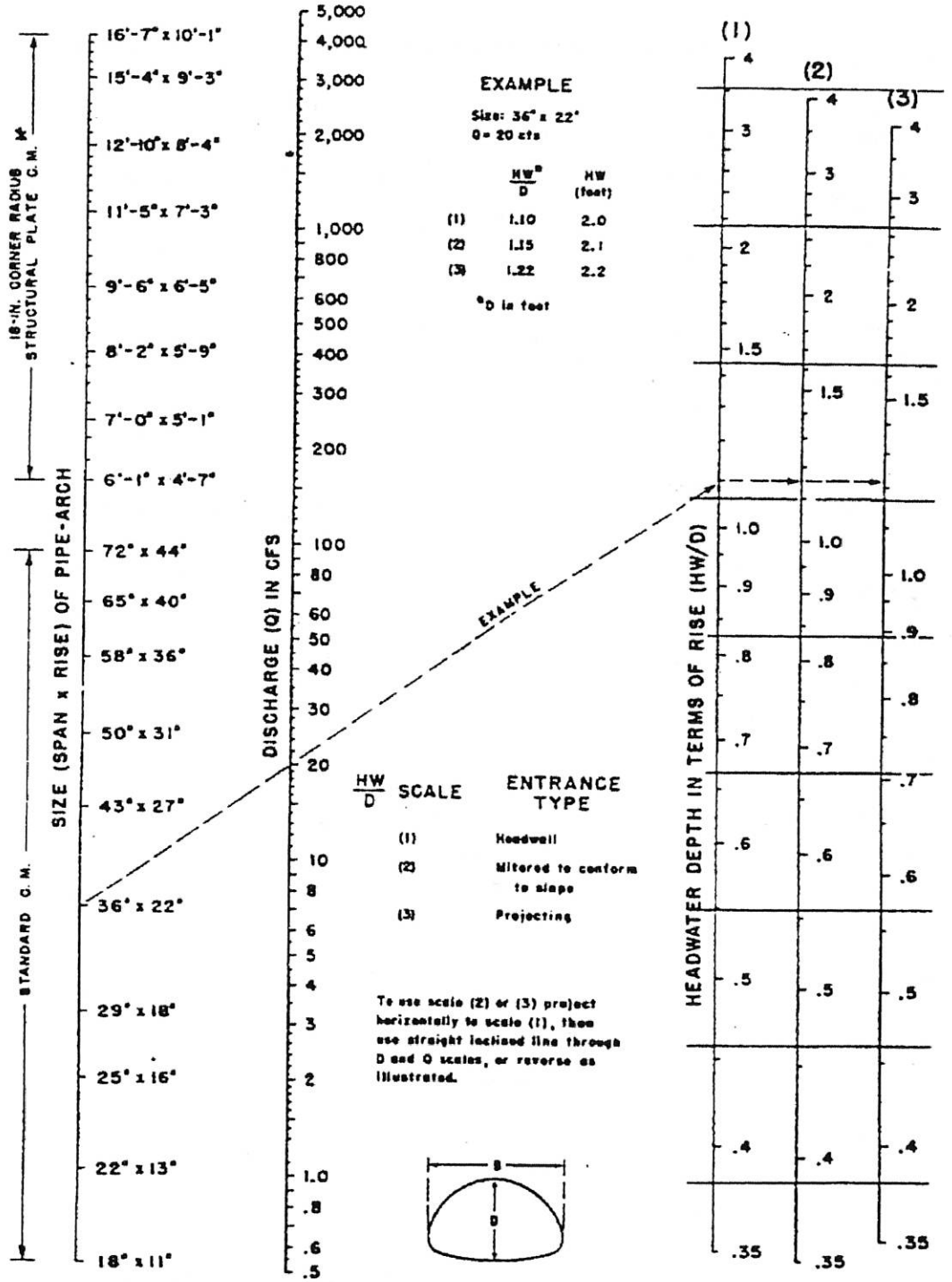


HEADWATER DEPTH FOR
OVAL CONCRETE PIPE CULVERTS
LONG AXIS HORIZONTAL
WITH INLET CONTROL

ADAPTED FROM MARYLAND STATE HIGHWAY ADMINISTRATION I/63 SHA-61.1-420.3-1.0

SARB_005152

FIGURE D.15.2 HEADWATER DEPTH FOR CMP ARCH CULVERTS WITH INLET CONTROL



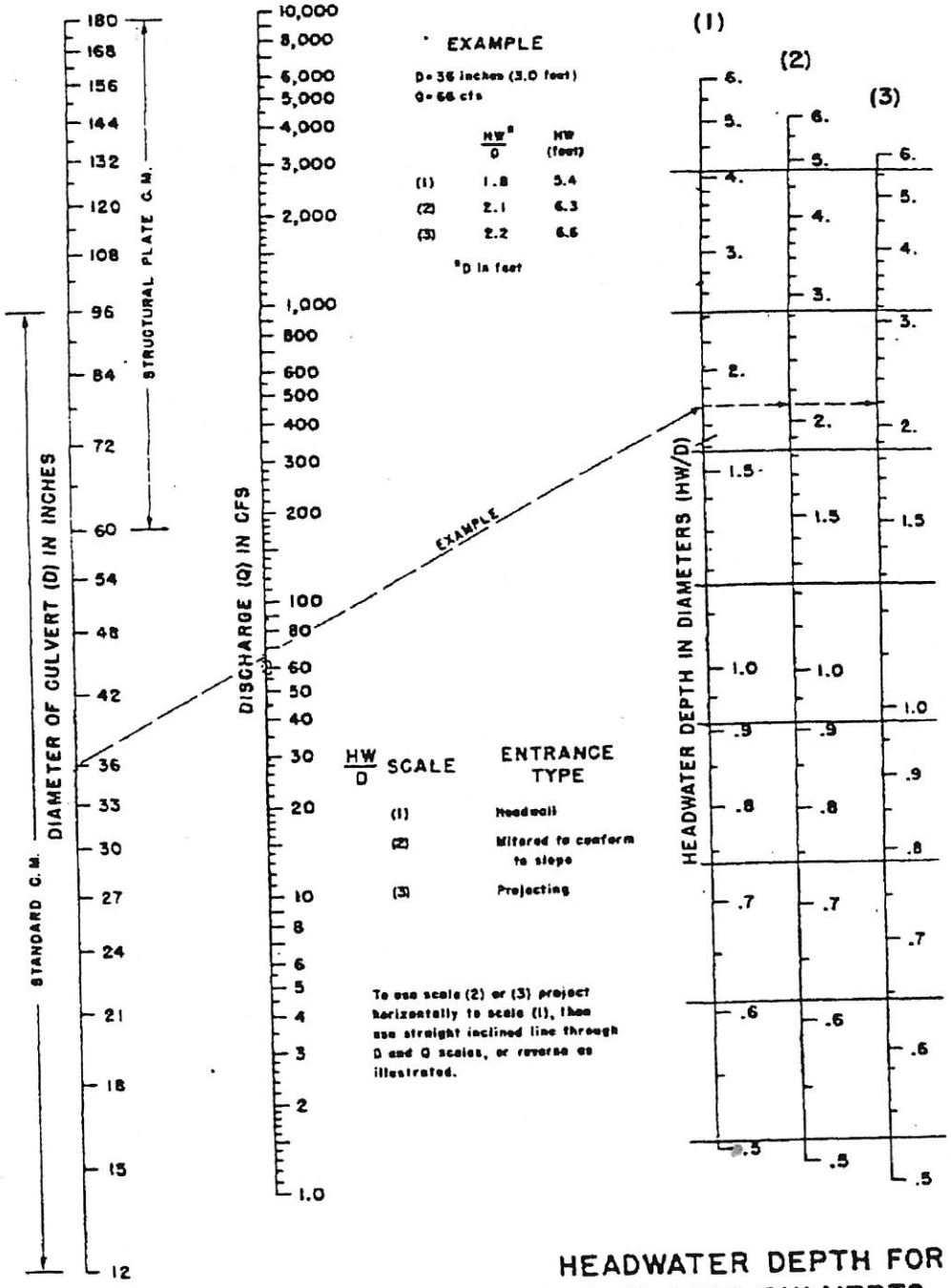
FOR ADDITIONAL SIZES THAT ARE NOT DIMENSIONED REFER TO CHARTS 442.00 AND 443.00

HEADWATER DEPTH FOR C. M. PIPE-ARCH CULVERTS WITH INLET CONTROL

ADAPTED FROM MARYLAND STATE HIGHWAY ADMINISTRATION I/63 SHA-61.1-420.2-2.0

SARB_005153

FIGURE D.15.3 HEADWATER DEPTH FOR CMP CULVERTS WITH INLET CONTROL



HEADWATER DEPTH FOR C. M. PIPE CULVERTS WITH INLET CONTROL

ADAPTED FROM MARYLAND STATE HIGHWAY ADMINISTRATION I/63 SHA-61.1-420.1-2.0

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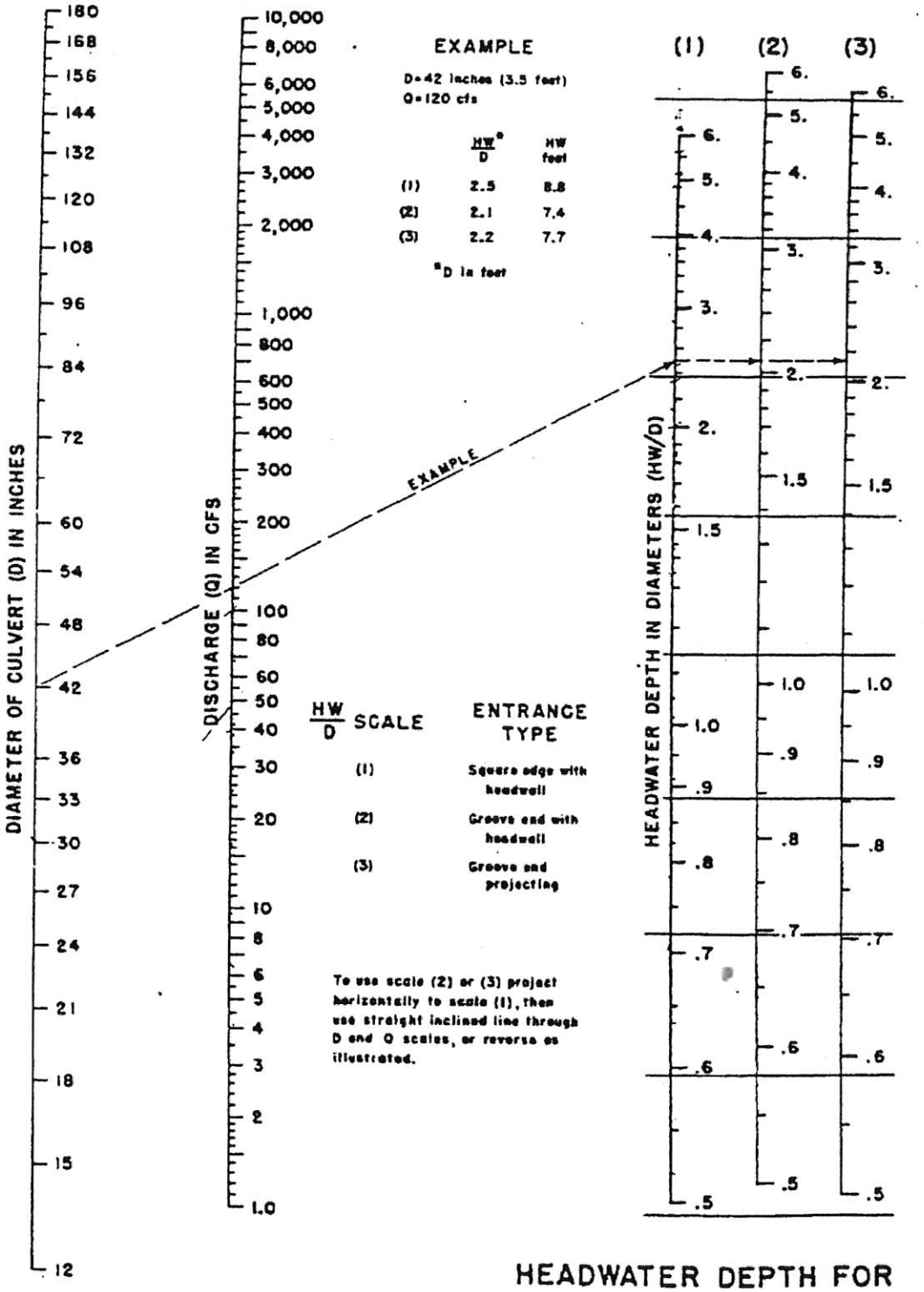
FIGURE D.15.4 HEADWATER DEPTH FOR CONCRETE PIPE CULVERTS WITH INLET CONTROL



HEADWATER SCALES 2&3
REVISED MAY 1964

HEADWATER DEPTH FOR CONCRETE PIPE CULVERTS WITH INLET CONTROL

ADAPTED FROM MARYLAND STATE HIGHWAY ADMINISTRATION 5/64 SHA-61.1-420.1-1.0

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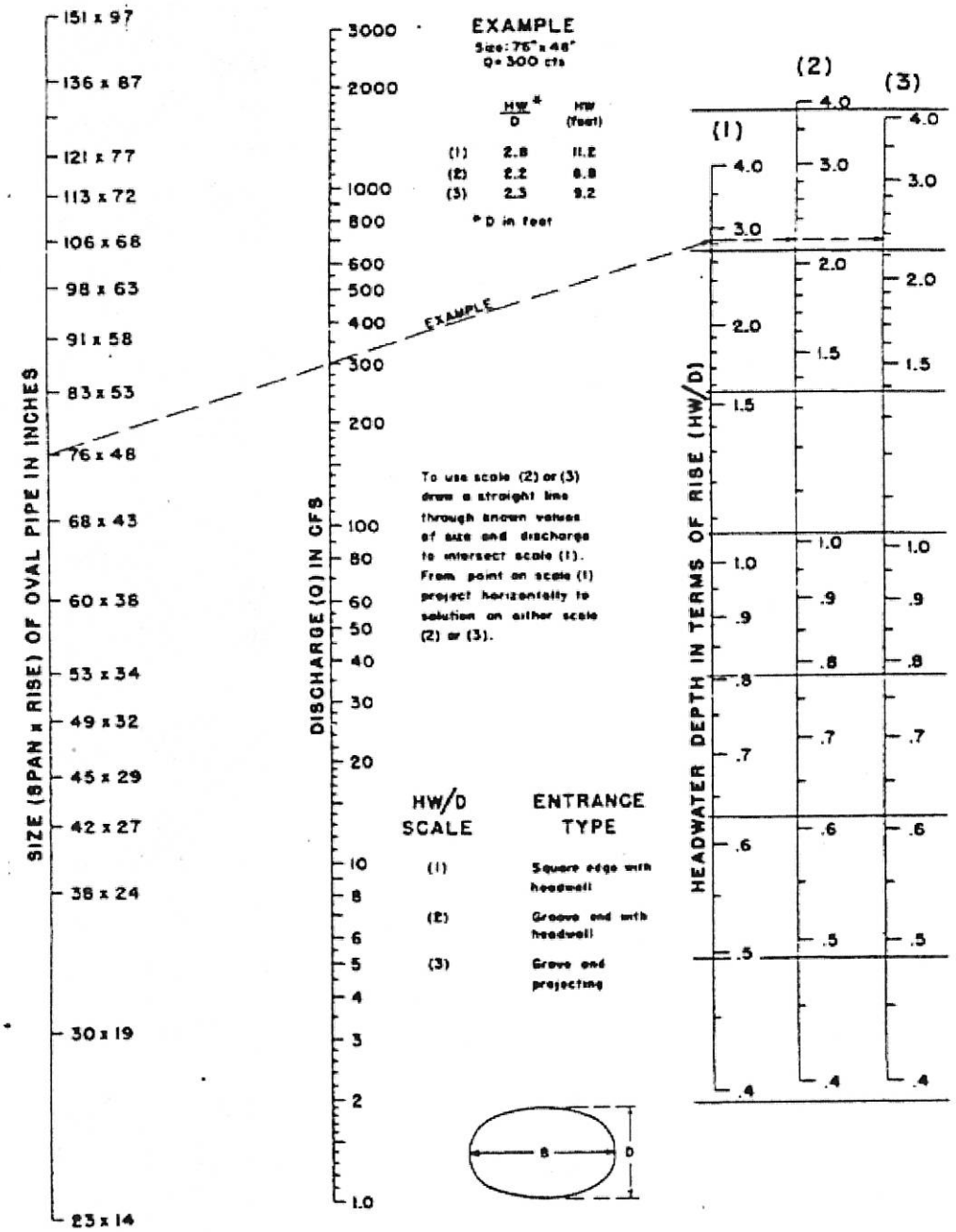
Appendix

D.15

Miscellaneous MD SHA Design Charts for Determining Pipe Inlet Control

FIGURE D.15.1 HEADWATER DEPTH FOR OVAL CONCRETE PIPE CULVERTS



HEADWATER DEPTH FOR
OVAL CONCRETE PIPE CULVERTS
LONG AXIS HORIZONTAL
WITH INLET CONTROL

ADAPTED FROM MARYLAND STATE HIGHWAY ADMINISTRATION I/63 SHA-61.1-420.3-1.0

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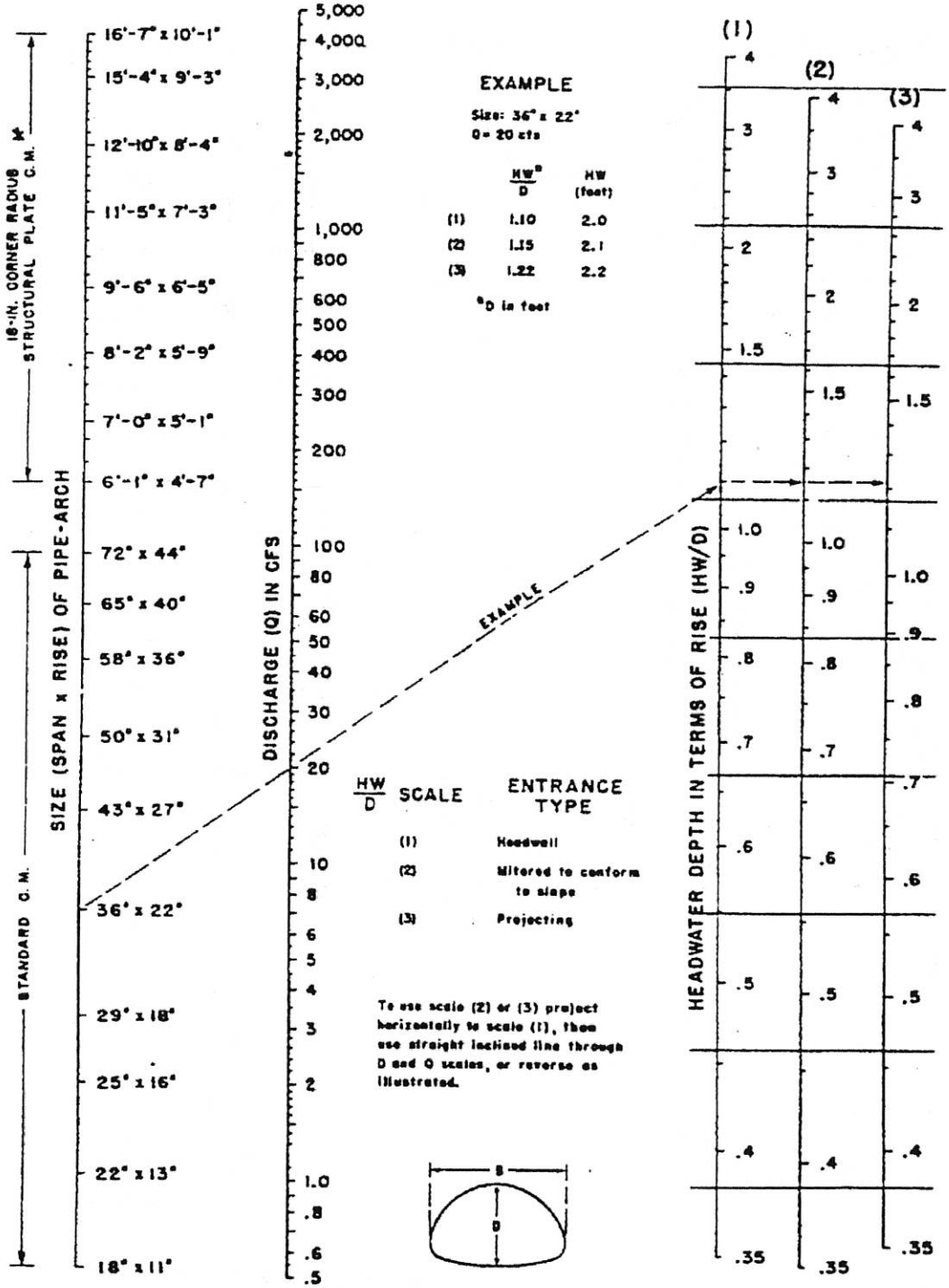
FIGURE D.15.2 HEADWATER DEPTH FOR CMP ARCH CULVERTS WITH INLET CONTROL



FOR ADDITIONAL SIZES THAT ARE NOT DIMENSIONED REFER TO CHARTS 442.00 AND 443.00

HEADWATER DEPTH FOR C. M. PIPE-ARCH CULVERTS WITH INLET CONTROL

ADAPTED FROM MARYLAND STATE HIGHWAY ADMINISTRATION I/63 SHA-61.1-420.2-2.0

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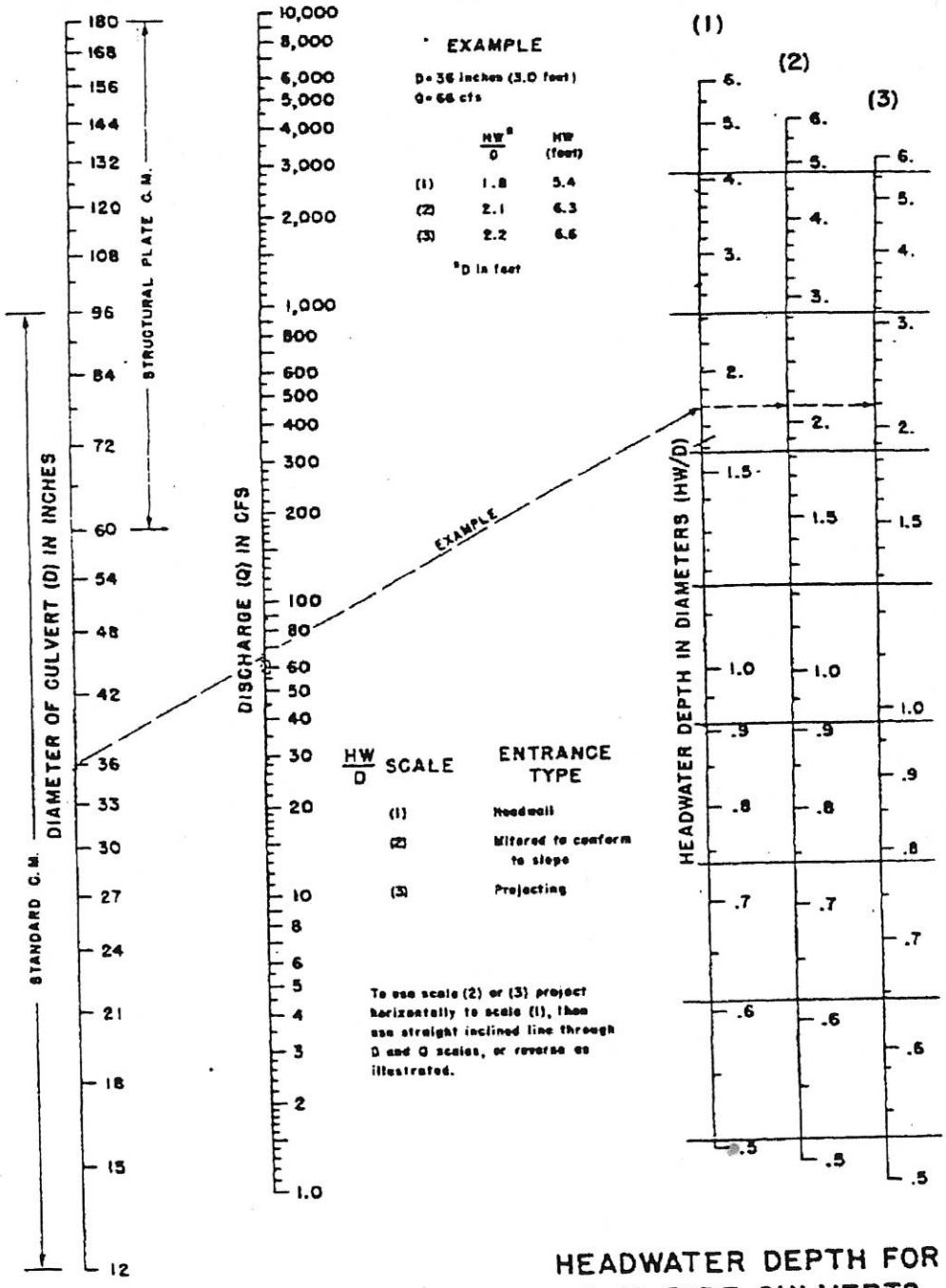
FIGURE D.15.3 HEADWATER DEPTH FOR CMP CULVERTS WITH INLET CONTROL



HEADWATER DEPTH FOR C. M. PIPE CULVERTS WITH INLET CONTROL

ADAPTED FROM MARYLAND STATE HIGHWAY ADMINISTRATION I/63 SHA-61.1-420.1-2.0

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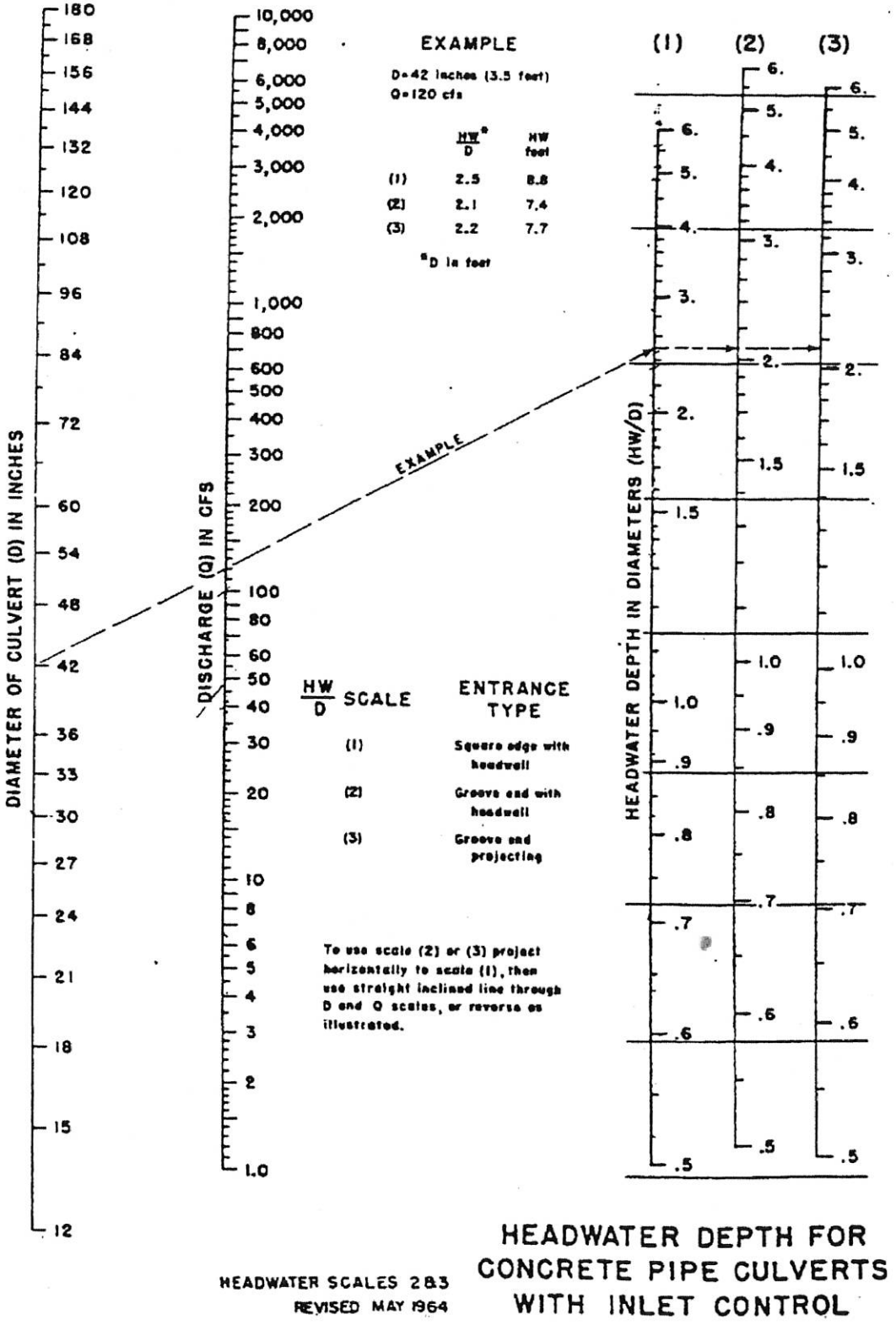
FIGURE D.15.4 HEADWATER DEPTH FOR CONCRETE PIPE CULVERTS WITH INLET CONTROL



ADAPTED FROM MARYLAND STATE HIGHWAY ADMINISTRATION 5/64 SHA-61.1-420.1-1.0

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Chapter 1.0

Introduction

1.0 Introduction and Purpose of Manual

Title 4, Subtitle 2 of the Environment Article of Annotated Code of Maryland states that "…the management of stormwater runoff is necessary to reduce stream channel erosion, pollution, siltation and sedimentation, and local flooding, all of which have adverse impacts on the water and land resources of Maryland." The program designed in the early 1980s to address this finding of the General Assembly concentrated primarily on controlling runoff increases and mitigating water quality degradation associated with new development. The counties and municipalities in Maryland are responsible for administering effective stormwater management programs that "…maintain after development, as nearly as possible the predevelopment characteristics…" These localities have performed remarkably in establishing Maryland as a national leader in stormwater management technology. Over the last 14 years, tens of thousands of best management practices (BMPs) have been constructed in an attempt to meet program mandates. However, the experience gained since Maryland's stormwater statute was enacted has identified necessary improvements and revealed a need to refocus the approach to fulfill the original intent of this essential water pollution control program.

Recently, increased emphasis on water quality, resource protection needs, increased BMP maintenance costs, and identified shortcomings in Maryland's program have all contributed to basic philosophical changes regarding stormwater management. The "Maryland Stormwater Design Manual" is an effort to incorporate the significant experiences gained by the State's stormwater community and accommodate much needed improvements for managing urban runoff. It is hoped that the design standards and environmental incentives provided below will produce better methods and advance the science of managing stormwater by relying less on single BMPs for all development projects and more on mimicking existing hydrology through total site design policies. Additionally, the inherent philosophical change should produce smaller less obtrusive facilities that are more aesthetic and less burdensome on those responsible for long-term maintenance and performance.

The purpose of this manual is threefold:

❶ to protect the waters of the State from adverse impacts of urban stormwater runoff,

❷ to provide design guidance on the most effective structural and non-structural BMPs for development sites, and

❸ to improve the quality of BMPs that are constructed in the State, specifically with regard to performance, longevity, safety, ease of maintenance, community acceptance and environmental benefit.

The BMPs and the required design criteria below represent conventional stormwater management technology for controlling runoff from new development projects. Based upon current available research, the Maryland Department of the Environment, Water Management

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Administration (MDE/WMA) has evaluated each BMP group and the associated design variants and has developed standards for each so that all perform similarly. The "General Performance Standards" outlined in this manual (see Section 1.2, page 1.13) specify those criteria that were used to create runoff control options that would perform equally. The BMPs contained in this manual are by no means exclusive. MDE encourages the development of innovative practices that meet the intent of Maryland's stormwater management law and can perform according to the standards in Section 1.2. In the future, should structural or non-structural practices be developed that meet the standards specified below, MDE will approve their use for controlling new development runoff.

MDE encourages wise, environmentally sensitive site designs to reduce the generation of runoff borne pollution. Additionally, Maryland has adopted "Smart Growth" policies that are geared toward concentrating development where it currently exists thereby reducing "suburban sprawl." Therefore, redevelopment is encouraged. A stormwater management policy for redevelopment is established in the Code of Maryland Regulations (COMAR 26.17.02). Additionally, redevelopment is defined in both COMAR and this manual. While certainly recommended, the BMPs listed below may not be appropriate for redevelopment areas where site size is constrained and existing infrastructure prevents conventional technology. Therefore, redevelopment projects are not required to meet the design standards and performance criteria established in this manual.

The policy required in COMAR for redevelopment basically specifies a 20% reduction in impervious surface area below existing conditions. Because this may be impractical due to site constraints, MDE is requiring the use of BMPs to meet the equivalent in water quality control of a 20% decrease in impervious surface area. Therefore, various BMPs that do not necessarily meet the performance criteria established in this manual and cannot be used as stand alone stormwater management facilities may be implemented for redevelopment projects. BMPs that cannot be used as stand alone structures may also be implemented to satisfy the pretreatment volume requirements established in Chapter 3 below. Individual project designers should contact the appropriate approval authority for the specific practices allowed for redevelopment and pretreatment purposes.

The approval of new control technologies, modifications to the practices contained in this manual, and alternative policies regarding stormwater management for new development is the responsibility of MDE. Typically, information is submitted to the WMA that describes the policy or practice. For new BMPs, monitoring data need to be submitted that demonstrate that the performance criteria in this manual can be met. WMA then reviews this material to determine if the proposed practice is appropriate for use on new development projects. Because of local variations in ownership policies, maintenance abilities, cost, design standards, hydrology, etc., information on practices to be used for redevelopment and pretreatment should be submitted to the appropriate authority for approval.

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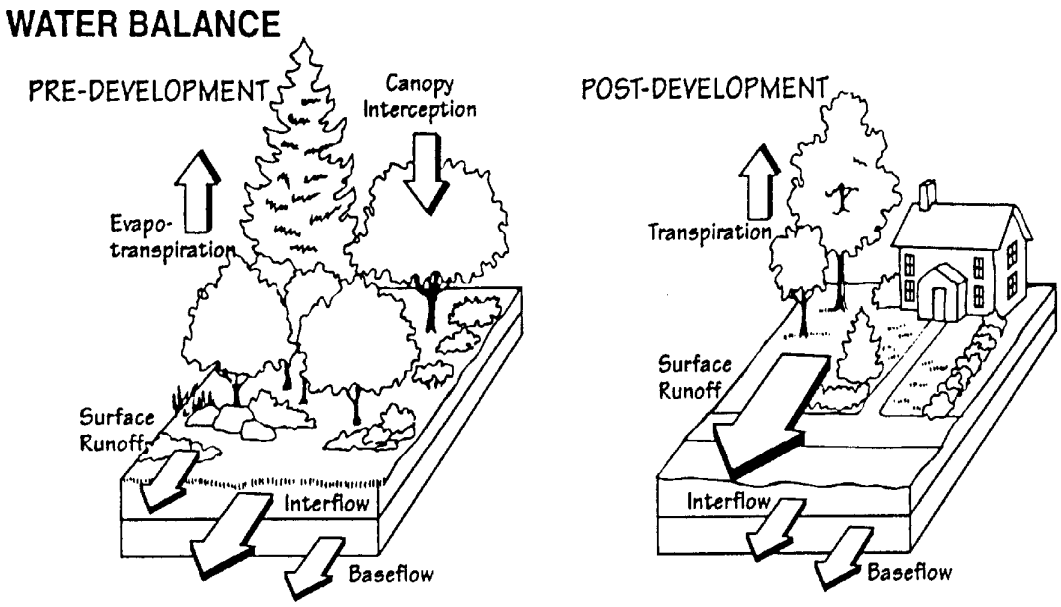
Section 1.1 Why Stormwater Matters: Impact of Runoff on Maryland's Watersheds

Urban development has a profound influence on the quality of Maryland's waters. To start, development dramatically alters the local hydrologic cycle (see Figure 1.1). The hydrology of a site changes during the initial clearing and grading that occur during construction. Trees, meadow grasses, and agricultural crops that had intercepted and absorbed rainfall are removed and natural depressions that had temporarily ponded water are graded to a uniform slope. Cleared and graded sites erode, are often severely compacted, and can no longer prevent rainfall from being rapidly converted into stormwater runoff.

Figure 1.1 Water Balance at a Developed and Undeveloped Site
(Source: Schueler, 1987)



Surface runoff is minimal in an undeveloped site, but dominates the water balance at a highly impervious site.

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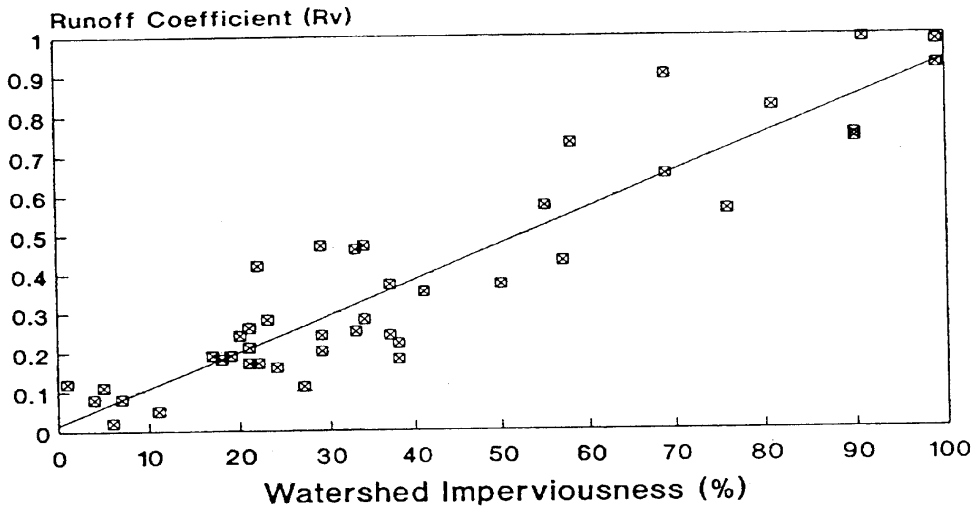
The situation worsens after construction. Roof tops, roads, parking lots, driveways and other impervious surfaces no longer allow rainfall to soak into the ground. Consequently, most rainfall is converted directly to stormwater runoff. This phenomenon is illustrated in Figure 1.2, which shows the increase in the volumetric runoff coefficient (R_v) as a function of site imperviousness. The runoff coefficient expresses the fraction of rainfall volume that is converted into stormwater runoff. As can be seen, the volume of stormwater runoff increases sharply with impervious cover. For example, a one acre parking lot can produce 16 times more stormwater runoff than a one acre meadow each year (Schueler, 1994).

The increase in stormwater runoff can be too much for the existing natural drainage system to handle. As a result, the natural drainage system is often "improved" to rapidly collect runoff and quickly convey it away (using curb and gutter, enclosed storm sewers, and lined channels). The stormwater runoff is subsequently discharged to downstream waters such as streams, reservoirs, lakes or estuaries.

Figure 1.2 Relationship between Impervious Cover and the Volumetric Runoff Coefficient (Source: Schueler, 1987)



The runoff coefficient (R_v) expresses the fraction of rainfall that is converted into runoff. The data points reflect over 35 monitoring stations in the U.S.

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1.1.1 Declining Water Quality

Impervious surfaces accumulate pollutants deposited from the atmosphere, leaked from vehicles, or windblown from adjacent areas. During storm events, these pollutants quickly wash off and are rapidly delivered to downstream waters. Some common pollutants found in urban stormwater runoff are profiled in Table 1.1 and include:

Nutrients. Urban runoff has elevated concentrations of both phosphorus and nitrogen, which can enrich streams, lakes, reservoirs and estuaries (known as eutrophication). In particular, excess nutrients have been documented to be a major factor in the decline of Chesapeake Bay. Excess nutrients promote algal growth that blocks sunlight from reaching underwater grasses and depletes oxygen in bottom waters. Urban runoff has been identified as a key and controllable source. Maryland has committed to reducing tributary nutrient loadings by 40% as part of the Chesapeake Bay restoration effort.

Suspended solids. Sources of sediment include washoff of particles that are deposited on impervious surfaces and the erosion of streambanks and construction sites. Both suspended and deposited sediments can have adverse effects on aquatic life in streams, lakes and estuaries. Sediments also transport other attached pollutants.

Organic Carbon. Organic matter, washed from impervious surfaces during storms, can present a problem in slower moving downstream waters. As organic matter decomposes, it can deplete dissolved oxygen in lakes and tidal waters. Low levels of oxygen in the water can have an adverse impact on aquatic life.

Bacteria. Bacteria levels in stormwater runoff routinely exceed public health standards for water contact recreation. Stormwater runoff can also lead to the closure of adjacent shellfish beds and swimming beaches and may increase the cost of treating drinking water at water supply reservoirs.

Hydrocarbons. Vehicles leak oil and grease that contain a wide array of hydrocarbon compounds, some of which can be toxic at low concentrations to aquatic life.

Trace Metals. Cadmium, copper, lead and zinc are routinely found in stormwater runoff. These metals can be toxic to aquatic life at certain concentrations and can also accumulate in the sediments of streams, lakes and the Chesapeake Bay.

Pesticides. A modest number of currently used and recently banned insecticides and herbicides have been detected in urban streamflow at concentrations that approach or exceed toxicity thresholds for aquatic life.

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Chlorides. Salts that are applied to roads and parking lots in the winter months appear in stormwater runoff and meltwater at much higher concentrations than many freshwater organisms can tolerate.

Thermal Impacts. Impervious surfaces may increase temperature in receiving waters, adversely impacting aquatic life that requires cold and cool water conditions (e.g., trout).

Trash and Debris. Considerable quantities of trash and debris are washed through storm drain networks. The trash and debris accumulate in streams and lakes and detract from their natural beauty.

Table 1.1 Typical Pollutant Concentrations Found in Urban Stormwater

Typical Pollutants Found in Stormwater Runoff (Data Source)	**Units**	**Average Concentration (1)**
Total Suspended Solids (a)	mg/l	80
Total Phosphorus (b)	mg/l	0.30
Total Nitrogen (a)	mg/l	2.0
Total Organic Carbon (d)	mg/l	12.7
Fecal Coliform Bacteria (c)	MPN/100 ml	3600
E. coli Bacteria (c)	MPN/100 ml	1450
Petroleum Hydrocarbons (d)	mg/l	3.5
Cadmium (e)	ug/l	2
Copper (a)	ug/l	10
Lead (a)	ug/l	18
Zinc (e)	ug/l	140
Chlorides (f) (winter only)	mg/l	230
Insecticides (g)	ug/l	0.1 to 2.0
Herbicides (g)	ug/l	1 to 5.0

(1) these concentrations represent *mean or median* storm concentrations measured at typical sites and may be greater during individual storms. Also note that mean or median runoff concentrations from *stormwater hotspots* are 2 to 10 times higher than those shown here. Units = mg/l = milligrams/liter, µg/l = micrograms/liter, MPN = Most Probable Number.

Data Sources: (a) Schueler (1987) (b) Schueler (1995), (c) Schueler (1997), (d) Rabanal and Grizzard (1996) (e) USEPA (1983) (f) Oberts (1995) (g) Schueler, (1996)

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1.1.2 Diminishing Groundwater Recharge and Quality

The slow infiltration of rainfall through the soil layer is essential for replenishing groundwater. The amount of rainfall that recharges groundwater varies, depending on the slope, soil, and vegetation. Some indication of the importance of recharge is shown in Table 1.2 which shows Natural Resources Conservation Service (NRCS) regional estimates of average annual recharge volume based on soil type.

Table 1.2 NRCS Estimates of Annual Recharge Rates, Based on Soil Type

Hydrologic Soil Group (NRCS)	**Average Annual Recharge Volume**
"A" Soils	18 inches/year
"B" Soils	12 inches/year
"C" Soils	6 inches/year
"D" Soils	3 inches/year
Average annual rainfall is about 42 inches per year across Maryland.	

Groundwater is a critical water resource across the State. Not only do many residents depend on groundwater for their drinking water, but the health of many aquatic systems is also dependent on its steady discharge. For example, during periods of dry weather, groundwater sustains flows in streams and helps to maintain the hydrology of non-tidal wetlands (Figure 1.3). Because development creates impervious surfaces that prevent natural recharge, a net decrease in groundwater recharge rates can be expected in urban watersheds. Thus, during prolonged periods of dry weather, stream flow sharply diminishes. In smaller headwater streams, the decline in stream flow can cause a perennial stream to become seasonally dry.

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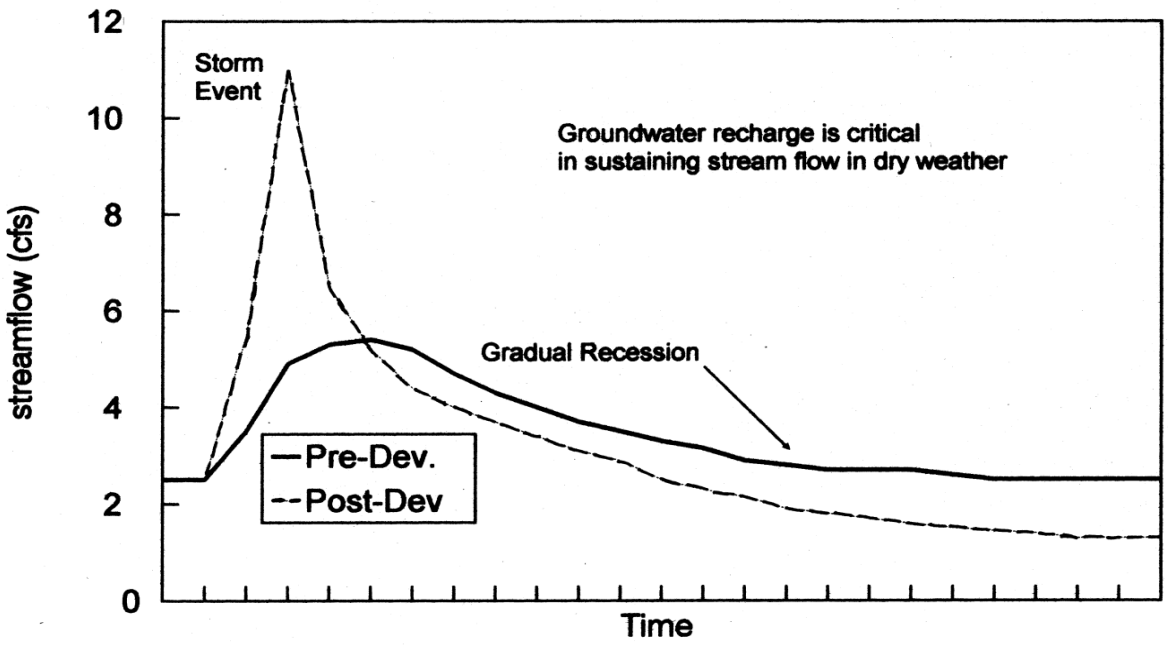
Figure 1.3 Decline in Stream Flow Due to Diminished Groundwater Recharge



After development, stream flow declines during extended periods of dry weather because of the diminished recharge of groundwater.

Urban land uses and activities can also degrade *groundwater quality* if stormwater runoff is directed into the soil without adequate treatment. Certain land uses and activities are known to produce higher loads of metals and toxic chemicals and are designated as *stormwater hotspots*. Soluble pollutants, such as chloride, nitrate, copper, dissolved solids and some polycyclic aromatic hydrocarbons (PAH's) can migrate into groundwater and potentially contaminate wells. Stormwater runoff should never be infiltrated into the soil if a site is a designated hotspot.

1.1.3 Degradation of Stream Channels

Stormwater runoff is a powerful force that influences the geometry of streams. After development, both the frequency and magnitude of storm flows increase dramatically. Consequently, urban stream channels experience more bankfull and sub-bankfull flow events each year than they had prior to development (see Figure 1.4).

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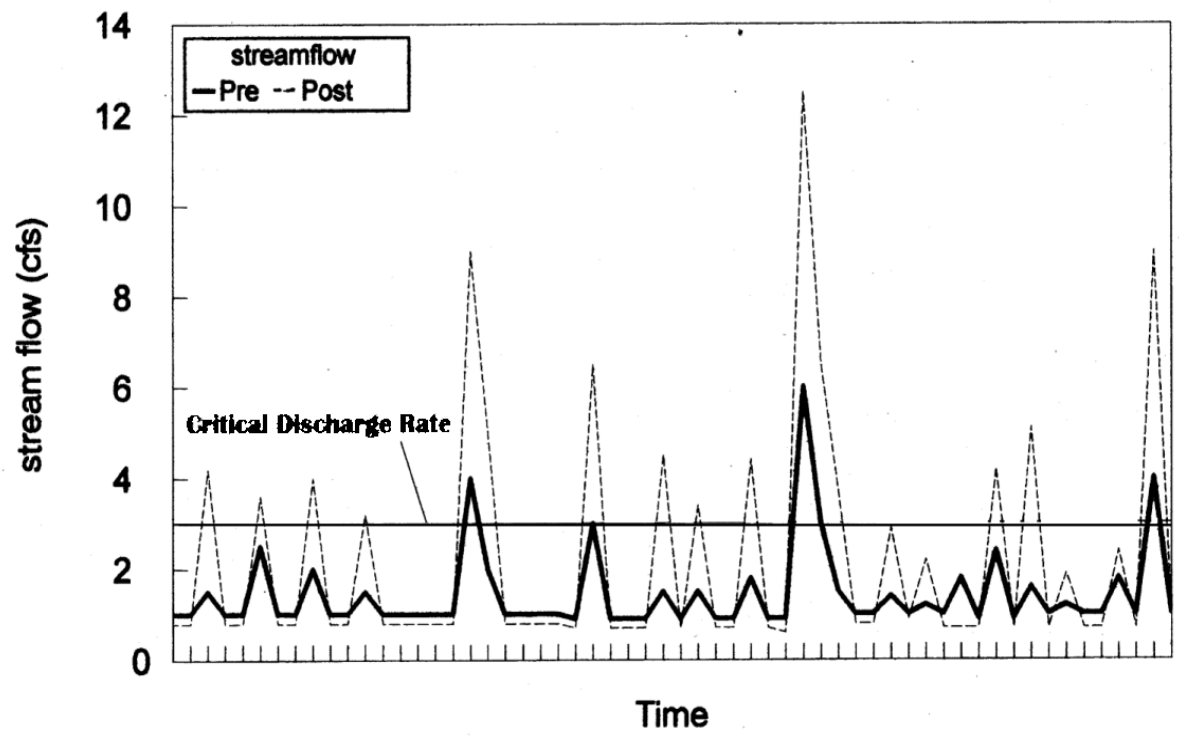
Figure 1.4 Increased Frequency of Flows Greater than the Critical Discharge Rate in a Stream Channel after Development



Development greatly increases the frequency that a stream exceeds the critical discharge rate (the discharge rate associated with bankfull flow) that corresponds to the onset of channel erosion and enlargement.

As a result, the stream bed and banks are exposed to highly erosive flows more frequently and for longer periods. Streams typically respond to this change by increasing cross-sectional area to handle the more frequent and erosive flows either by channel widening or down cutting, or both. This results in a highly unstable phase where the stream experiences severe bank erosion and habitat degradation. In this phase, the stream often experiences some of the following changes:

- rapid stream widening
- increased streambank and channel erosion
- decline in stream substrate quality (through sediment deposition and embedding of the substrate)
- loss of pool/riffle structure in the stream channel
- degradation of stream habitat structure

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The decline in the physical habitat of the stream, coupled with lower base flows and higher stormwater pollutant loads, has a severe impact on the aquatic community. Recent research has shown the following changes in stream ecology:

- decline in aquatic insect and freshwater mussel diversity
- decline in fish diversity
- degradation of aquatic habitat

Traditionally, Maryland has attempted to provide some measure of channel protection by imposing the two-year storm peak discharge control requirement, which requires that the discharge from the two-year post development peak rates be reduced to pre development levels. However, recent research and experience indicate that the two-year peak discharge criterion is not capable of protecting downstream channels from erosion. In some cases, controlling the two-year storm may actually accelerate streambank erosion because it exposes the channel to a longer duration of erosive flows than it would have otherwise received.

1.1.4 Increased Overbank Flooding

Flow events that exceed the capacity of the stream channel spill out into adjacent floodplains. These are termed "overbank" floods and can damage property and downstream drainage structures.

While some overbank flooding is inevitable and even desirable, the historical goal of drainage design in most of Maryland has been to maintain pre development peak discharge rates for both the two and ten-year frequency storms after development, thus keeping the level of overbank flooding the same over time. This prevents costly damage or maintenance for culverts, drainage structures, and swales.

Overbank floods are ranked in terms of their statistical return frequency. For example, a flood that has a 50% chance of occurring in any given year is termed a "two-year" flood. The two-year storm is also known as the "bankfull flood," as researchers have demonstrated that most natural stream channels in the State have just enough capacity to handle the two-year flood before spilling into the floodplain. In Maryland, about 3.0 to 3.5 inches of rain in a 24-hour period produces a two-year or bankfull flood. This rainfall depth is termed the two-year design storm.

Similarly, a flood that has a 10% chance of occurring in any given year is termed a "ten-year flood." A ten-year flood occurs when a storm event produces about 4.5 to 5.5 inches of rain in a 24 hour period. Under traditional engineering practice, most channels and storm drains in Maryland are designed with enough capacity to safely pass the peak discharge from the ten-year design storm.

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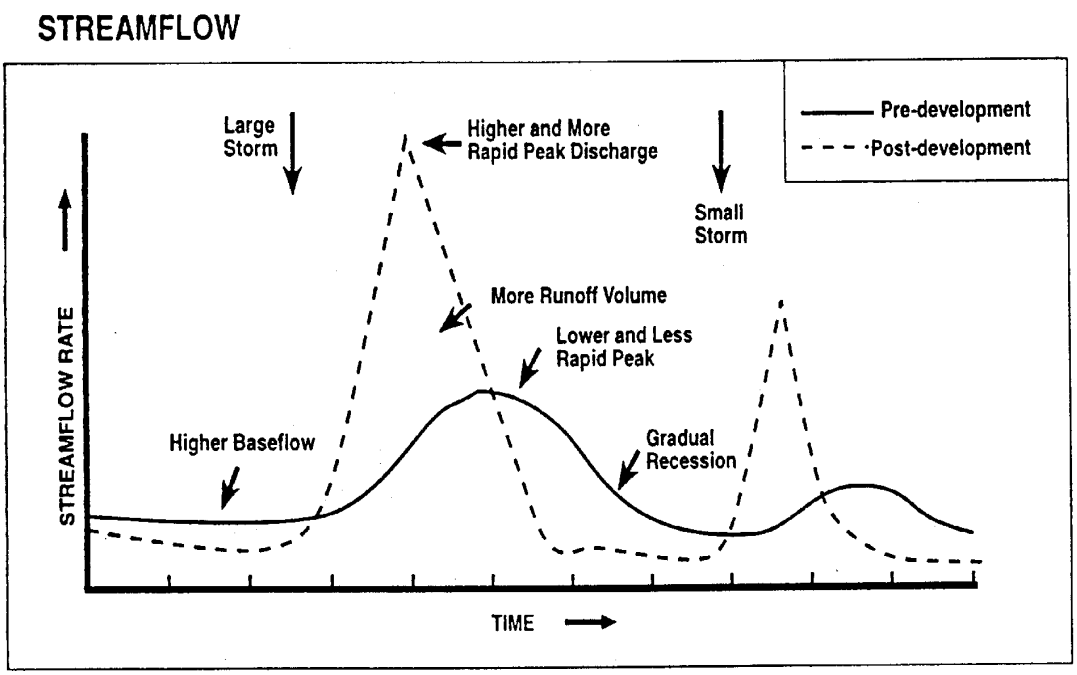
Urban development increases the peak discharge rate associated with a given design storm because impervious surfaces generate greater runoff volumes and drainage systems deliver it more rapidly to a stream. The change in post development peak discharge rates that accompany development is profiled in Figure 1.5.

Figure 1.5 Change in Hydrograph following Development
(Source: Schueler, 1987)



The impervious surfaces and conveyance systems of developed sites result in an earlier and higher peak discharge rate.

1.1.5 Floodplain Expansion

The level areas bordering streams and rivers are known as floodplains. Operationally, the floodplain is usually defined as the land area within the limits of the 100-year storm flow water elevation. The 100-year storm has a 1% chance of occurring in any given year and typically serves as the basis for controlling development in the State and establishing insurance rates by the Federal Emergency Management Agency. In Maryland, a 100-year flood occurs after about 7 to 8 inches of rainfall in a 24 hour period (e.g., the 100-year storm). These floods can be very destructive and can pose a threat to property and human life. Floodplains are natural flood storage areas and help to attenuate downstream flooding.

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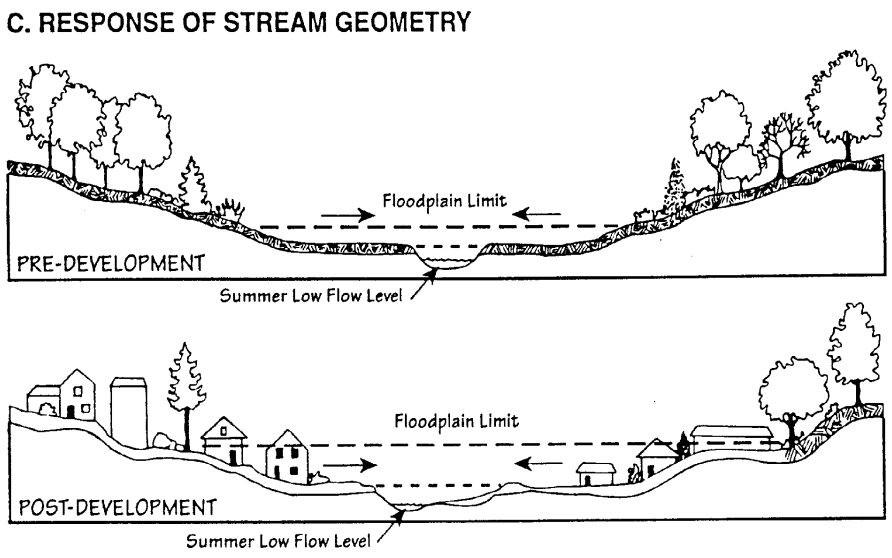
Floodplains are very important habitat areas, encompassing riparian forests, wetlands, and wildlife corridors. Consequently, all local jurisdictions in Maryland restrict or even prohibit new development within the 100-year floodplain to prevent flood hazards and conserve habitats. Nevertheless, prior development that has occurred in the floodplain remains subject to periodic flooding during these storms.

As with overbank floods, development sharply increases the peak discharge rate associated with the 100-year design storm. As a consequence, the elevation of a stream's 100 year floodplain becomes higher and the boundaries of its floodplain expand (see Figure 1.6). In some instances, property and structures that had not previously been subject to flooding are now at risk. Additionally, such a shift in a floodplain's hydrology can degrade wetlands and forest habitats.

Figure 1.6 Change in Floodplain Elevations
(Source: Schueler, 1987)



Both the elevation and the lateral boundaries of the 100-year floodplain increase when development occurs upstream.

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Section 1.2 General Performance Standards for Stormwater Management in Maryland

To prevent adverse impacts of stormwater runoff, the State of Maryland has developed fourteen performance standards that must be met at development sites. These standards apply to any construction activity disturbing 5,000 or more square feet of earth. The following development activities are exempt from these performance standards in Maryland:

1. Additions or modifications to existing single family structures;
2. Developments that do not disturb more than 5000 square feet of land; or
3. Agricultural land management activities.

The following performance standards shall be addressed at all sites where stormwater management is required:

*Standard No. **1*** *Site designs shall minimize the generation of stormwater and maximize pervious areas for stormwater treatment.*

*Standard No. **2*** *Stormwater runoff generated from development and discharged directly into a jurisdictional wetland or waters of the State of Maryland shall be adequately treated.*

*Standard No. **3*** *Annual groundwater recharge rates shall be maintained by promoting infiltration through the use of structural and non-structural methods. At a minimum, the annual recharge from post development site conditions shall mimic the annual recharge from pre development site conditions.*

*Standard No. **4*** *Water quality management shall be provided through the use of structural and/or non-structural practices.*

*Standard No. **5*** *Structural BMPs used for new development shall be designed to remove 80% of the average annual post development total suspended solids load (TSS) and 40% of the average annual post development total phosphorous load (TP). It is presumed that a BMP complies with this performance standard if it is:*

- *sized to capture the prescribed water quality volume (WQ_v),*
- *designed according to the specific performance criteria outlined in this manual,*
- *constructed properly, and*
- *maintained regularly.*

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*Standard No. **6*** *On the Eastern Shore* (see Figure 2.4)*, the post development peak discharge rate shall not exceed the pre development peak discharge rate for the two-year frequency storm event. On the Western Shore, local authorities may require that the post development ten-year peak discharge not exceed the pre development peak discharge if the channel protection storage volume (Cp_v) is provided (see Standard No. 7). In addition, safe conveyance of the 100-year storm event through stormwater management practices shall be provided.*

*Standard No. **7*** *To protect stream channels from degradation, Cp_v shall be provided by 12 to 24 hours of extended detention storage for the one-year storm event. Cp_v shall not be provided on the Eastern Shore unless the appropriate approval authority deems it is necessary on a case by case basis.*

*Standard No. **8*** *Stormwater discharges to critical areas with sensitive resources [e.g., cold water fisheries, shellfish beds, swimming beaches, recharge areas, water supply reservoirs, Chesapeake Bay Critical Area (see Appendix D.4)] may be subject to additional performance criteria or may need to utilize or restrict certain BMPs.*

*Standard No. **9*** *All BMPs shall have an enforceable operation and maintenance agreement to ensure the system functions as designed.*

*Standard No. **10*** *Every BMP shall have an acceptable form of water quality pretreatment.*

*Standard No. **11*** *Redevelopment, defined as any construction, alteration or improvement exceeding five thousand square feet of land disturbance on sites where existing land use is commercial, industrial, institutional or multi-family residential, is governed by special stormwater sizing criteria depending on the amount of increase or decrease in impervious area created by the redevelopment.*

*Standard No. **12*** *Certain industrial sites are required to prepare and implement a stormwater pollution prevention plan and file a notice of intent (NOI) under the provisions of Maryland's Stormwater Industrial National Pollutant Discharge Elimination System (NPDES) general permit (a list of industrial categories subject to the pollution prevention requirement can be found in Appendix D.6). The requirements for preparing and implementing a stormwater pollution prevention plan are described in the general discharge permit available from MDE and guidance can be found in the United States Environmental Protection Agency's (EPA) document entitled, "Storm Water Management for Industrial Activities, Developing Pollution Prevention Plans and Best Management Practices" (1992). The stormwater pollution*

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prevention plan requirement applies to both existing and new industrial sites.

*Standard No. **13*** *Stormwater discharges from land uses or activities with higher potential for pollutant loadings, defined as hotspots in Chapter 2, may require the use of specific structural BMPs and pollution prevention practices. In addition, stormwater from a hotspot land use may not be infiltrated without proper pretreatment.*

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*Standard No. **14*** *In Maryland, local governments are usually responsible for most stormwater management review authority. Therefore, prior to design, applicants should always consult with their local reviewing agency to determine if they are subject to additional stormwater design requirements. In addition, certain earth disturbances may require NPDES construction general permit coverage from MDE (see Appendix D.7).*

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Section 1.3 How to Use the Manual

The Maryland Stormwater Design Manual is provided in two volumes. This *first volume* provides designers a general overview on how to size, design, select and locate BMPs at a new development site to comply with State stormwater performance standards. The *second volume* contains appendices with more detailed information on landscaping, BMP construction specifications, step-by-step BMP design examples and other assorted design tools.

Section 1.3.1 VOLUME ONE: STORMWATER MANAGEMENT CRITERIA

The first volume of the manual is organized as follows:

Chapter 1. Introduction to the Manual.

Chapter 2. Unified Stormwater Sizing Criteria. This chapter explains the five new sizing criteria for water quality, recharge, channel protection, overbank flood control, and extreme flood management in the State of Maryland. The chapter also outlines the basis for design calculations. Three step-by-step design examples are provided to familiarize the reader with the new procedures for computing storage volumes under the five sizing criteria. The chapter also briefly outlines the six groups of acceptable BMPs that can be used to meet recharge and water quality volume sizing criteria. Acceptable BMP groups are:

- Stormwater Ponds
- Stormwater Wetlands
- Infiltration Practices
- Filtering Systems
- Open Channel Practices
- Non-structural Practices

Lastly, the chapter presents a list of land uses or site activities that have been designated as "stormwater hotspots." If a development site is considered a "hotspot," it may have special requirements for pollution prevention and groundwater protection.

Chapter 3. Performance Criteria for Urban BMP Design. The third chapter presents specific performance criteria and guidelines for the design of five groups of structural BMPs. The performance criteria for each group of BMPs are based on six factors:

- General Feasibility
- Conveyance
- Pretreatment
- Treatment Geometry
- Landscaping
- Maintenance

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In addition, Chapter 3 presents a series of schematic drawings to illustrate typical BMP designs.

Chapter 4. Guide to BMP Selection and Location in the State of Maryland

This chapter presents guidance on how to select the best BMP or group of practices at a new development site, as well as environmental and other factors to consider when actually locating each BMP. The chapter contains six comparative tables that evaluate BMPs from the standpoint of the following factors:

- Watershed Factors
- Terrain Factors
- Stormwater Treatment Suitability
- Physical Feasibility Factors
- Community and Environmental Factors
- Location and Permitting Factors

Chapter 4 is designed so that the reader can use the tables in a step-wise fashion to identify the most appropriate BMP or group of practices to use at a site.

Chapter 5. Stormwater Credits for Innovative Site Planning

Innovative site planning is increasingly recognized as a critical feature of a stormwater plan. This chapter outlines stormwater "credits" that can be obtained when a designer employs progressive planning techniques at the site. The credits not only reduce the impact of development on the environment, but also reduce the size and cost of stormwater practices needed at the site. The six credits include:

- Natural Area Conservation
- Disconnection of Rooftop Runoff
- Disconnection of Non-rooftop Runoff
- Sheet Flow to Buffers
- Open Channel Use
- Environmentally Sensitive Development

The chapter describes how to determine if a site is eligible for credit and how the credit is computed using hypothetical site plan examples.

Section 1.3.2 VOLUME TWO: STORMWATER DESIGN APPENDICES

The second volume is provided separately and contains the technical information needed to actually design, landscape and construct a BMP. Volume Two is divided into four appendices, including:

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Appendix A. Landscaping Guidance for Stormwater BMPs. Good landscaping can often be an important factor in the performance and community acceptance of many stormwater BMPs. The Landscaping Guide provides general background on how to determine the appropriate landscaping region and hydrologic zone in Maryland. Appendix A also includes tips on how to establish more functional landscapes within stormwater BMPs and contains an extensive list of trees, shrubs, ground covers, and wetland plants that can be used to develop an effective and diverse planting plan.

Appendix B. BMP Construction Specifications. Good designs only work if careful attention is paid to proper construction techniques and materials. Appendix B contains detailed specifications for constructing infiltration practices, filters, bioretention areas and open channels. In addition, Appendix B includes a copy of the NRCS Code 378 Standards and Specifications for Ponds.

Appendix C. Step-by-Step Design Examples. A series of design examples are provided in this appendix to help designers and plan reviewers better understand the new stormwater sizing criteria and design procedures. Step-by-step design examples are provided for a pond, a sand filter, an infiltration trench, a dry swale, and a bioretention area.

Appendix D. Assorted Design Tools. The last appendix contains an assortment of design tools for stormwater management, including guidance on geotechnical testing, calculating water balance, documenting whether a site complies with the Chesapeake Bay Critical Area "10% Rule," NPDES stormwater permits, pollution prevention, design details, State Water Use Designations and other useful design information.

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Section 1.4 Revising the Design Manual

The Maryland Stormwater Design Manual establishes minimum performance criteria that should be met by all techniques and devices used for stormwater management in Maryland. On occasion, variations or other techniques and devices may be found to function better or be more desirable for stormwater management by plan approval authorities. As stated above, MDE is responsible for approving the use of new techniques for controlling runoff from new development. If an approval authority decides it would like to utilize a revised technique or device on a regular basis, it needs to prepare a Standard and accompanying Specifications with a cover letter to be submitted to the MDE/WMA.

A subcommittee consisting of MDE technical personnel will review the revised technique or device and any supporting data submitted. When the technique or device is approved by the technical subcommittee, an approval authorization from the Director of WMA and the technical representative of the local approval authority will be issued. Once the revised or new technique or device has received approval it can be used on a regular basis within the jurisdiction. If other jurisdictions desire to utilize the same technique or device then they must seek approval from the technical subcommittee. A great amount of deviation from the methods within this design manual is not anticipated, but when better stormwater management can be achieved, revisions will generally be looked upon favorably.

Section 1.5 What's New?

This section highlights some of the new stormwater design requirements that are being introduced in the manual. It is provided to help designers understand how the new manual may affect how they prepare stormwater plans and practices. At most sites, designers shall now:

- Measure the amount of impervious cover created by the development.
- Determine if the proposed land use or activity at the site is designated as a "stormwater hotspot."
- Determine the Use Designation of the receiving water and the condition of the watershed.
- Provide a volume that mimics the natural rate of groundwater recharge using structural and/or non-structural BMPs (Re_v).
- Provide storage for extended detention of the one-year, 24 hour storm event to protect downstream channels from erosion (Cp_v).
- Calculate water quality volume using a new methodology (WQ_v).
- Provide water quality volume storage using an approved BMP option that can meet pollutant removal targets.
- Provide extended detention for water quality (ED) in ponds and wetlands as a separate volume. This volume may be calculated apart from the Cp_v.
- Ensure that the BMP selected meets specific performance criteria with respect to feasibility, conveyance, pretreatment, treatment, landscaping and maintenance.

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- Follow new geotechnical testing procedures and provide the contractor with formal construction specifications.
- Consider where the BMP is located in relation to natural features and development infrastructure.
- Consider innovative site planning techniques to obtain stormwater credits that can reduce both the size and cost of structural stormwater practices.
- Include operation and maintenance information on approved stormwater management plans.

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Section 1.6 Symbols and Acronyms

As an aid to the reader, the following table outlines the symbols and acronyms that are used throughout the text. In addition, a glossary is provided at the end of this volume that defines the terminology used in the text.

Table 1.3 Key Symbols and Acronyms Cited in Manual

A	drainage area	Q_p	overbank flood protection volume
A_f	filter bed area	q_u	unit peak discharge
A_{sf}	surface area, sedimentation basin full	q_p	water quality peak discharge
A_{sp}	surface area, sedimentation basin partial	Re_v	recharge volume
BMP	best management practice	R_v	volumetric runoff coefficient
cfs	cubic feet per second	R/W	right of way
Cp_v	channel protection storage volume (extended detention of the 1-year post development runoff)	S	soil specific recharge factor
CMP	corrugated metal pipe	SD	separation distance
CN	curve number	t_c	time of concentration
d_f	depth of filter bed	t_f	time to drain filter bed
du	dwelling units	TP	total phosphorous
ED	24 hour drawdown of the water quality volume	t_t	time of travel
f	soil infiltration rate	TR-20	Technical Release No. 20 Project Formulation-Hydrology, computer program
fps	feet per second	TR-55	Technical Release No. 55 Urban Unit Hydrology for Small Watersheds
h_f	head above filter bed	TSS	total suspended solids
HSG	hydrologic soil group	V_f	filter bed volume
Ia	initial abstraction	V_r	volume of runoff
I	percent impervious cover	V_s	volume of storage
k	coefficient of permeability	V_t	total volume
P	precipitation depth	V_v	volume of voids
Q_f	extreme flood protection volume	WQ_v	water quality storage volume
q_i	peak inflow discharge	WSE	water surface elevation
q_o	peak outflow discharge		

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Chapter

2.0

Unified Stormwater Sizing Criteria

2.0 Unified Stormwater Sizing Criteria

This chapter presents a unified approach for sizing stormwater BMPs in the State of Maryland to meet pollutant removal goals, maintain groundwater recharge, reduce channel erosion, prevent overbank flooding, and pass extreme floods. For a summary, please consult Table 2.1 below. The remaining sections describe the five sizing criteria in detail and present guidance on how to properly compute and apply the required storage volumes.

This chapter also presents a list of acceptable BMP options that can be used to comply with the sizing criteria. Lastly, the chapter designates certain land uses as "stormwater hotspots" which restrict the use of certain BMPs and may also require a pollution prevention plan.

Table 2.1 Summary of the Statewide Stormwater Criteria

Sizing Criteria	Description of Stormwater Sizing Criteria
Water Quality Volume (WQ_v) (acre-feet)	$WQ_v = [(P)(R_v)(A)]/12$ P= rainfall depth in inches and is equal to 1.0" in the Eastern Rainfall Zone and 0.9" in the Western Rainfall Zone (Fig. 2.1), R_v = volumetric runoff coefficient, and A = area in acres.
Recharge Volume (Re_v) (acre-feet)	Fraction of WQ_v, depending on pre development soil hydrologic group. $Re_v = [(S)(R_v)(A)]/12$ S = soil specific recharge factor in inches.
Channel Protection Storage Volume (Cp_v)	Cp_v = 24 hour (12 hour in USE III and IV watersheds) extended detention of post-developed one-year, 24 hour storm event. Not required for direct discharges to tidal waters and the Eastern Shore of Maryland. (See Figure 2.4.)
Overbank Flood Protection Volume (Q_p)	Controlling the peak discharge rate from the ten-year storm event to the pre development rate (Q_{p10}) is optional; consult the appropriate review authority. For Eastern Shore: Provide peak discharge control for the two-year storm event (Q_{p2}). Control of the ten-year storm event is not required (Q_{p10}).
Extreme Flood Volume (Q_f)	Consult with the appropriate reviewing authority. Normally, no control is needed if development is excluded from 100-year floodplain and downstream conveyance is adequate.

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Section 2.1 Water Quality Volume (WQ_v)

The Water Quality Volume (denoted as the WQ_v) is the storage needed to capture and treat the runoff from 90% of the average annual rainfall. In numerical terms, it is equivalent to an inch of rainfall multiplied by the volumetric runoff coefficient (R_v) and site area. The specific rainfall depth to be used depends on whether the site is located in the Eastern or Western rainfall zone of Maryland (see Figure 2.1).

The following equations are used to determine the storage volume, WQ_v (in acre-feet of storage):

$$WQ_v = \frac{(1.0)\,(R_v)(A)}{12}$$ Eastern Rainfall Zone P = 1.0 inches of rainfall

$$WQ_v = \frac{(0.9)\,(R_v)(A)}{12}$$ Western Rainfall Zone P = 0.9 inches of rainfall

where:
- WQ_v = water quality volume (in acre-feet)
- R_v = 0.05 + 0.009(I) where I is percent impervious cover
- A = area in acres*

Treatment of the WQ_v shall be provided at all developments where stormwater management is required. A minimum WQ_v of 0.2 inches per acre shall be met at sites or in drainage areas that have less than 15% impervious cover.

Drainage areas having no impervious cover and no proposed disturbance during development may be excluded from the WQ_v calculations. Designers are encouraged to use these areas as non-structural practices for WQ_v treatment (see Chapter 5, "Stormwater Credits for Innovative Site Planning").

The WQ_v is directly related to the amount of impervious cover created at a site. The relationship between WQ_v and impervious cover is shown in Figure 2.2.

* The water quality volume (WQ_v) is required to be controlled only for the specific project. WQ_v for offsite areas is not required (see page 2.4 "Offsite Drainage Areas")

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Figure 2.1 Location of the Eastern and Western Rainfall Zones in Maryland (For use in selecting the appropriate WQ_v equation.)

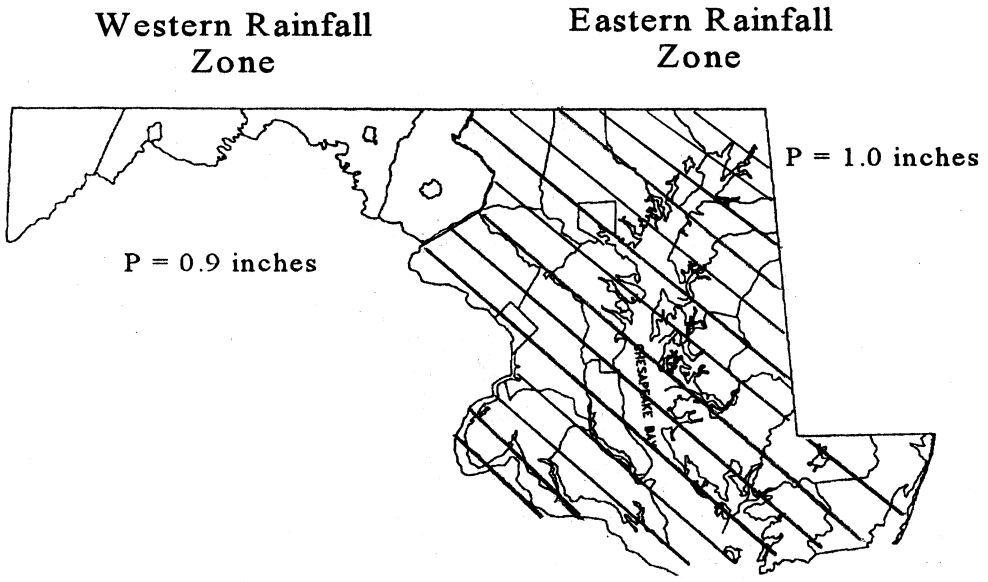
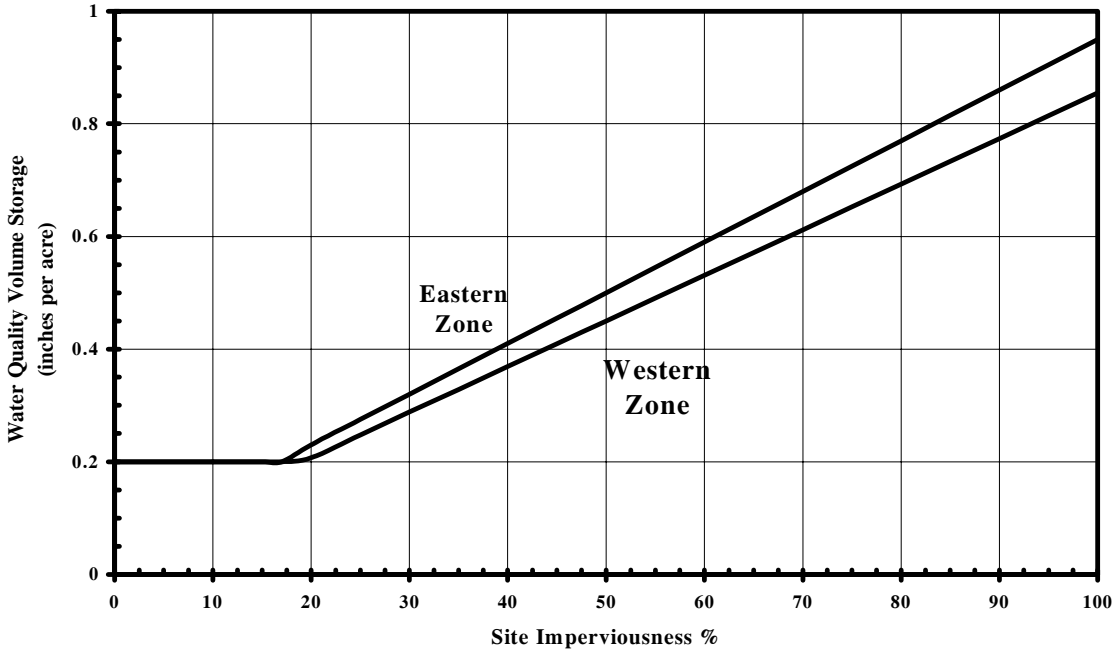


Figure 2.2 Relationship between Impervious Cover and the Water Quality Volume



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Basis for Determining Water Quality Treatment Volume

As a basis for design, the following assumptions may be made:

- **Measuring Impervious Cover**: the measured area of a site plan that does not have vegetative or permeable cover shall be considered total impervious cover. Where direct measurement of impervious cover is impractical, NRCS land use/impervious cover relationships can be used to estimate impervious cover (see Table 2.2a in TR-55, NRCS, 1986). Estimates should be based on actual land use and homogeneity.

- **Multiple Drainage Areas**: When a project contains or is divided by multiple drainage areas, the WQ_v volume shall be addressed for each drainage area. See the design examples in Chapter 2, Section 2.6.

- **Offsite Drainage Areas***:* The WQ_v shall be based on the impervious cover of the proposed site. Offsite existing impervious areas may be excluded from the calculation of the water quality volume requirements.

- **Sensitive Streams**: Consult with the appropriate local review authority to determine if a greater WQ_v is warranted to protect sensitive streams.

- **BMP Treatment**: The final WQ_v shall be treated by an acceptable BMP(s) from the list presented in Chapter 2, Section 2.7, or an equivalent practice allowed by the appropriate review authority.

- **Subtraction for Structural Practices***:* Where structural practices for treating the Re_v are employed upstream of a BMP, the Re_v may be subtracted from the WQ_v used for design.

- **Subtraction for Non-structural Practices**: Where non-structural practices are employed in the site design, the WQ_v volume can be reduced in accordance with the conditions outlined in Chapter 5.

- **Determining Peak Discharge for WQ_v Storm**: When designing flow splitters for off-line practices, consult the small storm hydrology method provided in Appendix D.10.

- **Extended Detention for Water Quality Volume**: The water quality requirement can be met by providing a 24 hour drawdown of a portion of the water quality volume (WQ_v) in conjunction with a stormwater pond or wetland system as described in Chapter 3. Referred to as ED, this is different than providing the extended detention of the one-year storm for the channel protection volume (Cp_v). The ED portion of the WQ_v may be included when routing the Cp_v.

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Section 2.2 Recharge Volume Requirements (Re_v)

The criteria for maintaining recharge is based on the average annual recharge rate of the hydrologic soil group(s) (HSG) present at a site as determined from USDA, NRCS Soil Surveys or from detailed site investigations. More specifically, each specific recharge factor is based on the USDA average annual recharge volume per soil type divided by the annual rainfall in Maryland (42 inches per year) and multiplied by 90%. This keeps the recharge calculation consistent with the WQ_v methodology. Thus, an annual recharge volume requirement is specified for a site as follows:

Site Recharge Volume Requirement

$Re_v = [(S)(R_v)(A)]/12$ (percent volume method)

where: R_v = 0.05 + 0.009(I) where I is percent impervious cover

A = site area in acres

$Re_v = (S)(A_i)$ (percent area method)

where: A_i = the measured impervious cover

Hydrologic Soil Group	Soil Specific Recharge Factor (S)
A	0.38
B	0.26
C	0.13
D	0.07

The recharge volume is considered part of the total WQ_v that must be provided at a site and can be achieved either by a structural practice (e.g., infiltration, bioretention), a non-structural practice (e.g., buffers, disconnection of rooftops), or a combination of both.

Drainage areas having no impervious cover and no proposed disturbance during development may be excluded from the Re_v calculations. Designers are encouraged to use these areas as non-structural practices for Re_v treatment (see Chapter 5, "Stormwater Credits for Innovative Site Planning").

Note: Re_v and WQ_v are inclusive. When treated separately, the Re_v may be subtracted from the WQ_v when sizing the water quality BMP (see page 2.4, 'Subtraction for Structural Practices).

The intent of the recharge criteria is to maintain existing groundwater recharge rates at development sites. This helps to preserve existing water table elevations thereby maintaining the hydrology of streams and wetlands during dry weather. The volume of recharge that occurs on a site depends on slope, soil type, vegetative cover, precipitation and evapo-transpiration. Sites with natural ground cover, such as forest and meadow, have higher recharge rates, less runoff, and greater transpiration losses under most conditions. Because development increases impervious surfaces, a net decrease in recharge rates is inevitable.

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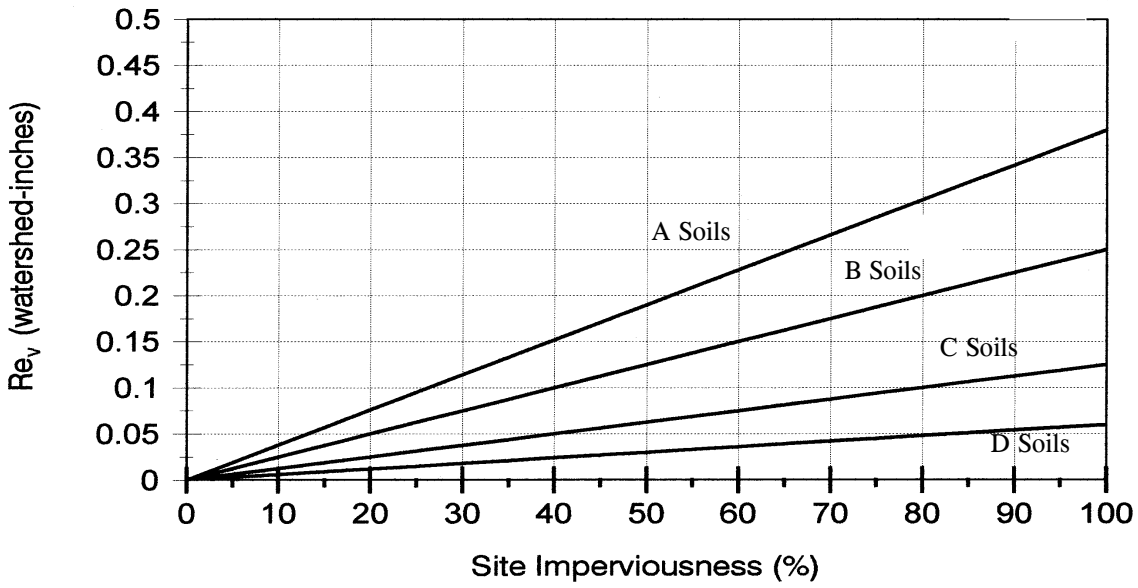
The relationship between Re_v and site imperviousness is shown in graphical form in Figure 2.3.

Figure 2.3 Relationship between Re_v and Site Impervious Cover



Basis for Determining Recharge Volume

- If more than one HSG is present at a site, a composite soil specific recharge factor shall be computed based on the proportion of total site area within each HSG. The recharge volume provided at the site shall be directed to the most permeable HSG available.

- The "percent volume" method is used to determine the Re_v treatment requirement when structural practices are used to provide recharge. These practices must provide seepage into the ground and may include infiltration and exfiltration structures (e.g., infiltration, bioretention, dry swales or sand filters with storage below the underdrain). Structures that require impermeable liners, intercept groundwater, or are designed for trapping sediment (e.g., forebays) may not be used. In this method, the volume of runoff treated by structural practices shall meet or exceed the computed recharge volume.

- The "percent area" method is used to determine the Re_v treatment requirements when non-structural practices are used. Under this method, the recharge requirement is evaluated by mapping the percent of impervious area that is effectively treated by an acceptable non-structural practice and comparing it to the minimum recharge requirements.

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- Acceptable non-structural practices include filter strips that treat rooftop or parking lot runoff, sheet flow discharge to stream buffers, and grass channels that treat roadway runoff (see Chapter 5.)

- The recharge volume criterion does not apply to any portion of a site designated as a stormwater hotspot nor any project considered as redevelopment. In addition, the appropriate local review authority may alter or eliminate the recharge volume requirement if the site is situated on unsuitable soils (e.g., marine clays), karst or in an urban redevelopment area. In this situation, non-structural practices (percent area method) should be implemented to the maximum extent practicable and the remaining or untreated Re_v included in the WQ_v treatment.

- If Re_v is treated by structural or non-structural practices separate and upstream of the WQ_v treatment, the WQ_v is adjusted accordingly.

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Section 2.3 Channel Protection Storage Volume Requirements (Cp_v)

To protect channels from erosion, **24 hour extended detention of the one-year, 24 hour storm event** (MDE, 1987) shall be provided. In Use III and IV watersheds, only 12 hours of extended detention shall be provided. The rationale for this criterion is that runoff will be stored and released in such a gradual manner that critical erosive velocities during bankfull and near-bankfull events will seldom be exceeded in downstream channels.

The Cp_v requirement does not apply to direct discharges to tidal water or Maryland's Eastern Shore (as defined in Figure 2.4) unless specified by an appropriate review authority on a case by case basis. Local governments may wish to use alternative methods to provide equivalent stream channel protection such as the Distributed Runoff Control method or bankfull capacity/duration criteria (MacRae, 1993).

The method for determining the Cp_v requirement is detailed in Appendix D.11. A detention pond or underground vault is normally needed to meet the Cp_v requirement (and subsequent Q_{p10} and Q_f criteria). Schematics of a typical design are shown in Figures 2.5.

Figure 2.4 Regions of Maryland Not Subject to the Channel Protection Requirement (Cp_v)

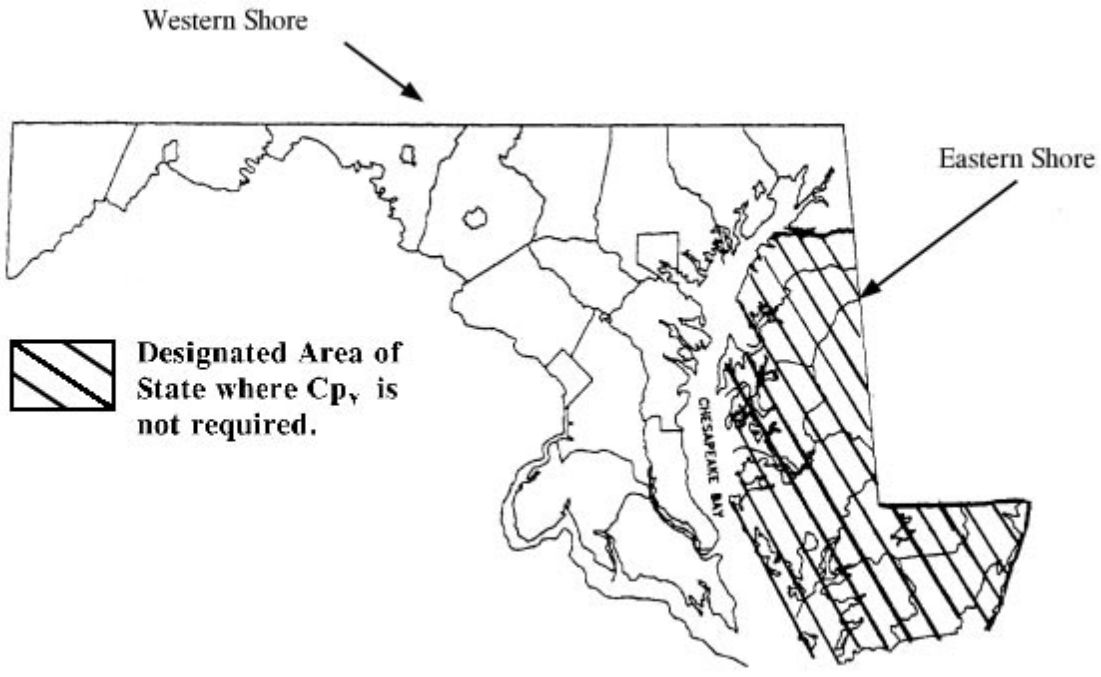

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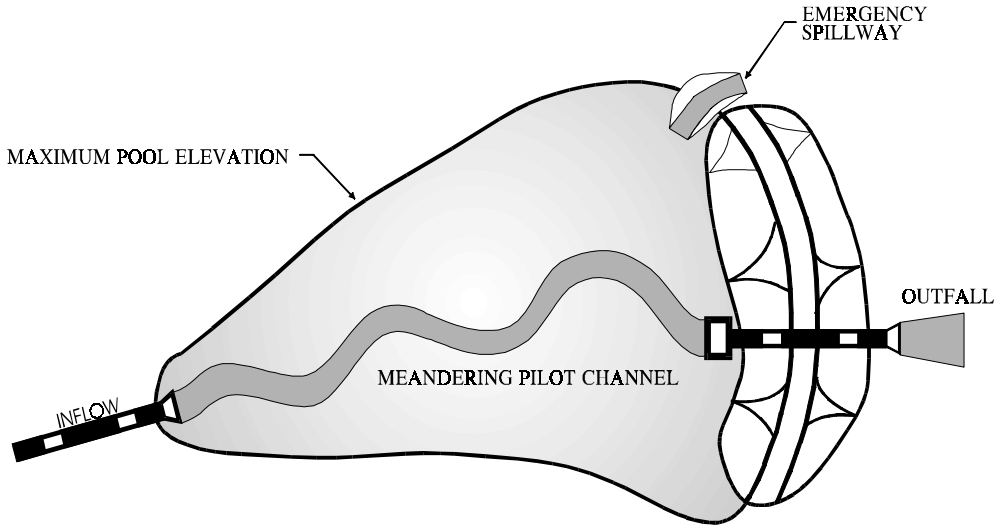
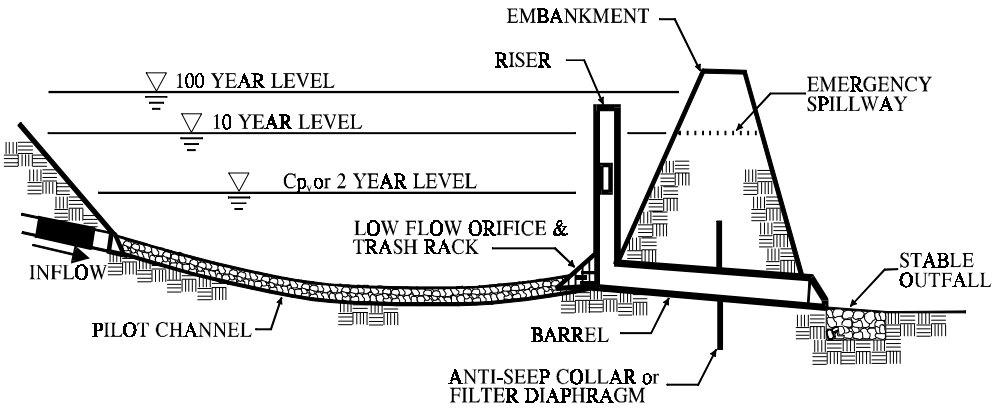
Figure 2.5 Example of Conventional Stormwater Detention Pond



PLAN VIEW



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A typical detention facility provides channel protection control (Cp_v) and overbank flood control (Q_p) but not water quality control (WQ_v).

Basis for Determining Channel Protection Storage Volume

The following represent the minimum basis for design:

- The models TR-55 and TR-20 (or approved equivalent) shall be used for determining peak discharge rates.
- Rainfall depths for the one-year, 24 hour storm event are provided in Table 2.2.
- Off-site areas should be modeled as present land use in good condition for the one-year storm event.
- The length of overland flow used in time of concentration (t_c) calculations is limited to no more than 100 feet for post development conditions. On the Eastern Shore, the maximum distance for t_c calculations is 150 feet for the post development conditions.
- The Cp_v storage volume shall be computed using the detention lag time between hydrograph centroids developed in "Design Procedures for Stormwater Management Extended Detention Structures" (MDE, 1987) and outlined in Appendix D.11. The detention lag time (T) for the one-year storm is defined as the interval between the center of mass of the inflow hydrograph and the center of mass of the outflow hydrograph. Examples of this technique are shown in Appendix C.1 and in the design example under Section 2.6.
- Cp_v is not required at sites where the one-year post development peak discharge (q_i) is less than or equal to 2.0 cfs. A Cp_v orifice diameter (d_o) of less than 3.0" is subject to approval by the appropriate review authority and is not recommended unless an internal control for orifice protection is used (see Appendix D.8).
- Cp_v shall be addressed for the entire site. If a site consists of multiple drainage areas, Cp_v may be distributed proportionately to each drainage area.
- Extended detention storage provided for the Cp_v does not meet the WQ_v requirement (that is Cp_v and WQ_v should be treated separately).
- The stormwater storage needed for Cp_v may be provided above the WQ_v storage in stormwater ponds and wetlands; thereby meeting all storage criteria except Re_v in a single facility with appropriate hydraulic control structures for each storage requirement.
- Infiltration is not recommended for Cp_v control because of large storage requirements.

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Table 2.2 Rainfall Depths Associated with the 1,2,10 and 100-year, 24-hour Storm Events

County	Rainfall Depth			
	1 yr - 24 hr	2 yr-24 hr	10 yr-24 hr	100 yr-24 hr
Allegany	2.4 inches	2.9 inches	4.5 inches	6.2 inches
Anne Arundel	2.7	3.3	5.2	7.4
Baltimore	2.6	3.2	5.1	7.1
Calvert	2.8	3.4	5.3	7.6
Caroline	2.8	3.4	5.3	7.6
Carroll	2.5	3.1	5.0	7.1
Cecil	2.7	3.3	5.1	7.3
Charles	2.7	3.3	5.3	7.5
Dorchester	2.8	3.4	5.4	7.8
Frederick	2.5	3.1	5.0	7.0
Garrett	2.4	2.8	4.3	5.9
Harford	2.6	3.2	5.1	7.2
Howard	2.6	3.2	5.1	7.2
Kent	2.7	3.3	5.2	7.4
Montgomery	2.6	3.2	5.1	7.2
Prince George's	2.7	3.3	5.3	7.4
Queen Anne's	2.7	3.3	5.3	7.5
St. Mary's	2.8	3.4	5.4	7.7
Somerset	2.9	3.5	5.6	8.1
Talbot	2.8	3.4	5.3	7.6
Washington	2.5	3.0	4.8	6.7
Wicomico	2.9	3.5	5.6	7.9
Worcester	3.0	3.6	5.6	8.1

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Section 2.4 Overbank Flood Protection Volume Requirements (Q_p)

The primary purpose of the overbank flood protection volume sizing criteria is to prevent an increase in the frequency and magnitude of out-of-bank flooding generated by development (e.g., flow events that exceed the bankfull capacity of the channel and therefore must spill over into the floodplain). Overbank flood protection for the ten-year storm shall only be required if local approval authorities have no control of floodplain development, no control over infrastructure and conveyance system capacity design, or determine that downstream flooding will occur as a result of the proposed development.

For most regions of the State, the overbank flood control criteria translates to preventing the post development ten-year, 24 hour storm peak discharge rate (Q_{p10}) from exceeding the pre development peak discharge rate.

On the Eastern Shore of Maryland, the overbank flood control criteria is defined as preventing the post development two-year, 24 hour storm peak discharge rate (Q_{p2}) from exceeding the pre development peak discharge rate. The rainfall depths associated with the two and ten-year, 24 hour storm events are shown in Table 2.2.

Basis for Determining Overbank Flood Protection Volume

When addressing the overbank flooding design criteria, the following represent the minimum basis for design:

- The models TR-55 and TR-20 (or an equivalent approved by the appropriate local authority) will be used for determining peak discharge rates. The Eastern Shore Dimensionless Hydrograph may be used for sites where appropriate (see Appendix D.14). Any adjustments for unique land features such as Karst topography shall be determined by the local approving authority.

- The standard for characterizing pre development hydrologic land use for non-forested vegetated areas (including agriculture) shall be meadow in good hydrologic condition.

- Off-site areas should be modeled as "present land use condition" in good hydrologic condition for both the 2 and 10-year storm events.

- The length of overland flow used in t_c calculations is limited to no more than 150 feet for pre development conditions and 100 feet for post development conditions. On the Eastern Shore (see Figure 2.4) this maximum distance is extended to 250 feet for pre development conditions and 150 feet for post development conditions.

- Overbank flood protection does not apply to direct discharges to tidal water.

SARB_005199

Section 2.5 Extreme Flood Volume (Q_f)

The intent of the extreme flood criteria is to (a) prevent flood damage from large storm events, (b) maintain the boundaries of the pre development 100-year Federal Emergency Management Agency (FEMA) and/or locally designated floodplain, and (c) protect the physical integrity of BMP control structures. This is typically done in two ways:

100-Year Control: requires storage to attenuate the post development 100-year, 24 hour peak discharge (Q_f) to pre development rates. The Q_f is the most stringent and expensive level of flood control and is generally not needed if the downstream development is located out of the 100-year floodplain. In many cases, the conveyance system leading to a stormwater structure is designed based on the discharge rate for the ten-year storm (Qp_{10}). In these situations, the conveyance systems may be the limiting hydrologic control.

Reserve Ultimate 100-Year Floodplain: 100-year storm control may be required by an appropriate review authority if:

- buildings or development are located within the ultimate 100-year floodplain, or
- the reviewing authority does not completely control the 100-year floodplain.

Hydraulic/hydrologic investigations may be required to demonstrate that downstream roads, bridges and public utilities are adequately protected from the Q_f storm. These investigations typically extend to the first downstream tributary of equal or greater drainage area or to any downstream dam, highway, or natural point of restricted stream flow.

Basis for Determining Extreme Flood Criteria

- Consult with the appropriate review authority to determine the analyses required for the Q_f storm.

- The same hydrologic and hydraulic methods used for overbank flood control shall be used to analyze Q_f.

- In addition, off-site areas should be modeled as “ultimate condition” when the 100-year design storm event is analyzed. Table 2.2 indicates the depth of rainfall (24 hour) associated with the 100-year storm event for all counties in the State of Maryland

SARB_005200

Section 2.6 Design Examples: Computing Stormwater Storage Volumes

Design examples are provided only to illustrate how the five stormwater management sizing criteria are computed for hypothetical development projects. These design examples are also utilized elsewhere in the manual to illustrate structural and non-structural BMP design.

Design Example No. 1: Residential Development - Reker Meadows

Site data and the layout of the Reker Meadows subdivision are shown in Figure 2.6.

Step 1. Compute WQ_v Volume

$$WQ_v = \frac{(P)(R_v)(A)}{12}$$

Step 1a. Compute Volumetric Runoff Coefficient (R_v)

R_v = 0.05 + (0.009) (I); I = 13.8 acres/38.0 acres = 36.3%
= 0.05 + (0.009) (36.3) = 0.38

Step 1b. Determine Rainfall Zone for WQ_v Formula

Location	**Rainfall (*P*)**
Eastern Rainfall Zone	1.0 inches
Western Rainfall Zone	0.9 inches
Minimum WQv (I ≤ 15%)	0.2 inches

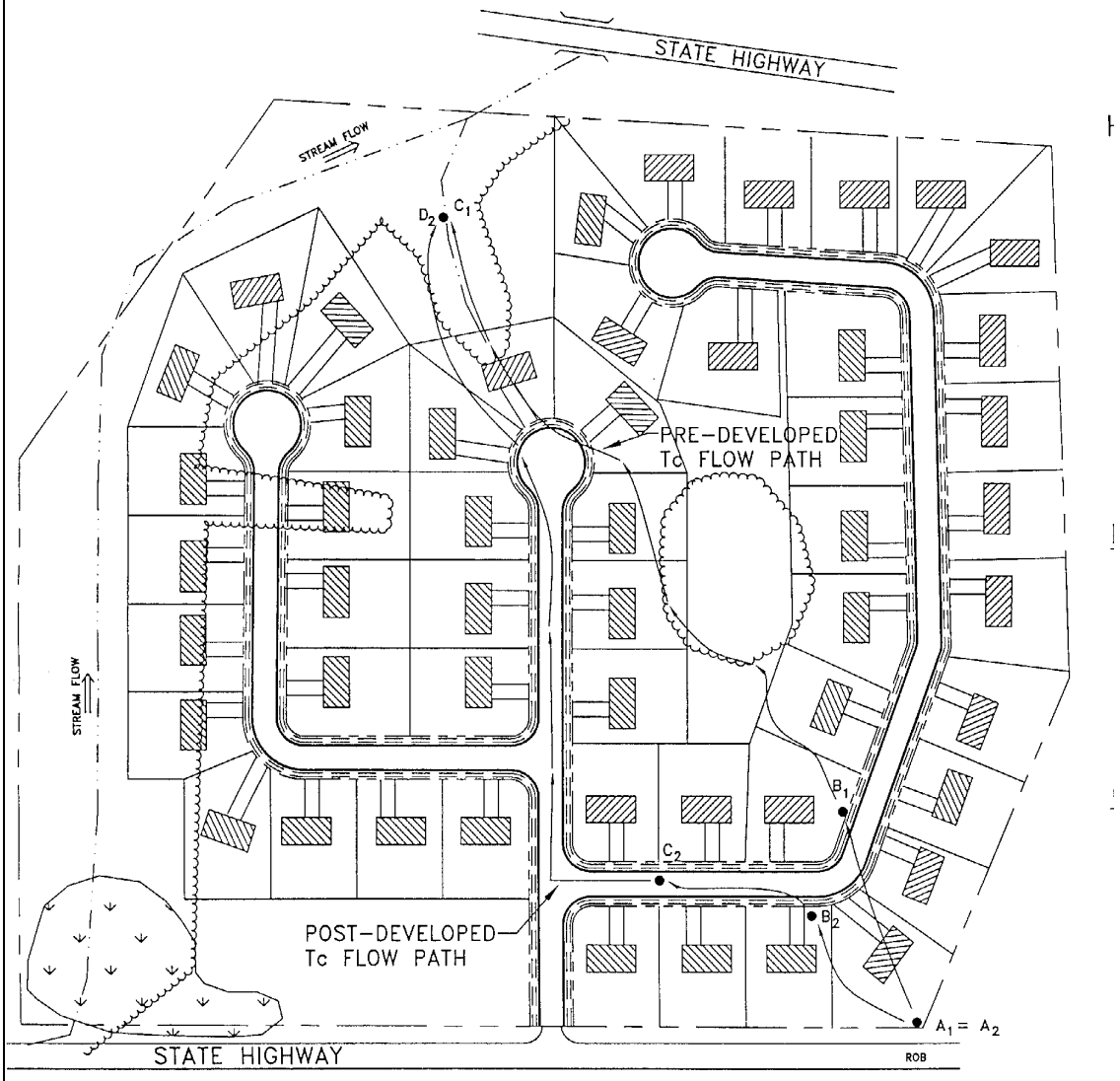
Because this site is located in the Western Rainfall Zone, use 0.9″ of rainfall to determine WQ_v.

Step 1c. Compute WQ_v

WQ_v = [(0.9″) (R_v) (A)]/12
= [(0.9″)(0.38)(38.0 ac)]/12
= 1.08 ac-ft

Check Minimum: [(0.2″)(38.0 ac)]/12 = 0.63 ac-ft < 1.08 ac-ft
∴ Use WQ_v = 1.08 ac-ft

Figure 2.6 Reker Meadows



Base Data
Location: Frederick, MD
Site Area = Total Drainage Area (A) = 38.0 ac
Measured Impervious Area = 13.8 ac; I=13.8/38 = 36.3%
Soils Types: 60% "B", 40% "C"
Stream Use Designation – I
Zoning: Residential (½ acre lots)

Hydrologic Data		
	Pre	Post
CN	63	78
t_c	0.35 hr	0.19 hr

Step 2. Compute Recharge Volume (Re_v)

$$Re_v = \frac{(S)(R_v)(A)}{12}$$ (percent volume method)

or

$$Re_v = (S)(A_i)$$ (percent area method)

Step 2a. Determine Soil Specific Recharge Factor (*S*) Based on Hydrologic Soil Group

HSG	Soil Specific Recharge Factor (*S*)
A	0.38
B	0.26
C	0.13
D	0.06

Assume imperviousness is located proportionally (60/40) in B and C soils and compute a composite S:

S = (0.26)(0.60) + (0.13)(0.40) = 0.208; Use 0.208 or 20.8% of site imperviousness

Step 2b. Compute Recharge Using Percent Volume Method

Re_v = [(*S*)(R_v)(*A*)]/12
= [(0.208)(0.38)(38 ac)]/12
= 0.25 ac-ft

or

For "B" soils =[(0.26)(.38)(38 ac)]/12 × 60% = 0.19 ac-ft
For "C" soils =[(0.13)(.38)(38 ac)]/12 × 40% = .06 ac-ft

Add recharge requirement for both soils for a total volume of 0.25 ac-ft

Step 2c. Compute Recharge Using Percent Area Method

Re_v = (*S*)(A_i)
= (0.208)(13.8 ac)
= 2.87 acres

or

For "B" soils = (0.26)(13.8 ac)(60%) = 2.15 acres
For "C" soils = (0.13)(13.8 ac)(40%) = 0.72 acres
Added together = 2.87 acres of the total site impervious area needs to be treated by non-structural practices.

The Re_v requirement may be met by: a) treating 0.25 ac-ft using structural methods, b) treating 2.87 acres using non-structural methods, or c) a combination of both (e.g., 0.12 ac-ft structurally and 1.44 acres non-structurally).

Step 3. Compute Channel Protection Volume (Cp_v): (See Appendix D.11)

Step 3a. Select Cp_v Sizing Rule

For channel protection, provide 12 or 24 hours of extended detention time (*T*) for the one-year design storm event.

Use Classification	Maximum Hours Allowable
Use I (general)	24
Use II (tidal)	N/A (if direct discharge)
Use III (reproducing trout)	12
Use IV (recreational trout)	12

Given that our stream is Use I, we will use a *T* of 24 hours for the one-year design storm event.

Step 3b. Develop site hydrologic and TR-55 Input Parameters

Per attached TR-55 calculations (see Figures 2.7 and 2.8).

Condition	CN	t_c	Runoff (Q_a) 1 yr storm	Q 1-year	Q 2-year	Q 10-year	Q 100 year
		hours	*inches*	*cfs*	*cfs*	*cfs*	*cfs*
pre-developed	63	0.35	0.2	4.62	13.58	50.38	102.6
developed	78	0.19	0.8	35.0	54.94	129.96	216.30

Step 3c. Utilize MDE Method to Compute Storage Volume (Appendix D.11)

Initial abstraction (I_a) for CN of 78 is 0.564: (TR-55) [I_a = (200/CN) - 2]

I_a/P = (0.564)/2.5" = 0.226
t_c = 0.19 hours

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Figure D.11.1 (App. D.11), q_u = 740 csm/in
Knowing q_u and T (extended detention time) find q_o/q_i from Figure D.11.2, "Detention Time Versus Discharge Ratios."

Peak outflow discharge/peak inflow discharge (q_o/q_i) = 0.024

With q_o/q_i, compute V_s/V_r for a Type II rainfall distribution,

$V_s/V_r = 0.683 - 1.43(q_o/q_i) + 1.64(q_o/q_i)^2 - 0.804(q_o/q_i)^3$ (App. D.11)
$V_s/V_r = 0.65$

Therefore, $V_s = 0.65(0.8'')(1/12)(38 \text{ ac}) = 1.65$ ac-ft

Step 3d. Define the Cp_v Release Rate

q_i is known (35.0 cfs), therefore,
$q_o = (q_o/q_i)\ q_i = .024\ (35.0) = .84$ cfs

Step 4. Compute Overbank Flood Protection Volume (Q_p):

Step 4a. Determine Appropriate Q_p Requirement

Location	**Type of Peak Control**
Eastern Shore	2 year/2 year
Western Shore	10 year/10 year

Because this site is located on the Western Shore, ten-year quantity peak control may be required. Assume ten-year control is needed.

Step 4b. Model Site Using TR-55 for 10 year storm

Per TR-55, Figure 6-1 (Page 6-2 of TR-55) for a Q_{in} of 130.0 cfs, and an allowable Q_{out} of 50.4 cfs, the V_s necessary for control is 2.83 ac-ft, with a developed CN of 78. (See TR-55 Worksheet 6a, Page 6-5 of TR-55). Note that there is 5.0 inches of rainfall during this event, with 2.7 inches of runoff.

Step 5. Extreme Flood Volume (Q_f)

For this example, management of Q_f is not required. However, at final design the 100-year event must be conveyed safely through the stormwater management practice. Based on field observation, downstream conveyance may require analysis for passing the 100-year event through an existing culvert.

SARB_005205

Table 2.3 Summary of General Storage Requirements for Reker Meadows

Step	Requirement	Volume Required (ac- ft)	Notes
1.	Water Quality Volume (WQ_v)	1.08	
2.	Recharge Volume (Re_v)	.25 (or 2.87 acres)	this volume is included within the WQ_v storage
3.	Channel Protection Volume (Cp_v)	1.65	Cp_v release rate is .84 cfs
4.	Overbank Flood Protection Volume (Q_p)	2.83	10-year, in this case
5.	Extreme Flood Volume (Q_f)	N/A	provide safe passage for the 100-year event in final design

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Figure 2.7: Reker Meadows – Pre Developed Conditions
(Source: TR-55 computer printouts)

```
                    RUNOFF CURVE NUMBER COMPUTATION            Version 2.00
Project : REKER MEADOWS                          User: SRC      Date: 08-01-97
County  : FREDERICK            State: MD      Checked: ____     Date: ________
Subtitle: PRE-DEVELOPED CONDITIONS
--------------------------------------------------------------------------------
                                                   Hydrologic Soil Group
         COVER DESCRIPTION                       A        B        C        D
                                                        Acres (CN)
--------------------------------------------------------------------------------
OTHER AGRICULTURAL LANDS
Meadow -cont. grass (non grazed) ----            -  22.8(58)  9.2(71)       -

Woods                              good          -        -   6.0(70)       -

Total Area (by Hydrologic Soil Group)              22.8     15.2
                                                   ====     ====
                TOTAL DRAINAGE AREA: 38 Acres        WEIGHTED CURVE NUMBER: 63*

                     TIME OF CONCENTRATION AND TRAVEL TIME        Version 2.00
--------------------------------------------------------------------------------
Flow Type   2 year   Length   Slope  Surface   n   Area     Wp   Velocity  Time
             rain     (ft)   (ft/ft)   code       (sq/ft)  (ft)  (ft/sec)  (hr)
--------------------------------------------------------------------------------
Sheet        3.1      150      .025     F                                  0.306
Shallow Concent'd     500      0.04     U                                  0.043
                                                Time of Concentration = 0.35*
                                                                        =====
        --- Sheet Flow Surface Codes ---
    A Smooth Surface           F Grass, Dense     --- Shallow Concentrated ---
    B Fallow (No Res.)         G Grass, Burmuda   ---     Surface Codes    ---
    C Cultivated < 20 % Res.   H Woods, Light              P Paved
    D Cultivated > 20 % Res.   I Woods, Dense              U Unpaved
    E Grass-Range, Short       J Range, Natural
* - Generated for use by GRAPHIC method

                      GRAPHICAL PEAK DISCHARGE METHOD            Version 2.00
 Data: Drainage Area        :  38 * Acres
       Runoff Curve Number  :  63 *
       Time of Concentration:  0.35 * Hours
       Rainfall Type        :  II
       Pond and Swamp Area  :  NONE

=================================================================================
| Storm Number          |   1   |   2   |   3   |   4   |   5   |   6   |   7   |
|-----------------------|-------|-------|-------|-------|-------|-------|-------|
| Frequency  (yrs)      |   1   |   2   |   5   |  10   |  25   |  50   |  100  |
| 24-Hr Rainfall (in)   |  2.5  |  3.1  |   4   |   5   |  5.4  |  6.1  |   7   |
| Ia/P Ratio            | 0.47  | 0.38  | 0.29  | 0.23  | 0.22  | 0.19  | 0.17  |
| Runoff (in)           | 0.24  | 0.48  | 0.92  | 1.51  | 1.77  | 2.25  | 2.90  |
| Unit Peak Discharge   |0.504  |0.698  |0.834  |0.880  |0.894  |0.913  |0.932  |
|    (cfs/acre/in)      |       |       |       |       |       |       |       |
| Pond and Swamp Factor | 1.00  | 1.00  | 1.00  | 1.00  | 1.00  | 1.00  | 1.00  |
|    0.0% Ponds Used    |       |       |       |       |       |       |       |
|-----------------------|-------|-------|-------|-------|-------|-------|-------|
| Peak Discharge (cfs)  |   5   |   13  |   29  |   50  |   60  |   78  |  103  |
=================================================================================
* - Value(s) provided from TR-55 system routines
```


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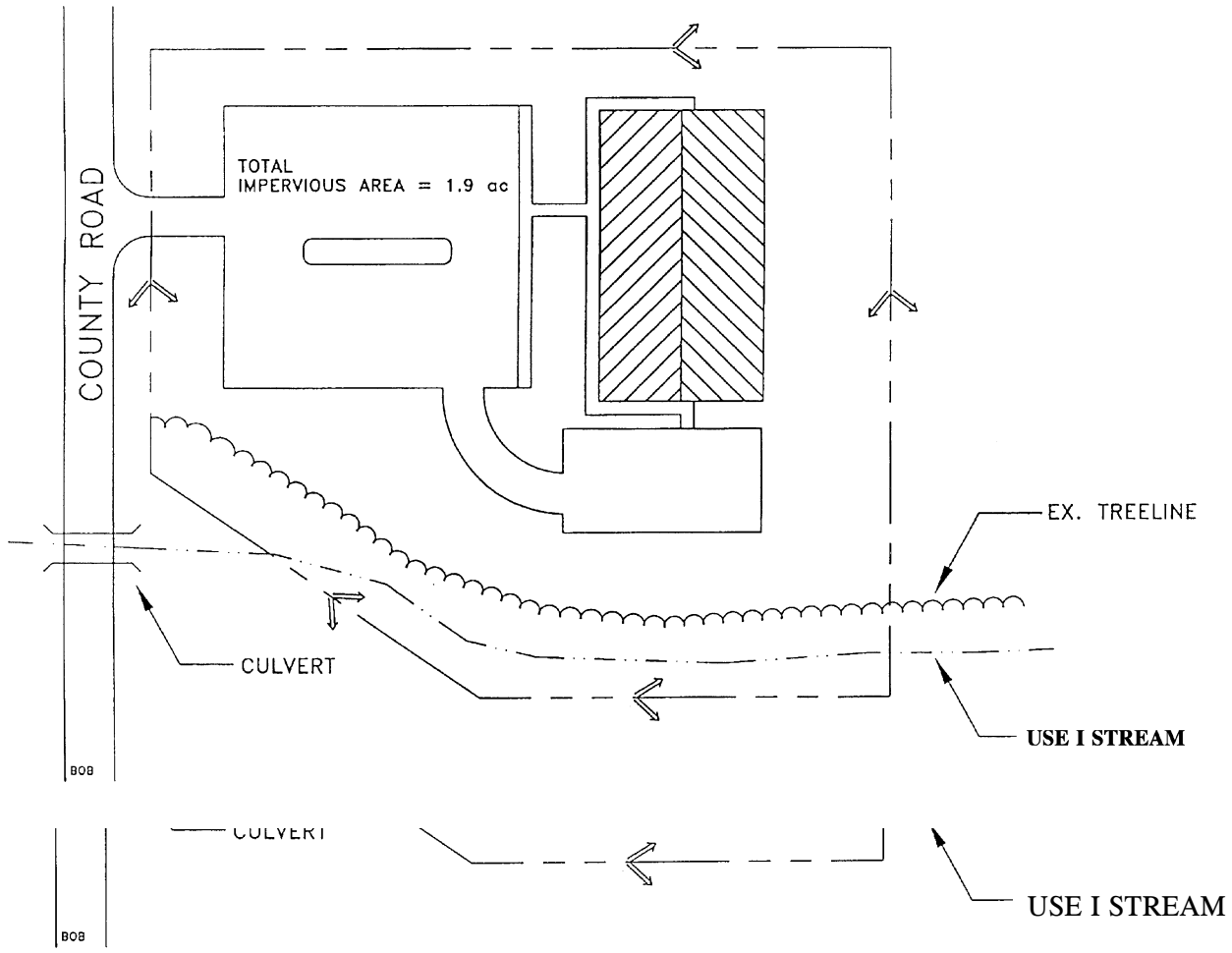
Figure 2.8: Reker Meadows –Developed Conditions
(Source: TR-55 Computer Printouts)

```
                      RUNOFF CURVE NUMBER COMPUTATION            Version 2.00
Project : REKER MEADOWS                          User: SRC      Date: 08-01-97
County  : FREDERICK          State: MD      Checked: ____      Date: ________
Subtitle: DEVELOPED CONDITIONS
--------------------------------------------------------------------------------
                                                    Hydrologic Soil Group
        COVER DESCRIPTION                        A        B        C        D
                                                        Acres (CN)
--------------------------------------------------------------------------------
FULLY DEVELOPED URBAN AREAS (Veg Estab.)
Open space (Lawns,parks etc.)
  Good condition; grass cover > 75%              -  13.0(61)  5.2(74)       -
Impervious Areas
  Paved parking lots, roofs, driveways           -   7.9(98)  5.9(98)       -
OTHER AGRICULTURAL LANDS
Woods                            good            -        -   6.0(70)       -

Total Area (by Hydrologic Soil Group)              20.9     17.1
                                                   ====     ====
               TOTAL DRAINAGE AREA: 38 Acres        WEIGHTED CURVE NUMBER: 78*

                     TIME OF CONCENTRATION AND TRAVEL TIME        Version 2.00
--------------------------------------------------------------------------------
Flow Type   2 year   Length   Slope  Surface   n   Area     Wp   Velocity  Time
             rain     (ft)   (ft/ft)   code       (sq/ft)  (ft)  (ft/sec)  (hr)
--------------------------------------------------------------------------------
Sheet        3.1      100      .025     E                                  0.152
Shallow Concent'd     300      0.02     P                                  0.029
Open Channel          600                                      16.2        0.010
                                                Time of Concentration = 0.19*
                                                                        =====
        --- Sheet Flow Surface Codes ---
    A Smooth Surface          F Grass, Dense     --- Shallow Concentrated ---
    B Fallow (No Res.)        G Grass, Burmuda   ---     Surface Codes    ---
    C Cultivated < 20 % Res.  H Woods, Light              P Paved
    D Cultivated > 20 % Res.  I Woods, Dense              U Unpaved
    E Grass-Range, Short      J Range, Natural
* - Generated for use by GRAPHIC method

                      GRAPHICAL PEAK DISCHARGE METHOD            Version 2.00
Data: Drainage Area        :  38 * Acres
        Runoff Curve Number  :  78 *
        Time of Concentration:  0.19 * Hours
        Rainfall Type        :  II
        Pond and Swamp Area  :  NONE
=================================================================
| Storm Number          |   1   |   2   |   3   |   4   |   5   |   6   |   7   |
|-----------------------|-------|-------|-------|-------|-------|-------|-------|
| Frequency  (yrs)      |   1   |   2   |   5   |  10   |  25   |  50   |  100  |
| 24-Hr Rainfall (in)   |  2.5  |  3.1  |   4   |   5   |  5.4  |  6.1  |   7   |
| Ia/P Ratio            | 0.23  | 0.18  | 0.14  | 0.11  | 0.10  | 0.09  | 0.08  |
|            Used       | 0.23  | 0.18  | 0.14  | 0.11  | 0.10  | 0.10  | 0.10  |
| Runoff (in)           | 0.79  | 1.20  | 1.89  | 2.71  | 3.05  | 3.67  | 4.47  |
| Unit Peak Discharge   |1.175  |1.209  |1.242  |1.264  |1.271  |1.275  |1.275  |
|    (cfs/acre/in)      |       |       |       |       |       |       |       |
| Pond and Swamp Factor | 1.00  | 1.00  | 1.00  | 1.00  | 1.00  | 1.00  | 1.00  |
|    0.0% Ponds Used    |       |       |       |       |       |       |       |
|-----------------------|-------|-------|-------|-------|-------|-------|-------|
| Peak Discharge (cfs)  |   35  |   55  |   89  |  130  |  148  |  178  |  217  |
=================================================================
* - Value(s) provided from TR-55 system routines
```

Design Example No. 2: Commercial Development - Claytor Community Center

Site data and the layout of the Claytor Community Center are shown in Figure 2.9.

Figure 2.9 Claytor Community Center



Base Data
Location: Easton, MD
Site Area = Total Drainage Area (A) = 3.0 ac
Impervious Area = 1.9 ac; I= 1.9/3.0 = 63.3%
R_v = 0.05 + (63.3)(0.009) = 0.62
Soils Type "B"
Stream Use Designation I

Hydrologic Data		
	Pre	Post
CN	57	83
t_c	0.42 hr	0.16 hr

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Step 1. Compute Water Quality Volume WQ_v

$$WQ_v = \frac{(P)(R_v)(A)}{12}$$

Step 1a. Compute Volumetric Runoff Coefficient (R_v)

$R_v = 0.05 + (0.009)\ (I)$; $I = 1.9\ _{acres}/3.0\ _{acres} = 63.3\%$
$= 0.05 + (0.009)\ (63.3) = 0.62$

Step 1b. Determine Rainfall Zone for WQ_v Formula

Location	**Rainfall (*P*)**
Eastern Rainfall Zone	1.0 inches
Western Rainfall Zone	0.9 inches
Minimum WQ_v ($I \leq 15\%$)	0.2 inches

Because this site is located in the Eastern Rainfall Zone, use the 1″ of rainfall to determine WQ_v.

Step 1c. Compute WQ_v

$WQ_v = [(1.0'')(R_v)(A)]/12$
$= [(1.0'')(0.62)(3.0ac)]/12 \times (43560ft^2/acre)$
$= \underline{6752\ ft^3}$

Check Minimum: $[(0.2'')(3.0\ ac)]/12 \times (43560ft^2/acre) = 2178\ ft^3 < 6752\ ft^3$
$\therefore$ Use $WQ_v = 6752\ ft^3$

Step 2. Compute Recharge Volume (Re_v)

$$Re_v = \frac{(S)(R_v)(A)}{12}$$ (percent volume method)

or

$$Re_v = (S)(A_i)$$ (percent area method)

Step 2a. Determine Soil Specific Recharge Factor (*S*) Based on Hydrologic Soil Group

HSG	Soil Specific Recharge Factor (*S*)
A	0.38
B	0.26
C	0.13
D	0.06

Site is located within B soils, $\therefore S = 0.26$; Use 0.26 or 26%

Step 2b. Compute Recharge Using Percent Volume Method

$$Re_v = [(S)(R_v)(A)]/12$$
$$= [(0.26)(0.62)(3.0\ ac)]/12 \times (43560 ft^2/acre)$$
$$= \underline{1{,}755.5\ ft^3}$$

Step 2c. Compute Recharge Using Percent Area Method

$$Re_v = (S)(A_i)$$
$$= (0.26)(1.9\ ac) \times (43560 ft^2/acre)$$
$$= 21{,}518.6\ ft^2$$

The Re_v requirement may be met by: a) treating 1,755 ft^3 using structural methods, b) treating 21,518.6 ft^2 using non-structural methods, or c) a combination of both (e.g., 580 ft^3 structurally and 14,200 ft^2 non-structurally).

Step 3. Compute Channel Protection Volume (Cp_v):

Because this site is located on the Eastern Shore (see Fig. 2.4), Cp_v is not required.

Step 4. Compute Overbank Flood Protection Volume (Q_p):

Step 4a. Determine Appropriate Q_p Requirement

Location	Type of Peak Control
Eastern Shore	2-year/2-year
Western Shore	10-year/10-year

Per attached TR-55 calculations (Figure 2.10 and 2.11)

Condition	CN	t_c	Q 1-year	Q 2-year	Q 10-year	Q 100-year
		hours	*cfs*	*cfs*	*cfs*	*cfs*
pre-developed	57	0.42	0.22	0.58	2.91	6.75
developed	83	0.16	5.08	7.11	13.97	22.69

Because this site is located on the Eastern Shore, two-year quantity peak control is required (Q_{p2}). Per TR-55, Figure 6-1 (Page 6-2 in TR-55), for a Q_{in} of 7.11 cfs, and an allowable Q_{out} of 0.58 cfs, the Vs necessary for 2-year control is 0.24 ac-ft or 10,630 ft^3, under a developed CN of 83. (See TR-55 Worksheet 6a, Page 6-5 of TR-55.) Note that there is 3.4 inches of rainfall during this event, with 1.8 inches of runoff.

Step 5. Extreme Flood Volume (Q_f):

For this example, management of Q_f is not required. However, at final design the 100-year event must be conveyed safely through the stormwater management practice and to receiving waters.

Table 2.4 Summary of General Design Information for Claytor Community Center

Step	Category	Volume Required (cubic feet)	Notes
1	Water Quality Volume (WQ_v)	6,752	
2	Recharge Volume (Re_v)	1,688	this volume can be included within the WQ_v storage
3	Channel Protection Volume (Cp_v)	N/A	not required on the Eastern Shore
4	Overbank Flood Protection Volume (Q_p)	10,630	2-year, in this case
5	Extreme Flood Volume (Q_f)	N/A	provide safe passage for the 100-year event in final design

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Figure 2.10: Claytor Community Center – Pre Developed Conditions

```
                      RUNOFF CURVE NUMBER COMPUTATION            Version 2.00
Project : CLAYTOR COMMUNITY CENTER              User: SRC      Date: 07-31-97
County  : DORCHESTER          State: MD      Checked: ____     Date: ________
Subtitle: PRE-DEVELOPED
-------------------------------------------------------------------------------
                                                    Hydrologic Soil Group
        COVER DESCRIPTION                         A        B        C        D
                                                        Acres (CN)
-------------------------------------------------------------------------------
OTHER AGRICULTURAL LANDS
Meadow -cont. grass (non grazed) ----           -   2.4(58)       -        -
Woods                            good           -   0.6(55)       -        -
Total Area (by Hydrologic Soil Group)             3
                                                ====
               TOTAL DRAINAGE AREA: 3 Acres         WEIGHTED CURVE NUMBER: 57*

             TIME OF CONCENTRATION AND TRAVEL TIME        Version 2.00
  ------------------------------------------------------------------------------
Flow Type   2 year   Length   Slope  Surface   n   Area     Wp   Velocity  Time
             rain     (ft)   (ft/ft)   code       (sq/ft)  (ft)  (ft/sec)  (hr)
-------------------------------------------------------------------------------
Sheet        3.4      150      0.015    F                                  0.358
Shallow Concent'd     500      0.02     U                                  0.061
                                                Time of Concentration = 0.42*
                                                                        =====
        --- Sheet Flow Surface Codes ---
    A Smooth Surface           F Grass, Dense     --- Shallow Concentrated ---
    B Fallow (No Res.)         G Grass, Burmuda   ---     Surface Codes    ---
    C Cultivated < 20 % Res.   H Woods, Light              P Paved
    D Cultivated > 20 % Res.   I Woods, Dense              U Unpaved
    E Grass-Range, Short       J Range, Natural

                      GRAPHICAL PEAK DISCHARGE METHOD            Version 2.00
Data: Drainage Area        :  3 * Acres
        Runoff Curve Number  :  57 *
        Time of Concentration:  0.42 * Hours
        Rainfall Type        :  II
        Pond and Swamp Area  :  NONE
=============================================================================
| Storm Number          |   1   |   2   |   3   |   4   |   5   |   6   |   7   |
|-----------------------|-------|-------|-------|-------|-------|-------|-------|
| Frequency  (yrs)      |   1   |   2   |   5   |  10   |  25   |  50   |  100  |
| 24-Hr Rainfall (in)   |  2.8  |  3.4  |  4.6  |  5.4  |  6.2  |  6.9  |  7.8  |
| Ia/P Ratio            | 0.54  | 0.44  | 0.33  | 0.28  | 0.24  | 0.22  | 0.19  |
|            Used      | 0.50  | 0.44  | 0.33  | 0.28  | 0.24  | 0.22  | 0.19  |
| Runoff (in)           | 0.19  | 0.38  | 0.90  | 1.32  | 1.80  | 2.25  | 2.86  |
| Unit Peak Discharge   |0.392  |0.511  |0.712  |0.769  |0.796  |0.814  |0.833  |
|    (cfs/acre/in)      |       |       |       |       |       |       |       |
| Pond and Swamp Factor | 1.00  | 1.00  | 1.00  | 1.00  | 1.00  | 1.00  | 1.00  |
|    0.0% Ponds Used    |       |       |       |       |       |       |       |
|-----------------------|-------|-------|-------|-------|-------|-------|-------|
| Peak Discharge (cfs)  |   0   |   1   |   2   |   3   |   4   |   5   |   7   |
=============================================================================
* - Value(s) provided from TR-55 system routines
```

Figure 2.11: Claytor Community Center - Developed Conditions

```
                        RUNOFF CURVE NUMBER COMPUTATION            Version 2.00
Project : CLAYTOR COMMUNITY CENTER              User: SRC      Date: 07-31-97
County  : DORCHESTER          State: MD      Checked: ____     Date: ________
Subtitle: POST-DEVELOPED
--------------------------------------------------------------------------------
                                                    Hydrologic Soil Group
         COVER DESCRIPTION                        A        B        C        D
                                                        Acres (CN)
--------------------------------------------------------------------------------
FULLY DEVELOPED URBAN AREAS (Veg Estab.)
Open space (Lawns,parks etc.)
  Good condition; grass cover > 75%              -   0.5(61)       -        -
Impervious Areas
  Paved parking lots, roofs, driveways           -   1.9(98)       -        -
OTHER AGRICULTURAL LANDS
Woods                             good           -   0.6(55)       -        -

Total Area (by Hydrologic Soil Group)                 3
                                                    ====
                TOTAL DRAINAGE AREA: 3 Acres          WEIGHTED CURVE NUMBER: 83*

                     TIME OF CONCENTRATION AND TRAVEL TIME        Version 2.00
--------------------------------------------------------------------------------
Flow Type   2 year   Length   Slope  Surface   n   Area     Wp   Velocity  Time
             rain     (ft)   (ft/ft)   code       (sq/ft)  (ft)  (ft/sec)  (hr)
--------------------------------------------------------------------------------
Sheet        3.4      50       0.015    E                                  0.102
Shallow Concent'd     600      0.02     P                                  0.058
Open Channel          50                                          7.25     0.002
                                                 Time of Concentration = 0.16*
                                                                         =====
        --- Sheet Flow Surface Codes ---
    A Smooth Surface           F Grass, Dense     --- Shallow Concentrated ---
    B Fallow (No Res.)         G Grass, Burmuda   ---     Surface Codes    ---
    C Cultivated < 20 % Res.   H Woods, Light              P Paved
    D Cultivated > 20 % Res.   I Woods, Dense              U Unpaved
    E Grass-Range, Short       J Range, Natural
* - Generated for use by GRAPHIC method

                       GRAPHICAL PEAK DISCHARGE METHOD            Version 2.00
  Data: Drainage Area        :  3 * Acres
        Runoff Curve Number  :  83 *
        Time of Concentration:  0.16 * Hours
        Rainfall Type        :  II
        Pond and Swamp Area  :  NONE
================================================================================
| Storm Number          |   1   |   2   |   3   |   4   |   5   |   6   |   7   |
|-----------------------|-------|-------|-------|-------|-------|-------|-------|
| Frequency  (yrs)      |   1   |   2   |   5   |  10   |  25   |  50   |  100  |
| 24-Hr Rainfall (in)   |  2.8  |  3.4  |  4.6  |  5.4  |  6.2  |  6.9  |  7.8  |
| Ia/P Ratio            | 0.15  | 0.12  | 0.09  | 0.08  | 0.07  | 0.06  | 0.05  |
|            Used       | 0.15  | 0.12  | 0.10  | 0.10  | 0.10  | 0.10  | 0.10  |
| Runoff (in)           | 1.29  | 1.77  | 2.81  | 3.54  | 4.28  | 4.93  | 5.79  |
| Unit Peak Discharge   |1.322  |1.342  |1.357  |1.357  |1.357  |1.357  |1.357  |
|    (cfs/acre/in)      |       |       |       |       |       |       |       |
| Pond and Swamp Factor| 1.00  | 1.00  | 1.00  | 1.00  | 1.00  | 1.00  | 1.00  |
|    0.0% Ponds Used    |       |       |       |       |       |       |       |
|-----------------------|-------|-------|-------|-------|-------|-------|-------|
| Peak Discharge (cfs)  |   5   |   7   |   11  |   14  |   17  |   20  |   24  |
================================================================================
* - Value(s) provided from TR-55 system routines
```


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Design Example No. 3: Multiple Drainage Areas – Pensyl Pointe

Site data and the layout of the Pensyl Pointe subdivision are shown in Fig. 2-12.

Step 1. Compute WQ_v Volume

$$WQ_v = \frac{(P)(R_v)(A)}{12}$$

Step 1a. Compute Runoff Coefficient

Drainage Area 1
$R_v = 0.05 + (0.009)(I)$; $I = 2.25_{\text{ acres}} / 7.6_{\text{ acres}} = 29.6\%$
$= 0.05 + (0.009)(29.6) = 0.32$

Drainage Area 2
$R_v = 0.05 + (0.009)(I)$; $I = 11.55_{\text{ acres}} / 30.4_{\text{ acres}} = 38.0\%$
$= 0.05 + (0.009)(38.0) = 0.39$
or

Total Site
$R_v = 0.05 + (0.009)(I)$; $I = 13.8_{\text{ acres}} / 38.0_{\text{ acres}} = 36.3\%$
$= 0.05 + (0.009)(36.3) = 0.38$

Step 1b. Determine Rainfall Zone for WQ_v Formula

Location	Formula
Eastern Rainfall Zone	1.0 inches
Western Rainfall Zone	0.9 inches
Minimum WQ_v ($I \leq 15\%$)	0.2 inches

Because this site is located in the Eastern Rainfall Zone and imperviousness exceeds 15%, use 1.0" of rainfall to determine WQ_v.

Step 1c. Compute WQ_v

Drainage Area 1
$WQ_v = [(1.0")(R_v)(A)]/12$
$= [(1.0")(0.32)(7.6\text{ ac})]/12$
$= \underline{0.20\text{ac-ft}}$

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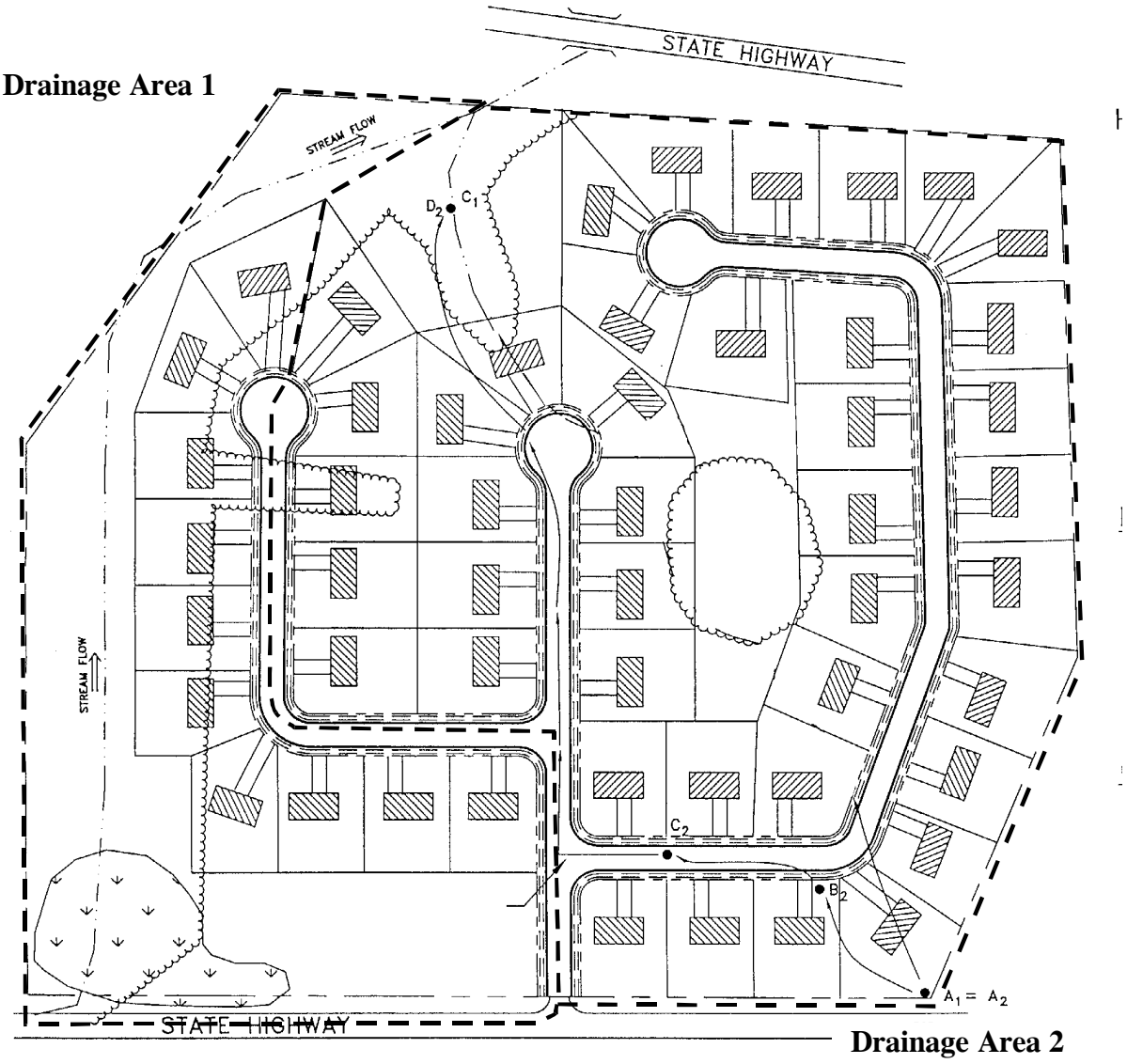
Figure 2.12 Pensyl Pointe



Base Data
Location: Olney, MD
Site Area = 38.0 ac
Measured Site Impervious Area = 13.8 ac; I = 13.8/38 = 36.3%
Soils Types: 60% "B", 40% C
Stream Use Designation – III, Zoning: Residential (½ acre lots)

Drainage Area (DA) 1
Area = 7.6 ac.
Measured Impervious Area = 2.25 ac; I = 2.25/7.6 = 30.0%

Drainage Area (DA) 2
Area = 30.4 ac.
Measured Impervious Area = 11.55 ac; I = 11.55/30.4 = 38.0%

Hydrologic Data
(Post-developed)

	DA 1	DA 2
CN	76	78
t_c	0.15	0.19

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Drainage Area 2
WQ_v = [(1.0")(R_v)(A)]/12
= [(1.0")(0.39)(30.4 ac)]/12
= 0.99 ac-ft

or

Total Site
WQ_v = [(1.0")(R_v)(A)]/12
= [(1.0")(0.38)(38.0)]/12
= 1.20 ac-ft

Step 2. Compute Recharge Volume

Step 2a. Determine Recharge Equation Based on Hydrologic Soil Group

HSG	Soil Specific Recharge Factor (*S*)
A	0.38
B	0.26
C	0.13
D	0.06

Assume imperviousness is located proportionally (60/40) in B and C soils and compute a composite *S*:

$$S = \frac{(0.26 \times 22.8\ acres)(0.13 \times 15.2\ acres)}{38.0\ acres} = 0.208\ or\ 20.8\ \%$$

Step 2b. Compute Recharge Using Percent Volume Method

Drainage Area 1
Re_v = [(*S*)(R_v)(*A*)]/12
= [(0.208)(0.32)(7.6 ac)]/12
= 0.04 ac-ft

Drainage Area 2
Re_v = [(*S*)(R_v)(*A*)]/12
= [(0.208)(0.39)(30.4 ac)]/12
= 0.21 ac-ft

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or

Total Site
$Re_v = [(S)(R_v)(A)]/12$
$= [(0.208)(0.38)(38.0 \text{ ac})]/12$
$= \underline{0.25 \text{ ac-ft}}$

Step 2c. Compute Recharge Using Percent Area Method

Drainage Area 1
$Re_v = (S)(A_i)$
$= (0.208)(2.25 \text{ ac})$
$= 0.47 \text{ acres}$

Drainage Area 2
$Re_v = (S)(A_i)$
$= (0.208)(11.55 \text{ ac})$
$= 2.40 \text{ acres}$

or

Total Site
$Re_v = (S)(A_i)$
$= (0.208)(13.8 \text{ ac})$
$= 2.87 \text{ acres}$

The Re_v requirement may be met by: a) treating 0.25 ac-ft using structural methods, b) treating 2.87 acres using non-structural methods, or c) a combination of both (e.g., 0.19 ac-ft structurally and 0.72 acres non-structurally).

Step 3. Compute Channel Protection Volume (Cp_v):

Step 3a. Select Cp_v Sizing Rule

For channel protection, provide 12 or 24 hours of extended detention time (*T*) for the one-year design storm event.

Stream Use Designation	Maximum Hours Allowable (*T*)
Use I (general)	24
Use II (tidal)	N/A
Use III (reproducing trout)	12
Use IV (recreational trout)	12

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Given that our stream is Use III, we will use a T of 12 hours for the one-year design storm event.

Step 3b. Develop site hydrologic and TR-55 Input Parameters.

Per attached TR-55 calculations (see Figures 2.13 and 2.14)

.

Drainage Area	**CN**	t_c	**Runoff (Q_a), 1 yr storm**	**Discharge (Q) 1 yr storm**
		hrs	*inches*	*cfs*
1	76	0.15	0.76	7.40
2	78	0.19	0.85	30.5

Step 3c. Utilize MDE Method to Compute Storage Volume (Appendix D.11)

Drainage Area 1

Initial abstraction (I_a) for CN of 76 is 0.63: (TR-55) [I_a = (200/CN) – 2]

I_a/P = (0.63)/2.6" = 0.24
t_c = 0.15 hours

From Figure D.11.1, q_u = 840 csm/in
Knowing q_u and T, find q_o/q_i from Figure D.11.2, "Detention Time Versus Discharge Ratios"

Peak outflow discharge/peak inflow discharge (q_o/q_i) = 0.040

With q_o/q_i, compute V_s/V_r ; for a Type II rainfall distribution,

$V_s/V_r = 0.683\text{-}1.43(q_o/q_i)+1.64(q_o/q_i)^2\text{-}0.804(q_o/q_i)^3$ (App.D.11)
$V_s/V_r = 0.62$

Therefore V_s = 0.62(0.76")(1'/12")(7.6 ac) = 0.30 ac-ft

Drainage Area 2

Initial abstraction (I_a) for CN of 78 is 0.564: (TR-55) [I_a = (200/CN) – 2]

I_a/P = (0.63)/2.6" = 0.22
t_c = 0.19 hours

From Figure D.11.1, q_u = 740 csm/in

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Knowing q_u and T, find q_o/q_i from Figure D.11.2, "Detention Time Versus Discharge Ratios"
Peak outflow discharge/peak inflow discharge (q_o/q_i) = 0.050

With q_o/q_i, compute V_s/V_r ; for a Type II rainfall distribution,

$V_s/V_r = 0.683\text{-}1.43(q_o/q_i)+1.64(q_o/q_i)^2\text{-}0.804(q_o/q_i)^3$ (App. D.11)
$V_s/V_r = 0.61$

Therefore $V_s = 0.61(0.85")(1'/12")(30.4 \text{ ac}) = 1.31$ ac-ft

Step 3d. Define the Cp_v Release Rate

Drainage Area 1

q_i is known (7.4 cfs), therefore,
$q_o = (q_0/q_i)\ q_i = .040\ (7.4 \text{ cfs}) = 0.30$ cfs

Drainage Area 2

q_i is known (30.5 cfs), therefore,
$q_o = (q_0/q_i)\ q_i = .050\ (30.5 \text{ cfs}) = 1.53$ cfs

Step 4. Compute Overbank Flood Protection Volume (Q_p):

Step 4a. Determine Appropriate Q_p Requirement

Location	Type of Peak Control
Eastern Shore	2-year/2-year
All Other Areas	10-year/10-year *

*Varies according to local approval authority.

Because the site is located on the Western Shore, ten-year peak management for quantity control may be required. For the purpose of this example, the local approval authority has not required the ten-year peak management requirement.

Step 5. Extreme Flood Volume (Q_f)

For this example, management of Q_f is not required. However, at final design the 100-year event must be conveyed safely through any stormwater management practices. Based on field observation, downstream conveyance may require analysis for passing the 100-year event through existing infrastructure.

Table 2.5 Summary of General Storage Requirements for Pensyl Pointe

No.	Category	Volume Required		Notes
		Drainage Area 1	Drainage Area 2	
1	Water Quality Volume (WQ_v)	0.20 ac-ft	0.99 ac-ft	
2	Recharge Volume (Re_v)	0.04 ac-ft	0.21 ac-ft	this volume is included within the WQ_v storage
3	Channel Protection Volume (Cp_v)	0.30 ac-ft	1.31 ac-ft	release rates are 0.30 and 1.53 cfs, respectively.
4	Overbank Flood Protection Storage Volume (Q_p)	N/A	N/A	10-year peak management has been waived.
5	Extreme Flood Volume (Q_f)	N/A	N/A	provide safe passage for the 100-year event in final design.

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Figure 2.13: Pensyl Pointe, Drainage Area 1 – Post Developed Conditions

```
              RUNOFF CURVE NUMBER COMPUTATION            Version 2.00

Project : Pensyl Pointe                          User: SRC      Date: 08-31-98
County  : Montgomery           State: MD      Checked: ____     Date: ________
Subtitle: Design Example 3
Subarea : DRAINAGE AREA 1
-------------------------------------------------------------------------------
                                                    Hydrologic Soil Group
         COVER DESCRIPTION                        A        B        C        D
                                                        Acres (CN)
-------------------------------------------------------------------------------
FULLY DEVELOPED URBAN AREAS (Veg Estab.)
Open space (Lawns,parks etc.)
  Good condition; grass cover > 75%              -    2.60(61) 1.04(74)     -

Impervious Areas
  Paved parking lots, roofs, driveways           -    1.35(98) 0.90(98)     -


OTHER AGRICULTURAL LANDS
Woods                              good          -      -      1.71(70)     -

Total Area (by Hydrologic Soil Group)                3.95     3.65
                                                     ====     ====
-------------------------------------------------------------------------------
SUBAREA: DA 1   TOTAL DRAINAGE AREA: 7.6 Acres       WEIGHTED CURVE NUMBER: 76
-------------------------------------------------------------------------------
GRAPHICAL PEAK DISCHARGE METHOD            Version 2.00


Project : Comstock Pointe                          User: SRC      Date: 08-31-98
County  : Montgomery           State: MD      Checked: ____     Date: ________
Subtitle: Design Example 3

  Data: Drainage Area        :  7.6 * Acres
        Runoff Curve Number  :  76 *
        Time of Concentration:  0.15   Hours
        Rainfall Type        :  II
        Pond and Swamp Area  :  NONE
=============================================================================
| Storm Number          |   1  |   2  |   3  |   4  |   5  |   6  |   7  |
|-----------------------|------|------|------|------|------|------|------|
| Frequency  (yrs)      |   1  |   2  |   5  |  10  |  25  |  50  |  100 |
| 24-Hr Rainfall (in)   |  2.6 |  3.2 |  4.2 |  5.1 |  5.6 |  6.3 |  7.2 |
| Ia/P Ratio            | 0.24 | 0.20 | 0.15 | 0.12 | 0.11 | 0.10 | 0.09 |
|           Used        | 0.24 | 0.20 | 0.15 | 0.12 | 0.11 | 0.10 | 0.10 |
| Runoff (in)           | 0.76 | 1.15 | 1.89 | 2.62 | 3.04 | 3.64 | 4.44 |
| Unit Peak Discharge   |1.281 |1.315 |1.351 |1.371 |1.379 |1.388 |1.388 |
|    (cfs/acre/in)      |      |      |      |      |      |      |      |
| Pond and Swamp Factor | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
|    0.0% Ponds Used    |      |      |      |      |      |      |      |
|-----------------------|------|------|------|------|------|------|------|
| Peak Discharge (cfs)  |    7 |   12 |   19 |   27 |   32 |   38 |   47 |
=============================================================================
```


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Figure 2.14: Pensyl Pointe, Drainage Area 2 – Post Developed Conditions

```
              RUNOFF CURVE NUMBER COMPUTATION            Version 2.00

Project : Pensyl Pointe                          User: SRC      Date: 08-31-98
County  : Montgomery           State: MD      Checked: ____     Date: ________
Subtitle: Design Example 3
Subarea : DRAINAGE AREA 2
--------------------------------------------------------------------------------
                                                    Hydrologic Soil Group
         COVER DESCRIPTION                        A        B        C        D
                                                          Acres (CN)
--------------------------------------------------------------------------------
FULLY DEVELOPED URBAN AREAS (Veg Estab.)
Open space (Lawns,parks etc.)
  Good condition; grass cover > 75%               -     10.4(61) 4.16(74)    -

Impervious Areas
  Paved parking lots, roofs, driveways            -     6.63(98) 4.92(98)    -


OTHER AGRICULTURAL LANDS
Woods                              good           -           -  4.29(70)    -



Total Area (by Hydrologic Soil Group)                   17.0     13.3
                                                        ====     ====
--------------------------------------------------------------------------------
SUBAREA: DA 2   TOTAL DRAINAGE AREA: 30.4 Acres      WEIGHTED CURVE NUMBER: 78

GRAPHICAL PEAK DISCHARGE METHOD            Version 2.00

  Data: Drainage Area        :  30.4   Acres
        Runoff Curve Number  :  78
        Time of Concentration:  0.19   Hours
        Rainfall Type        :  II
        Pond and Swamp Area  :  NONE
================================================================================
| Storm Number          |   1   |   2   |   3   |   4   |   5   |   6   |   7   |
|-----------------------|-------|-------|-------|-------|-------|-------|-------|
| Frequency  (yrs)      |   1   |   2   |   5   |  10   |  25   |  50   |  100  |
| 24-Hr Rainfall (in)   |  2.6  |  3.2  |  4.2  |  5.1  |  5.6  |  6.3  |  7.2  |
| Ia/P Ratio            | 0.22  | 0.18  | 0.13  | 0.11  | 0.10  | 0.09  | 0.08  |
|           Used        | 0.22  | 0.18  | 0.13  | 0.11  | 0.10  | 0.10  | 0.10  |
| Runoff (in)           | 0.85  | 1.27  | 2.05  | 2.80  | 3.23  | 3.85  | 4.66  |
| Unit Peak Discharge   |1.182  |1.214  |1.247  |1.266  |1.274  |1.275  |1.275  |
|    (cfs/acre/in)      |       |       |       |       |       |       |       |
| Pond and Swamp Factor | 1.00  | 1.00  | 1.00  | 1.00  | 1.00  | 1.00  | 1.00  |
|    0.0% Ponds Used    |       |       |       |       |       |       |       |
|-----------------------|-------|-------|-------|-------|-------|-------|-------|
| Peak Discharge (cfs)  |  31   |  47   |  78   |  108  |  125  |  149  |  180  |
================================================================================
```

Section 2.7 Acceptable Urban BMP Options

This section sets forth six acceptable groups of BMPs that can be used to meet the water quality and/or groundwater recharge volume criteria.

2.7.1 Urban BMP Groups

The dozens of different BMP designs currently used in the State of Maryland are assigned into six general categories for stormwater quality control (WQ_v and/or Re_v):

BMP Group 1 stormwater ponds
BMP Group 2 stormwater wetlands
BMP Group 3 infiltration practices
BMP Group 4 filtering practices
BMP Group 5 open channel practices
BMP Group 6 non-structural practices

Within each BMP group, detailed performance criteria are presented that govern feasibility, conveyance, pretreatment, treatment, environmental/landscaping and maintenance requirements (see Chapter 3).

To be considered an effective BMP for stand-alone treatment of WQ_v, a design shall be capable of:

1. capturing and treating the required water quality volume (WQ_v),
2. removing 80% of the TSS,
3. removing 40% of the TP, and
4. having an acceptable longevity rate in the field.

A combination of structural and/or non-structural BMPs are normally required at most development sites to meet all five stormwater sizing criteria. Documentation of the capability of the BMPs to remove TSS is provided in Appendix D.5. Guidance on selecting the most appropriate combination of BMPs is provided in Chapter 4.

BMP Group 1. Stormwater Ponds

Practices that have a combination of a permanent pool, extended detention or shallow wetland equivalent to the entire WQ_v include:

P-1 micropool extended detention pond
P-2 wet pond
P-3 wet extended detention pond

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P-4 multiple pond system
P-5 pocket pond

BMP Group 2. Stormwater Wetlands

Practices that include significant shallow wetland areas to treat urban stormwater but often may also incorporate small permanent pools and/or extended detention storage to achieve the full WQ_v include:

W-1 shallow wetland
W-2 ED shallow wetland
W-3 pond/wetland system
W-4 pocket wetland

BMP Group 3. Infiltration Practices

Practices that capture and temporarily store the WQ_v before allowing it to infiltrate into the soil over a two day period include:

I-1 infiltration trench
I-2 infiltration basin

BMP Group 4. Filtering Practices

Practices that capture and temporarily store the WQ_v and pass it through a filter bed of sand, organic matter, soil or other media are considered to be filtering practices. Filtered runoff may be collected and returned to the conveyance system. Design variants include:

F-1 surface sand filter
F-2 underground sand filter
F-3 perimeter sand filter
F-4 organic filter
F-5 pocket sand filter
F-6 bioretention*

* may also be used for infiltration.

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BMP Group 5. Open Channel Practices

Vegetated open channels that are explicitly designed to capture and treat the full WQ_v within dry or wet cells formed by checkdams or other means include:

O-1 dry swale
O-2 wet swale

BMP Group 6. Non-structural BMPs

Non-structural BMPs are increasingly recognized as a critical feature of stormwater BMP plans, particularly with respect to site design. In most cases, non-structural BMPs shall be combined with structural BMPs to meet all stormwater requirements. The key benefit of non-structural BMPs is that they can reduce the generation of stormwater from the site; thereby reducing the size and cost of structural BMPs. In addition, they can provide partial removal of many pollutants. The non-structural BMPs have been classified into seven broad categories. To promote greater use of non-structural BMPs, a series of credits and incentives are provided for developments that use these progressive site planning techniques in Chapter 5.

- natural area conservation
- disconnection of rooftop runoff
- disconnection of non-rooftop impervious area
- sheet flow to buffers
- open channel use
- environmentally sensitive development
- impervious cover reduction

2.7.2 Structural BMPs that do not fully meet the WQ_v Requirement

Many current and future stormwater management structures may not meet the performance criteria specified in Section 1.2 above to qualify to be used as "stand-alone" practices for full WQ_v treatment. Reasons for this include poor longevity, poor performance, inability to decrease TSS by 80% and TP by 40%, or inadequate testing. Some of these practices include:

- catch basin inserts
- dry extended detention ponds
- water quality inlets and oil/grit separators
- hydro-dynamic structures
- filter strips
- grass channels
- street sweeping

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- deep sump catch basins
- dry wells
- on-line storage in the storm drain network

In some cases, these practices are appropriately used for pretreatment, to meet recharge volume (Re_v) requirements, as part of an overall BMP system, or may be applied in redevelopment situations on a case-by-case basis where other practices are not feasible.

New structural BMP designs are continually being developed, including many proprietary designs. All current and future structural practice design variants should fit in one of the six BMP groups referenced above if the intent is to use them independently to treat the full WQ_v. Current or new BMP design variants cannot be accepted for inclusion on the list until independent pollutant removal performance and monitoring data determine that they can meet the 80% TSS and 40% TP removal targets and that the new BMPs conform with local and/or State criteria for treatment, maintenance, and environmental impact.

Section 2.8 Designation of Stormwater Hotspots

A stormwater hotspot is defined as a land use or activity that generates higher concentrations of hydrocarbons, trace metals or toxicants than are found in typical stormwater runoff, based on monitoring studies. Table 2.6 provides a list of designated hotspots for the State of Maryland. If a site is designated as a hotspot, it has important implications for how stormwater is managed. First and foremost, untreated stormwater runoff from hotspots cannot be allowed to infiltrate into groundwater where it may contaminate water supplies. Therefore, the Re_v requirement is NOT applied to development sites that fit into the hotspot category (the entire WQ_v must still be treated). Second, a greater level of stormwater treatment is needed at hotspot sites to prevent pollutant washoff after construction. This typically involves preparing and implementing a ***stormwater pollution prevention plan*** that involves a series of operational practices at the site that reduces the generation of pollutants by preventing contact with rainfall.

Under EPA's NPDES stormwater program, some industrial sites are required to prepare and implement a stormwater pollution prevention plan. A list of industrial categories that are subject to the pollution prevention requirement can be found in Appendix D.6. In addition, Maryland's requirements for preparing and implementing a stormwater pollution prevention plan are also described in the general discharge permit provided in the same Appendix. The stormwater pollution prevention plan requirement applies to both existing and new industrial sites.

In addition, if a site falls into a "hotspot" category outlined in Table 2.6, a pollution prevention plan may also be required by the appropriate reviewing authority. Golf courses and commercial nurseries may also be required to implement a plan by the appropriate approval authority.

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Table 2.6 Classification of Stormwater Hotspots

The following land uses and activities are deemed ***stormwater hotspots:***
► vehicle salvage yards and recycling facilities* ► vehicle service and maintenance facilities ► vehicle and equipment cleaning facilities* ► fleet storage areas (bus, truck, etc.)* ► industrial sites (for SIC codes outlined in Appendix D.6) ► marinas (service and maintenance)* ► outdoor liquid container storage ► outdoor loading/unloading facilities ► public works storage areas ► facilities that generate or store hazardous materials* ► commercial container nursery ► other land uses and activities as designated by an appropriate review authority
* stormwater pollution prevention plan implementation is required for these land uses or activities under the EPA NPDES stormwater program (see Appendix D.6).

The following land uses and activities are not normally considered hotspots:

- residential streets and rural highways
- residential development
- institutional development
- commercial and office developments
- non-industrial rooftops
- pervious areas, except golf courses and nurseries [which may need an Integrated Pest Management Plan (IPM)].

While large highways [average daily traffic volume (ADT) greater than 30,000] and retail gasoline outlet facilities are not designated as stormwater hotspots, it is important to ensure that highway and retail gasoline outlet stormwater management plans adequately protect groundwater.

SARB_005228

Chapter 3.0

Performance Criteria for Urban BMP Design

3.0 Performance Criteria for Urban BMP Design

This chapter outlines performance criteria for five groups of structural water quality stormwater BMPs that include ponds, wetlands, infiltration practices, filtering systems and open channels.

Each set of BMP performance criteria, in turn, is based on six factors:

- General Feasibility
- Conveyance
- Pretreatment
- Treatment/Geometry
- Environmental/Landscaping
- Maintenance

One significant caveat applies to all performance criteria. The criteria represent a set of conditions that ensure an effective and durable BMP. In this chapter, *Mandatory* performance criteria are distinguished from suggested design criteria (the former is required at all sites in Maryland, while the latter are only recommended for most sites and conditions). Thus, in the text, mandatory performance criteria are indicated by *italics*, whereas suggested design criteria are shown in normal typeface.

IMPORTANT NOTES:

1) Any stormwater management BMP that uses an embankment for impounding water is required to follow the latest version of the NRCS-MD 378 Pond Code Standards And Specifications For Small Pond Design (Appendix B.1) and obtain approval from the local Soil Conservation District (SCD) or appropriate review authority.

2) In USE III watersheds, temperature increases caused by development are a primary impact to the quality of receiving waters. Stormwater BMPs may contribute to this problem. Therefore, to minimize temperature increases caused by new development in USE III watersheds, stormwater BMP designs should:
   a) Minimize permanent pools,
   b) Limit extended detention times for Cp_v to 12 hours (see Appendix D.11),
   c) Provide shading for pools and channels,
   d) Maintain existing forested buffers, and
   e) Bypass available baseflow and/or springflow.

SARB_005231

Section 3.1 Stormwater Ponds

Definition: Practices that have a permanent pool, or a combination of extended detention or shallow wetland with a permanent pool equivalent to the entire WQ_v. Design variants include:

- P-1 micropool extended detention pond (Figure 3.1)
- P-2 wet pond (Figure 3.2)
- P-3 wet extended detention pond (Figure 3.3)
- P-4 multiple pond system (Figure 3.4)
- P-5 pocket pond (Figure 3.5)

The term "pocket" refers to a pond or wetland that has such a small contributing drainage area that little or no baseflow is available to sustain water elevations during dry weather. Instead, water elevations are heavily influenced and, in some cases, maintained by a locally high water table.

Dry extended detention ponds that have no permanent pool are not considered an acceptable option for meeting WQ_v.

Stormwater ponds may also provide storage for the Cp_v, Q_p and/or Q_f above the WQ_v storage elevation.

IMPORTANT NOTE: Any stormwater management BMP that uses an embankment for impounding water is required to follow the latest version of the NRCS-MD 378 Pond Code Standards And Specifications For Small Pond Design (Appendix B.1) and obtain approval from the local Soil Conservation District (SCD) or appropriate review authority.

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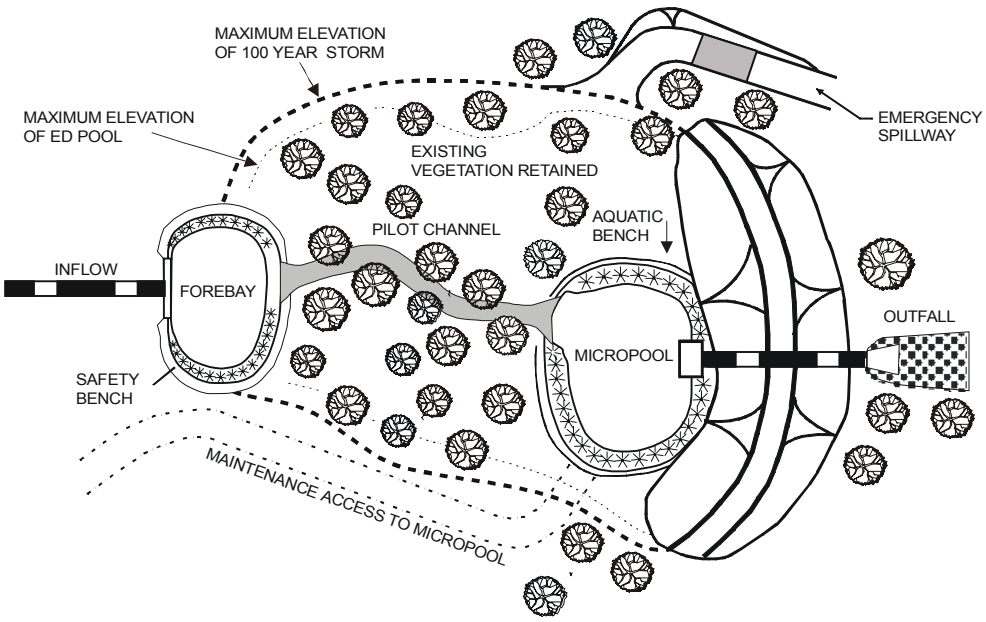
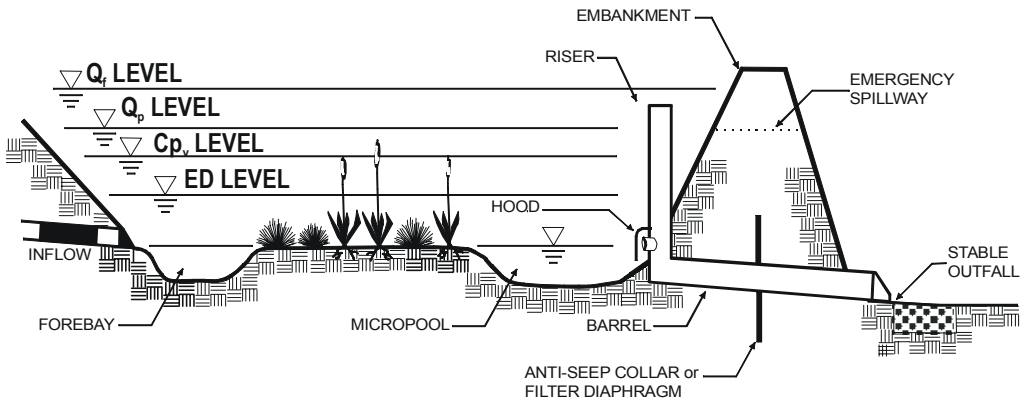
P-1	**Figure 3.1** Example of "Micropool" Extended Detention Pond	P-1



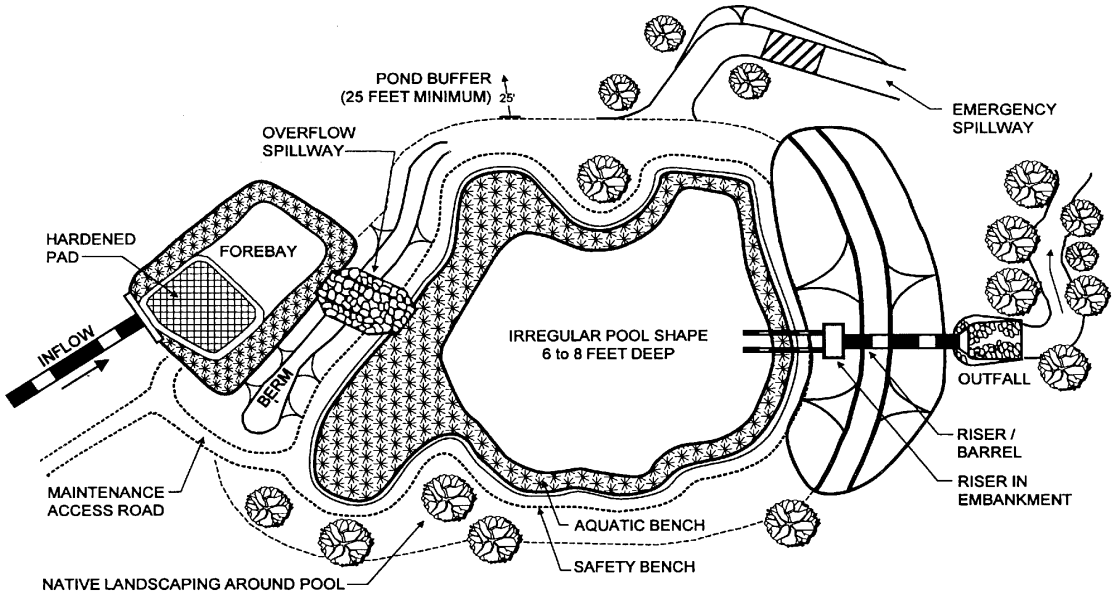
PLAN VIEW

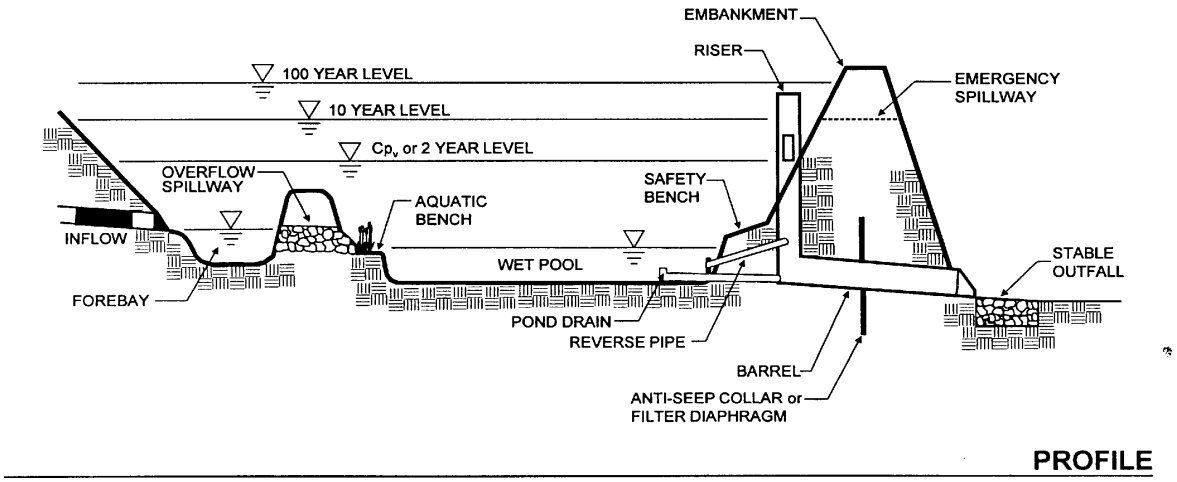


PROFILE

A micropool is provided in an extended detention pond to prevent resuspension of previously settled sediments and prevent clogging of the low flow orifice.

P-2	Figure 3.2 Example of Wet Pond	P-2





A wet pond provides all of water quality volume storage in a permanent pool.

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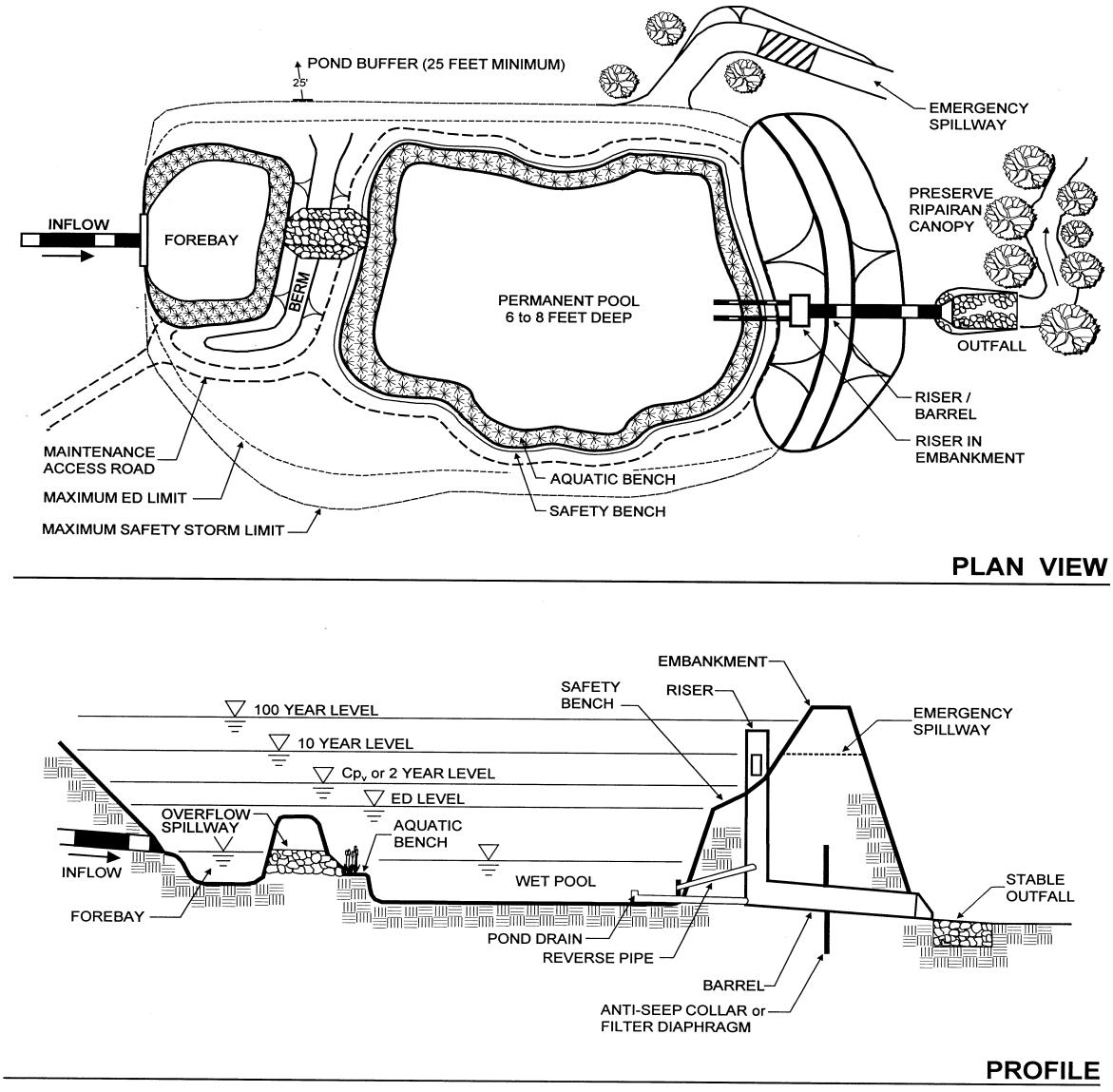
P-3	**Figure 3.3** Example of Wet Extended Detention Pond	P-3



The wet ED pond provides water quality storage through a combination of permanent pool and extended detention storage.

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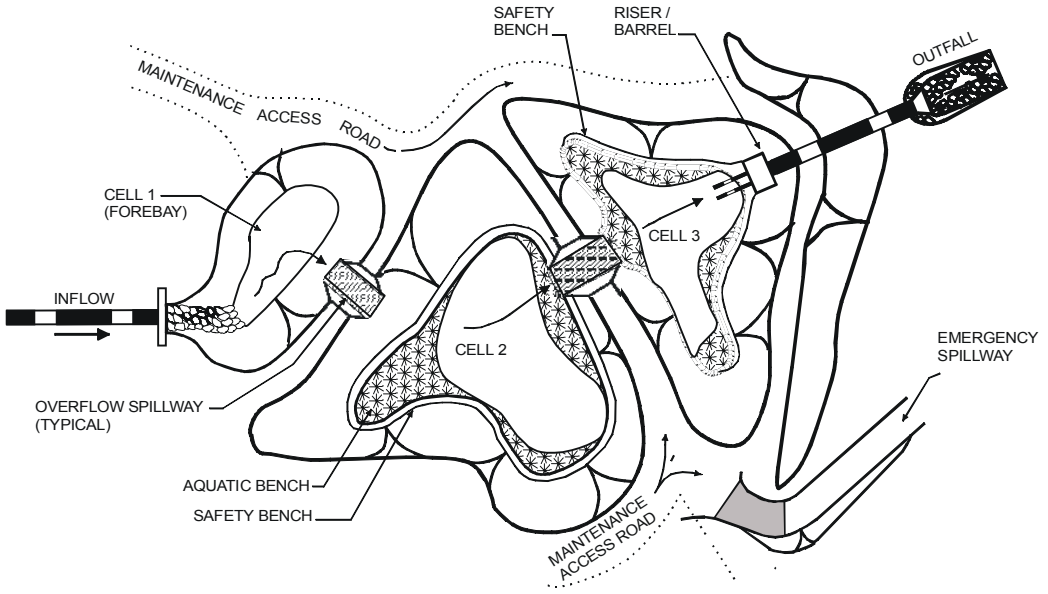
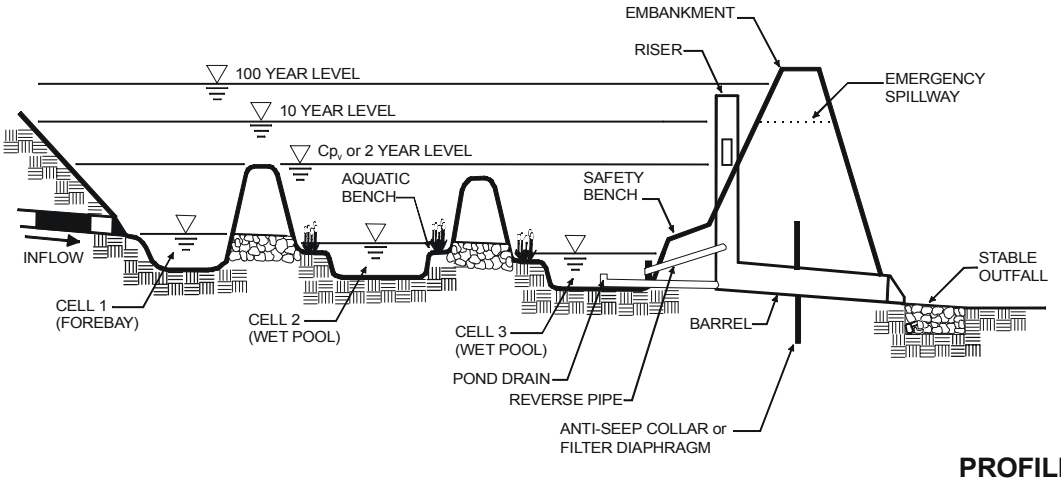
P-4	**Figure 3.4** Example of Multiple Pond System	P-4



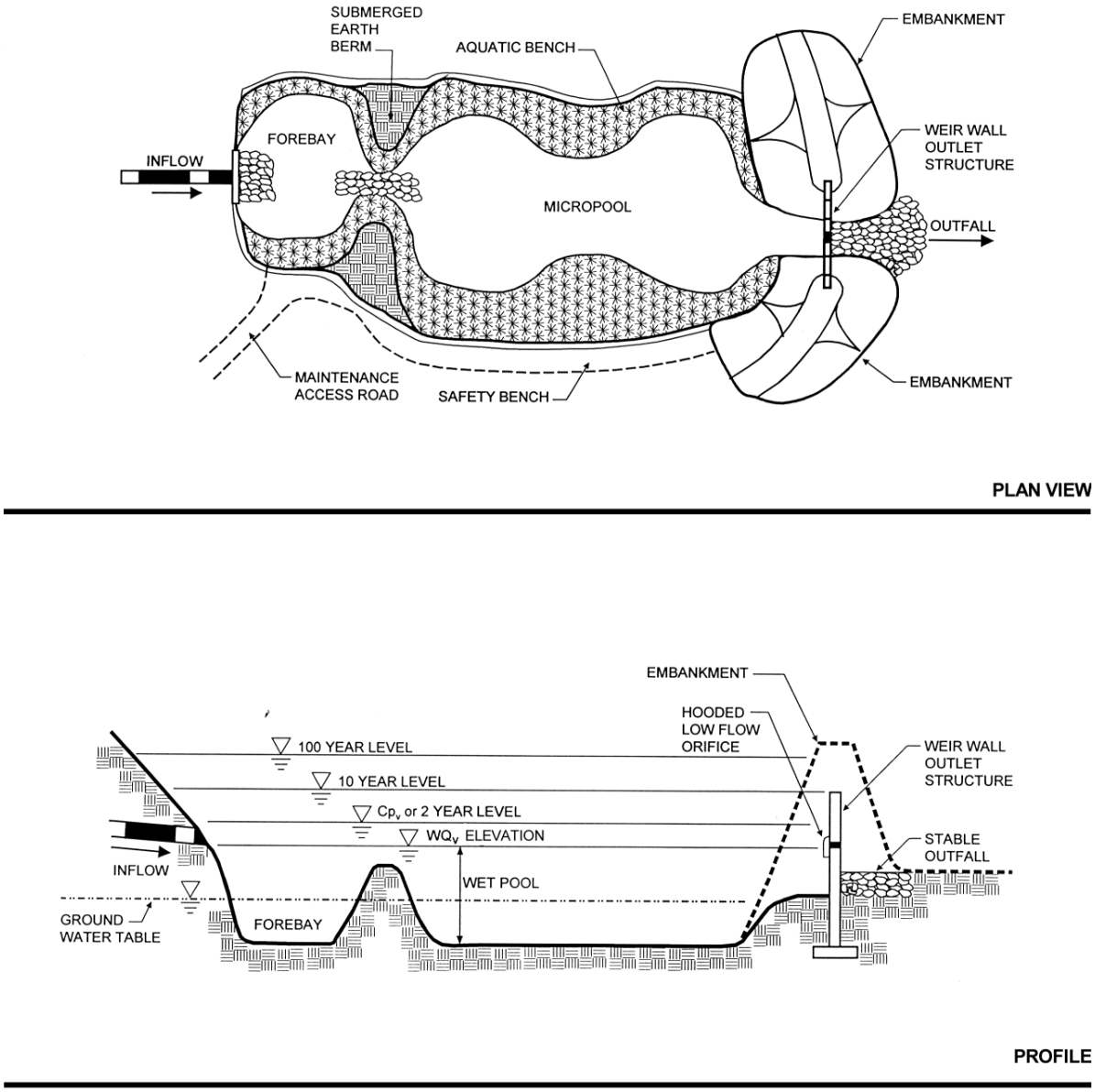
PLAN VIEW



PROFILE

Multiple pond systems provide WQ_v storage in two or more cells that create longer pollutant removal pathways.

P-5	**Figure 3.5** Example of Pocket Pond	P-5



A high water table or groundwater interception maintains permanent pool level in a pocket pond. However, excavation to groundwater interception should be avoided where the land uses draining to the pond may contaminate drinking water supplies.

3.1.1 Pond Feasibility Criteria

Stormwater ponds shall have a minimum contributing drainage area of ten acres or more (25 or more are preferred)*, unless groundwater is confirmed as the primary water source (e.g., pocket pond)*.

Stormwater ponds cannot be located within jurisdictional waters, including wetlands, without obtaining a Section 404 permit under the Clean Water Act and a State of Maryland wetlands and waterway permit (See Chapter 4, Section 4.6.).

Stormwater ponds located within USE III watersheds shall require a small pond review and approval from the MDE Dam Safety Division.

The use of stormwater ponds on coldwater streams capable of supporting trout (Use III and IV) may be prohibited. Stormwater ponds located in Use III and IV watersheds should be designed to significantly reduce and/or eliminate thermal impacts (See Chapter 4, Section 4.1).

The design and construction of stormwater management ponds are required to follow the latest version of the NRCS-MD 378 Pond Code Standards and Specifications for Small Pond Design (Appendix B.1) and obtain approval from the local Soil Conservation District (SCD) or appropriate review authority.

Pages 1 and 2 of the NRCS-MD 378 Pond Code Standards and Specifications for Small Pond Design (MD-378) describe the conditions for exemption from formal review by the local SCD. **While not required to meet all conditions of MD-378, facilities that are exempt shall be approved by the appropriate authority and conform to the following minimum design and construction criteria:**

1) *design for a stable outfall using the ten year design storm (or two year design storm if the pond is an off-line structure providing WQ_v storage only)*.

2) *dams shall meet class A dam safety hazard classification,*

3) *principal spillway/riser shall provide anti-floatation, anti-vortex, and trash-rack designs*.

4) *one (1) foot of freeboard shall be provided above the design high water for the 10 year storm*.

5) *material and construction specifications for the principal spillway shall be in accordance with MD 378 code*.

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6) *material and construction specifications for the embankment shall be in accordance with MD 378 code, except that fill material for the embankment shall conform to Unified Soil Classification GC, SC, SM, MH, ML, CH, or CL, and no cutoff trench is required.*

7) *woody vegetation is prohibited on the embankment.*

A pond structure requires review and approval by the MDE Dam Safety Division if any of the following conditions apply:

a) *the proposed embankment is twenty feet or greater in height from the upstream toe to the top of dam, or*

b) *the contributing drainage area is a square mile (640 acres) or greater, or*

c) *the structure is classified as "high" or "intermediate" hazard, according to the MD Dam Safety Manual, or*

d) *the proposed pond is in USE III waters.*

3.1.2 Pond Conveyance Criteria

When reinforced concrete pipe is used for the principal spillway to increase its longevity, "O-ring" gaskets (ASTM C-361) should be used to create watertight joints and should be inspected during installation.

Inlet Protection

Inlet pipes to the pond should not be fully submerged at normal pool elevations.

A forebay shall be provided at each inlet, unless the inlet provides less than 10% of the total design storm inflow to the pond.

Adequate Outfall Protection

Flared pipe sections that discharge at or near the stream invert or into a step-pool arrangement should be used at the spillway outlet.

The channel immediately below the pond outfall shall be modified to prevent erosion and conform to natural dimensions in the shortest possible distance, typically by use of large rip-rap placed over filter cloth.

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A stilling basin or other outlet protection should be used to reduce flow velocities from the principal spillway to non-erosive velocities (see Appendix D.12 for critical non-erosive velocities for grass and soil).

If a pond daylights to a channel with dry weather flow, care should be taken to minimize tree clearing along the downstream channel and to reestablish a forested riparian zone in the shortest possible distance. Excessive use of rip-rap should be avoided to reduce stream warming.

Pond Liners

When a pond is located in karst topography, gravelly sands or fractured bedrock, a liner may be needed to sustain a permanent pool of water. If geotechnical tests confirm the need for a liner, acceptable options include: (a) 6 to 12 inches of clay soil (minimum 15% passing the #200 sieve and a maximum permeability of 1 x 10^{-5} cm/sec), (b) a 30 mil poly-liner, (c) bentonite, (d) use of chemical additives (see NRCS Agricultural Handbook No. 387, dated 1971, Engineering Field Manual), or (e) other suitable materials approved by the appropriate review authority.

3.1.3 Pond Pretreatment Criteria

Sediment Forebay

Each pond shall have a sediment forebay or equivalent upstream pretreatment. The forebay shall consist of a separate cell, formed by an acceptable barrier.

The forebay shall be sized to contain 0.1 inches per impervious acre of contributing drainage. The forebay storage volume counts toward the total WQ_v requirement. Exit velocities from the forebay shall be non-erosive.

Direct maintenance access for appropriate equipment shall be provided to the forebay.

The bottom of the forebay may be hardened (e.g., using concrete, paver blocks, etc.) to make sediment removal easier.

A fixed vertical sediment depth marker should be installed in the forebay to measure sediment deposition over time.

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3.1.4 Pond Treatment Criteria

Minimum Water Quality Volume (WQ_v)

Ponds shall be designed to capture and treat the computed WQ_v through any combination of permanent pool, extended detention (ED) or wetland. If treated separately, the Re_v may be subtracted from the WQ_v for pond design.

It is generally desirable to provide water quality treatment off-line when topography, head and space permit (e.g., apart from stormwater quantity storage).

Water quality storage can be provided in multiple cells. Performance is enhanced when multiple treatment pathways are provided by using multiple cells, longer flowpaths, high surface area to volume ratios, complex microtopography, and/or redundant treatment methods (combinations of pool, ED, and wetland).

If ED is provided in a pond, storage for WQ_v and Cp_v shall be computed and routed separately (e.g., the WQ_v requirement cannot be met simply by providing Cp_v storage for the one-year storm).

Minimum Pond Geometry

Flowpaths from inflow points to outlets shall be maximized. Flowpaths of 1.5:1 (length relative to width) and irregular shapes are recommended.

3.1.5 Pond Landscaping Criteria

Pond Benches

The perimeter of all deep permanent pool areas (four feet or greater in depth) shall be surrounded by two benches with a combined minimum width of 15 feet:

- *A safety bench* that extends outward from the normal water edge to the toe of the pond side slope. The maximum slope of the safety bench shall be 6%.

- *An aquatic bench* that extends inward from the normal shoreline and has a maximum depth of eighteen inches below the normal pool water surface elevation. An aquatic bench is not required in forebays.

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Landscaping Plan

A landscaping plan for a stormwater pond and its buffer shall be prepared to indicate how aquatic and terrestrial areas will be vegetatively stabilized and established. Landscaping guidance for stormwater ponds is provided in Appendix A.

Wherever possible, wetland plants should be encouraged in a pond design, either along the aquatic bench (fringe wetlands), the safety bench and side slopes (emergent wetlands) or within shallow areas of the pool itself.

The best elevations for establishing wetland plants, either through transplantation or volunteer colonization, are within six inches (plus or minus) of the normal pool.

The soils of a pond buffer are often severely compacted during the construction process to ensure stability. The density of these compacted soils is so great that it effectively prevents root penetration, and therefore, may lead to premature mortality or loss of vigor. Consequently, it is advisable to excavate large and deep holes around the proposed planting sites, and backfill these with uncompacted topsoil.

As a rule of thumb, planting holes should be at least six inches larger than the diameter of the rootball (of balled and burlap stock), and three inches wider for container grown stock. This practice should enable the stock to develop unconfined root systems. Avoid species that require full shade, are susceptible to winterkill, or are prone to wind damage. Extra mulching around the base of the tree or shrub is strongly recommended as a means of conserving moisture and suppressing weeds.

Pond Buffers and Setbacks

A pond buffer should be provided that extends 25 feet outward from the maximum water surface elevation of the pond. The pond buffer should be contiguous with other buffer areas that are required by existing regulations (e.g., stream buffers). An additional setback may be provided to permanent structures.

Existing trees should be preserved in the buffer area during construction. It is desirable to locate forest conservation areas adjacent to ponds. To discourage resident geese populations, the buffer can be planted with trees, shrubs and native ground covers.

Woody vegetation may not be planted on nor allowed to grow within 15 feet of the toe of the embankment and 25 feet of the principal spillway structure.

Annual mowing of the pond buffer is only required along maintenance rights-of-way and the embankment. The remaining buffer can be managed as a meadow (mowing every other year) or forest.

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3.1.6 Pond Maintenance Criteria

Maintenance Measures

Maintenance responsibility for a pond and its buffer shall be vested with a responsible party by means of a legally binding and enforceable maintenance agreement that is executed as a condition of plan approval or local permitting processes.

The principal spillway shall be equipped with a trash rack that provides access for maintenance.

Sediment removal in the forebay shall occur when 50% of the total forebay capacity has been lost.

Sediments excavated from stormwater ponds that do not receive runoff from designated hotspots are not considered toxic or hazardous material and can be safely disposed by either land application or land filling. Sediment testing may be required prior to sediment disposal when a hotspot land use is present.

Sediment removed from stormwater ponds should be disposed of according to current erosion and sediment control regulations.

Maintenance Access

A maintenance right-of-way or easement shall extend to a pond from a public or private road.

Maintenance access should be at least 12 feet wide; have a maximum slope of no more than 15%; and be appropriately stabilized to withstand maintenance equipment and vehicles.

The maintenance access should extend to the forebay, safety bench, riser, and outlet and be designed to allow vehicles to turn around.

Non-clogging Low Flow Orifice

The low flow orifice shall have a minimum diameter of 3 inches and shall be adequately protected from clogging by an acceptable external trash rack. Two examples of approved external trash racks are provided in Detail No. 1 and 2 of Appendix D.8. *The low flow orifice diameter may be reduced to one inch if an internal orifice is used* (e.g., an over-perforated vertical standpipe that is protected by hardware cloth and a stone filtering jacket). A schematic design of an acceptable internal orifice protection design is provided in Detail No. 3 of Appendix D.8.

SARB_005243

The preferred method is a submerged reverse-slope pipe that extends downward from the riser to an inflow point one foot below the normal pool elevation.

Alternative methods are to employ a broad crested rectangular, V-notch, or proportional weir, protected by a half-round corrugated metal pipe (CMP) or similar device that extends at least 12 inches below the normal pool. (See Detail No. 7 of Appendix D.8.)

The use of horizontal perforated pipe protected by geotextile and gravel is not recommended.

Vertical pipes may be used as an alternative if a permanent pool is present.

Riser

The riser shall be located within the embankment for maintenance access, safety and aesthetics.

Access to the riser is to be provided by lockable manhole covers and manhole steps within easy reach of valves and other controls. Riser openings should be fenced with pipe or rebar to prevent trash accumulation.

Pond Drain

Each pond shall have a drain pipe that can completely or partially drain the pond within 24 hours. This requirement is waived for the Lower Eastern Shore where positive drainage is difficult to achieve due to very low relief.

Care should be exercised during pond drawdowns to prevent downstream discharge of sediments or anoxic water and slope instability caused by rapid drawdown.

The approving jurisdiction shall be notified before draining a pond.

Valves

The pond drain shall be equipped with an adjustable valve (typically a handwheel activated knife or gate valve).

The pond drain should be sized one pipe size greater than the calculated design diameter.

Valve controls shall be located inside of the riser at a point where they (a) will not normally be inundated and (b) can be operated in a safe manner.

To prevent vandalism, the handwheel should be chained to a ringbolt, manhole step or other fixed object.

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Safety Features

Fencing of ponds is not generally desirable but may be required by the local review authority. A preferred method is to manage the contours of the pond to eliminate dropoffs and other safety hazards.

Internal side slopes to the pond should not exceed 3:1 (h:v) and should terminate on a safety bench. Both the safety bench and the aquatic bench may be landscaped to prevent access to the pool. The bench requirement may be waived if slopes are 4:1 or gentler.

Riser openings shall not permit unauthorized access. Riser tops that are four feet or greater above the ground shall include railings for safety. Endwalls above pipe outfalls greater than 48 inches in diameter shall be fenced to prevent injury.

Warning signs prohibiting swimming and skating should be posted.

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Section 3.2 Stormwater Wetlands

Definition: Practices that create shallow wetland areas to treat urban stormwater and often incorporate small permanent pools and/or extended detention storage to achieve the full WQ_v. Design variants include:

- W-1 shallow wetland (Figure 3.6)
- W-2 ED shallow wetland (Figure 3.7)
- W-3 pond/wetland system (Figure 3.8)
- W-4 pocket wetland (Figure 3.9)

Stormwater wetlands may also provide Cp_v and Q_p storage above the WQ_v storage.

IMPORTANT NOTES:

1) Except for specific minimum contributing drainage area and the use of these practices in coldwater streams (USE III AND IV), all of the pond performance criteria presented in section 3.1 also apply to the design of stormwater wetlands. Additional criteria that govern the geometry and establishment of created wetlands are presented in this section.

2) Any stormwater management BMP that uses an embankment for impounding water is required to follow the latest version of the NRCS-MD 378 Pond Code Standards And Specifications For Small Pond Design (Appendix B.1) and obtain approval from the local SCD or appropriate review authority.

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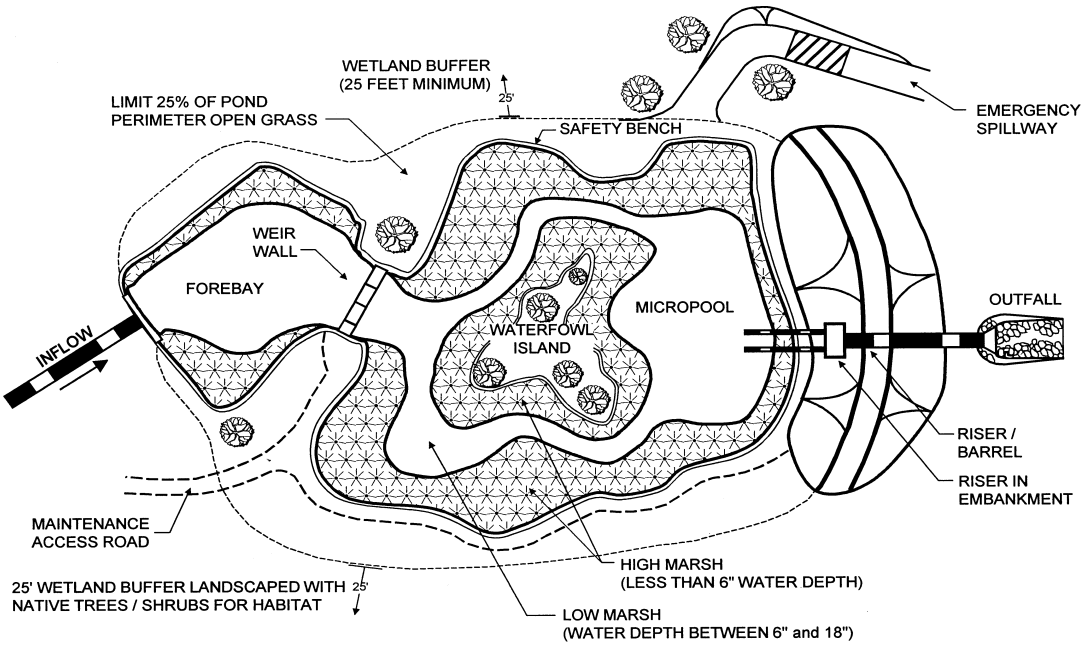
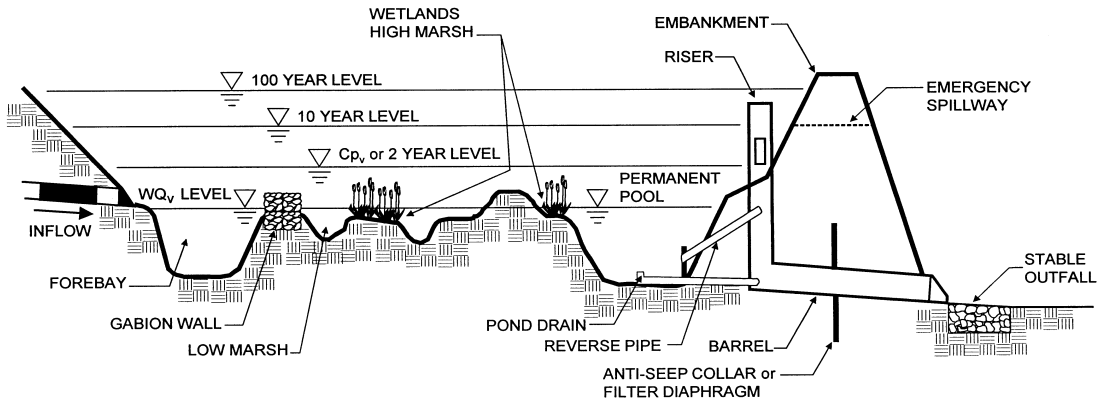
W-1	**Figure 3.6** Example of Shallow Wetland	W-1



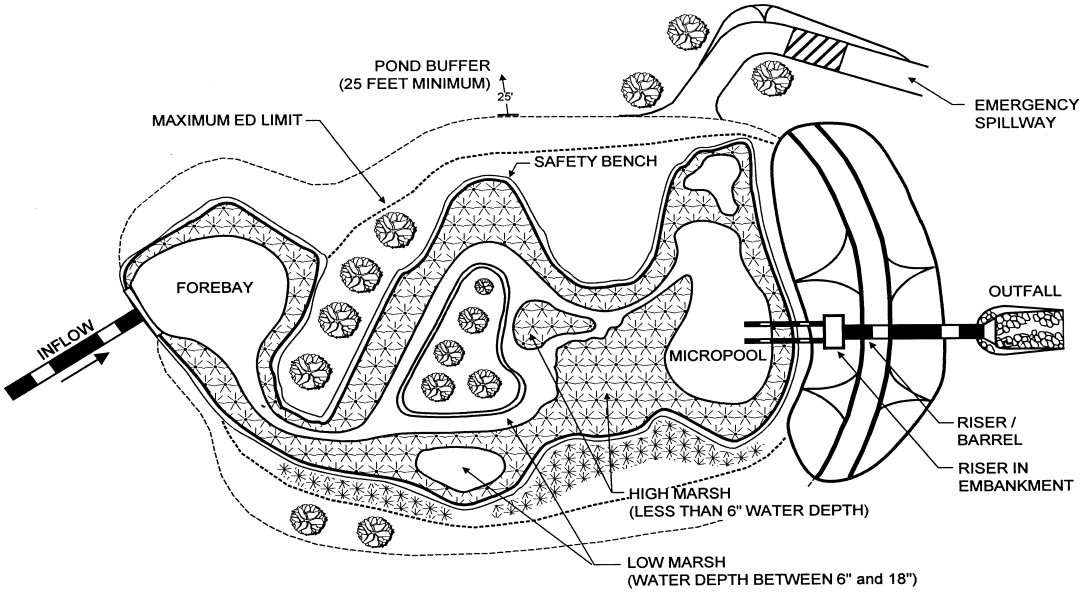
PLAN VIEW



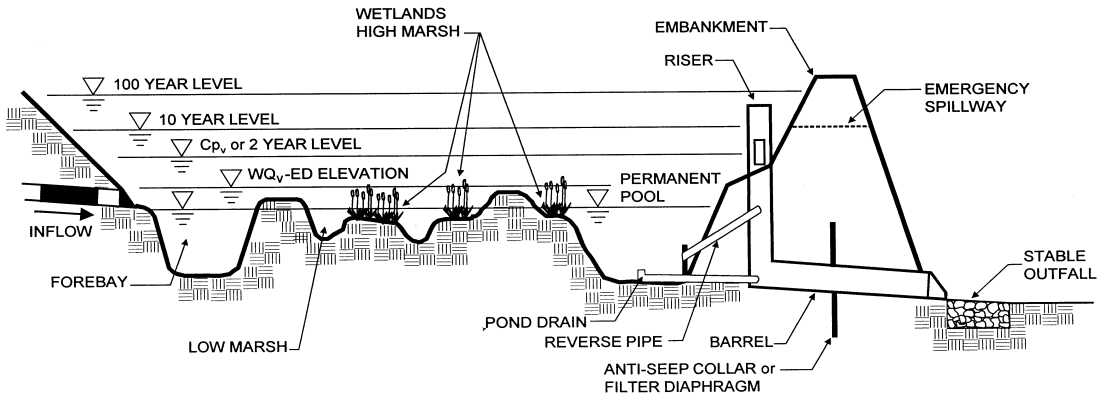
PROFILE

Shallow wetlands provide WQ_v in a shallow pool that has a large surface area.

W-2	**Figure 3.7** Example of Extended Detention Shallow Wetland	W-2



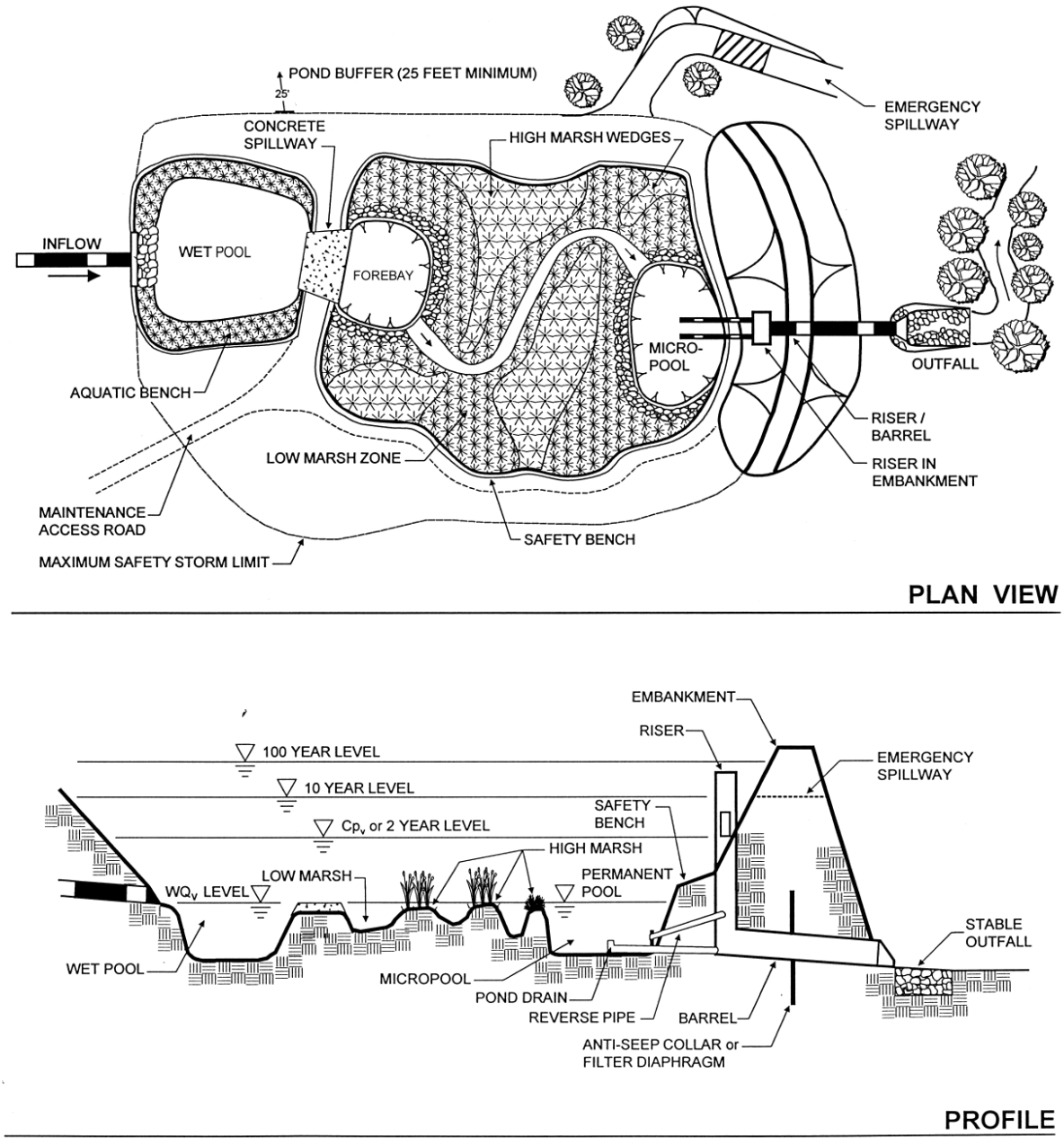
PLAN VIEW



PROFILE

ED shallow wetlands provide water quality storage by a combination of shallow wetland pool and extended detention storage.

W-3	**Figure 3.8** Example of Pond/Wetland System	W-3



In this BMP, a deep permanent pool is placed before the shallow wetland.

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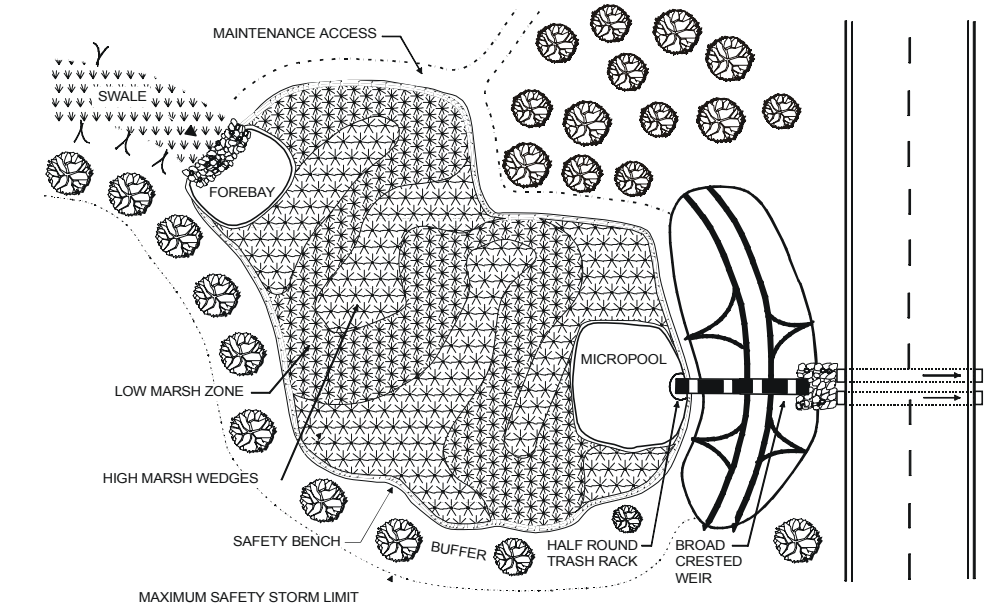
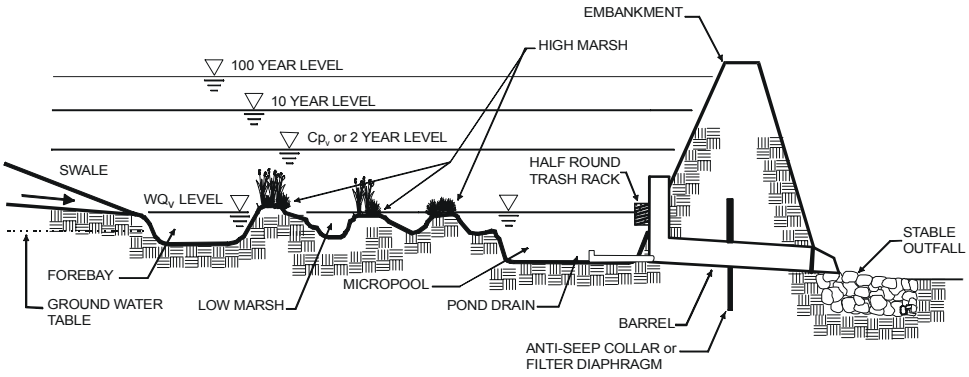
W-4	**Figure 3.9** Example of Pocket Wetland	W-4





A high water table or groundwater interception helps maintain the shallow wetland pool in a pocket wetland.

3.2.1 Wetland Feasibility Criteria

A water balance must be performed to demonstrate that a stormwater wetland can withstand a thirty day drought at summer evaporation rates without completely drawing down. See Appendix D.3 for a shortcut assessment method for determining the adequacy of water balance.

Stormwater wetlands may not be located within jurisdictional waters, including wetlands without obtaining a Section 404 permit and/or State of Maryland wetlands and waterways permit (see Chapter 4, Section 4.6.).

In USE III watersheds, stormwater wetlands that include permanent ponds as an integral design component [e.g., pond/wetland systems (W-3)] may require a small pond review and approval from the MDE Dam Safety Division (see Appendix B.1.2).

3.2.2 Wetland Conveyance Criteria

Flowpaths from inflow points to outflow points within stormwater wetlands shall be maximized. Flowpaths of 1.5:1 (length relative to width) and irregular shapes are recommended. These paths may be achieved by constructing internal berms (e.g., high marsh wedges or rock filter cells). Microtopography is encouraged to enhance wetland diversity.

3.2.3 Wetland Pretreatment Criteria

Sediment regulation is critical to sustaining stormwater wetlands. Consequently, *a forebay shall be located at the inlet and a micropool shall be located at the outlet*. Forebays are designed in the same manner as ponds (see Section 3.1.3). A micropool is a three to six foot deep pool used to protect the low flow pipe from clogging and prevent sediment resuspension. Forebays in Use III watersheds should be designed to drain within 24 hours.

3.2.4 Wetland Treatment Criteria

The surface area of the entire stormwater wetland shall be at least one percent of the total drainage area to the facility (1.5% for the shallow wetland design).

At least 25% of the total WQ_v shall be in deepwater zones with a minimum depth of four feet (the forebay and micropool may meet this criteria). This criteria may be reduced if the wetland is located where thermal impacts are a primary concern (e.g., Use III watersheds).

A minimum of 35% of the total surface area shall have a depth of six inches or less and at least 65% of the total surface area shall be shallower than 18 inches.

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The bed of the wetland should be graded to create a maximum internal flowpath and microtopography.

If extended detention is utilized in a stormwater wetland, *the ED volume shall not comprise more than 50% of the total wetland design, and the maximum water surface elevation shall not extend more than three feet above the normal pool*. Q_p and/or Cp_v storage can be provided above the maximum WQ_v elevation within the wetland.

To promote greater nitrogen removal, rock beds may be used as a medium for the growth of wetland plants. The rock should be one to three inches in diameter and placed up to the normal pool elevation. Rock beds should also be open to flow-through from either direction.

3.2.5 Wetland Landscaping Criteria

A landscaping plan shall be provided that indicates the methods used to establish and maintain wetland coverage. Minimum elements of a plan include: delineation of pondscaping zones, selection of corresponding plant species, planting configuration, and sequence for preparing wetland bed (including soil amendments, if needed).

Landscaping plans for stormwater wetlands located within Use III and IV watersheds should incorporate features and plant species commonly found in wooded wetlands.

Structures such as fascines, coconut rolls, or straw bales can be used to create shallow marsh cells in high energy areas of the stormwater wetland.

The landscaping plan should provide elements that promote greater wildlife and waterfowl use within the wetland and buffers.

A wetland buffer should extend 25 feet outward from the maximum water surface elevation with an additional 15 foot setback to structures.

Wetland Establishment Guidance

The most common and reliable technique for establishing an emergent wetland community in a stormwater wetland is to transplant nursery stock obtained from local aquatic plant nurseries. The following guidance is suggested when transplants are used to establish a wetland.

The transplanting window extends from early April to mid-June. Planting after these dates is not recommended, as the wetland plants need a full growing season to build the root reserves needed to get through the winter. If at all possible, the plants should be ordered at least three months in advance to ensure the availability of the desired species.

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The optimal depth requirements for several common species of emergent wetland plants are often six inches of water or less.

To add diversity to the wetland, 5 to 7 species of emergent wetland plants should be used, drawn from the suggested species listed in Appendix A. Of these, at least three species should be selected from the "aggressive colonizer" group (e.g., bulrush, pickerelweed, arrow arum, three square and rice cutgrass) (MDE, 1986).

The wetland area should be sub-divided into separate planting zones of more or less constant depth. Approximately half the wetland surface area should be planted. One plant species should be planted within each flagged planting zone, based on their approximate depth requirements. Plants should be installed in clumps with individual plants located an average of 18 inches on center within each clump. Individual plants should be spaced 12 inches to 24 inches on center.

Post-nursery care of wetland plants is very important in the interval between delivery of the plants and their subsequent installation, as they are prone to desiccation. Stock should be frequently watered and shaded while on-site.

A wet hydroseed mix should be used to establish permanent vegetative cover in the buffer outside of the permanent pool. For rapid germination, scarify the soil to ½ inch prior to hydroseeding. Alternatively, red fescue or annual rye can be used as a temporary cover for the wet species.

Because most stormwater wetlands are excavated to deep sub-soils, they often lack the nutrients and organic matter needed to support vigorous growth of wetland plants. At these sites, three to six inches of topsoil or wetland mulch should be added to all depth zones in the wetland from one foot below the normal pool to six inches above. Wetland mulch is preferable to topsoil if it is available.

The stormwater wetland should be staked at the onset of the planting season. Depths in the wetland should be measured to the nearest inch to confirm the original planting zones. At this time, it may be necessary to modify the pondscape plan to reflect altered depths or the availability of wetland plant stock. Surveyed planting zones should be marked on an “as-built” or design plan and located in the field using stakes or flags.

The wetland drain should be fully opened at least three days prior to the planting date (which should coincide with the delivery date for the wetland plant stock).

Wetland mulch is another technique to establish a plant community that utilizes the seedbank of wetland soils to provide the propagules for marsh development. The majority of the seedbank

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is contained within the upper six inches of the donor soils. The mulch is best collected at the end of the growing season. Best results are obtained when the mulch is spread 3 to 6 inches deep over the high marsh and semi-wet zones of the wetland (-6 inches to +6 inches relative to the normal pool).

Donor soils for wetland mulch shall not be removed from natural wetlands without proper permits.

3.2.6 Wetland Maintenance Criteria

If a minimum coverage of 50% is not achieved in the planted wetland zones after the second growing season, a reinforcement planting will be required

Stormwater wetlands that are created in upland areas and away from jurisdictional wetlands are not regulated under the appropriate federal and State laws as long as they are regularly maintained.

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Section 3.3 Stormwater Infiltration

Definition: Practices that capture and temporarily store the WQ_v while allowing infiltration into the soil over a prescribed period. Design variants include:

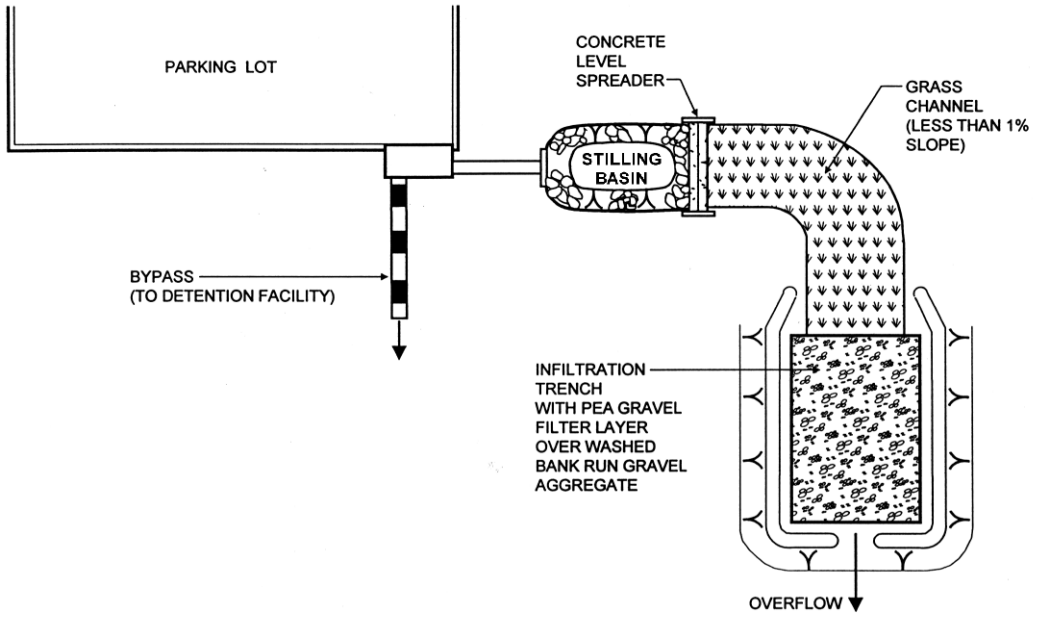
- I-1 infiltration trench (Figure 3.10)
- I-2 infiltration basin (Figure 3.11)

Infiltration practices are an excellent technique for meeting the Re_v requirement and may also provide Cp_v and Q_p storage in certain limited cases.

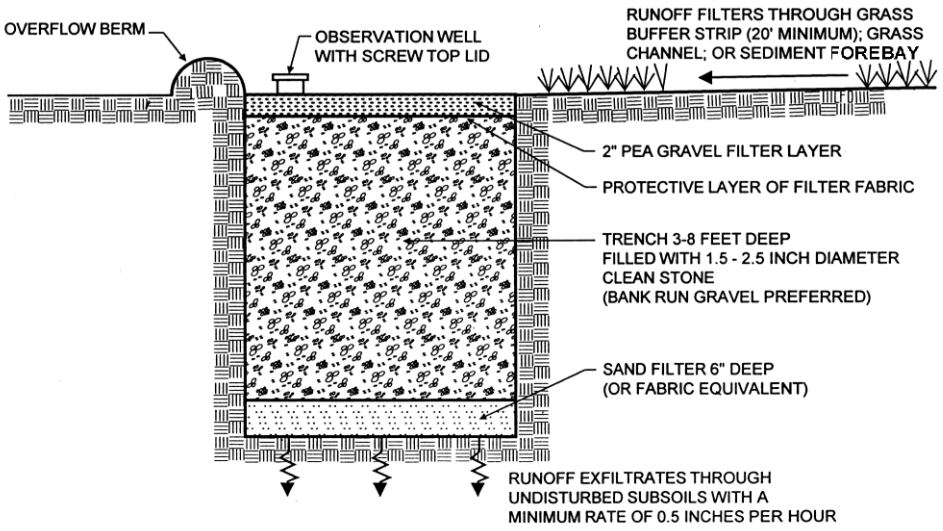
IMPORTANT NOTE: Any stormwater management BMP that uses an embankment for impounding water is required to follow the latest version of the NRCS-MD 378 Pond Code Standards And Specifications For Small Pond Design (Appendix B.1) and obtain approval from the local SCD or appropriate review authority.

SARB_005255

I-1	**Figure 3.10** Example of Infiltration Trench	I-1



PLAN VIEW



PROFILE

The infiltration trench provides Re_v and WQ_v in one location.

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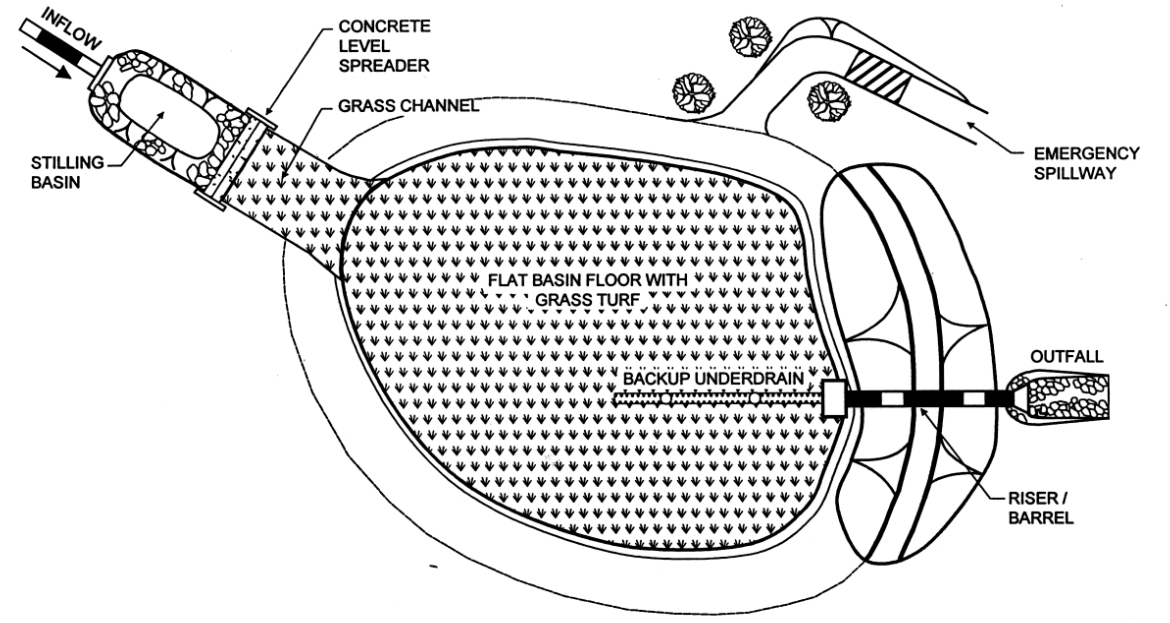
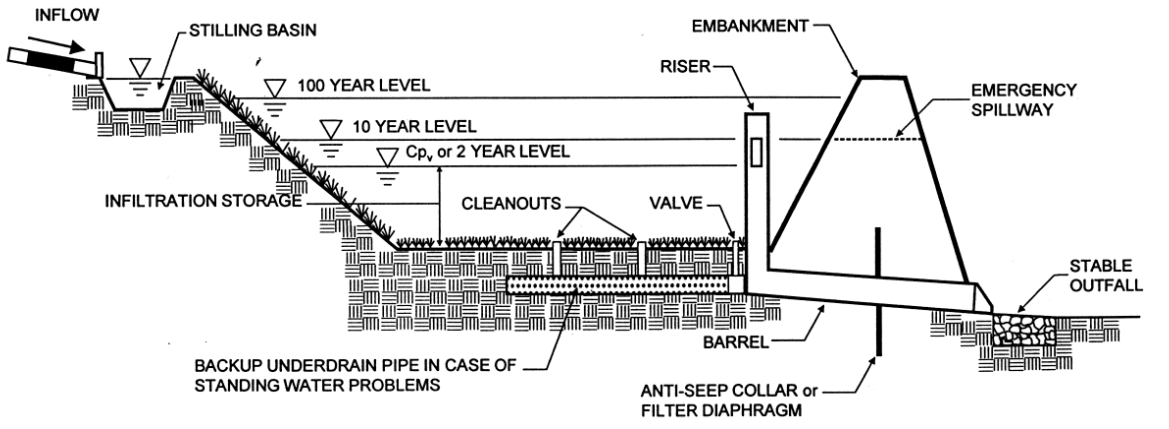
I-2	**Figure 3.11** Example of Infiltration Basin	I-2



PLAN VIEW



PROFILE

The WQ_v is retained in an infiltration basin, where it percolates through the floor of the basin in a two day period.

3.3.1 Infiltration Feasibility Criteria

To be suitable for infiltration, underlying soils shall have an infiltration rate (f) of 0.52 inches per hour or greater, as initially determined from NRCS soil textural classification and subsequently confirmed by field geotechnical tests. Approved geotechnical testing procedures for feasibility and design are outlined in Appendix D.1. The minimum geotechnical testing is one test hole per 5000 sf, with a minimum of two borings per facility (taken within the proposed limits of the facility).

Soils should also have a clay content of less than 20% and a silt/clay content of less than 40%.

Infiltration cannot be located on slopes greater than 15% or within fill soils.

To protect groundwater from possible contamination, runoff from designated hotspot land uses or activities cannot be infiltrated without proper pretreatment to remove hydrocarbons, trace metals, or toxicants. A list of designated stormwater hotspots is provided in Section 2.8.

Infiltration may be prohibited within areas of karst topography. If a site overlies karst geology, the local approval authority should be consulted for specific design requirements. Recommended procedures for determining whether a site overlies karst are provided in Appendix D.2.

The bottom of the infiltration facility shall be separated by at least four feet vertically from the seasonally high water table or bedrock layer, as documented by on-site soil testing. This distance is reduced to 2 feet on the Lower Eastern Shore (see Figure 4.1).

Infiltration facilities should be located a minimum of 100 feet horizontally from any water supply well.

The maximum contributing area to an individual infiltration practice should generally be less than 5 acres.

Infiltration practices should not be placed in locations that cause water problems to downgrade properties. Infiltration facilities should be setback 25 feet (10 feet for dry wells) down-gradient from structures.

3.3.2 Infiltration Conveyance Criteria

A conveyance system shall be included in the design of all infiltration practices in order to ensure that excess flow is discharged at non-erosive velocities.

The overland flow path of surface runoff exceeding the capacity of the infiltration system shall be evaluated to preclude erosive concentrated flow. If computed flow velocities do not exceed

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the non-erosive threshold, overflow may be accommodated by natural topography (see Appendix D.12 for the critical erosive velocities for grass and soil).

All infiltration systems shall be designed to fully de-water the entire WQ_v within 48 hours after the storm event.

The truncated hydrograph method shall be used if infiltration is used to control Cp_v or Q_p (see Appendix D.13 for details on this method).

If runoff is delivered by a storm drain pipe or along the main conveyance system, the infiltration practice should be designed as an off-line practice. (See Detail No. 5, Appendix D.8 for example of an off-line infiltration practice.)

Adequate stormwater outfalls shall be provided for the overflow associated with the ten-year design storm event (non-erosive velocities on the down-slope).

3.3.3 Infiltration Pretreatment Criteria

Pretreatment Volume

A minimum of 25% of the WQ_v must be pretreated prior to entry to an infiltration facility. If the f for the underlying soils is greater than 2.00 inches per hour, 50% of the WQ_v shall be pretreated prior to entry into an infiltration facility. This can be provided by a sedimentation basin, stilling basin, sump pit or other acceptable measures. *Exit velocities from pretreatment shall be non-erosive during the two-year design storm.*

The Camp-Hazen equation (Chapter 3.4.3) may be used as an acceptable alternative for determining infiltration pretreatment requirements.

Pretreatment Techniques to Prevent Clogging

Each system shall have redundant methods to protect the long term integrity of the infiltration rate. The following techniques, at least three per trench (I-1) and two per basin (I-2), must be installed in every infiltration practice:

- *grass channel* (see Chapter 5 - Credit #5 for example computation and requirements for use)
- *grass filter strip* (minimum 20 feet and only if sheet flow is established and maintained)
- *bottom sand layer*
- *upper sand layer (6" minimum) with filter fabric at the sand/gravel interface.*
- *use of washed bank run gravel as aggregate*

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The sides of infiltration trenches shall be lined with an acceptable filter fabric that prevents soil piping but has greater permeability than the parent soil (see Appendix B.2).

3.3.4 Infiltration Treatment Criteria

Infiltration practices shall be designed to exfiltrate the entire WQ_v less the pretreatment volume through the floor of each practice using the design methods outlined in Appendix D.13.

Infiltration practices are best used in conjunction with other BMPs and often downstream detention is still needed to meet the Cp_v and Q_p sizing criteria.

The construction sequence and specifications for each infiltration practice shall be followed, as outlined in Appendix B.2. Experience has shown that the longevity of infiltration practices is strongly influenced by the care taken during construction.

A porosity value "*n*" ($n = V_v/V_t$) of 0.40 should be used in the design of stone reservoirs for infiltration practices.

3.3.5 Infiltration Landscaping Criteria

A dense and vigorous vegetative cover shall be established over the contributing pervious drainage areas before runoff can be accepted into the facility. Infiltration trenches shall not be constructed until all of the contributing drainage area has been completely stabilized.

3.3.6 Infiltration Maintenance Criteria

Infiltration practices may not serve as a sediment control device during the site construction phase. In addition, the erosion and sediment control plan for the site must clearly indicate how sediment will be prevented from entering the infiltration site.

An observation well shall be installed in every infiltration trench, consisting of an anchored six-inch diameter perforated PVC pipe with a lockable cap. (See Detail No. 4, Appendix D.8.)

It is recommended that infiltration designs include dewatering methods in the event of failure. This can be done with underdrain pipe systems that accommodate drawdown.

Direct access shall be provided to all infiltration practices for maintenance and rehabilitation.

Infiltration practices should not be covered by an impermeable surface.

OSHA safety standards should be consulted for trench excavation.

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Section 3.4 Stormwater Filtering Systems

Definition: Practices that capture and temporarily store the WQ_v and pass it through a filter bed of sand, organic matter, soil or other media. Filtered runoff may be collected and returned to the conveyance system or allowed to partially exfiltrate into the soil. Design variants include:

- F-1 surface sand filter (Figure 3.12)
- F-2 underground sand filter (Figure 3.13)
- F-3 perimeter sand filter (Figure 3.14)
- F-4 organic filter (Figure 3.15)
- F-5 pocket sand filter (Figure 3.16)
- F-6 bioretention (Figure 3.17)

Filtering systems shall not be designed to meet Cp_v or Q_p requirements except under extremely unusual conditions. Filtering practices shall generally be combined with a separate facility to provide those controls. Filtering systems may be used to meet the Re_v if designed to exfiltrate into the soil (e.g., if additional storage is provided below the invert of the underdrain).

IMPORTANT NOTE: Any stormwater management BMP that uses an embankment for impounding water is required to follow the latest version of the NRCS-MD 378 Pond Code Standards And Specifications For Small Pond Design (Appendix B.1) and obtain approval from the local Soil Conservation District (SCD) or appropriate review authority.

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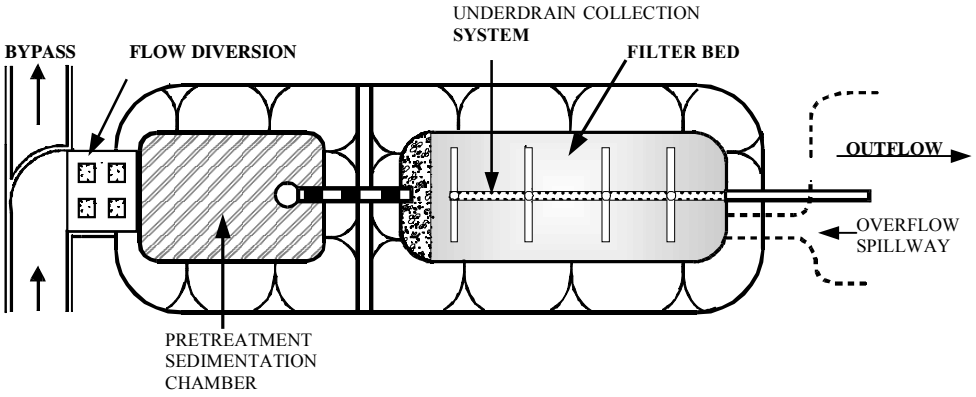
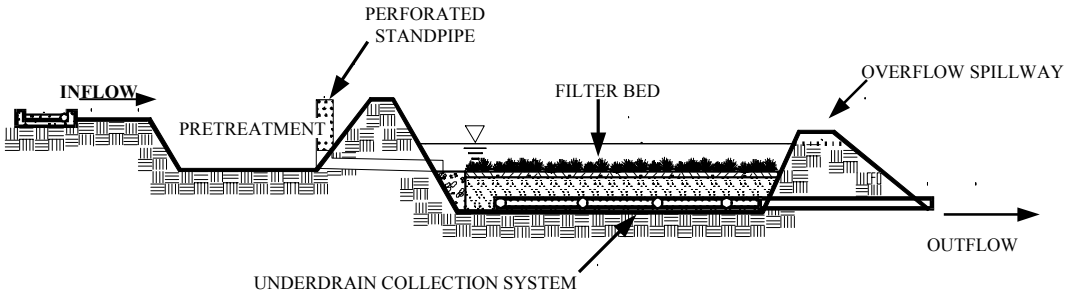
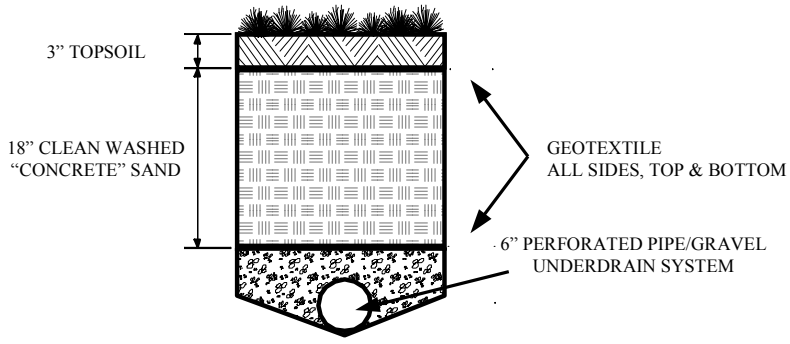
F-1	**Figure 3.12** Example of Surface Sand Filter	F-1



PLAN VIEW



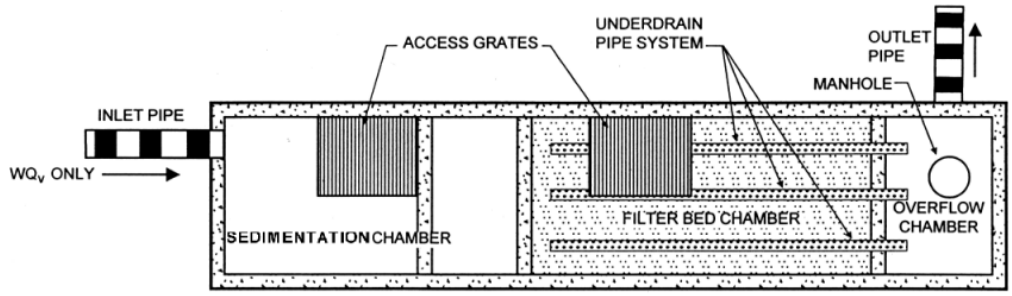
PROFILE



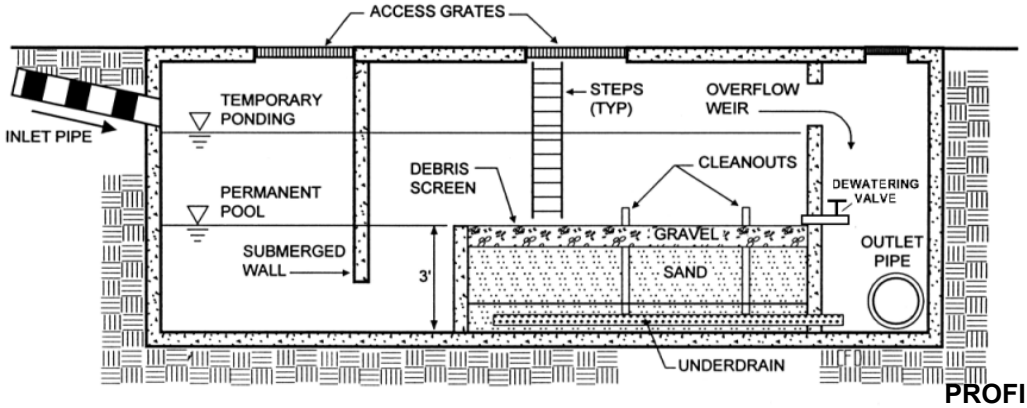
TYPICAL SECTION

Surface sand filters can treat the largest drainage area of all the filtering systems.

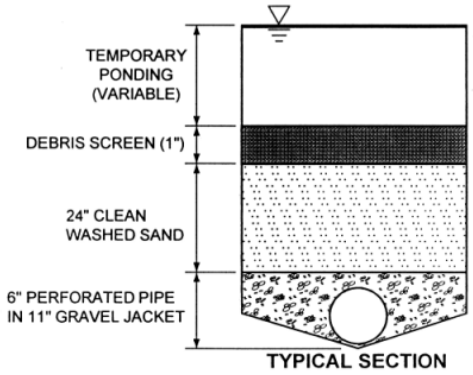
F-2	**Figure 3.13** Example of Underground Sand Filter	F-2



PLAN VIEW



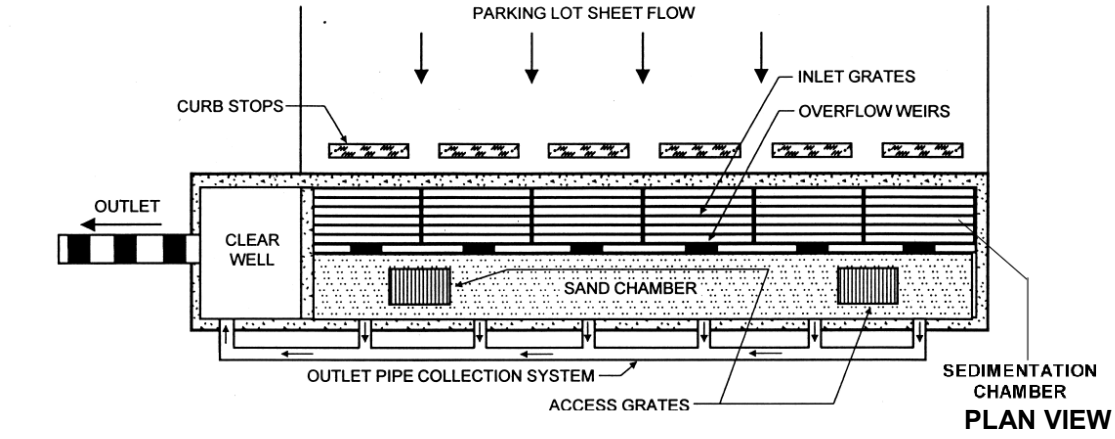
PROFILE

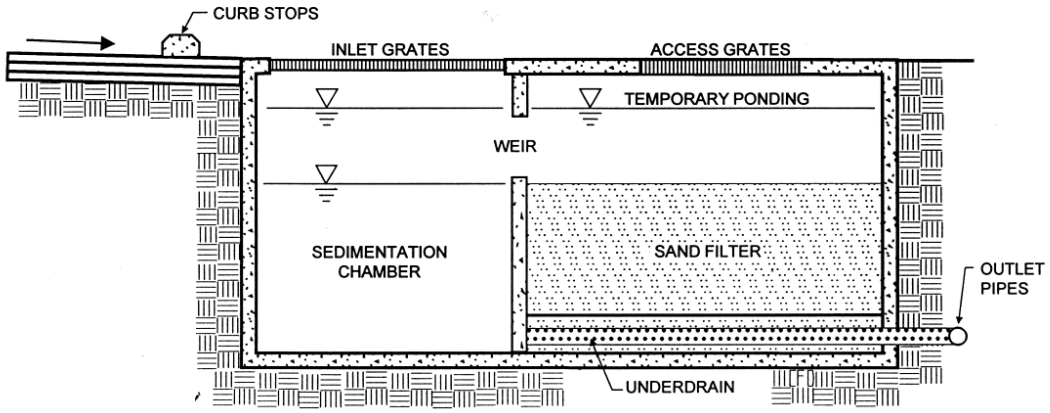


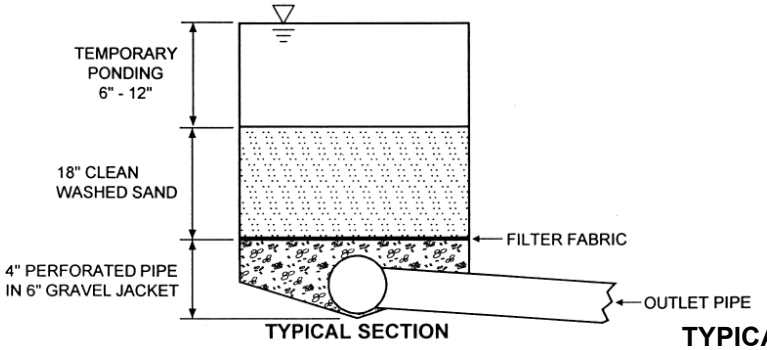
TYPICAL SECTION

The underground sand filter is an option for providing WQ_v where space is limited.

F-3	**Figure 3.14** Example of Perimeter Sand Filter	F-3

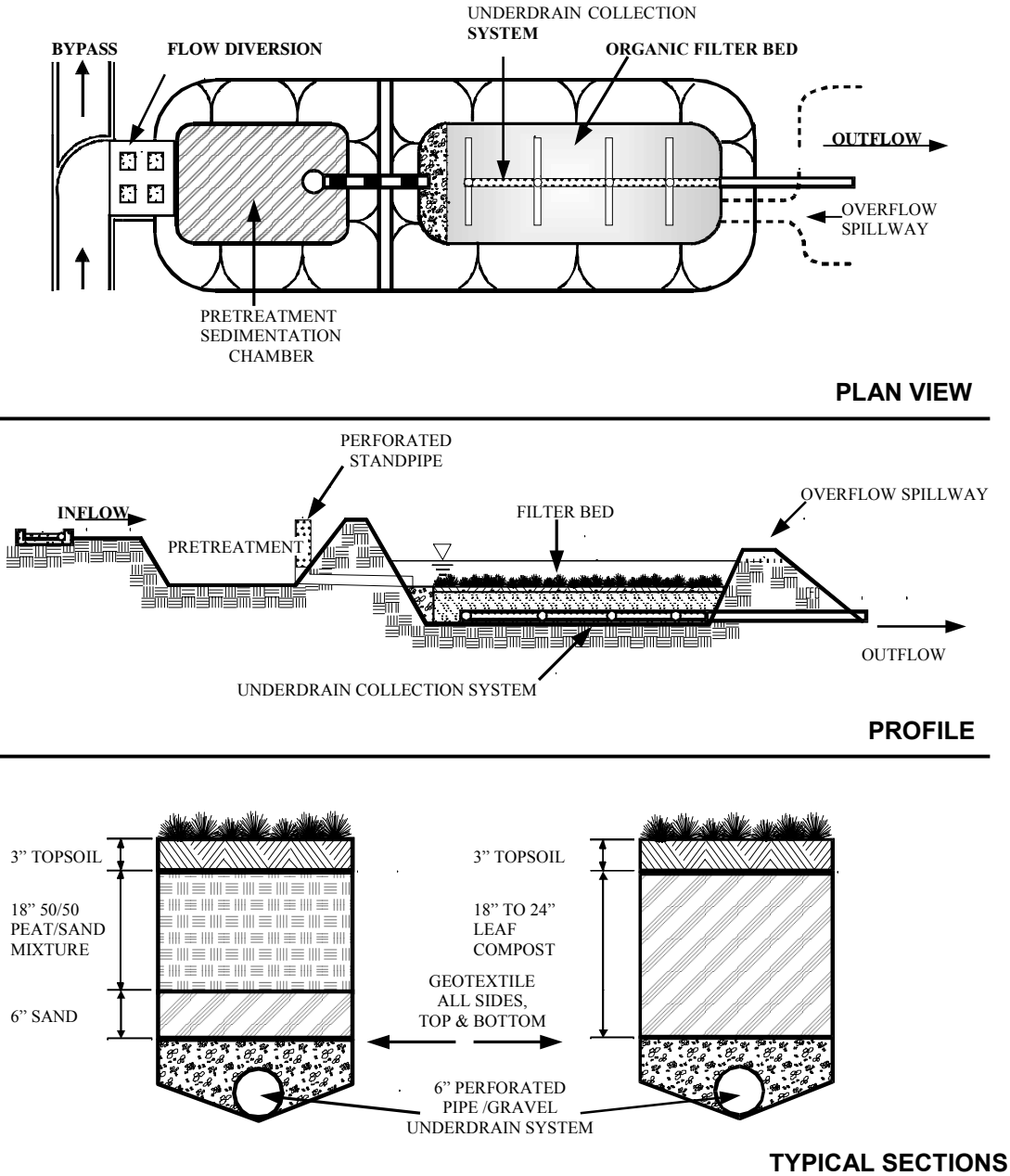






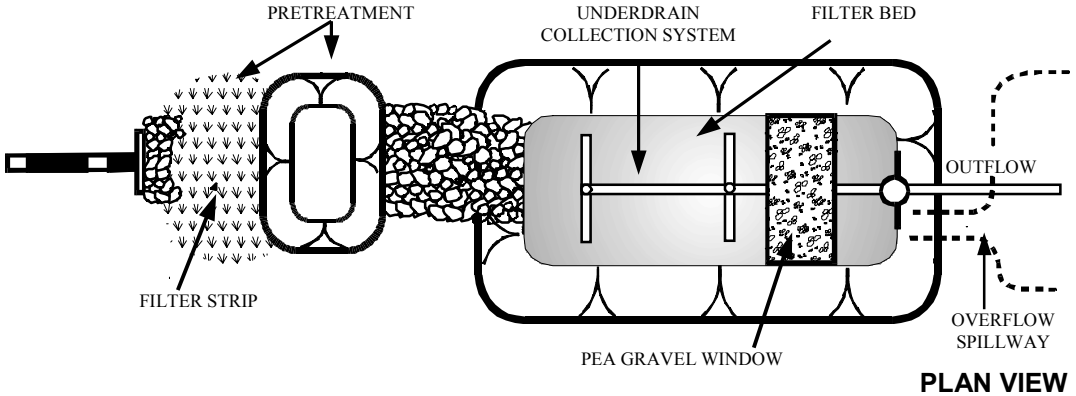
The perimeter sand filter is most practical for small sites with flat terrain or a high water table.

F-4	**Figure 3.15** Example of Organic Filter	F-4

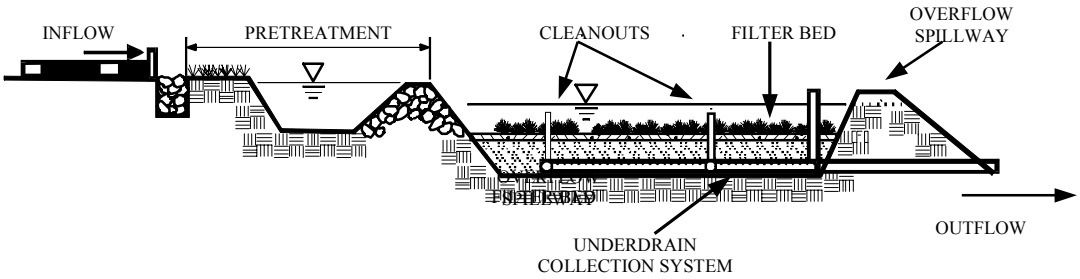


The organic filter is used when maximum nutrient or trace metal removals are desired.

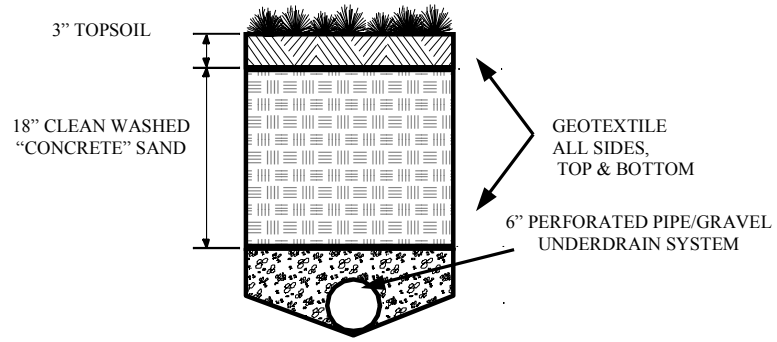
F-5	**Figure 3.16** Example of Pocket Sand Filter	F-5



PLAN VIEW



PROFILE



TYPICAL SECTION

The pocket sand filter is applied to small sites where sediment loads are expected to be moderate to low. The pea gravel windows allow runoff into the filter if the surface becomes clogged.

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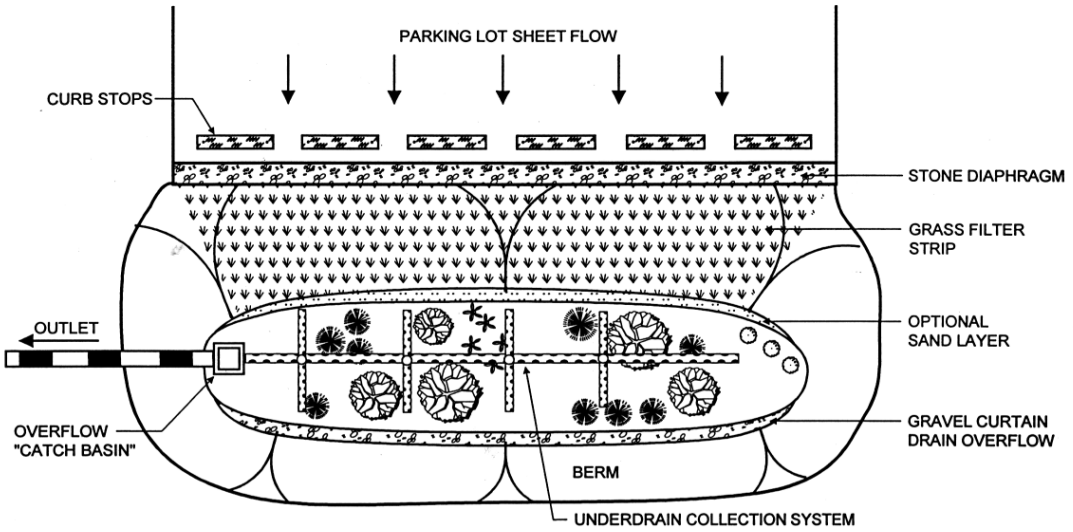
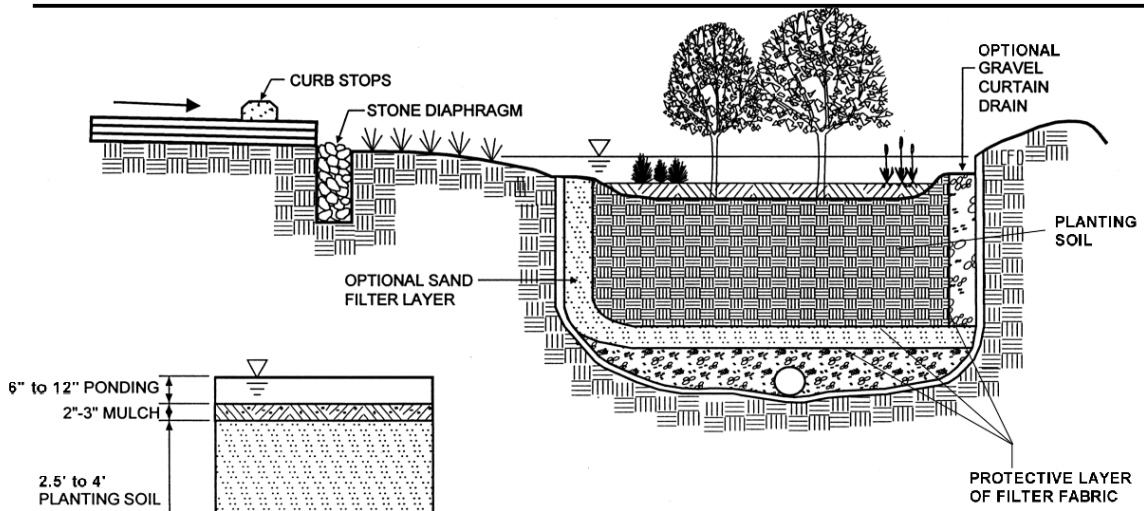
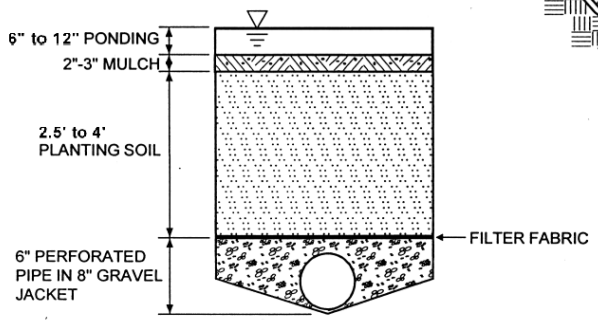
F-6	**Figure 3.17** Example of Bioretention	F-6



PLAN VIEW



PROFILE



TYPICAL SECTION

Bioretention combines open space with stormwater treatment.

3.4.1 Filtering Feasibility Criteria

Most stormwater filters normally require two to six feet of head. However, the perimeter sand filter (F-3) can be designed to function with as little as one foot of head.

The maximum contributing area to an individual stormwater filtering system is usually less than 10 acres.

Sand and organic filtering systems are generally applied to land uses with a high percentage of impervious surfaces. *Drainage areas with imperviousness less than 75% discharging to a filtering practice shall require full sedimentation pretreatment techniques (see Equation on p. 3.39).*

3.4.2 Filtering Conveyance Criteria

If runoff is delivered by a storm drain pipe or is along the main conveyance system, the filtering practice shall be designed off-line. (See Detail No. 5 in Appendix D.8.)

Overflow for the ten-year storm shall be provided to a non-erosive outlet point (e.g., prevent downstream slope erosion). See Appendix D.12 for critical non-erosive velocities for grass and soil.

A flow regulator (or flow splitter diversion structure) shall be provided to divert the WQ_v to the filtering practice (see Detail No. 5, Appendix D.8).

Stormwater filters shall be equipped with a minimum 4" perforated pipe underdrain (6" is preferred) in a gravel layer. A permeable filter fabric (Appendix B.3) shall be placed between the gravel layer and the filter media.

3.4.3 Filtering Pretreatment Criteria

Dry or wet pretreatment equivalent to at least 25% of the computed WQ_v shall be provided prior to filter media. The typical method is a sedimentation basin that has a length to width ratio of 2:1. The Camp-Hazen equation, which accounts for the effects of turbulent flow, is used to compute the required minimum surface area for sand and organic filters for pretreatment (WSDE, 1992).

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The required sedimentation basin minimum surface area is computed using the following equation:

$$A_s = \frac{Q_o}{W} \times E'$$

where:

A_s = sedimentation basin surface area (ft^2)
Q_o = discharge rate from basin = (WQ_v/24 hr)
W = particle settling velocity (ft/sec)
for I ≤ 75%, use 0.0004 ft/sec (particle size=20 microns)
for I >75%use 0.0033 ft/sec (particle size=40 microns) [1]
(I = percent impervious)
E' = sediment trapping efficiency constant; for a sediment trapping efficiency (E) of 90%, $E' = 2.30$ [2]

1) Sites with greater than 75% imperviousness have a higher percentage of coarse-grained sediments (Shaver and Baldwin, 1991). Therefore, the target particle size for sedimentation basins may be increased to 40 microns and the surface area reduced.

2) The sediment trapping efficiency constant (E') may be calculated from the sediment trapping efficiency (E) using the following equation: $E' = -\ln [1-(E/100)]$

The equation reduces to:

A_{sf} = (0.066) (WQ_v) ft^2 for I ≤ 75%
A_{sp} = (0.0081) (WQ_v) ft^2 for I > 75%

where:

A_{sf} = sedimentation basin surface area full
A_{sp} = sedimentation basin surface area partial

Adequate pretreatment for bioretention systems (F-6) is provided when all of the following are provided: (a) 20' grass filter strip below a level spreader or optional sand filter layer, (b) gravel diaphragm and (c) a mulch layer.

3.4.4 Filtering Treatment Criteria

The entire treatment system (including pretreatment) shall temporarily hold at least 75% of the WQ_v prior to filtration.

The filter bed typically has a minimum depth of 18". *Sand filters shall have a minimum filter bed depth of 12".*

Filtering practices typically cannot provide Cp_v or Q_p under most site conditions.

The filter media shall conform to the specifications listed in Table B.3.1 (Appendix B.3).

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The filter area for filter designs F-1 to F-5 shall be sized based on the principles of Darcy's Law. A coefficient of permeability (k) shall be used as follows:

Sand:	*3.5 ft/day (City of Austin 1988)*
Peat:	2.0 ft/day (Galli 1990)
Leaf compost:	*8.7 ft/day (Claytor and Schueler, 1996)*
Bioretention Soil:	*0.5 ft/day (Claytor and Schueler, 1996)*

Bioretention systems (F-6) shall consist of the following treatment components: A 2½ to 4 foot deep planting soil bed, a surface mulch layer, and a 12" deep surface ponding area.

The required filter bed area (A_f) is computed using the following equation:

$$A_f = (WQ_v)\ (d_f) \ / \ [\ (k)\ (h_f + d_f)\ (t_f)]$$

where:

A_f = Surface area of filter bed (ft^2)
WQ_v = water quality volume (ft^3)
d_f = filter bed depth (ft)
k = coefficient of permeability of filter media (ft/day)
h_f = average height of water above filter bed (ft)
t_f = design filter bed drain time (days)*

*1.67 days is recommended maximum for sand filters, 2.0 days for bioretention

3.4.5 Filtering Landscaping Criteria

A dense and vigorous vegetative cover shall be established over the contributing drainage area before runoff can be accepted into the facility.

Landscaping is critical to the performance and function of bioretention areas. Therefore, a landscaping plan shall be provided for bioretention areas per the guidance provided in Appendix-A.

Filters F-1, F-4 and F-5 may have a grass cover to aid in pollutant adsorption. The grass should be capable of withstanding frequent periods of inundation and drought (see Appendix A for grass species selection guide).

Planting recommendations for bioretention facilities are as follows:

- Native plant species should be specified over non-native species.
- Vegetation should be selected based on a specified zone of hydric tolerance.
- A selection of trees with an understory of shrubs and herbaceous materials should be provided.

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- Woody vegetation should not be specified at inflow locations.

3.4.6 Filtering Maintenance Criteria

The sediment chamber outlet devices shall be cleaned/repaired when drawdown times within the chamber exceed 36 hours. Trash and debris shall be removed as necessary.

Sediment should be cleaned out of the sedimentation chamber when it accumulates to a depth of more than six inches. Vegetation within the sedimentation chamber should be limited to a height of 18 inches.

When the filtering capacity of the filter diminishes substantially (e.g., when water ponds on the surface of the filter bed for more than 72 hours), the top few inches of discolored material shall be removed and shall be replaced with fresh material. The removed sediments should be disposed in an acceptable manner (e.g., landfill). Silt/sediment should be removed from the filter bed when the accumulation exceeds one inch.

Organic filters (F-4) or surface sand filters (F-1) that have a grass cover should be mowed a minimum of 3 times per growing season to maintain maximum grass heights less than 12 inches.

*A drop of at least six inches shall be provided at the inlet of bioretention facilities (F-6) (*stone diaphragm*). Dead or diseased plant material shall be replaced.* Areas devoid of mulch should be re-mulched on an annual basis.

Direct maintenance access shall be provided to the pretreatment area and the filter bed.

Construction of sand filters and bioretention areas shall conform to the specifications outlined in Appendix B.3.

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Section 3.5 Open Channel Systems

Definition: Vegetated open channels that are designed to capture and treat the full WQ_v within dry or wet cells formed by check dams or other means. Design variants include:

- O-1 dry swale (Figure 3.18)
- O-2 wet swale (Figure 3.19)

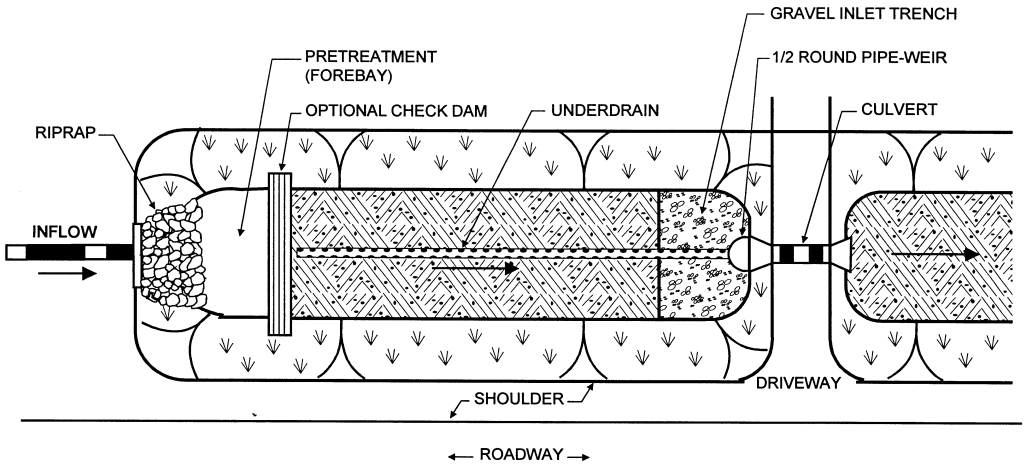
Open channel systems shall not be designed to meet Cp_v or Q_p requirements except under extremely unusual conditions. Open channel practices shall generally be combined with a separate facility to provide those controls. Additionally, these systems may be used to meet the Re_v if designed to exfiltrate through the soil (e.g., if additional storage is provided below the invert of the underdrain).

Grass channels (also known as biofilters) that are not designed in accordance with Section 3.5 are not considered an acceptable practice to meet the WQ_v requirements unless designed according to the criteria in Chapter 5.

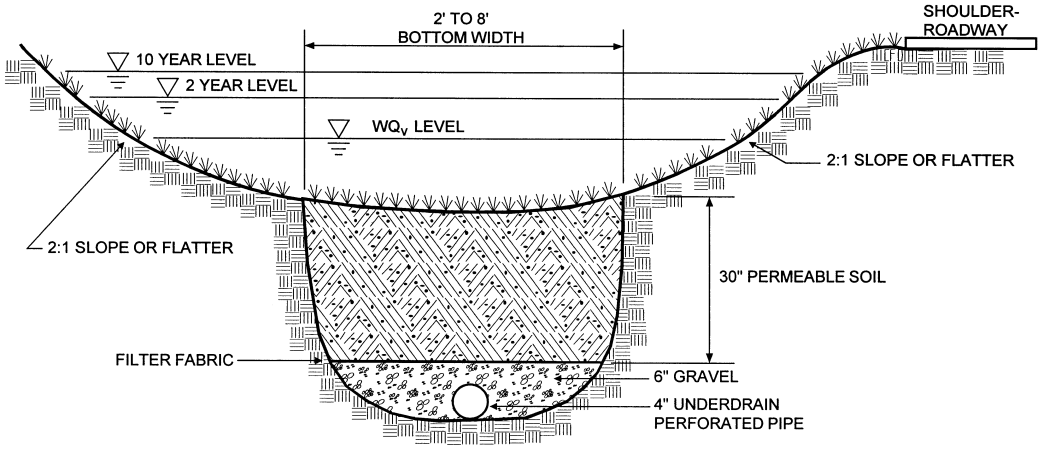
IMPORTANT NOTE: Any stormwater management BMP that uses an embankment for impounding water is required to follow the latest version of the NRCS-MD 378 Pond Code Standards And Specifications For Small Pond Design (Appendix B.1) and obtain approval from the local Soil Conservation District (SCD) or appropriate review authority.

SARB_005272

O-1	**Figure 3.18** Example of Dry Swale	O-1



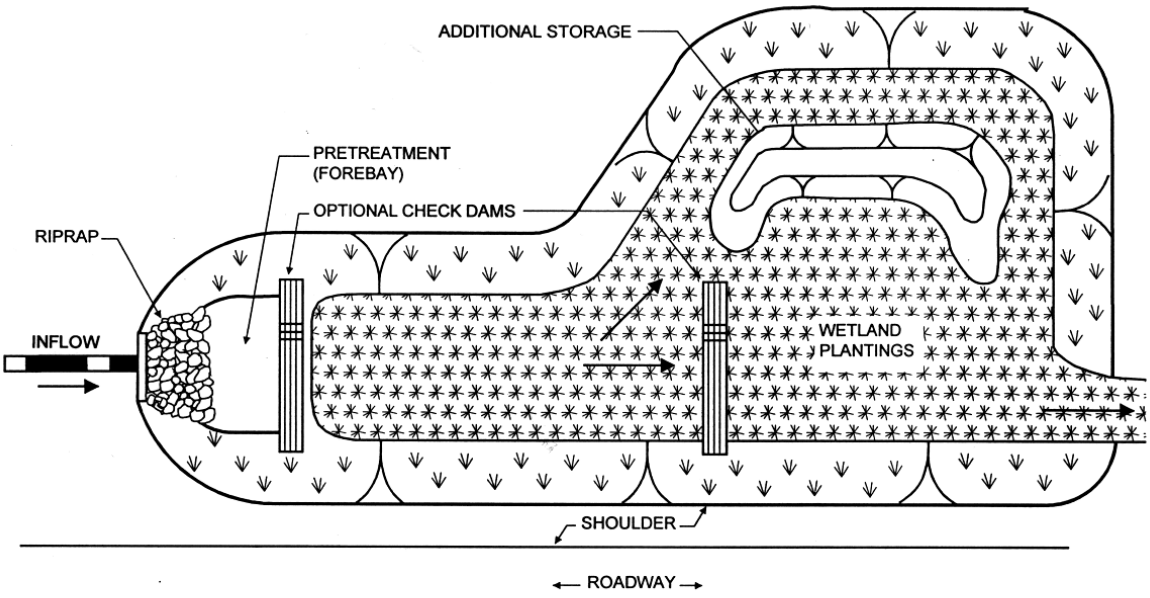
PLAN VIEW



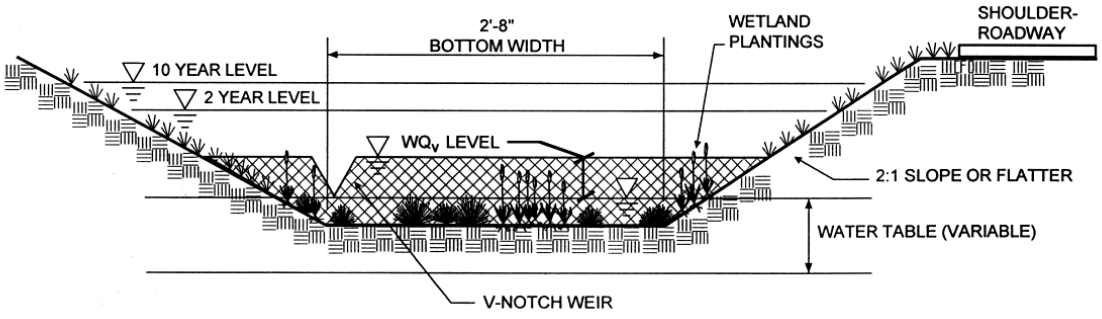
SECTION

Dry swales are used at low density residential projects or for very small impervious areas.

O-2	**Figure 3.19** Example of Wet Swale	O-2



PLAN VIEW



PROFILE

Wet swales are ideal for treating highway runoff in low lying or flat terrain areas.

SARB_005274

3.5.1 Open Channel Feasibility Criteria

Open channel systems shall have longitudinal slopes less than 4.0% to qualify for WQ_v treatment.

Open channel systems, designed for WQ_v treatment, are primarily applicable for land uses such as roads, highways, residential development (dry swales only), and pervious areas.

3.5.2 Open Channel Conveyance Criteria

The peak velocity for the ten-year storm shall be non-erosive (see Appendix D.12 for critical non-erosive velocities for grass and soil) for the soil and vegetative cover provided.

Open channels shall be designed to safely convey the ten-year storm. Three inches of freeboard should be provided.

Channels should be designed with moderate side slopes (flatter than 3:1) for most conditions. *In no event may side slopes be steeper than 2:1.*

The maximum allowable ponding time within a channel shall be less than 48 hours. The minimum ponding time of 30 minutes is recommended for meeting WQ_v treatment goals.

Open channel systems which directly receive runoff from impervious surfaces may have a six inch drop onto a protected shelf (pea gravel diaphragm) to minimize clogging of the inlet.

An underdrain system shall be provided for the dry swale to ensure a maximum ponding time of 48 hours.

3.5.3 Open Channel Pretreatment Criteria

Pretreatment storage of 0.1 inch of runoff per impervious acre storage shall be provided. This storage is usually obtained by providing check dams at pipe inlets and/or driveway crossings.

A pea gravel diaphragm and gentle side slopes should be provided along the top of channels to accommodate pretreatment for lateral sheet flows.

Direct discharge of concentrated flow (e.g., by pipe) shall be pretreated.

SARB_005275

3.5.4 Open Channel Treatment Criteria

Dry and wet swales shall be designed to temporarily store the WQ_v within the facility for a maximum 48 hour period.

Open channels shall have a bottom width no wider than 8 feet or a meandering drainage pattern shall be established to avoid gullying or channel braiding.

Dry and wet swales should maintain a maximum ponding depth of one foot at the "mid-point" of the channel profile (longitudinal dimension) and a maximum depth of 18" at the downstream end point of the channel (for storage of the WQ_v).

3.5.5 Open Channel Landscaping Criteria

Wet swales are not recommended for residential developments as they can create potential nuisance or mosquito breeding conditions.

Landscape design should specify proper grass species and wetland plants based on specific site, soils and hydric conditions present along the channel (see Appendix A).

3.5.6 Open Channel Maintenance Criteria

Open channel systems and grass filter strips should be mowed as required during the growing season to maintain grass heights in the 4 to 6 inch range. Wet swales, employing wetland vegetation or other low maintenance ground cover do not require frequent mowing of the channel.

Sediment build-up within the bottom of the channel or filter strip shall be removed when 25% of the original WQ_v has been exceeded.

Construction specifications for open channel systems are specified in Appendix B.3.

SARB_005276

Chapter

4.0

A Guide to BMP Selection and Location in the State of Maryland

4.0 Selecting the Best BMP at a Site

This chapter outlines a process for selecting the best BMP or group of BMPs for a development site and provides guidance on factors to consider when deciding where to locate them. The process is used to screen which BMPs can meet the pollutant removal targets for the WQ_v and guides the designer through six steps that progressively screen:

- Watershed Factors
- Terrain Factors
- Stormwater Treatment Suitability
- Physical Feasibility Factors
- Community and Environmental Factors
- Locational and Permitting Factors

More detail on the step-wise screening process is provided below:

Step ❶ Watershed Factors

Is the project located in a watershed that has special design objectives or constraints that must be met? Table 4.1 outlines BMP restrictions or additional design requirements that must be considered if a project lies within the Maryland Critical Area, a cold water watershed, a sensitive watershed, an aquifer protection area, a water supply reservoir, or a shellfish/beach protection zone.

Step ❷ Terrain Factors

Is the project located in a portion of the State that has particular design constraints imposed by local terrain and or underlying geology? Table 4.2 details BMP restrictions for regions of Maryland that have karst, mountainous terrain, or low relief.

Step ❸ Stormwater Treatment Suitability

Can the BMP meet all five stormwater sizing criteria at the site or are a combination of BMPs needed? In this step, designers can screen the BMP list using Table 4.3 to determine if a particular BMP can meet the Re_v, Cp_v and/or Q_p storage requirements. In addition, Table 4.3 indicates whether a BMP is capable of treating hotspot runoff and provides comparative indexes on land consumption and safety risks that may preclude a BMP. At the end of this step, the designer can screen the BMP options down to a manageable number and determine if a single BMP or a group of BMPs is needed to meet stormwater sizing criteria at the site.

SARB_005279

Step ❹ Physical Feasibility Factors

Are there any physical constraints at the project site that may restrict or preclude the use of a particular BMP? In this step, the designer screens the BMP list using Table 4.4 to determine if the soils, water table, drainage area, slope or head conditions present at a particular development site might limit the use of a BMP. In addition, the matrix indicates which BMP options work well in highly urban areas.

Step ❺ Community and Environmental Factors

Do the remaining BMPs have any important community or environmental benefits or drawbacks that might influence the selection process? In this step, Table 4.5 is used to compare BMP options with regard to maintenance, habitat, community acceptance, cost and other environmental factors.

Step ❻ Locational and Permitting Factors

What environmental features must be avoided or considered when locating the BMP system at a site to fully comply with local, State and federal regulations? In this step, the designer may use Table 4.6 as a checklist that asks whether any of the following are present at the site: wetlands, waters of the United States, stream or shoreline buffers, floodplains, forest conservation areas, and development infrastructure. Brief guidance is then provided on how to locate BMPs to avoid impacts to sensitive resources. If a BMP must be located within a sensitive environmental area, a brief summary of applicable permit requirements is provided.

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Section 4.1 Watershed Factors

The design of urban BMPs is fundamentally influenced by the nature of the downstream water body that will be receiving the stormwater discharge. Consequently, designers must determine the Use Designation of the watershed in which their project is located prior to design (see COMAR 26.08.02.08 and Appendix D.9).

In some cases, higher pollutant removal or environmental performance is needed to fully protect aquatic resources and/or human health and safety within a particular watershed or receiving water. Therefore, a shorter list of BMPs may need to be considered for selection within these watersheds or zones. The areas of concern include:

Maryland Critical Area Intensely Developed Areas. BMPs located within the Intensely Developed Area (IDA) of the Maryland Critical Area (a zone extending 1000 feet landward from mean high tide and the landward edge of tidal wetlands) shall demonstrate compliance with the "10% Rule." The rule mandates that post development stormwater phosphorus loads must be reduced to 10% below pre development loads, using the methodology developed by Herson et al. (1994). For a summary review of the 10% Rule and updated estimates of long term phosphorus pollutant removal rates please consult Appendix D.4.

Coldwater Streams (Use III and IV). Cold and cool water streams have habitat qualities capable of supporting trout and other sensitive aquatic organisms. Therefore, the design objective for these streams is to maintain habitat quality by preventing stream warming, maintaining natural recharge, preventing bank and channel erosion, and preserving the natural riparian corridor. Techniques for accomplishing these objectives may include:

- Minimizing the creation of impervious surfaces,
- Minimizing surface areas of permanent pools,
- Preserving existing forested areas,
- Bypassing existing baseflow and/or springflow, or
- Providing shade-producing landscaping

Some BMPs can have adverse downstream impacts on cold water streams and their use is highly restricted.

Sensitive Streams (e.g., streams with a watershed impervious cover less than 15%). These streams may also possess high quality cool water or warm water aquatic resources. The design objectives are to maintain habitat quality through the same techniques used for cold water streams, with the exception that stream warming is not as severe of a design constraint. These streams may also be specially designated by local authorities.

SARB_005281

Wellhead Protection. Areas that recharge existing public water supply wells present a unique management challenge. The key design constraint is to prevent possible groundwater contamination by preventing infiltration of hotspot runoff. At the same time, recharge of unpolluted stormwater is needed to maintain flow in streams and wells during dry weather.

Reservoir Protection (Use I-P, III-P and IV-P). Watersheds that deliver surface runoff to a public water supply reservoir or impoundment are of special concern. Depending on the treatment available at the water intake, it may be necessary to achieve a greater level of pollutant removal for the pollutants of concern such as bacteria pathogens, nutrients, sediment or metals. One particular management concern for reservoirs is ensuring that stormwater hotspots are adequately treated so that they do not contaminate drinking water.

Shellfish/Beach (Use II). Watersheds that drain to specific shellfish harvesting areas or public swimming beaches require a higher level of BMP treatment to prevent closings caused by bacterial contamination from stormwater runoff. In these watersheds, BMPs are explicitly designed to maximize bacteria removal.

Other Criteria. Designers should consult with the appropriate review authority to determine if their development project is subject to additional stormwater BMP criteria as a result of an adopted local watershed plan or protection zone.

SARB_005282

Table 4.1 BMP Selection - Watershed Factors

BMP GROUP	CRITICAL AREA	COLD WATER	SENSITIVE STREAM	AQUIFER PROTECTION	RESERVOIR PROTECTION	SHELLFISH BEACH
Ponds	Drainage Area may limit except for P-5, P-1 has lower removal rates	Restricted (see Appendix B.1.2) Offline design recommended Maximize shading of open pool areas	Require additional storage for control of Cp_v	May require liner if A soils are present Pretreat hotspots 2-4 ft SD*	Require control of Cp_v	Moderate bacteria removal, design to prevent geese problems, provide permanent pools
Wetlands	Drainage area may limit, W-4 excepted	May be restricted (see Appendix B.1.2)	Require additional storage for control of Cp_v	May require liner if A soils are present 2-4 ft SD*	Require control of Cp_v	Provide 48 hr ED for max. bacterial dieoff
Infiltration	Often infeasible due to soils or water table in tidal areas.	OK, if site has appropriate soils	OK, if site has appropriate soils	SD* from wells and water table No untreated hotspot runoff OK to infiltrate rooftop runoff	SD* from bedrock and water table	OK, but a min. 2 to 4 ft SD* is required
Filtering Systems	OK	OK, but evaluate for stream warming	May be necessary for pretreatment	OK, if designed w/out exfiltration	May be necessary for pretreatment prior to another BMP	OK, Moderate to high bacterial removal
Open Channels	OK	OK	Should be linked w/basin to provide Cp_v	OK, but hotspot runoff must be adequately pretreated	OK, but hotspot runoff must be adequately pretreated	Poor bacterial removal for O-2

*SD = Separation Distance or distance from well or water table to BMP.

SARB_005283

Section 4.2 Terrain Factors

Three key factors to consider are low-relief, karst and mountainous terrain. In Maryland, **Low Relief Areas** are located in the lower Eastern Shore, particularly below the Choptank River (see Figure 4.1 below). **Karst** and major carbonaceous rock areas are found in portions of Carroll, Frederick, Washington, and Garrett Counties. Mountainous areas are found in the Western part of the State. Special geotechnical testing requirements may be needed in karst areas (see Appendix D.2). The terrain regions shown on the map are approximate. Please consult with your local reviewing authority to determine if your project is subject to terrain constraints.

Figure 4.1 Map of Maryland Showing Key Terrain Factors

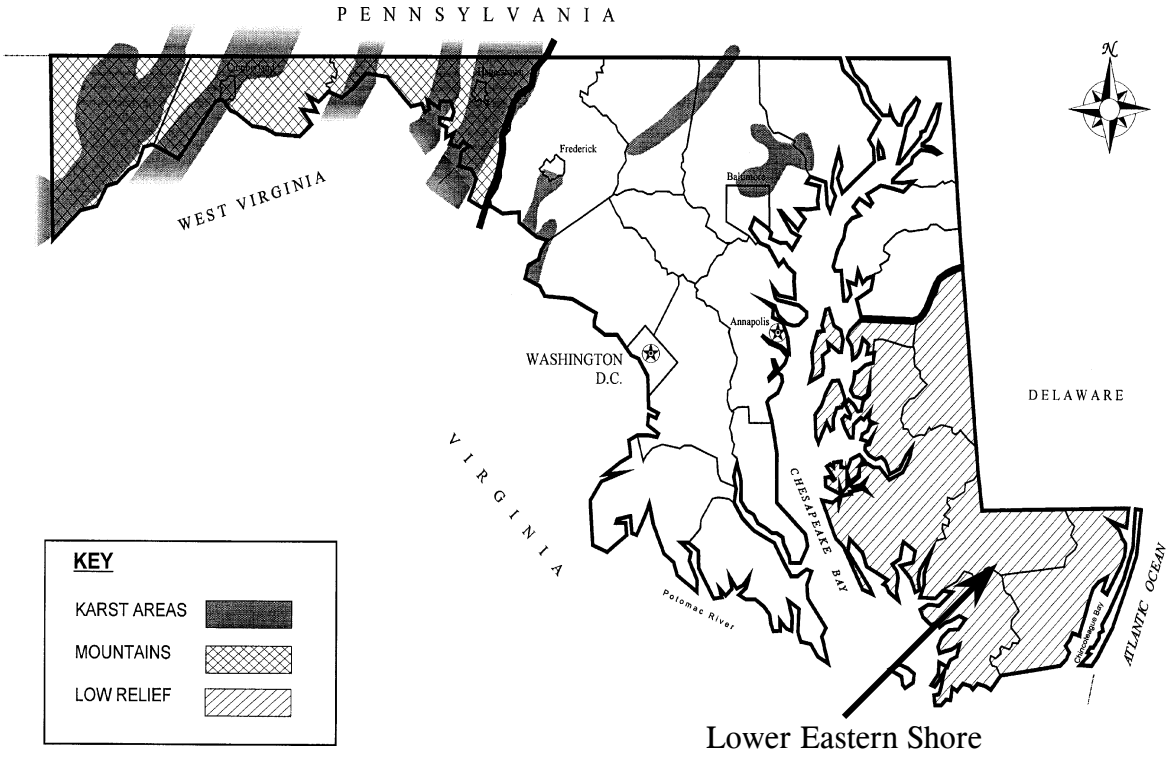

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Table 4.2 BMP Selection - Terrain Factors

BMP GROUP	LOW RELIEF	KARST	MOUNTAINOUS
Ponds	Maximum normal pool depth of 4 feet (dugout)	• geotechnical tests • max ponding depth • Require poly or clay liner	Embankment heights restricted
Wetlands	OK		Embankment heights restricted
Infiltration	Minimum distance to water table of 2 feet	May be prohibited. Consult with local approval authority.	Max slope 15% trenches must have flat bottom
Filtering Systems	Several designs limited by low head (F-1 and F-2)	Require poly-liner or impermeable membrane to seal bottom	OK
Open Channels	Generally feasible due to low slopes	OK	Often infeasible in steeper slopes

SARB_005285

Section 4.3 Stormwater Treatment Suitability

Table 4.3 examines the capability of each BMP option to meet the five stormwater treatment sizing criteria outlined in Chapter 2. Thus, it shows whether a BMP has:

Ability to Meet the Re_v. It should be noted that other practices, not on the BMP list, are capable of meeting the Re_v requirement (e.g., grass channel, filter, disconnection of rooftop runoff and other practices outlined in Chapter 5). Thus, if a BMP cannot meet the Re_v requirement, supplemental practices that can provide recharge may be needed.

Ability to Provide Cp_v. The table indicates whether the BMP can typically provide the Cp_v that is needed in some watersheds. The finding that a particular BMP cannot meet the Cp_v requirement does not necessarily imply that it should be eliminated from consideration, but is a reminder that more than one practice may be needed at a site (e.g., a bioretention area and a downstream pond).

Ability to Provide Q_{p2} and/or Q_{p10}. The table indicates whether the BMP can typically provide the Q_p criteria for the site. Again, the finding that a particular BMP cannot meet the requirement does not necessarily mean that it should be eliminated from consideration, but rather is a reminder that more than one practice may be needed at a site (e.g., a dry swale and a downstream pond)

Additional Safety Concerns. A comparative index expresses the potential need for additional safety features within a BMP. A "no" indicates no additional features are needed while a "yes" indicates deep pools may create potential safety risks. The safety factor is included at this stage of the screening process because liability and safety are a prime concern in many residential settings.

Adequate Space. This comparative index expresses how much space a BMP typically consumes at a site. A "yes" indicates that the BMP consumes a relatively small amount of land, whereas a "no" indicates the BMP may consume a relatively high fraction of land at the site. Again, this factor is included in this early screening stage because many BMPs are severely constrained by land consumption.

Ability to Accept Hotspot Runoff. This last column examines the capability of a BMP to treat runoff from designated hotspots as defined in Chapter 2. A BMP that receives hotspot runoff may have design restrictions as noted and may require additional measures to protect downstream resources from potential spills.

SARB_005286

Table 4.3 BMP Selection - Stormwater Treatment Suitability

CODE	BMP List	Re_v Ability	Cp_v Control	Qp Control	Additional Safety Concerns	SPACE	ACCEPT HOTSPOT RUNOFF
P-1	Micropool ED	No[1]	Yes	Yes	No	Yes	Yes[3]
P-2	Wet Pond	No[1]	Yes	Yes	Yes	Varies	Yes[3]
P-3	Wet ED Pond	No[1]	Yes	Yes	Yes	Yes	Yes[3]
P-4	Multiple Pond	No[1]	Yes	Yes	Yes	No	Yes[3]
P-5	Pocket Pond	No[1]	Yes	Yes	Varies	Yes	Yes[3]
W-1	Shallow Wetland	Varies[2]	Yes	Yes	No	No	Yes[3]
W-2	ED Wetland	Varies[2]	Yes	Yes	Varies	Varies	Yes[3]
W-3	Pond/Wetland	Varies[2]	Yes	Yes	Yes	No	Yes[3]
W-4	Pocket Wetland	No	Varies	Varies	No	Varies	Yes[3]
I-1	Infiltration Trench	Yes	Varies	Varies	No	Yes	No[3]
I-2	Infiltration Basin	Yes	Varies	Varies	No	Varies	No[3]
F-1	Surface Sand Filter	Varies[2]	Varies	Varies	No	Yes	Yes[4]
F-2	Underground SF	No	No	No	Varies	Yes	Yes
F-3	Perimeter SF	No	No	No	No	Yes	Yes
F-4	Organic Filter	Varies[2]	Varies	Varies	No	Yes	Yes[4]
F-5	Pocket Sand Filter	Varies[2]	Varies	Varies	No	Yes	Yes[4]
F-6	Bioretention	Yes	Varies	Varies	No	Varies	Yes[4]
O-1	Dry Swale	Yes	No	No	No	Varies	Yes[4]
O-2	Wet Swale	No	No	No	No	Varies	No

1 Structures that require impermeable liners or that intercept groundwater may not be used for groundwater recharge.

2 Re_v may be provided by exfiltration (see Chapter 3.4).

3 Not allowed unless pretreatment to remove hydrocarbons, trace metals, and toxicants is provided.

4 Yes, but only if bottom of facility is lined with impermeable filter fabric that prevents leachate infiltration.

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Section 4.4 Physical Feasibility Factors

At this point, the designer has narrowed the BMP list to a manageable size and can evaluate the remaining options given the physical conditions at a site. This table cross-references testing protocols needed to confirm physical conditions at the site. The six primary factors are:

Soils. The key evaluation factors are based on an initial investigation of the USDA hydrologic soils groups at the site. Note that more detailed geotechnical tests are usually required for infiltration feasibility and during design to confirm permeability and other factors (see Appendix D.1).

Water Table. This column indicates the minimum depth to the seasonally high water table from the bottom or floor of a BMP.

Drainage Area. This column indicates the recommended minimum or maximum drainage area that is considered suitable for the practice. If the drainage area present at a site is slightly greater than the maximum allowable drainage area for a practice, some leeway is permitted or more than one practice can be installed. The minimum drainage areas indicated for ponds and wetlands are flexible depending on water availability (baseflow or groundwater) or the mechanisms employed to prevent clogging.

Slope Restriction. This column evaluates the effect of slope on the practice. Specifically, the slope restrictions refer to how flat the area where the practice may be.

Head. This column provides an estimate of the elevation difference needed at a site (from the inflow to the outflow) to allow for gravity operation within the practice.

Ultra-Urban Sites. This column identifies BMPs that work well in the ultra-urban environment, where space is limited and original soils have been disturbed. These BMPs are frequently used at redevelopment sites.

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Table 4.4 BMP Selection - Physical Feasibility

CODE	BMP LIST	SOILS	WATER TABLE	DRAINAGE AREA (Acres)	SLOPE RESTRICT.	HEAD (Ft)	ULTRA URBAN
P-1	Micropool ED	"A" Soils May Require Pond Liner "B" Soils May Require Testing	4 Feet[1] If Hotspot Or Aquifer	10 Min[2]	None	6 to 8 Ft	Not Practical
P-2	Wet Pond			25 Min[2]			
P-3	Wet ED Pond						
P-4	Multiple Pond						
P-5	Pocket Pond	OK	Below WT	5 Max[3]		4 Ft	OK
W-1	Shallow Wetland	"A" Soils May Require Liner	4 Feet[1] If Hotspot Or Aquifer	25 Min	None	3 to 5 Ft	Not Practical
W-2	ED Wetland						
W-3	Pond/Wetland						
W-4	Pocket Wetland	OK	Below WT	5 Max		2 To 3 Ft	Depends
I-1	Infiltration Trench	$f \geq 0.52$ Inch/Hr	4 Feet[1]	5 Max	Installed in No More Than 15% Slopes	1 Ft	Depends
I-2	Infiltration Basin			10 Max		3 Ft	Not Practical
F-1	Surface Sand Filter	OK	2 Feet	10 Max [3]	None	5 Ft	Depends
F-2	Underground SF			2 Max [3]		5 to 7ft	OK
F-3	Perimeter SF			2 Max [3]		2 to 3 Ft	
F-4	Organic Filter			5 Max[3]		2 to 4 Ft	
F-5	Pocket SF			5 Max [3]		2 to 5 Ft	
F-6	Bioretention	Made Soil				5 Ft	
O-1	Dry Swale	Made Soil	2 Feet	5 Max	4% Max Cross-slope	3 to 5 Ft	Not Practical
O-2	Wet Swale	OK	Below WT	5 Max		1 Ft	

Notes: OK= not restricted, WT= water table

1 Four foot separation distance is maintained to the seasonally high water table (2 feet on Lower Eastern Shore).

2 Unless adequate water balance and anti-clogging device installed

3 Drainage area can be larger in some instances

SARB_005289

Section 4.5 Community and Environmental Factors

The fifth step assesses community and environmental factors involved in BMP selection. This table employs a comparative index approach indicating whether the BMP has a high or low benefit.

Ease of Maintenance. This column assesses the relative maintenance effort needed for a BMP in terms of three criteria: frequency of scheduled maintenance, chronic maintenance problems (such as clogging) and reported failure rates. It should be noted that **all BMPs** require routine inspection and maintenance.

Community Acceptance. This column assesses community acceptance as measured by three factors: market and preference surveys, reported nuisance problems, and visual aesthetics. It should be noted that a low rank can often be improved by a better landscaping plan.

Construction Cost. The BMPs are ranked according to their relative construction cost per impervious acre treated as determined from cost surveys and local experience.

Habitat Quality. BMPs are evaluated on their ability to provide wildlife or wetland habitat, assuming that an effort is made to landscape them appropriately. Objective criteria include size, water features, wetland features and vegetative cover of the BMP and its buffer.

Other Factors. This column indicates other considerations in BMP selection.

SARB_005290

Table 4.5 BMP Selection - Community and Environmental Factors

CODE	BMP LIST	EASE OF MAINTENANCE	COMMUNITY ACCEPTANCE	COST (Relative To Drainage Area)	HABITAT QUALITY	OTHER FACTORS
P-1	Micropool ED	Medium	Medium	Low	Medium	Trash/debris
P-2	Wet Pond	Easy	High	Low	High	
P-3	Wet ED Pond	Easy	High	Low	High	
P-4	Multiple Pond	Easy	High	Medium	High	
P-5	Pocket Pond	Difficult	Medium	Low	Low	Drawdowns
W-1	Shallow Wetland	Medium	High	Medium	High	
W-2	ED Wetland	Medium	Medium	Medium	High	Limit ED depth
W-3	Pond/Wetland	Difficult	High	Medium	High	
W-4	Pocket Wetland	Medium	Low	Low	Medium	Drawdowns
I-1	Infiltration Trench	Difficult	High	Medium	Low	Avoid large stone
I-2	Infiltration Basin	Medium	Low	Medium	Low	Frequent pooling
F-1	Surface SF	Medium	Medium	High	Low	
F-2	Underground SF	Difficult	High	High	Low	Underground ∴ Out of sight
F-3	Perimeter SF	Difficult	High	High	Low	Traffic Bearing
F-4	Organic Filter	Medium	High	High	Low	Filter Media Replacement
F-5	Pocket SF	Medium	Medium	Medium	Low	
F-6	Bioretention	Medium	Medium	Medium	Low	Landscaping
O-1	Dry Swale	Easy	High	Medium	Low	
O-2	Wet Swale	Easy	High	Low	Low	Mosquitoes Possible

SARB_005291

Section 4.6 Checklist: Location and Permitting Factors

In the last step, a designer assesses the physical and environmental features at the site to determine the optimal location for the selected BMP or group of BMPs. The checklist below provides a condensed summary of current BMP restrictions as they relate to common site features that may be regulated under local, State or federal law. These restrictions fall into one of three general categories:

1. Locating a BMP within an area that is expressly **prohibited** by law.

2. Locating a BMP within an area that is **strongly discouraged** and is only allowed on a case by case basis. Local, State and/or federal permits shall be obtained and the applicant will need to supply additional documentation to justify locating the BMP within the regulated area.

3. BMPs must be **setback** a fixed distance from the site feature.

This checklist is only intended as a general guide to location and permitting requirements as they relate to siting stormwater BMPs. Consultation with the appropriate regulatory agency is the best strategy.

The symbol "✔" denotes when an MDE Nontidal Wetland And Waterways Permit shall be obtained.

SARB_005292

Table 4.6 Location and Permitting Factors Checklist

SITE FEATURE	LOCATION AND PERMITTING GUIDANCE
❑ **Jurisdictional Wetland** U.S. Army Corps of Engineers Section 404 Permit and/or MDE Wetlands Permit ✔	• wetlands should be delineated prior to siting stormwater BMPs. • use of wetlands for stormwater treatment **strongly discouraged** and requires State and federal permit. • BMPs are also **restricted** in the 25 to 100 foot required wetland buffer. • buffers may be utilized as a non-structural filter strip (e.g., accept sheetflow). • must justify that no practical upland treatment alternatives exist. • stormwater must be treated prior to discharge into a wetland. • where practical, excess stormwater flows should be conveyed away from jurisdictional wetlands.
❑ **Stream Channel** (Waters of the U.S) U.S. Army Corps of Engineers (COE) Section 404 Permit MDE Wetlands and Waterways Permit ✔	• stream channels should be delineated prior to design using MDE criteria. • instream ponds require MDE review and permit. • instream ponds are **prohibited** in Use III waters. • ponds located within USE III watersheds may require small pond review and approval from the MDE Dam Safety Division. • must justify that no practical upland treatment alternatives exist. • Q_p and Cp_v treatment is preferred over WQ_v treatment. • implement measures that reduce downstream warming.
❑ **100 Year Floodplain** Local Stormwater review Authority MDE Wetlands and Waterways Permit ✔	• grading and fill for BMP construction is **strongly discouraged** within the ultimate 100 year floodplain, as delineated by FEMA flood insurance rate, FEMA flood boundary and floodway, or local floodplain maps. • floodplain fill cannot raise the floodplain water surface elevation by more than a tenth of a foot.
❑ **Stream Buffer** Check with appropriate review authority whether stream buffers are required	• consult local authority for stormwater policy. • ponds located within 100 feet of a flowing stream in a USE III watershed may require a small pond approval by the MDE Dam Safety Division • BMPs are **strongly discouraged** in the stream-side zone (within 25 feet of streambank). • consider how outfall channel will cross buffer to reach stream. • BMPs can be located within the outer portion of a buffer.

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Table 4.6 Location and Permitting Factors Checklist (Continued)

SITE FEATURE	LOCATION AND PERMITTING GUIDANCE
❑ **Forest Conservation** District Forest Conservation Review Authority	• BMPs are **strongly discouraged** within Priority 1 Forest Retention Areas. • BMPs must be **setback** at least 25 feet from the critical root zone of specimen trees, or • designers should consider the effect of more frequent inundation for Q_p, Cp_v and WQ_v on existing forest stands. • BMP buffer areas are acceptable as reforestation sites if they are protected by a conservation agreement
❑ **Critical Area** Local Critical Area Review Authority	• BMPs w/in the Critical Area shoreline buffer are prohibited unless a variance is obtained from the local review authority. • BMPs are acceptable within mapped buffer exemption areas. • BMPs in the IDA must meet the 10% Rule - see Appendix D.4.
❑ **Utilities** Local Review Authority	• call Miss Utility to locate existing utilities prior to design. • note the location of proposed utilities to serve development. • BMPs are **discouraged** within utility easements or rights of way for public or private utilities.
❑ **Roads** Local DOT, DPW, or State Highway Administration	• consult local DOT or DPW for any **setback** requirement from local roads. • consult SHA for setbacks from State maintained roads. • approval must also be obtained for any stormwater discharges to a local or State-owned conveyance channel.
❑ **Structures** Local Review Authority	• consult local review authority for BMP **setbacks** from structures. • recommended *setbacks* for each BMP group are provided in the performance criteria in Chapter 3 of this manual.
❑ **Septic Drain fields**	• consult local health authority. • recommended **setback** is a minimum of 50 feet from drain field edge.
❑ **Water Wells** Local Health Authority	• 100 foot **setback** for stormwater infiltration. • 50 foot **setback** for all other BMPs. • water appropriation permit needed if well water used for water supply to a BMP.
❑ **Sinkholes**	• infiltration or pooling of stormwater near sinkholes is **prohibited.** • geotechnical testing may be required within karst areas (see Appendix D.2).

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Chapter

5.0

Stormwater Credits for Innovative Site Planning

5.0 Stormwater Credits

In Maryland, there are many programs at both the State and local level that seek to minimize the impact of land development. Critical Areas, forest conservation, and local stream buffer requirements are designed to reduce nonpoint source pollution. Non-structural practices can play a significant role in reducing water quality impacts and are increasingly recognized as a critical feature of every stormwater BMP plan, particularly with respect to site design. In most cases, non-structural practices must be combined with structural practices to meet stormwater requirements. The key benefit of non-structural practices is that they can reduce the generation of stormwater from the site; thereby reducing the size and cost of stormwater storage. In addition, they can provide partial removal of many pollutants. Non-structural practices have been classified into six broad groups and are designed to mesh with existing state and local programs (e.g., forest conservation, stream buffers etc.). To promote greater use, a series of six stormwater credits are provided for designers that use these site planning techniques.

Credit 1.	Natural Area Conservation
Credit 2.	Disconnection of Rooftop Runoff
Credit 3.	Disconnection of Non Rooftop Runoff
Credit 4.	Sheet Flow to Buffers
Credit 5.	Open Channel Use
Credit 6.	Environmentally Sensitive Development

This chapter describes each of the credits for the six groups of non-structural practices, specifies minimum criteria to be eligible for the credit, and provides an example of how the credit is calculated. Designers should check with the appropriate approval authority to ensure that the credit is applicable to their jurisdiction. Clearly both of the site designs used to illustrate the credits could be more creative to provide more non-structural opportunities.

In general, the stormwater sizing criteria provide a strong incentive to reduce impervious cover at development sites (e.g., Re_v, WQ_v, Cp_v or Qp and Qf). Storage requirements for all five stormwater sizing criteria are directly related to impervious cover. Thus, significant reductions in impervious cover result in smaller required storage volumes and, consequently, lower BMP construction costs.

These and other site design techniques can help to reduce impervious cover, and consequently, the stormwater treatment volume needed at a site. The techniques presented in this chapter are considered options to be used by the designer to help reduce the need for stormwater BMP storage capacity. Due to local safety codes, soil conditions, and topography, some of these site design features will be restricted. Designers are encouraged to consult with the appropriate approval authority to determine restrictions on non-structural strategies.

NOTE: In this chapter, *italics* indicate mandatory performance criteria, whereas suggested design criteria are shown in normal typeface.

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These credits are an integral part of a project's overall stormwater management plan and BMP storage volume calculation. Therefore, use of these credits shall be documented at the initial (concept) design stage, documented with submission of final grading plans, and verified with "as-built" certifications. If a planned credit is not implemented, then BMP volumes shall be increased appropriately to meet Re_v, WQ_v, Cp_v, and Q_p where applicable.

Table 5.1 Summary of Stormwater Credits

Stormwater Credit	**WQ_v**	**Re_v**	**Cp_v or Q_p**
Natural Area Conservation	Reduce Site Area	No credit. Use as receiving area w/Percent Area Method.	Forest/meadow CN for natural areas
Disconnection of Rooftop Runoff	Reduced R_v	No credit. Use with Percent Area Method.	Longer t_c (increased flow path). CN credit.
Disconnection of Non-Rooftop Runoff	Reduced R_v	No credit. Use with Percent Area Method.	Longer t_c (increased flow path) CN credit
Sheet Flow to Buffers	Subtract contributing site area to BMP	Reduced Re_v	CN credit
Open Channel Use	May meet WQ_v	Meets Re_v	Longer t_c (increased flow path) No CN credit
Environmentally Sensitive Development	Meets WQ_v	Meets Re_v	No CN credit t_c may increase

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Section 5.1 Natural Area Conservation Credit

Natural Area Conservation Credit

A stormwater credit is given when natural areas are conserved at development sites, thereby retaining pre development hydrologic and water quality characteristics. A simple WQ_v credit is granted for all conservation areas permanently protected under conservation easements or other locally acceptable means. Examples of natural area conservation include:

- forest retention areas
- non-tidal wetlands and associated buffers
- other lands in protective easement (floodplains, open space, steep slopes)
- stream systems

Under the credit, a designer can subtract conservation areas from total site area when computing the water quality volume. The volumetric runoff coefficient, R_v, is still calculated based on the percent impervious cover for the entire site.

As an additional incentive, the post development curve number (CN) used to compute the Cp_v or Qp_2, and Qp_{10} for all natural areas protected by conservation easements can be assumed to be woods in good condition when calculating the total site CN.

As an example, the required WQ_v for a ten acre site with three acres of impervious area and three acres of protected conservation area before the credit would be:

$WQ_v = [(P)(R_v)(A)]/12$; where $P = 1$", $R_v = 0.05 + 0.009(30\%)$
$WQ_v = [(1")\ (0.32)(10\ \text{acres})]/12 = 0.266$ acre-feet.

Under the credit, three acres of conservation are subtracted from total site area, which yields a smaller storage volume:

$WQ_v = [(P)(R_v)(A)]/12$; where $P = 1$", $R_v = 0.05 + 0.009(30\%)$
$WQ_v = [(1")(0.32)(10\text{-}3\ \text{acres})]/12 = 0.187$ acre-feet.

The recharge requirement (Re_v) is not reduced using this credit.

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Criteria for Natural Area Credit

To receive the credit, the proposed conservation area:

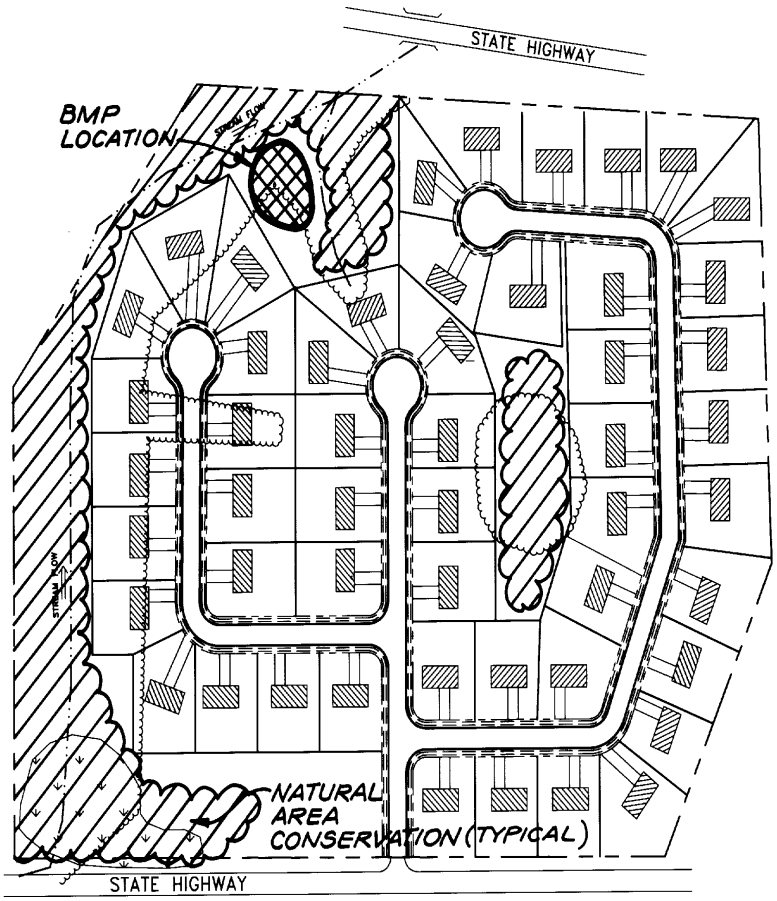
- *Shall not be disturbed during project construction (e.g., cleared or graded) except for temporary impacts associated with incidental utility construction or mitigation and afforestation projects,*

- *Shall be protected by having the limits of disturbance clearly shown on all construction drawings and delimited in the field except as provided for above,*

- *Shall be located within an acceptable conservation easement or other enforceable instrument that ensures perpetual protection of the proposed area. The easement must clearly specify how the natural area vegetation shall be managed and boundaries will be marked* [Note: managed turf (e.g., playgrounds, regularly maintained open areas) is not an acceptable form of vegetation management]*, and*
- *Shall be located on the development project*.

Example of Calculating Natural Area Credit

Site Data - 51 Single Family Lots
Area = 38 ac.
Conservation Area = 7.0 ac
Impervious Area = 13.8 ac
R_v = .38, P= 0.9"
Post dev. CN = 78
Original WQ_v = 1.08 ac-ft.
Original Re_v = .25 ac-ft.
Original Cp_v = 1.65 ac-ft.
Original Qp_{10} = 2.83 ac-ft.



Computation of Stormwater Credits

WQ_v = [(P)(R_v)(A)]/12
= [(0.9)(.38)(38.0 - 7.0 ac.)]/12
= 0.89 ac-ft

Re_v = Same as original
(However, area draining to Natural Area may used with the Percent Area Method)

Cp_v and Q_{p10} (total site): CN reduced from 78 to 75

Section 5.2 Disconnection of Rooftop Runoff Credit

Disconnection of Rooftop Runoff Credit

A credit is given when rooftop runoff is disconnected and then directed to a pervious area where it can either infiltrate into the soil or filter over it. The credit is typically obtained by grading the site to promote overland filtering or by providing bioretention areas on single family residential lots.

If a rooftop is adequately disconnected, the disconnected impervious area may be deducted from total impervious cover (therefore reducing WQ_v). In addition, disconnected rooftops can be used to meet the Re_v requirement as a non-structural practice using the percent area method (see Chapter 2).

Post development CN's for disconnected rooftop areas used to compute Cp_v and Qp can be assumed to be woods in good condition.

Criteria for Disconnection of Rooftop Runoff Credit

The credit is subject to the following restrictions:

- *Rooftop cannot be within a designated hotspot,*
- *Disconnection shall cause no basement seepage,*
- *The contributing area of rooftop to each disconnected discharge shall be 500 square feet or less,*
- *The length of the "disconnection" shall be 75' or greater, or compensated using Table 5.2,*
- *Dry wells, french drains, rain gardens, or other similar storage devices may be utilized to compensate for areas with disconnection lengths less than 75 feet. (See Table 5.2 and Figure 5.1, dry wells are prohibited in "D" soils),*
- *In residential development applications, disconnections will only be credited for lot sizes greater than 6000 sq. ft.,*
- *The entire vegetative "disconnection" shall be on an average slope of 5% or less,*
- *The disconnection must drain continuously through a vegetated channel, swale, or through a filter strip to the property line or BMP,*
- *Downspouts must be at least 10 feet away from the nearest impervious surface to discourage "re-connections", and*
- *For those rooftops draining directly to a buffer, only the rooftop disconnection credit or the buffer credit may be used, not both.*

Figure 5.1 Schematic of Dry Well

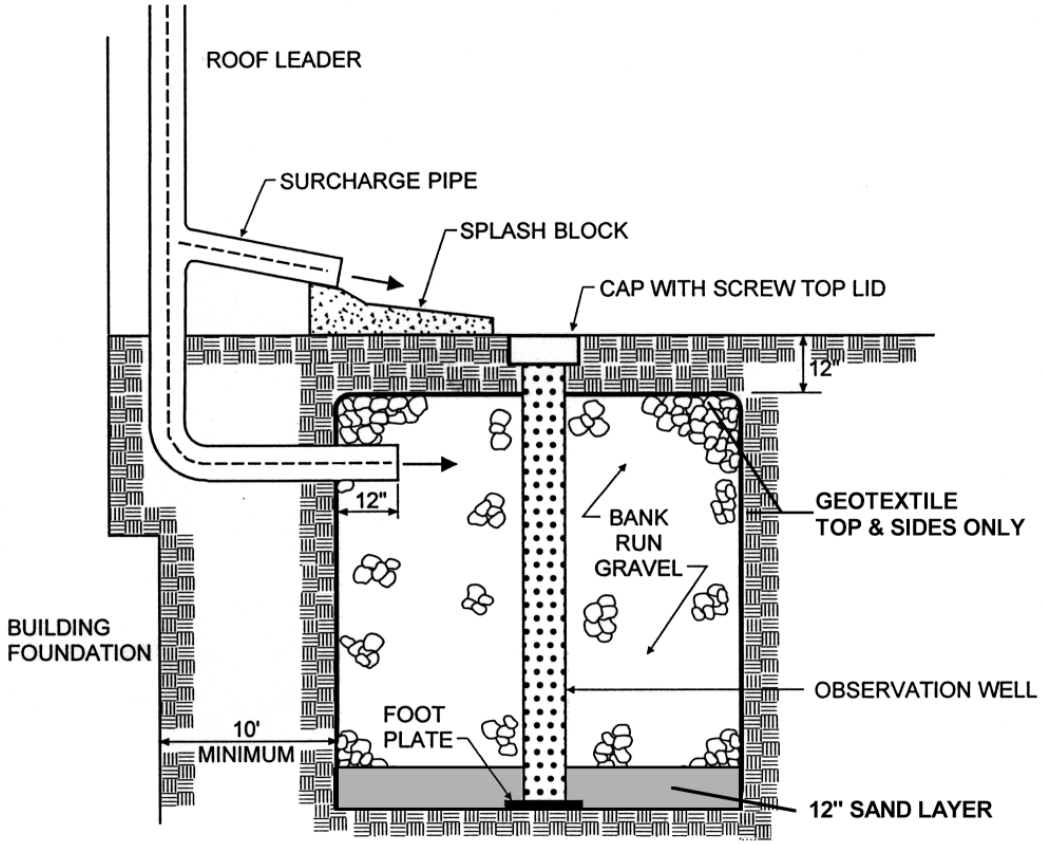


Table 5.2 Rooftop Disconnection Compensation Storage Volume Requirements
(Per Disconnection Using Drywells, Raingardens, etc.)

Disconnection Length Provided	0 - 14 ft.	15 - 29 ft.	30 - 44 ft.	45 - 59 ft.	60 - 74 ft.	≥ 75 ft.
% WQ_v Treated by Disconnect	0%	20%	40%	60%	80%	100%
% WQ_v Treated by Storage	100%	80%	60%	40%	20%	0%
Max. Storage Volume* (Eastern Rainfall Zone)	40 cu-ft.	32 cu-ft.	24 cu-ft.	16 cu-ft.	8 cu-ft.	0 cu-ft.
Max. Storage Volume* (Western Rainfall Zone)	36 cu-ft.	28.8 cu-ft.	21.6 cu-ft.	14.4 cu-ft.	7.2 cu-ft.	0 cu-ft.

*Assuming 500 square feet roof area to each downspout.

Example of Using the Rooftop Disconnection Credit

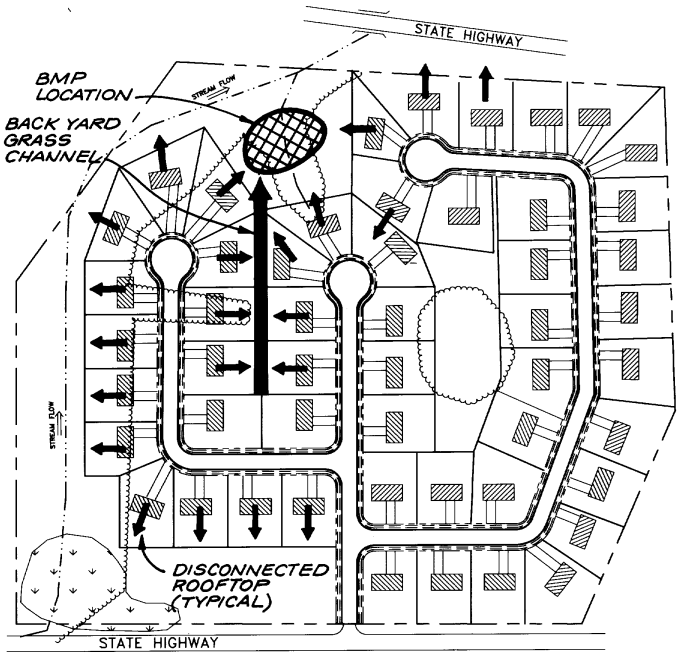
Site Data - 51 Single Family Lots
Area = 38 ac., ½ acre lots
Original Impervious Area = 13.80 ac.
Original R_v = .38
Post dev. CN = 78
# of Disconnected Rooftops = 22
Original WQ_v = 1.08 ac-ft
Original Re_v = 0.25 ac-ft
Original Cp_v = 1.65 ac-ft
Original Qp_v = 2.83 ac-ft

60% B Soils
40% C Soils
Composite S=0.208 (20.8%)

22 Lots Disconnected w/5 Downspouts each.
∴ 2500 sq. ft. each lot

Net impervious area reduction = (22)(2500)/43560 = 1.3 ac

Net Impervious Area =
13.8 - 1.3 = 12.5 acres



Computation of Stormwater Credit:

New R_v = 0.05 + .009 (12.5 ac/38 ac) = .35
∴ WQ_v = [(0.9)(.35)(38 ac)]/12 = 1.00 ac-ft.

Required Re_v (Percent Area Method)
Re_v = 20.8% × 13.8 ac. = 2.87 acres
Re_v treated by disconnection = 1.3 acres
Re_v remaining for treatment = 1.57 acres non structurally or 0.14 acre-feet structurally

Cp_v and Q_p (total site): CN reduced from 78 to 76

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Section 5.3 Disconnection of Non Rooftop Runoff Credit

Disconnection of Non Rooftop Runoff Credit

Credit is given for practices that disconnect surface impervious cover runoff by directing it to pervious areas where it is either infiltrated into the soil or filtered (by overland flow). This credit can be obtained by grading the site to promote overland vegetative filtering or providing bioretention areas on single family residential lots.

These "disconnected" areas can be subtracted from the impervious area when computing WQ_v. In addition, disconnected surface impervious cover can be used to meet the Re_v requirement as a non-structural practice using the percent area method (See Chapter 2).

Criteria for Disconnection of Non Rooftop Runoff Credit

The credit is subject to the following restrictions:

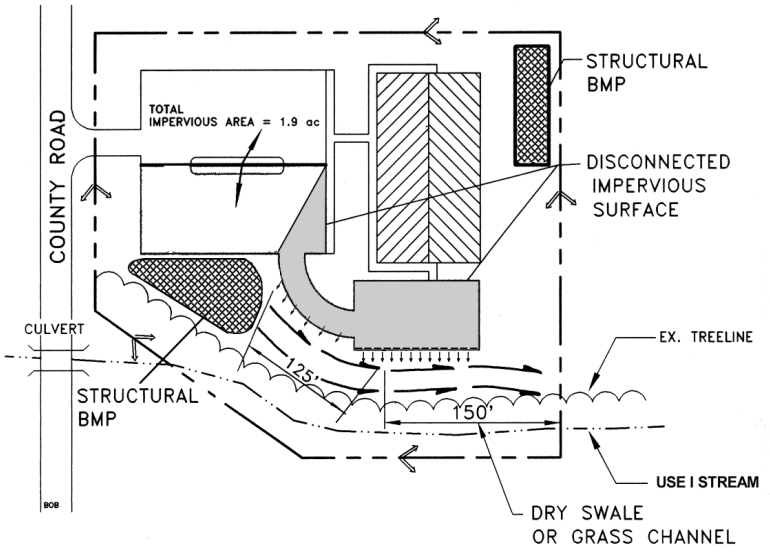
- *Runoff cannot come from a designated hotspot,*
- *The maximum contributing impervious flow path length shall be 75 feet,*
- *The disconnection shall drain continuously through a vegetated channel, swale, or filter strip to the property line or BMP,*
- *The length of the "disconnection" must be equal to or greater than the contributing length,*
- *The entire vegetative "disconnection" shall be on an average slope of 5% or less,*
- *The surface impervious area to any one discharge location cannot exceed 1,000 ft^2.*
- *Disconnections are encouraged on relatively permeable soils (HSG's A and B),*
- *If the site cannot meet the required disconnect length, a spreading device, such as a french drain, rain garden, gravel trench or other storage device may be needed for compensation, and*
- *For those areas draining directly to a buffer, only the non rooftop disconnection credit or the stream buffer credit can be used, not both.*

Example of Calculating the Non Rooftop Disconnection Credit

Site Data -Community Center
Area = 3.0 ac
Original Impervious Area = 1.9 ac. = 63.3%
Original R_v = .62
Post dev. CN = 83
B Soils, S = 0.26
Original WQ_v = 6752 ft^3
Original Re_v = 1688 ft^3
Original Cp_v = N/A
Original Qp_2 = 10,630 ft^3

0.33 ac of surface imperviousness disconnected

Net impervious area reduction
1.9 - 0.33 = 1.57 ac.



Computation of Stormwater Credit:

New $R_v = 0.05 + .009\ (1.57\ ac/3.0\ ac) = .52$
$\therefore WQ_v = [(1.0)(0.52)(3.0\ ac)]/12 = 0.13$ ac-ft (5662.8 cf)

Required Re_v (Percent area method)
$Re_v = (S)(A_i) = (0.26)(1.9\ ac.) = 0.49$ acres
Re_v treated by disconnection = 0.33 acres
Re_v remaining for treatment = 0.16 acres non structurally or 551.2 cf structurally

Cp_v and Q_p Post developed CN may be reduced

Section 5.4 Sheetflow to Buffer Credit

Sheetflow to Buffer Credit

This credit is given when stormwater runoff is effectively treated by a natural buffer to a stream or forested area. Effective treatment is achieved when pervious and impervious area runoff is discharged to a grass or forested buffer through overland flow. The use of a filter strip is also recommended to treat overland flow in the green space of a development site. The credits include:

1. The area draining by sheet flow to a buffer is subtracted from the total site area in the WQ_v calculation.
2. The area draining to the buffer contributes to the recharge requirement, Re_v.
3. A *wooded* CN can be used for the contributing area if it drains to a forested buffer.

Criteria for Sheetflow to Buffer Credit

The credit is subject to the following conditions:

- *The minimum buffer width shall be 50 feet as measured from bankfull elevation or centerline of the buffer,*
- *The maximum contributing length shall be 150 feet for pervious surfaces and 75 feet for impervious surfaces,*
- *Runoff shall enter the buffer as sheet flow. Either the average contributing overland slope shall be 5.0% or less, or a level spreading device shall be used where sheet flow can no longer be maintained (see Detail No. 9 in Appendix D.8),*
- *Not applicable if rooftop or non rooftop disconnection is already provided (see Credits 2 & 3),*
- *Buffers shall remain unmanaged other than routine debris removal, and*
- *Shall be protected by an acceptable conservation easement or other enforceable instrument that ensures perpetual protection of the proposed area. The easement must clearly specify how the natural area vegetation shall be managed and boundaries will be marked* [Note: managed turf (e.g., playgrounds, regularly maintained open areas) is not an acceptable form of vegetation management].

Figure 5.2 illustrates how a buffer or filter strip can be used to treat stormwater from adjacent pervious and impervious areas.

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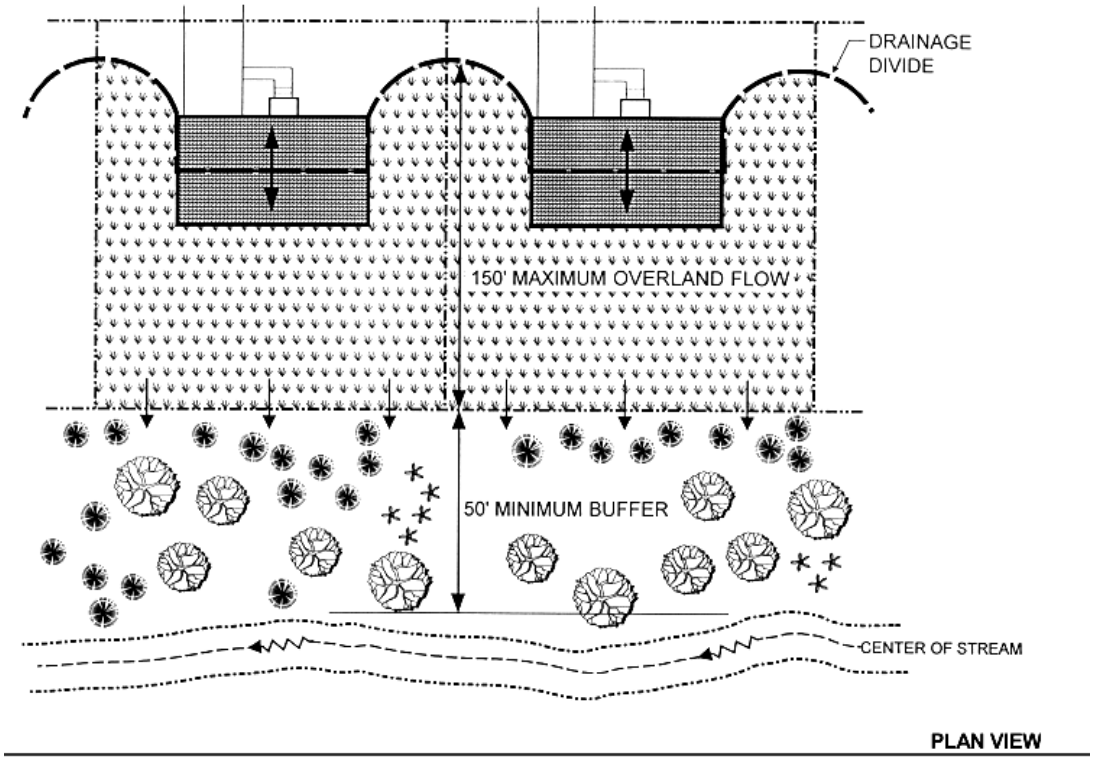
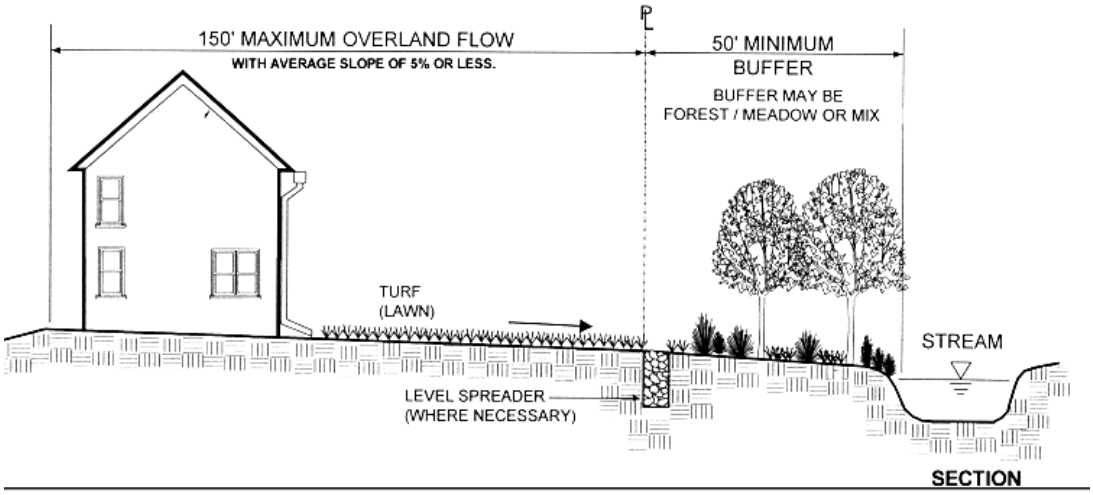
Figure 5.2 Example of Sheetflow to Buffer Credit



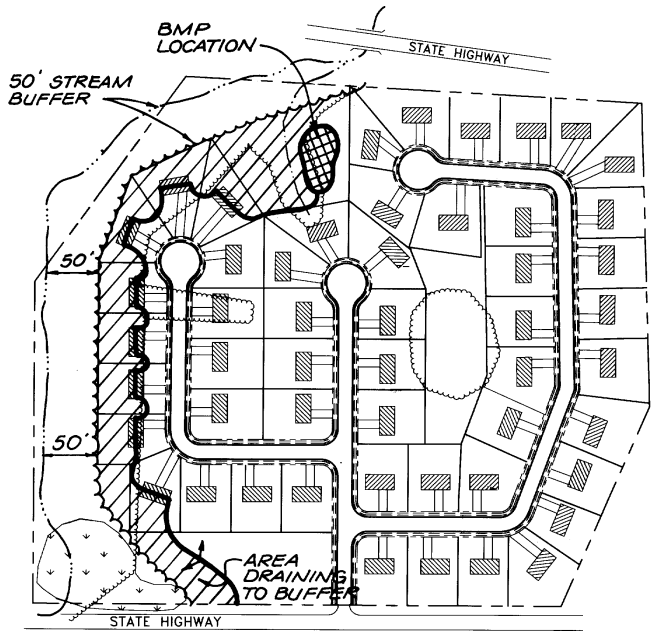


Example of Using the Sheetflow to Buffer Credit

Site Data - 51 Single Family
Area = 38.0 ac
Original Impervious Area = 13.8 ac = 36.3%
Original R_v = .38
Post-dev. CN = 78

Original WQ_v = 1.08 ac-ft
Original Re_v = 0.24 ac-ft
Original Cp_v = 1.65 ac-ft
Original Qp_v = 2.83 ac-ft

Credit
5.0 ac draining to buffer/filter strip
Rooftops represent 3% of site imperviousness = 0.41 acres



Computation of Stormwater Credits

New drainage area = 38 ac.– 5 ac.= 33.0 acres
R_v remains unchanged to BMP; $R_v = 0.05 + 0.009(36.3) = 0.38$

$WQ_v = [(P)(R_v)(A)]/12$
$= [(0.9)(0.38)(33.0 \text{ ac.})]/12$
$= 0.94$ ac-ft

Required Re_v (Percent Area Method)
$Re_v = 20.8\% \times 13.8$ ac. = 2.87 acres
Re_v treated by disconnection = 0.41 acres
Re_v remaining for treatment = 2.46 acres non structurally or 0.214 ac-ft structurally

Cp_v and Q_p (total site): CN is reduced slightly.

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Section 5.5 Grass Channel Credit

Grass Channel Credit (in lieu of Curb and Gutter):

Credit may be given when open grass channels are used to reduce the volume of runoff and pollutants during smaller storms (e.g., < 1 inch). The schematic of the grass channel is provided in Figure 5.3.

Use of a grass channel will automatically meet the Re_v for impervious areas draining into the channel. However, Re_v for impervious areas not draining to grass channels must still be addressed. If designed according to the following criteria, the grass channel will meet the WQ_v as well.

CNs for channel protection or peak flow control (Cp_v or Q_p) will not change.

Criteria for the Grass Channel Credit

The WQ_v credit is obtained if a grass channel meets the following criteria:

- *The maximum flow velocity for runoff from the one-inch rainfall shall be less than or equal to 1.0 fps (see Appendix D.10 for methodology to compute flowrate),*
- *The maximum flow velocity for runoff from the ten-year design event shall be non erosive,*
- *The bottom width shall be 2 feet minimum and 8 feet maximum,*
- *The side slopes shall be 3:1 or flatter,*
- *The channel slope shall be less than or equal to 4.0%, and*
- *Not applicable if rooftop disconnection is already provided (see Credit 2).*

An example of a grass channel is provided in Figure 5.3.

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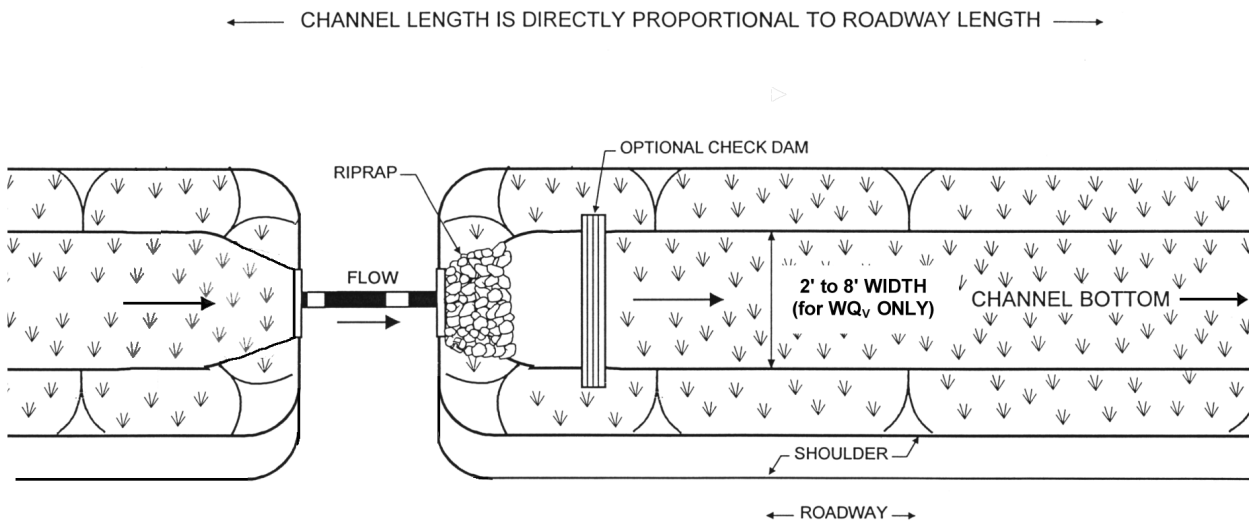
Figure 5.3 Example of Grass Channel



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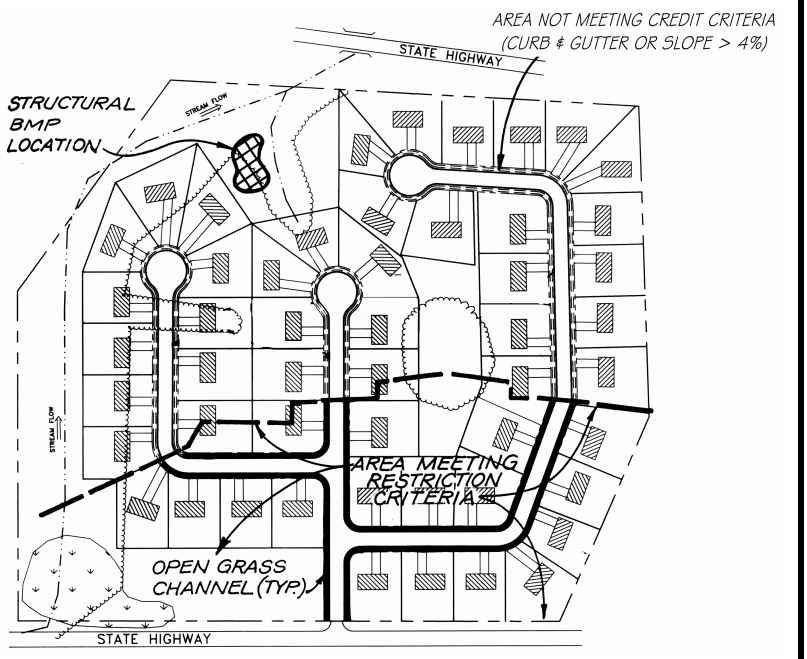
Example of Grass Channel Credit

Site Data - 51 Single Family Residences
Area = 38.0 ac
Original Impervious Area = 13.8 = 36.3%
R_v = .38
CN = 78

Original WQ_v = 1.08 ac-ft
Original Re_v = 0.25 ac-ft
Original Cp_v = 1.65 ac-ft
Original Qp_v = 2.83 ac-ft

Credit
12.5 acres meet grass channel criteria



Computation of Stormwater Credits

New WQ_v Area = 38 ac - 12.5 ac = 25.5 ac
WQ_v = [(0.9)(0.38)(25.5 ac.)]/12
= 0.74 ac-ft

Required Re_v (Percent Area Method)
Re_v =20.8%×13.8 ac. =2.87 acres
4.5 acres of imperviousness lie within area drained by grass channels, and
4.5 acres > 2.87 acres
∴ Re_v requirement is met.
Cp_v and Q_p: No change

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Section 5.6 Environmentally Sensitive Development Credit

Environmentally Sensitive Development

Credit is given when a group of environmental site design techniques are applied to low density or residential development. The credit eliminates the need for structural practices to treat both the Re_v and WQ_v and is intended for use on large lots.

Criteria for Environmentally Sensitive Development Credit

These criteria can be met without the use of structural practices in certain low density residential developments when the following conditions are met:

For Single Lot Development:

- *total site impervious cover is less than 15%,*
- *lot size shall be at least two acres,*
- *rooftop runoff is disconnected in accordance with the criteria outlined in Section 5.2, and*
- *grass channels are used to convey runoff versus curb and gutter.*

For Multiple Lot Development:

- *total site impervious cover is less than 15%,*
- *lot size shall be at least two acres if clustering techniques are not used,*
- *if clustering techniques are used, the average lot size shall not be greater than 50% of the minimum lot size as identified in the appropriate local zoning ordinance and shall be at least one half acre,*
- *rooftop runoff is disconnected in accordance with the criteria outlined in Section 5.2,*
- *grass channels are used to convey runoff versus curb and gutter,*
- *a minimum of 25% of the site is protected in natural conservation areas (by permanent easement or other similar measure), and*
- *the design shall address stormwater (Re_v, WQ_v, Cp_v, and/or Qp_{10}) for all roadway and connected impervious surfaces.*

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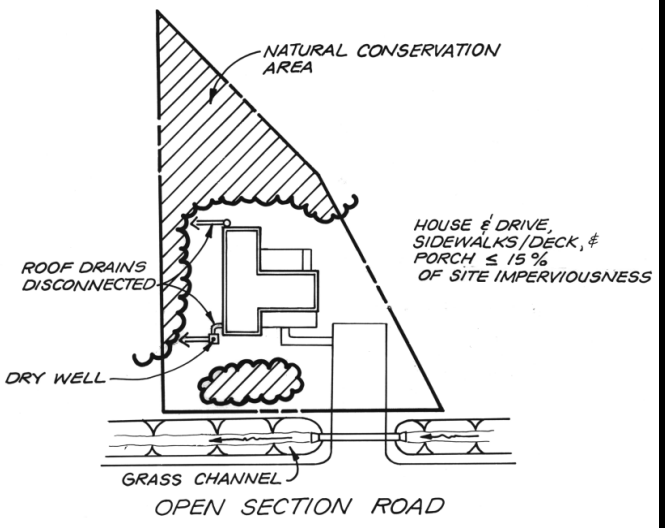
Example of Environmentally Sensitive Development

Site Data - 1 Single Family Lot
Area = 2.5 ac
Conservation Area = 0.6 ac
Impervious Area = .35 ac (includes adjacent road surface) = 14%
B soils
Eastern Rainfall Zone for WQ_v
$R_v = 0.05+0.009(14) = .18$
CN = 65

WQ_v : Use P=0.2 as I<15%
$WQ_v = [(0.2)(A)]/12$
$= [(0.2)(2.5)]/12\times(43560\ ^{ft}/_{ac.})$
$= 1{,}815\ ft^3$
$Re_v = [(S)(R_v)(A)]/12$
$= [(0.26)(0.18)(2.5)]/12\times(43{,}560^{ft}/_{ac.})$
$= 424.7\ ft^3$



Computation of Stormwater Credits:

WQ_v is met by site design
Re_v is met by site design
Cp_v and Q_p: No change in CN, t_c may be longer which would reduce Q_p requirements

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Section 5.7 Dealing with Multiple Credits

Site designers are encouraged to utilize as many credits as they can on a site. Greater reductions in stormwater storage volumes can be achieved when many credits are combined (e.g., disconnecting rooftops and protecting natural conservation areas). However, credits cannot be claimed twice for an identical area of the site (e.g. claiming credit for stream buffers and disconnecting rooftops over the same site area).

Section 5. 8 Other Strategies to Reduce Impervious Cover

Definition: Site planning practices that reduce the creation of impervious area in new residential and commercial development and therefore reduce the WQ_v for the site.

Examples of progressive site design practices that minimize the creation of impervious cover include:

- Narrower residential road sections
- Shorter road lengths
- Smaller turnarounds and cul-de-sac radii
- Permeable spill-over parking areas
- Smaller parking demand ratios
- Smaller parking stalls
- Angled one way parking
- Subdivisions with open space
- Smaller front yard setbacks
- Shared parking and driveways
- Narrower sidewalks

It should be noted that most site designers may have little ability to control these requirements, which are typically enshrined in local subdivision, parking and/or street codes.

Where these techniques are employed, it may be possible to reduce stormwater storage volumes. For example, because the WQ_v is directly based on impervious cover, a reduction in impervious cover reduces WQ_v. For Cp_v and Qp, the designer can compute curve numbers (CN) based on the actual measured impervious area at a site using:

$$CN = \frac{(98)I + \sum (CN)(P)}{A}$$

where:

CN = curve number for the appropriate pervious cover
I = impervious area at the site
P = pervious area at the site
A = total site area

SARB_005315

MARYLAND DEPARTMENT OF THE ENVIRONMENT

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Secretary

Instruction Sheet

COMAR 26.17.02.01-1

Title: 2000 Maryland Stormwater Design Manual, Vol. I & II
(Maryland Department of the Environment, April 2000)

Proposed Supplement No. Notice of Final Action

To: INTERESTED PARTIES

Instructions: The document 2000 Maryland Stormwater Design Manual, Volumes I & II is being proposed for adoption. This submittal includes the following **REVISED** pages (all pages are inclusive):

Chapter 1:	1.15—1.16
Chapter 2:	2.3—2.8 2.13—2.14
Chapter 3:	3.9—3.16 3.39—3.40
Chapter 4:	4.9—4.10 4.13—4.14
Chapter 5:	5.1—5.2 5.5—5.6 5.9—5.12
Appendix B.2:	B.2.1—B.2.4
Appendix B.3:	Title Page B.3.5—B.3.10
Appendix C.1:	C.1.1—C.1.2
Appendix C.2:	Title Page C.2.1—C.2.29
Appendix D.1:	D.1.3—D.1.4

Check to make certain that you have all the pages listed above. Please remove and replace the existing pages with these revised pages.

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Baltimore, MD 21224
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prevention plan requirement applies to both existing and new industrial sites.

*Standard No. **13*** *Stormwater discharges from land uses or activities with higher potential for pollutant loadings, defined as hotspots in Chapter 2, may require the use of specific structural BMPs and pollution prevention practices. In addition, stormwater from a hotspot land use may not be infiltrated without proper pretreatment.*

.

*Standard No. **14*** *In Maryland, local governments are usually responsible for most stormwater management review authority. Therefore, prior to design, applicants should always consult with their local reviewing agency to determine if they are subject to additional stormwater design requirements. In addition, certain earth disturbances may require NPDES construction general permit coverage from MDE (see Appendix D.7).*

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Section 1.3 How to Use the Manual

The Maryland Stormwater Design Manual is provided in two volumes. This *first volume* provides designers a general overview on how to size, design, select and locate BMPs at a new development site to comply with State stormwater performance standards. The *second volume* contains appendices with more detailed information on landscaping, BMP construction specifications, step-by-step BMP design examples and other assorted design tools.

Section 1.3.1 VOLUME ONE: STORMWATER MANAGEMENT CRITERIA

The first volume of the manual is organized as follows:

Chapter 1. Introduction to the Manual.

Chapter 2. Unified Stormwater Sizing Criteria. This chapter explains the five new sizing criteria for water quality, recharge, channel protection, overbank flood control, and extreme flood management in the State of Maryland. The chapter also outlines the basis for design calculations. Three step-by-step design examples are provided to familiarize the reader with the new procedures for computing storage volumes under the five sizing criteria. The chapter also briefly outlines the six groups of acceptable BMPs that can be used to meet recharge and water quality volume sizing criteria. Acceptable BMP groups are:

- Stormwater Ponds
- Stormwater Wetlands
- Infiltration Practices
- Filtering Systems
- Open Channel Practices
- Non-structural Practices

Lastly, the chapter presents a list of land uses or site activities that have been designated as "stormwater hotspots." If a development site is considered a "hotspot," it may have special requirements for pollution prevention and groundwater protection.

Chapter 3. Performance Criteria for Urban BMP Design. The third chapter presents specific performance criteria and guidelines for the design of five groups of structural BMPs. The performance criteria for each group of BMPs are based on six factors:

- General Feasibility
- Conveyance
- Pretreatment
- Treatment Geometry
- Landscaping
- Maintenance

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Figure 2.1 Location of the Eastern and Western Rainfall Zones in Maryland (For use in selecting the appropriate WQ_v equation.)

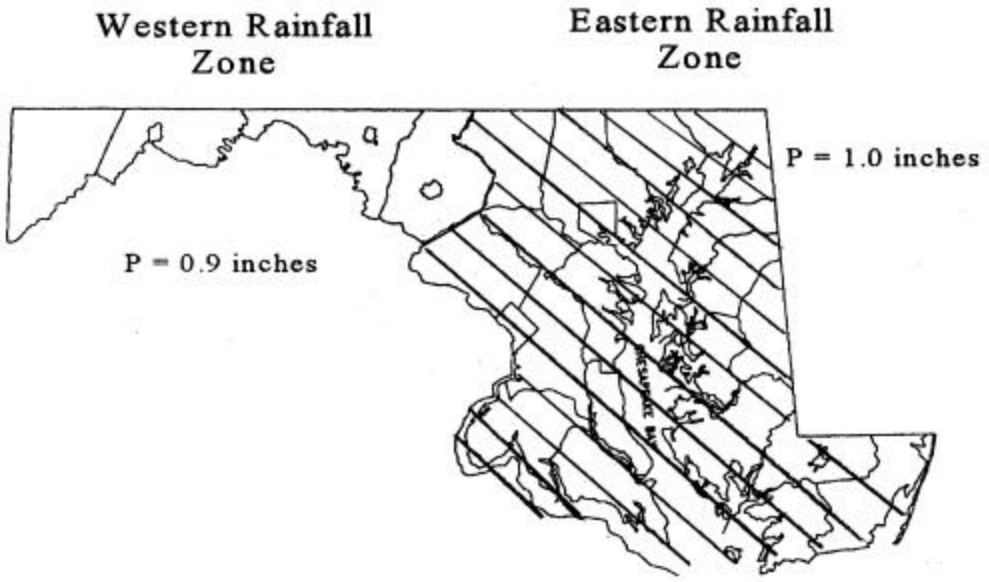
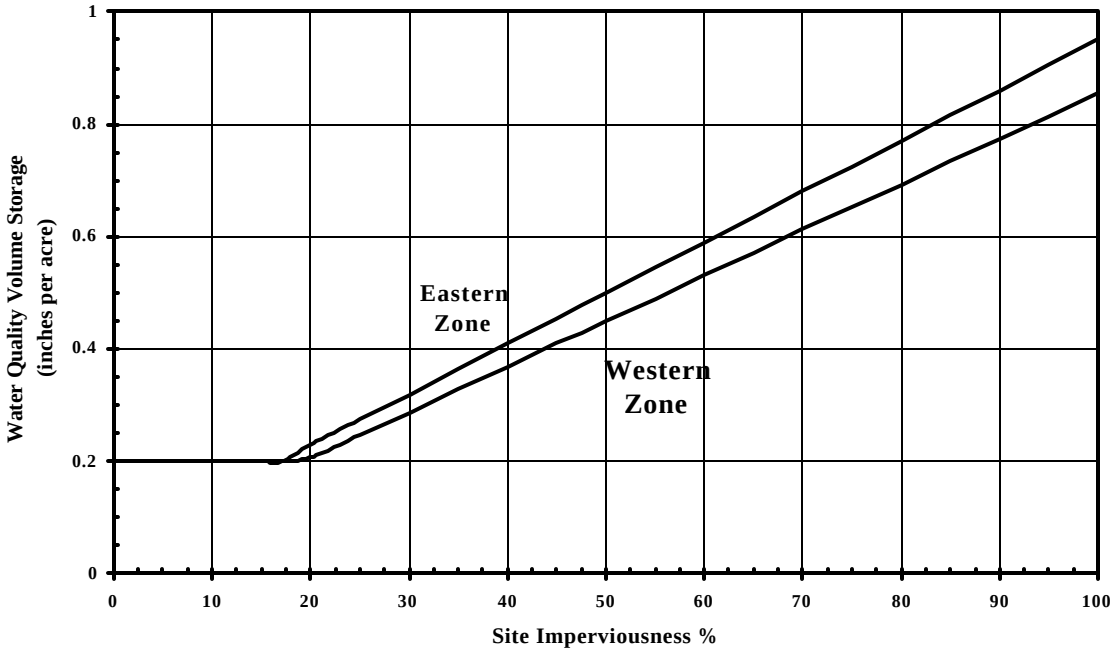


Figure 2.2 Relationship between Impervious Cover and the Water Quality Volume



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Basis for Determining Water Quality Treatment Volume

As a basis for design, the following assumptions may be made:

- **Measuring Impervious Cover**: the measured area of a site plan that does not have vegetative or permeable cover shall be considered total impervious cover. Where direct measurement of impervious cover is impractical, NRCS land use/impervious cover relationships can be used to estimate impervious cover (see Table 2.2a in TR-55, NRCS, 1986). Estimates should be based on actual land use and homogeneity.

- **Multiple Drainage Areas**: When a project contains or is divided by multiple drainage areas, the WQ_v volume shall be addressed for each drainage area. See the design examples in Chapter 2, Section 2.6.

- **Offsite Drainage Areas***:* The WQ_v shall be based on the impervious cover of the proposed site. Offsite existing impervious areas may be excluded from the calculation of the water quality volume requirements.

- **Sensitive Streams**: Consult with the appropriate local review authority to determine if a greater WQ_v is warranted to protect sensitive streams.

- **BMP Treatment**: The final WQ_v shall be treated by an acceptable BMP(s) from the list presented in Chapter 2, Section 2.7, or an equivalent practice allowed by the appropriate review authority.

- **Subtraction for Structural Practices***:* Where structural practices for treating the Re_v are employed upstream of a BMP, the Re_v may be subtracted from the WQ_v used for design.

- **Subtraction for Non-structural Practices**: Where non-structural practices are employed in the site design, the WQ_v volume can be reduced in accordance with the conditions outlined in Chapter 5.

- **Determining Peak Discharge for WQ_v Storm**: When designing flow splitters for off-line practices, consult the small storm hydrology method provided in Appendix D.10.

- **Extended Detention for Water Quality Volume**: The water quality requirement can be met by providing a 24 hour drawdown of a portion of the water quality volume (WQ_v) in conjunction with a stormwater pond or wetland system as described in Chapter 3. Referred to as ED, this is different than providing the extended detention of the one-year storm for the channel protection volume (Cp_v). The ED portion of the WQ_v may be included when routing the Cp_v.

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Section 2.2 Recharge Volume Requirements (Re_v)

The criteria for maintaining recharge is based on the average annual recharge rate of the hydrologic soil group(s) (HSG) present at a site as determined from USDA, NRCS Soil Surveys or from detailed site investigations. More specifically, each specific recharge factor is based on the USDA average annual recharge volume per soil type divided by the annual rainfall in Maryland (42 inches per year) and multiplied by 90%. This keeps the recharge calculation consistent with the WQ_v methodology. Thus, an annual recharge volume requirement is specified for a site as follows:

Site Recharge Volume Requirement

$Re_v = [(S)(R_v)(A)]/12$ (percent volume method)

where: R_v = 0.05 + 0.009(I) where I is percent impervious cover

A = site area in acres

$Re_v = (S)(A_i)$ (percent area method)

where: A_i = the measured impervious cover

Hydrologic Soil Group	Soil Specific Recharge Factor (*S*)
A	0.38
B	0.26
C	0.13
D	0.07

The recharge volume is considered part of the total WQ_v that must be provided at a site and can be achieved either by a structural practice (e.g., infiltration, bioretention), a non-structural practice (e.g., buffers, disconnection of rooftops), or a combination of both.

Drainage areas having no impervious cover and no proposed disturbance during development may be excluded from the Re_v calculations. Designers are encouraged to use these areas as non-structural practices for Re_v treatment (see Chapter 5, "Stormwater Credits for Innovative Site Planning").

Note: Re_v and WQ_v are inclusive. When treated separately, the Re_v may be subtracted from the WQ_v when sizing the water quality BMP (see page 2.4, 'Subtraction for Structural Practices).

The intent of the recharge criteria is to maintain existing groundwater recharge rates at development sites. This helps to preserve existing water table elevations thereby maintaining the hydrology of streams and wetlands during dry weather. The volume of recharge that occurs on a site depends on slope, soil type, vegetative cover, precipitation and evapo-transpiration. Sites with natural ground cover, such as forest and meadow, have higher recharge rates, less runoff, and greater transpiration losses under most conditions. Because development increases impervious surfaces, a net decrease in recharge rates is inevitable.

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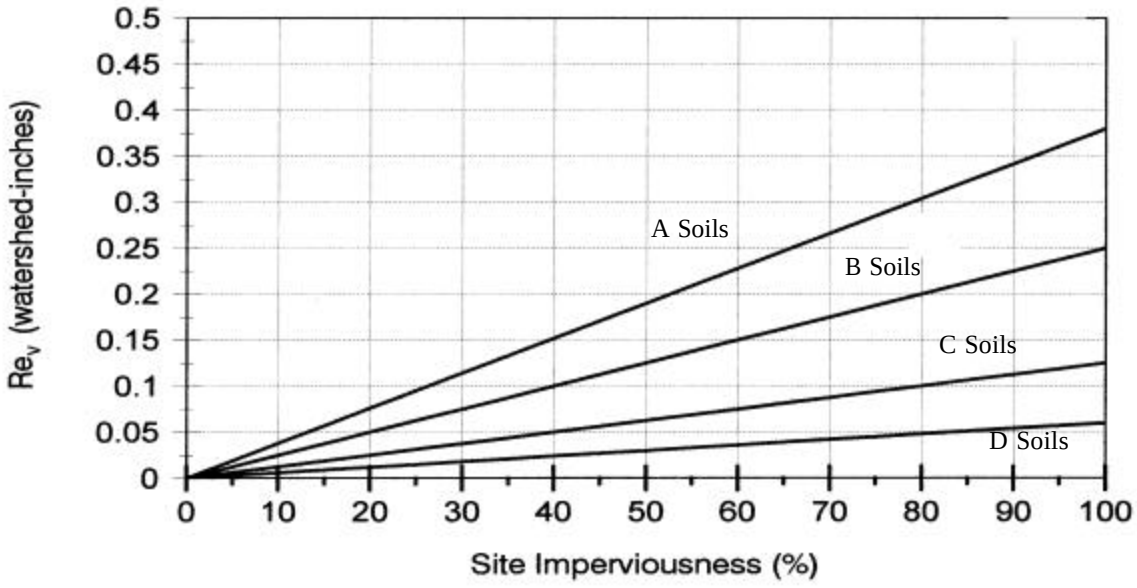
The relationship between Re_v and site imperviousness is shown in graphical form in Figure 2.3.

Figure 2.3 Relationship between Re_v and Site Impervious Cover



Basis for Determining Recharge Volume

- If more than one HSG is present at a site, a composite soil specific recharge factor shall be computed based on the proportion of total site area within each HSG. The recharge volume provided at the site shall be directed to the most permeable HSG available.

- The "percent volume" method is used to determine the Re_v treatment requirement when structural practices are used to provide recharge. These practices must provide seepage into the ground and may include infiltration and exfiltration structures (e.g., infiltration, bioretention, dry swales or sand filters with storage below the underdrain). Structures that require impermeable liners, intercept groundwater, or are designed for trapping sediment (e.g., forebays) may not be used. In this method, the volume of runoff treated by structural practices shall meet or exceed the computed recharge volume.

- The "percent area" method is used to determine the Re_v treatment requirements when non-structural practices are used. Under this method, the recharge requirement is evaluated by mapping the percent of impervious area that is effectively treated by an acceptable non-structural practice and comparing it to the minimum recharge requirements.

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- Acceptable non-structural practices include filter strips that treat rooftop or parking lot runoff, sheet flow discharge to stream buffers, and grass channels that treat roadway runoff (see Chapter 5.)

- The recharge volume criterion does not apply to any portion of a site designated as a stormwater hotspot nor any project considered as redevelopment. In addition, the appropriate local review authority may alter or eliminate the recharge volume requirement if the site is situated on unsuitable soils (e.g., marine clays), karst or in an urban redevelopment area. In this situation, non-structural practices (percent area method) should be implemented to the maximum extent practicable and the remaining or untreated Re_v included in the WQ_v treatment.

- If Re_v is treated by structural or non-structural practices separate and upstream of the WQ_v treatment, the WQ_v is adjusted accordingly.

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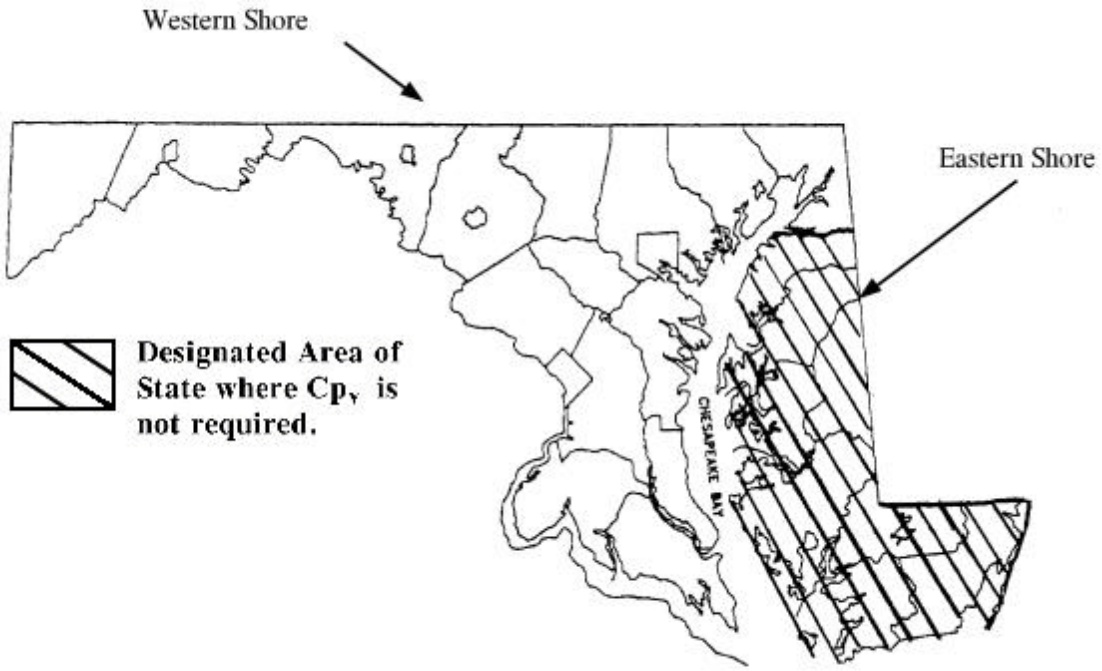
Section 2.3 Channel Protection Storage Volume Requirements (Cp_v)

To protect channels from erosion, **24 hour extended detention of the one-year, 24 hour storm event** (MDE, 1987) shall be provided. In Use III and IV watersheds, only 12 hours of extended detention shall be provided. The rationale for this criterion is that runoff will be stored and released in such a gradual manner that critical erosive velocities during bankfull and near-bankfull events will seldom be exceeded in downstream channels.

The Cp_v requirement does not apply to direct discharges to tidal water or Maryland's Eastern Shore (as defined in Figure 2.4) unless specified by an appropriate review authority on a case by case basis. Local governments may wish to use alternative methods to provide equivalent stream channel protection such as the Distributed Runoff Control method or bankfull capacity/duration criteria (MacRae, 1993).

The method for determining the Cp_v requirement is detailed in Appendix D.11. A detention pond or underground vault is normally needed to meet the Cp_v requirement (and subsequent Q_{p10} and Q_f criteria). Schematics of a typical design are shown in Figures 2.5.

Figure 2.4 Regions of Maryland Not Subject to the Channel Protection Requirement (Cp_v)



Section 2.5 Extreme Flood Volume (Q_f)

The intent of the extreme flood criteria is to (a) prevent flood damage from large storm events, (b) maintain the boundaries of the pre development 100-year Federal Emergency Management Agency (FEMA) and/or locally designated floodplain, and (c) protect the physical integrity of BMP control structures. This is typically done in two ways:

100-Year Control: requires storage to attenuate the post development 100-year, 24 hour peak discharge (Q_f) to pre development rates. The Q_f is the most stringent and expensive level of flood control and is generally not needed if the downstream development is located out of the 100-year floodplain. In many cases, the conveyance system leading to a stormwater structure is designed based on the discharge rate for the ten-year storm (Qp_{10}). In these situations, the conveyance systems may be the limiting hydrologic control.

Reserve Ultimate 100-Year Floodplain: 100-year storm control may be required by an appropriate review authority if:

- buildings or development are located within the ultimate 100-year floodplain, or
- the reviewing authority does not completely control the 100-year floodplain.

Hydraulic/hydrologic investigations may be required to demonstrate that downstream roads, bridges and public utilities are adequately protected from the Q_f storm. These investigations typically extend to the first downstream tributary of equal or greater drainage area or to any downstream dam, highway, or natural point of restricted stream flow.

Basis for Determining Extreme Flood Criteria

- Consult with the appropriate review authority to determine the analyses required for the Q_f storm.

- The same hydrologic and hydraulic methods used for overbank flood control shall be used to analyze Q_f.

- In addition, off-site areas should be modeled as "ultimate condition" when the 100-year design storm event is analyzed. Table 2.2 indicates the depth of rainfall (24 hour) associated with the 100-year storm event for all counties in the State of Maryland

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Section 2.6 Design Examples: Computing Stormwater Storage Volumes

Design examples are provided only to illustrate how the five stormwater management sizing criteria are computed for hypothetical development projects. These design examples are also utilized elsewhere in the manual to illustrate structural and non-structural BMP design.

Design Example No. 1: Residential Development - Reker Meadows

Site data and the layout of the Reker Meadows subdivision are shown in Figure 2.6.

Step 1. Compute WQ_v Volume

$$WQ_v = \frac{(P)(R_v)(A)}{12}$$

Step 1a. Compute Volumetric Runoff Coefficient (R_v)

R_v = 0.05 + (0.009) (I); I = 13.8 $_{acres}$/38.0 $_{acres}$ = 36.3%
= 0.05 + (0.009) (36.3) = 0.38

Step 1b. Determine Rainfall Zone for WQ_v Formula

Location	**Rainfall (*P*)**
Eastern Rainfall Zone	1.0 inches
Western Rainfall Zone	0.9 inches
Minimum WQv (I ≤ 15%)	0.2 inches

Because this site is located in the Western Rainfall Zone, use 0.9″ of rainfall to determine WQ_v.

Step 1c. Compute WQ_v

WQ_v = [(0.9″) (R_v) (A)]/12
= [(0.9″)(0.38)(38.0 ac)]/12
= 1.08 ac-ft

Check Minimum: [(0.2″)(38.0 ac)]/12 = 0.63 ac-ft < 1.08 ac-ft
∴ Use WQ_v = 1.08 ac-ft

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6) *material and construction specifications for the embankment shall be in accordance with MD 378 code, except that fill material for the embankment shall conform to Unified Soil Classification GC, SC, SM, MH, ML, CH, or CL, and no cutoff trench is required.*

7) *woody vegetation is prohibited on the embankment.*

A pond structure requires review and approval by the MDE Dam Safety Division if any of the following conditions apply:

a) *the proposed embankment is twenty feet or greater in height from the upstream toe to the top of dam, or*

b) *the contributing drainage area is a square mile (640 acres) or greater, or*

c) *the structure is classified as "high" or "intermediate" hazard, according to the MD Dam Safety Manual, or*

d) *the proposed pond is in USE III waters.*

3.1.2 Pond Conveyance Criteria

When reinforced concrete pipe is used for the principal spillway to increase its longevity, "O-ring" gaskets (ASTM C-361) should be used to create watertight joints and should be inspected during installation.

Inlet Protection

Inlet pipes to the pond should not be fully submerged at normal pool elevations.

A forebay shall be provided at each inlet, unless the inlet provides less than 10% of the total design storm inflow to the pond.

Adequate Outfall Protection

Flared pipe sections that discharge at or near the stream invert or into a step-pool arrangement should be used at the spillway outlet.

The channel immediately below the pond outfall shall be modified to prevent erosion and conform to natural dimensions in the shortest possible distance, typically by use of large rip-rap placed over filter cloth.

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A stilling basin or other outlet protection should be used to reduce flow velocities from the principal spillway to non-erosive velocities (see Appendix D.12 for critical non-erosive velocities for grass and soil).

If a pond daylights to a channel with dry weather flow, care should be taken to minimize tree clearing along the downstream channel and to reestablish a forested riparian zone in the shortest possible distance. Excessive use of rip-rap should be avoided to reduce stream warming.

Pond Liners

When a pond is located in karst topography, gravelly sands or fractured bedrock, a liner may be needed to sustain a permanent pool of water. If geotechnical tests confirm the need for a liner, acceptable options include: (a) 6 to 12 inches of clay soil (minimum 15% passing the #200 sieve and a maximum permeability of 1×10^{-5} cm/sec), (b) a 30 mil poly-liner, (c) bentonite, (d) use of chemical additives (see NRCS Agricultural Handbook No. 387, dated 1971, Engineering Field Manual), or (e) other suitable materials approved by the appropriate review authority.

3.1.3 Pond Pretreatment Criteria

Sediment Forebay

Each pond shall have a sediment forebay or equivalent upstream pretreatment. The forebay shall consist of a separate cell, formed by an acceptable barrier.

The forebay shall be sized to contain 0.1 inches per impervious acre of contributing drainage. The forebay storage volume counts toward the total WQ_v requirement. Exit velocities from the forebay shall be non-erosive.

Direct maintenance access for appropriate equipment shall be provided to the forebay.

The bottom of the forebay may be hardened (e.g., using concrete, paver blocks, etc.) to make sediment removal easier.

A fixed vertical sediment depth marker should be installed in the forebay to measure sediment deposition over time.

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3.1.4 Pond Treatment Criteria

Minimum Water Quality Volume (WQ_v)

Ponds shall be designed to capture and treat the computed WQ_v through any combination of permanent pool, extended detention (ED) or wetland. If treated separately, the Re_v may be subtracted from the WQ_v for pond design.

It is generally desirable to provide water quality treatment off-line when topography, head and space permit (e.g., apart from stormwater quantity storage).

Water quality storage can be provided in multiple cells. Performance is enhanced when multiple treatment pathways are provided by using multiple cells, longer flowpaths, high surface area to volume ratios, complex microtopography, and/or redundant treatment methods (combinations of pool, ED, and wetland).

If ED is provided in a pond, storage for WQ_v and Cp_v shall be computed and routed separately (e.g., the WQ_v requirement cannot be met simply by providing Cp_v storage for the one-year storm).

Minimum Pond Geometry

Flowpaths from inflow points to outlets shall be maximized. Flowpaths of 1.5:1 (length relative to width) and irregular shapes are recommended.

3.1.5 Pond Landscaping Criteria

Pond Benches

The perimeter of all deep permanent pool areas (four feet or greater in depth) shall be surrounded by two benches with a combined minimum width of 15 feet:

- *A safety bench* that extends outward from the normal water edge to the toe of the pond side slope. The maximum slope of the safety bench shall be 6%.

- *An aquatic bench* that extends inward from the normal shoreline and has a maximum depth of eighteen inches below the normal pool water surface elevation. An aquatic bench is not required in forebays.

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Landscaping Plan

A landscaping plan for a stormwater pond and its buffer shall be prepared to indicate how aquatic and terrestrial areas will be vegetatively stabilized and established. Landscaping guidance for stormwater ponds is provided in Appendix A.

Wherever possible, wetland plants should be encouraged in a pond design, either along the aquatic bench (fringe wetlands), the safety bench and side slopes (emergent wetlands) or within shallow areas of the pool itself.

The best elevations for establishing wetland plants, either through transplantation or volunteer colonization, are within six inches (plus or minus) of the normal pool.

The soils of a pond buffer are often severely compacted during the construction process to ensure stability. The density of these compacted soils is so great that it effectively prevents root penetration, and therefore, may lead to premature mortality or loss of vigor. Consequently, it is advisable to excavate large and deep holes around the proposed planting sites, and backfill these with uncompacted topsoil.

As a rule of thumb, planting holes should be at least six inches larger than the diameter of the rootball (of balled and burlap stock), and three inches wider for container grown stock. This practice should enable the stock to develop unconfined root systems. Avoid species that require full shade, are susceptible to winterkill, or are prone to wind damage. Extra mulching around the base of the tree or shrub is strongly recommended as a means of conserving moisture and suppressing weeds.

Pond Buffers and Setbacks

A pond buffer should be provided that extends 25 feet outward from the maximum water surface elevation of the pond. The pond buffer should be contiguous with other buffer areas that are required by existing regulations (e.g., stream buffers). An additional setback may be provided to permanent structures.

Existing trees should be preserved in the buffer area during construction. It is desirable to locate forest conservation areas adjacent to ponds. To discourage resident geese populations, the buffer can be planted with trees, shrubs and native ground covers.

Woody vegetation may not be planted on nor allowed to grow within 15 feet of the toe of the embankment and 25 feet of the principal spillway structure.

Annual mowing of the pond buffer is only required along maintenance rights-of-way and the embankment. The remaining buffer can be managed as a meadow (mowing every other year) or forest.

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3.1.6 Pond Maintenance Criteria

Maintenance Measures

Maintenance responsibility for a pond and its buffer shall be vested with a responsible party by means of a legally binding and enforceable maintenance agreement that is executed as a condition of plan approval or local permitting processes.

The principal spillway shall be equipped with a trash rack that provides access for maintenance.

Sediment removal in the forebay shall occur when 50% of the total forebay capacity has been lost.

Sediments excavated from stormwater ponds that do not receive runoff from designated hotspots are not considered toxic or hazardous material and can be safely disposed by either land application or land filling. Sediment testing may be required prior to sediment disposal when a hotspot land use is present.

Sediment removed from stormwater ponds should be disposed of according to current erosion and sediment control regulations.

Maintenance Access

A maintenance right-of-way or easement shall extend to a pond from a public or private road.

Maintenance access should be at least 12 feet wide; have a maximum slope of no more than 15%; and be appropriately stabilized to withstand maintenance equipment and vehicles.

The maintenance access should extend to the forebay, safety bench, riser, and outlet and be designed to allow vehicles to turn around.

Non-clogging Low Flow Orifice

The low flow orifice shall have a minimum diameter of 3 inches and shall be adequately protected from clogging by an acceptable external trash rack. Two examples of approved external trash racks are provided in Detail No. 1 and 2 of Appendix D.8. *The low flow orifice diameter may be reduced to one inch if an internal orifice is used* (e.g., an over-perforated vertical standpipe that is protected by hardware cloth and a stone filtering jacket). A schematic design of an acceptable internal orifice protection design is provided in Detail No. 3 of Appendix D.8.

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The preferred method is a submerged reverse-slope pipe that extends downward from the riser to an inflow point one foot below the normal pool elevation.

Alternative methods are to employ a broad crested rectangular, V-notch, or proportional weir, protected by a half-round corrugated metal pipe (CMP) or similar device that extends at least 12 inches below the normal pool. (See Detail No. 7 of Appendix D.8.)

The use of horizontal perforated pipe protected by geotextile and gravel is not recommended.

Vertical pipes may be used as an alternative if a permanent pool is present.

Riser

The riser shall be located within the embankment for maintenance access, safety and aesthetics.

Access to the riser is to be provided by lockable manhole covers and manhole steps within easy reach of valves and other controls. Riser openings should be fenced with pipe or rebar to prevent trash accumulation.

Pond Drain

Each pond shall have a drain pipe that can completely or partially drain the pond within 24 hours. This requirement is waived for the Lower Eastern Shore where positive drainage is difficult to achieve due to very low relief.

Care should be exercised during pond drawdowns to prevent downstream discharge of sediments or anoxic water and slope instability caused by rapid drawdown.

The approving jurisdiction shall be notified before draining a pond.

Valves

The pond drain shall be equipped with an adjustable valve (typically a handwheel activated knife or gate valve).

The pond drain should be sized one pipe size greater than the calculated design diameter.

Valve controls shall be located inside of the riser at a point where they (a) will not normally be inundated and (b) can be operated in a safe manner.

To prevent vandalism, the handwheel should be chained to a ringbolt, manhole step or other fixed object.

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Safety Features

Fencing of ponds is not generally desirable but may be required by the local review authority. A preferred method is to manage the contours of the pond to eliminate dropoffs and other safety hazards.

Internal side slopes to the pond should not exceed 3:1 (h:v) and should terminate on a safety bench. Both the safety bench and the aquatic bench may be landscaped to prevent access to the pool. The bench requirement may be waived if slopes are 4:1 or gentler.

Riser openings shall not permit unauthorized access. Riser tops that are four feet or greater above the ground shall include railings for safety. Endwalls above pipe outfalls greater than 48 inches in diameter shall be fenced to prevent injury.

Warning signs prohibiting swimming and skating should be posted.

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Section 3.2 Stormwater Wetlands

Definition: Practices that create shallow wetland areas to treat urban stormwater and often incorporate small permanent pools and/or extended detention storage to achieve the full WQ_v. Design variants include:

- W-1 shallow wetland (Figure 3.6)
- W-2 ED shallow wetland (Figure 3.7)
- W-3 pond/wetland system (Figure 3.8)
- W-4 pocket wetland (Figure 3.9)

Stormwater wetlands may also provide Cp_v and Q_p storage above the WQ_v storage.

IMPORTANT NOTES:

1) Except for specific minimum contributing drainage area and the use of these practices in coldwater streams (USE III AND IV), all of the pond performance criteria presented in section 3.1 also apply to the design of stormwater wetlands. Additional criteria that govern the geometry and establishment of created wetlands are presented in this section.

2) Any stormwater management BMP that uses an embankment for impounding water is required to follow the latest version of the NRCS-MD 378 Pond Code Standards And Specifications For Small Pond Design (Appendix B.1) and obtain approval from the local SCD or appropriate review authority.

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The required sedimentation basin minimum surface area is computed using the following equation:

$$A_s = \frac{Q_o}{W} \times E'$$

where:

A_s = sedimentation basin surface area (ft^2)
Q_o = discharge rate from basin = (WQ_v/24 hr)
W = particle settling velocity (ft/sec)
for I ≤ 75%, use 0.0004 ft/sec (particle size = 20 microns)
for I > 75%use 0.0033 ft/sec (particle size = 40 microns) [1]
(I = percent impervious)
$E¢$ = sediment trapping efficiency constant; for a sediment trapping efficiency (E) of 90%, $E¢$ = 2.30 [2]

1) Sites with greater than 75% imperviousness have a higher percentage of coarse-grained sediments (Shaver and Baldwin, 1991). Therefore, the target particle size for sedimentation basins may be increased to 40 microns and the surface area reduced.

2) The sediment trapping efficiency constant ($E¢$) may be calculated from the sediment trapping efficiency (E) using the following equation: $E¢ = -\ln [1-(E/100)]$

The equation reduces to:

A_{sf} = (0.066) (WQ_v) ft^2 for I ≤ 75%
A_{sp} = (0.0081) (WQ_v) ft^2 for I > 75%

where:

A_{sf} = sedimentation basin surface area full
A_{sp} = sedimentation basin surface area partial

Adequate pretreatment for bioretention systems (F-6) is provided when all of the following are provided: (a) 20' grass filter strip below a level spreader or optional sand filter layer, (b) gravel diaphragm and (c) a mulch layer.

3.4.4 Filtering Treatment Criteria

The entire treatment system (including pretreatment) shall temporarily hold at least 75% of the WQ_v prior to filtration.

The filter bed typically has a minimum depth of 18". *Sand filters shall have a minimum filter bed depth of 12".*

Filtering practices typically cannot provide Cp_v or Q_p under most site conditions.

The filter media shall conform to the specifications listed in Table B.3.1 (Appendix B.3).

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The filter area for filter designs F-1 to F-5 shall be sized based on the principles of Darcy's Law. A coefficient of permeability (k) shall be used as follows:

Sand:	*3.5 ft/day (City of Austin 1988)*
Peat:	2.0 ft/day (Galli 1990)
Leaf compost:	*8.7 ft/day (Claytor and Schueler, 1996)*
Bioretention Soil:	*0.5 ft/day (Claytor and Schueler, 1996)*

Bioretention systems (F-6) shall consist of the following treatment components: A 2½ to 4 foot deep planting soil bed, a surface mulch layer, and a 12" deep surface ponding area.

The required filter bed area (A_f) is computed using the following equation:

$$A_f = (WQ_v)\ (d_f) / [\ (k)\ (h_f + d_f)\ (t_f)]$$

where:

A_f = Surface area of filter bed (ft^2)
WQ_v = water quality volume (ft^3)
d_f = filter bed depth (ft)
k = coefficient of permeability of filter media (ft/day)
h_f = average height of water above filter bed (ft)
t_f = design filter bed drain time (days)*

*1.67 days is recommended maximum for sand filters, 2.0 days for bioretention

3.4.5 Filtering Landscaping Criteria

A dense and vigorous vegetative cover shall be established over the contributing drainage area before runoff can be accepted into the facility.

Landscaping is critical to the performance and function of bioretention areas. Therefore, a landscaping plan shall be provided for bioretention areas per the guidance provided in Appendix-A.

Filters F-1, F-4 and F-5 may have a grass cover to aid in pollutant adsorption. The grass should be capable of withstanding frequent periods of inundation and drought (see Appendix A for grass species selection guide).

Planting recommendations for bioretention facilities are as follows:

- Native plant species should be specified over non-native species.
- Vegetation should be selected based on a specified zone of hydric tolerance.
- A selection of trees with an understory of shrubs and herbaceous materials should be provided.

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Table 4.3 BMP Selection - Stormwater Treatment Suitability

CODE	BMP List	Re_v Ability	Cp_v Control	Qp Control	Additional Safety Concerns	SPACE	ACCEPT HOTSPOT RUNOFF
P-1	Micropool ED	No[1]	Yes	Yes	No	Yes	Yes[3]
P-2	Wet Pond	No[1]	Yes	Yes	Yes	Varies	Yes[3]
P-3	Wet ED Pond	No[1]	Yes	Yes	Yes	Yes	Yes[3]
P-4	Multiple Pond	No[1]	Yes	Yes	Yes	No	Yes[3]
P-5	Pocket Pond	No[1]	Yes	Yes	Varies	Yes	Yes[3]
W-1	Shallow Wetland	Varies[2]	Yes	Yes	No	No	Yes[3]
W-2	ED Wetland	Varies[2]	Yes	Yes	Varies	Varies	Yes[3]
W-3	Pond/Wetland	Varies[2]	Yes	Yes	Yes	No	Yes[3]
W-4	Pocket Wetland	No	Varies	Varies	No	Varies	Yes[3]
I-1	Infiltration Trench	Yes	Varies	Varies	No	Yes	No[3]
I-2	Infiltration Basin	Yes	Varies	Varies	No	Varies	No[3]
F-1	Surface Sand Filter	Varies[2]	Varies	Varies	No	Yes	Yes[4]
F-2	Underground SF	No	No	No	Varies	Yes	Yes
F-3	Perimeter SF	No	No	No	No	Yes	Yes
F-4	Organic Filter	Varies[2]	Varies	Varies	No	Yes	Yes[4]
F-5	Pocket Sand Filter	Varies[2]	Varies	Varies	No	Yes	Yes[4]
F-6	Bioretention	Yes	Varies	Varies	No	Varies	Yes[4]
O-1	Dry Swale	Yes	No	No	No	Varies	Yes[4]
O-2	Wet Swale	No	No	No	No	Varies	No

1 Structures that require impermeable liners or that intercept groundwater may not be used for groundwater recharge.

2 Re_v may be provided by exfiltration (see Chapter 3.4).

3 Not allowed unless pretreatment to remove hydrocarbons, trace metals, and toxicants is provided.

4 Yes, but only if bottom of facility is lined with impermeable filter fabric that prevents leachate infiltration.

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Section 4.4 Physical Feasibility Factors

At this point, the designer has narrowed the BMP list to a manageable size and can evaluate the remaining options given the physical conditions at a site. This table cross-references testing protocols needed to confirm physical conditions at the site. The six primary factors are:

Soils. The key evaluation factors are based on an initial investigation of the USDA hydrologic soils groups at the site. Note that more detailed geotechnical tests are usually required for infiltration feasibility and during design to confirm permeability and other factors (see Appendix D.1).

Water Table. This column indicates the minimum depth to the seasonally high water table from the bottom or floor of a BMP.

Drainage Area. This column indicates the recommended minimum or maximum drainage area that is considered suitable for the practice. If the drainage area present at a site is slightly greater than the maximum allowable drainage area for a practice, some leeway is permitted or more than one practice can be installed. The minimum drainage areas indicated for ponds and wetlands are flexible depending on water availability (baseflow or groundwater) or the mechanisms employed to prevent clogging.

Slope Restriction. This column evaluates the effect of slope on the practice. Specifically, the slope restrictions refer to how flat the area where the practice may be.

Head. This column provides an estimate of the elevation difference needed at a site (from the inflow to the outflow) to allow for gravity operation within the practice.

Ultra-Urban Sites. This column identifies BMPs that work well in the ultra-urban environment, where space is limited and original soils have been disturbed. These BMPs are frequently used at redevelopment sites.

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Table 4.5 BMP Selection - Community and Environmental Factors

CODE	BMP LIST	EASE OF MAINTENANCE	COMMUNITY ACCEPTANCE	COST (Relative To Drainage Area)	HABITAT QUALITY	OTHER FACTORS
P-1	Micropool ED	Medium	Medium	Low	Medium	Trash/debris
P-2	Wet Pond	Easy	High	Low	High	
P-3	Wet ED Pond	Easy	High	Low	High	
P-4	Multiple Pond	Easy	High	Medium	High	
P-5	Pocket Pond	Difficult	Medium	Low	Low	Drawdowns
W-1	Shallow Wetland	Medium	High	Medium	High	
W-2	ED Wetland	Medium	Medium	Medium	High	Limit ED depth
W-3	Pond/Wetland	Difficult	High	Medium	High	
W-4	Pocket Wetland	Medium	Low	Low	Medium	Drawdowns
I-1	Infiltration Trench	Difficult	High	Medium	Low	Avoid large stone
I-2	Infiltration Basin	Medium	Low	Medium	Low	Frequent pooling
F-1	Surface SF	Medium	Medium	High	Low	
F-2	Underground SF	Difficult	High	High	Low	Underground ∴Out of sight
F-3	Perimeter SF	Difficult	High	High	Low	Traffic Bearing
F-4	Organic Filter	Medium	High	High	Low	Filter Media Replacement
F-5	Pocket SF	Medium	Medium	Medium	Low	
F-6	Bioretention	Medium	Medium	Medium	Low	Landscaping
O-1	Dry Swale	Easy	High	Medium	Low	
O-2	Wet Swale	Easy	High	Low	Low	Mosquitoes Possible

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Section 4.6 Checklist: Location and Permitting Factors

In the last step, a designer assesses the physical and environmental features at the site to determine the optimal location for the selected BMP or group of BMPs. The checklist below provides a condensed summary of current BMP restrictions as they relate to common site features that may be regulated under local, State or federal law. These restrictions fall into one of three general categories:

1. Locating a BMP within an area that is expressly **prohibited** by law.

2. Locating a BMP within an area that is **strongly discouraged** and is only allowed on a case by case basis. Local, State and/or federal permits shall be obtained and the applicant will need to supply additional documentation to justify locating the BMP within the regulated area.

3. BMPs must be **setback** a fixed distance from the site feature.

This checklist is only intended as a general guide to location and permitting requirements as they relate to siting stormwater BMPs. Consultation with the appropriate regulatory agency is the best strategy.

The symbol "✓" denotes when an MDE Nontidal Wetland And Waterways Permit shall be obtained.

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5.0 Stormwater Credits

In Maryland, there are many programs at both the State and local level that seek to minimize the impact of land development. Critical Areas, forest conservation, and local stream buffer requirements are designed to reduce nonpoint source pollution. Non-structural practices can play a significant role in reducing water quality impacts and are increasingly recognized as a critical feature of every stormwater BMP plan, particularly with respect to site design. In most cases, non-structural practices must be combined with structural practices to meet stormwater requirements. The key benefit of non-structural practices is that they can reduce the generation of stormwater from the site; thereby reducing the size and cost of stormwater storage. In addition, they can provide partial removal of many pollutants. Non-structural practices have been classified into six broad groups and are designed to mesh with existing state and local programs (e.g., forest conservation, stream buffers etc.). To promote greater use, a series of six stormwater credits are provided for designers that use these site planning techniques.

Credit 1.	Natural Area Conservation
Credit 2.	Disconnection of Rooftop Runoff
Credit 3.	Disconnection of Non Rooftop Runoff
Credit 4.	Sheet Flow to Buffers
Credit 5.	Open Channel Use
Credit 6.	Environmentally Sensitive Development

This chapter describes each of the credits for the six groups of non-structural practices, specifies minimum criteria to be eligible for the credit, and provides an example of how the credit is calculated. Designers should check with the appropriate approval authority to ensure that the credit is applicable to their jurisdiction. Clearly both of the site designs used to illustrate the credits could be more creative to provide more non-structural opportunities.

In general, the stormwater sizing criteria provide a strong incentive to reduce impervious cover at development sites (e.g., Re_v, WQ_v, Cp_v or Qp and Qf). Storage requirements for all five stormwater sizing criteria are directly related to impervious cover. Thus, significant reductions in impervious cover result in smaller required storage volumes and, consequently, lower BMP construction costs.

These and other site design techniques can help to reduce impervious cover, and consequently, the stormwater treatment volume needed at a site. The techniques presented in this chapter are considered options to be used by the designer to help reduce the need for stormwater BMP storage capacity. Due to local safety codes, soil conditions, and topography, some of these site design features will be restricted. Designers are encouraged to consult with the appropriate approval authority to determine restrictions on non-structural strategies.

NOTE: In this chapter, *italics* indicate mandatory performance criteria, whereas suggested design criteria are shown in normal typeface.

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These credits are an integral part of a project's overall stormwater management plan and BMP storage volume calculation. Therefore, use of these credits shall be documented at the initial (concept) design stage, documented with submission of final grading plans, and verified with "as-built" certifications. If a planned credit is not implemented, then BMP volumes shall be increased appropriately to meet Re_v, WQ_v, Cp_v, and Q_p where applicable.

Table 5.1 Summary of Stormwater Credits

Stormwater Credit	**WQ_v**	**Re_v**	**Cp_v or Q_p**
Natural Area Conservation	Reduce Site Area	No credit. Use as receiving area w/Percent Area Method.	Forest/meadow CN for natural areas
Disconnection of Rooftop Runoff	Reduced R_v	No credit. Use with Percent Area Method.	Longer t_c (increased flow path). CN credit.
Disconnection of Non-Rooftop Runoff	Reduced R_v	No credit. Use with Percent Area Method.	Longer t_c (increased flow path) CN credit
Sheet Flow to Buffers	Subtract contributing site area to BMP	Reduced Re_v	CN credit
Open Channel Use	May meet WQ_v	Meets Re_v	Longer t_c (increased flow path) No CN credit
Environmentally Sensitive Development	Meets WQ_v	Meets Re_v	No CN credit t_c may increase

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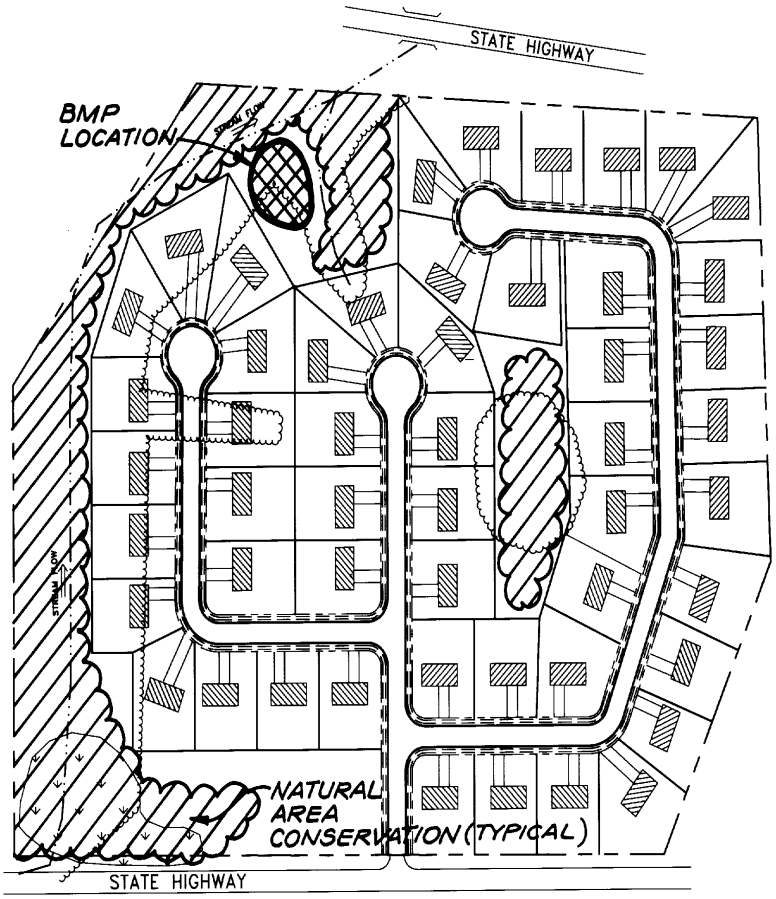
Example of Calculating Natural Area Credit

Site Data - 51 Single Family Lots
Area = 38 ac.
Conservation Area = 7.0 ac
Impervious Area = 13.8 ac
R_v = .38, P = 0.9”
Post dev. CN = 78
Original WQ_v = 1.08 ac-ft.
Original Re_v = .25 ac-ft.
Original Cp_v = 1.65 ac-ft.
Original Qp_{10} = 2.83 ac-ft.



Computation of Stormwater Credits

$WQ_v = [(P)(R_v)(A)]/12$
$= [(0.9)(.38)(38.0 - 7.0 \text{ ac.})]/12$
$= 0.89$ ac-ft

Re_v = Same as original
(However, area draining to Natural Area may used with the Percent Area Method)

Cp_v and Q_{p10} (total site): CN reduced from 78 to 75

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Section 5.2 Disconnection of Rooftop Runoff Credit

Disconnection of Rooftop Runoff Credit

A credit is given when rooftop runoff is disconnected and then directed to a pervious area where it can either infiltrate into the soil or filter over it. The credit is typically obtained by grading the site to promote overland filtering or by providing bioretention areas on single family residential lots.

If a rooftop is adequately disconnected, the disconnected impervious area may be deducted from total impervious cover (therefore reducing WQ_v). In addition, disconnected rooftops can be used to meet the Re_v requirement as a non-structural practice using the percent area method (see Chapter 2).

Post development CN's for disconnected rooftop areas used to compute Cp_v and Qp can be assumed to be woods in good condition.

Criteria for Disconnection of Rooftop Runoff Credit

The credit is subject to the following restrictions:

- *Rooftop cannot be within a designated hotspot,*
- *Disconnection shall cause no basement seepage,*
- *The contributing area of rooftop to each disconnected discharge shall be 500 square feet or less,*
- *The length of the "disconnection" shall be 75' or greater, or compensated using Table 5.2,*
- *Dry wells, french drains, rain gardens, or other similar storage devices may be utilized to compensate for areas with disconnection lengths less than 75 feet. (See Table 5.2 and Figure 5.1, dry wells are prohibited in "D" soils),*
- *In residential development applications, disconnections will only be credited for lot sizes greater than 6000 sq. ft.,*
- *The entire vegetative "disconnection" shall be on an average slope of 5% or less,*
- *The disconnection must drain continuously through a vegetated channel, swale, or through a filter strip to the property line or BMP,*
- *Downspouts must be at least 10 feet away from the nearest impervious surface to discourage "re-connections", and*
- *For those rooftops draining directly to a buffer, only the rooftop disconnection credit or the buffer credit may be used, not both.*

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Section 5.3 Disconnection of Non Rooftop Runoff Credit

Disconnection of Non Rooftop Runoff Credit

Credit is given for practices that disconnect surface impervious cover runoff by directing it to pervious areas where it is either infiltrated into the soil or filtered (by overland flow). This credit can be obtained by grading the site to promote overland vegetative filtering or providing bioretention areas on single family residential lots.

These "disconnected" areas can be subtracted from the impervious area when computing WQ_v. In addition, disconnected surface impervious cover can be used to meet the Re_v requirement as a non-structural practice using the percent area method (See Chapter 2).

Criteria for Disconnection of Non Rooftop Runoff Credit

The credit is subject to the following restrictions:

- *Runoff cannot come from a designated hotspot,*
- *The maximum contributing impervious flow path length shall be 75 feet,*
- *The disconnection shall drain continuously through a vegetated channel, swale, or filter strip to the property line or BMP,*
- *The length of the "disconnection" must be equal to or greater than the contributing length,*
- *The entire vegetative "disconnection" shall be on an average slope of 5% or less,*
- *The surface impervious area to any one discharge location cannot exceed 1,000 ft^2.*
- *Disconnections are encouraged on relatively permeable soils (HSG's A and B),*
- *If the site cannot meet the required disconnect length, a spreading device, such as a french drain, rain garden, gravel trench or other storage device may be needed for compensation, and*
- *For those areas draining directly to a buffer, only the non rooftop disconnection credit or the stream buffer credit can be used, not both.*

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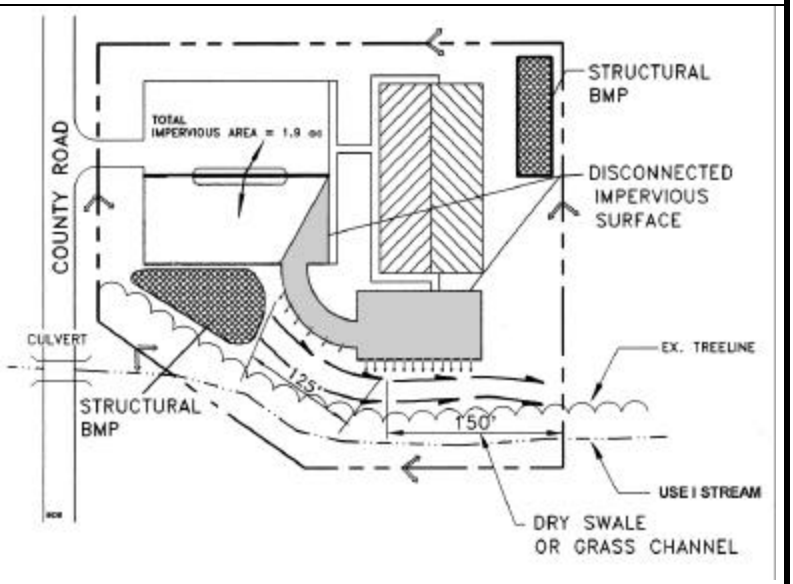
Example of Calculating the Non Rooftop Disconnection Credit

Site Data -Community Center
Area = 3.0 ac
Original Impervious Area = 1.9 ac. = 63.3%
Original R_v = .62
Post dev. CN = 83
B Soils, S = 0.26
Original WQ_v = 6752 ft^3
Original Re_v = 1688 ft^3
Original Cp_v = N/A
Original Qp_2 = 10,630 ft^3

0.33 ac of surface imperviousness disconnected

Net impervious area reduction
1.9 - 0.33 = 1.57 ac.



Computation of Stormwater Credit:

New R_v = 0.05 + .009 (1.57 ac/3.0 ac) = .52
$\therefore WQ_v$ = [(1.0)(0.52)(3.0 ac)]/12 = 0.13 ac-ft (5662.8 cf)

Required Re_v (Percent area method)
Re_v = $(S)(A_i)$ = (0.26)(1.9 ac.) = 0.49 acres
Re_v treated by disconnection = 0.33 acres
Re_v remaining for treatment = 0.16 acres non structurally or 551.2 cf structurally

Cp_v and Q_p Post developed CN may be reduced

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Section 5.4 Sheetflow to Buffer Credit

Sheetflow to Buffer Credit

This credit is given when stormwater runoff is effectively treated by a natural buffer to a stream or forested area. Effective treatment is achieved when pervious and impervious area runoff is discharged to a grass or forested buffer through overland flow. The use of a filter strip is also recommended to treat overland flow in the green space of a development site. The credits include:

1. The area draining by sheet flow to a buffer is subtracted from the total site area in the WQ_v calculation.
2. The area draining to the buffer contributes to the recharge requirement, Re_v.
3. A *wooded* CN can be used for the contributing area if it drains to a forested buffer.

Criteria for Sheetflow to Buffer Credit

The credit is subject to the following conditions:

- *The minimum buffer width shall be 50 feet as measured from bankfull elevation or centerline of the buffer,*
- *The maximum contributing length shall be 150 feet for pervious surfaces and 75 feet for impervious surfaces,*
- *Runoff shall enter the buffer as sheet flow. Either the average contributing overland slope shall be 5.0% or less, or a level spreading device shall be used where sheet flow can no longer be maintained (see Detail No. 9 in Appendix D.8),*
- *Not applicable if rooftop or non rooftop disconnection is already provided (see Credits 2 & 3),*
- *Buffers shall remain unmanaged other than routine debris removal, and*
- *Shall be protected by an acceptable conservation easement or other enforceable instrument that ensures perpetual protection of the proposed area. The easement must clearly specify how the natural area vegetation shall be managed and boundaries will be marked* [Note: managed turf (e.g., playgrounds, regularly maintained open areas) is not an acceptable form of vegetation management].

Figure 5.2 illustrates how a buffer or filter strip can be used to treat stormwater from adjacent pervious and impervious areas.

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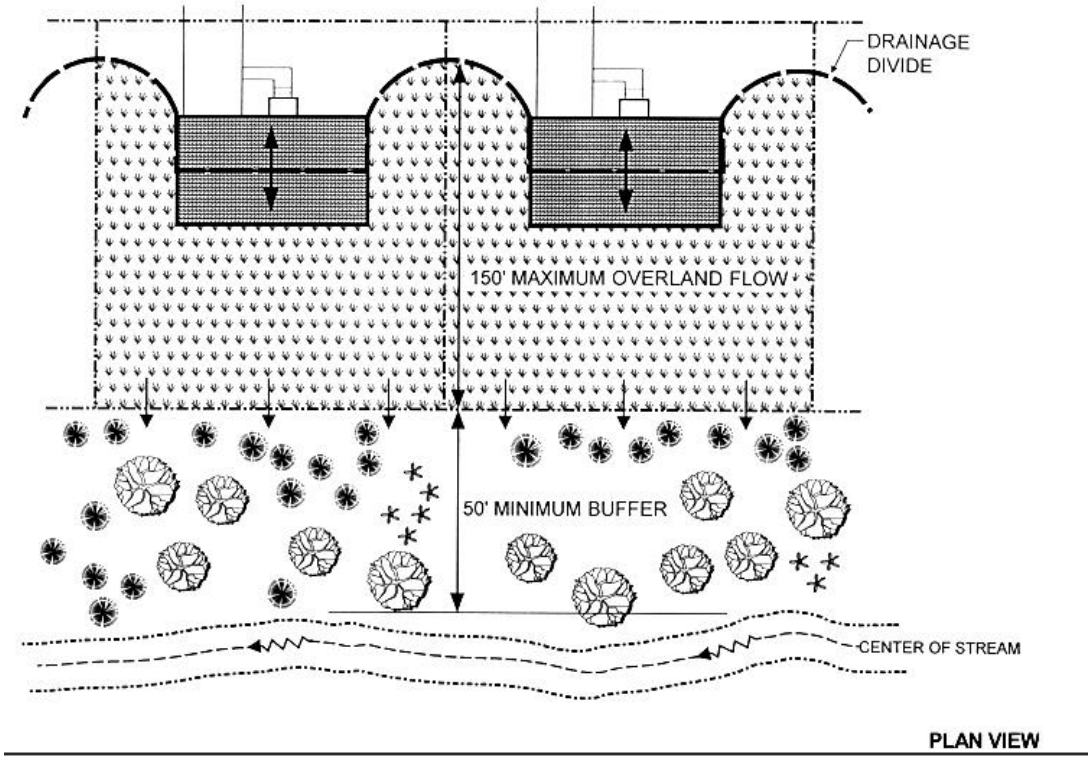
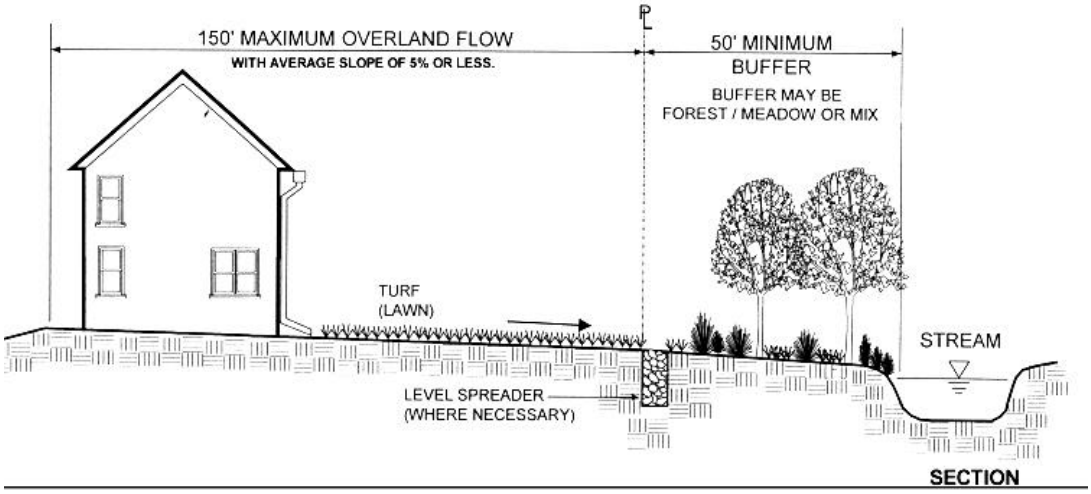
Figure 5.2 Example of Sheetflow to Buffer Credit





B.2.A Infiltration Trench General Notes and Specifications

An infiltration trench may not receive run-off until the entire contributing drainage area to the infiltration trench has received final stabilization.

1. Heavy equipment and traffic shall be restricted from traveling over the proposed location of the infiltration trench to minimize compaction of the soil.

2. Excavate the infiltration trench to the design dimensions. Excavated materials shall be placed away from the trench sides to enhance trench wall stability. Large tree roots must be trimmed flush with the trench sides in order to prevent fabric puncturing or tearing of the filter fabric during subsequent installation procedures. The side walls of the trench shall be roughened where sheared and sealed by heavy equipment.

3. A Class "C" geotextile or better (see Section 24.0, Material Specifications, 1994 Standards and Specifications for Soil Erosion and Sediment Control, MDE, 1994) shall interface between the trench side walls and between the stone reservoir and gravel filter layers. A partial list of non-woven filter fabrics that meet the Class "C" criteria follows. Any alternative filter fabric must be approved by the plan approval authority.

Amoco 4552	Carthage FX-80S
GEOLON N70	Mirafi 180-N
WEBTEC N07	

   The width of the geotextile must include sufficient material to conform to trench perimeter irregularities and for a 6-inch minimum top overlap. The filter fabric shall be tucked under the sand layer on the bottom of the infiltration trench for a distance of 6 to 12 inches. Stones or other anchoring objects should be placed on the fabric at the edge of the trench to keep the trench open during windy periods. When overlaps are required between rolls, the uphill roll should lap a minimum of 2 feet over the downhill roll in order to provide a shingled effect.

4. If a 6 inch sand filter layer is placed on the bottom of the infiltration trench, the sand for the infiltration trench shall be washed and meet AASHTO-M-43, Size No. 9 or No. 10. Any alternative sand gradation must be approved by the plan approval authority.

5. The stone aggregate should be placed in a maximum loose lift thickness of 12 inches. The gravel (rounded "bank run" gravel is preferred) for the infiltration trench shall be washed and meet one of the following AASHTO-M-43, Size No. 2 or No. 3.

6. Following the stone aggregate placement, the filter fabric shall be folded over the stone aggregate to form a 6-inch minimum longitudinal lap. The desired fill soil or stone

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aggregate shall be placed over the lap at sufficient intervals to maintain the lap during subsequent backfilling.

7. Care shall be exercised to prevent natural or fill soils from intermixing with the stone aggregate. All contaminated stone aggregate shall be removed and replaced with uncontaminated stone aggregate.

8. Voids may occur between the fabric and the excavation sides shall be avoided. Removing boulders or other obstacles from the trench walls is one source of such voids. Therefore, natural soils should be placed in these voids at the most convenient time during construction to ensure fabric conformity to the excavation sides.

9. Vertically excavated walls may be difficult to maintain in areas where soil moisture is high or where soft cohesive or cohesionless soils are dominant. These conditions may require laying back of the side slopes to maintain stability.

10. PVC distribution pipes shall be Schedule 40 and meet ASTM-D-1785. All fittings shall meet ASTM-D-2729. Perforations shall be 3/8 inch in diameter. A perforated pipe shall be provided only within the infiltration trench and shall terminate 1 foot short of the infiltration trench wall. The end of the PVC pipe shall be capped. **Note:** PVC pipe with a wall thickness classification of SDR-35 meeting ASTM-D-3034 is an acceptable substitute for the Schedule 40 pipe.

11. The observation well is to consist of 6-inch diameter perforated PVC Schedule 40 pipe (M 278 OR F758, Type PS 28) with a cap set 6 inches above ground level and is to be located near the longitudinal center of the infiltration trench. The pipe shall have a plastic collar with ribs to prevent rotation when removing the cap. The screw top lid shall be a cleanout with a locking mechanism or special bolt to discourage vandalism. The depth to the invert shall be marked on the lid. The pipe shall be placed vertically within the gravel portion of the infiltration trench and a cap provided at the bottom of the pipe. The bottom of the cap shall rest on the infiltration trench bottom.

12. Corrugated metal distribution pipes shall conform to AASHTO-M-36, and shall be aluminized in accordance with AASHTO-M-274. Aluminized pipe in contact with concrete shall be coated with an inert compound capable of preventing the deleterious effect of the aluminum on the concrete. Perforated distribution pipes shall conform to AASHTO-M-36, Class 2 and shall be provided only within the infiltration trench and shall terminate 1 foot short of the infiltration trench wall. An aluminized metal plate shall be welded to the end of the pipe.

13. If a distribution structure with a wet well is used, a 4-inch drain pipe shall be provided at opposite ends of the infiltration trench distribution structure. Two (2) cubic feet of porous backfill meeting AASHTO-M-43, Size No. 57 shall be provided at each drain.

14. If a distribution structure is used, the manhole cover shall be bolted to the frame.

B.2.B Infiltration Basins Notes and Specifications

An infiltration basin may not receive run-off until the entire contributing drainage area to the basin has received final stabilization.

1. The sequence of various phases of basin construction shall be coordinated with the overall project construction schedule. A program should schedule rough excavation of the basin with the rough grading phase of the project to permit use of the material as fill in earthwork areas. The partially excavated basin, however, **cannot** serve as a sedimentation basin.

   Specifications for basin construction should state: (1) the earliest point in progress when storm drainage may be directed to the basin, and (2) the means by which this delay in use is to be accomplished. Due to the wide variety of conditions encountered among projects, each should be separately evaluated in order to postpone use as long as is reasonably possible.

2. Initial basin excavation should be carried to within 2 feet of the final elevation of the basin floor. Final excavation to the finished grade should be deferred until all disturbed areas on the watershed have been stabilized or protected. The final phase excavation should remove all accumulated sediment. Relatively light tracked equipment is recommended for this operation to avoid compaction of the basin floor. After the final grading is completed, the basin should provide a well-aerated, highly porous surface texture.

3. Infiltration basins may be lined with a 6- to 12-inch layer of filter material such as coarse sand (AASHTO-M-43, Sizes 9 or 10) to help prevent the buildup of impervious deposits on the soil surface. The filter layer can be replaced or cleaned when it becomes clogged. When a 6-inch layer of coarse organic material is specified for discing (such as hulls, leaves, stems, etc.) or spading into the basin floor to increase the permeability of the soils, the basin floor should be soaked or inundated for a brief period, then allowed to dry subsequent to this operation. This induces the organic material to decay rapidly, loosening the upper soil layer.

4. Establishing dense vegetation on the basin side slopes and floor is recommended. A dense vegetative stand will not only prevent erosion and sloughing, but will also provide a natural

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means of maintaining relatively high infiltration rates. Erosion protection of inflow points to the basin shall also be provided.

5. Selection of suitable vegetative materials for the side slope and all other areas to be stabilized with vegetation and application of soil amendments (e.g., lime, fertilizer, etc.) shall be done in accordance with the NRCS Standards and Specifications for Critical Area Planting (MD-342) or the 1994 Maryland Standards and Specifications for Soil Erosion and Sediment Control.

6. Grasses of the fescue family are recommended for seeding primarily due to their adaptability to dry sandy soils, drought resistance, hardiness, and ability to withstand brief inundations. The use of fescues will also permit long intervals between mowings. This is important due to the relatively steep slopes which make mowing difficult. Mowing twice a year, once in June and again in September, is generally satisfactory. Refertilization with 10-6-4 ratio fertilizer at a rate of 500 lb per acre (11 lb per 1000 sq ft) may be required the second year after seeding.

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Appendix B.3

Construction Specifications for Sand Filters, Bioretention and Open Channels

rubber tires with large lugs, or high pressure tires will cause excessive compaction resulting in reduced infiltration rates and is not acceptable. Compaction will significantly contribute to design failure.

Compaction can be alleviated at the base of the bioretention facility by using a primary tilling operation such as a chisel plow, ripper, or subsoiler. These tilling operations are to refracture the soil profile through the 12 inch compaction zone. Substitute methods must be approved by the engineer. Rototillers typically do not till deep enough to reduce the effects of compaction from heavy equipment.

Rototill 2 to 3 inches of sand into the base of the bioretention facility before backfilling the optional sand layer. Pump any ponded water before preparing (rototilling) base.

When backfilling the topsoil over the sand layer, first place 3 to 4 inches of topsoil over the sand, then rototill the sand/topsoil to create a gradation zone. Backfill the remainder of the topsoil to final grade.

When backfilling the bioretention facility, place soil in lifts 12" to 18". Do not use heavy equipment within the bioretention basin. Heavy equipment can be used around the perimeter of the basin to supply soils and sand. Grade bioretention materials with light equipment such as a compact loader or a dozer/loader with marsh tracks.

4. Plant Material

Recommended plant material for bioretention areas can be found in Appendix A, Section A.2.3.

5. Plant Installation

Mulch should be placed to a uniform thickness of 2" to 3". Shredded hardwood mulch is the only accepted mulch. Pine mulch and wood chips will float and move to the perimeter of the bioretention area during a storm event and are not acceptable. Shredded mulch must be well aged (6 to 12 months) for acceptance.

Root stock of the plant material shall be kept moist during transport and on-site storage. The plant root ball should be planted so $1/8^{th}$ of the ball is above final grade surface. The diameter of the planting pit shall be at least six inches larger than the diameter of the planting ball. Set and maintain the plant straight during the entire planting process. Thoroughly water ground bed cover after installation.

Trees shall be braced using 2" by 2" stakes only as necessary and for the first growing season only. Stakes are to be equally spaced on the outside of the tree ball.

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Grasses and legume seed should be drilled into the soil to a depth of at least one inch. Grass and legume plugs shall be planted following the non-grass ground cover planting specifications.

The topsoil specifications provide enough organic material to adequately supply nutrients from natural cycling. The primary function of the bioretention structure is to improve water quality. Adding fertilizers defeats, or at a minimum, impedes this goal. Only add fertilizer if wood chips or mulch are used to amend the soil. Rototill urea fertilizer at a rate of 2 pounds per 1000 square feet.

6. Underdrains

Underdrains are to be placed on a 3'-0" wide section of filter cloth. Pipe is placed next, followed by the gravel bedding. The ends of underdrain pipes not terminating in an observation well shall be capped.

The main collector pipe for underdrain systems shall be constructed at a minimum slope of 0.5%. Observation wells and/or clean-out pipes must be provided (one minimum per every 1000 square feet of surface area).

7. Miscellaneous

The bioretention facility may not be constructed until all contributing drainage area has been stabilized.

SARB_005355

Table B.3.2 Materials Specifications for Bioretention

Material	Specification	Size	Notes
Plantings	see Appendix A, Table A.4	n/a	plantings are site-specific
planting soil [2.5' to 4' deep]	sand 35 - 60% silt 30 - 55% clay 10 - 25%	n/a	USDA soil types loamy sand, sandy loam or loam
mulch	shredded hardwood		aged 6 months, minimum
pea gravel diaphragm and curtain drain	pea gravel: ASTM-D-448 ornamental stone: washed cobbles	pea gravel: No. 6 stone: 2" to 5"	
geotextile	Class "C" - apparent opening size (ASTM-D-4751), grab tensile strength (ASTM-D-4632), puncture resistance (ASTM-D-4833)	n/a	for use as necessary beneath underdrains only
underdrain gravel	AASHTO M-43	0.375" to 0.75"	
underdrain piping	F 758, Type PS 28 or AASHTO M-278	4" to 6" rigid schedule 40 PVC or SDR35	3/8" perf. @ 6" on center, 4 holes per row; minimum of 3" of gravel over pipes; not necessary underneath pipes
poured in place concrete (if required)	MSHA Mix No. 3; f'_c = 3500 psi @ 28 days, normal weight, air-entrained; reinforcing to meet ASTM-615-60	n/a	on-site testing of poured-in-place concrete required: 28 day strength and slump test; all concrete design (cast-in-place or pre-cast) *not using previously approved State or local standards* requires design drawings sealed and approved by a professional structural engineer licensed in the State of Maryland - design to include meeting ACI Code 350.R/89; vertical loading [H-10 or H-20]; allowable horizontal loading (based on soil pressures); and analysis of potential cracking
sand [1' deep]	AASHTO-M-6 or ASTM-C-33	0.02" to 0.04"	Sand substitutions such as Diabase and Graystone #10 are not acceptable. No calcium carbonated or dolomitic sand substitutions are acceptable. No "rock dust" can be used for sand.

SARB_005356

B.3.C Specifications for Open Channels and Filter Strips

1. Material Specifications

The recommended construction materials for open channels and filter strips are detailed in Table B.3.3.

2. Dry Swales

Permeable soil mixture (20" to 30" deep) should meet the bioretention specifications.

Check dams, if required, shall be placed as specified.

System to have 6" of freeboard, minimum above 2 year water surface elevation.

Side slopes to be 3:1 maximum; (4:1 or flatter is preferred).

No gravel or perforated pipe is to be placed under driveways.

Bottom of facility to be above the seasonally high water table per Table 2 of Appendix D.1.

Seed with flood/drought resistant grasses; see Appendix A, Section 2.4.

Longitudinal slope to be 4%, maximum.

Bottom width to be 8' maximum to avoid braiding; larger widths may be used if proper berming is supplied. Width to be 2' minimum.

3. Wet Swales

Follow above information for dry swales, with the following exceptions: the seasonally high water table may inundate the swale; but not above the design bottom of the channel [NOTE: if the water table is stable within the channel, the WQ_v storage may start at this point – see Figure 3.19]

Excavate into undisturbed soils; do not use an underdrain system.

SARB_005357

4. Filter Strips

Construct pea gravel diaphragms 12" wide, minimum, and 24" deep minimum.

Pervious berms to be a sand/gravel mix [sand (35-60%), silt (30-55%), and gravel (10-25%)]. Berms to have overflow weirs with 6 inch minimum head.

Slope range to be 2% minimum to 6% maximum.

5. Plant Selection

Recommended grass species for use in establishing permanent ground cover are provided in Section 2.4 of Appendix A.

SARB_005358

Table B.3.3 Open Channel Systems and Filter Strip Materials Specifications

Material	Specification	Size	Notes
dry swale soil	USCS; ML, SM, SC	n/a	soil with a higher percent organic content is preferred
dry swale sand	ASTM C-33 fine aggregate concrete sand	0.02” to 0.04”	
check dam (pressure treated)	AWPA Standard C6	6” by 6” or 8” by 8”	do not coat with creosote; embed at least 3’ into side slopes
check dam (natural wood)	Black Locust, Red Mulberry, Cedars, Catalpa, White Oak, Chestnut Oak, Black Walnut	6” to 12” diameter; notch as necessary	do not use the following, as these species have a predisposition towards rot: Ash, Beech, Birch, Elm, Hackberry, hemlock, Hickories, Maples, Red and Black Oak, Pines, Poplar, Spruce, Sweetgum, Willow
filter strip sand/gravel pervious berm	sand: per dry swale sand gravel; AASHTO M-43	sand: 0.02” to 0.04” gravel: ½ ” to 1”	mix with approximately 25% loam soil to support grass cover crop; sand (35-60%), silt (30-55%), and gravel (10-25%) see Bioretention planting soil notes for more detail.
pea gravel diaphragm and curtain drain	ASTM D 448	varies (No. 6) or (1/8” to 3/8”)	use clean bank-run gravel
underdrain gravel	AASHTO M-43	0.25” to 0.75”	
underdrain	F 758 Type PS 28 or AASHTO M-278	4” to 6” rigid schedule 40 PVC or SDR35	3/8” perf. @ 6” on center, 4 holes per row; minimum of 3” of gravel over pipes; not necessary underneath pipes
geotextile	Class “C” - apparent opening size (ASTM-D-4751), grab tensile strength (ASTM-D-4632), puncture resistance (ASTM-D-4833)	n/a	
rip rap	per county criteria; if none given, use MSHA Standards and Specs Section 905	size per county DOT requirements based on 10-year design flows	

SARB_005359

Design Example 1 – Shallow Wetland (W-1)

The following example demonstrates the process for the design of a shallow wetland (W-1) BMP.

Site Specific Data

Clevenger Community Center is a recreational center located in Charles County, Maryland. The site area and drainage area to the proposed stormwater management facility is 5.3 acres. The project consists of constructing the community center and parking for a total impervious area of 1.94 acres. Existing ground at the outlet of the facility is 44.5' above mean sea level (MSL). Soil borings indicate that the seasonally high water table is at elevation 41'. The underlying soils are loams. TR-55 calculations for the existing and developed hydrologic conditions are shown in Figures C.1.2 and C.1.3.

Confirm Design Criteria

The site is within the Eastern Rainfall Zone and located on the Western Shore of the Chesapeake Bay (see Volume I, Chapter 2, Figures 2.1 and 2.4). Additionally, the site is located within a USE I watershed. Therefore, the following criteria apply:

1. WQ_v treatment is required. In the Eastern Rainfall Zone, P = 1".
2. Re_v treatment is required.
3. Cp_v treatment is required.
4. Q_{p10} may be required by the local jurisdiction. For this example, Q_{p10} will be required.
5. Q_f may be required by the local jurisdiction. For this example, Q will not be required. However, safe conveyance of the 100-year design storm is required through the proposed stormwater management facility.

Preliminary Design

Step 1. Compute WQ_v

Step 1a. Compute Volumetric Runoff Coefficient (R_v)

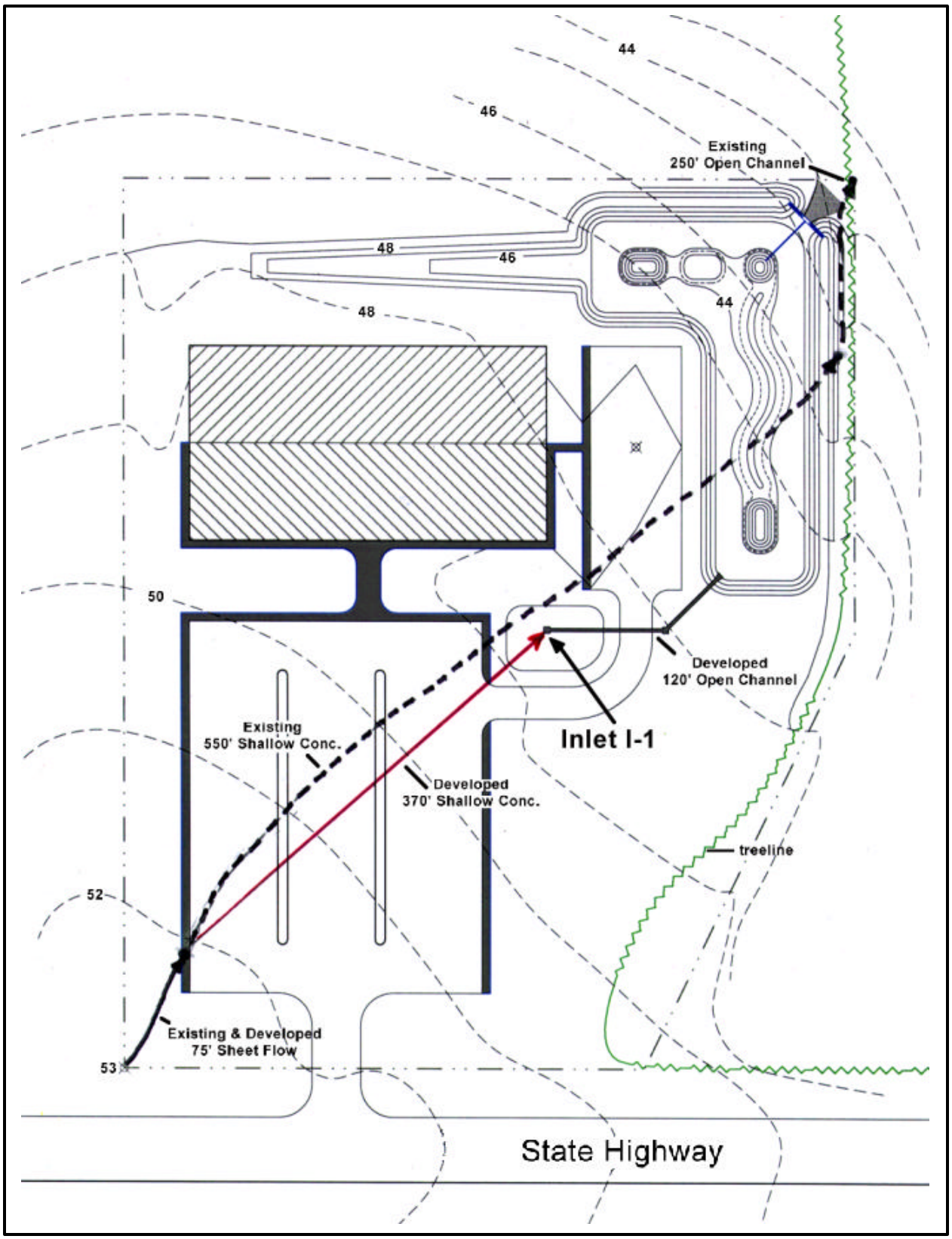
R_v = 0.05 + (0.009)(I); I = 1.94 acres / 5.3 acres = 0.366 or 36.6%
= 0.05 + (0.009)(36.6) = 0.379

Step 1b. Compute WQ_v

WQ_v = [(P)(R_v)(A)]/12
= [(1")(0.379)(5.3 ac)]/12
= 0.167 ac-ft (7,292 cf.)

SARB_005360

Figure C.1.1 Clevenger Community Center Site Plan



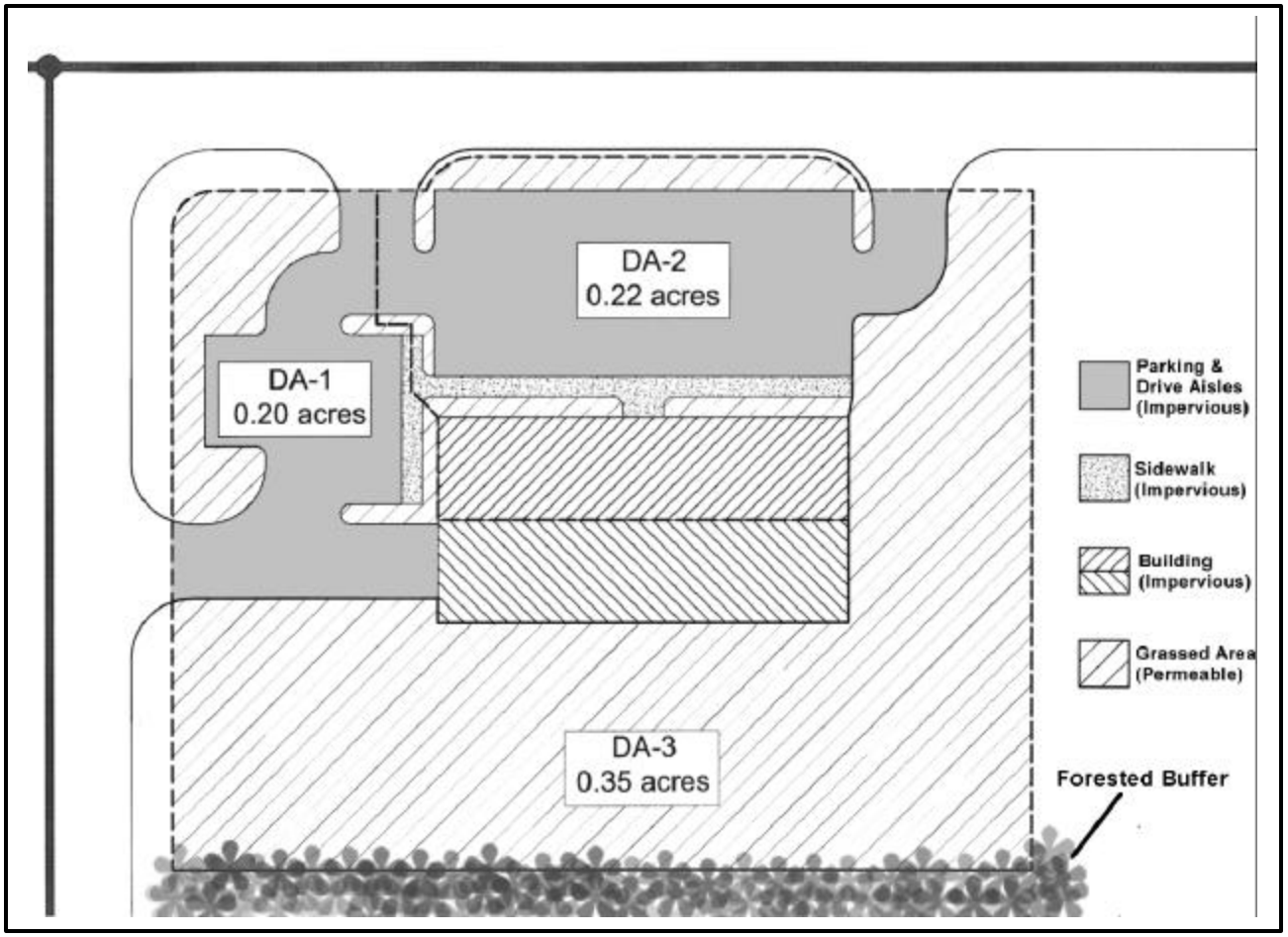
Appendix C.2

Design Example 2 – Water Quality BMPs

Design Example 2 – Water Quality BMPs

The following example demonstrates the design of several different BMPs for WQ_v and Re_v treatment including filtering, infiltration, and open channel practices.

Figure C.2.1 Comstock Commercial Center Site Plan



Site Specifc Data

Comstock Commercial Center is a 0.77 acre retail store located in Howard County, Maryland. The developed area of the site may be divided into two drainage areas of 0.20 and 0.22 acres respectively with a remaining drainage area of 0.35 acres. Total impervious area for the development is 0.36 acres; 0.16 acres in DA-1 and 0.20 acres in DA-2. Existing and proposed topography are not given for this exercise; it may be assumed that these conditions are amenable for each specific design. Likewise, the seasonally high water table will not be a factor in infiltration designs. The underlying soils are loams (HSG B). TR-55 calculations for the developed hydrologic conditions are shown in Figures C.2.2, C.2.3 and C.2.4.

SARB_005363

C.2.1 Design Criteria

The site is within the Eastern Rainfall Zone and located on the Western Shore of the Chesapeake Bay (see Volume I, Chapter 2, Figures 2.1 and 2.4). Additionally, the site is located within a USE I watershed. Therefore, the following criteria apply:

1. WQ_v treatment is required. In the Eastern Rainfall Zone, P = 1".
2. Re_v treatment is required.
3. Cp_v treatment is required.
4. Q_{p10} may be required by the local jurisdiction. For this example, Q_{p10} will not be required.
5. Q_f may be required by the local jurisdiction. For this example, Q will not be required. However, safe conveyance of the 100-year design storm is required through the proposed stormwater management facility.

C.2.2 Preliminary Design

Step 1. Compute WQ_v

Step 1a. Compute Volumetric Runoff Coefficient (R_v)

R_v = 0.05 + (0.009)(I); I = (0.36 acres / 0.77 acres) = 0.468or 46.8%
= 0.05 + (0.009)(46.8) = 0.471

Step 1b. Compute WQ_v

WQ_v = [(P)(R_v)(A)]/12
= [(1")(0.471)(0.77 ac)]/12
= 0.0302 ac-ft (1,316.5 cf.)

SARB_005364

Figure C.2.2 Comstock Commercial Center – Developed Conditions
(source: TR-55 computer printouts)

```
              RUNOFF CURVE NUMBER COMPUTATION            Version 2.10
Project : COMSTOCK COMMERCIAL                    User: SRC      Date: 09-17-1999
County  : HOWARD              State: MD      Checked: ____     Date: ________
Subtitle: DEVELOPED CONDITIONS
--------------------------------------------------------------------------------
                                                    Hydrologic Soil Group
         COVER DESCRIPTION                        A        B        C        D
                                                         Acres (CN)
--------------------------------------------------------------------------------
FULLY DEVELOPED URBAN AREAS (Veg Estab.)
Open space (Lawns,parks etc.)
  Good condition; grass cover > 75%              -  0.41(61)       -        -
Impervious Areas
  Paved parking lots, roofs, driveways           -  0.36(98)       -        -

Total Area (by Hydrologic Soil Group)               .77
--------------------------------------------------------------------------------
                TOTAL DRAINAGE AREA: .77 Acres       WEIGHTED CURVE NUMBER: 78*

                        GRAPHICAL PEAK DISCHARGE METHOD            Version 2.10


Project : COMSTOCK COMMERCIAL CENTER             User: SRC      Date: 12-07-1999
County  : HOWARD              State: MD      Checked: ____     Date: ________
Subtitle: DEVELOPED CONDITIONS

  Data: Drainage Area        :  .77   Acres
        Runoff Curve Number  :  78
        Time of Concentration:  0.10   Hours (MINIMUM VALUE)
        Rainfall Type        :  II
        Pond and Swamp Area  :  NONE

================================================================================
| Storm Number          |   1  |   2  |   3  |   4  |   5  |   6  |   7  |
|-----------------------|------|------|------|------|------|------|------|
| Frequency  (yrs)      |   1  |   2  |   5  |  10  |  25  |  50  |  100 |
| 24-Hr Rainfall (in)   |  2.6 |  3.2 |  4.2 |  5.1 |  5.6 |  6.3 |  7.2 |
| Ia/P Ratio            | 0.22 | 0.18 | 0.13 | 0.11 | 0.10 | 0.09 | 0.08 |
|            Used       | 0.22 | 0.18 | 0.13 | 0.11 | 0.10 | 0.10 | 0.10 |
| Runoff (in)           | 0.85 | 1.27 | 2.05 | 2.80 | 3.23 | 3.85 | 4.66 |
| Unit Peak Discharge   |1.511 |1.534 |1.558 |1.572 |1.578 |1.578 |1.578 |
|    (cfs/acre/in)      |      |      |      |      |      |      |      |
| Pond and Swamp Factor| 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
|    0.0% Ponds Used    |      |      |      |      |      |      |      |
|-----------------------|------|------|------|------|------|------|------|
| Peak Discharge (cfs)  |    1 |    2 |    2 |    3 |    4 |    5 |    6 |
================================================================================

* - Value(s) provided from TR-55 system routines
```


SARB_005365

Figure C.2.3 Comstock Commercial Center – Drainage Area (DA) 1
(source: TR-55 computer printouts)

```
              RUNOFF CURVE NUMBER COMPUTATION            Version 2.10
Project : COMSTOCK COMMERCIAL                    User: SRC      Date: 09-27-1999
County  : HOWARD              State: MD      Checked: ____     Date: ________
Subtitle: DRAINAGE AREA DA-1
--------------------------------------------------------------------------------
                                                    Hydrologic Soil Group
        COVER DESCRIPTION                        A        B        C        D
                                                        Acres (CN)
--------------------------------------------------------------------------------
FULLY DEVELOPED URBAN AREAS (Veg Estab.)
Open space (Lawns,parks etc.)
  Good condition; grass cover > 75%              -  .04 (61)       -        -

Impervious Areas
  Paved parking lots, roofs, driveways           -  0.16(98)       -        -

Total Area (by Hydrologic Soil Group)               .20
                                                    ====
--------------------------------------------------------------------------------
                TOTAL DRAINAGE AREA: .20 Acres      WEIGHTED CURVE NUMBER: 91*
--------------------------------------------------------------------------------
* - Generated for use by GRAPHIC method

                       GRAPHICAL PEAK DISCHARGE METHOD           Version 2.10


Project : COMSTOCK COMMERCIAL CENTER             User: SRC      Date: 12-07-1999
County  : HOWARD               State: MD      Checked: ____     Date: ________
Subtitle: DEVELOPED CONDITIONS DA-1

  Data: Drainage Area        :  .2   Acres
        Runoff Curve Number  :  91
        Time of Concentration:  0.10   Hours
        Rainfall Type        :  II
        Pond and Swamp Area  :  NONE

=================================================================================
| Storm Number          |   1  |   2  |   3  |   4  |   5  |   6  |   7  |
|-----------------------|------|------|------|------|------|------|------|
| Frequency  (yrs)      |   1  |   2  |   5  |  10  |  25  |  50  |  100 |
| 24-Hr Rainfall (in)   |  2.6 |  3.2 |  4.2 |  5.1 |  5.6 |  6.3 |  7.2 |
| Ia/P Ratio            | 0.08 | 0.06 | 0.05 | 0.04 | 0.04 | 0.03 | 0.03 |
|            Used      | 0.10 | 0.10 | 0.10 | 0.10 | 0.10 | 0.10 | 0.10 |
| Runoff (in)           | 1.70 | 2.26 | 3.21 | 4.08 | 4.57 | 5.25 | 6.14 |
| Unit Peak Discharge   |1.578 |1.578 |1.578 |1.578 |1.578 |1.578 |1.578 |
|    (cfs/acre/in)      |      |      |      |      |      |      |      |
| Pond and Swamp Factor| 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
|    0.0% Ponds Used    |      |      |      |      |      |      |      |
|-----------------------|------|------|------|------|------|------|------|
| Peak Discharge (cfs)  |    1 |    1 |    1 |    1 |    1 |    2 |    2 |
=================================================================================
```


SARB_005366

Figure C.2.4 Comstock Commercial Center – Drainage Area (DA) 2
(source: TR-55 computer printouts)

```
               RUNOFF CURVE NUMBER COMPUTATION            Version 2.10
Project : COMSTOCK COMMERCIAL CENTER             User: SRC      Date: 09-21-1999
County  : HOWARD               State: MD      Checked: ____     Date: ________
Subtitle: DRAINAGE AREA DA-2 DEVELOPED
--------------------------------------------------------------------------------
                                                    Hydrologic Soil Group
        COVER DESCRIPTION                        A        B        C        D
                                                        Acres (CN)
--------------------------------------------------------------------------------
FULLY DEVELOPED URBAN AREAS (Veg Estab.)
Open space (Lawns,parks etc.)
  Good condition; grass cover > 75%              -  0.02(61)       -        -

Impervious Areas
  Paved parking lots, roofs, driveways           -  0.20(98)       -        -

Total Area (by Hydrologic Soil Group)               .22
                                                    ====
--------------------------------------------------------------------------------
                TOTAL DRAINAGE AREA: .22 Acres       WEIGHTED CURVE NUMBER: 95*
--------------------------------------------------------------------------------
* - Generated for use by GRAPHIC method

                       GRAPHICAL PEAK DISCHARGE METHOD            Version 2.10
  Data: Drainage Area        :  .22 * Acres
        Runoff Curve Number  :  95 *
        Time of Concentration:  0.10   Hours (MINIMUM VALUE)
        Rainfall Type        :  II
        Pond and Swamp Area  :  NONE

=================================================================================
| Storm Number          |   1  |   2  |   3  |   4  |   5  |   6  |   7  |
|-----------------------|------|------|------|------|------|------|------|
| Frequency  (yrs)      |   1  |   2  |   5  |  10  |  25  |  50  |  100 |
| 24-Hr Rainfall (in)   |  2.6 |  3.2 |  4.2 |  5.1 |  5.6 |  6.3 |  7.2 |
| Ia/P Ratio            | 0.04 | 0.03 | 0.03 | 0.02 | 0.02 | 0.02 | 0.01 |
|            Used      | 0.10 | 0.10 | 0.10 | 0.10 | 0.10 | 0.10 | 0.10 |
| Runoff (in)           | 2.06 | 2.64 | 3.63 | 4.52 | 5.01 | 5.71 | 6.60 |
| Unit Peak Discharge   |1.578 |1.578 |1.578 |1.578 |1.578 |1.578 |1.578 |
|    (cfs/acre/in)      |      |      |      |      |      |      |      |
| Pond and Swamp Factor| 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
|    0.0% Ponds Used    |      |      |      |      |      |      |      |
|-----------------------|------|------|------|------|------|------|------|
| Peak Discharge (cfs) |    1 |    1 |    1 |    2 |    2 |    2 |    2 |
=================================================================================

* - Value(s) provided from TR-55 system routines
```


SARB_005367

Step 2. Compute Re_v

Step 2a. Determine Soil Specific Recharge Factor (*S*) Based on Hydrologic Soil Group

Soils found throughout the site are loams (HSG B) therefore $S = 0.26$

Step 2b. Compute Re_V Using Percent Volume Method

$$Re_v = [(S)(R_v)(A)]/12$$
$$= [(0.26)(0.471)(0.77)]/12$$
$$= \underline{0.0078 \text{ ac-ft.}} \text{ (342.3 cf)}$$

Step 2c. Compute Re_v Using Percent Area Method

$$Re_v = (S)(A_i)$$
$$= (0.26)(0.36 \text{ ac.})$$
$$= 0.094 \text{ acres (4,095 sf.)}$$

The Re_v requirement may be met by: a) treating 342.3 cubic feet using structural methods, b) treating 4,095 square feet using non-structural methods, or c) a combination of both.

Step 3. Compute Cp_v

The proposed community center is located within a USE I watershed, therefore use an extended detention time (*T*) of 24 hours for the one-year storm event. The time of concentration (t_c) and one-year runoff (Q_a) are 0.10 hours and 0.85" respectively.

Use the MDE Method to Compute Storage Volume (Appendix D.11):

Initial abstraction (I_a) for CN of 78 is 0.564: (TR-55) [$I_a = (200/CN)-2$]

$I_a/P = (0.564)/2.6" = 0.22$
$t_c = 0.10$ hours

$q_u = 975$ csm/in. (Figure D.11.1, Appendix D.11)

$q_i = q_u A Q_a$ where *A* is the drainage area in square miles
$= (975 \text{ csm})(0.0012 \text{ square miles})(0.85")$
$= 1.0$ cfs; $q_i < 2.0$ cfs $\therefore$ Cp_v is not required.

SARB_005368

Step 4. Compute Requirements for Sub-Drainage Areas DA-1, DA-2 and DA-3

DA-1: $R_v = 0.05 + (0.009)(I)$; $I = 0.16$ acres / 0.20 acres = 0.80 or 80%
$= 0.05 + (0.009)(80.0) = 0.77$

$WQ_v = [(P)(R_v)(A)]/12$
$= [(1")(0.77)(0.20\ ac)]/12$
$=$ 0.0128 ac-ft (557.5 cf.)

$Re_v = [(S)(R_v)(A)]/12$
$= [(0.26)(0.77)(0.20\ ac)]/12$
$=$ 0.0033 ac-ft (145 cf.)

DA-2: $R_v = 0.05 + (0.009)(I)$; $I = 0.20$ acres / 0.22 acres = 0.91 or 91%
$= 0.05 + (0.009)(91) = 0.87$

$WQ_v = [(P)(R_v)(A)]/12$
$= [(1")(0.87)(0.22\ ac.)]/12$
$=$ 0.0160 ac-ft (694.8 cf.)

$Re_v = [(S)(R_v)(A)]/12$
$= [(0.26)(0.87)(0.22\ ac.)]/12$
$=$ 0.0041 ac-ft (180.6 cf.)

DA-3: $R_v = 0.05 + (0.009)(I)$; $I = 0.0$ acres / 0.35 acres = 0.0 or 0%
$= 0.05 + (0.009)(0.0) = 0.05$

Because $I < 15\%$, $WQ_v = 0.2"$/acre
$WQ_v = [(0.2")(0.35\ ac.)]/12$
$=$ 0.0058 ac-ft (254.1 cf.)

$Re_v = [(S)(R_v)(A)]/12$
$= [(0.26)(0.05)(0.35\ ac.)]/12$
$=$ 0.0004 ac-ft (16.5 cf.)

NOTE: Although DA-3 has no proposed impervious surfaces, portions of DA-3 will be disturbed to construct structural BMPs for DA-1 and DA-2. As a result, WQ_v and Re_v must be addressed for DA-3. For this example, the portion of DA-3 not disturbed for BMP construction shall be treated by promoting sheet flow into the adjacent forested buffer (see Chapter 5.4, "Sheetflow to Buffer Credit").

SARB_005369

Table C.2.1 Summary of General Storage Requirements for Comstock Commercial Center

Requirement	Drainage Area	Volume Required (cubic feet)	Notes
WQ_v^*	Total	1,316.5	The sum of treatment volumes for DA-1, DA-2 and DA-3 is greater than that calculated for the entire site.
	DA-1	557.5	
	DA-2	694.8	
	DA-3	254.1	
Re_v^*	Total	342.3 (or 4,095 sf.)	volume is included within the WQ_v storage
	DA-1	145.6 (or 1,812 sf.)	
	DA-2	180.6 (or 2,265 sf.)	
	DA-3	16.1	
Cp_v		N/A	Cp_v inflow rate is < 2.0 cfs
Q_{p10}		N/A	not required
Q_f		N/A	provide safe passage for the 100-year event in final design

SARB_005370

C.2.3 BMP Design Option 1

The first option consists of the design of a perimeter sand filter (F-3) for DA-1 and a pocket sand filter (F-5) for DA-2. In both designs, Re_v storage will be provided below the filter's underdrain system. As a result, the entire WQ_v must be considered in the design of each filter system. A plan view for Option 1 is shown in Figure C.2.5

C.2.3.1 Perimeter Sand Filter (F-3) for DA-1

Pretreatment

The pretreatment requirements for a perimeter sand filter are as follows:

The pretreatment volume (*Vp*) for the perimeter sand filter shall be at least 25% of the computed WQ_v:

$$V_p = (0.25)(WQ_v)$$
$$= (0.25)(557.5 \text{ cf.})$$
$$= 139.4 \text{ cf.}$$

The minimum required surface area as computed by the Camp-Hazen equation:

$$A_s = \frac{Q_o}{W} \times E' \qquad \text{(see Section 3.4.3 for terms)}$$

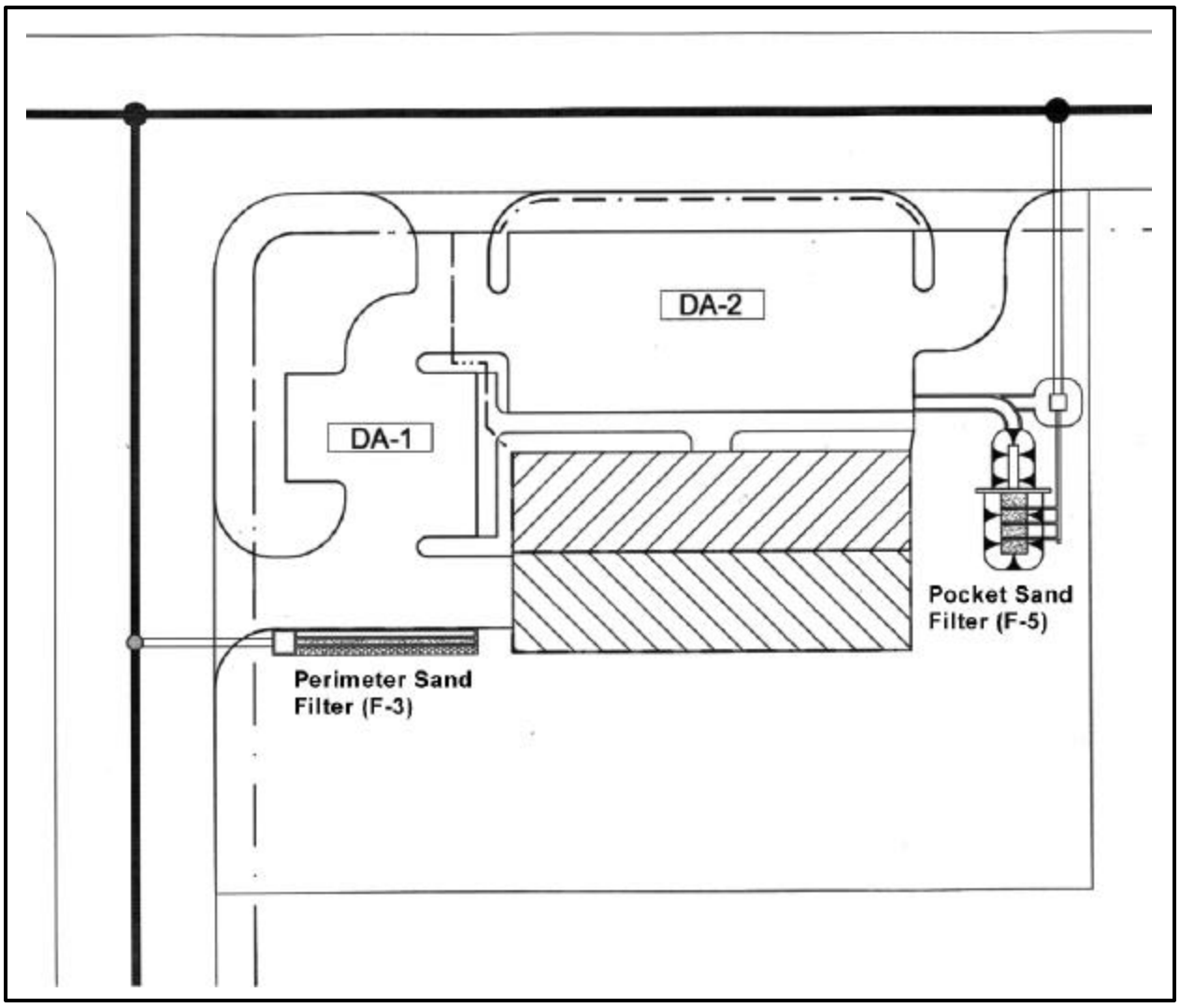
For imperviousness (I) > 75%, this equation reduces to:

$$A_{sp} = (0.0081)(WQ_v)$$
$$= (0.0081)(557.5 \text{ cf.})$$
$$= 4.52 \text{ sf.}$$

Using a width (w) = 1.5 ft. and length (l) = 45 ft., the required depth for the sedimentation chamber = 139.4 cf. / (1.5 ft.)(45 ft.) = 2.06 ft.; **Use a sedimentation chamber 1.5 ft. by 45 ft. by 2.1 ft.**

SARB_005371

Figure C.2.5 Design Option 1 - Plan View



Treatment

The treatment requirements for the perimeter sand filter are as follows:

The entire treatment system (including pretreatment) shall temporarily hold at least 75% of the WQ_v prior to filtration:

$$V_{temp} = (0.75)(WQ_v)$$
$$= (0.75)(557.5 \text{ cf.})$$
$$= 418.1 \text{ cf.}$$

The required filter bed area (A_f) is computed using the following equation:

$$A_f = \frac{(WQ_v)(d_f)}{[k \times (h_f + d_f) \times t_f)]}$$ (see Section 3.4.4)

Minimum filter bed depth (d_f) = 12"; for this design use d_f = 12" (1.0 ft)

The coefficient of permeability (k) for sand filters = 3.5 ft./day

The average height of water above the filter bed (h_f) = (0.5)(design ponding depth). For this design, the ponding depth = 1.0 ft. ∴ hf = 0.5 ft.

The design filter bed drain time (t_f) = 1.67 days

Therefore: $A_f = \dfrac{(557.5\ cf.)(1.0\ ft.)}{[(3.5\ {}^{ft}\!/_{day})(0.5\ ft. + 1.0\ ft.)(1.67\ days)]}$ = 63.6 sf.

Setting the filter chamber width (w) to 1.5 ft., the length (l) of the filter chamber = 63.6 sf./1.5 ft. = 42.4 ft; **Use a filter chamber 1.5 ft. by 45 ft.**

Check V_{temp}: $V_{temp} = V_p + V_{treatment}$

$= 139.4 + [(1.0)(1.5)(45) + (1.0)(1.5)(45)(0.4)] = 236.5$ cf.

note: 0.4 is the porosity of the filter media

Approximately 182 cf. of additional storage is needed to meet this requirement. Either increase the storage in one or both chambers or design parking area to provide additional storage. For this design, the pretreatment chamber width will be increased to 3.5 ft.

$V_{temp} = V_p + V_{treatment}$

$= (3.5)(45.0)(2.1) + [(1.0)(1.5)(45) + (1.0)(1.5)(45)(0.4)] = 425.25$ cf.

Groundwater Recharge (Re_v)

Re_v storage will be provided within a stone-filled trench adjacent to the perimeter sand filter. Setting the trench length (l) = 45 ft., and the width (w) = 2.0 ft, the trench depth (d) needed to store the Re_v volume (V = 145.6 cf.) is:

$$d = \frac{V}{l \times w \times n}$$ where n is the porosity of stone; use n = 0.4

Therefore, d = 145.6 cf./(45.0 ft. × 2.0 ft. × 0.4) = 4.04 ft.; **use a stone-filled trench 45.0 ft. by 2.0 ft. by 4.1 ft.**

Overflow

Flow splitters and overflow devices may be designed using volume or flow rate. For this example, a weir discharging from the sedimentation chamber into the clear well

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will provide volume overflow for the ten-year storm. For DA-1, the ten-year flow (Q_{10}) = 1.0 cfs. Using a weir length of 1.5 ft., the head required to safely convey Q_{10} may be calculated using the weir equation: $Q = Clh^{3/2}$ where C = 3.1, l = weir length (1.5 ft.), and h = head. By rearranging the weir equation and solving for h; $h = [Q/(C \times l)]^{2/3}$ = 0.40 ft. **Design perimeter sand filter with at least 0.4 ft. freeboard to safely convey Q_{10}.**

Design details for the perimeter sand filter are shown in Figures C.2.6.

C.2.3.2 Pocket Sand Filter (F-5) for DA-2

Pretreatment

The pretreatment requirements for a pocket sand filter are as follows:

V_p for the pocket sand filter shall be at least 25% of the computed WQ_v:

$$V_p = (0.25)(WQ_v)$$
$$= (0.25)(694.8 \text{ cf.})$$
$$= 173.7 \text{ cf.}$$

The minimum required surface area as computed by the Camp-Hazen equation:

$$A_s = \frac{Q_o}{W} \times E'$$

For I > 75%, this equation reduces to:

$$A_{sp} = (0.0081)(WQ_v)$$
$$= (0.0081)(694.8 \text{ cf.})$$
$$= 5.62 \text{ sf.}$$

Maintaining at least a 2:1 ratio (l:w); set w = 6.5 ft. and l = 13.0 ft. The required d for the sedimentation area = 173.7 cf. /(6.5 ft.)(13.0 ft.) = 2.0 ft.; **Use a sedimentation chamber 6.5 ft. by 13.0 ft. by 2.0 ft.**

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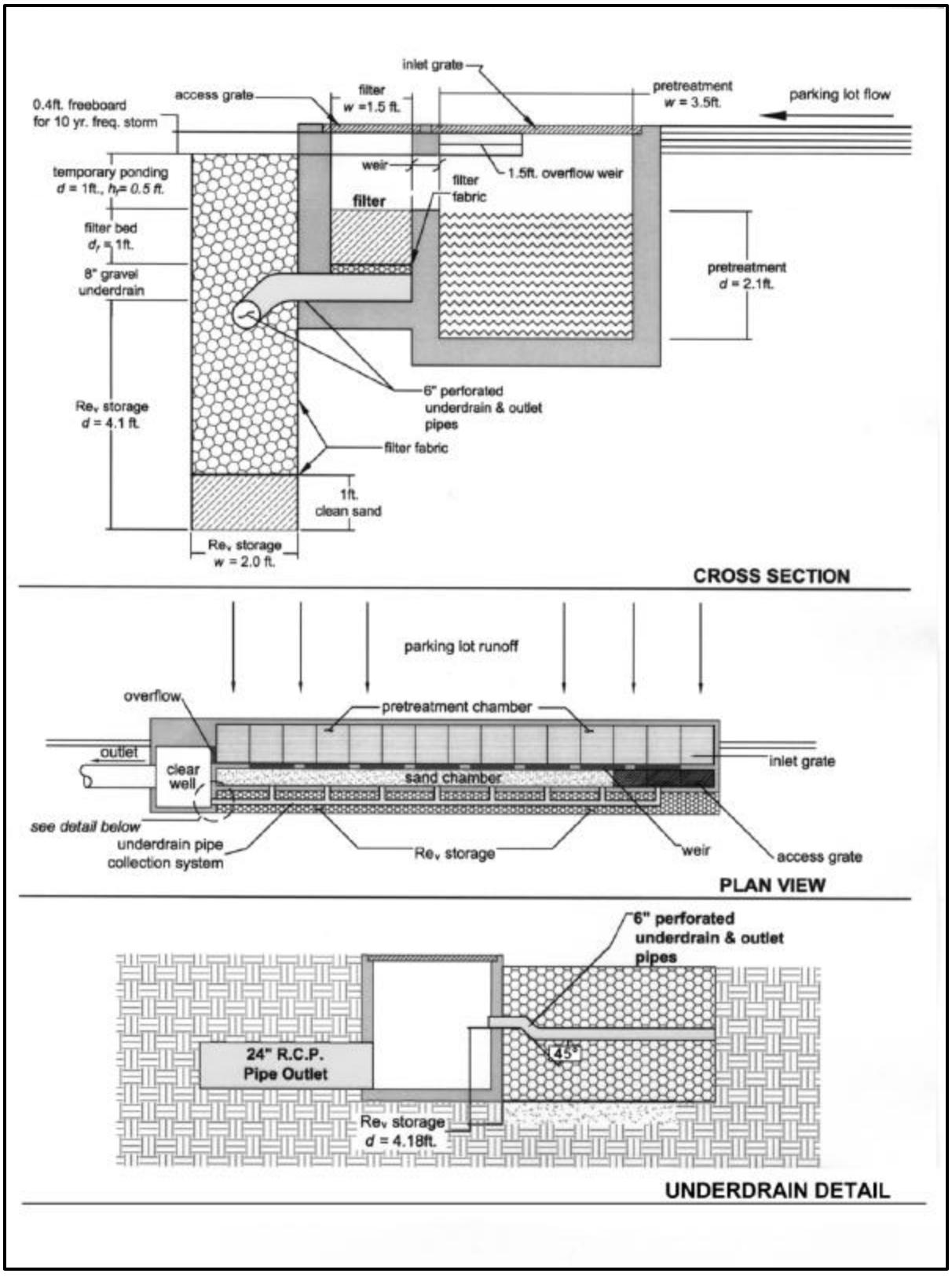
Figure C.2.6 Perimeter Sand Filter Design Details



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Treatment

The treatment requirements for the pocket sand filter are as follows:

The entire treatment system (including pretreatment) shall temporarily hold at least 75% of the WQv prior to filtration:

$$V_{temp} = (0.75(\text{WQv})$$
$$= (0.75)(694.8 \text{ cf.})$$
$$= 521.1 \text{ cf.}$$

The required filter bed area is computed using the following equation:

The minimum d_f for a pocket sand filter = 18"; for this design use d_f = 18" (1.5').

$$A_f = (WQ_v)(d_f) \Big/ [k \times (h_f + d_f) \times t_f)]$$

The coefficient of permeability (k) for sand filters = 3.5 ft/day

The average height of water (h_f) above the filter bed for this design = 0.5 ft.

The design filter bed drain time (t_f) = 1.67 days.

Therefore: $A_f = \dfrac{(694.8\ cf.)(1.5\ ft.)}{[(3.5\ ^{ft}/_{day})(0.5\ ft. + 1.5\ ft.)(1.67\ days)]} = 89.2\ sf.$

Setting the filter chamber width (w) to 6.5 ft. l = 89.2 ft./6.5 ft. = 13.7 ft.; **Use a filter chamber 6.5 ft. by 13.7 ft.**

Check V_{temp}: $V_{temp} = V_p + V_{treatment}$
$= 173.7 + [(1.0)(6.5)(13.7) + (1.5)(6.5)(13.7)(0.4)] = 316.1$ cf.
note: 0.4 is the porosity of the filter media

Approximately 205 cf. of additional storage is needed to meet this requirement. Either increase the storage in one or both chambers or design parking area to provide additional storage. For this design, the pretreatment chamber width will be increased to 9.0 ft. and the depth increased to 3.0 ft.

$V_{temp} = V_p + V_{treatment}$
$= (9.0)(13.0)(3.0) + [(1.5)(6.5)(13.7) + (1.5)(6.5)(13.7)(0.4)] = 538.0$ cf

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Groundwater Recharge (Re_v)

Re_v storage will be provided within a stone-filled reservoir directly below the filter chamber's underdrain system. Using w = 6.5 ft. and l = 13.7 ft., the depth needed to store the Re_v volume (V = 180.6 cf.) is:

$$d = \frac{V}{l \times w \times n}$$ where n is the porosity of stone; use n = 0.4

Therefore, $d = 180.6/(13.7 \text{ ft.} \times 6.5 \text{ ft.} \times 0.4) = 5.1$ ft.; **Use a stone-filled reservoir 6.5 ft. by 13.7 ft. by 5.1 ft.**

Overflow/Bypass

As the pocket sand filter will be located "off-line" from the main conveyance system, a flow splitter will be required to divert the WQv into the filter. Flow splitters may be designed using volume or flow rate. For this example, use a concrete flume with a bottom width of 4.0 ft designed to divert the flow associated with the WQ_v. The head required to divert the WQv flow may be calculated using the weir equation: $Q = Clh^{3/2}$ where Q is flow associated with WQv (using Appendix D.10, Q = 0.3 cfs), C = 3.1, l = 4.0 ft., and h = head. By rearranging the equation and solving for h; $h = [Q/(C \times l)]^{2/3} = 0.084$ ft. **Design flow splitter with a 1 inch high diversion.** NOTE: With this type of flow splitter, runoff in excess of the WQ_v may continue to flow into the sand filter.

Design details for the pocket sand filter are shown in Figures C.2.7 and C.2.8.

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Figure C.2.7 Pocket Sand Filter – Plan View

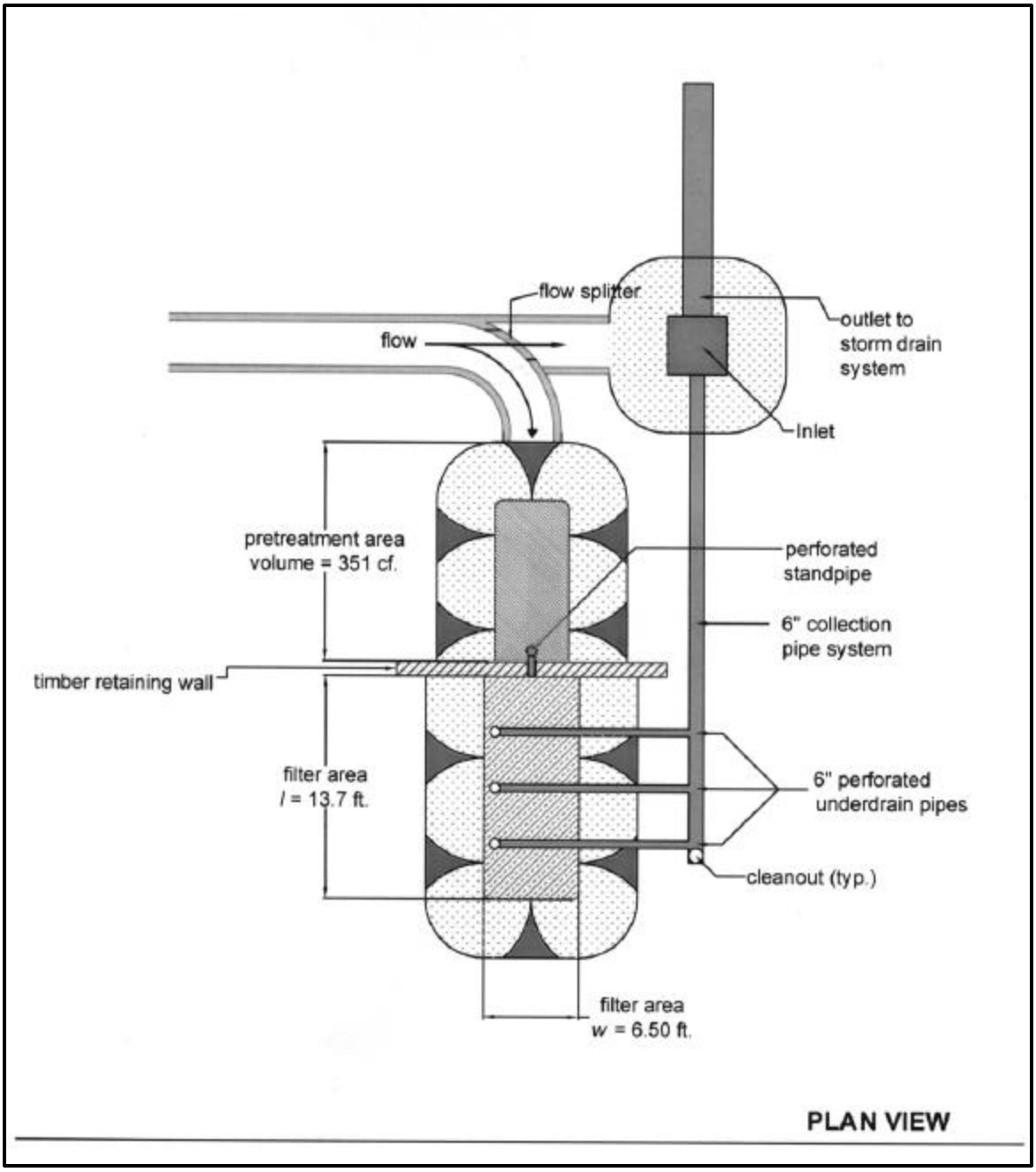

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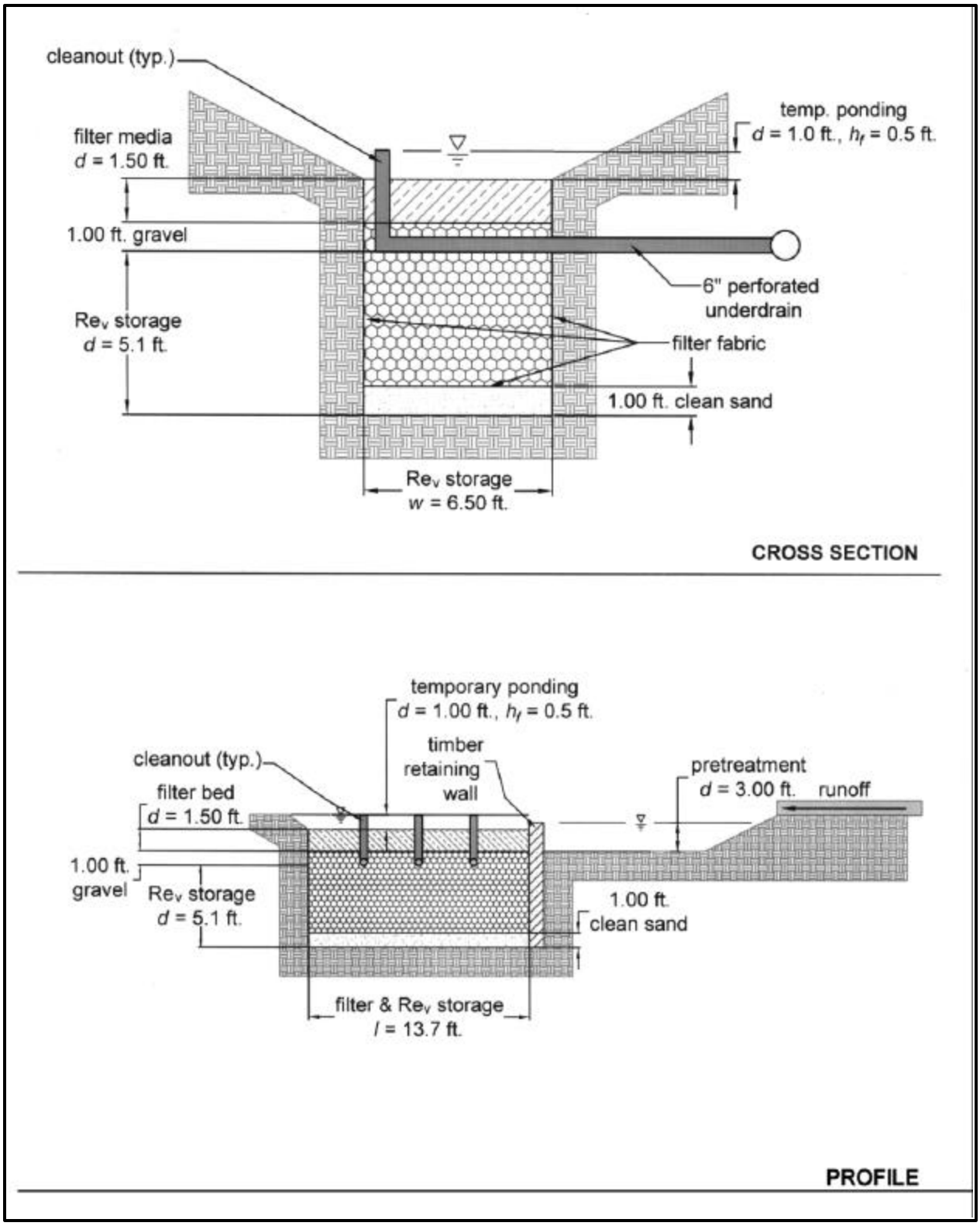
Figure C.2.8 Pocket Sand Filter Design Details



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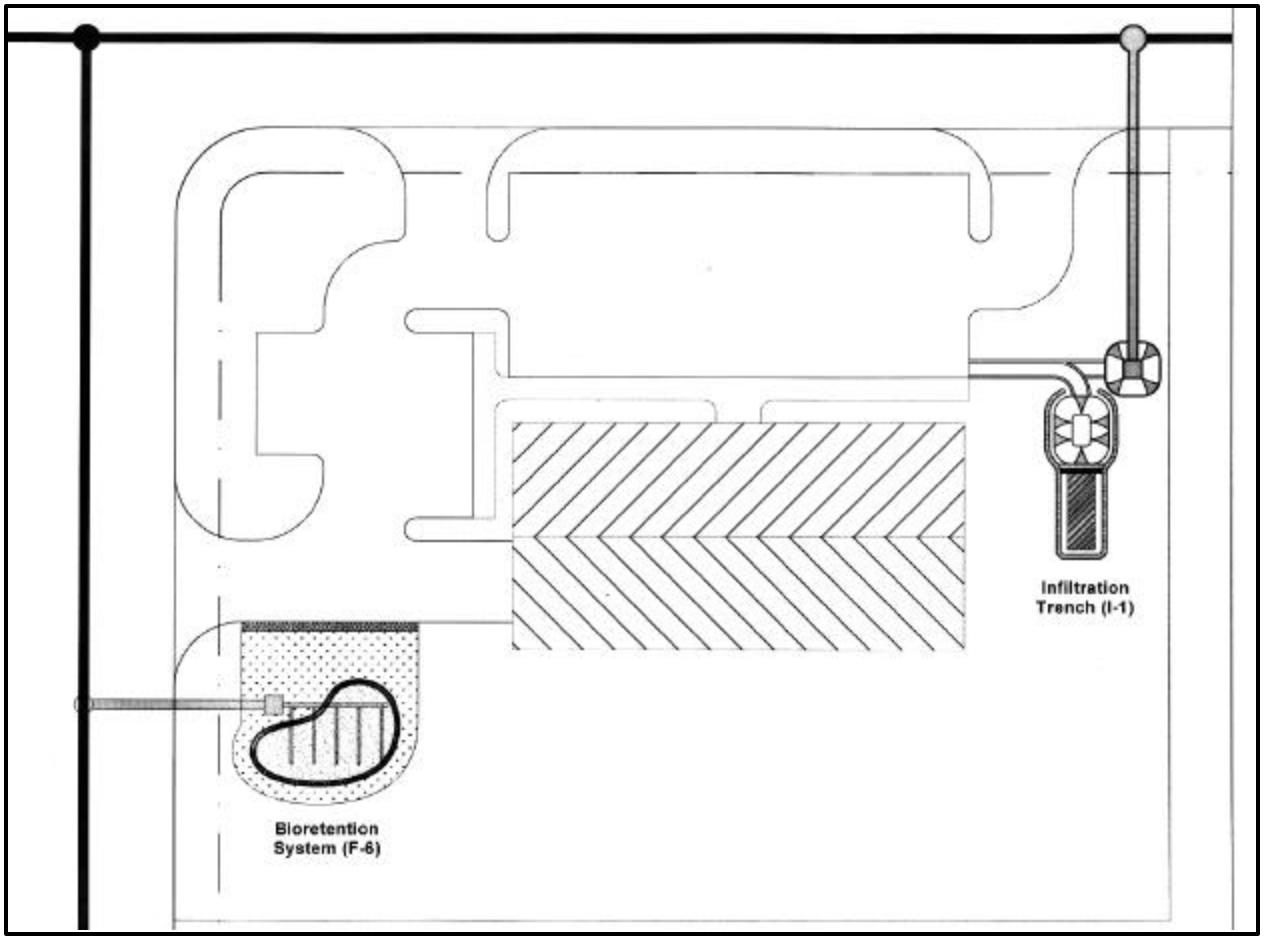
C.2.4 BMP Design Option 2.

The second option consists of the design of a bioretention area (F-6) for DA-1 and an infiltration trench (I-1) for DA-2. For the bioretention system, Re_v storage will be provided below the underdrain system, and as a result, the entire WQ_v will be used as the design. The infiltration trench automatically meets the Re_v requirement. A plan view of Option 2 is shown in Figure C.2.9.

Figure C.2.9 Design Option 2 – Plan View



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C.2.4.1 Bioretention System (F-6) for DA-1

Pretreatment

Adequate pretreatment for a bioretention system is provided when all of the following are provided:

1. 20 ft. grass filter strip below a level spreader or an optional sand filter layer;
2. gravel diaphragm; and
3. 2" to 3" mulch layer.

Treatment

The treatment requirements for the bioretention system are as follows (Section 3.4.3 & 4):

The entire treatment system (including pretreatment) shall temporarily hold at least 75% of the WQv prior to filtration:

$$V_{temp} = (0.75)(WQ_v)$$
$$= (0.75)(557.5 \text{ cf.})$$
$$= 418.1 \text{ cf.}$$

The required filter bed area (A_f) is computed using the following equation:

$$A_f = \frac{(WQ_v)(d_f)}{[k \times (h_f + d_f) \times t_f)]}$$

Recommended filter bed depth (d_f) for a bioretention system is 2.5 to 4.0 ft. For this design, use d_f = 3.0 ft.

The coefficient of permeability (k) for bioretention systems = 0.5 ft./day

The average height of water above the filter bed (h_f) = 0.5 ft. (Note: The maximum ponding depth for a bioretention system is 1.0 ft.)

The design filter bed drain time (t_f) = 2.0 days

Therefore: $A_f = \frac{(557.5\ cf.)(3.0\ ft.)}{[(0.5\ ^{ft}/_{day})(0.5\ ft. + 3.0\ ft.)(2.00\ days)]} = 477.9\ sf.$

Use a bioretention system with minimum surface area = 478 sf.

Check V_{temp}: $V_{temp} = V_{treatment} = (1.0)(478\ sf) + (3.0)(478\ sf)(0.4) = 1051.6$ cf.

note: 0.4 is the porosity of the filter media

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Groundwater Recharge (Re_v)

Re_v storage will be provided in a stone-filled reservoir directly below the underdrain system. Setting the reservoir area (A_r) = 478 sf., the depth (d) needed to store the Re_v volume ($V = 145.6$ cf.) is:

$$d = \frac{V}{A_r \times n}$$ where n is the porosity of stone; use $n = 0.4$

Therefore; $d = 145.6 \text{ cf.} / (478.0 \text{ft.} \times 0.4) = 0.76$ ft.; **Use a stone-filled reservoir 478 sf. by 0.76 ft.**

Overflow

Overflow for the ten-year storm shall be provided to a non-erosive outlet. For this design, a standard inlet will be used to bypass the volume in excess of the WQ_v by setting the inlet invert at the elevation corresponding to the WQ_v treatment volume (1.0 ft. above the bioretention system filter bed).

Design details and a planting plan for the bioretention system are shown in Figures C.2.10 and C.2.11.

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Figure C.2.10 Bioretention System Details

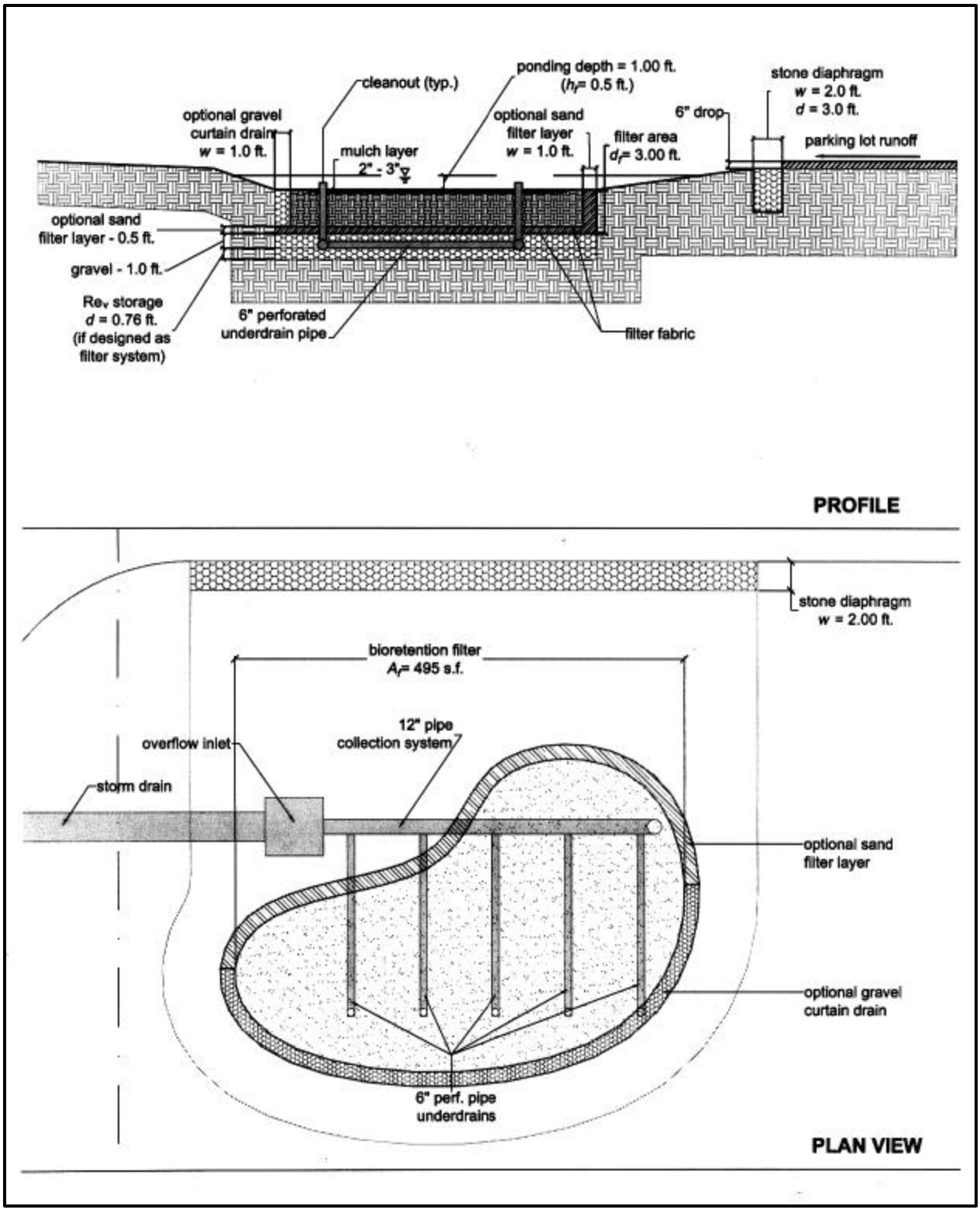
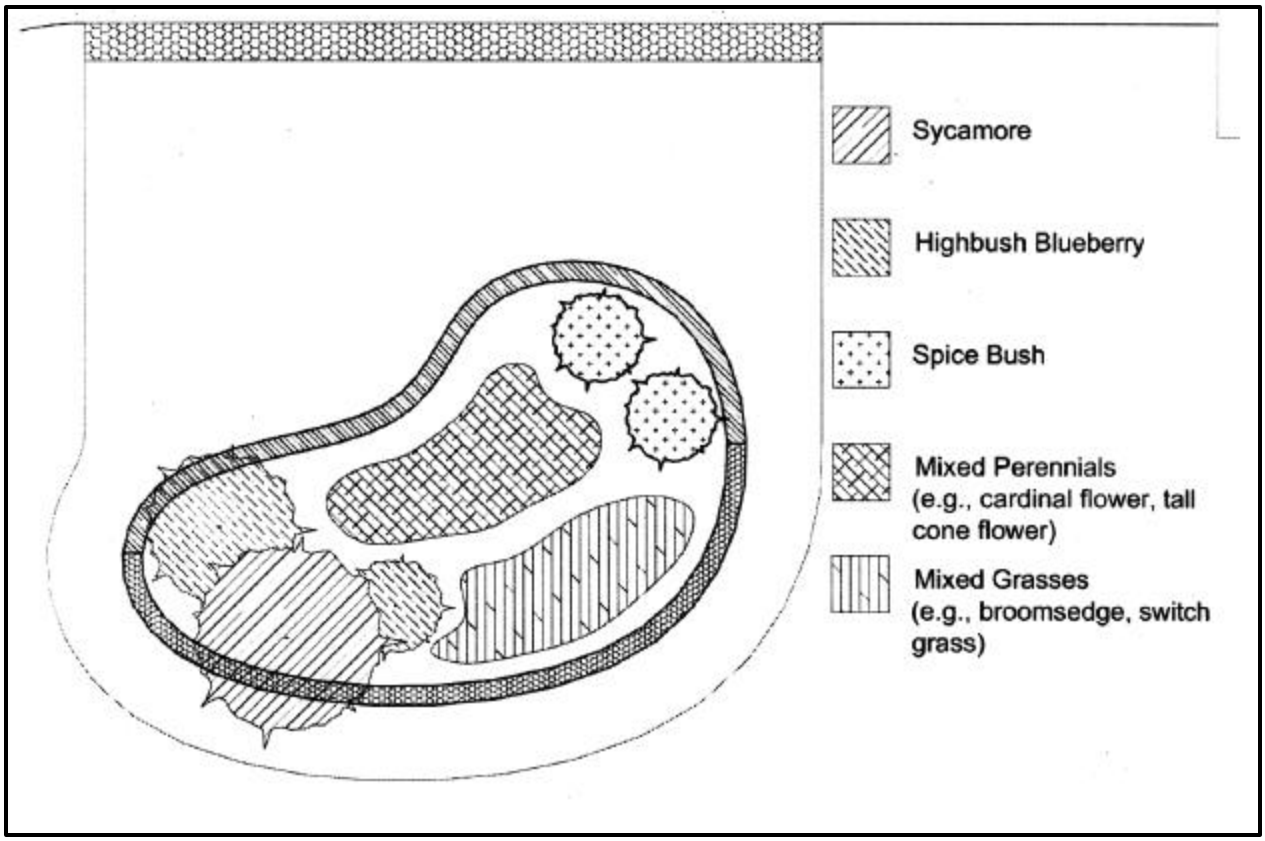


Figure C.2.11 Bioretention Planting Plan



C.2.4.2 Infiltration Trench (I-1) for DA-2

Pretreatment

The pretreatment requirements for an infiltration trench are as follows:

The pretreatment volume (V_p) for the infiltration trench shall be at least 25% of the computed WQ_v:

$$V_p = (0.25)(WQ_v)$$
$$= (0.25)(694.8 \text{ cf.})$$
$$= 173.7 \text{ cf.}$$

Using a width (w) of 8.0 ft. and a length (l) of 11.0 ft., the required depth for the sedimentation chamber = 173.7 cf. /(8.0 ft.)(11.0 ft.) = 1.97 ft.; **Use a sedimentation chamber 8.0 ft by 11.0 ft. by 2.0 ft.**

Additionally, each infiltration trench shall have at least three of the following measures to prevent clogging and maintain the long-term integrity of the trench:

1. grass channel;
2. grass filter strip (minimum 20 ft.);

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3. bottom sand layer
4. upper sand layer (minimum 6") with filter fabric at sand/gravel interface; and
5. use washed bank run gravel as aggregate.

This design will use a bottom sand layer, upper sand layer, and washed bank run gravel.

Treatment

The treatment requirements for an infiltration trench are as follows:

The practice shall be designed to exfiltrate the entire WQv less the pretreatment volume through the floor of the practice. The design volume (V_w) = WQv-V_p = 521.1 cf.

Infiltration practices are designed using the methodology in Appendix D.13.

The maximum allowable depth (d_{max}) of an infiltration trench is

$$d_{\max} = f \times \frac{T_s}{n}$$

where:

f is the infiltration rate, for this design $f = 0.52$ $^{inches}/_{hour}$
T_s is the maximum allowable storage of 48 hours
n is the porosity of the stone reservoir, use 0.4

Therefore, d_{max} = $0.52^{inches}/_{hour} \times (48\ hours/0.4) = 62.4$ inches (5.2 ft). **Use a trench depth (d_t) = 5.0 ft.**

Using equation D.13.3, the area of the infiltration trench (A_t) is:

$$A_t = \frac{V_w}{nd_t + fT}$$ where the time to fill the trench (T) is 2.0 hours.

$$A_t = \frac{521.1\ cf.}{(0.4 \times 5.0) + (0.52^{inches}/_{hour} \times 2.0\ hours \times {}^{1\ ft}/_{12\ in})} = 249.7\ sf.$$

Use an infiltration trench 7.5 ft. by 35.0 ft. by 5.0 ft.

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Groundwater Recharge (Re_v)

Infiltration trenches automatically meet the Re_v storage requirement; no additional storage is required.

Overflow

As the infiltration trench will be located "off-line" from the main conveyance system, a flow splitter will be required to divert the WQv into the filter. Use the flow splitter design from the pocket sand filter above.

Design details for the infiltration trench are shown in Figures C.2.12.

C.2.5 BMP Design Option 3

The third option consists of the bioretention area (F-6) previously designed for DA-1 and a dry swale (O-1) for DA-2. In the dry swale design, Re_v storage will be provided below the swale's underdrain system. As a result, the entire WQv must be considered in the design of the dry swale. A plan view of Option 3 is shown in Figure C.2.13.

C.2.5.1 Dry Swale (O-1) for DA-2

Pretreatment

The pretreatment requirements for a dry swale are as follows:

> Pretreatment storage of 0.1 inch of runoff from impervious area shall be provided. This is equivalent to 10% of WQv. Therefore, $V_p = (10\%)(WQv) = 69.5$ cf. **Use a forebay or sedimentation chamber sized to store 62.5 cf.**

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Figure C.2.12 Infiltration Trench Details

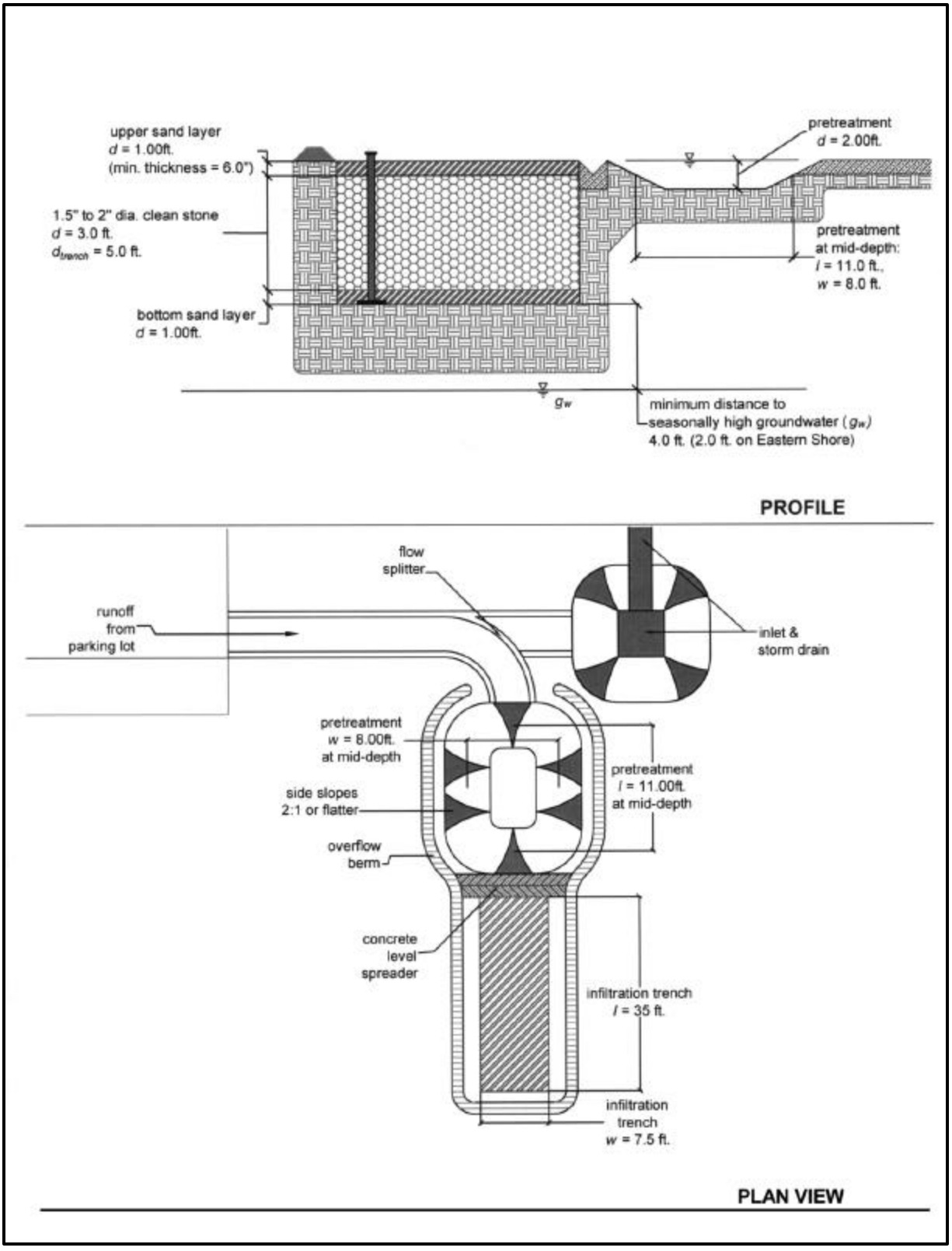
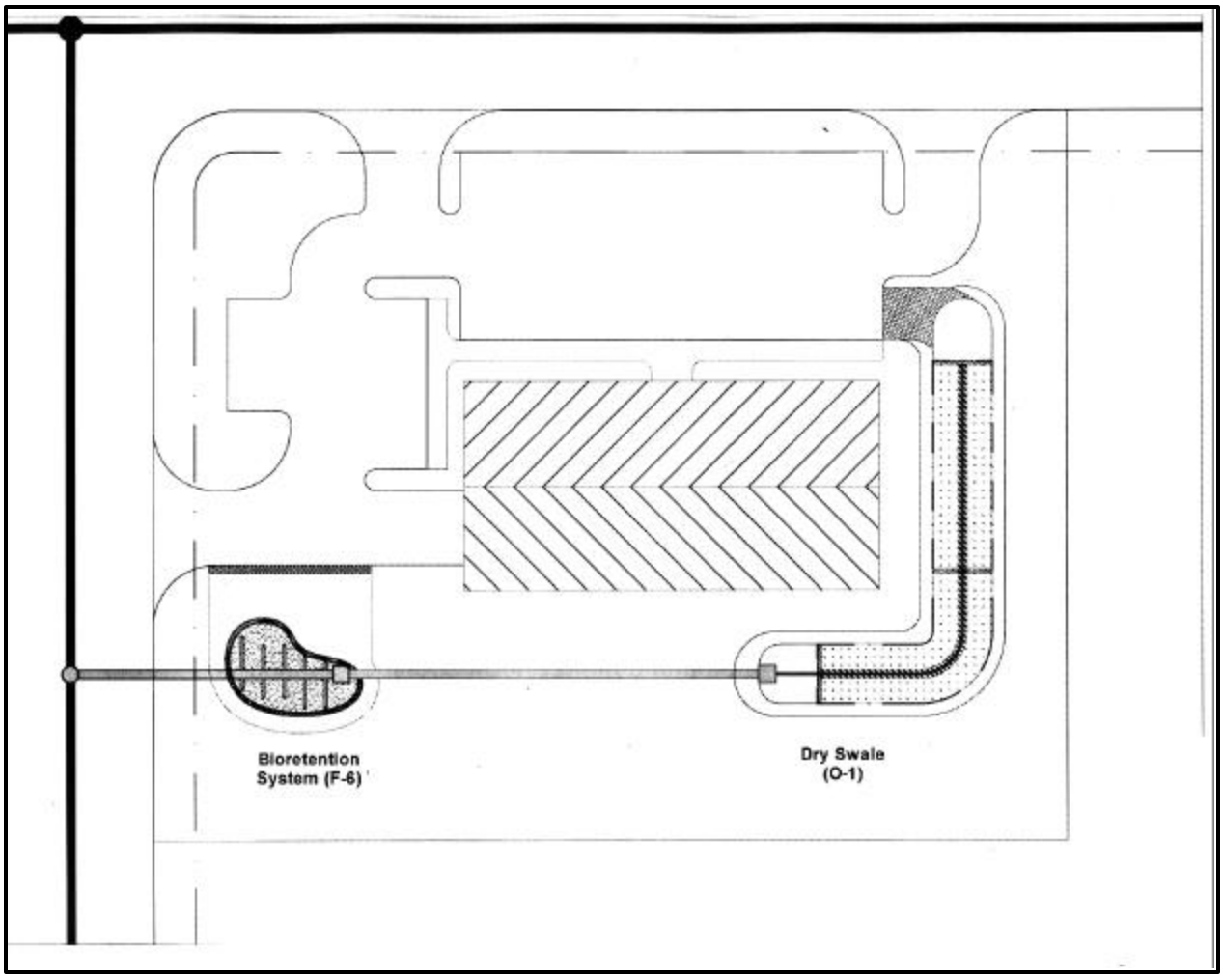


Figure C.2.13 Design Option 3 – Plan View



Treatment

The treatment requirements for the dry swale are as follows:

Dry swales shall be designed to temporarily store the WQv for a maximum 48-hour period. An underdrain system shall provided to ensure the maximum ponding time is not exceeded.

Dry swales shall have a maximum longitudinal slope (*s*) of 4.0%. **For this design, s = 3.0%.**

Channel side slopes (*z*:1) should be no steeper than 2:1. **For this design, side slopes shall be 4:1 (z = 4).**

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Dry swales shall have a bottom width (w_b) no narrower than 2.0 ft. and no wider than 8.0 ft. (if wider than 8.0 ft., a meandering drainage pattern shall be established).

Maximum ponding depths (d_{mid},d_{end}) of 1.0 ft. at the channel mid-point and 1.5 ft. at the downstream end shall be maintained. *Use d_{mid} = 0.75 ft. and d_{max} = 1.5 ft.*

Due to the length (100 ft.) and grade (3.0%) of the channel, the channel will be divided into two contiguous channels separated by a check dam to achieve d_{mid} and d_{end} requirements. *Use three check dams located at the entrance, mid-point and end of the swale*.

With three check dams, there will be two ponding areas of equal storage. Using $d_{mid} = 0.75$', and setting the total length of the swale to 100 ft., the treatment volume of the swale is:

$$WQ_v - V_p = w \times l \times d_{mid}$$

By rearranging this equation and solving for the width of storage surface (w):

$$w = \frac{WQ_v - V_p}{l \times d_{mid}} = \frac{694.8\ cf. - 69.5\ cf.}{100\ ft. \times 0.75\ ft.} = 8.3\ ft.$$

Using w = 8.3 ft. and 4:1 side slopes, $w_b = w\text{-}(2 \times z \times d_{mid}) = 8.3\text{-}(2 \times 4 \times 0.75) = 2.3$ ft. **Use a dry swale with bottom dimensions of 2.3 ft. by 100 ft. with 4:1 side slopes.**

Groundwater Recharge (Re_v)

Re_v storage will be provided within a stone-filled reservoir below the dry swale underdrain system. Using the swale dimensions (2.3 ft by 100 ft.), the reservoir depth (d) needed to store the Re_v volume (V = 180.6 cf.) is:

$$d = \frac{V}{l \times w \times n}$$ where n is the porosity of stone; use $n = 0.4$

Therefore, $d = 180.6\ cf./(100\ ft. \times 2.3\ ft. \times 0.4) = 1.96$ ft. **Use a stone-filled reservoir 2.3 ft. by 100.0 ft. by 2.0 ft.**

Overflow (Q_{10} Conveyance)

A dry swale is required to safely convey the 10-year design storm with minimum freeboard of 3 inches. Check the design to ensure that the 10-year storm is conveyed non-erosively and that the minimum freeboard is provided. For DA-2, the 10-year peak flow (Q_{10}) = 2.0 cfs. At d_{max}, the width (w_{max}) = $w + (2 \times z \times d_{mid}) = 14.3$ ft. Using a trapezoidal channel with a bottom width = 14.3 ft., 4:1 side slopes, and a longitudinal

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slope (s) = 3.0%, the depth (d) and velocity (v) of flow can be calculated using the Manning equation:

$$v = \frac{1.49}{n} r^{2/3} s^{1/2}$$

where: n is the roughness coefficient of the channel lining, use 0.025
r is the hydraulic radius of the channel; at d = 0.10 ft., r is very nearly 0.10

Therefore, at d = 0.1 ft.:

$$v = \frac{1.49}{0.025}(0.10)^{2/3}(0.03)^{1/2} = 2.2 \ fps$$

The cross-sectional area of the channel (A) needed to safely pass Q_{10} can be calculated using $A = Q_{10}/v$ = 2.0 cfs / 2.2 fps = 0.91 sf. At d = 0.1 ft., A = 1.4 sf. **The proposed design will safely convey the 10-year storm.**

The minimum depth of the channel (d_c) may be determined by adding the required depths:

$d_c = d_{max} + d_{10\ yr.\ storm} + d_{freeboard}$
= 1.5 ft. + 0.1 ft. + 0.25 ft.
= 1.85 ft. **Use channel depth (d_c) = 2.0 ft.**

Design details for the dry swale are shown in Figures C.2.14.

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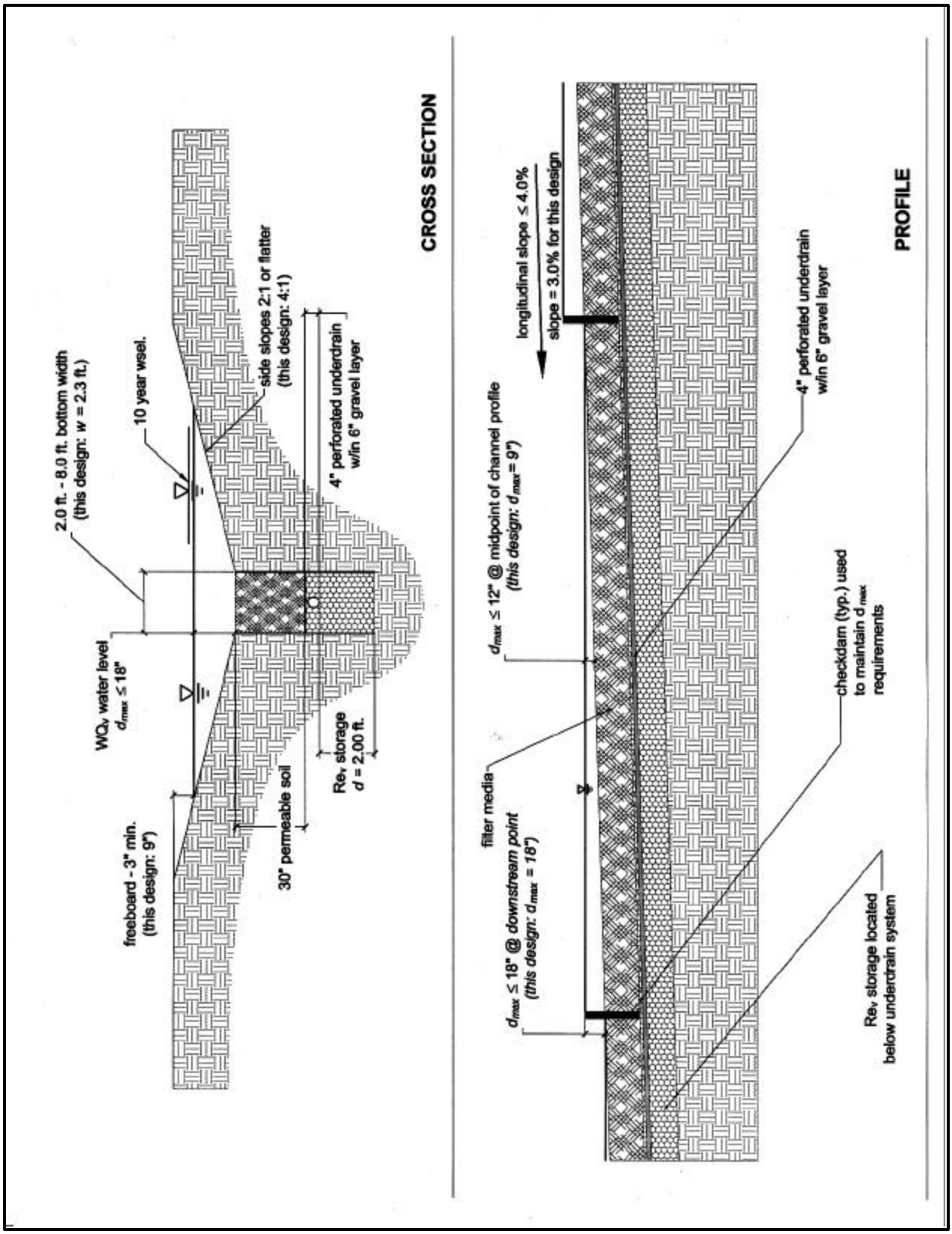
C.2.14 Dry Swale Design Details



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d. Determine United States Department of Agriculture (USDA) or Unified Soil Classification (USC) System textures at the proposed bottom and 4 feet below the bottom of the best management practice (BMP);

e. Determine depth to bedrock (if within 4 feet of proposed bottom);

f. The soil description should include all soil horizons; and

g. The location of the test pit or boring shall correspond to the BMP location; test pit/soil boring stakes are to be left in the field for inspection purposes and shall be clearly labeled as such.

Infiltration Testing Requirements (field testing required)

a. Install casing (solid 5 inch diameter, 30" length) to 24" below proposed BMP bottom (see Figure D.1.1).

b. Remove any smeared soiled surfaces and provide a natural soil interface into which water may percolate. Remove all loose material from the casing. Upon the tester's discretion, a two (2) inch layer of coarse sand or fine gravel may be placed to protect the bottom from scouring and sediment. Fill casing with *clean* water to a depth of 24" and allow to pre-soak for twenty-four hours.

c. Twenty-four hours later, refill casing with another 24" of clean water and monitor water level (measured drop from the top of the casing) for 1 hour. Repeat this procedure (filling the casing each time) three additional times, for a total of four observations. Upon the tester's discretion, the final field rate may either be the average of the four observations, or the value of the last observation. The final rate shall be reported in inches per hour.

d. May be done through a boring or open excavation.

e. The location of the test shall correspond to the BMP location.

f. Upon completion of the testing, the casings shall be immediately pulled, and the test pit shall be back-filled.

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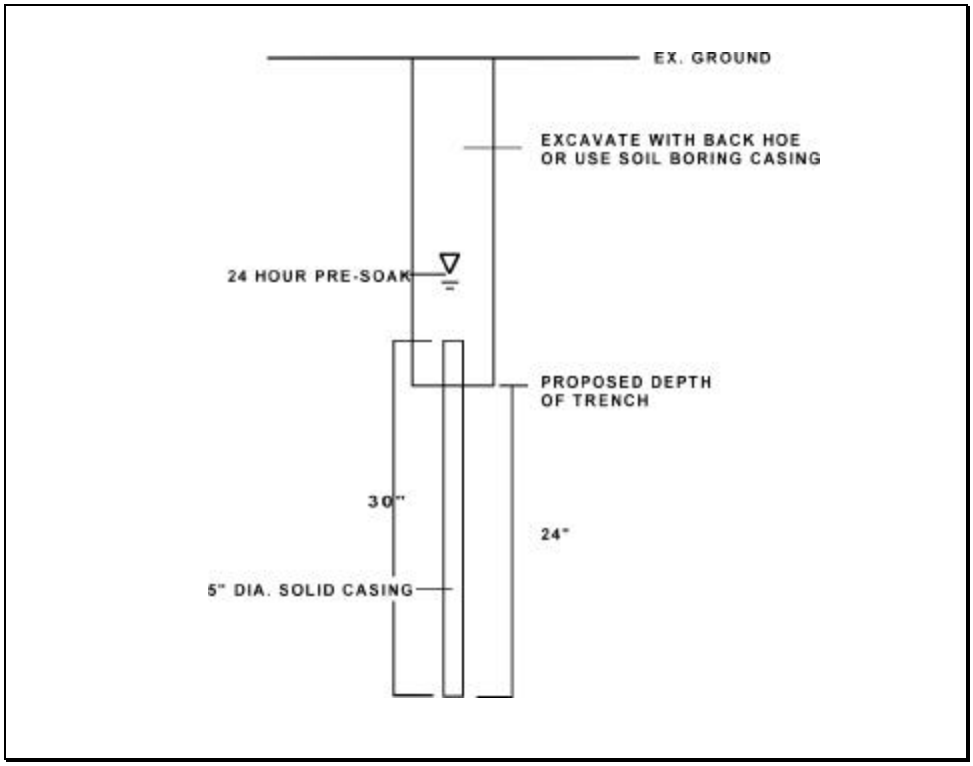
Figure D.1.1 Infiltration Testing Requirements



Laboratory Testing

Use grain-size sieve analysis and hydrometer tests (where appropriate) to determine USDA soils classification and textural analysis. Visual field inspection by a qualified professional may also be used, provided it is documented. The use of lab testing to establish infiltration rates is prohibited.

Bioretention Testing

All areas tested for application of F-6 facilities shall be back-filled with a suitable sandy loam planting media. The borrow source of this media, which may be the same or different from the bioretention area location itself, must be tested as follows:

If the borrow area is undisturbed soil one test is required per 200 square feet of borrow area. The test consists of "grab" samples at one foot depth intervals to the bottom of the borrow area. All samples at the testing location are then mixed, and the resulting sample is then lab-tested to meet the following criteria:

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Glossary
G

Glossary

G.1 Glossary

Portions of this glossary were adapted from the "*1994 Maryland Standards and Specifications for Soil Erosion and Sediment Control*" produced by the Maryland Department of the Environment, Water Management Administration.

ANTI-SEEP COLLAR - An impermeable diaphragm usually of sheet metal or concrete constructed at intervals within the zone of saturation along the conduit of a principal spillway to increase the seepage length along the conduit and thereby prevent piping or seepage.

ANTI-VORTEX DEVICE - A device designed and placed on the top of a riser or the entrance of a pipe to prevent the formation of a vortex in the water at the entrance.

AQUATIC BENCH - A bench which is located around the inside perimeter of a permanent pool and is normally vegetated with aquatic plants; the goal is to provide pollutant removal and enhance safety in areas using stormwater pond BMP's.

AQUIFER – A porous water bearing geologic formation generally restricted to materials capable of yielding an appreciable supply of water

"AS-BUILT" - Drawing or certification of conditions as they were actually constructed.

BAFFLES - Guides, grids, grating or similar devices placed in a pond to deflect or regulate flow and create a longer flow path.

BANKFULL FLOW - The condition where streamflow fills a stream channel to the top of the bank and at a point where the water begins to overflow onto a floodplain.

BARREL - The closed conduit used to convey water under or through an embankment; part of the principal spillway.

BASE FLOW - The stream discharge from groundwater.

BERM - A shelf that breaks the continuity of a slope; a linear embankment or dike.

BEST MANAGEMENT PRACTICE (BMP) - A structural or non-structural device designed to temporarily store or treat stormwater runoff in order to mitigate flooding, reduce pollution and provide other amenities.

BIORETENTION - A water quality practice that utilizes landscaping and soils to treat urban stormwater runoff by collecting it in shallow depressions before filtering through a fabricated planting soil media.

BUFFER – Zone of variable width located along both sides of a natural feature (e.g., stream or forested area) and designed to provide a protective area along a corridor.

CHANNEL - A natural stream that conveys water; a ditch or channel excavated for the flow of water.

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CHANNEL PROTECTION VOLUME (Cpv) - A design criteria which requires 24 hour detention of the one year post-developed, 24 hour storm event for the control of stream channel erosion and is calculated according to Appendix D.11.

CHANNEL STABILIZATION - Erosion prevention and stabilization of velocity distribution in a channel using jetties, drops, revetments, structural linings, vegetation and other measures.

CHECK DAM - A small dam constructed in a gully or other small watercourse to decrease flow velocity (by reducing the channel gradient), minimize scour, and promote deposition of sediment.

CHUTE - A high velocity, open channel for conveying water to a lower level without erosion.

CLAY (SOILS) - 1. A mineral soil separate consisting of particles less than 0.002 millimeter in equivalent diameter. 2. A soil texture class. 3. (Engineering) A fine grained soil (more than 50 percent passing the No. 200 sieve) that has a high plasticity index in relation to the liquid limit. (Unified Soil Classification System)

COCONUT ROLLS - Also known as coir rolls, these are rolls of natural coconut fiber designed to be used for streambank stabilization.

COMPACTION (SOILS) - Any process by which the soil grains are rearranged to decrease void space and bring them in closer contact with one another, thereby increasing the weight of solid material per unit of volume, increasing the shear and bearing strength and reducing permeability.

CONDUIT - Any channel intended for the conveyance of water, whether open or closed.

CONTOUR - 1. An imaginary line on the surface of the earth connecting points of the same elevation. 2. A line drawn on a map connecting points of the same elevation.

CORE TRENCH - A trench, filled with relatively impervious material intended to reduce seepage of water through porous strata.

CRADLE - A structure usually of concrete shaped to fit around the bottom and sides of a conduit to support the conduit, increase its strength and, in dams, to fill all voids between the underside of the conduit and the soil.

CREST - 1. The top of a dam, dike, spillway or weir, frequently restricted to the overflow portion. 2. The summit of a wave or peak of a flood.

CRUSHED STONE - Aggregate consisting of angular particles produced by mechanically crushing rock.

CURVE NUMBER (CN) - A numerical representation of a given area's hydrologic soil group, plant cover, impervious cover, interception and surface storage derived in accordance with Natural Resources Conservation Service methods. This number is used to convert rainfall depth into runoff volume.

CUT - Portion of land surface or area from which earth has been removed or will be removed by excavation; the depth below original ground surface to excavated surface.

CUT-AND-FILL - Process of earth moving by excavating part of an area and using the excavated material for adjacent embankments or fill areas.

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CUTOFF - A wall or other structure, such as a trench, filled with relatively impervious material intended to reduce seepage of water through porous strata.

CZARA - Acronym used for the Coastal Zone Act Reauthorization Amendments of 1990. These amendments sought to address the nonpoint source pollution issue by requiring states to develop coastal nonpoint pollution control programs in order to receive federal funds.

DAM - A barrier to confine or raise water for storage or diversion, to create a hydraulic head, to prevent gully erosion, or for retention of soil, sediment or other debris.

DETENTION - The temporary storage of stormwater runoff in a BMP with the goals of controlling peak discharge rates and providing gravity settling of pollutants.

DETENTION STRUCTURE – A permanent structure for the temporary storage of runoff that is designed to not create a permanent pool of water.

DIKE - An embankment to confine or control water, for example, one built along the banks of a river to prevent overflow to lowlands; a levee.

DISTRIBUTED RUNOFF CONTROL (DRC) - A stream channel protection criteria which utilizes a non-uniform distribution of the storage-stage-discharge relationship within a BMP to minimize the change in channel erosion potential from pre-developed to developed conditions.

DISTURBED AREA - An area in which the natural vegetative soil cover has been removed or altered and, therefore, is susceptible to erosion.

DIVERSION - A channel with a supporting ridge on the lower side constructed across the slope to divert water to areas where it can be used or disposed of safely. Diversions differ from terraces in that they are individually designed.

DRAINAGE - 1. The removal of excess surface water or ground water from land by means of surface or subsurface drains. 2. Soil characteristics that affect natural drainage.

DRAINAGE AREA (WATERSHED) – That area contributing runoff to a single point measured in a horizontal plane, which is enclosed by a ridge line.

DROP STRUCTURE - A structure for dropping water to a lower level and dissipating surplus energy; a fall.

DRY SWALE - An open drainage channel explicitly designed to detain and promote the filtration of stormwater runoff through an underlying fabricated soil media.

EMERGENCY SPILLWAY - A dam spillway, constructed in natural ground, that is to discharge flow in excess of the principal spillway design discharge.

ENERGY DISSIPATOR - A designed device such as an apron of rip-rap or a concrete structure placed at the end of a conduit for the purpose of reducing the velocity, energy and turbulence of the discharged water.

EROSION - 1. The process by which the land surface is worn away by the action of water, wind, ice, or gravity. 2. Detachment and movement of soil or rock fragments by water, wind, ice or gravity. The following terms are used to describe different types of water erosion:

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Accelerated erosion - Erosion much more rapid than normal, natural or geologic erosion, primarily as a result of the influence of the activities of man or, in some cases, of other animals or natural catastrophes that expose base surfaces.

Gully erosion - The erosion process whereby water accumulates in narrow channels and removes the soil from this narrow area to considerable depths ranging from 1 or 2 feet to as much as 75 to 100 feet.

Rill erosion - An erosion process in which numerous small channels only several inches deep are formed. See rill.

Sheet erosion - The spattering of small soil particles caused by the impact of raindrops on wet soils. The loosened and spattered particles may or may not subsequently be removed by surface runoff.

EROSIVE VELOCITIES - Velocities of water that are high enough to wear away the land surface. Exposed soil will generally erode faster than stabilized soils. Erosive velocities will vary according to the soil type, slope, structural, or vegetative stabilization used to protect the soil.

EXFILTRATION - The downward movement of water through the soil; the downward flow of runoff from the bottom of an infiltration BMP into the soil.

EXTENDED DETENTION - A stormwater design feature that provides for the gradual release of a volume of water in order to increase settling of pollutants and protect downstream channels from frequent storm events.

EXTREME FLOOD VOLUME (Q_f) - The storage volume required to control those infrequent but large storm events in which overbank flows reach or exceed the boundaries of the 100-year floodplain.

FILTER BED - The section of a constructed filtration device that houses the filter media and the outflow pipe.

FILTER FENCE - A geotextile fabric designed to trap sediment and filter runoff.

FILTER MEDIA - The sand, soil, or other organic material in a filtration device used to provide a permeable surface for pollutant and sediment removal.

FILTER STRIP - A strip of permanent vegetation above ponds, diversions and other structures to retard the flow of runoff, causing deposition of transported material, thereby reducing sedimentation.

FINES (SOIL) - Generally refers to the silt and clay size particles in soil.

FLOODPLAIN - Areas adjacent to a stream or river that are subject to flooding or inundation during a storm event that occurs, on average, once every 100 years (or has a likelihood of occurrence of 1/100 in any given year).

FLOW SPLITTER - An engineered, hydraulic structure designed to divert a percentage of storm flow to a BMP located out of the primary channel, or to direct stormwater to a parallel pipe system or to bypass a portion of baseflow around a BMP.

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FOREBAY - Storage space located near a stormwater BMP inlet that serves to trap incoming coarse sediments before they accumulate in the main treatment area.

FREEBOARD (HYDRAULICS) - The distance between the maximum water surface elevation anticipated in design and the top of retaining banks or structures. Freeboard is provided to prevent overtopping due to unforeseen conditions.

FRENCH DRAIN - A type of drain consisting of an excavated trench filled with pervious material, such as coarse sand, gravel or crushed stone; water percolates through the voids in this material and flows to an outlet.

GABION - A flexible woven wire basket composed of rectangular cells filled with small stones. Gabions may be assembled into many types of structures such as revetments, retaining walls, channel liners, drop structures and groins.

GABION MATTRESS - A thin gabion, usually six or nine inches thick, used to line channels for erosion control.

GRADE - 1. The slope or finished surface of a road, channel, canal bed, roadbed, top of embankment, bottom of excavation, or natural ground; any surface prepared for the support of construction, like paving or laying a conduit. 2. To finish the surface of a canal bed, roadbed, top of embankment or bottom of excavation.

GRASS CHANNEL - An open vegetated channel used to convey runoff and to provide treatment by filtering pollutants and sediments.

GRAVEL - 1. Aggregate consisting of mixed sizes of 1/4 inch to 3 inches which normally occur in or near old streambeds and have been worn smooth by the action of water. 2. A soil having particle sizes, according to the Unified Soil Classification System, ranging from the No. 4 sieve size, angular in shape, as produced by mechanical crushing.

GRAVEL DIAPHRAGM - A stone trench filled with small, river-run gravel used as pretreatment and inflow regulation in stormwater filtering systems.

GRAVEL FILTER - Washed and graded sand and gravel aggregate placed around a drain or well screen to prevent the movement of fine materials from the aquifer into the drain or well.

GRAVEL TRENCH - A shallow excavated channel backfilled with gravel and designed to provide temporary storage and permit percolation of runoff into the soil substrate.

GROUND COVER - Plants which are low-growing and provide a thick growth which protects the soil as well as providing some beautification of the area occupied.

GULLY - A channel or miniature valley cut by concentrated runoff through which water commonly flows during and immediately after heavy rains or snow melt. The distinction between gully and rill is one of depth. A gully is sufficiently deep such that it would not be obliterated by normal tillage operations, whereas a rill is of lesser depth and would be smoothed by ordinary farm tillage or grading activities.

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HEAD (HYDRAULICS) - 1. The height of water above any plane of reference. 2. The energy, either kinetic or potential, possessed by each unit weight of a liquid expressed as the vertical height through which a unit weight would have to fall to release the average energy possessed. Used in various terms such as pressure head, velocity head, and head loss.

HERBACEOUS PERENNIAL (PLANTS) - A plant whose stems die back to the ground each year.

HIGH MARSH - A pondscaping zone within a stormwater wetland that exists from the surface of the normal pool to a six inch depth and typically contains the greatest density and diversity of emergent wetland plants.

HIGH MARSH WEDGES - Slices of shallow wetland (less than or equal to 6 inches) dividing a stormwater wetland.

HOTSPOT - Area where land use or activities generate highly contaminated runoff, with concentrations of pollutants in excess of those typically found in stormwater.

HYDRAULIC GRADIENT - The slope of the hydraulic grade line. That includes static and potential head.

HYDRODYNAMIC STRUCTURE – An engineered structure to separate sediments and oils from stormwater runoff using gravitational separation and/or hydraulic flow.

HYDROGRAPH - A graph showing variation in stage (depth) or discharge of a stream of water over a period of time.

HYDROLOGIC SOIL GROUP (HSG) - A Natural Resource Conservation Service classification system in which soils are categorized into four runoff potential groups. The groups range from A soils, with high permeability and little runoff production, to D soils, which have low permeability rates and produce much more runoff.

HYDROSEED – An application of seed or other material applied with forced water in order to revegetate.

IMPERVIOUS COVER (I) - Those surfaces in the landscape that cannot infiltrate rainfall consisting of building rooftops, pavement, sidewalks, driveways, etc..

INDUSTRIAL STORMWATER PERMIT - An NPDES permit issued to an identified land use that regulates the pollutant levels associated with industrial stormwater discharges or specifies on-site pollution control strategies.

INFILTRATION RATE (f) - The rate at which stormwater percolates into the subsoil measured in inches per hour.

INFLOW PROTECTION - A water handling device used to protect the transition area between any water conveyance (dike, swale, or swale dike) and a sediment trapping device.

KARST GEOLOGY - Regions that are characterized by formations underlain by carbonate rock and typified by the presence of limestone caverns and sinkholes.

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LEVEL SPREADER - A device for distributing stormwater uniformly over the ground surface as sheet flow to prevent concentrated, erosive flows and promote infiltration.

MANNING'S FORMULA (HYDRAULICS) - A formula used to predict the velocity of water flow in an open channel or pipeline:

$$V = \frac{1.486}{n} r^{2/3} s^{1/2}$$

Where V is the mean velocity of flow in feet per second; r is the hydraulic radius; s is the slope of the energy gradient or for assumed uniform flow the slope of the channel, in feet per foot; and n is the roughness coefficient or retardance factor of the channel lining.

MICROPOOL - A smaller permanent pool which is incorporated into the design of larger stormwater ponds to avoid resuspension of particles and minimize impacts to adjacent natural features.

MICROTOPOGRAPHY - The complex contours along the bottom of a shallow wetland system, providing greater depth variation that increases the wetland plant diversity and increases the surface area to volume ratio.

MULCH - Covering on the soil surface to protect and enhance certain characteristics, such as water retention qualities.

MUNICIPAL STORMWATER PERMIT - An NPDES permit issued to municipalities to regulate discharges from municipal separate storm sewers for compliance with EPA regulations.

NPDES - Acronym for the National Pollutant Discharge Elimination System, which regulates point source discharges.

NON-STRUCTURAL BMPs - Stormwater runoff treatment techniques which use natural measures to reduce pollution levels, do not require extensive construction efforts and/or promote pollutant reduction by eliminating the pollutant source.

NITROGEN-FIXING (BACTERIA) - Bacteria having the ability to fix atmospheric nitrogen, making it available for use by plants.

NORMAL DEPTH - Depth of flow in an open conduit during uniform flow for any given conditions.

OUTFALL - The point where water discharges from a conduit, stream, or drain.

OFF-LINE - A management system designed to control a storm event by diverting a percentage of stormwater events from a stream or storm drainage system.

ON-LINE - A management system designed to control stormwater in its original stream or drainage channel.

ONE YEAR STORM - A stormwater event which occurs on average once every year or statistically has a 100% chance on average of occurring in a given year.

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ONE HUNDRED YEAR STORM - An extreme flood event which occurs on average once every 100 years or statistically has a 1% chance on average of occurring in a given year.

OPEN CHANNEL - Also known as swale, grass channel, and biofilter. This system is used for the conveyance, retention, infiltration and filtration of stormwater runoff.

OUTLET - The point at which water discharges from such things as a stream, river, lake, tidal basin, pipe, channel or drainage area.

OUTLET CHANNEL - A waterway constructed or altered primarily to carry water from man-made structures such as terraces, subsurface drains, diversions and impoundments.

OVERBANK FLOOD PROTECTION VOLUME (Q_p) – The volume controlled by structural practices to prevent an increase in the frequency of out of bank flooding generated by development.

PEAK DISCHARGE RATE - The maximum instantaneous rate of flow during a storm, usually in reference to a specific design storm event.

PERCENT AREA METHOD - Technique used to evaluate the compliance of a non-structural BMP for meeting recharge requirements by calculating the percent of impervious area effectively treated and comparing to a minimum recharge target percentage for the various soil groups.

PERCENT VOLUME METHOD - Procedure used with structural BMPs to evaluate compliance with recharge requirements by assuring that the volume of runoff treated by the practice exceeds the computed recharge volume.

PERMANENT SEEDING - The establishment of perennial vegetation which may remain for many years.

PERMEABILITY - The rate of water movement through a soil column under saturated conditions.

PERMEABLE COVER – Those surfaces in the landscape consisting of open space, forested areas, meadows, etc. that infiltrate rainfall.

PERMISSIBLE VELOCITY (HYDRAULICS) - The highest average velocity at which water may be carried safely in a channel or other conduit. The highest velocity that can exist through a substantial length of a conduit and not cause scour of the channel. A safe, non-eroding or allowable velocity

pH - A number denoting the common logarithm of the reciprocal of the hydrogen ion concentration. A pH of 7.0 denotes neutrality, higher values indicate alkalinity, and lower values indicate acidity.

PIPING - Removal of soil material through subsurface flow channels.

PLUGS - Pieces of turf or sod, usually cut with a round tube, which can be used to propagate the turf or sod by vegetative means.

POCKET POND - A stormwater pond designed for treatment of small drainage area (< 5 acres) runoff and which has little or no baseflow available to maintain water elevations and relies on groundwater to maintain a permanent pool.

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POCKET WETLAND - A stormwater wetland design adapted for the treatment of runoff from small drainage areas (< 5 acres) and which has little or no baseflow available to maintain water elevations and relies on groundwater to maintain a permanent pool.

POND BUFFER - The area immediately surrounding a pond which acts as a filter to remove pollutants and provide infiltration of stormwater prior to reaching the pond. Provides a separation barrier to adjacent development.

POND DRAIN - A pipe or other structure used to drain a permanent pool within a specified time period.

PONDSCAPING - Landscaping around stormwater ponds which emphasizes using native vegetative species to meet specific design intentions. Species are selected for up to six zones in the pond and its surrounding buffer based on their ability to tolerate inundation and/ or soil saturation.

POROSITY (n) - Ratio of pore volume to total volume.

PRETREATMENT - Techniques employed in stormwater BMPs to provide storage or filtering to help trap coarse materials and other pollutants before they enter the system.

PRINCIPAL SPILLWAY - The primary pipe or weir which carries baseflow and storm flow through a dam embankment.

RECHARGE RATE - Annual amount of rainfall which contributes to groundwater as a function of hydrologic soil group.

RECHARGE VOLUME (Re_v) – The portion of the water quality volume (WQ_v) used to maintain groundwater recharge rates at development sites.

REDEVELOPMENT - Any construction, alteration, or improvement exceeding five thousand square feet of land disturbance performed on sites where existing land use is commercial, industrial, institutional, or multifamily residential.

RETENTION - The amount of precipitation on a drainage area that does not escape as runoff. It is the difference between total precipitation and total runoff.

REVERSE-SLOPE PIPE - A pipe which draws from below a permanent pool extending in a reverse angle up to the riser and determines the water elevation of the permanent pool.

RIGHT-OF-WAY - Right of passage, as over another's property. A route that is lawful to use. A strip of land acquired for transport, conveyance or utility construction.

RIP-RAP - Broken rock, cobbles, or boulders placed on earth surfaces, such as the face of a dam or the bank of a stream, for protection against the action of water (waves); also applies to brush or pole mattresses or brush and stone, or similar materials used for soil erosion control.

RISER - A vertical pipe or structure which extends from the bottom of a pond and houses the control devices (weirs/orifices) to achieve the discharge rates for specified designs.

ROUGHNESS COEFFICIENT (HYDRAULICS) - A factor in velocity and discharge formulas representing the effect of channel roughness on energy losses in flowing water. Manning's "n" is a commonly used roughness coefficient.

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RUNOFF (HYDRAULICS) - That portion of the precipitation on a drainage area that is discharged from the area in the stream channels. Types include surface runoff, groundwater runoff or seepage.

SAFETY BENCH - A relatively flat area above the permanent pool and surrounding a stormwater pond designed to provide a separation to adjacent slopes.

SAND - 1. (Agronomy) A soil particle between 0.05 and 2.0 millimeters in diameter. 2. A soil textural class. 3. (Engineering) According to the Unified Soil Classification System, a soil particle larger than the No. 200 sieve (0.074mm) and passing the No. 4 sieve (approximately 1/4 inch).

SEDIMENT – Soils or other surficial materials transported or deposited by the action of wind, water, ice, or gravity as a product of erosion.

SEEPAGE - 1. Water escaping through or emerging from the ground. 2. The process by which water percolates through soil.

SEEPAGE LENGTH - In sediment basins or ponds, the length along the pipe and around the anti-seep collars that is within the zone of saturation through an embankment.

SETBACKS - The minimum distance requirements for locating certain structures in relation to roads, wells, septic fields, or other structures.

SHEET FLOW - Water, usually storm runoff, flowing in a thin layer over the ground surface.

SIDE SLOPES (ENGINEERING) - The slope of the sides of a channel, dam or embankment. It is customary to name the horizontal distance first, as 1.5 to 1, or frequently, 1 ½: 1, meaning a horizontal distance of 1.5 feet to 1 foot vertical.

SILT - 1. (Agronomy) A soil separate consisting of particles between 0.05 and 0.002 millimeter in equivalent diameter. 2. A soil textural class. 3. (Engineering) According to the Unified Soil Classification System a fine grained soil (more than 50 percent passing the No. 200 sieve) that has a low plasticity index in relation to the liquid limit.

SOIL TEST – 1. Physical analysis of soil properties such as grain size, plasticity, or texture. 2. Chemical analysis of soil to determine the need for fertilizers or amendments for species of plant being grown.

SPILLWAY - An open or closed channel, or both, used to convey excess water from a reservoir. It may contain gates, either manually or automatically controlled to regulate the discharge of excess water.

STABILIZATION - Providing vegetative and/or structural measures that will reduce or prevent erosion.

STAGE (HYDRAULICS) - The variable water surface or the water surface elevation above any chosen datum.

STILLING BASIN - An open structure or excavation at the foot of an outfall, conduit, chute, drop, or spillway to reduce the energy of the descending stream of water.

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STORMWATER FILTERING - Stormwater treatment methods which utilize an artificial media to filter out pollutants entrained in urban runoff.

STORMWATER PONDS - A land depression or impoundment created for the detention or retention of stormwater runoff.

STORMWATER WETLANDS - Shallow, constructed pools that capture stormwater and allow for the growth of characteristic wetland vegetation.

STREAM BUFFERS - Zones of variable width which are located along both sides of a stream and are designed to provided a protective natural area along a stream corridor.

STRUCTURAL BMPs - Devices which are constructed to provide temporary storage and treatment of stormwater runoff.

SUBGRADE - The soil prepared and compacted to support a structure or a pavement system.

TAILWATER - Water, in a river or channel, immediately downstream from a structure.

TECHNICAL RELEASE No. 20 (TR-20) - A Soil Conservation Service (now NRCS) watershed hydrology computer model that is used to compute runoff volumes and provide routing of storm events through stream valleys and/or ponds.

TECHNICAL RELEASE No. 55 (TR-55) - A watershed hydrology model developed by the Soil Conservation Service (now NRCS) used to calculate runoff volumes and provide a simplified routing for storm events through stream valleys and/or ponds.

TEMPORARY SEEDING - A seeding which is made to provide temporary cover for the soil while waiting for further construction or other activity to take place.

TEN-YEAR STORM - The 24 hour storm event which exceeds bankfull capacity and occurs on average once every ten years (or has a likelihood of occurrence of 1/10 in a given year).

TIME OF CONCENTRATION (t_c) - Time required for water to flow from the most remote point of a watershed, in a hydraulic sense, to the outlet.

TOE (OF SLOPE) - Where the slope stops or levels out. Bottom of the slope.

TOE WALL - Downstream wall of a structure, usually to prevent flowing water from eroding under the structure.

TOPSOIL - Fertile or desirable soil material used for the preparation of a seedbed.

TOTAL PHOSPHORUS (TP) – The total amount of phosphorus that is contained within the water column.

TOTAL SUSPENDED SOLIDS (TSS) - The total amount of particulate matter that is suspended in the water column.

TRASH RACK - Grill, grate or other device installed at the intake of a channel, pipe, drain or spillway for the purpose of preventing oversized debris from entering the structure.

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TRUNCATED HYDROGRAPH - A method of computing the required design infiltration storage volume utilizing the differences from post-developed and pre-developed hydrograph volumes over a specific time frame.

TWO-YEAR STORM - The 24 hour storm event which exceeds bankfull capacity and occurs on average once every two years (or has a likelihood of occurrence of 1/2 in a given year).

ULTIMATE CONDITION - Full watershed build-out based on existing zoning.

ULTRA-URBAN - Densely developed urban areas in which little pervious surface exists.

VELOCITY HEAD - Head due to the velocity of a moving fluid, equal to the square of the mean velocity divided by twice the acceleration due to gravity (32.16 feet per second per second)[$v^2/2g$].

VOLUMETRIC RUNOFF COEFFICIENT (R_v) - The value that is applied to a given rainfall volume to yield a corresponding runoff volume based on the percent impervious cover in a drainage basin.

WATER QUALITY VOLUME (WQ_v) - The volume needed to capture and treat 90% of the average annual stormwater runoff volume equal to 1" (or 0.9" in Western Rainfall Zone) times the volumetric runoff coefficient (R_v) times the site area.

WATER SURFACE PROFILE - The longitudinal profile assumed by the surface of a stream flowing in an open channel; the hydraulic grade line.

WATER USE DESIGNATION - State of Maryland water use classification for the protection of resources (i.e., Use I-contact recreational use, Use II-shellfish harvest waters, Use III-natural trout waters, Use IV-recreational trout waters).

WEDGES - Design feature in stormwater wetlands that increases flow path length to provide for extended detention and treatment of runoff.

WET SWALE - An open drainage channel or depression, explicitly designed to retain water or intercept groundwater for water quality treatment.

WETTED PERIMETER - The length of the wetted surface of the channel.

WING WALL – Side wall extensions of a structure used to prevent sloughing of banks or channels.

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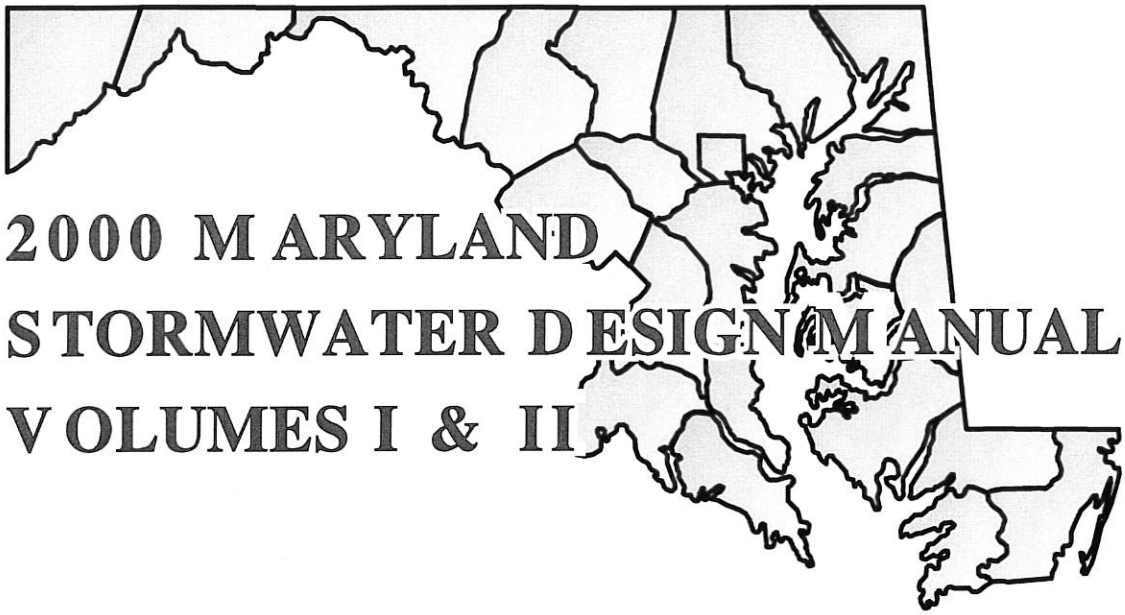

2000 MARYLAND STORMWATER DESIGN MANUAL VOLUMES I & II

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MARYLAND STORMWATER DESIGN MANUAL

VOLUMES I AND II

MDE

Preface

Stormwater management has evolved dramatically in Maryland since it became the first state to adopt stormwater quality regulations some fifteen years ago. Much has been learned about what works in the field and what does not. The goal for this project is to compile this hard-won knowledge and experience into a single comprehensive design manual that is truly useful to engineers and plan reviewers who design and construct stormwater practices.

We would like to acknowledge the many people who helped us get to this point. In particular, we are grateful to the staff at the Water Management Administration of the Maryland Department of Environment who played an active role in getting the manual to this point. In particular, the patience and support of Stewart Comstock (Project Manager), Ken Pensyl, Brian Clevenger and James Tracy is gratefully acknowledged. In addition, the assistance of other MDE staff was most helpful.

The manual could never have been produced without the talents, experience and hard work of our project team partners, Environmental Quality Resources, Inc. (EQR), and Loiederman Associates, Inc (LAI). In particular, we would like to acknowledge the great contributions of Timothy Schueler, Richard Scafidi, and Joanne Reker of EQR, and Karen Carpenter, Michael Wagner, Josie Greenberg, and Cliff Deward of LAI.

Thanks are also extended to the members of the Stormwater Management Regulations Committee (SMRC), whose insightful comments and local perspective in reviewing earlier drafts were most helpful in improving the manual. SMRC members who graciously gave their time and advice included: David Bourdon (Prince George's Soil Conservation District), Richard Brush (Montgomery County), Michael Clar (Engineering Technology Associates), Andrew Daneker (Howard County Bureau of Highways), Neal Fitzpatrick (Audubon Naturalist Society), John Galli (Metropolitan Washington Council of Governments), James Gracie (Brightwater, Inc.), Terrence McGee (Washington County), John Mickley (Washington County Soil Conservation District), Joseph Necker (The Rouse Company), Steven Oder (Cavalier Development), Daniel O'Leary (Parsons Brinkerhoff, Inc), John Redden (Wicomico County), James Slater (Carroll County), Susan Straus (City of Rockville), William Street (Chesapeake Bay Foundation), Raja Veeramachaneni (Maryland State Highway Administration) and Tom Vidmar (Baltimore County).

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Special thanks are extended to Hye Yeong Kwon of the Center for Watershed Protection (CWP) for her heroic efforts to assemble and knit together the many pieces of the manual into a final product. Chris Swann and Deborah Caraco also provided valuable input and review.

This manual was prepared for the Water Management Administration under a cooperative agreement between that agency and the Maryland Department of Natural Resources pursuant to National Oceanic and Atmospheric Administration Grant No. NA67OZ0302. Reference to any particular commercial products and trade names in this manual does not in any way constitute an endorsement by the State.

Thomas Schueler Richard Claytor

Center for Watershed Protection

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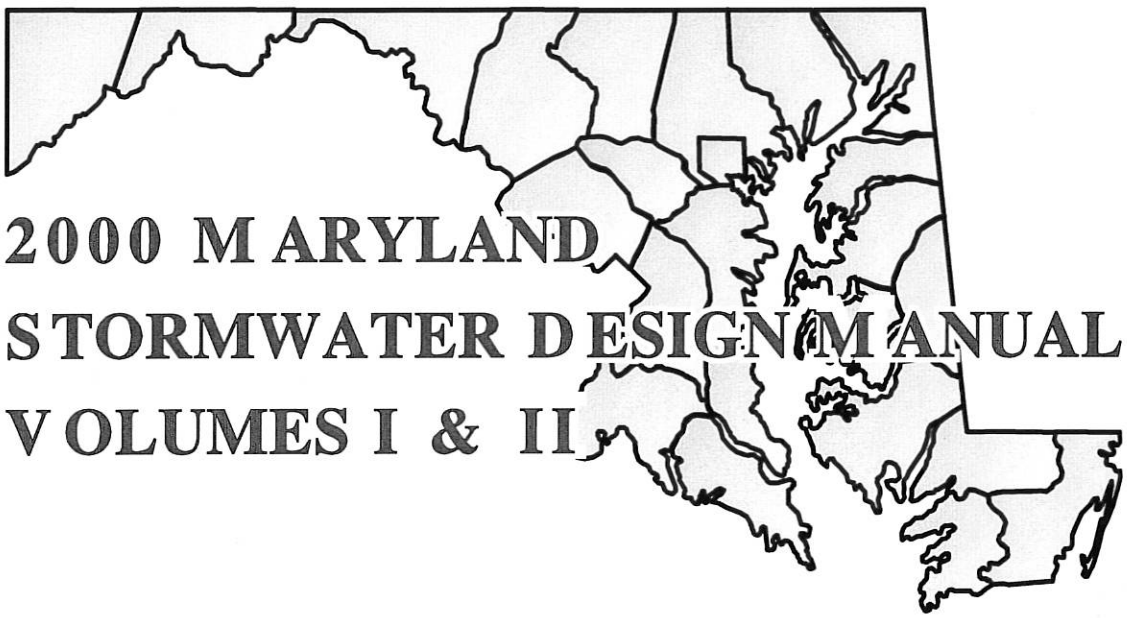

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- NPDES Phase II General Discharge Permit No. 03-IM-5500

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2	Buzzards Bay National Estuary Program	Action Plan 3: Promoting Low Impact Development	10/23/06 (draft)	http://www.buzzardsbay.org/newccmp-lid.htm; http://www.buzzardsbay.org/newccmp/bb-lid-10-23-06.pdf
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4	City of Union City, California	Green Building and Landscaping Practices in Private Development Projects Standards Policy Statement	3/14/2006	http://www.unioncity.org/commdev/comdev.pdf2/Bay-Friendly%20Landscaping%20Policy%20Statement.pdf
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21Action Plan 2: Managing Stormwater Runoff

Problem

Untreated stormwater poses many threats to the environment. Runoff from rainfall and snowmelt carries natural and human-derived pollutants into wetlands, lakes, streams, estuaries and groundwater, which can affect water quality, habitat and living resources. Pollutants associated with stormwater runoff may include bacteria, road salt, nutrients, pesticides, metals and organic contaminants such as hydrocarbons. Stormwater also conveys sediments, atmospheric fallout and other particles that cause siltation of aquatic and wetland habitats, increased turbidity and declining water quality. Such sediment particles often serve as carriers of metals and organic contaminants that adsorb to particles. Stormwater also contributes floatable debris, resulting in littered shorelines and impacts on marine animals due to ingestion and entanglement. Stormwater pollutants can lead to swimming beach closures, loss of habitat and resources, and changes in species composition and diversity. In coastal areas, excessive stormwater pollutants (primarily bacteria) can also result in shellfish bed closures. Chronic runoff of polluted stormwater to sensitive resources can result in aesthetic impacts as well as economic impacts, such as those associated with the loss of commercial and recreational fisheries.

Figure 2-1. A stormwater discharge pipe in Onset Bay.

In the Buzzards Bay watershed, like other urbanized areas, water from melting snow and rain flowing off streets, parking lots, roofs, lawns, golf courses, agricultural land, and other pervious and impervious areas, carries contaminants to the bay and contributing streams, groundwater and wetlands in the watershed. This stormwater enters surface waters via storm drain systems, including catch basins, pipes and road cuts, and via other overland flow.

The BBNEP's 2003 *Atlas of Stormwater Discharges in the Buzzards Bay Watershed* documented more than 2,000 pipes and 600 road cuts that discharge to Buzzards Bay or to streams and wetlands near the coast in eight towns[a]. These discharges are summarized in Table 2-1 and Figure

[a] The study did not include the City of New Bedford, the Town of Acushnet, or the Elizabeth Island Chain of Gosnold. A description of this project is provided insubsequent pages of this Action Plan.

2-1. The atlas also mapped more than 12,000 catch basins, most of which were linked to the more than 2,600 discharges cited in Table 2-1. The actual number of catch basins associated with each discharge varied greatly, but most appeared to have only one or two catch basins draining various lengths of contributing road and other impervious surfaces. More than 375 miles of road and pipe connected to these mapped discharges.

Table 2-1. Summary of discharges by town, showing numbers of basins tied to treatment systems

Municipality	Pipes	Road cuts	Total	UA Total[1]
Bourne	169	62	231	220
Dartmouth	255	168	423	412
Fairhaven	224	25	249	185
Falmouth	202	40	242	242
Marion	227	53	280	167
Mattapoisett	276	42	318	172
Wareham	592	118	710	513
Westport	88	85	173	12
Grand Total	2,033	593	2,626	1,923

1. "UA Total" equals number of discharges mapped in the National Pollutant Discharge Elimination System Stormwater Phase II urbanized areas. This permit program is further described in the Background section of this Action Plan.

The extent of water quality impairments in Buzzards Bay has been documented to a considerable degree in the Massachusetts DEP's Section 303d list. Twenty-two of the roughly 32 major Buzzards Bay embayments are listed as impaired due to fecal coliform bacteria (Figure 2-3). Further evidence of the problem is illustrated by the distribution of shellfish bed restrictions in Buzzards Bay (Figure 2-4) and the temporary closures of swimming beaches in both fresh and salt water in the watershed. While some of these closures are related to municipal wastewater facility discharges, in most cases stormwater conveying pollutants from various non-point sources is the principal cause of the impairment.

Numerous studies in Massachusetts and nationwide have consistently pointed to stormwater as a major source of fecal coliform bacteria contributing to closures of swimming beaches and shellfish areas. Any stormwater pipe near a swimming beach represents a potential health risk and often contributes to floatable debris on beaches. On rare occasions, illegal sanitary hookups from septic systems to stormwater pipes have been found. However, many other "non-point" sources contribute to elevated fecal coliform levels in stormwater. These non-point sources include wildlife droppings, pet waste, overland run-off of manure from farms, and breakout from failed septic systems.

Figure 2-2. Stormwater discharges documented in the Atlas of Stormwater Discharges in the Buzzards Bay Watershed (BBPNEP 2003).

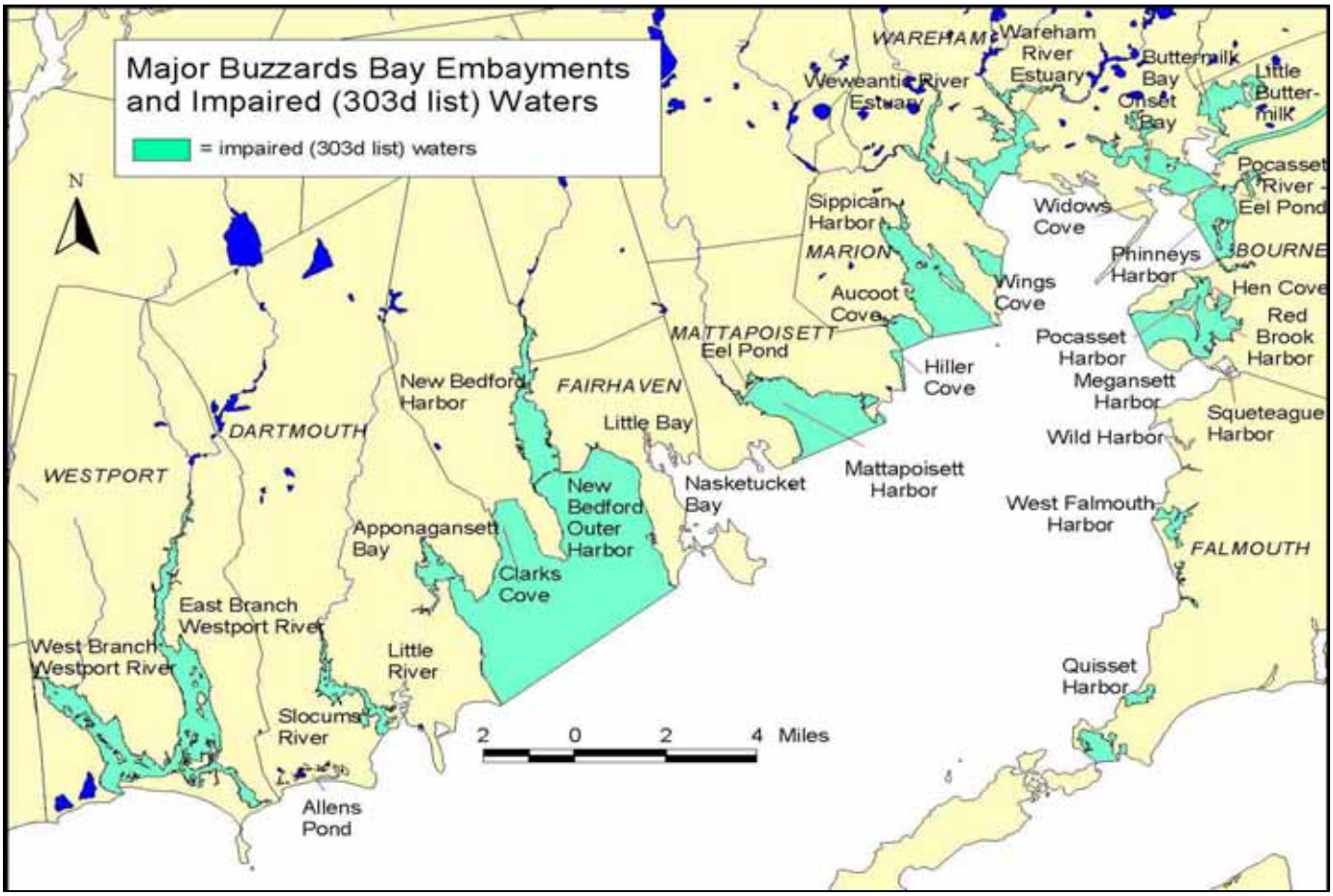

Figure 2-3. Waters of Buzzards Bay on the Massachusetts Section 303(d) list for waters impaired or threatened by pathogens. Note: West Pond and Cuttyhunk Pond on Cuttyhunk Island are not shown. Boundaries are approximate based on published verbal descriptions.

Every three years the Massachusetts Division of Marine Fisheries (DMF) completes sanitary surveys for shellfish areas in Buzzards Bay. These surveys contain a wealth of information on existing stormwater drains that are sources of fecal coliform bacteria and are causing or threatening to cause the closure of shellfish beds, as well as streams and rivers that have consistently elevated levels of coliforms. This information is provided in reports to all Buzzards Bay communities and provides an excellent summary of potential pollution sources. However, due to limited funding, actual stormwater discharges during runoff events from pipes are usually not monitored for fecal coliforms, nor are upstream pollution sources identified in the rivers and streams contributing to high fecal coliform loads.

Background

Prior to the late 1990s, the responsibility for controlling new storm drains was regulated largely at the local level through subdivision regulations and wetlands bylaws. Unfortunately, local regulations were inconsistent from one community to the next, and for the most part, municipalities did not adequately address management of the *rate*, *volume*, and *quality* of stormwater discharges. Management of all three parameters is now recognized as essential for improving or protecting water quality. In the late 1990's, however, the regulatory landscape expanded with additional state and federal authority to better address stormwater discharges to wetlands and surface waters. These changes coincided with increased local awareness and sophistication by local government pertaining to stormwater issues.

First, in 1992, Phase I of the National Pollution Discharge Elimination System (NPDES) program required the permitting of stormwater discharges from large municipalities (municipalities with a population of 100,000 or more) to federal wetlands. In 1996, the Massachusetts Department of Environmental Protection (DEP) adopted Stormwater Standards and Policy, to be implemented primarilty in association with the Wetlands Protection Act. This new policy prohibited "untreated stormwater discharges" to waters of the Commonwealth, required water quality treatment for runoff of up to 1-inch from impervous surfaces, identified appropriate "best management practices" (BMPs), required recharge of stormwater to balance the hydrologic budget and required operation and maintenance plans for stormwater facilities. These standards and policies are currently being updated by DEP.

In December, 1999, EPA published the "Phase II Final Rule" (Phase 2) for the NPDES program in the Federal Register. This rule expanded coverage of the stormwater permit program to include stormwater discharges from, "certain regulated small municipal separate storm sewer systems

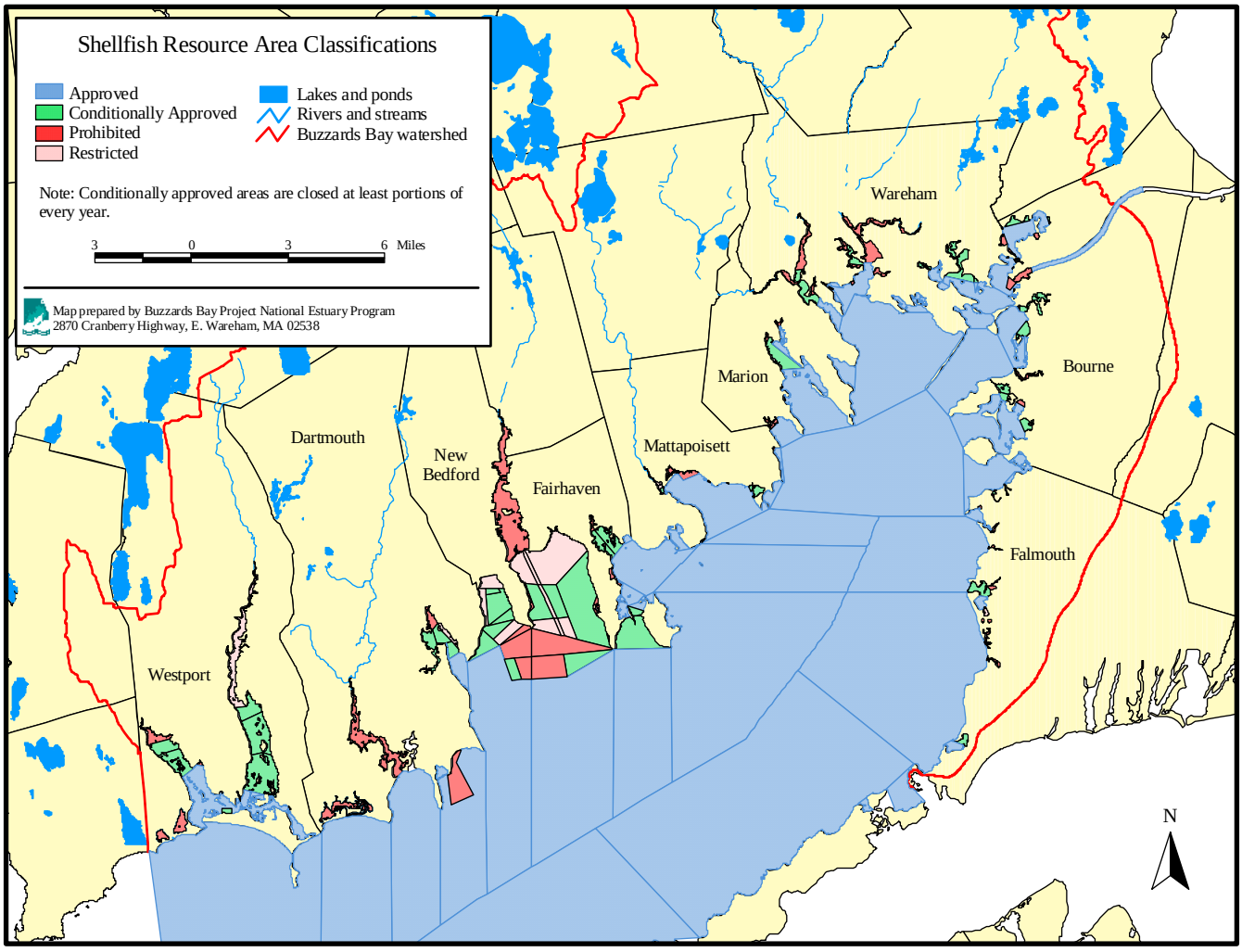

Figure 2-4. Shellfish Resource Area Classification in Buzzards Bay, circa July 1, 2000.

(MS4s); and construction activities disturbing between 1 and 5 acres of land (i.e., small construction activities)." The rule also revised "the 'no exposure' exclusion and the temporary exemption for certain industrial activities." In plain English, the rule required municipalities

located within “urbanized areas”, as defined by the U.S. Census Bureau, to submit permit applications (Notices of Intent) by 2003 for their municipally owned stormwater discharges ("MS4s"), as well as "industrial facilities", waste transfer stations, landfills, and sewage treatment plants (separate from the wastewater discharge permit). Due to an omission in the 1999 Phase II published rule, municipal and state DPW garages were exempt. Developers altering as little as 1 acre of land were also required to comply with the Phase II NPDES program beginning in 2003.

Perhaps even more significant than the adoption of the Phase II rule was the fact that the U.S. Census Bureau redefined "urbanized areas" for the 2000 census. This redefinition greatly expanded the geographic extent of the federal definition of urbanized areas, particularly in the northeast U.S. Because the U.S. EPA had used the U.S. Census urbanized maps as the jurisdictional boundary for the Phase II program, the geographic area covered by the program now included at least a portion of nearly every municipality in eastern Massachusetts, including every Buzzards Bay watershed community. These changes in the urbanized area are shown in Figure 2-5. While the geographic extent of the Phase II program may not seem appreciable for some municipalities, those areas covered essentially represent the existing moderately developed areas in each community, and more importantly triggers the requirement for management and regulatory actions in the municipalities as required in their permit.

Another regulatory program that has been moving forward in recent years is the MA DEP program to develop Total Maximum Daily Loads (TMDLs) in accordance with the Federal clean Water Act to address pollutant loading to impaired waterbodies throughout the state. Of particular relevance in Buzzards Bay is the recently published Draft Pathogen TMDL for the Buzzards Bay Watershed, developed jointly by MA DEP, USEPA Region 1, and ENSR International. This TMDL has established a concentration discharge limit equivalent to the regulatory threshold for impaired waters. Thus, for stormwater discharges to waters closed to shellfishing, stormwater mean stormwater discharge concentrations cannot exceed 14 fecal coliform per 100 ml. Adoption of this TMDL by the MA DEP would have important implications for municipalities in addressing stormwater and pathogen sources, as well as for individual land owners with existing discharges. This TMDL would be implemented through the NPDES permit program, as well as through other local and state regulatory mechanisms. This TMDL would trigger a legal requirement for municipalities and others to retrofit existing stormwater discharges in order to meet prescribed loading allocations and associated water quality discharge standards.

The Coastal Pollutant Remediation Grant Program at the MA CZM office has also evolved into a positive funding mechanism for nonpoint source pollutant remediation in Buzzards Bay and other coastal MA areas. For several years, the BBNEP has received funding through MA CZM from the MA legislature to address nonpoint pollution in the watershed. The BBNEP used this money to fund specific projects through a mini-grant program. This program was so successful that MA CZM adopted the program for the entire Coastal Zone in Massachusetts. These grants have been successful in fostering public education and addressing nonpoint pollution from roadways and other land uses throughimplementation of innovative stormwater practices. This program continues as of fiscal year 2006.

Stormwater Management Design

Stormwater management is best accomplished as part of a holistic, integrated water management approach, and should not be simply viewed as problematic flood waters and as a pollution source. Stormwater should be considered part of the hydrologic cycle. To accomplish this, stormwater runoff volumes, rates and quality need to be managed to mimic and/or to restore natural

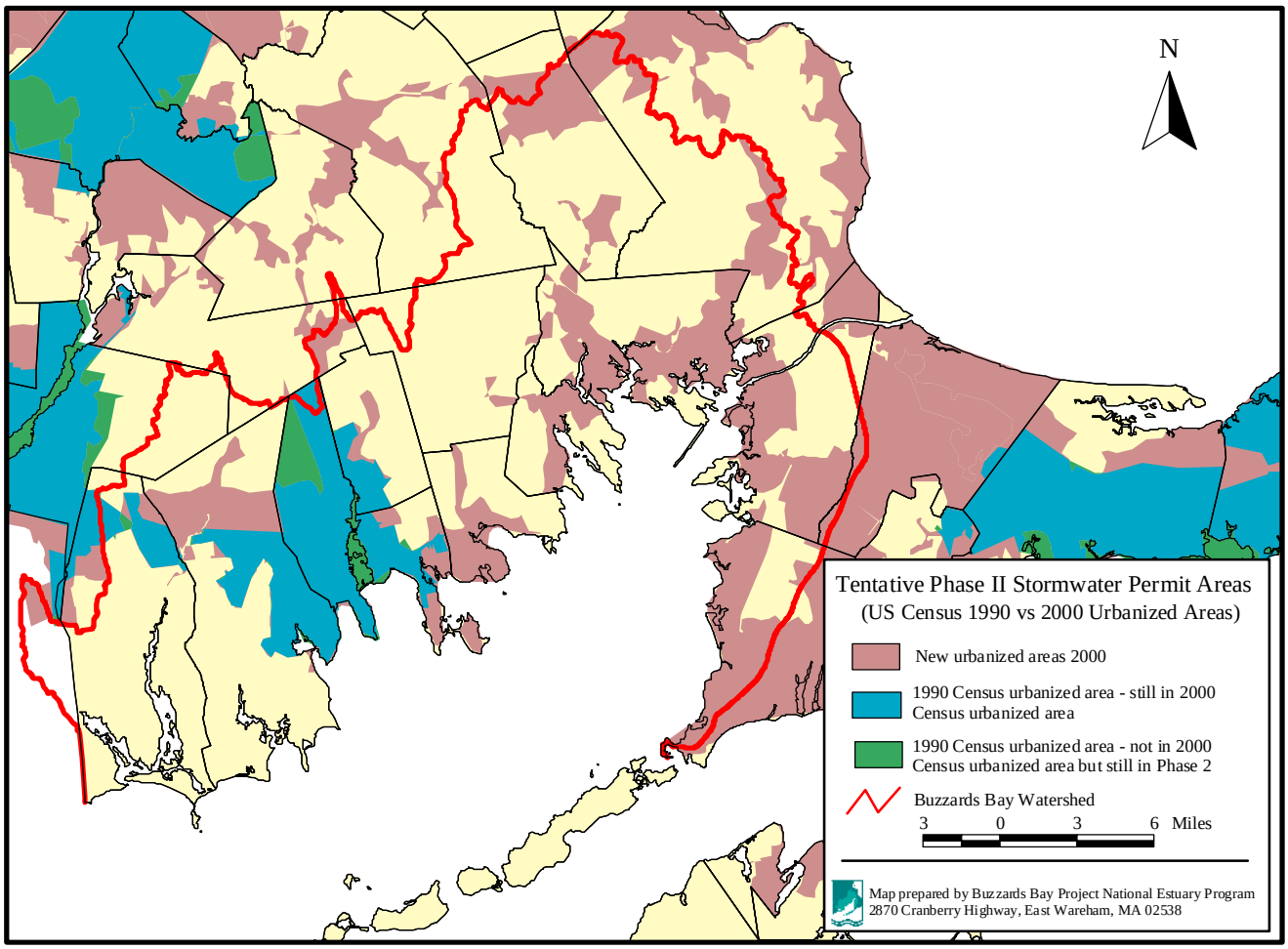

Figure 2-5. Newly defined urbanized areas from the 2000 US Census. All urbanized areas shown are included in the EPA NPDES Phase II Program for Municipal Small Storm Sewer Systems (MS4s).

conditions.

Treated stormwater runoff from impervious surfaces can be "re-used" as an irrigation source, as an alternative non-potable water supply source and for groundwater recharge and baseflow augmentation. From this standpoint, treated stormwater is a "resource" and not a 'wastewater" to be disposed of. Stormwater runoff from rooftops can be collected in rainbarrels or cisterns and used for the irrigation of gardens and landscaped areas, reducing the need to use drinking water for these purposes. It can also be infiltrated into the subsurface to recharge the groundwater system to restore drinking water supplies and to maintain critical (natural) freshwater baseflow that may alleviate the impacts of withdrawal rates to streams, wetlands and estuaries. Stormwater runoff can be managed to prevent water quality degradation of downstream resources.

Stormwater management must address four criteria:

1. Peak rate flood control: The large, infrequent storms (e.g., 2, 10, 25 and 100-year) must be managed to avoid flooding and erosion impacts.

2. Channel protection: The bank-full event (1-year) must be managed to balance pre- and post-

development runoff rates to avoid impacting stream banks and channels.

3. Recharge to groundwater: The goal of this criterion is to maintain the water balance at a site and within a watershed to the natural (pre-development) annual volume of recharge to groundwater after development occurs (in the post-development condition). Annual recharge (infiltration) depends on rainfall, runoff, and evapotranspiration during each rainfall event during a given year (See Figure 2-6), and simply put, these volumes are influenced by the combination of hydrologic soil groups (ability of a soil to infiltrate water), ground cover, and climate. For the Buzzards Bay Watershed as a whole, the annual recharge volume is approximately 20 – 24 inches per year across the entire watershed. In order to get this volume of water back into the ground, the site designer must size stormwater infiltration practices to capture and infiltrate the first 0.6 inches of runoff from impervious surfaces. This will result in a cumulative total annual recharge volume approximating the natural annual recharge volume.

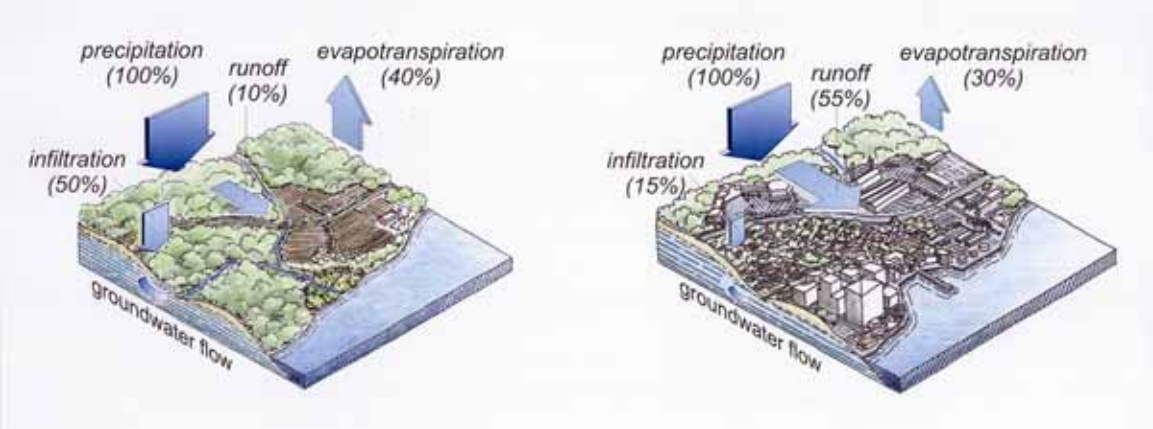

Figure 2-6. In increase in impervious surfaces vegetation resulting from development (as shown on right) shifts the water balance from a more natural state (as shown on left), causing a significant increase in the volume of runoff and a decrease in infiltration and evaporation as a percentage of precipitation.

However, to truly balance the water budget, stormwater recharge should also compensate for "consumptive" drinking water losses. These are primarily related to lawn and landscape irrigation, which result in water losses via additional evapotranspiration and runoff. This could be accomplished by either promoting the use of rainwater storage structures (e.g., rainbarrels/cisterns) as an alternative irrigation source or by increasing the stormwater management recharge requirement from 0.6 inches to 1.0 inches of runoff.

4. Water quality: The Massachusetts Stormwater Standards and Policy (established by DEP) requires that the first 0.5 inch (or 1.0 inch in critical areas) be effectively treated. This is based upon the so called "first flush" principle where most pollutants are transported by smaller rainstorms during the first portion of larger events. While this is true for suspended solids, this principle is not directly applicable for bacteria and nitrogen. Therefore, the larger 1.0 inch design event is more applicable for the Buzzards Bay Watershed.

A broad range of best management practices (BMPs) have been developed to manage stormwater runoff. While some of these BMPs have been shown to be effective at removing at least 80% of the total suspended solids (TSS), the minimum required state and federal standard, only certain management practices are effective at treating fecal coliforms and nitrogen (two of the critical pollutants of concern for Buzzards Bay). These BMPs that treat both nitrogen and fecal coliforms are:

1. Filtration practices: Sand filters, organic filters and infiltration systems (with proper pre-treatment) that trap bacteria.

2. Vegetated practices: Bioretention areas, rain gardens, vegetated swales and constructed wetlands that provide for nutrient uptake and/or nitrification-dentrification processes.

Proper design, construction and operation and maintenance of all stormwater BMPs is critical to their success. Without this, stormwater facilities provide only a false sense of security. In addition, stormwater BMPS should be repaired, rebuilt or retrofitted as needed if they are observed to be malfunctioning, improperly sized, or otherwise failing to meet the stormwater management control objectives.

Accomplishments in Addressing Existing Stormwater Discharges

By far, the greatest amount of federal and state financial resources associated with BBNEP implementation efforts and technical assistance has been spent on remediation of existing stormwater discharges. A key first step in remediation is locating the discharges and source areas. The BBNEP published an "Atlas of Stormwater Discharges in the Buzzards Bay Watershed" in 2003 to serve as a tool for guiding remediation projects, as well as an educational tool. The Coalition for Buzzards Bay (CBB), a local citizens' non-profit group, coordinated a BBNEP funded mapping project by interns from the Massachusetts Maritime Academy to locate and describe all stormwater catch basins, conveyance piping, and discharges in most of the Bay area. This information was eventually refined and improved upon by BBNEP staff with funding from the Massachusetts Highway Department, and in 2001 the BBNEP drafted a stormwater atlas of every known storm drain pipe and associated catch basin in eight Buzzards Bay municipalities. A final atlas was published in 2003. A sample map is included in Appendix D.

These discharges contribute to shellfish bed closures and water quality degradation throughout the bay watershed. Funding for these projects was provided by the BBNEP through its EPA funded Municipal Grant Program, by the Massachusetts Department of Environmental Protection through the federal Nonpoint Source Pollution (Clean Water Act Section 319) Program, and by the Massachusetts Office of Coastal Zone Management's (CZM) Coastal Pollutant Remediation (CPR) Program. A recent CZM project completed in 2006 evaluated the effectiveness of stormwater BMPs that were constructed using CPR funding and found that while these facilities have tremendous potential for pollutant remediation, maintenance was lacking at many facilities, compromising the effectiveness of these BMPs. The BBNEP staff continues to help local officials in the identification of funding sources and the development of successful projects. This allows the BBNEP and local communities to leverage Estuary Program funds far beyond their limits. Rough estimates contained in the CCMP Financial Plan on the remediation costs for all of the Bay's untreated discharges were approximately $10 million.

The BBNEP has been greatly assisted in this work through a partnership with the USDA Natural Resources Conservation Service in which NRCS staff works with the BBNEP in design and review of various forms of stormwater remediation facilities. These projects include such varied forms of stormwater BMPs as traditional stormwater infiltration structures, innovative constructed wetland systems, improved agricultural management practices, and urban sewer/stormwater cross connection remediation.

Improved Management of Stormwater in New Development

Preventing new untreated discharges to surface waters was one of the most important goals outlined in the 1992 Buzzards Bay CCMP. It was common sense considering the high cost of

remediating existing discharges; it is simply true that an ounce of prevention is worth a pound of cure. At the time of completion of the 1992 CCMP, all of the towns surrounding Buzzards Bay had regulations on the books addressing the construction of new stormwater conveyance systems to control flooding or stormwater volume, consistent with state and federal flood control and roadway engineering standards. The stormwater drainage design was generally focused on addressing the site being drained rather than addressing any downstream impacts from stormwater runoff, and/or impacts on the hydrologic budget. Often these rules required that stormwater be delivered as quickly and as directly as possible to the nearest water body or wetland with little or no attention to the quality of the stormwater and its effect on water resources and shellfish habitat. Only if both stormwater quantity and quality are addressed can a town expect to prevent new problems with shellfish bed closures and water quality degradation. Another problem the BBNEP observed was that requirements among town boards were not consistent and sometimes even contradictory.

To address these problems, the BBNEP developed a model stormwater management regulation entitled, Unified Rules and Regulations for Stormwater Management for use by Planning Boards, Boards of Health, and Conservation Commissions, which was released in January 1996. BBNEP also provided technical assistance and educational outreach to communities interested in adopting these standards. To date, these standards were adopted by Rochester (Planning Board Subdivision Rules and Regulations), Marion (Planning Board Subdivision Rules and Regulations, Plan and Site Review), Fairhaven (Planning Board Subdivision Rules and Regulations) and Falmouth (Conservation Commission Rules and Regulations). In the spring of 2006, the BBNEP published a revised set of unified standards to incorporate low impact development techniques, recharge, and more effective water quality and channel erosion protection measures.

Major Issues

There appears to be a general lack of public knowledge and recognition of the importance of stormwater management and the impacts from poorly managed stormwater runoff on surrounding properties and downstream resources. Additionally, stormwater runoff is still generally viewed as a waste that should be disposed of rather than a resource that is integral to the water budget. This makes it difficult to implement local regulatory changes to address stormwater management, and it limits the support for making stormwater improvements within a community. In addition, stormwater management design for permitting purposes requires engineering skills and more recently, site planning skills. Therefore, it is becoming increasingly necessary to incorporate a technical review and technical expertise on behalf of the local boards and commission in the local permit process. Education of the public, local boards and commissions, municipal employees, as well as engineers and site planners about stormwater management and the details of stormwater management design is critical to successful protection of our vital water resources.

Local stormwater management regulations and standards, NPDES Phase II permitting, and the MA DEP Stormwater Policy generally focus on new development and redevelopment, but do not focus on stormwater impacts from existing developments. Implementation of management measures to address water quality improvements through retrofits to existing development is generally not receiving much attention. However, with the potential adoption of the Pathogen TMDL for Buzzards Bay, and the next round of NPDES permitting to start in 2008, communities will need to begin to address stormwater from existing development to bring them into compliance.

Implementation of an effective and comprehensive stormwater management program can be expensive. With significant growth expected in the next decade throughout the Buzzards Bay watershed, together with the evolution of more technical stormwater and water quality

regulations, coordination and implementation of a stormwater management program in any given community will likely be fairly expensive. Communities need to consider innovative mechanisms and models to fund a stormwater program, including technical oversight and engineering review, enforcement, and maintenance of stormwater practices.

The management solutions for controlling stormwater discharges range from simple to complex, inexpensive to costly, and can involve different levels of government as well as private landowners. In developed areas, structural controls may be expensive to implement and land for retention basins may be either prohibitively expensive or not available at all. The costs of installing stormwater BMPs are usually borne by the municipality and its residents, but benefits accrue to all users of the municipality's water resource. These benefits can include restored recreational opportunities, maintenance of land values due to the aesthetic appearance of receiving waters, and, of greatest relevance here, restored or continued shellfishing opportunities.

Any town that is contemplating the construction of stormwater treatment facilities must consider all facets of the issue, including land acquisition, installation techniques, cost, treatment effectiveness, and maintenance requirements. Sampling data may be needed to determine the relative impact of each drain on water quality degradation. Before targeting a particular storm drain for action, the town should ensure that the problem is not emanating from septic systems or other illicit discharges that are "cross-connecting" with the drain.

The NPDES Phase II Program requires that communities (MS4s) covered by the program prepare and implement a stormwater management plan in accordance with a five-year schedule each community sets in an initial Notice of Intent. While U.S. EPA and MA DEP require that each MS4 file an annual report to provide an update on progress, and the reports are posted on the internet, there is little other enforcement to ensure that communities are following the schedule. At the same time, most communities are understaffed to meet all the responsibilities outlined in their NOIs. Communities need technical assistance to work efficiently and effectively to meet the Phase II requirements, together with other water quality requirements such as the pending pathogen TMDL for Buzzards Bay.

The Massachusetts Highway Department (MassHighway) has as one of its primary concerns the construction and maintenance of safe roads. Until recently, this typically included the removal of stormwater from those roads as quickly as possible. Accordingly, resource protection and water quality considerations must be balanced with MassHighway's primary mission of building safe roads. In January 2006 MassHighway released an updated manual for the design of State roads, this manual, entitled "Project Development and Design Guidebook" features more emphasis on design flexibility, streamlined procedures, and improved collaboration between MassHighway and the cities and towns it serves. MassHighway also developed a Stormwater Handbook for Roads and Bridges (May 2004) and is required to meet NPDES Stormwater Phase II permit requirements for the storm sewer systems from the roads and facilities operated by MassHighway. These new guidance manuals coupled with the regulatory requirement of Phase II will help foster a climate where Buzzards Bay towns will work collaboratively with MassHighway to ensure that water quality and quantity impacts are evaluated in a comprehensive manner for road and bridge planning, design and construction projects. The activities of town DPWs should receive the same attention.
Transportation planning should avoid siting new traffic corridors or hubs near sensitive receiving waters, and an Alternatives Analysis should identify sites that pose minimal or least impact due to stormwater runoff. Existing corridors/hubs near sensitive resources should be remediated.

Stormwater runoff from more than one town may be contributing to water quality degradation or shellfish-bed closures in a specific embayment. Each contributing town must implement similar and equitable stormwater controls in order for the affected resource to be fully protected.

Most stormwater drainage outfalls in Buzzards Bay are primarily wet weather discharges only. Those that have continuous dry weather flows may be an indication of illegal cross connections with sewer lines or septic systems. Many that do have dry weather discharges may merely indicate groundwater infiltration, or in some communities, the discharge of sump pumps from basements.

Federal implementation of the Phase II requirements cover all applicable areas of a regulated community, whereas state implementation of the DEP Stormwater Policy only covers activities within the jurisdiction of the Wetlands Protection Act (i.e., within a regulated resource area and/or a buffer to a regulated resource area). Municipalities implementing Phase II program requirements will have the flexibility to implement a stormwater program across the entire municipal limits either in accordance with the provisions of the DEP Stormwater Policy or to a greater level as offered by the BBNEP Model Stormwater Bylaw, updated in the spring of 2006.

Action Plan 2: Managing Stormwater Runoff

Goals

1. Prevent new or increased untreated stormwater flows to Buzzards Bay and contributing watershed areas that would adversely affect shellfish harvesting areas, swimming beaches, water quality, and wetlands.

2. Correct existing stormwater runoff flows to Buzzards Bay and contributing watershed areas that are adversely affecting shellfish harvesting areas, swimming beaches, water quality, and wetlands.

3. Maintain and restore natural hydrologic conditions to provide baseflow conditions to streams, wetlands and estuaries.

Objectives

1. To institutionalize at the local level (through education, laws, and regulations) the use of appropriate best management practices for stormwater management associated with new development, redevelopment, and agriculture.

2. To develop effective stormwater pollution remediation projects that include proper design, construction, operation and maintenance of facilities.

3. To establish and implement clear criteria to manage stormwater for flood control, channel protection, groundwater recharge, water quality and wetland habitat.

4. To provide guidance and incentives for better site design that reduces stormwater runoff, provides for re-use of stormwater and reduces the need for structural practices.

Changes to the Goals and Objectives contained in the 1992 CCMP

Goal 1 was not changed.

Goal 2 was made similar to goal 1 by expanding the endpoints. Revised from: Correct existing stormwater runoff problems that are causing or contributing to water quality degradation *or shellfish-bed closures in Buzzard Bay.*

Goal 3 is new.

Objective 1 expanded from: To institutionalize at the local level (through education and regulations) the use of best management practices for stormwater control *in newly developed areas*.

Objective 2 was simplified somewhat from: To develop a regional and local program to execute appropriate mitigation measures for existing stormwater discharges. The program would include construction, operation, and maintenance of stormwater control structures.

Objectives 3 and 4 are new.

CCMP Recommendations and Commitments

Buzzards Bay National Estuary Program

2.1 The BBNEP will update its 1996 municipal model regulations to better incorporate more stringent performance standards for fecal coliform bacteria and nitrogen removal and Low Impact Development (LID) principles and to achieve the goals and requirements of the municipal Phase II NPDES program. The BBNEP will incorporate the LID bylaw model now being developed by MCZM and the work of DCR and promote this work among municipalities.

Responsible Agent(s): BBPNEP
Commitment: The BBNEP has committed to this task
Legislation required: None
Estimated Costs: Using existing staff for development, and new ½ FTE to work with towns
Potential Funding: 319 or other grant
Implementation Strategy: Review policies by other states and organizations, grant needed for in depth technical assistance
Performance Tracking:

Target Date: Initiate by December 2006
Comment: The level of technical assistance of BBP support to the towns will be defined by available grant funding.

The following Action Item has been removed from Watersheet Zoning AP and should be inserted into the Stormwater AP, per comments.

2.2. Encourage "green" marinas, boatyards, docks and waterfront construction.

Responsible agent(s): BBNEP, CBB, and BBAC for education and outreach to marina operators and towns, EPA for improved stormwater permit program compliance (multi sector general permit for stormwater in the NPDES program). CZM to implement a clean marina program
Legislation required:
Estimated costs:
Potential funding:
Schedule:
Implementation strategy:

a) Improve marina compliance with MSGP "Industrial" Stormwater NPDES permit program

2.3 The BBNEP should develop and manage a grant program to support Buzzards Bay communities in retrofitting stormwater discharges.
Responsible Agent(s): BBNEP
Commitment: The BBNEP has committed to this.
Legislation required: None
Estimated Costs: 1/2 FTE (Planning Assistant)
Potential Funding: MCZM and/or Federal 319 Grant program
Implementation Strategy: Work closely with towns and citizen groups.
Performance Tracking: # of acres existing development managed by an effective stormwater practice
Target Date: Initiated June 2007
Comment:

2.4 The BBNEP and the BBAC will create a "Stormwater /LID Round Table" for developers, businesses, municipalities, and state and federal officials to promote understanding and use of stormwater management and LID, obtain funding, and to assist the private and public sectors in implementing controls of nonpoint source pollution.
Responsible Agent(s): BBNEP and BBAC
Commitment:
Legislation required: None
Estimated Costs:
Potential Funding:
Implementation Strategy: Training workshops, outreach materials, demonstration projects, school and university projects, fund research projects or demonstration projects, media involvement.
Performance Tracking:
Target Date:
Comment:

2.5 The BBNEP and BBAC will work with other existing nearby coastal NGOs, educational and research institutions to promote stormwater management and LID techniques. Examples of such organizations include, but are not limited to:

Coalition for Buzzards Bay
SeaGrant institutions
Woods Hole Science and Technology Education Partnership (WHSTEP)
Coastal Training Program, MA CZM
University of Massachusetts at Dartmouth (UMass-Dartmouth)
Woods Hole Oceanographic Institution

Responsible Agent(s): BBEP and BBAC
Commitment:
Legislation required: None
Estimated Costs:
Potential Funding: Coastal Training Program, MA CZM
Implementation Strategy: Training workshops, outreach materials, demonstration projects, school and university projects, fund research projects or demonstration projects, media involvement.
Performance Tracking:
Target Date:
Comment: Should this be consolidated with 2.4?

Commonwealth of Massachusetts

2.6 DEP will work cooperatively with EPA and CZM to revise its 1996 Stormwater Standards and Policy to better address volume, quality, and rate of stormwater discharges, and to require reductions in fecal coliforms and other pollutants (such as nitrogen). Revised standards will minimize environmental degradation, help to restore impaired waters, and reduce other ecological impacts of stormwater discharges. DEP should also develop a policy to exempt constructed wetlands designed for stormwater management purposes from jurisdiction as resource areas under the Wetlands Protection Regulations, so as not to discourage project applicants to include these BMPs in their site plans.

Responsible Agent(s): DEP, Bureau of Resource Protection
Commitment: DEP has recently convened a Stormwater Advisory Committee that has made several recommendations to strengthen the recharge criteria and methods, incorporate new provisions for LID and redevelopment projects, and provide additional guidelines on BMP pollutant removal effectives. The Advisory Committee identified a number of additional regulatory issues that should be incorporated into a revised Stormwater Policy, such as requirements for fecal coliform bacteria and nitrogen load reduction. These issues were raised as future items to be addressed. A recommendation was made to change the policy on wetlands jurisdiction for constructed wetlands, exempting them.
Legislation required: None
Estimated Costs: Several FTE staff commitments
Potential Funding: State Legislature if required
Implementation Strategy: Review policies by other states, EPA, stormwater organizations
Performance Tracking: Adoption of regulations
Target Date: December 2006 (constructed wetlands exemption) and June 2007 (bacteria and nitrogen performance standards).
Comment: Currently, the stormwater management policy requires 80% TSS removal. Most commercial BMPs that meet this standard do little to remove fecal coliforms or nitrogen which are impairing 22 Buzzards Bay embayments (303d listed). The list of acceptable BMPs needs to be further refined to specifically address the pollutants of concerned for Buzzards

Bay.

2.7 DEP will provide an adequate number of staff to help ensure compliance with the Phase II NPDES stormwater program and the Buzzards Bay TMDL for bacteria (pending, draft under review).

Responsible Agent(s): Bureau of Resource Protection
Commitment: DEP has not yet committed to this task
Legislation required: None
Estimated Costs: 3 additional FTEs statewide
Potential Funding: State Legislature if required
Implementation Strategy: Review policies by other states, EPA, stormwater organizations
Performance Tracking:
Target Date: Beginning 2006 FY
Comment: Currently two employees are working with 207 Massachusetts municipalities to address nonpoint source pollution, including local program review, permit compliance, and technical assistance. This level of support is not adequate to ensure the success of the program.

2.8 The Commonwealth, through the EOEA and DEP, will continue to provide funding for local stormwater remediation projects, including within Phase II areas.

Responsible Agent(s): EOEA, MCZM, DEP, DCR
Commitment: The agencies have not committed to this task
Legislation Required:
Estimated Costs: $500,000 annually directed to Buzzards Bay
Potential Funding:
Implementation Strategy:
Performance Tracking: Dollars awarded
Target Date: beginning immediatly and as funds allow.
Commitment: CZM CPR Grant program is available
Comment: dependent on State legislature and administration support.

2.9 The State Legislature should discontinue exemption of bridge work by the Massachusetts Highway Department from review by local conservation commissions when it passes special legislation to fund road widening or bridge repair or expansion.

Performance Tracking:

Responsible Agent(s): Legislators
Commitment:
Legislation Required:
Estimated Costs: None.
Potential Funding:
Implementation Strategy: Outreach and education of legislatures by towns, BBP, and state agencies
Performance Tracking:
Target Date: Immediately
Comment: The legislature continues this practice. Often MHD still meets with Conservation Commissions to resolve wetland issues, but this does not always occur for exempted projects. Eliminating this exemption will help Buzzards Bay communities to better protect sensitive wetlands from stormwater runoff from roads. MCZM should deny federal consistency for federally funded projects.

Federal Agencies

2.10 NRCS should continue their ongoing program to assist farmers to implement best management practices on agricultural lands in the Buzzards Bay area. Specifically, more detailed recommendations should be developed to minimize nitrogen and phosphorous loading from fertilizers and fecal coliform loading where manure is used as a fertilizer. NRCS should work with DEP to develop updated guidance on understanding the exemptions and responsibilities afforded to agriculture under the MA Wetlands Protection Act, and how to incorporate agriculture under the MA Stormwater Policy. Farm plans should be reviewed annually and performance monitored to ensure that BMPs are being implemented. Adequate staff should be provided to ensure that farmers are implementing their farm plans.

Performance Tracking:

Responsible Agent(s): NRCS
Commitment NRCS has not yet committed to this.:
Legislation Required:
Estimated Costs: adequate FTEs
Potential Funding:
Implementation Strategy: Outreach and education of legislatures by towns, BBP, and state agencies
Performance Tracking:
Target Date: Immediately
Comments: There is inadequate follow up to ensure that farmers are adhering to their farm plans.

2.11 The US EPA should target enforcement in the Buzzards Bay watershed for businesses and developers not complying with the multi-sector general permit and construction permits in the Phase II stormwater NPDES program. Phase II stormwater permit applications, focusing on implementation of the required Stormwater Pollution Prevention Plans, should be tracked through mandatory inspections and reporting review.

Responsible Agent(s): EPA
Commitment:
Legislation Required:
Estimated Costs: adequate FTEs
Potential Funding:
Implementation Strategy:
Performance Tracking:
Target Date: Immediately
Comments: Only a small fraction of projects and regulated industries are believed to be complying with the stormwater management program.

2.12 Federal and State agencies should create a "Stormwater Revolving Fund" for grants to municipalities to improve stormwater management, or create one locally based on income from fees for Phase II permitting. (Thus the developer helps defray the cost of stormwater management).

Responsible Agent(s):
Commitment:
Legislation required:
Estimated Costs: $500,000 annually
Potential Funding:
Implementation Strategy:
Performance Tracking:
Target Date:
Comment: The state/federal Revolving fund can already be used for stormwater, so should the

first part of this be dropped?

Regional Planning Agencies

2.13 Southeast Regional Planning and Development District (SERPDD) and the Cape Cod Commission (CCC) should actively provide outreach and training for the adoption and implementation of model stormwater management bylaws and regulations. Recommendations should be consistent with those of the BBNEP.

Responsible Agent(s):
Commitment: No
Legislation required: None
Estimated Costs: negligible
Potential Funding:
Implementation Strategy:
Performance Tracking:
Target Date: 7/2007
Comment:

2.14 CCC should incorporate the Buzzards Bay bacterial total maximum daily load (TMDL) limits for Buzzards Bay in their regulatory reviews or design recommendations for the stormwater management facilities associated with projects under their review. They should also require project applicants to investigate stormwater re-use as an alternative water supply for non-potable uses.

Responsible Agent(s): SRPEDD and CCC
Commitment:
Legislation required: CCC must revise their regulations
Estimated Costs: negligible after initial training and regulatory adoption, compliance costs for developers
Potential Funding: NA
Implementation Strategy: revised review standards adopted, revised regulations for CCC
Performance Tracking: change in regulations or review strategy
Target Date: 7/2007
Comment:

Municipalities

2.15 Each Buzzards Bay community should implement best management practices for storm drains that are contributing to shellfish bed closures or other impacts to wetlands, water quality, or other natural resources. The communities to commit to work with the BBNEP to develop a priority list (and map) of existing discharges. The list should be posted on the community's website to provide outreach and education to residents and to build support for annual town meeting appropriations for remediation projects.

Responsible Agent(s): DPWs are lead
Commitment: Towns have agreed to this task, but cannot adopt a schedule because implementation depends on available funds. BBNEP has committed to assist.
Legislation Required:
Estimated Costs: at least $40,000,000 required
Potential Funding:
Implementation Strategy: Continue pursuing state and federal grants, obtain match through in-kind local support and funding through town meeting.
Performance Tracking: Number of storm discharges remediated, % of total, acres of shellfish beds opened.
Target Date: beginning immediately and as funds allow.

Comment: This remains one of the most costly and most significant issues in Buzzards Bay. The level of effort by the municipalities is limited by local capacity to provide funds or manpower if a local match is required for state or federal grants.

2.16 Each Buzzards Bay watershed municipality will implement its Phase II stormwater management plan and meet or exceed the implementation schedule outlined in its Notice of Intent. Implementation will include:

a) mapping of all stormwater discharges, catch basins, and drainage networks

b) implementation of maintenance BMPs for existing networks

c) update stormwater regulations of Conservation Commissions, Boards of Health, and Planning Boards, and adopt stormwater bylaws to ensure consistency, and compliance with Phase II permit requirements, including meeting one-acre thresholds for projects requiring stormwater management compliance, and preventing new untreated stormwater discharges to wetlands and surface waters.

Responsible Agent(s): Planning Boards, DPWS, and Conservation Commissions principally, Building Inspectors, etc.
Commitment: Each community is committed to this, through the NPDES Permit
Legislation required: Municipal bylaws, regulations, and policies
Estimated Costs: varies
Potential funding: stormwater fees or utility, others
Implementation Strategy:
Performance Tracking:
Target Date: June 2009 Comments: There is inadequate follow up to ensure that farmers are adhering to their farm plans.
Comment: Towns need to address projects that may not go through the permit process like ANRs, and adopt adequate site plan review regulations.

2.17 Each Buzzards Bay watershed municipality will develop and implement a catch basin and storm drainage network maintenance program: They will also maintain and update the stormwater discharge and drainage system database provided by the BBNEP and BBAC.
Performance Tracking:

Responsible Agent:
Commitment:
Legislation Required:
Estimated Costs:$20,000 to $50,000 per town
Potential Funding:
Implementation Strategy: CZM CPR funding can be used to assist in the funding of these projects to develop a maintenance program. Funds should be obtained for joint purchase of vacuum trucks or other maintenance equipment to share costs.
Performance Tracking:
Target Date: June 2007
Comments: Keeping catch basins free of sediments and debris is one of the biggest stormwater concerns and can have an immense impact on the receiving waters.

2.18 Each municipality should establish a stormwater management authority who is adequately funded and will be responsible for adopting and implementing stormwater bylaws and regulations and will also be responsible to ensure that BMPs are properly designed, constructed, operated and maintained.

Responsible Agent: The Stormwater authority can be the Board of Selectmen, the DPW, the Planning Board, the Conservation Commission or a newly-established Stormwater Management Authority as authorized under the MGL Chapters 40, Section 1A and Chapter

83, Section 16.
Commitment:
Legislation Required:
Estimated Costs: initial costs will vary depending upon which agency is selected. Operational costs could be funded through permit fees.
Potential Funding:
Implementation Strategy:
Performance Tracking:
Target Date: December 2006
Comments: Experience has shown that DPWs and other existing town department/agencies are under-funded to adequately carry out this responsibility. If towns are unable to increase funding to these existing departments/agencies a Stormwater Management Authority with revenue-generating authority is the preferred approach.
Note: The BBAC has advised this recommendation be deleted because there is not widespread support for a separate new regulatory within each municipality.

2.19 Buzzards Bay watershed municipal Conservation Commissions will work with USDA-NRCS to review farm plans of farmers conducting work as an agricultural exemption as required under the state wetland regulations.

Responsible Agent(s): Conservation Commissions
Commitment: The towns have not committed to this task
Legislation required: None- existing regulations
Estimated Costs: adequate staffing required
Potential Funding: Town Meeting if required
Implementation Strategy: Contact farmers not appearing before the commission who are undertaking work contributing sediment discharge to waters and wetlands, and review for compliance with the NRCS farm plans if applicable, and otherwise insure compliance with state wetlands protection laws. Also contact US Army Corps of Engineers to report apparent violations.
Performance Tracking: documentation of actions by conservation commissions
Target Date: Begin immediately
Comment:

Non-Governmental Organizations

2.20 The Buzzards Bay Action Committee should review progress on this action plan annually.

Responsible Agent(s): BBAC
Commitment: The BBAC has committed to this task
Legislation required: None
Estimated Costs: None
Potential Funding: NA
Implementation Strategy: The action plan review should be conducted during one of the BBACs regular monthly meetings
Performance Tracking:
Target Date: Ongoing
Comment: Review of CCMP progress is part of the BBAC's primary mission

2.21 The BBNEP and BBAC will assist communities in implementing stormwater programs by helping to seek funding and by providing technical assistance, including workshops and bylaw review.

Responsible Agent(s): BBAC
Commitment: The BBAC has not committed to this task

Legislation required: None
Estimated Costs:
Potential Funding: NA
Implementation Strategy:
Performance Tracking:
Target Date: Ongoing
Comment:

2.22 The Coalition for Buzzards Bay should reactivate its "Don't Dump in Catch Basin" program in every community.

Responsible Agent(s): CBB
Commitment: The CBB has committed to this task
Legislation required: None
Estimated Costs: ¼ FTE for program coordinator salary plus volunteers
Potential Funding: member support, various state grant programs
Implementation Strategy: Coordinator and volunteers will work with municipal DPWs and local citizen groups and volunteers.
Performance Tracking:
Target Date: Starting 2005
Comment: The Coalition had an active don't dump campaign in the 1990s funded in part by the Buzzards Bay Project

2.23 The Coalition for Buzzards Bay will provide trained volunteers to assist municipal Boards of Health, Shellfish wardens, and the Buzzards Bay Project identify upstream sources of fecal coliforms contributing to shellfish bed closures.

Responsible Agent(s): CBB
Commitment: The CBB has committed to this task..
Legislation required: None
Estimated Costs: Testing costs can be paid by the Buzzards Bay Project. CBB requires ¼ FTE for program coordinator salary, plus trained volunteers
Potential Funding: member support, various state grant programs
Implementation Strategy: Coordinator and volunteers will work with municipal boards of health and shellfish wardens, especially those preparing subwatershed management plans for 319 program eligibility.
Performance Tracking:
Target Date: Starting 2005 and ongoing
Comment: The Coalition has participated with the Buzzards Bay Project previously on such monitoring. The CBB has committed to actively advocate for stormwater remediation efforts and updated stormwater bylaws in Buzzards Bay municipalities.

Status of Previous Recommendations in the 1992 CCMP

1. DEP will work cooperatively with EPA to develop a policy including criteria to determine when permits for stormwater discharges are required. DEP will include these criteria in its State Water Quality Standards. DEP will also consolidate its regulatory authority for controlling stormwater runoff.
👍*Status: The DEP accomplished much of this through stormwater remediation policy adopted in 1996, and through adoption of the Phase II NPDES stormwater permit program with the US EPA.*

2. All Buzzards Bay communities should adopt subdivision bylaws that require that best management practices for stormwater runoff be incorporated into any new development plans.
👍👎*Status: Some town boards adopted regulations that are helped reduce environmental impacts of stormwater, others did not. The new NPDES Phase II requirements establishes a new set of standards that all Buzzards Bay municipalities must now adopt.*

3. Each Buzzards Bay community should implement best management practices for storm drains that are contributing to shellfish-bed closures. Communities should prioritize storm drains based on their effect on critical waters and the feasibility and cost…. Target date: beginning immediately and as funds allow.
👍👎*Status: Individual subwatershed assessments over the years, and the 2004 BBP stormwater atlas are continuing to help establish priorities. With local funding, and state and federal grants, municipalities have been continually addressing problematic stormwater discharges, but progress has been slow, and thousands of discharges must still be addressed. This single task remains one of the most important undertakings in the CCMP.*

4. The Commonwealth, through the Executive Office of Environmental Affairs, should provide funding for local stormwater remediation projects.
👍*Status: For three years, the state legislature provided funds to EOEA ($200,000 annually) for Buzzards Bay watershed stormwater grants. This program was so successful MCZM expanded the program statewide as the Coastal Pollution Remediation (CPR) program at roughly $400,000 annually. CZM also dedicated hundreds of thousands annually in their 6217 NPS program to municipal NPS projects. DEP also aggressively targeted Section 319 NPS grant to stormwater remediation, including millions of dollars to Buzzards Bay communities since 1991. The existence of the Buzzards Bay CCMP made Buzzards Bay municipalities eligible for 319-grants by meeting their watershed plan requirements.*

5. Each Buzzards Bay community should implement best management practices for storm drains that are contributing to shellfish-bed closures. Communities should prioritize storm drains based on their effect on critical waters and the feasibility and cost….
👍👎*Status: Individual subwatershed assessments over the years, and the 2004 BBP stormwater atlas are continuing to help establish priorities. With local funding, and state and federal grants, municipalities have been continually addressing problematic stormwater discharges, but progress has been slow, and thousands of discharges must still be addressed.*

6. NRCS should institute a program for implementing best management practices on agricultural lands in the Buzzards Bay area.
👍 *Status: This program was in place in the early 1990s.*

7. The State Legislature should not continue to exempt bridge work by the [Massachusetts Highway Department] from review by local conservation commissions when it passes special legislation to fund road widening.
👍👎*Status: The legislature continues this practice, although it occurs less frequently, and often MHD still meets with Conservation Commissions to resolve wetland issues*

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Stormwater Action Plan Success Stories:

Vegetated Bioretention BMP, Marion

The Town of Marion, Massachusetts received a grant from MA CZM to design and construct a series of stormwater management treatment practices for a portion of Marion Village draining to Island Wharf and Sippican Harbor. The more than 5-acre watershed was developed over the last two hundred years with unmanaged stormwater runoff discharging directly to the harbor. Past landfill and high groundwater restricted the application of most conventional stormwater treatment practices. A series of bioretention systems (also commonly referred to as biofilters and/or rain gardens) were identified as the most appropriate practices for the area. The bioretention systems are landscaped features designed to pond up to 9-inches of water during a rain event, and treat stormwater runoff via filtration through a soil media.

Design plans and specifications were developed for:

- more than half a dozen bioretention locations;
- modification and enhancement of the enclosed drainage system;
- repaving and grading of parking and turf areas; and
- erosion and sediment control for facility construction.

Stormwater BMPs were installed in 2005 and are being monitored to document their effectiveness.

Stormwater Remediation and Mamagement, Buttermilk Bay

Extensive work in Buttermilk Bay at the northeast corner of the Bay between the towns of Wareham and Bourne early in the CCMP development process revealed a total of 20 stormwater discharges, which were delivering the majority of bacterial and other pollutant loadings to the embayment. As a result, large portions of Buttermilk Bay were closed to the harvest of shellfish.

After nearly a decade of work, all but the most minor discharges to Buttermilk Bay have or are currently being remediated. Due to availability of sandy soils along the shores of Buttermilk, infiltration of stormwater was the preferred alternative at all of the sites. Stormwater remediation has proved more difficult in the western portions of the Bay watershed where soil impermeability and high groundwater have ruled out infiltration as a viable alternative.

Funding Buttermilk Bay:

- Electric Avenue, Wareham $100,000 (EPA)
- Buttermilk Bay Stormwater 319, Bourne $144,000 (MA DEP 319 Nonpoint Pollutant Remediation Program)
- Red Brook, Wareham $65,000 (EPA)
- Indian Mound Beach, Wareham $111,562 (MCZM Coastal Pollutant Remediation Program); 2000 CPR Grant: $60,000 (CZM)

Grant awards represent Federal and State funding support and do not include local contributions.

Wetland for Stormwater Treatment, Marion

Sprague Cove is on the western side of Sippican Harbor in the Town of Marion. The Cove's shellfish beds, immediately adjacent to the town's only public bathing beach, were closed due to bacterial contamination from stormwater runoff. Two storm drain systems discharged into Sprague Cove, the largest of which drained a 64 acre area of roads and driveways in the densely developed lower portions of Marion village.

In 1991, the Town of Marion and the Buzzards Bay Project began exploring options for treating this stormwater runoff prior to discharge. The result was the design (provided by NRCS) and construction of a 3-acre manmade wetland system to treat the "first flush" of stormwater entering the Cove. Stormwater contaminants such as bacteria, sediments, and nutrients are removed through natural physical and biological processes within the staged wetland and open water system. Along with the water quality benefits, the Sprague Cove stormwater wetland provides enhanced wildlife and fish habitat and replaces a filled parking area that was formerly a salt marsh.

The system was constructed in 1995 with funding from the Buzzards Bay Project, an EPA/DEP 319 Nonpoint Source Pollution grant, the Town of Marion, US Fish and Wildlife Service, and private contributions. Once the construction was completed, a large citizen effort was mobilized to plant the system with a variety of wetland species such as cattail, bulrush, and lily in order to make the system function like a wetland to remove contaminants. The Sprague Cove Project has been and continues to be not only an extremely successful stormwater remediation project but an equally important community environmental education and wetlands restoration effort. Initial water quality monitoring during the summer of 1996 has revealed large reductions in fecal coliform bacteria by the system.

Stormwater BMPs, Onset Bay

Driven in large part by a $1.9 million investment by the Town of Wareham to extend municipal sewer service to portions of Onset village, the BBNEP assisted town managers in pulling together funding and technical assistance toward coordinating the installation of stormwater BMPs in conjunction with planned sewer installation. The result was a comprehensive remediation of all wastewater and stormwater flows contributing to the closure of 111 acres of shellfish harvest beds in the East River, Broad Cove, and Muddy Cove. Muddy Cove was classified as Prohibited to harvest and East River/Broad Cove was Seasonally Approved for partial harvest of shellfish. Once complete, this work will have addressed all primary pollution sources to the Coves and is expected to reopen much of the area to harvest.

- Riverside & Onset Design, Wareham $15,000 (BBNEP Municipal Grant Program)
- Riverside & Oneset Construction, Wareham $100,000 (BBNEP Municipal Grant Program)
- Point Independence Construction, Wareham $71,600 (MCZM Coastal Pollutant Remediation)
- Point Independence Design, Wareham $15,000 (MCZM Coastal Pollutant Remediation Program)

Grant awards represent Federal and State funding support and do not include local contributions.

Action Plan 3: Promoting Low Impact Development

Problem

Most development projects are designed and built using conventional development approaches, subdivision layouts and structural practices that encourage sprawl by maximizing road widths, parking areas and other impervious areas, and involve indiscriminate clearing and grading. The increase in impervious cover combined with soil compaction and removal of protective vegetation causes stormwater runoff to accelerate over land rather than infiltrate into the ground. The result is reduced groundwater recharge, increased flooding, increased downstream erosion and other negative impacts on water resources, wetlands, and habitat.

Although a significant portion of the Buzzards Bay watershed remains undeveloped, historically developed areas, including the industrial and port areas of New Bedford, Fairhaven, and Acushnet, and residential areas such as Wareham and Bourne, tend to reflect older zoning and development practices. Less densely developed or undeveloped areas of the Buzzards Bay watershed tend to be located further from coastal areas. Southeastern Massachusetts is favorably viewed as being within commuting distance of Boston and Providence, creating the need for new housing and businesses. Redevelopment in attractive coastal areas is continuing, along with new development inland of the coast. One of the largest tracts of undeveloped land remaining in southeastern Massachusetts, comprising several thousand of primarily forests and cranberries, is currently being planned for development.

This ongoing development of land in the Buzzards Bay watershed brings potential changes to the hydrological characteristics and water quality threats in the watershed. Cumulatively, these projects can add up to significant impacts to receiving waters including reduction of groundwater recharge and increased pollution such as nutrients and bacteria.

Background

Low-impact development (LID) offers an alternative approach in land development, an opportunity to develop land in a way that results in low impacts, and in some aspects, positive impacts. LID involves careful site planning and parcel level management strategies, including site design and stormwater design techniques that infiltrate, filter, store, evaporate, and detain runoff close to the source of origin. This strategy helps to achieve the goals of mimicking a site's pre-development hydrology, protecting native vegetation, maintaining natural water budgets capable of sustaining sensitive water resources, and keeping pollutants out of the stormwater stream before they can negatively impact downstream water resources.

As discussed by the Puget Sound Action Team (www.psat.wa.gov), LID is based on the premise that nature knows how to manage water and stormwater runoff best. Forests and other natural land covers are extremely effective in recharging groundwater. In these areas, most of the rainfall infiltrates into the ground, is absorbed by vegetation, or evaporates to the atmosphere with very little stormwater runoff generated. Development activities that clear forests and other natural areas and replace them with impervious surfaces and stormdrain pipes alter the natural hydrology. These "hard" surfaces no longer allow rainfall to soak into the ground, resulting in an increase in surface runoff.

To counteract the effects of conventional development, stormwater storage facilities are often used to reduce flooding and treat stormwater-related pollution. These structures, however, are often maintenance intensive, unsightly and costly to install. Rather than collecting and conveying stormwater runoff through storm drain pipes or other conveyances to a centralized stormwater facility, LID-minimizes the use of impervious surfaces and incorporates natural vegetation and small-scale treatment systems to treat and infiltrate stormwater runoff. This involves strategic placement of linked lot-level controls that address specific pollutants and stormwater timing, flow rate, and volume issues.

Low impact development is defined by the Commonwealth's Executive Office of Environmental Affairs Smart Growth Toolkit as "an approach to environmentally friendly land use planning. It includes a suite of landscaping and design techniques that attempt to maintain the natural, pre-developed ability of a site to manage rainfall. LID techniques capture water onsite, filter it through vegetation, and let it soak into the ground where it can recharge the local water table rather than being lost as surface runoff. An important LID principle includes the idea that stormwater is not merely a waste product to be disposed of, but rather than rainwater is a resource."

Site planning using the LID approach starts with identifying critical environmental resource areas on, adjacent to and downgradient of the site. Such resource areas can include drinking water protection areas, sensitive wildlife habitats, and buffers to wetlands, streams and estuaries. House sites and roads are then planned out providing the maximum buffers to these resource areas. The site design reflects the site's natural runoff patterns, soil types, sensitive areas, and other key features and relies on those features to dictate the develop-

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ment pattern, rather than forcing a pre-conceived design upon an unwilling landscape. Refer to Action Plan 4: Improving Land Management and Smart Growth for more detailed discussion of site planning and design tools.

In LID developments, buildings are often clustered to protect natural areas by preserving open space. LID designs incorporate narrower roads and use permeable pavement for parking lots, driveways, and other impervious surfaces. Runoff from remaining impervious surfaces, such as rooftops, can be directed onto vegetated areas with porous soils. Roof gardens use soil and plants to absorb and evaporate water and slow runoff. Rooftop runoff can also be collected and re used. The proximity of the development to other developed areas (including village centers) can provide reduced costs associated with shared (neighborhood) wastewater treatment systems.

Some of the key goals of LID are as follows:

- Integrate stormwater management early in site planning activities;
- Mimic natural hydrologic functions;
- Focus on prevention rather than mitigation;
- Emphasize simple, nonstructural, low-technology, and low cost methods;
- Manage stormwater as close to the source as possible;
- Distribute small-scale practices throughout the landscape;
- Rely on natural features and processes; and
- Create a multifunctional landscape.

The minimization of impervious areas is a key LID feature and directly ties into the protective goals of maintaining natural site hydrology, allowing for adequate groundwater recharge, and reducing pollution and erosion from stormwater runoff. Other common LID techniques include:

- Green Rooftops that store and transpirate precipitation before it can leave the rooftop surface;
- Raingardens, rain barrels, cisterns, and other rainwater storage technologies that capture and store runoff for later use immediately after the runoff has exited roofs, driveways, or other impervious areas;
- Bioretention areas, constructed wetlands, and vegetated swales that transport, capture, store, infiltrate, and treat larger volumes of runoff while reducing the reliance on maintenance-intensive hard structures for stormwater management; and
- Better parking lot design, which divides large expanses of pavement into smaller sections where runoff can be managed and infiltrated in smaller quantities.

An integration of LID principles and management practices allows for stormwater to be delayed (increased time of concentration) and infiltrated onsite, thereby reducing runoff volume and downstream flood damage (peak runoff control), and improving downstream water quality. The infiltration of stormwater provided by LID practices can result in more groundwater recharge than may have occurred under pre-development conditions, which in turn can help offset increasing water supply demand from other locations in the watershed. Finally, the hydrologic benefits of LID are also accompanied by an aesthetically pleasing landscape and neighborhood layout that manages stormwater more economically and with lower maintenance requirements than is generally the case with traditional stormwater management practices.

Major Issues

As the Buzzards Bay watershed becomes increasingly developed, environmental impacts will also increase unless proactive measures are undertaken now. Conventional development may offer quick profits because the methods are well known and have been widely utilized; however, conventional development may not be the best way to protect sensitive resources. LID represents a sustainable approach to development that minimizes or eliminates impacts of development on water resources and habitat associated with Buzzards Bay. The key challenge is to encourage developers, planners, engineers and the public to utilize LID and other smart growth development approaches as the preferred alternative to conventional development.

A significant obstacle to the acceptance of LID principles is the perception that conventional development may be less expensive than LID and other methods of sustainable development. According to the Natural Resources Defense Council (www.nrdc.org/water), LID can often cost less than conventional stormwater management systems from both an installation and maintenance standpoint. LID design allows for less road surface and encourages less underground storm drain infrastructure (pipes, catch basins, manholes). In addition, the associated vegetation also offers human quality of life benefits by greening the neighborhood, contributing to livability and aesthetics. This “greening” can enhance property values and marketability, and provide wildlife habitat along with pollution reduction and decreased flooding. Instituting change throughout the planning and development community will require showing that conventional development will cost Buzzards Bay communities more, in terms of environmental degradation and quality of life impacts, than the cost of changing over to sustainable development approaches.

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Action Plan:
Promoting Low Impact Development

Goal

1. To encourage low-impact development (LID) and redevelopment that minimizes and/or eliminates environmental impacts.

Objectives

1. Promote incentives to developers and project proponents to incorporate LID into project site designs.

2. Provide training to local and state regulatory officials and developers/designers on LID.

3. Adopt and implement LID bylaws regulations, and policies at the local and state governmental level.

CCMP Recommendations and Commitments

<u>*Buzzards Bay National Estuary Program*</u>

3.1 The Buzzards Bay NEP should promote adoption of LID Bylaws and unified regulations.
Priority: High
Responsible Agent(s): BBNEP for training, NGOs raise support for passage of bylaws
Commitments:
Legislation required: None
Estimated costs: Costs of providing training will vary, but could range between $5K to $20K depending on workshop length, speakers fees and expenses, rental fees for facility, etc.
Potential funding: EOEA Smart Growth grants and CZM CPR and NPS grants.
Schedule:
Implementation strategy: The BBNEP should work with Buzzards Bay municipalities to assist with the adoption and implementation of the LID Bylaws and unified stormwater regulations among town boards. They should also provide training in the review of plans and stormwater calculations for compliance with local regulations, and to identify when professional engineering reviews are required.
Measuring success: BBNEP provide training opportunities to the target audience. Effective outreach is provided to a wide audience, including the intended target audience. There is widespread understanding of the problems with conventional development and the need for LID. There is increasing or widespread support for using the recommended measures. There is widespread use of LID measures. At least half the Buzzards Bay communities have participated in workshops and formally considered whether LID bylaws are appropriate in their town.

3.2 The BBNEP should develop a comparison of the costs and impacts of conventional development vs. LID and smart growth development, and provide this information to the municipalities.
Priority: Medium
Responsible Agent(s): The BBNEP in cooperation with MCZM/EOEA
Commitments: The BBNEP is committed to this task.
Legislation required: None
Estimated costs: Estimated $20K
Potential funding:
Schedule: Study drafted by December 2007, ongoing data collection continues beyond 2007.
Implementation strategy: CZM/EOEA will provide information to BBNEP on relevant case studies with cost data.
Measuring success: The analysis results in information that is useful for decision-making and management and the information is used for decision-making and management.
Comments: Case studies that compare similar sites, where one site was developed using conventional methods and another site was developed using LID, should be developed to help illustrate the benefits of LID. Examples most likely already exist in the watershed. The evaluation of costs should include a comparison of the short-term development costs and the costs of long-term environmental remediation needed to address impacts (e.g., costs of funding stormwater BMP retrofits to remediate existing untreated stormwater discharges).

3.3 The BBNEP should develop an inventory of pilot LID implementation projects and provide a guidance document and map that identifies the location, site information, costs, benefits and specific data relative to the project.
Priority: Medium
Responsible Agent(s): The BBNEP
Commitments: The BBNEP has committed to his task.
Legislation required: None
Estimated costs: Estimated $20K
Potential funding:
Schedule: Commence inventory in 2007, ongoing data collection continues beyond 2007.
Implementation strategy: CZM/EOEA will provide information to BBNEP on relevant case studies with site data.
Measuring success: A completed inventory and map identifying LID implementation projects in southeastern Massachusetts.

<u>*Federal*</u>

3.4 The US EPA should promote LID through funding and partnership building, as part of nation-wide Smart Growth initiatives.
Priority: Medium
Responsible Agent(s): U.S. EPA Region 1
Commitments:
Legislation required: None for funding. Change in NPDES Phase II permit required for next 5-year cycle, to begin in 2008.
Estimated costs: unknown
Potential funding:
Schedule:
Implementation strategy:
Measuring success: EPA provides funding for training and implementation of LID techniques as part of Smart Growth initiatives. EPA funds pilot implementation projects and produces guidance to municipalities on how LID can meet Phase II requirements.
Comments: Stormwater management is a key goal of the recent Phase II NPDES program and Clean Water Act provisions, which are implemented by the U.S. EPA. The use of LID as a component of stormwater management therefore should be promoted by EPA, through funding for training and outreach programs, developing and distributing outreach materi-

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als, and encouraging local-regional-state-federal partnerships to manage stormwater, and during EIS/EA reviews. Funding may be to state and/or regional agencies, such as EOEA, MA CZM, SERPDD, CCC, Massachusetts Highway Department, US EPA headquarters, and others. In addition, EPA should incorporate LID implementation among the requirements of the next 5-year cycle of the Phase II NPDES permit program.

3.5 NRCS should work with EPA to incorporate LID hydrology into the TR-55 model used by engineers and regulators.

Priority: High
Responsible Agent(s): NRCS, EPA
Commitments:
Legislation required: None
Estimated costs: Unknown
Potential funding: NRCS budget
Schedule: Initiate development of revised TR-55 model, or alternative, by July 2007. Publish revised model by December 31, 2008.
Implementation strategy: NRCS should work with EPA to identify hydrologic methods and a core set of LID BMPS that should be incorporated into the TR-55 model, or an alternative model. NRCS can then develop the revised model using existing peer-reviewed data and design characteristics. Training and outreach by NRCS, EPA, and local state agencies and LID experts will then be needed to teach engineers and reviewers how to use this model.
Measuring success: A model is published by NRCS and engineers begin using the model regularly to incorporate LID design into site development by the end of 2008.
Comments: Development of this model should be undertaken with assistance from engineering associations and research institutes to ensure proper understanding of the design and function of the LID BMPs, and to define the set of user-specified variables that will be needed in the model for LID BMPs. Training and outreach will be needed in order to teach practitioners how to use this software.

Commonwealth of Massachusetts

3.6 EOEA should showcase LID through a series of demonstration projects.

Priority: Medium
Responsible Agent(s): EOEA and MCZM
Commitments:
Legislation required: None
Estimated costs: $30,000 per demonstration project
Potential funding: Smart Growth Technical Assistance Grants, EPA/MA DEP 319 Grants, CZM CRP/NPS Grants
Schedule: Beginning in 2007 and ongoing
Implementation strategy: Identify interested parties and discuss possible projects. Develop proposal. Identify and obtain funding. Develop design and final plans. Construct LID development. EPA and EOEA should consider an award program for implementation of LID projects that may provide incentives to developers and/or institutions to implement LID projects.
Measuring success: LID demonstration project is successfully funded, built, and documented and provides an example for others to follow.
Comments: LID demonstration projects should be undertaken to provide an example to developers, agencies and the public. Existing examples of LID principles should be showcased. Demonstration projects can be undertaken by a partnership involving private and public sectors, the BBNEP, NGOs, educational institutions, or combinations thereof. Partnership-building is needed. EOEA has undertaken similar efforts recently.

3.7 MEPA should require the submission of an LID alternatives analysis for commercial and residential projects that meet MEPA thresholds (for land, rare species, wetlands, water, wastewater, transportation and ACEC) for EIRs.

Priority: High
Responsible Agent(s): EOEA MEPA Office,
Commitments:
Legislation required: Change in MEPA regulations required.
Estimated costs: Unknown
Potential funding:
Schedule: Change implemented by Dec 2007.
Implementation strategy: MEPA Office and EOEA should have a Task Force to develop recommendations for requirements of an LID Alternatives Analysis and present that to EOEA Secretary and MEPA Director for consideration. The MEPA Office should add changes to their website that promotes LID as part of a pre-project planning process, and MEPA should distribute appropriate guidance materials that encouraging LID strategies prior to project submissions.
Measuring success: Projects filing EIRs under MEPA begin to include LID alternatives analyses in the filing, and begin to select LID design as the preferred alternative.

3.8 EOEA should keep its LID Model Bylaw and Smart Growth Toolkit up-to-date.

Priority: High
Responsible Agent(s): EOEA should continue to provide training workshops to promote LID and other Smart Growth techniques, and keep the Toolkit up to date. The BBNEP and BBAC should continue to facilitate training workshops in LID. Municipalities should provide support for staff and board to attend training. The target audience for LID should include municipal staff and boards involved in policy and permitting of development (e.g., Planning Boards, Building Inspectors, Conservation Commissions, Zoning Boards, Boards of Health, and others), developers, builders, engineering firms, homeowners associations, trade associations, and the public.
Commitments:
Legislation required: None
Estimated costs: Cost of providing training workshops, outreach materials, and updating the Toolkit and LID Model By law, as necessary.
Potential funding: EOEA.
Schedule: Beginning in FY 2007 and ongoing.
Implementation strategy:
Measuring success: EOEA continues to provide training opportunities to the target audience. Effective outreach is provided to a wide audience, including the intended target audience. There is widespread understanding of the problems with conventional development and the need for LID. There is increasing or widespread support for using the recommended measures. There is wide-spread use of LID measures. There is noticeable improvement in water quality and habitat, or at least no further degradation.
Comments: has published the Smart Growth Toolkit that provides guidance on LID, including an LID Model Bylaw. This toolkit must be kept up to date and outreach should be provided to local governments and the development community.

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3.9. MA CZM should continue to sponsor the LID Working Group that meets monthly and provides education and outreach to a wide range of participants.

Priority: High
Responsible Agent(s): MA CZM
Commitments:
Legislation required: None
Estimated costs: $100,000
Potential funding: EOEA
Schedule: Meets monthly and shares information through email network
Implementation strategy: This group should continue to meet, compile useful LID information and case studies and continue to conduct workshops.
Measuring success: MA CZM plan for and provide training opportunities to the target audience. Effective outreach is provided to a wide audience, including the intended target audience. There is widespread understanding of the problems with conventional development and the need for LID. There is increasing or widespread support for using the recommended measures. There is widespread use of LID measures. There is noticeable improvement in water quality and habitat, or at least no further degradation.

3.10. DEP, with EOEA and MCZM guidance, should complete the update of MA Stormwater Standards and Policy.

Priority: High
Responsible Agent(s): MA DEP is responsible for updating the Stormwater Standards and Policy. Other agencies and organizations that should encourage incorporation of LID and completion of the Standards and Policy include the BBNEP, BBAC, municipal Planning Boards and Conservation Commissions, and the Coalition for Buzzards Bay. Local bylaws among town boards should be consistent as illustrated in the Buzzards Bay NEP "Unified Stormwater Regulations" for municipalities.
Commitments:
Legislation required: None
Estimated costs: Unknown
Potential funding:
Schedule: Beginning in the fall of 2006 with annual updates, as necessary.
Implementation strategy: Advisory Committee meets regularly to advise DEP and make recommendations.
Measuring success: The revised Stormwater Standards and Policy incorporating LID techniques is published and becomes effective. There is widespread use of LID techniques and wide understanding of its important role in watershed protection. Impaired water bodies and habitat improve or at least do not degrade further.
Comments: MA DEP is currently updating their Stormwater Standards and Policy. One of the recommendations from the Advisory Committee is to incorporate and encourage LID. MA DEP should look to promote and, if possible, require LID development throughout the Commonwealth. Higher standards for LID should be promoted in sensitive coastal areas such as the Buzzards Bay watershed and in "stressed basins" identified by DCR.

3.11 State Board of Building regulations should revise the State Building Codes to require LID measures.

Priority: Low
Responsible Agent(s): State Board of Building Regulations and Standards
Commitments:
Legislation required: Revision of State Building Code at 780 CMR.
Estimated costs:
Potential funding:
Schedule: Adoption of LID within the State Building Code by 2009.
Implementation strategy: The State Building Code at 780 CMR should be revised to allow or require the use of LID measures where feasible, just as requirements for energy conservation measures were incorporated in the late 1990's.
Measuring success: Revised building code incorporating LID is adopted and implemented locally. Implementation of LID measures is universal and consistent, and results in minimal or reduced impacts on the watershed and on Buzzards Bay.
Comments: The State Board of Building Regulations and Standards is the agency that promulgates building code changes according to a public process. Implementation of State Building Codes is carried out by local Building Commissioners in each municipality.

Regional Planning Agencies

3.12 SRPEDD and CCC should continue to provide LID training and outreach and education to municipalities and developers. CCC should incorporate LID into their Regional Policy Plan and apply these standards to projects under their regulatory review.

Priority: High
Responsible Agent(s): SRPEDD and CCC are to incorporate LID in their outreach and planning. Municipalities should adopt LID bylaws, measures and policies. Developers and building associations should attend LID workshops and promote its use, including providing opportunities for demonstration projects.
Commitments:
Legislation required: Promoting LID through outreach will not require legislation. However, SRPEDD and CCC can promote the adoption of Model LID Bylaws in municipalities. Municipalities should adopt and implement LID bylaws.
Estimated costs:
Potential funding:
Schedule: Ongoing. LID incorporated in CCC Regional Policy Plan by July 2008.
Implementation strategy:
Measuring success: LID standards and approaches are incorporated into regional planning guidance and requirements. Municipalities adopt and implement LID bylaws. LID is used widely by developers. There is improvement or at least no further degradation of water quality and habitat in the Buzzards Bay watershed and the Bay itself.

Municipalities

3.13 Each Buzzards Bay community should adopt an LID Bylaw and revise Planning Board, Conservation Commission and other applicable board regulations to reflect the new code.

Priority: High
Responsible Agent(s): All Buzzards Bay municipalities (Planning Boards, Conservation Commissions, Building Departments).
Commitments:
Legislation required: Requires municipal approval of the LID Bylaw (town meeting) or regulations (individual boards, where applicable).
Estimated costs: Costs could include labor to modify and tai-

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lor the existing LID Model Bylaw to suit a particular municipality.
Potential funding: Under M.G.L. Ch. 83, S. 16 ("Charge for use of sewers"), municipalities may create a stormwater management utility to raise fees to manage stormwater facilities that serve multiple residents and/or commercial properties. Such a stormwater utility is analogous to a sewer utility, and may include LID measures. A "water pollution abatement" district needs to be defined first, under M.G.L. Ch. 40, S. 1A.
Other funding sources include EOEA Smart Growth Technical Assistance Grants and CZM CRP and NPS Grants.
Schedule: Beginning in 2007 and ongoing.
Implementation strategy: Combine efforts with TMDL requirements and Phase II permits (refer to Action Plan 2: Managing Stormwater Runoff). Municipalities can utilize the Buzzards Bay NEP Unified Regulations for Town Boards but need to modify it for local application.
Measuring success: LID bylaws are adopted and implemented by municipalities within the watershed. Water quality and habitat within the watershed do not degrade further, and degraded environments may improve.
comments: The LID Bylaws should contain provisions for the treatment and infiltration of stormwater runoff and an incentive (credit) system to encourage developers to minimize impacts by reducing impervious areas, disconnecting rooftops and driveways from street drainage and maintaining naturally vegetated buffers to wetlands, streams and marine waters.

3.14 Local government staff and municipalities board members should attending LID training meetings and workshops to learn about sustainable development practices

Priority: High
Responsible Agent(s): DPW personnel, Town Planners, Planning Board members, Zoning Board of Appeals members, Selectmen, Building Inspectors, Conservation Agents, Conservation Commissions, and other municipal staff and boards dealing with permitting development and redevelopment. To provide training: Buzzards Bay NEP, MA CZM, regional planning agencies, building associations.
Commitments:
Legislation required: None.
Estimated costs: $5,000 per town per year
Potential funding: Selectmen and mayors should provide general funds, or use development permit fee. Alternative funding may include EOEA Smart Growth Technical Assistance Grants
Schedule: Beginning in 2007 and ongoing.
Implementation strategy: Key state and local staff and municipalities boards should become familiar with LID and other sustainable development practices, and attend training workshops where applicable. including DPW personnel, Town Planners, Planning Board members, Zoning Board of Appeals members, Selectmen, Building Inspectors, Conservation Agents, Conservation Commissions, and others to become trained and familiar with LID and other sustainable development practices.
Measuring success: Agencies provide training opportunities to the target audience. Effective outreach is provided to a wide audience, including the intended target audience. There is widespread understanding of the problems with conventional development and the need for LID. There is increasing or widespread support for using the recommended measures. There is widespread use of LID measures. There is noticeable improvement in water quality and habitat, or at least no further degradation.
Comments:

Non-Governmental Organizations (NGOs)

3.15. The development industry should promote the adoption of LID Bylaws.

Priority: Medium
Responsible Agent(s): The Cape Cod Homebuilders Association, Massachusetts Homebuilders Association, Massachusetts Association of Municipal Employees, American Planning Association, and other development and planning organizations should provide LID training to their members. EOEA, MCZM, BBNEP, and the BBAC should provide "Train-the-trainer" workshops to ensure the that the industry can provide LID training to their members
Commitments:
Legislation required: None
Estimated costs: Cost of providing train-the-trainer and other workshops could vary between $5K to $20K depending on workshop length, complexity, invited speakers, etc.
Potential funding: NAHB, EOEA, EPA
Schedule: Beginning in the spring of 2007 and ongoing.
Implementation strategy:
Measuring success: Industry provides training opportunities to the target audience. Effective outreach is provided to a wide audience, including the intended target audience. There is widespread understanding of the problems with conventional development and the need for LID. There is increasing or widespread support for using the recommended measures. There is widespread use of LID measures. There is noticeable improvement in water quality and habitat, or at least no further degradation.
Comments: "Train-the-trainer" workshops should be provided to these organizations and their members on the benefits of LID, and the construction specifications and sequencing to construct LID BMPs.

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Building a Vision: Putting the Pieces Together

Celeste Cantú, Executive Director
California Water Boards

Building Liveable, Sustainable Communities:
Water Quality and Supply is Linked to Growth

April 5, 2006

Our Mission and Framework

- "Our mission is to preserve and enhance the quality of California's water resources, and ensure their proper allocation and efficient use for the benefit of present and future generations."
- *Q: Why are we so focused on discharges?*
- *A: The legal framework (Clean Water Act) drives us to be discharge-oriented.*

But is that the best way to address our water quality and supply future?

- Is it “Sustainable”?
- Is there a better way?
- Can we address the problems before they are problems?

Population Growth and Land Use may be the LARGEST Threat to Water Quality

- Growth projections:
  - 39 million by 2010
  - 43 million by 2020
  - Almost 50 million by 2025, we will then be as densely populated as China is now.
- Housing Starts - over 200,000 per year for last 3 years

California's Urban Expansion Driven by Population Growth

- In California, per capita land use is actually declining.
- Expansion continues – driven by population growth.
- Population growth is not something we can change – so we better be preparing to handle it properly! THINK SUSTAINABILITY

Sustainability and Water Resources

- Sustainability has many definitions and applications (some very specialized)
- In our communities there are three main test / elements (each of which is undergoing a paradigm shift today).

Sustainability Tests

- Resource – protection to enhancement and reuse (“runoff is a resource”)
- Technical – complex, technological standard-based to simple, natural, performance-based solutions
- Institutional – centralized, subsidized approaches to decentralized, self-supporting approaches

What can the State do to help implement / enforce the CWA?

- Appropriate designation, development and enforcement of appropriate Beneficial Uses would encourage smarter growth.
- We also need to develop effective criteria for protecting uses from pollutants and/or habitat disturbance associated with urbanization impacts.
- Apply all our tools to encourage avoidance and minimization of impacts through better sighting and management practices.

Low Impact Development (LID) Principles

- Modelled after nature:
  - manage rainfall at the source using uniformly distributed **decentralized** micro-scale controls.

LID Principles (cont.)

LID's goal is to mimic a site's predevelopment hydrology by using design techniques that infiltrate, filter, store, evaporate, and detain runoff close to its source.

LID Principles (cont.)

- IMPORTANT: LID is a principled approach that uses many different techniques (some greener than traditional techniques) that **collectively** mimic predevelopment runoff patterns and/or protect aquatic resources.

- The application of "green techniques" alone does **not ensure** achievement of LID – i.e., green roofs and rain catchments alone do not ensure the predevelopment runoff is matched.

How does LID relate to Smart Growth and Conservation Design?

- Key distinction is that LID is an ecosystem-based approach – it seeks to design the built environment to remain a functioning part of the ecosystem
- LID is not a growth management or land use control strategy
- Does not take a stand on larger, growth issues, but can be integrated with Smart Growth and Conservation design to achieve multiple benefits.

The Basic Tools of LID

1. Encourage conservation measures
2. Promote impact minimization techniques such as impervious surface reduction
3. Provide for strategic runoff timing by slowing flow using the landscape
4. Use an array of integrated management practices to reduce and cleanse runoff
5. Advocate pollution prevention measures to reduce the introduction of pollutants to the environment

LID Examples

- LID is a principled application of techniques, including:
  - Site design/planning
  - Permeable pavement
  - Green roofs
  - Bioretention
  - Tree box planters
  - Disconnected downspouts
  - Rain gardens
  - A general reduction of connected, impervious surfaces in runoff pathways

LID Benefits

- **Multifunctionality** – landscaping costs also serve as stormwater treatment costs, etc.
- **Lower lifetime costs** – e.g., lower overall operation, repair, maintenance, and decommissioning costs

- **Reduced offsite costs** – fewer offsite sewer collection and treatment costs
- **Functional use of open space land** – LID practices can be put in open space, thereby not reducing developable land

- **Additional environmental and social benefits** – multiple objectives met

LID is Cost Effective

TRADITIONAL DEVELOPMENT		LOW IMPACT
$ Pay to Pipe / Pump offsite $ Risk onsite WQ violations / fines	→	Treat onsite
$ Pay to treat at end of Pipe	→	Reduced piping / pumping costs
$ Excavate, grade site and haul away materials	→	Utilize natural terrain / preserve natural channels

Reports of Reduced Costs

- Case studies show reduction of 25-30% over conventional projects.
- Somerset Rain Gardens[1]
  - Original retention ponds - $400,000
  - Implementation using natural drainage - $100,000
- Pembroke subdivision[2]
  - Used LID practices to eliminate stormwater ponds
  - Saved $200,000

Sources: 1- “Low-impact Development” by Mary Catherine Hager
2- “Stormwater Strategies: Community Responses to Runoff Pollution” NRDC

LID is Cost Effective for Development and Redevelopment

Incorporate LID into project design from the beginning

Multi-benefit projects reduce traditional piping, pumping and offsite treatment costs.

Incorporate LID into Urban Redevelopment

When retrofitting existing sewer system or re-landscaping sidewalk area, incorporate tree-box filters into storm drains.

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NPDES Stormwater Permits – help or hindrance?

- Municipal Separate Storm Sewer Systems (MS4s), in both large and small communities, are required to comply with MS4 requirements
- Much of the permit requirements focus on traditional BMPs and general, indirect municipal efforts (like general planning, outreach/education etc.)
- In 2002, Standard Urban Storm Water Mitigation Plans (SUSMPs – but they are called "performance standards" in some parts of the State) became mandatory for all MS4 permits

SUSMPs and Sustainability

- SUSMPs and other “performance standards” in MS4 permits require new developments and, in some cases, “significant” redevelopments to apply rigorous measures to mitigate the effects of urbanization.
- In the San Francisco Bay Area, some MS4s are required to develop Hydrograph Modification Management Plans (HMPs).
- The technical approaches and science behind some of the issues are still being debated in the State.
- Q: Does Low Impact Development = SUSMPs and HMP compliance?

Yes, LID = SUSMPs

- In theory, a well designed and executed LID project would fully comply with MS4 permit requirements (and probably avoid 404/401 permits, too).
- Translators are needed to help communities demonstrate compliance with MS4 requirements

LID and SUSMPs (cont.)

- Clearly SUSMP=LID works best for new development and significant redevelopment
- But strategic LID projects could also be used to retrofit urban landscapes to address other watershed problems
- State Board staff are working on developing translator tools for municipal officials who must comply with SUSMPs and wish to use LID-like approaches

Sustainable Projects Present Real Community Opportunities

- If done right, more sustainable projects will deliver:
  - NPDES compliance
  - Clean Water Act promises
  - Low Lifetime Costs to operate, maintain, decommission, etc.
  - Community buy-in and support through meeting multiple objectives, etc.
  - Unpredictable community economic opportunities (e.g., tourism and other ancillary benefits to the community)

Critical Mass for Sustainability and Low Impact Development

- Many upcoming activities and events
- State Board staff involved in a new partnership (the California Water and Land Use Partnership) along with LGC staff to develop more tools for local officials
- Consolidated Grants Program to fund Urban Stormwater Projects (Low Impact Development criteria)
- State Board staff working with Water Education Foundation to develop translator for SUSMPs to LID/sustainability
- MS4 and other Permits are being reissued with LID language and drivers
- Lots of training and workshops planned

Evidence of Shift

- Performance measures that would SHOW we are moving in the right direction.
- More NPDES permits for municipal separate storm sewer systems (MS4s) that contain LID-type requirements for New Development (we see more of this now).
- Increased judicial support for current need / approach to protecting water resources from stormwater discharges (we see this now).

Shift (cont.)

- Planning departments and land use agencies are excited about natural systems (we see this now)
- Natural Systems (low tech, natural function-based technologies) are embraced as cornerstones of “sustainable development”
- A number of disciplines integrated into stormwater management.

The End (or just the beginning?)

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CITY OF UNION CITY
GREEN BUILDING AND LANDSCAPING PRACTICES
IN PRIVATE DEVELOPMENT PROJECTS
STANDARDS POLICY STATEMENT,
ADOPTED BY CITY COUNCIL RESOLUTION NO. 3136-06
ON MARCH 14, 2006

GOAL:

To encourage private development projects to incorporate green measures into the design, construction, demolition, renovation, operation, and maintenance of buildings and landscaping. This Policy Statement has been developed to ensure that the appropriate resources, guidelines, and standards are made available to private developers regarding the creation of environmentally and economically sustainable building and landscapes.

POLICY:

The following is a list of objectives and criteria to be utilized as a guide for developers, and by the City Council, Planning Commission, and staff to help create green buildings and landscapes and evaluate the environmental performance of development projects.

GREEN BUILDING AND BAY-FRIENDLY LANDSCAPING

1. All commercial and institutional projects shall be encouraged to incorporate green building practices from the Leadership in Energy and Environmental Design™ (LEED™) Rating System and achieve standards set by LEED™.

2. All projects using the LEED™ Rating System shall be encouraged to have a LEED™ accredited professional as a principal member of the design team and to pursue LEED™ registration and certification by the U.S. Green Building Council.

3. All residential projects (including multi-family, single-family, and home remodeling) shall be encouraged to incorporate green building practices from the Alameda County Green Building Guidelines and achieve standards set by StopWaste.Org.

4. All landscaping projects or building projects with a landscaping component shall be required to incorporate green landscaping measures from the Bay-Friendly Landscape Guidelines and achieve the standards set by StopWaste.Org.

5. Staff shall provide to private developers resources and contact information for the LEED™, Alameda County Green Building Guidelines, and Bay-Friendly Landscape Guidelines systems.

Please see attached pages for resource and contact information for the LEED™ and Alameda County Green Building systems as well as guidelines from Bay-Friendly Landscaping program.

GREEN BUILDING AND BAY-FRIENDLY LANDSCAPING RESOURCES

The following reference guides are available for green building and Bay-Friendly landscaping in residential, commercial, and institutional projects:

Residential Projects

- Home Remodeling Green Building Guidelines
- New Home Construction Green Building Guidelines
- Multifamily Green Building Guidelines

These reference materials are available at www.BuildGreenNow.org

Commercial and Institutional Projects

- Leadership in Energy and Environmental Design™ (LEED™) Rating System
    - LEED-NC: New commercial construction and major renovation projects
    - LEED-EB: Existing building operations
    - LEED-CI: Commercial interiors projects
    - LEED-CS: Core and shell projects

These reference materials are available at www.usgbc.org/LEED

Landscaping Projects

- Bay-Friendly Landscape Guidelines
- Bay-Friendly Gardening

These reference materials are available at www.BayFriendly.org

BAY-FRIENDLY LANDSCAPE GUIDELINES

"Bay-Friendly Landscaping is a whole systems approach to the design, construction, and maintenance of the landscape in order to support the integrity of the San Francisco Bay watershed." – excerpt from the **Bay-Friendly Landscape Guidelines**. *For the complete handbook, visit www.BayFriendly.org*

PRINCIPLES OF BAY-FRIENDLY LANDSCAPING

1. **Landscape locally.** When choosing plant species, understand and take into consideration the following local conditions of the area: soil type, microclimate, sun exposure, drainage, and naturally-occurring plant communities. Careful evaluation will reveal both the opportunities and limits of the site.

2. **Landscape for less to the landfill.** Reducing waste starts with not generating it in the first place. Selecting the right plants for the right place, as well as watering and fertilizing judiciously are important ways to reduce the tons of plant debris that end up in the landfills in the Bay Area.

3. **Nurture the soil.** Healthy soil results in healthy plants. To maintain soil vitality: use natural soil amendments such as compost, protect soil from compaction, and mulch regularly.

4. **Conserve water.** Water-wise landscaping is more than just controlling irrigation. It also means increasing the water holding capacity of the soil, fostering healthier plants that thrive with less

water, and planning for the use of alternatives to potable water such as graywater, recycled, and captured stormwater.

5. **Conserve energy.** Landscaping choices can influence energy use. A strategically planted tree can conserve energy and money by providing valuable shade which assists in moderating building temperatures. Conserve energy by reducing the amount of lawn in your landscaping. Nationally, forty million lawnmowers consume 200 million gallons of gasoline per year.

6. **Protect water and air quality.** By incorporating Bay-friendly landscaping principles into your project, you can help protect the Bay area's water and air from pollution. Reduce use of pesticides and utilize an Integrated Pest Management approach to deal with harmful insects. Maximize pervious surfaces in your developments to reduce the amount of pollutants flowing into our local creeks. Plant trees to assist in absorbing air pollutants and removing harmful greenhouse gases from our environment.

7. **Create and protect wildlife habitat.** Developed landscapes can provide food, water, shelter, and nesting sites for birds, butterflies, beneficial insects, and other creatures, thus helping to conserve valuable wildlife resources, restore damaged ecosystems, and maintain the Bay Area's biodiversity.

PLANT SELECTION

1. Plant California Natives or Mediterranean species where appropriate.
2. Create a diverse plant palette of many different sizes, shapes, colors, and textures as well as blooming times, canopy levels, and root zones.
3. Choose plants to match the microclimate and soil conditions.
4. Choose plants that can grow to their natural shape and size and do not require extensive pruning.
5. Plant trees, especially large-canopy species, to moderate building temperatures and shade paved areas and air conditioners.
6. Implement hydrozoning—group plants by water needs.
7. Avoid planting invasive species.

SOIL, GROUNDCOVER, AND HARDSCAPE

1. Minimize lawn area.
2. Minimize impervious surfaces.
3. Assess soil conditions to ensure adequate drainage and minimize compaction.
4. Amend the soil, pursuant to a soil test, and apply mulch to encourage drought-resistance.
5. Remove and store top soil during construction.
6. Incorporate erosion control measures.

MAINTENANCE

1. Design and install high-efficiency irrigation systems.
2. Minimize the use of chemicals such as pesticides, herbicides, and fertilizers.
3. Minimize plant waste by grasscycling, composting, and producing mulch from plant debris on site.
4. Prune selectively and properly.
5. Water judiciously.
6. Reduce and recycle construction waste.
7. Use salvaged items and recycled content materials.
8. In the hillside area, consider mechanical methods and grazing for controlling weeds and creating firebreaks.

UFC 3-210-10
25 October 2004

UNIFIED FACILITIES CRITERIA (UFC)

LOW IMPACT DEVELOPMENT

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UNIFIED FACILITIES CRITERIA (UFC)

LOW IMPACT DEVELOPMENT

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U.S. ARMY CORPS OF ENGINEERS

NAVAL FACILITIES ENGINEERING COMMAND (Preparing Activity)

AIR FORCE CIVIL ENGINEER SUPPORT AGENCY

Record of Changes (changes are indicated by **1**\ ... /**1**/)

Change No.	Date	Location
1	Dec 2005	FOREWORD

FOREWORD

\1\
The Unified Facilities Criteria (UFC) system is prescribed by MIL-STD 3007 and provides planning, design, construction, sustainment, restoration, and modernization criteria, and applies to the Military Departments, the Defense Agencies, and the DoD Field Activities in accordance with USD(AT&L) Memorandum dated 29 May 2002. UFC will be used for all DoD projects and work for other customers where appropriate. All construction outside of the United States is also governed by Status of forces Agreements (SOFA), Host Nation Funded Construction Agreements (HNFA), and in some instances, Bilateral Infrastructure Agreements (BIA.) Therefore, the acquisition team must ensure compliance with the more stringent of the UFC, the SOFA, the HNFA, and the BIA, as applicable.

UFC are living documents and will be periodically reviewed, updated, and made available to users as part of the Services' responsibility for providing technical criteria for military construction. Headquarters, U.S. Army Corps of Engineers (HQUSACE), Naval Facilities Engineering Command (NAVFAC), and Air Force Civil Engineer Support Agency (AFCESA) are responsible for administration of the UFC system. Defense agencies should contact the preparing service for document interpretation and improvements. Technical content of UFC is the responsibility of the cognizant DoD working group. Recommended changes with supporting rationale should be sent to the respective service proponent office by the following electronic form: Criteria Change Request (CCR). The form is also accessible from the Internet sites listed below.

UFC are effective upon issuance and are distributed only in electronic media from the following source:

- Whole Building Design Guide web site http://dod.wbdg.org/.

Hard copies of UFC printed from electronic media should be checked against the current electronic version prior to use to ensure that they are current. /1/

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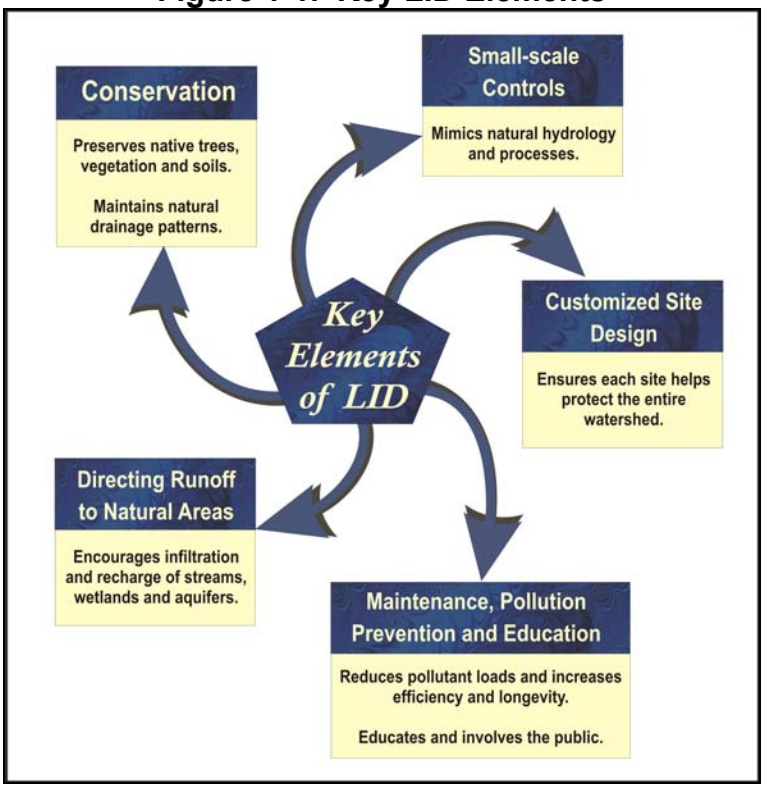
CHAPTER 1

INTRODUCTION TO LID AND MANUAL OVERVIEW

1-1 **DEFINITION OF LID.** Low Impact Development (LID) is a stormwater management strategy concerned with maintaining or restoring the natural hydrologic functions of a site to achieve natural resource protection objectives and fulfill environmental regulatory requirements. LID employs a variety of natural and built features that reduce the rate of runoff, filter out its pollutants, and facilitate the infiltration of water into the ground. By reducing water pollution and increasing groundwater recharge, LID helps to improve the quality of receiving surface waters and stabilize the flow rates of nearby streams.

LID incorporates a set of overall site design strategies as well as highly localized, small-scale, decentralized source control techniques known as Integrated Management Practices (IMPs). IMPs may be integrated into buildings, infrastructure, or landscape design. Rather than collecting runoff in piped or channelized networks and controlling the flow downstream in a large stormwater management facility, LID takes a decentralized approach that disperses flows and manages runoff closer to where it originates. Because LID embraces a variety of useful techniques for controlling runoff, designs can be customized according to local regulatory and resource protection requirements, as well as site constraints. New projects, redevelopment projects, and capital improvement projects can all be viewed as candidates for implementation of LID.

Figure 1-1. Key LID Elements



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1-2 **BACKGROUND ON THE USE OF LID.** The use of LID was pioneered in the 1990s by the Prince George's County, Maryland Department of Environmental Resources (PGDER). Prince George's County has a population of over 800,000, and land uses within the County are very diverse, ranging from sparsely populated natural and agricultural areas to densely populated urban centers. The LID effort in Prince George's County began with the development and use of bioretention cells. A bioretention cell is created by replacing existing soil with a highly porous soil mixture, grading the area to form a shallow depression, and replanting the area with specially selected vegetation. The vegetation must be able to tolerate temporarily saturated soil conditions as well as the pollutants contained in the local runoff. When it rains, bioretention areas collect the runoff and then filter out the pollutants as the water passes down through the soil.

The County's initial experience with bioretention led to a full-scale effort to incorporate LID into the County's resource protection program. In 1998, the County produced the first municipal LID manual. This was later expanded into a nationally distributed LID manual published in 2000.[1] A feasibility study was prepared by the Low Impact Development Center in 2002 that provided guidance on how LID could be used to retrofit urban areas.[2] Numerous municipalities, including Portland, Oregon,[3] are incorporating LID techniques into their urban resource protection programs. Although LID concepts and techniques are new to many planners in the United States, many of these techniques have been successfully used in Europe and Asia for many years.[4]

Several successful pilot projects have been constructed by the Navy and other Department of Defense (DoD) agencies during the last several years. The effectiveness of these projects in managing runoff, reducing construction and maintenance costs, and creating ancillary benefits such as community involvement has created significant interest in LID. The challenge is to adapt these approaches and techniques to the unique requirements of DoD facilities on a wider scale.

1-3 **INTRODUCTION TO UFC.** This UFC provides guidelines for integrating LID planning and design into a facility's regulatory and resource protection programs. It will be useful to engineers, planners, maintenance personnel, regulatory compliance staff, and community outreach staff who want a basic understanding of the technical and administrative concepts associated with the design, construction, and maintenance of LID features. The UFC answers the following questions:

- What is LID and what value does it have for DoD facilities?
- What are the basic planning, design, construction, and maintenance considerations?
- How can this approach be incorporated into facility operations?

[1] PGDER, 2000a.
[2] LID Center, 2002.
[3] BES, 2000.
[4] Ibid.

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- Where are successful examples of LID DoD facilities and programs?
- What does a typical LID design look like?
- Where can additional guidance be obtained?

This UFC is divided into ten chapters, including this introductory chapter. Chapter 2 provides a brief summary of issues related to compliance and the review process for any DoD project. Chapter 3 discusses regulations that apply to water resource and sustainability concerns for DoD projects, and how implementation of LID will affect compliance. Chapter 4 compares the ways that LID and conventional stormwater management approaches utilize hydrologic data and concepts in the design process. Chapter 5 discusses the goals of an LID design and the principles and strategies to meet them. Chapter 6 provides an overview of LID devices and the objectives they are designed to meet. Chapter 7 discusses the relative benefits of LID and conventional stormwater management practices. Chapter 8 details the appropriate use, cost, and maintenance issues for the LID devices introduced in Chapter 6. Chapter 9 provides a detailed outline of the LID planning process. Finally, Chapter 10 offers two examples of LID techniques put into practice, with accompanying calculations.

1-4 **LID SITE DESIGN STRATEGIES.** The goal of LID site design is to reduce the hydrologic impact of development and to incorporate techniques that maintain or restore the site's hydrologic and hydraulic functions. The optimal LID site design minimizes runoff volume and preserves existing flow paths. This minimizes infrastructural requirements. By contrast, in conventional site design, runoff volume and energy may increase, which results in concentrated flows that require larger and more extensive stormwater infrastructure.

Generally, site design strategies for any project will address the arrangement of buildings, roads, parking areas, and other features, and the conveyance of runoff across the site. LID site design strategies achieve all of the basic objectives of site design while also minimizing the generation of runoff. Some examples of LID site design strategies discussed in this UFC include:

- Grade to encourage sheet flow and lengthen flow paths.
- Maintain natural drainage divides to keep flow paths dispersed.
- Disconnect impervious areas such as pavement and roofs from the storm drain network, allowing runoff to be conveyed over pervious areas instead.
- Preserve the naturally vegetated areas and soil types that slow runoff, filter out pollutants, and facilitate infiltration.
- Direct runoff into or across vegetated areas to help filter runoff and encourage recharge.

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- Provide small-scale distributed features and devices that help meet regulatory and resource objectives.

- Treat pollutant loads where they are generated, or prevent their generation.

1-4.1 **LID Devices.** Reevaluate the site design once all of the appropriate site design strategies are considered and proposed to determine whether the stormwater management objectives have been met. Stormwater management controls, if required, should be located as close as possible to the sources of potential impacts. The management of water quality from pavement runoff, for example, should utilize devices that are installed at the edge of the pavement. These types of controls are generally small-scale (because the site planning strategies have created small-scale drainage areas and runoff volumes) and can be designed to address very specific management issues. The objective is to consider the potential of every part of the landscape, building(s), and infrastructure to contribute to the site stormwater management goals. When selecting LID devices, preference should be given to those that use natural systems, processes, and materials. The following list briefly defines the LID devices (or IMPs) described in this UFC.

1-5 **BASIC LIST OF IMPs.** Here is a basic list of IMPs that are available. More detailed descriptions are presented in Chapter 8. Appendix B contains a list of acronyms and abbreviations cited in the UFC.

Bioretention: Vegetated depressions that collect runoff and facilitate its infiltration into the ground.

Dry Wells: Gravel- or stone-filled pits that are located to catch water from roof downspouts or paved areas.

Filter Strips: Bands of dense vegetation planted immediately downstream of a runoff source designed to filter runoff before entering a receiving structure or water body.

Grassed Swales: Shallow channels lined with grass and used to convey and store runoff.

Infiltration Trenches: Trenches filled with porous media such as bioretention material, sand, or aggregate that collect runoff and exfiltrate it into the ground.

Inlet Pollution Removal Devices: Small stormwater treatment systems that are installed below grade at the edge of paved areas and trap or filter pollutants in runoff before it enters the storm drain.

Permeable Pavement: Asphalt or concrete rendered porous by the aggregate structure.

Permeable Pavers: Manufactured paving stones containing spaces where water can penetrate into the porous media placed underneath.

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Rain Barrels and Cisterns: Containers of various sizes that store the runoff delivered through building downspouts. Rain barrels are generally smaller structures, located above ground. Cisterns are larger, are often buried underground, and may be connected to the building's plumbing or irrigation system.

Soil amendments: Minerals and organic material added to soil to increase its capacity for absorbing moisture and sustaining vegetation.

Tree Box Filters: Curbside containers placed below grade, covered with a grate, filled with filter media and planted with a tree in the center.

Vegetated Buffers: Natural or man-made vegetated areas adjacent to a water body, providing erosion control, filtering capability, and habitat.

Vegetated Roofs: Impermeable roof membranes overlaid with a lightweight planting mix with a high infiltration rate and vegetated with plants tolerant of heat, drought, and periodic inundation.

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CHAPTER 2

INSTITUTIONAL ISSUES

2-1 **INTRODUCTION.** As with other types of construction projects, LID designs must meet DoD criteria and specifications before they can be approved. In addition, state and local zoning requirements and building codes may apply. This section provides an overview of these institutional issues and how they can be addressed effectively.

2-2 **COMPLIANCE WITH DOD CRITERIA.** Three primary concerns associated with obtaining DoD approval for using LID are listed below.

2-2.1 **Compliance with DoD Design Criteria.** LID techniques will comply with DoD design criteria. This UFC has the approval of Naval Facilities Engineering Command for compliance with Navy and DoD criteria and is written with the express purpose of assisting site engineers with satisfying DoD design criteria.

2-2.2 **Cost-Effectiveness.** The cost-effectiveness of LID-based projects may affect DoD approval. LID projects that incorporate newer technology may involve higher design and construction costs and may take more time to receive approval as a result. Whether or not this is the case for a particular site will depend on the level of experience that the project managers, engineers, and contractors have with LID techniques, and on the receptiveness of permitting authorities to LID practices. As with any new approach, the cost of implementing LID will decrease as institutional experience increases and the benefits of using LID are realized in practice.

2-2.3 **Antiterrorism/Force Protection.** All DoD facilities must comply with UFC 4-010-01, *Design: DoD Minimum Antiterrorism Standards for Buildings*. If any conflict occurs between this UFC and UFC 4-010-01, the requirements of UFC 4-010-01 take precedence.

2-3 **FEDERAL, STATE, AND LOCAL GOVERNMENT ACCEPTANCE.** Every new construction or retrofit project must meet applicable federal, state, and local regulatory requirements pertaining to construction materials, elevation and drainage, stormwater management, historic features, and wetlands protection. Because LID may be a new concept in some areas, DoD personnel may have to plan for additional reviews to gain support for LID as an effective alternative to traditional stormwater management control.

2-4 **BUILDING CODES.** For some DoD facilities, all projects, including LID designs, must meet UFC 1-200-01, *Design: General Building Requirements*. As with any project, the project manager or contractor must ensure that the project meets all applicable zoning, land use, or development regulations and must identify any special waivers, modifications, or processes that may be needed to gain approval. The design details should be evaluated for conformance with standard building codes to address access, safety and health issues.

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CHAPTER 3

WATER RESOURCE PROBLEMS, ISSUES, AND CHALLENGES

3-1 **INTRODUCTION.** Stormwater management efforts at DoD facilities will have a higher value when the design objectives involve not only the control of runoff at the drainage area outlet but also on-site water conservation, strategic conveyance of runoff, pollution prevention, stormwater treatment, and habitat preservation. DoD facility staff, however, currently face several significant challenges when pursuing these objectives because they must simultaneously consider mission, environmental, facility and budgetary goals. In many instances, LID can benefit several of these goals at the same time. For instance, LID can help to reduce expenditures on piped or channelized conveyance systems and large retention basins, because a fundamental LID technique is to provide storage and treatment on-site before runoff builds up in significant quantities. The following sections present the key issues and challenges associated with implementing LID on DoD facilities.

3-2 **COASTAL ZONE ISSUES.** Coastal zone issues are of particular concern for the DoD. DoD facilities located on the coast or along major water bodies often receive increased public and regulatory scrutiny. The primary stormwater management challenge facing DoD facility managers is minimizing uncontrolled runoff from industrial operations (e.g., ship maintenance operations and fueling areas) and from impervious areas (e.g., cantonment areas, docks, parking lots). Retrofitting a site using strategically placed LID components will enable DoD to conduct operations on a landscape that is less detrimental to water quality.

3-3 **REGULATORY COMPLIANCE.** This section lists the major federal laws concerning stormwater management and natural resource conservation at DoD facilities, and how implementing LID can help reduce the burdens associated with complying with these regulations.

3-3.1 **Clean Water Act.** The Clean Water Act (CWA) is the primary Federal law concerned with protecting the quality of the nation's waters. The major CWA programs pertaining to stormwater management are:

3-3.1.1 **Section 303. Total Maximum Daily Loads.** Section 303 of the CWA requires states, territories, and authorized tribes to develop lists of impaired waters and establish total maximum daily loads (TMDLs) allowable for these waters. States use the TMDL process to allocate pollutant loadings among pollution sources in a watershed and to provide a basis for establishing controls to reduce both point and non-point source pollutant loadings. LID can be used to help states meet TMDL targets in designated watersheds.

3-3.1.2 **Section 311. Spill Prevention, Control and Countermeasure Requirements.** Section 311 addresses pollution from oil and hazardous substance releases, providing EPA and the U.S. Coast Guard with the authority to establish a program for preventing, preparing for, and responding to oil spills that occur in navigable waters of the United States. EPA requires that certain facilities develop and implement

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oil spill prevention, control, and countermeasures (SPCC) plans. The goal of an SPCC plan is to ensure that facilities install containment and other countermeasures to prevent oil spills from reaching navigable waters.

3-3.1.3 **Section 319. State Non-Point Source Management Program.** This section delegates the regulation of non-point source pollution to the states and establishes the Non-Point Source Management Program. Although Section 319 of the CWA includes no enforcement mechanism to ensure that states actually develop and implement programs, CWA Section 303 requires that states identify all the activities that are causing a water body to be impaired, including non-point source pollutants, and develop mitigation plans.

3-3.1.4 **Section 401. Certification and Wetlands.** Section 401 of the CWA gives states, territories and authorized tribes the authority to review and approve, deny or condition all Federal permits or licenses that might result in a discharge to State or Tribal waters, including wetlands. State wetland water quality standards will limit the degradation of its waters and wetlands resulting from Federal activity. (In states without such standards, Federal water quality standards apply.) In order to obtain state certification, a development project may be required to prevent potential degradation of receiving waters caused by the discharge of stormwater runoff. LID can be used to reduce pollutant concentrations in stormwater runoff. Because of their small footprint and their manner of operation (i.e. filtering and dewatering devices rather than wet systems) LID devices themselves will not be subject to regulation as wetlands.

3-3.1.5 **Section 402. National Pollutant Discharge Elimination System (NPDES) Program.** The CWA prohibits the discharge of any pollutant to waters of the United States from a point source unless the discharge is authorized by a NPDES permit. Facilities that discharge stormwater from certain activities (including industrial activities, construction activities, and municipal stormwater collection systems) require NPDES permits. These facilities must implement commonly-accepted stormwater discharge management controls, often referred to as best management practices (BMPs), to effectively reduce or prevent the discharge of pollutants into receiving waters. Using LID to eliminate the volumes of effluent discharges of permit–requiring activities can help reduce the need for NPDES permits.

For many DoD facilities, the CWA Stormwater Phase II rule will expand their NPDES permitting requirements. Under the CWA Stormwater Phase II rule, EPA (or a state given CWA enforcement authority) can require a facility with a stormwater system to obtain a permit, even if it is not automatically regulated, if the facility's stormwater system discharges via a point source to an impaired water (the CWA 303d list), or to sensitive waters. Facilities that fall under the Phase II rule must develop and implement various BMPs including expanded stormwater management. LID techniques can help a facility to meet stormwater control requirements in a manner that minimizes impacts to the facility and natural environment and reduces the amount of infrastructure to be constructed and maintained.

Stormwater management solutions must qualify as state and local government-approved BMPs and meet technical performance criteria. For

example, an infiltration trench must provide a minimum level of pollutant removal as well as meet other performance requirements. A number of regulators are specifically encouraging the use of LID techniques and other innovative stormwater management solutions that reduce pollution associated with runoff. Many already encourage the use of bioretention, dry wells (where permitted), filter strips, vegetated buffers, grassed swales, and infiltration trenches. In some cases, stormwater credits may be given for using LID approaches.

3-3.1.6 **Section 404. Regulation of Dredged or Fill Material.** Section 404 of the CWA establishes programs to regulate the discharge of dredged or fill material into U.S. waters, including wetlands. The U.S. Army Corps of Engineers and the EPA jointly administer Section 404. According to these regulations,[5] no discharge of dredged or fill material can be permitted if a practicable alternative exists that is less damaging to the aquatic environment, or if the nation's waters would be significantly degraded. In other words, a permit applicant must demonstrate that they have:

- taken steps to avoid wetland impacts where practicable;
- minimized potential impacts to wetlands; and
- provided compensation for any remaining, unavoidable impacts through activities to restore or create wetlands.

LID features can reduce potential impacts to wetlands in several ways. First, filtering out pollutants from runoff helps to preserve the quality of water reaching the wetlands. Additionally, enhancing infiltration in the vicinity of the wetlands helps to sustain the supply of groundwater that feeds them. Finally, by reducing runoff energy, LID devices help prevent downstream erosion, reducing the volume of material that must ultimately be dredged from a channel or reservoir.

3-3.2 **Safe Drinking Water Act Wellhead Protection Program.** The Wellhead Protection Program protects the recharge areas of public water system wells from all sources of contamination. Groundwater recharge often results from LID techniques that increase rates of infiltration. Care should be taken, however, to ensure that any pollutants contained in runoff are adequately filtered out before the stormwater percolates down to aquifers in wellhead protection zones.

3-3.3 **Coastal Zone Management Act.** The Coastal Zone Management Act requires DoD facilities located in coastal states with approved coastal zone management programs to conform to the state program. As part of their programs, states must develop and implement coastal non-point source pollution control programs. States may object to permits for activities that are inconsistent with the state's coastal zone management plan. LID techniques can comprise a constructive response to state implementation of a non-point source pollution control program.

[5] http://www.epa.gov/owow/wetlands/facts/fact10.html

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3-3.4 **Energy Policy Act of 1992.** The Energy Policy Act of 1992 created conservation and energy-efficiency requirements for the federal government and consumers. The Act requires federal agencies to install, by January 1, 2005, energy and water conservation measures that will achieve acceptable payback periods. (A payback period is the time required to recoup the initial investment in a product or service.) LID techniques such as vegetated roofs and landscape shading can help a facility treat stormwater runoff, meet energy reduction goals, and possibly extend the life of infrastructure such as roofs. Water collected from rain barrels and cisterns for landscaping can be used to reduce a facility's water consumption, again helping to meet the Act's goals.

3-3.5 **Estuaries and Clean Waters Act of 2000.** The Estuaries and Clean Waters Act of 2000 established a program to utilize federal, state and private funding to support locally proposed watershed restoration projects. Under the Act, all Chesapeake Bay agreements are now codified, meaning that all agreements that DoD has signed are now law. Under the Act, federal agencies that own or operate a facility within the Chesapeake Bay watershed must participate in regional and sub-watershed planning and restoration programs. Additionally, the Act states that:

> "The head of each Federal agency that owns or occupies real property in the Chesapeake Bay watershed shall ensure that the property, and actions taken by the agency with respect to the property, complies with the Chesapeake Bay Agreement, the Federal Agencies Chesapeake Bay Unified Plan, and any subsequent agreements and plans."

Lastly, by 2010, the Chesapeake Bay watershed must be off the impaired waters list or it will be subject to TMDL requirements. Stricter discharge limits may result. Wherever discharge limits are imposed, LID techniques can be used to control the discharge of pollutants in stormwater.

3-3.6 **National Environmental Policy Act of 1969.** The National Environmental Policy Act of 1969 requires facilities to conduct and document environmental analyses and seek advice, participation, or comment from appropriate governmental agencies, and inform interested public and private organizations. The analyses include many aspects covering land use, air and water quality, wildlife and their habitats, socioeconomic factors, human health and safety, and natural and historical resources. By incorporating LID into site design, facilities can minimize adverse affects of new development on the environment (e.g., topography, stormwater, vegetation).

3-3.7 **Sikes Act.** The Sikes Act requires facilities to manage natural resources via an approved Integrated Natural Resource Management Plan. This plan serves as the facility plan for managing its ecosystems, including watersheds and wetlands. Consistent with the goals of the Sikes Act, the use of LID techniques will help maintain the natural landscape and its hydrology.

3-4 **DIRECTIVES.** DoD facilities also must meet various Presidential Executive Orders (EOs) or directives in addition to meeting federal laws. This section lists the

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major directives that relate to stormwater management and conservation and indicates how implementing LID designs can help reduce compliance burdens.

3-4.1 **EO 13148, Greening the Government through Leadership in Environmental Management.** Each agency must strive to promote the sustainable management of federal facility lands through the implementation of cost-effective, environmentally sound landscaping practices and programs designed to reduce adverse impacts on the natural environment. Sustainable environmental management can be implemented directly and visibly through the use of LID.

3-4.2 **LEED Green Building Rating System™.** The U.S. Green Building Council has developed the LEED Green Building Rating System™, a national standard for developing high-performance, sustainable buildings. Projects can earn LEED™ certification for sustainability based on the number of sustainable practices incorporated into the project. DoD facilities that implement LID techniques can receive LEED™ points for limiting the disruption of natural water flows by minimizing stormwater runoff, increasing on-site infiltration, and reducing contaminants. Currently, Navy and Air Force policies encourage the use of the LEED checklist, which the Army soon plans to adopt as well. Other DoD criteria such as the Army's Sustainable Project Rating Tool (SPiRiT), which is adapted from the LEED checklist, may also apply.

3-5 **VOLUNTARY PROGRAMS AND AGREEMENTS.** Partnerships between federal, state, local, and private entities have developed voluntary, watershed-wide guidelines aimed at preserving and restoring water quality in water bodies such as the Potomac River or Chesapeake Bay. One such partnership is the Chesapeake Bay Program, of which DoD is a partner. The Chesapeake Bay Program offers specific guidelines such as providing riparian buffers and implementing new stormwater management technologies in targeted watersheds. (Riparian land is adjacent to a stream or river and has an elevated level of biological activity because of that proximity.[6]) The use of LID as a design approach will help to fulfill the aims of these facilities agreements and partnerships.

3-6 **COSTS.** LID practices offer opportunities to reduce the life cycle cost of a site's stormwater infrastructure. It is impractical to make broad generalizations about costs for stormwater facilities because of the inherent variability between sites and the complexity of management issues. Although initial construction costs for LID practices may be higher than initial costs for conventional stormwater practices, this initial expense is often offset by cost savings in operations and maintenance. This savings is possible because the maintenance of LID features can generally be incorporated into regular landscaping maintenance activities and does not require expensive training or hiring of a separate contractor for maintenance. Details for specific LID practices are presented in Chapter 8.

3-7 **RETROFITS.** Older DoD facilities were developed either with traditional approaches or with no stormwater management at all. Eventually, stormwater management components will have to be installed, replaced or retrofitted – a costly

[6] Lee, 1998.

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task. DoD will inevitably need to replace pipes and dredge stormwater ponds. LID techniques, particularly non-structural techniques such as disconnecting impervious areas, can significantly reduce the cost of retrofitting or providing stormwater management.

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CHAPTER 4

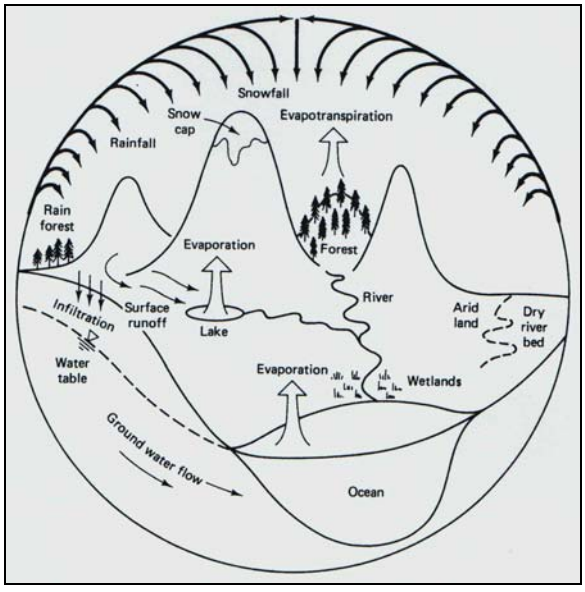
STORMWATER MANAGEMENT USING THE HYDROLOGIC CYCLE APPROACH

4-1 **INTRODUCTION.** Development affects the natural hydrologic cycle as shown in Figures 4-1 and 4-2. The hydrologic cycle consists of the following processes: convection, precipitation, runoff, storage, infiltration, evaporation, transpiration, and subsurface flow.

A hydrologic budget describes the amounts of water flowing into and out of an area along different paths over some discrete unit of time (daily, monthly, annually). Grading, the construction of buildings, and the laying of pavement typically affect the hydrologic budget by decreasing rates of infiltration, evaporation, transpiration and subsurface flow, reducing the availability of natural storage, and increasing runoff. In a natural condition such as a forest, it may take 25 to 50 mm (one to two inches) of rainfall to generate runoff. In the developed condition, even very small amounts of rainfall can generate runoff because of soil compaction and connected impervious areas. The result is a general increase in the volume and velocity of runoff. This, in turn, increases the amount of pollution that is carried into receiving waters and amplifies the generation of sediment and suspended solids resulting from bank erosion.

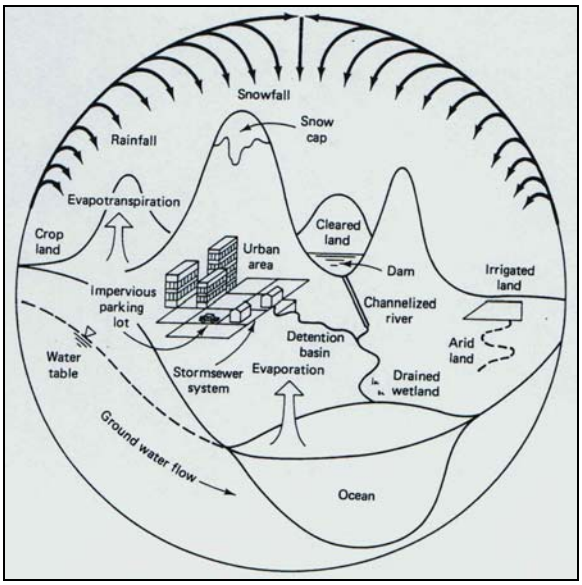
4-2 **DESIGN INPUTS.** Both LID and conventional stormwater management techniques attempt to control rates of runoff using accepted methods of hydrologic and hydraulic analysis. The particular site characteristics that are considered will depend on the nature of the project. Land use, soil type, slope, vegetative cover, size of drainage area and available storage are typical site characteristics that affect the generation of runoff. The roughness, slope and geometry of stream channels are key characteristics that affect their ability to convey water.

Figure 4-1. Natural Hydrologic Cycle



Source: McCuen, 1998.

Figure 4-2. Hydrologic Cycle of a Developed Environment



Source: McCuen, 1998.

While conventional approaches to stormwater management design typically include only the hydrologic components of precipitation, runoff conveyance and storage capacity within their scopes, LID design recognizes the significance of other components of the hydrologic cycle as well. How these other components are actually taken into account will depend on the information available and purpose of the design. One LID design objective, for example, may be to maintain a natural groundwater recharge rate for a given site. Determining the appropriate number, size, and location of infiltration devices can require an extensive atmospheric data set (temperature and precipitation) to calculate evapotranspiration rates, along with measures of soil hydraulic conductivity.

The following section describes how LID design can make use of precipitation, storage, infiltration, evaporation, and transpiration data. The discussion includes a brief description of each of these types of data, and compares the use of these data from LID and conventional stormwater management perspectives.

4-3 **PRECIPITATION DATA.** Precipitation data is often analyzed in terms of the frequency at which storm events of different magnitudes and durations occur at a given location. Stormwater management designs may take into account the total annual depths or the volume generated by a storm of a specific frequency and duration (e.g. 2-year 24-hour storm event). Hydrologic models may use precipitation data to develop a synthetic design storm that reflects the pattern and intensity of precipitation for the project location region or use actual gage data from a given storm event.

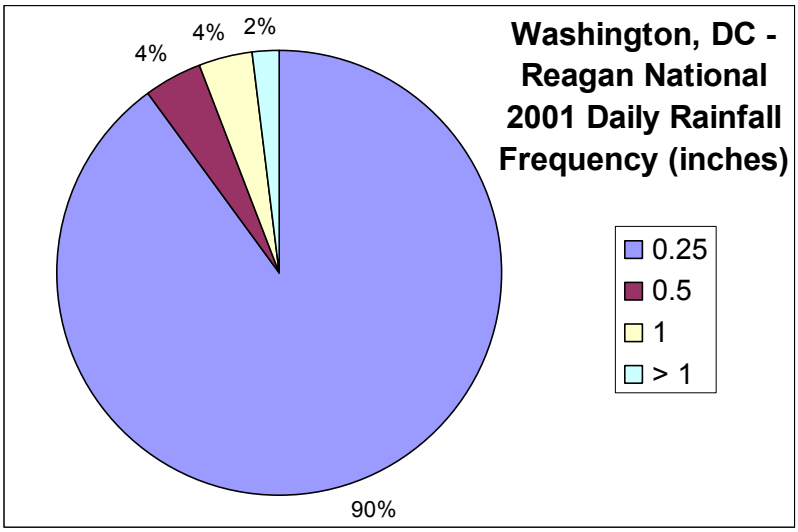
The level of detail and accuracy of data used is dependent on the requirements of the hydrologic model. For example, to develop a simple water balance for on-site irrigation only a few years of annual rainfall totals may be required. Some advanced urban

hydraulic models, on the other hand, may require the collection of rainfall data in 2-minute intervals over several years to determine the appropriate system design.

4-3.1 **LID Precipitation Analysis.** An important approach to analyzing the effectiveness of an LID design is to consider the number of storm events for which the design will provide enough storage and infiltration capacity to capture all of the precipitation on-site. This is useful because maintaining the hydrologic integrity or water balance of a site is better accomplished by managing the frequent smaller events rather than the occasional large events.

For example, in the Washington, D.C. region there are approximately 80 storm events per year that collectively generate approximately 1000 mm (40 in) of precipitation. Approximately 75 of these storm events generate 13 mm (0.5 in) or less of precipitation. Figure 4-3 illustrates this concept.

Figure 4-3. Frequency of Small Storms



Source: NOAA.

This kind of analysis allows the designer to determine the overall storage and infiltration capacity required to control the desired number of storm events within any given year or period. The analysis can also be undertaken in terms of the precipitation depth associated with discrete storm events such as the 1-year 24-hour storm.

4-3.2 **Conventional Precipitation Analysis.** Conventional practices, as well as many state and local regulations, often require site engineers to control only specific events such as the 2-year 24-hour storm events. In the Washington, D.C. area, this would mean reducing the peak runoff to predevelopment rates for only those events in which 76 mm (3 in) of rainfall. Events that occur more or less frequently would be less effectively controlled.

4-4 **STORAGE.** Precipitation may be temporarily detained within site depressions or held in the soil. When the capacity of a depression is exceeded, the water is released as runoff that may be captured further downstream. Water that is not

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released as runoff will be infiltrated into the soil, taken up by plants, or evaporated back into the atmosphere. Natural land cover often provides depression storage in small undulations in the topography. Greater storage capacity is provided in ponds or lakes.

4-4.1 **LID Storage Concepts.** LID employs site planning and grading techniques to direct or maintain the flow of runoff to naturally occurring storage areas such as wetlands. Keeping the storage area volume stable helps to maintain the existing hydrologic and biological function of the storage area.

An LID design may also include small-scale retention components (retention is defined as the volume of runoff that never reaches the drainage area outlet). Retention can be provided in a variety of ways that not only support the management of runoff, but also supply water for on-site use. For example, a cistern may be used to store and release water for peak flow control as well as to store water for domestic purposes. Additionally, some industrial buildings can provide roof storage and release water for use in cooling systems. Another example, shown in Figure 4-4, is a green wall within a building. The green wall is used to modify temperature and improve air quality by having stored roof water flow across the vegetation.

Capturing runoff in small volumes helps to prevent erosion, because the runoff is less likely to reach damaging flow rates. The distribution of storage components also tends to result in a more robust stormwater management system, because the failure of one component will not cause the entire system to fail. Care must be taken when ponding or storing water to make sure there is adequate flow, infiltration, evaporation, or discharge, and that unwanted carriers of disease such as mosquitoes are adequately controlled.

Figure 4-4. Greenwall

Source: Greenland International Consulting, Inc., Ontario, Canada.

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4-4.2 **Conventional Storage Concepts.** Conventional stormwater strategies often include the storage of water in large centralized end-of-pipe facilities. Site designs direct and convey most runoff as quickly as possible to these facilities and then discharge through an outlet structure at a limited release rate (e.g., 2-year 24-hour pre-development runoff rate). Conventional runoff management techniques can dramatically reduce the flow of runoff into natural storage areas such as wetlands, depriving a variety of organisms of the level of moisture they need.

Conventional approaches can have other negative impacts. By removing opportunities for storage onsite, rates of ground water recharge will be reduced. In addition, the concentrated flow conveyed to large-scale facilities accumulates pollutants and increases the erosive force of the water, which must be slowed down and treated to maintain the natural energy and chemical balance of the ecosystem. An increase in temperature as the water is pooled may also be detrimental to the ecological integrity of the receiving water.

4-5 **INFILTRATION.** Water stored in depressions will infiltrate into the soil at different rates, depending on the soil type and the amount of moisture already in the soil. Some of the water that infiltrates into the ground may then percolate further downward into an aquifer, or travel horizontally and reappear as surface flow in a stream. A portion of the water will be held in the soil and extracted by vegetation.

The capacity of the soil to absorb and infiltrate water is dependent on a variety of factors such as soil structure (e.g., pore spaces and particle size), classification (percentage of sand, silt, and clay) and biological activity (e.g., roots, worms). Water is filtered by the soil system by various mechanisms such as adsorption and chemical and biological reactions. Under natural conditions, a significant portion of the annual precipitation may infiltrate into the ground. As land is developed, however, many natural depressions that would otherwise collect water are eliminated, the soil is compacted, and impervious area is added in the form of buildings and pavement. Consequently, levels of infiltration typically decrease when a site is developed. The additional runoff generated often results in degradation of the watercourse because of bank erosion, increased flooding, and alteration of habitat characteristics.[7]

The infiltration flow patterns and processes are extremely important to maintain the water balance in wetlands and the base flow in stream channels. Figure 4-5 illustrates how groundwater feeds an aquatic system.

[7] Gordon et al., 1992.

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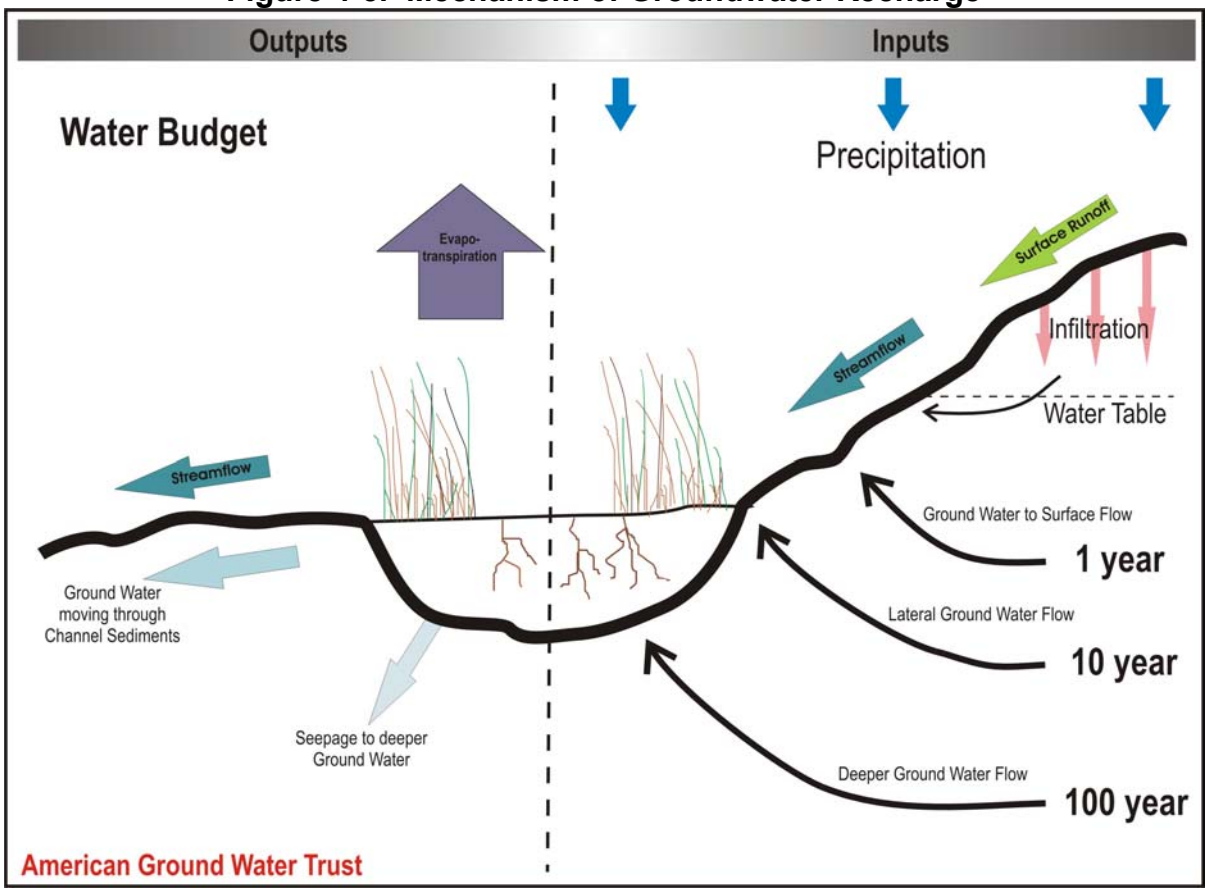
Figure 4-5. Mechanism of Groundwater Recharge



4-5.1 **LID Infiltration Concepts.** Maintaining natural infiltration rates is an important aspect of LID design. Accomplishing this requires an accurate understanding of the existing soils and groundcover conditions. For example, a clay soil on a pre-development site may have very little infiltration capacity or a sandy soil, which is compacted, may have reduced capacity. The design should take care not to overload the hydraulic conductivity of existing soils.

Soil maps by themselves are not sufficient to determine the capacity of the soils to absorb and filter water; additional field testing is required. Dispersing flows, maintaining natural flow patterns, and directing flows towards soils with high capacities for infiltration will help maintain ground water levels. Amending soils by adding organic materials, reducing compaction by aeration, maintaining leaf or “duff” layers in natural areas, and reducing compaction requirements for non-load bearing areas will also enhance and maintain infiltration rates and patterns.

Although soils and natural areas have a high capacity to filter and treat pollutants, careful planning must take place to ensure that potential pollutants such as nitrates, oils, or other urban runoff contaminants are adequately treated before entering any potential water supply. Infiltration areas should not be located near areas that have potential for hazardous waste spills or contamination. It is important to ensure that runoff is adequately filtered before it is allowed to infiltrate, especially if local aquifers

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are particularly shallow. In cases where the water table is very high, it is often advisable to avoid infiltration altogether.

4-5.2 **Conventional Infiltration Concepts.** Conventional approaches concentrate on the infiltration capacity of a single end-of-pipe management facility such as a pond. Infiltration potential elsewhere on the site is often discounted or only analyzed for its effect on the flow of runoff into the facility. The conventional infiltration objective is to concentrate flows in one area and then utilize the infiltration capacity of the natural soil or conduits such as gravel. Natural groundwater flow patterns and recharge are often not considered. Conventional approaches may result in the elimination of critical volumes of flows to sensitive areas such as wetlands. Additionally, in many urban areas, the high loads of fine sediments to centralized facilities and the impacts of construction compaction can severely limit the infiltration capacity of the facility.

4-6 **EVAPOTRANSPIRATION.** Evapotranspiration is the loss of water from the ground by evaporation and transpiration. Evaporation is the return of moisture to the atmosphere from depressions, pond areas, or other surfaces. Transpiration is the return of water to the atmosphere through plants; moisture is absorbed by the roots and released through the leaves. The rate of evapotranspiration is dependent on air temperature, humidity, wind speed, sunlight intensity, vegetation type, and soil conditions.

4-6.1 **LID Evapotranspiration Concepts.** LID designs use open areas and vegetation to promote evapotranspiration. Larger areas used for evaporation, such as ponds, should have a flow regime that controls mosquito breeding. LID designs should not pond water for more than 72 hours as it may provide an opportunity for mosquitoes to breed. By keeping surface areas small and shallow, water can quickly evaporate and pollutants volatilize through plant uptake or evaporation.

LID designs also employ the capacity of vegetated areas to absorb, process, volatilize, and treat non-point source pollution as well as atmospheric pollution. Interception by leaves can significantly reduce the requirement for storage and infiltration. A mature canopy can intercept a significant number of small-volume, frequently occurring storms, absorbing precipitation into the plant leaves or evaporating precipitation from the leaf surface.[8] Additionally, uptake of soil moisture by plants helps to maintain the soil's capacity to absorb rainfall.

4-6.2 **Conventional Evaporation Concepts.** Conventional stormwater approaches are based on peak flow control over a short duration (usually 24 hours or less). For these single event designs, the evaporation process is often discounted or not considered.

[8] Sanders, 1986.

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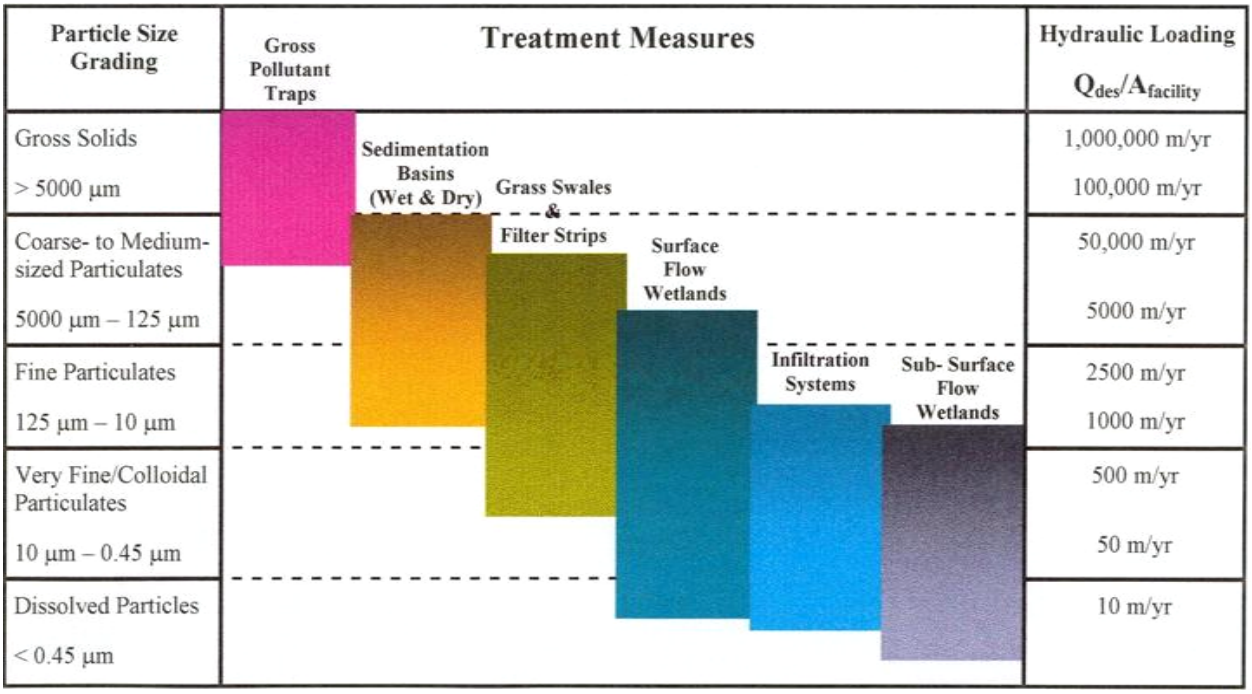
CHAPTER 5

LID DESIGN GOALS AND OBJECTIVES

5-1 **INTRODUCTION.** DoD facilities are faced with the responsibility of managing and protecting the natural resources of often large parcels of land reserved for many different functions. Uses can be intensive and can pose a variety of stormwater challenges. For example, a truck maintenance facility or post-exchange may generate stormwater pollutants and alter the downstream hydrology. Alternatively, a vehicle training range may pose a high risk for pollution (e.g., high TSS) but on an infrequent basis. There is no single management practice that can be universally applied to all drainage areas.

Figure 5-1 illustrates the removal effectiveness of various BMPs for a variety of pollutants. The graph illustrates the complexity of stormwater management; there is no single BMP or technique that can be used to effectively address all of the potential watershed issues.

Figure 5-1. Removal Effectiveness of Various BMPs



Source: Wong.

5-2 **REGULATORY AND NATURAL RESOURCE DESIGN ISSUES.** Many regulatory compliance or flood control (peak rate design) schemes for construction are designed to achieve only one objective (e.g., pre-development control for the 2-year 24-hour storm event). Regulations often fail to consider overall natural resource management, hydrologic objectives, and stewardship responsibilities of facilities.

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Budget constraints often limit construction funding to that necessary for conveyance or flood control requirements. The limited framework may create situations where regulatory requirements are met but the design results in degradation of the natural resources. LID principles use hydrology as the integrating framework of design, and protect the overall ecology of the watershed. LID allows facilities to meet the regulatory requirement for flood control (by storing and infiltrating a sufficient volume) while sufficiently filtering targeted pollutants through natural and man-made systems.

5-3 **FUNDAMENTAL SITE PLANNING CONCEPTS.** The goal of LID site planning is to allow for full development and function of the intended site activity while maintaining the site's essential natural or existing hydrologic function. The LID site design process is sequential and iterative, and embraces the following five concepts:[9]

- Hydrology is the Integrating Framework for the Design
- Distribute Controls through Micromanagement
- Stormwater is Controlled at the Source
- Utilize Non-structural Systems Where Possible
- Create Multifunctional Landscape, Buildings and Infrastructures

5-3.1 **Hydrology is the Integrating Framework for the Design.** LID designs have the goal of mimicking the natural site drainage processes and functions. Techniques are used to modify hydrologic processes, such as infiltration or storage, to meet the specific water quality, water quantity, and natural resource objectives. LID designs create an effective drainage process for stormwater on the site. A stormwater management system will come closest to mimicking natural flow patterns when storage and infiltration components are distributed across the site.

5-3.2 **Distribute Controls Through Micromanagement.** In order to emulate natural processes, it is imperative to view the site as a series of interconnected small-scale design controls. Such a structure creates opportunities for redundancy in treatment and control, the development of a "treatment train" for water quality control, and the opportunity to strategically locate LID components.

5-3.3 **Stormwater is Controlled at the Source.** Controlling and treating runoff as it is being generated reduces or eliminates the risks associated with transporting pollutants further downstream through pipes and channels. Management of stormwater at the source is especially valuable if remediation is required, such as in the case of an accidental spill of pollutants, because the problem can be easily isolated or the treatment system adjusted.

5-3.4 **Incorporate Non-Structural Systems.** LID designs recognize the potential of natural systems to intercept and filter pollutants. Phytoremediation techniques that

[9] PGDER, 2000a.

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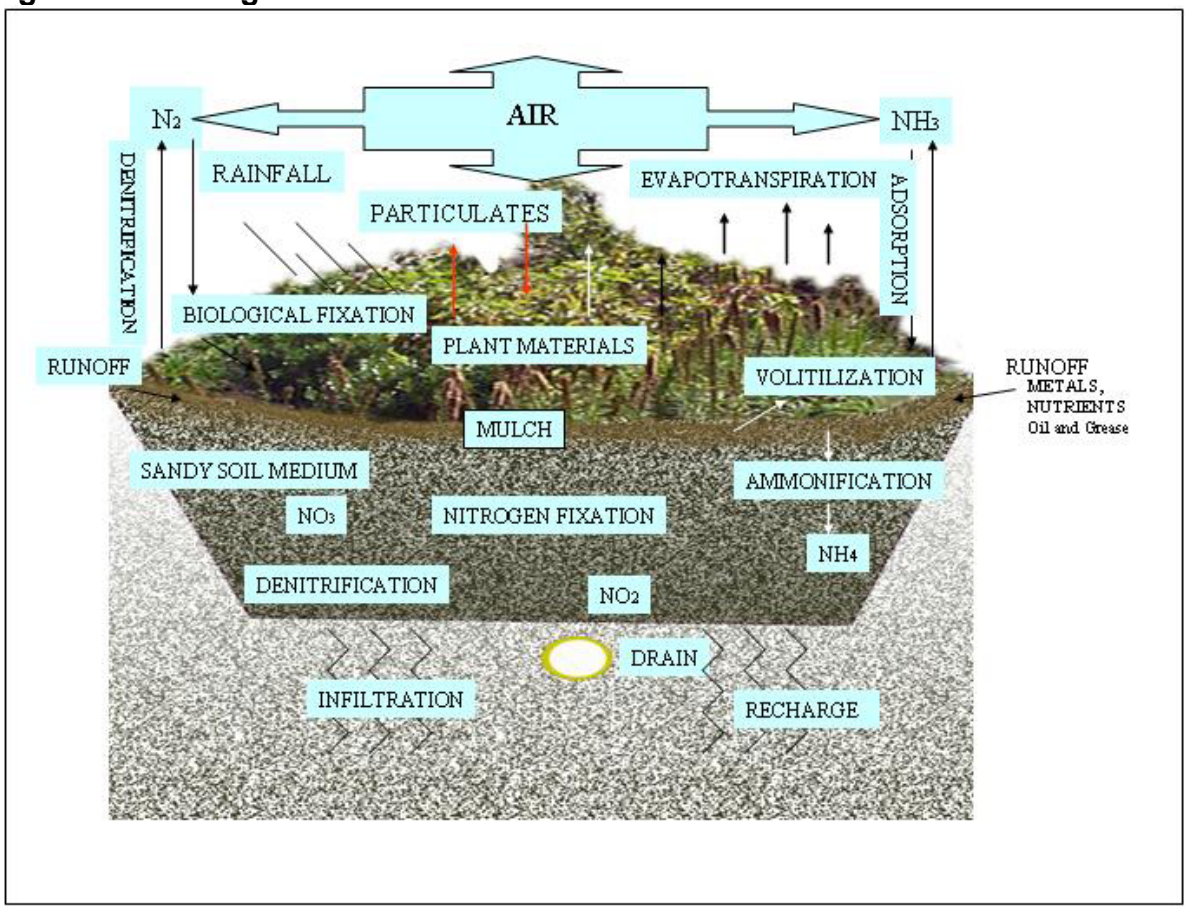
take advantage of the biological and chemical processes of the plant soil complex have shown tremendous potential in stormwater management. These natural systems are easy to design, construct, and maintain, even though the naturally occurring filtering and treatment processes may be quite complex and multidimensional. Benefits of using these small-scale and simplified systems (such as soil amendments, landscaping, or re-vegetation) include the reduced need for costly large-scale construction projects (such as underground concrete vaults or proprietary filters).

Figure 5-2 illustrates the range of biological and chemical processes that have been documented to occur in a bioretention cell. The bioretention cell is a landscape area constructed of specialized soil and plants that can effectively absorb and treat urban runoff.

Figure 5-2. Biological and Chemical Processes that Occur in a Bioretention Cell



Source: Prince George's County, Maryland Department of Environmental Resources (PGDER), 2000.

5-3.5 **Utilize Multifunctional Landscape, Buildings and Infrastructures.** There are a wide variety of LID practices available. The primary criterion in selecting LID practices is that the design of the component contributes to satisfying the design and regulatory objectives. Design features are often multifunctional and satisfy multiple objectives. The development of vegetated roofs is a good example. A vegetated roof can reduce the effects of atmospheric pollution, reduce runoff volume and frequency,

reduce energy costs, create an attractive environment, and have reduced replacement and maintenance, and longer life cycle costs. There are many types of vegetated roofs that can be developed including pre-made grids, or cells, or whole systems.

5-4 **LID MANAGEMENT AND DESIGN STRATEGIES.** LID design is an iterative process that requires a thorough understanding of the management objectives, a detailed understanding of the physical and natural resources of the site, a conceptual site design that can be refined to achieve the goal of a hydrologically functional landscape, and a long-term maintenance plan.

5-4.1 **LID Site Planning Components.** This section presents the aims of LID site planning and, in light of existing site development requirements, describes how LID site design can be best approached to manage runoff.

5-4.1.1 **Hydrologic and Hydraulic Objectives.** The purpose of LID site planning is to significantly maintain the predevelopment runoff volume and flow rate. Ideally, and where site conditions allow, this will be achieved in a way that replicates the site's predevelopment hydrologic functions. Sites that are characterized before development by porous soils, substantial vegetative ground cover, and ungraded topography naturally perform several important hydrologic functions:

- Facilitate infiltration, evapotranspiration, retention and detention of runoff
- Limit runoff flow rates because of ground surface roughness
- Help control water quality through surface and subsurface filtering of pollutants and sediments

On a developed site, these hydrologic functions can continue to be provided by the preservation of natural features or construction of a variety of man-made features (as described in Chapter 9). Taken together, the utilization of these features comprises a distributed source control strategy that is designed to not only meet regulatory requirements but also to provide superior natural resource protection.

Maintaining areas with high soil porosity, vegetative ground cover, and shallow ponding will help meet the following objectives:

- Flood control. Facilitating the infiltration of runoff and decreasing overland flow rates reduces the risk of flooding in receiving waters. To meet design objectives and regulatory requirements completely, supplemental controls may still be required.
- Volume Control. The overall volume of runoff that leaves a site is kept as close as possible to predevelopment levels.
- Peak Control. The peak runoff rate does not increase above predevelopment levels, and the entire runoff hydrograph emulates the predevelopment hydrograph.

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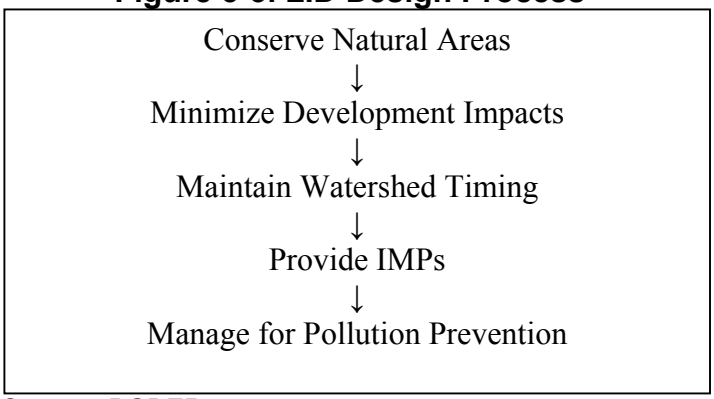
- Filtering and Treatment of Pollutants. Runoff is directed across vegetated areas and through porous media to provide significant reductions in the concentration of sediments and pollutants in the water.

- Groundwater Recharge. Infiltration is expedited to enhance groundwater recharge rates and help sustain base flows in nearby streams.

5-4.2 **LID Design Approach.** The LID approach to site design seeks to maintain or restore the hydrologic impacts of site development using a combination of runoff management strategies, site design techniques, and distributed source controls (IMPs). LID design requires that site plans address the overall natural resource and compliance issues within the watershed. The long-term success of this approach requires an understanding of the maintenance requirements and life-cycle effectiveness of the LID practices and the development of an appropriate maintenance and pollution prevention plan for the facility.

While the influence of each of the components of the design process varies from site to site, a general process has been developed to ensure that all of these components are considered. Although the preference in LID design is to reduce the hydrologic impacts on the site and to retain naturally effective hydrologic features, it is recognized that significant impacts may occur because of the nature of DoD activities. When compensating features are required, LID emphasizes the use of integrated site features that control runoff as close as possible to the source, rather than transporting pollutants and attempting to mitigate for lost functions elsewhere. Figure 5-3 illustrates the general flow of the design process.

Figure 5-3. LID Design Process



Source: PGDER.

This approach is often an iterative process that requires several attempts to balance all of the design components in the most economical and environmentally effective way. Described below are the individual design components.

5-4.2.1 **Conservation of Natural Areas.** LID is a stormwater management strategy that addresses the overall regulatory and resource protection goals of a site in a watershed context. Because development typically occurs incrementally, this approach will allow for adjustments or modifications to site design strategies and techniques to

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reflect dynamic resource protection and regulatory issues. Communities and bases often have extensive watershed management and natural resources conservation goals; master plans identify sensitive environmental areas and preservation areas such as wetlands, mature woods, and habitats. The LID site design should address any potential impacts to these areas and encourage conservation of these areas within the site. Examples of conservation include:

- Preserving a forest corridor that connects with an existing stream valley
- Maintaining flow volume and discharge rates to offsite wetlands
- Incorporating buffers around sensitive habitat areas

5-4.3 **Minimization of Development Impacts.** Within the portion of the site selected for the placement of roads, buildings, and other development activities, minimal disturbance techniques (site fingerprinting) can be used to avoid soil compaction, retain mature trees, and limit the environmental impact of staging areas. Examples of minimal disturbance techniques include:

- Delineating and flagging the smallest site disturbance area possible
- Minimizing the size of construction impacts or offsite easements and property acquisition
- Minimizing the size of material storage areas during and after construction
- Maintaining flow patterns

5-4.4 **Control of Watershed Timing and Runoff Patterns.** Maintaining the site's natural runoff control areas and restricting building over the site's more pervious soils will help keep the infiltration capacity of the site close to predevelopment levels. Maintaining the watershed timing of a site is also important. The cumulative effects of decreasing the post-development watershed times of concentration of several sites can have a significant impact on downstream habitat. It is also desirable to maintain natural vegetation in steeply sloped areas and to retain natural drainage divides. This will encourage dispersed flow paths and, consequently, help reduce the development of channels that lead to erosion and flooding problems.

Adequate drainage from buildings, walkways, and roads must be provided. Traditional designs often create a drainage system that has the effect of increasing the rate at which runoff moves into receiving waters during storm events. In turn, this produces a higher volume of runoff, a higher peak rate of flow, and an earlier runoff event than would occur under less developed conditions. The opportunity for groundwater recharge is eliminated, because infiltration into swales and grassed areas cannot effectively occur if runoff passes through quickly.

The overall grading objective for LID is to provide a surface landform that will distribute flows in a shallow and slow moving pattern toward areas where the infiltration

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capacity is highest. Examples of LID techniques to control rates of runoff and watershed timing include:

- Use flatter rather than steeper grades, provided that adequate drainage for buildings and traffic is maintained
- Reduce the height of slopes, to prevent runoff from gaining speed as it moves downhill
- Where flow begins to accumulate, increase the length of flow paths, diverting and redirecting the flow, preferably with vegetated features
- Minimize use of curb and gutter systems and piped drainage systems in favor of grassed swales
- Minimize the amount of impervious area used for pavement
- Disconnect impervious areas by directing runoff from buildings and pavements onto lawns or other vegetated areas, keeping flow velocities at a level that will not cause erosion
- Preserve naturally vegetated areas and existing topography in places where these help slow runoff and encourage infiltration
- Use weirs and check dams in swales

5-4.5 **Use of Integrated Management Practices (IMPs).** Once all of the design strategies and techniques have been implemented, IMPs are selected to achieve the site water quality and quantity objectives. IMPs are distributed, multifunctional, small-scale controls, selected based on their ability to achieve the site design water quality and quantity objectives in a cost effective manner. IMPs are not a “one-size-fits-all” approach. For example, using amended soils to filter and store runoff may be appropriate for a rural road section with high traffic but inappropriate next to a parking area that may be subjected to compaction from overflow parking or vehicle movement. More details on IMPs and their selection are found in Chapter 8.

5-4.6 **Pollution Prevention.** The goal of pollution prevention is to reduce, reuse and recycle a variety of pollutants before they become environmental problems. The final step of the LID design approach is to incorporate programs that keep pollution out of runoff in the first place and, consequently, to increase the longevity of the IMPs. Reduction of fertilizer, pesticide and herbicide use and the implementation of regular street sweeping are some common pollution prevention activities.

NAVY: Pollution Prevention (P2) is one of the four pillars of the Navy’s Environmental Quality Initiative (EQI). EQI aims to use P2 to attain environmental compliance, while minimizing life cycle costs. Rather than promoting pollution prevention because it is desirable from an environmental standpoint, EQI uses pollution prevention to minimize the cost of environmental compliance. For example, building a bioretention cell to treat runoff from a parking lot before discharge into a stream is a

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much more efficient and cost effective alternative to discharging directly into the stream and paying for stream restoration later.

AIR FORCE: Air Force Instruction (AFI) 32-7080 lays the framework for P2 implementation. Compliance by all Air Force installations is required. Air and water pollutant reduction is one of the six P2 program elements. P2 is mandated at the Major Command (MAJCOM) level, and the Air Force Center for Environmental Excellence is the primary provider of P2 technical support services. Installations must implement P2 management plans and conduct regular P2 opportunity assessments, which should be based on existing waste stream management plans when they exist.[10]

ARMY: P2 is a required element in the Army's Sustainable Project Rating Tool (SPiRiT); compliance with SPiRiT is now mandatory for MILCON construction projects. P2 plans for Army installations are developed from opportunity assessments of existing waste stream data and are designed to maximize environmental compliance. The U.S. Army Environmental Center provides P2-related technical and policy assistance.

5-5 DESIGN GUIDANCE AND STANDARDS

5-5.1 **Methods to Determine Effectiveness.** Stormwater projects are typically designed with a particular objective in mind, such as flood control or water quality improvement. Such projects typically require that the designer evaluate the effectiveness of the proposed treatments at meeting the stated objectives.

A number of hydrologic models have been developed to model surface runoff from a given drainage area. Because conventional models are primarily concerned with computing flow rates or flood hydrographs at a point of interest, this approach to hydrologic analysis must be modified in cases where not all of the runoff from a given site converges to a single point. Typical watershed models take into account general land cover and stream channel characteristics. To account for LID features and runoff management devices, refinement of the analysis may be desirable. A variety of tools are freely available from public agencies:

5-5.1.1 **Natural Resources Conservation Service (NRCS).** The NRCS, formerly called the Soil Conservation Service, has been developing runoff models for decades. The NRCS models TR-20 and TR-55 account for variations in land cover and the velocity of water movement across a watershed. Of particular interest are the determination of a drainage area's curve number (CN) and time of concentration (T_c). The value of CN reflects the degree to which land surface conditions will generate runoff, while the value of T_c indicates how quickly the runoff will converge at a particular point downstream. TR-20 and TR-55 are popular for watershed modeling but are generally not recommended for predicting runoff from small storms.

5-5.1.2 **Federal Highway Administration (FHWA).** The FHWA has developed a variety of software packages, primarily concerned with channel and pipe hydraulics.

[10] Air Force, 1994.

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These programs are most useful in those areas where detailed analysis of flow behavior based on predetermined flow rates is required.

5-5.1.3 **Hydrologic Engineering Center of the U.S. Army Corps of Engineers (HEC).** The Hydrologic Engineering Center of the U.S. Army Corps of Engineers actively maintains a suite of tools for modeling surface water hydrology and hydraulics.

5-5.1.4 **EPA.** The EPA maintains the Storm Water Management Model (SWMM) that performs simulations of both water quantity and quality for urban runoff events.[11] In late 2002, EPA extensively revised SWMM to include more detailed analysis of small-scale stormwater management devices. The SWMM algorithm is able to explicitly simulate storage and, therefore, is particularly appropriate for simulating discrete LID systems. Obtaining reasonable estimates of storage parameters needed in SWMM is of critical importance. Creative adaptations of SWMM may be necessary because the model does not directly model runoff from an impervious surface onto a pervious one.

5-5.1.5 **Prince George's County, Maryland.** The Prince George's County Department of Environmental Resources – Programs and Planning Division, working with Tetra Tech, Inc., has developed a BMP evaluation module to assist in assessing the effectiveness of LID technology. This module uses simplified process-based algorithms to simulate BMP control of modeled flow and water quality time series generated from runoff models such as the Hydrologic Simulation Program, FORTRAN (HSPF). These simple algorithms include weir and orifice control structures, storm swale characteristics, flow and pollutant transport, flow routing and networking, infiltration and saturation, evapotranspiration, and a general loss/decay representation for pollutants. It offers the user the flexibility to design retention style or open-channel BMPs, define flow routing through a BMP or BMP network, simulate IMPs such as reduced or discontinuous impervious surfaces through flow networking, and compare BMP controls against a defined benchmark such as a simulated pre-development condition. Because the underlying algorithms are based on physical processes, BMP effectiveness can be evaluated and estimated over a wide range of storm conditions, BMP designs, and flow routing configurations. Such a tool provides a quantitative medium for assessing and designing TMDL allocation scenarios and evaluating the effectiveness of a proposed management approach.

Five basic design aspects were used to develop the methodology for the module. They are: (1) the incorporation of input runoff data, (2) design and representation of a site plan, (3) configuration of BMPs of various sizes and functions, (4) schematic representation of flow routing through a network of BMPs, and (5) evaluation of the impact of a site design with BMPs. The module interface is the platform for an interactive linkage between each of the five design features of the module.

5-5.1.6 **Commercial Sources.** In addition to the freely available models, there are a variety of commercial models on the market. Information about these other tools can be found on the Internet.

[11] EPA, 1983.

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5-5.2 **Monitoring Strategies.** A variety of techniques are available to monitor the effectiveness of LID features for managing water quantity and quality. A well-implemented monitoring program will be valuable not only for the purpose of local runoff management objectives, but can also provide useful information to the Engineering Service Center, which is developing a web-based expert system.

5-5.2.1 **Water Quantity Monitoring.** The effectiveness of LID in controlling runoff volume and peak flow rates can be monitored either at individual features on a site or at some selected point downstream where flow paths converge and a measurement device can be installed.

5-5.2.1.1 **Small Scale.** On a small scale, both manual and automatic sampling methods can be used to calculate flow rates upstream and downstream of an LID installation, based on the depth measured using a weir or a rate of flow measured using a conveyance device.

5-5.2.2 **Large Scale.** On a larger scale, where LID features are used as retrofits in developed areas, the effectiveness of the retrofits can be assessed by comparing pre-LID and post-LID flow rates downstream. Using these data and some straightforward hydrologic calculations, a characteristic hydrograph can be developed to evaluate the site's response to storm events resulting from the implementation of LID treatments. Data from stream gages should indicate that runoff from smaller storms has decreased after LID implementation. As more LID features are used for stormwater retrofits on a site, the decrease in runoff will become more significant.

5-5.2.3 **Water Quality Monitoring Parameters.** The effectiveness of a runoff management feature can be evaluated using the flow through the feature, the quality of the receiving waters, or both. The Nationwide Urban Runoff Program (NURP) has identified the following "standard pollutants characterizing urban runoff:"[12]

Table 5-1. Standard Pollutants in Urban Runoff

Pollutant	Abbreviation
Suspended Solids Concentration	SSC
Biochemical Oxygen Demand	BOD
Chemical Oxygen Demand	COD
Copper	Cu
Zinc	Zn
Total Phosphorous	TP
Soluble Phosphorus	SP
Total Kjeldahl Nitrogen	TKN

[12] Ibid.

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Nitrate + Nitrite	$NO_2 + NO_3$

5-5.2.4 **Biological Monitoring.** Pollutants in stormwater runoff have a direct effect on the biological integrity of the receiving waters. The effectiveness of water quality controls can therefore be evaluated by assessing the biological health of the receiving waters in the vicinity of the stormwater outfall. The EPA has developed Rapid Bioassessment Protocols (RBP)[13] that can be used to characterize the existence and severity of impairments to streams, and help to identify sources and causes of impairment.

5-5.2.5 **Monitoring Program.** There are four phases to develop a monitoring program:[14]

1. Determine the objectives and scope of the monitoring program
2. Develop the monitoring plan in view of the objectives
3. Implement the monitoring plan
4. Evaluate and report the results

Monitoring programs are shaped by the site characteristics, the goals of the project, regulatory requirements, and available funds.

5-5.2.6 **Variability.** The high variability of stormwater flows and pollutant concentrations at any location makes it difficult to obtain useful monitoring results. Typically, facilities must collect a large number of samples to adequately characterize how a device is functioning under natural conditions. The monitoring approach used on any given site will depend on regulatory requirements, the pollutants of concern, the physical characteristics of the runoff management features, and the availability of funds and personnel for planning, sampling and analysis.

5-5.2.7 **State and Local Program Conformance.** Water quality monitoring programs should be undertaken to conform to state and local protocols. A detailed guidance manual for water quality data collection, management and interpretation is available from the Environmental Protection Agency[15] and the Department of Transportation.[16] The guidelines, which are primarily concerned with meeting the national stormwater BMP database requirements, can be easily adapted for use in a variety of monitoring activities.

5-5.2.8 **Sampling Locations.** An effective monitoring effort for decentralized runoff management requires a judicious selection of sampling locations as well as sampling times and techniques. The challenge is often to complete the monitoring effort

[13] Barbour et al., 1999.
[14] DOT, 2000; EPA, 2002.
[15] EPA, 2002.
[16] DOT, 2000.

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effectively under budget constraints. If the site design includes many LID features, sampling only a few may provide a reasonable basis to estimate the effectiveness of the full suite of features.

5-5.2.9 **Sampling Protocols.** Monitoring protocols vary depending on the expected chemical composition of the runoff, the pollutant of concern, the desirability of monitoring the effectiveness of a device at a given location, and the importance of assessing water quality at points downstream. As sampling data is collected over time, trends in the water quality become apparent. Adjustments in the monitoring plan may be appropriate to ensure that across the site samples are not taken any more or less frequently than necessary to ensure that a desirable level of water quality is maintained.

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CHAPTER 6

DISTRIBUTED MICRO-SCALE SYSTEMS

6-1 **INTRODUCTION.** In addition to land surface strategies, LID practices include incorporating small landscaped features and manufactured devices into a site. The management of runoff as it is generated reduces the need for management further downstream. Small distributed systems can perform several important runoff management functions:

- Increase rates of infiltration
- Slow down runoff, reducing flow rates from the site and increasing time for infiltration
- Add retention (the amount of water stored at the surface for the duration of the storm event)
- Add detention, which causes water to be restrained temporarily before it moves further downstream
- Improve water quality by filtering pollutants through media

6-2 **REPRESENTATIVE LID PRACTICES.** LID uses design components (IMPs) that can be selected and customized for specific stormwater management objectives. The selective use and customization of these components will involve a variety of standards and specifications for construction and maintenance. Described below is a collection of LID practices and their design, construction and maintenance characteristics.

Distributed micro-scale systems can include, but are not limited to:

- Soil amendments
- Bioretention
- Dry Wells
- Filter Strips
- Vegetated Buffers
- Grassed Swales
- Infiltration Trenches
- Inlet Pollution Removal Devices
- Rain Barrels and Cisterns

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- Tree Box Filters
- Vegetated Roofs
- Permeable Pavers

Table 6-1 presents the variety of runoff management functions provided by these features. A more detailed description and design approach for these features is provided in Chapter 8.

Table 6-1. Functions of LID Features

Feature	Effect or Function				
	Slower Runoff	Infiltration	Retention	Detention	Water Quality Control
Soil Amendments		X			
Bioretention		X	X	X	X
Dry Wells		X	X		X
Filter Strips	X				X
Vegetated Buffers	X				X
Grassed Swales	X				X
Infiltration Trenches		X			X
Inlet Devices					X
Rain Barrels			X		
Cisterns			X		
Tree Box Filters					X
Vegetated Roofs	X			X	X
Permeable Pavers		X			X

6-2.1 **Nutrient Processing.** Surface water runoff in urban areas can include significant quantities of chemical nutrients, particularly nitrogen and phosphorous. When these nutrients reach local water bodies, they can contribute to eutrophication. (Eutrophication is a naturally occurring process in which nutrients accumulate in a body of water over time; the term is often used to signify acceleration of this process by human activity.) Several of the LID components described in this UFC (see Chapter 8) filter out these nutrients to various degrees of effectiveness, depending on the design. LID approaches that utilize vegetation not only filter nitrogen and phosphorous out of

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the water and into the soil, but also make these nutrients available to the plants to form plant tissue.

6-2.2 **Treatment Train Approach to Water Quality.** Following a typical flow path beginning where runoff is generated from an impervious area, runoff water quality control can be implemented in the following steps:

1. Minimization. Design the site to treat pollutants effectively in small quantities, rather than allow larger quantities of runoff to accumulate before treatment.

2. Natural Filtration. Use the physical, chemical and biological processes of vegetation and soils to filter pollutants.

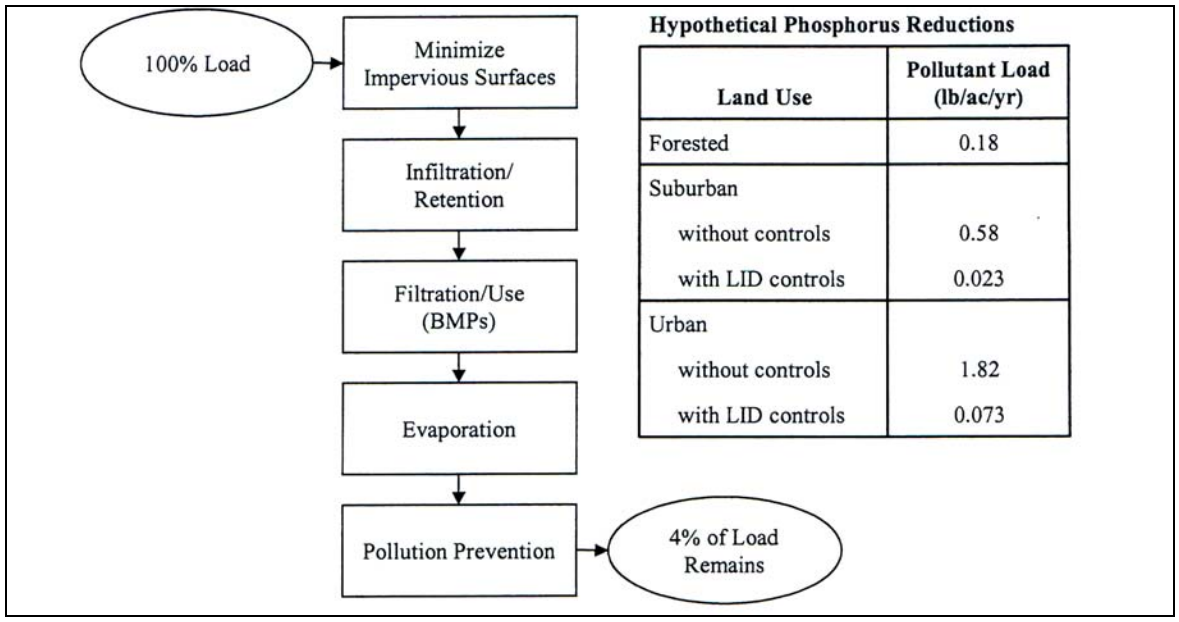
3. Constructed Filtration. Use the physical, chemical and biological processes of distributed micro-scale systems to filter pollutants.

4. Evaporation. Store and evaporate water in shallow depressions so that particulates can be removed.

5. Pollution prevention. Incorporate management practices such as restricted fertilizer use and diligent street sweeping to reduce pollutant loads. (Note that while the first four steps above pertain to site features, this final step pertains to post-construction maintenance).

Figure 6-1 shows a typical treatment train process for phosphorus removal.

Figure 6-1. Treatment Train Process for Phosphorus Removal



Hypothetical Phosphorus Reductions

Land Use	Pollutant Load (lb/ac/yr)
Forested	0.18
Suburban	
without controls	0.58
with LID controls	0.023
Urban	
without controls	1.82
with LID controls	0.073

Source: Adapted from PGDER.

6-2.3 **Energy Processing.** LID features that incorporate vegetation can help to moderate high ambient air temperatures. Even on a small scale, vegetation will have a local cooling effect. Vegetation can be selected and placed to improve shading, or to provide a buffer against winds. Using vegetated roofs can result in significant energy savings in the operation of a building's air conditioning system.

6-2.4 **Multifunctional Infrastructure and Buildings.** Some LID features can simultaneously provide a variety of hydrologic functions. A bioretention area, for example, can filter runoff for quality control, detain it, and infiltrate the stormwater into the ground. Similarly, vegetated roofs on buildings reduce runoff, reduce pollutants in both the water and the air, and moderate the internal building temperature.

6-2.5 **Ancillary Benefits.** This UFC describes LID primarily in terms of hydrologic impacts. LID runoff management strategies can also contribute to an aesthetically pleasing landscape, increasing the value of the property where these strategies are employed. In a variety of completed projects, micro-scale runoff management features have provided architectural interest in various forms, such as employing berms in otherwise open spaces, rainwater channels along pedestrian streets, fountains fed by intermittent stormwater, and bioretention areas that attractively subdivide large parking lots. The visibility of these features also provides opportunities for citizens and property owners to become more aware of the importance of stormwater in our urban environment.

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CHAPTER 7

COMPARISON OF LID TO CONVENTIONAL PRACTICES

7-1 **INTRODUCTION.** Conventional stormwater management practices focus on providing an efficient site drainage system that rapidly conveys runoff away from buildings and off pavement, and then attenuates the peak runoff rate at a large stormwater management facility downstream. In contrast, LID provides runoff management as far upstream as possible – where it originates – and if necessary, also at multiple points along each flow path. LID and conventional practices can be further compared in a variety of ways:

7-2 **COMPLIANCE VS. WATER RESOURCE OBJECTIVES.** While conventional stormwater management is primarily concerned with attenuating the peak runoff rate from a developed site, the principal goal of LID is to ensure maximum protection of the ecological integrity of the receiving waters by maintaining the watershed's hydrologic regime.

7-3 **WATER QUANTITY CONTROL.** Conventional drainage practices effectively reduce peak runoff rates, but do not reduce runoff volume. Instead, conventional drainage practices increase runoff volume by not mitigating the effects of the increased impervious area. The LID features that facilitate infiltration, by comparison, help to reduce runoff volume directly. Runoff volume reductions using LID features can be significant when infiltration is increased over a sufficiently large area.

Conventional drainage reduces the amount of subsurface water available to the base flow in nearby streams. LID features that enhance infiltration can have the beneficial effect of helping to maintain those base flows. Other LID features allow the strategic use of stormwater on-site, while conventional drainage designs focus on moving the water rapidly off-site.

A conventional stormwater management facility has a limited ability to manage water quality because it is limited to removal by settlement of pollutants. An LID approach, by comparison, takes advantage of a variety of mechanisms that filter water either overland or via infiltration to the subsurface.

7-4 **CONSTRUCTION COSTS.** Construction costs for LID will vary depending on the characteristics of predevelopment site features, the density of development, the particular LID features selected, and their size and design. For example, the cost of bioretention areas will be a function of the depth of porous backfill and the degree to which underdrains are utilized. Case studies for commercial, townhouse, and detached home residential areas in Prince George's County, Maryland, have demonstrated that LID site design costs can compare favorably with conventional approaches.[17] Costs are not simple to generalize. The scale of the project, availability of materials, and skills and training of staff are all factors. IMPs involving landscaped areas are often simple to maintain because work can often be performed by landscaping crews or residents; hard

[17] Greenhorne and O'Mara, 1998.

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structures, such as permeable paving systems with underdrains, may require more specialized maintenance.

7-5 **OPERATION AND MAINTENANCE.** Regular inspections of conventional stormwater management facilities are required to ensure that the storage volume has not been reduced by sediment, outlets are not clogged by debris, and structural features maintain their integrity. For a site designed using an LID approach, runoff management features will tend to be higher in number and several types of features (e.g., bioretention areas) need to be maintained by the property owner. The maintenance of these LID features is straightforward and can easily be performed as part of regular landscaping. Other LID features typically employed along public streets (such as tree filters) require more specialized maintenance to ensure that the filter media are not clogged and toxic materials such as heavy metals do not accumulate to a level at which they become a health hazard.

7-6 **RETROFIT POTENTIAL.** Retrofitting an already developed area with a conventional stormwater management system requires a considerable amount of space and is likely to involve extensive site disturbance. The LID micro-scale systems listed in the previous chapter require less site disturbance for each installment. LID retrofits may be much easier than conventional retrofits on sites where intensive development has already occurred. Locating sites for installing small devices is far easier than finding a large site for a stormwater management facility. LID retrofits can be customized to pollutant loads, allowing more complete control over pollutant removal.

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CHAPTER 8

INTEGRATED MANAGEMENT PRACTICES

8-1 **INTRODUCTION.** This chapter gives an overview of several of the most common and well-researched integrated management practices (IMPs) currently in use. Information is given on appropriate use, typical cost, maintenance needs, and commonly required corrective actions. This information is meant to facilitate the selection of IMPs appropriate for individual situations. This chapter is not exhaustive: many other IMP types are in use or are under development. Evaluation of other practices is left to the facility and regulatory agencies.

8-1.1 **Most Appropriate Uses.** This section outlines how each of the IMPs should be incorporated into a site plan.

8-1.2 **Cost Data.** Cost data is given in 2003 U.S. dollars, except where noted. All costs are estimates, and are given in broad ranges. These represent only initial costs and do not account for life cycle costs such as maintenance. These cost estimates are to be used for general planning purposes, not to create accurate project budgets.

8-1.3 **Maintenance Issues.** This section highlights some of the maintenance requirements of the IMPs. It is meant to give a general sense of the maintenance intensity of each of the technologies.

8-1.4 **Corrective Actions.** This section highlights some of the common problems associated with each of the IMPs.

8-2 **SOIL AMENDMENTS.** Soil amendments, which include both soil conditioners and fertilizers, make the soil more suitable for the growth of plants and increase water retention capabilities. The use of soil amendments is conditional on their compatibility with existing vegetation, particularly native plants.

Figure 8-1. Southern Maryland Wood Treating Site: On-site Thermal Desorption of Contaminated Soils. Final Grading and LeafGro® Placement

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Source: EPA.

8-2.1 **Most Appropriate Uses.** Soil amendments increase the soil's infiltration capacity and help reduce runoff from the site. They have the added benefit of changing physical, chemical and biological characteristics so that the soils become more effective at maintaining water quality.

8-2.2 **Cost Data.** Compared to the costs of traditional lawn preparation practices, enhancing native soil with soil amendments may have increased upfront costs. However, the cost of using amended soils can be at least partially offset by reductions in the required volume of stormwater ponds or other detention or retention practices. Tilled Compost-Amended Turf (TCT) practices, besides requiring greater site preparation, require larger volumes of material to be delivered to the site as well as methods to ensure that the amendments are well mixed with the existing soil.[18] The following cost estimates are based upon 1996 prices in the Seattle, Washington metropolitan area. Potential soils analysis costs are not included, but can cost as much as $125 per sample.

Table 8-1. Costs Associated with Soil Amending[19]

Component	Average Cost (1996 U.S. dollars)
Soil and Site Preparation	61¢ per square foot
Soil Amendments	$16 per cubic yard
Blower Application	5¢ to 10¢ per square foot

8-2.3 **Maintenance Issues.** In some jurisdictions across the country, soil amendments may be inspected as part of the sediment control plan for a site, usually upon site completion. Routine inspection of amended soils should evaluate factors that may affect the soil's infiltration capacity, aeration and organic content. Typical post construction concerns include areas subject to compaction, hydric or waterlogged soils, poor cover conditions, increased development, and a decrease in organic content. In addition, a routine soil infiltration rate analysis of amended soils in potential problem areas is recommended.

8-2.4 **Corrective Actions.** Corrective actions for soil amendments involve restoring the infiltration capacity of the soil. Reductions in infiltration capacity typically result from compaction or extensive root matting of groundcovers, such as grasses. The first step of corrective action should be extensive mechanical aeration. If this does not restore the infiltration rate, organic amendments should be disked into the soil for a depth of several inches and the site restabilized.

8-3 **BIORETENTION.** Bioretention areas typically have porous backfill under the vegetated surface, and an underdrain that encourages infiltration and water quality filtering while avoiding extended ponding.

[18] Chollak and Rosenfeld, 1998.
[19] Ibid.

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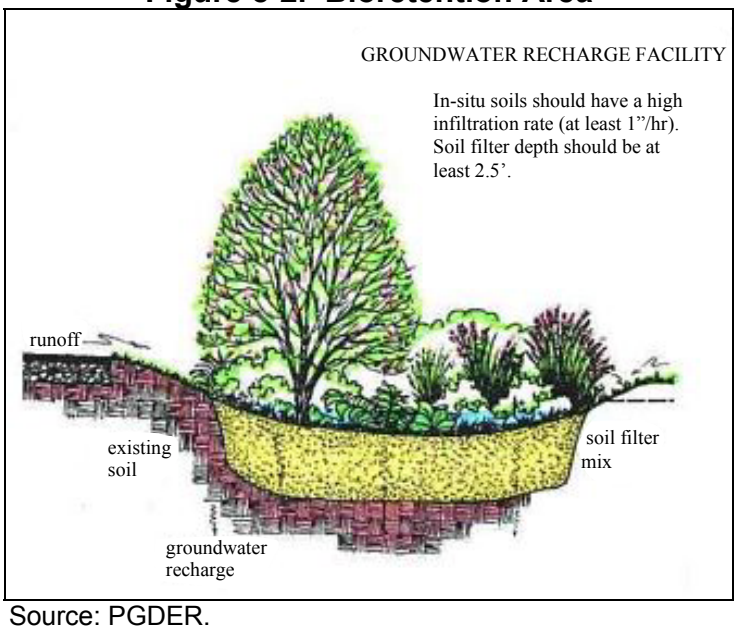
Figure 8-2. Bioretention Area



Source: PGDER.

8-3.1 **Most Appropriate Uses.** Bioretention features are used to treat stormwater that has run over impervious surfaces in commercial, residential, and industrial areas.[20] Use of bioretention for stormwater management is ideal for median strips, parking lot islands, and swales.

8-3.2 **Cost Data.** Construction cost estimates for a bioretention area are slightly greater than for required landscaping at a new development.[21] Commercial, industrial and institutional site costs range between $107 and $430 per square meter ($10 and $40 per square foot,) based on the need for control structures, curbing, storm drains and underdrains.

8-3.3 **Maintenance Issues.** Routine maintenance should include a biannual health evaluation of the trees and shrubs and subsequent removal of any dead or diseased vegetation.[22] This maintenance can be incorporated into regular maintenance of the site landscaping. If the bioretention feature is located in a housing development, the maintenance responsibility could be delegated to the residents. The use of native plant species in the bioretention cell will reduce fertilizer, pesticide, water, and overall maintenance requirements.

8-3.4 **Corrective Actions.** Treat diseased vegetation as needed using preventative and low-toxic measures. When levels of pollutants reach toxic levels that impair plant growth and the effectiveness of the BMP, soil replacement may be

[20] EPA, 1999a.
[21] Ibid.
[22] Ibid.

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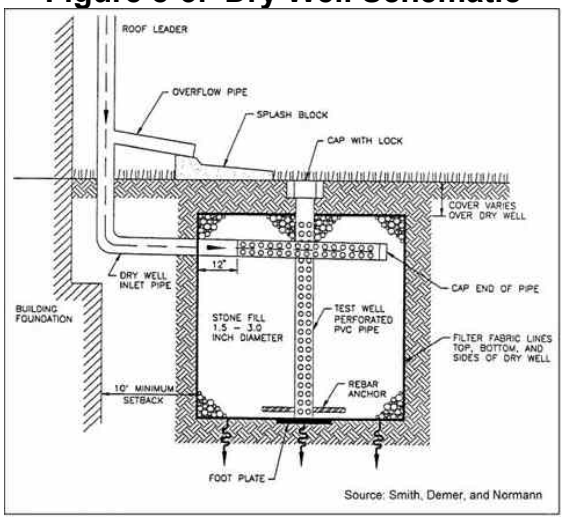
required.[23] Other potential tasks include replacement of dead vegetation, soil pH regulation, erosion repair at inflow points, mulch replenishment, unclogging the underdrain, and repairing overflow structures. Depending on pollutant loads, soils may need to be replaced within 5-10 years of construction.[24]

8-4 **DRY WELLS.** A dry well typically consists of a pit filled with aggregate such as gravel or stone and is located to catch water from roof downspouts or paved areas.

Figure 8-3. Dry Well Schematic



Source: Stormwater Management for Maine, 1995.

8-4.1 **Most Appropriate Uses.** Dry wells are suitable for treating small impervious areas (as an alternative to infiltration trenches) and may be useful on steeper slopes where trenches or other facilities cannot be installed. Dry wells are particularly suited to treat runoff from residential driveways or rooftop downspouts. It is important to avoid installation in large areas with high sediment loads and in soils with limited permeability. Dry wells are not appropriate for treating runoff from large impervious surfaces such as parking lots.

8-4.2 **Cost Data.** Costs for dry wells are site specific. Cost is determined by the cost of excavation and the price of gravel. This will depend on the well volume and the source of the gravel.

8-4.3 **Maintenance Issues.** Dry wells are typically employed in single-family homes; maintenance is usually the responsibility of the homeowner. Maintenance is minimal and includes clearing the rain gutters of debris that clogs the downspout.

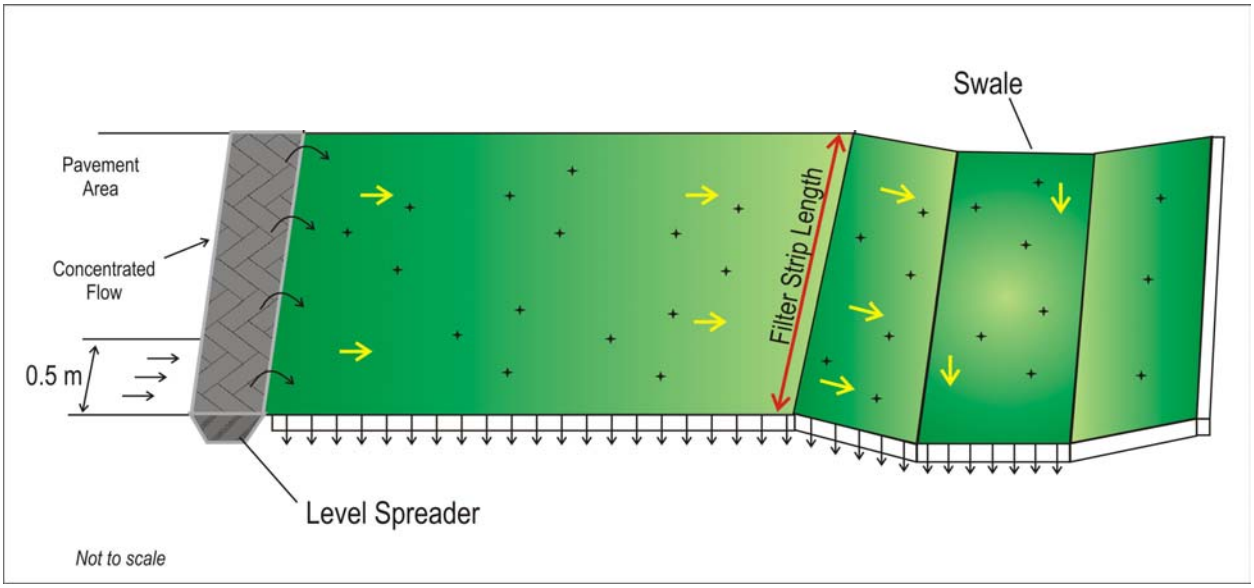
8-4.4 **Corrective Actions.** Dry wells can clog over time if there is extensive loading of fine grained sediment. Clogging is evident if there is standing water after a rain event at the surface of the facility. The appropriate corrective action is to first dig

[23] PGDER, 1993.
[24] LID Center, 2000.

out the gravel and then excavate to remove the sediment and uncover a layer of soils that has sufficient infiltration capacity.

8-5 **FILTER STRIPS** are bands of dense vegetation planted downstream of a runoff source.

Figure 8-4. Filter Strip



8-5.1 **Most Appropriate Uses.** The use of natural or engineered filter strips is limited to gently sloping areas where the vegetative cover is well-established and where channelized flow is not likely to develop. Filter strips are well suited for treating runoff from roads and highways, roof downspouts, very small parking lots, and pervious surfaces. They are also ideal components for the fringe of a stream buffer, or as pretreatment for a structural practice.

8-5.2 **Cost Data.** A rough estimate of filter strip construction costs includes the cost of seed or sod, approximately 30¢ per square foot for seed or 70¢ per square foot for sod. This amounts to a cost of between $32,000 and $74,000 per hectare ($13,000 and $30,000 per acre) for filter strips. The cost of filter strip construction may be higher than other stormwater management practices, but the construction costs are offset by low maintenance costs, roughly $865 per hectare ($350 per acre) per year.[25] Additionally, maintenance costs might overlap with regular landscape maintenance costs.

8-5.3 **Maintenance Issues.** Filter strips require standard vegetation management, such as mowing, irrigation, and weeding. Typical maintenance activities include inspection of filter strips at least twice annually for erosion or damage to vegetation and additional inspection after periods of heavy runoff. Recent research on biofiltration swales indicates that grass height and mowing frequency have little impact on pollutant

[25] Adapted from SWRPC, 1991.

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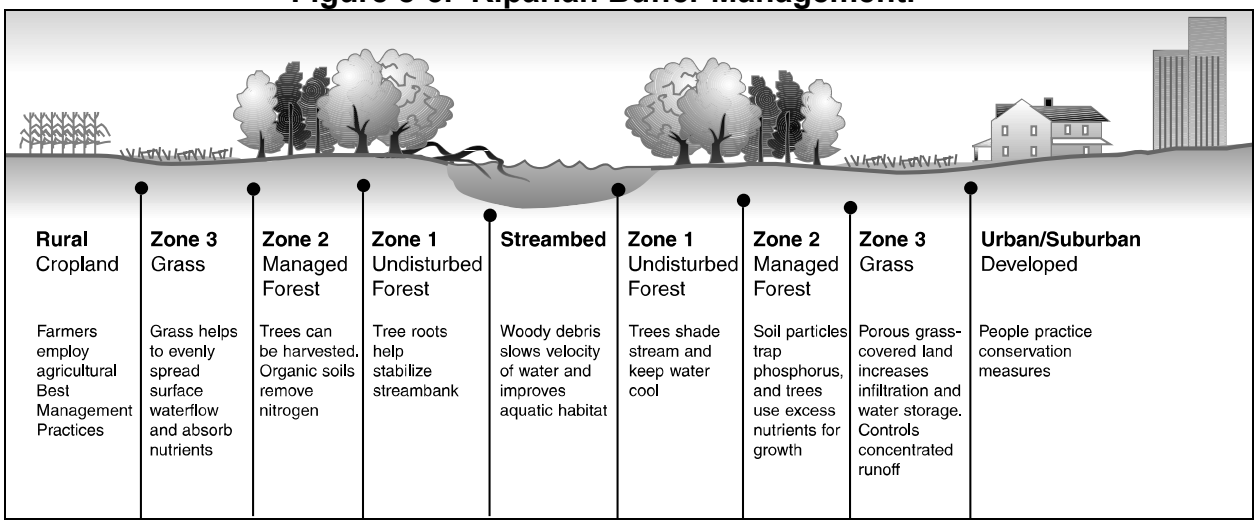
removal rates.[26] Therefore, mowing may only be necessary once or twice a year for safety and aesthetics or to suppress weeds and woody vegetation.

8-5.4 **Corrective Actions.** Trash tends to accumulate in filter strip areas, particularly along highways. The need for litter removal should be determined through periodic inspection, but litter should always be removed prior to mowing.

8-6 **VEGETATED BUFFERS.** Vegetated buffers trap and filter sediments, nutrients, and chemicals from surface runoff and shallow groundwater.

Figure 8-5. Riparian Buffer Management.



Source: Maryland Cooperative Extension Fact Sheet 724.

8-6.1 **Most Appropriate Uses.** Maintaining a vegetated buffer along creeks, streams, and rivers provides an attractive landscape and can improve water quality by removing sediment and chemicals before they reach the waterway. In addition, buffers provide flood control, help recharge groundwater, prevent soil erosion, and preserve or improve certain types of wildlife habitat. Well-designed buffers can also stabilize the stream bank and help absorb stormwater runoff.

8-6.2 **Cost Data.** Forest buffer costs range between $540 and $1800 per hectare ($218 and $729 per acre) to plant and maintain. Planting costs depend on geographic location, number of acres planted, number of trees planted per acre, species of trees, and whether or not the trees are from bare root or container stock. Grass buffers tend to cost less than forest buffers to plant and maintain ($415 to $ 1000 per hectare [$168 to $400 per acre]).

8-6.3 **Maintenance Issues.** Buffers should be monitored and managed to maintain their maximum water quality benefits and, where desired, wildlife habitat benefits. They should be inspected at least once a year, and always within a few days after severe storms, for evidence of sediment deposition, erosion, or development of concentrated flow channels. Weed and invasive species control is essential for the survival and rapid

[26] Colwell et al., 2000.

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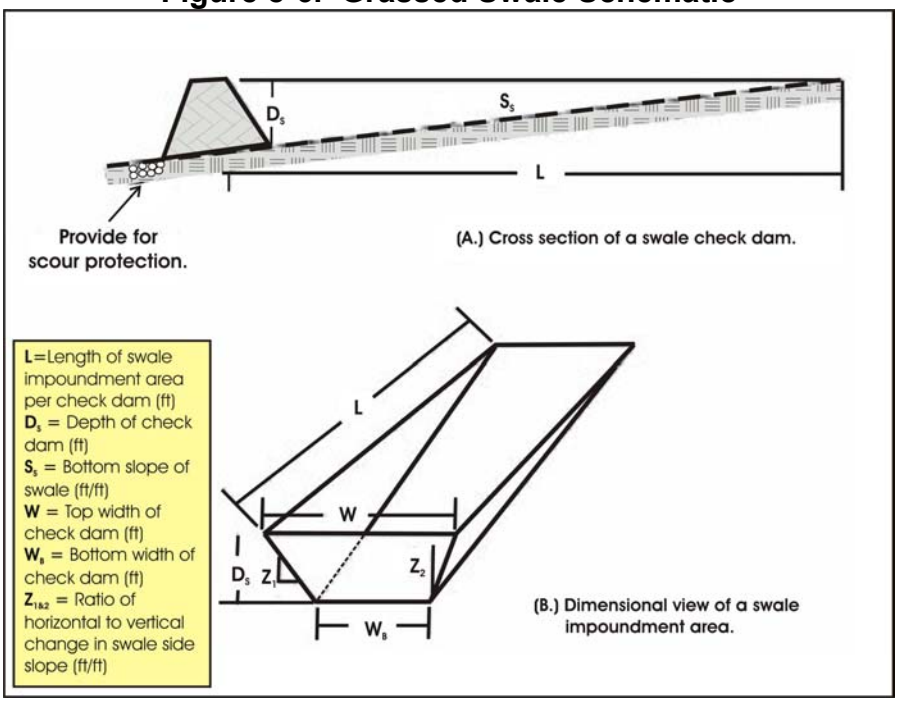
growth of trees and shrubs. It is best to avoid working in the riparian area between April 15 and August 15, when a variety of animals are bearing their young.

8-6.4 **Corrective Actions.** If the buffer width is sufficient, vegetated buffers should be self-maintaining. Changes in hydrology, drought, over-grazing or natural disasters such as flooding or fire may require the replanting or reestablishment of the buffer.

8-7 **GRASSED SWALES** are shallow grass-covered hydraulic conveyances that help to slow runoff and facilitate infiltration.

Figure 8-6. Grassed Swale Schematic



Source: NVPDC, 1991. In EPA, 1999d.

8-7.1 **Most Appropriate Uses.** The suitability of grassed swales depends on land use, soil type, slope, imperviousness of the contributing watershed, and dimensions and slope of the grassed swale system.[27] In general, grassed swales can be used to manage runoff from drainage areas that are less than 4 ha (10 acres) in size, with slopes no greater than 5 percent. Use of natural low-lying areas is encouraged and natural drainage courses should be preserved and utilized.[28]

[27] Schueler et. al., 1992.
[28] Young et al., 1996

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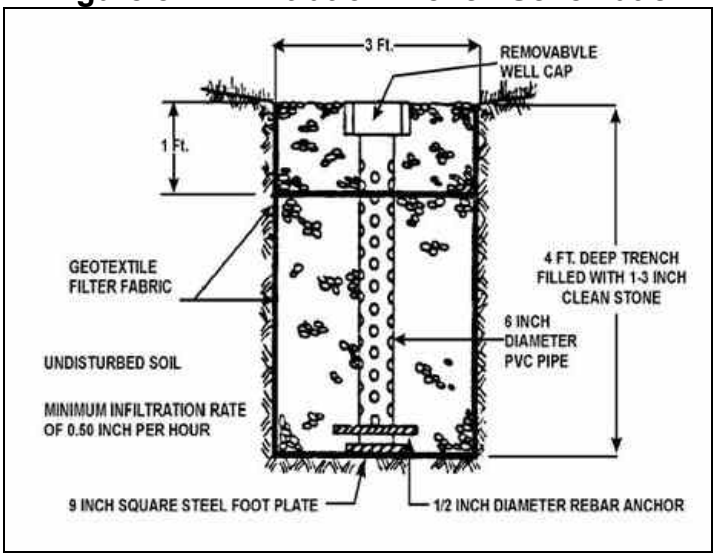
8-7.2 **Cost Data.** Grassed swale construction costs are estimated at approximately $2.70 per square meter ($0.25 per square foot.)[29] These costs, however, do not include design costs, raising the total cost to approximately $5.40 per square meter ($0.50 per square foot.) Grassed swale costs compare favorably with other stormwater management practices.[30]

8-7.3 **Maintenance Issues.** The maintenance objectives include keeping up the hydraulic and removal efficiency of the channel and maintaining a dense, healthy grass cover. Maintenance activities should include periodic mowing (with grass never cut shorter than the design flow depth), weed control, watering during drought conditions, reseeding of bare areas, and clearing of debris and blockages.

8-7.4 **Corrective Actions.** Cuttings should be removed from the channel. Accumulated sediment should also be removed manually to avoid concentrated flows in the swale. Avoid applying fertilizers and pesticides. The grass cover should be thick and reseeded as necessary. Any standing water removed during the maintenance operation must be properly disposed of at an approved discharge location.

8-8 **INFILTRATION TRENCHES.** Infiltration trenches are trenches that have been back-filled with stone. These trenches collect runoff during a storm event and release it into the soil by infiltration**.**

Figure 8-7. Infiltration Trench Schematic



Source: SWRPC, 1991. In EPA, 1999c.

8-8.1 **Most Appropriate Uses.** Infiltration trenches may be used in conjunction with another stormwater management device, such as a detention pond, to provide both water quality control and peak flow attenuation.[31] Runoff that contains high levels of sediments or hydrocarbons (oil and grease) that may clog the trench are often

[29] SEWRPC, 1991.
[30] Brown and Schueler, 1997.
[31] Harrington, 1989.

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pretreated with other devices such as grit chambers, water quality inlets, sediment traps, swales, and vegetated filter strips.[32]

8-8.2 **Cost Data.** Construction costs include clearing, excavation, placement of the filter fabric and stone, installation of the monitoring well and, where desired, establishment of a vegetated buffer strip. The 1993 construction cost for a large infiltration trench (1.8 m (6 ft) deep, 1.2 m (4 ft) wide, and with a 68 m^3 (2,400 ft^3) volume) ranges from $8,000 to $19,000. A smaller trench (0.9 m (3 ft) deep, 1.2 m (4 ft) wide, and with a 34 m^3 (1,200 ft^3) volume) is estimated to cost from $3,000 to $8,500.

8-8.3 **Maintenance Issues.** The principal maintenance objective is to prevent clogging, which may lead to trench failure. Infiltration trenches should be inspected after large storm events and any accumulated debris or material should be removed. A thorough annual inspection should include monitoring of the observation well to confirm that the trench is draining properly. Trenches with filter fabric should be inspected for sediment deposits by removing a small section of the top layer and examining the material in the trench itself. When vegetated buffer strips are used, they should be mowed regularly and inspected for erosion or other damage after each major storm event.

8-8.4 **Corrective Actions**. The corrective action for infiltration trench failure is to remove the stone and sediment that has clogged the system. The trench should be over excavated and scarified to ensure that the infiltration capacity of the soil is sufficient. The stone is washed to remove any sediment and then replaced. It is critical that any surrounding areas be stabilized to eliminate the potential for sediment clogging.

8-9 **INLET DEVICES** (a.k.a. hydrodynamic separators). Inlet devices are flow-through structures with a settling or separation unit to remove sediments and other stormwater pollutants.

[32] SEWRPC, 1991; Harrington, 1989.

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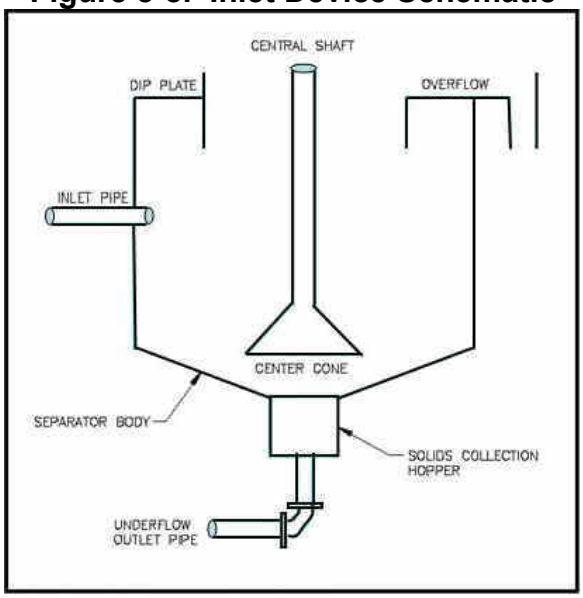
Figure 8-8. Inlet Device Schematic



Source: Tyack & Fenner, 1997. In EPA, 1999b.

8-9.1 **Most Appropriate Uses.** This technology may be used by itself or in conjunction with other stormwater management devices as part of an overall stormwater control strategy. Hydrodynamic separators are ideal for areas with limited land availability. In addition, hydrodynamic separators can be placed in almost any location in a system, making them ideal for use in potential stormwater "hotspots" (areas where higher concentrations of pollutants are more likely to occur; e.g. gas stations). Decreasing land availability for the installation of large stormwater management facilities is fueling the need for solutions such as hydrodynamic separators.

8-9.2 **Cost Data.** Costs are influenced by several factors including the amount of runoff to be treated, the amount of land available, and any other treatment technologies that are presently being used. Capital costs can range from $2,300 to $40,000 per pre-cast unit. Units that are site-specifically designed typically are more costly. Total costs for hydrodynamic separators often include pre-design costs, capital costs, and operation and maintenance costs.

8-9.3 **Maintenance Issues.** Proper maintenance of a hydrodynamic separator involves frequent inspections throughout the first year of installation to ensure that sediments are removed before the unit's sediment capacity is reached. Sediment depth can be measured using a "dip stick" or rod. Subsequently, sediment removal may be performed with a sump-vac or vacuum truck, depending on which type of separator is used. After the first year of installation, inspections can be scheduled according to observed rates of sediment accumulation. In general, hydrodynamic separators require a minimal amount of maintenance, but lack of attention will lower their overall pollutant removal efficiency.

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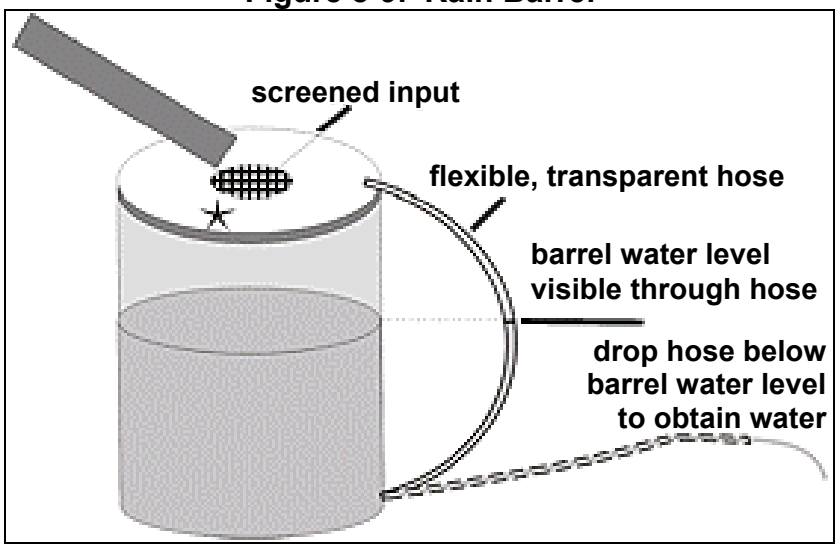
8-9.4 **Corrective Actions.** Corrective action for structure or device failure typically requires removal and replacement of the device. Excessive bypass of sediments or pollutants may require additional devices or modification of the device.

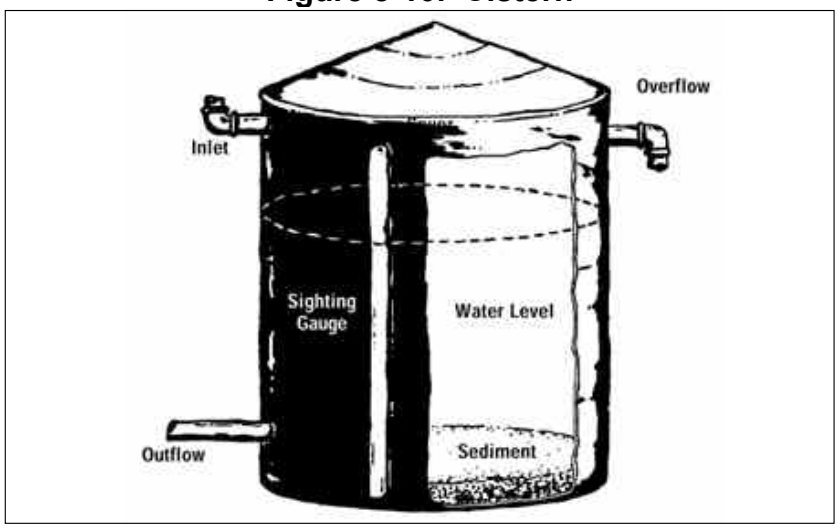
8-10 **RAIN BARRELS.** Rain barrels are placed outside of a building at roof downspouts to store rooftop runoff for later reuse in lawn and garden watering. **Cisterns** also collect rooftop runoff but store the water in significantly larger volumes in manufactured tanks or built underground storage areas. Both cisterns and rain barrels can be implemented without the use of pumping devices, instead relying on gravity flow.

Figure 8-9. Rain Barrel



Source: Maryland DNR Green Building Program.

Figure 8-10. Cistern



Source: Texas Guide to Rainwater Harvesting.

8-10.1 **Most Appropriate Uses.** Rain barrels and cisterns are low-cost water conservation devices that reduce runoff volume and, for very small storm events, delay and reduce the peak runoff flow rates. Both rain barrels and cisterns can provide a

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source of chemically untreated 'soft water' for gardens and compost, free of most sediment and dissolved salts.

8-10.2 **Cost Data.** The cost of a single rain barrel without any other attachments or accessories is typically around $120. The cost of constructing cisterns can vary greatly depending upon their size, material, location (above- or below-ground), and whether they are prefabricated. Pre-manufactured tanks utilized as cisterns can vary in price from hundreds to tens of thousands of dollars. Sizes can vary from hundreds of gallons for residential use to tens of thousands of gallons for commercial and industrial uses.

The use of water stored in rain barrels or cisterns for non-potable applications such as landscaping or toilets, or for potable applications if properly treated, may reduce potable water supply costs in areas where water costs are at a premium.

8-10.3 **Maintenance Issues.** Maintenance requirements for rain barrels are minimal and consist only of regular inspection of the unit as a whole and any of its constituent parts and accessories. All components should be inspected at least twice a year and repaired or replaced as needed. If cisterns are used to provide a supplemental supply of irrigation water, maintenance requirements for cisterns are often low. Cisterns designed for drinking water supply have much higher maintenance requirements, including biannual testing for water quality and filtering systems. Cisterns, along with all their components and accessories, should undergo regular inspection at least twice a year. Replacement or repair of the unit as a whole, and any of its constituent parts and accessories should be completed as necessary.

8-10.4 **Corrective Actions.** There are few mechanical parts on cisterns or rain barrels. Items such as screens or valves may fail, but are easily replaced. Large cisterns constructed out of materials such as metal or concrete may need repairs to walls by parging (for concrete) or welding (for metal).

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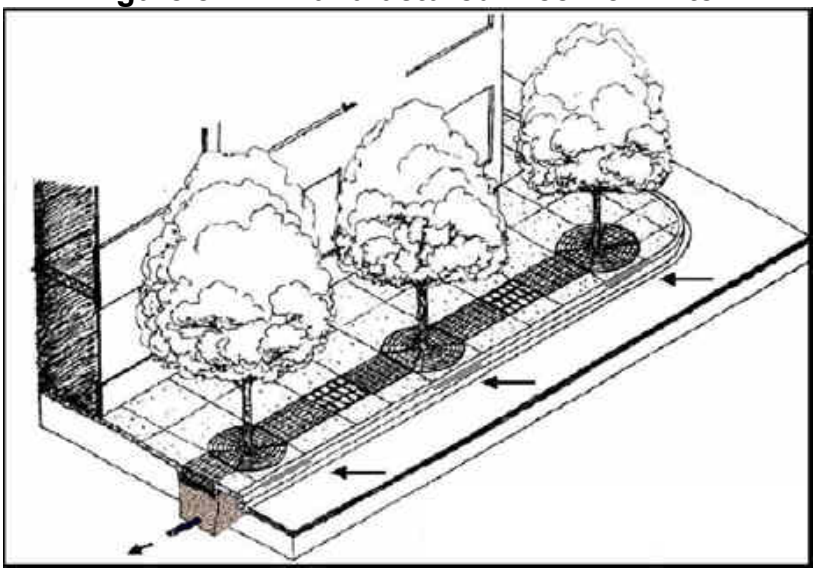
8-11 **TREE BOX FILTERS.** Tree box filters are in-ground containers typically containing street trees in urban areas. These filters can be very effective at controlling runoff water quality, especially when numerous units are distributed throughout a site. Runoff is directed to the tree box, where it is filtered by vegetation and soil before entering a catch basin.

Figure 8-11. Manufactured Tree Box Filter



Source: Virginia DCR Stormwater Management Program.

8-11.1 **Most Appropriate Uses.** Tree box filters can help meet a variety of stormwater management goals, satisfy regulatory requirements for new development, protect and restore streams, control combined sewer overflows (CSOs), retrofit existing urban areas, and protect reservoir watersheds. The compact size of tree box filters allows volume and water quality control to be tailored to specific site characteristics. Tree box filters provide the added value of aesthetics while making efficient use of available land for stormwater management. Typical landscape plants (e.g., shrubs, ornamental grasses, trees and flowers) are an integral part of the bioretention system. Ideally, plants should be selected that can withstand alternating inundation and drought conditions, and that do not have invasive root systems which may reduce the soil's filtering capacity.

8-11.2 **Cost Data.** A single-unit tree box filter costs approximately $6,000 per unit per 0.1 ha (1/4 acre) of impervious surface (total cost = $24,000 per acre). This estimate includes two years of operating maintenance and filter material and plants. Additional costs include installation and annual maintenance. Installation varies with each site, but is approximately $1500 per unit. Annual maintenance is $500 per unit when performed by the manufacturer and $100 per unit when performed by the owner. (This sample cost estimate is based on a commercial tree box filter, the Filterra™ Stormwater Bioretention Filtration System.)

8-11.3 **Maintenance Issues.** Tree box filters require little maintenance. Maintenance includes annual routine inspection and the regular removal of trash and debris. The first two years of maintenance are typically included with the purchase of

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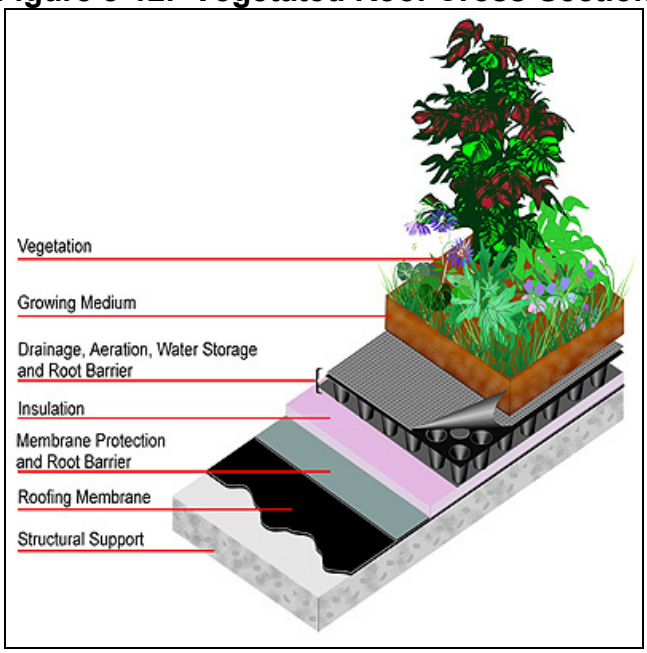
single and multiple-unit tree box filters. These would include removal of trash, debris and sediment, replenishment of the mulch, and care or replacement of plants. During extreme droughts, the plants may need to be watered in the same manner as any other landscape material.

8-11.4 **Corrective Actions.** Plants may have to be replaced because they have overgrown the filter, in which case their root structure may overwhelm the area of the soils, or because of environmental stress. The grates on top of the structure may become cracked and have to be replaced, although this should rarely occur because they are designed to be traffic bearing. The soil may become contaminated from a spill and have to be removed and properly disposed.

8-12 **VEGETATED ROOFS.** Vegetated roofs, also known as green roofs, eco-roofs or nature roofs, are structural components that help to mitigate the effects of urbanization on water quality by filtering, absorbing or detaining rainfall.

Figure 8-12. Vegetated Roof Cross-Section



Source: American Wick Drain Corp.

8-12.1 **Most Appropriate Uses.** Through a variety of physical, biological and chemical treatment processes that filter pollutants and reduce the volume of runoff, vegetated roofs reduce the amount of pollution delivered to the local drainage system and, ultimately, to receiving waters. One pollutant that vegetated roofs help control, for example, is nitrogen. While nitrogen gas occurs naturally as a major component of the atmosphere, nitrogen compounds from automobile exhaust, agricultural fertilizers and industrial activities can create a significant pollution problem. Airborne nitrogen compounds can fall to the ground in dust, raindrops, or simply by gravity. When these compounds are carried away with stormwater runoff, they contribute to eutrophication problems in surface water. Vegetated roofs can help control nitrogen pollution in stormwater runoff.

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8-12.2 **Cost Data.** Costs for vegetated roofs in the United States are estimated to average between $161 and $215 per square meter ($15 and $20 per square foot) for all use types (i.e., high density residential, commercial, or industrial).[33] These costs include all aspects of vegetated roof installation, from the waterproofing membrane to soil substrate creation to planting. By far the highest costs associated with vegetated roof creation are the soil substrate and growth medium and the associated plant components. Vegetated roof retrofit projects may have increased cost associated with traffic and resource scheduling concerns as well as the on-site availability of equipment and materials. Planting costs are higher if plants are placed individually rather than pre-grown on vegetation mats.

8-12.3 **Maintenance Issues.** Once a properly installed vegetated roof is well established, its maintenance requirements are usually minimal. There are two basic types of vegetated roofing systems: extensive and intensive.

Extensive roofs form a thin vegetated sheath of self-sufficient mosses, sedums, and small shrubs. Their low profile allows them to be added to existing buildings, including those with sloping roofs.

By contrast, intensive roofs are integral to the roof structure, permitting the use of trees and walkways. A greater depth of media may be required to accommodate larger vegetation and surface features. Intensive roofs require more structural as well as horticultural maintenance, similar to a conventional garden, because plantings tend to be both heavier and more elaborate than on extensive roofs. For both types of roofs, maintenance requirements typically include inspection of the roof membrane, the most crucial element of a vegetated roof, as well as inspection and preventive maintenance of the drainage layer flow paths.

8-12.4 **Corrective Actions.** Corrective actions for vegetated roofs are generally to repair localized problems. More complex systems may have monitoring devices incorporated into the membrane. Leak detection systems can be brought to the site to locate breaches in the membrane. The soil media can be removed and the membrane repaired. Long periods of drought or loss of soil to high winds may require replacement of the media or replanting. If drought becomes an issue, corrective actions include installing an irrigation system or scheduling supplemental watering.

8-13 **PERMEABLE PAVERS.** Permeable pavers allow water to seep through regularly interspersed void areas in order to reduce runoff and associated pollutants.

[33] Scholz-Barth, 2001.

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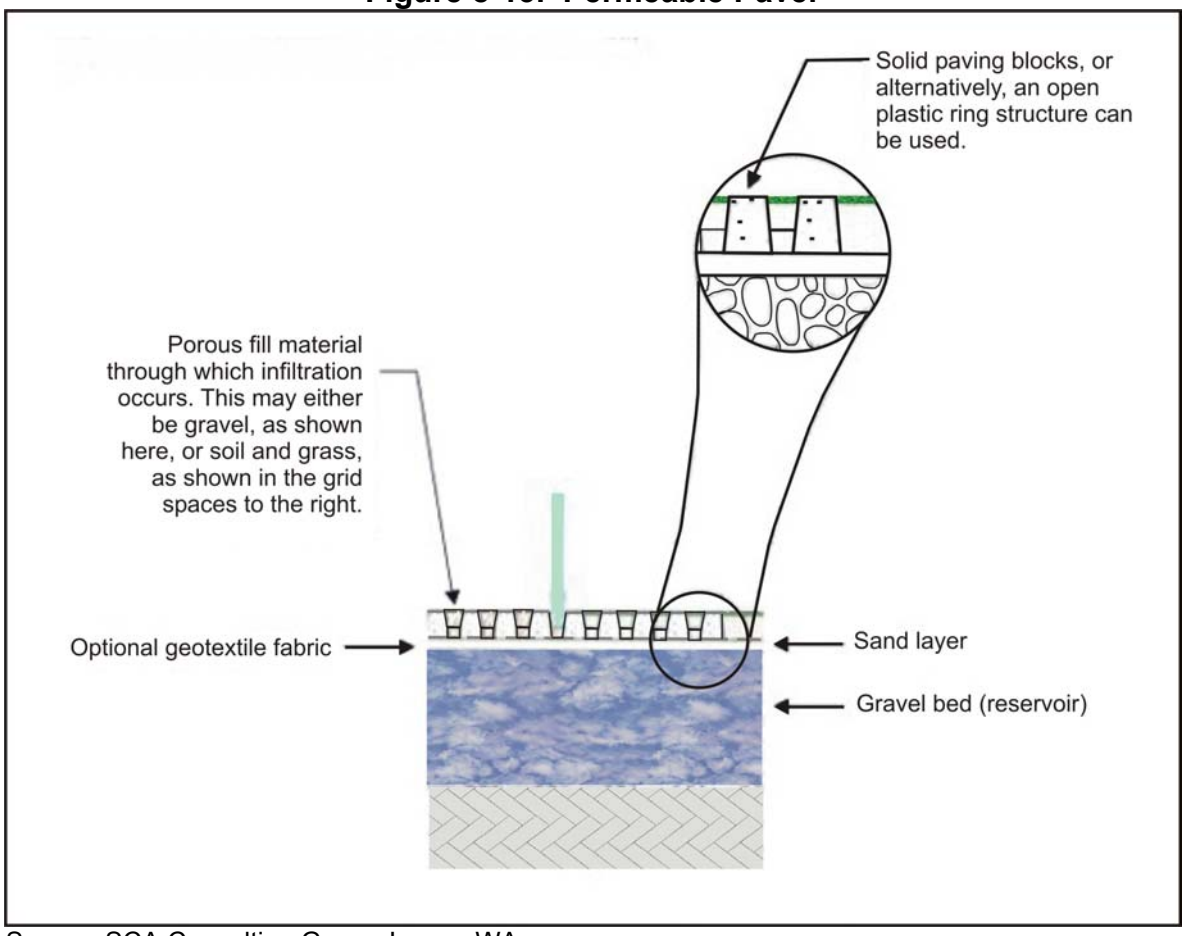
Figure 8-13. Permeable Paver



Source: SCA Consulting Group, Lacey, WA.

8-13.1 **Most Appropriate Uses.** Runoff percolates through voids in permeable pavers and may be detained in the gravel bed, infiltrated into the underlying soil, or both. By reducing the volume of runoff, permeable pavers help to decrease downstream flooding, the frequency of combined sewer overflows, and the thermal pollution of sensitive waters. Permeable pavers can reduce or eliminate the requirement for underground sewer pipes and conventional stormwater retention and detention systems. Use of these materials can eliminate problems with standing water, provide for groundwater recharge, control erosion of streambeds and riverbanks, facilitate pollutant removal, and provide for a more aesthetically pleasing site. The drainage of paved areas and traffic surfaces by means of permeable systems is an important building block within an overall Low Impact Development scheme that seeks to achieve a stormwater management system that mimics natural conditions.

8-13.2 **Cost Data.** Initial expenses for alternative paving materials may be greater than conventional materials. However, the use of permeable pavers can often eliminate the requirement for underground storm drainpipes and conventional stormwater systems. Cost savings resulting from decreased investments in reservoirs, storm sewer extensions, and the repair and maintenance of storm drain systems should be considered. Interlocking concrete paving blocks cost $54 to $108 per square meter

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($5.00 to $10.00 per square foot.) In general, the multifunctional nature of permeable pavers reduces overall costs.

8-13.3 **Maintenance Issues.** After installation of a permeable paver system, maintenance is minimal but absolutely necessary to ensure the long lifetime of the system. Grass pavers will require the normal watering and mowing maintenance of any turf system. Porous concrete and interlocking concrete paving blocks require that the surface be kept clean of organic materials (leaves, for example). Periodic vacuuming and low-pressure washing should be used to clear out voids and extend the paver's functional life. Conventional street sweepers should be used with vacuums, brushes and water ideally four (4) times a year, but the actual required frequency will be determined by local conditions. With the interlocking system, additional aggregate fill material may be required after cleaning.

8-13.4 **Corrective Actions.** If there is an extensive buildup of a "scum" layer within the voids, the chip stone should be vacuumed, power-washed, cleaned and replaced. In case of localized settling, individual paver blocks can be removed, new gravel added, and the blocks replaced. In case of spills or contamination, the blocks and gravel layers can be removed and the area remediated.

8-14 **PERMEABLE PAVEMENT** can be either asphalt or concrete. As with permeable pavers, water is allowed to pass through voids and infiltrate into the underlying soil. Permeable pavement lacks most of the fine material found in conventional pavements, allowing water to flow through voids in the aggregate. (By contrast, paver blocks themselves are not necessarily permeable; infiltration occurs in the gaps between the blocks.) A layer of clean, uniformly graded gravel lies beneath the pavement, and geotextile separates this stone bed from the soil below. Runoff from the paved surface and adjacent impervious areas slowly passes through the gravel layer, which also may serve as a storage area. Permeable pavement has the same structural properties as conventional pavement. Environmental benefits are similar to other IMPs: reduction of runoff volume and rate, pollutant filtering, flow dispersion, and groundwater recharge. In addition, permeable pavements reduce the footprint of a site's impervious area.

8-14.1 **Most Appropriate Uses.** Permeable pavement may be substituted for conventional pavement in any application; however, it is most commonly and successfully used in parking lots and walkways. Permeable pavements simultaneously serve as hardscape and as stormwater infrastructure, and are therefore especially practicable where space constraints preclude the use of other IMPs such as bioretention. Cahill Associates reports that large permeable paved areas are still functioning after 20 years, outlasting conventional pavements in some cases. Permeable pavements reduce the likelihood of sinkhole formation because runoff is dispersed over a large area (i.e., the entire paved surface), rather than concentrated in a small area such as a pond or catch basin.[34]

[34] Cahill Associates, 2003.

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8-14.2 **Cost Data.** Permeable asphalt costs range from $5 t0 $11 per square meter ($0.50 to $1.00 per square foot,) while permeable concrete costs between $22 and $70 per square meter ($2.00 and $6.50 per square foot.) In addition, permeable pavements may reduce or eliminate the need for additional stormwater infrastructure, so a more accurate price comparison would involve the costs of the full stormwater management paving system. For example, a grass/gravel paver and porous concrete representative stated that when impervious paving costs for drains, reinforced concrete pipes, catch basins, outfalls and storm drain connections are included, an asphalt or conventional concrete stormwater management paving system costs between $102 and $125 per square meter ($9.50 and $11.50 per square foot,) compared to a permeable pavement stormwater management system at $50 to $70 per square meter ($4.50 to $6.50 per square foot.) The savings are considered to be even greater when permeable paving systems are calculated for their stormwater storage; if designed properly, they can eliminate retention pond requirements.[35]

8-14.3 **Maintenance Issues.** Maintenance requirements are similar to those for permeable pavers. To maintain its permeability, the pavement must be vacuumed or cleaned with a street sweeper twice a year. This removes sediments, organic matter, and atmospheric deposition that would otherwise clog the pavement over time.

8-14.4 **Corrective Actions.** With proper preventative maintenance, no additional actions should be necessary to maintain permeability. Pavements that have clogged as a result of neglect may require intensive vacuuming. As with conventional pavement, normal wear and tear may require repairs. For asphalt, however, care should be taken to *replace* the affected areas, because re-sealing would create an impervious surface. Contractors and maintenance staff should be acquainted with the differences between conventional and permeable pavement in order to prevent such a scenario.

Figure 8-14. Permeable Pavement Cross-Section

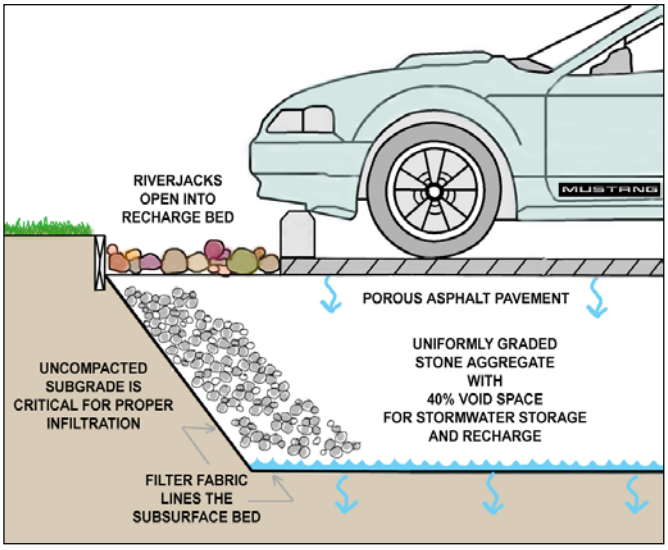
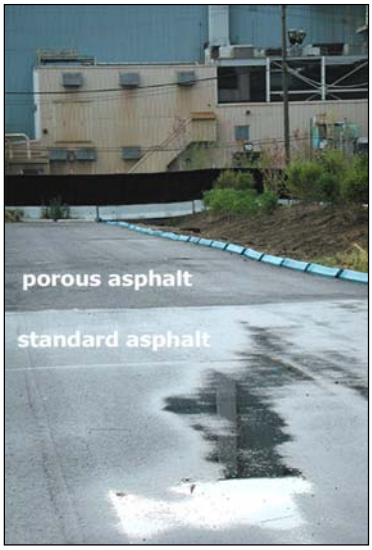


Figure 8-15. Drainage in Both Types of Pavement



[35] Peterson, 2002.

Source: Cahill Associates.

Source: Cahill Associates.

8-15 **TECHNICAL CONSULTATION.** With the possible exception of dry wells, infiltration trenches, and inlet devices, the vegetated IMPs described here are integral to a site's landscape design. Accordingly, they should be designed by, or under the direct supervision of, an appropriate licensed professional such as a landscape architect.

8-16 **DEVELOPMENT AND EVALUATION OF ADDITIONAL PRACTICES.** Additional practices not discussed in this UFC may also be appropriate for use as IMPs. The practice's applicability, effectiveness, cost and maintenance requirements must be considered in order to evaluate its potential use as an IMP.

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CHAPTER 9

LID SITE PLANNING PROCESS

9-1 **INTRODUCTION.** This is a representative process for planning LID retrofits. Individual facilities will have unique needs and should adapt this process accordingly.

9-2 MODEL PLANNING PROCESS.

Step 1: Define project objectives and goals

1. Identify the LID objectives for the project. Consider these four fundamental aspects of stormwater control:[36]

   - Runoff volume
   - Peak runoff rate
   - Flow frequency and duration
   - Water quality

2. Evaluate existing stormwater infrastructure in terms of how well it functions with respect to each of these aspects.

3. Determine the goals and feasibility for control of runoff volume, flow frequency and duration, and water quality; as well as on-site use of stormwater (e.g. irrigation).

4. Prioritize and rank basic objectives.

5. Define hydrologic controls required to meet objectives (i.e. infiltration, filtration, discharge frequency, volume of discharges, groundwater recharge).

Step 2: Perform site evaluation and analysis

A site evaluation will facilitate LID design development by providing site details that will assist in the development of an LID program.

1. Conduct a detailed investigation of the site using available documents such as drainage maps, utilities information, soils maps, land use plans, and aerial photographs.

2. Perform an on-site evaluation highlighting opportunities, such as pollutant-generating areas, potential disconnects from combined sewer systems, and potential green corridors. Note potential LID practices and areas where water quality and quantity controls could be installed.

[36] PGDER, 2000b.

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3. Evaluate site constraints such as available space, soil infiltration characteristics, water table, slope, drainage patterns, sunlight and shade, wind, critical habitat, circulation and underground utilities.

4. Identify protected areas, setbacks, easements, topographic features, subdrainage divides, and other site features that should be protected such as floodplains, steep slopes, and wetlands.

5. Delineate the watershed and microwatershed areas. Take into account previously modified drainage patterns, roads, and stormwater conveyance systems.

6. Locate baseline hydrologic and water quality data. In order of preference, try to locate:

   a) Local stream gage data and site water quality sampling data
   b) Data from a similar area within region
   c) Local averages
   d) Modeling results

7. Identify applicable local regulations or codes.

Step 3: Develop LID control strategies

Use hydrology as a design element. In order to minimize the runoff potential of the development, the hydrologic evaluation should be an ongoing part of the design process. An understanding of site drainage can suggest locations both for green areas and potential building sites. An open drainage system can help integrate the site with its natural features, creating a more aesthetically pleasing landscape.

1. Determine the design storm(s). Regulatory requirements for design storms may also be stipulated in local ordinances, and these may limit or constrain the use of LID techniques or necessitate that structural controls be employed in conjunction with LID techniques.

2. Define modeling technique(s) to be employed. Section 5-5.1 includes a detailed description several available hydrologic models. The model selected will depend on the type of watershed, complexity of the site planning goals, familiarity with the model, and level of detail desired.

3. Evaluate current conditions. Use the results of modeling to estimate baseline values for the four evaluation measures: runoff volume, peak runoff rate, flow frequency and duration, and water quality.

4. Implement non-structural site planning techniques:

   a) Minimize total site impervious area.

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- Use alternative roadway layouts that minimize imperviousness.
- Reduce road widths.
- Limit sidewalks to one side of roads.
- Reduce on-street parking.
- Use permeable paving materials.

b) Minimize directly connected impervious areas.

- Disconnect roof drains. Direct flows to vegetated areas.
- Direct flows from paved areas to stabilized vegetated areas.
- Break up flow directions from large paved surfaces.
- Encourage sheet flow through vegetated areas.
- Locate impervious areas so that they drain to permeable areas.

c) Modify drainage flow paths to increase time of concentration (T_c).

- Maximize overland sheet flow.
- Lengthen flow paths and increase the number of flow paths.
- Maximize use of open swale systems.
- Increase (or augment) the amount of vegetation on the site.

d) Define the development envelope.

- Use site fingerprinting. Restrict ground disturbance to the smallest possible area.
- Reduce paving.
- Reduce compaction of highly permeable soils.
- Minimize size of construction easements and material stockpiles.
- Place stockpiles within development envelope during construction.
- Avoid removal of existing trees.
- Disconnect as much impervious area as possible.
- Maintain existing topography and associated drainage divides to encourage dispersed flow paths.
- Locate new development in areas that have lower hydrologic function, such as barren clayey soils.

5. Evaluate site planning benefits and compare with baseline values. The modeling analysis is used to evaluate the cumulative hydrologic benefit of the site planning process in terms of the four evaluation measures.

6. Evaluate the need for Integrated Management Practices (IMPs). If site planning is not sufficient to meet the site's LID objectives, additional hydrologic control needs may be addressed through the use of IMPs (described in Chapter 8). After IMPs are selected for the site, a second-level hydrologic evaluation can be conducted that combines the IMPs with the controls provided by the planning techniques. Results of this hydrologic evaluation are compared with the baseline conditions to verify

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that the site LID objectives have been achieved. If not, additional IMPs are located on the site to achieve the optimal condition.

7. Evaluate supplemental needs. If supplemental control for either volume or peak flow is still needed after the use of IMPs, selection and listing of additional management techniques should be considered. For example, where flood control or flooding problems are key design objectives, or where site conditions, such as poor soils or a high water table, limit the use of IMPs, additional conventional end-of-pipe methods, such as large detention ponds or constructed wetlands, should be considered. In some cases their capacity can be reduced significantly by the use of LID upstream. It may be helpful to evaluate several combinations of LID features and conventional stormwater facilities to determine which combination best meets the stated objectives. Use of hydrologic evaluations can assist in identifying the alternative solutions prior to detailed design and construction costs.

For residential areas, Prince George's County, Maryland, has developed a detailed illustration of an approach for conducting a hydrologic evaluation based on the NRCS TR-55 method. Where NRCS methods (TR-20, TR-55) are accepted for hydrologic evaluation, the effect of LID features should be reflected in the curve numbers and times of concentration selected for the analysis. A full description of this process is available from Prince George's County.[37]

Step 4: Design LID Site or Master Plan

1. Sketch a design concept that distributes the LID practices appropriately around the project site. Try to use all surface types (built, hardscape, and landscape). Keep in mind the multifunctional capability of LID technologies (i.e., parking lot with detention facility underground).

2. Develop a master plan that identifies all key control issues (water quality, water quantity, water conservation) and implementation areas. Specify specific LID technologies and any connections they have to stormwater overflow units and sub-surface detention facilities.

Step 5: Develop Operation and Maintenance Procedures

Develop operation and maintenance procedures for each of the LID practices implemented in the site plan. Different types of IMPs will have different maintenance requirements, but some general principles will apply:

- Keep IMPs and flow paths clear of debris.
- Water vegetation regularly during dry periods.
- Grassed areas should be mowed regularly.
- Plantings should be pruned as needed.

[37] PGDER, 2000b.

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Specific maintenance requirements of the different IMPs are discussed in Chapter 8.

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CHAPTER 10

DESIGN EXAMPLES

10-1 **OFFICE COMPLEX RETROFIT.** This example illustrates how an existing office building complex can be retrofit with LID components to improve water quality. This complex is located at the Anacostia Annex of the Washington Navy Yard in Washington, D.C. This area has extremely flat topography with clay soils. Because of its proximity to the Anacostia River, there is a high water table. No stormwater management quantity or quality controls are currently being used. The existing asphalt surface has been patched several times and is in poor condition. A full-depth replacement of the parking area is required. Many of the drainage inlets and old brick drainage structures are cracked or broken and need to be replaced. Much of the sidewalk surrounding the building is also cracked or heaving and the site pedestrian access does not comply with current Americans with Disabilities Act (ADA) Standards. Much of the existing vegetation around the building is overgrown and the lawn areas are in poor condition from compaction and poor management. This condition creates an opportunity to retrofit the parking area for immediate water quality improvements and make long-term recommendations for the entire area.

Figure 10-1. Landscaped Area and Parking Area

10-1.1 **PROJECT OBJECTIVES.** The objectives for this retrofit are to:

- Integrate water quality management practices into the repaving of parking areas
- Repair the sidewalks
- Re-landscape

Funding for LID retrofits has been approved as part of the paving and reconstruction so that the area will comply with local stormwater quality regulations. Pollutants of concern for this watershed are oils and grease, total suspended solids, nitrogen, and phosphorus. All of these pollutants are generated by the land use. In this

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case, as with many retrofits, the goal is to improve stormwater quality generally rather than to meet a specific load reduction goal. Quantity control is not required because the site outfall is located near the outlet of the watershed of a major watercourse and the facility's storm drain network has adequate capacity.

10-1.2 **RANK AND PRIORITIZE OPPORTUNITES.** For this project, retrofit opportunities will be ranked and prioritized according to the following criteria:

- Greatest potential to reduce non-point source pollutant loads
- Minimal costs for new structures or materials
- Minimal disturbance and ability to integrate construction into storm drain repair
- Minimal maintenance cycles
- Minimal maintenance costs and training
- Ancillary benefits (landscaping, energy conservation, water conservation)

10-1.3 **SITE CONDITIONS.** The site has minimal topographic relief. The groundwater table is approximately 3 feet (0.91 m) below the surface elevation. The soils in the area are fill soils with poor infiltration rates. The site is fronted by a landscaped buffer along the access road. There is an existing drainage system below the buffer. The adjacent parking area has several mature trees and drains towards the landscape buffer area. Figure 10-1 is a picture of the landscaped area taken from the parking area. Several yard inlets are located in the parking areas and along the access road. Figure 10-2 is a picture of a drainage inlet that has a concrete pilot channel to help collect runoff from the parking areas.

Figure 10-2. Drainage Inlet

Utility maps, topographic maps, and aerial photography were gathered and a site visit was conducted. Drainage patterns were verified during the site visit. (Drainage areas and patterns found in the field often deviate from those shown on plans because of changing field conditions, new utilities, repairs, or inaccuracies in the data.)

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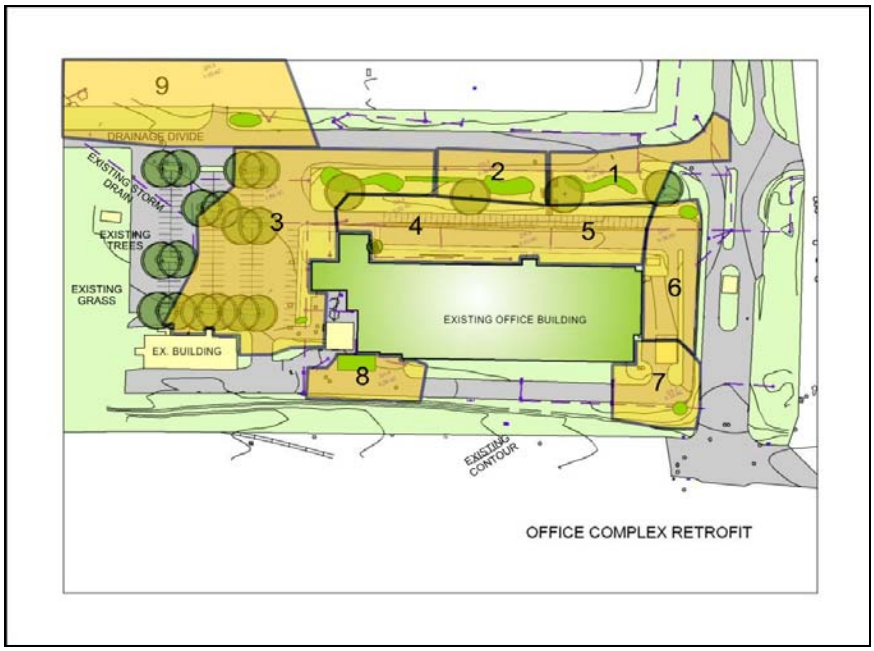
10-1.4 **LID DESIGN.** Four types of LID components were selected: bioretention, permeable pavers, tree box filters, and a vegetated roof. Because of the poor infiltration capacity of the soil, these features will not be capable of infiltrating stormwater into the ground. Instead, they will be equipped with underdrains and used to control water quality and provide detention storage. Site drainage areas were delineated, and LID features were located in places both appropriate to the technology and to the runoff patterns and volumes. Figure 10-3 shows the site drainage patterns and Figure 10-4 shows the locations of the LID features.

Figure 10-3 Drainage Areas of Proposed Practices



The description of the practices and their locations is as follows:

- **Drainage Areas One through Three:** Several LID components will be installed in the large vegetated island behind the parking areas along the access road. The design includes three bioretention cells, a bioretention swale, and a footpath constructed using permeable pavers. Installation will require that the existing curb be removed and replaced with wheel stops. These LID components can then treat the sheet flow from the access road and adjacent parking area and the parking lot to the south. A slight regrading of the drive area around the access road to the building will be required in order to direct runoff from the parking lot to the bioretention cells.

- **Drainage Area Four:** A tree box filter is designated for this area. This structure is appropriate because of space limitations.

- **Drainage Area Five:** Permeable pavers will be constructed in the existing valley between the access road and the parking area. This will require reconstruction of the inlet tops and some regrading. The curb in the back

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of the parking area is also deteriorated and should be replaced. The width of the pavers will be based on their infiltration capacity. The depth to groundwater also needs to be determined to make sure that the gravel bed underneath the pavers can be properly constructed to store and drain stormwater.

- **Drainage Area Six:** A bioretention cell will be constructed within a vegetated island at the north end of this parking area.

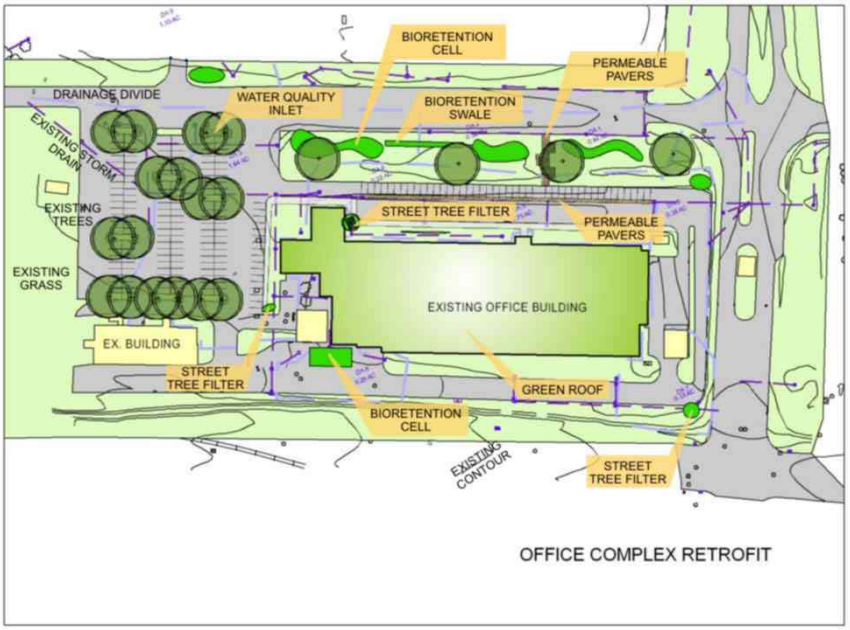
- **Drainage Area Seven:** An area of the pavement will be removed and replaced with a bioretention cell.

- **Drainage Area Eight:** This is near the loading dock area. Permeable pavers will be constructed. A sand layer may be incorporated into the system to increase efficiency.

- **Drainage Area Nine:** A bioretention cell will be located to the east of the access road, near the entrance to the storage lot to the south of building 399. This area will treat runoff from the access road and the storage area. The driveway apron will be reconstructed to direct runoff to the cell.

- **Rooftop:** A vegetated roof is proposed for building 168. This will filter pollutants from rain falling on the rooftop and will provide detention of rooftop runoff.

Figure 10-4. Office Complex Retrofit



Pollutant load calculations were developed for this project using a spreadsheet and a modification of the Simple Method[38] to determine the optimal areas in which to locate water quality improvement features. Although this method is more appropriate for larger watersheds and preliminary planning, the local jurisdiction uses it to evaluate water quality loading. Equation 10-1 is the water quality calculation.

$$L = 0.226 \times R \times C \times A$$ **Equation 10-1**

Where: L = Annual load (lbs)
R = Annual runoff (inches)
C = Pollutant concentration (mg/l)
A = Area (acres)
0.226 = Unit conversion factor
(Schueler, 1987)

Equation 10-2 is the projected load reduction.

$$D = L \times (1 - E)$$ **Equation 10-2**

Where: D = Annual load reduction (lbs)
L = Annual load (lbs)
E = Pollutant removal efficiency (fraction)

For the purposes of this study, removal rates of 70 percent were used for bioretention and tree box filters, and a removal rate of 50 percent was used for permeable pavers. Calculations were performed for lead, copper, zinc, phosphorus and total nitrogen. The results show an overall reduction of almost 65 percent of the aggregate load for the areas directly controlled by the practices and 55 percent of the total annual load for the pollutants studied. Table 10-1 shows the projected load reduction for various pollutants.

Table 10-1. Projected Load Reduction After LID Retrofit

Pollutant	Annual Load kg (lbs) Existing Condition	Annual Load (lbs) After LID Retrofit
Zinc	7.94 (17.5)	2.8 (6.1)
Lead	7.76 (17.1)	2.7 (6.0)
Copper	2.1 (4.6)	0.73 (1.6)
Nitrogen (TKN)	43.4 (95.6)	15.1 (33.2)
Phosphorus	20.2 (44.5)	7.03 (15.5)

10-2 **NEW HOUSING DESIGN.** This example will demonstrate the differences between conventional and LID stormwater management approaches for a typical DoD housing community in a coastal area. The design objectives are to maintain the peak runoff rate for a Type II NRCS 2-year 24-hour storm event and provide water quality control for the development. Following the hydrologic analysis presented here, a series

[38] Schueler, 1987.

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of pictures are presented to illustrate how selected LID components would look in a recently constructed housing development.

10-2.1 **Curve Number Calculations For Existing Site Condition.** The site being evaluated has a 2.6 ha (6.5 acre) drainage area. The land is relatively flat and drains to a small channel with wetlands at the outfall of the drainage area. The slopes are gentle, averaging 2 percent. The soils are classified as belonging to NRCS Hydrologic Soils Group (HSG) B. These soils have moderate infiltration rates and moderately fine to moderately coarse textures. They generally have a moderate rate of water transmission (0.15 to 0.30 in/hr), and the textures may be classified as a silt loam or loam.[39] Approximately 1.5 ha (3.6 acres) near the outfall is classified hydrologically as "Woods in Fair Condition". The upper portion of the property is classified as "Brush in Poor Condition". Figure 10-5 is a map of the existing condition.

The procedures from Worksheet 2, Figure 2-5 from TR-55[40] are used to calculate the composite curve number (CN) for the site. The resulting CN from Equation 10-3 is 63 for the 2.6 ha (6.5 acres.) Table 10-2 is a summary of those calculations.

Weighted CN = Sum of Products ÷ Drainage Area **Equation 10-3**

Table 10-2. Composite Curve Number Calculation for Existing Condition

Hydrologic Soils Group	Cover Description	CN (Table 2-2 TR-55)	Area (Acres)	Product of CN x Area
B	Brush, Poor Condition	67	2.9	194.3
B	Woods, Fair	60	3.6	216.0
			Sum of Products	**410.3**
			÷ Drainage Area	6.5
			Weighted CN	**63**

[39] NRCS, 1986.
[40] Ibid.

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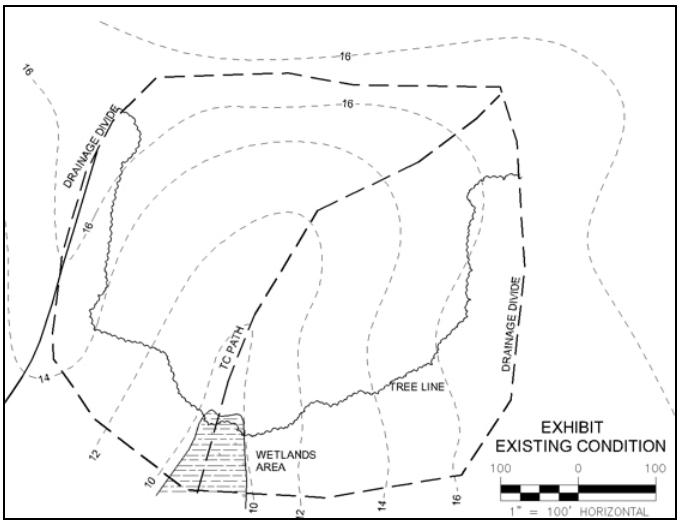
Figure 10-5. Map of Existing Conditions



10-2.2 **Post Development Curve Number Calculations.** The conventional method for assigning a curve number to a residential development is to choose a single curve number for the entire site from a source such as Table 2-2a of TR-55.[41] Figure 10-6 is a picture of the proposed housing type, which can be classified as "Townhouse Residential District". For this land use, the CN from Table 2-2a of TR-55 is 85.

The LID method allows for the calculation of a "customized" CN that reflects the actual field conditions rather than a broad estimation. For this example, the amounts of impervious cover and other land covers were calculated directly from Figure 10-7. Table 10-3 is a summary of the proposed condition's "customized" CN using the LID calculation method.

Table 10-3. Composite Curve Number Calculation for Proposed Condition

Hydrologic Soils Group	Cover Description	CN (Table 2-2 TR-55)	Area (Acres)	Product of CN x Area
B	Lawn (fair condition)	69	3.2	220.8
B	Woods, Fair	60	0.7	42.0
B	Impervious	98	2.6	254.8
			Sum of Products	**517.6**
			÷ Drainage Area	6.5
			Weighted CN	**80**

[41] Ibid.

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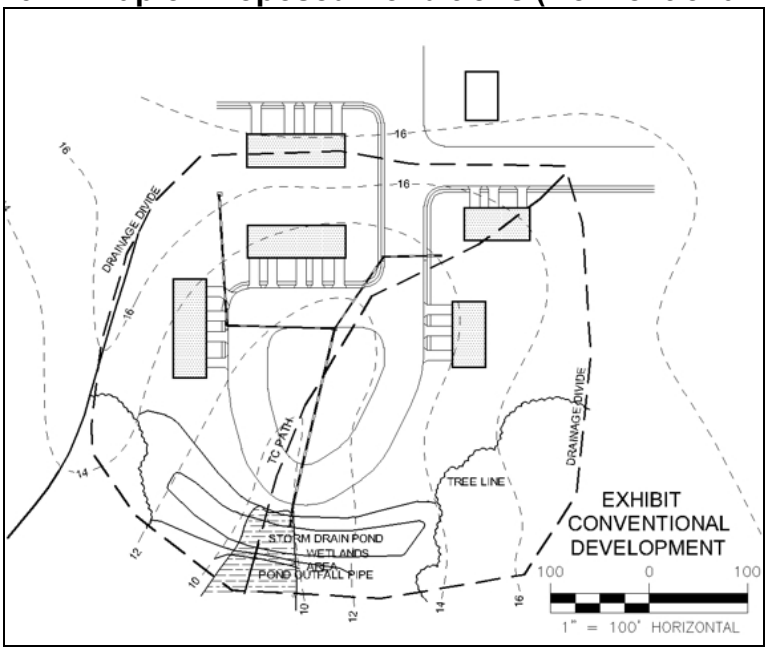
Figure 10-6. Proposed Housing

Figure 10-7. Map of Proposed Conditions (Conventional Design)



10-2.3 **Runoff Volume For Existing And Proposed Conditions.** The difference in runoff volume between the existing and proposed conditions can be quite significant for

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both annual accumulations and peak events. A comparison of the volume (depth) of runoff from the pre- and post-development curve numbers for a 130 mm (5-in) rainfall using Equation 2-1 from TR-55[42] (Equation 10-4) is shown in Table 10-4.

$$Q = \frac{(P - I_a)^2}{(P - I_a) + S}$$ **Equation 10-4**

Where: Q = runoff depth (in)
P = rainfall depth (in)
I_a = initial abstraction (in)

$$I_a = 0.2S$$ **Equation 10-5**

Where: S = potential maximum retention after runoff begins (in)

$$S = \frac{1000}{CN} - 10$$ **Equation 10-6**

Table 10-4. Runoff Depth for Existing and Proposed Conditions (5-inch Rainfall)

Condition	Runoff (in)
Existing (CN = 63)	1.5
Proposed (CN = 80)	2.9

10-2.4 **LID Site Planning Strategies.** Several LID site design strategies will be employed to reduce the CN for the proposed condition. A lower CN value will be obtained by:

- Reducing impervious cover
- Disconnecting impervious areas
- Reducing the grading footprint to retain more wooded area
- Restoring the infiltration capacity of disturbed and compacted soils

Figure 10-8 shows the resulting site plan. A significant amount of disturbance to the woods and wetlands has been avoided by eliminating the centralized stormwater facility and distributing the stormwater management among LID components throughout the site. (The elimination or reduction of impacts to wetlands and water bodies may have a significant effect on permitting in many areas.) The condition of lawn areas will be improved by ensuring that adequate topsoil and aeration are included in the final grading and stabilization of the project. The road width has been reduced from 15 m (48 ft) to 9.8 m (32 ft). The parking areas have been maintained as head-in parking and the green space in the central island is expanded. Additional reductions in impervious area could be incorporated into the design, such as further reducing the road width or sharing driveways. Remaining impervious areas should be disconnected to the greatest possible extent. Table 10-5 summarizes the CN calculations for the proposed conditions using the LID site planning approach.

[42] Ibid.

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Figure 10-8. Map of Proposed Conditions (LID Design)

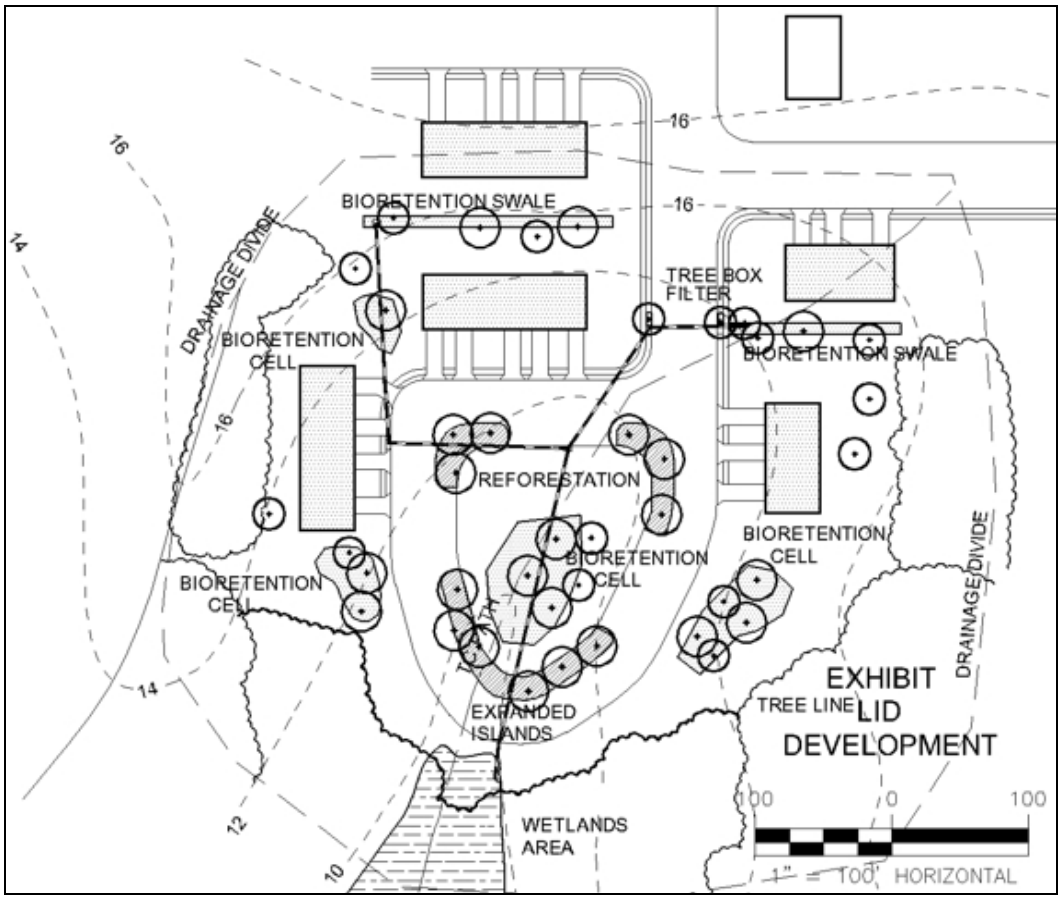

Table 10-5. Composite CN Calculation for Proposed Condition Using LID

Hydrologic Soils Group	Cover Description	CN (Table 2-2 TR-55)	Area (Acres)	Product of CN x Area
B	Lawn (good condition)	61	1.8	109.8
B	Woods, Fair	60	2.5	150.0
B	Impervious	98	2.2	215.6
			Sum of Products	**475.4**
			÷ Drainage Area	6.5
			Composite CN	**73**

10-2.5 **Time Of Concentration For Existing And Proposed Conditions.** The time of concentration (T_c) was calculated for the pre-development and conventional post-development conditions using the procedures in TR-55. A summary of these calculations is included in Appendix C. The conventionally developed condition causes T_c to decrease from 0.24 hours to 0.22 hours, or a 1.2 minute difference. The LID site design results in a T_c that matches the existing condition; in this case, 0.24 hours. Additional calculations for flow through the bioretention cells or rougher vegetated areas were not included in the analysis, but would be expected to further increase post-development LID T_c.

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10-2.6 **Storage Volume Comparison.** A comparison of the storage volumes required for the conventional and LID site designs is given below. The 2-year 24-hour and the 10-year 24-hour storms are often used as the design storms for channel protection and adequate conveyance. Although the design objective here is to maintain the peak runoff rate for the 2-year 24-hour storm, the 10-year 24-hour storm is also used to further illustrate the differences in peak runoff rate and volume between the two approaches. In order to determine the storage volume required to maintain the pre-development peak runoff rate for these design storms, the runoff depths and peak runoff rates for the existing condition and both proposed conditions were first calculated using the Graphical Peak Discharge Method from TR-55. Table 10-6 is a summary of those calculations.

Table 10-6. Summary of Graphical Peak Discharge Results

Condition	CN	T_c	Peak Discharge (CFS)		Runoff depth (in.)	
			2-year storm (3" depth)	10-year storm (5" depth)	2-year storm	10-year storm
Existing Condition	63	0.24	2	10	0.4	1.5
Proposed Condition – conventional CN	80	0.22	9	23	1.3	2.9
Proposed Condition using LID site design	73	0.24	6	17	0.9	2.3

The TR-55[43] computer program was used to estimate the post-development storage volume required to maintain the 2-year 24-hour pre-development peak runoff rate for both the conventional and LID site designs. As shown in Table 10-6 above, the target (existing) 2-year 24-hour peak outflow is 2 cfs and the target 10-year 24-hour peak outflow is 10 cfs. (It is purely coincidental that the values of the return periods match the values of the discharges.) The results are given in Table 10-7.

Table 10-7. Post-Development Storage Volumes

Design storm	Conventional site design		LID site design	
	Depth, inches (mm)*	Volume, ac-ft (m^3)	Depth, inches (mm)*	Volume, ac-ft (m^3)
2-year 24-hour	0.52 (13)	0.28 (347)	0.28 (7)	0.15 (187)
10-year 24-hour	0.85 (22)	0.46 (568)	0.53 (13)	0.29 (354)

** depth of runoff distributed across the 6.5 acre (2.6 ha) area*

For the 2-year 24-hour storm, the LID site design results in a 46% reduction in required storage volume as compared to the conventional site design, and for the 10-year 24-hour storm, the volume reduction is 38%. The pond shown in Figure 10-7 was sized using the computed 2-year conventional detention basin storage volume. Appendix C shows a summary of the computer program results.

[43] Ibid.

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10-2.7 **Distributed Detention And Retention Storage Requirements.** The previous section demonstrates that significant reductions in runoff volume (and correspondingly, storage volume) can be achieved by following the LID site design approach. A conventional detention pond, however, will not normally be used in an LID design; instead, storage will be provided using *distributed* retention and detention. The LID Design Charts (see Appendix D)[44] were used to determine the total volume of storage required to maintain the pre-development 2-year 24-hour peak runoff rate using retention (Chart 1) and detention (Chart 2). The CN of 63 was used for the pre-development condition and the CN of 73 was used for the post-development condition. The depth of storage across the site needed to maintain the pre-development discharge rate using retention is 12 mm (0.48 in). Equation 10-7 shows that this is equivalent to a volume of 321 m^3 (0.26 acre-feet). Using detention, the required depth of storage across the site is 8 mm (0.3 in), or using Equation 10-7, a volume of 194 m^3 (0.16 acre-feet).

Storage Volume (acre-feet) = Drainage Area (acres) x Depth of Storage (feet) **Equation 10-7**

The soils are HSG B; therefore, they have good potential for infiltration and the use of retention is appropriate. Hybrid designs that use both retention and detention are intended for soils with poor infiltration capacity (HSG C and HSG D). The use of retention will also encourage recharge and maintain the water balance for the site.

A site may be required not only to maintain the pre-development peak discharge rate, but to maintain the pre-development runoff *volume* as well. The total storage volume required to maintain the pre-development runoff volume can be calculated using Chart 3 in Appendix D, and in this example it equals 11 mm (0.42 in). This is less than the volume needed to maintain the pre-development peak discharge rate (13 mm [0.48 in,] calculated above). Although maintaining the pre-development runoff volume is not a requirement in this case study, this calculation illustrates the feasibility of maintaining the pre-development recharge and runoff characteristics of the site (i.e. peak discharge *and* volume) for frequently occurring storm events up to and including the 2-year 24-hour storm. Therefore, there is full hydraulic and hydrologic control of small-scale, frequently-occurring storms.

10-2.8 **Selection of Appropriate IMPs.** The retention storage volume calculated above, 321 m^3 (0.26 acre-feet,) was used as the total storage volume to be distributed between the selected IMPs. The selected LID components include bioretention cells, bioretention swales, and tree box filters. A ponding depth of 305 mm (12 in) was used to size each of the bioretention devices. Using Equation 10-8, the total area required for bioretention is approximately 1050 m^2 (11,300 sq. ft). Accounting for the volume of runoff that can be stored in the pore spaces in the bioretention media will further decrease the required storage area.

Bioretention Area = Storage Volume ÷ Bioretention Depth **Equation 10-8**

[44] PGDER, 2000b.

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These features have been located to intercept and manage the stormwater drainage in small areas. The storm drain pattern remains the same as in the conventional system and provides adequate conveyance. Because of the runoff volume and peak reductions achieved by the LID site design and IMPs, a smaller storm drain diameter can be used if desired.

Figure 10-8 illustrates that the storage volume required to maintain the pre-development 2-year 24-hour peak discharge can be met by using distributed stormwater management. These components can be maintained by the residents, with the exception of the tree box filter. All of the facilities can be maintained by landscape maintenance crews, with minimal training. Figures 10-9 to 10-14 illustrate how the LID features can be incorporated into a residential development.

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Figure 10-9. Street Island Modifications

Before

After

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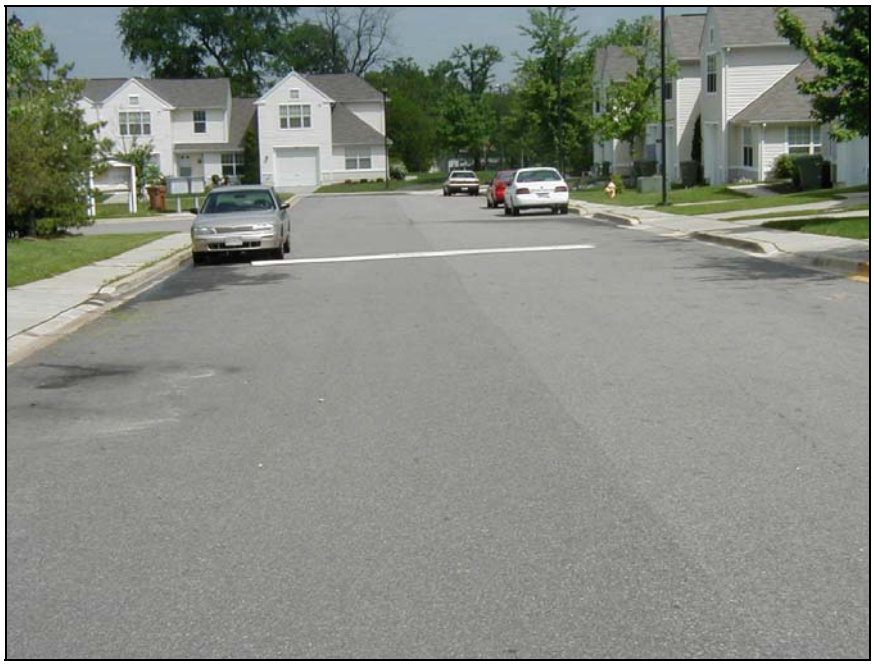
Figure 10-10. Street Alterations



Before

After

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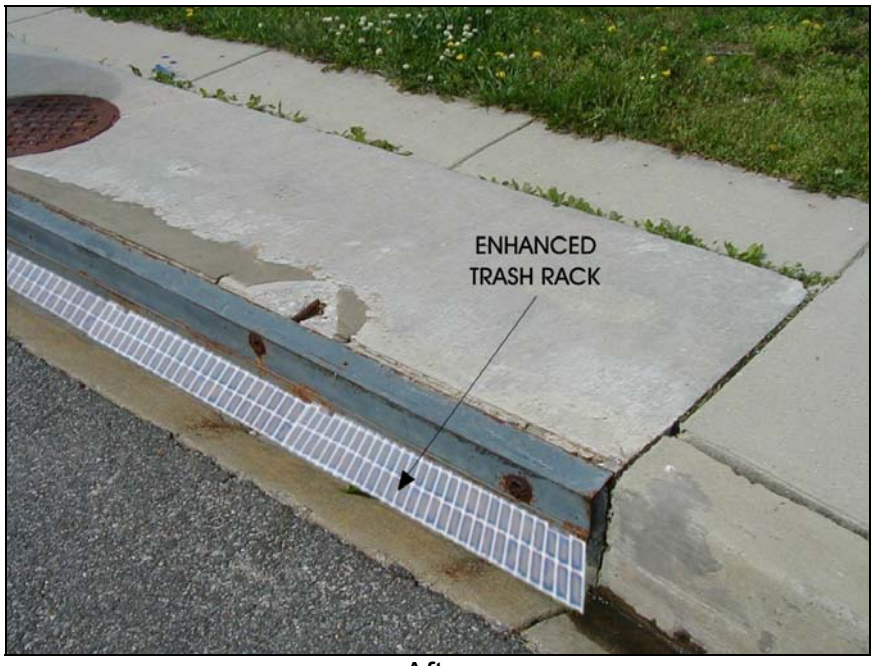
Figure 10-11. Trash Rack

Before



After

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Figure 10-12. Tree Box Filter

Before

After

Figure 10-13. Bioretention (Rain Garden)

Before

After

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Figure 10-14. Reforestation

Before

After

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10-2.9 **WATER QUALITY CALCULATIONS.** There are a variety of strategies and methods available to provide water quality control. One conventional approach is to capture a certain volume of runoff and hold it in a detention pond to allow pollutants to settle out of the water. A common regulatory requirement is to store the first 13 mm (0.5 in) of runoff from impervious areas (e.g. roofs, pavement or walks).[45] Based on this requirement and the fact that there are 0.85 ha (2.1 acres) of impervious area in the proposed development, 111 m^3 (0.09 acre-feet) of water quality storage is needed. Since this is less than the total retention storage requirement of 321 m^2 (0.26 acre-feet,) the water quality storage volume is already contained in the proposed design.

Many LID components use the biological, chemical and physical processes of plant and soil interactions to filter and treat pollutants. The effectiveness of these components can be measured in terms of a relative reduction in pollutant concentration or a reduction in the total mass of the pollutant that reaches the receiving waters annually. For this method, the reduction is based on the removal efficiency and flow rates rather than a storage volume. A detailed analysis of the combined effectiveness of the LID components will demonstrate, in some cases, that a storage volume for water quality is not necessary.

10-2.10 **CONCLUSION.** This case study has shown how LID can be incorporated into the design of a residential housing development. The use of LID practices has eliminated the need for a traditional stormwater detention pond, thereby reducing the disturbance to existing forested area. The retention of this forested buffer will in turn reduce impacts to the wetland and receiving waters. The need for piped stormwater conveyances has been eliminated. The LID approach has the added benefit of improving the aesthetics of the development and can provide opportunities for community involvement in the protection and maintenance of the local environment.

[45] Novotny and Olem, 1994.

SARB_005579

APPENDIX A

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SARB_005585

APPENDIX B

GLOSSARY: ACRONYMS AND ABBREVIATIONS

ADA	Americans with Disabilities Act
BMP	Best Management Practice
CN	Curve Number
CSO	Combined Sewer Overflow
CWA	Clean Water Act
DoD	Department of Defense
EO	Executive Order
EPA	Environmental Protection Agency
EQI	Environmental Quality Initiative
FHWA	Federal Highway Administration
HEC	Hydraulic Engineering Center
IMP	Integrated Management Practice
LEED	Leadership in Energy and Environmental Design
LID	Low Impact Development
NPDES	National Pollutant Discharge Elimination System
NRCS	Natural Resources Conservation Service
NURP	Nationwide Urban Runoff Program
P2	Pollution Prevention
PGDER	Prince George's County Department of Environmental Resources
RBP	Rapid Bioassessment Protocols
SCS	Soil Conservation Service
SPCC	Spill Prevention, Control, and Countermeasures
SWMM	Storm Water Management Model
T_c	Time of concentration
TCT	Tilled Compost-Amended Turf
TMDL	Total Maximum Daily Load
TSS	Total Suspended Solids

SARB_005586

APPENDIX C

SUPPORTING CALCULATIONS FOR SECTION 10-2

SARB_005587

Exhibit A. TR-55 Time of Concentration Calculation for Existing Condition

```
TIME OF CONCENTRATION AND TRAVEL TIME                          Version 2.10


Project : RESIDENTIAL CASE STUDY              User:          Date: 07-11-2003
County  :                      State:       Checked: ____     Date: ________
Subtitle: EXISTING CONDITION

------------------------------- Subarea #1 - 1 -------------------------------
Flow Type   2 year   Length   Slope  Surface   n   Area     Wp   Velocity  Time
             rain     (ft)   (ft/ft)   code       (sq/ft)  (ft)  (ft/sec)  (hr)
-------------------------------------------------------------------------------
Sheet        3        100      .02      E                                0.169
Shallow Concent'd     565      .02      U                                0.069
                                                Time of Concentration = 0.24*
                                                                        =====

        --- Sheet Flow Surface Codes ---
    A Smooth Surface          F Grass, Dense     --- Shallow Concentrated ---
    B Fallow (No Res.)        G Grass, Burmuda   ---     Surface Codes    ---
    C Cultivated < 20 % Res.  H Woods, Light               P Paved
    D Cultivated > 20 % Res.  I Woods, Dense               U Unpaved
    E Grass-Range, Short      J Range, Natural
```

Exhibit B. TR-55 Time of Concentration Calculation for Proposed Condition

```
TIME OF CONCENTRATION AND TRAVEL TIME                          Version 2.10


Project : RESIDENTIAL CASE STUDY              User:          Date: 07-11-2003
County  :                      State:       Checked: ____     Date: ________
Subtitle: PROPOSED CONDITION

------------------------------- Subarea #1 - 1 -------------------------------
Flow Type   2 year   Length   Slope  Surface   n   Area     Wp   Velocity  Time
             rain     (ft)   (ft/ft)   code       (sq/ft)  (ft)  (ft/sec)  (hr)
-------------------------------------------------------------------------------
Sheet        3        100      .02      E                                0.169
Shallow Concent'd     150      .02      U                                0.018
Open Channel          415                                         4.0     0.029
                                                Time of Concentration = 0.22*
                                                                        =====

        --- Sheet Flow Surface Codes ---
    A Smooth Surface          F Grass, Dense     --- Shallow Concentrated ---
    B Fallow (No Res.)        G Grass, Burmuda   ---     Surface Codes    ---
    C Cultivated < 20 % Res.  H Woods, Light               P Paved
    D Cultivated > 20 % Res.  I Woods, Dense               U Unpaved
    E Grass-Range, Short      J Range, Natural
```


SARB_005588

Exhibit C. TR-55 Detention Basin Storage Volume Calculation for Proposed Condition, Conventional Site Design

TR-55 STORAGE VOLUME FOR DETENTION BASINS Version 2.10

>>>>> Identification Data <<<<< Date 04-23-2004

Project RESIDENTIAL CASE STUDY

Subtitle PROPOSED CONDITION (CONVENTIONAL)

>>>>> Basic Data <<<<<

Drainage Area **6.5** Acres

Rainfall-Type (I,IA,II,III) **II**

Rainfall Frequency **2** years 24-Hour Rainfall 3 inches

Runoff 1.25 inches Runoff Curve Number 80

Peak Inflow 9.3451 cfs Peak Outflow **2.3229** cfs

Detention Basin Storage Volume: 0.52 inches or 0.3 acre feet

TR-55 STORAGE VOLUME FOR DETENTION BASINS Version 2.10

>>>>> Identification Data <<<<< Date 04-23-2004

Project RESIDENTIAL CASE STUDY

Subtitle PROPOSED CONDITION (CONVENTIONAL)

>>>>> Basic Data <<<<<

Drainage Area **6.5** Acres

Rainfall-Type (I,IA,II,III) **II**

Rainfall Frequency **10** years 24-Hour Rainfall 5 inches

Runoff 2.89 inches Runoff Curve Number 80

Peak Inflow 22.638 cfs Peak Outflow **10.328** cfs

Detention Basin Storage Volume: 0.85 inches or 0.5 acre feet

SARB_005589

Exhibit D. TR-55 Detention Basin Storage Volume Calculation for Proposed Condition, LID Site Design

```
                  TR-55 STORAGE VOLUME FOR DETENTION BASINS        Version 2.10

                     >>>>> Identification Data <<<<<           Date 04-23-2004

Project RESIDENTIAL CASE STUDY

Subtitle PROPOSED CONDITION (LID)

                          >>>>> Basic Data <<<<<

Drainage Area 6.5 Acres

Rainfall-Type (I,IA,II,III) II

Rainfall Frequency 2 years           24-Hour Rainfall 3 inches

Runoff .857 inches                   Runoff Curve Number 73

Peak Inflow 5.8163 cfs               Peak Outflow 2.3229 cfs

    ╔═══════════════════════════════════════════════════════════════════╗
    ║ Detention Basin Storage Volume:   0.28 inches  or  0.1 acre feet  ║
    ╚═══════════════════════════════════════════════════════════════════╝
```

```
                  TR-55 STORAGE VOLUME FOR DETENTION BASINS        Version 2.10

                     >>>>> Identification Data <<<<<           Date 04-23-2004

Project RESIDENTIAL CASE STUDY

Subtitle PROPOSED CONDITION (LID)

                          >>>>> Basic Data <<<<<

Drainage Area 6.5

Rainfall-Type (I,IA,II,III) II

Rainfall Frequency 10 years          24-Hour Rainfall 5 inches

Runoff 2.28 inches                   Runoff Curve Number 73

Peak Inflow 16.652 cfs               Peak Outflow 10.328 cfs

    ╔═══════════════════════════════════════════════════════════════════╗
    ║ Detention Basin Storage Volume:   0.53 inches  or    0.3 acre feet ║
    ╚═══════════════════════════════════════════════════════════════════╝
```

APPENDIX D

LID DESIGN CHARTS

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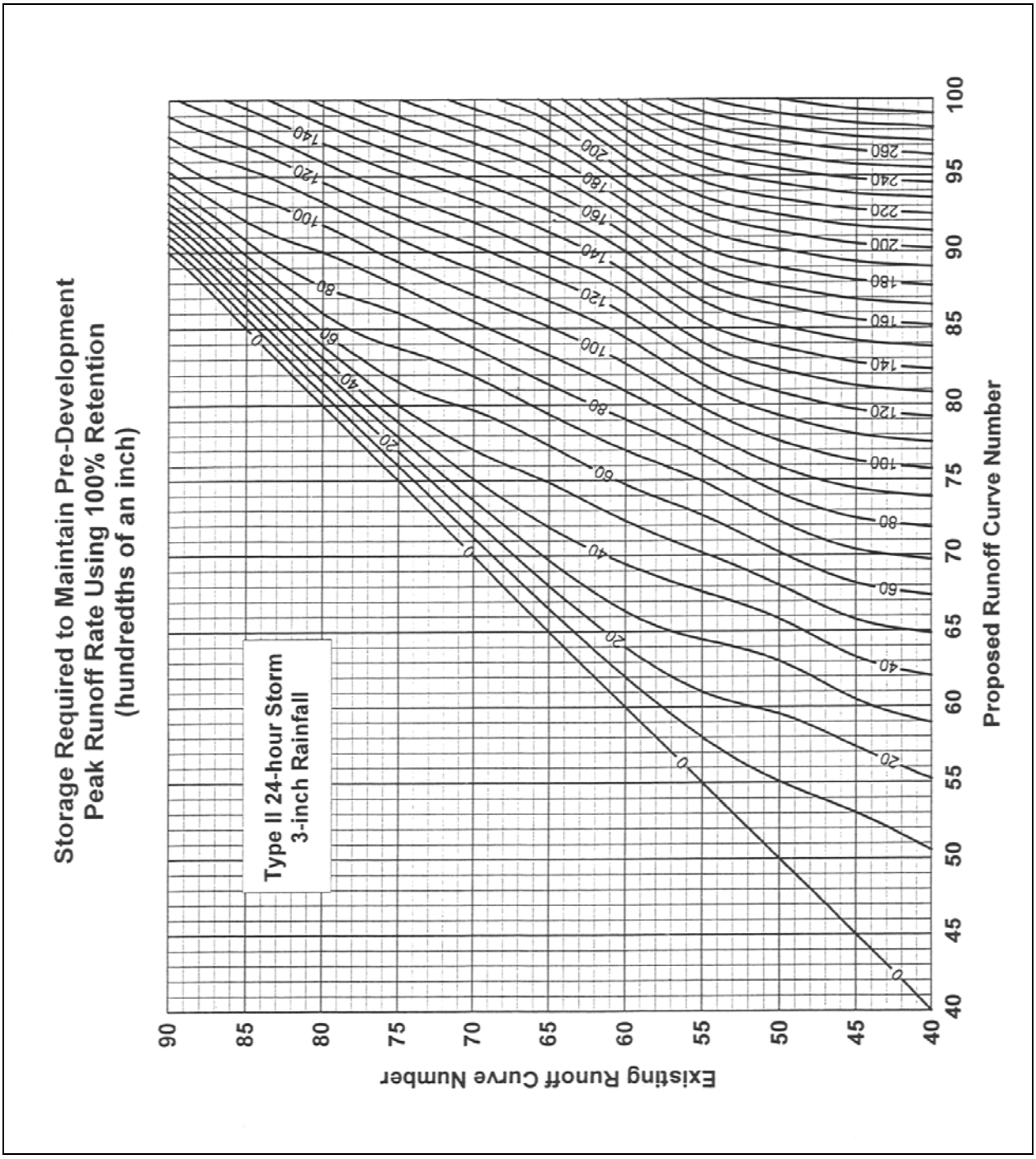
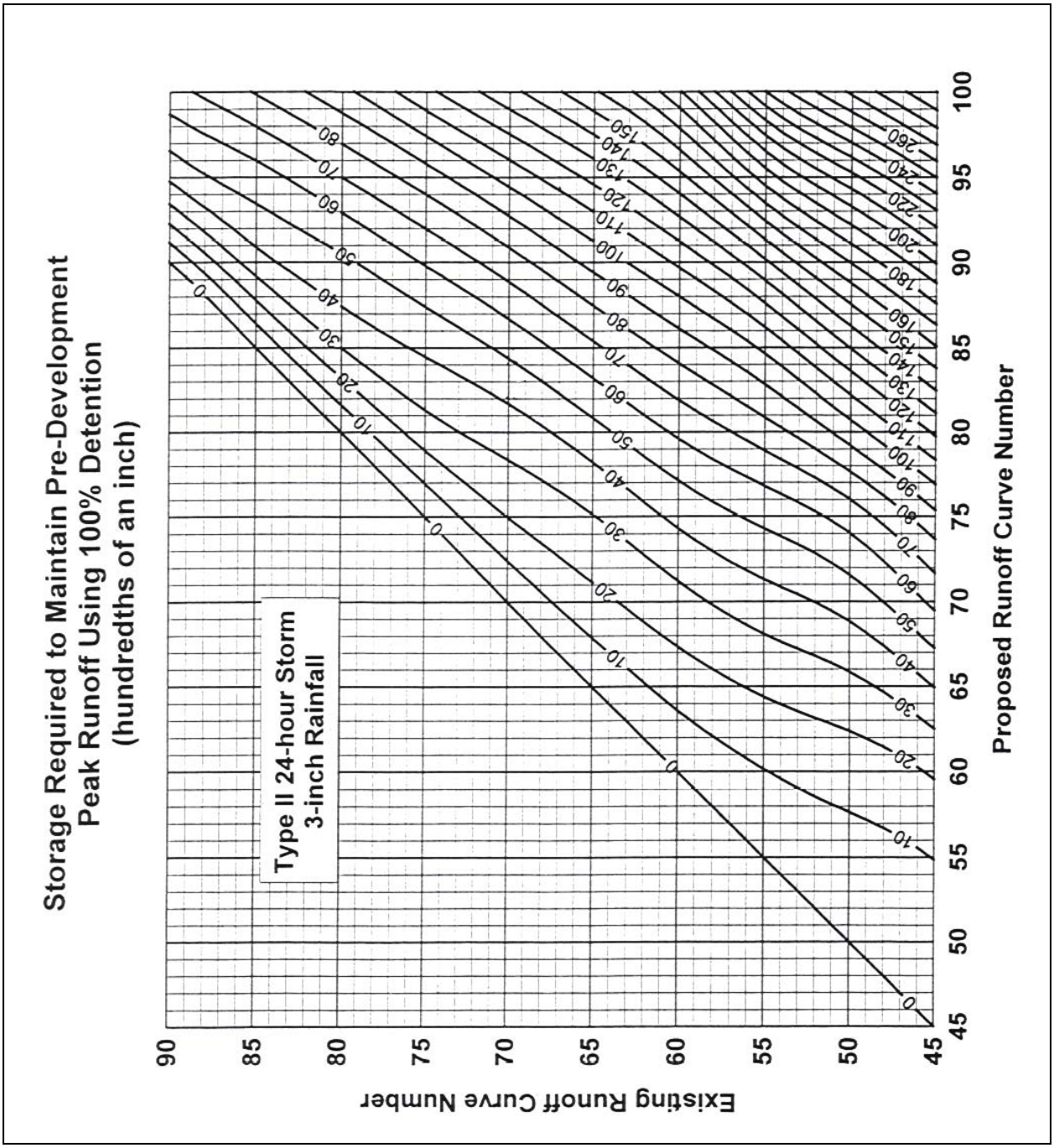
Chart 1



Source: PGDER, 2000b.

Chart 2



Source: PGDER 2000b.

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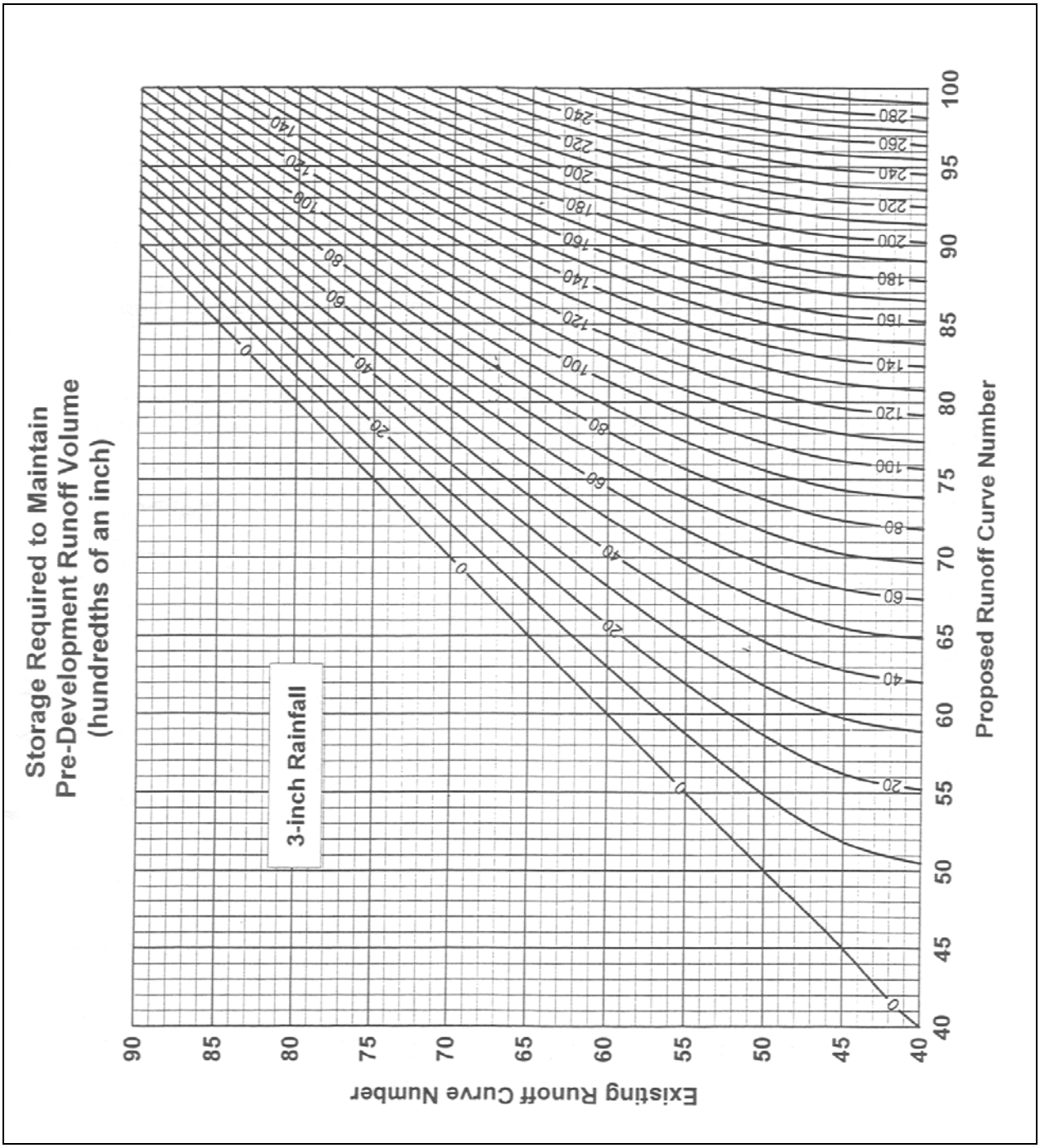
Chart 3



Source: PGDER 2000b.

United States
Environmental Protection
Agency

Risk Reduction
Engineering Laboratory
Cincinnati, OH 45268

Research and Development

EPA/600/SR-94/051 May 1994

EPA

Project Summary

Potential Groundwater Contamination from Intentional and Nonintentional Stormwater Infiltration

Robert Pitt, Shirley Clark, and Keith Parmer

The research summarized here was conducted during the first year of a 3-yr cooperative agreement to identify and control stormwater toxicants, especially those adversely affecting groundwater. The purpose of this research effort was to review the groundwater contamination literature as it relates to stormwater. Potential problem pollutants were identified, based on their mobility through the unsaturated soil zone above groundwater, their abundance in stormwater, and their treatability before discharge. This information was used with earlier EPA research results to identify the possible sources of these potential problem pollutants. Recommendations were also made for stormwater infiltration guidelines in different areas and monitoring that should be conducted to evaluate a specific stormwater for its potential to contaminate groundwater.

This Project Summary was developed by EPA's Risk Reduction Engineering Laboratory, Cincinnati, OH, to announce key findings of the research project that is fully documented in a separate report of the same title (see Project Report ordering information at back).

Introduction

Before urbanization, groundwater was recharged by precipitation infiltrating through pervious surfaces, including grasslands and woods. This infiltrating water was relatively uncontaminated. Urbanization, however, reduced the permeable soil surface area through which recharge by infiltration could occur. This resulted in much less groundwater recharge and greatly increased surface runoff. In addition, the waters available for recharge generally carried increased quantities of pollutants. With urbanization, waters having elevated contaminant concentrations also recharge groundwater, including effluent from domestic septic tanks, wastewater from percolation basins and industrial waste injection wells, infiltrating stormwater, and infiltrating water from agricultural irrigation. This report addresses potential groundwater problems associated with stormwater toxicants and describes how conventional stormwater control practices can reduce these problems.

Sources of Pollutants

High bacteria populations have been found in sheetflow samples from sidewalks, roads, and some bare ground (collected from locations where dogs would most likely be "walked"). Tables 1 and 2 summarize toxicant concentrations and likely sources or locations having some of the highest concentrations found during an earlier phase of this EPA-funded research. The detection frequencies for the heavy metals are all close to 100% for all source areas, and the detection frequencies for the organics listed on these tables ranged from about 10% to 25%. Vehicle service areas had the greatest abundance of observed organics.

Table 1. *Concentrations of Heavy Metals in Observed Areas (µg/L)*

Toxicant	*Highest Median*		*Highest Observed*	
Cadmium	*Vehicle service area runoff*	*8*	*Street runoff*	*220*
Chromium	*Landscaped area runoff*	*100*	*Roof runoff*	*510*
Copper	*Urban receiving water*	*160*	*Street runoff*	*1250*
Lead	*CSO*	*75*	*Storage area runoff*	*330*
Nickel	*Parking area runoff*	*40*	*Landscaped area runoff*	*130*
Zinc	*Roof runoff*	*100*	*Roof runoff*	*1580*

Table 2. *Maximum Concentrations of Toxic Organics from Observed Sources*

Toxicant	*Maximum, µg/L*	*Detection Frequency, %*	*Significant Sources*
Benzo (a) anthracene	*60*	*12*	*Gasoline, wood preservative*
Benzo (b) fluoranthene	*226*	*17*	*Gasoline, motor oils*
Benzo (k) fluoranthene	*221*	*17*	*Gasoline, bitumen, oils*
Benzo (a) pyrene	*300*	*17*	*Asphalt, gasoline, oils*
Fluoranthene	*128*	*23*	*Oils, gasoline, wood preservative*
Naphthalene	*296*	*13*	*Coal tar, gasoline, insecticides*
Phenanthrene	*69*	*10*	*Oils, gasoline, coal tar*
Pyrene	*102*	*19*	*Oils, gasoline, bitumen, coal tar, wood preservative*
Chlordane	*2.2*	*13*	*Insecticide*
Butyl benzyl phthalate	*128*	*12*	*Plasticizer*
Bis (2-chloroethyl) ether	*204*	*14*	*Fumigant, solvents, insecticides, paints, lacquers, varnishes*
Bis (2-chloroisopropyl) ether	*217*	*14*	*Pesticide manufacturing*
1,3-Dichlorobenzene	*120*	*23*	*Pesticide manufacturing*

Stormwater Constituents Having High Potential to Contaminate Groundwater

Nutrients

Nitrates are one of the most frequently encountered contaminants in groundwater. Phosphorus contamination of groundwater has not been as widespread, or as severe, as that of nitrogen compounds. Whenever nitrogen-containing compounds come into contact with soil, a potential exists for nitrate leaching into groundwater, especially in rapid-infiltration wastewater basins, stormwater infiltration devices, and agricultural areas. Nitrate has leached from fertilizers and affected groundwaters under various turf grasses in urban areas, including golf courses, parks, and home lawns. Significant leaching of nitrates occurs during the cool, wet seasons. Cool temperatures reduce denitrification and ammonia volatilization and limit microbial nitrogen immobilization and plant uptake. The use of slow-release fertilizers (including composted organic mulches, urea formaldehyde (UF), methylene urea, isobutylidene diurea (IBDU), and sulfur-coated urea) is recommended in areas having potential groundwater nitrate problems.

Residual concentrations of nitrate in soil vary greatly and depend on the soil texture, mineralization, rainfall and irrigation patterns, organic matter content, crop yield, nitrogen fertilizer/sludge application rate, denitrification, and soil compaction. Nitrate is highly soluble (>1 kg/L) and will stay in solution in the percolation water. If it leaves the root zone without being taken-up by plants, it will readily reach the groundwater.

Pesticides

Urban pesticide contamination of groundwater can result from municipal and homeowner use for pest control and the subsequent collection of the pesticide in stormwater runoff. Pesticides that have been found in urban groundwaters include: 2,4-D, 2,4,5-T, atrazine, chlordane, diazinon, ethion, malathion, methyl trithion, silvex, and simazine. Heavy repetitive use of mobile pesticides (those that are not likely to be retained by various processes in the soil before they reach the groundwater, such as 2,4-D, acenaphthylene, alachlor, atrazine, cyanazine, dacthal, diazinon, dicamba, and malathion) on irrigated and sandy soils will likely contaminate groundwater. Fungicides and nematocides must be mobile to reach the target pest, and hence, they generally have the highest groundwater contamination potential. Pesticide leaching depends on patterns of use, soil texture, total organic carbon content of the soil, pesticide persistence, and depth to the water table.

The greatest pesticide mobility occurs in areas with coarse-grained or sandy soils without a hardpan layer, and with soils that have low clay and organic matter content and high permeability. Structural voids, generally found in the surface layer of finer-textured soils rich in clay, can transmit pesticides rapidly when the voids are filled with water and the adsorbing surfaces of the soil matrix are bypassed. In general, pesticides with low water solubilities, high octanol-water partitioning coefficients, and high carbon partitioning coefficients are less mobile. The slower moving pesticides that may better sorb to soils have been recommended for use in areas of groundwater contamination concern. These include the fungicides iprodione and triadimefon, the insecticides isofenphos and chlorpyrifos, and the herbicide glyphosate.

Pesticides decompose in soil and water, but the total decomposition time can range from days to years. Literature half-lives for pesticides generally apply to surface soils and do not account for the reduced microbial activity found deep in the vadose zone. Pesticides with a 30-day half life can show considerable leaching. An order-of-magnitude difference in half-life results in a five- to ten-fold difference in percolation loss. Organophosphate pesticides are less persistent than organochlorine pesticides, but they also are not strongly adsorbed by the sediment and are likely to leach into the vadose zone and the groundwater.

Other Organics

The most commonly occurring organic compounds found in urban groundwaters include phthalate esters (especially bis(2-ethylhexyl)phthalate) and phenolic compounds. Other, more rarely found, organics include the volatiles: benzene, chloroform, methylene chloride, trichloroethylene, tetrachloroethylene, toluene, and xylene. Polycyclic aromatic hydrocarbons (PAHs) (especially benzo(a)anthracene, chrysene, anthracene, and benzo(b)fluoroanthenene) have also been found in groundwaters near industrial sites.

Groundwater contamination from organics, like that from other pollutants, occurs

more readily in areas with sandy soils and where the water table is near the land surface. Organics can be removed from the soil and recharge water by volatilization, sorption, and degradation. Volatilization can significantly reduce the concentrations of the most volatile compounds in groundwater, but the rate of gas transfer from the soil to the air is usually limited by the presence of soil water. Hydrophobic sorption onto soil organic matter limits the mobility of less soluble base/neutral and acid extractable compounds through organic soils and the vadose zone. Sorption is not always a permanent removal mechanism, however. Organic resolubilization can occur during wet periods following dry periods. Many organics can be degraded by microorganisms, at least partially, but others cannot. Temperature, pH, moisture content, ion exchange capacity of the soil, and air availability may limit the microbial degradation potential for even the most degradable organic compound.

Microorganisms

Viruses have been detected in groundwater where stormwater recharge basins were located short distances above the aquifer. Enteric viruses are more resistant to environmental factors than are enteric bacteria, and they exhibit longer survival times in natural waters. They can occur in potable and marine waters in the absence of fecal coliforms. Enteroviruses are also more resistant to commonly used disinfectants than are indicator bacteria (such as fecal coliforms), and they can occur in groundwater in the absence of indicator bacteria.

The factors that affect the survival of enteric bacteria and viruses in the soil include pH, antagonism from soil microflora, moisture content, temperature, sunlight, and organic matter. The two most important attributes of viruses that permit their long-term survival in the environment are their structure and very small size. These characteristics permit virus occlusion and protection within colloid-size particles. Viral adsorption is promoted by increasing cation concentration, decreasing pH, and decreasing soluble organics. Since the movement of viruses through soil to groundwater occurs in the liquid phase and involves water movement and associated suspended virus particles, the distribution of viruses between the adsorbed and liquid phases determines the viral mass available for movement. Once the virus reaches the groundwater, it can travel laterally through the aquifer until it is either adsorbed or inactivated.

The major bacterial removal mechanisms in soil are straining at the soil surface and at intergrain contacts, sedimentation, sorption by soil particles, and inactivation. Because their size is larger than viruses, most bacteria are retained near the soil surface because of this straining effect. In general, enteric bacteria survive in soil between 2 and 3 mo, although survival times up to 5 yr have been documented.

Metals

From a groundwater pollution standpoint, the metals in stormwater presenting the most environmental concern are aluminum, arsenic, cadmium, chromium, copper, iron, lead, mercury, nickel, and zinc. The majority of these metals (with the common exception of zinc) are, however, mostly associated with the particulate fractions and can be mostly removed by either sedimentation or filtration processes.

In general, studies of recharge basins receiving large metal loads found that most of the heavy metals are removed either in the basin sediment or in the vadose zone. Dissolved metal ions are removed from stormwater during infiltration mostly by adsorption onto the near-surface particles in the vadose zone, and the particulate metals are filtered out at the soil surface. Studies at recharge basins found that lead, zinc, cadmium, and copper accumulated at the soil surface with little downward movement over many years. At a commercial site, however, nickel, chromium, and zinc concentrations have exceeded regulatory limits in the soils below a recharge area. Allowing percolation ponds to go dry between storms can be counterproductive to the removal of lead from the water during recharge. Apparently, the adsorption bonds between the sediments and the metals can be weakened during the drying period.

Similarities in water quality between runoff water and groundwater have shown that there is significant downward movement of copper and iron in sandy and loamy soils. Arsenic, nickel, and lead, however, did not significantly move downward through the soil to the groundwater. The exception to this was some downward movement of lead with the percolation water in sandy soils beneath stormwater recharge basins. Zinc, which is more soluble than iron, has been found in higher concentrations in groundwater than iron. The order of attenuation in the vadose zone from infiltrating stormwater is: zinc (most mobile) > lead > cadmium > manganese > copper > iron > chromium > nickel > aluminum (least mobile).

Salts

Salt applications for winter traffic safety is a common practice in many northern areas, and the sodium and chloride, which are collected in the snowmelt, travel down through the vadose zone to the groundwater with little attenuation. Soil is not very effective at removing salts. Salts that are still in the percolation water after it travels through the vadose zone will contaminate the groundwater. Infiltrating stormwater has increased sodium and chloride concentrations above background concentrations. Fertilizer and pesticide salts also accumulate in urban areas and can leach through the soil to the groundwater.

Studies of depth of pollutant penetration in soil have shown that sulfate and potassium concentrations decrease with depth, whereas sodium, calcium, bicarbonate, and chloride concentrations increase with depth. Once contamination with salts begins, the movement of salts into the groundwater can be rapid. The salt concentration may not lessen until the source of the salts is removed.

Treatment of Stormwater

Table 3 summarizes the filterable fraction of toxicants found in runoff sheet flows from many urban areas found during an earlier phase of this EPA-funded research. Pollutants that are mostly in filterable forms have a greater potential of affecting groundwater and are more difficult to control with the use of conventional stormwater control practices which mostly rely on sedimentation and filtration principles. Luckily, most of the toxic organics and metals are associated with the nonfilterable (suspended solids) fraction of the wastewaters during wet weather. Possible exceptions include zinc, fluoranthene, pyrene, and 1,3-dichlorobenzene, which may be mostly found in the filtered sample portions. Pollutants in dry-weather storm drainage flows, however, tend to be much more associated with filtered sample fractions and would not be as readily controlled with the use of sedimentation.

Sedimentation is the most common fate and control mechanism for particulate-related pollutants. This would be common for most stormwater pollutants, as noted above. Particulate removal can occur in many conventional stormwater control processes, including catchbasins, screens, drainage systems, and detention ponds. Sorption of pollutants onto solids and metal precipitation increases the sedimentation potential of these pollutants and also encourages more efficient bonding of the pollutants in soils to prevent their leaching

SARB_005597

Table 3. *Reported Filterable Fractions of Stormwater Toxicants from Source Areas*

Constituent	Filterable Fraction (%)
Cadmium	20 to 50
Chromium	<10
Copper	<20
Iron	Small amount
Lead	<20
Nickel	Small amount
Zinc	>50
Benzo (a) anthracene	None found in filtered fraction
Fluoranthene	65
Naphthalene	25
Phenanthrene	None found in filtered fraction
Pyrene	95
Chlordane	None found in filtered fraction
Butyl benzyl phthalate	Irregular
Bis (2-chloroethyl) ether	Irregular
Bis (2-chlrorisopropyl) ether	None found in filtered fraction
1,3-Dichlorobenzene	75

to groundwaters. Detention ponds are probably the most common management practice for the control of stormwater runoff. If properly designed, constructed, and maintained, wet detention ponds can be very effective in controlling a wide range of pollutants. The monitored performance of wet detention ponds indicates more than 90% removal for suspended solids, 70% for BOD_5 and COD, about 60% to 70% for nutrients, and about 60% to 95% for heavy metals. Catchbasins are very small sedimentation devices. Adequate cleaning can help reduce the total solids and lead urban runoff yields by between 10% and 25%, and COD, total Kjeldahl nitrogen, total phosphorus, and zinc by between 5% and 10%. Other important fate mechanisms available in wet detention ponds, but which are probably not important in small enclosed sump devices such as catchbasins, include volatilization and photolysis. Biodegradation, biotransformation, and bioaccumulation (into plants and animals) may also occur in larger and open ponds.

Upland infiltration devices (such as infiltration trenches, porous pavements, percolation ponds, and grass roadside drainage swales) are located at urban source areas. Infiltration (percolation) ponds are usually located at stormwater outfalls or at large paved areas. These basins, along with perforated storm sewers, can infiltrate flows and pollutants from all upland sources combined. Infiltration devices can safely deliver large fractions of the surface flows to groundwater, if carefully designed and located. Local conditions that can make stormwater infiltration inappropriate include steep slopes, slowly percolating soils, shallow groundwater, and nearby groundwater uses. Grass filter strips may be quite effective in removing particulate pollutants from overland flows. The filtering effects of grasses, along with increased infiltration/recharge, reduce the particulate sediment load from urban landscaped areas. Grass swales are another type of infiltration device and can be used in place of curb and gutter drainages in most land uses, except possibly strip commercial and high density residential areas. Grass swales allow the recharge of significant amounts of surface flows. Swales can also reduce pollutant concentrations because of filtration. Soluble and particulate heavy metal (copper, lead, zinc, and cadmium) concentrations can be reduced by at least 50%, COD, nitrate nitrogen, and ammonia nitrogen concentrations can be reduced by about 25%, but only inconsistent concentration reductions can be expected for organic nitrogen, phosphorus, and bacteria.

Sorption of pollutants to soils is probably the most significant fate mechanism of toxicants in biofiltration devices. Many of the devices also use sedimentation and filtration to remove the particulate forms of the pollutants from the water. Incorporation of the pollutants onto soil with subsequent biodegradation and minimal leaching to the groundwater is desired. Volatilization, photolysis, biotransformation, and bioconcentration may also be significant in grass filter strips and grass swales. Underground seepage drains and porous pavements offer little biological activity to reduce toxicants.

Results and Conclusions

This entire research project will provide guidance on critical source area treatment, especially for the protection of groundwater quality. Much of the information will also be useful for analyzing stormwater problems and needed controls for surface water discharges.

Table 4 is a summary of the pollutants found in stormwater that may cause groundwater contamination problems for various reasons. This table does not consider the risk associated with using groundwater contaminated with these pollutants. Causes of concern include high mobility (low sorption potential) in the vadose zone, high abundance (high concentrations and high detection frequencies) in stormwater, and high soluble fractions (small fraction associated with particulates that would have little removal potential using conventional stormwater sedimentation controls) in the stormwater. The contamination potential is the lowest rating of the influencing factors. As an example, when no pretreatment is used before percolation through surface soils, the mobility and abundance criteria are most important. When a compound is mobile but in low abundance (such as for volatile organic compounds, VOCs), then the groundwater contamination potential would be low. When the compound is mobile, however, and also in high abundance (such as for sodium chloride, in certain conditions), then the groundwater contamination potential would be high. When sedimentation pretreatment is to be used before infiltration, then some of the pollutants will likely be removed before infiltration. In this case, all three influencing factors (pollutant mobility, pollutant abundance in stormwater, and fraction of the pollutant associated with the filtered sample fraction) would be considered. As an example, chlordane would have a low contamination potential with sedimentation pretreatment, whereas it would have a moderate contamination potential when no pretreatment is used. In addition, when subsurface infiltration/injection is used instead of surface percolation, the compounds would most likely be more mobile, making the abundance criteria the most important, with some regard given to the filterable fraction information for operational considerations.

This table is only appropriate for initial estimates of contamination potential because of the simplifying assumptions made, such as the worst case mobility conditions assumed (for sandy soils having low organic content). When the soil is clayey and has a high organic content, then most of the organic compounds would be less mobile than that shown on this table. The abundance and filterable fraction information is generally applicable for warm weather stormwater runoff in residential and commercial areas. The pollutant concentrations and detection

SARB_005598

frequencies, however, would be greater for critical source areas (especially vehicle service areas) and critical land uses (especially manufacturing industrial areas).

The stormwater pollutants of most concern (those that may have the greatest adverse impacts on groundwaters) include:

- Nutrients: nitrate has a low to moderate potential for contaminating groundwater when both surface percolation and subsurface infiltration/injection are used because of its relatively low concentrations in most stormwaters. When the stormwater nitrate concentration is high, then the groundwater contamination potential would likely also be high.
- Pesticides: lindane and chlordane have moderate potentials for contaminating groundwater when surface percolation (with no pretreatment) or when subsurface injection (with minimal pretreatment) are used. The groundwater contamination potentials for both of these compounds would very likely be substantially reduced with adequate sedimentation pretreatment.
- Other organics: 1,3-dichlorobenzene may have a high potential for contaminating groundwater when subsurface infiltration/injection (with minimal pretreatment) is used. It would, however, probably have a lower groundwater contamination potential for most surface percolation practices because of its relatively strong sorption to vadose zone soils. Both pyrene and fluoranthene would also very likely have high groundwater contamination potentials for subsurface infiltration/injection practices, but lower contamination potentials for surface percolation practices because of their more limited mobility through the unsaturated zone (vadose zone). Others (including benzo(a)anthracene, bis (2-ethylhexyl) phthalate, pentachlorophenol, and phenanthrene) may also have moderate groundwater contamination potentials when surface percolation with no pretreatment, or subsurface injection/infiltration, is used. These compounds would have low groundwater contamination potentials when surface infiltration is used with sedimentation pretreatment. VOCs may also have high groundwater contamination potentials if present in the stormwater (which is possible for some industrial and commercial facilities and vehicle service establishments).
- Pathogens: enteroviruses very likely have high potentials for contaminating groundwater when any percolation or subsurface infiltration/injection practice is used, depending on their presence in stormwater (especially if contaminated with sanitary sewage). Other pathogens, including *Shigella*, *Pseudomonas aeruginosa*, and various protozoa, would also have high groundwater contamination potentials when subsurface infiltration/injection practices are used without disinfection. When disinfection (especially by chlorine or ozone) is used, then disinfection by-products (such as trihalomethanes or ozonated bromides) would have high groundwater contamination potentials.
- Heavy Metals: nickel and zinc possibly have high potentials for contaminating groundwater when subsurface infiltration/injection is used. Chromium and lead would have moderate groundwater contamination potentials for subsurface infiltration/injection practices. All metals would possibly have low groundwater contamination potentials when surface infiltration is used with sedimentation pretreatment.
- Salts: chloride would very likely have a high potential for contaminating groundwater in northern areas where road salts are used for traffic safety, irrespective of the pretreatment, infiltration, or percolation practices used.

Pesticides have been mostly found in urban runoff from residential areas, especially in dry weather flows associated with landscaping irrigation runoff. The other organics, especially the volatiles, are mostly found in industrial areas. The phthalates are found in all areas. The PAHs are also found in runoff from all areas, but they are in higher concentrations and occur more frequently in industrial areas. Pathogens are most likely associated with sanitary sewage contamination of storm drainage systems, but several bacterial pathogens are commonly found in surface runoff in residential areas. Zinc is mostly found in roof runoff and other areas where galvanized metal comes into contact with rainwater. Salts are at their greatest concentrations in snowmelt and early spring runoff in northern areas.

The control of these compounds requires various approaches, including source area controls, end-of-pipe controls, and pollution prevention. All dry weather flows should be diverted from infiltration devices because of their potentially high concentrations of soluble heavy metals, pesticides, and pathogens. Similarly, all runoff from manufacturing industrial areas should also be diverted from infiltration devices because of their relatively high concentrations of soluble toxicants. Combined sewer overflows should also be diverted because of sewage contamination. In areas of snow and ice control, winter snowmelt and runoff and early spring runoff should also be diverted from infiltration devices.

All other runoff should include pretreatment using sedimentation processes before infiltration, to both minimize groundwater contamination and to prolong the life of the infiltration device (if needed). This pretreatment can take the form of grass filters, sediment sumps, wet detention ponds, etc., depending on the runoff volume to be treated, treatment flow rate, and other site specific factors. Pollution prevention can also play an important role in minimizing groundwater contamination problems, including reducing the use of galvanized metals, pesticides, and fertilizers in critical areas. The use of specialized treatment devices, such as those being developed and tested during this research, can also play an important role in treating runoff from critical source areas before these more contaminated flows commingle with cleaner runoff from other areas. Sophisticated treatment schemes, especially the use of chemical processes or disinfection, may not be warranted, except in special cases, especially when the potential of forming harmful treatment by-products (such as THMs and soluble aluminum) is considered.

The use of surface percolation devices (such as grass swales and percolation ponds) that have a substantial depth of underlying soils above the groundwater is preferable to the use of subsurface infiltration devices (such as dry wells, trenches or seepage drains, and especially injection wells), unless the runoff water is known to be relatively free of pollutants. Surface devices are able to take greater advantage of natural soil pollutant removal processes. Unless all percolation devices are carefully designed and maintained, however, they may not function properly and may lead to premature hydraulic failure or contamination of the groundwater.

Recommendations

With a reasonable degree of site-specific design considerations to compensate for soil characteristics, infiltration may be

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Table 4. *Potential of Stormwater Pollutants to Contaminate Groundwater*

Compounds		Mobility (sandy/low organic soils)	Abundance in Stormwater	Fraction Filterable	Contamination Potential: Surface Infilt. and No Pretreatment	Contamination Potential: Surface Infilt. with Sedimentation	Contamination Potential: Sub-surface Inj. with Minimal Pretreatment
Nutrients	nitrates	mobile	low/moderate	high	low/moderate	low/moderate	low/moderate
Pesticides	2,4-D	mobile	low	likely low	low	low	low
	γ-BHC (lindane)	intermediate	moderate	likely low	moderate	low	moderate
	malathion	mobile	low	likely low	low	low	low
	atrazine	mobile	low	likely low	low	low	low
	chlordane	intermediate	moderate	very low	moderate	low	moderate
	diazinon	mobile	low	likely low	low	low	low
Other organics	VOCs	mobile	low	very high	low	low	low
	1,3-dichloro-benzene	low	high	high	low	low	high
	anthracene	intermediate	low	moderate	low	low	low
	benzo(a) anthracene	intermediate	moderate	very low	moderate	low	moderate
	bis (2-ethylhexyl) phthalate	intermediate	moderate	likely low	moderate	low	moderate
	butyl benzyl phthalate	low	low/moderate	moderate	low	low	low/moderate
	fluoranthene	intermediate	high	high	moderate	moderate	high
	fluorene	intermediate	low	likely low	low	low	low
	naphthalene	low/inter.	low	moderate	low	low	low
	pentachlorophenol	intermediate	moderate	likely low	moderate	low	moderate
	phenanthrene	intermediate	moderate	very low	moderate	low	moderate
	pyrene	intermediate	high	high	moderate	moderate	high
Pathogens	enteroviruses	mobile	likely present	high	high	high	high
	Shigella	low/inter.	likely present	moderate	low/moderate	low/moderate	high
	Pseudomonas aeruginosa	low/inter.	very high	moderate	low/moderate	low/moderate	high
	protozoa	low/inter.	likely present	moderate	low/moderate	low/moderate	high
Heavy metals	nickel	low	high	low	low	low	high
	cadmium	low	low	moderate	low	low	low
	chromium	inter./very low	moderate	very low	low/moderate	low	moderate
	lead	very low	moderate	very low	low	low	moderate
	zinc	low/very low	high	high	low	low	high
Salts	chloride	mobile	seasonally high	high	high	high	high

very effective in controlling both urban runoff quality and quantity problems. This strategy encourages infiltration of urban runoff to replace the natural infiltration capacity lost through urbanization and to use the natural filtering and sorption capacity of soils to remove pollutants; however, the potential for some types of urban runoff to contaminate groundwater through infiltration requires some restrictions. Infiltration of urban runoff having potentially high concentrations of pollutants that may pollute groundwater requires adequate pretreatment or the diversion of these waters away from infiltration devices. The following general guidelines for the infiltration of stormwater and other storm drainage effluent are recommended in the absence of comprehensive site-specific evaluations:

- Dry weather storm drainage effluent should be diverted from infiltration devices because of their probable high concentrations of soluble heavy metals, pesticides, and pathogenic microorganisms.
- Combined sewage overflows should be diverted from infiltration devices because of their poor water quality, especially their high pathogenic microorganism concentrations and high clogging potential.
- Snowmelt runoff should be diverted from infiltration devices because of its potential for having high concentrations of soluble salts.
- Runoff from manufacturing industrial areas should be diverted from infiltration devices because of its potential for having high concentrations of soluble toxicants.
- Construction site runoff must be diverted from stormwater infiltration devices (especially subsurface devices) because of its high suspended solids concentrations, which would quickly clog infiltration devices.
- Runoff from other critical source areas, such as vehicle service facilities and large parking areas, should at least receive adequate pretreatment to eliminate their groundwater contamination potential before infiltration.
- Runoff from residential areas (the largest component of urban runoff in most cities) is generally the least polluted urban runoff flow and should be considered for infiltration. Very little treat-

SARB_005600

ment of residential area stormwater runoff should be needed before infiltration, especially if surface infiltration is through the use of grass swales. When subsurface infiltration (seepage drains, infiltration trenches, dry wells, etc.) is used, then some pretreatment may be needed, such as by using grass filter strips, or other surface filtration devices.

Recommended Stormwater Quality Monitoring to Evaluate Potential Groundwater Contamination

Most past stormwater quality monitoring efforts have not adequately evaluated stormwater's potential for contaminating groundwater. The following list shows the stormwater contaminants that are recommended for monitoring when stormwater contamination potential needs to be considered, or when infiltration devices are to be used. Other analyses are appropriate for additional monitoring objectives (such as evaluating surface water problems). In addition, all phases of urban runoff should be sampled, including stormwater runoff, dry-weather flows, and snowmelts.

- Urban runoff contaminates with the potential to adversely affect groundwater:
  - Nutrients (especially nitrates)
  - Salts (especially chloride)
  - VOCs (if expected in the runoff, such as runoff from manufacturing industrial or vehicle service areas, could screen for VOCs with purgable organic carbon analyses)
  - Pathogens (especially enteroviruses, if possible, along with other pathogens such as *Pseudomonas aeruginosa*, *Shigella*, and pathogenic protozoa)
  - Bromide and total organic carbon (to estimate disinfection by-product generation potential, if disinfection by either chlorination or ozone is being considered)
  - Pesticides, in both filterable and total sample components (especially lindane and chlordane)
  - Other organics, in both filterable and total sample components (especially 1,3 dichlorobenzene, pyrene, fluoranthene, benzo(a)anthracene, bis (2-ethylhexyl) phthalate, pentachlorophenol, and phenanthrene)
  - Heavy metals, in both filterable and total sample components (especially chromium, lead, nickel, and zinc)
- Urban runoff compounds with the potential to adversely affect infiltration and injection operations:
  - Sodium, calcium, and magnesium (to calculate the sodium adsorption ratio to predict clogging of clay soils)
  - Suspended solids (to determine the need for sedimentation pretreatment to prevent clogging)

SARB_005601

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***Richard Field** is the EPA Project Officer (see below).*
The complete report, entitled "Potential Groundwater Contamination from Intentional and Nonintentional Stormwater Infiltration," (Order No. PB94-165354AS; Cost: $27.00, subject to change) will be available only from:
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Effluent Guidelines

Preliminary Studies

Preliminary Data Summary of Urban Stormwater Best Management Practices

EPA-821-R-99-012; August 1999

EPA conducted a study of urban storm water discharges in 1997-98 to explore how the Effluent Guidelines program can contribute to the Agency's efforts in implementing the national storm water program requirements under Section 402(p) of the Clean Water Act. The study is intended to complement the ongoing implementation of the National Pollutant Discharge Elimination System (NPDES) Storm Water permit program.

The study is based largely on existing literature and data on best management practices (BMPs) that are used to control urban storm water runoff. Topics covered include: BMP performance measures and measurable goals, availability of measurement methods, design criteria, monitoring issues, costs and cost minimization opportunities, and the benefits and economic impacts of constructing and operating BMPs.

SARB_005603

The discussion of BMP performance includes structural BMPs such as infiltration devices, ponds, filters and constructed wetlands; and the effectiveness of non-structural BMPs, low impact development practices and management measures such as maintenance practices, street sweeping, public education and outreach programs. Literature sources include BMP performance studies compiled for the new National Storm Water BMP Database and BMP design manuals and guidance prepared by EPA and other Federal agencies, states and local governments.

In early 1999, shortly after completion of this report, EPA began development of Effluent Guidelines for the Construction and Development Industry, focusing on storm water discharges.

- Download Report
- National Storm Water BMP Database
- Storm Water Links

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  - Chapter 3: Existing Storm Water Regulations and Permits
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  - Chapter 4: Environmental Assessment
- Part C (PDF) (86 pages, 756 K)
  - Chapter 5: Description and Performance of Storm Water Best Management Practices
- Part D (PDF) (45 pages, 841 K)
  - hapter 6: Costs and Benefits of Storm Water BMPs
- Part E (PDF) (17 pages, 109 K)
  - References and Index

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National Storm Water BMP Database

The American Society of Civil Engineers has developed a comprehensive database on BMP performance under an EPA cooperative agreement. The long-term goal of the project is to promote technical design improvements for BMPs and to better match their selection and design to the local storm water problems being addressed.

EPA and ASCE invite organizations who have conducted BMP performance monitoring to submit their data to the database and share their findings with the public.

- National Stormwater BMP Database EXIT Disclaimer
- Urban Stormwater BMP Performance Monitoring: Manual on conducting monitoring for assessing BMP effectiveness

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Storm Water Links

- NPDES Storm Water Permit Program
- Effluent Guidelines for the Construction and Development Category
- Other Stormwater Links: EPA, state and local governments, and non-profit organizations

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Print As-Is

United States
Environmental Protection Agency

Office of Water (4203)
Washington, DC 20460

EPA-841-B-00-005B
October 2000

Field Evaluation of Permeable Pavements for Stormwater Management

Olympia, Washington

Key Concepts:

- Structural Controls
- Volume Reduction
- Space Savings

LOW-IMPACT DEVELOPMENT CENTER

Project Benefits:

- Elimination of Stormwater Ponds
- Demonstration of Water Quality Benefits
- Lower Maintenance

Introduction

This study demonstrates the potential of permeable pavement systems to restore soil infiltration functions in the urban landscape. It is based on the results of a project that included installing and monitoring several porous pavement systems in a parking area. The project's objectives were to

- Review existing information on permeable pavements
- Construct full-scale test sites
- Evaluate the long-term performance of these systems

The report outlines the difficulties encountered, costs of installing and maintaining the systems, performance based on existing soil systems, special benefits of filling the open cells with grass as opposed to gravel, and other water quality benefits.

Project Area

The demonstration site was in an office parking lot in Olympia, Washington. Two adjacent parking stalls were constructed using four types of permeable pavement systems that consisted of a combination of grass and gravel, as shown in Figure 1. The designs were

1. A flexible system consisting of a plastic network of cells with grass infill and virtually no impervious area coverage.
2. A flexible system consisting of a plastic network of cells similar to design 1 but filled with gravel.
3. A system consisting of impervious blocks with the space between the blocks filled with grass. (Total surface area is 60 percent impervious).
4. A system consisting of impervious blocks with the space between the blocks filled with gravel. (Total surface area is 90 percent impervious).

A control stall was constructed out of traditional asphalt. A system of pipes, gutters, and automatic sampling gauges was installed to collect and measure the quantity and chemistry of surface runoff and subsurface infiltrate. Figure 2 shows a schematic of the test facility.

Figure 1. Different types of permeable pavement. From top left: reinforced gravel and grass pavement, reinforced grass pavement, 60% impervious concrete blocks with grass, 90% impervious blocks with gravel.

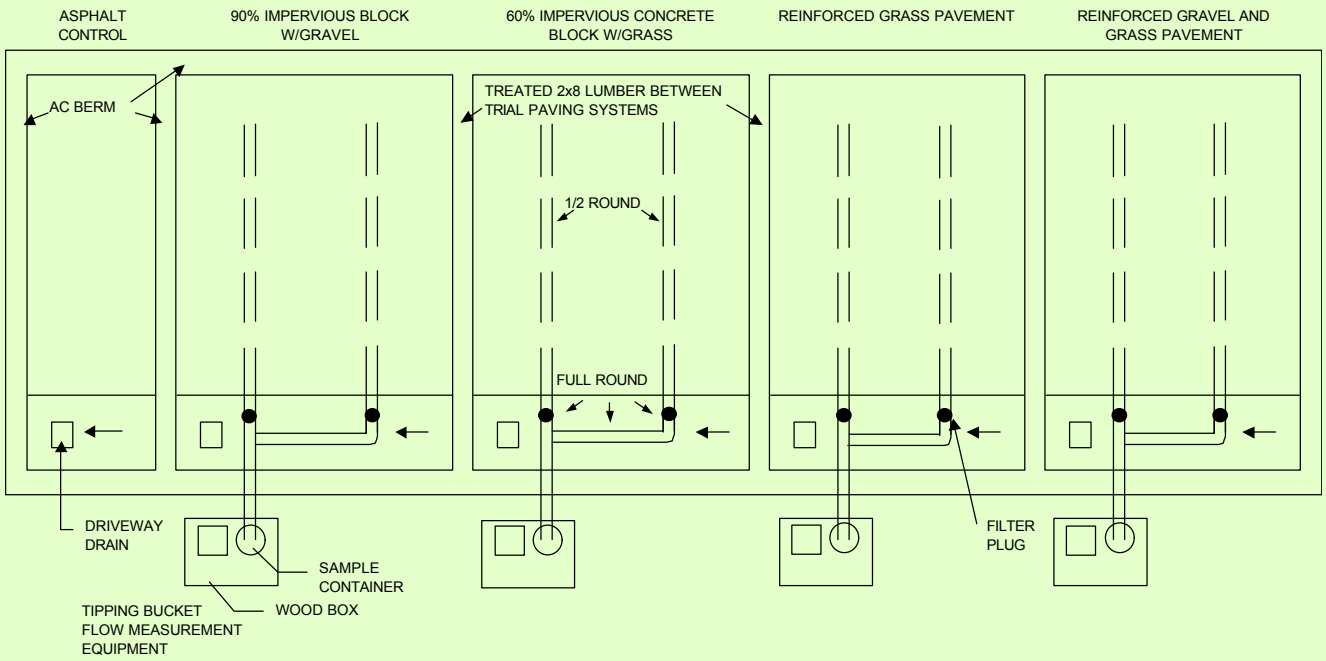

Figure 2. Schematic of the test facility showing treatments and runoff collection devices.

Project Summary and Benefits

The results of this study showed the following relationships:

- The use of permeable pavement systems dramatically reduced surface runoff volume and attenuated the peak discharge, as shown in Figure 3.
- Although there were significant structural differences between the systems, the hydrologic benefits were consistent.
- Storm characteristics and weather conditions influenced the hydrologic responses of the systems.
- Permeable pavement system types vary widely in cost and are more expensive than typical asphalt pavements. Cost comparisons between permeable pavement installations and conventional ponds or underground vaults are limited. However, the elimination of conventional systems and reduced life cycle and maintenance costs can result in significant cost savings over the long term.
- A significant contribution of permeable pavements is the ability to reduce *effective impervious area*, which has a direct connection with downstream drainage systems. This strategy of hydrologic and hydraulic disconnectivity can be used to control runoff timing, reduce runoff volume, and provide water quality benefits.

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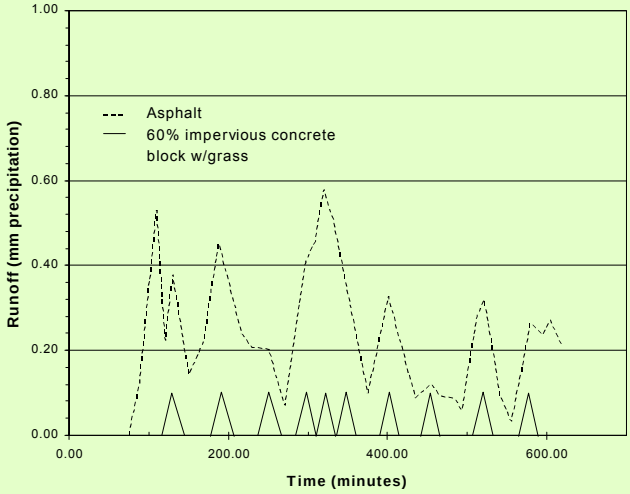

Figure 3. Runoff volumes from asphalt and permeable pavements.

United States Environmental Protection Agency
Office of Water (4203) Washington, DC 20460
EPA-841-B-00-005 October 2000

LOW-IMPACT DEVELOPMENT CENTER

Low Impact Development (LID)

A Literature Review

SARB_005609

EXECUTIVE SUMMARY

A literature review was conducted to determine the availability and reliability of data to assess the effectiveness of low impact development (LID) practices for controlling stormwater runoff volume and reducing pollutant loadings to receiving waters.

Background information concerning the uses, ownership and associated costs for LID measures was also compiled. In general LID measures are more cost effective and lower in maintenance than conventional, structural stormwater controls. Not all sites are suitable for LID. Considerations such as soil permeablility, depth of water table and slope must be considered, in addition to other factors. Further, the use of LID may not completely replace the need for conventional stormwater controls.

Maintenance issues can be more complicated than for conventional stormwater controls because the LID measures reside on private property. In most instances, homeowners agree to only the first year of maintenance. Homeowner associations could be a mechanism for providing long-term maintenance to these areas. Generally, bioretention facilities require replacement of dead or diseased vegetation, remulching as needed, and replacement of soils after 5–10 years. Grass swales require periodic mowing and removal of sediments. Maintenance of permeable pavements requires annual high-powered vacuuming of the area to remove sediments.

Several studies have been conducted to analyze the effectiveness of various LID practices based on hydrology and pollutant removal capabilities. Bioretention areas, grass swales, permeable pavements and vegetated roof tops were the most common practices studied. These techniques reduce the amount of Effective Impervious Area (EIA) in a watershed. EIA is the directly connected impervious area to the storm drain system and contributes to increased watershed volumes and runoff rates. There are documented case studies that conclusively link urbanization and increased watershed imperviousness to hydrologic impacts on streams. Existing reports and case studies provide strong evidence that urbanization negatively affects streams and results in water quality problems such as loss of habitat, increased temperatures, sedimentation and loss of fish populations (USEPA, 1997)

In general bioretention areas were found to be effective in reducing runoff volume and in treating the first flush (first ½ inch) of stormwater. Results from three different studies indicate that removal efficiencies were quite good for both metals and nutrients. Removal rates for metals were more consistent than for nutrients. Removal rates for metals ranged from 70–97% for lead, 43–97% for copper and 64–98% for zinc. Nutrient removal was more variable and ranged from 0–87% for phosphorus, 37–80% for Total Kjeldahl Nitrogen, <0–92% for ammonium and for nitrate <0–26%. Effluent volumes were lower than influent volumes. These studies were conducted by means of simulated rainfall events. Analysis of actual long-term rainfall events would produce more reliable data.

The effectiveness of grass swales was also quite good for both pollutant removal and runoff volume reduction. A study of three different sites in the United States reveal similar results despite the differences in location. In general, performance of swales is

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dependant on not only channel length, but also longitudinal slope and the use of check dams to slow flows and allow for greater infiltration. Further, the removal of metals was found to be directly related to the removal rate of total suspended solids, and the removal rate of metals was greater than removal of nutrients.

Reduction of impervious surfaces can greatly reduce the volume of runoff generated by rainfall. Several methods can be employed to reduce total impervious surface area. Permeable pavements and vegetated rooftops are two methods to accomplish this goal. Vegetated rooftops have been used extensively in Germany for more than 25 years and results show up to 50% reduction in annual runoff in temperate climates. Many opportunities exist to retrofit these systems into older highly urbanized areas of the United States. The Philadelphia project case study provides an example of this practice.

Permeable pavements can also reduce impervious surfaces. However, they are more expensive to construct than traditional asphalt pavements. Costs of these systems may be off set by the reduction of traditional curb and gutter systems to convey stormwater. Benefits of these alternate pavement types include better infiltration, ground water recharge, reduction in runoff volume and treatment of stormwater for pollutants. The study conducted in Tampa, Florida outlines these benefits as well as the opportunity to retrofit permeable pavements into existing parking lots with little or no loss of parking space. Less than 20% of rainfall was converted to runoff when using permeable pavements. Study results from the University of Washington, compare several different treatments of varying permeablility. The study shows that the higher the amount of perviousness of the treatment, the greater the reduction of runoff volume and pollutant loadings.

The use of LID is relatively new and not widespread. Most of the available data are from Prince George's County, Maryland, which pioneered the use of LID. The data available for bioretention analysis were from single simulated storm events in actual bioretention facilities or from laboratory constructed and tested bioretention systems. The data for grass swales were for only a few storm events, collected over a short period of time. The only available data for a long-term study came from the Aquarium parking lot in Tampa, Florida and the Washington permeable pavement project. More long-term analysis is required to more accurately assess the effectiveness of LID and to determine long term trends.

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1 LOW IMPACT DEVELOPMENT

1.1 Introduction

Low impact development (LID) is a relatively new concept in stormwater management. LID techniques were pioneered by Prince George's County, Maryland, in the early 1990's, and several projects have been implemented within the state. Some LID principles are now being applied in other parts of the country, however, the use of LID is infrequent and opportunities are often not investigated. The purpose of this report is to conduct a literature review to determine existing information about the application of LID in new development and existing urbanized areas, including ownership, operation and maintenance issues. A related objective was to locate relevant studies of LID projects, which would provide evidence of the effectiveness of LID in retaining predevelopment hydrology and as a mechanism for pollutant removal for stormwater. The data from the studies were analyzed for usefulness and validity and the findings are summarized.

LID is a site design strategy with a goal of maintaining or replicating the pre-development hydrologic regime through the use of design techniques to create a functionally equivalent hydrologic landscape. Hydrologic functions of storage, infiltration, and ground water recharge, as well as the volume and frequency of discharges are maintained through the use of integrated and distributed micro-scale stormwater retention and detention areas, reduction of impervious surfaces, and the lengthening of flow paths and runoff time (Coffman, 2000). Other strategies include the preservation/protection of environmentally sensitive site features such as riparian buffers, wetlands, steep slopes, valuable (mature) trees, flood plains, woodlands and highly permeable soils.

LID principles are based on controlling stormwater at the source by the use of micro-scale controls that are distributed throughout the site. This is unlike conventional approaches that typically convey and manage runoff in large facilities located at the base of drainage areas. These multifunctional site designs incorporate alternative stormwater management practices such as functional landscape that act as stormwater facilities, flatter grades, depression storage and open drainage swales. This system of controls can reduce or eliminate the need for a centralized best management practice (BMP) facility for the control of stormwater runoff. Although traditional stormwater control measures have been documented to effectively remove pollutants, the natural hydrology is still negatively affected (inadequate base flow, thermal fluxes or flashy hydrology), which can have detrimental effects on ecosystems, even when water quality is not compromised (Coffman, 2000). LID practices offer an additional benefit in that they can be integrated into the infrastructure and are more cost effective and aesthetically pleasing than traditional, structural stormwater conveyance systems.

Conventional stormwater conveyance systems are designed to collect, convey and discharge runoff as efficiently as possible. The intent is to create a highly efficient drainage system, which will prevent on lot flooding, promote good drainage and quickly convey runoff to a BMP or stream. This runoff control system decreases groundwater

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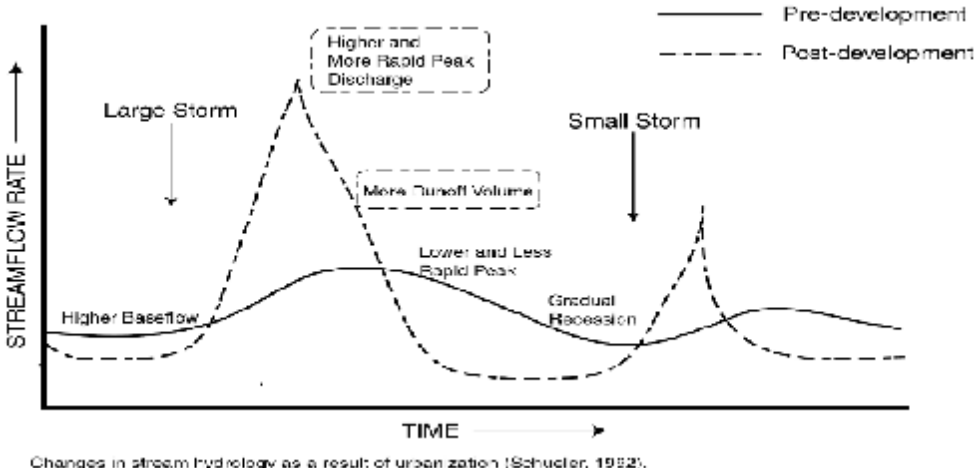
recharge, increases runoff volume and changes the timing, frequency and rate of discharge. These changes can cause flooding, water quality degradation, stream erosion and the need to construct end of pipe BMPs. Discharge rates using traditional BMPs may be set only to match the predevelopment peak rate for a specific design year. This approach only controls the rate of runoff allowing significant increases in runoff volume, frequency and duration of runoff from the predevelopment conditions and provides the mechanisms for further degradation of receiving waters (Figure 1).

LID has often been compared to other innovative practices, such as Conservation Design, which uses similar approaches in reducing the impacts of development, such as reduction of impervious surfaces and conservation of natural features. Although the goals of Conservation Design protect natural flow paths and existing vegetative features, stormwater is not treated directly at the source. Conservation Design protects large areas adjacent to the development site and stormwater is directed to these common areas.



Changes in stream hydrology as a result of urbanization (Schueler, 1992).

Figure 1: Changes in Stormwater Hydrology as a Result of Urbanization

Although this approach protects trees and does reduce runoff, there is still potentially a significant amount of connected impervious area and centralized stormwater facilities that may contribute to stream degradation through stormwater volume, frequency and thermal impacts. Therefore, the hydrologic and hydraulic impacts of this approach on receiving waters may still be significant, although the volume and flows will be less than without the conservation design. The stormwater control measures used in Conservation Design are off-site and therefore not the individual property owner's responsibility. However, maintenance is generally provided by the homeowners association and financed through association fees.

1.2 Benefits and Limitations

The use of LID practices offers both economical and environmental benefits. LID measures result in less disturbance of the development area, conservation of natural features and can be less cost intensive than traditional stormwater control mechanisms. Cost savings for control mechanisms are not only for construction, but also for long-term

maintenance and life cycle cost considerations. For example, an alternative LID stormwater control design for a new 270 unit apartment complex in Aberdeen, NC will save the developer approximately 72% or $175,000 of the stormwater construction costs. On this project, almost all of the subsurface collection systems associated with curb and gutter projects have been eliminated. Strategically located bioretention areas, compact weir outfalls, depressions, grass channels, wetland swales and specially designed storm water basins are some of the LID techniques used. These design features allow for longer flow paths, reduce the amount of polluted runoff and filter pollutants from stormwater runoff (Blue Land, Water and Infrastructure, 2000).

Today many states are facing the issue of urban sprawl, a form of development that consumes green space, promotes auto dependency and widens urban fringes, which puts pressure on environmentally sensitive areas. "Smart growth" strategies are designed to reconfigure development in a more eco-efficient and community oriented style. LID addresses many of the environmental practices that are essential to smart growth strategies including the conservation of open green space. LID does not address the subject of availability of public transportation.

LID provides many opportunities to retrofit existing highly urbanized areas with pollution controls, as well as address environmental issues in newly developed areas. LID techniques such as rooftop retention, permeable pavements, bioretention and disconnecting rooftop rain gutter spouts are valuable tools that can be used in urban areas. For example, stormwater flows can easily be directed into rain barrels, cisterns or across vegetated areas in high-density urban areas. Further, opportunities exist to implement bioretention systems in parking lots with little or no reduction in parking space. The use of vegetated rooftops and permeable pavements are 2 ways to reduce impervious surfaces in highly urbanized areas.

LID techniques can be applied to a range of lot sizes. The use of LID, however, may necessitate the use of structural BMPs in conjunction with LID techniques in order to achieve watershed objectives. The appropriateness of LID practices is dependent on site conditions, and is not based strictly on spatial limitations. Evaluation of soil permeability, slope and water table depth must be considered in order to effectively use LID practices. Another obstacle is that many communities have development rules that may restrict innovative practices that would reduce impervious cover. These "rules" refer to a mix of subdivision codes, zoning regulations, parking and street standards and other local ordinances that determine how development happens (Center for Watershed Protection, 1998). These rules are responsible for wide streets, expansive parking lots and large-lot subdivisions that reduce open space and natural features. These obstacles are often difficult to overcome.

Additionally, community perception of LID may prevent its implementation. Many homeowners want large-lots and wide streets and view reduction of these features as undesirable and even unsafe. Furthermore, many people believe that without conventional controls, such as curbs and gutters and end of pipe BMPs, they will be required to contend with basement flooding and subsurface structural damage.

2 LOW IMPACT DEVELOPMENT PRACTICES

LID measures provide a means to address both pollutant removal and the protection of predevelopment hydrological functions. Some basic LID principles include conservation of natural features, minimization of impervious surfaces, hydraulic disconnects, disbursement of runoff and phytoremediation. LID practices such as bioretention facilities or rain gardens, grass swales and channels, vegetated rooftops, rain barrels, cisterns, vegetated filter strips and permeable pavements perform both runoff volume reduction and pollutant filtering functions.

2.1 Bioretention

Bioretention systems are designed based on soil types, site conditions and land uses. A bioretention area can be composed of a mix of functional components, each performing different functions in the removal of pollutants and attenuation of stormwater runoff (Figure 2).

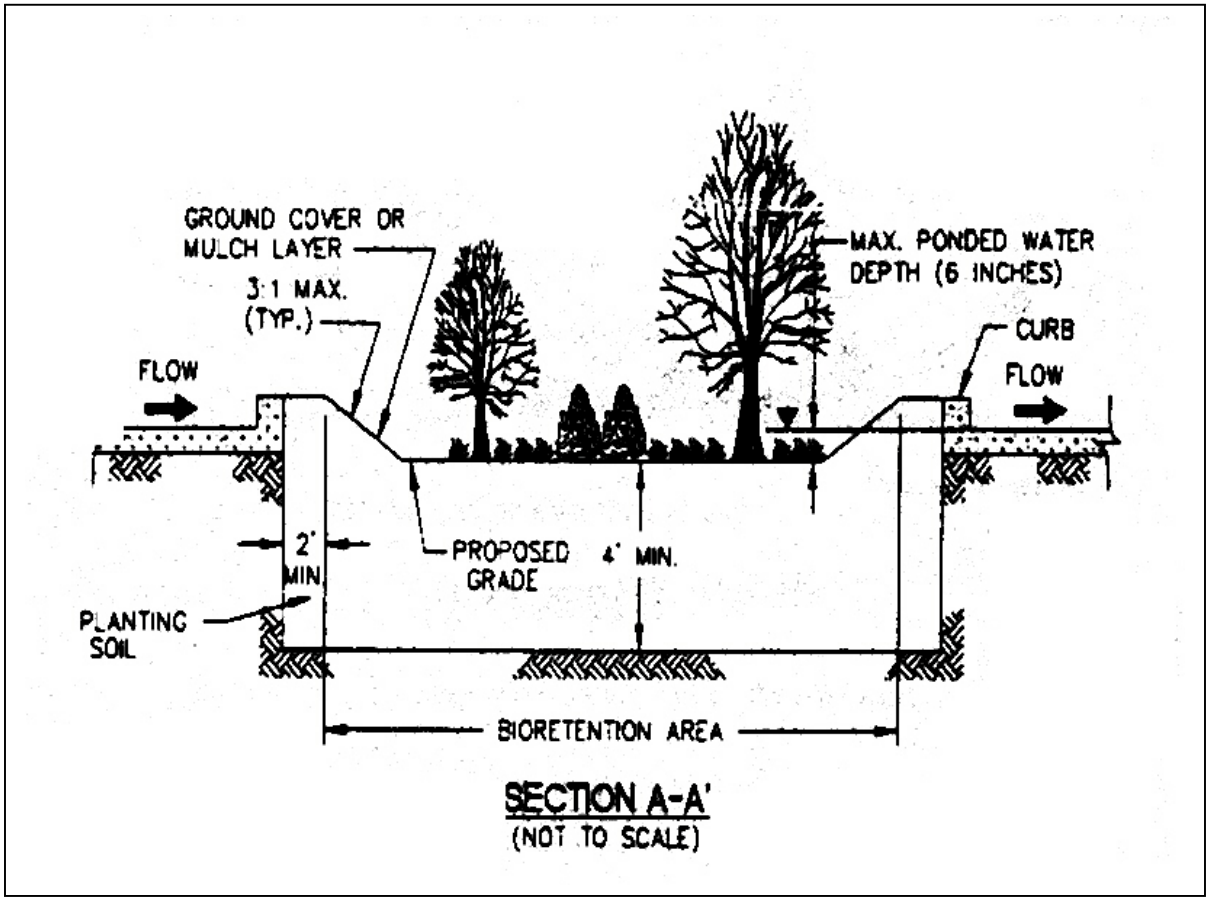


Figure 2: Typical Bioretention System (Prince George's County Department of Environmental Resources, 1993)

Six typical components found in bioretention cells:

- Grass buffer strips reduce runoff velocity and filter particulate matter.
- Sand bed provides aeration and drainage of the planting soil and assists in the flushing of pollutants from soil materials.
- Ponding area provides storage of excess runoff and facilitates the settling of particulates and evaporation of excess water.
- Organic layer performs the function of decomposition of organic material by providing a medium for biological growth (such as microorganisms) to degrade petroleum-based pollutants. It also filters pollutants and prevents soil erosion.
- Planting soil provides the area for stormwater storage and nutrient uptake by plants. The planting soils contain some clays which adsorb pollutants such as hydrocarbons, heavy metals and nutrients.
- Vegetation (plants) functions in the removal of water through evapotranspiration and pollutant removal through nutrient cycling.

Bioretention facilities are less cost intensive than traditional structural stormwater conveyance systems. Construction of a typical bioretention area in Prince George's County, Maryland is between $5,000 and $10,000 per acre drained, depending on soil type (Weinstein, 2000). Other sources estimate the costs for developing bioretention sites at between $3 and $15 per square foot of bioretention area. Design guidelines recommend that bioretention systems occupy 5-7% of the drainage basin. Additional savings can be realized in reduced construction costs for storm drainpipe. For example, bioretention practices reduced the amount of storm drain pipe at a Medical Office building in Prince George's County, Maryland from 800 to 230 feet, which resulted in a cost savings of $24,000 or 50% of the overall drainage cost for the site (Dept. of Env. Resources, 1993).

Components of the bioretention area should meet required guidelines in order to provide the most productive system possible. The mulch layer should be approximately 2-3 inches thick and replaced annually. Soil should be tested for several criteria before being used.

- pH range 5.5–6.5
- Organic matter 1.5–3.0%
- Magnesium (Mg) 35lbs/acre
- Phosphorus (P2O5) 100lbs/acre
- Potassium (K2O) 85lbs/acre
- Soluble salts < 500 ppm

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Plant material should be obtained from certified nurseries that have been inspected by state or federal agencies (Dept. of Env. Resources, 1993). Native species should be used and selected according to their moisture regime, morphology, susceptibility to pests and diseases and tolerance to pollutants. Selection of plant species should be based on site conditions and ecological factors. A minimum of three species of trees and three species of shrubs should be selected to insure diversity, differing rates of transpiration and ensure a more constant rate of evapotransportation and nutrient and pollutant uptake throughout the growing season (Dept. of Env. Resources, 1993). Species that require regular maintenance should be avoided or restricted. Prince George's County recommends a warranty be established with the nursery as part of the plant installation, and should include care and 80% replacement of plants for the first year.

Table 1: Example Maintenance Schedule for Bioretention Areas (Prince George's County, Department of Environmental Resources, 1993)

Description	Method	Frequency	Time of Year
Soil			
Inspect and Repair Erosion	Visual	Monthly	Monthly
Organic Layer			
Remulch void areas	By Hand	As Needed	As Needed
Remove previous mulch layer before applying new layer (optional)	By Hand	Once a Year	Spring
Additional mulch added (optional)	By Hand	Once a Year	Spring
Plants			
Remove and replace all dead and diseased vegetation that cannot be treated	See Planting Specifications	Twice a Year	Mar 15–Apr 30 and Oct 1–Nov 30
Treat all diseased trees and shrubs	Mechanical or by Hand	N/A	Varies, depends on insect or disease infestation
Water of plant materials, at the end of the day for 14 consecutive days after planting	By Hand	Immediately after Completion of Projects	N/A
Replace stakes after one year	By Hand	Once a Year	Remove only in the Spring
Replace deficient stakes or wires	By Hand	N/A	As Needed

Annual maintenance is required for the overall success of bioretention systems. This includes maintenance of plant material, soil layer and the mulch layer. A maintenance schedule outlining methods, frequency and time of year for bioretention maintenance should be developed. Table 1 is a typical maintenance checklist. Plants will provide enhanced environmental benefit over time as root systems and leaf canopies increase in size and pollutant uptake and removal efficiencies. Soils, however, begin filtering pollutants immediately and can lose their ability to function in this capacity over time. Therefore, evaluation of soil fertility is important in maintaining an effective bioretention system. Substances in runoff such as nutrients and metals eventually disrupt normal soil

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functions by lowering the cation exchange capacity (CEC) (Dept. of Env. Resources, 1993). CEC is the soil's ability to adsorb pollutant particles through ion attraction and will decrease over time. It is recommended that soils be tested annually and replaced when soil fertility is lost. Depending on environmental factors, this usually occurs within 5-10 years of construction. Replacement of soil can be accomplished in 1-2 days for approximately $1,000-$2,000 for a typical system which will drain one acre in the northeastern U.S. (Weinstein, 2000).

2.2 Grass Swales

Grass swales or channels are adaptable to a variety of site conditions, are flexible in design and layout, and are relatively inexpensive (USDOT, 1996). Generally open channel systems are most appropriate for smaller drainage areas with mildly sloping topography (Center for Watershed Protection, 1998). Their application is primarily along residential streets and highways. They function as a mechanism to reduce runoff velocity and as filtration/infiltration devices. Sedimentation is the primary pollutant removal mechanism, with additional secondary mechanisms of infiltration and adsorption. In general grass channels are most effective when the flow depth is minimized and detention time is maximized. The stability of the channel or overland flow is dependant on the erodibility of the soils in which the channel is constructed (USDOT, 1996). Decreasing the slope or providing dense cover will aid in both stability and pollutant removal effectiveness.

Engineered swales are less costly than installing curb and gutter/storm drain inlet and storm drain pipe systems. The cost for traditional structural conveyance systems ranges from $40–$50 per running foot. This is two to three times more expensive than an engineered grass swale (Center for Watershed Protection, 1998). Concerns that open channels are potential nuisance problems, present maintenance problems, or impact pavement stability can be alleviated by proper design. Periodic removal of sediments and mowing are the most significant maintenance requirements.

2.3 Vegetated Roof Covers

Vegetative roof covers or green roofs are an effective means of reducing urban stormwater runoff by reducing the percentage of impervious surfaces in urban areas. They are especially effective in older urban areas with chronic combined sewer overflow (CSO) problems, due to the high level of imperviousness. The green roof is a multilayered constructed material consisting of a vegetative layer, media, a geotextile layer and a synthetic drain layer. Vegetated roof covers in urban areas offer a variety of benefits, such as extending the life of roofs, reducing energy costs and conserving valuable land that would otherwise be required for stormwater runoff controls. Green roofs have been used extensively in Europe to accomplish these objectives. Many opportunities are available to apply this LID measure in older U.S. cities with stormwater infrastructures that have reached their capacities.

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Green roofs are highly effective in reducing total runoff volume. Simple vegetated roof covers, with approximately 3 inches of substrate can reduce annual runoff by more than 50 percent in temperate climates (Miller, 2000). Research in Germany shows that the 3-inch design offers the highest benefit to cost ratio. Properly designed systems not only reduce runoff flows, but also can be added to existing rooftops without additional reinforcement or structural design requirements. The value of green roofs for reducing runoff is directly linked to the design rainfall event considered. Design should be developed for the storm events that most significantly contribute to CSOs, hydraulic overloads and runoff problems for a given area.

2.4 Permeable Pavements

The use of permeable pavements is an effective means of reducing the percent of imperviousness in a drainage basin. More than thirty different studies have documented that stream, lake and wetland quality is reduced sharply when impervious cover in an upstream watershed is greater than 10%. Porous pavements are best suited for low traffic areas, such as parking lots and sidewalks. The most successful installations of alternative pavements are found in coastal areas with sandy soils and flatter slopes (Center for Watershed Protection, 1998). Permeable pavements allow stormwater to infiltrate into underlying soils promoting pollutant treatment and recharge, as opposed to producing large volumes of rainfall runoff requiring conveyance and treatment. Costs for paving blocks and stones range from $2 to $4, whereas asphalt costs $0.50 to $1 (Center for Watershed Protection, 1998).

2.5 Other LID Strategies

Another strategy to minimize the impacts of development is the implementation of rain gutter disconnects. This practice involves redirecting rooftop runoff conveyed in rain gutters out of storm sewers, and into grass swales, bioretention systems and other functional landscape devices. Redirecting runoff from rooftops into functional landscape areas can significantly reduce runoff flow to surface waters and reduce the number of CSO events in urban areas. As long as the stormwater is transported well away from foundations, concerns of structural damage and basement flooding can be alleviated. As an alternative to redirection of stormwater to functional landscape, rain gutter flows can be directed into rain barrels or cisterns for later use in irrigating lawns and gardens. Disconnections of rain gutters can effectively be implemented on existing properties with little change to present site designs.

Many strategies exist to reduce the amount of impervious surface in development areas. Designing residential streets for the minimum required width needed to support traffic, on-street parking and emergency service vehicles, can reduce imperviousness. Other practices include shared driveways and parking lots, alternative pavements for overflow parking areas, center islands in cul-de-sacs, alternative street designs rather than traditional grid patterns and reduced setbacks and frontages for homes.

3 EVALUATION OF LID EFFECTIVENESS

3.1 Hydrological Measures

Enhancements in site drainage from traditional stormwater control measures, such as curbs and gutters that eliminate potential on-site flooding, often result in an increase in surface runoff. These alterations can cause an increase in volume, frequency and velocity of runoff flows, resulting in flooding, high erosion and a reduction in groundwater infiltration, as well as a reduction in water quality and habitat degradation. Four hydrological functions should be considered when investigating the effectiveness of LID practices. The runoff curve number (CN), time of concentration, retention and detention. LID techniques and the hydrological design and analysis components are represented in (Table 2).

Table 2: Low Impact Hydrologic Design and Analysis Components (Coffman, 2000)

	Low Impact Hydrologic Design and Analysis Components			
LID Practice	Lower Post-Development CN	Increase Tc	Retention	Detention
Flatten Slopes		X		
Increase Flow Path		X		
Increase Roughness		X		
Minimize Disturbances	X			
Flatten Slopes on Swale		X		X
Infiltration Swales	X		X	
Vegetative Filter Strips	X	X	X	
Disconnected Impervious Areas	X	X		
Reduce Curb and Gutter	X	X		
Rain Barrels		X	X	X
Rooftop Storage		X	X	X
Bioretention	X	X	X	
Revegetation	X	X	X	
Vegetation Presentation	X	X	X	

The runoff potential for a site is characterized by the runoff curve number or CN. One method of measuring hydrological function on a developed site is to compare the pre and post developed curve number. The CN method is used extensively in the analysis of environmental impact and design rainfall-runoff hydrology. The curve number measures a watershed or subwatershed's hydrological response and is determined based on soil type, land cover and amount of impervious surfaces (Hawkins 1998). A detailed evaluation of both proposed and existing land cover is the basis for determining the low-impact development CN, which is a calculation of the potential for runoff at a development site. One of the goals of LID is to design a system so that the post-developed CN is as close as possible to the predevelopment CN for the site. Limiting the percent of imperviousness is one technique to accomplishing this. The runoff coefficient, which can be derived from the CN, calculates the percent of rainfall converted to runoff.

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The time of concentration (Tc) refers to the amount of time it takes for water to travel from the most distant point to the watershed outlet. By retaining predevelopment Tc, negative impacts associated with development can be reduced. Retention and detention of rainfall are the key components of increases in Tc. As the amount of impervious surface increases within a site, altering drainage paths, the contribution of total land area to excess rainfall increases, causing the time for stormwater to reach downstream outlets to decrease. This decrease in Tc reduces the pollutant removal capabilities of the site as well as resulting in an increase in the peak runoff rate. Maintaining Tc can be achieved by:

- Maintaining flow path lengths
- Increasing surface roughness
- Detaining flows
- Minimizing disturbances at the site
- Flattening grades in impact areas
- Disconnecting impervious surfaces
- Connecting pervious surfaces

3.2 Pollutant Removal Measures

Changes in site runoff characteristics can contribute to a reduction in water quality and degradation of aquatic and terrestrial habitats. LID practices provide a high level of water quality treatment controls due to runoff volume control of the "first flush" (first ½ inch) of runoff, which contains the highest pollutant loadings. Often LID practices control up to the first 2 inches of runoff and therefore treat a much greater volume of annual runoff (Coffman, 2000). By increasing the Tc and decreasing the flow velocity, LID practices result in a reduction in pollutant transport capacity and overall pollutant loading. Further, LID practices support pollution prevention by modifying human activities, which lower the introduction of pollutants into the environment.

LID practices such as bioretention facilities or rain gardens can be used as a mechanism for infiltration and pollutant removal, which is performed through physical and biological treatment processes occurring in the plant and soil complex. These processes include filtration, decomposition, ion exchange, adsorption and volatilization (Dept. of Env. Resources, 1993). Pollutant loadings are concentrated in the "first flush" of runoff from impervious surfaces and contain grease and oil, nutrients (nitrogen and phosphorous), sediments and heavy metals. Pollutant loadings and water quality impacts from development have been well documented in numerous studies. Concentrations of pollutants are appropriate to look at bio affects, but pollutant loads are better for assessing impacts to downstream habitats when cumulative effects are considered (Rushton, 1999). Studies should consider investigating both total metals and dissolved metals, when analyzing LID practice's effectiveness.

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4 CASE STUDIES

The LID "functional landscape" is designed to mimic the predevelopment hydrological conditions through runoff volume control, peak runoff rate control, flow frequency/duration control and water quality control. Determining effectiveness of LID practices can be achieved by evaluating hydrological function and pollutant removal capabilities. Little investigation has been done to prove the actual effectiveness of LID in retaining predevelopment hydrology and preventing or reducing pollutant loadings caused by stormwater runoff on developed sites. LID is a relatively new concept in stormwater management and not widely implemented in all areas and climates in the United States. Limited research and analysis has been conducted on the various practices, due to this limited application.

The following case studies, though limited, represent the best examples of projects that use LID concepts for stormwater management. Both hydrologic and pollutant removal effectiveness are investigated. The most significant source for data is Prince George's County, Maryland where many of the LID practices were developed and first implemented. The Low-Impact Development Center, also located in Maryland, has done significant work in design and planning of LID sites. First year data from a two-year study of a Tampa, Florida, retrofit parking lot and an on-going permeable pavement project in Washington state provide the only long term analysis for the effectiveness of LID concepts (permeable pavements and swales) currently available.

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4.1 Bioretention Facility Laboratory and Field Study Beltway Plaza Mall Parking Lot, Greenbelt, MD

Introduction

Land development results in increased stormwater runoff at the expense of infiltration. Additionally, surface runoff contains a broad range of pollutants and has been identified as one of the major sources for pollution of natural waters. Detention basins are commonly used for stormwater quality improvement and to optimize the infiltration of stormwater for recharge. A simple, yet effective method to control stormwater is through the use of bioretention areas or rain gardens.

Bioretention systems generally require less space, are more economical to build and require less maintenance than large-scale detention ponds. In addition these landscaped areas have aesthetic value. The design capacity for the system is generally for a typical storm event (0.5-0.7 inches per hour of rainfall over six hours) and to handle runoff from a small development area. The goal of this study is to compare field results with baseline data obtained through a laboratory constructed and tested bioretention systems.

Study Site

This study was conducted in two phases. The first phase took place at the University of Maryland, Department of Civil Engineering, Stormwater Lab in College Park, Maryland. Two different-sized bioretention prototypes were constructed and fitted with ports at varying depths in order to collect and analyze water quality and infiltration data. The small prototype was 2.5 ft wide and 3.5 ft long with a depth of 24 inches of material. The small bioretention system was fitted with two port depths. The large prototype was 10 ft long, 5 ft wide with a depth of 36 inches, and was fitted with three ports at various depth levels. Both systems had a freeboard of 6 inches, to allow water to accumulate if necessary. The soil, organic mulch layer and vegetation, were analyzed prior to construction to assure that the system was constructed according to design recommendations. Simulated runoff was applied to both systems at a rate of 1.6 inches per hour for six hours. A total of 16 simulations were tested on the small box, and four on the large prototype. The total volume of runoff applied to the small system was 200 L, and 1,000 L for the large system. These volumes represent the bioretention prototypes occupying 5% of a drainage area.

The second phase, a field study, took place at an existing bioretention facility located in the parking lot of Beltway Plaza in Greenbelt, Maryland. The depth of the system is 42" and is designed so that runoff infiltrates through the system and is collected by a 6-inch diameter perforated pipe underdrain, which feeds into the main storm drain system. A 7.5-ft x 7.5-ft area of the bioretention facility was used to conduct the study. Approximately 1,000 L of synthetic runoff, with characteristics similar to those used in the laboratory, were applied to the system over a 6-hour period. Effluent samples were collected from the main storm drain at 25-30 minutes intervals.

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Study Results Summary

The laboratory results for the smaller prototype showed overall that the removal of heavy metals by the system was good. Cooper, lead and zinc levels in both upper and lower effluents had removal of more than 90%. Copper removal from samples taken from both ports was 94%. Lead removal was more effective from lower ports at 98%, but still good from upper ports at 94%. The average zinc removal from upper and lower ports was >96% (Table 3). No major variation of removal of metals occurred over time and all samples were less than EPA standards for freshwater. Nutrient removal for phosphorous was 65-75% from lower ports and approximately 40% from upper ports. The Total Kjeldahl Nitrogen (TKN) removal is 45-60% for the upper ports and 65-80% for the lower ports. Ammonium and nitrate removal followed no pattern and ranged from zero to 90%.

Table 3: Summary of Results for Smaller System—Standard Conditions

	Cu	Pb	Zn	P	TKN	NH_4^+	NO_3^-	Tn
Removal Upper	94%	94%	97%	25%	55%	60%	11%	60%
Removal Lower	94%	98%	98%	83%	80%	83%	26%	75%

Results from the large prototype correlated with those of the smaller constructed system. Experimental results indicated that removal of metals in most cases was more than 90%. Average copper removal for upper ports was 90% and 93% for middle and lower ports. Lead removal from upper ports was 93%, and >97% for middle and lower ports. The removal of zinc was 87% for upper ports and >96% for middle and lower ports. The data showed a trend of greater metal removal with depth. Nutrient removal was better from lower ports in most cases compared to removal of middle and upper ports. Phosphorous removal for lower ports was about 70-80% and 50-60% for middle ports. The upper ports showed a 10-15% increase in phosphorous levels above the influent amounts. The TKN removal was 50-75% for the lower and middle ports and a 45-30% increase was noted for upper ports. Removal of ammonium was 54% at upper ports, 86% for middle ports and 79% at lower ports (Table 4). Doubling or halving the influent pollutant levels during the laboratory testing had little effect on the effluent pollutant levels. Higher levels of phosphorous and TKN in effluent at the upper ports can be attributed to the vegetation.

Table 4: Summary of Results for Large System—Standard Conditions

	Cu	Pb	Zn	P	TKN	NH_4^+	NO_3^-	TN
Removal Upper	90%	93%	87%	0%	37%	54%	(-97%)	(-29%)
Removal Middle	93%	>97%	>96%	73%	60%	86%	(-194%)	0%
Removal Lower	93%	>97%	>96%	81%	68%	79%	23%	43%

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During the field test at Beltway Plaza, a total of 1,000 L of synthetic runoff were applied to the bioretention area over a 6 hour period at a rate of approximately 0.5 inches per hour. Of the 1,000 L of influent, only 39% left the system. The remaining water leaked through cracks into the manhole, was held in the facility, or infiltrated. Effluent samples were analyzed for removal of nutrients and heavy metals (copper, lead and zinc).

The TKN removal was about 50% and the phosphorous removal was observed at approximately 65%. Nitrate concentrations were below input levels, with a removal of about 17%. The removal for ammonia was very good at >95%. Removal of metals was very good and was consistent with the laboratory results. The removal of copper was 97% and for lead, and zinc, the removal was >95% (Table 5).

Table 5: Summary of Results for Field Bioretention Study

	Cu	Pb	Zn	P	TKN	NH_4^+	NO_3^-	TN
Removal	97%	>95%	>95%	65%	52%	92%	16%	49%

Removal rates for the field study corresponded with the rates observed for the two laboratory constructed bioretention systems. In all cases pollutant removal rates approached 100% for the metals copper, zinc and lead. Doubling or halving the concentration levels of the influent had no effect on removal efficiencies and were statistically equivalent in nearly all cases. Pollutant removal rates for all systems are compared in the above graph (Figure 3). The negative removal rate for nitrate in the large prototype, upper and middle ports, was attributed to the release of previously captured nitrated or nitrate from nitrification processes.

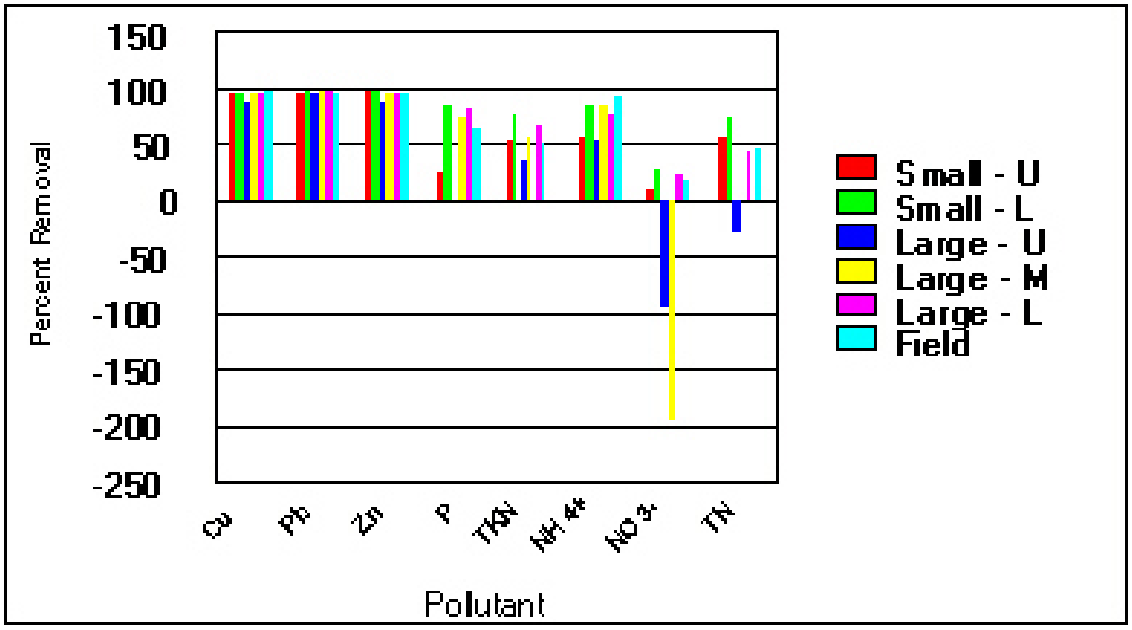

Figure 3: Pollutant Removal Rates for All Systems

4.2 Bioretention Facility Field Study Peppercorn Plaza Parking Lot at Inglewood Center, Landover, MD

Introduction

Impervious surfaces, such as parking lots, are a major contributor to pollutant loads in receiving waters in urban areas. These surfaces provide a place for pollutants to accumulate and later wash-off in the first flush of rainfall events. Parking lots are good site locations for bioretention systems, since they can be retrofit into existing lots with little or no loss of parking space. In addition, patrons have expressed appreciation of green space within parking areas. Bioretention areas are a natural means of controlling pollutants from entering urban water bodies. The hydrologically functional landscape, can be used as a mechanism for pollutant removal, through physical and biological treatment processes occurring in the plant and soil complex. The bioretention area in the Inglewood Center Parking lot, was analyzed for pollutant removal efficiency during a simulated rainfall event.

Study Site

The study was conducted at one of the two bioretention areas in the Inglewood Plaza parking lot. An area of 50 ft^2 was used in the south facility for the simulated rainfall event. The bioretention facility contains a T-shaped under drain that runs the entire length of the system and is located 32.5 inches below the surface (Figure 4). The under drain directly connects with the storm drainage system. Samples were collected from a pool of water in the storm drain observation area. Output samples were collected every 30 minutes. The soil was dry at the onset of the experiment, due to lack of rainfall for a period of several days prior to the experiment. The synthetic rainfall was applied at a rate of 1.6 inches per hour for a duration of six hours. A total of 300 gallons (1100L) was applied over the course of the experiment.

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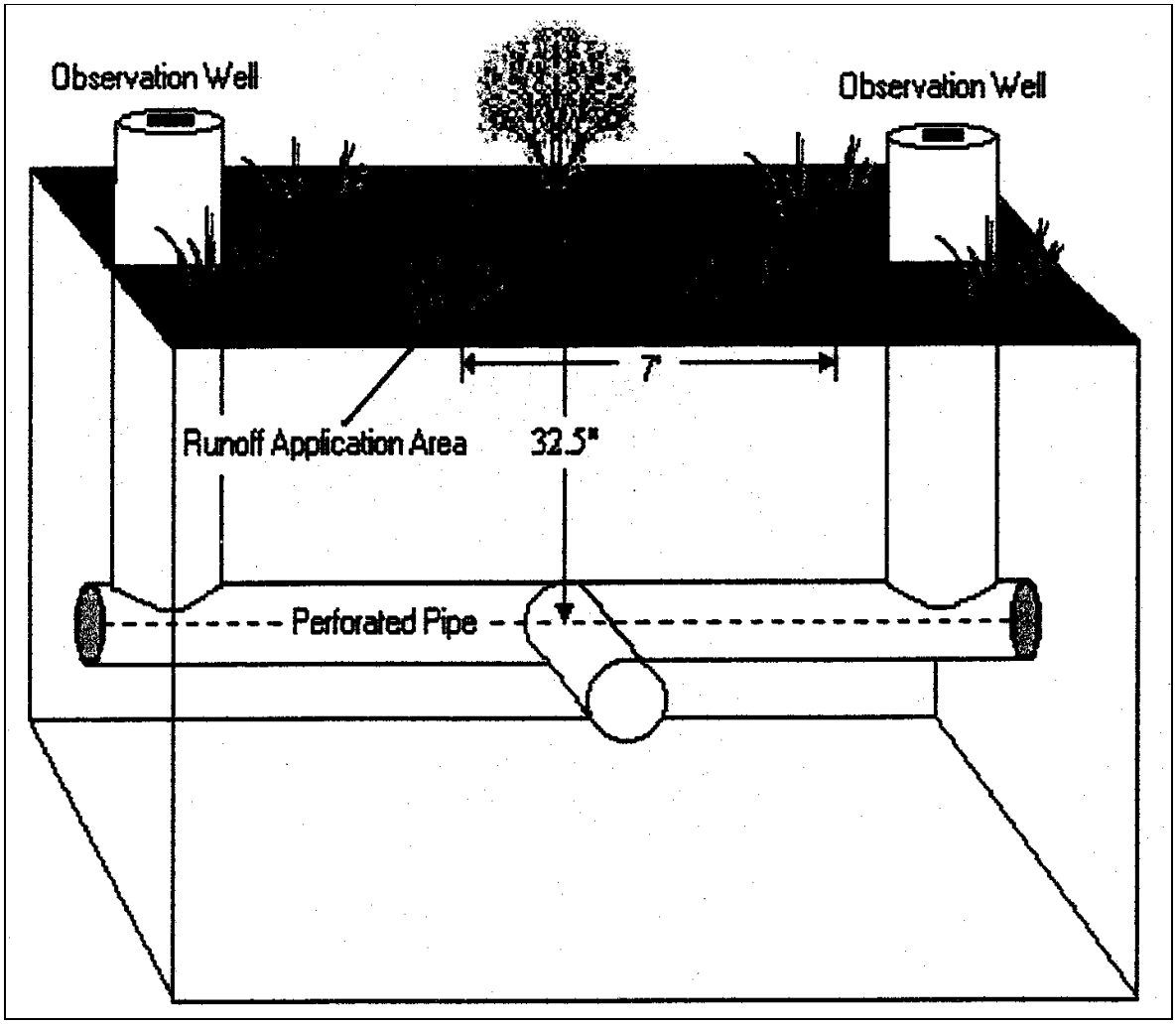

Figure 4: Bioretention System at Peppercorn Place, Inglewood Plaza (Davis, 1999)

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Project Results Summary

Effluent concentrations for metals were fairly constant over the sampling period, with zinc being the exception by showing improved removal over time. Average removals for total copper was 43%, total lead was 70% and total zinc 64%. The removals were 5–14% better for dissolved metals. Nutrient concentrations were all below input levels. Removal of phosphorous was very good at 87%. Removal of TKN was observed at 67% and nitrate averaged 15% (Table 6). Ammonium was not detected in either the influent or the effluent. In addition, the bioretention facility removed some calcium, however chloride concentrations were higher in the effluent than in the influent, which is attributed to salting of the parking lot in the winter. Also, temperature variations during the experiment showed evidence of the system cooling the runoff water temperature.

Table 6: Summary of Pollutant Removal Results of Bioretention System at Inglewood Place

	Cu	Pb	Zn	Ca	P	TKN	NO_3^-
Removal	43%	70%	64%	27%	87%	67%	15%

By using synthetic runoff, the concentrations of applied pollutants could be controlled and accurately measured and compared to levels found in the effluent. However, testing has not been done on an actual rainfall event to determine effectiveness of the system for reducing runoff volume and pollutant loads.

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4.3 Permeable Pavements and Swales Field Study Stormwater Management, Florida Aquarium Parking Lot, Tampa, FL

Introduction

Impervious surfaces are responsible for more stormwater runoff than any other type of land use. Paved surfaces that often replace vegetated areas increase the volume and frequency of rainfall runoff. In addition, these surfaces provide a place for pollutants to accumulate between rainfall events, and are later washed off into receiving waters. Keeping runoff on-site to allow for infiltration as well as chemical, physical and biological processes to take place is the most effective means of reducing pollutant loadings. This study quantifies how much runoff and pollutant loadings can be reduced by using swales and landscaped depressions in parking lots. In additional to investigating basins with and without swales, three paving surfaces were compared. The research is designed to determine pollutant load reductions measured from three different treatments within the parking lot; different paving materials in the parking lot, a planted strand with native trees and a small pond used for final treatment. Pollutant concentrations and infiltration were measured and analyzed for the various control methods. First year data collected in the parking lot between August 1998 and August 1999 were evaluated for this study. Also, sediment samples were collected from each of the swales, two locations in the strand and two locations in the pond.

Project Area

The study site is a parking lot at the Florida Aquarium in Tampa, Florida. The study uses the entire parking area, 4.65 ha, to define the drainage basin. The parking lot was modified for the study by reducing the length of each parking space by 61 centimeters, which allows for a 122-cm wide grass swale between rows. The vehicle front end now hangs over a grass swale instead of pavement, which prevented any reduction in the number of parking spaces within the parking area. Four different scenarios were investigated to determine the most efficient method of runoff reduction and pollutant removal. Eight basins, two of each type, were constructed and fitted with instrumentation to collect flow weighted water quality samples and measure discharge amounts during storm events (Figure 5). The four treatment types are:

- Asphalt paving with no swale
- Asphalt paving with a swale
- Cement paving with a swale
- Permeable pavement with a swale

Rainfall quality and volume were compared to runoff quality and volume to determine the effectiveness of each treatment type.

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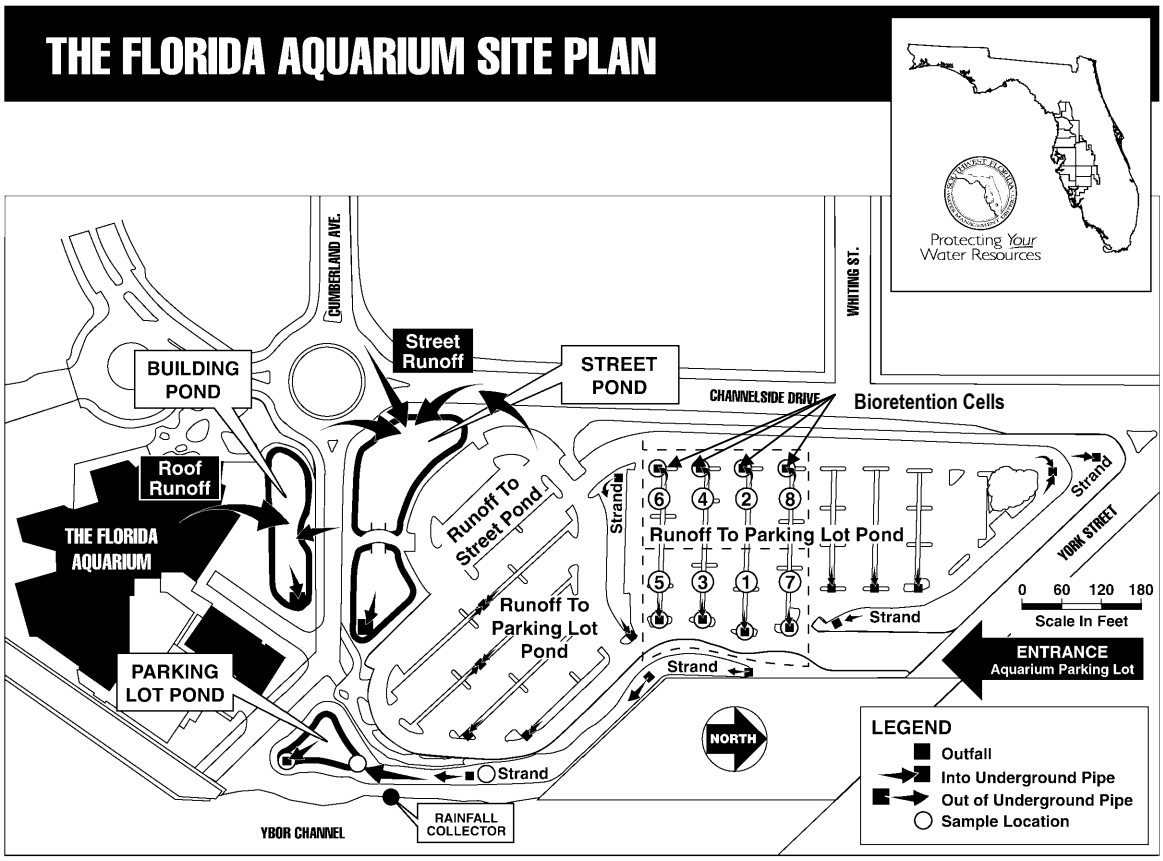

Figure 5: Florida Parking Lot Study Site (Rushton, 1999)

Project Results Summary

The larger garden areas (approximately the size of one parking space) account for a runoff coefficient calculation reduction of 40-50 percent for the smaller basins. The runoff coefficient is a value that ranges from zero to one and expresses the fraction of rainfall volume that is actually converted into storm runoff volume. The runoff coefficient closely tracks percent impervious cover. For rainfall events less than 2 cm, basins with swales and permeable pavement have 80-90% less runoff than basins without swales, and 60-80% less runoff than basins with the other pavement types and swales. The percent of rainfall converted to runoff for each treatment type is shown in Figure 6.

Larger rainfall amounts show fewer differences in runoff amounts between the different pavement types, but basins with swales have approximately 40% less runoff than the basins without swales. Soil analysis at the site shows a higher than average gravel content (8.9%) which may account for the good infiltration rates. Comparisons of rainfall with storm runoff amounts showed that swales reduced runoff for all rainfall events and paving types.

Water quality analysis shows that average concentrations varied by paving and depression storage types. Rainfall has been identified in other studies as a significant source of nitrogen in runoff. This site displayed the same correlation between

concentrations of ammonia and nitrate in rainfall and their concentrations in runoff. Phosphorous concentrations displayed the inverse, since concentrations were higher in effluent samples than in the initial rainfall. The levels were somewhat higher in the runoff of basins without planted swales and the highest concentrations of phosphorous were noted in basins where runoff traveled through grassed swales.

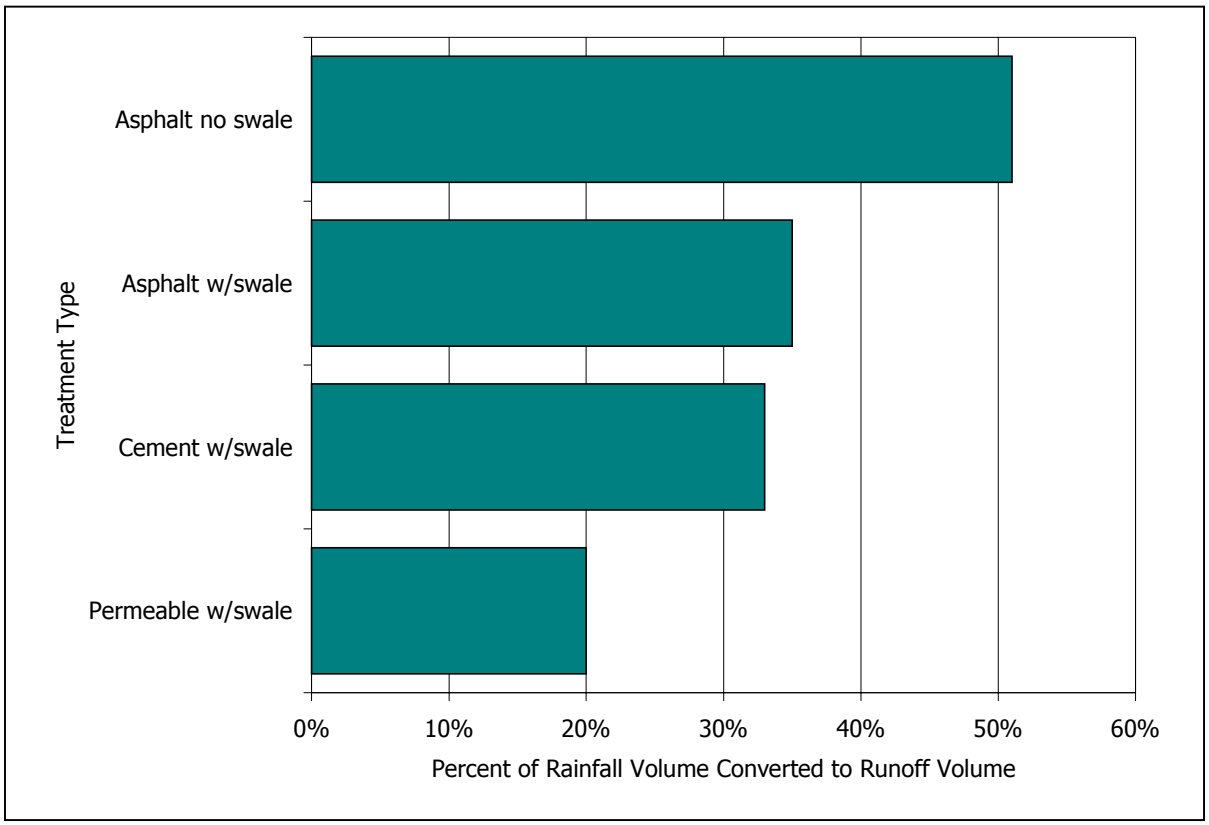

Figure 6: Percent of Rainfall Volume Converted to Runoff Volume for Events Less Than 2cm

Paving material showed an effect on the concentration of metals in runoff. Basins paved with asphalt showed higher concentrations of iron, manganese, lead, copper and zinc than those paved with cement or permeable paving. Many of the major ions also showed a correlation with the paving material. Potassium, sodium, sulfate and calcium concentration were much higher in the basins paved with cement, which is made from limestone, although these levels were still well below levels considered detrimental to the environment. No consistent pattern was discernable for suspended solids, but generally measurements were low when compared to similar stormwater studies.

Water quality loads were examined because they provide a more realistic measure for understanding the impacts of stormwater on receiving waters. Pollutant loads include both the volume of water discharged and the concentration of pollutants measured. Higher loads for all constituents, except phosphorous, were noted for basins without swales, since more water was discharged from these basins. Although phosphorous concentrations were much lower in basins without swales, loads were about the same.

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Removal for Ammonia was 45% for asphalt with swale, 73% for cement with swale and 85% for permeable pavement with swale. Total nitrogen removal was 42% for permeable pavement with swale, 16% for cement with swale and 9% for asphalt with swale. TSS removal varied from 91% for permeable pavement with swales to 46% for asphalt with swales.

Table 7 summarizes the constituent load efficiency of the various treatments. The concentrations and loads measured during this study were compared to other stormwater studies conducted in Florida, and the values were much lower than measured values at other sites. Metal removal was good for the permeable pavement with swale treatment, with copper at 81%, iron 92%, lead 85%, manganese 92% and zinc 75%. The removals for the cement with swale treatment were somewhat lower, with the asphalt with swale treatment showing the poorest performance of the three treatments with swales.

Table 7: Summary of Pollutant Removal Efficiency for the Various Treatment Types

Constituent	Asphalt with swale	Cement with swale	Permeable with swale
Ammonia	45%	73%	85%
Nitrate	44%	41%	66%
Total Nitrogen	9%	16%	42%
Ortho Phosphorus	-180%	-180%	-74%
Total Phosphorus	-94%	-62%	3%
Suspended Solids	46%	78%	91%
Copper	23%	72%	81%
Iron	52%	84%	92%
Lead	59%	78%	85%
Manganese	40%	68%	92%
Zinc	46%	62%	75%

The concentrations of metals in sediment samples collected in swales were consistent with concentrations measured in stormwater runoff. Higher concentrations of metals were found in swales paved with asphalt than those of grass. None of the metals measured in the sediments exceed the level where toxicity to organisms is probable when compared to the Environmental Protection Agency (EPA) and the National Oceanic and Atmospheric Administration (NOAA) chemical toxicity guidelines for marine environments. However, copper and zinc concentrations were above the level where toxicity is possible.

Nutrient concentrations measured in sediment samples for TKN and total phosphorus were lower in the basins without grassed swales. Sediment samples taken from locations in the strand and the wet-detention pond were compared to swale samples. The comparison showed that most of the metals are being settled out in the swales or

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deposited in the drop boxes. Sediment samples at the site were tested for 100 organic pollutants, but only 16 were detected at the site. The high concentrations found in this and similar studies indicate that atmospheric deposition is the source for most of the 16 detected organic pollutants.

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4.4 Vegetated Roof Covers
Field Study
Green Rooftop, Philadelphia, PA

Introduction

Many older American cities are plagued with nuisance flooding on roads and walkways and chronic overflows of combined sewer systems. In highly impervious cities, vegetated rooftops offer a practical solution for controlling runoff at the source. A vegetated roof cover is a veneer of living vegetation installed on top of a conventional roof. By mimicking natural hydrologic processes, they can achieve runoff characteristics similar to open space conditions. Green roofs are comprised of three components; subsurface drainage, growth media and vegetation. Specific hydraulic performance objectives are achieved through the appropriate selection of these components. Vegetated roof covers have been used extensively in Germany for 25 years.

Project Area

A 3,000-ft^2 rooftop in Philadelphia was fitted with a demonstration vegetated rooftop. The performance objective was the restoration of predevelopment runoff peak rates for a 24-hour, 2-year return-frequency storm. Although in the Philadelphia area, 90% of all rainfall is contributed by storms with volumes of 2 inches or less over a 24-hour period. The "green roof" used is only 3.4 inches (8.6cm) thick, including the drain layer (Figure 7). Its maximum saturated weight is less than 17 lb/ft^2 and it weighs less than 5lb/ft^2 when dry. No additional structural support was necessary for installation. The saturated infiltration capacity is 3.5 inches per hour. The key features of this system are a synthetic under drain layer which promotes rapid water drainage from the roof surface, thin, lightweight growth media suitable for installation on existing roof surfaces and a meadow-like setting of perennial *Sedum* varieties selected for hardiness and the ability to withstand seasonal conditions typical of the area.

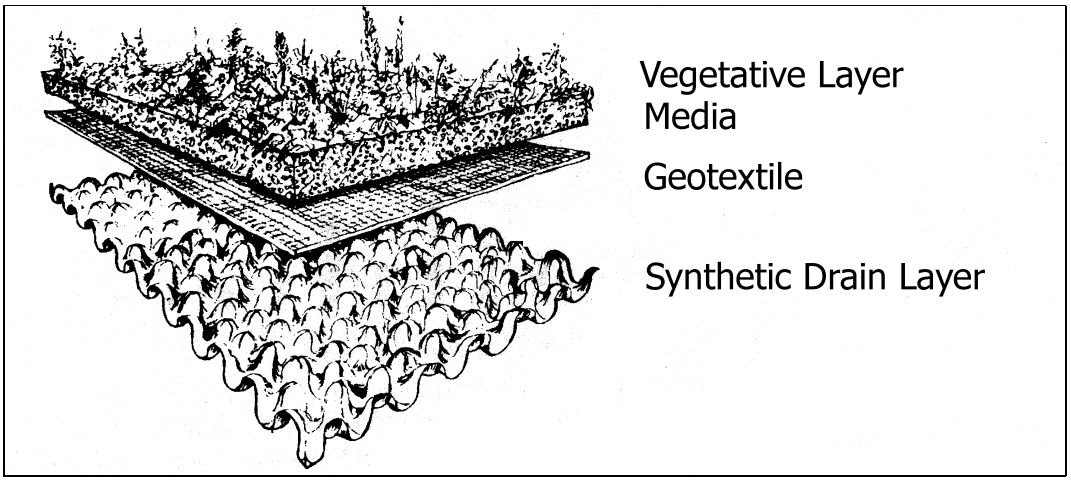

Figure 7: Structure of the Philadelphia Vegetated Roof Cover (Miller, 1998)

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Project Results Summary

Currently too few storms have been observed to permit quantitative assessment of the vegetative covered roof. Data are available from one intense storm monitored during a 0.4 inch, 20-minute rainfall event (Figure 8). Supplemental data from a pilot-scale experimental station were used in this study. Test data show that for storms with less than 0.6 inches, runoff is negligible. During a 9-month period, 44 inches of rainfall was recorded at the pilot-scale test station, with only 15.5 inches of runoff generated. Runoff occurred for precipitation events between 0.6 and 1.0 inches, but lagged rainfall significantly. Attenuation was lower for the pilot-scale experiment than the anticipated modeled value (40% vs. 48%), which has been attributed to differing drain conditions and a steeper slope at the test site. Additional benefits of this project include extended life of the underlying roof materials, reduction of energy costs by improving effectiveness of insulation and restoration of ecological aesthetic value of open space in densely populated areas.

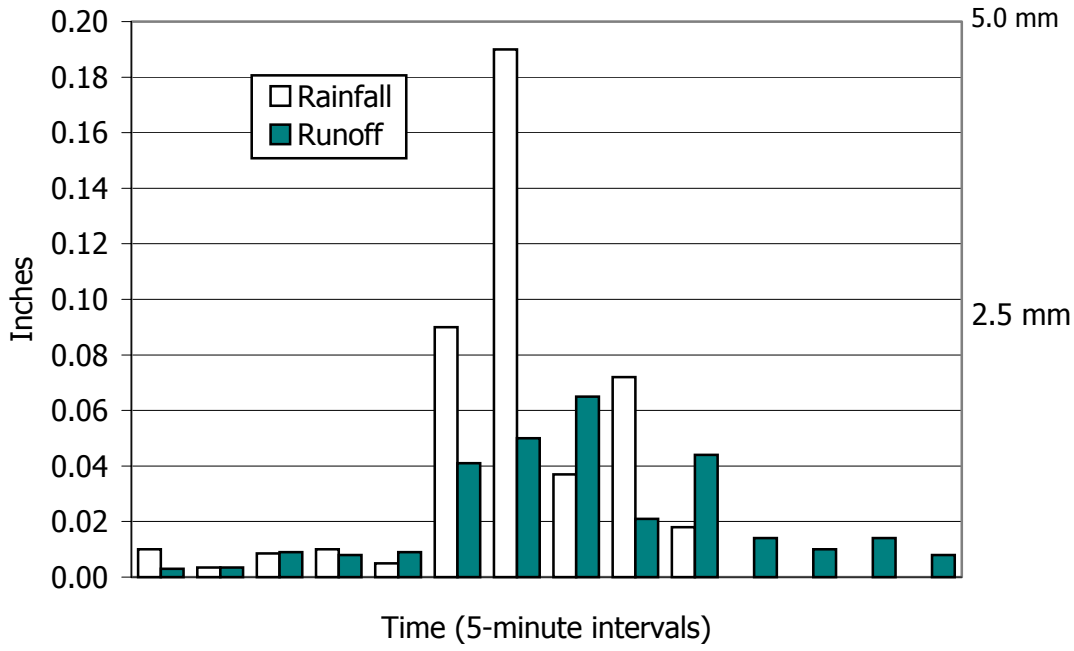

Figure 8: A Rainfall Event of 0.4 inches with Media Completely Saturated (Miller, 1998)

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4.5 Permeable Pavements
Field Study
Permeable Pavements for Stormwater Management, Olympia, WA

Introduction

This study demonstrates the use of permeable surfaces for reducing runoff volume, improving infiltration and reducing pollutant loadings in an urban parking area. Numerous problems associated with urbanization, such as flooding, channel erosion and destruction of aquatic habitats are directly linked to the loss of water-retaining function of soil in urban landscape. As imperviousness increases, a stormwater runoff reservoir of tremendous volume is removed. Water that may have lingered in this reservoir for anywhere from a few hours to many weeks now flows rapidly across land surfaces and arrives at stream channels in short, concentrated bursts. The scope of this project was to review existing information on types and characteristics of permeable pavements, construct and monitor a full-scale test site and evaluate long-term performance of these systems. This study of permeable pavements evolved from a growing recognition of the limitations of traditional stormwater management in keeping water in the soil by allowing excess of water to the soil over large areas of landscape.

Study Site

The study site is an employee parking lot on the southeast corner of the King County Public Works facility in Renton, Washington. The permeable pavement sections of the lot were constructed for the purpose of this study. A total of eight stalls using four different pavement types were constructed. In addition a ninth stall of traditional asphalt was used as a control. The parking stalls are fitted with pipe, gutters and gauges to collect and measure the quantity and quality of storm runoff from each pavement type. Subsurface troughs were constructed down the middle of each stall and imbedded into the subgrade six to 8 inches below the surface. This allows for the collection of only a fraction of the infiltrated water (about 1.8%). The permeable pavement types studied were:

- A plastic network with grass infilling (<5% impervious)
- An equivalent plastic network with gravel infilling (<5% impervious)
- Impervious blocks with grass infilling (~60% impervious)
- Impervious blocks with gravel infilling (~90% impervious)

Project Results Summary

Data used to monitor the various permeable pavements were from three different storm events during the autumn of 1996. The volume of runoff generated from cement blocks with 60% impervious surface stalls and runoff from traditional asphalt are compared (Figure 9). The storm had a fairly uniform distribution of rainfall (4mm per hour) throughout the duration of the event. Rain falling on the asphalt yielded sharp hydrograph

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peaks and a high total volume of runoff water. Only about one peak per hour (0.03mm per hour of runoff) was recorded for the cement blocks with 60% impervious surface. These data are representative of data gathered at the other stalls and reflect little or no runoff from the permeable pavement stalls.

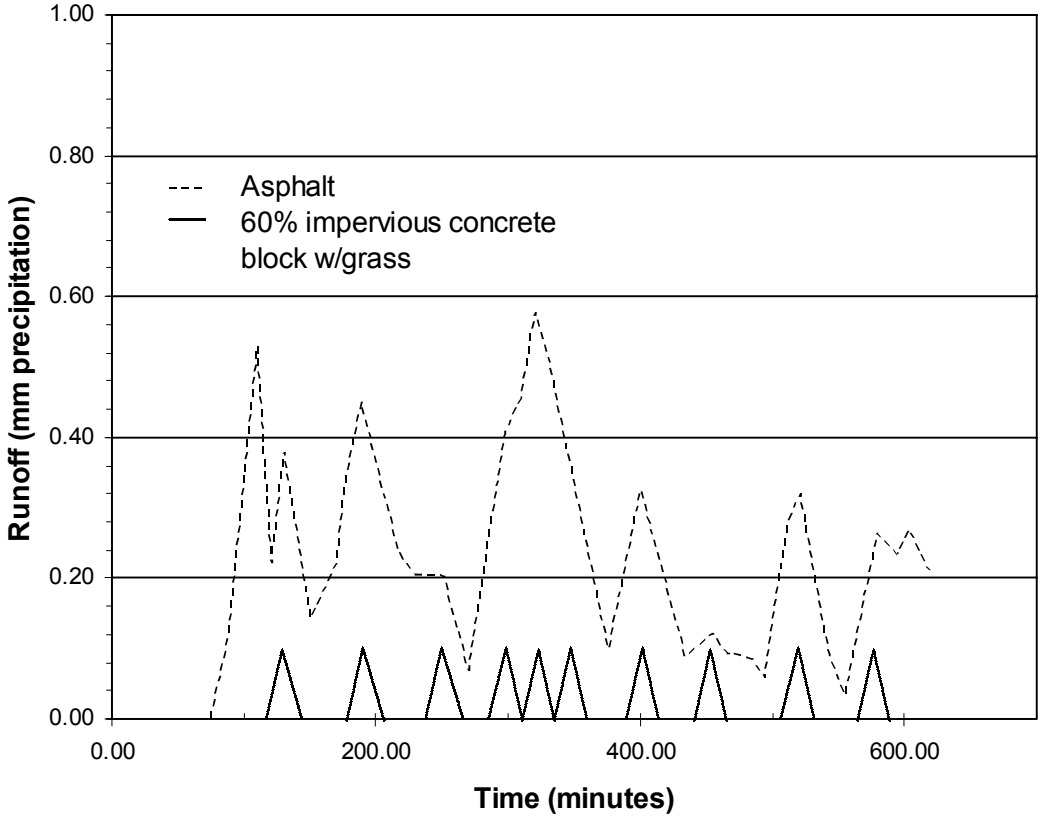

Figure 9: Surface Runoff from 60% Impervious Pavement vs. Asphalt (Booth, 1996)

In contrast to surface runoff, subsurface flow generally responds more slowly and more uniformly. The data for a storm of short duration and moderate intensity are represented in the following graph (Figure 10). Individual peaks on the bar graph indicate rainfall rates as high as 14mm per hour, lasting for short durations (15-minute intervals). Runoff gauges on all four systems showed virtually no surface runoff (on average 0.03 mm). It displays a characteristically attenuated discharge peak and lagged response to the rainfall inputs. All pervious surfaces responded similarly. For the asphalt surface, the volume of water running off the asphalt responded quickly to changes in the rate of rainfall. This is indicated by high peak flows corresponding with precipitation amounts, with little lag time noted (Figure 11).

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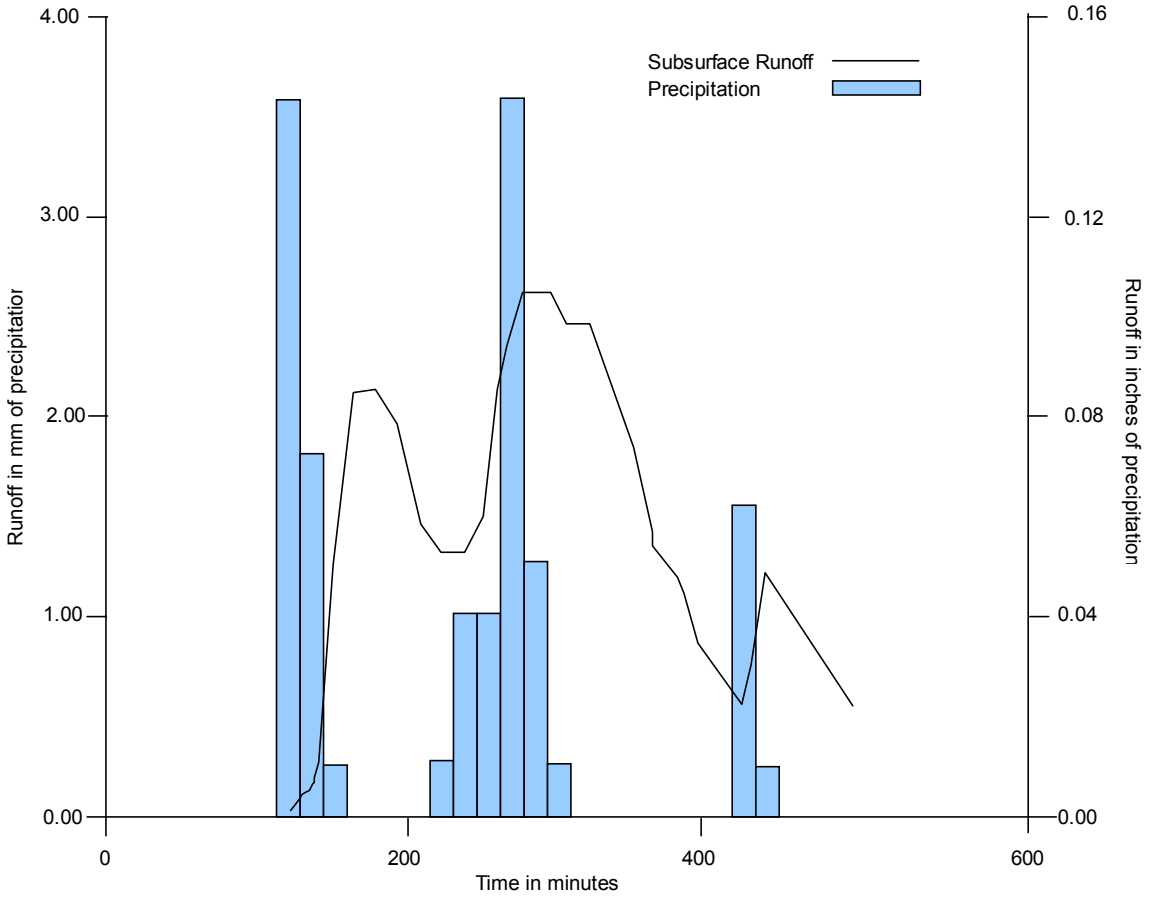

Figure 10: Subsurface Runoff From Pavement Less Than 5% Impervious Compared to Precipitation (Booth, 1996)

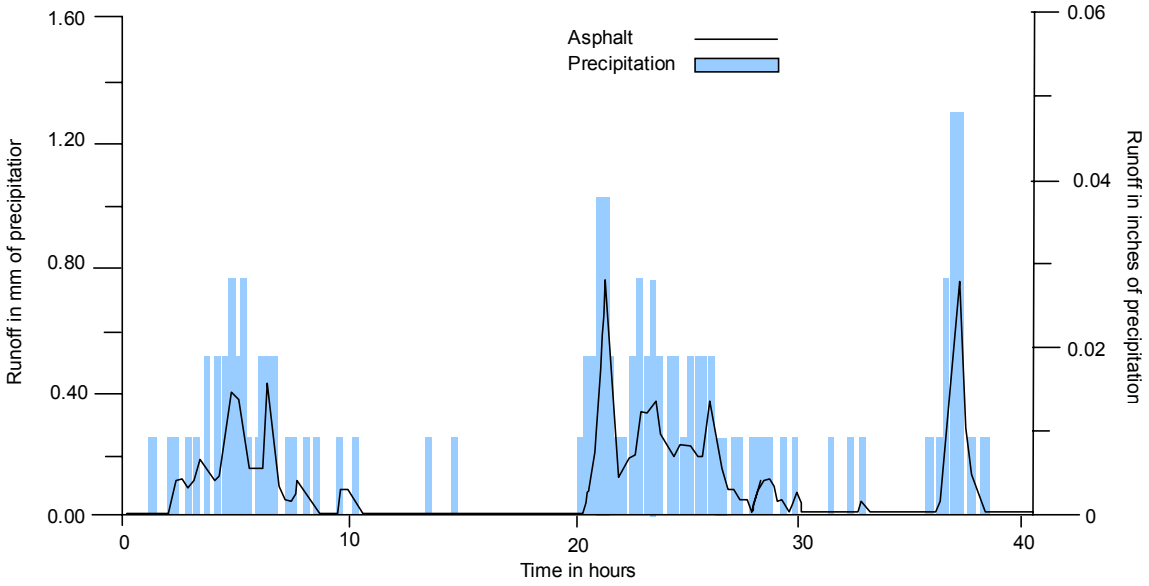

Figure 11: Surface Runoff From Asphalt Compared to Precipitation (Booth, 1996)

Water quality results were obtained from samples collected directly from tipping bucket gauges. Only five samples from the four subsurface collection troughs and the asphalt surface runoff were analyzed. Chemical analysis of the subsurface samples showed sub-detection levels for many of the constituents and relatively low levels for all tested compounds. Measured concentrations of common metals (copper, lead, zinc aluminum and iron) were substantially below the reported national averages. Subsurface samples did show slightly higher concentrations than runoff, which can be attributed to the troughs collecting the "dirtiest" 2 percent of runoff, from directly under where vehicles park. Still, these concentrations were below typical values seen in urban runoff.

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4.6 Grass Swales
Field Study
Highway Grass Channels, Northern Virginia, Maryland, and Florida

Introduction

The U.S. Department of Transportation, Federal Highway Administration conducted a field study to determine the pollutant removal efficiencies of grassed channels and swales along highways in Northern Virginia, Maryland and Florida. Sampling was conducted at the inflow and outflow areas of the channels, which provided data for quantity and quality of waters entering and leaving the channels. The samples were analyzed for the following pollutants:

- Total Suspended Solids (TSS)
- Heavy Metals (cadmium, copper, lead and zinc)
- Nitrogen (Total Kjeldahl Nitrogen and nitrite/nitrate)
- Total Phosphorus
- Total Organic Carbon

Twelve rainfall events were monitored, including both frequent and infrequent rainfall periods, most involving discrete stormwater runoff events following a minimum of two days of dry weather. In addition continuous rainfall periods of seven to 14 days were included to determine overall removal efficiencies.

Project Area

The test area in northern Virginia is located along I-66. The channel has an average slope of 4.7% with a total drainage area of 1.27 acres (0.51 ha). Stormwater enters the channel indirectly, by means of overland flow. Stormwater data were collected from June 13, 1987 through November 12, 1987. The test site in Maryland is a grass channel located alongside I-270. This channel has a slope of 3.2% and a total drainage area of 1 acre (0.40 ha) with stormwater entering by means of overland flow. Data were collected for the period beginning June 18, 1987 and ending mid-September 1987. The Florida test site is a grass channel median located between the East and West lanes of I-4. The Florida grass channel has a lower slope than the other two test sites with a drainage area of 0.56 acres (0.23 ha). Data collection began at this site on February 25, 1988 and ended on October 31, 1988.

Project Results Summary

All three locations showed some effectiveness with regard to pollutant removals, although results varied depending on the method of analysis and the location. The results for all three locations are represented in Table 8. Sediment core samples were obtained from the channels and compared to samples from adjacent, upland areas, to determine

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pollutant removal effectiveness of the grass channels. Based on the data from the analysis the following conclusions were made. Removal of metals appears to be directly related to the removal of TSS, whereas nutrient removal is not. Removal of TSS can be estimated using flow depth and travel time relationships. Relatively low nutrient removal may be observed in channels that are effective in removing other pollutants. The controlling factors in pollutants removal of grass channels are length, channel geometry, channel slope and average flow. Both metals and nutrients are removed in grass channels, but metal removal is more reliable.

Table 8: Long Term Pollutant Removal Estimates for Grassed Swales

	TSS	TOC	TKN	NO_2/NO_3	TP	Cd	Cr	Cu	Pb	Zn
VA	65%	76%	17%	11%	41%	12-98%	12-16%	28%	41-55%	49%
MD	-85%	23%	9%	-143%	40%	85-91%	22-72%	14%	18-92%	47%
FL	98%	64%	48%	45%	18%	29-45%	51-61%	62-67%	67-94%	81%

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5 CONCLUSION

Pollutant loading reduction data for bioretention systems are promising in that removal percentages for heavy metals and nutrients seem quite high. Generally, the experimental data show a fairly consistent removal rate for all of the tested bioretention systems for heavy metals and most nutrients (Table 9). Field study results support the laboratory baseline data collected by the University of Maryland, College Park. However, the field studies provide data for single, simulated rainfall events using synthetic rainfall. A larger number of sampled events would be required for statistical validity of the results.

Table 9: Pollutant Removal Efficiencies for Laboratory and Field Bioretention Studies

Pollutant	Laboratory (small)	Laboratory (large)	Beltway Plaza	Inglewood Plaza
Pb	93–97%	93–97%	>95%	70%
Cu	91–97%	90–93%	97%	43%
Zn	93–98%	87–96%	>95%	64%
P	16–83%	0–81%	65%	87%
TKN	55–80%	37–68%	52%	67%
NH_4^+	<0 -83%	54 -86%	92%	N/A
NO_3^-	11–26%	<0–23%	16%	15%
TN	60–75%	<0–43%	49%	N/A

The use of synthetic runoff during the bioretention experiments, both in the lab and field, allowed the concentrations of applied pollutants to be controlled and accurately measured, so that influent and effluent levels could be compared. In addition, infiltration could be determined based on the volume of runoff verses volume input. The statistical analysis applied for the mass loadings was sound. However, testing for these studies has not been conducted for any actual rainfall events to determine effectiveness of the system for reducing runoff volume and pollutant loads. A comparison of average pollutant removal efficiencies is shown in Figure 12.

The grass swale data from the Federal Highway study show trends in removal of metals as they relate to TSS removal for three different areas in the United States. However a short study period, using data from only a few storm events, is used to quantify the results. Additional data from numerous storm events would be required to provide statistical validity to the analysis. The data from additional, less extensive studies conducted by the University of Virginia help to validate the highway data, as pollutant loading removal rates and runoff volume reduction rates were fairly consistent between the two studies. Conclusions drawn from both studies indicate that not only length, but also longitudinal slope and the presence of check dams increase the pollutant removal capabilities (Kuo, 1999).

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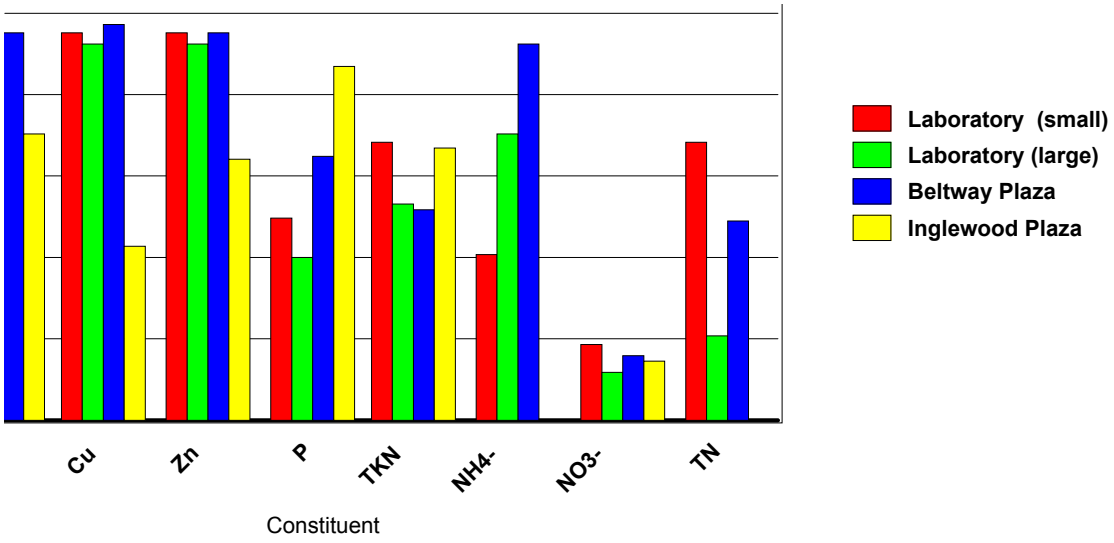

Figure 12: Pollutant Removal Rates for Laboratory and Field Experiments of Bioretention Systems

In addition, a study conducted in Ontario, Canada concluded that no evidence existed to show that nutrient or metal concentrations in soils increased with age in grass swales, as concentrations varied regardless of age. Also, the Canadian study determined that no degradation in vegetative quality resulted from continuous exposure to stormwater runoff. It was shown that vegetation quality was similar to what would be found along conventional systems (Sabourin, 1999). The Canadian study also showed that total runoff volumes from grassed swales were 6-30% less than conventional systems and that a loading comparison revealed that the system released significantly less pollutants than conventional systems.

Permeable pavements can reduce the percent imperviousness for urban areas, which allows for greater infiltration rates and reduced runoff volumes. In addition these alternate pavement types function as stormwater pollutant removal mechanisms. Preliminary data from the Washington project show effectiveness, but too few storms have been analyzed. Only the Florida Aquarium parking lot data represent an analysis of a significant number of actual storm events. As the study continues, and second year data become available, more compelling proof of the pollutant removal effectiveness and runoff volume reduction can be realized. The methodology for testing runoff volume reduction and mass pollutant loadings in the Florida study provided reliable data.

Extensive data exist that show runoff volume reduction using vegetated roof covers in Europe, especially Germany. The data are specific to temperate climates and results may vary considerably for other areas in the United States. However, the Philadelphia project shows the benefits of this application in reducing runoff volume by reducing the level of imperviousness in urbanized areas. Further, it demonstrates the capacity for retrofit of green roofs in highly impervious, older, urbanized U.S. cities experiencing chronic CSO problems. Little data are available from this demonstration project. However, with continued monitoring, evidence of the suitability of green roofs in the United States may become more apparent.

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6 RECOMMENDATIONS

A detailed comparison of pre- and post-development conditions and an analysis of adjacent areas using traditional stormwater controls and LID practices side-by-side, would provide the best possible assessment of LID effectiveness hydrologically and as a mechanism for reducing pollutant loadings. The Jordan Cove Urban Watershed project in Waterford, Connecticut, is currently under construction for a side-by-side analysis, however, no data are available at this time. Baseline predevelopment hydrological data are currently being collected for comparison once the development is completed and monitoring begins.

Most of the current field data available for bioretention facilities are for single, simulated rainfall events. Fitting the existing, tested bioretention areas in Prince George's County with monitoring equipment and running a significant number of tests on actual rainfall events over 9 months to 1 year, would provide higher quality data. Long term studies would prove or disprove the long-term effectiveness of bioretention systems, as well as provide information on trends in soil fertility lifetimes and trends in reduced capabilities over time. The two-year Florida Aquarium study is currently the best possible source for these data.

The majority of case studies cited above are ongoing investigations, and reported data represent preliminary findings. Follow-up on these studies will provide better support for proof of effectiveness of LID practices. Additional studies testing LID practices should be identified as the use of these practices grows. Preliminary findings should be viewed as a starting point, and not the empirical proof of effectiveness for the various LID practices studied. The development of a database for entry and storage of LID study data could provide a useful tool for future investigation of LID effectiveness.

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Protecting Water Resources with Higher-Density Development

United States Environmental Protection Agency

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Front cover photos:

Left: The Snake River flows outside Jackson, Wyoming. Photo courtesy of USDA NRCS.
Top right: Rosslyn-Ballston Corridor, Arlington County, Virginia. Arlington County Department of Community Planning, Housing, and Development received a 2002 National Award for Smart Growth Achievement in the Overall Excellence category for its planning efforts in the Rosslyn-Ballston Corridor. Photo courtesy of Arlington County.
Middle right: People gather at Pioneer Square in Portland, Oregon. Photo courtesy of US EPA.

Back cover photos:

Top left: This hillside in Northern California is covered by wildflowers. This open space provides habitat to wildlife as well as serving important watershed services. Photo courtesy of USDA NRCS.
Middle left: A family enjoys open space in central Iowa. Photo courtesy of USDA NRCS.
Bottom left: A stream flows through western Maryland. Photo courtesy of USDA NRCS.
Right: This redevelopment site in Arlington, Virginia, which includes stores, apartments townhomes, single family homes, parking garages, and a one-acre public park, was formerly a large department store surrounded by surface parking. Photo courtesy of US EPA.

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UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
WASHINGTON, D.C. 20460

Dear Colleague:

We are excited to share with you the enclosed report, *Protecting Water Resources with Higher-Density Development*. For most of EPA's 35-year history, policymakers have focused on regulatory and technological approaches to reducing pollution. These efforts have met with significant success. But, the environmental challenges of the 21st century require new solutions, and our approach to environmental protection must become more sophisticated. One approach is to partner with communities to provide them with the tools and information necessary to address current environmental challenges. It is our belief that good environmental information is necessary to make sound decisions. This report strives to meet that goal by providing fresh information and perspectives.

Our regions, cities, towns, and neighborhoods are growing. Every day, new buildings or houses are proposed, planned, and built. Local governments, working with planners, citizen groups, and developers, are thinking about where and how this new development can enhance existing neighborhoods and also protect the community's natural environment. They are identifying the characteristics of development that can build vibrant neighborhoods, rich in natural and historic assets, with jobs, housing, and amenities for all types of people. They are directing growth to maintain and improve the buildings and infrastructure in which they have already invested.

In addition to enjoying the many benefits of growth, communities are also grappling with growth's challenges, including development's impact on water resources. In the face of increasing challenges from non-point source pollution, local governments are looking for, and using, policies, tools, and information that enhance existing neighborhoods and protect water resources. This report gives communities a different perspective and set of information to address the complex interactions between development and water quality.

Protecting Water Resources with Higher-Density Development is intended for water quality professionals, communities, local governments, and state and regional planners who are grappling with protecting or enhancing their water resources while accommodating growing populations. We hope that you find this report informative as your community strives to enjoy the many benefits of growth and development and cleaner water.

For additional free copies, please send an e-mail to ncepimal@one.net or call (800) 490-9198 and request EPA publication 231-R-06-001. If you have any questions concerning this study, please do not hesitate to contact Lynn Richards at (202) 566-2858.

Sincerely,

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Executive Summary

Growth and development expand communities' opportunities by bringing in new residents, businesses, and investments. Growth can give a community the resources to revitalize a downtown, refurbish a main street, build new schools, and develop vibrant places to live, work, shop, and play. However, with the benefits come challenges. The environmental impacts of development can make it more difficult for communities to protect their natural resources. Where and how communities accommodate growth has a profound impact on the quality of their streams, rivers, lakes, and beaches. Development that uses land efficiently and protects undisturbed natural lands allows a community to grow and still protect its water resources.

The U.S. Census Bureau projects that the U.S. population will grow by 50 million people, or approximately 18 percent, between 2000 and 2020. Many communities are asking where and how they can accommodate this growth while maintaining and improving their water resources. Some communities have interpreted water-quality research to mean that low-density development will best protect water resources. However, some water-quality experts argue that this strategy can backfire and actually harm water resources. Higher-density development, they believe, may be a better way to protect water resources. This study intends to help guide communities through this debate to better understand the impacts of high- and low-density development on water resources.

To more fully explore this issue, EPA modeled three scenarios of different densities at three scales—one-acre level, lot level, and watershed level—and at three different time series build-out examples to examine the premise that lower-density development is always better for water quality. EPA examined stormwater runoff from different development densities to determine the comparative difference between scenarios. This analysis demonstrated:

- The higher-density scenarios generate less stormwater runoff per house at all scales—one acre, lot, and watershed—and time series build-out examples;
- For the same amount of development, higher-density development produces less runoff and less impervious cover than low-density development; and
- For a given amount of growth, lower-density development impacts more of the watershed.

Taken together, these findings indicate that low-density development may not always be the preferred strategy for protecting water resources. Higher densities may better protect water quality—especially at the lot and watershed levels. To accommodate the same number of houses, denser developments consume less land than lower density developments. Consuming less land means creating less impervious cover in the watershed. EPA believes that increasing development densities is one strategy communities can use to minimize regional water quality impacts. To fully protect water resources, communities need to employ a wide range of land use strategies, based on local factors, including building a range of development densities, incorporating adequate open space, preserving critical ecological and buffer areas, and minimizing land disturbance.

Introduction

Growth and development expand communities' opportunities by bringing in new residents, businesses, and investments. Growth can give a community the resources to revitalize a downtown, refurbish a main street, build new schools, and develop vibrant places to live, work, shop, and play. However, with the benefits come challenges. The environmental impacts of development can make it more difficult for communities to protect their natural resources. Where and how communities accommodate growth has a profound impact on the quality of their streams, rivers, lakes, and beaches. Development that uses land efficiently and protects undisturbed natural lands allows a community to grow and still protect its water resources.

Which is a better strategy to protect water quality: low- or high-density development?

The U.S. Census Bureau projects that the U.S. population will grow by 50 million people, or approximately 18 percent, between 2000 and 2020. Many communities are asking where and how they can accommodate this growth while maintaining and improving their water resources. Some communities have interpreted water-quality research to mean that low-density development will best protect water resources. However, some water-quality experts argue that this strategy can backfire and actually harm water resources. Higher-density development, they believe, may be a better way to protect water resources. This study intends to help guide communities through this debate to better understand the impacts of high- and low-density development on water resources.

Virtually every metropolitan area in the United States has expanded substantially in land area in recent decades. According to the U.S. Department of Agriculture's National Resources Inventory (NRI), between 1954 and 1997, urban land area almost quadrupled, from 18.6 million acres to about 74 million acres in the contiguous 48 states (USDA, 1997b). From 1982 to 1997, when population in the contiguous United States grew by about 15 percent, developed land increased by 25 million acres, or 34 percent. Most of this growth is taking place at the edge of developed areas, on greenfield sites, which can include forestland, meadows, pasture, and rangeland (USDA, 1997a). Indeed, in one analysis of building permits in 22 metropolitan areas between 1989 and 1998, approximately 95 percent of building permits were on greenfield sites (Farris, 2001).

Between 1954 and 1997, urban land area almost quadrupled, from 18.6 million acres to about 74 million acres in the contiguous 48 states.

According to the American Housing Survey, 35 percent of new housing is built on lots between two and five acres, and the median lot size is just under one-half acre (Census, 2001). Local zoning may encourage building on relatively large lots, in part because local governments often believe that it helps protect their water quality. Indeed, research has revealed that more impervious cover can degrade water quality. Studies have demonstrated that at 10 percent imperviousness, a watershed is likely to become impaired and grows more so as imperviousness increases (Arnold, 1996; Schueler, 1994). This research has prompted many communities to adopt low-density zoning and site-level imperviousness limits, e.g., establishing a percentage of the site, such as 10 or 20 percent, that can be covered by

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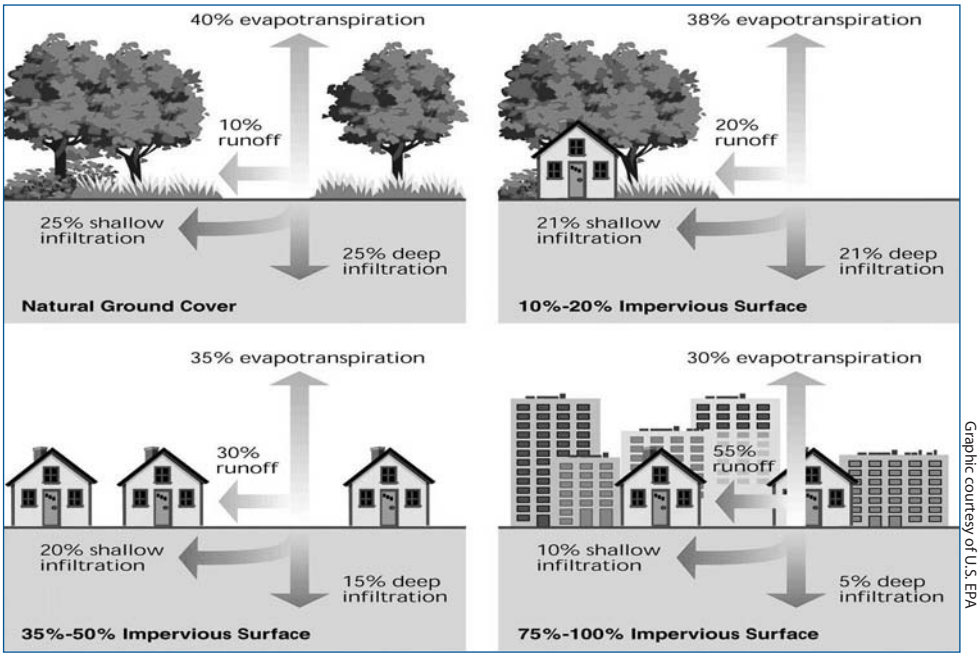
impervious surfaces such as houses, garages, and driveways. These types of zoning and development ordinances are biased against higher-density development because it has more impervious cover. But do low-density approaches protect our water resources?

This study examines the assumption that low-density development is always better for water quality.[1] EPA modeled stormwater runoff from different development densities at the site level and then extrapolated and analyzed these findings at the watershed level. Modeling results were used to compare stormwater runoff associated with several variations of residential density.

Impacts from Development on Watershed Functions

A watershed is a land area that drains to a given body of water. Precipitation that falls in the watershed will either infiltrate into the ground, evapotranspirate back into the air, or run off into streams, lakes, or coastal waters. This dynamic is described in Exhibit 1.

EXHIBIT 1: Watershed Services



Graphic courtesy of U.S. EPA

As land cover changes, so does the amount of precipitation that absorbs into the ground, evaporates into the air, or runs off.

A watershed may be large or small. The Mississippi River, for example, drains a one-million-square-mile watershed made up of thousands of smaller watersheds, such as the drainage basins of the creeks that flow into tributaries of the Mississippi. In smaller watersheds, a few acres of land may drain into small streams, which flow into larger streams or rivers; the lands drained by these streams or rivers make up a larger watershed. These streams support

[1] Stormwater runoff was used as a proxy for overall water quality. In general, the more stormwater runoff a region experiences, the more associated pollutants, such as total nitrogen, phosphorus, and suspended solids, will enter receiving waterbodies.

diverse aquatic communities and perform the vital ecological roles of processing the carbon, sediments, and nutrients upon which downstream ecosystems depend. Healthy, functioning watersheds naturally filter pollutants and moderate water quality by slowing surface runoff and increasing the infiltration of water into soil. The result is less flooding and soil erosion, cleaner water downstream, and greater ground water reserves.

Land development directly affects watershed functions. When development occurs in previously undeveloped areas, the resulting alterations to the land can dramatically change how water is transported and stored. Residential and commercial development create impervious surfaces and compacted soils that filter less water, which increases surface runoff and decreases ground water infiltration. These changes can increase the volume and velocity of runoff, the frequency and severity of flooding, and peak storm flows.

Moreover, during construction, exposed sediments and construction materials can be washed into storm drains or directly into nearby bodies of water. After construction, development usually replaces native meadows, forested areas, and other natural landscape features with compacted lawns, pavement, and rooftops. These largely impervious surfaces generate substantial runoff. For these reasons, limiting or minimizing the amount of land disturbed and impervious cover created during development can help protect water quality.

Critical Land Use Components for Protecting Water Quality for Both Low- and High-Density Development

What strategies can communities use to continue to grow while protecting their water quality? Watershed hydrology suggests that three primary land use strategies can help to ensure adequate water resource protection:

- Preserve large, continuous areas of absorbent open space;
- Preserve critical ecological areas, such as wetlands, floodplains, and riparian corridors; and
- Minimize overall land disturbance and impervious surface associated with development.

These approaches work because, from a watershed perspective, different land areas have different levels of ecological value. For example, a nutrient-rich floodplain has a higher ecological value than a grass meadow. Communities should view these strategies as basic steps to preserve watershed function and as the framework within which all development occurs.

Preserving Open Space

Preserving open space is critical to maintaining water quality at the regional level. Large, continuous areas of open space reduce and slow runoff, absorb sediments, serve as flood control, and help maintain aquatic communities. To ensure well-functioning watersheds, regions should set aside sufficient amounts of undisturbed, open space to absorb, filter, and store rainwater. In most regions, this undeveloped land comprises large portions of a watershed, filtering

out trash, debris, and chemical pollutants before they enter a community's water system. Open space provides other benefits, including habitat for plants and animals, recreational opportunities, forest and ranch land, places of natural beauty, and community recreation areas.

To protect these benefits, some communities are preserving undeveloped parcels or regional swaths of open space. One of the most dramatic examples is the New York City Watershed Agreement. New York City, New York State, over 70 towns, eight counties, and EPA signed the agreement to support an enhanced watershed protection program for the New York City drinking water supply. The city-funded, multi-year, $1.4-billion agreement developed a multi-faceted land conservation approach, which includes the purchase of 80,000 acres within the watershed as a buffer around the city's drinking water supply. This plan allows the city to avoid the construction of filtration facilities estimated to cost six to eight billion dollars (New York City, 2002).

Preserving Ecologically Sensitive Areas

Some types of land perform watershed functions better than others do. Preserving ecologically important land, such as wetlands, buffer zones, riparian corridors, and floodplains, is critical for regional water quality. Wetlands are natural filtration plants, slowing water flow and allowing sediments to settle and the water to clarify. Trace metals bound to clay carried in runoff also drop out and become sequestered in the soils and peat at the bed of the marsh instead of entering waterbodies, such as streams, lakes, or rivers. Preserving and maintaining wetlands are critical to maintain water quality.

Photo courtesy of USDA NRCS

Wetlands, such as this one in Butte County, California, provide critical watershed services for the region.

In addition, strips of vegetation along streams and around reservoirs are important buffers, with wooded buffers offering the greatest protection. For example, if soil conditions are right, a 20- to 30-foot-wide strip of woodland removes 90 percent of the nitrates in stormwater runoff (Trust for Public Land, 1997). These buffer zones decrease the amount of pollution entering the water system. Tree and shrub roots hold the bank in place, preventing erosion and its resulting sedimentation and turbidity. Organic matter and grasses slow the flow of runoff, giving the sediment time to settle and water time to percolate, filter through the soil, and recharge underlying ground water. Research has shown that wetlands and buffer zones, by slowing and holding water, increase ground water recharge, which directly reduces the potential for flooding (Schueler, 1994). By identifying and preserving these critical ecological areas, communities are actively protecting and enhancing their water quality.

Minimizing Land Disturbance and Impervious Cover

Minimizing land disturbance and impervious cover is critical to maintaining watershed health. The amount of land that is converted, or "disturbed," from undeveloped uses, such as forests and meadows, to developed uses, such as lawns and playing fields, significantly affects watershed health. Research now shows that the volume of runoff from highly compacted lawns is almost as high as from paved surfaces (Schueler, 1995, 2000; USDA, 2001). This research indicates that lawns and other residential landscape features do not function, with regard to water, in the same way as nondegraded natural areas. In part, the difference arises because developing land in greenfield areas involves wholesale grading of the site and removal of topsoil, which can lead to severe erosion during construction, and soil compaction by heavy equipment. However, most communities focus not on total land disturbed, but on the amount of impervious cover created.

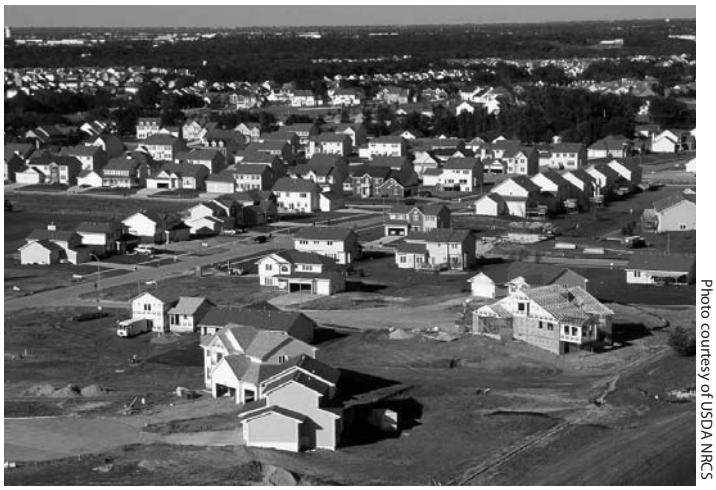


Photo courtesy of USDA NRCS

Current construction practices generally disturb the entire development site, as shown by this site in Des Moines, Iowa.

Research has revealed a strong relationship between impervious cover and water quality (Arnold, 1996; Schueler, 1994; EPA, 1997). Impervious surfaces collect and accumulate pollutants deposited from the atmosphere, leaked from vehicles, or derived from other sources. During storms, accumulated pollutants are quickly washed off and rapidly delivered to aquatic systems. Studies have demonstrated that at 10 percent imperviousness,[2] a watershed is likely to become impaired (Schueler, 1996; Caraco, 1998; Montgomery County, 2000), the stream channel becomes unstable due to increased water volumes and stream bank erosion, and water quality and stream biodiversity decrease. At 25 percent imperviousness, a watershed becomes severely impaired, the stream channel can become highly unstable, and water quality and stream biodiversity are poor[3] (Schueler, 2000). The amount of impervious cover is an important indicator of watershed health, and managing the degree to which a watershed is developed is critical to maintaining watershed function.

Although the 10 percent threshold refers to overall imperviousness within the watershed, municipalities have applied it to individual sites within the watershed, believing that lower densities better protect watershed functions. Indeed, as mentioned earlier, some localities have gone so far as to create strong incentives for, or even require, low densities—with water resource protection as an explicit goal. These communities are attempting to minimize hard

[2] The 10 percent figure is not an absolute threshold. Recent studies have indicated that in some watersheds, serious degradation may begin well below 10 percent. However, the level at which watershed degradation begins is not the focus of this study. For purposes of our analysis, EPA uses the 10 percent threshold as an indicator that water resources might be impacted.

[3] There are different levels of impairment. In general, when the term is used in EPA publications, it usually means that a waterbody is not meeting its designated water quality standard. However, the term can also imply a decline or absence of biological integrity; for example, the waterbody can no longer sustain critical indicator species, such as trout or salmon. Further, there is a wide breadth of levels of impairment, from waterbodies that are unable to support endangered species to waterbodies that cannot support any of the beneficial-use designations.

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surfaces at the site level. They believe that limiting densities within particular development sites limits regional imperviousness and thus protects regional water quality. The next section examines this proposition and finds that low-density development can, in fact, harm water quality.

Low-Density Development—Critiquing Conventional Wisdom

As discussed, studies have demonstrated that watersheds can suffer impairment at 10 percent impervious cover and that at 25 percent imperviousness, the watershed is typically considered severely impaired. Communities have often translated these findings into the notion that low-density development at the site level results in better water quality. Such conclusions often come from analysis such as: a one-acre site has one or two homes with a driveway and a road passing by the property. The remainder of the site is lawn. Assuming an average housing footprint of 2,265 square feet[4] (National Association of Home Builders, 2001), the impervious cover for this one-acre site is approximately 35 percent (Soil Conservation Service, 1986). By contrast, a higher-density scenario might have eight to 10 homes per acre and upwards of 85 percent impervious cover (Soil Conservation Service, 1986). The houses' footprints account for most of the impervious cover. Thus, low-density zoning appears to create less impervious cover, which ought to protect water quality at the site and regional levels. However, this logic overlooks several key caveats.

1. *The "pervious" surface left in low-density development often acts like impervious surface.* In general, impervious surfaces, such as a structure's footprint, driveways, and roads, have higher amounts of runoff and associated pollutants than pervious surfaces. However, most lawns, though pervious, still contribute to runoff because they are compacted. Lawns are thought to provide "open space" for infiltration of water. However, because of construction practices, the soil becomes compacted by heavy equipment and filling of depressions (Schueler, 1995, 2000). The effects of this compaction can remain for years and even increase due to mowing and the presence of a dense mat of roots. Therefore, a one- or two-acre lawn does not offer the same infiltration or other water quality functions as a one- or two-acre undisturbed forest. Minimizing impervious surfaces by limiting the number of houses but allowing larger lawns does not compensate for the loss of watershed services that the area provided before development (USDA, 2001).

   Lawns still contribute to runoff because they are compacted and disturbed.

2. *Density and imperviousness are not equivalent.* Depending on the design, two houses may actually create as much imperviousness as four houses. The impervious area per home can vary widely due to road infrastructure, housing design (single story or multistory), or length and width of driveways. To illustrate, a three-story condominium building of 10 units on one acre can have less impervious surface than four single-family homes on the same acre. Furthermore, treatment of the remaining undeveloped land on that acre can

[4] The average house built in 2001 included three or more bedrooms, two and a half baths, and a two-car garage.

vary dramatically between housing types. For example, in some dispersed, low-density communities, such as Fairfax County, Virginia, some homeowners are paving their front lawns to create more parking for their cars (Rein, 2002).

3. *Low-density developments often mean more off-site impervious infrastructure.* Development in the watershed is not simply the sum of the sites within it. Rather, total impervious area in a watershed is the sum of site developments plus the impervious surface associated with infrastructure supporting those sites, such as roads and parking lots. Lower-density development can require substantially higher amounts of this infrastructure per house and per acre than denser developments. Recent research has demonstrated that on sites with two homes per acre, impervious surfaces attributed to streets, driveways, and parking lots can represent upwards of 75 percent of the total site imperviousness (Cappiella, 2001). That number decreases to 56 percent on sites with eight homes per acre. This research indicates that low densities often require more off-site transportation-related impervious infrastructure, which is generally not included when calculating impervious cover.

   Water quality suffers not only from the increase in impervious surface, but also from the associated activities: construction, increased travel to and from the development, and extension of infrastructure.

   Furthermore, water quality suffers not only from the increase in impervious surface, but also from the associated activities: construction, increased travel to and from the development, extension of infrastructure, and chemical maintenance of the areas in and surrounding the development. Oil and other waste products, such as heavy metals, from motor vehicles, lawn fertilizers, and other common solvents, combined with the increased flow of runoff, contribute substantially to water pollution. As imperviousness increases, so do associated activities, thereby increasing the impact on water quality.

4. *If growth is coming to the region, limiting density on a given site does not eliminate that growth*. Density limits constrain the amount of development on a site but have little effect on the region's total growth (Pendall, 1999, 2000). The rest of the growth that was going to come to the region still comes, regardless of density limits in a particular place. Forecasting future population growth is a standard task for metropolitan planning organizations as they plan where and how to accommodate growth in their region. They project future population growth based on standard regional population modeling practices, where wage or amenity differentials, such as climate or culture (Mills, 1994)—and not zoning practices such as density limits—account for most of a metropolitan area's population gain or loss.[5] While estimates of future growth within a particular time frame are rarely precise, a region must use a fixed amount of growth to test the effects of adopting

   Growth is still coming to a region, regardless of density limits in a particular place.

[5] The most widely-used such model—the REMI® Policy Insight™ model—uses an amenity variable. However, even this is implemented as an additional change in the wage rate. See Remi Model Structure. <www.remi.com/Overview/Evaluation/Structure/structure.html>. The in-house model used by the San Diego Association of Governments is an advanced example of the type used by councils of governments around the country.<www.sandag.cog.ca.us/resources/demographics_and_other_data/demographics/forecasts/index.asp>.

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different growth planning strategies because it still must understand the economic, social, and environmental impacts of accommodating a growing population. Absent regional coordination and planning, covering a large part of a region with density limits will likely drive growth to other parts of the region. Depending on local conditions, water quality may be more severely impaired than if the growth had been accommodated at higher densities on fewer sites.

Testing the Alternative: Can Compact Development Minimize Regional Water Quality Impacts?

To more fully understand the potential water quality impacts of different density levels, this section compares three hypothetical communities, each accommodating development at different densities—one house per acre, four houses per acre, and eight houses per acre.[6] To assess regional water quality impacts, EPA modeled the stormwater impacts from different development densities. In general, the more stormwater runoff generated within a region, the more associated pollutants, such as total nitrogen, phosphorus, and suspended solids, will enter receiving waterbodies. The three density levels capture some of the wide range of zoning practices in use throughout the country. All of these densities are consistent with single-family, detached housing. EPA examined the stormwater impacts from each density scenario at various scales of residential development[7]—one-acre, lot, and watershed levels—and through a 40-year time series build-out analysis.

The Model and Data Inputs

The model used to compare the stormwater impact from the scenarios is the Smart Growth Water Assessment Tool for Estimating Runoff (SG WATER), which is a peer-reviewed sketch model that was developed specifically to compare water quantity and quality differences among different development patterns (EPA, 2002). SG WATER's methodology is based on the Natural Resources Conservation Service (NRCS) curve numbers (Soil Conservation Service, 1986), event mean concentrations, and daily rainfall data.[8] The model requires the total number of acres developed at a certain development density. If density is unknown, total percent imperviousness can be used. The model was run using overall percent imperviousness.

EPA believes that the results presented here are conservative. SG WATER uses a general and simple methodology based on curve numbers. One limitation of curve numbers is that they tend to underestimate stormwater runoff for smaller storms (less than one inch). This underestimate

[6] Densities at one, four, and eight residential units per acre are used here for illustrative purposes only. Many communities now are zoning for one unit per two acres at the low-density end of the spectrum. Low-density residential zoning exists in places as diverse as Franklin County, Ohio, which requires no less than two acres per unit <www.co.franklin.oh.us/development/franklin_co/LDR.html#304.041>) to Cobb County, Georgia, outside of Atlanta, which requires between one and two units per acre in its low-density residential districts (<www.cobbcounty.org/community/plan_bza_commission.htm>). By comparison, some communities are beginning to allow higher densities, upwards of 20 units per acre. For example, the high-density residential district in Sonoma County, California permits between 12 and 20 units per acre (<www.sonoma-county.org/prmd/Zoning/article_24.htm>), and the city of Raleigh, North Carolina, allows up to 40 units per acre in planned development districts.

[7] This example and others throughout this study compare residential units, but a similar comparison including commercial development could also be done .

[8] Daily time-step rainfall data for a 10-year period (1992-2001, inclusive) were used.

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can be significant since the majority of storms are small storms. In addition, the curve numbers tend to overestimate runoff for large storms. However, curve numbers more accurately predict runoff in areas with more impervious cover.[9] For the analysis here, the runoff from the low-density site is underestimated to a larger degree than the runoff from the higher-density site because the higher-density site has more impervious cover. Simply put, because of methodology, the difference in the numbers presented here is conservative—it is likely that the comparative difference in runoff between the sites would be greater if more extensive modeling were used.

To isolate the impacts that developing at different densities makes on stormwater runoff, EPA made several simplifying assumptions in the modeling:

- EPA modeled only residential growth and not any of the corresponding commercial, retail, or industrial growth that would occur in addition to home building. Moreover, EPA assumed that all the new growth would occur in greenfields (previously undeveloped land). Infill development, brownfield redevelopment, and other types of urban development were not taken into consideration, nor were multifamily housing, apartments, or accessory dwelling units.[10]
- The modeling did not take into account any secondary or tertiary impacts, such as additional stormwater benefits, that may be realized by appropriately locating the development within the watershed. For example, siting development away from headwaters, recharge areas, or riparian corridors could better protect these sensitive areas. Denser development makes this type of protective siting easier since less land is developed. However, these impacts are not captured or calculated within the modeling.
- Whether developed at one, four, or eight houses per acre, when one acre is developed, EPA assumed the entire acre is disturbed land (e.g., no forest or meadow cover would be preserved), which is consistent with current construction practices.
- All the new growth is assumed to be single-family, detached houses.[11] Whether developed at one, four, or eight houses per acre, each home has a footprint of 2,265 square feet, roughly the current average size for new houses (National Association of Home Builders, 2001).

[9] Most existing stormwater models incorrectly predict flows associated with small rains in urban areas. Most existing urban runoff models originated from drainage and flooding evaluation procedures that emphasized very large rains (several inches in depth). These large storms contribute only very small portions of the annual average discharges. Moderate storms, occurring several times a year, are responsible for the majority of the pollutant discharges. These frequent discharges cause mostly chronic effects, such as contaminated sediment and frequent high flow rates, and the inter-event periods are not long enough to allow the receiving water conditions to recover.

[10] Single-family, detached housing dominates many low-density residential developments. However, higher-density developments support a range of housing types, including townhouses, apartments, and other forms of multifamily housing. These housing types generally have a smaller footprint per house than 2,265 square feet. Therefore, a more realistic situation for the higher-density scenarios would either be a smaller housing footprint or an increase in the number of homes accommodated on one acre. In either case, including these different housing types in the analysis would produce less overall stormwater runoff and less per house runoff for the higher-density scenarios.

[11] It is possible that when additional land uses, such as commercial, transportation, or recreation, are included in the analysis, the low-density scenarios become relatively less dense while the higher-density scenarios become relatively more dense. In general, low-density residential development tends to be associated with low-density commercial development, characterized by large retail spaces, wide roads, large parking lots, and minimal public transportation. Higher-density residential areas are more likely to have high-density commercial options, with smaller retail spaces, mixed land uses, narrower streets, parking garages, on-street parking, and sometimes a well-developed public transportation system, which can reduce parking needs.

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- The same percentage of transportation-associated infrastructure, such as roads, parking lots, driveways, and sidewalks, is allocated to each community acre, based on the curve number methodology from the NRCS. For example, each scenario has the same width of road, but because the higher-density scenario is more compact, it requires fewer miles of roads than the lower-density scenarios. So while the same percentage is applied, the amounts differ by scenario. Collector roads or arterials that serve the development are not included.
- The modeled stormwater runoff quantity for each scenario is assumed to come from one hypothetical outfall.
- The model does not take into account wastewater or drinking water infrastructure, slope, or other hydrological interactions that the more complex water modeling tools use.

Summary of Scenarios

Example 1 examines the stormwater runoff impacts on a one-acre lot that accommodates one house (Scenario A), four houses (Scenario B), or eight houses (Scenario C). Example 2 expands the analysis to examine stormwater runoff impacts within a lot-level development that accommodates the same number of houses. Because of different development densities, this growth requires different amounts of land. Scenario A requires eight acres for eight houses, Scenario B requires two acres for eight houses, and Scenario C requires one acre for eight houses.

Examples 3, 4, and 5 explore the relationship between density and land consumption by building in a watershed at different densities. Again, different amounts of land are required to support the same amount of housing. Examples 6, 7, and 8 examine how the hypothetical community grows over a 40-year timeframe with different development densities.

The scenarios and scales of development are summarized in Exhibit 2. EPA expects to capture the differences in stormwater runoff associated with different development densities by using these three scenarios (Scenarios A, B, and C) at four different scales (one acre, lot, watershed, and build-out).

EXHIBIT 2: Summary of Scenarios

Scale of Analysis	Scenario A: One house per acre	Scenario B: Four houses per acre	Scenario C: Eight houses per acre
Example 1: One acre	1 house per acre	4 houses per acre	8 houses per acre
Example 2: Lot—Each development lot accommodates the same number of houses	8 houses built on 8 acres	8 houses built on 2 acres	8 houses built on 1 acre

Example 3: Watershed—Each 10,000-acre watershed accommodates the same number of houses	10,000 houses built on 10,000 acres	10,000 houses built on 2,500 acres or ¼ of the watershed	10,000 houses built on 1,250 acres or $^1/_8$ of the watershed
Example 4: Watershed—Each 10,000-acre watershed is fully built out at different densities	10,000 houses built on 10,000 acres	40,000 houses built on 10,000 acres	80,000 houses built on 10,000 acres
Example 5: Watershed—Each scenario accommodates the same number of houses	80,000 houses consume 8 watersheds	80,000 houses consume 2 watersheds	80,000 houses consume 1 watershed
Example 6: Hypothetical build-out in the year 2000	10,000 houses built on 10,000 acres	10,000 houses built on 2,500 acres	10,000 houses built on 1,250 acres
Example 7: Hypothetical build-out in the year 2020	20,000 houses built on 20,000 acres, or 2 watersheds	20,000 houses built on 5,000 acres, or ½ of 1 watershed	20,000 houses built on 2,500 acres, or ¼ of 1 watershed
Example 8: Hypothetical build-out in the year 2040	40,000 houses built on 40,000 acres, or 4 watersheds	40,000 houses built on 10,000 acres, or 1 watershed	40,000 houses built on 5,000 acres, or ½ of 1 watershed

Before analyzing the impacts of these different scenarios, it is useful to clarify some underlying premises. This analysis assumes that:

1. Metropolitan regions will continue to grow. This assumption is consistent with U.S. Census Bureau projections that the U.S. population will grow by roughly 50 million people by 2020 (Census, 2000). Given this projected population growth, most communities across the country are or will be determining where and how to accommodate expected population increases in their regions.
2. Housing density affects the distribution of new growth within a given region, not the amount of growth. Individual states and regions grow at different rates depending on a variety of factors, including macroeconomic trends (e.g., the technology boom in the 1980s spurring development in the Silicon Valley region in California) and demographic shifts. Distribution and density of new development do not significantly affect these factors.

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3. The model focuses on the comparative differences in stormwater runoff between scenarios, not absolute values. As discussed, using the curve number and event mean concentration approach can underestimate the total quantity of stormwater runoff for smaller storm events and in areas of lower densities. Because of this and other model simplifications discussed above, the analysis does not focus on the absolute value of stormwater runoff generated for each scenario but instead focuses on the comparative difference, or the delta, in runoff between scenarios.

Results

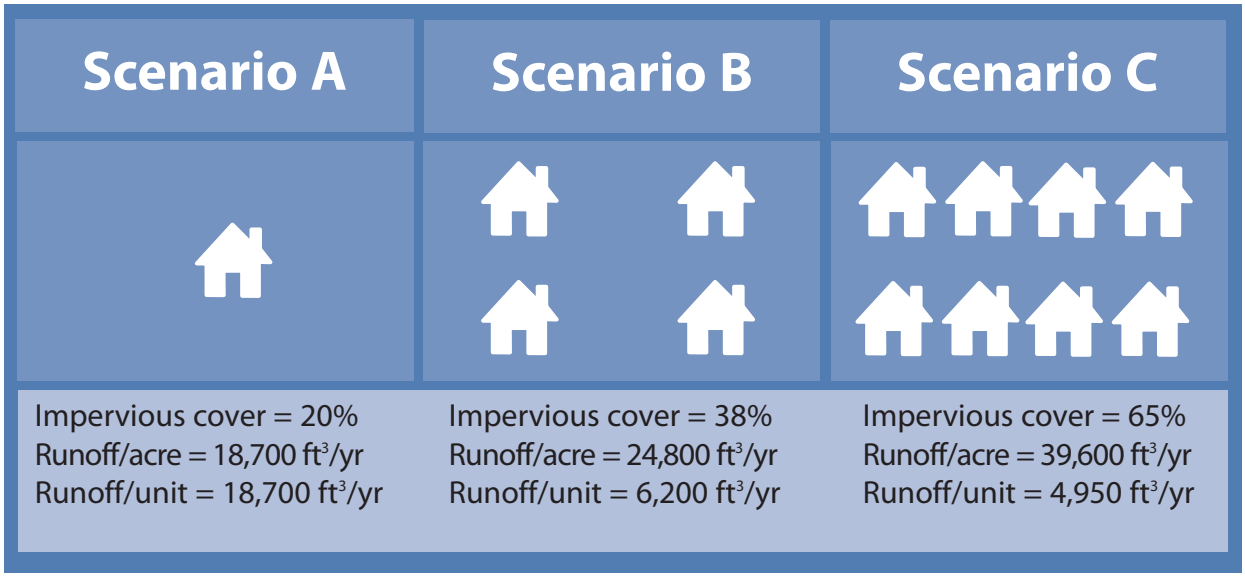
The results from the eight examples for all three scenarios are presented below.

Example 1: One-Acre Level

Scale of Analysis	Scenario A	Scenario B	Scenario C
One Acre	1 house	4 houses	8 houses

EPA examined one acre developed at three different densities: one house, four houses, and eight houses. The results are presented in Exhibit 3. As Exhibit 3 demonstrates, the overall percent imperviousness for Scenario A is approximately 20 percent with one house per acre, 38 percent for Scenario B with four houses per acre, and 65 percent for Scenario C with eight houses per acre (Soil Conservation Service, 1986).

EXHIBIT 3: Total Average Annual Stormwater Runoff for All Scenarios



Examining the estimated average annual runoff at the acre level, as illustrated in Exhibit 4, the low-density Scenario A, with just one house, produces an average runoff volume of 18,700 cubic feet per year (ft^3/yr). Scenario C, with eight houses, produces 39,600 ft^3/yr, and Scenario B falls between Scenarios A and C at 24,800 ft^3/yr. In short, looking at the comparative differences between scenarios, runoff roughly doubles as the number of houses increases from one house per acre to eight houses per acre. Scenario C, with more houses on the acre, has the greatest amount of impervious surface cover and thus generates the most runoff at the acre level.

Looking at the comparative difference of how much runoff each individual house produces, in Scenario A, one house yields 18,700 ft^3/yr, the same as the per acre level. In the denser Scenario C, however, each house produces 4,950 ft^3/yr average runoff. The middle scenario, Scenario B, produces considerably less runoff—6,200 ft^3/yr—per house than Scenario A, but more than Scenario C. Each house in Scenario B produces approximately 67 percent less runoff than a house in Scenario A, and each house in Scenario C produces 74 percent less runoff than a house in Scenario A. This is because the houses in Scenarios B and C create less impervious surface per house than the house in Scenario A. Therefore, per house, each home in the higher-density communities results in less stormwater runoff.

Each house in Scenario B produces approximately 67 percent less runoff than a house in Scenario A, and each house in Scenario C produces 74 percent less runoff than a house in Scenario A.

Modeling at the acre level demonstrates that, in this example, when density is quadrupled (from one house to four houses), stormwater runoff increases by one-third per acre, but decreases by two-thirds per house. Moreover, when density increases by a factor of eight—from one house to eight houses—stormwater runoff doubles per acre, but decreases by almost three-quarters per house.

These results indicate when runoff is measured by the acre, limiting density does minimize water quality impacts compared to the higher-density scenarios. However, when measured by the house, higher densities produce less stormwater runoff.

Example 2: Lot Level

Scale of Analysis	Scenario A	Scenario B	Scenario C
Lot	8 houses built on 8 acres	8 houses built on 2 acres	8 houses built on 1 acre

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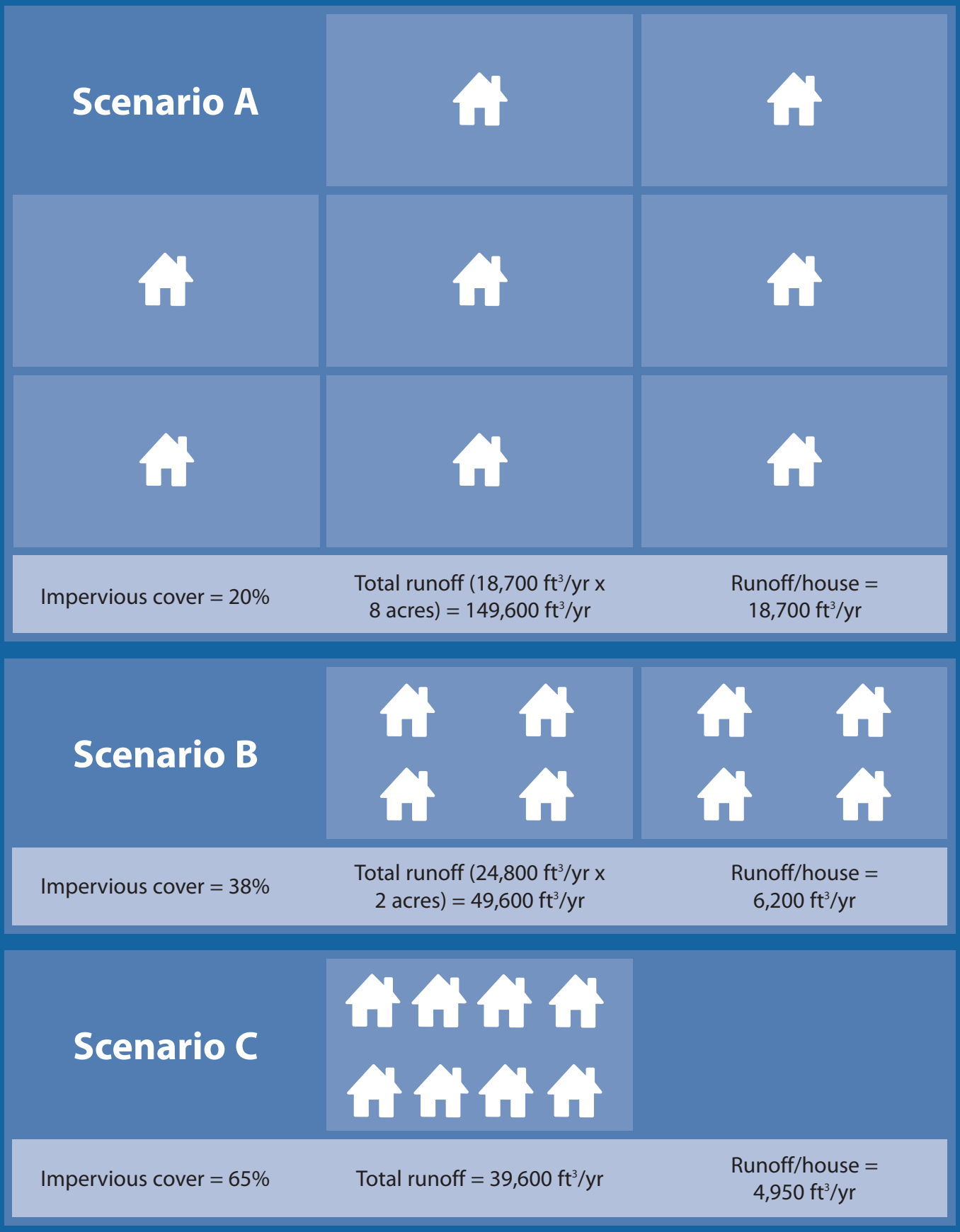
EXHIBIT 4: Each Scenario Accommodates Eight Houses



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For each development to accommodate the same number of houses, the lower-density scenarios require more land to accommodate the same number of houses that Scenario C has accommodated on one acre. Specifically, Scenario A must develop seven additional acres, or eight acres total, to accommodate the same number of houses as Scenario C. Scenario B must develop two acres to accommodate the same number of houses. Exhibit 4 illustrates.

The increase in runoff for Scenario A is due to the additional land consumption.

With each scenario accommodating the same number of houses, this analysis shows that total average runoff in Scenario A is 149,600 ft^3/yr (18,700 ft^3/yr x 8 acres), which is a 278 percent increase from the 39,600 ft^3/yr total runoff in Scenario C. Total average runoff from eight houses in Scenario B is 49,600 ft^3/yr (24,800 ft^3/yr x 2 acres), which is a 25 percent increase in runoff from Scenario C. The increase in runoff for Scenario A is due to the additional land consumption and associated runoff. The impervious cover for Scenario A remains the same at 20 percent, but now, seven additional acres have 20 percent impervious cover.

Examining the comparative difference in runoff between scenarios shows that lower densities can create less total impervious cover, but produce more runoff when the number of houses is kept consistent between scenarios. Furthermore, the higher-density scenario produces less runoff per house and per lot.

Example 3: Watershed Level

Scale of Analysis	Scenario A	Scenario B	Scenario C
Watershed—Each 10,000-acre watershed accommodates the same number of houses	10,000 houses built on 10,000 acres	10,000 houses built on 2,500 acres	10,000 houses built on 1,250 acres

Taking the analysis to the watershed level, EPA examined the comparative watershed stormwater runoff impacts from accommodating growth at different densities. The watershed used in this analysis is a hypothetical 10,000-acre watershed accommodating only houses. As discussed, the modeling does not include retail, business centers, farms, or any other land uses typically seen in communities, nor does it take into consideration where the development occurs within the watershed. Research has shown that upper sub-watersheds, which contain smaller streams, are generally more sensitive to development than lower sub-watersheds (Center for Watershed Protection, 2001).

Accommodating 10,000 houses at one house per acre in the 10,000-acre watershed would fully build out the watershed. At the higher density of four houses per acre, one-quarter of the watershed would be developed, and at eight houses per acre, one-eighth of the watershed would be developed. Exhibit 5 shows the runoff associated with each of these scenarios.

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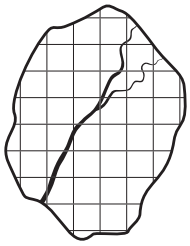
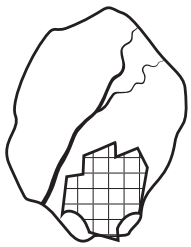
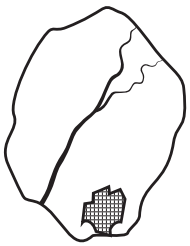
EXHIBIT 5: 10,000-Acre Watershed Accommodating 10,000 Houses

Scenario A	Scenario B	Scenario C
		
10,000 houses built on 10,000 acres produce: 10,000 acres x 1 house x 18,700 ft^3/yr of runoff = **187 million ft^3/yr of stormwater runoff** **Site: 20% impervious cover** **Watershed: 20% impervious cover**	10,000 houses built on 2,500 acres produce: 2,500 acres x 4 houses x 6,200 ft^3/yr of runoff = **62 million ft^3/yr of stormwater runoff** **Site: 38% impervious cover** **Watershed: 9.5% impervious cover**	10,000 houses built on 1,250 acres produce: 1,250 acres x 8 houses x 4,950 ft^3/yr of runoff = **49.5 million ft^3/yr of stormwater runoff** **Site: 65% impervious cover** **Watershed: 8.1% impervious cover**

As Exhibit 5 illustrates, if development occurs at a lower density, e.g., one house per acre, the entire watershed will be built out, generating 187 million ft^3/yr of stormwater runoff. Scenario B, at four houses per acre, consumes less land and produces approximately 62 million ft^3/yr of stormwater runoff, while Scenario C, at the highest density, consumes the least amount of land and produces just 49.5 million ft^3/yr of stormwater runoff. Looking at the comparative differences, Scenario A generates approximately three times as much runoff from development as Scenario B, and approximately four times as much stormwater runoff as Scenario C.

Exhibit 5 also illustrates that, in this example, overall impervious cover for the watershed decreases as site density increases. Scenario C, which has a lot-level imperviousness of 65 percent, has a watershed-level imperviousness of only 8.1 percent, which is lower than the 10

Overall impervious cover for the watershed decreases as site density increases.

percent threshold discussed earlier. Scenario B, with a density of four houses per acre, has a site-level impervious cover of 38 percent, but a watershed imperviousness of 9.5 percent, which is still lower than the 10 percent threshold. Finally, Scenario A, at a lot-level imperviousness of 20 percent, has the same overall imperviousness at the watershed level. **Both of the higher-density scenarios consume less land and maintain below-the-threshold imperviousness.**

This simplistic illustration demonstrates a basic point of this analysis—higher-density developments can minimize stormwater impacts because they consume less land than their lower-density counterparts. For example, imagine if Manhattan, which accommodates 1.54 million people on 14,720 acres (23 square miles) (Census, 2000), were developed not at its current density of 52 houses per acre, but at one or four houses per acre. At one house per acre, Manhattan would need approximately 750,000 more acres, or an additional 1,170 square miles, to accommodate its current population at two people per household. That's approximately the size of Rhode Island. At four houses per acre, Manhattan would need approximately 175,000 more acres, or an additional 273 square miles.

At one house per acre, Manhattan would need approximately 750,000 more acres, or an additional 1,170 square miles, to accommodate its current population at two people per household.

Reducing land consumption is crucial to preserving water quality because, as discussed previously, preserving large, continuous areas of open space and sensitive ecological areas is critical for maintaining watershed services. In addition, because of their dense development pattern, Scenarios B and C may realize additional stormwater benefits if the developed land is appropriately sited in the watershed to protect sensitive ecological areas, such as headwaters, wetlands, riparian corridors, and floodplains.

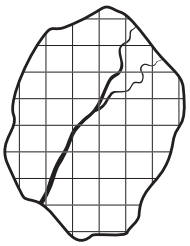
Example 4: Remaining Land in the Watershed Developed

What happens if the remaining undeveloped parts of the watershed in Scenarios B and C are developed? Exhibit 6 considers this situation.

Scale of Analysis	Scenario A	Scenario B	Scenario C
Watershed—Each 10,000-acre watershed is fully built out at different densities	10,000 houses built on 10,000 acres	40,000 houses built on 10,000 acres	80,000 houses built on 10,000 acres

EXHIBIT 6: 10,000-Acre Watershed Accommodating Different Numbers of Houses

Scenario A



The watershed is fully built out at *1 house per acre*. 10,000 acres accommodates **10,000 houses**, translating to:

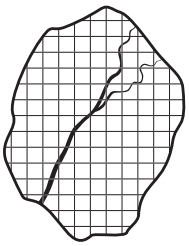
10,000 acres x 1 house x 18,700 ft^3/yr of runoff =

187 million ft^3/yr stormwater runoff

Site: 20% impervious cover

Watershed: 20% impervious cover

Scenario B



The watershed is fully built out at *4 houses per acre*. 10,000 acres accommodates **40,000 houses**, translating to:

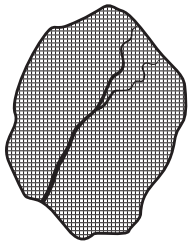
10,000 acres x 4 houses x 6,200 ft^3/yr of runoff =

248 million ft^3/yr stormwater runoff

Site: 38% impervious cover

Watershed: 38% impervious cover

Scenario C



The watershed is fully built out at 8 *houses per acre*. 10,000 acres accommodates **80,000 houses**, translating to:

10,000 acres x 8 houses x 4,950 ft^3/yr of runoff =

396 million ft^3/yr stormwater runoff

Site: 65% impervious cover

Watershed: 65% impervious cover

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Each watershed is fully built out, and the watershed developed at the highest density (Scenario C) is generating approximately double the total stormwater runoff of Scenario A. Scenario B is generating approximately one-third more runoff than Scenario A. Similar to the acre-level and lot-level results, Scenario C has the highest degree of impervious cover at 65 percent, while Scenario A maintains the lowest level at 20 percent.

Scenarios A and B accommodate only a small portion of the expected growth. The rest will have to be built in other watersheds.

The higher densities found in Scenario B and C are degrading their watershed services to a greater extent than Scenario A. However, the number of houses accommodated in each community is not the same. Scenario B is accommodating **30,000 more houses** (four times the number of Scenario A), and Scenario C is accommodating **70,000 more houses** (eight times the number of Scenario A). Recall that density limits shift growth and do not generally affect the total amount of growth in a given time period. Therefore, this is not a fair comparison. Scenarios A and B accommodate only one-eighth and one-half, respectively, of the 80,000 houses accommodated in Scenario C. Where do the other houses, households, and families go? To get a true appreciation for the effects of density, Scenarios A and B must also show where those homes will be accommodated. It is likely that they would be built in nearby or adjacent watersheds. Our hypothetical community that develops at one house per acre (Scenario A) is able to accommodate only 10,000 houses. For the community that develops at that density to accommodate the same number of houses that Scenario C contains, it must disturb and develop land from nearby or adjacent watersheds.

Example 5: Accommodating the Same Number of Houses

Scale of Analysis	Scenario A	Scenario B	Scenario C
Watershed—Each scenario accommodates the same number of houses	1 house per acre—80,000 houses consume 8 watersheds	4 houses per acre—80,000 houses consume 2 watersheds	8 houses per acre—80,000 houses consume 1 watershed

As discussed, the U.S. population will increase by an estimated 50 million people by 2020. Different areas of the country will grow at different rates in the future. Whether a region anticipates 1,000 or 80,000 new households to come to the region over the next 10 years, comparisons between build-out scenarios must keep the number of homes consistent. In this case, if Scenario C is developed so that its entire watershed is built out to 80,000 houses, then for a fair comparison, Scenarios A and B must also include 80,000 houses. Exhibit 7 illustrates this situation.

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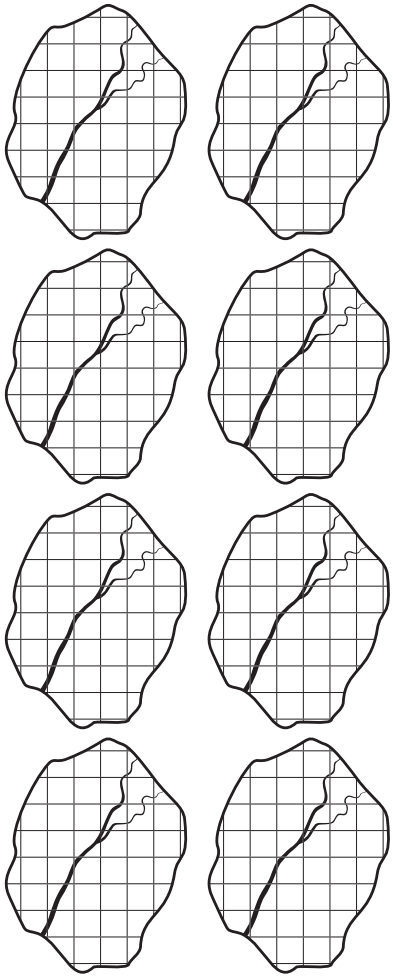
EXHIBIT 7: 80,000 Houses Accommodated

Scenario A



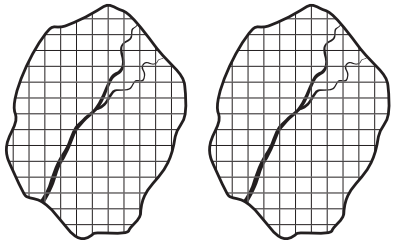
At 1 house per acre, 80,000 houses require 80,000 acres, or *8 watersheds*, translating to:

80,000 acres x 1 house x 18,700 ft^3/yr of runoff =

1.496 billion ft^3/yr of stormwater runoff

8 watersheds at 20% impervious cover

Scenario B



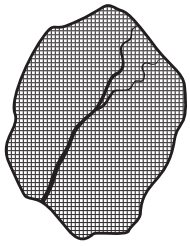
At 4 houses per acre, 80,000 houses require 20,000 acres, or *2 watersheds*, translating to:

20,000 acres x 4 houses x 6,200 ft^3/yr of runoff =

496 million ft^3/yr of stormwater runoff

2 watersheds at 38% impervious cover

Scenario C



At 8 houses per acre, 80,000 houses require 10,000 acres, or *1 watershed*, translating to:

10,000 acres x 8 houses x 4,950 ft^3/yr of runoff =

396 million ft^3/yr of stormwater runoff

1 watershed at 65% impervious cover

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When the number of houses is kept consistent, Scenario A would need to develop an *additional seven watersheds* (assuming the same size watersheds) and Scenario B would need to develop *one additional watershed* to accommodate the same growth found in Scenario C.

As Exhibit 7 demonstrates, for Scenario A to accommodate the additional 70,000 homes already accommodated in Scenario C, it must develop another seven watersheds. This generates 1.496 billion ft^3/yr of stormwater runoff. Scenario C, with a development density of eight houses per acre, has still developed just one watershed and is generating approximately 74 percent less stormwater runoff than Scenario A—or 396 million ft^3/yr. Scenario B, at four houses per acre, is generating 496 million ft^3/yr runoff, or two-thirds less runoff than Scenario A, but 100 million ft^3/yr more than Scenario C.

Scenario A would need to develop an *additional seven watersheds* and Scenario B would need to develop *one additional watershed* in order to accommodate the same growth found in Scenario C.

Example 6: Time Series Build-out Analysis: Build-out in 2000

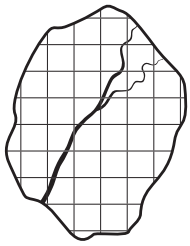
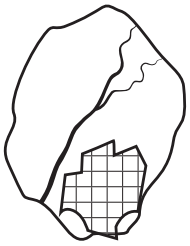
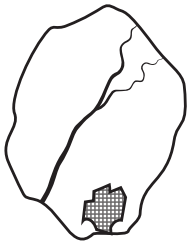
Scale of Analysis	Scenario A	Scenario B	Scenario C
Hypothetical build-out in the year 2000	10,000 houses built on 10,000 acres	10,000 houses built on 2,500 acres	10,000 houses built on 1,250 acres

Another way to examine this issue is to look at what happens to build-out of the three scenarios over time. A basic assumption for EPA's modeling is that growth is coming to the hypothetical community, and that growth will be accommodated within a fixed time horizon. But what happens to growth in the hypothetical community over several, sequential time horizons?

Given the dynamic nature of population growth, what will build-out look like in the hypothetical community in 2000, 2020, and 2040 at different development densities? The next several examples examine the amount of land required to accommodate increasing populations within a watershed that develops at different densities. The purpose of this time series build-out is to examine how much land is consumed as the population grows in 20-year increments.

Starting in the year 2000, the three watersheds each begin with 10,000 homes. The only difference between the watersheds is the densities at which the building occurs. In 2000, they might look something like Exhibit 8.

EXHIBIT 8: Time Series Build-out Analysis: Build-out in 2000

Scenario A	Scenario B	Scenario C
		
10,000 houses on 10,000 acres at a density of *1 house per acre* consume 1 entire watershed.	10,000 houses on 2,500 acres at a density of *4 houses per acre* consume ¼ of 1 watershed.	10,000 houses on 1,250 acres at a density of *8 houses per acre* consume ⅛ of 1 watershed.

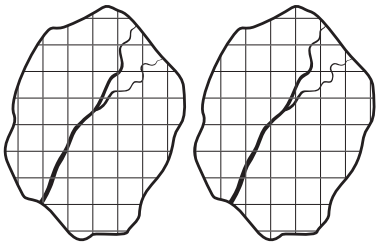
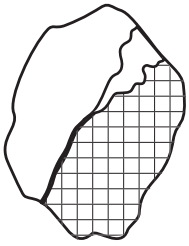
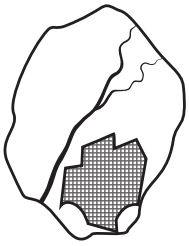
As previously demonstrated in Example 3, building at higher densities consumes, or converts, less land within the watershed. Scenario A, developing at one unit per acre, requires the entire 10,000-acre watershed to accommodate 10,000 houses. Scenario C, on the other hand, developing at eight units an acre, requires significantly less land to accommodate the same amount of development.

EXAMPLE 7: TIME SERIES BUILD-OUT ANALYSIS: BUILD-OUT IN 2020

Scale of Analysis	Scenario A	Scenario B	Scenario C
Hypothetical build-out in the year 2020	20,000 houses built on 20,000 acres, or 2 watersheds	20,000 houses built on 5,000 acres, or ½ of 1 watershed	20,000 houses built on 2,500 acres, or ¼ of 1 watershed

Fast-forwarding 20 years, the population in the hypothetical community has doubled from 10,000 houses to 20,000 houses. Each scenario must accommodate this additional growth at different development densities. Exhibit 9 demonstrates how this development might look.

EXHIBIT 9: Time Series Build-out Analysis: Build-out in 2020

Scenario A	Scenario B	Scenario C
		
20,000 houses accommodated on 20,000 acres at a density of *1 house per acre* will consume 2 watersheds.	20,000 houses accommodated on 5,000 acres at a density of *4 houses per acre* will consume ½ of 1 watershed.	20,000 houses accommodated on 2,500 acres at a density of *eight houses per acre* will consume ¼ of 1 watershed.

As Exhibit 9 demonstrates, Scenario A, developing at one house per acre, requires another whole watershed to accommodate the additional growth. Scenarios B and C, developing at higher densities, can accommodate the additional growth within the same watershed. Moreover, by developing at higher densities within the watershed, ample open space or otherwise undeveloped land remains to perform critical watershed functions. No such land exists in Scenario A, and, as previously discussed, lawns typically associated with one house per acre are not able to provide the same type of watershed services as forests, meadows, or other types of unconverted land.

Example 8: Time Series Build-out Analysis: Build-out in 2040

Scale of Analysis	Scenario A	Scenario B	Scenario C
Hypothetical build-out in the year 2040	40,000 houses built on 40,000 acres, or 4 watersheds	40,000 houses built on 10,000 acres, or 1 watershed	40,000 houses built on 5,000 acres, or ½ of 1 watershed

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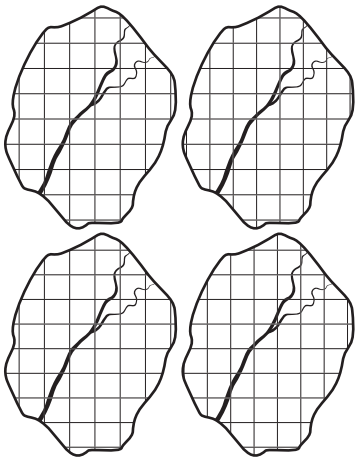
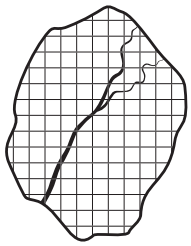
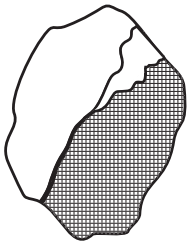
The hypothetical community continues to grow and, in another 20 years, population has doubled again, requiring each scenario to accommodate 20,000 more homes at different development densities. Exhibit 10 demonstrates how this development might look.

EXHIBIT 10: Time Series Build-out Analysis: Build-out in 2040

Scenario A	Scenario B	Scenario C
		
40,000 houses on 40,000 acres at a density *of 1 house per acre* will consume 4 watersheds.	40,000 houses on 10,000 acres at a density of *4 houses per acre* will consume 1 watershed.	40,000 houses on 5,000 acres at a density of *8 houses per acre* will consume ½ of 1 watershed.

As Exhibit 10 demonstrates, Scenario A, developing at one house per acre, must develop land in four watersheds, or 40,000 acres, to accommodate all its houses. Scenario B, developing at a slightly higher density, uses its remaining land to accommodate the additional growth. Scenario C is still developing within the same watershed and still has additional land available to provide watershed services. Scenario A and B do not. Any land for watershed services would need to come from additional watersheds.

Lower-density development always requires more land than higher densities to accommodate the same amount of growth.

This build-out analysis can continue indefinitely with the same result: lower-density development always requires more land than higher densities to accommodate the same amount of growth. Because more land is required, more undeveloped land is converted.

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Findings/Discussion

The results indicate when runoff is measured *by the acre*, limiting density does produce less stormwater runoff when compared to the higher-density scenarios. However, when measured *by the house*, higher densities produce less stormwater runoff. So, which is the appropriate measure?

Typically, a planning department analyzes the projected stormwater runoff impacts of a developer's proposal based on the acreage, not the number of houses being built. Based on the results from the one-acre level example, communities might conclude that lower-density development would minimize runoff. Runoff from one house on one acre is roughly half the runoff from eight houses. However, where did the other houses, and the people who live in those houses, go? The answer is almost always that they went somewhere else in that region—very often somewhere within the same watershed. Thus, those households still have a stormwater impact. To better understand the stormwater runoff impacts from developing at low densities, the impacts associated with those houses locating elsewhere need to be taken into account. This approach has two advantages:

- It acknowledges that the choice is not whether to grow by one house or eight but is instead where and how to accommodate the eight houses (or whatever number by which the region is expected to grow).
- It emphasizes minimization of total imperviousness and runoff within a region or watershed rather than from particular sites—which is more consistent with the science indicating that imperviousness within the watershed is critical.

To more fully explore this dynamic, EPA modeled scenarios at three scales—one acre, lot, and watershed—and at three different time series build-out examples to examine the premise that lower-density development better protects water quality. EPA examined stormwater runoff from different development densities to determine the comparative difference between scenarios. The higher-density scenarios generated less stormwater runoff per house at all scales and time series build-out examples. Exhibit 11 summarizes these findings.

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EXHIBIT 11: Summary of Findings

Scenario	Number of Acres Developed	Impervious Cover (%)	Total Runoff (ft^3/yr)	Runoff Per Unit (ft^3/yr)	Savings Over Scenario A: runoff per unit (%)
One-Acre Level: Different densities developed on one acre					
A: One house/acre	1	20.0	18,700	18,700	0
B: Four houses/acre	1	38.0	24,800	6,200	67
C: Eight houses/acre	1	65.0	39,600	4,950	74
Lot Level: Eight houses accommodated at different density levels					
Scenario A	8	20.0	149,600	18,700	0
Scenario B	2	38.0	49,600	6,200	67
Scenario C	1	65.0	39,600	4,950	74
Watershed Level: 10,000 houses accommodated in one 10,000-acre watershed					
Scenario A	10,000	20.0	187 M	18,700	0
Scenario B	2,500	9.5	62 M	6,200	67
Scenario C	1,250	8.1	49.5 M	4,950	74

Scenario	Summary of Build-out Examples
Watershed Level: Time Series Build-out Analysis: Build-out in 2000	
Scenario A	10,000 houses built on 10,000 acres: 1 watershed is consumed
Scenario B	10,000 houses built on 2,500 acres: ¼ of 1 watershed is consumed
Scenario C	10,000 houses built on 1,250 acres: ⅛ of 1 watershed is consumed
Watershed Level: Time Series Build-out Analysis: Build-out in 2020	
Scenario A	20,000 houses built on 20,000 acres: 2 watersheds are consumed
Scenario B	20,000 houses built on 5,000 acres: ½ of 1 watershed is consumed
Scenario C	20,000 houses built on 2,500 acres: ¼ of 1 watershed is consumed
Watershed Level: Time Series Build-out Analysis: Build-out in 2040	
Scenario A	40,000 houses built on 40,000 acres: 4 watersheds are consumed
Scenario B	40,000 houses built on 10,000 acres: 1 watershed is consumed
Scenario C	40,000 houses built on 5,000 acres: ½ of 1 watershed is consumed

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Specifically, this analysis demonstrates:

- With more dense development (Scenario C), runoff rates per house decrease by approximately 74 percent from the least dense scenario (Scenario A);
- For the same amount of development, denser development produces less runoff and less impervious cover than low-density development; and
- For a given amount of growth, lower-density development uses more of the watershed.

EPA found that the higher-density scenarios generate less stormwater runoff per house at all scales—one acre, lot, watershed—and time series build-out examples.

Taken together, these findings indicate that low-density development may not always be the preferred strategy for reducing stormwater runoff. In addition, the findings indicate that higher densities may better protect water quality—especially at the lot and watershed levels. Higher-density developments consume less land to accommodate the same number of houses as lower density. Consuming less land means less impervious cover is created within the watershed. To better protect watershed function, communities must preserve large, continuous areas of open space and protect sensitive ecological areas, regardless of how densely they develop.

However, while increasing densities on a regional scale can, on the whole, better protect water resources at a regional level, higher-density development can have more site-level impervious cover, which can exacerbate water quality problems in nearby or adjacent waterbodies. To address this increased impervious cover, numerous site-level techniques are available to mitigate development impacts. When used in combination with regional techniques, these site-level techniques can prevent, treat, and store runoff and associated pollutants. Many of these practices incorporate some elements of low-impact development techniques (e.g., rain gardens, bioretention areas, and grass swales), although others go further to include changing site-design practices, such as reducing parking spaces, narrowing streets, and eliminating cul-de-sacs.

Incorporating these techniques can help communities meet their water quality goals and create more interesting and enjoyable neighborhoods.

A University of Oregon study, *Measuring Stormwater Impacts of Different Neighborhood Development Patterns* (University of Oregon, 2001), supports this conclusion. The study, which included a study site near Corvallis, Oregon, compared stormwater management strategies in three common neighborhood development patterns. For example, best management practices, such as disconnecting

Photo courtesy of the City of Portland, Oregon

The city of Portland, Oregon, is developing urban stormwater strategies, such as these curb extensions that can absorb the street's runoff from large storm events.

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residential roofs and paved areas from the stormwater system, introducing swales and water detention ponds into the storm sewer system, and strategically locating open space, considerably reduced peak water runoff and improved infiltration. The study concluded that "some of the most effective opportunities for reducing stormwater runoff and decreasing peak flow are at the site scale and depend on strategic integration with other site planning and design decisions." The study also found that planting strips and narrower streets significantly reduced the amount of pavement and, as a result, runoff in developed areas.

A development in Tacoma, Washington, demonstrates that increasing densities and addressing stormwater at the site level can work effectively. The Salishan Housing District was built on Tacoma's eastern edge in the 1940s as temporary housing for ship workers. It is currently a public housing community with 855 units.

Redevelopment of Salishan will increase densities to include 1,200 homes (public housing, affordable and market rate rentals, and for-sale units), local retail, a farmers market, a senior housing facility, a daycare center, a health clinic, commercial office space, and an expanded community center. Among the most important priorities for the redevelopment is restoring the water quality of Swan Creek, which forms the eastern edge of Salishan. The creek is a spawning ground for indigenous salmon populations that feed into the Puyallup River and Puget Sound. The site plan seeks to restore 65 percent of the land to forest and pervious landscape. In addition, the streets will be narrowed to reduce impervious surfaces and also make the neighborhood more inviting for walking. Some streets may be eliminated and replaced with pedestrian paths. The remaining streets will be bordered by rain gardens that would accept, filter, and evapotranspire runoff. Most existing street surfaces would be reused, although some may be replaced with pervious pavers.

Salishan Housing District is replacing 855 public housing units with 1,200 units. Numerous site-level strategies, such as integrating uses, narrowing the streets, installing rain gardens, and daylighting a stream, are used to restore the water quality of Swan Creek and revitalize an existing neighborhood.

Communities can enjoy a further reduction in runoff if they take advantage of underused properties, such as infill, brownfield, or greyfield[12] sites. For example, an abandoned shopping center (a greyfield property) is often almost completely impervious cover and is already producing high volumes of runoff (Sobel, 2002). If this property were redeveloped, the net runoff increase would likely be zero since the property was already predominately impervious cover. In many cases, redevelopment of these properties breaks up or removes some portion of the impervious cover, converting it to pervious cover and allowing for some stormwater infiltration. In this case, redevelopment of these properties can produce a net improvement in regional water quality by decreasing total runoff. Exhibit 12 illustrates this opportunity.

[12] Greyfield sites generally refer to abandoned or underutilized shopping malls, strip malls, or other areas that have significant paved surface and little or no contamination.

EXHIBIT 12: Redevelopment of a Greyfield Property

Photos courtesy of Juan Ayala, Invisioneering, for the New Jersey Office of State Planning

Redevelopment of a former shopping mall in Boca Raton, Florida, provides an example of this type of opportunity. The Mizner Park shopping mall was redesigned from its original pattern of a large retail structure surrounded by surface parking lots; the 29-acre site now includes 272 apartments and townhouses, 103,000 square feet of office space, and 156,000 square feet of retail space. Most parking is accommodated in four multistory parking garages. Designed as a village within a city, the project has a density five times higher than the rest of the city and a mix of large and small retailers, restaurants, and entertainment venues (Cooper, 2003). Most significantly, the final build-out of Mizner Park decreased overall impervious surface on the site by 15 percent through the addition of a central park plaza, flower and tree planters, and a large public amphitheater.

Redeveloping brownfield and greyfield sites can reduce regional land consumption. A recent George Washington University study found that for every brownfield acre that is redeveloped, 4.5 acres of open space are preserved (Deason, 2001). In addition to redeveloping brownfield sites, regions can identify underused properties or land, such as infill or greyfield sites, and target those areas for redevelopment. For example, a recent analysis by King County, Washington, demonstrated that property that is vacant and eligible for redevelopment in the county's growth areas can accommodate 263,000 new houses—enough for

Photo courtesy of U.S. EPA

The redevelopment of Mizner Park, a former shopping mall, decreased impervious cover by 15 percent through the addition of this central plaza.

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500,000 people (Pryne, 2002). Redeveloping this property is an opportunity to accommodate new growth without expanding into other watersheds. As Kurt Zwikl, executive director of the Pottstown, Pennsylvania-based Schuylkill River Greenway Association, said, "Certainly, if we can get redevelopment going in brownfields and old industrial sites in older riverfront boroughs like Pottstown and Norristown, that's a greenfield further out in the watershed that has been preserved to absorb more stormwater" (Brandt, 2004).

Redeveloping brownfield and greyfield sites can reduce regional land consumption.

Other Research

Current research supports the findings of this study. Several site-specific studies have been conducted across the United States and in Australia that examine stormwater runoff and associated pollutants in relation to different development patterns and densities. Several case studies approach the research question with varying levels of complexity. Studies of Highland Park, Australia; Belle Hall, South Carolina; New Jersey; Chicago, Illinois; and the Chesapeake Bay each analyze the differences in runoff and associated water pollution from different types of development patterns.

Queensland University of Technology, Gold Coast City Council, and the Department of Public Works in Brisbane, Australia, examined the relationship between water quality and six different land uses to offer practical guidance in planning future developments. When comparing monitored runoff and associated pollutants from six areas, they found the most protective strategy for water quality was high-density residential development (Goonetilleke, 2005).

The Belle Hall study, by the South Carolina Coastal Conservation League, examined the water quality impacts of two development alternatives for a 583-acre site in Mount Pleasant, South Carolina. The town planners used modeling to examine the potential water quality impacts of each site design. In the "Sprawl Scenario," the property was analyzed as if it developed along a conventional suburban pattern. The "Town Scenario" incorporated traditional neighborhood patterns. In each scenario, the overall density and intensity (the number of homes and the square feet of commercial and retail space) were held constant. The results found that the "Sprawl Scenario" consumed eight times more open space and generated 43 percent more runoff, four times more sediment, almost four times more nitrogen, and three times more phosphorous than the "Town Scenario" development (South Carolina Coastal Conservation League, 1995).

These findings hold at a larger, state scale. New Jersey's State Plan calls for increasing densities in the state by directing development to existing communities and existing infrastructure. Researchers at Rutgers University analyzed the water quality impacts from current development trends and compared them to water quality impacts from the proposed compact development. The study found that compact development would generate significantly less water pollution than current development patterns, which are mostly characterized by low-density development, for all categories of pollutants (Rutgers University, 2000). The reductions ranged from over 40 percent for phosphorus and nitrogen to 30 percent for runoff. These conclusions supported a similar statewide study completed in 1992 that

concluded that compact development would result in 30 percent less runoff and 40 percent less water pollution than would a lower-density scenario (Burchell, 1995).

Researchers at Purdue University examined two possible project sites in the Chicago area (Harbor, 2000). The first site was in the city; the second was on the urban fringe. The study found that placing a hypothetical low-density development on the urban fringe would produce 10 times more runoff than a higher-density development in the urban core.

Finally, a study published by the Chesapeake Bay Foundation in 1996 comparing conventional and clustered suburban development on a rural Virginia tract found that clustering would convert 75 percent less land, create 42 percent less impervious surface, and produce 41 percent less stormwater runoff (Pollard, 2001). These studies suggest that a low-density approach to development is not always the preferred strategy for protecting water resources.

Conclusions

Our regions, cities, towns, and neighborhoods are growing. Every day, new buildings or houses are proposed, planned, and built. Local governments, working with planners, citizen groups, and developers, are thinking about where and how this new development can enhance existing neighborhoods and also protect the community's natural environment. They are identifying the characteristics of development that can build vibrant neighborhoods, rich in natural and historic assets, with jobs, housing, and amenities for all types of people. They are directing growth to areas that will maintain and improve the buildings and infrastructure in which they have already invested. In addition to enjoying the many benefits of growth, communities are also grappling with growth's challenges, including development's impact on water resources.

Many communities assume that low-density development automatically protects water resources. This study has shown that this assumption is flawed and that pursuit of low-density development can in fact be counterproductive, contributing to high rates of land conversion and stormwater runoff and missing opportunities to preserve valuable land within watersheds.

The purpose of this study is to explore the effects of development density on stormwater runoff and to illustrate the problems with the assumption that low-density development is automatically a better strategy to protect water quality. To that end, three different development densities were modeled at the one-acre, lot, and watershed levels, as well as in the time series build-out examples. The modeling results suggest that low-density development is not always the preferred strategy for protecting water resources. Furthermore, the results seem to suggest that higher-density development could better protect regional water quality because it consumes less land to accommodate the same number of homes.

However, while this study shows that low-density development does not automatically better protect water resources, it does not conclude that high-density development is therefore necessarily more protective. This study has not considered all factors, such as location of development within the watershed, varying soil types, slope, advanced post-construction controls (and their performance over time), and many other factors. In that sense, this study concludes that there

are good reasons to consider higher-density development as a strategy that can better protect water resources than lower-density development. However, any bias toward either is inappropriate from a water perspective. A superior approach to protect water resources locally is likely to be some combination of development densities, based on local factors, incorporating adequate open space, preserving critical ecological and buffer areas, and minimizing land disturbance.

These conclusions have implications for how communities can enjoy the benefits of growth and development while also protecting their water quality. Additional relevant information can be found in other resources, such as *Protecting Water Resources with Smart Growth* and *Using Smart Growth Techniques as Stormwater Best Management Practices*.[13] Both publications draw on the experience of local governments, which has shown that regional and site-specific strategies are most effective when implemented together. In addition, *Creating Great Neighborhoods: Density in Your Community*, by the Local Government Commission and the National Association of Realtors, can provide information on some of the other benefits from density that communities can enjoy.

Additional relevant information can be found in these resources:

- *Protecting Water Resources with Smart Growth,* available at: www.epa.gov/smartgrowth/pdf/waterresources_with_sg.pdf.
- *Creating Great Neighborhoods: Density in Your Community,* available at: www.epa.gov/smart growth/pdf/density.pdf.

Nationwide, state and local governments are considering the environmental implications of development patterns. As low-density development and its attendant infrastructure consume previously undeveloped land and create stretches of impervious cover throughout a region, the environment is increasingly affected. In turn, these land alterations are not only likely to degrade the quality of the individual watershed, but are also likely to degrade a larger number of watersheds. EPA believes that increasing development densities is one strategy communities can use to minimize regional water quality impacts.

[13] Forthcoming EPA publication.

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The Control of Nonpoint Sources of Water Pollution
The Ecological Management & Restoration of Watersheds

SPECIAL FOCUS ISSUE: Economic Benefits of Nonpoint Source Pollution Control

Notes on the National Scene

Saving Money Through Source Water Protection

Preventing contamination of raw drinking water supplies generally is more efficient than trying to identify and remove that contamination from the water stream at the treatment plant. By dedicating funds to restore and protect source water areas, communities are saving tremendous amounts of money over the long term. The following discussion, excerpted from "Protecting the Source: Conserving Forests to Protect Water," an article in the May 2004 issue of the American Water Works Association's newsletter, addresses the wastewater treatment economic benefits gained by protecting source water.

Clean Source Water is Key

Advancements in science and technology have enabled water utilities to effectively treat most known contaminants from drinking water sources and to provide American citizens with some of the safest drinking water in the world. However, these advancements have contributed to a movement away from protecting and managing our source areas and to the unfortunate notion that the quality of our raw water supplies is less important.

Oh noooo! Look who's helping Governor Blanco save Louisiana's wetlands. See article on page 12.

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Low-Impact Development Pays Off

What exactly is low-impact development (LID), and how does it compare with conventional stormwater management? In traditional stormwater management, water from a development site is moved away as quickly as possible to a centralized facility, such as a stormwater pond or a local stream. LID attempts to mimic the drainage patterns that were present before development by encouraging runoff infiltration, storage, filtering, evaporation, and detention.

Estimates from pilot projects and case studies suggest that LID projects can be completed at a cost reduction of 25 to 30 percent over conventionally developed projects. The need for costly stormwater ponds, drainage pipes, curbs and gutters, and wide streets is eliminated or dramatically reduced, which usually more than offsets the cost of relatively less expensive LID features such as rain gardens, cisterns, and permeable surfaces. The following examples show how rapidly LID is gaining acceptance across the country.

Prince George's County, Maryland. In the early 1990s, Somerset subdivision became one of the first large residential communities to include rain gardens as part of an LID drainage design. Rain gardens were a local innovation when Larry Coffman, associate director of the county's Department of Environmental Resources, considered options for the Somerset project. Coffman helped design a plan to create open drainage swales and replace the typical ponds, curbs, gutters, and sidewalks with special gardens on each lot to capture the runoff. Rain gardens are inexpensive to build, need very little maintenance, and restore water to the soil. Somerset is an 80-acre subdivision containing about 200 homes valued at approximately $160,000 in 1995. Most 10,000-square-foot lots have a 300- to 400- square-foot rain garden, although some of the subdivision was completed prior to inclusion of LID.

Each rain garden cost about $150 for excavation and $350 for plants. About $100,000 was needed to install rain gardens at Somerset, in comparison to nearly $400,000 needed to install conventional detention ponds, which did not include the expense of curbs, gutters, and sidewalks. Elimination of the need for a stormwater pond allowed the development of six extra lots and resulted in a cost savings of more than $4,000 per lot.

In November 2000, Prince George's County initiated a field monitoring program to compare the stormwater hydrologic and water quality responses between two watersheds in Somerset subdivision. Development in the first watershed was completed in the early 1990s with conventional stormwater conveyance techniques (curb, gutters, and pipes). Development in the second watershed, located directly next to the first, was completed in 2000 and includes the rain garden and grassed swale LID techniques (see photo). Preliminary monitoring results indicate that the LID site experienced a 20 percent lower average annual runoff volume per unit area than did the conventionally designed watershed. The LID watershed generated fewer runoff-producing events overall (see table 2).

Paired watershed study in Maryland's Somerset subdivision offered opportunity for comparison between conventional and LID stormwater design techniques.

Table 2. Somerset Paired Watershed Study: 2-Year Hydrologic Summary

Measurement	Watershed	
	Conventional	LID
Number of events with measurable runoff >100 cubic feet*	104	83
Total runoff volume (cubic feet/acre)*	41,403	33,391
Percent of rainfall converted to total runoff*	19.0%	15.3%

* Difference is significant at the 95% confidence interval

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Preliminary monitoring also showed that metal levels in the runoff in the LID watershed were significantly lower than in the conventional watershed (36%, 21%, and 37% lower for copper, lead, and zinc, respectively). However, nitrogen levels were the same in both watersheds, while phosphorus levels were actually higher in the LID watershed. Project leaders suspect the LID watershed has higher-than-expected nutrient levels because it is still relatively new and is experiencing unstable soils and over-fertilization by homeowners. Project leaders expect the water quality in the LID watershed to improve significantly over time.

Prince George's County is pleased with the performance of the LID techniques at Somerset. Residents are also pleased—they have enthusiastically accepted their rain gardens and maintain them like they do other parts of their yard. Originally viewed as "free landscaping" by many residents, the naturalized rain gardens have become a key part of subdivision's identity. (*Sources:* (1) *U.S. HUD, 2003.* The Practice of Low Impact Development *(LID). U.S. Department of Housing and Urban Development, Office of Policy Development and Research. Available online at www.lowimpactdevelopment.org/lid%20articles/practLowImpctDevel_jul03.pdf.* (2) Hydrological Responses from Low Impact Development comparing with Conventional Development*, by Mow-Soung Cheng, Larry S. Coffman, Yanping Zhang, and Z. John Licsko.*)

Sherwood, Arkansas. Developers of the Gap Creek Subdivision used LID concepts, allowing them to gain 17 additional lots. Each lot sold for $3,000 more than comparable competitors' lots, and lowered the total cost per lot by $4,800. The project also resulted in 23.5 acres of green space and parks, $2.2 million in additional profit, and national recognition. The new design worked with the land's features. For instance, drainage areas were preserved and buffered by green space called greenbelts. The network of greenbelts were connected to neighborhood hiking trails. Streets meandered with terrain to minimize excavation needs. By maximizing the number of lots that backed up to greenbelts, the developers provided homeowners with a sense of privacy which led to higher lot prices.

The original plan's street was changed to include green space buffers and traffic calming circles thus allowing the developer to reduce street widths from 36 to 27 feet. In addition, trees were allowed to stay close to the curb line. The site uses native vegetation such as buffalo grass, and cleared trees were transformed into mulch. The original plan preserved 1.5 acres of green space while the revised plan preserved 23.5 acres. Some of the development cost savings went to fund a neighborhood park with picnic facilities, a pavilion, and ball fields. (*Source: Tyne, Ron, 2000. Bridging the Gap: Developers Can See Green.* National Association of Home Builders Land Development Magazine, *Spring - Summer 2000, pp 27-31.*)

Aberdeen, North Carolina. Design engineers for the Poplar Street Apartments used an alternative LID stormwater control design for a new 270-unit apartment complex and saved the developer approximately 72 percent, or $175,000, of the conventional stormwater construction costs. At the site, almost all of the conventional underground storm drains associated with curb and gutter projects were eliminated. Strategically located bioretention areas, compact weir outfalls (see photo), depressions, grass channels, wetland swales, and specially designed stormwater basins were some of the LID techniques used. These design features allow for longer flow paths, reduce the amount of polluted runoff, and filter pollutants from stormwater runoff. (*Source: Storm Water Solutions For New Mandatory Federal Storm Water Regulations, Fall 1999 newsletter of* BLUE: Land, Water, and Infrastructure, *available at www.blwi.com/n_fall99.htm*)

In Aberdeen, NC, a compact weir releases water on all sides, distributing stormwater to bioretention cells.

Largo, Maryland. At the Inglewood Demonstration Project, engineers retrofitted an existing parking facility with a bioretention area. They selected a landscaped island measuring

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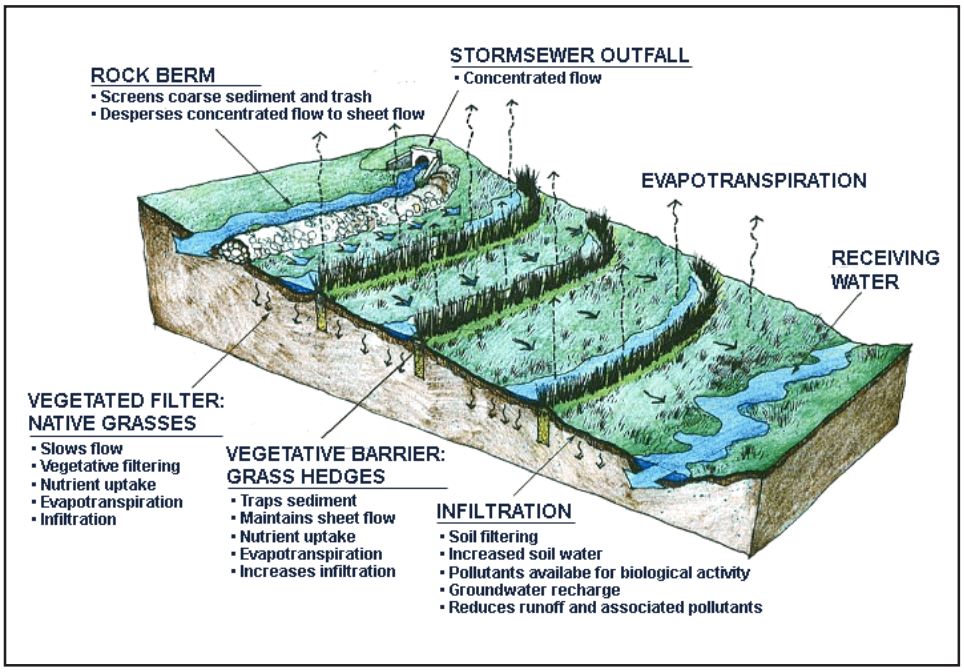
Low-Impact Development Pays Off (continued)

about 38 feet by 12 feet to be retrofitted to treat runoff from a half-acre of impervious surface. They cut a four-foot slot into the curb immediately before the storm drain inlet, excavated the landscaped island to a depth of four feet, and installed an underdrain that would allow the soil in the island to slowly drain, preventing oversaturation. Next, they covered the underdrain with eight inches of one- to two-inch gravel and backfilled with typical bioretention soil mix up to a depth of about 12 inches below the top of the curb. Finally, they planted the area and covered it with three inches of shredded hardwood mulch. Water collects in the island to a ponding depth of approximately six inches before a backwater is created at the curb opening.

Results showed that the project lowered runoff temperature by 12 degrees C, and significantly reduced metals and other pollutants present in the runoff. The retrofit cost $4,500 to construct, while usual methods of treating that runoff would have cost $15,000-$20,000 and involved fewer environmental benefits and higher maintenance costs. (*Source: USEPA, 2000.* Bioretention Applications. *Document 841-B-00-005A. Available online at epa.gov/nps/bioretention.pdf)*

Pierce County, Washington. Pierce County directed a study looking at the use of potential LID technologies in Kensington Estates, a conventional, 103-lot single-family development planned on 24 acres. The LID design of the roadways and utilities called for a reduced roadway width, porous paving, and cul-de-sac clusters. The cul-de-sac design included vegetated depressions in the center of each that would capture and retain six inches to one foot of runoff. These LID features generated costs that would be slightly higher than the costs for conventional materials and design. However, the study showed that over the entire 24-acre development site, the LID approach would generate construction cost savings of more than 20 percent over a conventional approach, preserve 62 percent of the site in open space, maintain the project density of 103 lots, reduce the need for, and size of, storm pond structures, eliminate catch basins and piped storm conveyances, and achieve "zero" effective impervious surfaces. *(Source: CH2MHill, 2001.* Pierce County Low Impact Development Study. *Available online at www.pierce.wsu.edu/Water_Quality/LID/CH_Final_LI_Report.pdf.)*

Austin, Texas. The City has had a plan for buffering streams for the protection of the Edwards Aquifer for many years, but in some cases, runoff from subdivisions was still collected by curb and gutter and discharged as a concentrated flow directly to the buffered streams. In Austin's Circle C Ranch subdivision, engineers converted the concentrated storm sewer point discharge to a system that encouraged sheet flow along the buffer (see picture). The redesign included placement of a rock berm along a drainage ditch located at the top of the grassed stream buffer. The runoff percolated through the berm and flowed across the entire width of the buffer before entering the stream. The engineers also planted a series of native grass hedges to help distribute flow along the buffer. This redesign created four biodetention areas at a total cost of $65,000, much less than the $250,000 sedimentation-filtration pond that would have otherwise been required. Per lot cost was approximately $450 compared to $1,700 for the sedimentation-filtration pond. Additional cost savings were realized through reductions in storm drain pipe sizes and trenching depth. (*Source: Scaief and Murfee. 2004.* Subdivision



At Austin, Texas' Circle C Ranch Subdivision, engineers designed a drainage system that encourages stormwater sheet flow across a vegetated buffer.

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Low-Impact Development Pays Off (continued)

Design to Maximize Utilization of Stream Buffers, *from AWRA Summer Specialty Conference, June 28-30, 2004. Murfee Engineering Co., Inc., 1101 Capital of Texas Highway South, D-110, Austin, TX 78746; Phone: 512-327-9204; E-mail: jscaie@murfee.com*)

River Stars Program Saves Money and the Environment

The nonprofit Elizabeth River Project's River Stars Program exemplifies the notion that pollution prevention can yield profits for companies. The southeastern Virginia-based program encourages industry, government, and other facilities in the Elizabeth River watershed to pursue voluntary pollution prevention and wildlife habitat goals, and rewards them for their successes. Since its inception in 1997, the River Stars Program has documented a reduction of hazardous waste and other pollution by more than 144 million pounds and restoration or conservation of more than 220 acres of wildlife habitat. Thanks to a bit of innovative thinking, the River Stars Program facilities found economically feasible—and sometimes economically beneficial—ways to reduce pollution.

The 200-square mile Elizabeth River watershed includes the Virginia cities of Norfolk, Portsmouth, Chesapeake, and part of Virginia Beach. The Elizabeth River drains into the Chesapeake Bay, and has been identified by the Chesapeake Bay Program as one of the three most toxic regions of concern in the bay watershed, due to high levels of pollution in its waters and sediments.

Program Promotes Ongoing Achievement

Through the River Stars Program, the Elizabeth River Project promotes a non-regulatory, partnership-based approach with private industry and others to reduce and prevent pollution. Elizabeth River Project staff provide River Stars facilities with project recommendations, project funding acquisition, project design and other technical assistance, volunteer event planning, documentation of results, and public recognition of successes. River Stars projects typically include reduction, elimination, or recycling of waste materials in an industrial process, establishment or restoration of a wildlife habitat area, and onsite stormwater management improvements such as efforts to capture and reuse stormwater. Most companies have enjoyed corresponding cost savings through reduced need for materials, labor, and waste treatment or disposal.

About 50 facilities currently participate in this program. (The Elizabeth River Project also has a separate River Stars schools program.) The program provides for three levels of achievement, each of which requires different degrees of success with pollution prevention or wildlife habitat projects. This three-tiered, interdisciplinary approach allows facilities to start small and build on their successes. Many River Star facilities maintain their designated level of environmental excellence from year to year by adding to previously initiated projects and enlarging wildlife habitat areas. The River Stars Program encourages participating facilities to continually implement new projects so they can be recognized each year and/or be awarded a higher level of achievement.

Reducing Pollution and Costs

River Stars' impact on nonpoint source pollution is growing. Historically, many of the projects were associated with pollution reduction in industrial processes and the impact on water quality was an indirect one. This impact was largely associated with reductions in landfill waste, air emissions, and contaminants in treated wastewater. Now, more River Stars facilities are branching out into stormwater management and wildlife habitat projects—projects that can directly reduce nonpoint source pollution. Many of these projects have also provided unexpected economic benefits.

NOVA Chemicals, Inc., a manufacturer of polystyrene resin, created an 11-acre "no-mow" area of 3,000 native trees and shrubs, designed to provide food and shelter for migrating songbirds. The native plants also reduce soil erosion and improve the quality of stormwater runoff reaching the river. After implementing the project in 1999 at a cost of less than $8,000, the company found it was saving $16,000 annually by no longer mowing the land. "We tried to do the right thing for

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Many Paths Lead to Adoption of Low Impact Development

Like the rapid growth of cities and suburbs that preceded it, low impact development is quickly spreading across the nation. More and more communities are recognizing that low impact development (LID) is a critical component of effective programs to reduce stormwater runoff and treatment costs, protect waterways, maintain aesthetics, and, in many cases, lower stormwater management costs. As with any innovation, widespread adoption takes time. In the following three locations across the United States, three very different types of organizations have led the charge toward incorporation of LID principles into their local developments.

LID from the Bottom-Up: Adoption Can Start at the Grassroots Level

Thanks in large part to one nonprofit watershed group, LID adoption in eastern Virginia is spreading quickly. When the LID movement was just beginning in the late 1990s, the Friends of the Rappahannock (FOR) recognized it for its potential environmental protection benefits. At that time, FOR began working with Stafford County, a rapidly growing area located about an hour's drive south of Washington, D.C., to educate county staff and elected officials about LID and build consensus for the need to amend building codes.

"Look! Up in the sky! It's … the EPA's Coastal Crusader! See article on page 5."

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Many Paths Lead to Adoption of Low Impact Development (continued)

In June 2003, thanks in large part to the efforts of FOR, Stafford County became the first county in Virginia to adopt regulations requiring use of low impact development (LID) principles whenever possible. The Stafford County Board of Supervisors amended the local development codes, waiving previous requirements like curb, gutters, and sidewalks; permitting the use of rain gardens and permeable pavers to reduce stormwater runoff; and facilitating the use of other LID practices. To support developers' efforts to comply with the new code, the County revised its *Stormwater Management Design Manual* (http://co.stafford.va.us/code/Stormwater_Management) to describe LID practices and how to incorporate them into site design.

The FOR has earned statewide and national attention for its efforts, and has been expanding its LID advocacy program to other counties and local governments in the area. FOR is currently working with Spotsylvania County (just south of Stafford County) to modify its existing codes. With support from a National Fish and Wildlife Foundation Small Watershed Grant, the FOR helped the small Town of Warsaw adopt a LID ordinance in 2003. While other localities in Virginia make LID use optional, or provide incentives to encourage LID use, the Town of Warsaw was the first locality in Virginia to require that LID techniques are used in any new development. FOR continues to reach out to its watershed community through demonstration projects and teaching tools. For more information about FOR's LID program, see www.riverfriends.org, or call the FOR office at 540-373-3448.

LID Can Trickle-Down: Intergovernmental Partnership Spreads LID Throughout Puget Sound

In Washington State's Puget Sound region, a diverse intergovernmental team is taking LID into the mainstream. Formed in 1996 by the Washington State legislature, the Puget Sound Action Team (Action Team) defines, coordinates, and implements Washington State's environmental agenda for the Puget Sound watershed—an area that includes 12 counties, 115 cities, and the lands of 17 tribes. The 17-member Action Team includes directors from 10 state agencies, representatives from three federal agencies, one representative of tribal governments, two representatives of local governments (city and county), and a chairperson appointed by the governor. The Action Team has a staff of more than 25 that provide professional and technical services. The 12-member Puget Sound Council, with representation from business, agriculture, the shellfish industry, environmental organizations, local and tribal governments, and the legislature, provides advice and guidance to the Action Team.

What is Low Impact Development?

In traditional stormwater management, water from a development site is moved away as quickly as possible to a centralized location, such as a pond or a local stream. When it rains, the large volumes of water that move through these systems can cause erosion and ecosystem degradation. In short, traditional approaches treat stormwater as a liability. By treating stormwater as an asset, LID is philosophically different. LID reduces runoff volumes by attempting to re-create the drainage patterns that were present before development. By incorporating practices such as rain gardens, green roofs, bioretention cells, cisterns, swales, and porous pavements, developers can increase runoff infiltration, storage, filtering, evaporation, and detention onsite. For more information about LID, including lists of available educational and technical resources, see the Low Impact Development Center Web site at www.lowimpactdevelopment.org or EPA's LID Web site at www.epa.gov/nps/lid.

The Action Team recognized the benefits of LID in the late 1990s and has worked with local jurisdictions throughout Puget Sound to encourage acceptance and adoption of LID practices. The Action Team has educated more than 800 planners, developers, engineers, and others at LID conferences and regional workshops throughout the Puget Sound region. The Action Team and numerous partners have worked together to develop an assortment of educational and technical support materials on the subject, including three technical memoranda detailing: (1) types of LID techniques, (2) analysis and recommendations for the use of LID techniques in Puget Sound, and (3) how to adapt the Washington stormwater management manual to include benefits of LID techniques. In 2005, the Action Team and Washington State University Extension released *Low Impact Development Technical Guidance Manual for Puget Sound*, the region's first technical guidance detailing the appropriate use of LID techniques in the region. These publications can be downloaded from the Action Team's Web site at www.psat.wa.gov/Programs/LID.htm.

The Action Team's outreach efforts are paying off. LID is spreading across the region, initiated in new places sometimes by the influence of just a few people involved in, or educated by, the Action Team. Thirteen of 38 municipalities (33 percent) that responded to an Action Team stormwater survey in 2004 indicated that they have adopted or revised ordinances to allow for LID. The Action Team knows of even more

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Many Paths Lead to Adoption of Low Impact Development (continued)

LID-using localities that either didn't respond or were not surveyed. The Action Team is currently helping 11 cities and counties in the Puget Sound basin revise their stormwater and development regulations to better incorporate the LID approach and techniques.

For examples of how these localities and others are implementing LID throughout the region, see *Natural Approaches to Stormwater Management* (www.psat.wa.gov/Publications/LID_studies/LID_approaches.htm). This 2003 publication highlights a range of LID applications in local government ordinances, individual sites, residential subdivisions, and new state road construction. For more information on LID activities in the Puget Sound region, contact the Action Team at 360-725-5444.

LID from the Top-Down: City Government Leads by Example

In Chicago, the City's government can take much of the credit for introducing widespread LID practice implementation. The City calls its efforts "green building" and "green infrastructure" rather than LID, but the practices are one and the same. Practices such as rain gardens, permeable paving, roof top gardens, and others help the city reduce the volume of runoff reaching the sewer and help counteract Chicago's significant urban heat island effect.

Going Green in Chicago

Chicago's green building and water management efforts are just two parts of a much larger campaign called "Conserve Chicago Together," which also includes air, land protection, solid waste, and energy initiatives. Mayor Richard Daley is promoting these initiatives in his quest to make Chicago the "most environmentally-friendly city in the world."

Why did Chicago decide to be so proactive about stormwater management? For years, Chicago had been plagued by combined sewer overflows and severe flooding problems on streets and in basements. Chicago's government leaders began to realize that they could only hope to successfully manage stormwater by incorporating upgrades into the "built" infrastructure (sewer lines, etc.) with new "green" infrastructure and practices.

And so Chicago's LID movement was born. In recent years, in addition to upgrading water and sewer lines, the City has been actively implementing LID practices. Some of the City's efforts include:

- disconnecting public buildings' downspouts if they lead to the sewer system;
- installing new permeable pavement alleys that detain stormwater and encourage infiltration over time;
- adding rain gardens and bioswales along roads and other public areas to capture and filter runoff;
- planting rooftop gardens on public buildings to help capture rain water;
- replacing hardscape with landscaped medians and parkways along major roadways; and
- creating campus parks adjacent to public schools.

The City also looks to its residents and businesses to help conserve water and reduce stormwater runoff. The City actively encourages homeowners to disconnect their downspouts from the sewer system and direct the water instead to their yards or gardens. They reach out to residents using public service announcements, community meetings, instructional videotapes, brochures, and discounts on materials for downspout disconnection. A recent rain barrel initiative by the City encouraged homeowners to go a step further and capture and reuse their stormwater to maintain their landscape.

Chicago leaders are stimulating demand for green buildings and green roofs by creating policies and incentives targeted to developers, building owners and managers, homeowners, insurance providers, and the financial community. The City has instituted a policy that encourages and, in some cases, requires green roofs and adherence to green building standards in any development, public or private, that receives public assistance from the City. For developments that do not rely on public assistance, the City offers incentives such as allowing more floor area or greater density for development projects that incorporate LID practices. Trained City staff work with developers to incorporate green design and infrastructure into their site plans.

Although the costs for green building can be greater than traditional building methods, Chicago is coming out ahead in many ways. In a 2004 speech, Mayor Richard Daley explained that, during his

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Many Paths Lead to Adoption of Low Impact Development (continued)

more than 15-year tenure as mayor, "we've learned that protecting the environment makes sense both economically and politically. We've learned that we can actually save money on taxes and on household and business expenses by paying attention to the environment. At the same time, we enhance our quality of life, which builds pride in our City and helps us attract new employers, residents, tourists and conventions—all the ingredients of a strong local economy."

For more information about Chicago's myriad environmental programs, see http://egov.cityofchicago.org and click on "environmental initiatives" in the right column.

The Future of LID

As the previous case studies indicate, communities need not follow any pre-ordained path in their efforts to better manage stormwater and protect the environment. People from all walks of life, from the concerned citizen to the mayor of a big city, can, and do, make a difference.

EPA Releases New Forestry National Management Measures Document

EPA has just published *National Management Measures to Control Nonpoint Source Pollution from Forestry*, a technical guidance and reference document designed to help state, territory, and authorized tribal managers, as well as the public, implement nonpoint source (NPS) pollution management programs in forest settings. The new guidance enhances and updates the technical information contained in the *Guidance Specifying Management Measures for Sources of Nonpoint Pollution in Coastal Waters*, published by EPA in January 1993 under section 6217(g) of the Coastal Zone Act Reauthorization Amendments of 1990 (CZARA). Whereas the 1993 guidance was regulatory within designated coastal areas, this document does not set new or additional standards for either CZARA section 6217 or Clean Water Act section 319 programs.

The new guidance contains information on the best available, economically achievable means of reducing NPS pollution that can result from forestry activities. The guidance is equally applicable to inland as well as coastal areas and provides background information about NPS pollution related to forestry activities, the broad concepts of assessing and addressing water quality problems on a watershed level, and up-to-date technical information about how to reduce forestry NPS pollution. Because the guidance is national in scope, it does not address all practices and techniques specific to local or regional soils, climates, or forest types. For more information about the guidance or to download the document, see www.epa.gov/owow/nps/forestrymgmt/. You can receive a free printed copy of this guidance by contacting the National Service Center for Environmental Publications via phone at 1-800-490-9198 or via the Web at www.epa.gov/ncepihom/ (request Publication # EPA 841-B-05-001).

Why is the Forestry Guidance Needed?

Forestry activities can generate significant NPS pollution, particularly in the form of sediment. In a forested watershed, logging has the effect of both compacting and loosening soils due to the construction and use of roads, use of heavy machinery, logs being dragged over the ground or otherwise transported to collection areas, and vegetation being removed. Roads and road ditches, ruts on the ground, and areas cleared of leaf litter or other soil coverings create opportunities for water channeling and flow diversion, which, if not properly controlled and directed, can generate erosive flows. The potential for sediment delivery to streams is a long-term (beyond two years) concern from almost all forest harvesting activities and from forest roads regardless of their level of use or age (i.e., for the life of the road).

Other pollutants of significance, including nutrients, temperature, toxic chemicals and metals, organic matter, pathogens, herbicides, and pesticides, can also be generated by timber harvesting and related activities. Problems associated with most of these other pollutants from forestry activities generally do not extend beyond two years from the time of harvest, or are associated with a specific activity, such as an herbicide application. Temperature pollution may remain much longer than two years because the riparian area must grow tall enough to shade the stream to keep temperatures down. All of these pollutants have the potential to affect water quality and aquatic habitat, and minimizing their delivery to surface waters and groundwater deserves serious consideration before and during forestry activities. The new guidance document helps managers identify and prepare for these potential sources of forestry-related NPS pollution before the activity begins. For more information about controlling NPS impacts from forestry, see www.epa.gov/owow/nps/forestry.html.

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EPA Acts to Reduce Bacteria Threats at Beaches

On November 8, 2004, EPA issued a final rule aimed at further protecting the health of the nation's beaches on coastal and Great Lakes waters. The rule establishes more protective health-based federal bacteria standards for those states and territories bordering Great Lakes or ocean waters that have not yet adopted standards in accordance with the Beaches Environmental Assessment and Coastal Health (BEACH) Act of 2000 (see box). The Act required coastal states and states bordering the Great Lakes to adopt bacteria standards by April 2004 to better protect beach bathers from harmful pathogens. For states that have not yet adopted more protective standards, the Act required EPA to establish standards for them.

What is the BEACH Act?

The Beaches Environmental Assessment and Coastal Health (BEACH) Act, signed into law on October 10, 2000, amended the Clean Water Act (CWA) to incorporate provisions to reduce the risk of illness to users of the Nation's recreational waters. Section 406(b) of the CWA, as amended by the BEACH Act, authorizes the U.S. EPA to award program development and implementation grants to eligible states, territories, tribes, and local governments to support microbiological testing and monitoring of coastal recreation waters that are adjacent to beaches or similar points of access used by the public. BEACH Act grants also support development and implementation of programs to notify the public of the potential exposure to disease-causing microorganisms in coastal recreation waters.

Of the 35 states and territories that have coastal or Great Lakes recreational waters, 14 have adopted water quality standards that are as protective of health as EPA's recommended criteria for all their coastal recreation waters, five have adopted the criteria for some of their coastal recreation waters, 13 states are in the process of fully adopting the criteria, and three have not begun the process. Although the agency has established federal standards through this final rule, any state that adopts its own standards that are as protective as EPA's and receives approval will be removed from these federal requirements. These federal water quality standards are part of the Administration's Clean Beaches Plan, which also includes grants to states and territories for beach monitoring and public notification programs, technical guidance, and scientific studies.

EPA is committed to ensuring continued monitoring of the nation's beaches and public notification of beach closures and advisories; therefore, EPA will continue to grant funding to all BEACH Act states and territories regardless of their compliance status. During the past four years, EPA has provided nearly $42 million in grant money to 35 coastal states and territories. For more information about the new criteria and the rule, see www.epa.gov/waterscience/beaches/bacteria-rule-final-fs.htm. For general information about beaches and EPA's activities to protect them, see www.epa.gov/beaches/.

Has your state adopted its own standards? To find out, visit www.epa.gov/waterscience/beaches/bacteria-rule.htm.

News from States, Tribes, and Localities

Helicopter Monitoring Program Protects Beachgoers

The EPA's Coastal Crusader helicopter monitors water quality to protect public health.

Sun- and surf-loving beachgoers in New York and New Jersey are accustomed to periodic visits by a low-flying helicopter that hovers over the water just offshore. This aircraft, rather than flying the customary boardwalk shop ad banner, is a U.S. EPA beach water surveillance helicopter. True to its name, "Coastal Crusader," it takes on a heroic responsibility—protecting human health by monitoring coastal water quality and watching for floating debris.

The EPA first began using a helicopter to collect water samples off the coasts of New York and New Jersey in 1977, after a massive algae bloom caused a large fish kill. The program has continued to expand since then. Currently the helicopter flies six days a week during beach season—from late May through early September—taking water samples and visually monitoring for floating debris. The pollution

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Helicopter Monitoring Program Protects Beachgoers (continued)

problems it targets, waterborne microorganisms and trash, are largely caused by nonpoint sources such as combined sewer overflows and urban runoff.

Assessing What's in the Water

EPA scientists and/or interns on the helicopter take weekly samples at more than 120 ocean stations along 180 miles of New Jersey and New York shoreline. They obtain a water sample by lowering a Kemmerer sampling device through a hatch cut through the floor of the specially adapted TwinStar helicopter. The Kemmerer sampling device is an open tube with locking end caps. The bottle is lowered to a particular depth while the water flows through until the desired depth is reached. Then a weight, called a messenger, is sent down the line holding the tube. The weight hits the all-angle locking trip head, allowing the end caps to close. The sampler is then retrieved with the desired sample of water being uncontaminated by water from other depths.

EPA intern Rob Livingston practices lowering the Kemmemmer sampling device through the helicopter floor.

Within hours, EPA staff brings the water samples to EPA's Edison, N.J. laboratory, where the samples are analyzed for dissolved oxygen concentration and counts of fecal coliform and enterococcus bacteria. As the summer grows hotter, low dissolved oxygen in the ocean can sometimes be a problem, so the helicopter periodically travels up to nine miles off the coastline to take samples. Low dissolved oxygen can impact the health of the ocean fish and other organisms, explained Helen Grebe, BEACH Program Coordinator for EPA's Region 2 office, so "we monitor the dissolved oxygen to identify trends from year to year."

EPA analyzes many samples for fecal coliform and enterococcus bacteria counts to protect people from illnesses that may be contracted from surface waters contaminated by fecal pollution. Although these bacteria typically do not cause illness directly, they serve as scientifically accepted indicators of more harmful pathogens that are more difficult to detect.

EPA staff members also send some water samples to the NJ Department of Environmental Protection to be analyzed for phytoplankton identification and quantification. The samples provide an early warning of noxious algae blooms that threaten water quality and other sea life. A new chlorophyll sensor recently fitted on the helicopter will be part of a pilot study this year—providing visual data on phytoplankton levels that can be compared to data gathered from the water sample analysis.

Assessing What's on the Water

In addition to taking water samples, the EPA staff members aboard the Coastal Crusader spend a significant portion of every day looking for floating debris or evidence of other pollution (oil slicks, etc.). This part of the monitoring effort began in 1989 after trash (including medical waste) washed onto southern Long Island and New Jersey beaches during the summers of 1987 and 1988, causing extensive beach closures. The beach closures lasted between several hours to several days and had significant economic and social impacts. The State University of New York Waste Management Institute estimated that the beach closures caused an economic loss of up to $4 billion in New Jersey and up to $2 billion in New York.

At that time, local, state, and federal officials determined that monitoring and cleanup of floating debris was necessary to protect human health and the local beach areas' economies. Under EPA's lead, the partners developed the Floatables Action Plan (FAP), which includes helicopter and vessel surveillance, a communications network to report sightings of floatable debris, coordinated clean-up response, and routine clean-ups conducted by skimmer vessels in the New York/New Jersey Harbor area.

Since the program began, the U.S. Army Corps of Engineers Drift Collection Vessels have collected 16,698 tons of floatable debris on scheduled "floatables days" (three days every new and full moons to coincide with tidal extremes), and an estimated 91,549 tons at other times throughout the year. Other local and state agencies, nonprofit organization, and civic groups conduct coastal cleanups of

For more information about bacteria in coastal waters, see EPA's *Draft Implementation Guidance for Ambient Water Quality Criteria for Bacteria* at www.epa.gov/waterscience/criteria/bacteria/.

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their own, and have collected more than 62,000 tons of debris during the past 15 years. The U.S. Army Corps of Engineers estimates that 90 percent (by volume) of its collection total consists of wood debris. Tires, plastic waste, cardboard, seaweed, sewage-related materials, and street runoff-related materials constitute the remaining 10 percent. For more information about the FAP and the successes achieved to date, see www.epa.gov/region2/water/action_plan/.

Communication is Key

EPA shares its water quality and floatables monitoring results with state, and local agencies to help local authorities decide whether there is any need to close the beaches. EPA issues immediate alerts to state and local officials when a pollution problem is detected. For example, in 2004, EPA's analysis showed that two out of 767 samples collected exceeded the standard for densities of enterococcus bacteria—one each in New Jersey and New York. In both cases, EPA immediately notified the local authorities, explained Grebe. "Then they decide whether to close the affected beach." If no pollution problems are detected, EPA sends a weekly data summary throughout the summer to keep the officials informed. All of EPA's data is maintained in STORET, so the detailed data is always publicly accessible through the Internet if it is needed.

EPA's data supplements the comprehensive beach water quality monitoring already performed by the localities. "New York and New Jersey have long-standing comprehensive monitoring programs," notes Grebe. "The helicopter monitoring program complements their programs by collecting additional samples to help fulfill state commitments."

Extending its Reach

The Coastal Crusader offers a helping hand for other environmental causes as well. The helicopter allows scientists to perform wetland delineations from the air, assess and visually monitor superfund sites, and to respond to environmental emergencies such as oil spills.

The Crusader also serves as an ever-present, very visible environmental education beacon, noted Grebe. "Beachgoers see the big EPA letters on the side and know what we are doing—they always wave." Most local people have heard about the program through EPA's annual press conferences or the resulting television and newspaper coverage. Every time beachgoers see the Crusader it reminds them that good water quality is not something to be taken for granted. Everyone must pitch in to keep local beaches clean and safe.

[For more information, contact Helen Grebe, MS220, U.S. EPA Facilities, Raritan Depot, 2890 Woodbridge Avenue, Edison, NJ 08837-3679; Phone: 732-321-6797; E-mail: grebe.helen@epa.gov; Web: www.epa.gov/r02earth/water/oceans/copter.htm.]

Nonpoint Source Pollution Still Plagues the Coastline

Although implementation of the Floatables Action Plan (FAP) has greatly reduced the need for beach closures due to debris, nonpoint source pollution problems still exist. Floatable debris continues to make its way to open water—the FAP partners are just very good at finding and removing it before it washes on shore. The principal sources of floatable debris and other nonpoint source pollutants (such as bacteria) in the area include 737 combined sewer overflow points discharging to the open waters of the NY/NJ Harbor or to its tributaries, hundreds of stormwater discharge points, construction activity, and highway drainage. Other sources include littering, poor landfill and marine transfer practices, decaying shoreline structures, sunken vessels, and vessel discharges. The FAP includes elements that continue to reduce the overall amount of floatable debris derived from these sources. New York and New Jersey both have active programs to combat other sources of nonpoint source pollution. For more information see: www.dec.state.ny.us/website/dow/bwam/ (New York), or www.state.nj.us/dep/watershedmgt/nps_program.htm (New Jersey).

Philadelphia Looks to Vacant Land to Control Stormwater

Philadelphia is a historic city—and an impervious one. During the past 300 years, Philadelphia changed from a New World settlement into one of the most densely built cities in the United States. The many impervious surfaces associated with this development, including buildings, roads, and parking lots, have led to large volumes of stormwater runoff and many combined sewer overflow events. Pollution was taking its toll on local rivers and streams—and something had to be done.

To address the problem, the Philadelphia Water Department (PWD) has embraced a comprehensive watershed management program that fosters regional cooperation and looks beyond traditional infrastructure projects as a solution to stormwater management and combined sewer overflow

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Philadelphia Looks to Vacant Land to Control Stormwater (continued)

mitigation. A key part of PWD's new program seeks to incorporate low impact development (LID) practices throughout Philadelphia watersheds whenever possible.

Vacant Land Offers Opportunity

During the past 50 years, Philadelphia's population has steadily declined because of migration to developing suburbs and the loss of many manufacturing jobs, among other factors. The result has been widespread property vacancy and abandonment—vacant lots or buildings cover approximately 2,600 acres. While the extent of disinvestment is daunting, the City has chosen to view its vacant lands as an opportunity to radically change its approach to stormwater management.

Philadelphia Water Department

The Philadelphia Water Department, one of the oldest municipal water departments in the United States, is an integrated drinking water, wastewater, and stormwater utility that serves the nation's fifth-largest city, with a population of over 1.4 million. Its massive sewer system network includes 1,600 miles of combined sewers, 1,200 miles of separate sanitary and storm sewer lines, 150 miles of intercepting sewers, 169 combined sewer regulating chambers, 85,600 manholes, and 75,000 stormwater inlets.

Most of the City's vacant land and buildings are located within areas served by combined sewers. By incorporating LID and site-specific infrastructure projects that detain stormwater runoff during storm events, or keep it out of the combined sewers entirely, PWD hopes to alleviate combined sewer overflows and minimize the scale and necessity of future large infrastructure projects. Furthermore, PWD believes that LID designs can effectively balance development costs and water pollution controls with projects that enhance community aesthetics, quality of life, sustainability, and environmental education.

Recognizing that LID design strategies are new to most people in the Philadelphia area, PWD has undertaken efforts to educate people and lead by example. With financial assistance from the Pennsylvania Department of Environmental Protection (DEP), PWD has provided conceptual design services to many institutional and nonprofit partners, and has undertaken LID demonstration projects of its own.

For more information about low impact development (LID), and to learn about how other localities are incorporating LID into their planning processes, see the article on page 1.

Vacant Land Serves as Educational Asset

The first demonstration project designed and implemented by PWD was the conversion of an overgrown, trash-strewn vacant lot into an outdoor classroom in West Philadelphia. The site was designed to mimic the transformation of a watershed from "natural" to "man-made," with the back planted with trees and bushes and the front paved with concrete. The hard surface area supports benches and serves as a clean gathering place for visiting children. Stormwater reaches the site as direct rainfall and from the downspout of a neighboring property. A rain barrel collects the initial roof runoff to provide a watering source for the onsite vegetation. The runoff overflow is allowed to drain across the site.

To provide on-site stormwater storage, PWD excavated a four-foot deep infiltration trench in the middle of the lot, added an impervious liner, inserted perforated PVC pipe for drainage, and backfilled it with layers of gravel and sand. PWD graded the lot so it directs the water to the middle of the lot, above the infiltration trench. Three small check dams on the surface above the trench slow the water, allowing it to puddle and infiltrate down through the mulch, soil, sand, and gravel.

Vacant lot is transformed into outdoor classroom.

Vacant Land Manages Stormwater While Waiting for New Life

While the project above transformed a vacant lot into a productive use (outdoor classroom), PWD felt that the intensity of the project is not appropriate for most vacant lot stabilization projects. The City of Philadelphia is pursuing an aggressive policy of demolishing derelict vacant structures and reclaiming the land, and decided to use many of these sites to demonstrate how minimal LID designs can help reduce stormwater runoff. For example, PWD has partnered with the Pennsylvania

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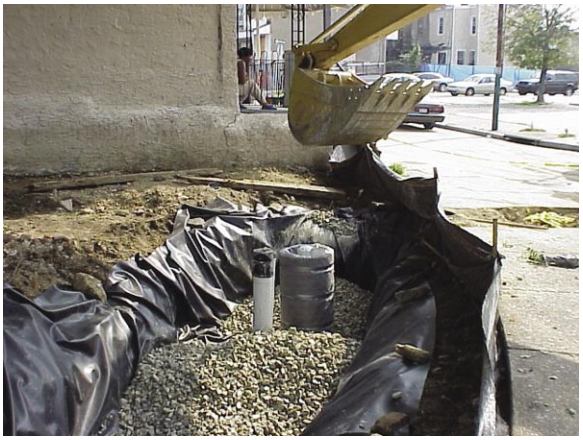
Horticultural Society's Philadelphia Green program to re-grade several vacant lots to direct runoff into strategically placed swales and depressions. PWD performs infiltration tests on lots prior to beginning re-grading work to ensure the site will drain within 48 hours. After grading is complete, the sites are planted with trees and shrubs and fenced to prevent dumping. PWD now views sites like this as assets—while these properties are awaiting development, most runoff is directed into small depressions and allowed to infiltrate, easing the burden on the City's combined sewer system.

Vacant Land Offers Natural Retreat

Not all of Philadelphia's vacant land is awaiting development. To improve neighborhoods, the City has transformed many vacant lots into long-term open space, often as community pocket parks or gardens. PWD's demonstration of this kind of project targeted a small corner lot at the end of a block. Although this parcel had been developed as a community pocket park several decades ago, deferred maintenance had essentially rendered the park unusable, except for the most unsavory of activities. Given the location of this lot at the bottom of a downward-sloped block, it was a logical choice for demonstrating how bioretention and sub-surface storage can be easily incorporated into a neighborhood. PWD cleared the lot, installed a gravel storage system, and planted a small bioretention garden along the perimeter of the lot. Trees, benches, and a new porous walkway completed the park-like setting. Currently, only runoff from the parcel itself is managed by the bioretention garden. In the future, PWD hopes to install a storm drain that will carry roof runoff from nearby properties and direct it to the subsurface storage available at the site.

Water collects in a large depression on a vacant lot along 8th Street.



LID pocket park under construction.

PWD has undertaken many additional innovative and significant demonstration projects on vacant lots, schoolyards, parking lots, recreation courts, rooftops, and large scale redevelopment efforts. For detailed descriptions and photographs of many of these LID demonstration projects, see *New Thinking in an Old City: Philadelphia's Movement Towards Low-Impact Development* (www.ncsu.edu/waterquality/issues/notes112.pdf). PWD recognizes the widespread benefits of LID practices, and will continue to use them as a key tool in the fight against the City's combined sewer overflow problem.

[For more information, contact Glen J. Abrams, Urban Watersheds Planner, Philadelphia Water Department, Office of Watersheds, 1101 Market St., 4th floor, Philadelphia, PA 19107; Phone: 215-685-6039; E-mail: Glen.Abrams@phila.gov. This article was adapted and updated with permission from the North Carolina State University Water Quality Group's NWQEP Notes *Newsletter, February 2004, Issue 112.*]

What are Combined Sewer Overflows?

Combined sewer systems are sewers that are designed to collect rainwater runoff, domestic sewage, and in some cases, industrial wastewater in the same pipe. The vast majority of these systems are relics from our oldest cities that predate separate sewer systems. Most of the time, combined sewer systems transport all of their wastewater to a sewage treatment plant, where it is treated to discharge permit standards and then discharged to a water body. During periods of heavy rainfall or snowmelt, however, the wastewater volume in a combined sewer system can overwhelm the capacity of the sewer system or treatment plant. For this reason, combined sewer systems are designed to overflow occasionally and discharge excess wastewater directly to nearby streams, rivers, or other water bodies. These overflows, called combined sewer overflows (CSOs), contain not only stormwater but also untreated human and industrial waste, toxic materials, and debris. They are a major water pollution concern for the approximately 772 cities in the U.S. that have combined sewer systems, including Philadelphia. For more information, see www.epa.gov/npdes/cso/.

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Karuk Tribe's Ecosystem Restoration Effort Still Going Strong

In July 2000, News-Notes Issue #61 featured an article describing the Karuk Indian Tribe's innovative efforts to restore its degraded watershed. Five years later, we now revisit the Tribe to see how its restoration program has fared.

For years, the tribal lands of the Karuk Tribe of California, located in Northern California near the Oregon state line, had been honeycombed with roads for mining (gold, gravel, and quartz) and timber harvesting. Almost all of the Karuk's ancestral land is located in the Klamath and Six Rivers National Forests, which had opened most of the area to natural resource removal. By 1997, the mines and forests—and associated jobs—were nearly depleted, and the Karuk people found themselves in a critical situation—they were out of work and left with a severely degraded watershed. Showing remarkable resilience, however, the Tribe devised a plan that began to boost their economy and restore the land that had been their ancestral home for thousands of years.

For more information about the decommissioning process, and to view pictures, see the Karuk Ecosystem Restoration Program: 2002 Final Report, available at www.karuk.us/dnr/pdf/wsdocuments/KarukWatershedFinalReport02.pdf.

As the mines and logging operations shut down, funding cuts had prevented the national forests from completing restoration of the damaged watersheds in a timely manner. The Tribe had to take matters into its own hands. In 1996, the Tribe entered into a Memorandum of Understanding (MOU) with the Klamath and Six Rivers National Forests. The MOU established a framework for the partners to jointly identify, plan, and accomplish mutually beneficial projects. The projects identified included watershed restoration, job training opportunities, and community economic development.

A few years later, the Tribe developed a Comprehensive Watershed Restoration Training and Implementation Program for tribal members and staff. The training program provided participants with a thorough foundation in the technicalities underlying watershed restoration. All trainees serve an on-the-job apprenticeship in completing critical restoration work on projects throughout the Karuk lands. The program has created a highly skilled local workforce that has a vested interest in protecting water quality and other natural resources while earning decent wages.

Tribe is Still Making Progress

When News-Notes last visited the Tribe in 2000, it had just established its restoration program and had successfully decommissioned 2.2 of 7.2 miles of Steinacher Road, an old logging road that contributed a large amount of sediment to the Klamath River basin. Since then, the Tribe has made much progress. It secured funds from a variety of federal and state sources and completed the Steinacher Road project in 2002. The Tribe has since moved its efforts to roads in the East Ishi Pishi Road area, which includes a number of severely impacted watersheds.

In December 2004, with funding from an EPA Section 319 grant, the Tribe completed the decommissioning of a portion of a road complex in the East Ishi Pishi Unit's Irving Creek watershed. In 64 days, working between 4 and 10 hours a day, the Tribal Restoration Division staff removed approximately 28,889 cubic yards of fill material from almost five miles of the road and moved it to stable road locations. Due to the erosive nature of soils in this area, project staff immediately incorporated post-project erosion control measures. Road decommissioning work within the Irving Creek Watershed should be complete by the end of 2005.

The Karuk Tribe and its partners have identified approximately 64 miles of road as candidates for future decommissioning, 36 miles of which already have decommissioning plans in place. The proposed actions will take more than eight to 12 years to complete, depending on funding availability. Without stable revenue, continuation of the restoration program is uncertain. If the past ten years is any indication, the Karuk Tribe will be successful in their continuing quest to restore the health of their sacred ancestral territory and the well-being of the Tribe.

Program Helps Tribal Members

Kevin Wilder, who has worked for the Karuk Tribe's Watershed Program since 1999, is pleased with the success of the program and hope it continues. He supports a family of nine and is sending a daughter to college this year. "I live in the Orleans area where there is very limited opportunity for employment, so I feel very fortunate to have such a well-paying job." The program has provided him with knowledge that he can apply for the rest of his life, Wilder adds. "I have been able to learn valuable skills—surveying stream crossings, designing road decommissioning prescriptions, and operating an excavator and a dozer."

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Why Excavate the Sediment?

When logging and mining roads were originally constructed, sediment was used to fill in around stream crossings and to build up the downslope portion of roads (this is called sidecast). The decommissioning efforts require the removal of road fill from stream crossings, swales, and unstable sidecast areas that threaten waterways and downstream salmonid habitat. Stream crossings are excavated either to original width, depth, and slope to expose natural channel armor and buried topsoil or to achieve stable engineered dimensions for maximum cost-effectiveness. Sidecast fill material, with high failure potentials affecting watercourses, is excavated to reduce erosion hazard and expose buried topsoil. Excavated material is moved to stable road locations and then shaped to specific slope and compaction requirements.

Referred to as "sediment savings," the sediment that the tribe removed would otherwise have entered salmon streams as culverts failed and road runoff continued unabated. Since the inception of this program, the tribe has removed approximately 270,000 cubic yards of fill material. To visualize this, imagine 27,000 dump trucks of fill material lined bumper-to-bumper for 102 miles.

[For more information, contact Earl Crosby, Karuk Tribe of CA, Watershed Restoration Coordinator, P.O. Box 282, Orleans, CA 95556; Phone: 530-469-3454; E-mail: ecrosby@karuk.us.]

Notes on Watershed Management

Siphoning Out a Legacy of Phosphorus Pollution in Devil's Lake

Once the bathtub water is polluted, how do you clean it? That was the question faced by scientists from the Wisconsin Department of Natural Resources (WDNR) in the mid-1980s when they began studying the causes of nutrient enrichment and other water quality problems in Devil's Lake, the 372-acre centerpiece to Wisconsin's most popular state park. Devil's Lake was formed during the Ice Age roughly 10,000 years ago and has no natural surface water outlet—the lake loses water only through evaporation and seepage. Sewage inputs from a variety of human sources had contributed nutrient pollution to the lake from the mid-1800s through the 1980s. Since then, the pollution has been trapped, cycling back and forth between the water, the organisms, and the lake's bottom sediments. In the end, WDNR's solution again brings to mind a bathtub—wait until the dirty water builds up in the bottom, and then pull the plug.

History of Pollution in Devil's Lake

Phytoplankton (free-floating algae) blooms first started appearing in August and September during the late 1970s—generating concern among state officials and the public that Devil's Lake, a lake known for its exceptional water clarity, was in trouble. Richard Lathrop, a limnologist at the Wisconsin Department of Natural Resources (WDNR), began studying the lake and its problems in 1986. A 2-year comprehensive study conducted by Lathrop and other WDNR scientists revealed that the lake contained a large amount of phosphorus (P) that was feeding the algae. The researchers also found that the high populations of algae, once dead, sank to the bottom and were broken down by decomposers, causing oxygen in the deeper parts of the lake to become depleted by mid-summer. These anoxic conditions allowed P that was temporarily bound to insoluble hydrous iron oxide compounds in the sediments to be released into the overlying water as the iron was reduced and made soluble. The P that built up in the lake's bottom waters (the hypolimnion) was then distributed throughout the lake as the lake destratified in late summer, culminating with complete lake "turnover" in mid-October (for more information on lake stratification, see www.waterontheweb.org/under/lakeecology/05_stratification.html). In subsequent years, as Lathrop continued studying the lake, the water clarity loss problem lessened slightly as free-floating algae blooms gave way to unsightly growths of filamentous algae and periphyton (attached algae) near the shore.

Picturesque Devil's Lake is surrounded by quartzite bluffs and talus boulder fields.

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Siphoning Out a Legacy of Phosphorus Pollution in Devil's Lake (continued)

The sources of P that feed these algae growths actually no longer enter the lake. As far back as the late 1860s, people built resorts and cottages along the shoreline of Devil's Lake. Some of the outhouses and septic tanks built to serve these residences likely leaked pollution into the lake. Four resorts and over 60 cottages were gradually removed after the state park grew from its inception in 1911. Additional pollution leaked into the lake from a broken park sewer main that the state discovered in the late 1970s and repaired by the early 1980s. Current P inputs to the lake are minor, coming from the lake's small, mostly forested watershed. Yet, the legacy of this P pollution remains in the lake because there is no natural outlet to gradually flush it out.

No Outlet? Create One!

WDNR decided to pull the plug. After much monitoring and investigation, Lathrop convinced WDNR managers and administrators that the best way to remove P was to siphon out water from the deepest part of the lake at the end of the summer, when P concentrations were highest there. This bottom withdrawal method has been used in other lakes (and reservoirs), most notably in Europe, but never before in a large seepage lake like Devil's Lake. In drainage lakes with outlets, systems can be designed to withdraw water from the bottom of the lake instead of the surface; and inflowing rivers and streams can naturally replace the withdrawn water. In the case of Devil's Lake, it was necessary both to find a stream to receive withdrawn water, and to find a source of clean replacement water to maintain lake levels. Providentially, an intermittent stream called Babbling Brook was nearby. In fact, Devil's Lake residents previously excavated a ditch in the 1890s to divert snowmelt water from Babbling Brook into Devil's Lake when lake levels dropped due to dry conditions earlier in the year. A buried metal culvert replaced the ditch in the early 1960s, but it hadn't been used since the early 1970s due to higher lake levels.

WDNR determined that the P-laden anoxic water siphoned from the bottom of the lake could be discharged into the lower part of Babbling Brook from late August or early September until lake turnover occurred around mid-October during a period when the stream was usually dry and without aquatic life. Babbling Brook eventually discharges into the Baraboo River, but WDNR determined that the P from Devil's Lake would not cause negative impacts in the downstream river for two reasons: (1) the withdrawn P would represent less than 0.001 of the Baraboo River's annual P load; and (2) the water would be released after the summer growing season. In years when Devil's Lake water levels were low, WDNR could replace the withdrawn water by diverting relatively clean snowmelt and rain runoff water from Babbling Brook primarily during late winter and early spring.

Will it Work?

WDNR expects that the reduction of P will result in the decline of all three types of algae: phytoplankton, filamentous, and periphyton. WDNR also anticipates two additional water quality benefits. First, reduction of P might indirectly reduce mercury (Hg) levels in fish. Currently, the excess algae can be indirectly linked to elevated Hg levels in the lake's fish population, ultimately reaching levels of public health concern in large sport fish such as walleye. Sulfate-reducing bacteria that thrive only in the anoxic (oxygen-depleted) bottom waters and underlying sediments in late summer convert the relatively harmless inorganic Hg (mainly from atmospheric deposition) to the toxic methyl-mercury (Me-Hg) form. Me-Hg builds up in the anoxic bottom waters until the lake mixes at fall turnover, when Me-Hg is readily taken up by phytoplankton and concentrated as it passes up the food chain to fish. By decreasing the duration and extent of bottom-water anoxia that allows sulfate-reducing bacteria to grow, the build-up of Me-Hg in the lake's bottom waters could be reduced and Hg concentrations in fish should decline.

Second, WDNR hopes that a reduction in P levels will reduce the prevalence of swimmer's itch, which has become so troublesome that fewer people visit the lake in summers when parasite infestation problems are high. The excess periphyton algae are feeding an overabundance of snails, some species of which are intermediate hosts to a parasite that causes swimmer's itch. The amount of periphyton would be expected to decrease as the P in the lake declines, thus decreasing the major source of food for snails. By starving the snails, their densities should decline dramatically, thereby reducing the number of free–swimming parasites in the water.

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Putting the Plan into Action

The plan to reduce P levels in Devil's Lake by siphoning P-rich bottom water from the lake is certainly no quick fix, given the legacy of P stored in the bottom sediments. WDNR expects to operate the system in September and early October for approximately 15 years. Because of the extended time frame of the project, the bottom withdrawal siphon design was ideal for Devil's Lake because it would require no maintenance and no electricity to run it—a huge cost savings on such a long-term restoration project. Additional savings during the system's installation were realized by WDNR performing land surveys and completing other preparations such as ordering materials. Despite these savings, WDNR still had to find an estimated $300,000 to install the system.

Fortunately, WNDR and other interested organizations found a way to fund the project. The Friends of Devil's Lake State Park applied for and was awarded a $200,000 State Lake Protection Grant. An EPA Clean Lakes Grant provided another $100,000, and an additional $5,000 came from a Friends of Wisconsin State Parks grant that was matched by the local Friends group, providing a total of $310,000. WDNR hired a consulting firm to conduct the engineering design work, which was underway by mid-February 2002.

How Do you Build a Giant Siphon?

A local contractor began constructing the bottom withdrawal siphon system in July 2002. The contractor fused 50-foot sections of 20-inch diameter plastic pipe to eventually make a giant straw 5,500 feet long. The 4,150-foot long lake portion of the siphon required 320-pound concrete weights to be attached every 12 feet to counteract the pipe's buoyancy. By the end of July, the pipe with 55 tons of attached weights was floating in place over the deepest part of the lake. After the contractor trenched the near-shore lakebed on the day of sinking, the 50-foot pipe intake was towed to the middle of the lake and attached. Two fire trucks on shore began filling the pipe, causing it to slowly sink—a process that took more than four hours. By the end of the day, the pipe lay on the lake bottom with the intake holes positioned eight inches above the sediments at the lake's deepest spot—46 to 50 feet depending on lake levels.

The next day the contractor began trenching the land section of the siphon pipe. A manhole was placed at the high point of the siphon where a flow meter and an air evacuation system were located and where a portable vacuum pump could be connected to prime the siphon (i.e., evacuate the air, causing lake water to fill the pipe)—a process that takes nearly six hours. The main flow valve was located near the siphon end, which is submersed in a manhole that drains via a short pipe to Babbling Brook. The difference in water levels between the terminal manhole and the lake surface creates a pressure head difference that determines the flow rate of the siphon. (Head differences of five to nine feet, depending on lake levels, produce flow rates of four to six cubic feet per second in the siphon).

Concrete weights attached to the pipe keep it on the lake bottom.

A barge helps position the pipe intake at the deepest part of the lake.

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Siphoning Out a Legacy of Phosphorus Pollution in Devil's Lake (continued)

By mid-August 2002, the 1,350-foot land section of pipe was joined to the lake portion. On August 29th, the main valve was opened and bottom water from Devil's Lake started pouring out. Average flow rates that year were 5.3 cubic feet per second (2,380 gallons per minute) during the seven-week run until it was shut down for the season when cooler weather naturally "turned over" the lake water on October 17th. By then, 981 pounds of phosphorus had been removed from the lake, far exceeding the initial goal of about 350 to 400 pounds. Because of high lake water levels, no water was diverted from Babbling Brook the following spring.

The pipe was buried underground from the lake to the discharge point.

However, 2003 turned out to be a drought year, which shortened the time the siphon was used. The system still managed to remove 377 pounds of P that season. In November 2003, runoff water from Babbling Brook began replacing water siphoned off earlier in the fall. Rainfall and snowmelt also added to the water in the lake during the late winter and early spring months of 2004. In fact, heavy rains caused so much flooding later in the spring of 2004 that WDNR administrators authorized the siphon to be activated for four weeks in early summer as a flood mitigation measure. In late summer 2004, Lathrop reactivated the siphon system for eight weeks and removed 1,300 pounds of P. Lake levels remained high enough that again no water needed to be diverted from Babbling Brook.

Monitoring Underway

Lathrop operates the bottom withdrawal siphon and water diversion systems each year, and directs the monitoring effort to evaluate the lake restoration project's success. P levels in the bottom withdrawal outfall water are determined from daily composite samples obtained by an automated sampler; other constituents including methyl and total mercury are periodically sampled by grab sampling at the outfall. Lake monitoring is conducted at the deepest spot in the lake approximately bi-weekly beginning each spring and continuing until early November, after fall turnover has occurred. Lathrop monitors a variety of constituents and water quality characteristics in the lake; including temperature and dissolved oxygen profiles, water clarity (Secchi disk), phosphorus and chlorophyll levels in the surface waters, and zooplankton. During the stratified season, phosphorus, iron, and sulfate levels are determined from samples collected at various depths in the lake bottom waters. Periphyton growth rates are also monitored in lake shoreline waters during the summer. Finally, each spring Lathrop collects mimic shiners—a variety of minnow—and has the tissues analyzed for mercury.

Water from Devil's Lake is released into Babbling Brook.

Because the project solution is so peculiar, the process of gaining acceptance and approval for it was difficult. Lathrop invested years of his career leading the research and project planning. Now Lathrop must be content to monitor the lake and wait to see if his efforts pay off as expected. Lathrop points out that the siphon project is a long-term one, but he hopes to start seeing improvements after seven or eight years of withdrawals. Lathrop adds that, as a career scientist for WDNR, he has been involved in many lake and watershed studies. "This one is special," he notes. "I feel like I have been a part of something that will really make a difference."

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Siphoning Out a Legacy of Phosphorus Pollution in Devil's Lake (continued)

[For more information, contact Dr. Richard C. Lathrop, Wisconsin Dept. Natural Resources c/o Univ. Wisconsin-Madison Center for Limnology, 680 N. Park St., Madison, WI 53706; Phone: 608-261-7593; E-mail: rlathrop@wisc.edu. Information for this article was taken from: Restoring Devil's Lake from the Bottom Up, Wisconsin Natural Resources*, June 2004, 28:4-9, and from: Lathrop, R.C. et al., 2005. Restoration of a Wisconsin Seepage Lake by Hypolimnetic Withdrawal.* Verh. Internat. Verein. 2q3. *29: (in press).]*

Beating Acid Mine Drainage in Pennsylvania's Swatara Creek

After decades of impairment from acid mine drainage (AMD), Swatara Creek is gaining a new lease on life. In 1990, Swatara Creek, a tributary of Pennsylvania's Susquehanna River, was found to be "fishless" in its headwaters because of acidic, metal-laden inflows from abandoned anthracite coal mine operations. Since then, federal, state, and local organizations have worked together to repair the creek by implementing numerous passive-treatment and surface-stabilization projects. Their efforts are paying off. Water quality monitoring and ecological surveys on Swatara Creek have indicated better water quality and increasing numbers of fish and other aquatic organisms. The partners are continuing to monitor Swatara Creek, gathering data that will help them determine which passive-treatment systems are most promising for successful long-term application in Swatara Creek and other similar watersheds.

What is Acid Mine Drainage?

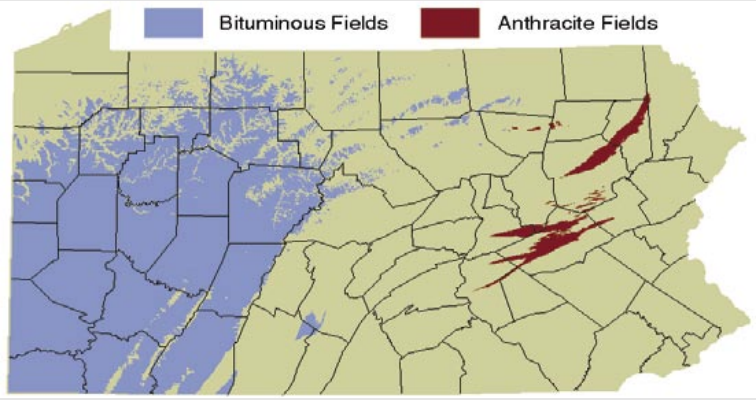
Coal and surrounding rocks contain pyrite, an iron-sulfide mineral also known as "fool's gold." A complex series of chemical weathering reactions are spontaneously initiated when surface mining activities expose the coal and surrounding rocks to an oxidizing environment. The pyrite mineral assemblages are not in equilibrium with the oxidizing environment and almost immediately begin reacting and transforming. The mineral transformation process can release damaging quantities of acidity, metals, and other soluble components into any water that comes into contact with the rocks. The polluted water that results is also known as acid mine drainage (AMD). Most aquatic organisms and plants cannot survive in AMD—the water is unfit for drinking or swimming, and structures such as bridges can be corroded or encrusted. As the AMD flows downstream and is diluted with fresh water, the dissolved metal ions can precipitate on to submerged objects, forming solid metal hydroxide particles that build rusty coatings on the streambed and stain the water reddish brown.

Addressing a Pervasive Problem

Most of the coal mines in the Swatara Creek Watershed were abandoned before 1960. Many of the abandoned underground mining tunnels have since flooded and collapsed, causing localized subsidence. Thinly vegetated piles of mined rock and coal waste continue to be sources of sediment, acidity, sulfate, iron, aluminum, and other metals in surface runoff. Surface water also can run off into subsidence pits and mine openings to the underground mines where it becomes contaminated with acidity, sulfate, and metals. In downstream reaches, the contaminated water resurfaces as AMD that discharges to Swatara Creek and its tributaries.

Pennsylvania Coal

Coal is a readily combustible rock whose composition consists of more than 50 percent by weight of carbonaceous material. Coal forms when layers of plant and animal matter accumulate in an oxygen-poor environment (such as a swamp), become covered with sediment, and are compacted and chemically altered by heat and pressure over geologic time.



Coal fields underlie portions of Pennsylvania.

Pennsylvania is underlain by fields of anthracite coal in the east and bituminous coal in the west. Anthracite coal is formed during mountain-building periods when compaction and friction subject the rocks to extremely high temperatures. Anthracite is typically composed of between 86 and 98 percent carbon. Most of the anthracite reserves in the United States are found in 11 counties in eastern Pennsylvania. Bituminous coal is formed at a lower temperature than anthracite and has a carbon content of between 45 to 86 percent. Bituminous coal, which underlies most of western Pennsylvania, is the most plentiful form of coal in the United States. For more information about coal, see http://energy.er.usgs.gov/coal.htm.

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Beating Acid Mine Drainage in Pennsylvania's Swatara Creek (continued)

The Pennsylvania Department of Environmental Protection's (PaDEP) Bureau of Mining and Reclamation, the U.S. Geological Survey (USGS), and Skelly and Loy Engineering Consultants collected water quality data from throughout the Swatara Creek basin beginning in 1975 and continuing through 1988. These data were used to help document stream conditions and identify problem areas prior to the development of a watershed restoration plan or the installation of passive treatment systems. Data from these previous investigations included analysis of typical AMD, metals, major ions, acidity, and alkalinity.

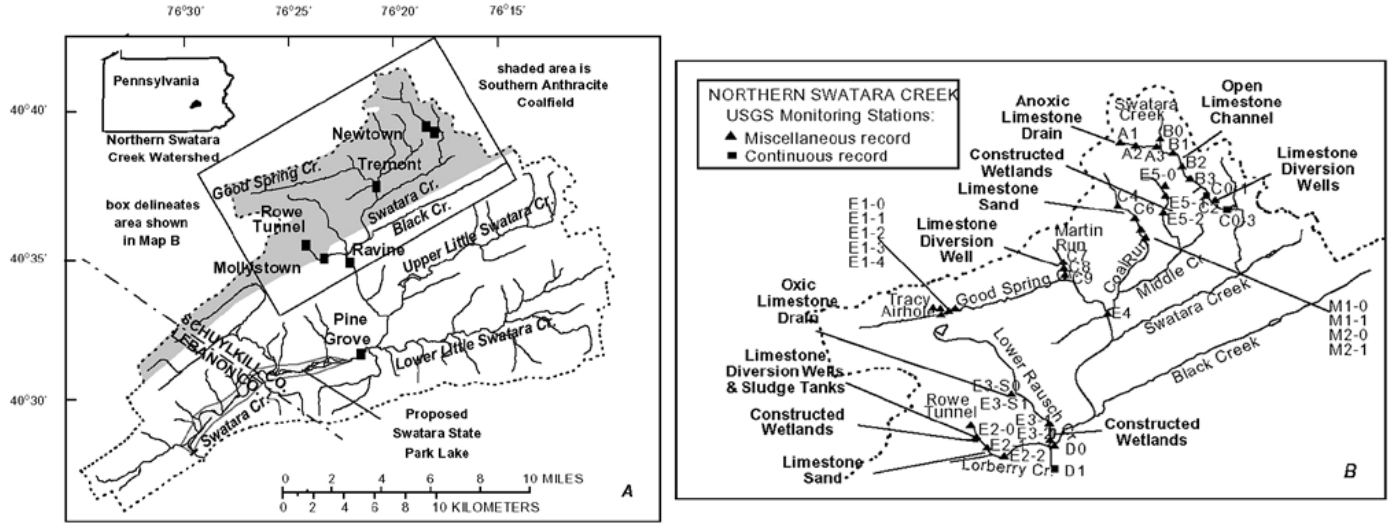
In the mid-1990s, the PaDEP developed a watershed remediation plan to restore Swatara Creek and its tributaries to their designated recreational and fishable uses. Several groups have helped implement the plan, including the Northern Swatara Creek Watershed Association and fishing and sportsman's groups. The Schuylkill County Conservation District (SCCD) has coordinated the implementation of passive-treatment measures for the AMD, and has led nutrient management and streambank stabilization efforts in the farming areas. Schuylkill County's Waste Management Coordinator has funded some of the stream improvement projects. Local coal companies and limestone quarries have donated supplies and services.

Implementation of Passive Treatment Projects

During 1995 through 1998, PaDEP and volunteers, with technical assistance from the USGS, constructed limestone-based passive-treatment systems at several major pollution sources in the Swatara Creek headwaters. These treatment systems were designed to raise the pH, which facilitates the precipitation of dissolved iron, aluminum, and associated metals. The systems include limestone-sand dosing, open limestone channels, anoxic limestone drains, and limestone diversion wells. Each passive-treatment system has different advantages and disadvantages; however, all suffer from possible complications associated with variability in flow rates, chemistry of the AMD and stream water, and from uncertainties about efficiency and longevity of the treatments. For more information about passive treatment systems, see box on next page.

Monitoring Shows Success

Since 1996, the USGS, in cooperation with the PaDEP and SCCD, has conducted water-quality monitoring to evaluate the effectiveness of specific implementation projects and their cumulative effects on a watershed scale. The Swatara Creek Project was accepted into the EPA's Section 319 National Monitoring Program in 1998, adding to the resources available to support the project. The total cost for the project for 1999-2002 was $670,000, and the estimated total cost of the project for 2003-2007 is $967,340. The USGS, SCCD, and PaDEP share costs, with EPA providing both technical resources and funding to PaDEP.



Map of project area showing locations of passive treatment systems and monitoring stations.

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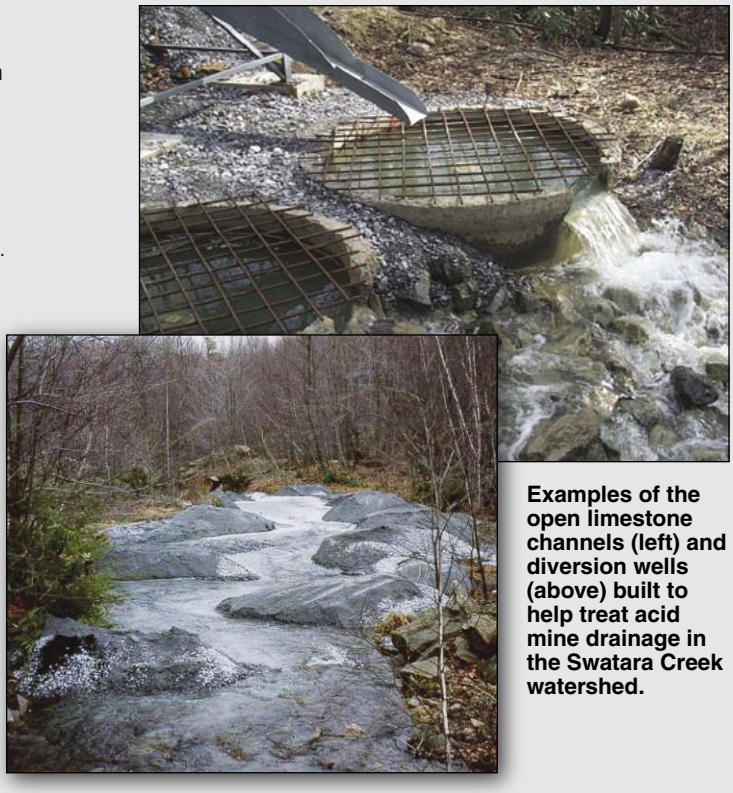
Passive Treatment Options for Acid Mine Drainage

Active chemical treatment of acid mine drainage (AMD) to remove metals and neutralize acidity is often an expensive, long-term process. Fortunately, many passive-treatment systems are now available that do not require continuous chemical inputs and that take advantage of naturally occurring chemical and biological processes to cleanse contaminated mine waters. The primary passive technologies include constructed wetlands, anoxic limestone drains, successive alkalinity-producing systems, limestone ponds, open limestone channels, diversion wells, and bioremediation.

Constructed Wetlands. Constructed wetlands promote precipitation of metal ions to hydroxides, which are retained in the wetland where they can be removed. In an anaerobic wetland, oxygen is excluded as water moves slowly through an organic layer above a crushed limestone bottom. The limestone raises the water's pH and metal is precipitated out and retained in the wetland. Microbial action also raises pH, and plant materials adsorb soluble metals and metal precipitates. The plant material eventually becomes saturated with metals and must be excavated and replaced.

Anoxic Limestone Drains. Acidic ground water can be channeled through anoxic limestone drains, which are buried trenches of limestone. The limestone dissolves, increasing pH and adding alkalinity. Under anoxic conditions, most dissolved iron does not precipitate until water pH approaches neutrality, thus the limestone does not become coated with iron hydroxides.

Successive Alkalinity Producing Systems. These systems combine the use of an anoxic limestone drain and an organic substrate. In some situations, dissolved oxygen concentrations are so high that oxygen must be removed from the water before it can be introduced into an anoxic limestone bed. In that case, water ponds over a layer of organic compost that is underlain by crushed limestone. Oxygen is consumed in the compost while the limestone raises the water's pH. Drainpipes below the limestone carry the water to an aerobic pond where metals are precipitated.



Examples of the open limestone channels (left) and diversion wells (above) built to help treat acid mine drainage in the Swatara Creek watershed.

Limestone Ponds. Limestone ponds are constructed on top of a spring that is discharging acid mine drainage. Crushed limestone is placed on the bottom of the pond and the water flows upward through it. Recently, such systems have incorporated automatic siphon flushing systems to remove solids that precipitate within the limestone bed.

Open Limestone Channels. Open limestone channels introduce alkalinity to surface water. The limestone is brought in and placed in the channel. These are more effective on a slope greater than 20 percent as the turbulence keeps the precipitates in solution and cleans precipitates from the limestone. They are often used with other passive systems to convey water to various treatment cells and to maximize treatment.

Diversion Wells. Diversion wells are wells constructed with a layer of crushed limestone on the bottom. Acidic water is introduced into the bottom of the well through a vertical pipe and flows upward through the limestone. The higher pH water and metal flocs flow out the top of the well and the metal can be precipitated in a downstream pond.

Bioremediation. Bioremediation involves the use of microorganisms to remediate contaminated sites. Different organisms can raise pH and remove metals from acid mine drainage solutions.

The physical and chemical characteristics of each mine drainage needs to be known before a restoration team can choose the remediation system that is most likely to be effective. The passive systems noted above work well and are relatively inexpensive, but all need monitoring for adjustments or limestone replenishment over time. For more information, and to view pictures of each type of system, see the following Web sites:

- www.dep.state.pa.us/dep/deputate/minres/reclaimpa/reclaimpahome.htm
- http://geology.er.usgs.gov/eastern/environment/drainage.html
- www.wvu.edu/~agexten/landrec/passtrt/passtrt.htm

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Beating Acid Mine Drainage in Pennsylvania's Swatara Creek (continued)

The monitoring data have shown improvements in water quality. For example, the team found that the anoxic limestone drain at the Buck Mountain discharge near the headwaters of Swatara Creek has had a great benefit on a watershed scale, producing measurable improvements in pH and alkalinity for several miles downstream. The original limestone dissolved so quickly that the team had to add an additional 100 tons of limestone to the treatment system in January 2002. They also found that the diversion wells have the greatest potential to treat stormflow, which generally is more acidic than baseflow; however, these systems require maintenance to ensure that they contain sufficient limestone through the duration of a stormflow event and that they do not become clogged with debris. The data also showed that wetlands installed at various locations on tributaries and at coal mine discharge sources are effective at reducing metals transport to the main stem of Swatara Creek.

Section 319 National Monitoring Program

Swatara Creek is designated as a Section 319 National Monitoring Program project. These projects comprise a small subset of NPS pollution control projects funded under Section 319 of the Clean Water Act. The goal of the program is to support 20 to 30 watershed projects nationwide that meet a minimum set of project planning, implementation, monitoring, and evaluation requirements designed to lead to successful documentation of project effectiveness with respect to water quality protection or improvement. For more information on this and other National Monitoring Program projects, see www.bae.ncsu.edu/programs/extension/wqg/319index.htm.

Data collected on Swatara Creek at the outlet of the project area indicate the combination of treatment systems has significantly improved water quality in Swatara Creek. Because minimum values of pH have increased to near neutral over the study period, the fish community in this location has rebounded from nonexistent in 1990 to 400 fish, representing 25 species, in 2002. Another good sign of improving health of the stream is an increased abundance of aquatic insects that are intolerant of pollution. Nevertheless, substantial transport of dissolved and suspended metals persists in Swatara Creek because of the long-term accumulation of iron hydroxide, aluminum hydroxide, and associated materials in the streambed during normal flows, and the scour and transport of accumulated metal-rich streambed deposits during stormflow events. The long-term performance of the individual treatment systems and continued recovery of the aquatic ecosystem remain uncertain. Ultimately, the project data and interpretations will be used to resolve uncertainties about the optimum designs and appropriate uses of these systems for long-term implementation in Swatara Creek and elsewhere.

[For additional information, contact: (1) Jane Earle, PA Dept. of Environmental Protection, Bureau of Conservation, PO Box 8555, Harrisburg, PA 17105-8555; Phone: 717- 787-7007; E-mail: jearle@state.pa.us; (2) Daniel Koury, PA Dept. of Environmental Protection, Bureau of Mining and Reclamation, 5 West Laurel Blvd, Pottsville, PA 17901-2454; Phone: 717-621-3118; E-mail: dkoury@state.pa.us; or (3) Charles Cravotta, U.S. Geological Survey, 215 Limekiln Road, New Cumberland, PA 17070; Phone: 717-730-6963; E-mail: cravotta@usgs.gov.]

Technical Notes

Satellite Data Open a New View on Water Quality

States in the Great Lakes Region are leading the country in the use of satellite data as a means for assessing the health of lakes. Minnesota, Michigan, and Wisconsin together are home to more than 30,000 lakes larger than 10 acres in area. The quality of each lake varies depending on its proximity to different land uses and pollution sources. Although each state has a number of agencies and volunteer organizations collecting monitoring data, the number of lakes far outstrips the monitoring resources available. Now, a handful of additional monitors—satellites—have joined the scene. These satellites collect and share statistically reliable data on an unprecedented scale.

Keeping up with the Science

For updated information on the rapidly advancing use of satellite data for lake monitoring in the Great Lakes region, visit The Regional Earth Science Applications Center (RESAC) Web site at http://resac.gis.umn.edu. RESAC was established by NASA as a consortium of universities, state and federal natural resource management agencies, and industry partners who are developing satellite remote sensing products, geospatial analysis methods, and biophysical process models to meet regional decision-making needs.

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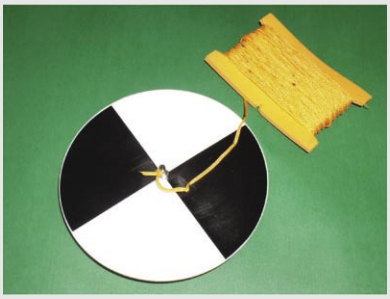
Satellite Data Open a New View on Water Quality (continued)

Researchers from Minnesota, Michigan, and Wisconsin have embraced the use of satellite data as a tool for assessing water quality. In 2003, they unveiled a Web site for their joint Regional Water Clarity project, an effort to compare satellite data and ground-based monitoring to assess lake water clarity across the Great Lakes region (for more information see http://resac.gis.umn.edu/water/regional_water_clarity/regional_water_clarity.htm). The researchers found that analysis of certain wavelengths of visible light in the satellite data correspond closely with that of on-the-ground Secchi disk readings, allowing accurate estimates of lake clarity for thousands of otherwise unmonitored lakes. Researchers are also mapping water clarity with archived satellite data enabling them to go back into the past and look at historical trends. This type of visual information helps resource managers identify and target problem areas and enables systematic ground-based monitoring of inland lakes.

What is a Secchi Disk?

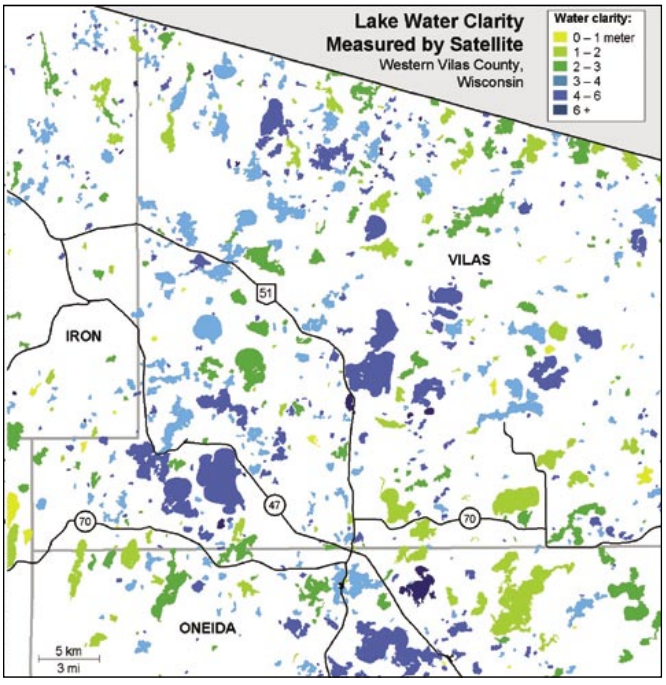
Resembling an oversized CD with a bold black-and-white pattern on top, a Secchi disk is lowered by rope into the water until it is just deep enough to disappear from sight. At that point, the user records the depth. The water clarity is then expressed in terms of Secchi depths.



Example of a typical Secchi disk (photo courtesy of Wildlife Supply Company (Wildco)).

Wisconsin's Story

Wisconsin completed its portion of the Regional Water Clarity Project in January 2003. "We couldn't have completed this project without the help of our statewide volunteer monitors," explained Thomas Lillesand, Director of the University of Wisconsin-Madison's Environmental Remote Sensing Center. As part of the Wisconsin Department of Natural Resources' Self-Help Citizen Lake Monitoring Program, volunteers across Wisconsin routinely measure the clarity of their local lakes with Secchi disks. To aid in Wisconsin's part of the Regional Clarity Project, Self-Help volunteers took Secchi readings on lakes beginning in 1999. The volunteers adhere to a strict monitoring time schedule that allows their measurements to occur just as the Landsat satellite passes overhead and gathers corresponding electronic images of these and other lakes. This coordinated data collection effort continues today.



Example of a lake clarity map generated using satellite data (map courtesy of the Environmental Remote Sensing Center at the University of Wisconsin-Madison).

Back at University of Wisconsin-Madison, researchers correlated the conventional water-clarity data with the corresponding Landsat data through 2001. Lillesand says in this way, Secchi readings from fewer than 400 lakes made it possible to estimate the clarity of all other lakes in the satellite's images without sampling each of them by hand. "Our research aims to integrate satellite data into the state's day-to-day lake management programs," he explained. "This won't eliminate the need for conventional water quality monitoring, but it will greatly increase the benefits of ground-based sampling."

Sharing Results with the Public

In January 2003, the University of Wisconsin-Madison researchers and their cooperators released a Web-based, interactive mapping resource (www.lakesat.org) for the state of Wisconsin. The map allows users to view the whole state or zoom in on a particular region or lake to see satellite data maps and maps depicting water clarity. The Web site was an instant success. "We had so many hits the first few days that it overwhelmed our server," Lillesand recalled. The site has received more than 20,000 visitors since January 2003.

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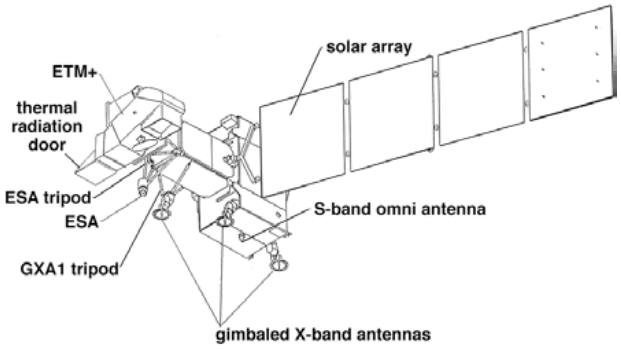
Satellite Data Open a New View on Water Quality (continued)

The researchers have discovered that a wide variety of people use the resources for different reasons. "Fishermen look for prime fishing spots, researchers and lake associations check the status of lakes, teachers use it to provides hands-on education, and more," explained Lillesand. "We have also noticed that the project is generating more interest in water quality protection. When people see that other nearby lakes are in better shape than theirs, they tend to want to get involved so they can do something about it." The number of volunteers in the state's lake monitoring program

Thirty Years of Satellite Data

The NASA Landsat program launched its first satellite into the earth's orbit in 1972. The satellite carried a television camera and a sensor called the Multi-Spectral Scanner, which collected data in four spectral bands and had a coarse resolution (one pixel to 80 square meters). The resolution refers to the level of detail available, which is determined by the fixed width represented in each square pixel of the satellite's digital composite image. This same sensor was aboard the next three Landsat satellites launched during the 1970s. Landsat 4 (1982) and Landsat 5 (1984) were equipped with an improved sensor, the Thematic Mapper, which provided greater resolution in the visible and near-infrared regions (30 meters versus 80 meters) and three additional spectral bands. Landsat 6 (1993) failed to reach orbit after launch.

Landsat 7, launched in April 1999, was equipped with an Enhanced Thematic Mapper-Plus sensor. The improved instrument has eight bands sensitive to different wavelengths of visible and infrared radiation, has better resolution in the thermal infrared band than the instruments carried by Landsats 4 and 5, and is also far more accurate. Every 16 days, the Landsat 7 system collects and archives high-quality multi-spectral data for the entire globe. The repeating, extensive coverage of Landsat 7 is excellent for observing seasonal changes on continental and global scales, and Landsat's fine resolution is ideal for perceiving important detail in land surfaces.



Schematic drawing of Landsat 7.

The Landsat 7 system offers the unique capability to seasonally monitor important small-scale processes on a global scale, such as the annual cycles of vegetation growth; deforestation; agricultural land use; erosion and other forms of land degradation; snow accumulation and melt and the associated fresh-water reservoir replenishment; and urbanization. The other systems affording global coverage do not provide the resolution needed to observe these processes in detail, and only the Landsat system provides a 26-plus year record of these processes.

Also in 1999, NASA launched the first Earth Observing System (EOS) satellite, called Terra, carrying five remote sensors. NASA launched a second EOS satellite, Aqua, in 2002. The most comprehensive EOS sensor is MODIS, the Moderate-resolution Imaging Spectroradiometer (http://modis.gsfc.nasa.gov). MODIS offers a unique combination of features: it detects a wide spectral range of electromagnetic energy; it takes measurements at three spatial resolutions; it takes measurements all day, every day; and it has a wide field of view. This continual, comprehensive coverage allows MODIS to complete an electromagnetic picture of the globe every two days. MODIS's frequent coverage complements other imaging systems such as Landsat's Enhanced Thematic Mapper Plus, which reveals the Earth in finer spatial detail, but can only image a given area once every 16 days—too infrequently to capture many of the rapid biological and meteorological changes that MODIS observes.

Landsat Problems Raise Scientists' Concerns

In May 2003, the scanning system on Landsat 7 began to malfunction, creating gaps in the sensor's coverage. Researchers at the University of Wisconsin say that the impact of these gaps on their lake monitoring program has not been as severe as originally feared, since most targeted lakes are at least partially covered by the satellite. But these data gaps may cause smaller lakes to be missed, and they may be more of a problem for other studies.

The aging of Landsat 5 (which is now sixteen years past the end of its five-year design life), combined with the scanning malfunction on Landsat 7, have left scientists feeling uncertain over the current status and future direction of the satellite program. These concerns increased last year when the proposed Landsat Data Continuity Mission was scrapped and plans for future satellites were sent back to the drawing board. A new plan calls for a replacement sensor called the Operational Land Imager to be carried on a series of standard weather satellites beginning in 2010. Response from the scientific community has been cautiously optimistic over the prospect of a long-term commitment to maintain a Landsat-like sensor on the weather satellites, combined with concern about the possibility of a gap between the likely end of operation of Landsats 5 and 7 and the launch of the new satellite series. For more information about the Landsat program, see http://landsat.usgs.gov.

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jumped dramatically after this resource came out—from about 650 volunteers statewide in 2000 to more than 1300 volunteers in 2004.

Looking Beyond Lake Clarity

"Demonstrating that lake clarity can be estimated over very large areas via satellite data at this level of detail is just the beginning of our research," said Lillesand. "We want to be able to answer such questions as how lake clarity has changed over time, where lake management activities might be most useful, and which lakes will be most subject to change in the future due to such factors as changes in land use and climate."

Can I Use Satellite Data in My Watershed?

In early 2005, the U.S. EPA Office of Wetlands, Oceans, and Watersheds' Monitoring Branch awarded a grant to the North American Lake Management Society (NALMS) to conduct a comparative study of different methods and sensors for lake management applications of remote sensing. Researchers from University of Wisconsin-Madison, the University of Minnesota, and the University of Nebraska-Lincoln will conduct studies on lakes in the Midwest region and produce a report that compares the capabilities, accuracy, and costs of all the various approaches. The report will serve as a guidance document for lake managers in the Midwest region who are considering whether and how to use remote sensing in their own work. Researchers expect the project to be completed within two years.

Under the sponsorship of the NASA Affiliated Research Center (ARC) program, Lillesand and his colleagues have also looked beyond Landsat to other satellite data to help them monitor lake water quality. Lillesand says that a new imaging system aboard NASA's state-of-the-art Terra and Aqua satellites, called MODIS, has a much wider field of view and can provide coverage nearly every day (see box "Thirty Years of Satellite Data" for more information on Terra, Aqua, MODIS, and Landsat). Although MODIS data are coarser in resolution, revealing far less detail than Landsat's, MODIS' broad coverage area and frequency permits scientists to monitor the clarity of large water bodies like Lake Winnebago and Green Bay daily except when clouds obscure them. "We are using MODIS data to monitor sediment plumes and nuisance algae blooms," explained Lillesand. "We hope to get a better idea of where the hot spots are so we can more accurately target the sources of the problems."

[For more information, contact Thomas Lillesand, Environmental Remote Sensing Center, University of Wisconsin-Madison, 1225 W Dayton St, Floor 12, Madison, WI 53706. Phone: 608-263-3251; E-mail: tmlilles@facstaff.wisc.edu; Web: www.ersc.wisc.edu.]

UNH Center Compares Stormwater Treatment Technologies

In a new regulatory environment, stormwater managers are often pushed to take a leading-edge approach to new stormwater treatment technologies that mitigate urban nonpoint source pollution. But which technologies are best suited for the different watershed conditions? Managers hesitate to invest large amounts of public funds in an innovative technology for fear they would be held accountable if the technology fails. Now, a new research facility at the University of New Hampshire (UNH) is helping to take some of the risk out of their decision-making.

Providing Answers to Tough Questions

In urban settings, stormwater has historically been piped away from buildings, city streets, and parking lots into outlets leading to nearby streams and rivers. Yet increasingly, under National Pollutant Discharge Elimination System (NPDES) Stormwater Phase II regulations, local stormwater managers are responsible for spending public dollars to formalize stormwater management programs and install treatment systems to control stormwater pollution.

Selecting a stormwater treatment system involves site-specific considerations on installation space and configuration, budgets, and desired outcomes. Ultimately, the questions that public officials want to answer with some degree of confidence—particularly if public tax revenue is at stake—is, "Will the treatment work here?" and "Will it improve water resources?"

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Empirical data of treatment system performance would increase confidence, but those data are often narrow, limited, or are published by vendors themselves along with marketing pitches for their product's performance. Newer stormwater treatment systems like low-impact development (LID) techniques backed by widely accepted theory may meet resistance to implementation because there are few installation sites and little monitoring data that offer "proof" that they work in practice.

So, if you are a municipal official ready to install innovative stormwater treatment for your town—and are wondering how to select an optimal system within the constraints of a tight budget and particular rainfall regime—you'll be happy to learn about UNH's Center for Stormwater Technology Evaluation and Verification (CSTEV).

A New Approach

Researchers at CSTEV conduct field-tests of multiple stormwater treatment technologies. Their mission is to fill the gap—of data, and the data's credibility—by monitoring and analyzing different technologies under the same control conditions. As a third party, independent research center, its sole focus is the testing, effectiveness, and nuances of each stormwater treatment technology. The lab has been operational since July 2004.

CSTEV's "experimental-laboratory" is in fields that skirt the perimeter of a nine-acre campus parking lot. Principal Investigator, Dr. Tom Ballestero, refers to this as an "ultra-urban watershed," with 99 percent impervious surface. All parking lot runoff flows to one location, and from there the water flows by gravity to different treatment systems. So, each system sees essentially the same runoff hydrograph and the same runoff water quality. At the site, 15 different treatment systems are installed side-by-side. Outflow hydrographs from each system are monitored as well as the outflow water quality. For a given storm, researchers collect and compare data on flow volume influent and effluent, time measurements, and pollutant removal efficiency for a suite of water quality parameters across all of the technologies. The availability of this type of data has long been on stormwater managers' wish lists. Now, when deciding which treatment technology to choose, the manager doesn't have to worry about the varying conditions that might have affected stormwater data reported for different technologies under different study conditions.

Director of the CSTEV, Dr. Robert Roseen, groups the 15 technologies under testing into three classes: conventional structural systems, manufactured devices, and low impact development treatment systems (see box). He estimates that 95 percent of stormwater treatment systems now used across the country are conventional structural systems like retention systems and vegetated swales, while less than one percent are LID techniques such as bioretention systems or gravel wetland systems. The manufactured devices under testing were provided by vendors themselves, following a widely cast solicitation by CSTEV.

Stormwater treatment systems studied at CSTEV*

Conventional Structural Systems	Manufactured Devices	Low-impact Development Systems
• Retention Pond • Vegetated Swale	• ADS Treatment Unit: Water Quality and Storage • Aqua Swirl and Aqua Filter Systems • Storm Drain Manhole Refit Systems • VortSentry™ Hydrodynamic Separator • Structural Stormwater Treatment System • Continuous Deflective Separation	• Surface Sand Filter • Porous Asphalt Pavement • Tree Box Filter • Bioretention Unit • Gravel Wetland Unit

**Fact sheets providing more information on each system are available at www.unh.edu/erg/cstev/fact_sheets.*

A Storm-by-Storm Analysis is Not Enough

A typical gauge of a treatment technology's effectiveness is to measure its removal efficiency—through a yardstick known as the event mean concentration (EMC). In effect, the EMC is the mass

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of the contaminant (flowing into or out of the system), and the removal efficiency is the percent of the mass (of a pollutant) removed from influent stormwater as it flows out of the technology. This number captures the result of one test, at one time, from one rainfall event. "Even repeating the event mean concentration test five or six, or ten times, in one summer, is a narrow measurement of the technology's effectiveness," says Ballestero. Instead, at CSTEV, Ballestero focuses on replicating how the technology works in practice over time.

Ballestero considers how a technology functions at different times during its operation: at the start-up phase, in different seasons, and after some acclimation such as vegetation growth and wildlife introduction around the technology. "A minimum period of measurement is one year," he says, while pointing out that ground frost penetration—which can affect different technologies—has differed by more than four feet in the previous two years in New Hampshire.

Measuring a series of responses to storms over the course of at least a year, he says, allows researchers to synthesize various factors into a probabilistic analysis of a technology's effectiveness. A distribution teases out slight variations in the technology's performance and can offer a better way to compare different technologies. For example, he says, "We might be able to say that Device X removes total suspended solids (TSS) to a benchmark level or better 75 percent of the time but has notable severe exceedances, but Device Y removes TSS slightly above a benchmark level 95 percent of the time. This information is exactly what managers need to figure out what would work for their waterbodies. This is ultimately more useful information than a removal efficiency ratio of a technology based on limited testing."

But … Will This Improve My Receiving Water?

CSTEV's extensive data collection and analysis may be just the bridge that managers need to cross over from research to real-world application. Ballestero stresses that the receiving water is usually a critical factor but may be overlooked in a manager's decision-making. An extended-period, probabilistic data analysis would better support matching an appropriate technology with waterbody or watershed goals. For example, if a receiving water's uses cannot support an occasional overload of a pollutant, but can more easily support a steady, moderate-level of pollutant, that is important to factor into a technology selection decision.

Beyond the focus on urban pollutants, CSTEV also examines what happens to the stormwater in the treatment technology itself. Exposure to air in some technologies and no exposure in others affects the quality of the stormwater. Some technologies are good at cleaning our urban pollutants, but they yield anaerobic water that could be problematic if discharged to a receiving water with low dissolved oxygen. Alternatively a technology with a surface expression, such as a pond, can generate water with high levels of microbes, which might pose problems for receiving waters that have existing high-microbe levels.

This bioretention unit is one of the low-impact development systems currently being tested at CSTEV.

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Price Tag for Multiple Beneficiaries

The independent status of the UNH researchers makes their research attractive both to the user community and to vendors who get high-credibility, in-depth testing of their system at no cost. To run a lab like this takes a large budget. "Larger," says, Ballestero, "than any single town or community, or even state should have to pay." NOAA provided grant funding to cover $400,000 in design and construction for the fifteen different treatment systems, and $300,000 to cover the monitoring equipment.

Pollutants Monitored

Being judicious about the parameters that are monitored is critical, says Ballestero, because it's easy to spend up to $100,000 on monitoring a single storm across fifteen different technologies. CSTEV monitors for the following pollutants, which are consistently above detection levels as they enter the treatment systems:

- Diesel range organics
- Zinc
- Chlorides
- Cyanide
- Nitrate/ammonia (depending on aerobic or anaerobic systems)
- TSS
- Enterococci (family of bacteria)

These data can be used to represent the likely behavior of entire classes of pollutants, such as microorganisms, metals, nutrients, organics, and sediment.

NOAA and UNH's Cooperative Institute for Coastal and Estuarine Environmental Technology, whose mission is to promote the use of technology to reverse estuarine degradation, also grant annual operational funding to the tune of $0.7 million.

Widely Applicable

The New Hampshire location places CSTEV at a unique advantage to generate data on technology effectiveness in cold-climates with heavy snowpacks, deep ground frost, and urban cold-weather management practices such as sand and salt applications. Yet New Hampshire still enjoys all four seasons and receives moderate rainfall, which allows the data to be applicable in warmer climates as well.

EPA Contributes to Technology Verification

In 1995, the U.S. EPA established its Environmental Technology Verification (ETV) Program. The ETV Program's mission is similar to that of the University of New Hampshire's CSTEV—to provide third party, quality-assured performance data on technologies that address problems that threaten human health and the environment. Unlike the CSTEV, the EPA's ETV Program evaluates treatment technology mostly in-situ at real world installation sites. Because ETV's tests for stormwater technologies are performed in different places under different conditions, developing a ranking of similar treatment technologies is not feasible. However, side-by-side comparison is not the goal of the ETV program testing; instead, ETV aims to verify that the technology performs in practice, and to gauge how well it performs its intended functions for particular circumstances.

The ETV Program operates as a public-private partnership through agreements between EPA and private testing and evaluation organizations. ETV now operates six centers and one pilot program that, in total, cover a broad range of environmental technology categories, including air, water, pollution prevention, and monitoring. At its Water Quality Protection (WQP) Center in Edison, New Jersey, ETV works in partnership with NSF International, a Michigan-based non-profit research organization, to evaluate wastewater and stormwater treatment devices. The ETV and NSF partnership will be in place until July 2007, at which time the ETV will cease to provide base level funding for verification projects at the WQP Center. Instead, the WQP Center will become self-sufficient and begin relying on full funding of the verification process by the participating vendors and other sources.

ETV's WQP Center and NSF are currently in various stages of testing and reporting on a number of commercial-ready treatment, control, and rehabilitation technologies, including decentralized wastewater treatment systems for residential nutrient reduction, watershed protection technologies (e.g., animal waste treatment), high-rate UV disinfection technologies, stormwater treatment, high-rate solids separation, and runoff collection models, among others. The WQP Center is also working with the U.S. Coast Guard and other federal agencies to develop testing protocols for ship ballast water treatment technologies designed to mitigate proliferation of aquatic invasive species. These technologies are similar to those used for advanced wastewater and stormwater treatment.

Information on the WQP Center, such as testing activities, final verification reports and statements, meeting announcements, and a current list of vendors participating in the program, may be found on the NSF and EPA ETV Web sites: www.nsf.org/business/ETV_EPA_NSF/ and www.epa.gov/etv.

[For more information, contact Ray Frederick, U.S. EPA Water Quality Protection Center, 2890 Woodbridge Ave., MS 104, Edison, NJ 08837; Phone: 732-321-6627; E-mail: frederick.ray@epa.gov.]

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UNH Center Compares Stormwater Treatment Technologies (continued)

Outreach and Public Access

A large function of the CSTEV, Roseen says, is to demonstrate new or different technologies. At 12 nominal-fee workshops run annually, attended by about 30 people each time, he says, "municipal officials go through our site, see first hand the footprint and configuration of systems they have heard, or read about, and get an evaluation of their cost, and their water quality performance." Many workshop participants are seeing LID technologies in practice for the first time. CSTEV's demonstration workshops have had "an overwhelming positive response," says Roseen, "where we are just keeping pace with the demand for more tours, individual follow-up questions, and information requests."

The outreach mission of CSTEV continues to expand, adds Roseen. "We continually analyze the data we collect, and present it at workshops and conferences." Roseen and Ballestero are waiting to collect a full year's worth of data before publishing a major scientific paper, accompanied by non-technical fact sheet publications for non-scientists. In the meantime, CSTEV maintains a comprehensive program Web site (www.unh.edu/erg/cstev/) to educate the public and provide updated information. An interactive site map shows where each system is located and offers detailed engineering diagrams of each. Supplemental fact sheets describe the specifications of each installed treatment technology. Monitoring data collected to date are presented within slide presentations available for download. Web site visitors can even enjoy a short virtual tour, thanks to a streaming video segment produced by a local cable access channel.

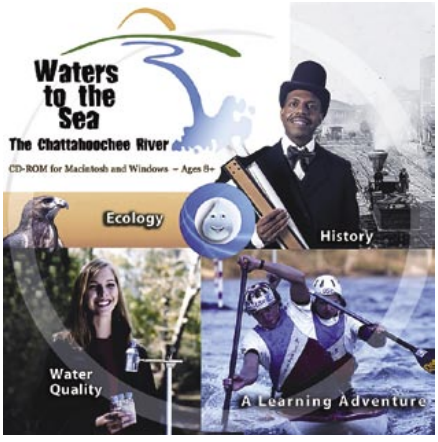
[For more information, contact either (1) Dr. Thomas P. Ballestero, Phone: 603-862-1405; E-mail: tom.ballestero@unh.edu; or (2) Dr. Robert M. Roseen, Phone: 603-862-4024; E-mail: robert.roseen@unh.edu; Mail: UNH Stormwater Center, Environmental Research Group, University of New Hamphire, Durham, NH 03824. Web site: www.unh.edu/erg/cstev]

Software Spotlight

Award-Winning Multimedia Software Takes Students Down the Chattahoochee River

Students are going on a virtual adventure along the Chattahoochee River via the new award-winning CD-ROM, *Waters to the Sea: The Chattahoochee River.* Produced by Hamline University's Center for Global Environmental Education (CGEE), this educational resource is designed to help Georgia students in grades 4-8 learn about their local waterways, the Chattahoochee River system, the water cycle, ecosystem concepts, and relevant local history concepts. Video, animation, and interactive segments teach students about the history of the area and motivate them to take action to protect the river and associated ecosystems.

The CD-ROM has caught the attention of people far and wide. In fact, CGEE earned the 2004 Panda Award—the world's top award for environmental multimedia—at the biannual Wildscreen Festival (www.wildscreenfestival.org) in England in October 2004. Wildscreen is the largest and most prestigious festival for environmental media. CGEE shared the award with the British Broadcasting Company (BBC), winning against many of the world's other top wildlife and nature production entities, such as the National Geographic Society, Discovery Channel, and Public Broadcasting Service (PBS).



The CD-ROM's cover portrays the wide variety of topics addressed.

CGEE developed the CD-ROM in partnership with the Upper Chattahoochee Riverkeeper, a river advocacy group in Atlanta, Georgia, and Columbus State University's Oxbow Meadows Environmental Learning Center in Columbus, Georgia. Coca-Cola North America, Georgia Power, the Robert Woodruff Foundation, and Georgia's Sustainable Forestry Initiative provided funding. Copies of the CD-ROM are available for $39.95 (see http://cgee.hamline.edu/waters2thesea/Chattahoochee).

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Award-Winning Multimedia Software Takes Students Down the Chattahoochee River (continued)

Series Will Expand Across the Nation

Waters to the Sea: The Chattahoochee River is the second in the *Waters to the Sea* series. The program's format is adaptable to any watershed region and serves to educate users about people's relationship to regional watersheds throughout history. The first CD-ROM in the series, *Waters to the Sea: The Upper Mississippi River*, took users on three virtual river journeys from prehistoric times up to the present, through the prairie, deciduous forest, and coniferous forest ecoregions of the river basin. CGEE has embarked on a series of educational multimedia products they hope will provide an overview of the nation's major river basins and the issues they each face. Additional regional installments are planned for the Colorado River and rivers of Southern California, the Rio Grande and the rivers of Texas, the Chesapeake Bay region, and rivers of the northeast and northwest.

Users of *Waters to the Sea: The Chattahoochee River* are guided through the CD by one of three historic guides from different eras who provide historic perspective on the watershed's environment. For example, one of the historic guides on the watershed tour is Mary Musgrove, a Creek Indian who was a tribal leader at the time of early European settlement in the Southeast. She leads users through two interactive modules concerning the Creek and Cherokee Indians and the many traditional uses of deer and river cane (American bamboo) within tribal subsistence culture.

Each *Waters to the Sea* installment has four to five hours of interactive content that strategically uses multimedia technology to enrich learning and inspire stewardship. Rich storytelling that weaves extensive video, landscape panoramas, audio, and original music complements fun, thought-provoking interactive segments that explore and reinforce science and social studies concepts. Importantly, modules are developed in alignment with state and national science education standards to assist educators. CGEE and its partners provide Web-supported study guides for teachers that provide hands-on, project-based learning experiences applicable in the classroom and in the field that augment standard curricula. Teachers also have access to orientations, workshops, online training, and graduate-level courses to help them integrate the program into their classrooms and use the product to its fullest potential.

[For more information, contact Tracy Fredin, Center for Global Environmental Education, Hamline University, 1536 Hewitt Ave., MS-A1760, St. Paul, MN 55104-1284; Phone: 651-523-3105; E-mail: tfredin@hamline.edu; Web: http://cgee.hamline.edu/waters2thesea.]

Notes on Education

Minnesota Elementary School Sees Green by Meeting LEED Standards

A school building that improves the capacity for learning and is friendly to the environment? Westwood Elementary School, a 75,000-square foot school located on 26 acres in Zimmerman, Minnesota, does just that. In August 2004, Westwood Elementary became one of only four K-12 schools in the country and the first building in Minnesota to earn the U.S. Green Building Council's Leadership in Energy and Environmental Design (LEED) certification, a widely recognized standard for developing high-performance, sustainable buildings that are good for people and gentle on the environment.

What is a LEED Certificate?

The LEED Green Building Rating System represents the U.S. Green Building Council's effort to provide a national standard for what constitutes a "green building." Through its use as a design guideline and third-party certification tool, the LEED rating system aims to improve occupant well being, environmental performance, and economic returns of buildings using established and innovative practices, standards, and technologies. Members of the U.S. Green Building Council, representing all segments of the building industry, developed LEED and continue to contribute to its evolution.

A project submitted for LEED certification is assessed by one or more third-party accredited professionals with building industry experience, demonstrated knowledge of green building practices and principles, and familiarity with LEED requirements, resources, and processes. The third party rates the project based on six categories of performance: sustainable sites, energy and atmosphere, water efficiency, indoor environmental quality, materials and resources, and innovation in design.

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To become certified, a project must earn at least 26 out of 69 possible points. Depending on the number of points achieved, a project receives either standard certification (26 to 32 points), or higher certification ratings—silver (33 to 38 points), gold (39 to 51 points), or platinum (52 points or more). Once LEED-certified, a project becomes a physical demonstration of the values of the organization that owns and/or occupies it. For more information about LEED certification, see www.usgbc.org.

LEED-certified Westwood Elementary protects the health of children and the environment.

Westwood is Gentle on the Environment

The Westwood Elementary School project, designed by KKE Architects, earned 28 LEED certification points for a variety of initiatives that reduce energy and water use, reduce solid waste, minimize impact on the land, and protect indoor air quality. For example, the bathrooms are equipped with low-flow and infrared-controlled fixtures to reduce water use. Photocell and motion sensors automatically turn off lights in unoccupied rooms or when rooms are sufficiently illuminated with natural light. During construction, a waste management plan spared 60 percent of would-be waste materials from the landfill.

Several building initiatives at Westwood reduce the potential for nonpoint source pollution, including: a two-story design that minimizes the school's impervious footprint and maximizes pervious ground cover; the placement of the school close to an existing road to further reduce the need for additional pavement; the use of ponds to capture and treat stormwater runoff; and the preservation of a wetland on school property. The wetland and other outdoor features are available for use as an outdoor environmental classroom and schoolyard habitat.

Westwood is Friendly to the Students

Marie Norman, principal of Westwood, says that although she doesn't have hard data to prove that her students perform better in the green building, studies have shown that exposure to natural light encourages better attendance and higher test scores. At Westwood, daylight reaches 84 percent of the two-story building's interior spaces because of super-sized windows—offering almost everyone a clear view of the outside.

Fresh air also helps keeps students healthy, adds Norman. "You can tell right away that the air is different; it is clean. Everything is filtered. Does it make people want to come to school? I think so." A displacement ventilation system delivers conditioned air into a room near ground level. The warmth of the occupants heats the air, which causes it, and airborne contaminants, to rise to the ceiling to exhaust ducts. An energy recovery system takes the exhaust air from the building and uses it to heat incoming outside air without mixing the two. Only fresh air is pumped back into the school.

Westwood is Easy on the Pocketbook

The building's $12 million cost compares favorably with traditional construction costs. In fact, the project was completed under budget—even though the budget had been established before the school district decided to build a green building. Elements such as minimizing both the size of the building's footprint and the amount of impervious surfaces contributed to cost savings. Westwood's construction will continue to provide cost savings over time. School officials expect to save $45,000 per year in energy costs compared with a more traditional building.

Westwood has had many people visit the school since it opened in the fall of 2003, adds Norman. "We've had busloads of teachers, administrators, school board members, and citizens from towns that are building new K-12 schools come to look." It may be an idea whose time has come.

[For more information, contact Lee Meyer, KKE Architects, Inc., 300 First Avenue North, Minneapolis, MN 55401; Phone: 612-336-9639; E-mail: lmeyer@kke.com. For more information about Westwood School, see http://westwood.elkriver.k12.mn.us.]

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Reviews and Announcements

Book Explores a Century of Forest and Wildland Watershed Lessons

The Society of American Foresters offers a new book summarizing the findings and lessons learned from key forest and watershed studies of the past century. *A Century of Forest and Wildland Watershed Lessons* provides information on studies across the United States. This book is only available in hard copy. To order, see http://store.safnet.org or contact the Society of American Foresters, 5400 Grosvenor Lane, Bethesda, Maryland 20814; Phone: 301-897-8720.

EPA Issues National Coastal Condition Report II

In January 2005, EPA released the National Coastal Condition Report II (NCCR II). The report is the second in a series of environmental assessments of U.S. coastal waters and the Great Lakes. NCCR II is based on analysis of coastal monitoring data, offshore fisheries data, and assessment and human health advisory data gathered by a variety of federal, state, and local sources between 1997 and 2000.

The report indicates that the overall condition of the nation's coastal waters is fair, which is essentially the same as the first report in 2001. This rating is based on five key indicators of ecological health: water quality, coastal habitat loss, sediment quality, benthic community condition, and fish tissue contaminants. For each of these five key indicators, EPA assigned a score of good, fair, or poor to each coastal region. EPA then averaged these ratings to create overall regional and national scores. Consistent with the recent Oceans Commission report (www.oceancommission.gov), this report sends a clear message about the serious challenges facing our nation's ocean and coastal resources. To download a free copy of NCCR II, see www.epa.gov/owow/oceans/nccr/2005.

EPA Releases Compliance Assistance Guide for the Construction Industry

EPA's Office of Compliance has just published the Managing Your Environmental Responsibilities: A Planning Guide for Construction and Development (the MYER Guide). This assistance tool reflects significant input from stakeholders and is a product of joint effort by the industry, states, other federal agencies, non-governmental organizations and EPA.

The MYER Guide contains two different sets of checklists and detailed discussion/case studies on major environmental areas (including stormwater) affecting the construction industry. It is designed to help the construction industry understand which environmental regulations apply to them, and can be used during different phases of a construction project. The industry can use the Guide at the pre-bid phase to learn about the applicable environmental requirements, so appropriate costs can be taken into consideration early. The industry can also use the responsibility-assignment checklist during the pre-construction phase to facilitate allocation of environmental responsibilities to all parties before breaking ground. Readers will find answers to many environmental questions and can conduct self-audits by using checklists during the construction phase. The MYER Guide is designed so that each of the checklists and chapters can be pulled out and used in the field. An electronic copy of the guide may be downloaded at www.cicacenter.org/links/. A hard copy is available at no cost from the National Service Center for Environmental Publications (NSCEP) at 800-490-9198 (document number EPA305-B-04-003).

New NEMO Report Released

NEMO recently released *Putting Communities in Charge* (2005), a 34-page report dedicated to the work of the NEMO Program in Connecticut. This report describes the origin, objectives, and progress of the NEMO program and includes overviews of a number of recent initiatives. The report also highlights case studies of towns that have worked with NEMO, and the ways that these towns are taking charge of their community's future development patterns. Profiled towns and areas

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include: Old Saybrook, Waterford, Woodstock, Salem, Central Naugatuck Valley, Watertown, East Haddam, Candlewood Lake Authority, and Stonington. The profiles of the towns are available for download at http://nemo.uconn.edu/publications (look under "CT Impact Reports").

Southeast Watershed Forum Offers Restoration Guide

The Southeast Watershed Forum's (SWF) *Return of the Natives: A Community Guide for Restoration of Fish and Aquatic Species* is a 20-page, full-color guide featuring case studies of various groups' efforts to protect native aquatic organisms. SWF wrote the guide to increase regional awareness of the importance of native species and implementation of land use practices that will protect the habitat and water quality essential to biological diversity. The guide is available at www.southeastwaterforum.org/pdf/newsletters/Return_of_Natives.pdf.

Technical Guidance on CAFOs Now Available

EPA recently released *Managing Manure Guidance for Concentrated Animal Feeding Operations* (CAFOs), a technical guidance designed to supplement the *NPDES Permit Writers' Guidance Manual and Example NPDES Permit for CAFOs.* This guidance provides additional technical information for owners, operators, technical service providers, consultants, and permit authorities on how to carry out EPA's revised regulatory requirements for NPDES permitting of CAFOs. It also provides information on voluntary technologies and management practices that may both improve the production efficiency of CAFOs and further protect the quality of the nation's waters. This document assumes that readers have a basic understanding of the CAFO regulations. The guidance is available for download at http://cfpub.epa.gov/npdes/afo/info.cfm#manure.

Updated Conservation Easement Handbook Available

The Land Trust Alliance and the Trust for Public Land recently released the second edition of their *Conservation Easement Handbook*, originally published in 1988. Intended for attorneys, land trusts, and conservation professionals developing easement programs, the thoroughly revised and expanded handbook offers 21 chapters (555 pages) containing information about drafting easements and managing an easement program. It provides how-to tips and checklists for land trust staff and board members; detailed drafting guidelines for attorneys; and a CD-ROM containing many sample documents. For more information, and to review the introduction and first chapter, see www.lta.org/publications. The handbook can be ordered for $49.95.

Urban Subwatershed Restoration Manual #4 Released

The Center for Watershed Protection recently released the *Urban Subwatershed Restoration Manual #4, Urban Stream Repair Practices*, which focuses on the practices used to enhance the appearance, stability, structure, or function of urban streams. The manual offers guidance on three broad approaches to urban stream repair: stream cleanups, simple repairs, and more sophisticated comprehensive repair applications. The manual explains the natural and man-made forces that influence urban streams, and presents guidance on how to set and meet appropriate stream restoration goals. It outlines methods to assess stream repair potential at the subwatershed level, including basic stream reach analysis, more detailed project investigations, and priority screenings. Finally, the manual offers practical advice to help design, permit, construct, and maintain stream repair practices in a series of more than 30 profile sheets. Thanks to a grant from the EPA Office of Wastewater Management, users may download this manual free for a limited time at www.cwp.org.

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Recent and Relevant Periodical Articles

Advances in Porous Pavement

The March/April 2005 Issue of *Stormwater Magazine* features this article by Tara Hun-Dorris. Hun-Dorris reviews the currently available types of porous pavement and discusses examples of their durability and effectiveness. See: www.stormh2o.com/sw_0503_advances.html.

Municipal Use of Stormwater Runoff

The May/June 2005 issue of *Stormwater Magazine* features this article by Peter C. Hall. Hall explores the potential for municipalities to capture and use stormwater runoff as a supplemental water supply source. He features examples of how the process could benefit two Texas cities: Lubbock and Austin. See: www.stormh2o.com/sw_0505_municipal.html.

Paved Paradise?

The September 4, 2004 (Vol. 166, No. 10, p. 152) issue of *Science News Online* features this article by Sid Perkins. Perkins examines what contributes to imperviousness and discusses how impervious surfaces can negatively affect a region's hydrology, water quality, ecosystems, and climate. See: www.sciencenews.org/articles/20040904/bob8.asp.

Web Sites Worth a Bookmark

EPA's National Menu of Best Management Practices for Stormwater Phase II

www.epa.gov/npdes/menuofbmps. The EPA developed this online menu to help regulated small MS4s select the types of practices they could use to develop and implement their stormwater management programs.

EPA's Water Use Efficiency Program Web Site

www.epa.gov/owm/water-efficiency. This site provides information on EPA's new national program to promote water-efficient products to consumers. A broad spectrum of stakeholders, from homeowners to state governments, can find information here that can help them become more water-efficient.

Hydrologic Cycle

http://ga.water.usgs.gov/edu/watercycle.html. This new U.S. Geological Survey Web site provides in-depth, illustrated discussions about the hydrologic cycle. Available in 37 languages, the site provides educational discussion on each of 15 primary areas of the cycle, including condensation, runoff, storage, springs, flow, and more.

North Carolina's Stormwater and Runoff Pollution Web Site

www.ncstormwater.org. North Carolina's new stormwater management Web site offers educational material ranging from novice to expert, children's activities, research, news, events, and a toolkit of outreach resources for local governments. Although developed for North Carolina, the site contains stormwater education information applicable to a wide audience.

Google Earth

http://earth.google.com. Google recently released a free utility for PC Windows that combines satellite imagery and aerial photos with other Google mapping tools. The program allows users to conduct flyovers of the Earth, and zoom in on particular addresses and locations. This amazing mapping resource, available to anyone with a computer and a fast connection, can serve as a useful watershed planning and outreach tool.

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Calendar

August 2005

18-19 Petroleum Hydrocarbons and Organic Chemicals in Ground Water: Prevention, Assessment, and Remediation Conference, Costa Mesa, CA. For more information, see www.ngwa.org/e/conf/0508175040.shtml.

28-31 Technology 2005 – 2nd Joint Specialty Conference for Sustainable Management of Water Quality Systems for the 21st Century: Working to Protect Public Health, San Francisco, CA. For more information, see www.wef.org/conferences/.

29-Sep 2 International Conference on Ecology and Transportation, San Diego, CA. For more information, see www.icoet.net.

31-Sep 2 Animal Agriculture and Processing: Managing Environmental Impacts, St. Louis, MO. For more information, see www.awma.org/events/confs/Animal.

September 2005

6-9 2005 Annual Conference of the Floodplain Management Association, Sacramento, CA. For more information, see www.floodplain.org.

14-16 Ecotourism in the United States, Bar Harbor, ME. For more information, see www.ecotourism.org.

19-22 13th National Nonpoint Source Monitoring Workshop, Raleigh, NC. For more information, see www.bae.ncsu.edu/programs/extension/wqg.

19-23 Oceans 2005, Washington, D.C. For more information, see www.oceans2005.org.

October 2005

12-13 Pennsylvania Stormwater Management Symposium, Villanova, PA. For more information, see www.villanova.edu/vusp.

17-20 National Conference on Nonpoint Source and Stormwater Pollution Education Programs, Chicago, IL. For more information, visit www.epa.gov/npdes/stormwater and select the "Trainings and Meetings" link on the right side box, or contact Bob Kirschner at the Chicago Botanic Garden by e-mail: bkirschn@chicagobotanic.org.

25-28 Eighth Annual Wetlands and Watersheds Workshop: Aquatic Systems and Water Quality, Atlantic City, NJ. For more information, see www.wetlandsworkgroup.org.

31-Nov 2 2005 Sustainable Beaches Conference, St. Petersburg, FL. For more information, see www.cleanbeaches.org.

November 2005

1-3 North Carolina Stream Restoration Institute's River Course: Stream Restoration Design Principles, Raleigh, NC. For more information, see www.bae.ncsu.edu/programs/extension/wqg/sri/RiverCourse.htm.

2-3 2005 Great Lakes Beach Association Annual Conference, Green Bay, WI. For more information, see www.great-lakes.net/glba/2005conference.html.

7-9 California 2005 Nonpoint Source Conference, Sacramento, CA. For more information, see www.swrcb.ca.gov/nps/fall2005.html.

15-16 Workshop: Integrated Restoration of Riverine Wetlands, Streams, Riparian Areas, and Floodplains, Amherst, MA. For more information, see www.aswm.org/calendar/integratingrest/integratedrest.htm.

17-18 Nature at Your Service – 2005 National Conference on Urban Ecosystems, Charlotte, NC. For more information, see www.americanforests.org/conference.

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Using Smart Growth Techniques as

Stormwater Best Management Practices

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About the Image on the Cover

The cover illustration depicts development that might occur as a result of the recently updated West Hyattsville (Maryland) Transit Oriented Development Overlay Zone. This area is served by the Metrorail (subway) and is home to the West Hyattsville Green Line station. The elements of the plan include many common features of transit oriented development (TOD): a compact footprint, development intensity focused on the station area, a rich mix of uses and housing types, and a variety of transportation options. These features, as illustrated in this publication, also have benefits related to preventing and managing stormwater, in particular, when considered at the watershed, neighborhood, and site levels simultaneously. The compact design can accommodate a higher intensity of development on a smaller footprint. This format, oriented toward transit and pedestrian travel, also lessens the imperviousness related to automobile-only travel. By accommodating a higher intensity of development in this preferred area, demand that might go elsewhere in the undeveloped parts of the watershed is absorbed.

The West Hyattsville TOD Plan goes further to address water and stormwater throughout the planning area. There is a heavy emphasis on open space, active parks, and integrated stormwater management. In developing the plan, use of natural drainage patterns and habitat restoration were coupled with development of parks, fields, and trails.

Image courtesy of PB PlaceMaking and the Maryland National Capital Parks and Planning Commission - Prince George's County Planning Department.

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Image: PB PlaceMaking, Stull and Lee

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EXECUTIVE SUMMARY

Communities around the country are adopting smart growth strategies to reach environmental, community, and economic goals. The environmental goals include water benefits that accrue when development strategies use compact development forms, a mix of uses, better use of existing infrastructure, and preservation of critical environmental areas. While the water quality and stormwater benefits of smart growth are widely acknowledged, there has been little explicit regulatory recognition of these benefits to date.

Regulations under the National Pollutant Discharge Elimination System (NPDES) stormwater program offer a structure for considering the water quality benefits associated with smart growth techniques. Compliance with federal, state, and local stormwater programs revolves around the use of "best management practices" (BMPs) to manage stormwater. Given the water benefits of smart growth at the site, neighborhood, and watershed levels, many smart growth techniques and policies are emerging as BMPs.

The goal of this document is to help communities that have adopted smart growth policies and plans recognize the water benefits of those smart growth techniques and suggest ways to integrate those policies into stormwater planning and compliance. Taking credit for the work a community is already doing can be a low-cost and practical approach to meeting water quality goals and regulatory commitments.

This document is related to a series of primers on smart growth. In 1999 and 2001, the International City/County Managers Association (ICMA) and the U.S. Environmental Protection Agency (EPA) released two primers that each listed 100 smart growth policies. In 2004, EPA released *Protecting Water Resources with Smart Growth*, which presented 75 policies directly related

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to water resources. This document also complements the EPA's National Management Measures to Control Nonpoint Source Pollution from Urban Areas (2005).

Who Can Use This Report?

Stormwater and Water Quality Professionals: This document is written to help water professionals understand urban planning documents to determine where stormwater improvements might already be included. This document can also be helpful to consultants who are helping communities develop comprehensive stormwater and planning documents, outreach programs, and compliance tracking.

Communities Regulated Under Phases I & II of the NPDES Stormwater Program: More than 6,000 communities are now required to develop stormwater management plans to comply with the NPDES requirements. As NPDES permits issued since 1990 under Phase I come up for renewal, this document offers innovative measures for further improving stormwater management through redevelopment, infill, urban parks, and green building techniques. Communities under Phase II are likely to be developing their stormwater management plans, guidance materials, and ordinances.

Local Land Use and Transportation Planners: Just as stormwater engineers are taking on more of an urban planning role, land use and transportation planners should consider the practice of stormwater control in ways that go beyond pipes, ponds, and gutters. This document introduces the concept of joint land use, transportation, and water planning as a way of providing water quality protection and satisfying regulatory commitments for compliance with local stormwater management plans and NPDES permits.

Zoning Administrators: Language in many federal and state model stormwater ordinances call for the development of "ordinances or other regulatory mechanisms" for implementation of new stormwater rules.

Most stormwater that is collected from curbs and gutters flows untreated into local waterways. Smart growth seeks to limit the number of outfalls in a watershed with compact development.

Photo: NRCS

The elements related to stormwater ordinances are likely to address the same aspects of project design as zoning codes, for example, setbacks, street widths, landscaping and parking requirements. Zoning administrators should be involved in the development of stormwater ordinances so that conflicts do not arise among codes.

City and County Managers: The stormwater requirements have focused attention on improving communications across various departments, from public works to transportation to subdivision planning. As new and revised stormwater rules are written at the local level, NPDES implementation has revealed the importance of pulling together traditionally autonomous departments to determine where separate departmental policies might pose barriers to efficient planning, investment, and environmental protection. City and county managers are often in a unique position to bridge planning and budgets and broker solutions where requirements developed by one department run counter to new smart growth plans.

Developers: Developers, particularly those building within urbanized areas affected by NPDES stormwater rules, are facing new requirements for water quality and quantity. This document will help developers assess their smart growth projects, improve the stormwater handling on site, and define how their projects meet stormwater goals and the site, neighborhood, and regional level.

Smart Growth Practitioners: Whether you are with a nonprofit organization, a local government office, or in private practice, your skills in reviewing and writing comprehensive environmental plans and policies can play a role in shaping joint smart growth and stormwater plans. Emerging stormwater programs offer a framework for constructive involvement.

Talking About Compact Development – Homebuilders

In 2005, the National Association of Homebuilders (NAHB) released talking points on compact development. They note that compact forms can include cluster development, higher-density development, mixed-used projects and traditional neighborhood developments. The Association encourages builders to review local ordinances to see where rules on set backs, infrastructure, street widths and the approval processes pose barriers or opportunities for compact development. In particular, the talking points mention alternative stormwater approaches to help support a more compact development form.
See <www.nahb.org/generic.aspx?sectionID=628&genericContentID=17373>.

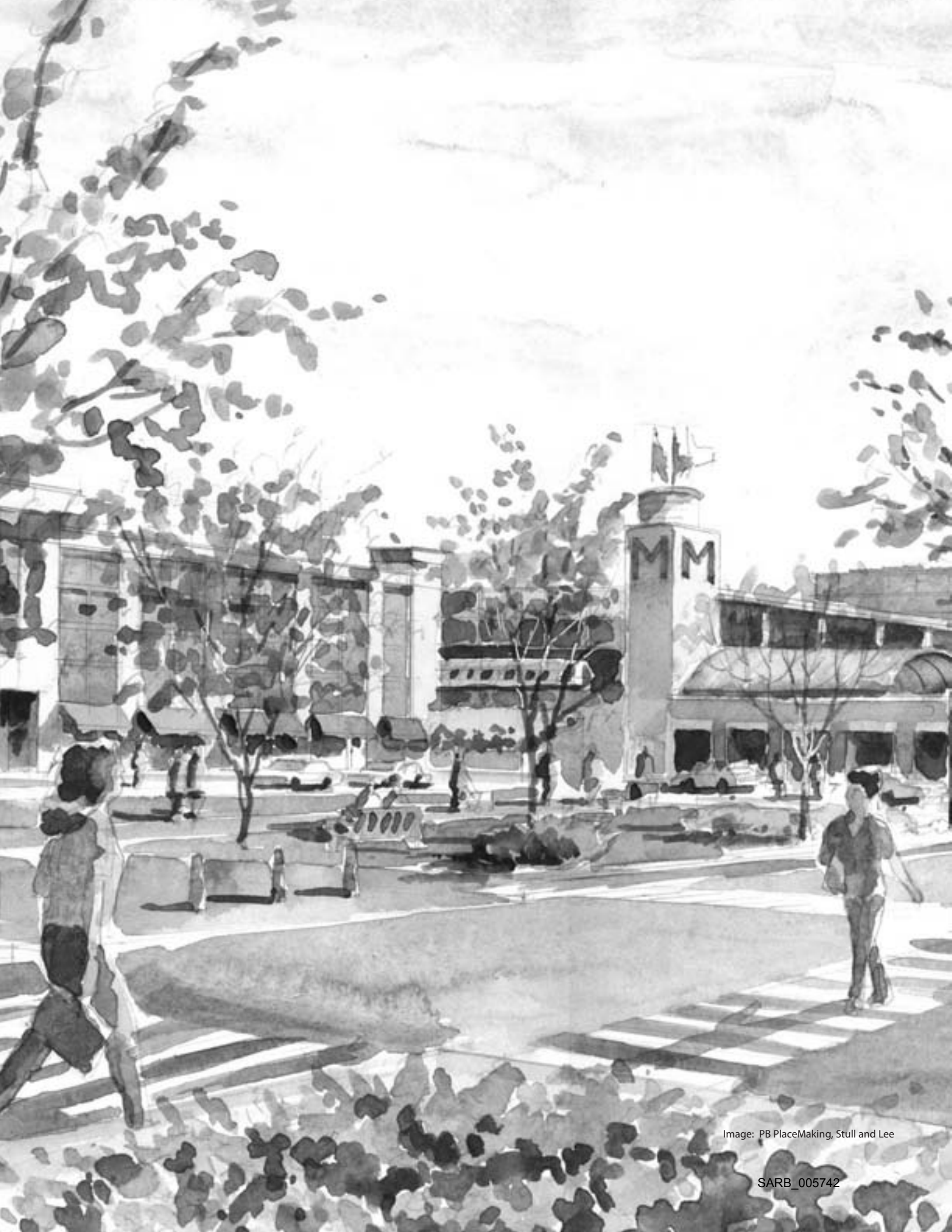

Image: PB PlaceMaking, Stull and Lee

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SECTION 1

Why Stormwater? The Nexus Between Land Development Patterns and Water Quality and Quantity

Since 1972, implementation of the Clean Water Act (CWA) has shown success in controlling water pollution from point sources such as municipal wastewater treatment plants and industrial discharges. This progress is overshadowed, however, by the emergence of nonpoint source pollution as a main contributor to water quality problems.

Nonpoint source (NPS) pollution comes from many diffuse sources. NPS pollution originates when rainfall or snowmelt moves over and through the ground. As the runoff moves, it picks up and carries away natural and human-made pollutants, finally depositing them into lakes, rivers, wetlands, coastal waters, and even underground sources of drinking water.

These pollutants include:

- Excess fertilizers, herbicides, and insecticides from agricultural lands and residential areas.
- Oil, grease, and toxic chemicals from urban runoff.
- Sediment from improperly managed construction sites, crop and forest lands, and eroding stream banks.
- Bacteria and nutrients from livestock, pet wastes, wildlife, and faulty septic systems.
- A myriad of other pollutants originating with a side variety of land based activities.
- Atmospheric deposition and hydromodification are also sources of nonpoint source pollution.[1]

For urban and urbanizing areas, these problems can largely be traced to activities that occur on the land. Whether the problem arises from lawn care chemicals, or motor oil and toxic metals from parking lots and streets, stormwater plays a large role in transporting pollutants to streams, drinking water sources, and other receiving water bodies.

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While land development necessarily involves creation of impervious surfaces, how and where development takes place can influence the ultimate degree of environmental impact from the streets, rooftops, and yards. Where development has occurred on forest and undeveloped land, critical areas for infiltration and aquifer recharge that soaked up rainwater prior to development now export runoff to lower lying areas and local receiving water bodies. Water flowing over pavement absorbs heat, which impacts waterways that support cold water species. It also flows faster, thus delivering water in pulses. The faster flows can scour stream banks and accelerate erosion, while increased temperatures can spur excessive algal growth. The higher rate of vegetative growth can interfere with a variety of ecological, industrial and water filtration processes. Conventional construction practices have relied on mass clearing and grading. This practice compacts the soil surface and further prevents infiltration, even on lots overlain with turf. Thus, the generation of stormwater volume, as well as the pollutant load carried in that volume, is very much tied to how and where land is developed.

Preserving open space, farmland and critical environmental areas is one of the 10 smart growth principals.

Summary of How Stormwater Runoff Is Regulated

In 1972, Congress amended the Federal Water Pollution Control Act (subsequently referred to as the Clean Water Act) to control the discharges of pollutants to waters of the United States from point sources. Initial efforts to improve water quality using the National Pollution Discharge Elimination System (NPDES) focused primarily on reducing pollutants from industrial process wastewater and municipal sewage discharges. These sources were easily identified as responsible for poor—often drastically degraded—water quality conditions.

As pollution control measures for industrial process wastewater and municipal sewage were implemented and refined, it became increasingly evident that more diffuse sources of water pollution were also significant causes of water quality impairment. Specifically, stormwater runoff was found to cause serious pollution problems. As a result Congress added section 402(p) of the Clean Water Act, which established a comprehensive, two-phase approach to stormwater control using the NPDES program.

In 1990 EPA issued the Phase I stormwater rule (55 *FR* 47990; November 16, 1990) requiring NPDES permits for operators of municipal separate storm sewer systems (MS4s) serving populations greater than 100,000 and for runoff associated with industrial activity, including runoff from construction sites 5 acres and larger. In 1999 EPA issued the Phase II stormwater rule (64 *FR* 68722; December 8, 1999) that expanded the requirements to small MS4s in urban areas and to construction sites between 1 and 5 acres in size.

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EPA has delegated NPDES permitting authority to all but five states, several territories, the District of Columbia, federal facilities in four states, and federal tribes. NPDES permits are reissued every five years to allow for modifications to meet changing conditions both with the discharge and with discharge standards and regulations. There are two standard types of NPDES permits: 1) An individual permit is issued to a single discharger, with customized requirements for that particular discharge. All Phase I MS4 permits are individual permits. 2) General permits are usually statewide permits with requirements that apply to all discharges of a particular type or category. Most Phase II MS4 permits are general permits and require each permittee to develop a stormwater management plan that details how stormwater discharges from that particular MS4 will be controlled. Though they are not framed identically, the stormwater management requirements for Phase I and Phase II MS4s are very similar. The recommendations in this publication are applicable to all communities subject to the stormwater regulations.

Evaluations of Phase I have shown that BMP maintenance continues to be a problem.[2] Both structural BMPs (e.g., sand filters) and nonstructural BMPs (e.g., swales) require periodic maintenance and care, which should be budgeted for and scheduled. As you read this document, think about the long-term maintenance program for smart growth techniques as BMPs to ensure that stormwater benefits are supported over time.

To learn more, visit EPA's stormwater program site at <www.epa.gov/npdes>.

What Is an MS4?

A municipal separate storm sewer system (MS4) is a conveyance or system of conveyances (e.g., roads with drainage systems, municipal streets, catch basins, curbs, gutters, ditches, man-made channels, storm drains) that are:

- Owned or operated by a state, city, town, borough, county, parish, district, association, or other public body (created by or pursuant to state law) having jurisdiction over disposal of sewage, industrial wastes, stormwater, or other wastes, including special districts under state law such as a sewer district, flood control district, or drainage districts, or similar entity, or an Indian tribe or an authorized Indian tribal organization, or a designated and approved management agency under section 208 of the Clean Water Act that discharges to waters of the United States.
- Designed or used for collecting or conveying stormwater.
- Not a combined sewer.
- Not part of a publicly owned treatment works.

Though not explicit, many larger institutions, such as hospitals, universities, military bases, and school districts fall under the definition, and thus must develop stormwater management plans. If these institutions have been involved with local smart growth efforts, check with them to see if there are smart growth elements in their stormwater management plan.

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Elements of a NPDES Stormwater Permit – What Stakeholders Should Look For

States and municipalities are responsible for developing a suite of information under the NPDES stormwater program. As you look for the documents that will govern stormwater rules and policies, be aware that there are several permit types within the NPDES stormwater program, including industrial, multi-sector, and construction permits. While these are important permits for environmental protection, the MS4 NPDES stormwater permits are the focus of this document. Section 2 includes guidance on what to specifically look for within these materials.

At the Federal Level:

EPA has issued many guidance documents to assist states and localities. These publications include:

- Sample and General Permits
- Fact Sheets and Outreach Materials
- Permit Applications and Forms
- Policy and Guidance Documents
- Program Status Reports
- A Menu of Best Management Practices
- Technical and Issue Papers
- Case Studies
- See <http://cfpub.epa.gov/npdes/stormwater/swphases.cfm>.
  For information, go the link on "Publications."

At the State Level:

Under the NPDES program, delegated states are required to develop and implement stormwater management plans to reduce pollutant loadings to the maximum extent practicable. Delegated states oversee both Phase I and Phase II of the stormwater program, so plans may be listed as medium and large MS4s (Phase I) and small MS4s (Phase II). The Web site <www.stormwaterauthority.org> lists links to each state's MS4 stormwater program. The elements to look for include the following:

- **A state permit**: Most states have developed a General MS4 permit, which establishes minimum requirements for permit coverage. Some states have also developed alternatives to the general permit, such as watershed permitting, to allow for customization and innovation. The permit lists the elements required to obtain permit coverage, which typically include: time tables; the minimum components of a stormwater management plan; and legal language defining responsibilities, enforcement, and penalties.
- **Guidance documents**: These documents are developed to assist localities as they write their stormwater management plans and develop menus of BMPs.
- **State requirements**: Many states have additional requirements to address special environmental needs; for example, special resource waters, water quality control in cold climates, or merging NPDES stormwater permitting with total maximum daily loads (TMDLs).
- **Forms and maps**

At the Local Level:

Check with your local environmental management or public works department to see if your locality has obtained NPDES permit coverage, or whether it is in the process of obtaining coverage. Although state requirements vary, most MS4s are required to submit the following documents:

- **A Stormwater Management Plan (SWMP) or Stormwater Pollution Prevention Plan (SWPP)**: For localities covered under Phase II, there are six minimum control measures. The SWMP should include strategies and BMPs for those measures:
  - Outreach
  - Education
  - Construction
  - Post-Construction
  - Illicit Discharges Elimination
  - Pollution Prevention

  Under the new rules, MS4s need to include measurable goals, and show how the SWMP relates to water quality goals. The minimum measures listed above were not part of the original permit structure for Phase I permits, though the general tasks were required. In reissuing stormwater permits, many permitting authorities are modifying the permits to more closely dovetail Phase I and Phase II requirements to make it easier for these communities to work together.
- **Stormwater Ordinances**: Most states require that MS4s develop ordinances or other regulatory mechanisms to implement stormwater management controls. As you read draft language for ordinances, be prepared to compare the proposed legal language with language in your local smart growth codes and alert stormwater managers to inconsistencies.
- **Schedules for public meetings, regulation development, milestones and training.**

For more detailed information on water regulations and the Clean Water Act, see the River Network's "Understanding the Clean Water Act" at <www.cleanwateract.org>.

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Connecting Stormwater Management and Smart Growth

Not so long ago, the predominant philosophy of stormwater control focused on flood control and directing water off an individual piece of property as quickly as possible. As towns grew, curbs, gutters, trenches, and pipes assisted the land use and stormwater planner alike in meeting this goal. While this turned out to be a successful strategy for individual properties, the additive effects of runoff from these individual properties on a watershed scale contributed to flooding and water quality problems. This has led water quality professionals to rethink stormwater control.

As a result, water professionals began to look at development site plans for opportunities to lessen the volume of stormwater generated from individual development projects. Better site design practices, such as low impact development, emerged as mechanisms to retain a site's natural hydrology and infiltrate stormwater within the boundaries of the development project. The conservation development movement was established—in particular, for new residential subdivisions.

These new subdivisions sparked debate over the overall environmental attributes of conservation development projects, however. Observers noted that, while these developments offer water-handling benefits on site, they can contribute to wider land disturbance activities, transportation impacts, and other quality problems related to the growth that follows housing subdivisions. At the same time, urban developers increasingly encountered resistance to infill and redevelopment projects based on predictions of additional stormwater-related impacts to urban streams. These discussions revealed the need for a more comprehensive view of the water quality impacts related to development, one that also considers a broader watershed context.

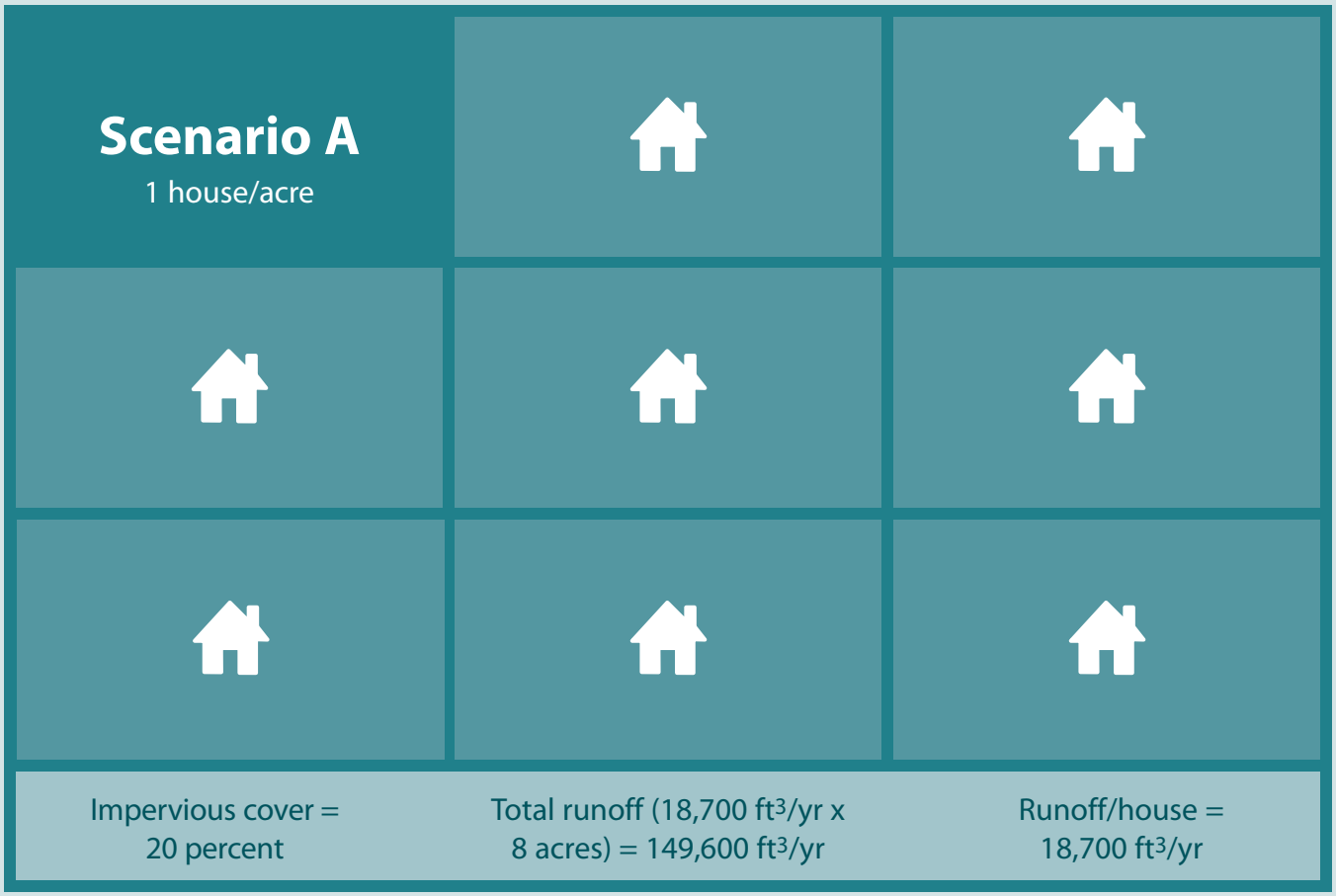
This new view poses challenges to how states and localities approach stormwater control, whether the topic is measuring performance or issuing permits. Typically, the performance of stormwater control is assessed site by site, or project by project in the site plan approval process for subdivisions or commercial districts. Thus, a conservation subdivision might rate high for stormwater management based on certain performance criteria, even when it brings unanticipated growth to sensitive reaches of a watershed. Likewise, a new apartment building and retail complex might get a low rating for creating impervious surface on an urban lot, even though the project absorbed development demand that would have gone to a "greenfield" site on a much larger footprint. In both these examples, a complex set of environmental considerations relate to the project's impact at the site, in the neighborhood, and at the watershed level.

Photo: EPA

This supermarket in West Palm Beach Florida was part of a downtown redevelopment project. The store, which brings everyday uses closer to in-town residential areas, is a smaller format and is accessible by several modes of transportation.

How Does Density Relate to Runoff? The Site Level

These three scenarios show how different housing densities on one acre can affect not only total runoff, but also runoff per house. Although the higher-density scenarios generate more stormwater per acre, they generate less total stormwater runoff and less stormwater runoff per house. Since most watershed growth is expected to be in the range of several thousand houses, not four or eight, the estimation of runoff based on per unit of housing is important. In addition, this illustration looks only at the lot and impervious cover related to the house footprint and driveway.



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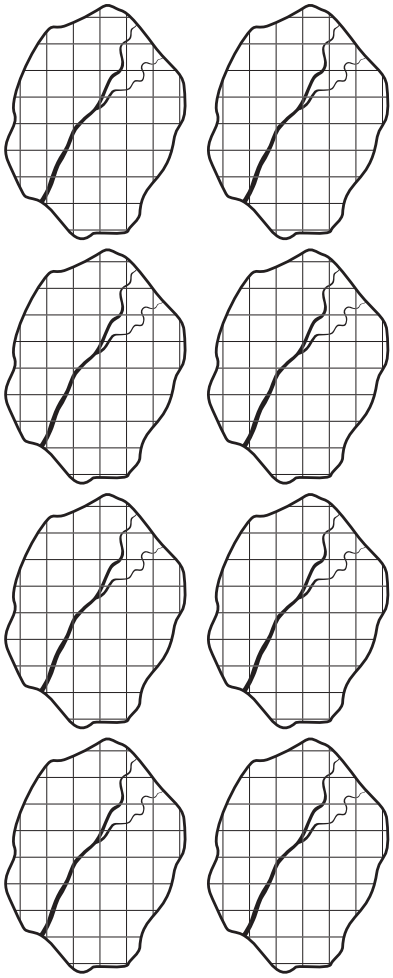
How Does Density Relate to Runoff? The Watershed Level

Housing density also affects the number of acres required to accommodate growth. At the site level, most regional and watershed managers are facing household growth estimates of several thousand units. By limiting housing production to one unit/acre, growth pressures do not cease, but rather growth goes elsewhere in the watershed, or expands to additional watersheds. Here, the higher-density scenarios consume fewer watersheds to accommodate the same number of houses. A fuller discussion of density and build-out is presented in EPA's 2005 document *Protecting Water Resources with Higher-Density Development*.

Scenario A



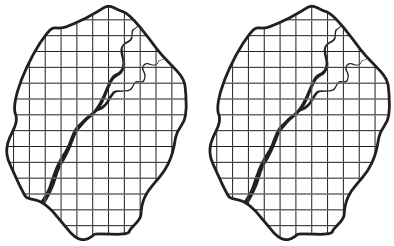
At one house per acre, 80,000 houses require 80,000 acres, or *8 watersheds*, translating to:

80,000 acres x 1 house x 18,700 ft^3 /yr of runoff

1.496 billion ft^3 /yr of stormwater runoff

8 watersheds at 20 percent impervious cover

Scenario B



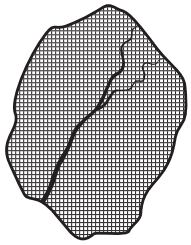
At four houses per acre, 80,000 houses require 20,000 acres, or *2 watersheds*, translating to:

20,000 acres x 4 houses x 6,200 ft^3 /yr of runoff

496 million ft^3 /yr of stormwater runoff

2 watersheds at 38 percent impervious cover

Scenario C



At eight houses per acre, 80,000 houses require 10,000 acres, or *1 watershed*, translating to:

10,000 acres x 8 houses x 4,950 ft^3 /yr of runoff

396 million ft^3 /yr of stormwater runoff

1 watershed at 65 percent impervious cover

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Many states and communities are using smart growth planning as a way to deal with the complex analysis for future growth and development. Smart growth is best described as a set of 10 principles, presented in Table 1.

While better stormwater management is not explicit in the 10 principles of smart growth, the water quality benefits are, quite literally, built in. These benefits typically emerge from policies that integrate local and regional decisions on transportation, housing, natural resources, and jobs. The interrelated benefits of smart growth are highlighted throughout this document and include:

- **Compact Project and Community Design:** One of the more powerful strategies for reducing the footprint of development, and hence the stormwater impacts, is to focus on compact development. For existing communities, policies to encourage infill and redevelopment can result in a smaller development footprint within the region. For new communities, compact designs that mix uses and cluster development help to accommodate development demand in a smaller area. Reducing the footprint of individual buildings can also be a strategy, though there are circumstances that call for greater lot coverage in districts where a higher development intensity is needed (for example, near transit stations). The compact form can also lend itself to more environmentally friendly transportation options, such as walking and biking.
- **Street Design and Transportation Options**: Well designed, compact communities are served by a highly connected street and trail system designed for multiple modes of transportation. The pattern need not be a grid, and in some areas, topography and environmentally sensitive areas will influence where roads go. Providing connections is the key to allow walking or bike trips, or to or to allow a "park once" trip for combining errands, recreation, and/or commuting. A compact district also provides for more efficient use (and reuse) of existing infrastructure.
- **Mix of Uses**: Another element that can contribute to decreasing the amount of stormwater generation lies in the development mix. By pulling a mix of jobs, housing, and commercial activities closer

Table1: Smart Growth Principles

1. Create a range of housing opportunities and choices.
2. Create walkable neighborhoods.
3. Encourage community and stakeholder collaboration.
4. Foster distinctive, attractive places with a strong sense of place.
5. Make development decisions predictable, fair, and cost effective.
6. Mix land use.
7. Preserve open space, farmland, natural beauty, and critical environmental areas.
8. Provide a variety of transportation choices of smart growth.
9. Strengthen and direct development toward existing communities.
10. Take advantage of compact building design.

together, not only do you increase the transportation options for a community, but the requirements for transportation and infrastructure also change. The need to accommodate fewer auto trips supports a reduction in standard parking requirements. A mix of daytime and nighttime uses, or weekday and weekend uses, increases the chance that parking spaces can be shared among businesses.

- **Use of Already-Developed Land**: Most literature on conservation development is focused on clustered housing in greenfield residential projects; however, reuse of existing impervious surfaces can be regarded as a powerful form of conservation development. First, redevelopment conserves land by absorbing demand that could go into undeveloped parts of the watershed. Second, there is typically no net increase in runoff since impervious cover is essentially replaced by impervious cover. When low impact techniques and creative landscape design accompany a redevelopment project, the water quality performance at the watershed and site level is enhanced. Finally, there are less obvious factors associated with redevelopment that drive stormwater outcomes. In older parts of cities and towns, the development standards used for the original development were likely to have called for fewer parking spaces, a zoning mix, less roadway and less dispersed infrastructure. Thus, a new 10-unit building on the urban edge will likely have more related impervious surface than a 10-unit redevelopment project, even if the two have the same building footprint.
- **Better Models for New Development**: Where development continues to take place in undeveloped areas, smart growth designs can be used to improve the environmental aspects of that new growth compared to conventional, separated designs. While conservation design principles are important, smart growth development incorporates connections to jobs, schools, and other existing economic centers. A mix of housing types can alleviate the pressure to build affordable housing on more distant parcels of land. New town models such as Traditional Neighborhood Design or New Urbanist communities are advanced, in particular for transportation improvements. When combined with traditional water quality BMPs, the connected, compact, and efficient neighborhood designs can amplify the water quality benefits.

Photo:. EPA

This mixed use center in Gainesville, Florida is served by a parking lot constructed of pavers, which helps support the street trees. The trees also provide shade for outdoor seating nearby.

Smart Growth Techniques as Best Management Practices

What do states and localities need to do to qualify smart growth policies as stormwater BMPs under stormwater permitting programs? Permitting authorities around the country are already introducing smart growth concepts into their guidance documents and permits. Some of the general concepts include:

- Coupling smart growth planning with site design criteria to further improve the watershed-wide benefits of the growth and redevelopment plans.
- Implementing watershed-wide or regional policies to consider simultaneously areas for growth and those for conservation.
- Better designs for reducing the impervious surfaces associated with development, such as compact street designs and lower parking requirements.

Notable examples include the following:

New Jersey has developed a successful strategy for considering both smart growth and stormwater in its state water quality and growth plans. In seeking to meet the dual goals of reducing runoff and replenishing aquifers, the state has developed policies to encourage growth in targeted areas while protecting environmentally sensitive areas and open space. The state's regulations are divided into requirements for runoff control and requirements for infiltration. Redevelopment and infill in designated urban areas are exempt from the stormwater infiltration rules. The reasons supporting the policy are: (1) recharge regulations can pose a regulatory barrier to redevelopment, (2) the regulations can be impractical in highly urbanized areas and (3) recharge is not always desirable in areas with environmentally compromised soils.

In **California**, the Santa Clara Valley Urban Runoff Pollution Prevention Program's (SCVURPPP's) 2001 Phase I permit renewal recognized that there could be cost-effective opportunities to implement stormwater control during the land use approval process. In particular, SCVURPPP noted several smart growth options, including neo-traditional street design standards and more effective use of existing parking spaces. The permit goes further, noting that certain development projects, such as transit villages, are likely to be exempt from several requirements because they are typically built in areas already covered with impervious surfaces.[3]

The SCVURPPP permit lists numerous criteria for onsite stormwater control requirements, but also include flexibility by allowing its permitees to document where standard criteria would be impractical, where compensatory mitigation would be allowed, and where localities could use alternative strategies to better match stormwater control techniques to the local condition.

Supplying workforce housing closer to job and activity centers often helps relieve development pressure to build more affordable housing further out.

Photo: EPA

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San Jose, California, is one of the co-permitees under the SCVURPPP program. The city sought to incorporate the new guidance from the 2001 permit into its local stormwater ordinance and into its smart growth initiative, the San Jose 2020 Plan.

The two main areas that allow consideration of smart growth include:

- **Finding of Impracticality**: San Jose structured its policy to take advantage of the SCVURPPP permit's flexibility, as noted above. Under the permit, deviations from the standard requirements could be established through a finding of impracticality. San Jose's policy includes some of the more common reasons for a finding of impracticality, such as soil type, but also recognized that the natural onsite measures for infiltration and runoff control can be impractical in built-out, urban areas.
- **Flexibility**: If there is a finding of impracticality, the San Jose policy allows several alternatives to the permit's standards that recognize the water benefits of smart growth projects. The city established a category of smart growth projects that exhibit water benefits by virtue of the development of the site itself, the nature of the site design, and its location in the watershed.

Smart growth projects are defined by the city to be:

a. Significant redevelopment within the urban core;

b. Low-income, moderate income, or senior housing development project, meeting one of the criteria listed in other sections of the city's code; and/or

c. Brownfields projects.

While affordable housing may seem like an unconventional BMP, the city recognized the demand for low-income and senior housing would not go away, but likely relocate in remote regions where jobs and services were not as likely to be close at hand. Incentivizing construction through redevelopment thus became not only a housing strategy, but a watershed one as well.

Another California city, **Poway**, has defined BMPs to include redevelopment and development projects that improve stormwater performance as compared to conventional designs. The ordinance reads:

> *"Site design BMP" means any project design feature that reduces the creation or severity of potential pollutant sources or reduces the alteration of the project site's natural flow regime. Redevelopment projects that are undertaken to remove pollutant sources (such as existing surface parking lots and other impervious surfaces) or to reduce the need for new roads and other impervious surfaces (as compared to conventional or low-density new development) by incorporating higher densities and/or mixed land uses into the project design, are also considered site design BMPs.*

(Ord. 569 § 2, 2002) See <www.codepublishing.com/ca/poway/Poway16/Poway16101.html#16.101.200>.

In **Texas**, the North Central Texas Council of Governments (NCTCOG) is helping its local MS4s by identifying useful techniques for stormwater control. NCTCOG's guidance also directs readers to the various local regulations or ordinances that control how and

North Central Texas Council of Governments Guidance

Minimize Impervious Surfaces

Impervious surfaces are roads, parking lots, driveways, and rooftops that do not allow infiltration of stormwater into the ground. The increase in stormwater runoff, along with the pollutants the runoff picks up from impervious surfaces, cause major problems for our waterways. Narrower streets and smaller parking lots benefit the environment and can make a development more attractive as well.

- Develop residential street standards for the minimum required pavement width needed to support travel lanes, on-street parking, and emergency vehicle access. *Street Specifications, Subdivision Ordinance*
- Consider limiting on-street parking to one side of the street. *Street Specifications, Subdivision Ordinance*
- Incorporate sunken landscaped islands in the middle of cul-de-sac turnarounds. *Street Specifications, Drainage Manual*
- Minimize street length by concentrating development in the least sensitive areas of site. *Zoning Ordinance*
- Reduce parking lot size by lowering the number of parking spaces (minimum and maximum ratios) and by sharing parking among adjacent businesses. *Zoning Ordinance, Development/Engineering Standards*
- Reduce parking requirements for developments in proximity to public transportation. *Zoning Ordinance*
- Provide incentives or opportunities for structured parking rather than surface parking. *Zoning Ordinance*
- Use pavers or porous pavement in parking overflow areas. *Development/Engineering Standards*
- Reduce frontage requirements in residential areas to reduce road length. *Zoning Ordinance*
- Reduce the rooftop area of buildings by constructing multiple level structures where feasible. *Zoning Ordinance*[4]

where impervious surfaces, such as parking lots or driveways, are located. (See box.)

The NCTCOG examples show that many of the most promising techniques for effectively managing runoff are often included in existing regulations and guidance traditionally associated with land development and transportation regulations, not stormwater control. In addition, the examples show that flexibility is needed, since not all regulations work equally well in all contexts. The North Carolina Smart Growth Alliance has pointed this out as well. In comments to the North Carolina Division of Water Quality on proposed stormwater rules, the Alliance notes that language in the state's 2003 proposal to establish impervious surface limitations on a site-by-site basis would have the effect of making sprawl-type developments easier to build, while making it more difficult to develop compact, walkable communities.[5] Blanket regulations that appear to make sense at the individual lot level can often have the unintended outcome of promoting development in areas of watersheds unable to handle new growth.

So, how do stormwater managers and their planning counterparts choose strategies and BMPs that serve the interrelated goals of watershed protection and successful growth and development? Matching the BMP (or

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Table 2: Best Management Practices and Development Context

BMP Strategies	Urban/High Density Settings	Suburban/ Urbanizing Areas	Rural and Conservation Areas
Strategies for individual buildings and building sites	Bio-infiltration cells, rooftop rain capture and storage, green roofs, downspout disconnection in older residential neighborhoods, programs to reduce lawn compaction, stormwater inlet improvements	Disconnecting downspouts, green roofs, programs to reduce lawn compaction, bio-infiltration cells, rooftop rain capture and storage	Green roofs, housing and site designs that minimize soil disruption
Low impact development (LID) or better site design strategies	Ultra-urban LID strategies: high-performing landscape areas, retrofitting urban parks for stormwater management, micro-dentention areas, urban forestry and tree canopy, green retrofits for streets	Swales, infiltration trenches, micro-detention for infill projects, some conservation design, retrofitting of parking lots for stormwater control or infill, tree canopy, green retrofits for streets. Depending on location, larger scale infiltration.	Large scale LID: forest protection, source water protection, water protection overlay zoning, conservation, aquifer protection, stormwater wetlands
Infrastructure	Better use of gray infrastructure: repair and expansion of existing pipes, installation of stormwater treatment, fix it first policies, improve street and facilities maintenance	Priority funding areas to direct development, better street design, infrastructure planning to incentivize smart growth development, improve street and facilities maintenance	Smart growth planning for rural communities using onsite systems
Structural BMPs	Commercially available stormwater control devices, urban drainage basins, repair of traditional gray infrastructure	Rain barrels, bio-infiltration techniques, constructed wetlands	
Design strategies	Transit districts, parking reduction, infill, improved use of curbside parking and rights of way, brownfields, urban stream clean-up and buffers, receiving areas for transfer of development rights	Infill, greyfields redevelopment, parking reduction, policies to foster a connected street system, open space and conservation design and rural planning, some impervious surface restrictions, stream restoration and buffers, targeted receiving areas for transfer of development, planned unit developments	Regional planning, use of anti-degradation provision of Clean Water Act, sending areas for transfer of development, watershed wide impervious surface limits, water protection overlay zoning districts
Watershed-wide or regional strategies	Transfer of development rights, waterfront restoration, participation in regional stormwater management planning/infrastructure	Regional park and open space planning, linking new transit investments to regional system, participation in regional stormwater management planning/infrastructure	Regional planning, use of anti-degradation provision of Clean Water Act, sending areas for transfer of development, watershed wide impervious surface limits, water protection overlay zoning districts, water supply planning and land acquisition

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combination of BMPs) to the development context is important. Some BMPs, such as green roofs, will work in almost any setting. Infiltration requirements pose challenges in urban areas, however, where legacy pollutants remain and/or where land costs are high. They also pose challenges in the development of new town centers or other compact districts that are constructed in greenfields.

Table 2 illustrates a breakdown of BMPs with respect to setting. It is not intended to serve as a fixed menu, but rather to provide a framework for refining the match of conventional stormwater BMPs to the development context. In fact, some of the measures that seem most fitting in suburban and rural areas, like stormwater wetlands, often have a role in ultra-urban settings. The Elizabeth River Project in Virginia is working with stakeholders to bring constructed wetlands and riparian buffers to urban areas and military facilities in the Portsmith/Norfolk area of the Chesapeake Bay.

Finally, and most importantly, BMPs are rarely used in isolation, but rather are strategically combined to achieve water quality goals and address target pollutants of concern. For example, a city may install a first line of BMPs to filter large debris, while a series of infiltration and filtering techniques are used to allow sediment to settle, improve infiltration, and reduce runoff. For smart growth techniques as BMPs, there are also strategic combinations of policies that serve to increase the environmental performance of development projects. For example, a plan for transit-oriented development may require that the mix of uses and density be coupled with better parking strategies so that walking and automobile travel are equally attractive. The ability to develop effective combinations of BMPs is among the most important features in developing joint stormwater and smart growth plans.

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[1] U.S. Environmental Protection Agency. 1994. EPA-841-F-94-005. http://www.epa.gov/owow/nps/qa.html

[2] Kosco, John, Wes Gunter, and James Collins. Lessons learned from in-field evaluations of Phase I Municipal Stormwater Programs. Presentation prepared for the 2003 National Conference on Urban Stormwater. Chicago, Illinois, February 17-20, 2003. www.epa.gov/owow/nps/natlstormwater03/19Kosco.pdf

[3] http://www.scvurppp-w2k.com/pdfs/other/NPDES_Permit_C3New_Finalodrtransltr.PDF

[4] Stormwater Management in North Central Texas. Post-construction runoff control, EPA recommendations. www.dfwstormwater.com/Storm_Water_BMPs/post-construct.asp#rec

[5] North Carolina Smart Growth Alliance. May 16, 2003. Comments to the Division of Water Quality, Re: Proposed NPDES Phase II Stormwater Rules. www.ncsmartgrowth.org/archive/stormwater%205%2016%2003.html

SECTION 2

Specific Smart Growth Techniques as Stormwater Best Management Practices

The purpose of this section is to present common smart growth techniques, their water quality attributes and how to present them within local, state, or federal stormwater requirements. The NPDES stormwater requirements—in particular the Post-Construction Minimum Measure—have focused attention on how development projects, both individually and collectively, impact a watershed after projects are built. This section is geared toward the post-construction measure under Phase II, though any city or county renewing a permit under Phase I can use them. Additionally, cities, counties, and townships that are not regulated, but that are proactively developing stormwater, flooding, or watershed plans, can use the information to meet water quality goals.

The following list contains smart growth techniques that have been adopted by state, regional, and local governments for a variety of benefits, including environmental quality. This section will look at each of these techniques in depth, though this list is not exhaustive.

1. Regional planning
2. Infill development
3. Redevelopment policies
4. Special development districts (e.g., transit oriented development and brownfields redevelopment)
5. Tree and canopy programs
6. Parking policies to reduce the number of spaces needed or the footprint of the lot
7. "Fix It First" policies
8. Smart growth street designs
9. Stormwater utilities

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Each subsection provides information and examples that:

- Define the smart growth technique.
- Give an overview of who to talk to about the techniques and relating it to stormwater.
- Define the stormwater benefits and provide tips on how to list the technique in your plan.
- Provide, if available, estimates of the costs associated with the technique.
- Provide examples where the technique has been adopted, or is in the development stage.
- Provide suggestions on "Measurable Goals," a requirement for all BMPs.
- Give "points to consider" in adopting the technique as a stormwater management strategy.

Outreach, Public Education, and Public Participation

Most smart growth initiatives include outreach to stakeholders, processes to integrate comments on plans, and schedules for gathering input. Stormwater managers should reach out to their counterparts in planning, zoning, transportation, and growth management departments to see where their established processes can integrate successful stormwater management. Ask the planning department or city/county manager if the following types of meetings are planned and whether they are open to a module or segment on growth and stormwater:

- Planning charrettes
- Visioning exercises
- Planning sessions on alternative growth scenarios
- Smart growth training sessions
- Transportation alternatives meetings with the public
- Watershed meetings

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1. Regional Planning

Definition

Regional planning is the process of considering community development options across a particular area that can include several political jurisdictions. For the purposes of stormwater quantity and quality, a watershed can be thought of as a region. If smart growth is a cornerstone of your stormwater planning efforts, regional planning is critical. A watershed or regional effort can facilitate discussions that reduce impacts by directing growth while preserving critical areas. EPA encourages watershed planning as a way to comprehensively prevent and control water quality and quantity impairments.

Local governments are encountering a complex, and growing, array of requirements to meet various state and federal rules, as well as growing public demand for "quality of life" benefits such as open space, transportation options, and amenities at the neighborhood level. The planning requirements can include transportation at a regional level, growth management plans, source water protection plans, economic development planning, emergency response and evacuation plans, and updated floodplain mapping. Many elements of the various planning exercises are similar and rely on the same data sets, such as population projections and GIS mapping of natural resources.

For water quality, regional cooperation and planning is crucial for aligning smart growth and water quality approaches such as:

- Minimizing imperviousness at the watershed level by targeting and redirecting development
- Identifying and preserving critical ecological areas and contiguous open space areas
- Making maximum use of existing infrastructure and previously developed sites

Photo: Local Government Commission

Effective stakeholder participation is a cornerstone of both stormwater and regional planning.

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Regional Visioning and Scenario Planning

Illustration 1
Kane County/Gilberts Present Day

Illustration 2
Kane County/Gilberts Build Out Under Conventional Planning and Development

Illustration 3
Kane County/Gilberts Build Out Under Smart Growth Planning and Development

Plans by Dodson Associates, Ltd.; Illustrations by Jack Werner

This series of illustrations was developed for the Chicago Regional Environmental Planning Project to show development alternatives at the western edge of the Chicago suburbs in Kane County. This agricultural area is characterized by poorly drained soils and the presence of the Fox River, which was once viewed as a natural boundary for growth. Illustration 1 shows the emergence of some housing in the background.

Kane County expects growth to emerge with the further expansion of housing, roadways and their use. Office and research are the prime industries that are expected to expand into the area first. Housing and retail are expected to follow. Illustration 2 shows that current planning trends would dictate separated land uses, large set-backs, and individual parking lots. The stormwater runoff from the large parcels and parking lots would eventually impact the streambed illustrated in the foreground.

Illustration 3 shows an alternative future using smart growth practices. The industrial uses are placed in the background closer to existing infrastructure and development. Housing developments are connected to services and retail. Illustration 3 envisions a county plan where certain areas are preserved for agriculture and drainage while accommodating growth in village centers. For more information, see the Environmental Law and Policy's "Visions" report at <www.elpc.org/trans/visions/visions.htm>.

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Who Do I Talk to About Regional Plans?

If your state has developed smart growth planning requirements, contact the state department of planning or community affairs. The Metropolitan Planning Organization (MPO) has the responsibility to develop master transportation plans. Subsection 8 (Smart Growth Street Designs, page 75) goes into more detail about planning for roads and transportation infrastructure. Your local Council of Governments (sometimes referred to as a COG) might also have information on planning efforts that span several jurisdictions. Although these may not be water plans per se, the population forecasting, maps showing undevelopable parcels, and vacant properties can all be helpful in developing a comprehensive stormwater management plan.

If your community is under the Phase II rules, and you are located near larger cities and/or counties covered by Phase I, determine if you can team up with them in developing plans. Since these communities are more than 10 years into planning and implementation, do not hesitate to contact the stormwater managers or public works department to see where you can share or expand upon plans and programs. Your area may also have other regional agreements that can be used to initiate stormwater plans, such as agreements on infrastructure or flooding prevention.

The Coastal Zone Management Act of 1972 (CZMA) and subsequent amendments have established a program for states and territories to voluntarily develop comprehensive programs to protect and manage coastal resources (including the Great Lakes). To receive federal approval and implementation funding, recipients are required to demonstrate that they have programs, including enforceable policies, that are sufficiently comprehensive and specific to regulate and resolve conflicts among land uses, water uses, and coastal development. There are currently 29 federally approved state and territorial programs. These plans may have elements and funding in place, and may include smart growth practices that can help develop elements of a stormwater management plan. For a link to state programs go to <http://coastalmanagement.noaa.gov/czm/>.

EPA's Office of Wetlands, Oceans, and Watersheds hosts a Web site called "Surf Your Watershed." This site allows users to enter their zip code, local stream name, or locality to find information about their watershed, as well as planning efforts and relevant watershed organizations. Visit <www.epa.gov/surf>.

Stormwater Benefits

Regional efforts to encourage development in strategic areas are one of the strongest approaches to coordinating growth and resource protection in a watershed. Regional efforts are often needed to effectively coordinate local approaches to development and achieve better watershed-wide results. Communities should determine areas where they want growth to occur and areas they want to preserve. When such areas are clearly defined and articulated within a region,

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New Jersey Highlands: Regional Planning for Water and Growth

The 800,000+-acre New Jersey Highlands Region covers more than 1,250 square miles and 88 municipalities in seven counties (Bergen, Hunterdon, Morris, Passaic, Somerset, Sussex and Warren). The Highlands Region is an essential source of drinking water for half of the residents of New Jersey. In 2004, the Highlands Water Preservation and Planning Act (The Act) was adopted to balance the management of water resources and growth.

The Highlands Act documents the geographical boundary of the Highlands region and establishes both the Highlands preservation area and the Highlands planning area. The Highlands Act requires the New Jersey Department of Environmental Protection to establish regulations to limit land disturbance in preservation areas, while creating a regional master plan to direct growth to desired areas within the region. To carry out the Act, the Highlands Water Protection and Planning Council was formed and charged with preparing the regional master by June 2006. While the focus of the regional plan is seen as land preservation for water quality and supply, the council was also charged with including elements to encourage appropriate development, redevelopment and economic growth for areas so designated.

In the Planning Area, municipal compliance with the Plan is voluntary. The Act provides incentives for conformance to the Regional Master Plan, however. The incentives include planning grants to assist in preparing local master plans and land use ordinances, technical assistance, tax stabilization funding for funding decreases accorded by participating in the plan, enforcement of the regional Master Plan and legal assistance to meet challenges to new master plans and zoning.

The council established several categories for grants, including grants to participate in Municipal Partnership Pilot Programs, Zoning and Parcel Analysis, Wastewater Capacity Analysis, and Affordable Housing. In 2005, Washington Borough was awarded a Municipal Partnership Pilot Program grant, which will be used to plan for three distinct areas: town center redevelopment, historic preservation, and stream corridor preservation (to include stormwater management). For more information on the New Jersey Highlands Council, visit <www.highlands.state.nj.us/index.html>.

For more information on the state of New Jersey's innovative state planning, see New Jersey's Web site on the Highlands Act, <www.state.nj.us/dep/highlands/faq_info.htm>.

development is encouraged on land with less ecological value, such as previously developed areas (as described in subsequent chapters for redevelopment, brownfields, greyfields, and vacant properties). Land with higher ecological value, such as aquifer recharges areas, wetlands, marshes, and riparian corridors, is then preserved or otherwise set aside for ecological services.

A 2004 study conducted by researchers at Texas A&M University evaluated development in a watershed in the greater Houston Texas area. The study tracked development trends over a 50-year period to evaluate watershed performance—in particular, as it relates to flooding. The study evaluated common indicators of development (e.g., impervious cover) and how various land development scenarios during that time period might have altered water flows and flooding.

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The study found that the impervious cover alone was an inadequate indicator, but when considered with other indicators, such as indicators of development dispersal, these measures together proved to be a better predictor of flooding. In assessing total developed area, the researchers looked not at estimates of impervious surface area per lot, but rather whether the lot had any development at all.

The researchers also evaluated off-site development features such as roads and highways. Over a 50 year period, the researchers mapped total developed areas, with special attention to roadway lengths, and the ratio of commercial and residential units. The risk of flooding increased exponentially once the percentage of developed properties in the watershed reached 25 percent. From a regional perspective, the authors suggest that the percentage of impervious surface cannot be used as an indicator independent of other factors such as the configuration of infrastructure, development form, and a total proportion of properties that have been developed.[6]

In evaluating the environmental performance of successful smart growth planning on a regional basis, some localities and states are using build-out and capacity analyses to predict the condition of water resources once developable parcels are developed. Build-out analyses can be conducted based on existing land use regulations, or according to conventional development practices that could shape future proposals. The goal is to compare a smart growth development plan or project to a conventional model under *status quo* zoning, and compare the stormwater benefits.

For example, many communities are updating floodplain maps. Suppose a review identifies 1,000 acres of sensitive land critical for water filtration, absorption, and flood prevention. As a result of the review, the local government alters scenarios in planning documents to upzone land in the floodplain for development. The city and county confer, and as a result, the two jurisdictions revise planning and zoning documents to redirect growth to an area of the watershed that is more appropriate for development. In this case, the stormwater benefits are not only environmental in nature, but also avert the costs associated with property damage from flooding. Thus, the benefits extend beyond typical environmental measures of water quality and quantity to economic factors as well.

Typical Costs

The costs of regional planning are related to administration and research, and vary significantly depending on the resources already available in your community. Before estimating the costs of developing or fine-tuning an existing plan, it is helpful to understand the elements of the plan, the data needed to develop the various plans, the shape of the final product, and details on how the plan will be implemented.

The costs associated with aligning multiple plans are typically driven by staff or consultant time. The Southeastern Watershed Forum estimates, as a rule of thumb, that analysis, review, and coordination takes two to three staff working over one year to 18 months.

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Once your community has decided to hire a consultant, the next step involves developing a Request for Proposals (RFP) or a Request for Qualifications (RFQ). The University of Wisconsin has developed a concise guidance document on the process of hiring a consultant. One step in the process can be issuing an RFQ to get a manageable pool of the most qualified consultants. As you draft your RFP or RFQ, keep in mind some of the unique challenges that will arise in drafting a joint stormwater and smart growth planning process, a comprehensive plan, and an implementation course. For example, you might want to have consultants review the comprehensive plan and NPDES permit (or permit renewal) and ask where there are barriers and flexibility. In addition, aligning multiple plans might reveal conflicting land use, transportation, and resource protection scenarios. Ask consultants how they would resolve these issues—in particular, where several jurisdictions are involved. Finally, ask them what elements of your strategic or smart growth plan can be borrowed for water quality and stormwater planning. These additional steps might add to the scope of work and budget; however, reviews of existing plans might reveal that work needed for comprehensive stormwater planning has already been completed. See <http://cecommerce.uwex.edu/pdfs/G3751.pdf> for more information.

Measurable Goals

The NPDES municipal stormwater program requires Phase II MS4s to include measurable goals in their program for each BMP. Increasingly, cities covered under Phase I MS4 permits are beginning to include measurable goals to track their performance in meeting water quality goals. Participation in a regional planning effort can be one way to track measurable goals, as can specific activities and steps outlined in a regional planning process. Information on counting participation in a regional group for meeting the requirements of the six minimum measures is described in the rest of this subsection, as are examples of specific activities that can count in the post-construction minimum measure.

Adoption of a regional master plan or watershed plan, as well as supporting policies and ordinances, are good candidates by which to measure progress in managing stormwater. These activities can also be documented to meet requirements on public education and outreach on stormwater impacts, as well as public involvement/participation. The key is to make sure you can track progress and relate the success back to the water quality goals in your regional stormwater management plan. For example, if a parcel of land identified for a regional park system is also contained in your regional aquifer protection plan, coordinate the acquisition and park design to meet stormwater and recreation goals. Include the acquisition in your monitoring and BMP maintenance plans as well.

In addition, efforts to coalesce common items among plans can be included in a stormwater management plan (e.g., merging plans to repair streets and sidewalks to spur redevelopment on a regional transportation corridor can be coupled with installation of microdetention areas between the curb and sidewalk). This effort can also help align capital spending decisions and be included in meeting regional stormwater goals to direct development.

Arlington, Virginia's high-density approach around the Rosslyn and Court House subway stations directs a large amount of growth to a small footprint. The county allows for high densities around stations, with a formula that tapers development intensity down to existing neighborhoods. This area, which stretches three miles from the Potomac River to the Ballston station, will ultimately absorb 8 million square feet of development on 2 square miles of land. This smaller footprint not only has regional stormwater benefits, but also has resulted in higher transit use and traffic counts that are far less than originally projected.

Photo: Arlington County, Virginia

Many areas across the country have identified specific plots of land to acquire. Buying parcels that have water-handling characteristics can provide a region with specific, measurable targets within a stormwater management plan.

For post-construction measures, the build-out analyses mentioned previously can be used to establish a baseline for setting measurable goals. Most states or regions develop build-out scenarios to assess how much developable land is available, whether the existing or planned infrastructure is likely to meet the needs of a built-out region, and to develop alternative planning scenarios. Most build-out analyses look at sewage capacity, source water, and water supply. With slight modifications, the build-out analysis can be used to also assess impervious surface coverage within a watershed and areas with the potential to effectively handle growth. If your city or county (or a regional organization) is developing build-out analyses, see if you can add a stormwater component so that alternative scenarios chosen include stormwater runoff parameters as well. EPA hosts a Web site with information on build-out analyses and other tools at <www.epa.gov/greenkit/2tools.htm>.

For meeting the post-construction minimum control measure, regional organizations might be called upon to develop model ordinances or individual policies to carry out regional plans. For example, the transfer of development rights is a tool used across the country to direct development away from environmentally sensitive lands while shifting the development to areas targeted for growth. This type of program might require setting measurable goals in a series. For example, in the first four years, the measurable goals might include (1) a formal agreement among participating jurisdictions, (2) a final comprehensive plan for the receiving area (3) a completed legal framework to administer trades and (4) software to track the number of trades. Given the complexity of each component, there are likely to be detailed sub-goals spelled out as well. To have a long-term effect on stormwater, your community should be prepared to count the numbers of transfers, not just the existence of a program.

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Many regional organizations rely on voluntary participation in regional planning. As such, regional growth and/or watershed plans offer incentives (see the box on page 30, New Jersey Highlands, for more information). In addition to taking advantage of the incentives, make sure to also count the steps taken for the regional plan into your Phase I or Phase II municipal NPDES permit.

Examples

Within **New Jersey**, the Regional Planning Partnership (RPP) has developed tools to compare smart growth versus conventional development impacts, including stormwater runoff. The partnership has developed a sketch tool called Goal Oriented Zoning. In 2003, RPP developed a comparison for Delaware River Basin communities. This analysis compared four scenarios and set an overall watershed impervious cover goal at 10 percent. From there, RPP developed different development scenarios based on the 10 percent coverage goal to compare watershed-wide impacts. The exercise also served to show graphically what build-out is allowed under current zoning. While the use of the tool was meant to focus on zoning and transportation issues, RPP was able to include several environmental indicators, which could be further explored with air and water quality-specific models on other scales. For more information, visit <www.planningpartners.org/services.html>.

The Association of New Jersey Environmental Commissions (ANJEC) has issued a series of reports to assist its member communities with tools needed to comply with New Jersey's planning laws. These reports include information on conducting build-out and capacity plans, increasing the supply of affordable housing and implementing master plans. Its "Smart Growth Survival Kits" contain information on the data needed, methods available, and additional contacts. Though New Jersey–specific, the information can be useful for other states. Visit <www.anjec.org> and click on "Smart Growth Survival Kit."

In 2005, the Southwestern Regional Planning Council, covering the southwest counties in the state of **Connecticut**, released its regional planning strategy. The goals of the regional plan focus on transportation, housing, and directing development to areas with existing infrastructure and investment. For more information on implementation and other related objectives, visit <www.swrpa.org/projects/regplan2005.htm#project_team>.

To assist the regulated municipalities in the **Syracuse** Urban Area in complying with Phase II stormwater regulations, the Central New York Regional Planning Board (CNY RPDB) has launched a unified, regional assistance program. Its Web site, which was developed specifically for decisionmakers, includes several layers of maps, including MS4 boundaries, watershed boundaries, and political boundaries. The CNY RPDB is also providing unified assistance in the areas of public education, outreach and participation, municipal training, research assistance, and efforts to secure funding for compliance. For more information, visit <www.cnyrpdb.org/stormwater-phase2/>.

The 1996 Amendments to the Safe Drinking Water Act resulted in a focus to protect drinking water sources to complement the original goal of removing contaminants from

drinking water. To meet the new requirements, states must ensure that each water system has a Source Water Assessment. Once the assessments are complete, states and localities work on action plans to address any issues found in the assessment. Source Water Assessments must include four basic elements:

- A delineation (or mapping) of the source water assessment area.
- An inventory of actual and potential sources of contamination in the delineated area.
- An analysis of the susceptibility of the water supply to those contamination sources.
- A mechanism for sharing the results widely with the public.

While the traditional sources of contaminants arise from agriculture or industrial uses, more and more communities are concerned about the cumulative effects of development and runoff on source water.

If you are developing a regional or comprehensive plan, check to see if there is a source water protection plan or ordinance in your area. A link to state programs can be found at <www.epa.gov/safewater/source/contacts.html>. In addition, the Trust for Public Land has issued a report called *Protecting the Source*, which contains information on joint land and water planning. Visit <www.tpl.org/tier3_cd.cfm?content_item_id=1337&folder_id=195>.

Points to Consider

In many parts of the country, local government boundaries have served more to foster competition than cooperation. Growth pressures, economic conditions, and the underlying structure for assessing taxes all put pressure on the local funding base. In addition, there are few incentives to plan across boundaries, much less develop interlocal agreements involving tax sharing, growth, or annexation laws. Nonetheless, some areas faced with mounting water-related problems are finding that shared solutions among counties and cities offer efficient options. Newspaper headlines on flooding, beach closures, and emergency water restrictions are motivating discussions on how to analyze problems and forge solutions that transcend boundaries. EPA has recognized the importance of watersheds as an effective organizing unit. A good resource for approaching interlocal agreements is the Joint Center for Sustainable Communities. The center represents an important collaboration between the National Association of Counties (NACo) and the U.S. Conference of Mayors (USCM). Its web site is <www.naco.org>.

Onsite Wastewater Treatment Systems (also referred as septic systems, package plants, or cluster systems) pose challenges to local governments trying to manage growth in rural counties, vacation areas with second homes, or in fringe areas where water infrastructure cannot be extended. In the past, soil percolation rates, drainage fields, and overall perceptions of septic tanks were limiting factors to widespread use. New technologies, growing demand for housing in rural areas, and changing perceptions have reduced barriers to their use, however. According to EPA's 2002 *Onsite*

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Wastewater Treatment Systems Manual, nearly one-third of new housing construction is served by onsite wastewater treatment systems.[7] The University of Rhode Island's Cooperative Extension Agency has released a new handbook entitled *A Creative Combination: Merging Alternative Wastewater Treatment with Smart Growth*. The aim of the handbook is to help local governments address growth and wastewater handling at the same time. In addition, the handbook addresses the important role of management, oversight, and enforcement in areas where a large percentage of households use onsite systems to treat wastewater. For more information, visit <www.uri.edu/ce/wq/mtp/PDFs/manuals/Creative%20Combination%203-10.pdf>.

As noted in this section, regional planning can result in decisions that direct growth to certain areas of the watershed. These identified growth centers might be in existing communities, or in undeveloped areas. Efficiently handling growth in these areas eventually leads to discussions on density. Commonly held views on density among stormwater engineers and environmental advocates tend to equate density with imperviousness, which is then equated with poor water quality outcomes. Stormwater ordinances that discourage "connected impervious surfaces" might run counter to smart growth plans that call for a compact, but connected, street development form. Even where localities understand the need to direct density, there may be discussions about requiring automatic "offsets" of open space tied to redevelopment decisions. While some communities will establish programs to connect infill development with land conservation, a blanket, inflexible requirement to obtain land might, in the end, stifle a region's ability to meet both growth and water goals. To address the issue, EPA has issued a report called *Protecting Water Resources with Higher-Density Development*. [8]

Comparing the environmental impacts of various development options can require an extensive amount of baseline data and resources to analyze the various build-out scenarios. The baseline data needed include an inventory of natural resource lands, an inventory of developable lands, an inventory of undevelopable land in both private and private hands, and comprehensive zoning maps. Even where these data are available and show opportunities for redevelopment and reuse of vacant properties, further work might be needed to determine which properties are market-ready and which are contaminated, or where ownership is uncertain. In some communities, incomplete data may be a huge constraint. In these situations, communities might want to canvass state, university, and conservation district offices to see where GIS work has been conducted.

A community that does not have all of the information listed above might want to begin work in a targeted area. For example, if your state is updating transportation plans, a city or county may want to update local zoning maps to support the redevelopment of parcels in proximity to the study area. Information from this type of review can be used to assess development potential, transportation impacts, and scenarios of how that same level of development might look if built elsewhere in an undeveloped portion of the watershed. A carrying capacity report can then evaluate the stormwater generated by each scenario. The targeted

Photo: www.pedbikeimages.org/Dan Burden

Main Street Programs have been successful in directing development to older downtowns.

review can reveal not only environmental information, but also economic barriers and transportation investments that need to be addressed before growth is redirected.

If you are a Phase II community and decide to team up with Phase I community, keep in mind that some of the requirements for Phase I can be more restrictive than Phase II. Some Phase I communities use numeric goals for BMPs or might have implemented rigorous water quality monitoring schedules. The additional requirements may be offset by the efficiencies of using an established program, however.

Finally, regional or watershed plans, like any other plan, are only meaningful if implemented. When identifying measurable goals, be sure to distinguish where development of a plan is a suitable short-term outcome and which actual policy changes are needed to ensure the long-term environmental outcomes desired.

2. Infill Development

Definition

For purposes of this document, infill is defined as development that occurs on previously undeveloped lots within existing developed areas (the following section on redevelopment covers development that occurs on previously developed lots). Infill development takes advantage of built-out areas that are already served by a variety of transportation modes and by infrastructure. Infill development also accommodates development that might otherwise occur on greenfields sites. EPA's model permit for Phase II <www.epa.gov/npdes/pubs/modpermit.pdf> states that communities can use policies that promote infill development and development in areas with existing infrastructure to meet the post-construction minimum control measure. This section describes how infill development is typically regulated, how infill is treated within smart growth plans, and special points to consider for infill and stormwater control. Much of the information presented here is also relevant for Subsections 3 (Redevelopment) and 4 (Development Districts) as well.

Who Do I Talk to About Infill Plans?

Decisions about where to develop are influenced by numerous factors. While the final decision nearly always is left to the local jurisdiction, regions and states also influence the decisions of both developers and the localities through incentives and policies. This subsection therefore addresses policies at all three levels of government.

Green roofs can help manage stormwater for infill development projects.

Photo: University of Connecticut Cooperative Extension System

Local Jurisdictions: To understand who to talk to and where to find the land use plans that guide infill development, it is helpful to understand the two ways that localities manage development activities. The most common method in urbanized and urbanizing areas is through zoning, which places limits on the use, type, size, and design of allowed development. Zoning can be either "by-right," meaning that developers can build any development provided it meets zoning standards, or conditional, meaning that developers must seek approval for specific proposals. Within zoning codes, there are standards, called "bulk regulations," that govern the maximum size of structures on a lot and how the building is located on the site (e.g., lot coverage, setbacks, parking, floor area ratio, and landscaping requirements). Localities often use a variance process where deviations from the standards are deemed acceptable.

A second method of steering development is through use of incentives. Local jurisdictions seeking specific types of development might give financial or other incentives to developers willing to build within desired parameters. Zoning and incentive programs are typically drafted by the planning and/or building departments of a city and codified in city land use and zoning ordinances. If you are in a smaller municipality without zoning, the city or county engineer might be the best person to explain development rules, since building standards—not zoning—guide where development can be located and how it is built. Some larger cities have separate entities to encourage redevelopment, so personnel in the economic development division are likely to have the best understanding of whether there are special business development zones, special tax zones, and maps showing the boundaries of these areas.

If you are unfamiliar with the terminology used for zoning and comprehensive planning, visit the Wisconsin Department of Natural Resources Web site, which posts a list of general land use terms to help natural resource professionals. See <http://dnr.wi.gov/org/es/science/landuse/education/GPZ.htm>.

Regions: Metropolitan planning organizations (MPOs) are inter-governmental institutions formed to handle transportation planning in areas with a population of 50,000 or more. They also have the responsibility of allocating transportation funding for areas with populations greater that 250,000. MPOs might seek to better match development and transportation investments through educational tools; for example, maps showing 20-year growth projections. Some MPOs are involved in water and stormwater planning. To find out if your area is served by an MPO, contact your planning staff, or go to <www.ampo.org>, which lists member MPOs.

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States: A number of states have passed statewide smart growth legislation, recognizing that, while development decisions are made locally, state policies often guide the decisionmaking process through financial incentives and policy decisions. Responsibility for statewide smart growth policies generally lies in a statewide smart growth office or planning office, or in a department of consumer or environmental affairs. In states that do not have a formal statewide plan, there may be separate policies that seek to streamline policies on growth. States that have embarked on growth management efforts might also have developed baseline data on natural resource lands and larger infrastructure programs. Contact the state office to see if you can make use of the GIS mapping or other data for making decisions on directing growth and infill. If your state has passed legislation, enabling legislation or programs to promote infill as a smart growth policy, but your locality has not adopted them, you might want to work with your zoning or economic development director to take advantage of the program for water and growth goals.

Photo: www.pedbikeimages.org/Dan Burden

Infill development can help a community grow over time. For example, a row of "liner shops" can be added to surround a surface or structured parking lot. This adds development intensity, reduces the overall amount of parking required for the district as a whole, and improves the pedestrian environment.

Stormwater Benefits

Infill can reduce potential runoff by ensuring that growth does not create additional impervious surfaces on the developed fringe and in environmentally sensitive areas. The impacts of such development can be considerable. Growth on the undeveloped fringe results in less groundwater flow into streams and less aquifer recharge as water runs over the surface. The 20 regions with the greatest amounts of land development over the period 1982 to 1997 now lose between 300 billions and 690 billion gallons of water annually that would otherwise have been captured in groundwater supplies through natural percolation.[9]

A modeling study conducted by Purdue University estimated that placing a hypothetical low-density development at the Chicago fringe area would produce 10 times more runoff than a mixed-use development in the urban core.[10] In Virginia, a Chesapeake Bay Foundation study found that clustered development across the state would convert 75 percent less land, create 42 percent less impervious cover, and produce 41 percent less runoff.[11]

In addition, infill development can make use of existing infrastructure. Guiding development to existing areas also increases the economic activity and tax base needed to support the maintenance, repair, and/or expansion of the water infrastructure in place. This investment can help repair areas prone to sewer overflows, or enhance treatment facilities in order to meet more stringent water quality standards.

The following measures are the types of regulations and programs that are used to promote infill, and thus facilitate stormwater improvements. In your permit application or plan for Post-Construction Minimum Control Measures, you can list these out separately, or include them under a general measure such as "infill policies."

Setbacks: Setback requirements can be one of the most important factors shaping the built environment—and hence impervious cover—in your community. Conventional codes often call for minimum setbacks: for example, requiring a building to be *at least* 50 feet from the street or adjacent properties. Smart growth codes often use maximum setbacks, which stipulate a maximum distance a building may be situated from the street or sidewalk. A maximum setback brings the building closer to the street and sidewalk, promoting a more interesting and efficient pedestrian environment. Alternatively, your smart growth code may stipulate a "build to" line. This requires that the building footprint meet a certain line along or within the property, such as up to the edge of a sidewalk. Check with your zoning, planning, or public works office to see if your community has minimum setbacks, or if it has made modifications to allow for maximum setbacks. The convention of setting minimum distances from the roadway can result in excess impervious cover and be ripe for reform to obtain stormwater benefits. Setback requirements can be found under individual zoning codes or apply to entire districts.

Mixed Use Zoning: Mixed use zoning allows (or sometimes requires) buildings with different uses (e.g., residential, office, retail) in the same area or in the same building. This mix allows for a greater intensity of development on a more compact scale, which reduces the amount of land needed on a per unit basis. Mixing uses also supports a range of transportation options and facilitates shared parking, thereby reducing the amount of surface needed for roads and parking lots.

Smart Growth Lot Sizes: In some areas, zoning codes and subdivision standards have been rewritten to allow for greater density and more efficient use of the land. Instead of requiring a minimum of a quarter acre per residential lot, as many current codes do, new smart growth codes allow smaller lots. This practice consumes less land per unit. The smaller lot sizes can also be instrumental to drawing development to smaller or oddly shaped infill lots within an older city. Large lots not only consume more land, but the lawns covering those lots handle less stormwater than undisturbed land. Under typical subdivision construction practices, sod is laid over highly compacted soil, so that water does not percolate. Where mass grading is a typical practice, the compaction of the underlying soil further reduces the potential for infiltration. Lawns treated with fertilizers and chemicals further add to stormwater problems, particularly if treatment occurs right before a rain event. Smart growth can minimize some of these impacts. When looking for language governing lot sizes, the zoning code may refer to "maximum lot sizes," or be presented as zoning categories, such as R-8 (or eight residential units per acre).

Density Bonuses: Density bonuses are used to provide incentives for developers who agree to integrate desired features into development projects. There can be stormwater benefits to increasing the development density in existing

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communities (e.g., less land consumption, more efficient use of existing impervious surfaces such as roads and sidewalks). One can also provide density bonuses to developers who agree to treat stormwater on site or who agree to replace older infrastructure serving the project. A density bonus may be used to reduce the footprint of the building by allowing the development intensity to be expressed through height. Density bonuses are typically part of a larger planning process that determines how much incentive is needed, what the amount of the bonus will be, enforcement to ensure both parties adhere to the arrangement, and other planning needs that accompany the added density (e.g. parking, fire protection). Density bonuses are typically listed in the zoning code or plans, or in footnotes to the plan.

Financial Incentives: Common incentives include the use of tax-increment financing, tax and economic incentives for redevelopment, and promotion of cost-of-service utility fees (instead of average cost pricing, which can subsidize dispersed development at a cost to higher density development). Tax increment financing (TIF) is a system whereby property taxes in a particular district are frozen at a certain level; when property values rise, the additional tax that would have been paid is instead directed back into redevelopment projects in the district. TIFs are built on the concept that new value will be created, and that the future value can be used to finance the initial investment.

Typical Costs

Both conventional development and infill involve costs to the public sector, because any new development requires public services or upgrades. Most research, however, finds that in the long run, there are fewer public costs to provide services to infill and redevelopment, because existing infrastructure is used or repairs or upgrades were needed whether infill took place or not.[12]

Measurable Goals

An initial goal might be to direct some percentage of growth into areas that are already developed, or to initiate a selected number of policies to encourage infill development. To ensure measurability, your community can establish a system to track building permits within an area designated for infill. In addition, your community can institute a priority system for infill and redevelopment projects that further improves stormwater management with features such as green building techniques. A longer-term goal might be to increase the overall density of developed areas and preserve open spaces from development. A locality may want to do a "code checkup" every so often to make sure that

Photo: EPA

Landscaping can be used to handle stormwater in tight infill projects. While native plants are often recommended, there may be other factors to include in plant selection, such as maintenance, canopy, root depth, and water uptake.

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the requirements for infill are not more - onerous than those established for new development on greenfields sites.

Examples

The state of **Washington** has developed a Phase II application that explicitly lists infill development as an option for fulfilling the post-construction minimum control measure. To view the Department of Ecology's permit application, go to: <www.ecy.wa.gov/programs/wq/stormwater/phase_2/Phase%20II%20Application.pdf> (see page 14 within the document for the language on infill development).

Clark County, Washington, adopted an infill ordinance in fall 2002. Its infill guidelines are applicable only in certain residential zoning districts for lots under 2.5 acres that adjoin existing development and can be served by existing infrastructure. The ordinance allows for two tiers of infill development. Tier 1 allows only detached single-family housing, but lot sizes can be smaller than existing zoning. Tier 2 allows attached and detached single-family housing, as well as duplexes and multi-family housing. Developers may also receive density bonuses. Infill projects are exempt from stormwater regulations if they create less than 5,000 square feet of new impervious surface. For more information on the infill ordinance and Clark County's comprehensive plan, visit <www.co.clark.wa.us/longrangeplan/review/index.html>.

In its state model stormwater ordinance, **New Jersey** has identified areas slated for redevelopment and infill. Rather than devote resources to establishing new boundaries for water policy documents, the state used definitions that already exist for economic planning. Thus, parcels in areas designated as "Urban Redevelopment Zones," such as "Urban Enterprise Zones" and "Urban Coordination Council Empowerment Neighborhoods," are exempt from infiltration requirements. By using the existing designations, the office overseeing stormwater efforts need not devote resources to drawing new boundaries. In addition, the use of economic development boundaries helps to tie environmental protection to economic development efforts. For more information, see <www.njstormwater.org> and go to the Tier A model permit.

Austin, Texas, has established a variety of water policies for its Desired Development Zones (DDZs) and Water Protection Zones (DWPZs). In the past, the city provided reimbursement for certain water and wastewater facilities over a three-year period. Under updated smart growth policies, major water and wastewater facilities located in the DDZ will be reimbursed in a single payment. Within the DWPZ, reimbursement for wastewater facilities will be discontinued, and the reimbursement schedule for water facilities will increase from three years to four. For more information on Austin's smart growth incentives page, see <www.ci.austin.tx.us/smartgrowth/incentives.htm>.

Some states have adopted priority funding areas (PFAs), which are areas designated for growth and, as such, gain priority for grants, infrastructure, and transportation investments. In creating these zones, the states typically inventory how funding is allocated, and create (or adjust) the funding formulas

Incorporating Infill into Stormwater Regulations: Wisconsin Department of Natural Resources

The Wisconsin Department of Natural Resources has developed technical materials and guidance for the post-construction minimum measure under Phase II, which address new development, redevelopment, and infill separately.

Definitions

The definitions help establish the development and regulatory context.

- "New development" occurs on undeveloped area including cropland and other vegetated areas.
- "Redevelopment" describes an area where impervious surfaces (e.g., buildings, parking lots, and roads) already exist.
- "Infill area" describes undeveloped land in existing sewer service areas that is surrounded by developed land or man-made features where development cannot occur.

The Post-Construction Rules

The rules focus on three aspects of stormwater-related impacts: 1) total suspended solids (TSS), 2) infiltration, and 3) peak runoff rates.

TSS refers to a measure of the amount of solids in the wastewater—in this case stormwater. TSS is a way to determine water "cloudiness," which has implications for the biological functions of aquatic species. To assess TSS, water samples are passed through a filter, and the amount of material captured is measured relative to the amount of water filtered.

Wisconsin's requirements for the percent reduction of TSS are measured from a "typical development pattern with no controls" or "no BMP" baseline and are tiered as follows. For new development, an 80 percent reduction from "no control." For redevelopment, a 40 percent reduction from "no control."

For infill, the requirements are:

- Less than 5 acres and developed prior to October 2014, a 40 percent reduction from "no control"
- Otherwise an 80 percent reduction from "no control"
- The 5-acre in-fill threshold is based on undeveloped area available (not amount of land disturbed).

For the infiltration standards, redevelopment sites are exempt. Otherwise, new residential development projects are required to infiltrate at least 90 percent of the water falling on the site and non-residential development infiltration volumes are required to be at least 60 percent.

Peak runoff rates (or peak discharge rates) refer to the maximum volume flow rate passing a particular location during a storm event. Peak discharge is typically increased with increased development as more water is collected and conveyed across impervious surfaces. For example water from two adjacent parking lots is collected and flows to a common gutter. This additive volume gathers energy as it flows downhill toward a discharge pipe. This increased volume can scour riverbanks and increase the risk for flooding. Peak discharge is typically expressed in units of volume/time (e.g., ft3/sec). Within Wisconsin's rules, the peak discharge for post-construction conditions are to be reduced to the pre-development conditions for the two-year, 24-hour storm (though some local ordinances may vary).

The peak discharge standards do not apply to:

- Sites classified as redevelopment
- Infill development less than 5 acres

For more information on Wisconsin's post-construction requirements, presented as PowerPoint presentations, visit <www.dnr.state.wi.us/org/water/wm/nps/stormwater/post-constr>.

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Courtyards and landscaped areas are common features of site plans. Small modifications in drainage and plant selection can improve the water handling performance of infill projects.

Photo: City of Portland, Washington

to support development in these targeted areas. **Maryland's** Smart Growth Initiative, passed in 1997, directs state infrastructure funds into PFAs. The initiative identified areas automatically included, and also allowed counties to designate certain areas within their boundaries as PFAs. Under this policy, local jurisdictions may allow development in non-PFAs, but must fund all infrastructure improvements locally. Phase II communities located in a PFA should make sure local stormwater policies complement the state plan. For example, a complementary plan would make sure that (1) comprehensive plans, zoning codes, and standards are in place to foster infill, (2) local funding investments match the state's commitment, including sewers, stormwater, and transportation, and (3) permitting processes do not pose barriers to infill.

Rather than require stormwater handling for each individual project, the city of **San Diego** adopted a policy in 2002 to allow infill developers to share in the cost of stormwater abatement. The Standard Urban Stormwater Mitigation Plan allows developers to contribute to stormwater mitigation that serves the entire drainage basin. Engineers estimate that individual developments projects can achieve savings of up to $40,000 by participating in a shared stormwater control program. For more detailed information on the Localized Equivalent Area Drainage program, (LEAD) visit <www.sannet.gov/stormwater> and type "Localized Equivalent Area Drainage" into the site's search engine.

Some of the best advocates for infill are developers themselves. The Center for Watershed Protection has two programs, Builders for the Bay and the Site Design Roundtable, which gather information from developers on the best ways to build stormwater-friendly developments. For more information, visit <www.cwp.org>.

Points to Consider

Lots slated for infill can be the last open spaces in a built-out community. In some instances, they may be the remaining open lots that handle urban stormwater. There is

no one method for determining whether these lots should be kept open for stormwater control or developed. The local development context is a critical consideration that comes into play. Green spaces and parks serve a multitude of purposes in urban areas for aesthetic purposes, recreation, and environmental benefits.

Some lots may not be critical for natural handling of stormwater, but may be in an area with waterways that are already compromised by development-related stormwater runoff. In this case, there are an increasing number of green building techniques and low impact development (LID) options for onsite stormwater control. Developers and their landscape architects should look at common urban development features, such as courtyards, small water features, and tree planting areas for stormwater control. Since these features are likely to already be included in site plans, small design modifications to handle runoff can improve your project's performance. The Center for Watershed Protection has developed several documents under its "Smart Sites" initiative, which can be found at <www.cwp.org/smartsites.pdf>.

As discussed elsewhere in this subsection, investments from infill development may be able to support improved stormwater handling by way of gray infrastructure. Localities should look at infrastructure financing plans, and how they can be used to attract infill investments. A mitigation plan for development projects can lessen stormwater impacts related to infill. Maryland's *Guide to BMP Selection and Location* includes tables of BMPs and in which setting they perform best. See <www.mde.state.md.us/assets/document/chapter4.pdf>.

Finally, even where there is strong consensus among the stormwater engineer and other planning departments on strategies for infill, local residents may oppose any new development project in their community. In a growing number of circumstances, the arguments are based on increased stormwater runoff. Several organizations have developed tools to help design better infill projects and develop community consensus early on. In addition, the low impact and site design options listed in this document may help developers, community members, and zoning officials understand the options for handling infill development in a way that also protects the local environment. The Greenbelt Alliance in California <www.greenbelt.org> has produced *Smarter Infill* and Smart Growth America <www.smartgrowthamerica.org> has released *Choosing Our Community's Future*.

Language to Look for in Ordinances

It is important to keep in mind that the language in your city or county's stormwater ordinances and guidance will be part of a regulatory and legal framework in the same manner that zoning ordinances are. Thus, the particular wording can have implications for whether the stormwater policies will work in concert with, or against, your smart growth policies. Most communities will have to balance the need for language that is legally binding, flexible, and designed to deliver stormwater benefits to the maximum extent practicable.

Language Fostering Creation of Joint Smart Growth and Stormwater Policies

Language specifying that post-development hydrology match the pre-development hydrology: Language to this effect may foster redevelopment. Because the pre-development state of the parcel was already developed, a redevelopment project with the same lot coverage will essentially have no effect. When you write your ordinance, however, you may want to avoid confusion by specifying that the pre-development condition refers to the site immediately prior to redevelopment.

Language classifying a smart growth technique as a BMP: This language will verify that your smart growth policies are recognized as stormwater practices. Note that your guidance or ordinance may also require maintenance and operation for the BMPs. For example, if your "Fix It First" policy is adopted by reference as a stormwater BMP, the BMP maintenance requirements are also likely to apply. If you have established a BMP maintenance fund, this could establish a new source of funding for priority repairs.

Adding "prevention" of stormwater to your ordinance's purpose or goals section: Stormwater BMPs have traditionally been designed for mitigation; that is, to lessen stormwater once it is generated. Adding stormwater prevention to your goals, however, can help support the prioritization of redevelopment, compact development plans, and "Fix It First" programs.

Language that includes smart growth policy techniques in the definitions: The "Definitions" section of your ordinance is an important feature. The legal definition will establish how narrow or broad your options can be, or even what measures can be classified as BMPs. In addition, having smart growth policy terms in the definition can assist you in cross-referencing other plans, which can save time and resources. For example, many cities are exempting projects in dense, urban areas from infiltration requirements. Rather than delineate new areas, some cities are using established districts, such as "Business Improvement Districts" or "core downtown" or boundaries set in economic development plans. Adopting these districts into the "Definitions" section of your stormwater plan automatically delineates where policies apply. Even if the policy is not fully used in the ordinance or guidance during the first five-year permit, establishing the definition can serve as a placeholder as your community works out the full details.

Language that refers to design manuals: Because the stormwater management aspects of a development project can be comprised of many interrelated elements, ordinances often refer to design manuals. The reference to a manual will allow localities to develop and maintain manuals that reflect their smart growth programs. You may want to see where a local manual and/or ordinance on "traditional neighborhood design" or "Main Street Redevelopment District" can be customized to add stormwater management criteria for hydraulic sizing and performance standards.

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Language Hindering Creation of Joint Smart Growth and Stormwater Policies

Language specifying that post-development hydrology match the pre-development hydrology: This language, which can help incentivize redevelopment as noted above, can block infill on undeveloped sites or smart growth on greenfields sites. Make sure there is flexibility within your stormwater and urban design plans so that the requirement for maintaining natural hydrology delivers projects that work in all contexts within a watershed.

Language requiring that BMPs replicate natural systems or non-structural natural BMPs: This might be a desired strategy in rural areas or those with pristine water resources. If this is a strict statement that covers all development projects in your city, county, or township, however, your community might face difficulties in directing growth to areas specifically targeted for a higher intensity of development. In addition, some strategies for replicating natural systems require large areas of land for infiltration or filtration of pollutants, which might consume land needed in a traditional town center or new urbanist plan to create a compact, walkable town center. Make sure there is flexibility so that there are options for stormwater management that are context-sensitive.

Language that classifies the intensity of control based on "housing units per acre": Most land use plans classify the intensity of residential development based on housing units per acre. This system is based on zoning conventions that tend to separate uses, and hence, can disperse development. Stormwater regulations based on units per acre will not only reinforce this system, but are likely to miss the importance of looking at water impacts on a "per unit" basis. Many watershed managers are faced with growth estimates over the next decade that range from several hundred households, to thousands of new households. Looking solely at "housing units per acre" on given acreage within a watershed may produce an unrealistically low picture of the planning and investment needed. Looking at impacts on a "per unit" basis may help communities—in particular, growing communities—fully assess water impacts of expected growth in total number of households in the watershed.

Language to tie priority funding to adoption of a model ordinance: Many states are developing model ordinances for local communities as a way to reduce the resources needed to develop and implement NPDES permit programs. These model ordinances are, by their nature, written to a minimum level of compliance, and written broadly as to be applicable in many different environmental settings. As an alternative to a model ordinance, states are also allowing communities to develop innovative alternative plans. When priority funding is given for adoption of the model ordinance, there is less incentive for a community to choose options for developing innovative and multi-objective plans. In addition, many communities will likely choose an option that is as simple and spelled-out as possible. By developing specialized manuals for Traditional Neighborhood Design and redevelopment areas, localities have a ready-to-use option for smart growth. Localities and state should look for ways to make a variety of options attractive through technical assistance and/or funding priorities.

Impervious coverage limitations: Many state and local permits have incorporated impervious surface limitations (or lot coverage limitations) based on studies that show that a watershed begins to deteriorate when 7 to 10 percent of the watershed is covered by impervious surface. This concept has been translated to the site level through ordinances that limit coverage of rooftops and parking to no more than 10 to 20 percent of the site. While this may be an effective strategy in some circumstances (for example, to protect pristine waters), in others, this type of ordinance serves to spread out development even more. Larger lots are needed for all development projects, which serves to extend the distances among uses. This, in turn, requires longer stretches of roadway and more water and sewer infrastructure per unit of development.

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3. Redevelopment

Definition

Redevelopment is development of a site that has been previously developed and is typically covered with impervious or compacted surface. For purposes of this subsection, the reader can assume that the lot is covered with compacted or impervious surface and has minimal to no value in handling stormwater. These projects can include development of vacant buildings, lots where a building has been torn down and replaced with gravel parking lots, or older malls.

Who Do I Talk to About Redevelopment Plans?

In most instances, redevelopment is left to market forces. Developers and real estate investors seek out available property and either redevelop by-right or petition for a variance or rezoning. In other jurisdictions, special entities are formed to foster redevelopment. There are often barriers to redevelopment, including complex approval processes and the perception from lenders that the deal will pose more risk than new development projects.

Thus the best resources for learning about redevelopment plans can be private sector organizations, or public/private partnerships. Economic entities, such as redevelopment authorities, "Main Street" programs and brownfields offices, often work to line up financing, zoning reforms, shared parking arrangements, and other incentives to overcome the barriers and perceptions that suppress market interest. Talk to your economic development director, chamber of commerce, or city manager to see if there are established redevelopment districts that can be added to your stormwater management plans. If you are the head of a redevelopment agency, talk to local experts on land development to develop scenarios of watershed growth. In this way, you can present not only the economic benefits of redevelopment, but also the regional water benefits that can accrue from successful implementation of your Main Street or brownfields program.

As a stakeholder in the stormwater process, you may also want to consult with commercial real estate brokers to investigate why a commercial district, mall, or older downtown is underperforming, and what steps are likely to revive interest.

Examples of programs that you can ask about include:

Vacant Property Reform: According to the National Vacant Properties Campaign, vacant and abandoned properties occupy about 15 percent of the area of a typical large city—more than 12,000 acres on average. Vacant property reforms are designed to encourage the redevelopment of vacant properties, allowing the utilization of existing buildings in potentially desirable urban and suburban locations. For more information, see <www.vacantproperties.org>. The International City/County Managers Association has researched and reported on successful local efforts to bring vacant commercial and residential properties back into use. For more information, see <www.icma.org/vacantproperties>.

Greyfields: Greyfields are a subcategory of vacant or underperforming properties. Greyfields are large, previously developed properties, such as older shopping malls and

warehouses. These sites tend to be large and well-served by transportation and stormwater infrastructure. These properties differ from brownfields in that they are not contaminated or perceived to be contaminated. To see if your community is working on a redevelopment strategy for old malls or other greyfield sites, contact the department of economic development or the local chamber of commerce. This strategy may include mixed-use rezoning, enhancing transportation on the site, and/or redevelopment incentives. Because these sites are so large and are not contaminated, you may be able to negotiate for better control of stormwater on site, and thus increase the stormwater benefits of the redevelopment project. The Congress for the New Urbanism published *Greyfields into Goldfields*, which presents information on common reasons behind the decline in malls and large properties and development options for reusing the sites. See <www.cnu.org/cnu_reports/Executive_summary.pdf>.

Renovation Codes: Renovation, or rehabilitation, codes are commonly developed to replace inflexible building codes with a set of coordinated standards for renovation and rehabilitation in older areas. For example, renovation of an old downtown might be prohibitively expensive, or impossible under building codes created for new development. Renovation codes meet safety objectives while setting workable standards for renovation. Renovation codes also help towns revitalize the economy of their downtowns, while relieving development pressure on greenfield sites (and thus retaining the stormwater benefits of open space). The United States Department of Housing and Urban Development published a report, *Smart Codes in Your Community: A Guide to Building Rehabilitation Codes*, describing various redevelopment codes and examples of rehabilitation codes from across the country. See <http://www.huduser.org/publications/destech/smartcodes.html>. If your community or state offers support for renovation and rehabilitation, also check to see if historic tax credits are allowed, and count this toward your stormwater credit for redevelopment. Check with your historic preservation office or local nonprofits that deal with historic preservation.

Typical Costs

The costs of redevelopment are distributed among several stakeholders. For a city or county, fostering redevelopment can include (1) the costs of redevelopment planning and stakeholder outreach, (2) the costs of any incentives provided, (3) upgrading and repair of existing street and water infrastructure, and (4) staff time if specific programs have been established. These costs, however, cannot be appraised without looking at the costs associated with vacant or underused commercial and residential properties. The Vacant Properties campaign has compiled information on these costs and are available at <www.vacantproperties.org>.

For developers, redevelopment projects in already-developed areas are typically more complex, and thus can be more expensive. These developers must work with existing street and circulation patterns, building configurations, and zoning and regulatory codes, many of which are decades or even centuries old. Developers look at the time and cost involved to see if projects "pencil out" economically. Local incentives and regulations play into cost, including stormwater management. Review your smart growth plan (and state programs) to see if funding mecha-

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nisms, open space and park funds, tax incentives, or permit review incentives are available. When packaged strategically, these incentives may serve not only as economic development incentives, but stormwater program incentives as well.

Measurable Goals

Since redevelopment projects are discrete and are typically tracked through permits, stormwater managers may be able to use databases that are already in use. Since many stormwater consultants are establishing tracking software, work with them to establish new fields to track the impervious surface reused through redevelopment. One example of a measurable goal would be to create an inventory of vacant properties and set goals for redeveloping them.

As noted in the previous section, you may also be able to track the amount of impervious surface avoided through your redevelopment programs. This approach would translate how the square footage, building footprint, parking and associated infrastructure would compare under conventional development standards elsewhere in the watershed. As a first step, the stormwater or planning office would need to estimate (1) where the development might go were it not for redevelopment programs, (2) the average parameters for conventional development (e.g., likely number of parking spaces, new road and access designs), and (3) any other secondary impacts that might come from new growth.

Examples

Comparing build-out scenarios was used to assess the transportation and water and air quality impacts of Atlantic Station, a brownfields redevelopment project in Atlanta.[13] The site design for Atlantic Station, located on a former steel factory, includes several stormwater improvements. The developer, Jacoby Development Inc., built stormwater handling features on the site, upgraded the storm and sanitary sewer network for the project, and addressed groundwater contamination.

As part of EPA's analysis, the Agency compared how the same intensity of development would perform if built according to conventional development standards in other parts of the Atlantic metropolitan region farther from the urban core.

This lake, located in the central part of the Atlantic Station redevelopment project in Atlanta, Georgia, is a development amenity, but also assists in stormwater management.

Photo: Paul Muldawer

Compared to a greenfields site, the redevelopment scenario had lower total phosphorous and nitrogen loadings, as well as reduced volume. In some cases, the comparative reductions were orders of magnitude lower. To learn more about this project, visit <www.epa.gov/projectxl/atlantic/index.htm>.

Points to Consider

Most of the "Points to Consider" listed under the previous section on "Infill Development" also apply. As noted above, many cities and counties are adding onsite water handling requirements to all development and redevelopment projects. Even where there is flexibility in stormwater ordinances, cities and counties should make sure that the BMP requirements for all projects are established on a "level playing field." Stormwater engineers and planners should compare the costs, the permitting process, and predictability of the BMPs required for development and redevelopment projects. For example, stormwater management programs that rely heavily on infiltration techniques might tilt the playing field in favor of large, dispersed projects on less expensive land. Typically, this land is located farther out in undeveloped reaches of the watershed, where infiltration on a larger scale is already taking place. Even with requirements for infiltration on site, the disturbance that takes place can be a net loss for the watershed. Thus, stormwater and watershed managers may want to assess the balance of requirements and incentives to make sure stormwater rules are not inadvertently pushing development to undeveloped land.

4. Development Districts

Definition

Development districts (or in some cases special zoning districts) are created to achieve comprehensive planning and urban design objectives in a specified area. While the previous subsections reviewed policies for individual sites and smaller projects, development districts are characterized by a larger site area and the need for complex and coordinated rezoning, transportation, and planning efforts. Examples of special zoning districts include transit oriented zoning districts (TOD), business improvement districts (BIDs), new urbanist projects, traditional neighborhood development (TNDs), brownfields redevelopment, and "Main Street" revitalization districts.

Who Do I Talk to About District Plans?

If an area is incorporated, any such district would be found in the city's zoning ordinance. If an area is unincorporated, county zoning applies. In some cases, the zoning regulations carefully delineate the sub-area plans or special districts and show them on a map.

If you are in a county that does not have zoning, or has not yet reviewed zoning codes for redevelopment areas, your locality may have developed special plans for certain areas, for example a BID or "Main Street" redevelopment plan. Check to see if there is a document listing specific policies or planned zoning changes related to development or redevelopment in the district. Many of the policies listed in Subsection 2 (Infill

Development) might be listed and can be included in your SWMP.

Innovations in zoning and building codes have emerged under a variety of names. The Smart Code, TND codes, form-based codes, unified development ordinances (UDOs), and model development codes are examples. These codes may apply to the entire municipality, to new development only, or in the form of an overlay zone. The Congress for New Urbanism has collected examples of various code innovations at <www.cnu.org/pdf/code_catalog_8-1-01.pdf>.

In reviewing codes with your local planning office or economic development department, make sure that the *all* pieces are in place to deliver on the smart growth benefits. For example a unified development ordinance might require sidewalks on both sides of the street; however, if state transportation and local zoning policies result in highly separated uses with mandated turning lanes and wide intersections, pedestrian trips may be reduced, if not eliminated. The stormwater benefits are likewise diminished. Thus, you may need to consult with the zoning and planning office, together with a transportation engineer. If one set of codes supercedes another, you may want to consult with the city or county manager to find flexibility and list all the benefits, including stormwater, that come from a smart growth development district.

Subdivision codes are a common method incorporated and unincorporated communities use to control development. Most subdivision codes establish how many housing units can be built by-right on undeveloped land. Over time, subdivision codes have evolved to control development-related aspects such as street widths, septic requirements, and/or infrastructure planning. Some subdivisions may also be governed under drainage districts, which place limits on impervious surface coverage and map development restrictions in areas of significant drainage flows. In some cases, subdivision requirements will govern the street network and control the number of connections required between the subdivision and surrounding parcels (see Subsection 8, Smart Growth Street Designs for more information). Consult your city or county's engineer or planning office to see if smart growth policies have been added to your subdivision codes.

Photo: www.pedbikeimages.org/Dan Burden

This path allows safe pedestrian and bike passage, but is also designed for access by emergency and service vehicles.

Check to see if your community has formed public/private partnerships or alliances to facilitate planning and implementation for these districts. Also check with a local historical society, the downtown business association, or the local chamber of commerce to see if they are aware of special planning or economic development districts.

Brownfields are properties with real or perceived contamination from prior uses and, in some cases, are classified as districts for the purposes of cleanup, financial incentives, and coordinated redevelopment. Larger brownfields can include former military bases, transportation facilities, and institutions. These large properties are often located in areas near existing transportation and infrastructure. The larger parcels pose opportunities to redesign a development program that includes smart growth features, like multi-modal street design, advantageous use of existing transportation routes, and open space. EPA estimates that for every acre of brownfields redevelopment, 4.5 acres of greenfields can be preserved.[14] Check to see if your community has developed plans for brownfields identification, cleanup and/or development plans. There may be opportunities to design large scale, onsite stormwater handling in areas where the contamination will not be transported after redevelopment has taken place.

Stormwater Benefits

As noted in the previous subsections, special zoning districts can limit overall stormwater runoff by directing development away from greenfields at the urban fringe into existing urban areas. (See Subsections 2, Infill Development, and 3, Redevelopment, for further information on the impacts of encouraging infill.) Coordination of planning, investment, and infrastructure for a district can also result in a more efficient site plan. Development decisions are made at a larger coordinated scale, which can facilitate efficient street layouts, a smaller footprint for parking facilities, and less expensive options for collecting and handling stormwater for the district.

In addition, mixed-use districts can support a wider variety of transportation options, which lessens the impacts of transportation on water quality. Auto emissions have deleterious effects through deposition of exhaust and accumulation of automotive related materials (brake linings and tire tread wear) that are carried into waterways through stormwater runoff.

A 2004 study conducted by Asad J. Khattak and Daniel Rodriguez of the University of North Carolina, Chapel Hill, suggests that households in the neo-traditional development substitute driving trips with walking trips. The study examined differences in travel behavior in a matched pair of neighborhoods (one conventional and one neo-traditional) in Chapel Hill and Carrboro, North Carolina. The survey and study of 453 households suggest that single-family households in the neo-traditional development make a similar number of total trips, but significantly fewer automobile trips, fewer external trips, and shorter trips than households in the conventional neighborhood, even after controlling for demographic characteristics of the households and for resident self-selection.[15] One term that transportation professionals often use to describe trip-making within a set district is "internal capture rate." When urban planners talk about a high internal capture rate for a proposed district, this forecast relates to a higher percentage of multi-modal and/or combined trips within the district. This is something stormwater professionals should look for when evaluating plans.

Paved Area per Dwelling Unit – a Comparison

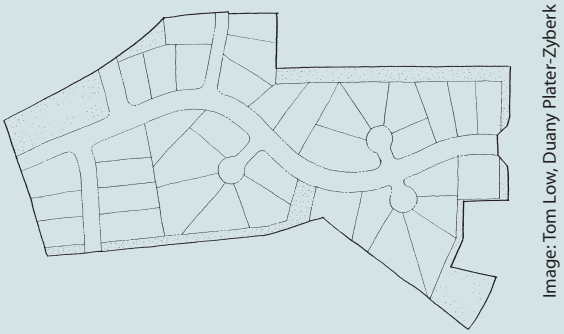

Image: Tom Low, Duany Plater-Zyberk

Conventional Residential Subdivision

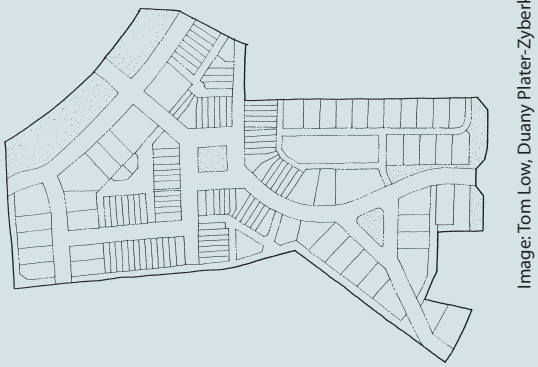

Image: Tom Low, Duany Plater-Zyberk

Mixed Use, Traditional Neighborhood Design

Vermillion is a traditional neighborhood outside Huntersville, North Carolina. The town enacted a TND ordinance to coordinate the approval process for TNDs. The two maps were drawn to compare the TND design and a more conventional, residential-only design.

In the new urbanist street plan, the greater part of the paved areas is taken up by narrow 18 feet roadway widths, whereas the conventional plan relies on wider 30 feet streets. Although the roadway area is higher in the TND plan, the street component per dwelling unit is far less, as indicated in the following tables.

Conventional Design

- 38 single family homes

Street Width (feet)	Street Length (feet)	Street Imperviousness (ft^2)
18	275	4,950
24	350	8,400
30	2111	63,330
		76,680
76,680/38 dwellings = 2,018 square feet street imperviousness/dwelling unit		

Traditional Neighborhood Design

- 40 single family homes
- 16 studio apartments
- 16 live/work dwellings
- 74 townhouses

Total 146 residential dwelling units

- One office building (4,400 square feet)
- Two medium sized office buildings (30,000 square feet total)
- Three smaller commercial buildings (15,000 square feet total)
- One restaurant (5,000 square feet)
- One church (10,000 square feet)

Street Width (feet)	Street Length (feet)	Street Imperviousness (ft^2)
18	3,270	58,860
24	750	18,000
30	525	15,750
		92,610
92,610/146 dwellings = 634 square feet street imperviousness/dwelling unit		

The analysis did not look at sidewalk lengths, or the street imperviousness related to commercial buildings.[16]

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Development and redevelopment plans that are based on districts might also allow stormwater officials to meet requirements under the Illicit Connection Minimum Control under Phase II. Many large redevelopment parcels are near waterways and offer the potential to correct stormwater and infrastructure problems. Many illicit connections are found in older manufacturing districts, so you may be able to also meet requirements to find and eliminate illicit discharges.

Finally, the stormwater performance of a site is the result of, or enhanced by, the additive effect of several redevelopment policies. For example, in a TOD district, policies to require higher density development are combined with maximum setback rules and reduced parking requirements. All three of these policies work together to support transit use and higher density projects on a smaller development footprint. It is worth noting that under current practice, development districts such as office and industrial parks do not carry these advantages. The dispersed arrangement, large surface parking lots and predominance of a single use (e.g., office only) serve to spread development—and the associated impervious surfaces—out further.

Typical Costs

For the public sector, the cost of planning a special district and setting or revising zoning is the staff time required to research, adopt, and implement the new codes. Some communities hire consultants to help gather and coordinate stakeholder input, draft design alternatives, and create final plans. The range of costs varies. You may be able to tap the expertise of a local university or nonprofit at a lower cost for gathering input and narrowing the scope of items that need the specialized skills of a consultant.

While brownfields redevelopment can be costly, new regulations and programs are in place to assist localities and developers. The variety of activities related to financing and redeveloping brownfields sites is beyond the scope of this publication, but you may have brownfields redevelopment activity underway which you can cite in your stormwater guidance materials. EPA has a comprehensive site on how to remediate, market, and develop brownfields sites at <www.epa.gov/swerosps/bf/index.html>.

Some communities may already have design manuals in place for transit districts, TNDs, or new urbanist communities. These can serve as a starting point for developing a joint smart growth/stormwater BMP manual. These manuals typically include detailed information on streets, building envelopes, the use mix, and transportation connections. Stormwater, zoning, and planning departments may be able to cost-effectively create a BMP manual for development districts from work that has already been completed. For example, a stormwater engineer could take the city's manual on TND and insert information on siting stormwater handling facilities within the TND, on using water features for stormwater control, and sizing criteria for various BMPs and performance criteria at the site and neighborhood scales.

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Measurable Goals

For a jurisdiction without comprehensive zoning for development districts, a short-term goal could include adoption of a special district ordinance. For a jurisdiction that already has special zoning districts in place, goals would depend on the type of ordinance adopted. For jurisdictions with TOD zoning, a goal might be to raise the percentage of new development built in already-developed areas by a certain percent over a specified time period. If detailed information is available on transit use, one can estimate the reduction in automobile-related deposition and runoff pollution.

As listed above, communities may also want to estimate stormwater performance of smart growth projects not only on the site level, but on the watershed or regional level as well. Redevelopment of an entirely developed site basically results in no net increase in stormwater at the local level, but also absorbs development demand that would otherwise result in the addition of impervious cover in an undeveloped portion of the watershed. Subsection 1, Regional Planning gives information on the methods for comparing smart growth and conventional development plans.

Examples

San Diego has launched a "City of Villages" plan to direct development via infill and redevelopment to certain neighborhoods. The planning update and the stormwater management cross-reference the City of Villages infill plan as a water strategy. To see more on the planning efforts, visit <www.sandiego.gov/cityofvillages>. For more on the Urban Runoff Management Plan, visit <www.sandiego.gov/stormwater>.

LEED Neighborhood Design

Check with your zoning or environmental works department to see if your locality has adopted the U.S. Green Building Council's (USGBC's) scorecards. These scorecards, called LEED (for Leadership in Environmental and Energy Design), contain rating systems for development and redevelopment projects. USGBC is developing a new scorecard called LEED Neighborhood Design – or LEED ND. This scorecard includes not only green aspects of individual buildings, but of their location as well. Thus, the scorecard takes into consideration the smart growth principles based on transportation options, a mix of housing types, and connections to the broader community. LEED scorecards, including LEED ND, include rating points for how the project or district handles stormwater, and might provide a template for measuring your locality's performance under NPDES. For more information on the LEED scorecards, visit <www.usgbc.org/leed/leed_main.asp>.

An example of creative stormwater financing comes from **Elm Grove, Wisconsin**. Flooding has been a significant problem for the city—in particular, for the downtown area. In 2001, the city developed an economic development plan for the downtown, with a focus on reducing the flooding. To address the flooding issue, the city has developed a stormwater mitigation plan with many elements, including restoration of concrete-lined creeks to their natural state, improving stormwater retention areas and redesigning the city's park with water control in mind. Because the flood management plan is expected to reduce the size of the 100-year floodplain, properties that are no longer in the floodplain as a result of the improvements will increase in value. The town is

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creating a TIF district to capture this value, and invest in the targeted stormwater improvements. The town is also creating a stormwater utility because the monies raised through the TIF are not expected to cover the costs of all of the needed improvements. The town is coordinating the water planning with the revised Master Plan for its downtown, which will include retaining a small town feel, creating a pedestrian friendly environment, and incentivizing redevelopment in the downtown area. For more information, visit <www.elmgrovewi.org>.

The Trust for Historic Preservation sponsors the Main Street Program to spur investment in older downtowns. Enterprise Zones and Elm Street Programs are other programs established to attract investment to older downtowns. These programs are evidence of growing interest in historic areas and what they offer, such as unique older buildings, a walkable layout, and economic potential. Stormwater professionals should look to these programs in their communities as a way to manage stormwater runoff within their watersheds. To learn about the specific policies and programs, visit <www.mainstreet.org>.

The **Mountain View, California**, transit station, called The Crossings, is an example of how redevelopment of a greyfields site into a transit district can include better stormwater management. Prior to redevelopment, the 16-acre site was 98 percent impervious cover and home to an underperforming shopping mall. Because the California Department of Transportation planned to build a commuter rail station immediately adjacent to the site, the city of Mountain View envisioned making the station a success through a higher density and mixed-use development program. As redevelopment occurred, planners were able to build in onsite handling of stormwater for more than 45 percent of the site. Open spaces designed to absorb water are complemented by compact building sites, a grid of narrow streets and a space-efficient parking plan. For this and other case studies, visit the Natural Resources Defense Council's "Stormwater Strategies" at <www.nrdc.org/water/pollution/storm/stoinx.asp>.

More information on the transportation and land use performance of the station area in Mountain View can be found at <transitorienteddevelopment.dot.ca.gov>; follow the links to "The Crossings."

Points to Consider

One type of special district that requires particular attention is the use of impervious surface coverage districts. Impervious surface zoning districts generally set maximum ratios on the amount of impervious surface within a zone or, more commonly, on a parcel. For example, an ordinance might state that no more than 20 percent of a lot may be covered with impervious surfaces such as rooftops, driveways, or accessory buildings. Often, the purpose behind impervious surface districts

Photo: EPA

A mixed-use district is used at The Crossings, in Mountain View, California.

is based on studies that show watershed decline begins once impervious surface coverage exceeds 10 percent.[17] The 10-percent figure has been applied to the individual site level within the watershed, suggesting that limiting development to lower densities that only cover a portion of the site will translate across the watershed to more pervious surfaces for stormwater control and preserved ecological function.

However, application of an impervious surface district on a parcel-by-parcel basis, might not help meet stormwater objectives, and in fact, might result in worsened water quality, particularly on a watershed scale. The following are points to consider regarding impervious surface districts that apply only to the site level:

Impervious surface ordinances consider only site cover, not the ultimate goal of reducing stormwater runoff volumes: For example, suppose a homeowner would like to build an addition to his/her house, which is located in an older urban area that the city has designated for economic redevelopment. The homeowner also would like to disconnect the downspouts and develop a rain garden and other features to handle all of the stormwater on site. An impervious surface code, read strictly, would prohibit that homeowner from building the addition, even though the homeowner would improve stormwater management on the lot. The impervious surface district has the effect of creating a low-density district, which may run counter to a community's wish to accommodate more density in certain neighborhoods to make use of transit, foster redevelopment, or respond to market demand.

Much of the "pervious" surface in low-density development acts like impervious surface for handling stormwater: Development practices can involve wholesale grading of a site, removal of topsoil, severe erosion during construction, compaction by heavy equipment, and filling of depressions. Research now shows that the runoff from highly compacted lawns is almost as high as runoff from paved surfaces.[18] The turfgrass planted in a typical new residential project does little to reverse the impacts to the soil by construction. Further, turfgrasses have shallow roots that do not provide the same soil anchoring, water uptake, and other ecological processes as deep-rooted native grasses and plants.

Low-density developments tend to be accompanied by more offsite impervious infrastructure: Development in a watershed is not simply the sum of the parcels within it. Rather, total impervious area in a watershed is the sum of site developments plus all of the infrastructure (e.g., water utility, transportation) supporting those sites. For example, the hard cover of a parking space with dimensions of 18 feet by 9 feet is not the only imperviousness associated with that space. Drive or access aisles are also typically coded into parking standards; a parking lot with 90-degree parking typically is served by a 24-foot drive aisle that spans the length of the parking lot and ties into other access lanes. Additionally, many modern street codes require additional lanes for turning, deceleration, and service lanes. An impervious surface coverage district that considers only development of individual sites might miss much of the impervious surface that is leading to degradation of water quality in the entire watershed.

Growth is coming to the region; limiting density on a given site doesn't eliminate that growth. Density limits are responses to—and attempts to manage—growth: Yet these limits do not, in fact, manage growth; they only manage the growth on the density-limited area. The rest of the growth that was going to come to the region still comes, but spreads throughout or across the watershed.

From a water resource protection perspective, defining the balance of developed areas and open space requires a broader look at watershed management, rather than limits on a parcel-by-parcel basis. A first step is to plan for strategic preservation of continuous tracts of open space. Second, preservation of critical ecological areas such as riparian corridors, stream buffers, flood plains, and wetlands is needed. These parcels are of critical importance in developed areas to absorb and filter stormwater. Third, for land that is to be developed, smart growth strategies such as higher density and more compact development serve to disturb less land and accommodate more development. As mentioned elsewhere in this publication, redevelopment sites are particularly attractive when considering development and stormwater mitigation options since they use already-developed sites and are likely to use existing infrastructure.

There is a spirited debate about the performance of impervious surface limitations and how they should be structured to achieve the intended water quality goals. One result of the debate is a better focus on comprehensive strategies needed in a watershed. Organizations like the Center for Watershed Protection <www.cwp.org> and Project NEMO's research division <nemo.uconn.edu/impervious_surfaces/index.htm> are fine-tuning the mapping, measurement, and characterization of impervious surface coverage and the relationship to water quality.

If an impervious surface special district is in your plan, one suggestion is to make sure the program looks at a watershed scale and the individual parcel, and includes all supporting impervious surfaces in the watershed. Another strategy involves modifying or eliminating the coverage limitations for certain districts to which you want to direct growth. You may want to conduct a survey of imperviousness per unit of development for conventional and smart growth plans. Impervious surface limitations may make sense in one part of the watershed (for example in headwater areas) or when applied watershed wide, but only when carefully reviewed with other subwatershed and subareas plans where redevelopment and development is desired.

If your locality has a smart growth plan, make sure your impervious surface zoning does not act as a barrier to that plan. If your plan calls for higher density in certain districts, such as TOD districts and downtown redevelopment areas, then your impervious surface district should have enough flexibility to allow such density. Many areas are exploring the possibility of trading systems that coordinate development and preservation efforts. Trading programs might be found within a total maximum daily load (TMDL) program, for trading of impervious surfaces on a watershed-wide basis, or through a "payment in lieu of" program for installing BMPs. EPA has launched efforts to facilitate trading as a way to improve water quality. To learn more about EPA policy and the steps involved in establishing a trading program, visit <www.epa.gov/OWOW/watershed/trading.htm>.

TMDLs, Stormwater, and Smart Growth

Across the country, more than 40 percent of waterways are impaired by pollutants, sediment, temperature (typically heat), and nutrients. These waterways can be stream segments, bays, estuaries, and lakes. Once a waterway is listed as an impaired waterbody, localities are responsible for developing a "budget" for how much of a pollutant load the waterbody can experience. This budget is referred to as a TMDL, or total maximum daily load. A process typically follows to identify major sources (e.g., agriculture, urban runoff) and allocate a portion of the pollutant load to each source. The goal of a TMDL program is to restore a waterway by reducing pollutant sources. Thus, sources often face reductions in how much pollutant they contribute.

Stormwater can be a major contributor to impairments due to the heat, nutrients, metals, and other pollutants carried in runoff. Thus, reducing stormwater runoff in areas with impaired waterbodies is often at the center of the TMDL process.

As discussed throughout this document, smart growth techniques can help prevent and/or reduce stormwater volume and the pollutants carried within the runoff. In other words, smart growth can offer load reductions. By encouraging designs with lower impacts, the locality has taken steps not only to lessen development's effect related to transportation and infiltration, but also to provide an incremental reduction in the pollutant load from stormwater discharges. Though not required, some states and localities are including budgets within TMDLs for future growth. Communities that adopt growth management strategies that encourage smart growth and discourage sprawl are in a better position to control pollutant loadings from stormwater discharges, soil erosion, wastewater treatment systems, and many other sources of pollutants.

Some states have expressed concern that implementation of TMDLs could impede smart growth strategies because TMDLs will prohibit additional sources, which is assumed to be a prohibition on redevelopment and infill for urban areas. The fear is that developers will be inclined to focus their proposals on "greenfields" on the urban fringe, where TMDLs are not in place. Consider, however, that (1) many vacant and unused properties in urban cores already are largely impervious as a result of paving and soil compaction, so putting new buildings on these sites is unlikely to make runoff outcomes worse, (2) as described elsewhere in this publication, green building and site design options present the potential for actually reducing runoff volume and pollutant loadings from infill and redevelopment sites, and (3) greenfields development projects commonly have their own stormwater requirements so that a developer of any site will need to think about appropriate controls.

Photo: NRCS

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5. Tree and Canopy Programs

Definition

Urban forestry programs are not typically considered stand-alone smart growth policies; however, tree programs are increasingly appearing as elements of larger urban design plans for landscaping or aesthetic purposes. In addition, tree policies are evolving to include abatement of urban heat island effects, or as part of transportation plans to improve the pedestrian environment. There are different types of plans and ordinances, from those that protect historically significant trees to tree planting programs. Street tree ordinances generally cover the planting and removal of trees within the public right-of-way.

These new urban forestry policies are also evolving to target tree canopy and shade cover, rather than policies that focus on numbers of individual trees. In other communities, trees are becoming part of the "public utility" as new methods are developed to measure and account for the environmental attributes of mature trees. The "utility" approach also recognizes that trees, like power lines and pipes, require maintenance and have costs associated with that maintenance. Whether it's the pedestrian environment, aesthetics, or air quality, the result of an effective urban forestry policy translates into stormwater benefits.

Who Do I Talk to About Tree and Canopy Programs?

Tree ordinances are typically overseen by public works departments or departments of environmental quality; however, also check with your local extension agent. The International Society of Arboriculture has a Web site describing the development, implementation, and evaluation of tree ordinances; go to <www.isa-arbor.com> and type "ordinances" into the site's search engine. Scenic America also lists a model tree ordinance, at <www.scenic.org>. American Forests' Web site at <www.americanforests.org> tracks tree policies and ordinances, as well as innovations in technology, research, and non-regulatory methods for supporting urban forestry.

Stormwater Benefits

A well maintained tree canopy can provide a variety of environmental benefits. Trees provide erosion control and help reduce the costs of structural stormwater management, including land acquisition costs and construction of stormwater retention facilities. Strategically preserving or planting trees along urban rivers, streams, and creeks can reduce water temperatures. Increased temperatures affect certain native aquatic species, can increase nuisance algae populations, and impact commercial activities that rely on stable water temperatures for recreation, industrial use, or aesthetics. Tree canopy intercepts rainwater, which provides for gradual release of rainwater into streams, thereby preventing flooding, filtering toxins and impurities, and extending water availability into dry months when it is most needed.

Examples from selected cities include:

- At a south **Miami** residential study site the existing tree canopy reduces stormwater runoff by 15 percent.[19]

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Photo: www.pedbikeimages.org/Dan Burden

On-street parking can be coupled with tree wells in a downtown setting.

- In **Milwaukee**, the existing tree canopy cover reduces stormwater flow by up to 22 percent and provides the city an estimated $15.4 million in benefits. On average, trees in Milwaukee sample sites reduced total stormwater runoff volume by 5.5 percent and reduce peak flow by 9.4 percent. At the residential study site, the 42 percent existing tree canopy reduces stormwater runoff by 22 percent. If all trees in the Milwaukee study were removed, the additional stormwater flow would be enough to require the construction of an estimated 357,083 cubic feet of retention capacity valued at approximately $15.4 million.

For information on other environmental benefits from trees, visit <www.treesatlanta.org>.

Typical Costs

Tree programs and ordinances have costs mainly associated with development, implementation, and enforcement. Maintenance of older trees can be expensive, particularly since the goal of your program is to nurture trees to maturity for maximum stormwater benefit. When these costs are considered as part of a community's stormwater infrastructure, however, they may prove worthwhile when compared to other water control expenses. Garland, Texas, used American Forests' software package CITYGreen to measure the cost savings associated with its tree canopy. Garland's trees provide 19 million cubic feet in avoided storage (for the average maximum two-year 24-hour storm event). The city estimated that it saves $2.8 million annually, calculating the cost of construction funding over the 30-year life of a facility.[20]

Measurable Goals

Short-term goals can include the establishment of a tree program that tracks the number of trees that have been saved or the number of trees planted in your jurisdiction.

As noted previously, maximum stormwater benefits come from tree canopy cover. Urban forest groups have established the environmental performance of tree cover. Software programs can help establish your baseline tree canopy and estimate the dollar value of the services provided to a community by its tree cover. Establishing a baseline and tracking cover with a software package can translate into numeric expressions of stormwater performance. For more information on one such program CITYGreen, visit <www.americanforests.org/download.php?file=/graytogreen/stormwater.pdf>.

Examples

The U.S. Department of Agriculture's **U.S. Forest Service–Southern Region** maintains information on trees and tree cover, including research, PowerPoint presentations, and model tree programs at <www.urbanforestrysouth.org>.

The **City of Roanoke, Virginia**, used CITYGreen to measure cost savings associated with its tree canopy. Roanoke's 32 percent tree canopy provides 64 million cubic feet in stormwater retention capacity, valued at $128 million (based on construction costs estimate at $2 per cubic foot). Based on the study results, the city council passed a 40 percent tree canopy goal as part of the city's comprehensive plan.

Points to Consider

Different trees have different absorption rates, growing condition needs, growth rates and life spans. Consult an arborist to determine which trees will suit the needs of your community. In the Pacific Northwest, Metro (Portland Oregon's regional government) has published a guide to the stormwater benefits associated with different trees. For specific interception rates for different types of trees and analysis of the benefits of different tree species, see *Trees for Green Streets: An Illustrated Guide*, (order from <www.metro-region.org/article.cfm?articleid=263>). Note that many climates in the United States are too arid to support a full canopy; these areas can use xeriscaping and other landscaping means to control runoff. Additionally, deciduous trees are far less effective at capturing stormwater once they shed their leaves in the winter.

When developing a tree ordinance, clearly outline your goals, methods of coordination and enforcement, and evaluation procedures. At least one tree ordinance has been successfully challenged in court as unenforceable by a developer because the language was too vague. In 1999, a Fulton County Superior Court Judge ruled in favor of developer against the city of Atlanta because a section of the city's tree ordinance lacked "sufficient" objective standards.

If you include urban forestry in your stormwater program as a BMP, think long term about maintenance requirements and be creative in finding funds for maintenance. If there are funds dedicated to funding all types of stormwater BMP maintenance, consider using these funds for tree pruning, tree care, and replacement programs. The state of Pennsylvania has proposed a BMP maintenance program that allows developers to pay a fee to cover maintenance for 10 years. For urban forestry programs, this can be an effective funding mechanism for getting a tree program started.

Photo: NRCS

Students at an elementary school in Des Moines, Iowa, plant a tree during Arbor Day celebrations.

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6. Parking Policies to Reduce Number of Spaces Needed

Definition

Parking lots are one of the more visible aspects of imperviousness within the built landscape, and managing stormwater through better parking lot design is contained in many of EPA's guidance documents on improving water quality. Retrofitting parking lots is emerging as a popular BMP; however, an equally effective approach is to reduce the footprint associated with parking spaces before they are actually built. Thus a parking policy that updates land development standards and zoning codes to reduce the parking footprint is a BMP.

This subsection looks at two broad techniques for reducing the amount of imperviousness associated with parking:

Photo: www.pedbikeimages.org/Dan Burden

This streetscape design ties together retail activity, landscaping and parking. Tree grates were designed to capture water and provide shade while also providing easy access for pedestrians and motorists as they exit the parking area along the street.

- **Structured parking**: Instead of surface lots, parking can be provided in garages. The same number of spaces can thus be provided on considerably less land. While parking can also be provided below grade, for most areas this is prohibitively expensive. Therefore, this subsection will discuss items mainly related to structured parking.
- **Reductions in number of spaces**: Reducing the number of parking spaces involves two main techniques:

  1) Reduce parking requirements which mandate a certain amount of parking. These requirements often require too many spaces but can be retooled to reduce spaces, provide flexibility for TOD, or change from minimum to maximum ratios.

  2) Encourage shared parking, by which users of two nearby facilities can share the same parking spaces at different times. For example, a church, which generally needs parking on Sunday mornings could share parking spaces with a movie theater, which needs parking spaces in the evenings. Shared parking can also apply to better use of on-street parking spaces.

This section does not include information on retrofitting parking lots with infiltration strips and landscaping since the focus is on the sizing and footprints for parking. There are links in the "Resources" section to more information on using infiltration techniques on new and existing parking lots.

Who Do I Talk to About Parking Plans and Requirements?

In general, parking requirements are contained in land use and zoning documents, and are typically expressed as minimum numbers of spaces per unit of development. They may be in plans held in the department of public works or in the office of planning. On-street parking is typically governed within the local traffic engineering office or in the department of public works. There are various types of parking and policies related to parking as discussed below.

Parking Requirements: Most zoning codes have detailed specifications of parking requirements by use (e.g., a commercial district may specify four parking spaces per 1000 ft^2 of office space). A residential district may require two off-street spaces per unit. Within a district, there may be further parking specification by use; for example, for a church or for fast food restaurants. Localities enacting smart growth plans are changing their parking standards in recognition that fewer spaces are needed when there are transportation options and a mix of uses. They are also changing policies to permit more flexible programs. For example, some jurisdictions are beginning to use maximum parking requirements instead of minimums. Review the parking requirements in your zoning codes, within special use permits, and in parking guidelines and stormwater ordinances that may serve as a barrier to flexibility. For example, language might require a business to satisfy its parking requirements within 400 feet and reserve parking only for that business. This could prohibit shared parking, as discussed below.

Photo: EPA

Transforming parallel spaces to diagonal ones on this wide retail street increases the amount of parking without adding impervious surface.

Parking Overlay Districts: Overlay districts introduce new requirements. Parking overlays are good for transit districts, where policies are needed to support several modes of travel. For example, a TOD district may have a parking overlay that reduces the number of spaces needed based on proximity to a transit stop. Combining a parking overlay district with complimentary policies, such as shared parking agreements among several building owners, can help to balance demand for spaces throughout the day in a parking overlay district. In this case of TOD districts, you may need to also consult the transit agency.

On-Street Parking: One of the most overlooked resources for parking is one that already exists—use of the street. There are a variety of management techniques to help use this resource, such as meters, permit parking and angled parking. These spaces

Photo: City of Boulder, Colorado

In Boulder, Colorado, downtown developers are discouraged from building parking for individual projects. Instead, they pay a parking and transportation in-lieu fee. These fees are then used to build public garages, as well as to fund transit, bicycle, and pedestrian improvements.

can be governed by the Public Works departments, or by a special parking office.

Site Plan Conditions or Proffers: If your jurisdiction negotiates site-specific development requirements, check the office that oversees site plan conditions or proffers. Often the number and location of parking spaces is a negotiated element on a project-by-project basis.

Structured parking: Structured parking can either be a multi-level lot or underground parking. Because of the expense involved, structured parking typically occurs in downtown areas, districts with higher densities, or near arenas and stadiums.

Shared parking: Some shared parking plans may be drawn by local redevelopment organizations or business improvement districts, or by large institutions like universities or hospitals. In larger cities, private parking companies may also exist, so check with them as you gather information on opportunities to improve parking policies.

Parking Pricing: Parking pricing introduces a fee for parking. Pricing typically serves as a transportation demand strategy (to reduce vehicle use), a parking management strategy (to reduce problems in specific locations), and/or as a means to raise money for parking and other projects.

Determining how much parking to provide for retail, offices and residential areas is a balancing act to make sure there is enough parking to support the range of intended uses, but not so much as to undermine good community design and stormwater improvements. As shown in Table 3, the decision on how many spaces to provide is more often than not tilted toward an oversupply.

Stormwater Benefits

Reducing the amount of surface parking reduces the quantity, speed, and impurities of the runoff. For example, one researcher calculated that a one-inch rainstorm on a one-acre meadow would produce 218 cubic feet of runoff, while a parking lot the same size would produce 3,460 cubic feet.[21] Among the pollutants that accumulate on parking lots are cadmium, copper, lead, zinc, nickel, cobalt, and iron, which are found in gasoline, grease and oils, antifreeze, brake linings, and rubber.

Under most parking standards, the number of spaces required is often dictated by times of "peak use," such as holiday shopping, which tends to be heavier than at other times

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Table 3: Conventional Minimum Parking Ratios

Land Use	Parking Requirement		Actual Average Parking Demand
	Parking Ratio	Typical Range	
Single family homes	2 spaces per dwelling unit	1.5 - 2.5	1.11 spaces per dwelling unit
Shopping center	5 spaces per 1000 ft^2 GFA	4.0 - 6.5	3.97 per 1000 ft^2 GFA
Convenience store	3.3 spaces per 1000 ft^2 GFA	2.0 - 10.0	--
Industrial	1 space per 1000 ft^2 GFA	0.5 - 2.0	1.48 per 1000 ft^2 GFA
Medical/dental office	5.7 spaces per 1000 ft^2 GFA	4.5 - 10.0	4.11 per 1000 ft^2 GFA
GFA: Gross floor area of a building without storage or utility spaces			

Source: *Parking Generation, 2nd edition*. Institute of Transportation Engineers, Washington, DC. 1987; Smith, Thomas. *Flexible Parking Requirements*. Planning Advisory Service Report No. 377. American Planning Association, Chicago, IL. 40 pp. 1984; Wells, Cedar. Impervious Surface Reduction Technical Study. Draft Report. City of Olympia Public Works Department. Washington Department of Ecology, Olympia, WA. 1994.

of year. By reducing the number of spaces and integrating flexibility to handle peaks, there can be an overall reduction in the amount of impervious surface.

In 1993, the city of Olympia, Washington, launched its impervious surface reduction study to simultaneously address water quality concerns and a growing population. As part of this larger study, the city conducted a comprehensive study of parking. The city found that, on average, 53 percent of commercial sites were taken up by parking lots. As part of the impervious surface reduction study, the researchers studied the feasibility of reducing commercial parking. They found that, while business owners did not think they provided too much parking, the typical occupancy rate in parking lots was only 46 to 67 percent. Eighteen of 31 representative sites had less than 75 percent occupancy rates during the busiest peak hours surveyed. The city also calculated that during a two-year rain event (2.8 inches in 24 hours), approximately 38 cubic feet of runoff would be generated by a 9-foot by 18.5-foot surface parking space (not including drive aisles and turn lanes).[22]

Typical Costs

Surface vs. structured parking: For a given parcel of land, structured parking is always more expensive than surface parking. According to one industry estimate, construction costs for parking spaces range from $1,500 to $1,800 per space for surface parking, and from $12,000 to $20,000 for structured parking (costs in 2000 dollars).[23]

Parking requirements: Although there is no hard cost to changing parking requirements, municipalities will need to devote staff time or resources to hire a consultant to write new

Photo: EPA

In Saint Louis, Missouri, rush hour lanes along a main arterial are converted to diagonal parking on Sunday for nearby churches. This system allows many more cars to use on-street parking for the limited hours on Sunday when demand for spaces is high and traffic volumes are less than that generated on weekdays during rush hour.

parking ordinances. If a locality wants to add more on-street metered parking, there are supply and administrative costs, though these can be offset by meter revenue. Note that some localities are using meter revenue to support the costs of planning and supporting parking for downtown and retail districts.

Shared parking: In situations that lend themselves to shared parking, there are two main costs to making it happen. First, the parties involved generally draw up an agreement, which may present costs in terms of researching what to include and legal fees. Second, ongoing maintenance costs must be divided. Providing on-street parking makes use of an asset that is technically paid for and shared, and thus adds no additional cost to the developer or user. In addition, supplying parking in a lot requires more impervious surface to provide drive aisles, entrances and ramps. On-street parking does not require this extra infrastructure, thus lowering the amount of land, and thus cost, to provide parking.

Measurable Goals

One quantifiable goal could be reducing the amount of parking in new developments or redevelopment projects; for example, reducing the percentage of surface parking in new developments' footprints by 5 percent. Another measurable goal could include changing ordinances to require maximum parking ratios instead of minimum ratios, adjusting downward the number of spaces used in a locality's standards for parking, and encouraging the use of shared parking.

Another measurable goal could be a surface lot replacement program. Where excess capacity is identified, the city can assess which lots are candidates for infill and which lots could be retrofitted with infiltration techniques. The decisions will likely be based on development trends, water quality goals and the availability of incentives. As with the discussion on infill and redevelopment, characterizing the performance should be conducted on a site, neighborhood, and watershed scale.

Examples

Surface vs. structured parking: Montgomery County, Maryland, contains four parking districts around rail stations. Special taxes are levied on development within the districts, and the zoning ordinance encourages structured parking by exempting parking garages from those taxes.

On-street Parking: In **Arlington County, Virginia**, the redevelopment plan for Columbia Pike places minimum requirements for providing public parking and maximums for the provision of private parking. A developer may pay an "in lieu of fee" if the parcel is too small to meet the standards. One innovative aspect of the plan is the ability to count adjacent on-street public spaces toward the parking requirement. The parking plan also includes a focus on centralized, shared parking that will create a "park once; then walk" environment for visitors who choose to drive.

Santa Rosa, California, is conducting a parking project in its downtown area with "back-in" diagonal parking. In the pilot phase, 22 spaces replaced 15 parallel on-street spaces. With these spaces, motorists traveling along a street would drive past a diagonal parking space and then back into it. This layout makes easing back into traffic safer, since the motorist can see oncoming traffic and bicyclists.

Parking requirements: A number of **California** jurisdictions have innovative parking requirements that effectively reduce the number of spaces required for residential development. For example, San Diego allows housing built in a transit-intensive area or designated for low-income residents to have 0.25 fewer spaces per unit. Sunnyvale allows 0.3 or 0.4 fewer spaces per unit if parking is unassigned (as opposed to available in private garages). Concord allows developers to request a variance from existing codes if housing will be occupied by seniors or disabled persons.

San Antonio, Texas, has both minimum and maximum parking requirements. For example, most retail uses must provide at least one space for each 300 square feet of gross floor area, but no more than one space per 200 square feet. In addition, structured parking and lots paved with pervious materials are exempted from maximums, providing an incentive for developers to reduce parking impacts.

The **University of Washington** has initiated a pay-per-use parking program that replaces monthly parking passes with a per-hour fee. University employees are electronically charged each time they park rather than paying a flat monthly fee. Users also receive a free bus pass and Flexcar membership.

Shared parking: The city of **Tualatin, Oregon**, granted a 25-percent reduction in parking spaces required by mixed-use development Tualatin Commons in return for shared parking.

Points to Consider

Once you have decided on new parking strategies like the ones outlined in this subsection, an important consideration is what to do with the land that is no longer dedicated to parking spaces. Water quality specialists might think the most obvious choice is to dedicate the land to absorbent open space. However, this open space may serve to scatter development and result in unwalkable "office parks." From a redevelopment position, the obvious answer might be to fill it up with development, though this action could eliminate options for handling more water on site. The answer will depend on your community's goals and site constraints.

Good urban planning will consider a compact form that addresses stormwater, a walkable and viable development program, and how people move in and around the site.

Surface vs. structured parking: Structured parking incentives can be coupled with parking regulations that allow a maximum parking footprint (or impervious area) per residential unit.

Parking requirements: Many neighborhoods oppose reducing parking requirements under the assumption that this will result in more commercial "spillover" parking in the neighborhoods. Some jurisdictions have adopted "zone" parking that only allows residents to park on streets in the affected neighborhood. These zones can be limited to rush hours or 24 hours if the neighborhoods are experiencing severe spillover pressure for parking. In addition, developers might wish to reduce the number of spaces they are required to supply, but feel pressure from their financial backers to oversupply parking. An ample supply of parking is often viewed as a necessity for financial success or the ability to sell the property in the future. As the Washington State study shows, this view may overlook the financial penalty that comes with building spaces that ultimately are rarely (or ever) used.

Shared parking: Although there are many potential instances in which shared parking can be used, there are several reasons why it is not as common as it might be. First, if the uses do not share a common property manager, they need formal or informal agreements to share parking. Second, they may not agree on whose responsibility it will be to maintain parking lots. Third, many business owners worry that their customers will stop patronizing them if they do not perceive that parking is adequate. Fourth, developers may fear that businesses will be less likely to lease their space or residents less likely to live there if they perceive the parking supply to be inadequate.

To overcome these problems, local jurisdictions can draw up shared parking guidelines to get the business community behind such plans. To see what a model shared parking agreement looks like, go to Metro-Portland's *Shared Parking Handbook* at <www.metro-region.org/article.cfm?articleid=435>.

Car sharing: Car sharing has emerged as a viable transportation option in many areas. Car sharing works best in urban environments that have a fairly high density of residential units (so that there are enough potential members to use the service) and other transportation options, such as transit and the ability to make pedestrian trips. Most of these cities were covered under Phase I of NPDES, but university towns developing plans and ordinances under Phase II might be good candidates for introducing a car sharing program. The Car Sharing Network publishes an updated list of all cities where car sharing is underway at <www.carsharing.net/where.html>.

The company Flexcar has studied the issue and estimates one shared car can take up to six cars off of the road (see <www.flexcar.com/vision/impact.asp>). The stormwater benefits are achieved when one car can be used to meet the needs of several drivers. These benefits include reduced demand for parking and car storage, as well as a reduction in automobile-related deposition on roads that can pollute runoff.

"**Green Parking:**" New technologies for pervious pavers and porous pavement are advancing rapidly. This technology is particularly attractive for low traffic areas and for spillover parking needed for athletic events, churches, fairs, and episodic activities. Replacing existing impervious cover for parking with pervious pavers has appeal and can provide water quality improvements where urban runoff is a main contributor to water quality problems. Replacing existing parking spaces with green technology and materials can help abate stormwater runoff and the pollutants carried in that runoff.

Green parking materials may not, however, lessen all of the environmental effects related to excess parking. Decisions on the total transportation system will be made to consider road design, number of turning lanes, drive aisles, and parking. In areas where your local transportation department is trying to balance transportation choices, the addition of new spaces, no matter the material, may work at cross purposes with smart growth plans aimed at making pedestrian trips as attractive as driving. In addition, green pavers require periodic maintenance. Fine debris and dirt accumulate in the drainage openings and reduce the pavement's flow capacity. It is natural for settling and clogging to occur over time, so maintenance schedules require vacuum sweeping several times per year.[24] When adopting policies for green pavement and materials, review the overall development design and transportation goals to find the right incentives or program for emerging technologies related to parking.

7. "Fix It First" Infrastructure Policies

Definition

"Fix It First" infrastructure policies place spending priorities on repair of existing infrastructure over installation of new infrastructure. Generally these refer to transportation infrastructure (e.g., roads, bridges, and rail systems) and water infrastructure (e.g., sewers and drinking water treatment/distribution), but may also apply to use of existing schools or other public buildings.

Who Do I Talk to About "Fix It First" Policies?

The first stop in any discussion about infrastructure is typically the public works department or city/county engineer, though your inquiries may be specific to a certain type of infrastructure.

Transportation: Your local public works department generally has a division devoted to streets, which would have information on projects underway or that are in the last stages of planning. The public works director or city/county manager might also know

Photo: Dan Burden

Reducing the amount of stormwater that enter curbs and gutters can be an effective means of lessening the effects of urban form on local waterways.

whether your locality has a framework for how transportation budgets are allocated for new construction and repair. On a regional level, the MPO or regional planning agency has knowledge of large-scale transportation planning and projects. MPOs are regional multi-jurisdictional organizations created for areas with a population greater than 50,000. They are mandated to make transportation spending decisions for metropolitan areas over 250,000 in population and would have information on any regional or state policies that prescribe funding priorities and allocation. At the state level, the department of transportation would have information on any such policies, though departments of community affairs or smart growth offices may have the most comprehensive information on statewide "Fix It First" policies.

Water: On a local level, the responsibility over water infrastructure (e.g., drinking water and sewer service) is typically shared by the local government and water utilities. New infrastructure, increases in capacity, and larger repairs are typically included in Capital Improvement budgets. Once installed, water utilities cover operation and maintenance for treatment plants and conveyance systems. Local and county governments often have the most control over the extension of water and sewer service into new development areas. These extensions can be governed by annexation rules, interlocal agreements among cities and counties, planning documents, or can be made on a case-by-case basis. You may need to talk to someone in the planning office to see how extensions and prioritization of repair decisions are governed.

Increasingly, infrastructure specific to handling stormwater is handled through a stormwater utility, though most funding lies within local capital improvement or operating budgets. Stormwater utilities are discussed in Subsection 9.

Because water infrastructure investments are large, funding might include state and federal money. How those funds are spent can rely on requirements established through a state revolving fund, a state capital improvement project or other programs. Thus, your local water infrastructure manager is likely to refer you to state offices and other Web sites. Further explanations may also be available through the city/county attorney, since the funding requirements are often established in regulations.

In some areas, large water projects may be planned and funded as part of large state and federal projects such as dams, canals and reservoirs. Though not a widespread practice, there are also some private water suppliers and engineering firms that could have control over capital and repair decisions.

Stormwater Benefits

"Fix It First" policies have long-term effects on stormwater management and can be a smart growth technique to encourage infill construction and redevelopment. In addition, "Fix It First" policies encourage replacement of older infrastructure, which can be a significant source of stormwater-related problems, particularly in older urban and suburban areas. In particular, sewer overflows during wet weather events can have severe environmental impacts. Inadequate or degraded sys-

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tems can also increase the chances or severity of property damage from flooding.

"Fix It First" programs also can include new treatment technologies to improve the performance of existing systems. Many people are unaware that most stormwater runoff entering storm drains is not filtered and flows untreated into waterbodies. Oil/grit separators and in-pipe systems can be incorporated into the repair or routine maintenance of storm drains and pipes. For even stronger results, "Fix It First" policies can be coupled with techniques listed in Table 2 on page 23 to handle and filter as much stormwater as possible on individual properties.

Photo: City of Portland, Bureau of Environmental Services

As part of Portland's "Green Streets Program," the city launched the Siskiyou project to add water-absorbing curb extensions. These vegetated extensions intercept some of the stormwater flow before it enters storm sewers. This type of feature can be added as part of a street repair program in older parts of town where a reduction in stormwater flow is needed.

Typical Costs

"Fix It First" policies are built on the assumption that funds for infrastructure are limited and thus rely on shifting spending rather than increasing available funds. The costs are therefore measured in both short-term and long-term impacts, since they shift spending from new infrastructure (new capital spending) to existing infrastructure (repair, operations, and maintenance).

Even in cases where cities are developing strong programs to attract redevelopment, the poor condition of pipes and water handling facilities can be a barrier. The cost to repair water infrastructure around the country has been the subject of discussion and review—in particular, the funding needs to replace aging infrastructure. EPA recently launched a Sustainable Water Infrastructure initiative to complement the traditional funding programs with management techniques to lower costs, add efficiencies to water distribution and treatment systems and use a watershed approach for managing water infrastructure. Localities that are developing or fine-tuning smart growth plans will recognize parallels in this sustainable approach. Common themes include efficient use of land and water resources, a focus on existing infrastructure and investments, and the use of a regional approach to manage resources. See <www.epa.gov/water/infrastructure>.

Measurable Goals

For a jurisdiction that has a "Fix It First" policy, a goal might be to rehabilitate 25 percent of existing water infrastructure, roads, and bridges over a five-year period. A locality could also express goals in terms of linear feet of pipes replaced. For a jurisdiction without such a program, the goal might be to adopt a "Fix It First" policy at the state level.

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Examples

Beaufort County, North Carolina, is part of a multi-county program to reduce nitrogen and phosphorous loadings to the Tar and Pamlico Rivers. The county has submitted a stormwater management plan to the state to meet both state laws governing nutrient reductions and Phase II. Its August 2004 draft stormwater plan includes the opportunity to allow an exemption from nutrient reduction requirements for projects included in redevelopment areas with a "Fix It First" policy. For more information, see <h2o.enr.state.nc.us/nps/TarPamlico_Nutrient_Trading_Program_files/documents/BeaufortPgm8-13-04.doc>.

New Jersey passed legislation in 2000 requiring its Department of Transportation (NJDOT) to reduce the backlog of bridges and pavement needing repair by half over a five-year period. It also forbids construction of new road investments unless approved by a joint resolution of the state legislature. The NJDOT must report annually on its progress in achieving these and other goals. Michigan and Massachusetts have adopted "Fix It First" legislation over the past two years as well.

Sometimes "Fix It First" policies are not explicitly called such, but are embedded in other programs. Directing a percentage of funds to priority spending areas can turn out to be a "Fix It First" policy. Many water utilities also have CMOMs, or "Capacity, Management, Operations and Maintenance" plans. These plans are used to ensure efficient use of water and wastewater distribution systems to ensure adequate baseflow into streams, to avoid overflows, and allocate resources to strained lines and connections in the system. Utility mangers establish policies to direct funding. If you are a developer or work in an economic development department, contact your local utility to see if the budget policies are aligned with your city's redevelopment or economic development plan to direct development to existing activity centers.

Points to Consider

States like New Jersey are finding that smart growth policies to direct development and

Keep Water Out

Even if your storm sewers are not in need of repair, one way to stay off of the "Fix It First" list is to "keep water out." EPA is developing tools to help municipalities lessen the amount of stormwater that flows into combined and separate stormwater systems. The reduced volume of water has many advantages, including a reduction in the risk of overflows, less stress on pipes and conveyance systems, and lowered pollutant loadings.

Some of the management practices to reduce the amount of water flowing into storm sewers are the same as many practices listed in this publication, including the promotion of better site designs and reduction of impervious surfaces, such as lowering the parking standards in your municipality's codes. Portland, Oregon, is a leader in implementing both smart growth and water policies. The city has instituted, among other things, a downspout disconnection program, discounts on stormwater utility bills for homeowners who handle stormwater on site, and a pilot stormwater credit trading program.

Once your "Fix It First" program has completed the investment in new infrastructure, you can prolong the investment by reducing stormwater flows that enter your gray infrastructure.

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redevelopment are complicated by the fact that workable infrastructure is sometimes not in place. This highlights the importance of having infrastructure in place as you implement plans for redevelopment and infill. Implementing a "Fix It First" policy before other policies are in place may help your community realize redevelopment on a more predictable track. Likewise, a strict "Fix It First" policy may have the unintended consequence of prohibiting development in "greenfields" that are desired growth areas. New Jersey recently included language in infrastructure grants to give priority to infrastructure funding in preferred growth areas. A successful joint policy may include the pairing of redevelopment and "Fix It First" programs in order to synchronize public and private smart growth investments.

The redrawing of funding allocations creates redistribution of existing funds (or has the appearance of doing so). Communities might find it helpful to consider the economic and environmental goals of infrastructure policy on a watershed wide basis.

Finally, much of the evolution in thinking on water and stormwater has turned to green infrastructure, or using natural systems to handle stormwater. Green infrastructure need not be isolated to rural or suburban areas, as pointed out in Subsection 5 (Tree and Canopy Programs). States and localities should recognize, however, that policies to prioritize green infrastructure should not come at the expense of fixing aging pipes in areas served by gray infrastructure. Communities may want to seek out where the green and gray infrastructure support each other, or better, where green infrastructure can alleviate stormwater flow into both combined and separated systems.

8. Smart Growth Street Designs

Definition

Smart growth street designs are based on a network of well-connected streets that support multiple modes of transportation. Some smart growth approaches to street design include multiple route choices, alternative street and sidewalk designs, adjusting the vehicular level of service (LOS) and/or creating LOS for other modes of transportation, and designing connected street networks and sidewalks to support multiple uses.

Increasingly, stormwater guidance manuals list "green" techniques to mitigate the runoff from existing streets or those in the preliminary design phase, such as swales and elimination of curbs and gutters. The main emphasis in this section is the underlying street patterns, the connecting of transportation networks and the retrofitting of existing streets for multiple uses. The "Resources" section lists green techniques for streets which may be used to complement your smart growth street plans.

Photo: Anacostia River Business Coalition Washington, DC.

Street and curb designs can be modified so stormwater flows into natural areas for treatment. Grates to handle overflow can reduce the chances of street flooding during heavy wet weather events.

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Who Do I Talk to About Street Designs?

The rules that govern local street designs are most likely to be found at the local level in the public works department or in subdivision guidelines. Check with your department of transportation or planning to find out what policies are in place. In addition, individual developers may develop their own street networks for planned unit developments (PUDs).

For streets that are already in place, there may be opportunities to improve connectivity and make better use of the existing street right-of-way. These may be included in long range comprehensive plans or redevelopment plans. Some of the improvements were listed in the previous subsection on parking. Other plans for streets may also be housed in the department that governs environmental improvements.

Subdivision codes may also have requirements about street design. Where the codes are not explicit about street design, check to see if there are requirements regarding connections to surrounding parcels, streets, or developments. Some jurisdictions require multiple connections, while others may limit the number of connections. For example, a code may require no more than two connections from the subdivision.

State departments of transportation play a role in building or improving state-controlled roads. In many growing areas, smaller highways and rural state roads are the main thoroughfares identified to serve new housing and commercial growth.

Stormwater Benefits

Because streets constitute the largest share of impervious cover in residential developments (about 40 to 50 percent), a shift to narrower streets can result in a 5- to 20-percent overall reduction in impervious area for a typical residential subdivision.[25] As nearly all the pollutants deposited on street surfaces or trapped along curbs are delivered to the storm drain system during storm events, this reduced imperviousness translates into a lower volume of stormwater runoff and pollutant loadings from the development. For stormwater quality factors, residential streets rank as a major source for many pollutants, including sediment, bacteria, nutrients, hydrocarbons, and metals.[26]

Understanding how a connected street network works to control stormwater on a watershed basis requires a review of how roadway design has evolved. Beginning in the 1960s, typical roadway design practices favored a less networked, "hierarchical" street design. This design begins at the lot level, with numerous unconnected streets, in particular for residential areas. Aerial photographs of subdivisions reveal common unconnected layouts, such as "lollipop" designs with cul de sacs, or communities with only one entrance. Within housing subdivisions, the individual, smaller streets feed into collector roads, which then lead, often through only one intersection, to arterials. The arterials (which in some cases are highways) link large, centralized trip generators, such as shopping centers, office parks, and subdivisions. Because there are few alternative routes of travel, the road system is designed to handle the collective flow of travel through key intersections onto other large

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arterials. This road and intersection system features multiple turning lanes, wide intersections, and access lanes designed to minimize congestion with the collected and concentrated flow of traffic. This type of system increases the amount of land needed to handle collected traffic, concentrates traffic onto fewer roads, increases the pressure to widen the roads that handle collected traffic, and creates barriers to travel options, such as pedestrian trips.

Communities developing alternatives for multi-modal networks often turn to the 10 smart growth principles (see page 18) for guidance. The principles of creating walkable neighborhoods, mixing land uses, providing transportation options, directing development to existing communities and taking advantage of compact building design all come into play. The street systems that make this combination of features possible are characterized by multiple connections, as well as appropriately sized streets and intersections to support safe travel for vehicle drivers, bicyclists, and pedestrians. These street patterns can be in grids, but may also include paths and other connections. Although cul-de-sacs and dead-end streets are discouraged, there are a variety of street designs that can provide the slower traffic and privacy that homebuyers prefer, with the connections that help avoid the chokepoints and large feeder routes built into a hierarchical system. For stormwater engineers, the most beneficial point for a watershed lies in the compact form, which facilitates a higher intensity of development and mix of uses on less land.

The stormwater performance of smart growth street systems can be further enhanced by policies to reduce the amount of runoff entering the curbs and gutters, mentioned throughout this document. Likewise, developers and landscape architects can plan for intermittent retention areas to collect and treat some of the road runoff prior to discharge into a storm sewer system.

Finally, the notion of better stormwater management related to a tighter, connected network of streets with sidewalks may seem counterintuitive. Most literature on water quality highlights the detrimental effect of "connected impervious surfaces." Most efficient urban layouts are just that—highly connected streets and blocks. Thus, when making the case for the stormwater benefits of smart growth street designs, urban planning and water resource professionals should establish the framework for considering the site, neighborhood, and region simultaneously, in the same way that has been presented for development districts. For most regions, the question of growth—and underlying road design—is not whether there will be growth or no growth, but rather what the growth (and roadway system) will look like and where it is located.

Typical Costs

Cost estimates vary widely. When building new street networks, narrower streets may cost less to build than wider streets. Considering that the cost of paving a road averages $15 per square yard, shaving even 4 feet from existing street widths can yield cost savings of more than $35,000 per mile of residential street. In addition, because narrower streets produce less impervious cover and runoff than wider streets, additional

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savings can be realized in the reduced size and cost of downstream stormwater management facilities.[27]

The costs will not necessarily always be lower, because specialized features like sidewalks, curb and gutter, street tree areas, and pavers are often included in the overall street design. These amenities, however, carry benefits for stormwater, transportation and community design, so a raw assessment of costs per mile or per trip might not capture the full range of benefits.

Installation of stormwater-friendly streets can also involve additional costs over streets constructed according to standard practices. Portland, Oregon, estimated a higher cost due to planting and maintaining landscaped buffers.[28] Where permeable or porous pavement is used, the site preparation for water storage involves additional costs. The cost savings these techniques bring for handling stormwater from streets can be hidden, however, because the budget for transportation and stormwater can be in separate accounts in different departments' budgets. In deliberations over stormwater utility rates, Portland estimated that 70 percent of its runoff could be attributed to transportation-related surfaces.[29] City and county managers should look to see where the higher costs of better street design are offset by lower demands on stormwater infrastructure.

Measurable Goals

Appropriate measurable goals for street design modifications are emerging. Like earlier discussions on development districts, local build-out analyses can help compare a "business as usual" scenario of build-out with one that contains more compact villages or districts. The streets component may be included with estimates of parking lanes, turning lanes, and other impervious surface coverage associated with roads and streets.

Another measurable goal might be the reuse—or new uses—of existing streets. For example, adding bike lanes, adding on-street parking, or adding medians could be included in your stormwater management plan.

Examples

The Institute for Transportation Engineers has developed two recommended practice guidelines: *Traditional Neighborhood*

Sidewalks on One Side of the Street – or Both?

Some states and localities are recommending that sidewalks be limited to one side of the street to reduce impervious cover, however, most smart growth plans endorse a network of sidewalks. Which is correct?

The answer lies not so much in stormwater control as it does in transportation. If sidewalks are designed as a prominent feature for handling a variety of trips (e.g., commuting, shopping, school travel, and recreation) and providing connections throughout the neighborhood, then placing them on both sides makes sense. If your project or plan envisions only recreational trips, however, then sidewalks on one side of the road makes sense. If you choose to only place sidewalks on one side, review the plan to make sure that future plans for growth and a mix of uses are taken into consideration so that sidewalks might be added later to meet the demand for pedestrian trips.

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This street and sidewalk in Hercules, California, shows how multiple objectives can be met at once. The streets are narrow; however, the rounded curb allows extra width in case emergency response vehicles need extra room. The sidewalk is constructed of pavers, and slopes toward the grassy areas on the straightaway.

Photo: Local Government Commission.

Development Street Design Guidelines (1999) and *Neighborhood Street Design Guidelines* (2003). These are available through ITE's bookstore at <www.ite.org>.

The metropolitan region around **Portland, Oregon** (Metro), has a regional street design manual, specifying stream treatments, street width, and associated water quality benefits. See <www.metro-region.org> and type "street design" into the site's search engine.

North Carolina's Department of Transportation (NCDOT) approved street design guidelines to make it easier for local governments to implement traditional neighborhood street networks in new developments. The guidelines specify street width and the provision of bicycle and pedestrian facilities. See <www.doh.dot.state.nc.us/operations/tnd.pdf> for more information and a link to the NCDOT *Traditional Neighborhood Development Guidelines*. The town of Cary, North Carolina, has adopted policies requiring street connections.

The Congress for New Urbanism (CNU), EPA, the Federal Highways Administration (FHWA) and the Institute of Transportation Engineers (ITE) are developing *Context Sensitive Solutions for the Design of Major Urban Thoroughfares*, which will provide alternatives for communities seeking smart growth street standards. Publication is expected in 2006. In the meantime, a literature review was developed in 2005 and is available at <cnu.org/pdf/lit_review_assigned.pdf>.

Dane County, **Wisconsin**, has established *Street Standards for its Traditional Neighborhood Design Ordinance*. See <www.co.dane.wi.us/plandev/build/pdf/tnd/20040225_append_C.pdf>.

Points to Consider

Street designs have traditionally been established through sets of commonly recognized standards. Standard-setting organizations, such as the Institute of Transportation Engineers and the American Association of

State Highway and Transportation Officials have issued standards that govern street designs, recommended road widths and design for turn lanes and access roads. These organizations are aware that the standards do not fit all situations, and are developing alternative standards and guidelines for communities that have smart growth plans. Because the alternative standards are new or in draft form, local transportation officials might be reluctant to adopt them. Stormwater and planning officials may want to meet with their transportation counterparts in developing a streets plan for joint stormwater and smart growth efforts.

Building green streets, narrower streets, and multi-purpose streets can cause citizen concern and raise objections from emergency service providers. In Portland, Oregon, engineers, planners, and emergency response providers made test runs of various street widths to come to a decision on a street width that meets both smart growth and emergency response needs. The Local Government Commission has developed fact sheets on designing multi-use streets, available at <www.lgc.org> (look under "Free Resources" for the fact sheets).

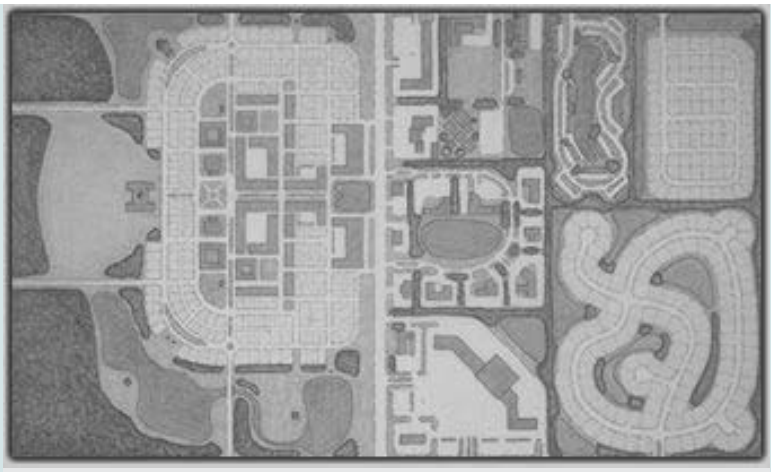

Image: Local Government Commission.

This diagram compares a traditional street layout with the unconnected streets associated with conventional subdivisions.

As noted earlier, a denser network of narrower streets can involve as much or more impervious surface within a concentrated district. This is where evaluating imperviousness on a "per unit" basis of development is helpful. This might be per unit of housing, or per square foot of development footprint. In redeveloping districts, smart growth designs often call for the addition of streets to break up larger blocks or connect centers of activity and the addition of sidewalks to promote walking. While these measures add impervious surface coverage, evaluating the environmental performance of this design requires a broader approach, as mentioned above.

Finally, street design and construction is increasingly delegated to the developer and his or her site planners. For conventional residential or commercial development projects, the main requirements for connecting the development project deal with access to state highways or local roads. As noted above this access point is typically the only point of ingress and egress for the project. Local governments might experience resistance from developers who are not used to planning multiple connections to neighboring developments, or providing connections to commercial areas. Communities with smart growth street plans that require multiple connections will find that early and constant outreach is necessary so builders, developers, and land owners are aware of the requirements. In addition, local governments and real estate agents need to make potential homebuyers aware of streets that will be connected to future development projects to avoid conflicts.

9. Stormwater Utilities

Definition

Like urban forestry programs, stormwater utilities are not typically listed as smart growth policies. Many states and localities, however, have investigated where the rate structure of other utility programs, such as electricity, cable, and gas service, might be unintentionally subsidizing new growth at the expense of more cost-efficient service areas. A stormwater utility, like other utilities, establishes an organization where a user pays for municipal services, such as water, trash pick-up and sewer. This subsection includes suggestions for communities that have already made the decision to establish a utility to finance stormwater improvements.

Stormwater regulations have spurred interest in stormwater utility creation as localities seek new ways to fund drainage and flooding projects. The legal structure and rate system for stormwater utilities vary around the country, and can depend on state legislative or enabling language. The legal aspects of establishing a stormwater utility are beyond the scope of this publication, but there are several things to look for in setting up a utility in coordination with smart growth goals. The mission statement, rate structure, and planning can all have influence over a locality's ability to shape a comprehensive approach to handling stormwater.

Who Do I Talk to About Stormwater Utilities?

Stormwater utilities are typically set up by a local government (as mentioned above, most states must first pass enabling legislation allowing localities to establish these utilities). Thus, the first step is to make sure that the legal framework exists for the creation of a utility. For ease of billing, stormwater utility fees typically appear on the same bill issued for water and sewer, so you might find contact information there or in your local government directory. The stormwater utility may also be located in the public works department. The local government will typically post information on how the stormwater utility is organized, the billing structure and the stormwater master plan on a Web site.

Photo: University of Connecticut Cooperative Extension System

Stormwater utility rates can be adjusted to add incentives for homeowners who collect and handle rainwater on their properties. Municipalities that have impaired waterways and are experiencing high rates of infill can use this approach to reduce stormwater volumes.

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Typical Costs

While costs vary, rates are typically in the $2 to $5 per month per household range. The main consideration for a stormwater utility is that all costs collected for the utility only be spent on stormwater projects. The costs of establishing a utility also vary. Most communities have created the stormwater utility within water and sewer departments for ease of administration. Where localities decide to introduce variable pricing and incentives within the rate system, resources will be needed to establish baseline rates and create maps and verification systems so that incentives are properly instituted. The "Resources" section includes several Web sites with more details on the costs associated with establishing and operating a stormwater utility.

Stormwater Benefits

Stormwater utilities have been established to provide a fair and predictable source of funding for stormwater projects. As towns experience growth, they need to fund systems to handle the stormwater that flows from newly developed parcels, as well as from older areas. Larger cities may need to repair and/or expand sewer and water systems to support redevelopment. Some older cities are also separating their old combined sewer pipes into two systems: one that handles stormwater from the streets and a second system to deliver sanitary sewerage to a wastewater treatment plant. A stormwater utility can provide stable funding to address the runoff problems associated with development and redevelopment.

Stormwater utilities also recognize that all properties within the utility district have a role in both producing and mitigating stormwater. For most municipalities affected by Phases I and II of the NPDES stormwater permitting program, improvements are tied to project approvals for development and redevelopment projects. Thus, the improvements for controlling post-construction runoff are made only when a building permit is issued for a site.

For many watersheds, however, the negative impacts of stormwater runoff arise from existing development that was constructed prior to adoption of improved site designs and construction practices. Where existing properties are the main source of stormwater volume and/or pollutants, the improvements enacted through Phases I and II are not likely to bring immediate relief to stressed or impaired waterways. However, when there is a program and/or dedicated source of revenue for improvements, stormwater problems for the entire community can be accomplished in a predictable fashion. Keep in mind a community need not have a stormwater utility to begin making improvements on existing properties.

Examples

Maturing stormwater utilities are experimenting with ways to structure rates to recognize property owners' actions that result in less burden on the public stormwater system. This can include reduced rates or tradable credits where the property owner (or manager) demonstrates that a BMP has been added and handles stormwater on site.

Many municipalities with stormwater utilities are developing credit manuals. The manuals assist property owners in assessing

(1) the types of activities that can receive a credit (2) how to apply for the credit, and (3) other factors, such as continuing maintenance. The most common activities that qualify for credits include onsite retention and detention and small scale BMPs, such as rain barrels.

The recently approved Stormwater Utility Credit Manual for non-residential users from **Lake County, Ohio**, recognizes that some non-traditional approaches can have stormwater benefits. In their manual, the county notes there are creative ways to reduce the pressure for additional impervious surfaces:

> *"Non-residential customers seeking a credit may request unique opportunities or approaches to improving water quality. For instance, a non-residential customer may also be an NPDES MS4 permitee that must implement a Stormwater Management Plan for its facility. Another example might be a retail outlet that provides "Park and Ride" space to encourage use of the transit system, thereby minimizing the growth of impervious area by reducing the need for additional parking lots and travel lanes on roadways. The LCSMD will review and evaluate these types of unique requests on a case-by-case basis to determine the credit value for a site to which the BMP is being applied."*[30]

The city of **Maryville, Tennessee**, allows smaller homes to qualify where total imperviousness on the site is less than 1,800 square feet. To view Maryville's manual, see <www.ci.maryville.tn.us/epc/IMAE.pdf>. Variations on this type of credit can be used for higher density development projects where the footprint of buildings is smaller in a district.

To recognize the site level and watershed level impacts that come with development, **Eugene, Oregon**, has split its stormwater utility rate into three components: impervious surface, administrative, and street-related. Homeowners can claim a credit only on the impervious surface portion of the fee when they adopt beneficial practices such as use of rain barrels or installation of rain gardens.

Points to Consider

At a basic level, the purpose of a stormwater utility is clear: to assess a charge for handling the stormwater runoff generated from a given piece of property. Measuring the exact volume of runoff from distinct properties is time and resource intensive, however. In addition, some properties are more vulnerable to the impacts of stormwater than others; even if the utility applies a rate evenly, the benefits can vary across the landscape. And third, much of the runoff (up to 40 percent) comes from publicly owned impervious surfaces such as roads and schools. So, what should you look for in a stormwater utility?

Residential properties: Most localities use some sort of simplified system for assessing rates. The easiest is a flat fee. This, however, would not provide homeowners with an incentive to handle more stormwater on their lots. For administrative ease, some localities have allowed homeowners to appeal for a rate reduction if they have installed rain gardens, added rain barrels, or disconnected downspouts.

Of particular smart growth interest is the method of charging based on the percent of impervious surface coverage. A fee based on the percent of impervious surface coverage might not recognize the benefits of smaller lots in a compact district. Where densities are higher, the individual plots are likely to have a greater percent of impervious surface coverage. As explained in Subsections 3 (Redevelopment, page 48) and Subsection 4 (Development Districts, page 51), this design has a lowered impact overall when one considers the per unit impact in a watershed. A rate that recognizes the overall water benefits of higher density housing can help recognize the lowered impact on a per unit basis. An alternative to charges based on percent impervious surface is to develop a charge based for the development district which recognizes the lowered impact for the watershed. Fees can then be assessed per house within the district.

The redevelopment of older commercial corridors often begins with streetscape improvements, which can be designed to capture stormwater, provide tree canopy and complement the redevelopment goals of more walkable and economically vibrant districts.

Photo: NRCS

Commercial properties: Assessing rates for commercial properties is a bit more predictable and straightforward, but it is important to examine for any barriers to developement projects that have benefits for the watershed. Commercial properties are generally assessed a fee based on impervious surface coverage. One of the more important smart growth considerations is accounting for the stormwater impacts of redevelopment of vacant or underperforming commercial properties. As these parcels are redeveloped, they often generate the same amount of runoff as before, but as noted elsewhere in this report, they take on development demand that could go to undeveloped areas elsewhere in the watershed. To further improve the performance of these sites, look for opportunities to handle water on site or disconnect the impervious surfaces with neighboring parcels. In addition, a locality may want to introduce a stormwater fee credit for improving "gray" infrastructure, particularly when a developer agrees to fix combined sewer pipes that overflow. With these modifications in the rate structure, a property is fairly assessed its contribution to local impacts, but gets a credit based on the watershed benefits.

Depending on specific legal requirements, a utility may be able to split the rate into other types of categories to recognize smart growth benefits. This is where it is important, in the development of your utility's charter and planning, to develop a "purpose" statement to describe the adverse impacts of stormwater and establish a framework for recognizing better practices within the utility and its rate structure.

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Summary and Conclusion

Cities, counties, towns and campuses around the country are well on their way developing stormwater plans under the Clean Water Act. What many local water quality managers might not realize is that their colleagues in the transportation and zoning departments are engaged in planning and development activities that parallel—and often overlap with—watershed and stormwater planning. Embedded in land use and comprehensive plans are features at the site, neighborhood, and even regional level that have a great impact on the quantity and quality of stormwater. Where the locality is pursuing smart growth development strategies and techniques, they are often unknowingly developing "best management practices" (BMPs) for Phases I and II.

This document was developed to help water quality practitioners, developers, smart growth advocates, and local/state government officials think in new ways about the overlapping demands of water planning and local comprehensive planning.

The Clean Water Act's stormwater permitting program offers opportunities to meet these overlapping demands. The water quality features of smart growth have not traditionally appeared in BMP menus or lists of stormwater performance measures. This document has taken common smart growth techniques, explained their water and stormwater benefits, and provided examples. Understanding the benefits, though, requires a new view of stormwater—one that considers multiple levels of environmental and development context. Thus, development projects must be evaluated at the site, neighborhood, and watershed levels to fully assess environmental performance.

In conclusion, the stormwater permitting program is designed to foster innovation and adaptive management. Over the next five years, your community is likely to observe opportunities for improvement. As your town engages in planning for transportation, regional planning, and development, pay attention to areas that are amenable to better water quality and stormwater management. You may find that you can gain water quality improvement while addressing transportation, housing, economic development, and community goals all in the same community.

Next Steps – Guidance and Technical Assistance for Municipalities

EPA also expects to improve its guidance and technical assistance on implementation of the NPDES stormwater permitting program for MS4s. For communities developing smart growth programs and stormwater management plans, the Agency is exploring activites that:

- Provide more information and assistance on watershed permitting for communities that want to integrate their smart growth plans.
- Support development of BMP manuals for common smart growth techniques and development districts, such as TNDs.
- Develop model codes, stormwater ordinances, and permit language that recognize the stormwater performance of smart growth and/or offer flexibility for redevelopment, infill, and smart growth site design for new development.
- Develop decision support tools to help localities and developers estimate the amount of stormwater pollution prevented through compact development and redevelopment.
- Develop information on strategic combinations of BMPs for urban infill and redevelopment that include smart growth and traditional stormwater BMPs

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EPA's Guidance on Post-Construction Stormwater Controls – Through a Smart Growth Lens

On December 8, 1999, EPA published the Phase II rules in the *Federal Register*, along with model language that could be adopted. EPA's language, presented below, was adopted in part or whole by many states and permitting authorities. The examples listed in the notice include a combination of traditional stormwater control techniques, as well as several smart growth techniques and concepts. If your state or locality has adopted some or all of the model language, here are some tips for integrating your existing smart growth plan with this guidance.

From the 1999 *Federal Register* Notice:

Post-construction storm water management in new development and redevelopment.

(i) You must develop, implement, and enforce a program to address stormwater runoff from new development and redevelopment projects that disturb greater than or equal to one acre, including projects less than one acre that are part of a larger common plan of development or sale, that discharge into your small MS4. Your program must ensure that controls are in place that would prevent or minimize water quality impacts.

(ii) You must:

(A) Develop and implement strategies which include a combination of structural and/or nonstructural best management practices (BMPs) appropriate for your community;

(B) Use an ordinance or other regulatory mechanism to address postconstruction runoff from new development and redevelopment projects to the extent allowable under state, tribal or local law; and

(C) Ensure adequate long-term operation and maintenance of BMPs.

(iii) Guidance: If water quality impacts are considered from the beginning stages of a project, new development and potentially redevelopment provide more opportunities for water quality protection. EPA recommends that the BMPs chosen: be appropriate for the local community; minimize water quality impacts; and attempt to maintain pre-development runoff conditions. In choosing appropriate BMPs, EPA encourages you to participate in locally based watershed planning efforts which attempt to involve a diverse group of stakeholders including interested citizens. When developing a program that is consistent with this measure's intent, EPA recommends that you adopt a planning process that identifies the municipality's program goals (e.g., minimize water quality impacts resulting from post-construction runoff from new development and redevelopment), implementation strategies (e.g., adopt a combination of structural and/or nonstructural BMPs), operation and maintenance policies and procedures, and enforcement procedures. In developing your program, you should consider assessing existing ordinances, policies, programs, and studies that address stormwater runoff quality. In addition to assessing these existing documents and programs, you should provide opportunities to the public to participate in the development of the program. Non-structural BMPs are preventative actions that involve management and source controls such as: policies and ordinances that provide requirements and standards to direct growth to identified areas, protect sensitive areas such as wetlands and riparian areas, maintain and/or increase open space (including a dedicated funding source for open space acquisition), provide buffers along sensitive water bodies, minimize impervious surfaces, and minimize disturbance of soils and vegetation; policies or ordinances that encourage infill development in higher density urban areas, and areas with existing infrastructure; education programs for developers and the public about project designs that minimize water quality impacts; and measures such as minimization of percent impervious area after development and minimization of directly connected impervious areas. Structural BMPs include: storage practices such as wet ponds and extended-detention outlet structures; filtration practices such as grassed swales, sand filters and filter strips; and infiltration practices such as infiltration basins and infiltration trenches. EPA recommends that you ensure the appropriate implementation of the structural BMPs by considering some or all of the following: preconstruction review of BMP designs; inspections during construction to verify BMPs are built as designed; postconstruction inspection and maintenance of BMPs; and penalty provisions for the noncompliance with design, construction, or operation and maintenance. Stormwater technologies are constantly being improved, and EPA recommends that your requirements be responsive to these changes, developments, or improvements in control technologies. (Citation: 64 *FR* 68843, December 8, 1999).

For communities that have embarked on smart growth planning, there are several overlapping themes:

"EPA recommends that the BMPs chosen: be appropriate for the local community; minimize water quality impacts; and attempt to maintain pre-development runoff conditions."

Listing your smart growth accomplishments and their water quality impacts is one way that your BMPs can be appropriately chosen. As mentioned in this document, maintaining pre-development runoff conditions for redevelopment projects is typically neutral since impervious cover replaces existing impervious cover. In some areas, localities have defined pre-development conditions as the **undeveloped** state. There may be water quality imperatives that call for this increased standard. The key is to ensure that all development projects in the watershed are held to standards that lead to increased protection so that redevelopment rules do not unintentionally penalize redevelopment compared to new development.

"…implementation strategies (e.g., adopt a combination of structural and/or non-structural BMPs)… "

For smart growth and stormwater goals, the most effective BMPs will be strategic combinations of mutually supportive policies. For example, policies to create better sidewalks might lead to pedestrian improvements at intersections, which in turn are supported by plans for a more compact town center to bring uses within walking distance of each other. These policies act to support each other and are synergistic, so that the end result is the cumulative benefits of the individual policies. Many comprehensive plans recognize the combinations or urban design policies; make sure that your stormwater plan reflects the same links among policies.

"…Non-structural BMPs are preventative actions…"

Note that prevention of stormwater-related problems is integral to EPA's guidance. As noted in this document, reusing existing developed areas and compact building forms prevent much of the stormwater generated from development activity.

"…and measures such as minimization of percent impervious area after development..."

EPA's guidance does emphasize reducing impervious area. When considering reductions, however, the development context for smart growth and stormwater are important. While each individual property may meet impervious surface caps, the development "footprint" becomes enlarged as individual development sites grow to include the required land set-aside. This, in turn disperses uses and the infrastructure needed to serve it, including roads and other impervious surfaces. Thus, while the narrow objective of minimizing impervious surface coverage on the development site level is met, the watershed can actually see an increase in land disturbance and impervious surface coverage. Water quality practitioners should recognize that while land development approvals are made on a site-by-site basis, the impact of the individual development project transcends boundaries. This is not to say that impervious surface caps do not have a place in protecting water quality. In some places, watershed-wide caps have been put into place, followed by assessments of the land conservation/development balance. Like other aspects of development decisions, the scale, location, and interrelationship with other policies are important.

"...minimization of directly connected impervious areas…"

Communities that are seeking to add a street to connect an older downtown to new residential areas might find that strict policies to reduce connected, impervious surfaces prohibit the connections that are needed for economic development and transportation improvements. Screen your impervious surface policies to see where improvements to make compact development work might be prohibited.

"EPA recommends…preconstruction review of BMP designs."

Preconstruction reviews can identify where there is disagreement among details in various land development policies. The preconstruction review should include several departments to identify where a city or county's smart growth policies and stormwater regulations run counter to each other, and to develop alternative site designs to accomplish the goals of all programs.

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SECTION 3

Resources

This section lists resources for general smart growth, for water resources by smart growth technique (as listed in the document for easy reference) and by state. A listing of these sites is not an EPA endorsement, and as materials are finalized and updated, links may change. Many stormwater programs at the state and local levels are being revised, so keep these keywords in mind if you need to use a search engine to find updated links:

"NPDES"

"Phase I" or "Phase II"

"MS4"

"stormwater"

"BMP"

"ordinance"

"design manual"

"post construction"

"redevelopment"

"infill"

These terms used singly or in various combinations, coupled with the name of your state and/or municipality, should take you to Web sites that contain information on the progress of stormwater programs, schedules for public meetings, drafts for review, opportunities for incorporation of smart growth techniques, and other information.

Many of these links cite regulatory documents, and thus are necessarily long; an electronic version can be found at <www.epa.gov/smartgrowth> to copy and paste Web addresses to your internet browser.

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Smart Growth

For more information on making the integrated smart growth and water case, visit
www.epa.gov/smartgrowth or www.smartgrowth.org.

A good introductory primer is "Why Smart Growth: A Primer"
www.epa.gov/smartgrowth/pdf/WhySmartGrowth_bk.pdf

"Our Built and Natural Environments: A Technical Review of the Interactions between Land Use, Transportation and Environmental Quality"
www.epa.gov/smartgrowth/pdf/built.pdf

Planetizen, a planning and smart growth Web site, lists 50 good Web sites:
www.planetizen.com/websites

The Congress for New Urbanism has a compendium of model codes on a variety of subjects, including street design, rehabilitation, and urban design. The compendium also includes place-specific codes.
www.cnu.org/pdf/code_catalog_8-1-01.pdf

Water and Smart Growth

EPA has issued several helpful resources on growth and water resources:

"Protecting Water resources with Smart Growth"
www.epa.gov/smartgrowth/water_resource.htm

EPA's Watershed Academy hosts an online training course.
www.epa.gov/watertrain/smartgrowth

EPA's Region 6 has compiled an exhaustive list of water resources that are applicable throughout the country. The site also lists the Web sites of state stormwater offices for each of the 50 states and U.S. territories.
www.epa.gov/region6/water/npdes/sw/resources.pdf

The Met Council has released a series of documents on controlling stormwater in cold climates.
www.metrocouncil.org/environment/watershed/bmp/manual.htm

Stormwater Sites

EPA's main site for NPDES permits:
http://cfpub.epa.gov/npdes/index.cfm

EPA's stormwater program home page
http://cfpub.epa.gov/npdes/home.cfm?program_id=6

EPA Fact Sheet on Phase II
www.epa.gov/npdes/pubs/fact2-0.pdf

State stormwater programs
http://cfpub.epa.gov/npdes/linkresult.cfm?program_id=6&link_category=2&view=link

Resource List for Stormwater Management Programs and Phase II
www.epa.gov/npdes/pubs/sw_resource_list.pdf

Menu of Best Management Practices (BMPs)
http://cfpub.epa.gov/npdes/stormwater/menuofbmps/menu.cfm

The Stormwater Authority lists state programs, news, white papers, and articles
www.stormwaterauthority.org/

The Natural Resources Defense Council's "Stormwater Strategies"
www.nrdc.org/water/pollution/storm/stoinx.asp

Project NEMO (Non-point Education for Municipal Officials)
http://nemo.uconn.edu

EPA's National Management Measures to Control NonPoint Source Pollution from Urban Areas
www.epa.gov/nps/urbanmm/

Innovations in Phase II Guidance and Permits to Include Smart Growth

EPA's model permit for Phase II includes language on specific smart growth techniques (e.g. infill), as well as flexibility to custom design ordinances and guidance.
www.epa.gov/npdes/pubs/modpermit.pdf

The Michigan Environmental Council is developing materials on smart growth and Michigan's innovative stormwater and watershed permitting.
www.michiganenvironmentalcouncil.org

The Santa Clara Valley Urban Runoff Pollution Prevention Program has developed a new Phase I permit to include many smart growth innovations. Under the reissued permit, the city of San Jose revised local ordinances to incentivize smart growth projects, such as affordable housing and redevelopment.

- The regional permit:
  www.scvurpppw2k.com/pdfs/other/NPDES_Permit_C3New_Finalodrtransltr.PDF
- The San Jose Policy changes:
  www.sanjoseca.gov/planning/stormwater/pol_stormwater.pdf

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The city of Poway, California, has defined BMP to include redevelopment and development projects that improve stormwater performance as compared to conventional designs.
www.codepublishing.com/ca/poway/Poway16/Poway16101.html#16.101.200

Resources by Smart Growth Technique

Regional Planning

EPA's Surf Your Watershed
www.epa.gov/surf

EPA hosts a page on build-out tools
www.epa.gov/greenkit/2tools.htm

EPA link to source water protection plans
www.epa.gov/safewater/protect.html

The Trust for Public Land published "Protecting the Source" on regional source water protection efforts.
www.tpl.org
www.tpl.org/tier3_cd.cfm?content_item_id=1337&folder_id=195

New Jersey's program for regional and integrated planning
www.smartgrowthgateway.org

For information on the Highlands (New Jersey) water protection plan
www.highlands.state.nj.us/index.html and
www.state.nj.us/dep/highlands/faq_info.htm

New Jersey's Regional Plan Association hosts research and position papers.
www.planningpartners.org

RPA developed a paper on goal oriented zoning using smart growth techniques.
www.planningpartners.org/projects/wma11/sg_alt/smartgrowthalt_text.pdf

The Association of New Jersey Environmental Commissions' Smart Growth Survival Kit
www.anjec.org

The Central New York Regional Planning Board's regional assistance program for Phase II communities
www.cnyrpdb.org/stormwater-phase2/

The University of Rhode Island's Cooperative Extension's A Creative Combination: Merging Alternative Wastewater Treatment with Smart Growth
http://www.uri.edu/ce/wq/mtp/PDFs/manuals/Creative%20Combination%203-10.pdf

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The Planning Commissioners Journal hosts a page on transfer of development rights programs, including examples, common challenges, and resources.
www.plannersweb.com/wfiles/w370.html

Appalachian Regional Commission's site on strategic planning and best practices.
www.arc.gov/index.do?nodeId=44

Infill

The Washington State Phase II permit application
www.ecy.wa.gov/programs/wq/stormwater/phase_2/Phase%20II%20Application.pdf
(see page 14 for the language on infill development).

The Greenbelt Alliance published "Smart Infill" with information on zoning codes, design, and public participation
www.greenbelt.org (go to "Resource Center" and "Reports")

The Metro Council published the Urban Small Sites Best Management Practice (BMP) Manual.
www.metrocouncil.org/environment/Watershed/bmp/manual.htm

Association of Metropolitan Planning Organizations
www.ampo.org

The Local Government Commission, the REALTORS, and EPA co-published "Creating Great Neighborhoods: Density in Your Community"
www.lgc.org/freepub/PDF/Land_Use/reports/density_manual.pdf

Smart Growth America produced "Choosing Our Community's Future" to assist neighborhood leaders in shaping growth in their neighborhoods.
www.smartgrowthamerica.org

Wisconsin developed post-construction standards that vary for development type (i.e., new development, redevelopment, infill).
www.dnr.state.wi.us/org/water/wm/nps/stormwater/post-constr/

Clark County's (Washington) comprehensive plan
www.co.clark.wa.us/longrangeplan/review/index.html

Wisconsin Department of Natural Resources' list of general land use terms
dnr.wi.gov/org/es/science/landuse/education/GPZ.htm.

New Jersey's two-tiered permit system for infiltration requirements
www.njstormwater.org

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Austin, Texas, smart growth incentives for infill
www.ci.austin.tx.us/smartgrowth/incentives.htm

San Diego's Localized Equivalent Area Drainage program (LEAD) for sharing stormwater costs across projects
www.sannet.gov/stormwater

The Center for Watershed Protection sponsors Builders for the Bay, "Smart Site," and the Site Design Roundtable
www.cwp.org

Maryland's Guide to BMP Selection
www.mde.state.md.us/assets/document/chapter4.pdf

Redevelopment

The National Vacant Properties Campaign has information on the most common conditions leading to vacated properties, and ways to develop programs that can bring unproductive property back.
www.vacantproperties.org/

The Congress for the New Urbanism's Greyfields into Goldfields
www.cnu.org/cnu_reports/Executive_summary.pdf

The U.S. Department of Housing and Urban Development's Smart Codes in Your Community: A Guide to Building Rehabilitation Codes
http://www.huduser.org/publications/destech/smartcodes.html

The Smart Growth Leadership Institute has a Web site devoted to code audits to identify barriers to redevelopment.
www.sgli.org/implementation.html

The U.S. Green Building Council's (USGBC's) scorecards, called LEED (for Leadership in Environmental and Energy Design), contain rating systems for development and redevelopment projects. USGBC has a new scorecard under development call LEED Neighborhood Design (LEED ND).
www.usgbc.org/leed/leed_main.asp

EPA's case study of the Atlantic Steel redevelopment project
www.epa.gov/projectxl/atlantic/index.htm

Development Districts

The state of Oregon created a design manual for development districts, which can serve as a base example for developing a joint smart growth and stormwater design manual.
egov.oregon.gov/LCD/docs/publications/wqgbchapter4dsnstan.PDF

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Emeryville, California, developed design guidelines for highly urbanized areas with limited opportunities for infiltration – Design Guidelines for Green, Dense Redevelopment. The final document will be released in 2006.
www.ci.emeryville.ca.us/planning

Elm Grove, Wisconsin, has developed plans to include downtown revitalization, stormwater control, and open space planning.
www.elmgrovewi.org

Chesterfield, Burlington County, in New Jersey has a code for transfer of development rights, including a "Planned Village Development" district ordinance for receiving areas.
www.smartgrowthgateway.org/ordinances/chesterfield.pdf

EPA Brownfields site
www.epa.gov/swerosps/bf/index.html

San Diego's "City of Villages" planning initiative
www.sandiego.gov/cityofvillages

San Diego's Urban Runoff Program
www.sandiego.gov/stormwater

The Trust for Historic Preservation sponsors the Main Street Program
www.mainstreet.org/

Caltrans has a site dedicated to transit oriented development. This site describes each project, giving information on land use plans, transportation performance, and project details.
transitorienteddevelopment.dot.ca.gov

The Congress for New Urbanism's compilation of code innovations
www.cnu.org/pdf/code_catalog_8-1-01.pdf.

New Urban News developed New Urbanism: Comprehensive Report & Best Practices Guide, which contains analyses, best practices, and examples. To order, go to
www.newurbannews.com.

Tree Programs

Treelink has a page with links to tree preservation, urban forestry, and urban design ordinances.
www.treelink.org/linx/?navSubCatRef=25

Casey Trees is developing detailed information on the amount of stormwater that can be intercepted by tree cover and green roofs.
www.greenroofs.org/resources/greenroofvisionfordc.pdf

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American Forests has information on research, ordinances, and CITYGreen software.
www.americanforests.org

International Society of Arboriculture
www.isa-arbor.com

Scenic America has a model tree ordinance and supporting information
www.scenic.org/portals/0/trees%20-%20ordinance.doc

Trees Atlanta's assessment of the benefits of tree canopy
www.treesatlanta.org

The USDA Forest Service Southern Region
www.urbanforestrysouth.org

Metro's Trees for Green Streets: An Illustrated Guide
www.metro-region.org/article.cfm?articleid=263

Parking Reduction Strategies

Parking Spaces/Community Spaces is set for release in 2006 from EPA.
www.epa.gov/smartgrowth.

The Stormwater Center has a fact sheet on planning, designing and retrofitting parking lots.
www.stormwatercenter.net/Assorted%20Fact%20Sheets/Tool4_Site_Design/GreenParking.htm

Olympia, Washington's Impervious Surface Reduction Study
depts.washington.edu/cwws/Research/Reports/ipds.pdf

Model agreement for shared parking
www.metro-region.org/article.cfm?articleid=435

The North Central Texas Council of Governments developed guidance, which includes parking reduction strategies.
www.dfwstormwater.com/Storm_Water_BMPs/post-construct.asp#rec

Information on car-sharing
www.carsharing.net/where.html

"Fix It First"

The National Governors Association issued an Issue Brief on "Fix it First."
www.nga.org/cda/files/0408FIXINGFIRST.pdf

EPA's Sustainable Water
www.epa.gov/water/infrastructure.

Smart Growth Street Design

The Institute for Transportation Engineers developed two recommended practice guidelines: "Traditional Neighborhood Development Street Design Guidelines" (1999) and "Neighborhood Street Design Guidelines" (2003).

www.ite.org

The Victoria Transport Policy Institute hosts an online transportation encyclopedia. This frequently updated site includes many details on transportation and street networks and includes examples from across the country, as well as international examples.

www.vtpi.org/tdm/index.php

The American Planning Association has issued a report, Planning for Connectivity: Getting from Here to There, Report PAS #515, written by Susan Handy, Robert Paterson, and Kentt Butler.

www.planning.org.

The metropolitan region around Portland, Oregon (Metro) developed a regional street design manual, specifying stream treatments, street width, and associated water quality benefits.

www.metro-region.org (type "street design" into the site's search engine)

North Carolina's Department of Transportation (NCDOT) approved street design guidelines for Traditional Neighborhood Development Design.

www.doh.dot.state.nc.us/operations/tnd.pdf

The Local Government Commission developed fact sheets on designing multi-use streets.

www.lgc.org (under "Free Resources")

The Congress for New Urbanism published a literature review of street designs for traditional neighborhood design and smart growth projects. This literature review will be used to support further work with the Institute of Transportation Engineers on the subject.

cnu.org/pdf/lit_review_assigned.pdf

Dane County, Wisconsin, adopted traditional street standards.

www.co.dane.wi.us/plandev/build/pdf/tnd/20040225_append_C.pdf

Seattle launched the Siskiyou Green Street Project to add vegetated curb extensions. These extensions handle some of the stormwater that would otherwise enter the storm sewer.

www.portlandonline.com/bes/index.cfm?c=dhfjc

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Stormwater Utilities

The Center for Urban Policy and the Environment at Indiana University-Purdue University Indianapolis (IUPUI), in cooperation with EPA, hosts a page dedicated to stormwater finance. Some of the case studies provide examples on how to creatively match the rate structure with impacts.

http://stormwaterfinance.urbancenter.iupui.edu/

Lake County (Ohio) Credit Manual for Tier 2 Cities, Lake County Stormwater Management Department.

www2.lakecountyohio.org/smd/Credit%20Manual%20Level%202%20%20Advisory%20Board%20Approved.pdf

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SECTION 4

New Jersey – A Case Study in Weaving Stormwater and Smart Growth Policies Together

The state of New Jersey has one of the most fully developed smart growth programs of any state. In 1985, the state adopted the State Planning Act, which led to the creation of a State Development and Redevelopment Plan (the State Plan). This plan was created through a statewide planning process called cross-acceptance, which ensures that governments at all levels, as well as stakeholders and the public, participate in deciding the future of New Jersey's growth. Early accomplishments included farmland protection, a land acquisition program, and comprehensive brownfields redevelopment policies.

In the early 1980s New Jersey passed its stormwater management rules. As attention to smart growth and the awareness of the environmental impacts of development increased, so did interest in updating stormwater rules. In the 1990s, with the new Phase II requirements on the horizon, the state developed rules with both growth and stormwater goals in mind. In 2003, the state passed two companion laws, one called the "MS4 Law" to establish a statewide permitting system, and the other called the "Stormwater Management Rule," which modernized the state's original stormwater laws and forged closer links between stormwater and other growth management plans.

Goals for Smart Growth

The purpose of the State Plan is to coordinate planning activities and establish statewide planning objectives in the following areas: land use, housing, economic development, transportation, natural resource conservation, agriculture and farmland retention, recreation, urban and suburban redevelopment, historic preservation, public facilities and services, and intergovernmental coordination

New Jersey uses the goals in the State Plan as a guide. The state is divided into five regions, with different goals based on the existing development profile, as well as plans for growth in that area. The accompanying State Plan Policy Map serves as the underlying land use-planning and management framework that directs funding, infrastructure improvements, and preservation for programs throughout New Jersey.

Goals for Water and Stormwater

The new stormwater rules are meant to complement other environmental and economic goals. The new rules place an emphasis on ground water recharge, though that requirement would be waived for urban areas. In urbanizing areas, LID techniques are to be used to maintain existing vegetation and drainage patterns. In all areas of the state, BMPs would be chosen to achieve an 80 percent reduction in certain pollutant loads. Areas along waterways designated as Category One (C1) water resources have special protections, such as the Highlands area of the state.

Specific Policies that Meet Both Water and Smart Growth Goals

This section describes policy areas that have both water and smart growth goals.

Tiered Stormwater Requirements:

Instead of creating blanket requirements for all areas of the state, New Jersey adopted two tiers to administer stormwater requirements. Municipalities within the state are assigned to either Tier A or Tier B. Tier A municipalities are generally located within the more densely populated regions of the state or along the coast. Tier B municipalities are generally more rural and in non-coastal regions. The Tier B Permit includes basic requirements and concentrates on new development and redevelopment projects and public education. The Tier A Permit includes the requirements found in the Tier B Permit, plus BMPs aimed at controlling stormwater pollutants from existing development.

Meeting Smart Growth Goals: By establishing tiers instead of general requirements, the state recognizes that the requirements based on development context can help create a level playing field so that greenfields development is not unintentionally favored due to less strict requirements.

Meeting Stormwater Goals: Tier A rules address stormwater problems found in urbanized areas, such as pet waste and litter. The infiltration requirements are tied to areas of the state critical for recharge, but are not required in urbanized areas where legacy pollutants may enter underground water systems.

"Fix It First:"

The New Jersey State Development and Redevelopment Plan and Infrastructure Needs Assessment, both adopted in March 2001, are used to encourage smart infrastructure investments. The "Fix It First" rules are particularly strong for transportation investments. For water and sewer infrastructure, the rules are not as explicit, but there are other policies that help direct funds for repair and replacements of water infrastructure. The State Planning Act links the state's annual capital budget recommendations to the State Development and Redevelopment Plan, and makes the Infrastructure Needs Assessment an integral part of the State Plan.

One concern voiced by developers is the poor condition of infrastructure in many of the designated growth areas. The state has responded through its "Water Quality Management Planning and Smart Growth Implementation Process" grant.

Meeting Smart Growth Goals: By focusing infrastructure investments in existing cities, towns, and suburbs, New Jersey can encourage downtown revitalization, decrease development pressures on farmland and other open space, and conserve limited funds by taking advantage of past infrastructure investments.

Meeting Stormwater Goals: Combined sewer overflows account for much of the pollution in New Jersey's waterways and harbors. Fixing aging infrastructure can mitigate —or eliminate—this source of pollution. Over a third of Newark's 170-mile collection system is brick. Fixing the infrastructure not only helps with overflows, but also decreases the strain on the system caused by inflow and infiltration (I/I). In addition, upgrades to infrastructure in designated growth areas can attract development that may go elsewhere in sensitive watersheds.

Utility Policies:

The New Jersey Board of Public Utilities (NJBPU) is the state's utility regulatory authority with oversight over the state's energy, telecommunications, water/wastewater, and cable television industries. Following the creation of a board-wide Smart Growth Policy Team, the NJBPU looked at its infrastructure extension formula and the extent to which developers will be required to pay for the necessary infrastructure. The formula was established to accommodate growth based on where development is occurring and how infrastructure improvements can best be financed to support increased development in designated growth areas. As stated in the 2005 strategic plan, NJBPU wants to make developers constructing on greenfield sites bear the full cost of gas, electric, and water line extensions, while reimbursing older communities and designated growth areas for laying utilities on their own.

Meeting Smart Growth Goals: Currently, builders negotiate the amount they contribute to gas, electrical, and water line extension on a case-by-case basis often with large reimbursements, while the total cost of service expansion to new subdivisions is subsidized by ratepayers in cities and older suburbs. Adjusting the formulae for rates and extensions to reflect actual costs brings transparency to the costs of various development patterns. Denser, older communities are more efficiently served per unit that dispersed development, thus holding down both installation and long term maintenance costs.

Meeting Stormwater Goals: The BPU's adjustments to extension and rate policies complement "Fix It First" policies and those geared to directing growth to designated growth areas. Funds can be targeted to repair, replacement, and capacity upgrades rather than installation to serve new, dispersed development. Holding down utility costs in urban areas can attract residents and commercial entities.

Infill and Redevelopment Districts:

New Jersey has several programs and policies geared toward redevelopment and revitalizing existing neighborhoods. The list is long, and the accompanying policies, grant programs and incentives are too long to list here. Among the programs are:

- New Jersey's Office of Brownfield Reuse
  www.state.nj.us/dep/srp/brownfields/obr/

- Rehabilitation Subcode
  www.nj.gov/dca/codes/rehab/index.shtml
- Transit Village Initiative
  www.state.nj.us/transportation/community/village

Meeting Smart Growth Goals: The recycling of brownfields and vacant sites allows the state to meet its smart growth goals of protecting open space by clustering development on existing sites, already served by infrastructure. In addition, the state has taken strides to provide affordable housing and save historic buildings through redevelopment. The transit villages and older areas that are served by multiple modes of transit offers options and reduces the amount of infrastructure needed to support automobile dependent types of development.

Meeting Stormwater Goals: Both public and private sector investment in older areas provides funding for infrastructure upgrades. The focus on larger sites (brownfields, transit station areas) allows localities to better plan for handling stormwater on site.

Agricultural Smart Growth Plan:

New Jersey's 2003 Agricultural Smart Growth Plan provides a roadmap for the future of agriculture across the state. The plan consists of five components: 1) farmland preservation, 2) innovative conservation planning, 3) economic development, 4) natural resource conservation, and 5) agricultural industry sustainability. Other components of the plan aim to preserve 20,000 acres of farmland per year through 2009 and integrate economic development and smart growth into the agricultural industry. The future of agriculture in an expanding, global market also depends upon innovative planning techniques, economic development, natural resource conservation, and programs and policies which keep the industry viable. For more information visit <www.nj.gov/agriculture/smartgrowthplan.pdf>.

Meeting Smart Growth Goals: The Agricultural Smart Growth Plan primarily strives to achieve the goal of preserving farmland, but the plan also involves community and stakeholder participation in the decisionmaking process and encourages a sense of place in rural communities by strengthening their economies.

Meeting Stormwater Goals: The Agricultural Smart Growth Plan brings innovative conservation goals to protect stream buffers and target land best suited for infiltration and forestry. In addition the agricultural smart growth plan provides better tools to design commercial and residential growth. Targeting commercial entities to existing downtowns and encouraging rural housing development designs can help minimize the development footprint overall.

Transfer of Development Rights:

The transfer of development rights (TDR) is a tool used to encourage a shift in growth away from agricultural, environmentally sensitive, or historic open space to designated areas where new development is desired. By incorporating TDR provisions in their land-use regulations, municipalities can encourage the protection of open space at a far lower cost than outright purchase. In a TDR program, a community identifies a conservation area within its boundaries where it would like to see protected from development (the sending zone) and another area where the community

desires more growth (the receiving zone) as identified in the municipality's land-use plan. Landowners in the sending zone are allocated a number of development credits, which can be sold to developers, speculators, or the community itself. In return for selling his or her development credits, the landowner in the sending zone agrees to place a permanent conservation easement on his or her land. Meanwhile, the purchaser of the development credits can apply them to develop at a higher density than otherwise allowed on property under the base zoning.

On March 29, 2004, then-Governor McGreevey signed a bill authorizing all municipalities in New Jersey to adopt TDR programs, making New Jersey the first state in the nation to make TDR available statewide. TDRs typically work best when they are used in combination with other policies. Receiving areas must be ready to accept the density being sent, which means the zoning and infrastructure must be in place.

Meeting Smart Growth Goals: New Jersey's TDR program meets several of the state's smart growth principles, most notably the protection of open space, farmland, and scenic resources; compact, clustered community design; and locating future growth in communities with existing infrastructure. The state has a well-developed program in the Pinelands. To see more on the details of how the TDR program has been established, see <www.nj.gov/dca/osg/resources/tdr/index.shtml>.

Meeting Stormwater Goals: Much of the land identified as sending areas are also critical for water and recharge. That water would become urban runoff if developed under conventional standards and would result in stream degradation throughout larger segments. Receiving areas, which can then be developed more intensively, can accommodate more development on a smaller footprint, thus making more efficient use of land on a per unit basis. While most TDR programs are geared toward farmland preservation, they can also be designed for erosion control and water quality. For example, a TDR program can be implemented along with a source water protection plan.

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Acronyms & Glossary

Acronyms

BID—Business Improvement District

BMP—Best Management Practices

COG—Council of Governments

CWA—Clean Water Act

CZMA—Coastal Zone Management Act

ICMA—International City/County Managers Association

LID—Low Impact Development

LOS—Level of Service

MPO—Metropolitan Planning Organization

NACO—National Association of Counties

NAHB—National Association of Homebuilders

NPDES—National Pollutant Discharge Elimination System

NPS—Nonpoint Source Pollution

NRCS—Natural Resource Conservation Services

PFA—Priority Funding Area

SWMP—Stormwater Management Plan

SWPP—Stormwater Prevention Plan or Stormwater Pollution Prevention Plan

TIF—Tax Increment Financing

TDR—Transfer of Development Rights

TMDL—Total Maximum Daily Load

TND—Traditional Neighborhood Development

TOD—Transit Oriented Development

UDO—Unified Development Ordinance

USEPA—United States Environmental Protection Agency

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Glossary

BMPs (Best Management Practices): Methods that have been determined to be the most effective, practical means of preventing or reducing pollution from non-point sources, such as pollutants carried by urban runoff. These methods can be structural (e.g., devices, ponds) or non-structural (e.g., policies to reduce imperviousness). BMPs classified as "non-structural" are those that rely predominantly on behavioral changes rather than construction in order to be effective. "Structural" BMPs are engineered or constructed to prevent or manage stormwater.

Biofiltration: The use of vegetation such as grasses and wetland plants to filter and treat stormwater runoff as it is conveyed through an open channel or swale.

Buffer Zone: A designed transitional area around a stream lake or wetland left in a natural, usually vegetated, state so as to protect the waterbed from runoff-related pollution. Development is typically prohibited or restricted in a buffer zone.

Charrette: A French word meaning "cart"; often used to describe the final, intense work effort expended by art and architecture students to meet a project deadline. In modern terms, a charrette is an intense community workshop, typically held over several consecutive days, conducted to gather ideas and develop feasible community design options.

Combined Sewer Overflows (CSOs) and Sanitary Sewer Overflow (SSOs): Overflows occur when pipes carrying sewage and/or stormwater are overwhelmed by a high volume of water, typically during rainstorms. Older cities tend to have combined sewers (stormwater and sewage are carried in the same pipe); however, sanitary sewers can overflow as well.

Detention: The storage and slow release of stormwater following a precipitation event by means of an excavated pond, enclosed depression, or tank. Detention is used both for pollutant removal, stormwater storage, and peak flow attenuation.

Exfiltration: The downward flow of water into the soil.

Floodplain: A natural or statistically derived area adjacent to a stream or river where water overflows its banks at some frequency during extreme weather events.

General Permit: A permit issued under the NPDES program to cover a certain class or category of stormwater discharges. These permits reduce the administrative burden of permitting stormwater discharges. Most permitting authorities also allow for individual permits, which are tailored to meet unique needs.

Hydrology: The science dealing with the properties, distribution, and circulation of water on and below the Earth's surface and in the atmosphere.

Impervious Surface: A hard surface area that either prevents or retards the entry of water into the soil mantle as occurs under natural conditions (prior to development), and from which water runs off at an increased rate of flow or in increased volumes. Common impervious surfaces include but are not

limited to rooftops, walkways, patios, driveways, parking lots, compacted soil, and roadways. "Effective impervious surface" is commonly used to describe impervious surfaces connected to receiving water directly or with a conveyance device (e.g., curbs, pipes, gutters).

Infiltration: The process or rate at which water percolates from the land surface into the ground. Infiltration is also a general category of BMPs designed to collect runoff and allow it to flow through the ground for treatment.

Infiltration/Inflow (I/I): Clean storm and/or groundwater that enters the sewer system through cracked pipes, leaky manholes, or improperly connected storm drains, down spouts and sump pumps. Most inflow comes from stormwater and most infiltration comes from groundwater. I/I affects the size of conveyance and treatment systems and, ultimately, the rate businesses and residents pay to operate and maintain them.

Maximum Extent Practicable (MEP): A standard that applies to all MS4 operators under NPDES permits. The standard has no exact definition, as it was intended to be flexible to allow operators to tailor their stormwater programs to their particular site

MS4 (Municipal Separate Storm Sewer System): A publicly owned conveyance or system of conveyances that discharges to waters of the United States or waters of the state, and is designed or used for collecting or conveying storm water. Conveyances can include any pipe; ditch or gully; or system of pipes, ditches, or gullies, that is owned or operated by a governmental entity and used for collecting and conveying storm water. For purposes of implementing NPDES, regulated communities have been divided into small, medium and large MS4s:

- **Large MS4**: all municipal separate storm sewers that are located in an incorporated place with a population of 250,000 or more according to the latest Census.
- **Medium MS4**: all municipal separate storm sewers that are located in an incorporated place with a population of more than 100,000 but less than 250,000.
- **Small MS4**: any municipal separate storm sewer that is not defined as being "large" or "medium," but which meets certain criteria on density or other factors used locally for designation.

National Pollutant Discharge Elimination System (NPDES): A provision of the Clean Water Act that prohibits the discharge of pollutants into waters of the United States unless a special permit is issued by EPA, a state (where designated), a tribal government or Indian reservation.

Nonpoint source (NPS) pollution: Pollution that is caused by or attributable to diffuse sources. Typically, NPS pollution results from land runoff, precipitation, atmospheric deposition, or percolation.

Notice of Intent (NOI): An application to notify the permitting authority of a facility's intention to be covered by a general permit; exempts a facility from having to submit an individual or group application.

Permitting Authority: The NPDES-authorized state agency or EPA regional office that

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administers the NPDES program, issuing permits, providing compliance assistance, conducting inspections, and enforcing the program.

Pollution-generating pervious surfaces: A non-impervious surface with vegetative ground cover subject to use of pesticides and fertilizers. Such surfaces include, but are not limited to, the lawn and landscaped areas of residential or commercial sites, golf courses, parks, and sports fields.

Post-Construction BMPs: A subset of BMPs including source control and structural treatment BMPs that detain, retain, filter, or educate to prevent the release of pollutants to surface waters during the final functional life of development.

Retention: The process of collecting and holding surface and stormwater runoff with no surface outflow.

Runoff: Any drainage that leaves an area as surface flow.

Sanitary Sewer: An underground pipe system that carries sanitary waste and other wastewater to a treatment plant

Stormwater Sewer System: A system of pipes and channels that carry stormwater runoff from surfaces of building, paved surfaces, and the land to discharge areas

Stormwater Management: The prevention, control, and mitigation of the effects of stormwater runoff. Management programs include regulatory and non-regulatory aspects, but are typically integrated with other water quality programs.

Stormwater Management Plan (SWMP): A plan, which may be integrated with other land development plans or regulations, that spells out how a regulated entity intends to prevent and treat stormwater runoff.

Stormwater Pollution Prevention Plan (SWPPP): A plan to describe a process though which a facility thoroughly evaluates potential pollutant sources at a site and selects and implements appropriate measures designed to prevent or control the discharge of pollutants in stormwater runoff.

Total Maximum Daily Load (TMDL): A regulatory limit of the greatest amount of pollutants that can be released into a body of water without adversely affecting water quality.

Water Quality Standards: State-adopted and EPA-approved ambient standards for waterbodies. The standards cover the use of the waterbody and the water quality criteria that must be met to protect the designated use or uses.

Watershed: A geographic area in which water flowing across the surface will drain into a certain stream or river and flow out of the area via that stream or river. All of the land that drains to a particular body of water.

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Low Impact Development (LID) and Other Green Design Strategies

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Minimum Measure: Post-Construction Stormwater Management in New Development and Redevelopment

Subcategory: Innovative BMPs for Site Plans

Urban development significantly alters the natural features and hydrology of a landscape. Development and redevelopment usually creates impervious surfaces like concrete sidewalks and asphalt roadways, commercial and residential buildings, and even earth compacted by construction activities. Prevented from soaking into the ground, rainwater runs across parking lots and streets, collecting used motor oil, pesticides, fertilizers, and other pollutants.

In most cities, a complex system of piping usually feeds contaminated stormwater flows directly into streams and coastal waters. More recently, stormwater control structures (sometimes called Best Management Practices or BMPs) like dry extended detention ponds or wet retention ponds have been installed, most in new development, to intercept stormwater on its way to surface waters.

Historically, the goal of stormwater planning has been to prevent localized flooding by moving large amounts of water offsite as quickly as possible. However, experience has shown that traditional stormwater management has many limitations.

Expensive, ever-expanding storm sewer systems strain municipal budgets. Fast moving stormwater discharges cause downstream flooding, erode stream banks, and contribute to water quality violations. Bacteria and other pathogens carried in stormwater contaminate coastal waters, often requiring beach closures. Rainwater diverted or otherwise unable to soak into the soil cannot recharge aquifers. This reduces stream base flows, which can cause streams to dry-up for extended periods of time. Stormwater that collects in detention basins or flows over impervious surfaces is often much warmer than the streams into which it flows. This is a problem because a temperature increase of just one or two degrees can stress fish and other aquatic organisms.

Mimicking Natural Hydrology

Efforts to address stormwater problems resulting from traditional development methods have produced a number of innovative design alternatives. For example, researchers and developers are experimenting with minimizing the distance between land uses to decrease infrastructure requirements. Another method reduces stormwater runoff by conserving forests and green spaces and protecting stream buffers. Yet another technique diminishes impervious surfaces, narrows road and sidewalk widths, reduces parking lot sizes, minimizes or removes cul-de-sacs, and replaces traditional paving materials with pervious concrete.

Such innovative site design grew out of concerns that rapid urban development was not only impairing water quality but eroding quality of life. Concerned by the development of sensitive agricultural and wetlands, and burdened by the rising costs of stormwater damage, some communities are implementing Green Design strategies, such as LID, Conservation Development, Better Site Design, and Smart Growth. The complementary goals of these design schemes lessen the impact of stormwater while still providing opportunities for development.

LID

Like other alternative development strategies, LID seeks to control stormwater at its source. Rather than moving stormwater offsite though a conveyance system, the goal of LID is to restore the natural, pre-developed ability of an urban site to absorb stormwater.

LID integrates small-scale measures scattered throughout the development site. Constructed green spaces, native landscaping, and a variety of innovative bioretention and infiltration techniques capture and manage stormwater on-site. LID reduces peak runoff by allowing rainwater to soak into the ground, evaporate into the air, or collect in storage receptacles for irrigation and other beneficial uses. In areas with slow drainage or infiltration, LID captures the first flush before excess stormwater is diverted into traditional storm conveyance systems. The result is development that more closely maintains pre-development hydrology. Furthermore, LID has been shown to be cost effective, and in some cases, cheaper than using traditional stormwater management techniques.

LID Techniques

LID can be simple and effective. Instead of relying solely on complex and costly collection, conveyance, storage and

treatment systems, LID employs a range of economical devices that control runoff at the source.

- Bioretention cells, commonly known as rain gardens, are relatively small-scale, landscaped depressions containing plants and a soil mixture that absorbs and filters runoff. For more information on bioretention cells, see Bioretention (Rain Gardens) fact sheet and Stormwater Technology: Biorention [PDF - 257 KB - 8 pp] and Bioretention Case Studies [PDF - 133 KB - 3 pp] .
- Cisterns and rain barrels harvest and store rainwater collected from roofs. By storing and diverting runoff, these devices help reduce the flooding and erosion caused by stormwater runoff. And because they contain no salts or sediment, they can provide "soft" chemical-free water for garden or lawn irrigation, reducing water bills and conserving municipal water supplies. More information on rain barrels and cisterns see On-Lot Treatment fact sheet.
- Green roofs are roof-tops partially or completely covered with plants. Used for decades in Europe, green roofs help mitigate the urban "heat island" effect and reduce peak stormwater flows. The vegetated cover also protects and insulates the roof, extending its life and reducing energy costs. More information on green roofs can be found at Green Roofs fact sheet and Vegetated Roof Cover [PDF - 150 KB - 3 pp].
- Permeable and porous pavements reduce stormwater runoff by allowing water to soak through the paved surface into the ground beneath. Permeable pavement encompasses a variety of mediums, from porous concrete and asphalt, to plastic grid systems and interlocking paving bricks suitable for driveways and pedestrian malls. Permeable pavement helps reduce runoff volumes at a considerably smaller cost than traditional storm drain systems. For more information, see Porous Pavement fact sheet and Stormwater Technology: Porous Pavement [PDF - 1.34 MB - 6 pp].
- Grass swales are broad, open channels sown with erosion resistant and flood tolerant grasses. Used alongside roadways for years primarily as stormwater conveyances, swales can slow stormwater runoff, filter it, and allow it to soak into the ground. Swales and other biofiltration devices like grass filter-strips improve water quality and reduce in-stream erosion by slowing the velocity of stormwater runoff before it enters the stream. They also cost less to install than curbs, storm drain inlets, and piping systems. For more information, see Grassed Swales fact sheet and Stormwater Technology: Vegetated Swales [PDF - 81 KB - 7 pp].

Conservation Development

Like LID, Conservation Development tries to mitigate the effects of urbanization, but it places additional emphasis on protecting aquatic habitat and other natural resources. Conservation Development subdivisions are characterized by compact clustered lots surrounding a common open space. Conservation Development's goal is to disturb as little land area as possible while simultaneously allowing for the maximum number of residences permitted under zoning laws.

Prior to new construction, conservation developers evaluate natural topography, natural drainage patterns, soils and vegetation. They deploy stormwater best management practices to help prevent flooding and protect natural hydrology. By maintaining natural hydrological processes, Conservation Development creates conditions that slow, absorb, and filter stormwater runoff onsite.

Because future development threatens valuable natural features, Conservation Development provides specific provisions for long-term and permanent resource protection. Conservation easements, transfer of development rights, and other "in perpetuity" mechanisms ensure that protective measures are more than just temporary. For more information, go to NOAA Alternatives for Coastal Development EXIT Disclaimer website.

Better Site Design

The goals of Better Site Design are to reduce impervious cover, preserve natural lands, and capture stormwater onsite. To meet these goals, designers employ a variety of methods. To reduce impervious cover, they narrow streets and sidewalks, minimize cul-de-sacs, tighten parking spaces, and reduce the size of driveways and housing lots.

To reduce stormwater runoff, designers preserve natural lands, using them as buffer zones along streams, wetlands and steep slopes. They employ landscaping techniques that flatten slopes and preserve native vegetation and clusters of trees. They create bioretention areas - open channels, filter strips and vegetated swales - to increase stormwater infiltration, helping to protect steams, lakes, and wetlands. For more information, see the Center for Watershed Protection's Better Site Design EXIT Disclaimer website.

Development Districts

Development districts are areas zoned specifically for the purpose of permitting property development. Development districts concentrate intense, mixed-use development in an area typically five-acres and larger. Although a development district's percentage of imperviousness may exceed those of surrounding areas, such focused, compact development creates a smaller "footprint" than traditional development patterns.

A well-designed development district can contribute to a number of water quality benefits. Compact development lends itself to more environmentally friendly transportation options, like biking or walking, and shorter and less frequent automobile trips. A development district that redevelops an urban area reuses existing infrastructure, which can reduce the demand for new construction elsewhere in a watershed. Many development districts incorporate tree-lined streets, rain gardens, green roofs and other best management practices into their designs, helping manage stormwater onsite. For more information, see Development Districts fact sheet.

Smart Growth

Smart Growth is a set of development strategies that seek to balance economic growth, urban renewal, and conservation. In newly developing areas, Smart Growth advocates compact, town-centered communities composed of open green space, businesses, and affordable housing, interconnected by pedestrian walkways and bicycle lanes. Smart Growth's emphasis on walkable communities and alternative forms of transportation can help alleviate the environmental consequences of automobile use. Smart Growth also advocates the revitalization of inner cities and older suburbs. Reusing existing infrastructure often costs less than new construction, and it helps slow the spread of large-scale impervious surfaces.

Ten core principles guide Smart Growth:

- Mix land use.
- Take advantage of compact building design.
- Create a range of housing opportunities and choices.
- Create walkable neighborhoods
- Foster distinctive, attractive communities with a strong sense of place.
- Preserve open space, farmland, natural beauty and critical environmental areas.
- Strengthen and direct development toward existing communities.
- Provide a variety of transportation choices.
- Make development decisions predictable, fair and cost effective.
- Encourage community and stakeholder collaboration in development decisions.

While not explicitly mentioned as a guiding principal, stormwater management nevertheless benefits from Smart Growth policies. Compact, high-density development reduces the spread of impervious surfaces on a watershed scale. This helps reduce overall stormwater runoff. Infill and redevelopment that reuses existing infrastructure can be cheaper than greenfield development, which requires expensive new infrastructure. The `Fix it First' management philosophy advocates repairing and upgrading existing, frequently crumbling infrastructure before spending on new infrastructure.

All of these development strategies can contribute to reducing sprawl and slow the rapid spread of impervious surfaces. All of the site design frameworks discussed in this fact sheet can be coupled with the Smart Growth approach so that small-scale reductions in run-off aren't offset by watershed-scale increases in run-off.

Holistic Planning

The damaging effects of stormwater runoff can be mitigated if urban planners use development designs that reduce the "footprint" of impervious structures. Traditional stormwater approaches, with their emphasis on collection, conveyance, storage and discharge, cannot adequately address the environmental problems caused by sprawling urbanization. Furthermore, with rapid development occurring beyond the fringe of metropolitan regions, urban stormwater is jeopardizing hard fought gains in U.S. water quality.

New land and stormwater management strategies take a more holistic approach. Communities employing conservation development techniques have found that natural features like undeveloped landscapes, vegetation, and buffer zones effectively reduce and filter stormwater flows. There are also other benefits like recreation, wildlife habitat, and increased property values.

Case studies of green design practices have shown substantial decreases in stormwater runoff in pre-existing communities refitted with bioretention basins, permeable pavements, vegetated roof covers, and grass swales.

For example, a study of runoff and pollutant loading conducted in the parking lot of The Florida Aquarium in Tampa revealed an 80 percent decline in runoff volumes when the parking lot was retrofitted with pervious pavement and grass swales. Amounts of copper, manganese, lead, and other metals found in runoff also dropped steeply. For more information, go to Infiltration Opportunities in Parking Lot Designs Reduce Runoff and Pollution [PDF - 701 KB - 10 pp] EXIT Disclaimer .

Similarly, a study of vegetated roofs in Philadelphia, PA found that an older building retrofitted with a green roof absorbed all but 15 inches of a total 44 inches of rainfall that fell during the nine-month test period. Twenty-five years of German research on green roofs support this finding. For more information, go to Vegetated Roof Cover [PDF - 150 KB - 3 pp].

LID integrates ecological considerations into each phase of urban development, from design to construction to post-construction. Pilot programs conducted in the U.S. and around the world show that LID saves money by reducing construction costs for curbing, paving materials, drainage pipes and land clearing. Techniques that manage runoff onsite, such as swales and rain gardens, deliver tangible improvements in water quality and ground water recharge. LID practices also improve air quality, reduce the heat island effect, and enhance community appearance.

Green Design concepts used individually can yield measurable improvements in stormwater runoff management. Used in combination, they can help local governments address significant sources of stormwater pollution, particularly in older urban and suburban areas.

Because Green Design practices like LID blend multiple technologies, they are more versatile than the more limited drain-and-discharge methods of traditional stormwater management. LID can effectively address sources of water pollution in new and existing developments, in brownfields and greenfields, in warm climates and cold, and wet and dry climates. In urban areas, green roofs used in combination with rain gardens, permeable pavement, bio-retention cells and rain barrels produce results far greater than a single technology used alone.

Sound engineering principals form the basis of Green Design practices. Years of experience derived from stormwater management, sanitary engineering, agriculture, and other disciplines, demonstrate soil's ability to effectively absorb and digest many waterborne pollutants. By capturing stormwater onsite, Green Design techniques not only reduce pollutants and runoff volume, but they do so cost-effectively.

Resources

Austin City Connection - Smart Growth Initiative. [http://www.ci.austin.tx.us/smartgrowth/ EXIT Disclaimer].

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Northeastern Illinois Planning Commission, Environment and Natural Resources Group - Conservation Development in Practice. [http://www. nipc.org/environment/sustainable/conservationdesign/Conservation%20Development%20in%20Practice/ EXIT Disclaimer].

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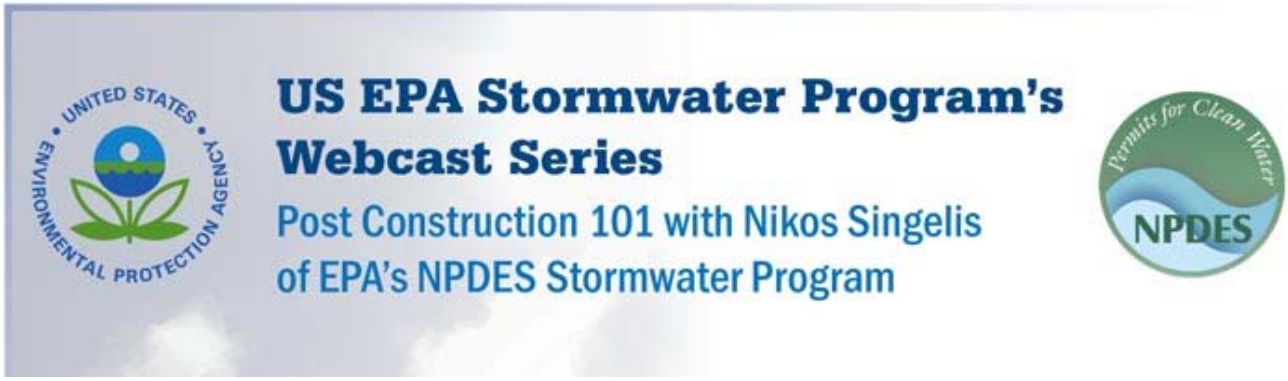

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Session Description

Over 5,000 municipal stormwater permittees are required to develop a post-construction program to address stormwater runoff from new development and redevelopment. The post-construction programs must include requirements to install BMPs and ensure maintenance of those BMPs. To implement an effective program, municipalities need to look beyond the individual site to assess how post-construction controls will affect the entire watershed. This presentation will describe the post-construction program requirements and how innovative programs such as **Low Impact Development and Smart Growth** can be used to help meet these requirements.

Speaker: Nikos Singelis, Senior Program Analyst with EPA's NPDES Stormwater Program.

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REFERENCE GUIDE FOR STORMWATER BEST MANAGEMENT PRACTICES

Stormwater Management Division
Bureau of Sanitation, Department of Public Works
City of Los Angeles

July 2000

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EXECUTIVE SUMMARY

Over the past two decades, local, regional, and national research programs have identified the principal causes of water pollution in most urban areas. Urban runoff, discharged from municipal and separate storm drain systems, has been one of the principal causes identified. Urban runoff discharged through storm drain system is further described as “non-point source pollution”, that is, a diffuse pollution that cannot be traced to a specific source. Because the pollution is discharged from the storm drain system, it is also referred to as “stormwater pollution.” Over time, stormwater pollution can deposit hundreds of tons of trash and debris at beaches and can also lead to public health and safety concerns. Urban runoff and stormwater pollution are not only a concern during the rainy season, but also year-round. This is due to the various ways in which urban water is used and discharged to the storm drain system, throughout the year. While the effect of stormwater pollution is not easily observed at the source, the impact upon receiving waters is apparent. One noticeable example is the presence of trash and debris along the beaches after a rainstorm event.

A less observable effect occurs when urban runoff and associated stormwater pollution impact aquatic plant and animal life in receiving waters. An example of this effect is the presence of potentially harmful viruses and bacteria now found in our coastal receiving waters along with soil particles, other solids, and litter. The City of Los Angeles storm drain system does not filter or treat contaminants or debris in the urban runoff, thus making urban runoff one of the most significant sources of surface water pollution in the region.

The City of Los Angeles is committed to implementing corrective measures to mitigate urban runoff and stormwater pollution problems. The City’s Stormwater Program has been directed to identify and implement mitigation and control measures via the application of Best Management Practices (BMPs). This manual has been prepared to assist departments and divisions of the City of Los Angeles in finding related information regarding BMPs for stormwater and urban runoff.

When implemented, BMPs best manage, prevent, control, remove, reduce, or treat urban runoff and stormwater pollution, before the pollution reaches receiving waters. BMPs include programs, operational measures or methods, engineered systems, technologies, processes, or siting criteria. This manual summarizes and details information on applicable BMPs for construction, source control, and treatment control as defined below:

- Construction BMPs are structural devices, measures, and operational methods or procedures used at construction sites to prevent, control, and treat pollution emanating from the site.
- Source control BMPs are schedules of activities, prohibitions of practices, maintenance procedures, management and operational procedures, and other methods employed at municipal, industrial, residential, and commercial sites, that help prevent stormwater pollution by reducing the potential for contamination at the source of pollution.
- Treatment control BMPs are engineered systems, technology, and structural devices that use physical, chemical, or biological processes to treat, control, remove, or reduce pollutants from stormwater and urban runoff.

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ACRONYMS AND ABBREVIATIONS

BMP	best management practice
BOD	biochemical oxygen demand
CDS	continuous deflective separation
cf	cubic feet
cfs	cubic feet per second
City	City of Los Angeles
COD	chemical oxygen demand
CWA	Federal Clean Water Act of 1987
gal	gallon
H	high
k	thousand
L	low
m	million
M	moderate
NPDES	National Pollutant Discharge Elimination System
O&M	operation and maintenance
RWQCB	Regional Water Quality Control Board (Los Angeles)
sf	square feet
SWPPP	Storm Water Pollution Prevention Plan
SWRCB	State Water Resources Control Board (California)
TSS	total suspended solids
UV	ultra-violet

INTRODUCTION

Purpose and Scope

This *Reference Guide for Stormwater Best Management Practices* has been prepared to provide general guidance and information on stormwater and urban runoff best management practices (BMPs). General guidance is provided to help locate related information on BMPs and to further identify, assess, and select appropriate BMPs. To help with the location and selection, the guide provides BMP listings, selection matrices, reference information, BMP cost information, and BMP target pollutant information. Background information is also provided and includes a general overview of associated pollutant and regulatory issues.

Designated manual users include engineers, planners, managers, and field operations personnel in the Stormwater Management Division, as well as other City of Los Angeles departments and divisions. This manual serves as a reference guide and a planning tool for designated users. The use of this manual however, does not supersede requirements of a National Pollutant Discharge Elimination System (NPDES) permit or other regulatory permits. Although this manual is currently not available to other users, it may in the future, be made available to developers, industries, commercial entities, and the general public, as appropriate. The current and primary purpose of this manual is to assist city engineers and managers in planning, developing, and selecting the optimum BMP(s) for various applications.

Manual Organization and Use

This manual consists of three major sections that correspond to different BMP categories, as listed below:

I. Construction BMPs
II. Source Control BMPs
III. Treatment Control BMPs

Section I describes BMPs for the construction category, Section II describes BMPs for the source control category, and Section III describes BMPs for the treatment control category. BMP definitions are provided for the described categories at the end of the Executive Summary and at the beginning of each section. Each section contains BMP guidance information for the specific category.

The guidance information presented in each section includes relevant background information, a listing of applicable stormwater BMPs, and associated tables to help with the BMP selection process. One of the tables included in each section is a BMP selection matrix. The other tables include a BMP reference table, a BMP cost table,

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and a BMP target pollutant table. If needed, directions for manual use, including table use, are provided in Appendix C. Table organization is described below.

Table Organization

The tables are organized in a series format as described below.

Series A includes Tables IA, IIA, and IIIA. All Series A tables are BMP Selection Matrices and are specific to one BMP category as follows:

Table IA Construction BMP Selection Matrix
Table IIA Source Control BMP Selection Matrix
Table IIIA Treatment Control BMP Selection Matrix

Each table listed above identifies BMPs that would be applicable to a certain activity, area of concern, or target pollutant associated with the category. The purpose of this table series is to identify and help select a BMP that would not only be applicable to the category, but also the activity or area of concern within the category.

Series B includes Tables IB, IIB, and IIIB. All Series B tables are BMP Reference Tables and are specific to one BMP category as follows:

Table IB Construction BMP References
Table IIB Source Control BMP References
Table IIIB Treatment Control BMP References

Each table listed above identifies BMPs that are applicable to the category along with a corresponding published reference for each BMP. Abbreviated number citations are included in the table. Full citations are in numerical order, in the Reference section at the end of the manual. The purpose of this table series is to provide reference information for BMPs that are being considered for selection within a category. Each BMP was identified from the latest available and applicable references, pilot study materials, and application results published by various federal, state, and local agencies, as well as those published by private companies.

Series C includes Tables IC, IIC and IIIC. All Series C tables are BMP Cost Tables and are specific to one BMP category as follows:

Table IC Construction BMP Costs
Table IIC Source Control BMP Costs
Table IIIC Treatment Control BMP Costs

Each table listed above identifies relative or estimated costs for BMPs applicable to that category. The purpose of this table series is to list applicable BMPs and corresponding qualitative and quantitative cost information. Costs vary depending

on a number of factors including site conditions, site location, and size and type of the project. Because of the unavailability of individual costs at this time, cost information on capital, training, and operation and maintenance are expressed in general qualitative costs (high, moderate, and low) only. The relative cost information was primarily obtained from the California Stormwater BMP Handbooks (References 2, 3, and 4). Information on quantitative costs for treatment control BMPs was also obtained from available data summary materials and pilot study technical reports (e.g. References 30, 39, and 42).

Series D includes Tables ID, IID, and IIID. All Series D Tables are BMP Target Pollutant Tables and are specific to one BMP category as follows:

Table ID Construction BMP Target Pollutants
Table IID Source Control BMP Target Pollutants
Table IIID Treatment Control BMP Target Pollutants

Each table listed above consists of BMP listings and corresponding pollutants targeted. The purpose of this table series is to identify the pollutants removed, treated, or reduced by the specific BMP. It should be noted that pollutants could be site-specific depending on the type of project or activity. The information included in the Series D tables was obtained primarily from the California Stormwater BMP Handbooks (References 2, 3, and 4) and pilot study reports (e.g. Reference 39). The degree of effectiveness in the pollutant removal process vary for each BMP due to site-specific conditions and other factors such as application, topography, weather conditions, and implementation methodology. Thus, information on pollutant removal efficiency for construction, source control, and treatment control BMP categories are not documented in this manual. Instead, a qualitative table of target pollutants for each BMP category is provided. It should be noted, however, that limited removal efficiency data for treatment control systems can be found in some reference materials cited in this manual (e.g. Reference 24). Also, information included on specific pollutants for treatment control systems are based on currently available data.

Target Pollutants

Target pollutants referred to in this manual and specifically listed in Series D tables, as described above, are grouped in eight general categories as follows:

1. Sediments – Sediments are soils or other surficial materials transported or deposited by the action of wind, water, ice, or gravity, as a product of erosion. For example, sediments can erode from land when disturbed by a construction activity or heavy rainfall. Sediments can increase turbidity, clog the gills of fish, reduce spawning, lower the ability of young aquatic organisms to survive, smother bottom dwelling organisms, and suppress the growth of aquatic vegetation.
2. Nutrients – Nutrients are inorganic substances, such as nitrogen and phosphorous. They commonly exist in the form of mineral salts that are either dissolved or

suspended in water. The primary source of nutrients in urban runoff has been identified as fertilizer products. Excessive use of fertilizer can result in the discharge of nutrients to water bodies and streams, resulting in excessive aquatic algae and plant growth. Overgrowth of aquatic algae and plants can lead to a state of eutrophication in the water body. Eutrophication occurs when overgrowth leads to excessive decay of organic matter in the water body, loss of oxygen in the water, and the eventual death of water body organisms. For non-point sources of pollution, phosphorous is the primary nutrient of concern.

3. Heavy Metals – Metals are inorganic substances that sometimes occur naturally in soil at small concentrations. Metals such as lead, copper, chromium, mercury, cadmium, and zinc, characterized by higher molecular weight, are called heavy metals. At small concentrations naturally-occurring in soil, heavy metals are not considered toxic. However, at higher concentrations, certain heavy metals can be toxic. Metals are also commercially available. Commercially available metals can be found in formed or manufactured metals, as well as metal products. Metals are also used as raw material components in non-metal products such as fuels, adhesives, paints, and other coatings. For example, certain heavy metals such as lead and chromium, have been used as corrosion inhibitors in primer coatings or cooling tower systems. A primary source of heavy metal pollution in stormwater however, is the use of commercially available metals and metal products. At certain conditions, these products can react or degrade such that their metal components are released to the environment and transported via leaching or erosion to local water bodies. Environmental concerns, regarding the potential for release to the environment, have restricted selected heavy metal usage in certain applications.

4. Toxic Chemicals – Toxic chemicals are either organic or inorganic substances, which at certain concentrations can indirectly or directly constitute a hazard to life or health. Chemicals exhibiting human and/or aquatic toxicity characteristics are considered toxic. Some commercially available or naturally occurring substances that may exhibit these characteristics include pesticides, cyanides, solvents, organic compounds, and hydrocarbons. For example, the excessive application of pesticides may result in runoff containing toxic levels of the pesticide's active component. Also, when rinsing off objects, toxic levels of solvents and cleaning compounds can be discharged to the storm drain. Dirt, grease, and grime retained in the cleaning fluid or rinse water may also be present at levels that are harmful or hazardous to the environment. Other sources of potentially toxic or hazardous substances include the following: automotive fluids that drip and leak from vehicles; illegally discharged motor fluids (such as motor oil and radiator fluid); cleanup wastes (such as concrete mixers, paints, adhesives, etc.); industrial, sanitary, and animal wastes; and certain types of litter.

5. Floatable Materials - Trash (e.g., paper, plastic, polystyrene packing foam, aluminum materials, etc.) and biodegradable organic matter (e.g., leaves, grass cuttings, food waste, etc.) are considered floatable materials. The presence of floatable materials has a significant impact on the recreational value of a water body and can potentially impact aquatic species habitat. Excess organic matter can create a high biochemical oxygen demand in a stream and thereby, lower the water quality of the

stream. Also, in areas where stagnant water exists, the presence of excess organic matter can promote septic conditions resulting in the growth of undesirable organisms and the release of odorous and hazardous compounds such as hydrogen sulfide.

6. Oxygen-Demanding Substances – Oxygen-demanding substances are those substances that require oxygen as part of their natural, biological, or chemical processes. The oxygen demand of a substance can lead to depletion of natural oxygen resources in a water body and possibly the development of septic conditions. Proteins, carbohydrates, and fats are examples of oxygen-demanding substances. They can also be referred to as "biodegradable organics." The presence of oxygen-demanding substances in water is measured as biochemical oxygen demand (BOD) and chemical oxygen demand (COD).
7. Oil and Grease – Oil and grease are characterized as high-molecular weight organic compounds. Primary sources of oil and grease are petroleum hydrocarbon products, motor products, esters, oils, fats, waxes, and high molecular-weight fatty acids. Migration of these pollutants to the water bodies are very possible due to the wide uses and applications of some of these products in either municipal, residential, commercial, industrial, or construction areas. Elevated oil and grease content can decrease the aesthetic value of the water body, as well as the water quality.
8. Bacteria and Viruses – Bacteria and viruses are micro-organisms that thrive under certain environmental conditions. Water, containing excessive bacterial and viral levels, can alter the aquatic habitat and create a harmful environment for humans and aquatic life. This type of water pollution is characterized by high coliform bacterial counts. It is typically caused by excess animal or human fecal wastes in the water. Also, the decomposition of excess organic waste causes increased growth of undesirable organisms in the water.

I. Construction Best Management Practices (BMPs)

This section lists and describes those BMPs most commonly used for construction activities. Construction BMPs include structural devices, measures, and operational methods or procedures used at construction sites to prevent, control, and treat stormwater pollution emanating from the site. This section presents the following information: background information, providing an overview of related pollutant and regulatory issues; a BMP listing, summarizing the applicable practices; and BMP guidance information, to assist in the BMP selection process. Guidance information is presented in a tabular format and includes: a BMP selection matrix, a BMP reference table, a BMP cost table, and a BMP target pollutant table.

A. Background Information

1. Pollutant Issues - Most construction activities disturb large areas and amount of earth and therefore result in significant erosion and transportation of related particulates such as sediments and dust to nearby waterways. In excess amounts, these particulates can increase water turbidity and consequently impair aquatic life and beneficial uses of the water.

   Pollutants such as hydrocarbons, metals, nutrients, toxic substances, trash, and other debris can be generated from a variety of construction activities and can travel with eroded sediments. Potential pollutants traveling with the sediments may include the organic components in the top soil, plant residues, nutrient elements, organic material, deposited atmospheric pollutants, and other liquid and solid wastes.

   Toxic substances have been found to adsorb or concentrate in sediments. When excessive loading occurs in an aquatic system, the toxic substances can interfere with the reproductive cycle of many plants and animals and cause tumors and lesions in fish. Toxic pollutants in sediments can also be re-mobilized under certain environmental conditions. When a pollutant is re-mobilized, it has the potential to further interfere with the natural cycle of aquatic life.

   Miscellaneous wastes that can be generated at a construction site include wash water from concrete mixers, paints and associated equipment cleaning wastes, solid wastes resulting from trees and shrubs removed during land clearing, wood and paper materials derived from building product packaging, food containers (such as paper, aluminum, and metal cans), and sanitary wastes. Discharge of these wastes into the drain system can lead to unsightly and polluted waterways.

2. Regulatory Issues - Based on the aforementioned pollutant issues, the amended federal Clean Water Act of 1987 (CWA) added a requirement to address construction site stormwater pollution. In California, construction activities

consisting of five acres or more are subject to the Construction National Pollutant Discharge Elimination System (NPDES) Permit requirements of the State Water Resources Control Board (SWRCB). These requirements include the preparation and implementation of a formal Storm Water Pollution Prevention Plan (SWPPP).

The CWA also requires that each municipality throughout the nation be issued an NPDES Permit (Permit). The goal of the Permit is to stop polluted discharges from entering the storm drain system and local coastal waters. The associated municipal stormwater NPDES Permit was granted by the Los Angeles Regional Water Quality Control Board (RWQCB) on July 15, 1996. It was issued to Los Angeles County and 85 co-permittee cities including the City of Los Angeles. The Permit contains a requirement for Los Angeles County and co-permittees to develop and implement a "Development Construction Model Program."

In 1999, the local "Development Construction Model Program" was adopted. This program requires construction sites of less than 5 acres of disturbed soil size, to incorporate stormwater pollution control measures. As described previously, the SWRCB's Construction NPDES Permit requires that construction sites of 5 acres or more prepare and implement an official SWPPP and also follow specific NPDES Permit requirements.

B. BMP Listing

Listed below are the specific BMPs for construction activities. The list includes erosion and sedimentation control measures, site management practices, materials and waste management, and general preventive maintenance and inspection.

A-1. Construction Scheduling
A-2. Preservation of Existing Vegetation
A-3. Employee/Subcontractor Training
A-4. Site Maintenance and Inspection
A-5. Vehicle and Equipment Cleaning
A-6. Vehicle and Equipment Fueling
A-7. Vehicle and Equipment Maintenance
A-8. Material Delivery and Storage
A-9. Material Use
A-10. Material Handling
A-11. Spill Prevention and Control
A-12. Solid Waste Management
A-13. Hazardous Waste Management
A-14. Contaminated Soil Management
A-15. Concrete Waste Management
A-16. Sanitary/Septic Waste Management

A-17. Dust Controls
A-18. Dewatering Operations
A-19. Paving Operations
A-20. Structure Construction and Painting
A-21. Seeding and Planting
A-22. Mulching
A-23. Geotextiles and Mats
A-24. Temporary Stream Crossing
A-25. Reinforced Soil Retaining System
A-26. Stabilized Construction Entrance
A-27. Construction Road Stabilization
A-28. Earthen Dike
A-29. Temporary Drains and Swales
A-30. Temporary Slope Drain
A-31. Storm Drain Outlet Protection
A-32. Check Dams
A-33. Slope Roughening/Terracing
A-34. Silt Fence
A-35. Straw Bale Barriers
A-36. Sandbag Barrier
A-37. Brush or Rock Filter
A-38. Storm Drain Inlet Protection
A-39. Temporary Sediment Trap
A-40. Temporary Sediment Basin

C. BMP Selection Matrix and Tables

The BMP selection matrix and tables are provided to help select construction BMPs that best meet the NPDES Permit requirements or other stormwater mitigation plan and most suitable for a subject construction site. The construction BMP selection matrix and tables can be found in the subsequent pages and are listed as follows:

Table IA - Construction BMP Selection Matrix
Table IB - Construction BMP References
Table IC - Construction BMP Costs
Table ID - Construction BMP Target Pollutants

Table IA
CONSTRUCTION BMP SELECTION MATRIX

Stormwater Best Management Practices (BMPs)		Category of Construction Activities																						
		Site Prep./ Earth		Underground Structures				Aboveground Structures				Roadways/ Walkways/ Parking Lots			Waterways					Planting/ Landscaping			
BMP Name	BMP Code	Clearing & Grubbing	Earthwork	Foundations	Conduits (Open Cut)	Drilling	Tunnels	Wood Frame	Structural Steel	Masonry & Concrete	Roofing & Coating	Concrete	Asphalt	Base & Subgrade	Channel Improvements	Water/Sediment Impoundment	Over Crossing	Under Crossing	Waterfront Construction	Irrigation Facilities	Seeding & Sodding	Mulching	Planting
Sediment Control																								
Scheduling	A-1	X	X		X							X	X	X	X	X	X	X	X	X	X	X	X	X
Preservation of Existing Vegetation	A-2	X	X		X		X					X	X	X	X	X	X	X	X	X		X	
Dust Control	A-3	X	X		X							X	X	X	X	X	X	X	X	X	X	X	X	X
Stabilized Construction Entrance	A-26	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
General Site Management																								
Construction Practices																								
Dewatering Operations	A-18														X	X	X	X	X					
Paving Operations	A-19			X	X	X	X					X	X	X			X	X						
Structure Construction & Paint	A-20			X			X	X	X	X	X						X	X	X					

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Stormwater Best Management Practices (BMPs)		Category of Construction Activities																				
		Site Prep./ Earth		Underground Structures				Aboveground Structures				Roadways/ Walkways/ Parking Lots			Waterways					Planting/ Landscaping			
BMP Name	BMP Code	Clearing & Grubbing	Earthwork	Foundations	Conduits (Open Cut)	Drilling	Tunnels	Wood Frame	Structural Steel	Masonry & Concrete	Roofing & Coating	Concrete	Asphalt	Base & Subgrade	Channel Improvements	Water/Sediment Impoundment	Over Crossing	Under Crossing	Waterfront Construction	Irrigation Facilities	Seeding & Sodding	Mulching	Planting
Vehicle & Equipment Management																							
Vehicle & Equipment Cleaning	A-6	X	X	X	X	X	X					X	X	X					X				

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Table IA (Cont.)
CONSTRUCTION BMP SELECTION MATRIX

Stormwater Best Management Practices (BMPs)		Category of Construction Activities																				
		Site Prep./ Earth		Underground Structures				Aboveground Structures				Roadways/ Walkways/ Parking Lots			Waterways					Planting/ Landscaping			
BMP Name	BMP Code	Clearing & Grubbing	Earthwork	Foundations	Conduits (Open Cut)	Drilling	Tunnels	Wood Frame	Structural Steel	Masonry & Concrete	Roofing & Coating	Concrete	Asphalt	Base & Subgrade	Channel Improvements	Water/Sediment Impoundment	Over Crossing	Under Crossing	Waterfront Construction	Irrigation Facilities	Seeding & Sodding	Mulching	Planting
Vehicle & Equipment Fueling	A-7	X	X	X	X	X	X					X	X	X					X				
Vehicle & Equipment Maintenance	A-8	X	X	X	X	X	X					X	X	X					X				
Tracking Control																							
Stabilized Construction Entrance	A-26	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Contractor Training																							
Employee/Subcontractor Training	A-4	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Construction Materials & Waste Management																							
Materials Management																							
Material Delivery & Storage	A-9			X	X			X	X	X	X	X	X	X	X		X	X	X		X	X	X
Material Use	A-10			X	X			X	X	X	X	X	X	X	X		X	X	X		X		
Spill Prevention & Control	A-12									X	X		X									X	X

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Stormwater Best Management Practices (BMPs)		Category of Construction Activities																					
		Site Prep./ Earth		Underground Structures				Aboveground Structures				Roadways/ Walkways/ Parking Lots			Waterways					Planting/ Landscaping			
BMP Name	BMP Code	Clearing & Grubbing	Earthwork	Foundations	Conduits (Open Cut)	Drilling	Tunnels	Wood Frame	Structural Steel	Masonry & Concrete	Roofing & Coating	Concrete	Asphalt	Base & Subgrade	Channel Improvements	Water/Sediment Impoundment	Over Crossing	Under Crossing	Waterfront Construction	Irrigation Facilities	Seeding & Sodding	Mulching	Planting
Waste Management																							
Solid Waste Management	A-13	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Hazardous Waste Management	A-14									X	X												

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Table IA (Cont.)
CONSTRUCTION BMP SELECTION MATRIX

Stormwater Best Management Practices (BMPs)		Category of Construction Activities																						
		Site Prep./ Earth		Underground Structures				Aboveground Structures				Roadways/ Walkways/ Parking Lots			Waterways					Planting/ Landscaping			
BMP Name	BMP Code	Clearing & Grubbing	Earthwork	Foundations	Conduits (Open Cut)	Drilling	Tunnels	Wood Frame	Structural Steel	Masonry & Concrete	Roofing & Coating	Concrete	Asphalt	Base & Subgrade	Channel Improvements	Water/Sediment Impoundment	Over Crossing	Under Crossing	Waterfront Construction	Irrigation Facilities	Seeding & Sodding	Mulching	Planting
Contaminated Soil Management	A-15	X	X	X	X	X	X																
Concrete Waste Management	A-16			X	X		X			X		X			X		X	X	X	X			
Sanitary/Septic Waste Mgmt.	A-17	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X

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Table IB
CONSTRUCTION BMP REFERENCES

Stormwater Best Management Practices	BMP Code	Sources of Information (See References)
Construction Scheduling	A-1	2, 9, 17, 19, 29
Preservation of Existing Vegetation	A-2	2, 6, 9, 15, 19, 29, 32
Employee/Subcontractor Training	A-3	2, 9, 24
Site Maintenance and Inspection	A-4	24
Vehicle and Equipment Cleaning	A-5	2, 9, 15, 19, 23, 41
Vehicle and Equipment Fueling	A-6	2, 9, 19, 23, 41
Vehicle and Equipment Maintenance	A-7	2, 9, 15, 19, 23, 41
Material Delivery and Storage	A-8	2, 9, 15, 19, 23, 27
Material Use	A-9	2, 9, 19, 24
Material Handling	A-10	25, 27
Spill Prevention and Control	A-11	2, 9, 17, 19, 23, 24, 41
Solid Waste Management	A-12	2, 9, 15, 16, 17, 19, 24, 27, 28, 41
Hazardous Waste Management	A-13	2, 9, 19, 24, 27, 28, 41
Contaminated Soil Management	A-14	2, 9, 15, 19, 24, 27, 28
Concrete Waste Management	A-15	2, 9, 15, 19, 24, 27, 28, 41
Sanitary/Septic Waste Management	A-16	2, 9, 19, 24, 41
Dust Controls	A-17	2, 9, 23, 24, 32
Dewatering Operations	A-18	2, 9, 19, 24, 35
Paving Operations	A-19	2, 6, 9, 19, 32
Structure Construction & Painting	A-20	2, 6, 9, 19
Seeding and Planting	A-21	2, 6, 9, 13, 15, 18, 19, 23, 24, 27, 29, 32
Mulching	A-22	2, 9, 13, 15, 18, 19, 23, 27, 29, 32
Geo-textiles and Mats	A-23	2, 9, 15, 19, 23, 24, 27, 29, 32
Temporary Stream Crossing	A-24	2, 9, 15, 19, 24, 29
Reinforced Soil Retaining System	A-25	15, 24, 29
Stabilized Construction Entrance	A-26	2, 6, 9, 15, 19, 24, 27, 29, 32
Construction Road Stabilization	A-27	2, 6, 9, 15, 19, 24, 32
Earth Dike	A-28	2, 9, 15, 19, 23, 24, 32
Temporary Drains and Swales	A-29	2, 6, 9, 18, 19, 23, 24, 32
Temporary Slope Drain	A-30	2, 9, 15, 19, 23, 24, 27, 29, 32
Storm Drain Outlet Protection	A-31	2, 9, 19, 23, 24, 32

Table IB (Cont.)
CONSTRUCTION BMP REFERENCES

Stormwater Best Management Practices	BMP Code	Sources of Information (See References)
Check Dams	A-32	2, 9, 15, 19, 23, 24, 29, 32, 35
Slope Roughening/Terracing	A-33	2, 9, 19, 23, 24, 27, 29, 32
Silt Fence	A-34	2, 9, 15, 18, 19, 23, 24, 27, 29, 32
Straw Bale Barriers	A-35	2, 9, 15, 18, 19, 23, 27, 29, 32
Sandbag Barrier	A-36	2, 9, 19
Brush or Rock Filter	A-37	2, 9, 19, 23, 24, 32
Storm Drain Inlet Protection	A-38	2, 9, 15, 18, 19, 23, 24, 29, 32
Temporary Sediment Trap	A-39	2, 9, 15, 18, 19, 20, 23, 24, 27, 29, 32
Temporary Sediment Basin	A-40	2, 9, 15, 18, 19, 23, 24, 27, 29, 32

Table IC
CONSTRUCTION BMP COSTS

([1] Individual quantitative cost information on capital, O&M, and training are not available for the specified BMP. The California Stormwater BMP Handbooks were used for relative cost [expressed as H – high, L – low, and M – moderate] information)

Stormwater Best Management Practices	BMP Code	Implementation Requirements			
		Capital Cost[1]	O&M Cost[1]	Training Cost[1]	Comments
Construction Scheduling	A-1	L	L	L	May increase other const. costs
Preservation of Existing Vegetation	A-2	L	L	L	May yield aesthetic benefits
Employee/Subcontractor Training	A-3	L	L	M	
Site Maintenance and Inspection	A-4	L	L	L	
Vehicle and Equipment Cleaning	A-5	L	L	L	
Vehicle and Equipment Fueling	A-6	M	L	M	
Vehicle and Equipment Maintenance	A-7	L	L	M	
Material Delivery and Storage	A-8	L	L	M	
Material Use	A-9	L	L	M	
Material Handling	A-10	L	L	L	
Spill Prevention and Control	A-11	L	M	M	
Solid Waste Management	A-12	L	L	M	
Hazardous Waste Management	A-13	L	L	M	Treatment/ disposal of contaminated soil can be costly
Contaminated Soil Management	A-14	L	M	M	
Concrete Waste Management	A-15	L	L	M	
Sanitary/Septic Waste Management	A-16	L	L	L	
Dust Controls	A-17	L	M	L	

Table IC (Cont.)
CONSTRUCTION BMP COSTS

([1] Individual quantitative cost information on capital, O&M, and training are not available for the specified BMP. The California Stormwater BMP Handbooks were used for relative cost [expressed as H – high, L – low, and M – moderate] information)

Stormwater Best Management Practices	BMP Code	Implementation Requirements			
		Capital Cost[1]	O&M Cost[1]	Training Cost[1]	Comments
Dewatering Operations	A-18	M	M	M	High disposal costs for contaminated groundwater
Paving Operations	A-19	L	L	M	
Structure Construction & Painting	A-20	L to M	L	M	
Seeding and Planting	A-21	M	M	M	
Mulching	A-22	M	M	L	
Geotextiles and Mats	A-23	H	M	L	
Temporary Stream Crossing	A-24	M	L	L	Bridge: $45-$95 per sq. ft.
Reinforced Soil Retaining System	A-25	M	L	L	
Stabilized Construction Entrance	A-26	M	L	L	
Construction Road Stabilization	A-27	M	M	L	
Earth Dike	A-28	M	L	L	$15-$55 per linear ft.
Temporary Drains and Swales	A-29	M	L	L	
Temporary Slope Drain	A-30	M	L	L	
Outlet Protection	A-31	M	L	L	
Check Dams	A-32	M	L	L	
Slope Roughening/Terracing	A-33	L	L	L	Terracing: $4 per linear ft.

Table IC (Cont.)
CONSTRUCTION BMP COSTS

([1] Individual quantitative cost information on capital, O&M, and training are not available for the specified BMP. The California Stormwater BMP Handbooks were used for relative cost [expressed as H – high, L – low, and M – moderate] information)

Stormwater Best Management Practices	BMP Code	Implementation Requirements			
		Capital Cost[1]	O&M Cost[1]	Training Cost[1]	Comments
Silt Fence	A-34	M	M	L	$7 per linear ft.
Straw Bale Barriers	A-35	H	H	L	Annual cost: $17 per linear ft.
Sandbag Barrier	A-36	H	L	L	Costly, longer life
Brush or Rock Filter	A-37	M	M	L	Rock filter can be more expensive
Storm Drain Inlet Protection	A-38	M	L	L	Annual cost: $150 per inlet
Temporary Sediment Trap	A-39	L	M	L	$1.3k per drainage acre
Temporary Sediment Basin	A-40	L	M	L	$350 - $700 per drainage acre

ft - feet
k - thousand
O&M – operation and maintenance

Table ID
CONSTRUCTION BMP TARGET POLLUTANTS

Stormwater Best Management Practices	BMP Code	Target Pollutants
Construction Scheduling	A-1	Sediment, Nutrients, Metals, Pesticides, Oil/Grease/Fuels, Toxic Chemicals, Miscellaneous Wastes
Preservation Existing Vegetation	A-2	Sediment, Miscellaneous Wastes
Employee/Subcontractor Training	A-3	Sediment, Nutrients, Metals, Pesticides, Oil/Grease/Fuels, Toxic Chemicals, Miscellaneous Wastes
Site Maintenance and Inspection	A-4	Sediments, Nutrients, Metals, Pesticides, Oil/Grease/Fuels, Toxic Chemicals, Miscellaneous Wastes
Vehicle and Equipment Cleaning	A-5	Oil/Grease/Fuels, Toxic Chemicals
Vehicle and Equipment Fueling	A-6	Oil/Grease/Fuels, Toxic Chemicals
Vehicle and Equipment Maintenance	A-7	Oil/Grease/Fuels, Toxic Chemicals
Material Delivery and Storage	A-8	Sediment, Nutrients, Metals, Pesticides, Oil/Grease/Fuels, Toxic Chemicals
Material Use	A-9	Sediment, Nutrients, Metals, Pesticides, Oil/Grease/Fuels, Toxic Chemicals
Material Handling	A-10	Sediment, Nutrients, Metals, Pesticides, Oil/Grease/Fuels, Toxic Chemicals
Spill Prevention and Control	A-11	Pesticides, Oil/Grease/Fuels, Toxic Chemicals, Miscellaneous Wastes
Solid Waste Management	A-12	Sediment, Metals, Miscellaneous Wastes
Hazardous Waste Management	A-13	Toxic Chemicals
Contaminated Soil Management	A-14	Sediment, Nutrients, Metals, Pesticides, Oil/Grease/Fuels, Toxic Chemicals, Miscellaneous Wastes
Concrete Waste Management	A-15	Sediment, Miscellaneous Wastes
Sanitary/Septic Waste Management	A-16	Miscellaneous Wastes
Dust Controls	A-17	Sediment, Metals, Toxic Chemicals
Dewatering Operations	A-18	Sediment, Nutrients, Metals, Pesticides, Oil/Grease/Fuels, Toxic Chemicals, Miscellaneous Wastes
Paving Operations	A-19	Sediment, Pesticides, Oil/Grease/Fuels, Miscellaneous Wastes
Structure Construction & Painting	A-20	Metals, Toxic Chemicals, Miscellaneous Wastes
Seeding and Planting	A-21	Sediment, Nutrients, Pesticides, Miscellaneous Wastes
Mulching	A-22	Sediment, Nutrients, Pesticides, Miscellaneous Wastes

Table ID (Cont.)
CONSTRUCTION BMP TARGET POLLUTANTS

Stormwater Best Management Practices	BMP Code	Target Pollutants
Geo-textiles and Mats	A-23	Sediment, Toxic Chemicals, Miscellaneous Wastes
Temporary Stream Crossing	A-24	Sediment
Reinforced Soil Retaining System	A-25	Sediment
Stabilized Construction Entrance	A-26	Sediment
Construction Road Stabilization	A-27	Sediment
Earth Dike	A-28	Sediment
Temporary Drains and Swales	A-29	Sediment, Nutrients, Metals, Pesticides, Oil/Grease/Fuels, Toxic Chemicals, Miscellaneous Wastes
Temporary Slope Drain	A-30	Sediment, Miscellaneous Wastes
Storm Drain Outlet Protection	A-31	Sediment
Check Dams	A-32	Sediment
Slope Roughening/Terracing	A-33	Sediment
Silt Fence	A-34	Sediment
Straw Bale Barriers	A-35	Sediment
Sandbag Barrier	A-36	Sediment
Brush or Rock Filter	A-37	Sediment
Storm Drain Inlet Protection	A-38	Sediment
Temporary Sediment Trap	A-39	Sediment
Temporary Sediment Basin	A-40	Sediment

II. Source Control Best Management Practices (BMPs)

This section lists and describes those BMPs most commonly used for source control at municipal, residential, industrial, and commercial sites. Source control BMPs help to prevent stormwater pollution by reducing the potential for contamination at the source of the pollution. Source control BMPs include schedules of activities, prohibitions of practices, maintenance procedures, management and operational procedures; and other methods employed at municipal, industrial, residential, and commercial sites to control pollution at the source. This section presents the following information: background information, providing an overview of related pollutant and regulatory issues; a BMP listing, summarizing the applicable source control practices by area or activity, and guidance information to assist in BMP selection. Guidance information is presented in a tabular format and includes a BMP selection matrix, a BMP reference table, a BMP cost table, and BMP target pollutant table.

A. Background Information

1. Pollutant Issues - Urban stormwater primary pollutant sources include the following areas and operations: industrial and commercial areas; high activity parking lots; material (including wastes) storage and handling areas; vehicle and equipment fueling, washing maintenance, repair areas; erodible soil; street and highways; and handling and application of landscape maintenance products.

   Reduction or the elimination of stormwater pollutants can be achieved by implementing operational source control BMPs including good housekeeping, employee training, spill prevention and cleanup, preventative maintenance, regular inspections, and record-keeping. These BMPs can be combined with engineering, structural, and physical controls (such as impervious containments and covers). If operational and structural source control BMPs are not feasible or adequate, then stormwater treatment BMPs may be necessary, as described in Section III. Selecting cost-effective BMPs should be based on an assessment of potential pollutants and their sources.

2. Regulatory Issues - Source controls can be used to assist industrial entities in complying with requirements of their individual NPDES permits and their industrial sector permits issued by the United States Environmental Protection Agency. Source controls may also be used in complying with requirements of the General Industrial NPDES permit issued by SWRCB. In the event that the identified BMPs become infeasible or inadequate to reduce the source of contamination, treatment controls may need to be utilized.

   City facilities, operations and departments may also utilize source controls to help meet the requirements of the Municipal Stormwater NPDES permit. This includes city vehicle maintenance yards and field operations.

Those in charge of private or city development can use source controls to help comply with the requirements of the newly adopted stormwater mitigation measures, issued by the RWQCB. Source controls may also be used to assist in reducing stormwater pollution from the entire City of Los Angeles drainage area including areas not covered by the described regulatory requirements.

B. BMP Listing

Listed below are the source control BMPs for municipal, residential, industrial, and commercial activities. The list includes vehicle management; material handling and storage; structure and facility maintenance; vegetation management; illicit discharge control; and general practices, preventive maintenance, and inspection. Specific industrial and commercial BMPs are individually listed in the references identified.

General

B-1. Public Education/Participation
B-2. Land Use Planning/Management
B-3. Employee Training
B-4. Housekeeping Practices
B-5. Safer Alternative Products
B-6. Above-Water Activities

Vehicle Fleet Management

B-7. Vehicle and Equipment Fueling
B-8. Vehicle and Equipment Washing and Steam Cleaning
B-9. Vehicle and Equipment Maintenance and Repair
B-10. Vehicle and Equipment Parking and Storage
B-11. Vehicle Leak and Spill Control

Raw Material, Products and By-Products

B-12. Aboveground Tank Leak and Spill Control
B-13. Outdoor Loading/Unloading of Material
B-14. Outdoor Container Storage of Liquids
B-15. Outdoor Equipment O&M
B-16. Outdoor Storage & Storage of Materials
B-17. Outdoor Manufacturing Activities
B-18. Waste Handling and Disposal
B-19. Household Hazardous Waste Collection
B-20. Used Oil Recycling
B-21. Material Handling
B-22. Material Use

Building Maintenance

B-23. Building and Grounds Maintenance
B-24. Building Repair and Remodeling
B-25. Roof/Building Drains

Illicit Connections/Illicit Discharges

B-26. Storm Drain System Signs
B-27. Illicit Connection-Prevention
B-28. Illicit Connection-Detection and Removal
B-29. Leaking Sanitary Sewer Control
B-30. Illegal Dumping Control
B-31. Non-Stormwater Discharges
B-32. Industrial/Commercial Discharger Control Program

Street/Storm Drain Maintenance

B-33. Street Cleaning
B-34. Catch Basin Cleaning
B-35. Storm Drain Flushing
B-36. Roadway/Bridge Maintenance
B-37. Detention/Infiltration Device Maintenance
B-38. Storm Channel/Creek Maintenance

Vegetation

B-39. Vegetation Controls
B-40. Pest Management & Lawn/Vegetation Management
B-41. Landscaping
B-42. Buffer (Vegetation) System Protection
B-43. Pesticide/Fertilizer Use

Others

B-44. Specific Industrial BMPs
B-45. Specific Commercial BMPs
B-46. General Preventive Maintenance
B-47. General Inspection and Maintenance

C. Selection Matrix and Tables

The BMP selection matrix and associated tables are provided to help select source control BMPs that best meet the requirements and suitable for a subject municipal, industrial, and commercial site. The source control BMP selection matrix and tables can be found in the subsequent pages and are listed as follows:

Table IIA - Source Control BMP Selection Matrix
Table IIB - Source Control BMPs References
Table IIC - Source Control BMP Costs
Table IID - Source Control BMP Target Pollutants

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Table IIA
SOURCE CONTROL BMP SELECTION MATRIX

Stormwater Best Management Practices (BMPs)		Category of Pollution Source Areas																
		Municipal								Residential					Industrial		Commercial	
BMP Name	BMP Code	Structures/Yards/ Facilities	Green Spaces	Parking Lots	Road/Bridge/Street	Storage Facility	Equipment/Vehicle Facilities	Loading/Unloading Areas	Other Areas	Garden/Yard Maintenance	Vehicle Storage/Maintenance	Animals/Household Pets	Septic Tanks	Other Areas	Existing/Old Development	New Development	Existing/Old Development	New Development
General																		
Public Education/Participation	B-1	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Land Use Planning/Management	B-2		X	X	X	X		X	X	X	X	X	X	X	X	X	X	X
Employee Training	B-3	X	X	X	X	X	X	X	X						X	X	X	X
Housekeeping Practices	B-4	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X	X
Safer Alternative Products	B-5					X	X	X	X	X	X			X	X	X	X	X
Above-Water Activities	B-6								X					X	X	X	X	X
Vehicle Fleet																		
Vehicle and Equipment Fueling	B-7						X				X				X	X	X	X
Vehicle and Equipment Washing and Steam Cleaning	B-8						X				X				X	X	X	X

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Table IIA (Cont.)
SOURCE CONTROL BMP SELECTION MATRIX

Stormwater Best Management Practices (BMPs)		Category of Pollution Source Areas																
		Municipal								Residential					Industrial		Commercial	
BMP Name	BMP Code	Structures/Yards/ Facilities	Green Spaces	Parking Lots	Road/Bridge/Street	Storage Facility	Equipment/Vehicle Facilities	Loading/Unloading Areas	Other Areas	Garden/Yard Maintenance	Vehicle Storage/Maintenance	Animals/Household Pets	Septic Tanks	Other Areas	Existing/Old Development	New Development	Existing/Old Development	New Development
Vehicle and Equipment Maintenance and Repair	B-9						X				X				X	X	X	X
Vehicle and Equipment Parking and Storage	B-10			X			X				X				X	X	X	X
Vehicle Leak and Spill Control	B-11			X			X				X				X	X	X	X
Raw Materials, Products, and By-Products																		
Aboveground Tank Leak and Spill Control	B-12	X			X	X	X	X	X		X				X	X	X	X
Outdoor Loading/Unloading of Material	B-13	X			X	X	X	X	X						X	X	X	X
Outdoor Container Storage of Liquids	B-14	X				X	X	X	X		X			X	X	X	X	X
Outdoor Process Equipment O&M	B-15					X			X						X	X	X	X
Outdoor Storage of Materials	B-16	X				X	X	X	X		X			X	X	X	X	X
Outdoor Manufacturing Activities	B-17														X			

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Table IIA (Cont.)
SOURCE CONTROL BMP SELECTION MATRIX

Stormwater Best Management Practices (BMPs)		Category of Pollution Source Areas																
		Municipal								Residential					Industrial		Commercial	
BMP Name	BMP Code	Structures/Yards/ Facilities	Green Spaces	Parking Lots	Road/Bridge/Street	Storage Facility	Equipment/Vehicle Facilities	Loading/Unloading Areas	Other Areas	Garden/Yard Maintenance	Vehicle Storage/Maintenance	Animals/Household Pets	Septic Tanks	Other Areas	Existing/Old Development	New Development	Existing/Old Development	New Development
Waste Handling and Disposal	B-18	X				X	X		X	X		X	X	X	X	X	X	X
Household Hazardous Waste Collection	B-19									X	X			X				
Used Oil Recycling	B-20					X	X		X		X				X	X	X	X
Material Handling	B-21	X				X	X	X	X	X	X			X	X	X	X	X
Material Use	B-22	X				X	X	X	X	X	X			X	X	X	X	X
Building/Facility Maintenance																		
Building and Grounds Maintenance	B-23	X	X	X	X	X	X	X	X	X	X	X		X	X	X	X	X
Building Repair and Remodeling	B-24	X				X	X		X					X	X		X	
Roof/building Drains	B-25	X				X	X		X					X	X	X	X	X
Illicit Connections/Illicit Discharges																		
Storm Drain System Signs	B-26	X		X	X	X	X		X					X	X	X	X	X

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Table IIA (Cont.)
SOURCE CONTROL BMP SELECTION MATRIX

Stormwater Best Management Practices (BMPs)		Category of Pollution Source Areas																
		Municipal								Residential					Industrial		Commercial	
BMP Name	BMP Code	Structures/Yards/ Facilities	Green Spaces	Parking Lots	Road/Bridge/Street	Storage Facility	Equipment/Vehicle Facilities	Loading/Unloading Areas	Other Areas	Garden/Yard Maintenance	Vehicle Storage/Maintenance	Animals/Household Pets	Septic Tanks	Other Areas	Existing/Old Development	New Development	Existing/Old Development	New Development
Illicit Connection-Prevention	B-27	X							X						X	X	X	X
Illicit Connection-Detection and Removal	B-28	X							X						X		X	
Leaking Sanitary Sewer Control	B-29	X				X	X		X				X	X	X	X	X	X
Illegal Dumping Control	B-30	X	X	X	X	X	X	X	X		X	X	X	X	X	X	X	X
Non-Stormwater Discharges	B-31	X				X	X		X						X	X	X	X
Industrial/Commercial Discharger Control Program	B-32														X	X	X	X
Street/Storm Drain Maintenance																		
Street Cleaning	B-33			X	X			X	X	X				X	X	X	X	X
Catch Basin Cleaning	B-34			X	X				X					X	X		X	
Storm Drain Flushing	B-35			X	X				X					X	X	X	X	X
Roadway/Bridge Maintenance	B-36				X										X		X	
Detention/Infiltration Device Maintenance	B-37	X		X	X				X					X	X		X	

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Table IIA (Cont.)
SOURCE CONTROL BMP SELECTION MATRIX

Stormwater Best Management Practices (BMPs)		Category of Pollution Source Areas																
		Municipal								Residential					Industrial		Commercial	
BMP Name	BMP Code	Structures/Yards/ Facilities	Green Spaces	Parking Lots	Road/Bridge/Street	Storage Facility	Equipment/Vehicle Facilities	Loading/Unloading Areas	Other Areas	Garden/Yard Maintenance	Vehicle Storage/Maintenance	Animals/Household Pets	Septic Tanks	Other Areas	Existing/Old Development	New Development	Existing/Old Development	New Development
Storm Channel/Creek Maintenance	B-38	X	X	X	X				X	X				X	X	X	X	X
Vegetation																		
Vegetation Controls	B-39	X	X	X	X	X	X	X	X	X				X	X	X	X	X
Pest Management & Lawn/Vegetation Management	B-40		X	X	X				X	X		X		X	X	X	X	X
Landscaping	B-41	X	X	X	X	X	X	X	X	X	X			X	X	X	X	X
Buffer (Vegetation) System Protection	B-42		X	X	X				X	X				X	X	X	X	X
Pesticide/Fertilizer Use	B-43	X	X			X			X	X				X	X	X	X	X
Other BMPs																		
Specific Industrial BMPs	B-44														X	X		
Specific Commercial BMPs	B-45																X	X
General Preventive Maintenance	B-46	X			X	X	X	X	X	X	X		X	X	X	X	X	X
General Inspection and Maintenance	B-47	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X

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Table IIB
SOURCE CONTROL BMP REFERENCES

Stormwater Best Management Practices	BMP Code	Sources of Information (See References)
General		
Public Education/Participation	B-1	3, 8, 10, 16, 17, 25, 27, 30, 36, 41
Land Use Planning/Management	B-2	3, 6, 8, 10, 15, 17, 27, 28, 36
Employee Training	B-3	4, 23, 25, 27
Housekeeping Practices	B-4	3, 10, 15, 23, 24, 26, 27, 30, 36
Safer Alternative Products	B-5	3, 10, 36
Above-Water Activities	B-6	4
Vehicle Fleet		
Vehicle and Equipment Fueling	B-7	4, 23, 33, 41
Vehicle and Equipment Washing and Steam Cleaning	B-8	4, 15, 23, 33, 41
Vehicle and Equipment Maintenance and Repair	B-9	4, 15, 23, 33, 41
Vehicle and Equipment Parking and Storage	B-10	3, 6, 33, 41
Vehicle Leak and Spill Control	B-11	3, 10, 27, 33, 36
Raw Materials, Products, and By-Products		
Aboveground Tank Leak and Spill Control	B-12	3, 10, 24, 33, 36
Outdoor Loading/Unloading of Material	B-13	4, 23, 25, 33
Outdoor Container Storage of Liquids	B-14	4, 23, 25, 33
Outdoor Process Equipment O&M	B-15	4, 23, 25, 33
Outdoor Storage of Materials	B-16	3, 4, 10, 15, 23, 25, 27, 33, 36
Outdoor Manufacturing Activities	B-17	23, 33
Waste Handling and Disposal	B-18	4, 17, 19, 25, 28
Household Hazardous Waste Collection	B-19	3, 10, 28, 30, 36, 41
Used Oil Recycling	B-20	3, 10, 36

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Table IIB (Cont.)
SOURCE CONTROL BMP REFERENCES

Stormwater Best Management Practices	BMP Code	Sources of Information (See References)
Material Handling	B-21	25, 27
Material Use	B-22	2, 9, 19, 24
Building and Facility Maintenance		
Building and Grounds Maintenance	B-23	4, 17
Building Repair and Remodeling	B-24	4, 17, 41
Roof/building Drains	B-25	2, 6, 8, 21, 29, 33
Illicit Connections/Illicit Discharges		
Storm Drain System Signs	B-26	3, 10, 36
Illicit Connection-Prevention	B-27	3, 10, 17, 33, 36
Illicit Connection-Detection and Removal	B-28	3, 10, 17, 27, 28, 30, 36
Leaking Sanitary Sewer Control	B-29	3, 10, 36
Illegal Dumping Control	B-30	3, 10, 17, 19, 36
Non-Stormwater Discharges	B-31	4, 8, 22, 23, 24, 27
Industrial/Commercial Discharger Control Program	B-32	17, 27
Street/Storm Drain Maintenance		
Street Cleaning	B-33	3, 10, 17, 18, 28, 30, 32, 33, 36
Catch Basin Cleaning	B-34	3, 10, 15, 18, 20, 27, 28, 30, 36
Storm Drain Flushing	B-35	3, 10, 17, 36
Roadway/Bridge Maintenance	B-36	3, 10, 17, 27, 30, 36
Detention/Infiltration Device Maintenance	B-37	3, 10, 23, 36
Storm Channel/Creek Maintenance	B-38	3, 10, 15, 20, 23, 32, 36
Vegetation		
Vegetation Controls	B-39	3, 6, 8, 10, 11, 15, 19, 21, 23, 24, 29, 30, 32, 36
Pest Management & Lawn/Vegetation Management	B-40	26, 30, 33, 41

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Table IIB (Cont.)
SOURCE CONTROL BMP REFERENCES

Stormwater Best Management Practices	BMP Code	Sources of Information (See References)
Landscaping	B-41	12, 15, 21, 27, 33, 40, 41
Buffer (Vegetation) System Protection	B-42	6, 8,11, 15, 19, 21, 23, 24, 27, 29, 32
Pesticide/Fertilizer Use	B-43	10, 15, 16, 24, 26, 28, 29, 30, 41
Others		
Specific Industrial BMPs	B-44	23, 24, 26, 27, 29, 33, 41
Specific Commercial BMPs	B-45	23, 24, 26, 27, 29, 33, 41
General Preventive Maintenance	B-46	23, 25, 27, 30
General Inspection and Maintenance	B-47	24

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Table IIC
SOURCE CONTROL BMP COSTS

([1] Individual quantitative cost information on capital, O&M, and training are not available for the specified BMP. The California Stormwater BMP Handbooks were used for relative cost [expressed as H – high, L – low, and M – moderate] information)

Stormwater Best Management Practices	BMP Code	Implementation Requirements			
		Capital Cost[1]	O&M Cost[1]	Training Cost[1]	Comments
General					
Public Education/Participation	B-1	M	M	M	
Land Use Planning/Management	B-2	L	M	H	
Employee Training	B-3	M	M	M	
Housekeeping Practices	B-4	L	M	H	
Safer Alternative Products	B-5	L	M	H	
Above-Water Activities	B-6	L	M	M	
Vehicle Fleet					
Vehicle and Equipment Fueling	B-7	M	L	M	
Vehicle and Equipment Washing and Steam Cleaning	B-8	M	L	M	
Vehicle and Equipment Maintenance and Repair	B-9	L	M	M	
Vehicle and Equipment Parking and Storage	B-10	L	L	M	
Vehicle Leak and Spill Control	B-11	L	M	H	
Raw Material, Products and By-Products					
Aboveground Tank Leak and Spill Control	B-12	L	M	H	
Outdoor Loading/Unloading of Material	B-13	M	L	M	
Outdoor Container Storage of Liquids	B-14	M	M	H	
Outdoor Equipment O&M	B-15	L	L	M	
Outdoor Storage of Materials	B-16	M	L	H	
Outdoor Manufacturing Activities	B-17	L	L	M	
Waste Handling and Disposal	B-18	L	M	M	
Household Hazardous Waste Collection	B-19	M	M	M	

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Table IIC (Cont.)
SOURCE CONTROL BMP COSTS

([1] Individual quantitative cost information on capital, O&M, and training are not available for the specified BMP. The California Stormwater BMP Handbooks were used for relative cost [expressed as H – high, L – low, and M – moderate] information)

Stormwater Best Management Practices	BMP Code	Implementation Requirements			
		Capital Cost[1]	O&M Cost[1]	Training Cost[1]	Comments
Used Oil Recycling	B-20	L	M	M	
Material Handling	B-21	M	L	M	
Material Use	B-22	L	L	M	
Building Maintenance					
Building and Grounds Maintenance	B-23	L	M	M	
Building Repair and Remodeling	B-24	L	M	M	
Roof/Building Drains	B-25	M	L	L	
Illicit Connection/Illicit Discharges					
Storm Drain System Signs	B-26	L	M	M	
Illicit Connection-Prevention	B-27	L	M	M	
Illicit Connection-Detection and Removal	B-28	L	H	L	
Leaking Sanitary Sewer Control	B-29	L	H	H	
Illegal Dumping Control	B-30	L	M	H	
Non-Stormwater Discharges	B-31	M	L	M	
Industrial/Commercial Discharger Control Program	B-32	L	M	H	
Street/Storm Drain Maintenance					
Street Cleaning	B-33	H	H	H	
Catch Basin Cleaning	B-34	H	H	M	
Storm Drain Flushing	B-35	M	H	M	
Roadway/Bridge Maintenance	B-36	L	L	M	
Detention/Infiltration Device Maintenance	B-37	M	M	L	
Storm Channel/Creek Maintenance	B-38	L	M	H	

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Table IIC (Cont.)
SOURCE CONTROL BMP COSTS

([1] Individual quantitative cost information on capital, O&M, and training are not available for the specified BMP. The California Stormwater BMP Handbooks were used for relative cost [expressed as H – high, L – low, and M – moderate] information)

Stormwater Best Management Practices	BMP Code	Implementation Requirements			
		Capital Cost[1]	O&M Cost[1]	Training Cost[1]	Comments
Vegetation					
Vegetation Control	B-39	L	L	M	
Pest Management & Lawn/ Vegetation Management	B-40	M	M	L	
Landscaping	B-41	M	L	L	
Buffer (Vegetation) System Protection	B-42	H	L	M	
Pesticide/Fertilizer Use	B-43	L	M	H	
Other					
Specific Industrial BMPs	B-44	L	M	L	
Specific Commercial BMPs	B-45	L	M	L	
General Preventive Maintenance	B-46	L	M	M	
General Inspection and Maintenance	B-47	L	M	M	

O&M – operation and maintenance

Table IID
SOURCE CONTROL BMP TARGET POLLUTANTS

Stormwater Best Management Practices	BMP Code	Target Pollutants
General		
Public Education/Participation	B-1	Sediment, Nutrients, Metals, Toxic Chemicals, Floatable Materials, Oxygen-Demanding Substances, Oil/Grease, Bacteria/Viruses
Land Use Planning/ Management	B-2	Sediment, Nutrients, Metals, Toxic Chemicals
Employee Training	B-3	Sediment, Nutrients, Metals, Toxic Chemicals, Floatable Materials, Oxygen-Demanding Substances, Oil/Grease, Bacteria/Viruses
Housekeeping Practices	B-4	Sediment, Nutrients, Toxic Chemicals, Oil/Grease, Oxygen-Demanding Substances
Safer Alternative Products	B-5	Sediment, Nutrients, Toxic Chemicals, Oil/Grease, Oxygen-Demanding Substances
Above-Water Activities	B-6	Metals, Toxic Chemicals, Oil/Grease, Oxygen-Demanding Substances, Floatable Materials, Bacteria/Viruses
Vehicle Fleet		
Vehicle and Equipment Fueling	B-7	Metals, Oil/Grease, Toxic Chemicals
Vehicle and Equipment Washing and Steam Cleaning	B-8	Sediment, Nutrients, Metals, Oil/Grease, Toxic Chemicals, Oxygen-Demanding Substances
Vehicle and Equipment Maintenance and Repair	B-9	Metals, Oil/Grease, Toxic Chemicals
Vehicle and Equipment Parking and Storage	B-10	Metals, Oil/Grease, Toxic Chemicals
Vehicle Leak and Spill Control	B-11	Metals, Oil/Grease, Toxic Chemicals
Raw Material, Products, and By-Products		
Aboveground Tank Leak and Spill Control	B-12	Toxic Chemicals, Oil/Grease
Outdoor Loading/Unloading of Material	B-13	Nutrients, Metals, Toxic Chemicals, Oil/Grease, Oxygen-Demanding Substances, Floatable Materials
Outdoor Container Storage of Liquids	B-14	Metals, Toxic Chemicals, Oxygen-Demanding Substances
Outdoor Process Equipment O&M	B-15	Sediment, Metals, Toxic Chemicals, Oil/Grease
Outdoor Storage of Materials	B-16	Sediment, Nutrients, Metals, Toxic Chemicals, Floatable Materials, Oil/Grease
Outdoor Manufacturing Activities	B-17	Sediments, Nutrients, Metals, Toxic Chemicals, Oil/Grease, Oxygen-Demanding Substances, Floatable Materials
Waste Handling and Disposal	B-18	Metals, Toxic Chemicals, Oil/Grease
Household Hazardous Waste Collection	B-19	Metals, Toxic Chemicals, Oil/Grease

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Used Oil Recycling	B-20	Metals, Oil/Grease

Table IID (Cont.)
SOURCE CONTROL BMP TARGET POLLUTANTS

Stormwater Best Management Practices	BMP Code	Target Pollutants
Material Handling	B-21	Sediment, Nutrients, Metals, Oil/Grease, Toxic Chemicals
Material Use	B-22	Sediment, Nutrients, Metals, Oil/Grease, Toxic Chemicals
Building and Facility Maintenance		
Building and Grounds Maintenance	B-23	Sediment, Nutrients, Metals, Toxic Chemicals, Floatable Materials, Oxygen-Demanding Substances, Oil/Grease
Building Repair and Remodeling	B-24	Sediment, Metals, Toxic Chemicals, Floatable Materials, Oil/Grease
Roof/Building Drains	B-25	Sediment, Metals, Floatable Materials
Illicit Connection/Illicit Discharges		
Storm Drain System Signs	B-26	Sediment, Nutrients, Toxic Chemicals, Floatable Materials, Oxygen-Demanding Substances, Oil/Grease
Illicit Connection-Prevention	B-27	Nutrients, Oxygen-Demanding Substances, Bacteria/Viruses
Illicit Connection-Detection and Removal	B-28	Nutrients, Oxygen-Demanding Substances, Bacteria/Viruses
Leaking Sanitary Sewer Control	B-29	Nutrients, Oxygen-Demanding Substances, Bacteria/Viruses
Illegal Dumping Control	B-30	Sediment, Metals, Toxic Chemicals, Floatable Materials, Oxygen-Demanding Substances, Oil/Grease, Bacteria/Viruses
Non-Stormwater Discharges	B-31	Nutrients, Metals, Toxic Chemicals, Floatable Materials, Oxygen-Demanding Substances, Oil/Grease, Bacteria/Viruses
Industrial/Commercial Discharger Control Program	B-32	Sediment, Nutrients, Metals, Toxic Chemicals, Floatable Materials, Oxygen-Demanding Substances, Oil/Grease, Bacteria/Viruses
Street/Storm Drain Maintenance		
Street Cleaning	B-33	Sediment, Nutrients, Metals, Floatable Materials, Oxygen-Demanding Substances
Catch Basin Cleaning	B-34	Sediment, Metals, Floatable Materials, Oxygen-Demanding Substances, Oil/Grease
Storm Drain Flushing	B-35	Sediment, Nutrients, Metals, Oxygen-Demanding Substances, Bacteria/Viruses
Roadway/Bridge Maintenance	B-36	Sediment, Nutrients, Metals, Oxygen-Demanding Substances, Bacteria/Viruses
Detention/Infiltration Device Maintenance	B-37	Sediment, Metals, Oxygen-Demanding Substances, Bacteria/Viruses
Storm Channel/Creek Maintenance	B-38	Sediment, Metals, Floatable Materials, Oxygen-Demanding Substances, Oil/Grease
Vegetation		
Vegetation Controls	B-39	Sediment, Nutrients, Floatable Materials, Oxygen-Demanding Substances

Table IID (Cont.)
SOURCE CONTROL BMP TARGET POLLUTANTS

Stormwater Best Management Practices	BMP Code	Target Pollutants
Pest Management & Lawn/Vegetation Management	B-40	Sediment, Nutrients, Floatable Materials, Oxygen-Demanding Substances, Bacteria/Viruses
Landscaping	B-41	Sediment, Nutrients, Floatable Materials, Oxygen-Demanding Substances
Buffer (Vegetation) System Protection	B-42	Sediment, Nutrients, Floatable Materials, Oxygen-Demanding Substances
Pesticide/Fertilizer Use	B-43	Nutrients, Pesticide, Toxic Chemicals, Oxygen-Demanding Materials
Other		
Specific Industrial BMPs	B-44	Sediment, Nutrients, Metals, Toxic Chemicals, Floatable Materials, Oxygen-Demanding Substances, Oil/Grease, Bacteria/Viruses
Specific Commercial BMPs	B-45	Sediment, Nutrients, Metals, Toxic Chemicals, Floatable Materials, Oxygen-Demanding Substances, Oil/Grease, Bacteria/Viruses
General Preventive Maintenance	B-46	Sediment, Nutrients, Metals, Toxic Chemicals, Floatable Materials, Oxygen-Demanding Substances, Oil/Grease, Bacteria/Viruses
General Inspection and Maintenance	B-47	Sediment, Nutrients, Metals, Toxic Chemicals, Floatable Materials, Oxygen-Demanding Substances, Oil/Grease, Bacteria/Viruses

N/A – not applicable

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III. Treatment Control Best Management Practices (BMPs)

This section lists and describes those BMPs most commonly used for treatment control. Treatment control BMPs include engineered systems, technology, and structural devices that use physical, chemical, or biological processes to treat, control, remove, or reduce pollutants from stormwater and urban runoff. This section presents the following: background information, providing an overview of related pollutant and regulatory issues; a BMP listing, summarizing the applicable practices; and guidance information to assist in the BMP selection process. Guidance information is presented in a tabular format and includes a BMP selection matrix, a BMP reference table, a BMP cost table, and a BMP target pollutant table.

A. Background Information

1. Pollutant Issues - Treatment control BMPs are designed to treat, reduce, or remove pollutants contained in urban runoff. The pollutants of concern may include suspended solids, sand, silt, heavy metals (e.g. copper, lead, zinc), nutrients (e.g. nitrogen, phosphorus), bacteria and viruses, and organics (e.g. petroleum hydrocarbons, pesticides). Floatable pollutants including oil, debris, and scum can also be removed by certain treatment control devices (e.g. separator structures). Treatment control BMPs include settling basins or vaults, oil/water separators, biofilters, wet ponds, constructed wetlands, infiltration, media filters, and others.

2. Regulatory Issues - Treatment control systems can fulfill the regulatory requirements of either construction or source control BMPs (see Sections I.B and II.B). Treatment control measures should be considered as part of the BMP selection process in the event that construction or source control BMPs are not sufficient to reduce stormwater pollution to met regulatory requirements. Treatment controls should also be considered if they are economically feasible and a preferrable measure. Also, in certain instances, regulatory requirements may require the implementation of treatment control instead of other control alternatives.

B. BMP Listing

Listed below are the treatment control BMPs. The list includes vegetative, infiltration, pavement, catch basin, hydrodynamic, clarifier, media filtration, and end-of-pipe systems.

Vegetative Systems

C-1. Biofiltration Swales (Vegetated Buffer System)

C-2. Vegetative Filter Strips

C-3. Bioretention

C-4. Existing Vegetation
C-5. Constructed Wetlands
C-6. Shallow Marsh

Infiltration/Retention/Detention

C-7. Infiltration Trench
C-8. Infiltration Basin
C-9. Cisterns
C-10. Wet (Retention) Pond
C-11. Dry (Extended Detention) Pond
C-12. Dry Well

Pavements

C-13. Asphalt Porous Pavements
C-14. Modular Concrete Block Porous Pavements
C-15. Poured Concrete Porous Pavements
C-16. Structural Soil

Catch Basin Systems

C-17. Boarding/Coarse Screens
C-18. Generic Catch Basin Filters
C-19. Fossil Filter™
C-20. Aqua-Guard™
C-21. StormFilter™
C-22. Ultra-Urban Filter™
C-23. Enviro-Drainâ
C-24. HydroKleen™

Vortex/Hydrodynamic Systems

C-25. Generic Hydrodynamic Systems
C-26. Downstream Defender
C-27. Vortechnics™
C-28. V2B1™
C-29. Continuous Deflective Separation (CDS™)
C-30. StormTreat™
C-31. Stormceptorâ
C-32. Aqua-Filter™

Clarifiers

C-33. Generic Clarifiers

C-34. Clarifiers with Rain Diversion
C-35. Oil/Water Separator
C-36. Jensenâ Interceptor
C-37. Teichert Interceptor™
C-38. BaySaverâ
C-39. Isoilater™

Media Filtration

C-40. Sand/Organic Beds
C-41. Organic Filters
C-42. StormFilter™

End-of-Pipe Systems

C-43. Diversion to Sewer
C-44. Disinfection
C-45. Water Reclamation

C. Selection Matrix and Tables

The BMP selection matrix and associated tables are provided to help select a treatment control BMP that best meets the requirements and suitable for a subject site. The treatment control BMP selection matrix and tables can be found in the subsequent pages and are listed as follows:

Table IIIA - Treatment Control BMP Selection Matrix
Table IIIB - Treatment Control BMP References
Table IIIC - Treatment Control BMP Costs
Table IIID - Treatment Control BMP Target Pollutants

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Table IIIA
TREATMENT CONTROL BMP SELECTION MATRIX

Stormwater Best Management Practices (BMPs)		Category of Pollutants Treated																							
		Solids						Nutrients				Metals		Oxygen Demanding Substances		Organics				Toxic Chemicals		Bacteria/Viruses			
BMP Name	BMP Code	Trash/Debris	Floatable Materials	Suspended Solids	Dissolved Solids	Settleable Solids	Sediments (General)	Total Nitrogen	Total Phosphorous	Org. Phosphorous	Nutrients (General)	Heavy	Metals(General)	General	COD/BOD	Oil & Grease	Fuels	Solvents	Other Organics	General	Organics/Inorganics	Total Coliform	Fecal Coliform	Bacteria	Viruses
Vegetative Systems																									
Biofiltration Swales/Vegetated Buffer System	C-1		X			X	X				X		X	X		X				X					
Vegetative Filter Strips	C-2		X			X	X				X		X	X		X				X					
Bioretention	C-3		X			X	X				X		X	X		X				X				X	X
Existing Vegetation	C-4		X			X	X				X		X	X		X				X					
Constructed Wetlands	C-5		X			X	X				X		X	X		X				X				X	X
Shallow Marsh	C-6		X			X	X				X		X	X		X				X					
Infiltration/Retention																									
Infiltration Trench	C-7		X	X	X	X	X				X		X	X		X				X				X	X

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Table IIIA (Cont.)
TREATMENT CONTROL BMP SELECTION MATRIX

Stormwater Best Management Practices (BMPs)		Category of Pollutants Treated																							
		Solids						Nutrients				Metals		Oxygen Demanding Substances		Organics				Toxic Chemicals		Bacteria/Viruses			
BMP Name	BMP Code	Trash/Debris	Floatable Materials	Suspended Solids	Dissolved Solids	Settleable Solids	Sediments (General)	Total Nitrogen	Total Phosphorous	Org. Phosphorous	Nutrients (General)	Heavy	Metals(General)	General	COD/BOD	Oil & Grease	Fuels	Solvents	Other Organics	General	Organics/Inorganics	Total Coliform	Fecal Coliform	Bacteria	Viruses
Infiltration Basin	C-8		X				X				X		X	X		X				X				X	X
Cisterns	C-9		X				X				X		X	X		X				X				X	X
Wet (Retention) Pond	C-10		X				X				X		X	X		X				X				X	X
Dry (Extended Detention) Pond	C-11		X				X				X		X	X		X				X					
Dry Well	C-12		X				X				X		X	X		X				X					
Pavements																									
Asphalt Porous Pavements	C-13		X			X	X				X		X	X		X				X					
Modular Concrete Block Porous Pavements	C-14		X			X	X				X		X	X		X				X					
Poured Concrete Porous Pavements	C-15		X			X	X				X		X	X		X				X					
Structural Soil	C-16					X	X				X		X	X		X				X					
Boarding/Coarse Screens	C-17		X																						

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Table IIIA (Cont.)
TREATMENT CONTROL BMP SELECTION MATRIX

Stormwater Best Management Practices (BMPs)		Category of Pollutants Treated																							
		Solids						Nutrients				Metals		Oxygen Demanding Substances		Organics				Toxic Chemicals		Bacteria/Viruses			
BMP Name	BMP Code	Trash/Debris	Floatable Materials	Suspended Solids	Dissolved Solids	Settleable Solids	Sediments (General)	Total Nitrogen	Total Phosphorous	Org. Phosphorous	Nutrients (General)	Heavy	Metals(General)	General	COD/BOD	Oil & Grease	Fuels	Solvents	Other Organics	General	Organics/Inorganics	Total Coliform	Fecal Coliform	Bacteria	Viruses
Catch Basins Systems																									
Generic Catch Basin Filters	C-18	X	X										X			X									
Fossil Filter™	C-19	X					X									X	X								
Aqua-Guard™	C-20	X	X				X					X				X	X								
StormFilter™	C-21			X	X	X	X	X	X		X	X	X		X	X									
Ultra-Urban Filter™	C-22	X	X	X	X	X	X									X									
Enviro-Drainâ	C-23						X									X	X								
HydroKleen™	C-24											X	X				X		X						
Vortex/Hydrodynamic Systems																									
Generic Hydrodynamic Systems	C-25		X	X	X	X	X									X									
Downstream Defender	C-26		X	X	X	X	X																		
Vortechnics™	C-27		X	X	X	X	X					X				X									
V2B1™	C-28		X	X	X	X	X									X									

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Table IIIA (Cont.)
TREATMENT CONTROL BMP SELECTION MATRIX

Stormwater Best Management Practices (BMPs)		Category of Pollutants Treated																							
		Solids						Nutrients				Metals		Oxygen Demanding Substances		Organics				Toxic Chemicals		Bacteria/Viruses			
BMP Name	BMP Code	Trash/Debris	Floatable Materials	Suspended Solids	Dissolved Solids	Settleable Solids	Sediments (General)	Total Nitrogen	Total Phosphorous	Org. Phosphorous	Nutrients (General)	Heavy	Metals(General)	General	COD/BOD	Oil & Grease	Fuels	Solvents	Other Organics	General	Organics/Inorganics	Total Coliform	Fecal Coliform	Bacteria	Viruses
Cont. Deflective Separation™	C-29	X	X	X	X	X	X	X	X		X			X	X										
StormTreat™	C-30			X				X	X	X	X	X			X	X						X	X	X	X
Stormceptorâ	C-31		X	X	X	X	X		X		X	X	X			X									
Aqua-Filter™	C-32	X		X			X	X		X	X		X		X	X	X								
Clarifiers																									
Generic Clarifiers	C-33		X	X	X	X	X									X									
Clarifiers with Rain Diversion	C-34						X									X	X								
Oil/Water Separator	C-35		X	X	X	X	X				X		X	X		X				X					
Jensenâ Interceptor	C-36		X	X	X	X	X									X									
Teichert Interceptor™	C-37		X	X	X	X	X																		
BaySaverâ	C-38	X	X	X	X	X	X									X									
Isoilater™	C-39		X	X							X				X	X									

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Table IIIA (Cont.)
TREATMENT CONTROL BMP SELECTION MATRIX

Stormwater Best Management Practices (BMPs)		Category of Pollutants Treated																							
		Solids						Nutrients				Metals		Oxygen Demanding Substances		Organics				Toxic Chemicals		Bacteria/Viruses			
BMP Name	BMP Code	Trash/Debris	Floatable Materials	Suspended Solids	Dissolved Solids	Settleable Solids	Sediments (General)	Total Nitrogen	Total Phosphorous	Org. Phosphorous	Nutrients (General)	Heavy	Metals(General)	General	COD/BOD	Oil & Grease	Fuels	Solvents	Other Organics	General	Organics/Inorganics	Total Coliform	Fecal Coliform	Bacteria	Viruses
Media Filtration																									
Sand/Organic Beds	C-40		X				X	X	X		X	X	X	X		X								X	X
Organic Filters	C-41		X				X				X		X	X		X								X	X
StormFilter™	C-42			X	X	X	X	X	X		X	X	X		X	X									
End-of-Pipe Systems																									
Diversion to Sewer	C-43	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Disinfection	C-44																					X	X	X	X
Water Reclamation	C-45		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X

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Table IIIB
TREATMENT CONTROL BMP REFERENCES

Stormwater Best Management Practices	BMP Code	Sources of Information (See References)
Vegetative Systems		
Biofiltration Swales/ Vegetated Buffer System	C-1	1, 3, 4, 5, 6, 7, 8, 11, 12, 13, 14, 15, 18, 20, 21, 23, 24, 27, 28, 29, 30, 31, 32, 34, 35, 36, 40, 42
Vegetative Filter Strips	C-2	1, 3, 4, 5, 6, 7, 11, 12, 13, 14, 18, 21, 23, 27, 28, 29, 30, 32, 34, 35, 36
Bioretention	C-3	5, 6, 7, 8, 12, 13, 21, 30
Existing Vegetation	C-4	1, 6, 10, 21, 23, 27, 32, 34
Constructed Wetlands	C-5	1, 3, 4, 7, 11, 20, 21, 27, 28, 29, 30, 34, 36
Shallow Marsh	C-6	1, 7, 11, 13, 14, 15, 18, 29, 30
Infiltration/Retention		
Infiltration Trench	C-7	1, 3, 4, 6, 7, 8, 11, 12, 13, 14, 15, 16, 18, 20, 21, 23, 27, 28, 30, 34, 35, 36
Infiltration Basin	C-8	1, 3, 4, 7, 11, 12, 13, 14, 15, 18, 20, 21, 27, 28, 30, 34, 35, 36
Cisterns	C-9	1, 3, 4, 40
Wet (Retention) Pond	C-10	1, 3, 4, 7, 8, 11, 12, 14, 15, 18, 20, 21, 27, 28, 29, 30, 31, 34, 35, 36
Dry (Extended Detention) Pond	C-11	1, 3, 4, 7, 11, 14, 15, 20, 21, 27, 28, 29, 30, 34, 35, 36
Dry Well	C-12	28, 30, 40
Pavements		
Asphalt Porous Pavements	C-13	1, 3, 4, 6, 11, 14, 15, 18, 21, 23, 27, 28, 30, 34, 35, 40
Modular Concrete Block Porous Pavements	C-14	1, 3, 4, 6, 14, 15, 18, 21, 23, 27, 28, 30, 34, 35, 40
Poured Concrete Porous Pavements	C-15	1, 3, 4, 6, 14, 15, 18, 21, 23, 27, 28, 30, 34, 35, 40
Structural Soil	C-16	3, 14, 40, 43
Catch Basin Systems		
Boarding/Coarse Screens	C-17	6, 38, 43
Generic Catch Basin Filters	C-18	34, 38
Fossil Filter™	C-19	37, 38, 42
Aqua-Guard™	C-20	37

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Table IIIB (Cont.)
TREATMENT CONTROL BMP REFERENCES

Stormwater Best Management Practices	BMP Code	Sources of Information (See References)
StormFilter™	C-21	6, 37, 38, 39, 42
Ultra-Urban Filter™	C-22	37, 38
Enviro-Drainâ	C-23	37, 42
HydroKleen™	C-24	42
Vortex/Hydrodynamic Systems		
Generic Hydrodynamic Systems	C-25	34, 42
Downstream Defender	C-26	37, 42
Vortechnics™	C-27	37, 39, 42
V2B1™	C-28	37, 39, 42
Continuous Deflective Separation™	C-29	37, 38, 42
StormTreat™	C-30	37, 39, 42
Stormceptorâ	C-31	1, 37, 38, 39, 42
Aqua-Filter™	C-32	42
Clarifiers		
Generic Clarifiers	C-33	4, 34
Clarifiers with Rain Diversion	C-34	43
Oil/Water Separator	C-35	3, 4, 14, 27, 34, 36
Jensenâ Interceptor	C-36	37, 42
Teichert Interceptor™	C-37	37, 42
BaySaverâ	C-38	37, 39
Isoilater™	C-39	39
Media Filtration		
Sand/Organic Beds	C-40	1, 3, 4, 5, 6, 7 12, 13, 14, 15, 20, 21, 27, 28, 30, 34, 36
Organic Filters	C-41	1, 5, 6, 7, 20, 21, 27, 34, 36
StormFilter™	C-42	37, 38, 39, 42

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Table IIIB (Cont.)
TREATMENT CONTROL BMP REFERENCES

Stormwater Best Management Practices	BMP Code	Sources of Information (See References)
End-of-Pipe Systems		
Diversion to Sewer	C-43	27, 43
Disinfection	C-44	43
Water Reclamation	C-45	11

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Table IIIC
TREATMENT CONTROL BMP COSTS

([1] Individual quantitative cost information on capital, O&M, and training are not available for the specified BMP. The California Stormwater BMP Handbooks were used for relative cost [expressed as H – high, L – low, and M – moderate] information)
([2] Numerical cost data was obtained from available technical and data summary reports [References 30, 39, 42, and 43])

Stormwater Best Management Practices	BMP Code	Implementation Requirements			
		Capital Cost[1]	O&M Cost[1]	Training Cost[1]	Comments[2]
Vegetative Systems					
Biofiltration Swales (Vegetated Buffer System)	C-1	L	M	L	$0.5/cf
Vegetative Filter Strips	C-2	L	M	L	$1.3/cf
Bioretention	C-3	M	M	L	$5.3/cf
Existing Vegetation	C-4	L	L	L	
Constructed Wetlands	C-5	H	M	L	$0.6-$1.25/cf
Shallow Marsh	C-6	M	M	L	
StormTreat™	C-30	M to H	M	L	$12k/cfs treated
Infiltration/Retention					
Infiltration Trench	C-7	M	M	L	$4/cf
Infiltration Basin	C-8	M	M	L	$1.30/cf
Cisterns	C-9	M	L	L	$7k/ 1,800-gal
Wet (Retention) Pond	C-10	H	M	L	$0.5-$1/cf
Dry (Extended Detention) Pond	C-11	H	M	L	$0.5-$1/cf
Dry Well	C-12	M	L	L	
Pavements					
Asphalt Porous Pavements	C-13	M	L	L	$10-$15/sf
Modular Concrete Block Porous Pavements	C-14	H	L	L	$10-$15/sf
Poured Concrete Porous Pavements	C-15	H	L	L	$10-$15/sf
Structural Soil	C-16	M	L	L	$10-$15/sf
Catch Basin Systems					
Boarding/Coarse Screens	C-17	L	M	L	$300/opening

Table IIIC (Cont.)
TREATMENT CONTROL BMP COSTS

([1] Individual quantitative cost information on capital, O&M, and training are not available for the specified BMP. The California Stormwater BMP Handbooks were used for relative cost [expressed as H – high, L – low, and M – moderate] information)
([2] Numerical cost data was obtained from available technical and data summary reports [References 30, 39, 42, and 43])

Stormwater Best Management Practices	BMP Code	Implementation Requirements			
		Capital Cost[1]	O&M Cost[1]	Training Cost[1]	Comments[2]
Generic Catch Basin Filters	C-18	L	M	L	$1k- 5k/ catch basin
Fossil Filter™	C-19	L	M	L	$3.1k/cfs
Aqua-Guard™	C-20	L to M	M	L	$3k/catch basin
StormFilter™	C-21	M to H	M	M	$39.6k-$74k/cfs
Ultra-Urban Filter™	C-22	L	M	L	$4.5k/cfs $3k/catch basin
Enviro-Drain®	C-23	L	L	L	$3k-$4k/cfs
HydroKleen™	C-24	L to M	L	L	$3.9k-$11.4k/cfs
Vortex/Hydrodynamic Systems					
Generic Hydrodynamic Systems	C-25	M to H	M	L	
Downstream Defender	C-26	M to H	M	L	$5.2k-$16.1k/cfs
Vortechnics™	C-27	M to H	M	L	$9k-$36.8k/cfs
V2B1™	C-28	M to H	M	L	$7k-$17k/cfs
Continuous Deflective Separation™	C-29	M to H	M	L	$7.5k-$12k/cfs
Stormceptor®	C-31	M to H	M	L	$16.7k-$33.1k/cfs $40k/7,200-gal
Aqua-Filter™	C-32	M to H	M	L	
Clarifiers					
Generic Clarifiers	C-33	M	M	L	$10k/5,000-gal tank
Clarifiers with Rain Diversion	C-34	M	M	L	$10k/5,000-gal tank
Oil/Water Separator	C-35	M	M	L	$10k/5,000-gal tank
Jensen® Interceptor	C-36	L to M	L	L	$11.8k-$12.4k/cfs
Teichert Interceptor™	C-37	L	L	L	$8.7k/cfs

Table IIIC (Cont.)
TREATMENT CONTROL BMP COSTS

([1] Individual quantitative cost information on capital, O&M, and training are not available for the specified BMP. The California Stormwater BMP Handbooks were used for relative cost [expressed as H – high, L – low, and M – moderate] information)
([2] Numerical cost data was obtained from available technical and data summary reports [References 30, 39, 42, and 43])

Stormwater Best Management Practices	BMP Code	Implementation Requirements			
		Capital Cost[1]	O&M Cost[1]	Training Cost[1]	Comments[2]
BaySaver®	C-38	L to M	L	L	$2.4k/cfs treated
Isoilater™	C-39	M	M	L	$4.7k/cfs treated
Media Filtration					
Sand/Organic Beds	C-40	H	M	L	$3-$6/cf
Organic Filters	C-41	H	M	L	
StormFilter™	C-42	H	M	M	$18.6k/cfs treated
End-of-Pipe Systems					
Diversion to Sewer	C-43	H	H	L	$1.5m/ 5 cfs $0.5m/ 0.5 cfs
Disinfection	C-44	H	H	M	$2.5m/ 5 cfs for UV
Water Reclamation	C-45	H	H	H	$5m for 5 cfs

cf – cubic feet
cfs – cubic feet per second
k - thousand
m – million
O&M – operation and maintenance

Table IIID
TREATMENT CONTROL BMP TARGET POLLUTANTS

Stormwater Best Management Practices	BMP Code	Target Pollutants
Vegetative Systems		
Biofiltration Swales (Vegetated Buffer System)	C-1	Sediment, Nutrients, Metals, Toxic Chemicals, Floatable Materials, Oxygen-Demanding Substances, Oil/Grease
Vegetative Filter Strips	C-2	Sediment, Nutrients, Metals, Toxic Chemicals, Floatable Materials, Oxygen-Demanding Substances, Oil/Grease
Bioretention	C-3	Sediment, Nutrients, Metals, Toxic Chemicals, Floatable Materials, Oxygen-Demanding Substances, Oil/Grease, Bacteria/Viruses
Existing Vegetation	C-4	Sediment, Nutrients, Metals, Toxic Chemicals, Floatable Materials, Oxygen-Demanding Substances, Oil/Grease
Constructed Wetlands	C-5	Sediment, Nutrients, Metals, Toxic Chemicals, Floatable Materials, Oxygen-Demanding Substances, Oil/Grease, Bacteria/Viruses
Shallow Marsh	C-6	Sediment, Nutrients, Metals, Toxic Chemicals, Floatable Materials, Oxygen-Demanding Substances, Oil/Grease
Infiltration/Retention		
Infiltration Trench	C-7	Sediment, Nutrients, Metals, Toxic Chemicals, Floatable Materials, Oxygen-Demanding Substances, Oil/Grease, Bacteria/Viruses
Infiltration Basin	C-8	Sediment, Nutrients, Metals, Toxic Chemicals, Floatable Materials, Oxygen-Demanding Substances, Oil/Grease, Bacteria/Viruses
Cisterns	C-9	Sediment, Nutrients, Metals, Toxic Chemicals, Floatable Materials, Oxygen-Demanding Substances, Oil/Grease, Bacteria/Viruses
Wet (Retention) Pond	C-10	Sediment, Nutrients, Metals, Toxic Chemicals, Floatable Materials, Oxygen-Demanding Substances, Oil/Grease, Bacteria/Viruses
Dry (Extended Detention) Pond	C-11	Sediment, Nutrients, Metals, Toxic Chemicals, Floatable Materials, Oxygen-Demanding Substances, Oil/Grease
Dry Well	C-12	Sediment, Nutrients, Metals, Toxic Chemicals, Floatable Materials, Oxygen-Demanding Substances, Oil/Grease

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Table IIID (Cont.)
TREATMENT CONTROL BMP TARGET POLLUTANTS

Stormwater Best Management Practices	BMP Code	Target Pollutants
Pavements		
Asphalt Porous Pavements	C-13	Sediment, Nutrients, Metals, Toxic Chemicals, Floatable Materials, Oxygen-Demanding Substances, Oil/Grease
Modular Concrete Block Porous Pavements	C-14	Sediment, Nutrients, Metals, Toxic Chemicals, Floatable Materials, Oxygen-Demanding Substances, Oil/Grease
Poured Concrete Porous Pavements	C-15	Sediment, Nutrients, Metals, Toxic Chemicals, Floatable Materials, Oxygen-Demanding Substances, Oil/Grease
Structural Soil	C-16	Sediment, Nutrients, Metals, Floatable Materials, Oil/Grease
Catch Basin Systems		
Boarding/Coarse Screens	C-17	Floatable Materials
Generic Catch Basin Filters	C-18	Floatable Materials, Trash & Debris, Oil/Grease, Metals
Fossil Filter™	C-19	Trash & Debris, Sediments, Oil & Grease, Fuels
Aqua-Guard™	C-20	Sediments, Floatable Materials, Trash & Debris, Oil/Grease, Metals, Fuels
StormFilter™	C-21	TSS, COD, Nutrients, Oil/Grease, Metals, Sediments
Ultra-Urban Filter™	C-22	Sediment, Floatable Materials, Trash & Debris, TSS, Oil & Grease
Enviro-Drainâ	C-23	Sediments, Fuels, Oil & Grease
HydroKleen™	C-24	Fuels, Other Organics, Metals
Vortex/Hydrodynamic Systems		
Generic Hydrodynamic Systems	C-25	Floatable Materials, Sediments, Oil/Grease, TSS
Downstream Defender	C-26	Sediments, Floatable Materials, TSS
Vortechnics™	C-27	TSS, Sediments, Floatable Materials, Metals, Oil & Grease
V2B1™	C-28	Sediments, Floatable Materials, TSS, Oil & Grease
Continuous Deflective Separation™	C-29	Sediments, Floatable Materials, Trash & Debris, TSS, Nutrients, COD, BOD
StormTreat	C-30	TSS, COD, Nutrients, Oil/Grease, Metals, Bacteria/Viruses
Stormceptorâ	C-31	TSS, Nutrients, Oil/Grease, Metals, Sediments, Floatable Materials
Aqua-Filter™	C-32	Trash & Debris, Sediments, TSS, COD, Nutrients, Oil/Grease, Metals, Fuels

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Table IIID (Cont.)
TREATMENT CONTROL BMP TARGET POLLUTANTS

Stormwater Best Management Practices	BMP Code	Target Pollutants
Clarifiers		
Generic Clarifiers	C-33	Sediments, Floatable Materials, Oil/Grease, TSS,
Clarifiers with Rain Diversion	C-34	Sediment, Floatable Materials, Oil & Grease, Fuels
Oil/Water Separator	C-35	Sediments, Nutrients, Metals, Toxic Chemicals, Floatable Materials, Oxygen-Demanding Substances, Oil/Grease, TSS
Jensenâ Interceptor	C-36	Sediments, Floatable Materials, TSS, Oil & Grease
Teichert Interceptor™	C-37	Sediments, Floatable Materials
BaySaverâ	C-38	TSS, Sediments, Floatable Materials, Oil & Grease
Isoilater™	C-39	TSS, COD, Nutrients, Oil/Grease, Floatable Materials, COD/BOD
Media Filtration		
Sand/Organic Beds	C-40	Sediments, Nutrients, Metals, Floatable Materials, Oxygen-Demanding Substances, Oil/Grease, Bacteria/Viruses
Organic Filters	C-41	Sediments, Nutrients, Metals, Floatable Materials, Oxygen-Demanding Substances, Oil/Grease, Bacteria/Viruses
StormFilter™	C-42	TSS, COD, Nutrients, Oil/Grease, Metals, Sediments
End-of-Pipe Systems		
Diversion to Sewer	C-43	Sediments, Nutrients, Metals, Floatable Materials, Oxygen-Demanding Substances, Oil/Grease, Bacteria/Viruses
Disinfection	C-44	Bacteria/Viruses
Water Reclamation	C-45	Sediments, Nutrients, Metals, Floatable Materials, Oxygen-Demanding Substances, Oil/Grease, Bacteria/Viruses

COD – chemical oxygen demand
TSS – total suspended solids

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APPENDIX A
ASSISTANCE DIRECTORY

Spill Response Agencies

City of Los Angeles, Stormwater Management Division ..... (800) 974-9794
City of Los Angeles Police Department, Hazardous Materials Program ..... (213) 485-4011
City of Los Angeles Fire Department, Hazardous Materials Program..... (213) 485-6185
County of Los Angeles Fire Department, Hazardous Materials Program ..... (323) 890-4045

Recycling & Hazardous Waste Disposal

City of Los Angeles, Household & Small Business Hazardous Waste Hotline..... (800) 988-6942
City of Los Angeles, Hazardous & Toxic Materials Program ..... (213) 580-1023
City of Los Angeles, Solid Resources Citywide Recycling Division..... (213) 473-8228
County of Los Angeles, Recycling & Household Hazardous Waste Hotline ..... (800) 522-5218

To Report Illegal Dumping

City of Los Angeles, Stormwater Program Hotline..... (800) 974-9794
County of Los Angeles, Illegal Dumping Hotline..... (800) 303-0003
Calif. Environmental Protection Agency, Dept. of Toxic Substances Control ..... (818) 551-2800

To Report Clogged Catch Basins

City of Los Angeles, Stormwater Program Hotline..... (800) 974-9794
County of Los Angeles, Department of Public Works ..... (888) 253-2652

For Assistance on BMP Requirements

City of Los Angeles, Stormwater Management Division..... (213) 847-6350

To Request a Copy of the Reference Guide

City of Los Angeles, Stormwater Management Division..... (800) 974-9794

APPENDIX B
VENDOR INFORMATION

The following is the list of vendors, proprietary treatment control systems, and web site addresses or phone numbers, as available:

1. Aqua-Guard™, Remedial Solutions, Inc./AquaShield™. Web Page: http://www.aquashieldinc.com
2. Aqua-Filter™, Remedial Solutions, Inc./AquaShield™. Web Page: http://www.aquashieldinc.com
3. BaySaverâ , BaySaver, Inc. Web Page: http://www.BaySaver.com
4. CDS™, Continuous Deflective Separation Technologies, Inc. Web Page: http://www.cdstech.com.au/usa/index.html
5. DrainPac™ Storm Drain Filter Insert, United Storm Water, Inc. Telephone: (877) 71-STORM • Web site: http://www.unitedstormwater.com
6. Enviro-Drainâ , Enviro-Drain, Inc. Web Page: http://www.members.aa.net/~filters
7. Ero-Con Filter, Ero-Con. Telephone: (800)891-0473
8. Fossil Filter™, KriStar Enterprises, Inc.. Web Page: http://www.fossilfilter.com
9. HydroKleen™, ALTECH Technology Systems, Inc. Web Page: http://www.altech-group.com
10. Isoilater™, Americast, Inc. Telephone: (800)999-2278
11. Jensenâ Interceptors, Jensenâ Precast. Telephone: (909)355-1819
12. V2B1™, Environment 21™, Kistner Concrete Products, Inc., http://www.kistner.com/env21-2.html
13. RDI Drain Inceptor™, Roberts Design, Inc. Web Page: http://www.auto-wise.com/related.htm
14. Storm*ceptor* â , Storm*ceptor* Corporation. Web Page: http://www.stormceptor.com
15. StormFilter™, Stormwater Management, Inc. Web Page: http://www.stormwatermgt.com

16. StormTreat™, StormTreat Systems, Inc. Telephone: (508)362-4449

17. Ultra-Urban Filter™, Abtech Industries, Inc. Web Page: http://www.abtechindustries.com

18. Vortechnics™, Vortechnics, Inc.. Web Page: http://www.vortechnics.com

APPENDIX C
HOW TO USE THE GUIDE

A. Input Data:

BMP Category: Source Control

Site/Area: Industrial

B. Find Applicable BMP(s):

1) Look under Section II – Source Control Best Management Practices.
2) Note BMP codes and listing in Subsection B - BMP Listing.
3) Locate Table IIA – Source Control BMP Selection Matrix (Please note that the BMPs are numbered sequentially from the top of the table).
4) Read columns under "Industrial" category (under "Category of Pollution Source Areas") and list corresponding BMP(s) marked with an "X". The "X" marks indicate suggested BMPs for that category.

   Example:

BMP Code	BMP Name
B-16	Outdoor Storage of Materials

5) Using the specific example in number 4) above, locate Table IIB – Source Control BMP References. List the specified reference numbers listed under "Sources of Information" column.
6) Find the reference names corresponding to the numbers in Table IIB from "References" section at the end of the manual. These references discuss partially or in detail the subject BMP (Outdoor Storage of Materials) and related topics.
7) From Table IIC – Source Control BMP Costs, locate BMP code B-16 and note the relative costs based on capital, O&M, and training as M (moderate), L (low), and H (high), respectively. These costs are site-specific and exact figures vary. Some references also indicate cost information.
8) From Table IID – Source Control BMP Target Pollutants, locate BMP code B-16 and note the target pollutants. Target pollutants are sometimes site-specific and also vary depending on the type of industrial activity.

APPENDIX D
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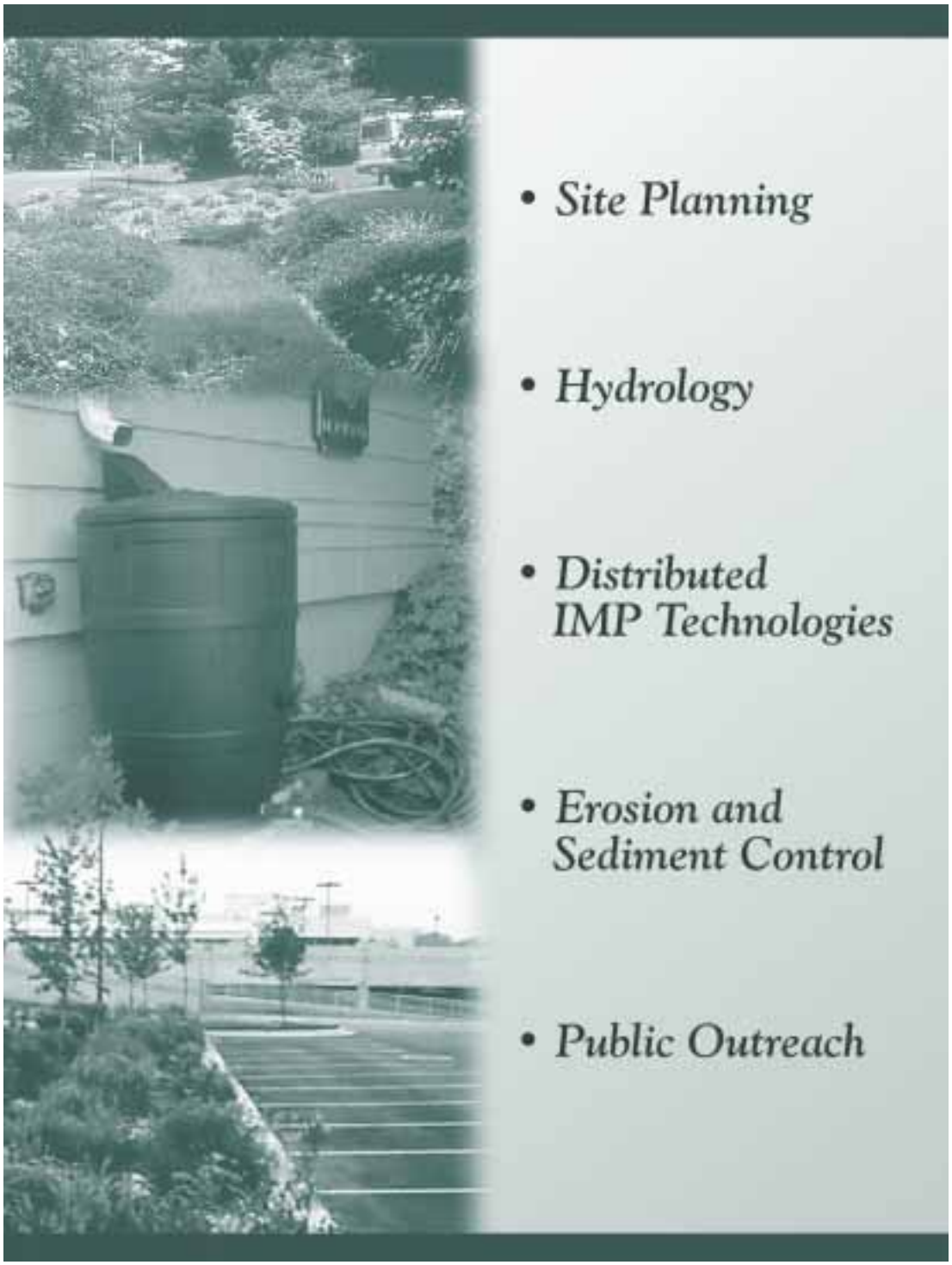
Low-Impact Development Design Strategies

An Integrated Design Approach



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Low-Impact Development:
An Integrated Design Approach

June 1999

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Preface

Low-impact development (LID) is a radically different approach to conventional stormwater management. It is our belief that LID represents a significant advancement in the state of the art in stormwater management. LID enhances our ability to protect surface and ground water quality, maintain the integrity of aquatic living resources and ecosystems, and preserve the physical integrity of receiving streams. Prince George's County, Maryland's Department of Environmental Resources has pioneered several new tools and practices in this field, which strive to achieve good environmental designs that also make good economic sense. The purpose of this manual is to share some of our experiences, and show how LID can be applied on a national level.

The LID principles outlined in these pages were developed over the last three years specifically to address runoff issues associated with new residential, commercial, and industrial suburban development. Prince George's County, which borders Washington, DC, is rich with natural streams, many of which support game fish. Preserving these attributes in the face of increasing development pressure was the challenge, which led to the development of LID techniques.

We describe how LID can achieve stormwater control through the creation of a hydrologically functional landscape that mimics the natural hydrologic regime. This objective is accomplished by:

- Minimizing stormwater impacts to the extent practicable. Techniques presented include reducing imperviousness, conserving natural resources and ecosystems, maintaining natural drainage courses, reducing use of pipes, and minimizing clearing and grading.
- Providing runoff storage measures dispersed uniformly throughout a site's landscape with the use of a variety of detention, retention, and runoff practices.

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- Maintaining predevelopment time of concentration by strategically routing flows to maintain travel time and control the discharge.
- Implementing effective public education programs to encourage property owners to use pollution prevention measures and maintain the on-lot hydrologically functional landscape management practices.

LID offers an innovative approach to urban stormwater management—one that does not rely on the conventional end-of-pipe or in-the-pipe structural methods but instead uniformly or strategically integrates stormwater controls throughout the urban landscape.

We wish to thank the US Environmental Protection Agency for their encouragement and support of this document. In particular, Robert Goo and Rod Frederick of EPA's Office of Water, Nonpoint Source Control Branch. I would also like to acknowledge the contributions of the many highly dedicated professionals who contributed to the development of LID technology, especially Dr. Mow-Soung Cheng and Derek Winogradoff of Prince George's County and the Tetra Tech project team led by Dr. Mohammed Lahlou and including: Dr. Leslie Shoemaker, Michael Clar, Steve Roy, Jennifer Smith, Neil Weinstein, and Kambiz Agazi.

It is my hope that the release of this manual will stimulate a national debate on this promising form of stormwater management. We are currently developing new LID principles and practices directly applicable to such issues as urban retrofit, combined sewer overflow, and highway design. This manual represents only the beginning of a new paradigm in stormwater management. I hope that you will take up the challenge and work with us to further develop LID practices.

Larry Coffman, Director
Programs and Planning Division
Department of Environmental Resources
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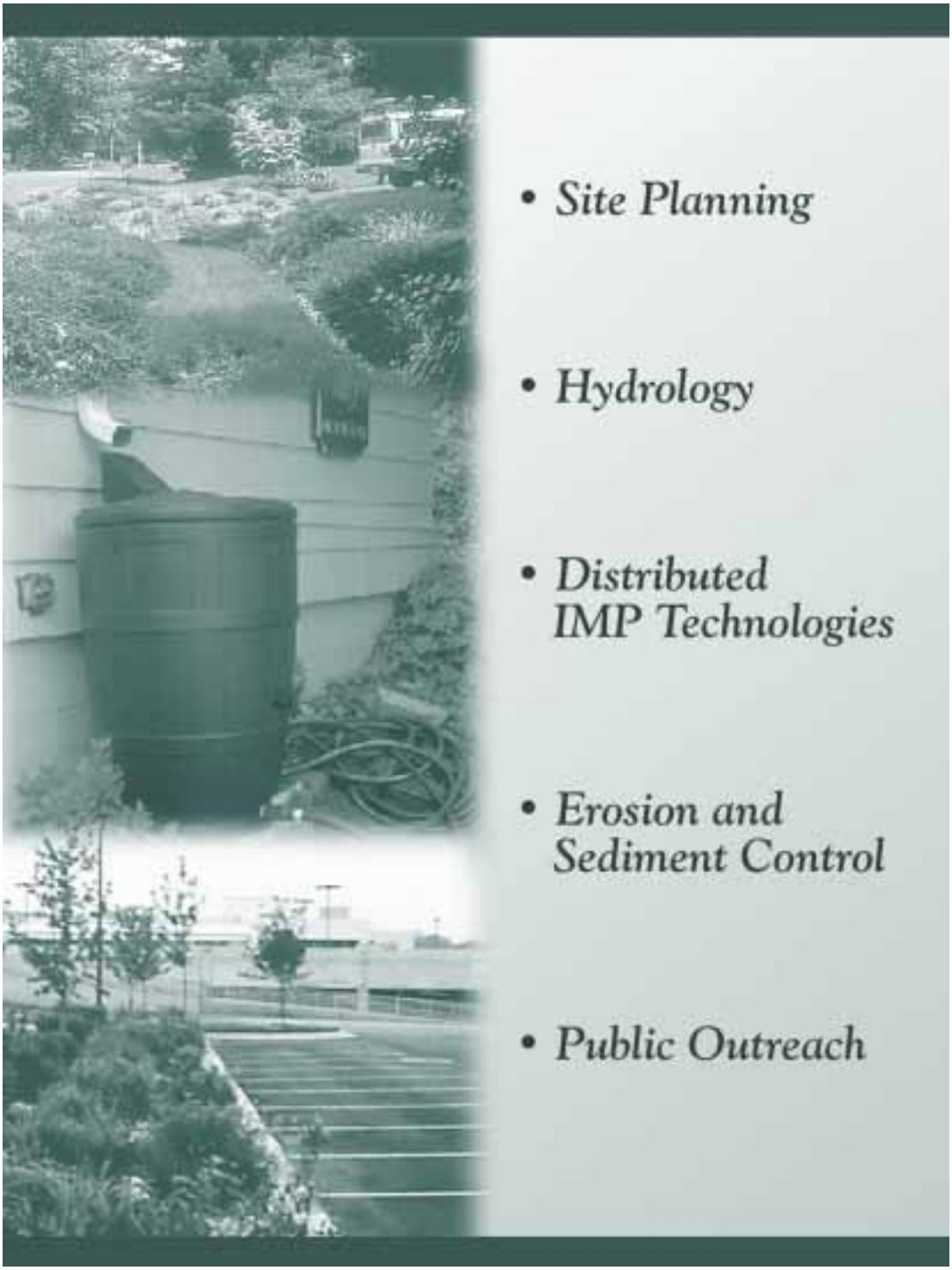
Chapter 1
Introduction



Chapter 1

Introduction

Figure 1-1. Parking lot bioretention area

The low-impact development (LID) approach combines a hydrologically functional site design with pollution prevention measures to compensate for land development impacts on hydrology and water quality. As shown in Figure 1-1, a parking lot bioretention area, LID techniques not only can function to control site hydrology, but also can be aesthetically pleasing.

In This Chapter…

Introduction

Low-impact Development Goals

How to Use This Manual

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Low-Impact Development Goals

The primary goal of Low Impact Development methods is to mimic the predevelopment site hydrology by using site design techniques that store, infiltrate, evaporate, and detain runoff. Use of these techniques helps to reduce off-site runoff and ensure adequate groundwater recharge. Since every aspect of site development affects the hydrologic response of the site, LID control techniques focus mainly on site hydrology.

There is a wide array of impact reduction and site design techniques that allow the site planner/engineer to create stormwater control mechanisms that function in a manner similar to that of natural control mechanisms. If LID techniques can be used for a particular site, the net result will be to more closely mimic the watershed's natural hydrologic functions or the water balance between runoff, infiltration, storage, groundwater recharge, and evapotranspiration. With the LID approach, receiving waters may experience fewer negative impacts in the volume, frequency, and quality of runoff, so as to maintain base flows and more closely approximate predevelopment runoff conditions.

The goals of low-impact development are discussed and demonstrated throughout the manual. The list below highlights some of the main goals and principles of LID:

- Provide an improved technology for environmental protection of receiving waters.
- Provide economic incentives that encourage environmentally sensitive development.
- Develop the full potential of environmentally sensitive site planning and design.
- Encourage public education and participation in environmental protection.
- Help build communities based on environmental stewardship.
- Reduce construction and maintenance costs of the stormwater infrastructure.
- Introduce new concepts, technologies, and objectives for stormwater management such as micromanagement and multifunctional landscape features (bioretention areas, swales, and conservation areas); mimic or replicate hydrologic functions; and maintain the ecological/biological integrity of receiving streams.

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- Encourage flexibility in regulations that allows innovative engineering and site planning to promote "smart growth" principles.
- Encourage debate on the economic, environmental, and technical viability and applicability of current stormwater practices and alternative approaches.

LID is a comprehensive technology-based approach to managing urban stormwater. Stormwater is managed in small, cost-effective landscape features located on each lot rather than being conveyed and managed in large, costly pond facilities located at the bottom of drainage areas. The source control concept is quite different from conventional treatment (pipe and pond stormwater management site design). Hydrologic functions such as infiltration, frequency and volume of discharges, and groundwater recharge can be maintained with the use of reduced impervious surfaces, functional grading, open channel sections, disconnection of hydrologic flowpaths, and the use of bioretention/filtration landscape areas. LID also incorporates multifunctional site design elements into the stormwater management plan. Such alternative stormwater management practices as on-lot microstorage, functional landscaping, open drainage swales, reduced imperviousness, flatter grades, increased runoff travel time, and depression storage can be integrated into a multifunctional site design (Figure 1-2).

Specific LID controls called Integrated Management Practices (IMPs) can reduce runoff by integrating stormwater controls throughout the site in many small, discrete units. IMPs are distributed in a small portion of each lot, near the source of impacts, virtually eliminating the need for a centralized best management practice (BMP) facility such as a stormwater management pond. By this process, a developed site can be designed as an integral part of the environment maintaining predevelopment hydrologic functions through the careful use of LID control measures. IMPs are defined and described in Chapter 4, Low-Impact Development Integrated Management Practices.

LID designs can also significantly reduce development costs through smart site design by:

- Reducing impervious surfaces (roadways), curb, and gutters
- Decreasing the use of storm drain piping, inlet structures, and
- Eliminating or decreasing the size of large stormwater ponds.

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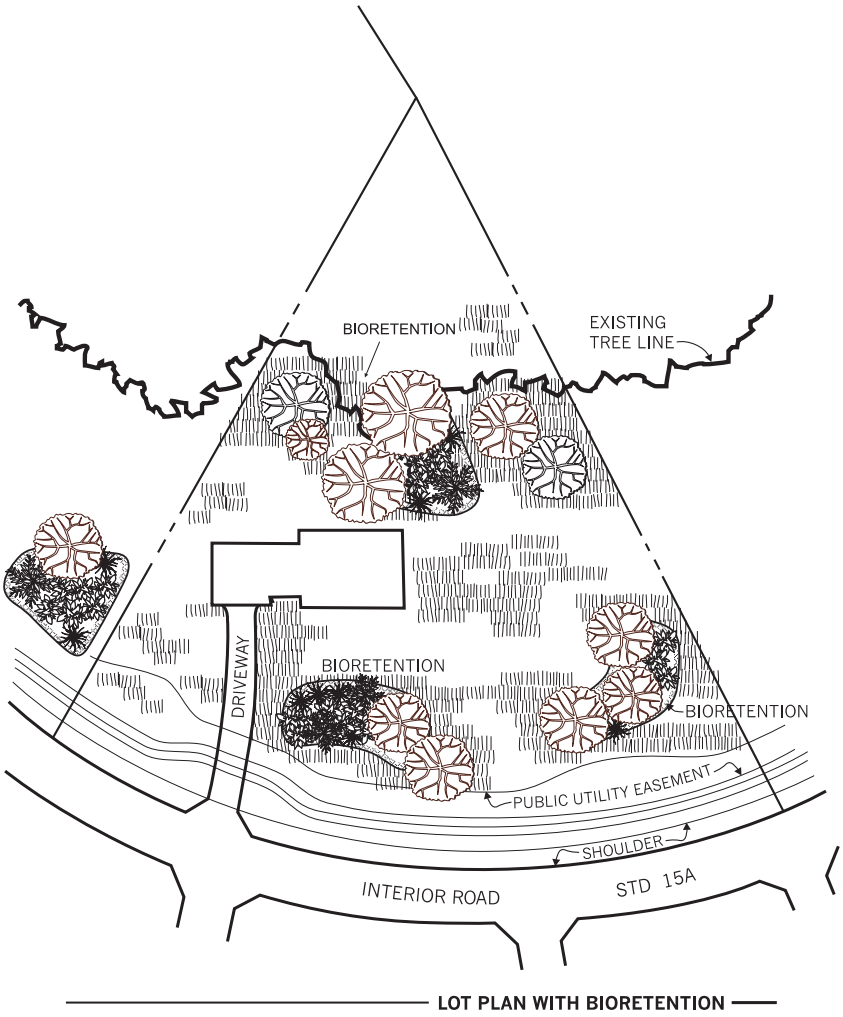

Figure 1-2

Residential lot with LID features

In some instances, greater lot yield can be obtained using LID techniques, increasing returns to developers. Reducing site development infrastructure can also reduce associated project bonding and maintenance costs.

Comparing Conventional Stormwater Management Site Design With Lid Site Design

One paradigm has typically dominated site planning and engineering—"Stormwater runoff is undesirable and must be removed from the site as quickly as possible to achieve good drainage." Current site development techniques result in the creation of an extremely efficient stormwater runoff conveyance system. Every feature of a conventionally developed site is carefully planned to quickly convey runoff to a centrally located management device, usually at the end of a pipe system. Roadways, roofs, gutters, downspouts, driveways, curbs, pipes, drainage swales, parking, and grading are all typically designed

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to dispose of the runoff in a rapid fashion. The magnitude of hydrologic changes (increases in volume, frequency, and rate of discharge) are amplified as natural storage is lost, the amount of impervious surfaces is increased, the time of concentration is decreased, runoff travel times are decreased, and the degree of hydraulic connection is increased. Typical conventional site design results in developments devoid of natural features that decrease travel times and that detain or infiltrate runoff. Lack of these features often adversely affects the ecosystem.

In contrast, the principal goal of low-impact development is to ensure maximum protection of the ecological integrity of the receiving waters by maintaining the watershed's hydrologic regime. This goal is accomplished by creatively designing hydrologic functions into the site design with the intent of replicating the predevelopment hydrology and thus having a significant positive effect on stream stability, habitat structure, base flows, and water quality. It is well documented that some conventional stormwater control measures can effectively remove pollutants from runoff. Water quality, however, is only one of several factors that affect aquatic biota or the ecological integrity of receiving streams. Fish macroinvertebrate surveys have demonstrated that good water quality is not the only determinant of biological integrity. In fact, the poor condition of the biological communities is usually attributed to poor habitat structure (cover, substrate, or sedimentation) or hydrology (inadequate base flow, thermal fluxes, or flashy hydrology). A conclusion that can be drawn from these studies and from direct experience is that perhaps stormwater pond technology is limited in its ability to protect the watershed and cannot reproduce predevelopment hydrological functions. With this in mind, LID can be a way to bridge this gap in protecting aquatic biota and provide good water quality as well. This manual was developed to provide a reference and a model for practitioners to use in experimenting with and applying LID techniques across the nation.

How to Use This Manual

Low-impact development allows the site planner/engineer to use a wide array of simple, cost-effective techniques that focus on site-level hydrologic control. This manual describes those techniques and provides examples and descriptions of how they work. It does not discuss detailed site planning techniques for the conservation of natural resources (trees, wetlands, streams, floodplains, steep slopes, critical areas, etc.). Such site features/constraints are typically addressed as part of existing county, state, and federal regulations. Compliance with the existing regulations is the starting point for defining the building envelope and the use of LID techniques. Once

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the basic building envelope has been defined, LID techniques may provide significant economic incentives to improve environmental protection and expand upon the conservation of natural resources areas. The manual has been formatted in a manner that allows the designer to incorporate LID into a specific building envelope in a logical step-by-step approach.

For ease of use and understanding, this document has been divided into six chapters and appendices. A glossary is provided at the end of the document. Figure 1-3 summarizes the major components of the LID approach.

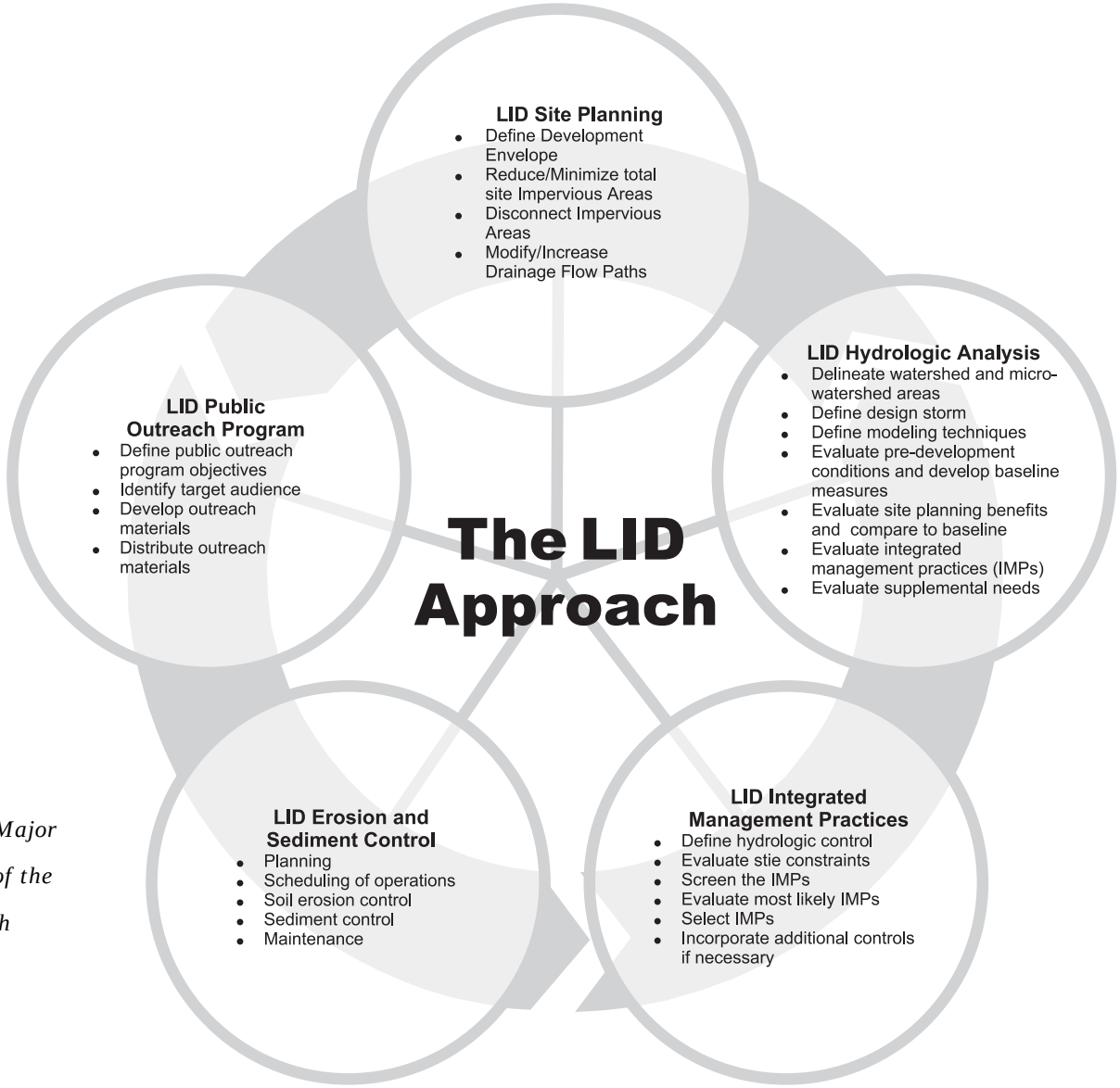

Figure 1-3. Major components of the LID approach

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Chapter 1. Introduction

Chapter 2. Low-Impact Development Site Planning. The site design philosophy and site planning techniques are described and illustrated in this chapter.

Chapter 3. Low-Impact Development Hydrologic Analysis. This chapter provides an overview and general description of the key hydrologic principles involved in low-impact development, and provides guidance on the hydrologic analysis required for the design of LID sites.

Chapter 4. Low-Impact Development Integrated Management Practices. Selection criteria and descriptions for specific LID IMPs are provided along with fact sheets on IMPs.

Chapter 5. Erosion and Sediment Control Considerations for Low-Impact Development. Erosion and sediment control and LID principles are closely interrelated since LID technology can result in improved erosion and sediment control. Chapter 5 addresses that relationship.

Chapter 6. Low-Impact Development Public Outreach Program. Chapter 6 explains why LID approaches require the education of homeowners, landowners, developers, and regulators and offers suggestions for conducting a successful public outreach program.

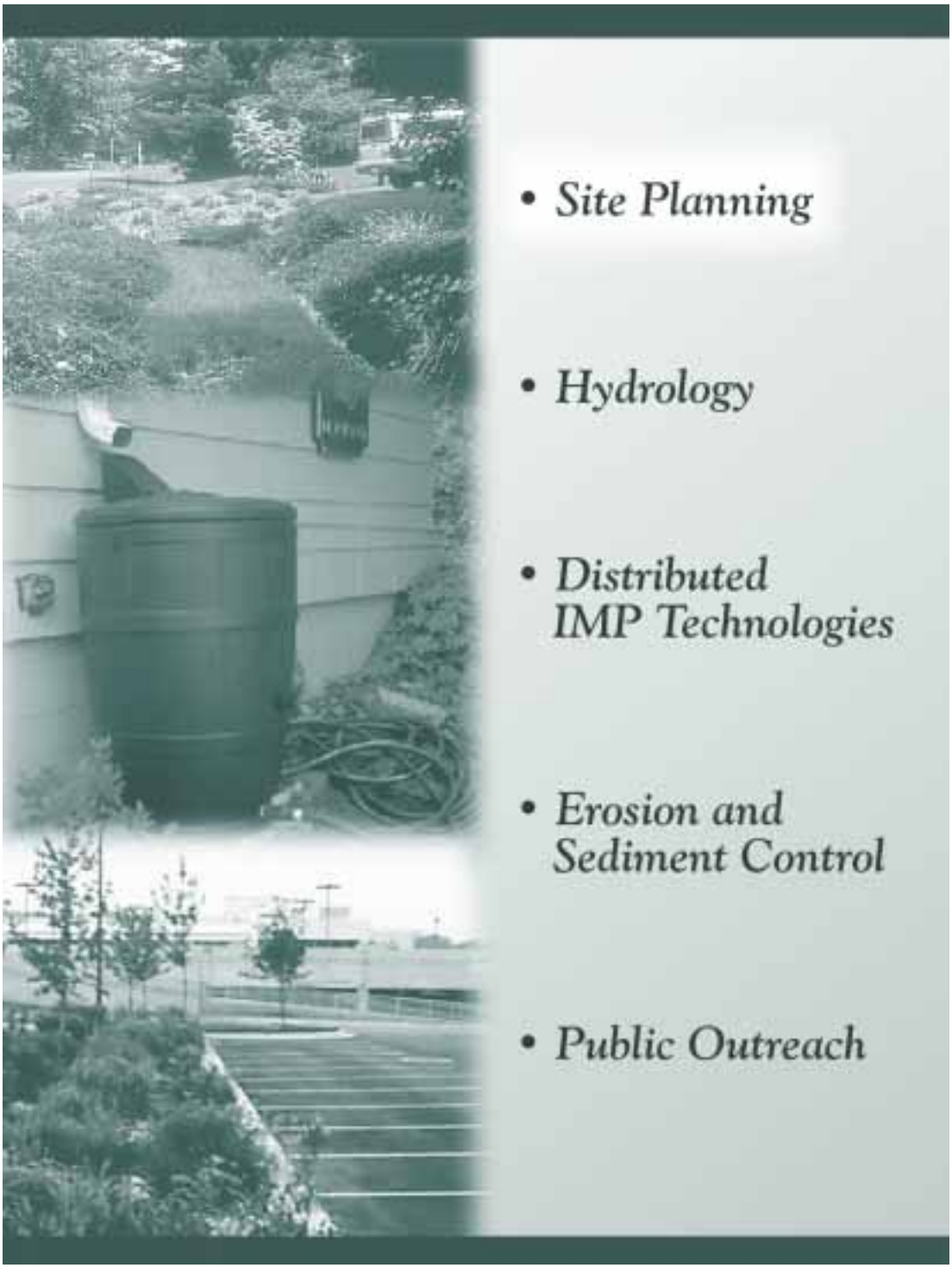
Appendix A. Example LID Hydrologic Computation

Appendix B. Sample Maintenance Covenant

Glossary.

Chapter 2

Low-Impact Development Site Planning



Chapter 2

Low-Impact Development Site Planning

Introduction

Site planning strategies and techniques provide the means to achieve stormwater management goals and objectives; facilitate the development of site plans that are adapted to natural topographic constraints; maintain lot yield; maintain site hydrologic functions; and provide for aesthetically pleasing, and often less expensive stormwater management controls. Hydrologic goals and objectives should be incorporated into the site planning process as early as possible.

The goal of LID site planning is to allow for full development of the property while maintaining the essential site hydrologic functions. This goal is accomplished in a series of incremental steps, which are presented in this chapter. These steps include first minimizing the hydrologic impacts created by the site development through site design and then providing controls to mitigate or restore the unavoidable disturbances to the hydrologic regime. The hydrologic disturbances are mitigated with the use of an at-source control approach, in contrast to the currently used end-of-pipe control approach. The newer approach results in the creation of hydrologically functional landscapes that preserve and maintain the essential hydrologic functions of the development site and the local watershed.

Lot Yield

The total number of buildable lots within the development

In This Chapter…

Introduction

Fundamental LID Site Planning Concepts

The LID Site Planning Process

Identify Applicable Zoning, Land Use, Subdivision, and Other Local Regulations

Define Development Envelope and Protected Areas

Use Drainage/Hydrology as a Design Element

Reduce/Minimize Total Impervious Areas

Develop Integrated Preliminary Site Plan

Minimize Directly Connected Impervious Areas

Modify/Increase Drainage Flow Paths

Compare Pre- and Post Development Hydrology

Complete LID Site Plan

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Fundamental LID Site Planning Concepts

A few fundamental concepts that define the essence of low-impact development technology must be integrated into the site planning process to achieve a successful and workable plan. These concepts are so simple that they tend to be overlooked, but their importance cannot be overemphasized. These fundamental concepts include:

- Using hydrology as the integrating framework
- Thinking micromanagement
- Controlling stormwater at the source
- Using simplistic, nonstructural methods
- Creating a multifunctional landscape

These fundamental concepts are defined in the following sections.

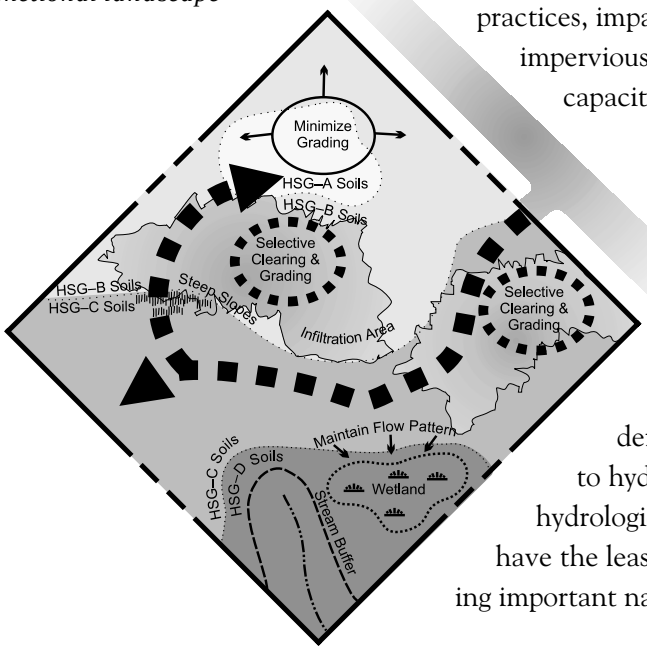
Hydrology

The movement of water into and across the site

Concept 1 - Using Hydrology as the Integrating Framework

In LID technology, the traditional approach to site drainage is reversed to mimic the natural drainage functions. Instead of rapidly and efficiently draining the site, low-impact development relies on various planning tools and control practices to preserve the natural hydrologic functions of the site. Planners may begin by asking, "What are the essential predevelopment hydrologic functions of the site, and how can these essential functions be maintained while allowing full use of the site?" The application of low-impact development techniques results in the creation of a hydrologically functional landscape (Figure 2-1), the use of distributed micromanagement practices, impact minimization, and reduced effective imperviousness allowing maintenance of infiltration capacity, storage, and longer time of concentration.

Figure 2-1. Hydrologically functional landscape



Integration of hydrology into the site planning process begins by identifying and preserving sensitive areas that affect the hydrology, including streams and their buffers, floodplains, wetlands, steep slopes, high-permeability soils, and woodland conservation zones. This process defines a development envelope, with respect to hydrology, which is the first step to minimizing hydrologic impacts. This development envelope will have the least hydrologic impact on the site while retaining important natural hydrologic features.

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Potential site development and layout schemes are then evaluated to reduce, minimize, and disconnect the total impervious area at the site. Further analysis is then conducted on the unavoidable impervious areas to minimize directly connected impervious surfaces. Bioretention areas, increased flow paths, infiltration devices, drainage swales, retention areas, and many other practices can be used to control and break up these impervious areas. The end result is an integrated hydrologically functional site plan that maintains the predevelopment hydrology in addition to improving aesthetic values and providing recreational resources by adding additional landscape features.

Development envelope

The total site areas that affect the hydrology (i.e., lots to be developed, streams, buffers, floodplains, wetlands, slopes, soils, and woodlands.

Interception

Water trapped on vegetation before reaching the ground

Concept 2 - Thinking Micromanagement

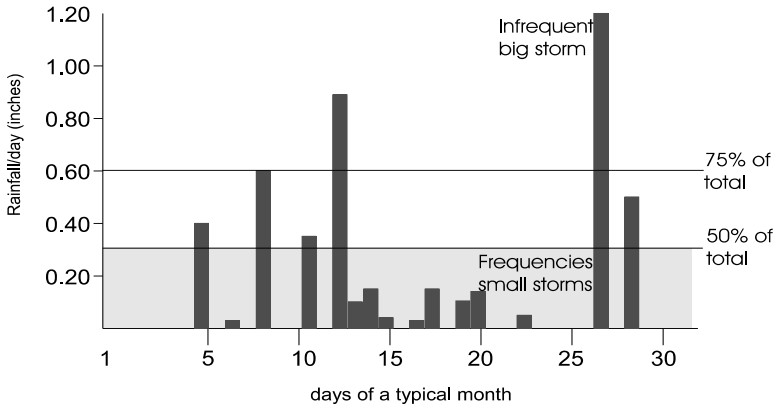
The key to making the LID concept work is to think small. This requires a change in perspective or approach with respect to the size of the area being controlled (i.e., microsubsheds), the size of the control practice (microtechniques), siting locations of controls, and the size and frequency of storms that are controlled. Micromanagement techniques implemented on small sub catchments, or on residential lots, as well as common areas, allow for a distributed control of stormwater throughout the entire site. This offers significant opportunities for maintaining the site's key hydrologic functions including infiltration, depression storage, and interception, as well as a reduction in the time of concentration. These micromanagement techniques are referred to as integrated management practices (IMPs).

Figure 2-2 presents a typical month's rainfall in the San Francisco Bay area, showing how small storms plus the first increment of the bigger storms account for half of the total rainfall volume. These small storms, because of their frequency and cumulative impacts, make the largest contribution to total annual runoff volume and have the greatest impact on water quality and receiving water hydrology.

Figure 2-2. Frequency of small storms at San Francisco International Airport (Source: BASMAA, 1997)

Other advantages of micromanagement techniques include the following:

- Provide a much greater range of control practices that can be used and adapted to site conditions.
- Allow use of control practices that can provide volume control and maintain predevelopment groundwater



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Depression storage

Small, water-holding pockets on the land surface

recharge functions, thereby compensating for significant alterations of infiltration capacity.

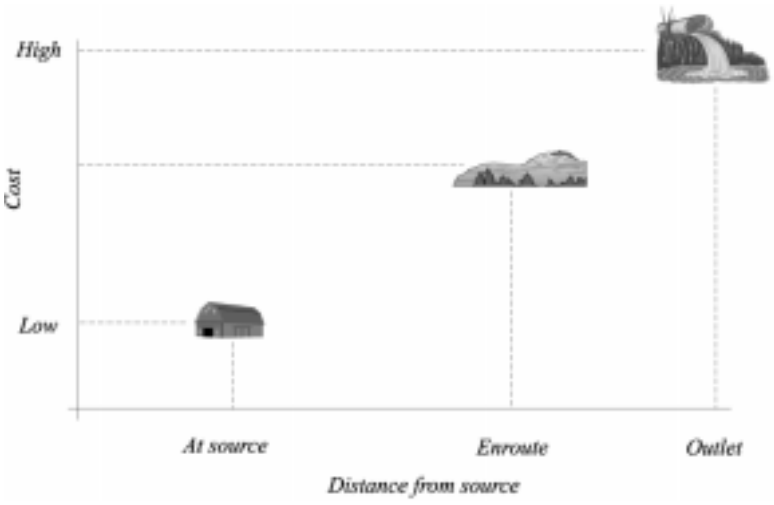
- Allow on-lot control practices to be integrated into the landscape, impervious surfaces, and natural features of the site.
- Reduce site development and long-term maintenance costs through cost-effective designs and citizen participation and acceptance.

Concept 3 - Controlling Stormwater at the Source

The key to restoring the predevelopment hydrologic functions is to first minimize and then mitigate the hydrologic impacts of land use activities closer to the source of generation. Natural hydrologic functions such as interception, depression storage, and infiltration are evenly distributed throughout an undeveloped site. Trying to control or restore these functions using an end-of-pipe stormwater management approach is difficult, if not impossible. Therefore, compensation or restoration of these hydrologic functions should be implemented as close as possible to the point or source, where the impact or disturbance is generated. This is referred to as a distributed, at-source control strategy and is accomplished using micromanagement techniques throughout the site. The distributed control strategy is one of the building blocks of low-impact development.

The cost benefits of this approach can be substantial. Typically, the most economical and simplistic stormwater management strategies are achieved by controlling runoff at the source. Conveyance system and control or treatment structure costs increase with distance from the source (Figure 2-3).

Figure 2-3. Relative cost as a function of distance from source (Source: BASMAA, 1997)



Concept 4 - Utilization of Simplistic, Nonstructural Methods

Traditionally, most stormwater management has focused on large end-of-pipe systems and there has been a tendency to overlook the consideration of small simple solutions. These simple solutions or systems have the potential to be more effective in preserving the hydrologic functions of the landscape and they can offer significant advantages over conventional engineered facilities

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such as ponds or concrete conveyances. In some cases LID techniques will need to be combined with traditional stormwater controls.

The use of LID techniques can decrease the use of typical engineering materials such as steel and concrete. By using materials such as native plants, soil and gravel these systems can be more easily integrated into the landscape and appear to be much more natural than engineered systems. The "natural" characteristics may also increase homeowner acceptance and willingness to adopt and maintain such systems.

Small, distributed, microcontrol systems also offer a major technical advantage: one or more of the systems can fail without undermining the overall integrity of the site control strategy.

These smaller facilities tend to feature shallow basin depths and gentle side slopes, which also reduce safety concerns. The integration of these facilities into the landscape throughout the site offers more opportunities to mimic the natural hydrologic functions, and add aesthetic value. The adoption of these landscape features by the general public and individual property owners can result in significant maintenance and upkeep savings to the homeowners association, municipality or other management entity.

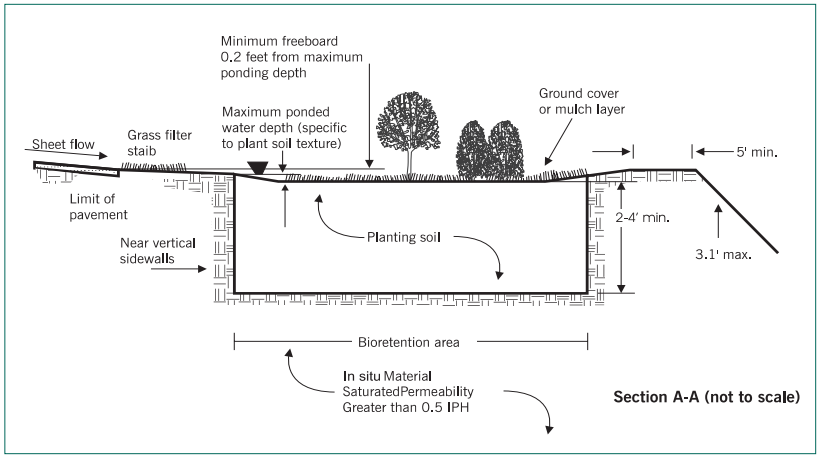
Concept 5 - Creating a Multifunctional Landscape and Infrastructure

LID offers an innovative alternative approach to urban stormwater management that uniformly or strategically integrates stormwater controls into multifunctional landscape features where runoff can be micromanaged and controlled at the sources. With LID, every urban landscape or infrastructure feature (roof, streets, parking, sidewalks, and green space) can be designed to be multifunctional, incorporating detention, retention, filtration, or runoff use.

Figure 2-4.

Bioretention cell

The bioretention cell in Figure 2-4 is perhaps the best example of a multifunctional practice and illustrates a number of functions. First the tree canopy provides interception and ecological, hydrologic, and habitat functions. The 6-inch storage area provides detention of runoff. The organic litter/mulch provides pollutant removal



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and water storage. The planting bed soil provides infiltration of runoff, removal of pollutants through numerous processes, groundwater recharge, and evapotranspiration through the plant material.

The opportunities, effectiveness, and benefits for control of runoff through numerous small-scale multifunctional landscape features have not been fully explored. To apply LID to any land use is simply a matter of developing numerous ways to creatively prevent, retain, detain, use, and treat runoff within multifunctional landscape features unique to that land use.

Table 2-1 Steps in LID Site Planning Process

Step 1	Identify Applicable Zoning, Land Use, Subdivision and Other Local Regulations
Step 2	Define Development Envelope
Step 3	Use Drainage/Hydrology as a Design Element
Step 4	Reduce/Minimize Total Site Impervious Areas
Step 5	Integrate Preliminary Site Layout Plan
Step 6	Minimize Directly Connected Impervious Areas
Step 7	Modify/Increase Drainage Flow Paths
Step 8	Compare Pre and Post Development Hydrology
Step 9	Complete LID Site Plan

The LID Site Planning Process

Site planning is a well-established process consisting of several elements. The incorporation of LID concepts into this process introduces a number of new considerations to better mimic the predevelopment hydrology and create a hydrologically functional landscape. These concepts include considering hydrology as a design focus, minimizing imperviousness, disconnecting impervious surfaces, increasing flow paths, and defining and siting micromanagement controls. Table 2-1 provides a summary of the steps involved in integrating the LID technology into the site planning process. These steps are described below.

Identify Applicable Zoning, Land Use, Subdivision, and Other Local Regulations

Zoning ordinances

Land use controls at the county or municipal level designed to regulate density, types, and extent of development

The planning process of a local governmental entity (county, district, borough, municipality, etc.)–zoning ordinances and comprehensive planning–provides a framework to establish a functional and visual relationship between growth and urbanization. Zoning ordinances predesignate the use and physical character of a developed geographic area to meet urban design goals. Common zoning components are summarized in Table 2-2. The zoning requirements are intended to regulate the density and geometry of development, specifying roadway widths and parking and drainage requirements, and define natural resource protection areas.

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Table 2-2 Common Zoning Components

Zoning Requirement	Purpose
Land use restriction	Separate residential, commercial and industrial uses and/or specify the percentage mix of these uses
Lot Layout Requirement	
Equal-sized or similarly shaped lots	Provide consistency among residential use or districts
Minimum lot sizes	Provide consistency among residential uses or districts
Frontage requirements	Provide additional distinction among residential zones; access
Fixed setbacks for front, back, and side yards	Provide additional distinction among residential and side yards provide consistency among residential zones; control coverage by buildings.
Road Layout Requirements	
Road width	Ensure vehicular and pedestrian safety and avoid rights-of-way public facility burdens
Road turnarounds	Prevent undue fire safety hazards; provide adequate fire safety vehicular access.
Sidewalks and pedestrian walkways	Ensure vehicular and pedestrian safety and avoid access public facility burdens.
Residential and commercial development	Ensure vehicular and pedestrian safety and avoid access public facility burdens.
Common or shared facilities	Prevent environmental or safety hazards from unmaintained facilities such as shared septic systems or driveways.
Drainage and Grading	
Curbs/gutters and storm drains	Prevent undue burden of development on off-site water, streets, and buildings
Stormwater quality and quantity Structures	Prevent undue burden of development on off-site water, streets, and buildings
Grading to promote positive drainage	Prevent soil erosion problems due to drainage

Identification of existing zoning ordinances and applicable subdivision regulations is not a new concept, but rather an established element of current site planning practices. The LID site planning process recognizes that in most instances, LID approaches need to meet the local zoning requirement. However, typical conventional zoning regulations are often inflexible and restrict development options regarding certain site planning parameters. Consequently, local planning agencies that wish to optimize the environmental and economic benefits provided by the LID approach will want to consider the adoption of environmentally sensitive and flexible zoning options that facilitate the use of LID technology.

Subdivision regulations

Local land use controls specify how large land parcels are broken into smaller pieces

The LID approach employs a number of flexible zoning options to meet the environmental objectives of a site without impeding urban growth. The use of these options provides added environmental sensitivity to the zoning and subdivision process over and above what conventional zoning can achieve. Alternative zoning options, such as

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Table 2-3 Alternative Zoning Options

Zoning Option	Functions Provided
Overlay District	Uses existing zoning and provides additional regulatory standard
Performance Zoning	Flexible zoning based on general goals of the site based on preservation of site functions
Incentive Zoning	Provides for give and take compromise on zoning restrictions allowing for more flexibility to provide environmental protection
Imperviousness Overlay Zoning	Subdivision layout options are based on total site imperviousness limits
Watershed-based Zoning	Uses a combination of the above principles to meet a predetermined watershed capacity or goal

those summarized in Table 2-3, include overlay districts, performance zoning, incentive zoning, impervious overlay zoning, and watershed-based zoning to allow for the introduction of innovative development, site layout, and design techniques.

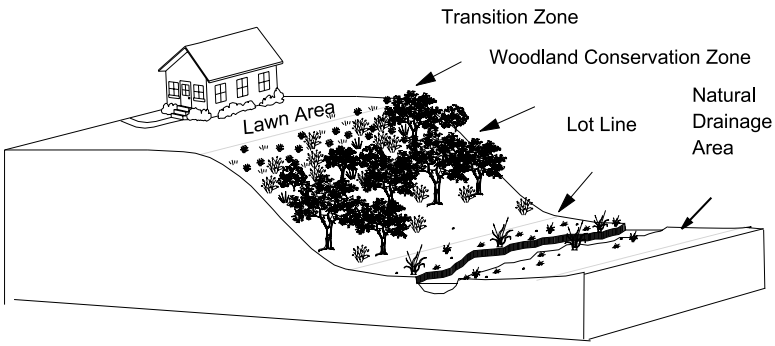
Define Development Envelope and Protected Areas

After the zoning code and subdivision regulations have been analyzed, a development envelope can be prepared for the proposed site. This is done by identifying protected areas, setbacks, easements, topographic features and existing subdrainage divides, and other site features. Site features to be protected are illustrated in Figure 2-5 and may include riparian areas such as floodplains, stream buffers, and wetlands; woodland conservation zones and important existing trees; steep slopes; and highly permeable and erosive soils. These features can be mapped in an overlay mode.

Reduce Limits of Clearing and Grading

The limits of clearing and grading refer to the site area to which development is directed. This development area will include all impervious areas such as roads, sidewalks, rooftops, and pervious areas such as graded lawn areas and open drainage systems. To minimize hydrologic impacts on existing site land cover, the area of development should be located in areas that are less sensitive to disturbance or have lower value in terms of hydrologic function (e.g., developing barren clayey soils will have less hydrologic impact than development of forested sandy soils). At a minimum, areas of development should be placed outside of sensitive area buffers such as streams, floodplains, wetlands, and steep slopes. Where practical and possible, avoid developing areas with soils which have high infiltration rates to reduce net hydrologic site impacts.

Figure 2-5. Some protected site features



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Use Site Fingerprinting

Site fingerprinting (minimal disturbance techniques) can be used to further reduce the limits of clearing and grading, thereby minimizing the hydrologic impacts. Site fingerprinting includes restricting ground disturbance by identifying the smallest possible area and clearly delineating it on the site. Land-cover impacts can be reduced through minimal disturbance techniques that include the following:

- Reduce paving and compaction of highly permeable soils.
- Minimizing the size of construction easements and material storage areas, and siting stockpiles within the development envelope during the construction phase of a project.
- Siting building layout and clearing and grading to avoid removal of existing trees where possible.
- Minimizing imperviousness by reducing the total area of paved surfaces.
- Delineating and flagging the smallest site disturbance area possible to minimize soil compaction on the site and restricting temporary storage of construction equipment in these areas.
- Disconnecting as much impervious area as possible to increase opportunities for infiltration and reduce water runoff flow.
- Maintaining existing topography and associated drainage divides to encourage dispersed flow paths.

Use Drainage/Hydrology as a Design Element

Site hydrology evaluation and understanding are required to create a hydrologically functional landscape. As illustrated in Figure 2-6, urbanization and increased impervious areas greatly alter

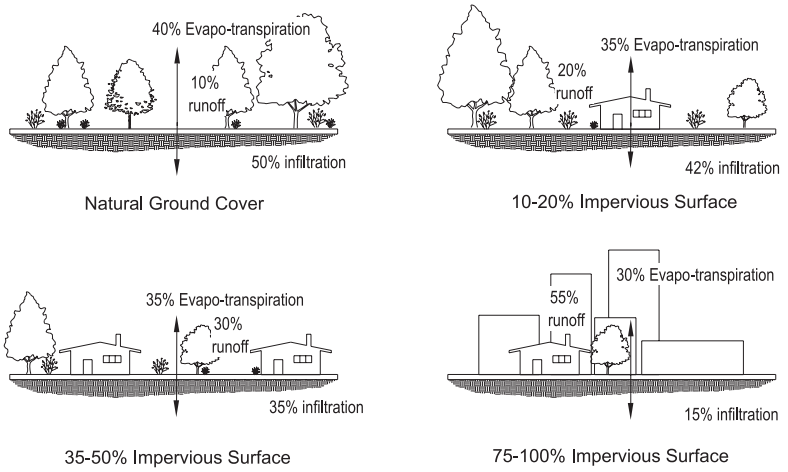

Figure 2-6. Impervious surface changes due to urbanization

Site fingerprinting

Site clearing and development using minimal disturbance of existing vegetation and soils

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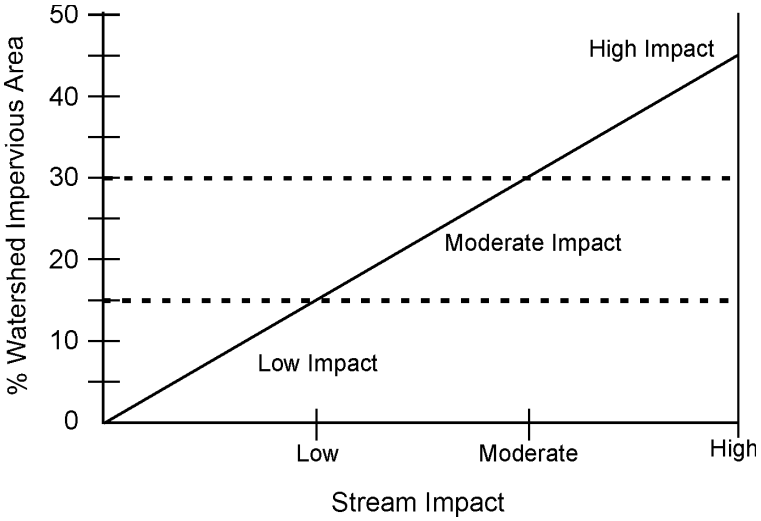

Figure 2-7. Increases in receiving stream impacts due to site imperviousness

the predevelopment hydrology (USEPA, 1993; Booth and Reinelt, 1993). This increase in impervious areas has been directly linked to increases in impacts on receiving streams (Figure 2-7) by numerous investigators (including Booth and Reinelt, 1993; Horner et al., 1994; Klein, 1979; May, 1997; Steedman 1988). To reduce these impacts created by land development, LID site planning incorporates drainage/hydrology by carefully conducting hydrologic evaluations and reviewing spatial site layout options.

Hydrologic evaluation procedures can be used to minimize the LID runoff potential and to maintain the predevelopment time of concentration. These procedures are incorporated into the LID site planning process early on to understand and take advantage of site conditions.

Spatial organization of the site layout is also important. Unlike pipe conveyance systems that hide water beneath the surface and work independently of surface topography, an open drainage system for LID can work with natural landforms and land uses to become a major design element of a site plan. The LID stormwater management drainage system can suggest pathway alignment, optimum locations for park and play areas, and potential building sites. The drainage system helps to integrate urban forms, giving the development an integral, more aesthetically pleasing relationship to the natural features of the site. Not only does the integrated site plan

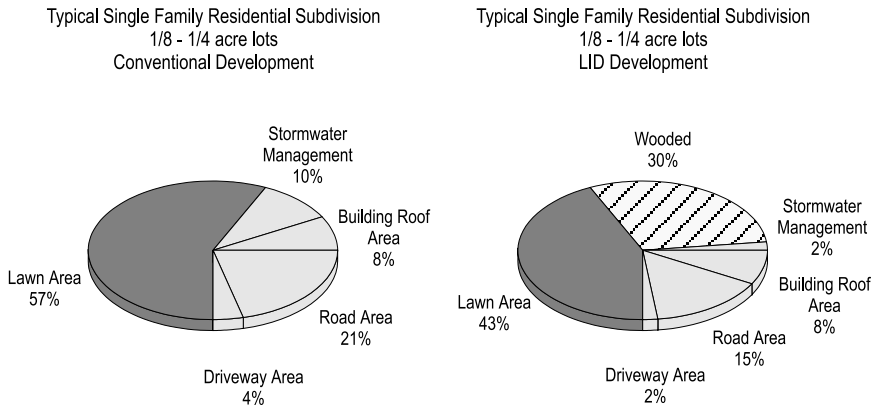

Figure 2-8. Typical imperviousness ratios for conventional and LID residential development design

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complement the land, but it can also save on development costs by minimizing earthwork and construction of expensive drainage structures.

Reduce/Minimize Total Impervious Areas

After, or concurrent with, the mapping of the development envelope, the traffic pattern and road layout and preliminary lot layout are developed. The entire traffic distribution network, (roadways, sidewalks, driveways, and parking areas), are the greatest source of site imperviousness, as shown in Figure 2-8. These changes in the impervious area alter runoff and recharge values and site hydrology (Figure 2-6). For LID sites, managing the imperviousness contributed by road and parking area pavement is an important component of the site planning and design process. Methods that can be used to achieve a reduction in the total runoff volume from impervious surfaces are presented below:

Alternative Roadway Layout. Traffic or road layout can have a very significant influence on the total imperviousness and hydrology of the site plan. Figure 2-9 illustrates that the total length of pavement or imperviousness for various road layout options can vary from 20,800 linear ft for a typical gridiron layout to 15,300 linear ft for a loops and lollipops layout. Selection of an alternative road layout can result in a total site reduction in imperviousness of 26 percent.

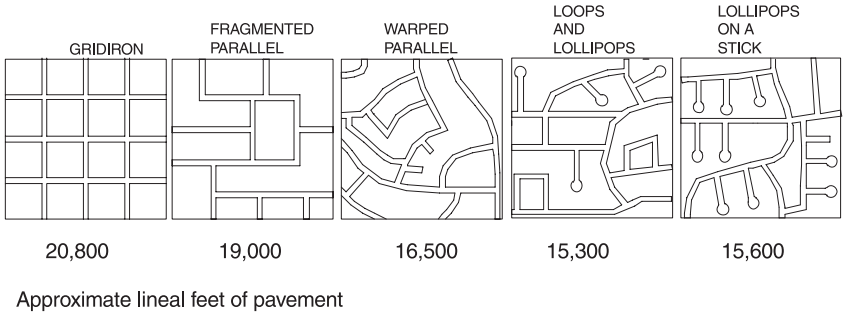

Figure 2-9. Length of pavement (imperviousness associated with various road layout options) (Adapted from ULI, 1980)

Narrow Road Sections. Reduced width road sections are an alternative that can be used to reduce total site imperviousness as well as clearing and grading impacts. Figure 2-10 shows a typical primary residential street road section and a typical rural residential street road section (Prince George's County, 1997). The right-of-way width for both sections is 60 feet. The widths of paving for the primary residential section is 36 feet wide and the section includes the use of curb and gutter. By using the rural residential road section in place of the primary residential section, the width of paving can be

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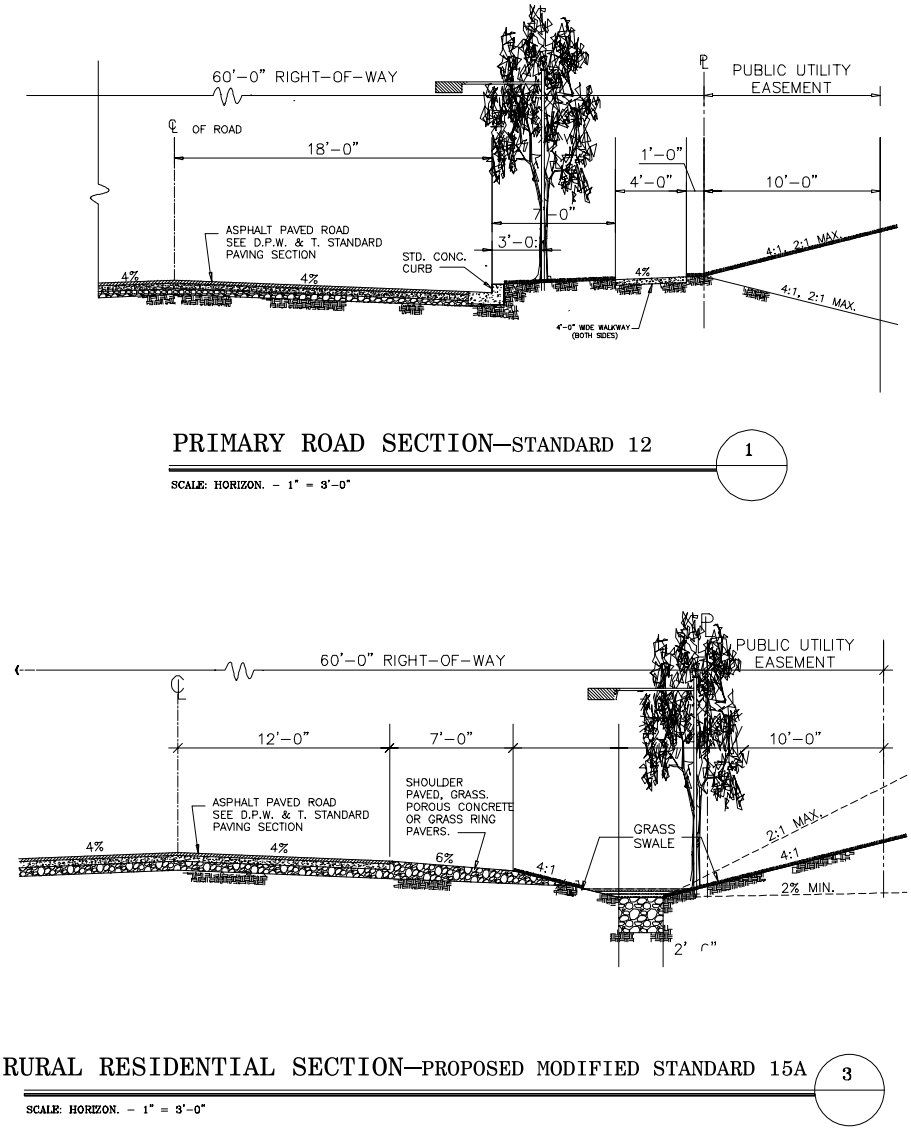

Figure 2-10. Typical road sections (Prince George's County, MD, 1997)

reduced from 36 to 24 feet, which represents a 33 percent reduction in paved width. The rural section also eliminates the use of concrete curb and gutter which reduces construction costs substantially and facilitates the use of vegetated roadside swales.

Reduced Application of Sidewalks to One Side of Primary Roads. Total site imperviousness can also be reduced by limiting sidewalks to one side of primary roads. In some cases, sidewalks or pedestrian paths can be eliminated on all other roads.

Reduced On-Street Parking. Reducing on-street parking requirements to one side, or even elimination of on-street parking altogether, has the potential to reduce road surfaces and therefore overall site imperviousness by 25 to 30 percent (Sykes, 1989). Two-sided parking requirements are often unnecessary to provide adequate parking

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facilities for each lot. For example, Sykes (1989) noted that allowing parking on both sides of the street provides space for 4.5 to 6.5 cars per residence.

Rooftops. Rooftops contribute to site imperviousness, and the number of lots per acre (or lot coverage) generally determines the site's rooftop impervious area. House type, shape, and size can affect rooftop imperviousness. For example, more rooftop coverage is generally required for ranch-type homes that spread out square footage over one level. With this in mind, vertical construction is favored over horizontal layouts to reduce the square footage of rooftops.

Driveways. Driveways are another element of the site plan that can be planned to reduce the total site imperviousness. Some techniques that can be used include

- Using shared driveways whenever possible, but especially in sensitive areas. This may require a subdivision waiver.
- Limiting driveway width to 9 feet (for both single and shared driveways).
- Minimizing building setbacks to reduce driveway length.
- Using driveway and parking area materials which reduce runoff and increase travel times such as pervious pavers or gravel.

Develop Integrated Preliminary Site Plan

After the development envelope has been delineated and the total site imperviousness has been minimized, an integrated prelimi-

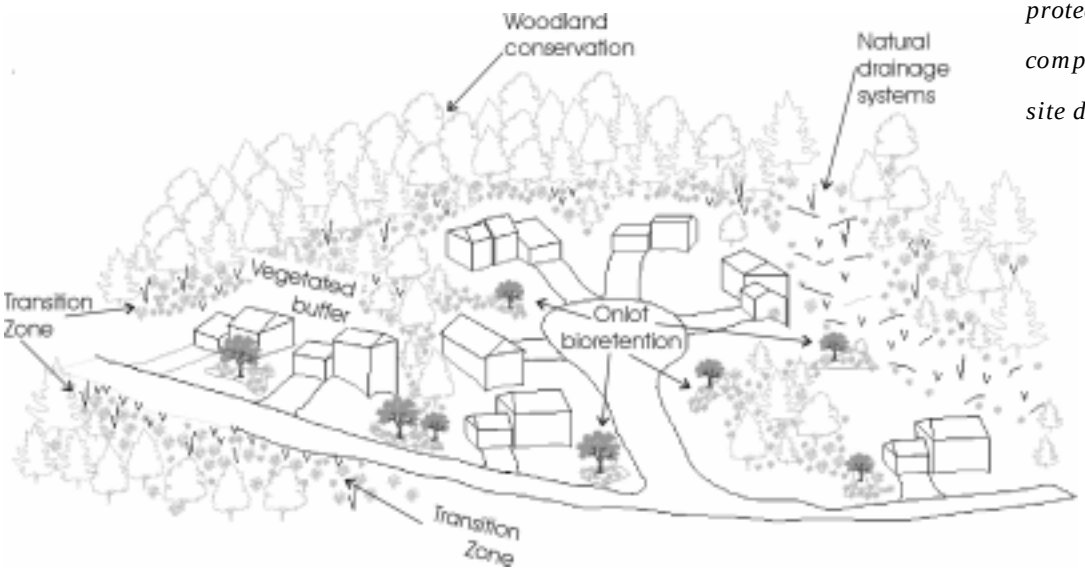

Figure 2-11. Integrated site plan. Low-impact, environmentally sensitive development incorporates a combination of all natural resources protection options into a comprehensive, integrated site design.

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integrated site plan will provide a base for conducting the hydrologic analysis to compare the pre- and postdevelopment site hydrology, and to confirm that the overall objective of creating a hydrologically functional site is being met. The procedures for conducting this analysis and fine tuning the preliminary plan to arrive at a final plan are described below. These procedures are aimed at disconnecting the unavoidable impervious areas, as well as using techniques to modify the drainage flow paths so that the postdevelopment time of concentration of stormwater runoff can be maintained as close as possible to the predevelopment conditions.

Sheet flow

Slow, shallow stormwater runoff over the land surface

Minimize Directly Connected Impervious Areas

After the total site imperviousness has been minimized and a preliminary site plan has been developed, additional environmental benefits can be achieved and hydrologic impacts reduced by disconnecting the unavoidable impervious areas as much as possible. Strategies for accomplishing this include

Open swale

Earthen channels covered with a dense growth of hardy grass

- Disconnecting roof drains and directing flows to vegetated areas.
- Directing flows from paved areas such as driveways to stabilized vegetated areas.
- Breaking up flow directions from large paved surfaces.
- Encouraging sheet flow through vegetated areas.
- Carefully locating impervious areas so that they drain to natural systems, vegetated buffers, natural resource areas, or infiltratable zones/soils.

Modify/Increase Drainage Flow Paths

Level spreader

A stormwater outlet designed to convert concentrated runoff to sheet flow

The time of concentration (Tc), in conjunction with the hydrologic site conditions, determines the peak discharge rate for a storm event. Site and infrastructure components that affect the time of concentration include

- Travel distance (flow path)
- Slope of the ground surface and/or water surface
- Surface roughness
- Channel shape, pattern, and material components

Techniques that can affect and control the Tc can be incorporated into the LID concept by managing flow and conveyance systems within the development site:

- Maximize overland sheet flow.

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Table 2-4 Permissible Velocities for Vegetated Channels

No.	Cover	Slope Range (percent)	Recommended Permissible Velocity: Erosion Resistant Soils K< .3 fps	Recommended Permissible Velocity: Easily Eroded Soils K> .3 fps
1.	Bermudagrass, Midland and Coastal, Tufcote	0-5 5-10 over 10	6.0 5.0 4.0	5.0 4.0 3.0
2.	Kentucky 31 Tall Fescue, Kentucky Bluegrass	0-5 5-10 over 10	5.0 4.0 3.0	4.0 3.0 2.0
3.	Grass-legume mixture	0-5[3] 5-10	4.0 3.0	3.0 2.0
4.	Red Fesuce, Redtop, Lespedeza, sericea, Alfalfa	0-5[4]	3.5	2.5
5.	Annuals[5], Common Lespedeza Sundangrass, Small grain, Ryegrass	0-5[5]	3.0	2.0

1 Common bermudagrass is a restricted noxious weed in Maryland.
2 Soil erodibility factor (K), < = less than, > = more than.
3 Do not use on slopes teepter than 10 percent, except for vegetated side slopes in combination with stone or concrete or highly resistant vegetative center sections.
4 Do not use on slopes steeper than 5 percent except for side slopes in a combination channel as in 3 above.
5 Annuals are used on mild slopes or as temporary protection until permanent covers are established. Use on slopes steeper than 5 percent is not recommended.
6 Good, dense vegatative cover is assumed.

Source: Maryland Standards and Specifications for Soil Erosion and Sediment Control (SCS), 1983.

- Increase and lengthen flow paths.
- Lengthen and flatten site and lot slopes.
- Maximize use of open swale systems.
- Increase and augment site and lot vegetation.

Overland Sheet Flow. The site should be graded to maximize the overland sheet flow distance and to minimize disturbance of woodland along the post-development Tc flow path. This practice will increase travel times of the runoff and thus the time of concentration. Consequently, the peak discharge rate will be decreased. Flow velocity in areas that are graded to natural drainage patterns should be kept as low as possible to avoid soil erosion. Velocities in the range of 2 to 5 feet per second are generally recommend. Table 2-4 provides recommended velocities for various combinations of slopes, soils and vegetative cover (SCS, 1983). Flows can be slowed by installing a level spreader along the upland ledge of the natural drainage way buffer, or creating a flat grassy area about 30 feet wide on the upland side of the buffer where runoff can spread out. This grassy area can be incorporated into the buffer itself. It may be unnecessary to set aside additional land to create this area.

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Flow Path. Increasing flow path of surface runoff increases infiltration and travel time. One of the goals of a LID site is to provide as much overland or sheet flow as allowed by local jurisdictional codes to increase the time it takes for rooftop and driveway runoff to reach open swale drainage systems. To accomplish this, the designer can direct rooftop and driveway runoff into bioretention facilities, infiltration trenches, dry wells, or cisterns that are strategically located to capture the runoff prior to its reaching the lawn. In addition, strategic lot grading can be designed to increase both the surface roughness and the travel length of the surface runoff.

Site and Lot Slopes. Constructing roads across steep sloped areas unnecessarily increases soil disturbance to a site. Good road layouts avoid placing roads on steep slopes, by designing roads to follow grades and run along ridge lines (see Figure 2-12). Steep site slopes often require increased cut and fill if roads are sited using conventional local road layout regulations. If incorporated into the initial subdivision layout process, slope can be an asset to the development. The adjacent table provides suggestions on how to incorporate slope into lot layout and road design to minimize grading and natural drainage way impacts.

Alternative road layout options use road plans that designate length of cul-de-sacs and the number of branches of side streets off collector streets based on the existing ridge lines and drainage patterns of a site:

- For areas with rolling terrain with dissected ridges use multiple short branch cul-de-sacs off collector streets.
- For flat terrain use fluid grid patterns. Interrupt grid to avoid natural drainage ways and other natural resources protection areas.

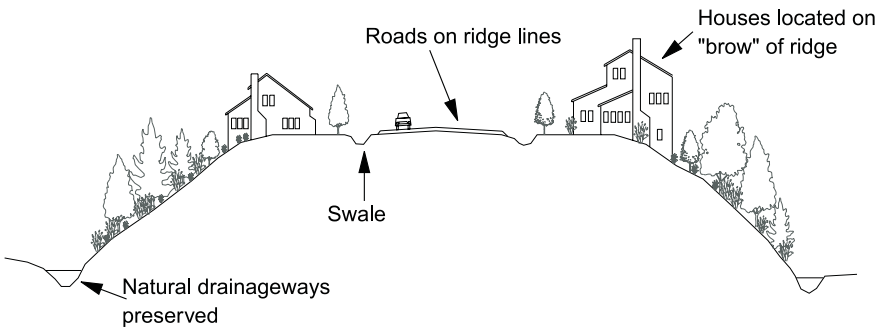

Figure 2-12. Roads placed along ridge lines preserve and utilize the natural drainage system (adapted from Sykes, 1989)

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Table 2-5. Alternative Road Layouts

Slope of the site	Site and Road Layout options
0 to 4 %	Use with flat lots and streets parallel to the contours. Use with rambler housing units.
4 to 8 %	Use with sloped lots and streets parallel to the contours. Use split-entry or walkout housing units. Use with streets perpendicular to the contours with side-to-side split-level type housing units.
8 to 11 %	Use with sloped lots and streets perpendicular to the contours. Use with side-to-side split-level type housing units.
> 11 %	These areas are not easily used for residential lots.

Adapted from Sykes, 1989.

Figure 2-13 illustrates low-impact development site grading techniques for a site with low relief. Lot slopes are flattened to approach a minimum grade of 1 percent to increase infiltration and travel time. For residential developments, low-impact development practices should be applied to lot areas outside the building pad area as shown. The building pad area is a 10 foot perimeter around the building with a positive drainage slope of 4 percent. The designer is responsible for ensuring that the slope of the lot does not cause flooding during a 100-year event (i.e, 1-foot vertical and 25 foot horizontal distance must by provided between the 100 year overflow path and the dwelling unit). Soil compaction in the lot area should by avoided to maximize the infiltration capacity of the soil. These infiltration areas can be hydraulically connected to impervious surfaces such as rooftops and driveways to decrease travel times for these areas.

Open Swales. Wherever possible, LID designs should use multi-functional open drainage systems in lieu of more conventional storm drain systems. To alleviate flooding problems and reduce the need for conventional storm drain systems, vegetated or grassed open drainage systems should be provided as the primary means of conveying surface runoff between lots and along roadways (Figure 2-14). Lots should be graded to minimize the quantity and velocity of surface runoff within the open drainage systems. Infiltration controls and terraces can be

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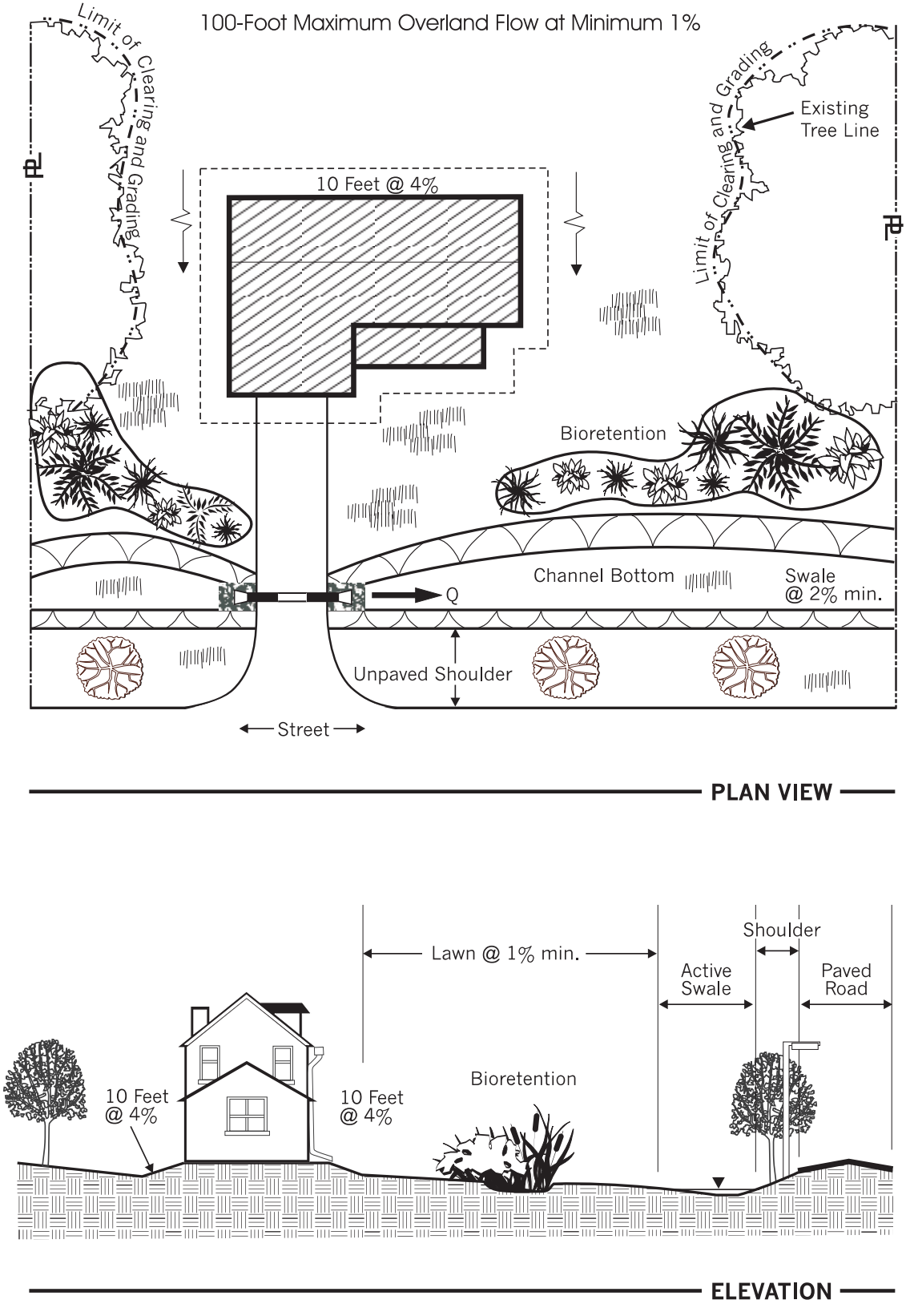

Figure 2-13. Low-impact development minimum lot grading and 100yr buffer requirements

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used to reduce the quantity and travel time of the surface runoff as the need arises.

Site and Lot Vegetation. Revegetating graded areas, planting, or preserving existing vegetation can reduce the peak discharge rate by creating added surface roughness as well as providing for additional retention, reducing the surface water runoff volume, and increasing the travel time (Figure 2-15). Developers and engineers should connect vegetated buffer areas with existing vegetation or forested areas to gain retention/detention credit for runoff volume and peak rated reduction. This technique has the added benefit of providing habitat corridors while enhancing community aesthetics.

Figure 2-14.

Vegetated swale

Compare Pre- and Postdevelopment Hydrology

At this stage of the LID site planning process, most of the site planning work is complete. Now the designer is ready to compare the pre- and postdevelopment hydrology of the site, using the hydrologic analysis procedures presented in Chapter 3. The hydrologic analysis will quantify both the level of control that has been provided by the site planning process and the additional level of control required through the use of the integrated management practices (IMPs).

Complete LID Site Plan

Completion of the LID site plan usually involves a number of iterative design steps. Based on the results of the hydrologic evaluation, additional stormwater control requirements of the LID site are identified. These requirements will be met using IMPs distributed throughout the site. A trial-and-error iterative process is then used until all the stormwater management requirements are met. In the event the site requirements cannot be met with IMPs alone, additional stormwater controls can be provided using conventional stormwater techniques (e.g., detention ponds). Mixed use of LID measures and conventional control is referred to as a hybrid system.

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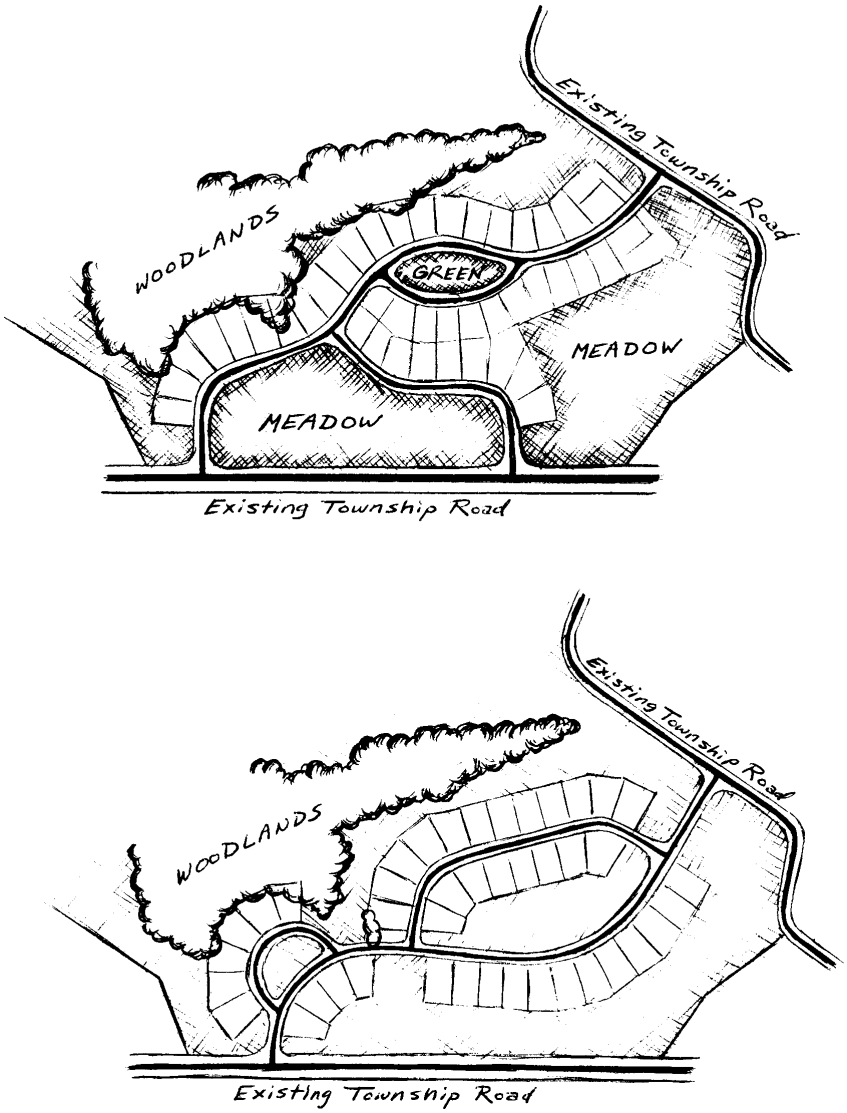

Figure 2-15. Site layouts with/without vegetation retention

Once the predevelopment hydrology objectives have been met, the designer can complete the site plan by incorporating the typical details, plan views, cross sections, profiles, and notes as required.

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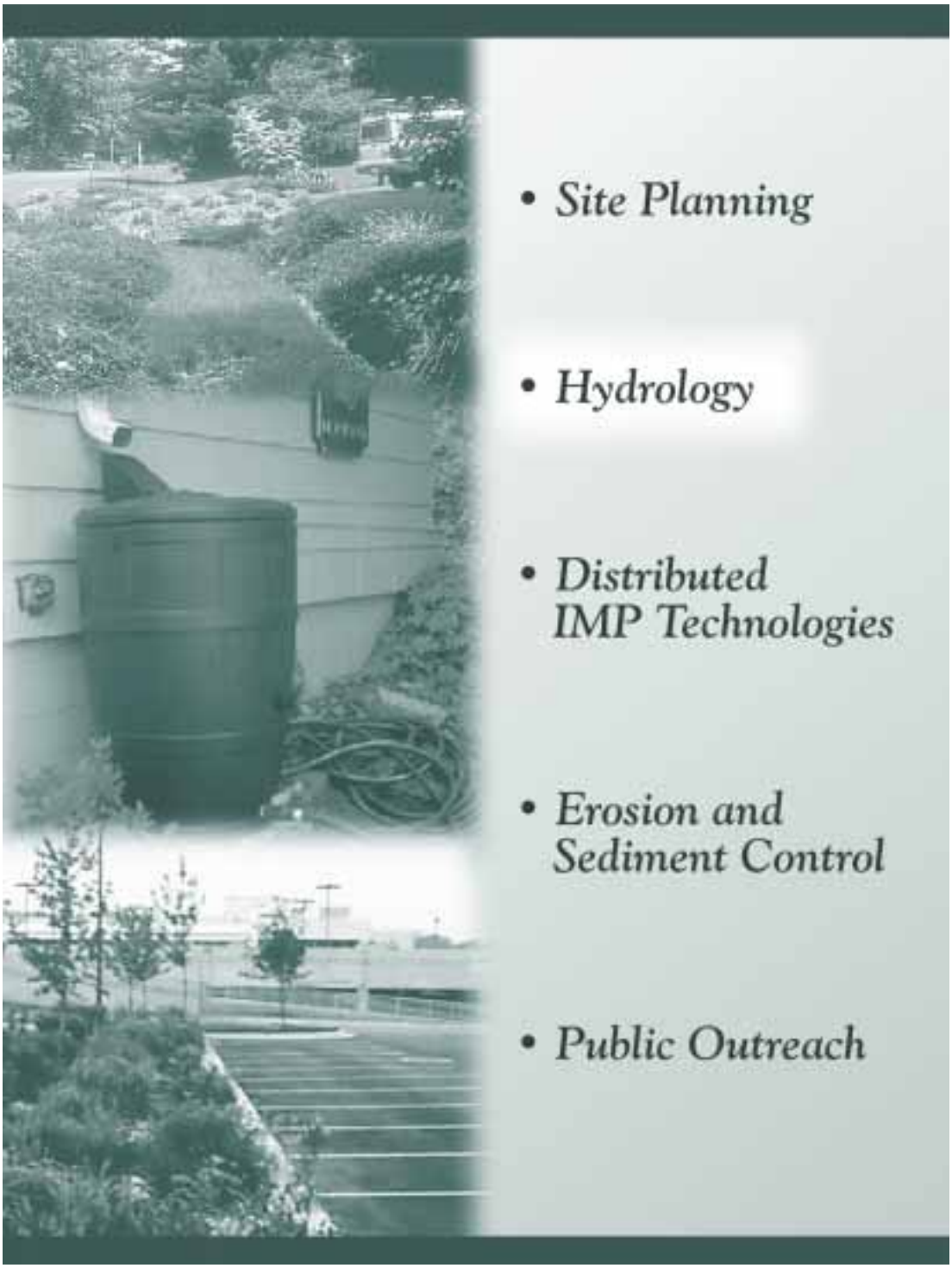
Chapter 3

Low-Impact Development Hydrologic Analysis



Chapter 3

Low-Impact Development Hydrologic Analysis

Introduction

Preserving or restoring the hydrologic functions of watersheds is a fundamental premise of the LID approach. Consideration of hydrologic principles in all phases of site development is necessary to maximize the effectiveness of planning and site design. Replication of the natural or predevelopment site hydrology not only reduces downstream stormwater impacts, but also helps control or reduce localized small-scale impacts.

The preservation of the predevelopment hydrologic regime of the site can be evaluated through consideration of the runoff volume, peak runoff rates, storm frequency and size, and water quality management. LID controls the full range of storm events, including those storm events smaller than the design storm.

This chapter reviews the basic hydrologic principles, LID hydrologic analysis concepts, methods for hydrologic evaluations, and compares conventional and LID approaches in terms of their effectiveness in controlling site hydrology.

Regional Considerations

The United States is composed of a wide range of climatic, geologic, and physiographic conditions, which result in regional provinces with widely varying combinations of these factors. Climate varies from arid

In This Chapter…

Introduction

Overview of Key Hydrologic Principles

Summary of Comparison Between Conventional and LID Approaches

LID Hydrologic Considerations

LID Modification Tools

LID Hydrologic Evaluation

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regions with annual rainfall of 4 to 10 inches all the way to regions of rainforest with annual precipitation of 100 inches. Geology includes sedimentary coastal deposits through regions of piedmont, valley, and ridge provinces to mountain terrain. Elevation ranges from sea level and very low relief along the coastal areas (which include the largest concentration of major cities and population), to areas of moderate elevation and relief, such as the piedmont regions, to areas of very high elevation, such as Denver and other areas in the Rocky Mountain region.

It has been documented by EPA's Nationwide Urban Runoff Program (USEPA, 1983) that although various regions of the country display a wide range of the factors described above, they do have some things in common. Any region of the country that is subject to urban development will experience the range of hydrologic impacts previously described. The major difference between regions is likely to be the relative importance or priority ranking for any one issue. A few examples of these regional differences are described below.

A number of the rapidly developing areas of Florida, which are heavily reliant on groundwater supplies, are experiencing a serious lowering of the regional water table. This condition is due to a combination of increasing withdrawals and the loss of natural ground water recharge as the naturally occurring permeable soils are converted to impervious areas. This lowering of the water table together with the associated increase in pollutants from urban runoff may be considered the highest urban runoff priorities for these areas.

The rapidly developing areas of the Puget Sound lowlands are experiencing a rapid degradation of the physical integrity of the receiving streams in the areas that are developed (May, 1997). This degradation and the associated loss of habitat that traditionally has served as spawning grounds for a broad range of salmonids native to this area are causing great concern in this region. Consequently, the stream channel degradation associated with urban runoff may be considered the highest urban runoff priority in this area.

The solution to these two examples, and to most urban runoff control problems, is to try to mimic or maintain the predevelopment site hydrology. This is precisely the objective of low-impact development.

Overview of Key Hydrologic Principles

Hydrology is the study of water and its movement through the hydrologic cycle. Understanding how hydrologic components respond

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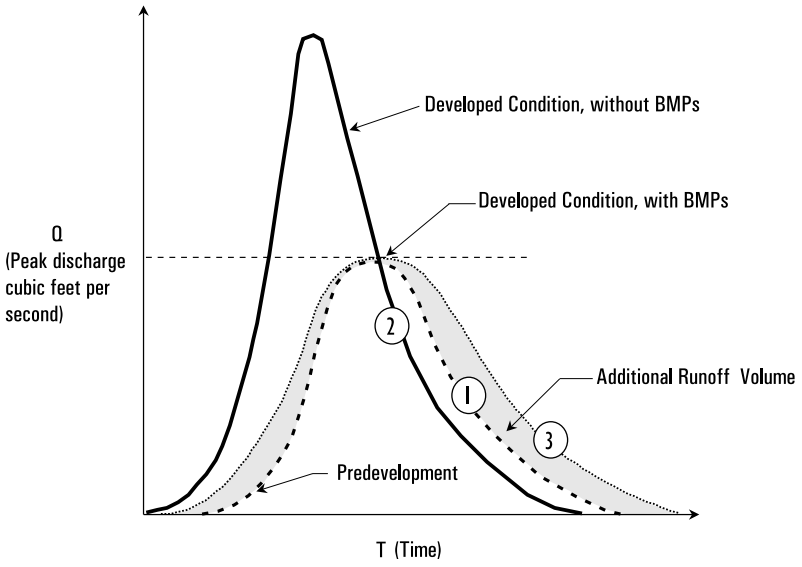

Figure 3-1. Hydrologic response of conventional BMPs

to land use changes and site development practices is the basis for developing successful watershed and stormwater management programs. One way of interpreting the hydrologic response of a system is through examination of a runoff hydrograph. A selection of typical runoff hydrographs under various land use conditions is shown in Figure 3-1.

- Hydrograph 1 represents the response to a given storm of a site in a predevelopment condition (i.e., woods, meadow). A gradual rise and fall of the peak discharge and volume define the hydrograph.
- Hydrograph 2 represents the response of a postdevelopment condition with no stormwater management BMPs. This hydrograph definition reflects a shorter time of concentration (Tc), and an increase in total site imperviousness from the predevelopment condition. The resultant hydrograph shows a decrease in the time to reach the peak runoff rate, a significant increase in the peak runoff and discharge rate and volume, and increased duration of the discharge volume.
- Hydrograph 3 represents a postdevelopment condition with conventional stormwater BMPs, such as a detention pond. Although the peak runoff rate is maintained at the predevelopment level, the hydrograph exhibits significant increases in the runoff volume and duration of runoff from the predevelopment condition, which is depicted by the shaded hydrograph area in Figure 3-1.

Key elements of the hydrologic cycle and their relationship to low-impact development technology are described below.

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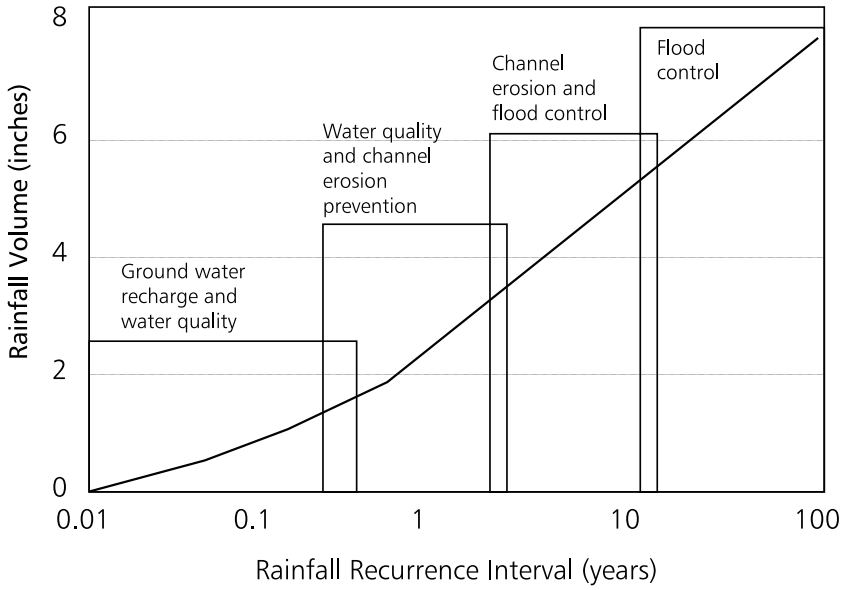

Figure 3-2. Relationship of the rainfall event recurrence interval and rainfall volume, and its application to stormwater management in Maryland (Source: CRC, 1996)

Precipitation and Design Storm Events. Data for precipitation, including both snow and rain, are used in site planning and stormwater design. Precipitation occurs as a series of events characterized by different rainfall amount, intensity, and duration. Although these events occur randomly, analysis of their distribution over a long period of time indicates that the frequency of occurrence of a given storm event follows a statistical pattern. This statistical analysis allows engineers and urban planners to further characterize storm events based on their frequency of occurrence or return period. Storm events of specific sizes can be identified to support evaluation of designs. Storms with 2- and 10-year return periods are commonly used for subdivision, industrial, and commercial development design.

Design storm

A specific size storm event used to plan for and design stormwater controls.

The 1- and 2-year storm events are usually selected to protect receiving channels from sedimentation and erosion. The 5- and 10-year storm events are selected to provide adequate flow conveyance design and minor flooding considerations. The 100-year event is used to define the limits of floodplains and for consideration of the impacts of major floods. Figure 3-2 provides a summary of the relationship of the rainfall event recurrence interval and rainfall volume, and its application to stormwater management in the state of Maryland.

There are numerous excellent texts and handbooks that describe the use of rainfall data to generate a "design storm" for the design of drainage systems (e.g., ASCE , 1994; Chow, 1964; SCS, 1972). For LID, a unique approach has been developed to determine the design storm based on the basic philosophy of LID (Prince George's County, MD, 1997).

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Rainfall abstraction

The physical process of interception evaporation, transpiration, infiltration, and storage of precipitation. Represented as a depth (inches) of water over a site.

Storm events commonly used for evaluation of designs differ for the various climatic regions of the United States Summaries of typical storm event characteristics (i.e., amount/intensity, duration, and return period) are provided in national maps in Technical Paper 40 (Department of Commerce, 1963). In humid regions such as the Mid-Atlantic states, the 2-year storm is approximately 3 inches of rainfall and the 10-year storm is approximately 5 inches of rainfall. The 2-year storm has a 50 percent probability of occurring in any given year, while the 10-year storm has a 10 percent probability of occurring in any given year. In dry areas, such as portions of Colorado and New Mexico, the 2-year storm is approximately 1.5 inches of rainfall and the 5-year storm is approximately 2.0 inches of rainfall.

The required storage volume for peak runoff control is heavily depended on the intensity of rainfall (rainfall distribution). Since the intensity of rainfall varies considerably over geographic regions in the nation, National Resource Conservation Service (NRCS) developed four synthetic 24-hour rainfall distributions (I, IA, II, and III) from available National Weather Service (NWS) duration-frequency data and local storm data. Type IA is the least intense and type II the most intense short-duration rainfall. Figure 3-3. shows approximate geographic boundaries for these four distributions.

Figure 3-3. Approximate geographic boundaries for NRCS rainfall distributions

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Rainfall Abstractions. Rainfall abstractions include the physical processes of interception of rainfall by vegetation, evaporation from land surfaces and the upper soil layers, transpiration by plants, infiltration of water into soil surfaces, and storage of water in surface depressions. Although these processes can be evaluated individually, simplified hydrologic modeling procedures typically consider the combined effect of the various components of rainfall abstraction.

The rainfall abstraction can be estimated as a depth of water (inches) over the total area of the site. This depth effectively represents the portion of rainfall that does not contribute to surface runoff. The portion of rainfall that is not abstracted by interception, infiltration, or depression storage is termed the excess rainfall or runoff.

The rainfall abstraction may change depending on the configuration of the site development plan. Of particular concern is the change in impervious cover. Impervious areas prevent infiltration of water into soil surfaces, effectively decreasing the rainfall abstraction and increasing the resulting runoff. Postdevelopment conditions, characterized by higher imperviousness, significantly decrease the overall rainfall abstraction, resulting not only in higher excess surface runoff volume but also a rapid accumulation of rainwater on land surfaces.

The LID approach attempts to match the predevelopment condition by compensating for losses of rainfall abstraction through maintenance of infiltration potential, evapotranspiration, and surface storage, as well as increased travel time to reduce rapid concentration of excess runoff. Several planning considerations combined with supplemental controls using LID integrated management practices (IMPs) can be used to compensate for rainfall abstraction losses and changes in runoff concentration due to site development. These practices are described in Chapters 2 and 4 of this document.

Runoff. The excess rainfall, or the portion of rainfall that is not abstracted by interception, infiltration, or depression storage, becomes surface runoff. Under natural and undeveloped conditions, surface runoff can range from 10 to 30 percent of the total annual precipitation (Figure 3-4). Depending on the level of development and the site planning methods used, the alteration of physical conditions can result in a significant increase of surface runoff to over 50 percent of the overall precipitation. In addition, enhancement of the site drainage to eliminate potential on-site flooding can also result in increases in surface runoff. Alteration in site runoff characteristics can cause an increase in the volume and frequency of runoff flows (discharge) and velocities that cause flooding, accelerated erosion, and reduced

Runoff

The portion of rainfall that is not abstracted by interception, infiltration, or depression storage.

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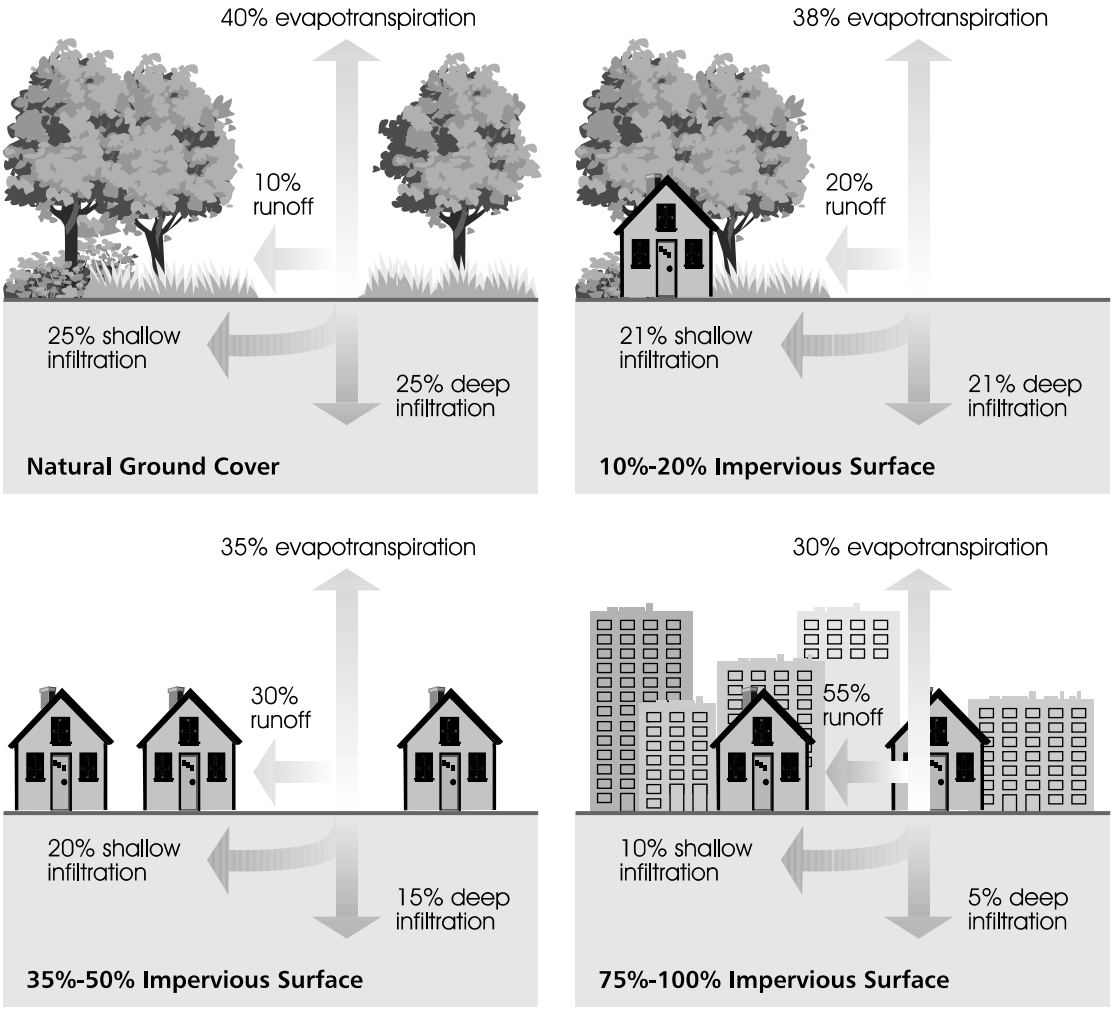
Figure 3-4. Runoff variability with increased impervious surfaces (FISRWG, 1998)



groundwater recharge and contribute to degradation of water quality and the ecological integrity of streams.

Time of Concentration. Time of concentration (Tc) is an idealized concept (Maidment, 1993) reflecting the response of a watershed to a given storm event. The Tc has been defined as the time it takes water from the most distant point (hydraulically) to reach the watershed outlet (NEH-4, SCS, 1985). Although Tc varies, it is often used as a constant. As the site imperviousness increases and the drainage pathways are altered, the contribution of land areas to excess rainfall water is likely to increase and the time to reach the downstream outlets is shortened. Traditional stormwater management approaches directed toward developing efficient drainage systems favor rapid concentration of excess water and routing it off-site through a drainage system of curbs and gutters, inlet structures, and storm drain pipes. Low-impact development relies on site planning tools and site-level management techniques to maintain the predevelopment time of concentration.

Time of concentration (Tc)

The time it takes for surface runoff to travel from the farthest point of the watershed to the outlet.

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Groundwater recharge

The amount of precipitation that infiltrates into the soil and contributes to groundwater.

Groundwater Recharge. A considerable percentage of the rainfall abstraction infiltrates into the soil and contributes to groundwater recharge. Groundwater may be part of a local, intermediate, or regional water table, as illustrated in Figure 3-5. The local water table is often connected to nearby streams, providing seepage to streams during dry periods and maintaining base flow essential to the biological and habitat integrity of streams. A significant reduction or loss of groundwater recharge can lead to a lowering of the water table and a reduction of base flow in receiving streams during extended dry weather periods. Headwater streams, with small contributing drainage areas, are especially sensitive to localized changes in groundwater recharge and base flow.

Summary of Comparison Between Conventional and LID Stormwater Management Approaches

Stormwater management efforts that follow the historical design storm approach focus on two elements:

1. ***Site Drainage.*** In conventional stormwater management design, site drainage was accomplished by designing a very efficient site drainage system. Curbs, gutters, and pipes are used and carefully designed to quickly and efficiently drain any excess rainwater off the site. This approach, although it provides excellent on-site drainage, greatly alters the natural hydrologic regime of the site and provides a higher pollutant transport capacity. In addition, this approach does not address on-site water quality controls and does not consider any of the LID site planning concepts.
2. ***Off-Site Flood Control.*** The total alteration of the natural site hydrologic regime due to an efficient on-site drainage system results in a significant increase in off-site flooding potential, as

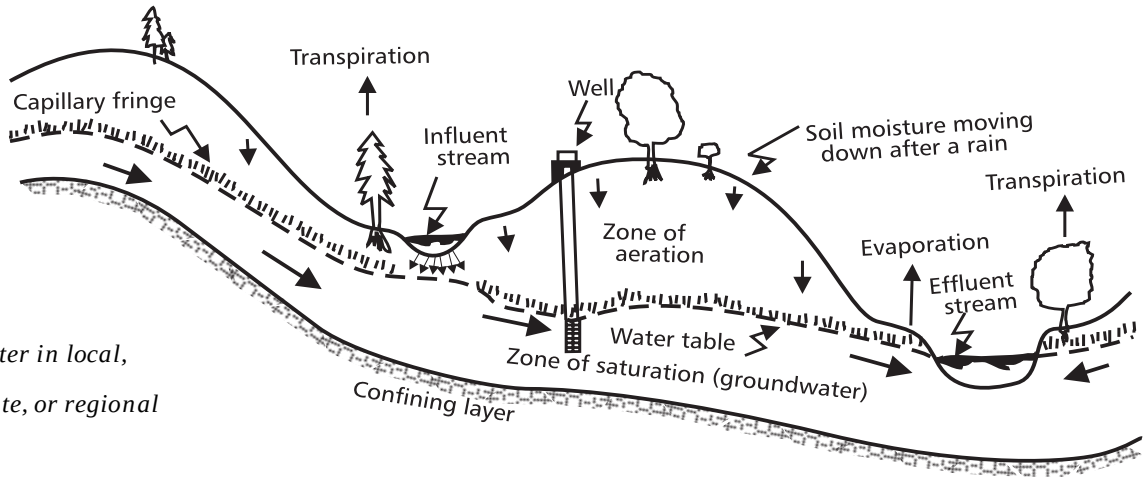

Figure 3-5. Groundwater in local, intermediate, or regional setting

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well as high downstream environmental impacts associated with increased peak flows and their frequency of occurrence, higher storm flow volumes, and increased delivery of pollutant loads (EPA, 1997). The traditional approach relies on designing treatment facilities targeted mainly to control peak flows for a given storm size (i.e., 10-year storm). These facilities typically consist of large stormwater ponds, strategically placed at the low point of the site. Since environmental concerns are becoming an integral component of stormwater management, it is assumed that such facilities are providing some controls. Since these facilities are designed for peak flow control and do not control those storm events smaller than the design storm, this approach is often referred to as the "end of pipe" control approach.

Table 3-1 summarizes how conventional stormwater management and LID technology alter the hydrologic regime for on-site and off-site conditions.

Table 3-1. Comparison of Conventional and LID Stormwater Management Technologies

Hydrologic Parameter	Conventional	LID
	Onsite	
Impervious Cover	Encouraged to achieve effective drainage	Minimized to reduce impacts
Vegetation/Natural Cover	Reduced to improve efficient site drainage	Maximized to maintain predevelopment hydrology
Time of Concentration	Shortened, reduced as a by-product of drainage efficiency	Maximized and increased to approximate predevelopment conditions
Runoff Volume	Large increases in runoff volume not controlled	Controlled to predevelopment conditions
Peak Discharge	Controlled to predevelopment design storm (2 year)	Controlled to predevelopment conditions for all storms
Runoff frequency	Greatly increased, especially for Small, frequent storms	Controlled to predevelopment conditions for all storms
Runoff duration	Increased for all storms, because volume is not controlled	Controlled to predevelopment conditions
Rainfall Abstractions (Interception, Infiltration, Depression Storage)	Large reduction in all elements	Maintained to predevelopment conditions
Groundwater Recharge	Reduction in recharge	Maintained to predevelopment conditions
	Offsite	
Water Quality	Reduction in pollutant loadings but limited control for storm events that are less than design discharge	Improved pollutant loading reductions, Full control for storm events that are less than design discharge
Receiving Streams	Severe impacts documented- Channel erosion and degradation Sediment deposition Reduced base flow Habitat suitability decreased, or eliminated	Stream ecology maintained to predevelopment
Downstream Flooding	Peak discharge control reduces flooding immediately below control structure, but can increase flooding downstream through cumulative impacts and superpositioning of hydrographs	Controlled to predevelopment conditions

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LID Hydrologic Considerations

In a LID system the fundamental hydrologic processes are considered throughout the site planning process. An understanding of the dynamics and interrelationships in the hydrologic cycle is used as a guide to preserving the predevelopment hydrology.

LID hydrologic considerations

- Runoff volume control
- Peak runoff rate control
- Flow frequency/ duration control
- Water quality control

The preservation of the predevelopment hydrology is evaluated by comparison of pre- and postdevelopment conditions. The comparison is facilitated by consideration of four fundamental measures-runoff volume control, peak runoff rate control, flow frequency/duration control, and water quality control. These four evaluation measures are discussed further below.

Runoff Volume Control. As the imperviousness of the site is increased, the runoff volume for a given storm increases. The ratio of the corresponding runoff volume (in inches) to the total rainfall event (in inches) is called the runoff coefficient. The typical site runoff coefficient can be maintained at the predevelopment level by compensating for the loss of abstraction (interception, infiltration, depression storage) through both site planning and design considerations.

Peak Runoff Rate Control. Low-impact development is designed to maintain the predevelopment peak runoff discharge for all the storms smaller than the selected design storm events. Use of site planning tools (see Chapter 2) and preferred management practices (Chapter 4) may control the peak runoff rate as well as the runoff volume. If additional controls are required to reach the predevelopment peak runoff rate, additional IMPs and supplemental management techniques might be needed.

Flow Frequency/Duration Control. Since low-impact development is designed to emulate the predevelopment hydrologic regime through both volume and peak runoff rate controls, the flow frequency and duration for the postdevelopment conditions should be almost identical to those for the predevelopment conditions (see Figure 3-6). The potential impacts on the sediment and erosion and stream habitat quality at downstream reaches can then be minimized.

Water Quality Control. Low-impact development is designed to provide water quality treatment control for at least the first half-inch of runoff from impervious areas using retention practices. In most LID applications, the use of distributed control and retention throughout the site will result in much higher levels of water quality treatment control for a number of reasons. First the runoff volume controlled will usually exceed the first half-inch of runoff, and frequently exceed two inches of runoff volume, thereby treating a much greater volume of

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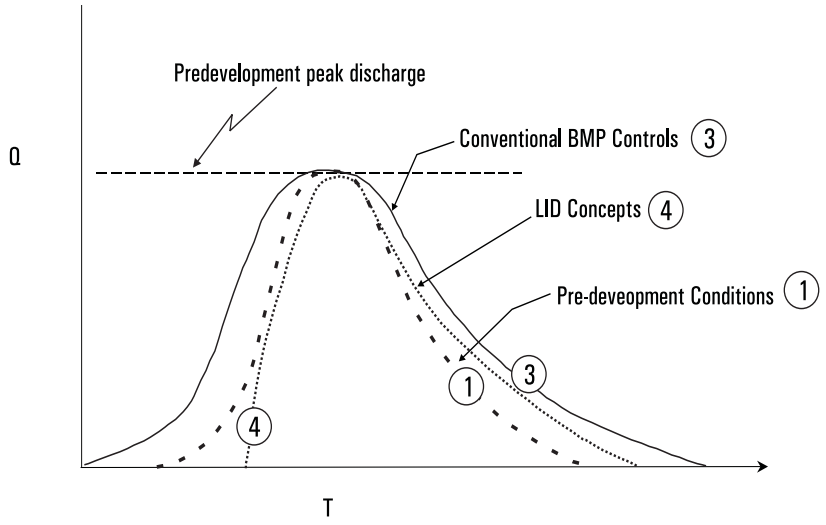

Figure 3-6. Comparison of the hydrologic response of conventional BMPs and LID IMPs

annual runoff. Also, this greater volume of runoff control will usually be associated with decreases in both the time of concentration and flow velocities which results in a reduction in the pollutant transport capacity and overall pollutant loading. Low-impact development also supports pollution prevention practices by modifying human activities to reduce the introduction of pollutants into the environment.

LID Hydrologic Tools

To achieve the goal of preserving the predevelopment hydrologic regime, a variety of LID site planning tools can be employed. The following tools are used in a variety of combinations in LID design:

- Reduce/minimize imperviousness. Change in postdevelopment hydrology can be minimized by reducing impervious areas and preserving more trees and meadows to reduce the storage requirements to maintain the predevelopment runoff volume.
- Disconnect unavoidable impervious surfaces. Additional environmental benefits can be achieved and the hydrologic impacts reduced by disconnecting unavoidable impervious surfaces as much as possible.
- Preserve and protect environmentally sensitive site features. Site features to be protected and preserved can include riparian areas, floodplains, stream buffers, and wetlands; woodlands, conservation zones, and valuable trees; steep slopes; and highly permeable and erosive soils.
- Maintain time of concentration (Tc). Maintaining the predevelopment Tc minimizes the increase of the peak runoff rate

LID hydrologic modification tools

- Reduce/minimize imperviousness
- Disconnect unavoidable impervious surfaces
- Preserve and protect environmentally sensitive site features
- Maintain time of concentration (Tc)
- Mitigate for impervious surfaces with PMPs

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LID hydrologic evaluation steps

1. Delineate the watershed and microwatershed areas
2. Define design storms
3. Define modeling techniques to be employed
4. Compile information for predevelopment conditions
5. Evaluate predevelopment conditions and develop baseline measures
6. Evaluate site planning benefits and compare with baseline
7. Evaluate integrated management practices (IMPs)
8. Evaluate supplemental needs

after development by lengthening flow paths and reducing the length of the runoff conveyance systems.

- Mitigate for impervious surfaces with IMPs. IMPs can provide retention storage for volume and peak control, as well as water quality control, to maintain the same natural initial abstraction volume as the predevelopment condition.
- Locate the impervious areas on less pervious soil types.

LID Hydrologic Evaluation

The purpose of the hydrologic evaluation is to determine the level of control required to achieve the stormwater management goals for LID sites. The required level of control may be achieved through application of the various hydrologic tools during the site planning process, the use of IMPs, and supplemental controls. The hydrologic evaluation is performed using hydrologic modeling and analysis techniques. The output of the hydrologic analysis provides the basis for comparison with the four evaluation measures (i.e., runoff volume, peak runoff, frequency, and water quality control).

LID Hydrologic Evaluation Steps

The hydrologic evaluation can be performed using various approaches and analytical techniques. Typically hydrologic evaluation follows a series of steps resulting in defining the needs for hydrologic control and management.

Step 1. Delineate the watershed and microwatershed areas. Hydrologic evaluation requires delineation of the drainage area for the overall study area or site and the subwatersheds contributing to key portions of the site. Delineation may need to consider previously modified drainage patterns, roads, or stormwater conveyance systems.

Step 2. Determine design storm(s). The design storms considered in the analysis should be determined based on the basic LID philosophy identified (see Section A.6 on page A.21). Regulatory requirements for design storms may also be stipulated in local ordinances, and these may limit or constrain the use of LID techniques or necessitate that structural controls be employed in conjunction with LID techniques.

Step 3. Define modeling technique(s) to be employed. Data gathering and analysis will depend on the specific type of model selected. The model selected will depend on the type of watershed, complexity of the site planning considerations, familiarity of the

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agency with the model, and level of detail desired. Certain models use simplified estimation methods whereas others provide detailed process-based representation of hydrologic interactions.

Step 4. Compile information for predevelopment conditions. Typical information needed includes area, soils, slopes, land use, and imperviousness (connected and disconnected).

Step 5. Evaluate predevelopment conditions and develop baseline measures. The selected modeling techniques are applied to the predevelopment conditions. The results of the modeling analysis are used to develop the baseline conditions using the four evaluation measures.

Step 6. Evaluate site planning benefits and compare with baseline. The site planning tools provide the first level of mitigation of the hydrologic impacts. The modeling analysis is used to evaluate the cumulative hydrologic benefit of the site planning process in terms of the four evaluation measures. The comparison is used to identify the remaining hydrologic control needs.

Step 7. Evaluate Integrated Management Practices (IMPs). The hydrologic control needs may be addressed through the use of IMPs (described in Chapter 4). This represents the second level of mitigation of the hydrologic impacts. After IMPs are identified for the site, a second-level hydrologic evaluation that combines the controls provided by the planning techniques with the IMPs can be conducted. Results of this hydrologic evaluation are compared with the predevelopment conditions to verify that the discharge volume and peak discharge objectives have been achieved. If not, additional IMPs are located on the site to achieve the optimal condition.

Step 8. Evaluate supplemental needs. If after use of IMPs supplemental control for either volume or peak flow is still needed, selection and listing of additional management techniques should be considered. For example, where flood control or flooding problems are a key design objective, or where site conditions, such as poor soils, or high water table limits the use of IMPs, additional conventional end-of-pipe methods, such as large detention ponds or constructed wetlands, should be considered. In some cases these controls can be sized much smaller than normal due to use of LID as part of the management system. The hydrologic evaluation is used to compare the supplemental management techniques and identify the preferred solutions.

The hydrologic evaluation steps are performed using an iterative process. Numerous site planning and management configurations may

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need to be evaluated to identify the optimum solutions. The concept of low-impact development is to emphasize the simple and cost-effective solutions. Use of hydrologic evaluations can assist in identifying these solutions prior to detailed design and construction costs.

Prince George's County, Maryland, has developed a detailed illustration of an approach for conducting a hydrologic evaluation based on the use of the SCS TR-55 method. A summary flow chart of the hydrologic evaluation process is shown in Figure 3-7. A full description of the application process is provided in Appendix A (Prince George's County, 1997).

Hydrologic Evaluation Techniques

A variety of models are available to simulate the rainfall-runoff processes for watersheds. The selection of the appropriate modeling technique will depend on the level of detail and rigor required for the application and the amount of data available for setup and testing of the model results. Four types of simulation models are briefly summarized below.

Hydrologic evaluation techniques

- HSPF
- SWMM
- HEC-1
- TR-55/TR-20
- The rational method

Hydrologic Simulation Program - FORTRAN (HSPF). The HSPF model is a comprehensive package developed and maintained by the U.S. Environmental Protection Agency for simulation of water quantity and quality from mixed land use watersheds. The model uses continuous simulation of rainfall-runoff processes to generate hydrographs, runoff flow rates, sediment yield, and pollutant washoff and transport. HSPF includes consideration of infiltration, subsurface water balance, interflow, and base flow.

Storm Water Management Model (SWMM). SWMM is an urban stormwater model developed and maintained by the U.S. Environmental Protection Agency. SWMM is applied to stormwater simulations including urban runoff, flood routing, and flooding analysis. The model provides continuous simulation, using variable timesteps, of rainfall-runoff processes and associated pollutant washoff and transport. SWMM also includes flow routing capabilities for open channels and piped systems.

HEC-1. The HEC-1 model was developed by the U.S. Army Corps of Engineers' Hydrologic Engineering Center (HEC). HEC-1 is designed to simulate the surface runoff response of a river basin to precipitation by representing the basin as an interconnected system of hydrologic and hydraulic components. Each component provides simulation of a rainfall-runoff process. The result of the modeling process is the computation of streamflow hydrographs at desired

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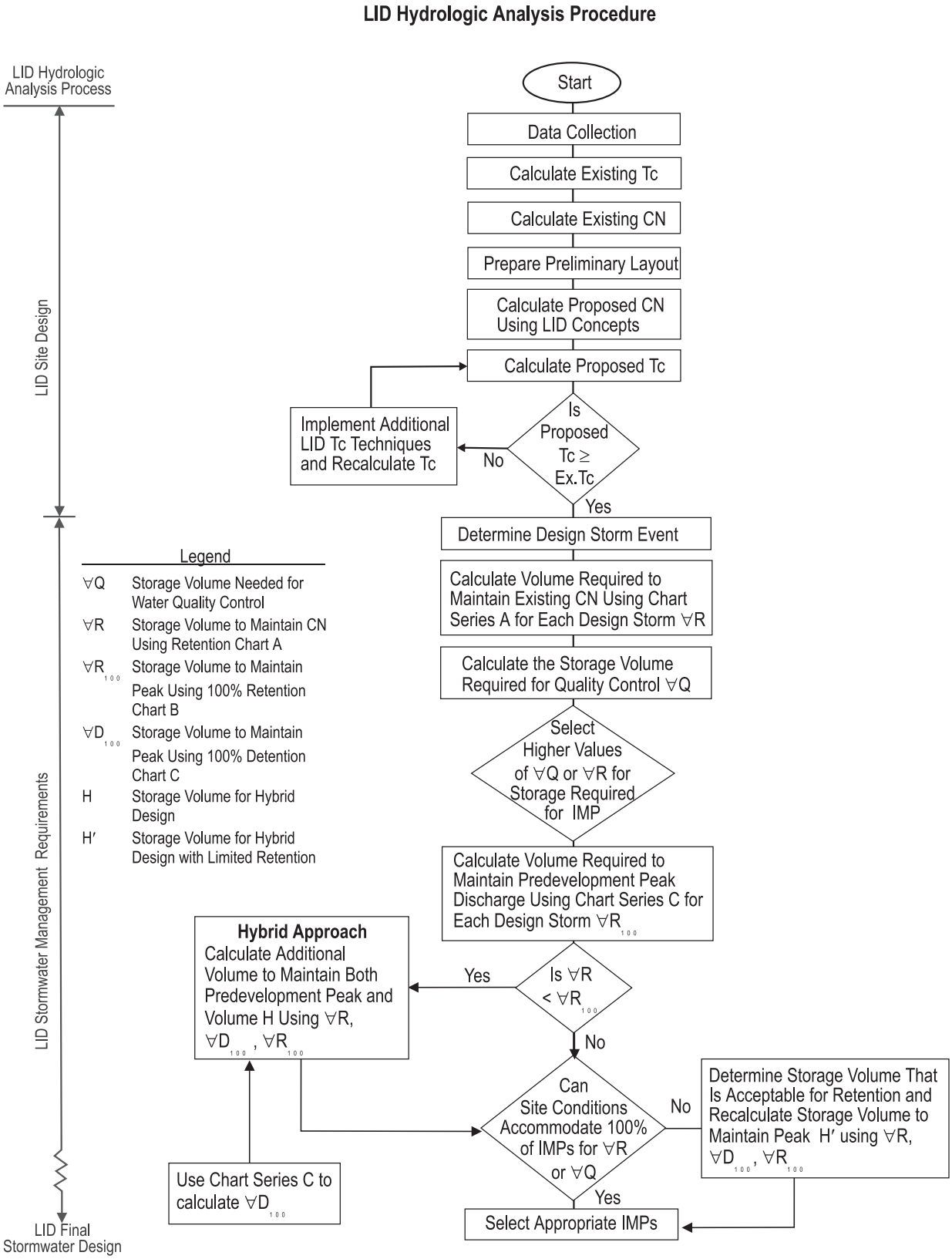

Figure 3-7. Prince George's County, Maryland, example of low-impact development analysis procedure (Prince George's County, 1997)

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locations in the river basin. The depth-area option computes flood hydrographs while preserving a user-supplied precipitation depth versus area relation throughout the stream network.

TR-55/TR-20. The U.S. Department of Agriculture, Natural Resources Conservation Service (NRCS), developed the TR-55/TR-20 model. TR-55 uses the runoff curve number method and unit hydrographs to convert rainfall into runoff. TR-55 and TR-20 are infiltration loss models that use the runoff curve number methods and synthetic storm flow hydrograph development to predict peak volume and flow rates for a given catchment area. The advantage of applying TR-55 and TR-20 is the convenience of tables and input parameters included for a wide range of soil and land use conditions. Also TR-55 and TR-20 models are widely used by field-level professionals.

The Rational Method. The rational method is a storm sewer evaluation method based on the rational formula (Maidment, 1993). The rational formula calculates the peak flow rate as a function of the rainfall intensity (for a specific design return period and time of concentration), the watershed area, and the runoff coefficient. The rational method is frequently used in land development applications due to its simplicity and ease of application.

Table 3-2 provides an overview of the attributes and functions of the selected models.

LID Hydrologic Illustrations

To illustrate the hydrologic analysis techniques employed by low-impact development, two examples from the Prince George's County Design Manual are discussed below (Prince George's County,

Table 3-2 Comparison of Model Attributes and Functions

Attribute	Model				
	HSPF	SWMM	TR-55/TR-20	HEC-1	Rational
Sponsoring agency	USEPA	USEPA	NRCS (SCS)	CORPS (HEC)	Method
Simulation type	Continuous	Continuous	Single event	Single event	Single event
Water quality analysis	Yes	Yes	None	None	None
Rainfall/runoff analysis	Yes	Yes	Yes	Yes	Yes
Sewer system flow routing	None	Yes	Yes	Yes	None
Dynamic flow routing equations	None	Yes	Yes	None	None
Regulators, overflow structures	None	Yes	None	None	None
Storage analysis	Yes	Yes	Yes	Yes	None
Treatment analysis	Yes	Yes	None	None	None
Data and personnel requirements	High	High	Medium	Medium	Low
Overall model complexity	High	High	Low	High	Low

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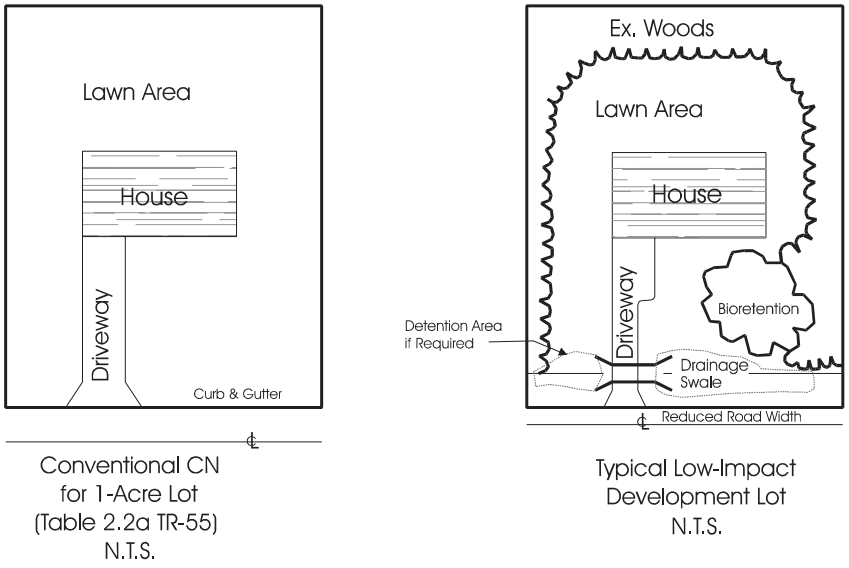

Figure 3-8. Customizing runoff CN for a low-impact development site

1997). The examples highlight the use of the LID tools in achieving the runoff volume and peak flow objectives. The first example describes the control of runoff volume and peak flow using a TR-55 application. The second example describes methods used to control the time of concentration to manage the peak flow rate.

LID Runoff Volume and Peak Flow Management

Calculation of the LID runoff potential is based on a detailed evaluation of the existing and proposed land cover so that an accurate representation of the potential for runoff can be obtained. This calculation requires the investigation of parameters associated with a low-impact development, such as the following:

- Land cover type
- Percentage and connectivity of impervious areas
- Soils type and texture
- Antecedent soil moisture conditions

Determination of LID Runoff Curve Number

The process for performing a hydrologic evaluation for a LID site is illustrated through the use of a TR-55 application example (SCS, 1986). As illustrated in Figure 3-8, customizing the curve number (CN) for a LID site allows the developer/engineer to take advantage of and get credit for a variety of LID site planning practices, which include in this case:

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- Narrower driveways and roads (minimizing impervious areas)
- Maximizing tree preservation or forestation (tree planting)
- Site fingerprinting (minimal disturbance)
- Open drainage swales
- Preservation of soils with high infiltration rates (locate impervious areas on low infiltration soils)
- Location of IMPs on high-infiltration soils

Table 3-3 Comparison of Conventional and LID Land Covers

Conventional Land Covers (TR-55 assumptions)	LID Land Covers
20% impervious 80% grass	15% impervious 25% woods 60% grass

Table 3-3 shows the resulting low-impact development CN land cover compared with those of a conventional development CN, as found in Table 2.2a of TR-55 (SCS, 1986) for the example 1-acre lot.

Table 3-4 shows how LID site planning can affect components of the CN, resulting in lower CN and more infiltration.

Figure 3-9 shows how hydrologic response is altered using LID example techniques to reduce the impervious areas and the associated runoff peak volume. Hydrograph 1 is the predevelopment condition, and hydrograph 2 is the postdevelopment condition without controls. Hydrograph 5 represents the resulting postdevelopment hydrograph

Table 3-4. LID Planning Techniques to Reduce the Postdevelopment Runoff Volume

Suggested Options Affecting Curve Number	Limit use of sidewalks	Reduce road length and width	Reduce driveway length and width	Conserve natural resources areas	Minimize disturbance	Preserve infiltratable soils	Preserve natural depression areas	Use transition zones	Use vegetated swales	Preserve Vegetation
Land Cover Type				✔	✔			✔	✔	✔
Percent of Imperviousness	✔	✔	✔					✔		
Hydrologic Soils Group				✔		✔				
Hydrologic Condition				✔	✔	✔				
Disconnectivity of Impervious Area	✔	✔	✔							
Storage and Infiltration							✔			✔

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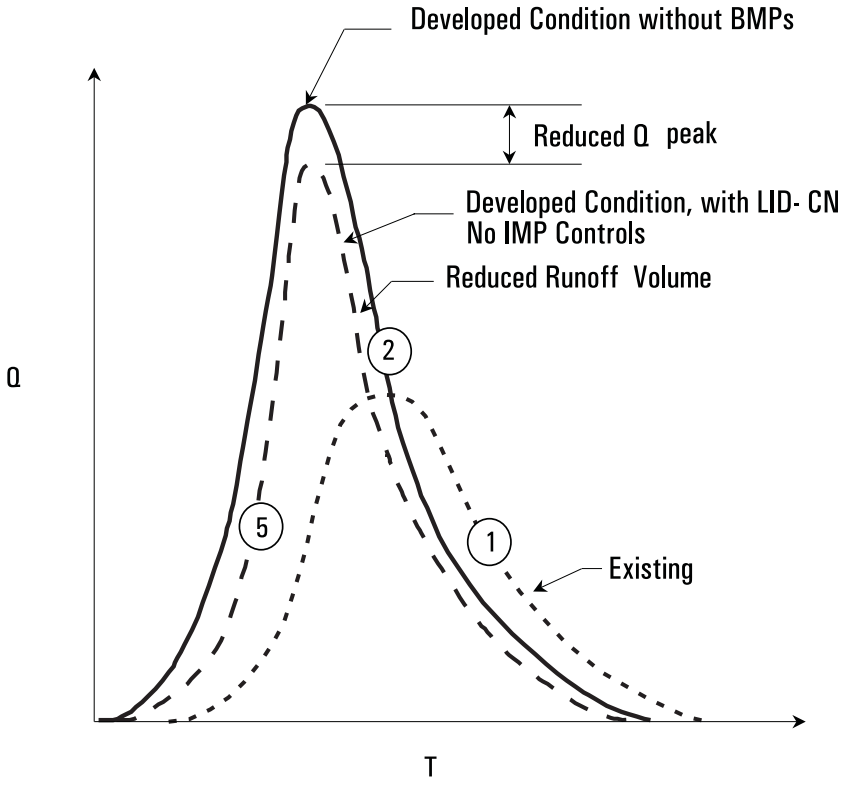

Figure 3-9. Effect of low-impact development CN on the postdevelopment hydrograph without stormwater BMPs

with a significant reduction in both postdevelopment peak rate and volume, which can be achieved by just using LID site planning techniques to reduce CN values and without the benefit of IMP.

Maintaining the Predevelopment Time of Concentration

The management of runoff volume, peak flow, and frequency requires that the postdevelopment time of concentration (Tc) be maintained close to the predevelopment Tc. The travel time (Tt) throughout individual lots and areas should be approximately the same so that the Tc is representative of the drainage. This is critical because low-impact development theory is based on a relatively homogeneous land cover and distributed IMPs. To maintain the Tc, low-impact developments use the following site planning techniques:

- Maintaining predevelopment flow path length by dispersing and redirecting flows, generally through open swales and natural drainage patterns.
- Increasing surface roughness (e.g., reserving woodlands, using vegetated swales).
- Detaining flows (e.g., open swales, rain gardens).

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- Minimizing disturbance (minimizing compaction and changes to existing vegetation).
- Flattening grades in impacted areas.
- Disconnecting impervious areas (e.g., eliminating curb/gutter and redirecting downspouts).
- Connecting pervious and vegetated areas (e.g., reforestation, forestation, tree planting).

To maintain predevelopment Tc, an iterative process that analyzes different combinations of the above appropriate techniques may be required. These site planning techniques are incorporated into the hydrologic analysis computations for postdevelopment Tc to demonstrate an increase in postdevelopment Tc above conventional techniques and a corresponding reduction in peak discharge rates.

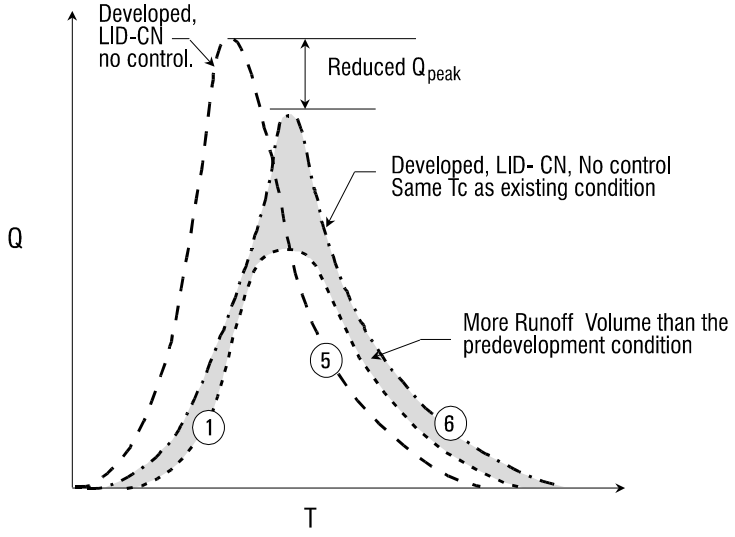

Figure 3-10. Low-impact development hydrograph that has a reduced CN and maintains the Tc without conventional stormwater controls

Figure 3-10 illustrates the hydrologic response to maintaining equal predevelopment and postdevelopment TCs. Hydrograph 1 is the predevelopment condition. Hydrograph 5, as previously described, shows the benefits of using LID techniques to reduce impervious areas and the associated runoff peak volume.

Hydrograph 6 represents the effects of using LID techniques to maintain the Tc. This effectively shifts the postpeak runoff time to that of the predevelopment condition and lowers the peak runoff rate.

Maintaining the same Tc in a small watershed can be mainly accomplished by maintaining or raising the Manning's roughness "n" for the initial overland (sheet) flow at the top of the watershed and increasing the flow path length to the most hydraulically distant point in the drainage area. After the transition to shallow concentrated flow, additional gains in Tc can be accomplished by:

- Decreasing the slope
- Increasing the flow length
- Directing the flow over pervious areas.

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In LID sites, the volume of flow in closed channels (pipes) should be minimized to the greatest extent possible. Swales and open channels should be designed with the following features:

- Increase surface roughness to retard velocity.
- Maximize sheet flow conditions.
- Use a network of wider and flatter channels to avoid fast-moving channel flow.
- Increase channel flow path.
- Reduce channel gradients to decrease velocity (many local jursidictions have a minimum slope requirement of 2 percent; 1 percent may be considered on a case-by-case basis).
- The channel should flow over pervious soils whenever possible to increase infiltration so that there is a reduction of runoff to maximize infiltration capacity.

Table 3-5 identifies LID techniques and objectives to maintain the predevelopment Tc.

Detailed guidance and computational examples are provided in the Appendix A, Example LID Hydrologic Computations, which has been adapted from the Prince George's County LID Hydrologic Analysis Manual (Prince George's County, 1997).

Table 3-5. LID Techniques to Maintain the Predevelopment Time of Concentration

	Low Impact Development Technique									
Low-Impact Development Objective	On-lot bioretention	Wider and flatter swales	Maintain sheet flow	Clusters of trees and shrubs in flow path	Provide tree conservation/ transition zones	Minimize storm drain pipes	Disconnect impervious areas	Save trees	Preserve existing topography	LID drainage and infiltration zones
Minimize disturbance	✔		✔	✔		✔	✔	✔	✔	✔
Flatten grades		✔	✔			✔			✔	✔
Reduce height of slopes						✔			✔	✔
Increase flow path (divert and redirect)		✔	✔	✔		✔	✔	✔		
Increase roughness "n"	✔		✔	✔		✔	✔	✔	✔	✔

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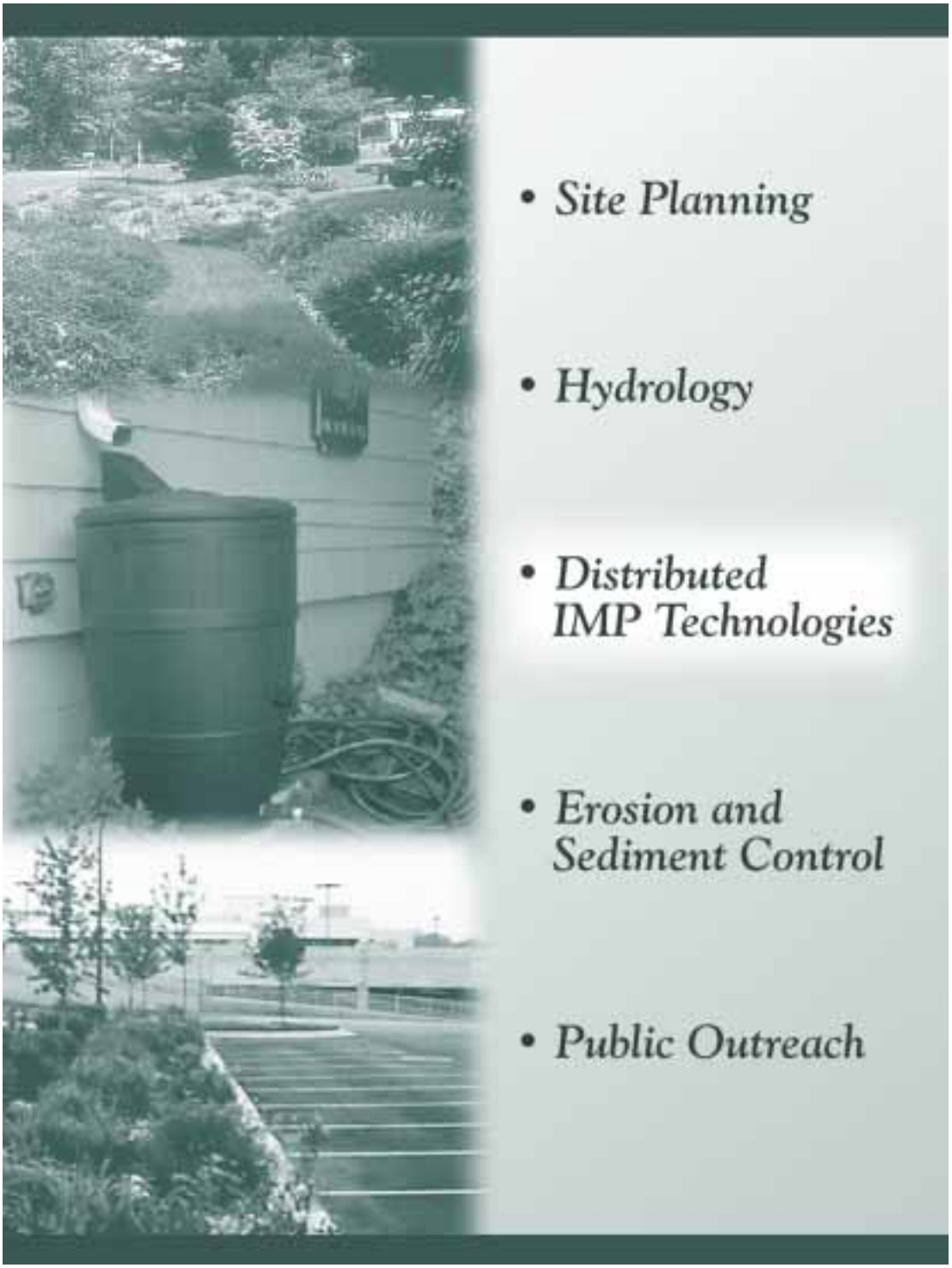
Chapter 4

Low-Impact Development Integrated Management



Chapter 4

Low-Impact Development Integrated Management Practices

Low-impact development technology employs microscale and distributed management techniques, called integrated management practices (IMPs), to achieve desired postdevelopment hydrologic conditions. The site planning process (Chapter 2) has identified how fundamental design techniques can be used to minimize the hydrologic effects of development. The hydrologic analysis (Chapter 3) demonstrates how to quantify the predevelopment and postdevelopment conditions under various design scenarios. This chapter presents the third step in the LID process—identifying and selecting IMPs. Detailed descriptions of the IMPs are included.

IMPs addressed in this chapter

- Bioretention
- Dry wells
- Filter/buffer strips
- Grassed swales
- Rain barrels
- Cisterns
- Infiltration trenches

Procedures for Selection and Design of IMPs

Site planning techniques can significantly reduce the hydrologic impacts of development. Once site-planning techniques have been exercised, additional modifications are likely to be required to match the predevelopment hydrograph. Measures used to evaluate the hydrologic impact include the runoff volume and the peak flow condition. The shaded portion of Figure 3-10 illustrates the remaining "control" that might be required to meet the development hydrology goal. IMPs can be used to provide that additional hydrologic control of peak discharge and runoff volume.

LID IMPs are used to satisfy the storage volume requirements calculated in Chapter 3. They are the preferred method because

In This Chapter…

Introduction

Procedures for selection and design of IMPs

Suitability criteria/factors

Integrated management practices (IMPs)

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they can maintain the predevelopment runoff volume and can be integrated into the site design. The design goal is to locate IMPs at the source or lot, ideally on level ground within individual lots of the development. Management practices that are suited to low-impact development include:

- Bioretention facilities
- Dry wells
- Filter/buffer strips and other multifunctional landscape areas
- Grassed swales, bioretention swales, and wet swales
- Rain barrels
- Cisterns
- Infiltration trenches

The process for selection and design begins with the control goals identified using the hydrologic techniques described in Chapter 3. The steps identify the opportunities for supplemental controls and guide the designer through the selection and design process (Figure 4-1):

Step 1: Define hydrologic control required.

Step 2: Evaluate site constraints.

Step 3: Screen for candidate practices.

Step 4: Evaluate candidate IMPs in various configurations.

Step 5: Select preferred configuration and design.

Step 6: Supplement with conventional controls, if necessary.

Fundamental questions addressed in the IMP selection and design process

What are the goals for reduction of the volume and peak flow conditions after development?

What are site constraints for selection of IMPs?

What types of IMPs are appropriate for my site?

How many IMPs do I need to plan for?

How much will it cost to install and maintain these practices?

Will IMPs be sufficient to meet the goals and regulatory requirements?

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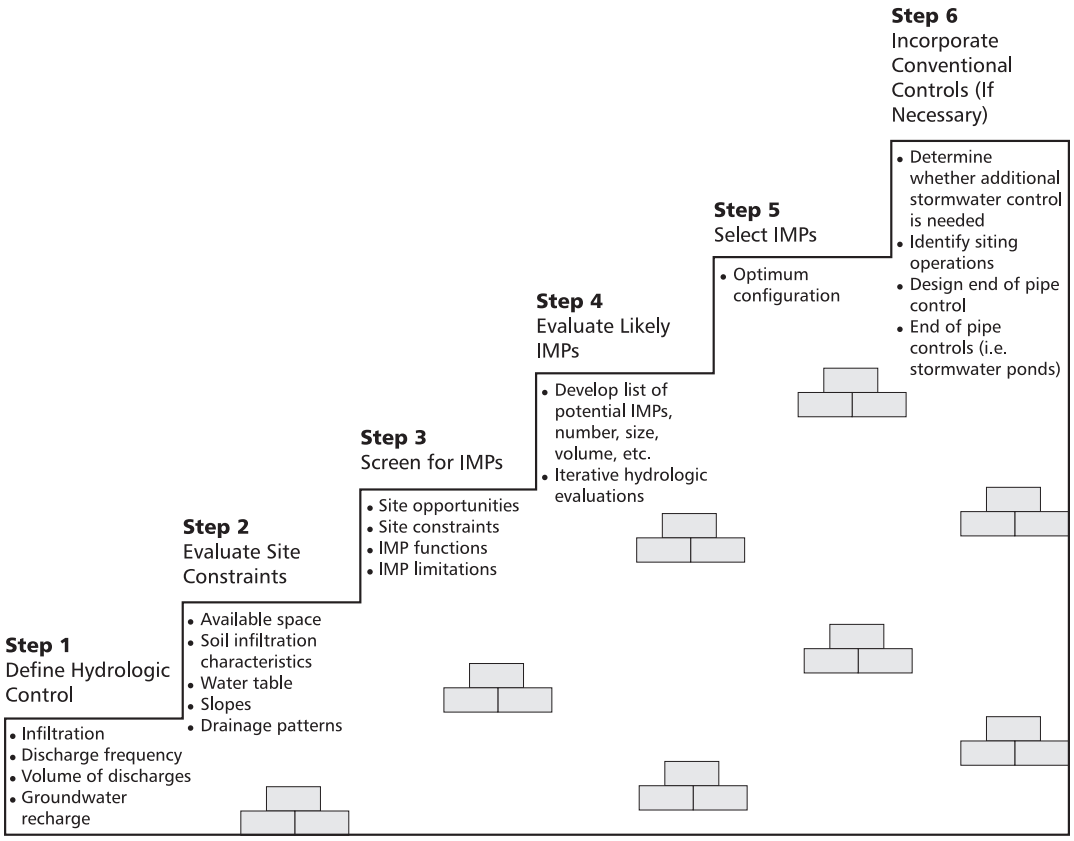

Figure 4-1. Key steps in developing stormwater plan using LID practices

Step 1: Define Hydrologic Controls Required

The goal of the LID approach is to mimic the predevelopment hydrologic regime of the site and thus maintain the predevelopment runoff volume, peak runoff rates, and frequency. These control objectives were defined and addressed, to the degree possible, through site planning techniques described in Chapter 2.

The remaining need for control must be identified based on the hydrologic goals identified in Chapter 3. This is illustrated in Figure 3-9.

Hydrologic functions such as infiltration, frequency and volume of discharges, and groundwater recharge become essential considerations when identifying and selecting IMPs. Following the procedures described in Chapter 3, the hydrologic functions can be quantified with respect to the various design parameters, which include runoff volume, peak discharge, frequency and duration of discharge, groundwater recharge, and water quality parameters. When these design parameters are quantified for predevelopment conditions, they define or quantify the hydrologic controls required for a specific site.

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Step 2: Evaluate Site Opportunities and Constraints

Each site has unique characteristics and opportunities for control. The LID concept encourages innovation and creativity in the management of site planning impacts. In this step the site should be evaluated for opportunities and constraints. Opportunities are locations where physical conditions like available space, infiltration characteristics, and slopes are amenable to IMP installation. These same conditions might also constrain the use of IMPs. Table 4-1 provides a summary of potential site constraints of IMPs.

Table 4-1. Site Constraints of IMPs

	Bioretention	Dry Well	Filter/Buffer Strip	Swales: Grass, Infiltration, Wet	Rain Barrels	Cistern	Infiltration Trench
Space Required	Minimum surface area range: 50 to 200 ft^2 Minimum width: 5 to 10 ft Minimum length: 10 to 20 ft Minimum depth: 2 to 4 ft	Minimum surface area range: 8 to 20 ft^2 Minimum width: 2 to 4 ft Minimum length: 4 to 8 ft Minimum depth: 4 to 8 ft	Minimum length of 15 to 20 ft	Bottom width: 2 ft minimum, 6 ft maximum	Not a factor	Not a factor	Minimum surface area range: 8 to 20 ft^2 Minimum width: 2 to 4 ft Minimum length: 4 to 8 ft
Soils	Permeable soils with infiltration rates > 0.27 inches/hour are recommended. Soil limitations can be overcome with use of underdrains	Permeable soils with infiltration rates > 0.27 inches/hour are recommended	Permeable soils perform better, but soils not a limitation	Permeable soils provide better hydrologic performance, but soils not a limitation. Selection of type of swale, grassed, infiltration or wet is influenced by soils	Not a factor	Not a factor	Permeable soils with infiltration rates > 0.52 inches/hour are recommended
Slopes	Usually not a limitation, but a design consideration	Usually not a limitation, but a design consideration. Must locate downgradient of building and foundations	Usually not a limitation, but a design consideration	Swale side slopes: 3:1 or flatter Longitudinal slope: 1.0% minimum; maximum based on permissible velocities	Usually not a limitation, but a design consideration for location of barrel outfall	Not a factor	Usually not a limitation, but a design consideration. Must locate down-gradient of buildings and foundations
Water Table/ Bedrock	2- to 4-ft clearance above water table/ bedrock recommended	2- to 4-ft clearance above water table/ bedrock recommended	Generally not a constraint	Generally not a constraint	Generally not a constraint		2- to 4-ft clearance
Proximity to build foundations	Minimum distance of 10 ft downgradient from buildings and foundations recommended	Minimum distance of 10 ft downgradient from buildings and foundations recommended	Minimum distance of 10 ft downgradient from buildings and foundations recommended	Minimum distance of 10 ft downgradient from buildings and foundations recommended	Not a factor		Minimum distance of 10 ft down-gradient from buildings and foundations recommended
Max. Depth	2- to 4-ft depth depending on soil type	6- to 10-ft depth depending on soil type	Not applicable	Not applicable	Not applicable		6- to 10-ft depth depending on soil type
Maintenance	Low requirement, property owner can include in normal site landscape maintenance	Low requirement	Low requirement, routine landscape maintenance	Low requirement, routine landscape maintenance	Low requirement		Moderate to high

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Suitability Criteria/Factors

The site designer should consider or evaluate the following factors when selecting LID IMPs.

Space/Real Estate Requirements. The amount of space required for stormwater management controls is always a consideration in the selection of the appropriate control. LID IMPs, because they are integrated into and distributed throughout the site's landscape, typically do not require that a separate area be set aside and dedicated to stormwater management.

Soils. Soils and subsoil conditions are a very important consideration in every facet of LID technology, including the site planning process, the hydrologic considerations, and the selection of appropriate IMPs. The use of micromanagement practices, as well as the use of underdrains to provide positive subdrainage for bioretention practices, helps to overcome many of the traditional soil limitations for the selection and use of IMPs.

Slopes. Slope can be a limiting factor when the use of the larger traditional stormwater controls is considered. With the application of the distributed micromanagement IMPs, however, slope is seldom a limiting factor; it simply becomes a design element that is incorporated into the hydrologically functional landscape plan.

Water Table. The presence of a high water table calls for special precautions in every aspect of site planning and stormwater management. The general criterion is to provide at least 2 to 4 feet of separation between the bottom of the IMP and the top of the seasonally high water table elevation. Also, the potential for contamination should be considered, especially when urban landscape hotspots are involved.

Proximity to Foundations. Care must be taken not to locate infiltration IMPs too close to foundations of buildings and other structures. Considerations include distance, depth, and slope.

Maximum Depth. By their nature, the micromanagement practices that make up the LID IMPs do not require much depth, and thus this factor is not usually a major concern. Bioretention cells, for example, usually allow only 6 inches of ponding depth, and 2 to 4 feet of depth for the planting soil zones.

Maintenance Burden. Maintenance costs for traditional stormwater controls are significant and have become a considerable burden for local governments and communities. Maintenance costs can equal or exceed the initial construction cost. In comparison, many of the IMPs require little more than normal landscaping maintenance treatment. Additionally, this cost is typically the responsibility of the individual property owner rather than the general public. Communities are advised to retain the authority to maintain their sites if they fail to function as designed.

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Suitability criteria/factors

- Soils
- Slopes
- Water table
- Proximity to foundations
- Maximum depth
- Maintenance burden

As previously discussed, one of the key concepts to making LID technology work is to think small with respect to the size of the area being controlled (microsubsheds) and the size of the practice (micropractices). This combination allows the designer to incorporate many of the LID practices into the landscape and to overcome potential site constraints with respect to available space, soils, slopes, and other factors in a way that would not be possible with the larger conventional methods.

Step 3: Screen for Candidate Practices

Based on the evaluation of site opportunities and constraints, a comparison with the available practices is made. IMPs that are inappropriate or infeasible for the specific site are excluded from further consideration. Screening should consider both the site constraints (Table 4-1) and the hydrologic and water quality functions identified in Table 4-2.

Table 4-2 provides an assessment of the hydrologic functions of the preferred LID management practices. Table 4-3 provides a summary of the reported water quality benefits provided by the LID IMPs.

It is important to recognize that LID stormwater management is not simply a matter of selecting from a menu of available preferred practices. Rather, it is an integrated planning and design process. The site planning process described earlier is a necessary and essential component of the LID stormwater management concept. The preferred practices by themselves might not be sufficient to restore the hydrologic functions of a site without the accompanying site planning procedures described in Chapter 2.

Table 4-2. Hydrologic Functions of LID Integrated Management Practices (IMPs)

	PMP						
Hydrologic Functions	Bio Ret	Dry Well	Filter/ Buffer	Swale Grass	Rain Barrel	Cistern	Infilt. Trench
Interception	H	N	H	M	N	N	N
Depression Storage	H	N	H	H	N	N	M
Infiltration	H	H	M	M	N	N	H
G.W. Recharge	H	H	M	M	N	N	H
Runoff Volume	H	H	M	M	L	M	H
Peak Discharge	M	L	L	M	M	M	M
Runoff Frequency	H	M	M	M	M	M	M
Water Quality	H	H	H	H	L	L	H
Base Flow	M	H	H	M	M	N	L
Stream Quality	H	H	H	M	N	L	H

H = High M = Moderate L = Low N = None

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Table 4-3 Reported Pollutant Removal Efficiency of IMPs

PMP	TSS	Total P	Total N	Zinc	Lead	BOD	Bacteria
Bioretention	-	81	43	99	99	-	-
Dry Well	80-100	40-60	40-60	80-100	80-100	60-80	60-80
Infiltration Trench	80-100	40-60	40-60	80-100	80-100	60-80	60-80
Filter/Buffer Strip	20-100	0-60	0-60	20-100	20-100	0-80	-
Vegetated Swale	30-65	10-25	0-15	20-50	20-50	-	Neg.
Infiltration Swale	90	65	50	80-90	80-90	-	-
Wet Swale	80	20	40	40-70	40-70	-	-
Rain Barrel	NA	NA	NA	NA	NA	NA	NA
Cistern	NA	NA	NA	NA	NA	NA	NA

Source: CRC, 1996; Davis et al. 1997; MWCG, 1987;Urbonas & Stahre, 1993; Yousef et al., 1985; Yu et al., 1992; Yu et al., 1993.

Step 4: Evaluate Candidate IMPs in Various Configurations

After the candidate IMPs are identified, they are deployed as appropriate throughout the site and the hydrologic methods described in Chapter 3 are applied to determine whether the mix of IMPs meets the hydrologic control objectives identified in Step 1. Typically, on the first design attempt the hydrologic control objectives are not met precisely but instead are overestimated or underestimated. An iterative process might be necessary, adjusting the number and size of IMPs until the hydrologic control objectives are optimized. An example LID hydrologic computation that illustrates this procedure is provided in the Appendix.

Step 5: Select Preferred Configuration and Design

The iterative design process typically identifies a number of potential configurations and mixes of IMPs. The designer has the option to use more or fewer bioretention structures, rain barrels, cisterns, dry wells, infiltration trenches, vegetated swales, and other practices. Design factors such as space requirements, site aesthetics, and construction costs can all be factored into the decision-making process to arrive at an optimum or preferred configuration and mix of IMPs that provide the identified level of hydrologic control at a reasonable cost.

Step 6: Design Conventional Controls if Necessary

If for any reason the hydrologic control objectives developed for a given site cannot be achieved using IMPs, it might be necessary to add some conventional controls. Sometimes site constraints like low-permeability soils, the pressure of a high water table or hard rock,

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or very intensive land uses such as commercial or industrial sites can preclude the use of sufficient IMPs to meet the hydrologic design objectives, particularly the peak discharge criteria. In these situations it is recommended that IMPs be used to the extent possible and then that additional conventional controls such as detention or retention practices (i.e. ponds) be used to meet the remaining hydrologic design objectives. An example computation that illustrates how to determine when additional conventional controls are required is provided in the Appendix.

LID Functions Include

- Groundwater recharge
- Retention or detention of runoff
- Pollutant settling
- Aesthetic value
- Multiple use

Integrated Management Practices (IMPs)

LID IMPs are designed for on-lot use. This approach integrates the lot with the natural environment and eliminates the need for large centralized parcels of land to control end-of-pipe runoff. The challenge of designing a low-impact site is that the IMPs and site design strategies must provide quantity and quality control and enhancement, including

- Groundwater recharge through infiltration of runoff into the soil.
- Retention or detention of runoff for permanent storage or for later release.
- Pollutant settling and entrapment by conveying runoff slowly through vegetated swales and buffer strips.

  In addition, LID also provides an added aesthetic value to the property, which increases a sense of community lifestyle.
- Multiple use of landscaped areas. In some cases, the on-lot or commercial hydrologic control also can satisfy local government requirements for green or vegetated buffer space.

Placing controls in series provides for the maximum on-lot stormwater runoff control (i.e., the maximum mitigation of site development impacts on the natural hydrology). This type of design control is known as a "hybrid" and is effective in reducing both volume and peak flow rate. Examples of specific IMPs are described below.

Bioretention

A practice using landscaped areas on lots to hold and infiltrate stormwater

Bioretention

Bioretention is a practice to manage and treat stormwater runoff by using a conditioned planting soil bed and planting materials to filter runoff stored within a shallow depression. The bioretention concept was originally developed by the Prince George's County, Maryland, Department of Environmental Resources in the early 1990s as an

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alternative to traditional BMP structures (ETA, 1993). The method combines physical filtering and adsorption with biological processes. The system can include the following components, as illustrated in Figures 4-2 and 4-3: a pretreatment filter strip of grass channel inlet area, a shallow surface water ponding area, a bioretention planting area, a soil zone, an underdrain system, and an overflow outlet structure.

Figure 4-2. Bioretention area

Design Considerations. The major components of the bioretention system all require careful design considerations. These major components include

- Pretreatment area (optional)
- Ponding area
- Ground cover layer
- Planting soil
- In situ soil
- Plant material
- Inlet and outlet controls
- Maintenance

The key design consideration for these components are summarized in Table 4-4. Detailed design guidance can be obtained from the *Prince George's County Bioretention Manual* (ETA, 1993).

Table 4-4. Bioretention Design Components

Pretreatment area	Required where a significant volume of debris or suspended material is anticipated such as parking lots and commercial areas. Grass buffer strip or vegetated swale are commonly used pretreatment devices
Ponding area	Typically limited to a depth of 6 inches
Groundcover area	3 inches of mature mulch recommended
Planting soil	Depth = 4 feet Soil mixtures include sand, loamy sand, and sandy loam Clay content ≤ 10%
In-situ soil	Infiltration rate ≥ 0.5 inches/hour w/o underdrains Infiltration rate ≤ 0.5 inch/hour underdrain required
Plant materials	Native species, minimum 3 species
Inlet and outlet controls	Non erosive flow velocities (0.5 ft/sec)
Maintenance	Routine landscape maintenance
Hydrologic design	Determined by state or local agency

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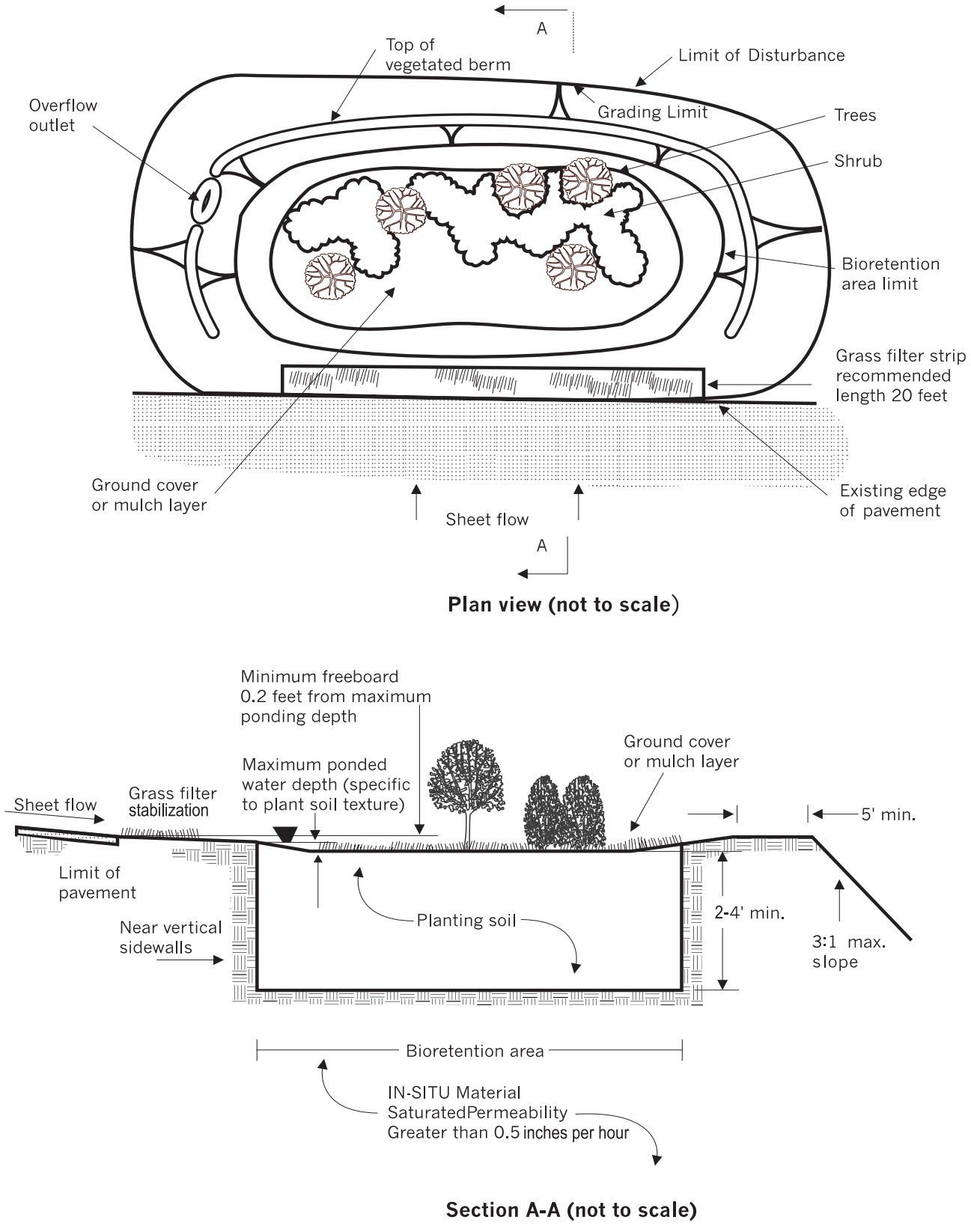

Figure 4-3. Typical bioretention facility

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Dry Wells

A dry well consists of a small excavated pit backfilled with aggregate, usually pea gravel or stone. Dry wells function as infiltration systems used to control runoff from building rooftops. Another special application of dry wells is modified catch basins, where inflow is a form of direct surface runoff. Figure 4-4 shows a typical detail of a dry well.

Dry wells provide the majority of treatment by processes related to soil infiltration, including adsorption, trapping, filtering, and bacterial degradation.

Design considerations. The key design considerations for dry wells are summarized in Table 4-5. Detailed design guidance can be obtained in *Maryland Standards and Specifications for Infiltration Practices* (MDDNR, 1984); *Maintenance of Stormwater Management Structures, a Departmental Summary* (MDE, 1986); and *Maryland Stormwater Design Manual* (MDE, 1998).

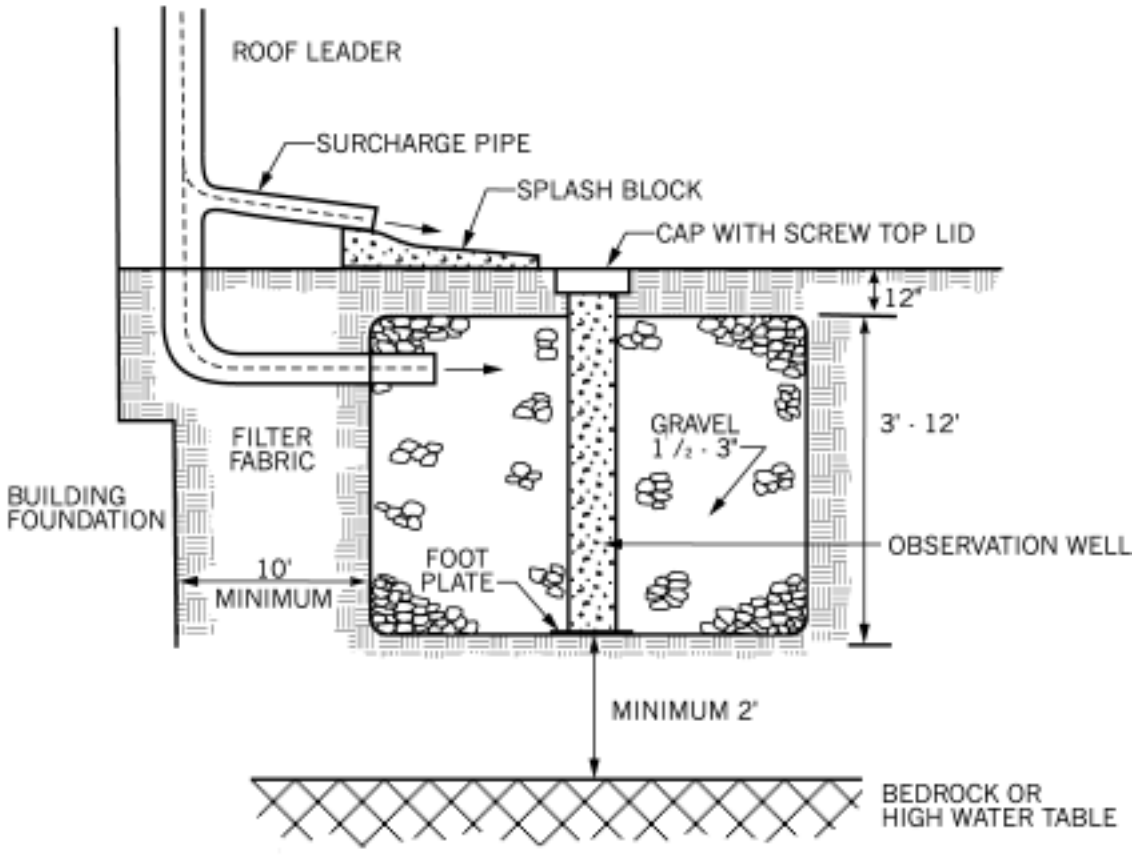

Figure 4-4. Typical dry well

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Table 4-5. Dry Well Design Considerations

Design storms	Determined by local or state agencies. Guidance provided in Prince George's County LID Manual is recommended
Soil permeability	≥ 0.27 – 0.50 inches /hour
Storage time	Empty within 3 days
Backfill	Clean aggregate ≥ 11/2, ≤ 3", surrounded by engineering filter fabric
Runoff filtering	Screens should be placed on top of roof leaders, grease, oil floatable organic materials and settable solids should be removed prior to entering well
Outflow structures	Overland flow path of surface runoff exceeding the capacity of the well must be identified and evaluated. An overflow system leading to a stabilized channel or watercourse including measures to provide non-erosive flow conditions must be provided
Observation well	Must be provided, 4-inch PVC or foot place constructed flush with ground surface, cap with lock
Depth of well	3 to 12 feet
Hydrologic design	Determined by state or local agency. Maryland Design Manual is recommended
Water quality	See Table 4.3 for performance data
Maintenance	Periodic monitoring—quarterly at first and annually thereafter

Filter Strips

Bands of close-growing vegetation, usually grass, planted between pollutant source areas and a downstream receiving waterbody

Filter Strips

Filter strips are typically bands of close-growing vegetation, usually grass, planted between pollutant source areas and a downstream receiving waterbody (Figure 4-5). They also can be used as outlet or pretreatment devices for other stormwater control practices. For LID sites, a filter strip should be viewed as only one component in a stormwater management system.

Design Considerations. The key design considerations for filter strips are summarized in Table 4-6. Detailed design guidance is provided in *Maryland Standards and Specifications for Infiltration Practices* (MDDNR, 1984), *Design of Stormwater Filtering Systems*, (CRC, 1996), and *Maryland Stormwater Design Manual* (MDE, 1998).

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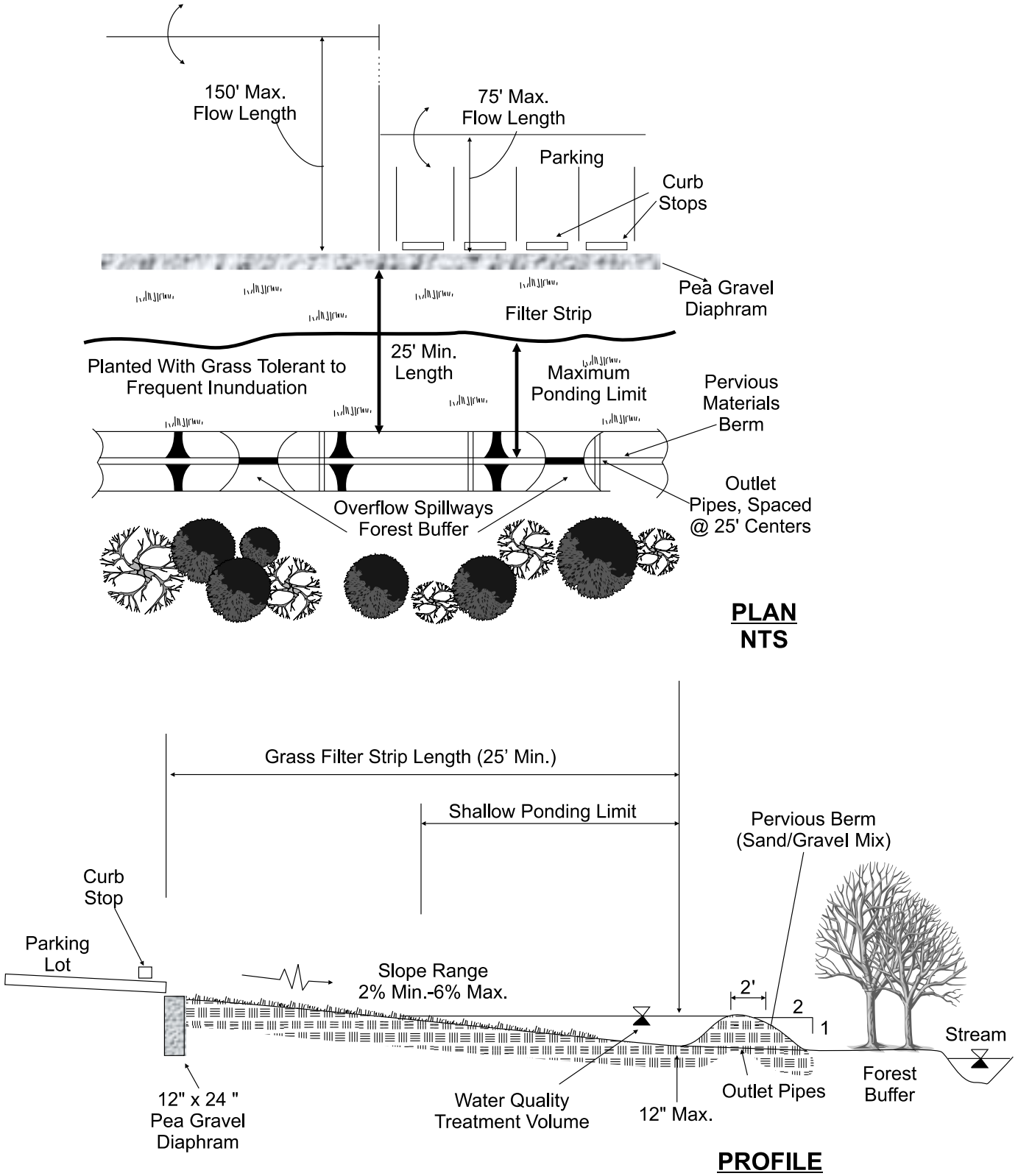

Figure 4-5. Typical filter strip (CRC, 1996).

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Table 4-6. Filter Strip Design Considerations

Design storm	Determined by state or local agency. Recommended guidance in Prince George's County, Maryland, LID Manual (PGC, 1997) and Maryland Stormwater Design Manual (MDE, 1998)
Drainage area	Maximum drainage area to filter strips is limited by the overland flow limits of 150 feet for pervious surfaces and 75 feet for impervious surfaces
Slope	Minimum slope = 1.0% Maximum slope = determined by field conditions
Flow	Should be used to control overland sheet flow only. Discharge should not exceed 3.5 cubic feet per second range
Length and size	The size of the filter strip is determined by the required treatment volume. A minimum length of 20 feet is recommended
Water quality	The pollution removal effectiveness of the filter strip is summarized in Table 4.3
Maintenance	Routine landscape maintenance required

Vegetated Buffers

Vegetated buffers are strips of vegetation, either natural or planted, around sensitive areas such as waterbodies, wetlands, woodlands, or highly erodible soils. In addition to protecting sensitive areas, vegetated strips help to reduce stormwater runoff impacts by trapping sediment and sediment-bound pollutants, providing some infiltration, and slowing and dispersing stormwater flows over a wide area.

Level Spreaders

A level spreader typically is an outlet designed to convert concentrated runoff to sheet flow and disperse it uniformly across a slope to prevent erosion. One type of level spreader is a shallow trench filled with crushed stone. The lower edge of the level spreader must be exactly level if the spreader is to work properly. Figure 4-6 shows a typical rock-filled trench level spreader detail.

Design Considerations. Sheet flow, or overland flow, is the movement of runoff in a thin layer (usually less than 1 inch in depth) over a wide surface, which begins when water ponded on the surface of the

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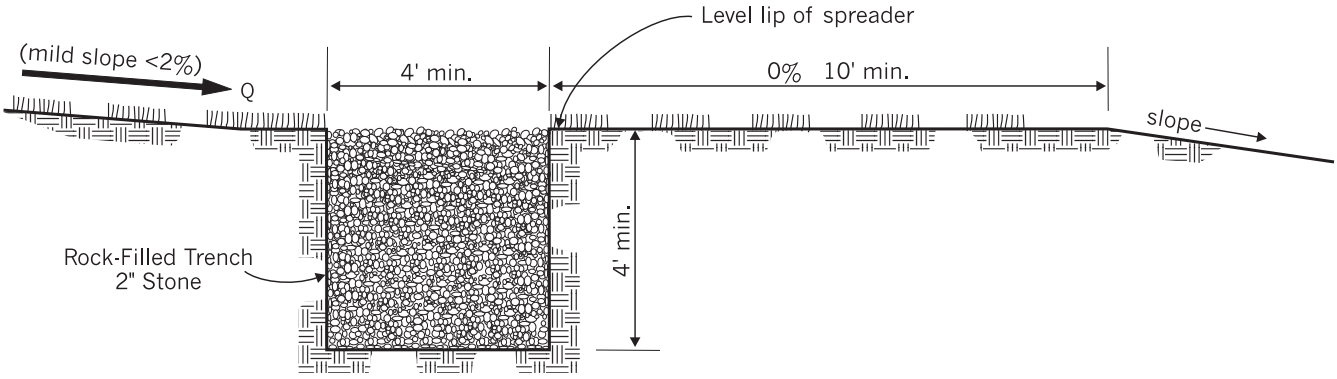

Figure 4-6. Typical rock trench level spreader

land becomes deep enough to overcome surface retention forces. Level spreaders can be used to convey sheet flow runoff from lawn areas within graded areas to bioretention facilities and transition areas.

They can also be used to deliver runoff from parking lots and other impervious areas to infiltration areas. The receiving area of the outlet must be uniformly sloped and not susceptible to erosion. Particular care must be taken to construct the outlet lip completely level in a stable, undisturbed soil to avoid formation of rilling and channeling. Erosion-resistant matting might be necessary across the outlet lip, depending on expected flows. Alternative designs to minimize erosion potential include hardened structures, stiff grass hedges, and segmenting of discharge flows into a number of smaller, adjacent spreaders. Sheet flow should be used over well-vegetated areas, particularly lawns, to achieve additional retention and increase the time of concentration.

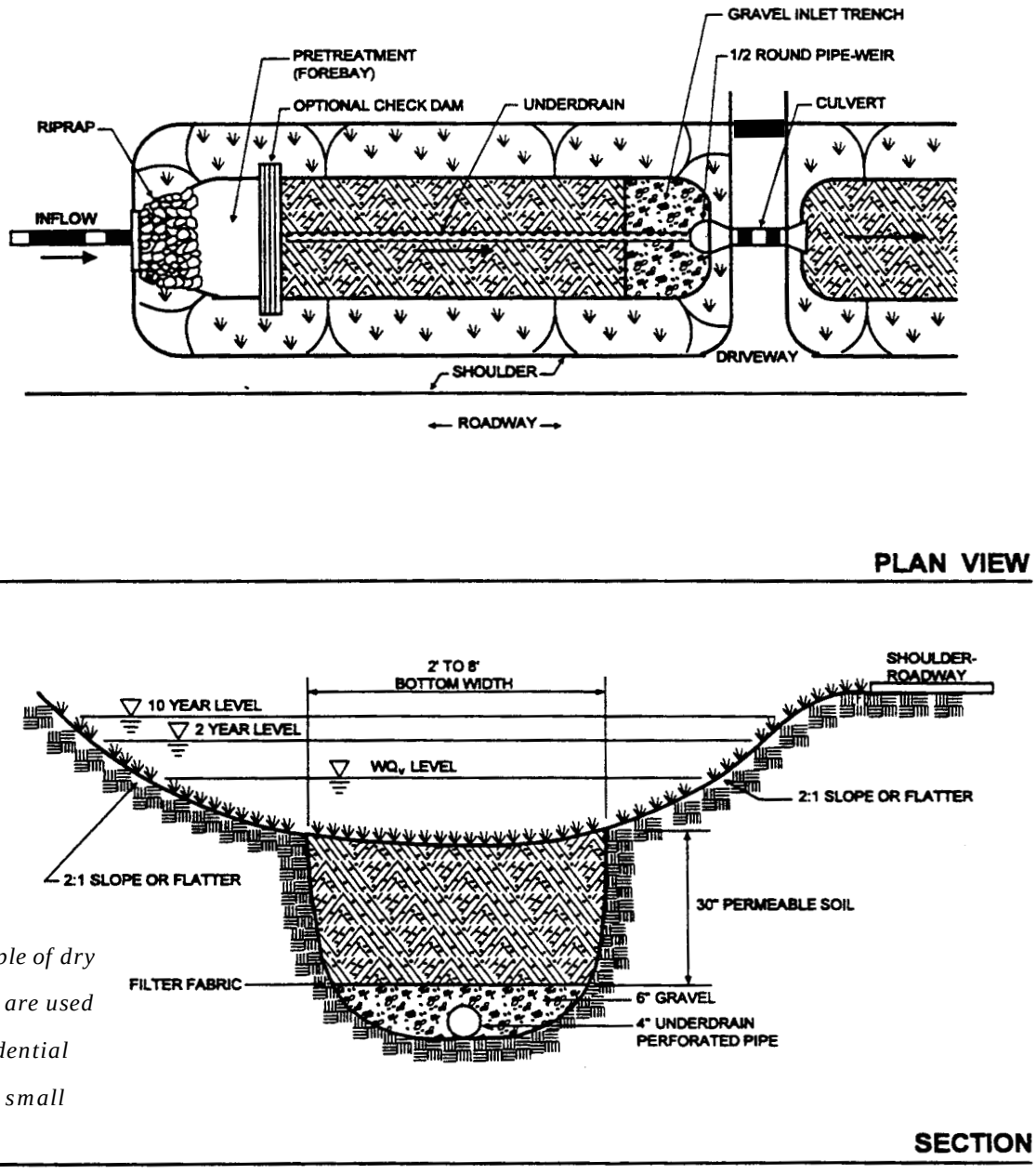

Figure 4-7. Example of dry swale. Dry swales are used at low density residential projects or for very small impervious areas

Grassed Swales

Traditionally, swale designs were simple drainage and grassed channels that primarily served to transport stormwater runoff away from roadways and rights-of-way. Today designers can design these channels to optimize their performance with respect to the various hydrologic factors. Two types of grassed swales are being used for this purpose—the dry swale, which provides both quantity (volume) and quality control by facilitating stormwater infiltration (Figure 4-7), and the wet swale, which uses residence time and natural growth to reduce

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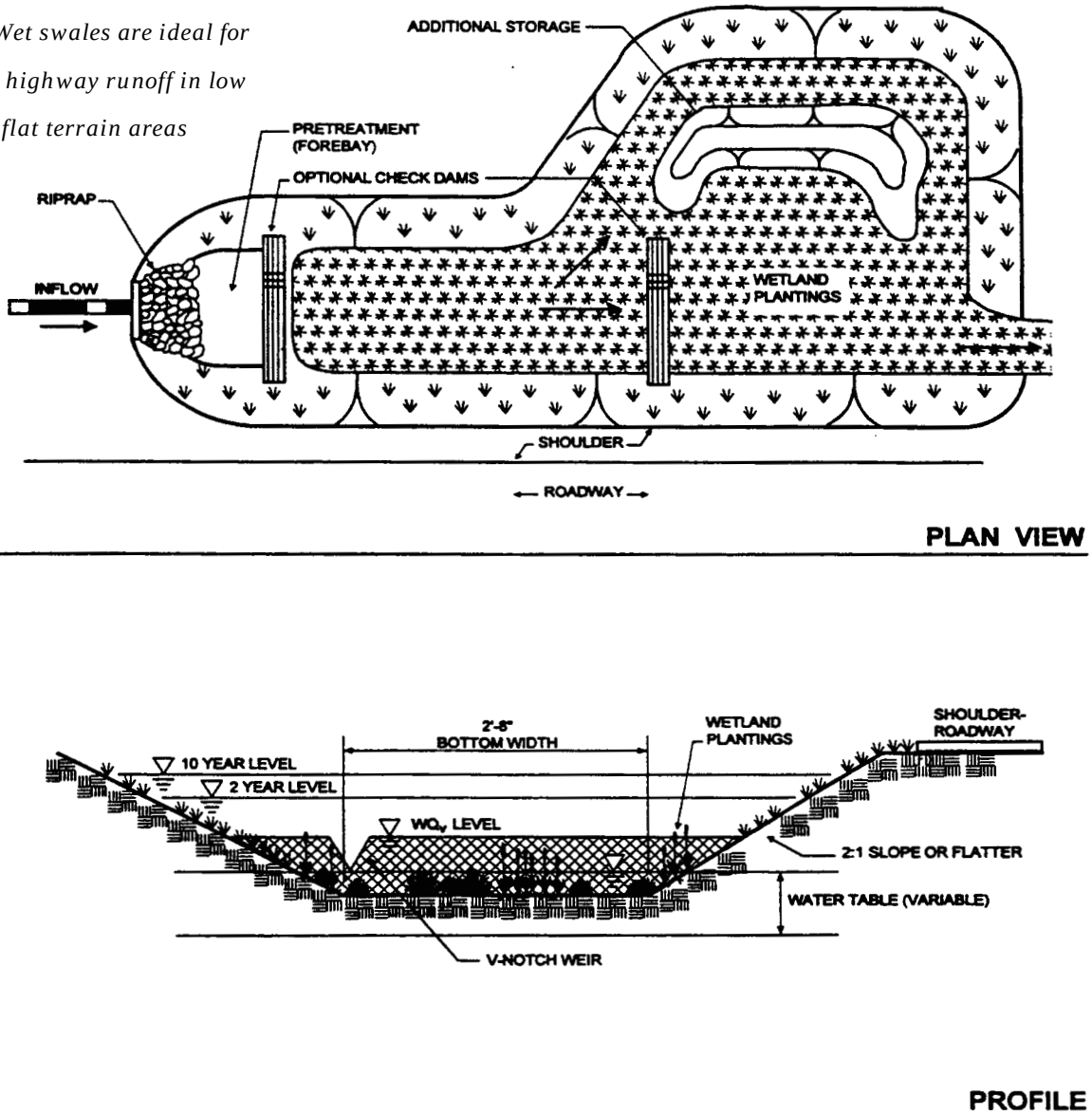
Figure 4-8. Example of wet swale. Wet swales are ideal for treating highway runoff in low lying or flat terrain areas



peak discharge and provide water quality treatment before discharge to a downstream location (Figure 4-8). The wet swale typically has water tolerant vegetation permanently growing in the retained body of water. These systems are often used on highway designs.

Design Considerations. The key design considerations for grassed swales are summarized in Table 4-7. Detailed design guidance is provided in *Maryland Standards and Specifications for Infiltration Practices* (MDDNR, 1984), *Design of Stormwater Filtering Systems* (CRC, 1996), and *Maryland Stormwater Design Manual* (MDE, 1998).

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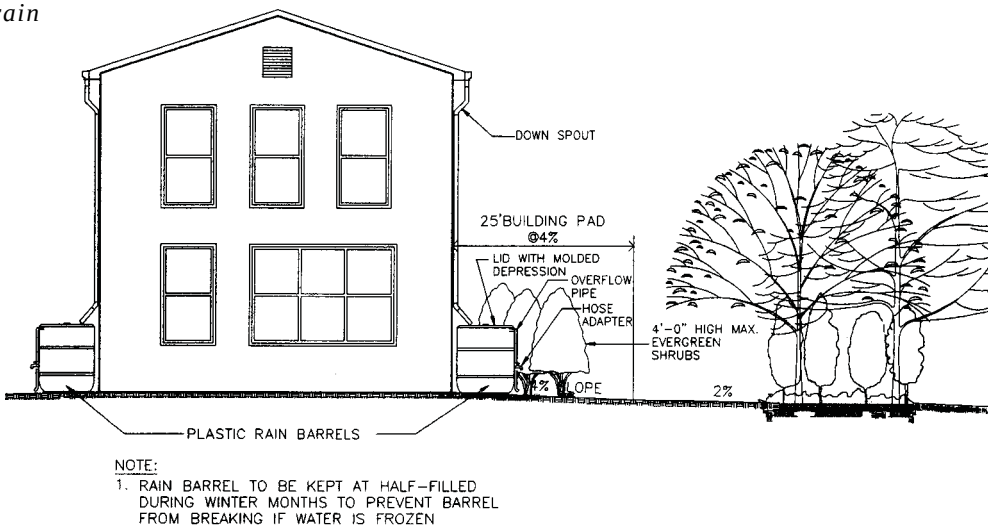
Table 4-7. Grassed Swale Design Considerations

Design Storm	Determined by state or local agency. Refer to guidance provided by the Prince George's County LID Design Manual and the Maryland Stormwater Design Manual (MDE, 1998). Local condition may necessitate adjustment of the recommendations in the guidance documents.
Channel Capacity	Swale must be sized to convey the peak discharge of the design storm
Soils	The permeability (infiltration rate) of the soils will determine whether a dry or wet swale can be used. It is recommended that soils used for dry swales have infiltration rates of 0.27 – 0.50 inches per hour.
Channel Shape	Trapezoidal or parabolic shape recommended
Bottom Width	2 foot minimum, 6 foot maximum
Side Slopes	3:1 or flatter
Channel Longitudinal Slope	1.0 % minimum, 6.0 % maximum
Flow Depth	4.0 inches for water quality treatment
Manning's n value	0.15 for water quality treatment (depth < 4") 0.15 – 0.03 for depths between 4" and 12" 0.03 minimum for depth 12"
Flow Velocity	1.0 fps for water quality treatment - 5.0 fps for 2 year storm fps for 10 year storm
Length of channel	Length necessary for 10 minute residence time
Water Quality	The pollutant removal effectiveness of grassed swales is summarized in Table 4-3
Maintenance	Routine landscape maintenance required.

Rain Barrels

Rain barrels are low-cost, effective, and easily maintainable retention devices applicable to both residential and commercial/ industrial LID sites. Rain barrels operate by retaining a predetermined volume of rooftop runoff (i.e., they provide permanent storage for a design volume); an overflow pipe provides some detention beyond the retention capacity of the rain barrel. Figure 4-9 and Figure 4-10 show

Figure 4-9. Typical rain barrel



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a typical rain barrel. Rain barrels also can be used to store runoff for later reuse in lawn and garden watering

Figure 4-10. Rain barrel application to LID

Design Considerations. Rainwater from any type of roofing material can be directed to rain barrels. To be aesthetically acceptable, rain barrels can be incorporated into the lot's landscaping plan or patio or decking design. Rain barrels placed at each corner of the front side of the house should be landscaped for visual screening. Gutters and downspouts are used to convey water from rooftops to rain barrels. Filtration screens should be used on gutters to prevent clogging of debris. Rain barrels should also be equipped with a drain spigot that has garden hose threading, suitable for connection to a drip irrigation system. An overflow outlet must be provided to bypass runoff from large storm events. Rain barrels must be designed with removable, child-resistant covers and mosquito screening on water entry holes. The size of the rain barrel is a function of the rooftop surface area that drains to the barrel, as well as the inches of rainfall to be stored. For example, one 42-gallon barrel provides 0.5 inch of runoff storage for a rooftop area of approximately 133 square feet.

Cisterns

Stormwater runoff cisterns are roof water management devices that provide retention storage volume in underground storage tanks. On-lot storage with later reuse of stormwater also provides an opportunity for water conservation and the possibility of reducing water utility costs.

Figure 4-11. Cistern. Image courtesy of Pow Plastics, Ltd., Devon, England

Design Considerations. Cisterns are applicable to residential, commercial, and industrial LID sites. Due to the size of rooftops and the amount of imperviousness of the drainage area, increased runoff volume and peak discharge rates for commercial or industrial sites may require larger-capacity cisterns. Individual cisterns can be located beneath each downspout, or storage volume can be provided in one large, common cistern. Premanufactured residential use cisterns come in sizes ranging from 100 to 1,400 gallons (Figure 4-11). Cisterns should be located for easy maintenance or replacement.

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Infiltration Trenches

An infiltration trench is an excavated trench that has been back-filled with stone to form a subsurface basin. Stormwater runoff is diverted into the trench and is stored until it can be infiltrated into the soil, usually over a period of several days. Infiltration trenches are very adaptable IMPs, and the availability of many practical configurations make them ideal for small urban drainage areas (Figure 4-12). They are most effective and have a longer life cycle when some form of pretreatment is included in their design. Pretreatment may include techniques like vegetated filter strips or grassed swales (Figure 4-7). Care must be taken to avoid clogging of infiltration trenches, especially during site construction activities.

Design Considerations. The key design considerations for the infiltration trench are summarized in Table 4-8. Detailed design guidance is provided in *Maryland Standards and Specifications for Infiltration Practices* (MDDNR, 1984), *Maintenance of Stormwater Management Structures: A Departmental Summary* (MDE, 1986); and *Maryland Stormwater Design Manual* (MDE, 1998).

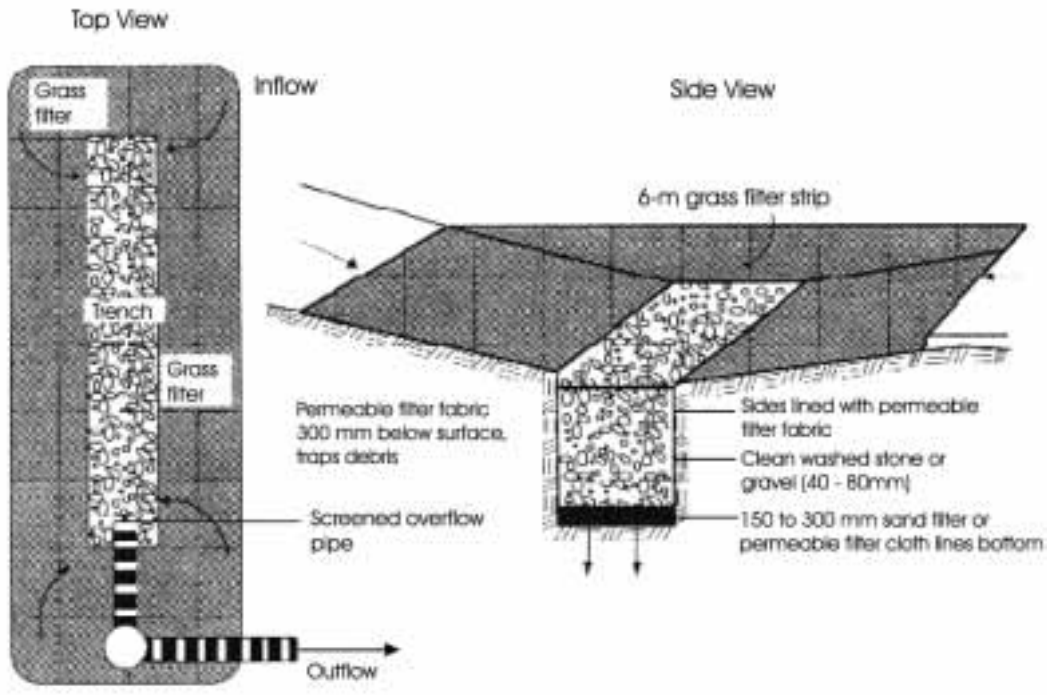

Figure 4-12. Median strip infiltration trench design (adapted from MWCOG, 1987).

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Table 4-8. Infiltration Trench Design Considerations

Design Storm	Determined by state or local agency. Guidance provided by the Prince George's County LID Design Manual and the Maryland Stormwater Design Manual is recommended. Local condition may necessitate adjustment of the recommendations in the guidance document.
Soil Permeability	> 0.27 – 0.50 inches per hour
Depth	3 – 12 feet
Storage Time	Empty within 3 days
Backfill	Clean aggregate > 11/2", < 3", surrounded by engineering filter fabric
Runoff Filtering	
Outflow Structures	Overland flow path of surface runoff exceeding the capacity of the trench must be identified and evaluated. An overflow system leading to a stabilized channel or watercourse including measures to provide non-erosive flow conditions must be provided.
Observation Well	Must be provided, 4" PVC on footplate, constructed flush with ground surface, cap with lock.
Hydrologic Design	Determined by state or local agency. Maryland Stormwater Design Manual is recommended
Water Quality	See Table 4.3 for performance data
Maintenance	Periodic monitoring; Quarterly during first year, annual thereafter.

Other Environmentally Sensitive Management Practices

Low-Impact Development is a relatively new concept. It is anticipated that over the next few years many additional integrated management practices and improvements to the LID approach will be introduced as local agencies and designers begin to experiment with the use of the practice. A number of interesting developments are currently underway that may prove useful in future application. However the information available on these techniques is still somewhat limited.

Rooftop Greening. Rooftop greening is a technique being developed in Germany by Strodthogff & Behrens which consists of the use of pre-cultivated vegetation mats(Figure 4-13 which are reported to provide the following benefits:

- improve air quality (up to 85% of dust particles can be filtered out of the air)
- cooler air temperatures and higher humidity can be achieved through natural evaporation.
- 30-100% of annual rainfall can be stored, relieving stormdrains and feeder streams.

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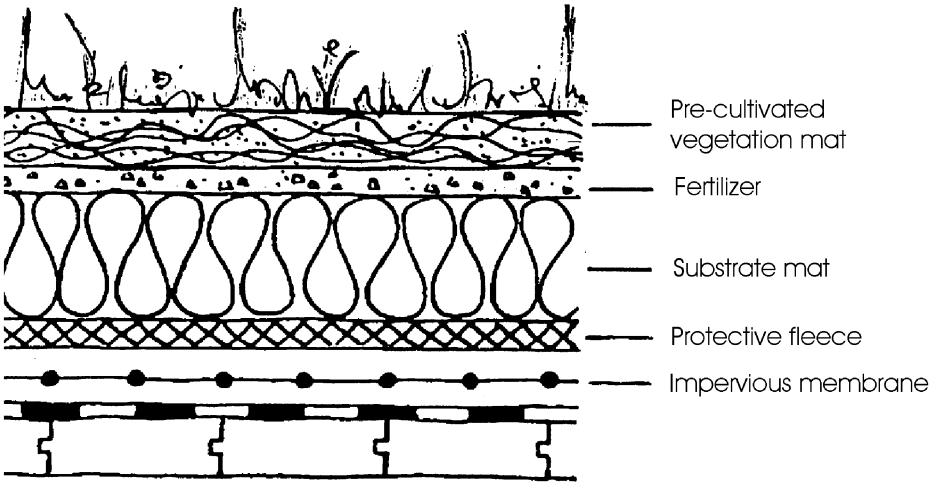
Figure 4-13.

Roof Greening

Greening of a roof with an incline of 15% to 20%



Roof construction with bituminous sealing

- Visible green roofs provide a more aesthetic landscape.

Conservation Design for Stormwater Management. Conservation design is a design approach to reduce stormwater impacts from land development and achieve multiple objectives related to land use. This approach has been jointly developed by the Delaware Department of Natural Resources and Environmental Control and Environmental Management Center of the Brandywine Conservancy.

Monitoring

Another and the final component of LID design includes the development of appropriate pre and post development monitoring protocols to document the effectiveness of individual IMPs as well at the overall LID approach. Effective stormwater monitoring, whether physical, chemical or biological is very difficult and expensive, and consequently the design of a monitoring program will have to be approached very carefully.

Providing guidance on a specific monitoring program is beyond the scope of this document. However, some general guidance can be provided.

Monitoring programs aimed at evaluating the effectiveness of a given management practice (IMP can adapt the monitoring approaches currently being used for BMPs. Table 4-9 provides a listing of parameters that should be reported with water quality data for various BMPs (Urbonas, 1995). In addition to a comprehensive discussion of

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Table 4-9. Parameters to Report with Water-Quality Data for Various BMPs

Parameter (1)	Retention Pond (2)	Extended Detention Basin (3)	Wetland Basin (4)	Wetland Channel (5)	Sand Filter (6)	Oil and Sand trap (7)	Infiltration and Percolation (8)
Tributary watershed area	▼	▼	▼	▼	▼	▼	▼
Total % tributary watershed is impervious	▼	▼	▼	▼	▼	▼	▼
Percent of impervious area hyd. Connected	▼	▼	▼	▼	▼	▼	▼
Gutter, sewer, swale, ditches, in watershed	▼	▼	▼	▼	▼	▼	▼
Average storm runoff volume	▼	▼	▼	▼	▼	▼	▼
50th percentile runoff volume	▼	▼	▼	▼	▼	▼	▼
Coefficient of variation of runoff volumes	▼	▼	▼	▼	▼	▼	▼
Average daily base flow volume	▼	▼	▼	▼	▼	▼	▼
Average runoff interevent time	▼	▼	▼	▼	▼	▼	▼
50th percentile interevent time	▼	▼	▼	▼	▼	▼	▼
Coefficient of variation of runoff volumes	▼	▼	▼	▼	▼	▼	▼
Average storm duration	▼	▼	▼	▼	▼	▼	▼
50th percentile storm duration	▼	▼	▼	▼	▼	▼	▼
Coefficient of variation of storm durations	▼	▼	▼	▼	▼	▼	▼
Water temperature	▼	▼	▼	▼	▼	▼	▼
Alkalinity, hardness and pH	▼	▼	▼	▼	▼	▼	▼
Sediment setting velocity distribution, when available	▼	▼	▼	▼	▼	▼	▼
Type and frequency of maintenance	▼	▼	▼	▼	▼	▼	▼
Inlet and outlet dimensions and details	▼	▼	▼	▼	▼	▼	▼
Solar radiation, when available	▼		▼	▼			
Volume of permanent pool	▼		▼		▼	▼	
Permanent pool surface area	▼		▼		▼	▼	
Littoral zone surface area	▼						
Length of permanent pool	▼		▼		▼	▼	
Detention (or surcharge) volume	▼	▼	▼		▼	▼	▼
Detention basin's surface area	▼	▼	▼		▼	▼	▼
Length of detention basin	▼	▼	▼		▼	▼	▼
Brim-full emptying time	▼	▼	▼		▼	▼	▼
Half-brimful emptying time	▼	▼	▼		▼	▼	▼
Bottom stage volume		▼					
Bottom stage surface area		▼					
Forebay volume	▼	▼	▼		▼	▼	▼
Forebay length	▼	▼	▼		▼	▼	▼
Wetland type, rock filter present			▼	▼			
Percent of wetland surface at P 0.3 and P 0.6 depths			▼	▼			
Meadow wetland surface area			▼	▼			
Plant species and age of facility	▼	▼	▼	▼			
2-year flood peak velocity				▼		▼	
Depth high ground water or impermeable layer		▼	▼				▼

monitoring considerations is provided in the publication, "Stormwater NPDES related Monitoring Needs" (ASCE, 1994).

Monitoring programs aimed at an overall evaluation of LID designs will be more difficult to design, particularly where cause and effect relationships in urban ecosystems are involved. Monitoring programs will need to be tailored to each specific site's requirement, and will likely require a mix of physical, chemical, and biological considerations. Guidance for undertaking this work can be found in the following publications: 1) Stormwater NPDES Related Monitoring Needs, (ASCE, 1994: Effects of Watershed Development & Management on Aquatic Ecosytems , (SCE, 1996): and "Urban Quality Monitoring and Assessment Approaches in Wisconsin, (Bannerman, 1998).

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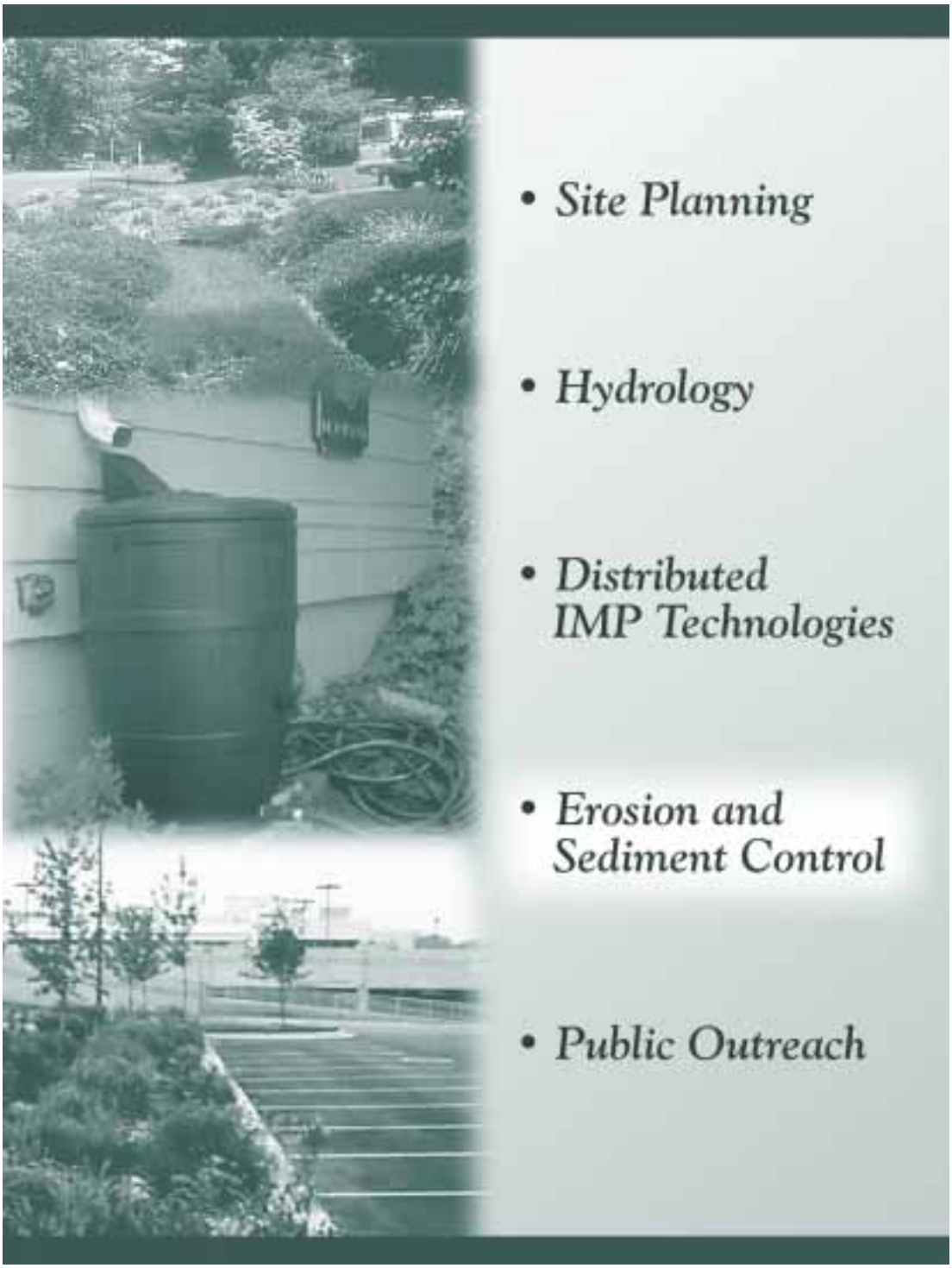
Chapter 5

Erosion and Sediment Control Considerations for Low-Impact Development



Chapter 5

Erosion and Sediment Control Considerations for Low-Impact Development

Erosion and sediment control and stormwater management are closely interrelated. The application of LID concepts and the associated emphasis on minimizing the areas disturbed, as well as breaking up drainage areas into small manageable subcatchment areas, is in total harmony with the basic principles of erosion and sediment control. The designer will find that the application of LID technology can easily result in improved erosion and sediment control without significant additional effort.

Erosion and Sediment Control Steps

The following five basic common sense steps govern the development and implementation of a sound erosion and sediment control plan for any land development activity.

Step One: Planning. Plan the operation to fit the existing site features, including topography, soils, drainage ways, and natural vegetation.

Step Two: Scheduling of Operations. Schedule grading and earthmoving operations to expose the smallest practical area of land for the shortest possible time. If possible, schedule land disturbance activities during dry seasons or periods.

Step Three: Soil Erosion Control. Apply soil erosion

Erosion and Sediment Control Steps

1. Planning
2. Scheduling of operations
3. Soil erosion control
4. Sediment control
5. Maintenance

In This Chapter…

Introduction

Erosion and Sediment Control Steps

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prevention and control practices as a first line of defense against off-site damage.

Step Four: Sediment Control. Apply sediment control practices as a second line of defense against off-site damage.

Step Five: Maintenance. Implement a thorough maintenance program before, during, and after development is completed.

Step One

Plan the development to fit the site features:

- **topography**
- **drainage ways**
- **soils**
- **vegetation**

The following sections describe in more detail how these steps are used in controlling erosion and sedimentation in an LID setting.

Step One: Planning. The first step in controlling erosion and sediment is to plan the development to fit the site features, including; topography, soils, drainage ways, and natural vegetation. It should be observed that this step is very similar to the planning guidelines provided for low impact development in Chapters 2 and 3 of this design manual. In other words, by following the planning guidelines set forth in Chapters 2 and 3 of this manual, the site planner or designer will also be implementing the first step of erosion and sediment control. Not surprisingly, the two processes are similar. Listed below are key considerations of the planning element.

Topography. The primary considerations are slope steepness and slope length. Because of the effect of runoff, the longer and steeper the slope, the greater the erosion potential. The percent of slope can be determined from the site topography. Areas of similar steepness can be identified and grouped together to produce a slope area map. Slope gradients can be grouped into three or more general ranges of soil erodibility as presented below:

0% - 7 %	Low erosion hazard
7% - 15 %	Moderate erosion hazard
15 % or over	High erosion hazard

Within these slope gradient ranges the greater the slope length, the greater the erosion hazard. Therefore, in determining potential critical areas the site planner should be aware of excessively long slopes. As a general rule, the erosion hazard will become critical if slope lengths exceed the following values:

0% - 7 %	300 feet
7% - 15 %	150 feet
15 % or over	75 feet

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Drainage ways. Natural drainage patterns that exist on the site should be identified to plan around these critical areas where water will concentrate. Where possible, natural drainage ways should be used to convey runoff over and off the site to avoid the expense and problems of constructing an artificial drainage system. These natural drainage ways should be protected with vegetative buffers whenever possible.

Man-made ditches, diversions, and waterways will become part of the erosion problem if they are not properly stabilized. Care should also be taken to be sure that increased runoff from the site will not erode or flood the existing natural drainage system.

Soils. Major soil considerations from an erosion and sediment control standpoint include erodibility, permeability, depth to water table and bedrock, and soils with special hazards including shrink/swell potential or slippage tendencies.

Soil considerations

- **Erodibility**
- **Permeability**
- **Depth**
- **Constraints**

Erodibility is a term that describes the vulnerability of a soil to erosion. The average particle size and gradation (texture), percentage of organic matter, and soil structure influence soil erodibility. The most erodible soils generally contain high proportions of silt and very fine sand. The presence of clay or organic matter tends to decrease soil erodibility. Clays are sticky and tend to bind soil particles together, which along with organic matter helps to maintain stable soil structure.

By combining the soils information with information on the topography, drainage, and vegetation on the site, the planner can determine the critically erodible and sensitive areas that should be avoided if possible during construction.

Natural Vegetation. Ground cover is the most important factor in terms of preventing erosion. Any existing vegetation that can be saved will help prevent erosion. Vegetative cover shields the soil surface from raindrop impact while the root mass holds soil particles in place. Vegetation also can "filter" sediment from runoff. Thus grass "buffer strips" can be used to remove sediment from surface runoff. Vegetation also slows the velocity of runoff and helps maintain the infiltration capacity of a soil. Trees and unique vegetation protect the soil as well as beautifying the site after construction. Where existing vegetation cannot be saved, the planner should consider staging of construction, temporary seeding, or temporary mulching.

Natural Vegetation

- **Protects soil surface**
- **Filters sediment**
- **Reduces runoff velocity**

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Step Two

Expose the smallest practical area for the shortest possible time.

Step Two: Scheduling of Operations. The second erosion and sediment control step is to expose the smallest practical area of land for the shortest possible time. The reason behind this step is rather simple-1 acre of exposed land will yield less sediment than 2 acres of exposed land, and an area exposed for 3 months will yield less sediment than an area exposed for 6 months.

The clearing, grubbing and scalping of excessively large areas of land at one time is an unnecessary invitation to sediment problems. As previously described in Chapter 2, these initial earth-disturbing activities should be kept to a bare minimum. On the areas where disturbance takes place, the site designer should consider staging of construction, temporary seeding, and/or temporary mulching as a technique to reduce erosion. Staging of construction involves stabilizing one part of the site before disturbing another. In this way the entire site is not disturbed at once and the time without ground cover is minimized. Temporary seeding and mulching involves seeding or mulching areas that would otherwise lie open for long periods of time. The time of exposure is limited and therefore the erosion hazard is reduced.

Step Three

Apply soil erosion practices as a first line of defense

Step Three: Soil Erosion Control Practices. The third important principle is to apply soil erosion control practices on disturbed areas as a first line of defense against off-site damage. Control does not begin with the perimeter sediment trap or basin. It begins at the source of the sediment, the disturbed land area, and extends down to the control structure.

Soil particles become sediment when they are detached and moved from their initial resting place. This process, which is called erosion, is accomplished for the most part by the impact of falling raindrops and the energy exerted by moving water and wind, especially water. A reduction in the rate of soil erosion is achieved by controlling the vulnerability of the soil to erosion processes or the capability of moving water to detach soil particles. In humid regions this is accomplished through the use of "soil stabilization" and "runoff control practices."

Soil stabilization practices include a variety of vegetative, chemical, and structural measures used to shield the soil from the impact of raindrops or to bind the soil in place, thus preventing it from being detached by surface runoff or wind erosion. Representative soil stabilization practices include the following:

- Vegetative stabilization, both temporary and permanent
- Topsoiling

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- Erosion control mattings (Figure 5-1)
- Mulching
- Tree protection

The use of mulch to achieve temporary stabilization is gaining increased attention and recognition. Ongoing research efforts are confirming the fact that mulching is a very effective method of reducing runoff as well as removing pollutants from runoff. Table 5-1 displays types of mulches.

Figure 5-1. Erosion control mattings

Runoff control practices, in contrast, include a number of measures designed to reduce the amount of runoff generated on a construction site, prevent off-site runoff from entering the disturbed area, or slow the runoff moving through and exiting the disturbed area.

Table 5-1. Types of Mulches

Mulch	Benefits	Limitations
Chipped wood	Readily available; inexpensive; judged attractive by most	High nitrogen demand; may inhibit seedlings; may float off-site in surface runoff
Rock	May be locally available and inexpensive	Can inhibit plant growth; adds no nutrients; suppresses diverse plant community; high cost where locally unsuitable or unavailable
Straw or hay	Available and inexpensive; may add undesirable seeds	May need anchoring; may include undesirable seeds
Hydraulic mulches	Blankets soil rapidly and inexpensively	Provides only shallow-rooted grasses, but may outcompete woody vegetation
Fabric mats	Relatively durable (organic) or very durable (inorganic); works on steep slopes	High costs; suppresses most plant growth; inorganic materials harmful to wildlife
Commercial compost	Excellent soil amendment at moderate cost	Limited erosion-control effectiveness; expensive over large areas

Stormwater runoff is the principal cause of soil erosion. Stormwater runoff control is achieved through the proper use of vegetative and structural practices, and construction measures that control the location, volume and velocity of runoff. Proper stormwater handling for erosion control can be accomplished in one or a combination of the following ways:

Step Four

Apply sediment control practices as a second line of defense against off-site damage

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- Reduction and detention of the runoff
  - staging operations
  - grading and shaping of soil surfaces
  - manipulation of slope length and gradient
- Interception and diversion of runoff
  - diversion berm or dike
  - reverse benches
  - drainage swales
  - vegetation buffers
- Proper handling and disposal of concentrated flow
  - vegetative swales
  - downdrain structures
  - outlet stabilization

Sediment removal is dependent upon

- Water flow rates
- Length of time water is detained
- Size, shape and weight of sediment particles

Step Four: Sediment Control Practices. The fourth step is to apply sediment control practices as a second line of defense against offsite damage. Even with the best erosion control plan, some sediment will be generated and controlling it is the objective of this step. Whereas erosion control practices are designed to prevent soil particles from being detached, sediment control involves using practices that prevent the detached particles from leaving the disturbed area and reaching the receiving waterways. This goal is accomplished by reducing the capacity of surface runoff to transport sediment and by containing the sediment on site.

Sediment control practices are designed to slow the flow of water by spreading, ponding, or filtering. By so doing, the capacity of the water to transport sediment is reduced, and sediment settles out of suspension. Commonly used control practices include (1) the preservation or installation of vegetated buffer areas downslope of the disturbed area to slow and filter the runoff, (2) the construction of small depressions or dikes to catch sediment (particularly coarse-textured material) as close to its point of origin as possible, and (3) the construction of sediment traps or basins at the perimeter of the disturbed area to capture additional sediment from the runoff.

The amount of sediment removed from the runoff is mostly dependent upon (1) the speed at which the water flows through the filter, trap, or basin; (2) the length of time the water is detained; and (3) the size, shape, and weight of the sediment particles.

Currently, the most frequently used approach to sediment control is simply to direct all surface runoff into a large sediment basin, which

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is later cleaned out and converted to a stormwater management pond. Although this approach is arguably the simplest and lowest cost method to control sediment, it often fails to address the other principles described above and thus may not represent the best way to prevent and control sediment.

One of the underlying concepts of LID technology involves breaking up the drainage areas of a given site into very small catchment areas to disconnect hydraulically connected areas and to provide opportunities to increase the time of concentration and thus reduce peak discharges. Accordingly, this approach will benefit sediment control efforts by diffusing surface flow into many directions and providing more flexibility in the use of a variety of sediment control practices.

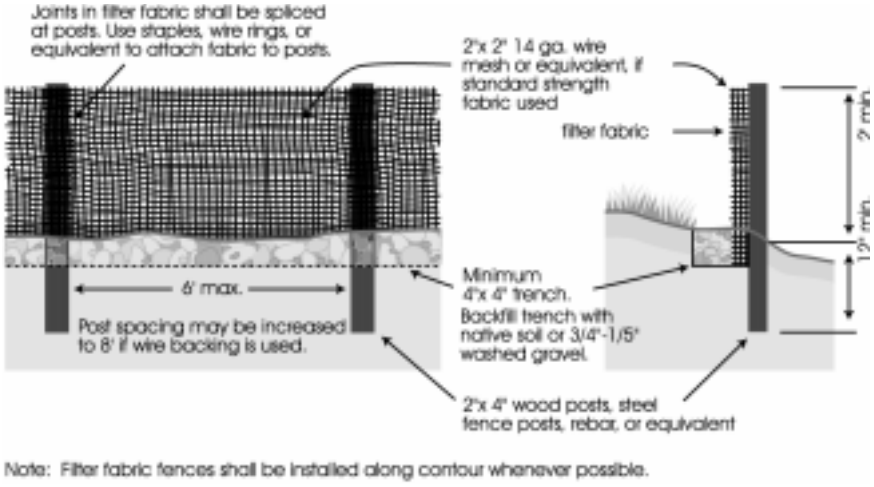

Figure 5-2. Silt fence installation guidelines

This approach will provide more opportunity to use silt fences (Figure 5-2) and small traps, such as the stone outlet trap and the rip-rap outlet trap, to control small catchment areas generally in the range of 1 to 3 acres in size. It will also allow more opportunity to integrate the use of vegetative buffers in sediment control. When bioretention practices are planned for stormwater management, they can first be used as a small temporary trap by excavating the top 2 feet of soil. Then after the site is stabilized the trap and accumulated silt can be removed and the bioretention cell can be installed. It should be noted that the bottom of the bioretention cell should be two (2) feet below the invert of sediment trap. Also, no long term controls are to be placed in use prior to completion of construction and permanent stabilization of all disturbed areas.

Step Five

Implement a thorough maintenance and follow-up operation

Step Five: Inspection and Maintenance. The final important control step is to implement a thorough inspection and maintenance program. This step is vital to the success of an erosion and sediment control program. A site cannot be controlled effectively without thorough, periodic checks of all erosion and sediment control practices.

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When inspections reveal problems, modifications, repairs, cleaning, or other maintenance operations must be performed expeditiously.

Particular attention must be paid to water-handling structures such as diversions, sediment traps, grade control structures, sediment basins, and areas being revegetated. Breaches in the structures or areas being revegetated must be repaired quickly, preferably before the next rainfall.

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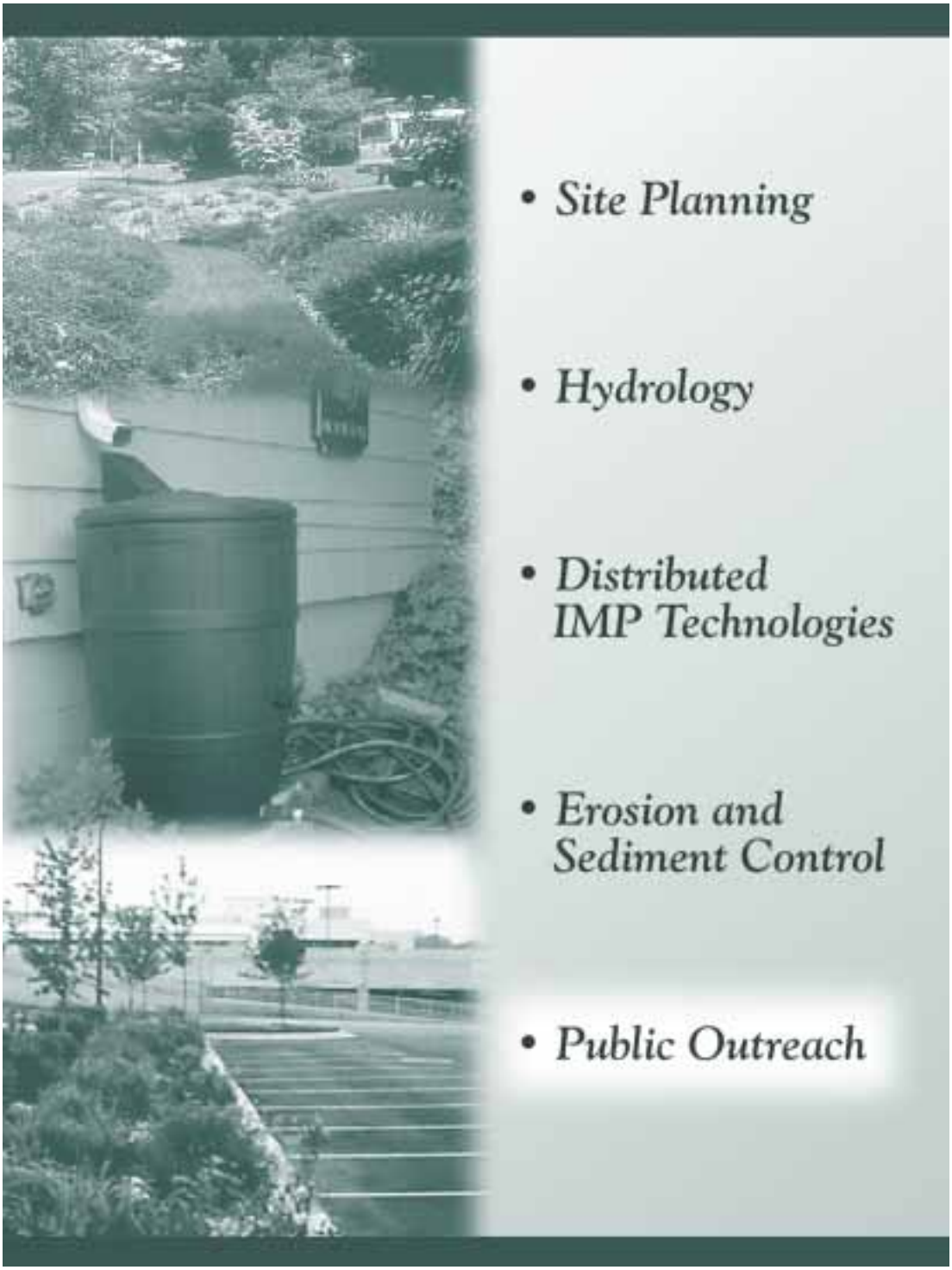
Chapter 6

Low-Impact Development Public Outreach Program



Chapter 6

Low-Impact Development Public Outreach Program

Introduction

Using LID approaches in new development can help achieve overall stormwater and pollution reduction goals. It has become more important for municipalities to be more creative in the ways they manage stormwater. LID approaches offer creative ways to control stormwater runoff, while at the same time achieving multiple development objectives. Several potential advantages include reducing the scale of maintenance costs to levels affordable by the property owner and the transfer of maintenance costs to the property owner. In addition, state and local governments may be able to decrease property acquisition costs due to a decreased need for structural stormwater controls.

A critical component to the success of LID approaches is the proper maintenance of installed IMPs by the property owners, or other designated entity. In addition information should be provided to commercial and residential property owners/managers about effective pollution prevention practices. The developer and local public agency/authority must effectively communicate the benefits of low-impact development as well as its maintenance responsibilities to potential and existing property owners. Proper maintenance practices for LID properties include maintaining vegetative buffers and removing trash and other debris from the outflow points. Property owners must also be educated about the

LID IMP Maintenance

- **Maintain vegetated buffers**
- **Remove trash and debris**

In This Chapter…

Introduction

Developing a Public Outreach Program

Step One: Define Public Outreach Program Objectives

Step Two: Identify Target Audiences

Step Three: Develop Outreach Materials

Step Four: Distribute Outreach Materials

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necessity of not disturbing, compacting, or eliminating IMPs. Pollution prevention practices that can support LID approaches include careful use of fertilizers on landscaped areas, parking lot sweeping, judicious mowing practices that allow the runoff to slowly percolate into the ground, and general water conservation habits. It is much more cost-efficient to prevent the pollutants from entering the stormwater than it is to remove the pollutants once they are in the system.

This chapter describes the components needed to ensure a successful low-impact development public outreach program. It is based on successful efforts by Prince George's County, Maryland.

Developing a Public Outreach Program

Effective public outreach programs for LID properties must be tailored not only for each site, but for specific audiences. One cannot develop or distribute a single brochure on maintaining IMPs to property owners. The key to effective outreach is to target a message to a specific audience and have them respond to that message. There are four key steps to follow in developing effective public outreach materials for LID properties:

- Step One: Define public outreach objectives.
- Step Two: Identify the target audiences.
- Step Three: Develop materials for those audiences.
- Step Four: Distribute outreach materials.

Each of these steps is reviewed below.

Step One: Define Public Outreach Program Objectives

The first step in developing a public outreach program is to clearly identify the objectives. Are you trying to educate a potential property owner about maintenance requirements of the IMPs on the property? Do you want to make commercial property owners aware of the potential cost savings of LID stormwater controls? The objectives identified will determine what messages are developed and how the outreach materials are distributed.

The LID education/awareness program accomplishes several objectives, including the following:

- Creating a marketing tool for developers to attract environmentally conscious buyers.

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- Promoting stewardship of our natural resources by empowering citizens to take initiatives on environmental protection measures.
- Promoting more aesthetically pleasing development by creating more landscaped areas.
- Educating property owners on effective pollution prevention practices.
- Educating residential and commercial property owners on the potential cost savings of using LID approaches.
- Encouraging a greater sense of community due to the unique environmental character of LID designs.
- Ensuring proper maintenance of installed IMPs.

To help define objectives and to take advantage of the vast amount of public outreach information available, it is helpful for the developer to coordinate the public outreach program with the review agencies. This effort should begin during the site planning phase. Once the potential IMPs are identified, the developer should meet with the regulatory agency to gain an understanding of the construction and maintenance requirements of the IMPs until they are transferred to the property owner or homeowners association.

The program and planning phase will help identify the relevant target audiences to receive the outreach materials, provide the developer with existing informational materials and identify additional materials that can be developed and possible distribution mechanisms for the materials.

Step Two: Identify Target Audiences

For each LID property, whether it is residential, commercial, or industrial, there are different audiences that the developer needs to reach with public outreach information-potential buyers, new property owners, builders and construction site managers, homeowner associations and existing property owners. Specific messages must be tailored to each of these audiences based on the kind of property in question. Each of these audiences is discussed in more detail below, along with recommended messages for the audiences.

Potential Buyers

Potential buyers make up a primary target audience for outreach of LID benefits and maintenance requirements. For residential properties,

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the developer has the opportunity to promote the "green" aspects of low-impact development. Not only can the developer promote the extensive effort to preserve natural resources on the site, but also the measures (such as reforestation and landscaping practices) that were conducted on each lot. Those same measures will increase the aesthetic appeal, value, and habitat potential of the property. This message also works to some degree on commercial properties, by conveying the message that customers appreciate shaded areas in parking lots and the aesthetics of landscaped areas around developments.

Potential buyers must also be made aware of their individual responsibilities, as well as community responsibilities, for the upkeep and improvement of the property. For residential properties, the maintenance of on-site IMPs by the individual owner is a unique concept. Although the anticipated amount of maintenance is small, the owner must be made aware of the importance of the upkeep of plant materials and making sure that drainage structures are unimpaired. It must also be impressed on the property owners that these systems should not just be considered another part of their yard that they can freely landscape. The concept of maintenance of IMPs by the owner of commercial properties is similar to conventional developments. The difference is that instead of a large centralized facility that requires an infrequent, but large-scale, maintenance effort (e.g., mucking, mowing, reseeding, cleaning, and pumping), there may be smaller facilities distributed throughout the site. The smaller sites may require more frequent maintenance, such as trash removal and replanting, but the long-term capital costs are less.

The maintenance materials given to the potential owner at this phase do not have to be detailed, but they must clearly convey the basic requirements for the potential IMPs located on each lot and within the community/commercial property.

Builders and Site Construction Managers

Builders and site construction managers need to be made aware of planned IMPs on the property. During the construction phase, the local regulatory inspectors will verify the procedures used to protect IMP facility locations, limits of clearing and grading, and adherence to construction practices. To avoid potential problems during construction that might require extensive remedial actions to ensure the success of a IMP facility, the developer should make the builder and site construction manager aware of the appropriate phasing and construction practices. The education program should

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include information on clearing and grading restrictions, timing of revegetation, sedimentation removal, and maintenance after construction. Experience with bayscapes has shown that a critical element that is often neglected is follow-up care of the LID vegetation directly after installation of the system. Without proper watering and care, these systems can fail due to plant mortality.

New Property Owners

The developer, or seller, must allow the new property owner to examine and then accept any conditions that have to be met with the acquisition of the land. LID sites may require legal information and instruments to ensure that the facilities will be properly maintained. These may include easements, covenants, or homeowners' association requirements, or other applicable instruments depending on the type of development. The developer's attorney will typically develop these documents. The maintenance requirements for easements and covenants can be developed from brochures, fact sheets, and example documents, which are available from Prince George's County. A sample maintenance covenant is provided in Appendix B. The requirements and wording to be included in the documents must be approved by the local regulatory agency. The documents that are to be conveyed must be complete and detailed. They should show maintenance schedules, equipment requirements, and lists of replacement plants for vegetated IMPs.

Existing Property Owners

Once the property owner has been made aware of the proper procedures for maintenance of IMPs, it is the responsibility of the community and property owner to implement these procedures. After the initial property transfer, the developer assigns someone, either a representative of the developer or of the homeowners association, to monitor and train the new property owners on proper maintenance procedures. This will help ensure that the facilities are kept up while other units are being sold and will ensure consistent operation of the facilities. Procedures include not only maintaining vegetation and keeping structures in good condition, but also employing pollution prevention practices. Local authorities should take enforcement actions on maintenance issues only when there is a public nuisance or safety issue, or clear intent to destroy or functionally alter the LID system. The best enforcement mechanisms are the understanding of the importance of the IMP maintenance functions and that the owner has

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pride in the community. It is considered advisable for local governments to have the requisite authority to take action and the mechanisms should be clearly identified before LID methods are adopted for private land owners.

Industrial and Commercial Property Owners

LID techniques are also applicable to industrial and commercial settings. Fact sheets in Chapter 4 and case studies in Chapter 5 explain LID techniques for stormwater management that can help to control and manage runoff from industrial sites including parking lots and industrial material storage areas. Local stormwater management agencies must work with commercial and industrial property owners both to retrofit existing sites with LID technologies and to incorporate LID approaches into the site planning process. In many instances, LID approaches may even save industrial and commercial property owners money by

- Requiring less land for stormwater management.
- Incorporating on-site infiltration into existing parking lot designs.
- Reducing the amount of piping and engineering required to convey stormwater.
- Lowering ongoing maintenance costs.
- Reducing the amount of grading and land disturbance when developing new sites.

Step Three: Develop Outreach Materials

Once the target audiences are identified, the appropriate materials can be developed. When identifying different target audiences it is important to consider the best formats for the audience. For example, homeowners may read a fact sheet sent to their residence about not mowing vegetative buffers, but commercial and industrial properties may benefit from a training session with accompanying materials to explain maintenance requirements for the IMPs. Many of the materials developed by Prince George's County, Maryland, to support the implementation of LID in residential settings can be modified for industrial applications.

In developing outreach materials, the developer should remember that the target audience must be shown why this information is important to them. This ties back to the

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objectives—cost savings, increased property values, reduction of pollutant runoff, etc.

To help the developer conduct effective outreach, local regulatory agencies can help prepare brochures, manuals, and fact sheets. Table 6-1 identifies the outreach materials developed by Prince George's County, Maryland, in support of its LID program. The table categorizes this information into critical areas, as well as showing general information on design and construction and pollution prevention. The developer may use this information directly or

Table 6-1 Educational Materials

	Application					
Document	Design and Construction	Pollution Prevention	Program Planning	Potential buyers	Settlement	Site visits
Bioretention Manual	▼					
State Infiltration Manual	▼					▼
Low-Impact Development Manual	▼		▼			▼
SWM Manual	▼		▼			▼
Bioretention Fact Sheet		▼		▼	▼	
Pollution Prevention Fact Sheet						▼
County's Pollution Laws		▼				
NPDES Fact Sheet		▼				
Bayscapes Brochure				▼	▼	▼
Car Care Brochure					▼	▼
Lawn Care Brochure					▼	▼
County Information and Service Numbers				▼	▼	▼
Household Hazardous Waste		▼		▼	▼	
Water Conservation				▼	▼	
Stream Teams				▼	▼	▼
Community Cleanup					▼	▼
Homeowners Drainage Manual				▼	▼	▼
Low-Impact Maintenance Manual					▼	▼
Reporting Pollution Prevention Fact Sheets		▼			▼	▼
Glossary of Stormwater Terms				▼		
Integrated Pest Management					▼	▼
Wildlife Habitat Improvement						
Pollution Prevention Manual						

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use it as a basis for customized brochures or legal documents tailored for the specific development.

Pollution Prevention Materials

In addition to specific information regarding the maintenance requirements for LID properties, it is important to provide materials on pollution prevention practices that residential, commercial, and industrial property owners can implement to reduce the amount of pollutants going into the stormwater. Dozens of fact sheets and brochures on pollution prevention practices are available.

Basic education programs can be considered a nonstructural IMP that should be implemented for everyone. Too much pollution enters streams, rivers and lakes through carelessness or ignorance. Many people will adopt new methods or use alternative materials if they are simply informed of techniques that can reduce the impacts on receiving waters. Industry employees can learn to properly handle and store materials and dispose of industrial wastes through in-house training courses, videotape presentations, and interactive seminars. Local libraries and government agencies, such as the Cooperative Extension Service and the Industrial Extension Service, are good sources of educational materials.

Residential property owners should know the proper way to dispose of litter, yard waste, used motor oil, and other household wastes. Industries, municipalities, and homeowners can also learn how to use fertilizer and pesticides correctly to maintain their lawns and gardens without polluting nearby streams and rivers.

Step Four: Distribute Outreach Materials

There are several points in the property transfer process at which the developer can distribute outreach materials:

Construction of IMPs. Developers can provide the builder and construction site managers with outreach materials to ensure that the planned IMPs are not disturbed during the building phase.

Potential Buyers. Potential property owners can be made aware of the benefits as well as the responsibilities of owning a LID property when they first express interest in the property.

At Settlement. Educational materials outlining maintenance procedures, as well as legal instruments such as covenants and easements, can be presented at settlement.

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Site Visits. Periodic site visits by the developer and/or homeowners associations and local government should be made to ensure that the IMPs are being properly maintained. Educational materials can be distributed at this time to reinforce the maintenance requirements and benefits.

Homeowner Association Meetings. Developers can make presentations and answer questions about LID maintenance requirements at homeowners association meetings. These meetings also offer a good opportunity to distribute information on pollution prevention practices.

By implementing a strong public outreach program the developer can increase the effectiveness of the IMPs installed on the property and promote LID approaches as the preferred alternative to conventional stormwater practices.

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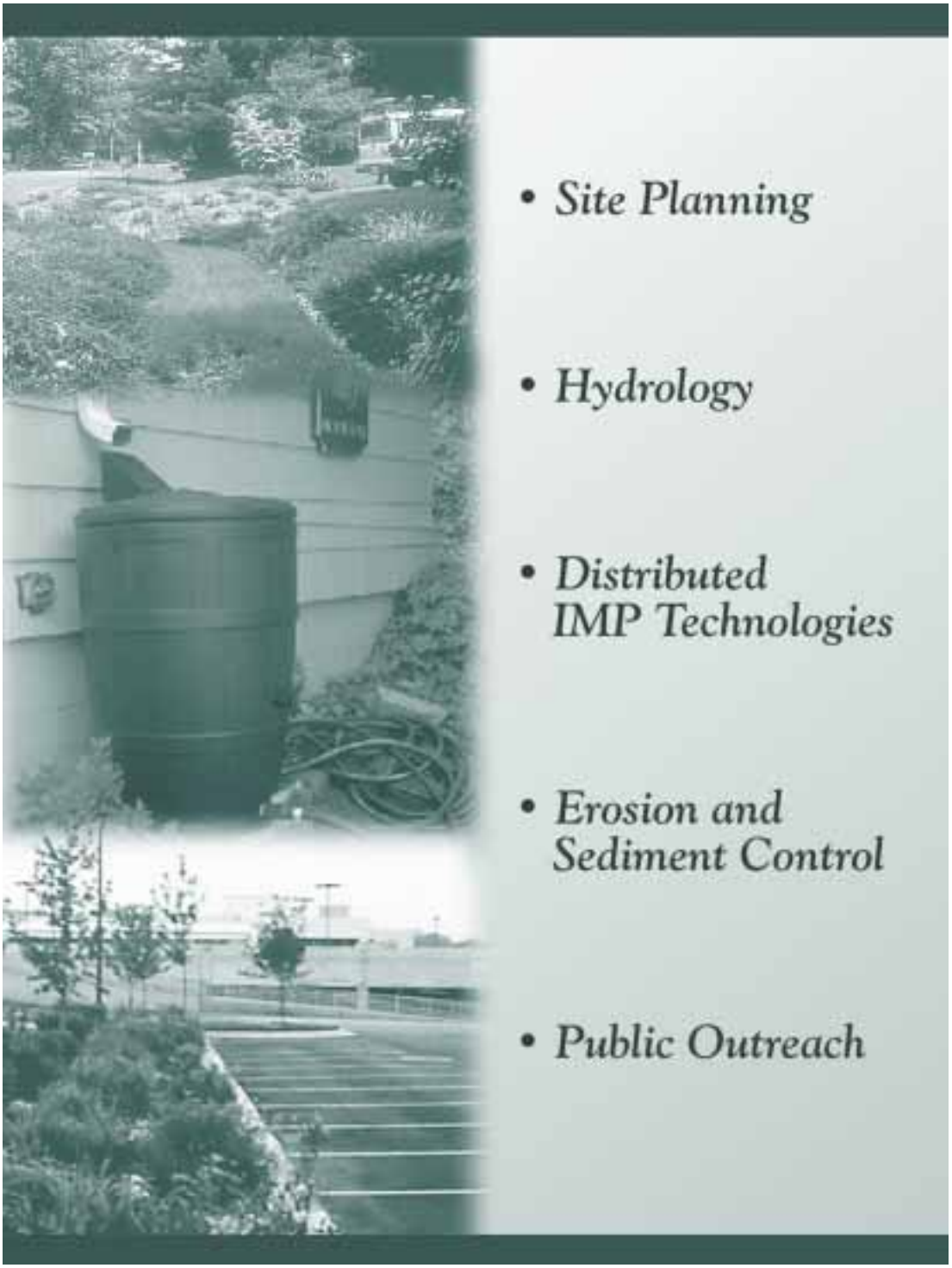
Appendices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• Distributed IMP Technologies
• Erosion and Sediment Control
• Public Outreach

Appendix A

Example Low-Impact Development Hydrologic Computation*

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* *Adapted from* Prince George's County, Maryland, Low Impact Development Hydrologic Analysis, 1999

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A.1 Introduction

The Appendix provides a detailed example of an LID hydrologic computation based on the use of the SCS TR-55 hydrologic model. This example computation is adapted from the *Low-Impact Development, Hydrologic Analysis Prince George's County, Maryland* (1999).

The hydrologic analysis of low-impact development is a sequential decision-making process that can be illustrated by the flow chart shown in Figure A.1. Several iterations may occur within each step until the appropriate approach to reduce stormwater impacts is determined. The procedures for each step are described below. Supporting design charts have been developed to determine the amount of storage required to maintain the existing volume and peak runoff rates to satisfy typical storm water management requirements at different geographic areas in the nation (Types I, IA, II and III storms). A few representative examples of these charts are provided in Exhibits A, B, and C.

A.2 Data Collection

The basic information used to develop the low-impact development site plan and used to determine the runoff curve number (CN) and time of concentration (Tc) for the pre- and postdevelopment condition is the same as conventional site plan and stormwater management approaches.

A.3 Determining the LID Runoff Curve Number

The determination of the low-impact development CN requires a detailed evaluation of each land cover within the development site. This will allow the designer to take full advantage of the storage and infiltration characteristics of low-impact development site planning to maintain the CN. This approach encourages the conservation of more woodlands and the reduction of impervious area to minimize the needs of IMPs.

The steps for determining the low-impact development CN are as follows:

Step 1: Determine percentage of each land use/cover.

In conventional site development, the engineer would refer to Figure 2.2.a of TR-55 (SCS, 1986) to select the CN that represents the proposed land use of the overall development (i.e., residential, commercial) without checking the actual percentages of impervious area, grass areas, etc. Because low-impact design emphasizes minimal

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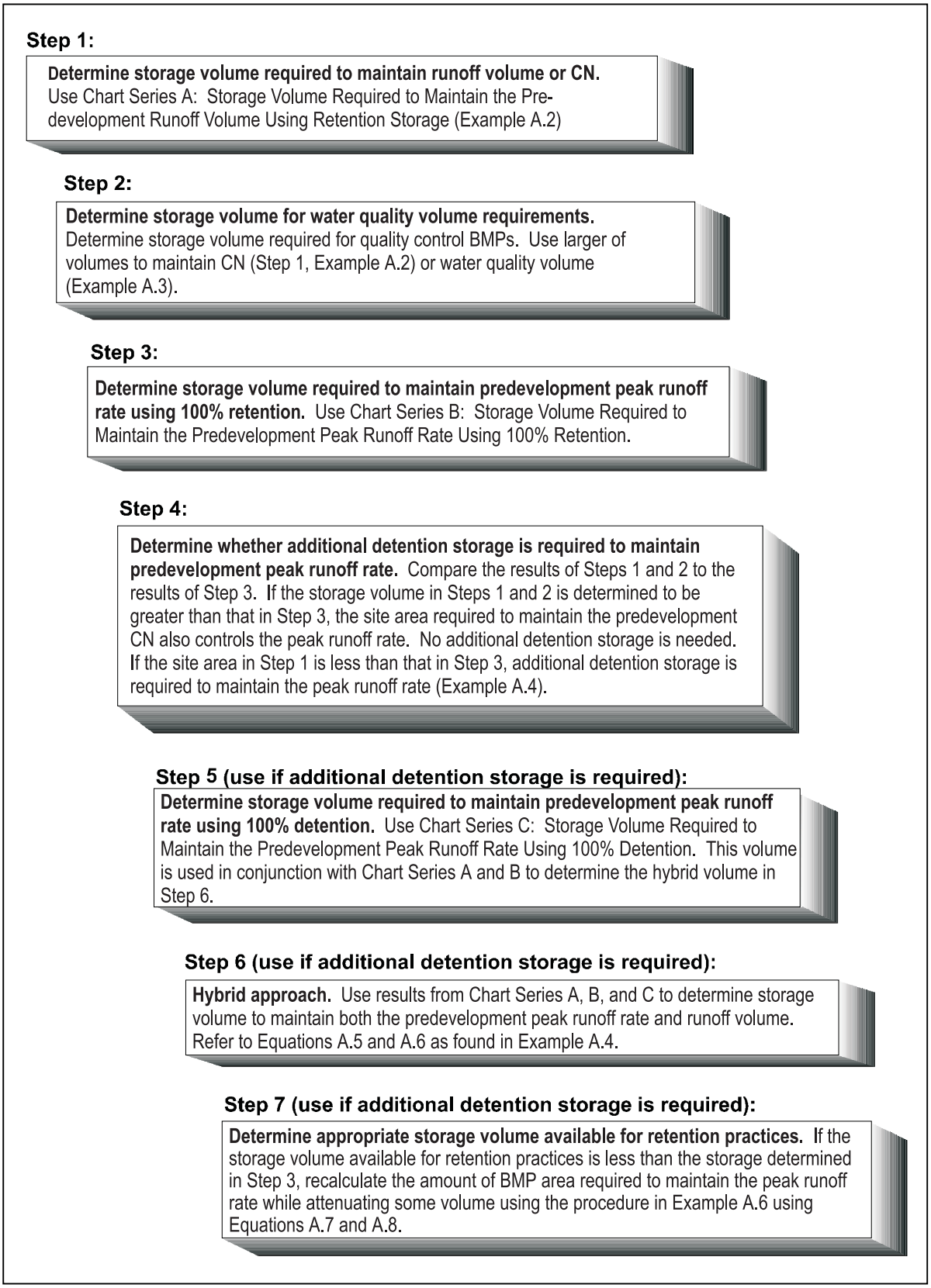

Figure A.1. Low-impact development analysis procedure

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site disturbance (tree preservation, site fingerprinting, etc.), it is possible to retain much of the pre-development land cover and CN.

Therefore, it is appropriate to analyze the site as discrete units to determine the CN. Table A.1 lists representative land cover CNs used to calculate the composite "custom" low-impact development CN.

Step 2: Calculate composite custom CN.

The initial composite CN is calculated using a weighted approach based on individual land covers *without* considering disconnectivity of the site imperviousness. This is done using Equation A.1. This weighted approach is illustrated in Example A.1.

Table A.1. Representative LID Curve Numbers

Land Use/Cover	Curve Number for Hydrologic Soils Groups[1]			
	A	B	C	D
Impervious Area	98	98	98	98
Grass	39	61	74	80
Woods (fair condition)	36	60	73	79
Woods (good condition)	30	55	70	77

[1]*Figure 2.2a, TR-55 (SCS, 1986).*

$$CN_c = \frac{CN_1 A_1 + CN_2 A_2 \ldots + CN_j A_j}{A_1 + A_2 \ldots + A_j} \qquad \text{Eq. A.1}$$

Where:

CNc = composite curve number;

A_j = area of each land cover; and

CN_j = curve number for each land cover.

Overlays of SCS Hydrologic Soil Group boundaries onto homogeneous land cover areas are used to develop the low-impact development CN. What is unique about the low-impact development custom-made CN technique is the way this overlaid information is analyzed as small discrete units that represent the hydrologic condition, rather than a conventional TR-55 approach that is based on a representative national average. This is appropriate because of the emphasis on minimal disturbance and retaining site areas that have potential for high storage and infiltration. This custom-made CN technique is documented in Example A.1.

This approach provides an incentive to save more trees and maximize the use of HSG A and B soils for recharge. Careful planning can result in significant reductions in post-development runoff volume and corresponding IMP costs.

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Step 3: Calculate low-impact development CN based on the connectivity of site impervious area.

When the impervious areas are less than 30 percent of the site, the percentage of the unconnected impervious areas within the watershed influences the calculation of the CN (SCS, 1986). Disconnected impervious areas are impervious areas without any direct connection to a drainage system or other impervious surface. For example, roof drains from houses could be directed onto lawn areas where sheet flow occurs, instead of to a swale or driveway. By increasing the ratio of disconnected impervious areas to impervious areas on the site, the CN and resultant runoff volume can be reduced. Equation A.2 is used to calculate the CN for sites with less than 30 percent impervious area.

$$CN_c = CN_p + \left(\frac{P_{imp}}{100}\right)(98 - CN_p) \times (1 - 0.5R) \qquad \text{Eq. A.2}$$

where:

R = ratio of unconnected impervious area to total impervious area;

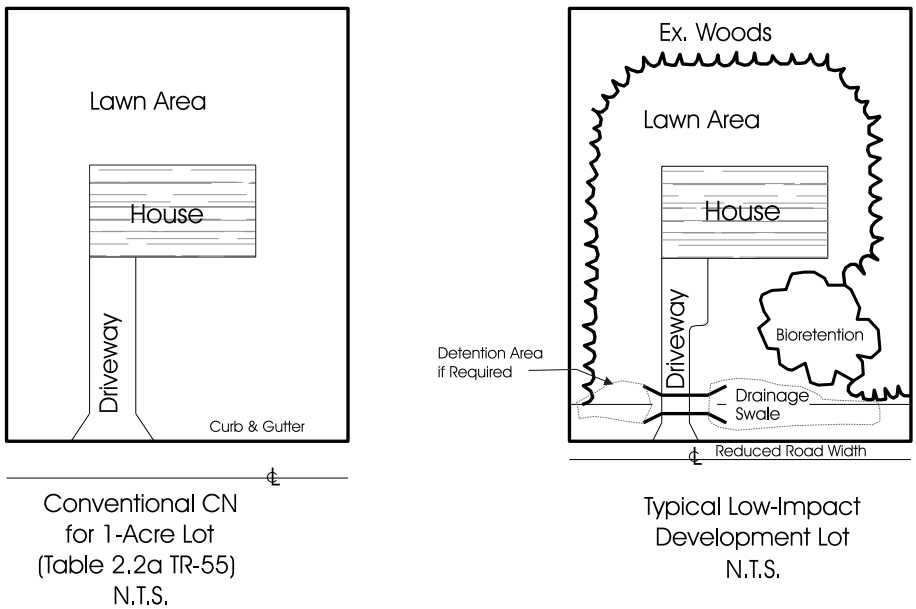
CN_c = composite CN;

CN_p = composite pervious CN; and

P_{imp} = percent of impervious site area.

Example A.1 uses steps 1 through 3 to compare the calculation of the curve number using conventional and low-impact development techniques using the percentages of land cover for a typical 1-acre residential lot from Figure A.2.

Figure A.2. Comparison of land covers between conventional and LID CNs



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Example A.1

Detailed CN Calculation

Given:

One-acre residential lot

Conventional CN: 68 (From TR-55 Table 2.2a-Runoff curve numbers for urban areas (SCS, 1986)) Table 2.2a assumes HSG B, 20% imperviousness with a CN of 98 and 80% open space in good condition.

Custom-made LID CN: CN for individual land covers based on Table 2.2a. Assume 25% of the site will be used for reforestation/ landscaping (see Figure A.2) HSG B.

Procedure:

Step 1: Determine percentage of each land cover occurring on site and the CN associated with each land cover.

Land Use	HSG (1)	CN (2)	% of Site (3)	Land Coverage (ft^2) (4)
Impervious (Directly Connected)	B	98	5	2,178
Impervious (Unconnected)	B	98	10	4,356
Open Space (Good Condition, Graded)	B	61	60	26,136
Woods (Fair Condition)	B	55	25	10,890

Step 2: Calculate composite custom CN (using Equation A.1).

$$CN_c = \frac{98 \quad 4{,}356 \quad 98 \quad 2{,}178 \quad 61 \times 26{,}136 \quad 55 \times 10{,}890}{43{,}560}$$

$$CN_c = 65$$

Step 3: Calculate low-impact development CN based on the connectivity of the site imperviousness (using Equation A.2).

$$CN_p = \frac{61 \times 26{,}136 + 55 \times 10{,}890}{37{,}026}$$

$$CN_p = 59.2$$

$$R = \frac{10}{15}$$

$$R = 0.67$$

$$CN_c = CN_p + \left(\frac{P_{imp}}{100}\right)(98 \quad CN_p)(1 - 0.5 \times R)$$

$$CN_c = 59.2 + \left(\frac{15}{100}\right)(98 \quad 59.2)(1 - 0.5 \times 0.67)$$

$$CN_c = 63.1 \text{ (use 63)}$$

LID custom CN of 63 is less than conventional CN of 68 (predevelopment CN is 55).

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A.4 Development of the Time of Concentration (Tc)

The pre- and postdevelopment calculation of the Tc for low-impact development is exactly the same as that described in the TR-55 (SCS, 1986) and NEH-4 (SCS, 1985) manuals.

A.5 Low-Impact Development Stormwater Management Requirements

Once the CN and Tc are determined for the pre- and postdevelopment conditions, the stormwater management storage volume requirements can be calculated. The low-impact development objective is to maintain all the predevelopment volume, predevelopment peak runoff rate, and frequency. The required storage volume is calculated using the design charts in Exhibits A (page A-25), B (page A-27), and C (page A-29) for different geographic regions in the nation.

As stated previously, the required storage volume for peak runoff control is heavily depended on the intensity of rainfall (rainfall distribution). Since the intensity of rainfall varies considerably over geographic regions in the nation, National Resource Conservation Service (NRCS) developed four synthetic 24-hour rainfall distributions (I, IA, II, and III) from available National Weather Service (NWS) duration-frequency data and local storm data. Type IA is the least intense and type II the most intense short-duration rainfall. Figure A.3. shows approximate geographic boundaries for these four distributions.

Figure A.3. Approximate geographic boundaries for NRCS rainfall distributions

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The remaining low-impact development hydrologic analysis techniques are based on the premise that the post-development Tc is the same as the pre-development condition. If the post-development Tc does not equal the pre-development Tc, additional low-impact development site design techniques must be implemented to maintain the Tc.

Three series of design charts are needed to determine the storage volume required to control the increase in runoff volume and peak runoff rate using retention and detention practices. The required storages shown in these design charts are presented as a depth in hundredths of an inch (over the development site area). Equation A.3 is used to determine the volume required for IMPs.

$$\text{Volume} = (\text{depth obtained from the chart}) \times (\text{development size})/100 \qquad \text{Eq. A.3}$$

It is recommended that 6-inch depth be the maximum depth for bioretention basins used in low-impact development.

The amount, or depth, of exfiltration of the runoff by infiltration or by the process of evapotranspiration is not included in the design charts. Reducing surface area requirements through the consideration of these factors can be determined by using Equation A.4.

$$\text{Volume of site area for IMPs} = (\text{initial volume}) \times (100 - x) / 100 \qquad \text{Eq. A.4}$$

where: x = % of the storage volume infiltrated and/or reduced by evaporation or transpiration. x% should be minimal (less than 10% is considered).

Stormwater management is accomplished by selecting the appropriate IMP, or combination of IMPs, to satisfy the surface area and volume requirements calculated from using the design charts as described below. The design charts to be used to evaluate these requirements are:

- Chart Series A: Storage Volume Required to Maintain the Predevelopment Runoff Volume Using Retention Storage (Exhibit A).
- Chart Series B: Storage Volume Required to Maintain the Predevelopment Peak Runoff Rate Using 100% Retention (Exhibit B).
- Chart Series C: Storage Volume Required to Maintain the Predevelopment Peak Runoff Rate Using 100% Detention (Exhibit C).

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These charts are based on the following general conditions:

- The land uses for the development are relatively homogeneous throughout the site.
- The stormwater management measures are to be distributed evenly across the development, to the greatest extent possible.
- The rainfall (design storm event) is based on 1-inch increments. Use linear interpolation for determining intermediate values.

The procedure to determine the IMP requirements is outlined in Figure A.4 and described in the following sections.

Step 1: Determine storage volume required to maintain predevelopment volume or CN using retention storage.

The post-development runoff volume generated as a result of the post-development custom-made CN is compared to the predevelopment runoff volume to determine the surface area required for volume control. Use Chart Series A: Storage Volume Required to Maintain the Predevelopment Runoff Volume using Retention Storage. The procedure for calculating the site area required for maintaining runoff volume is provided in Example A.2. It should be noted that the practical and reasonable use of the site must be considered. The IMPs should not restrict the use of the site, unless the regulatory authority decides that the sensitivity of the receiving water body requires such restrictions.

The storage area found, is for runoff volume control only; additional storage may be required for water quality control. The procedure to account for the first ½-inch of runoff from impervious areas, which is the current water quality requirement, is found in Step 2.

Step 2: Determine storage volume required for water quality control.

The surface area, expressed as a percentage of the site, is then compared to the percentage of site area required for water quality control. The volume requirement for stormwater management quality control is based on the requirement to treat the first ½ inch of runoff (approximately 1,800 cubic feet per acre) from impervious areas. This volume is translated to a percent of the site area by assuming a storage depth of 6 inches. The procedure for calculating the site area required

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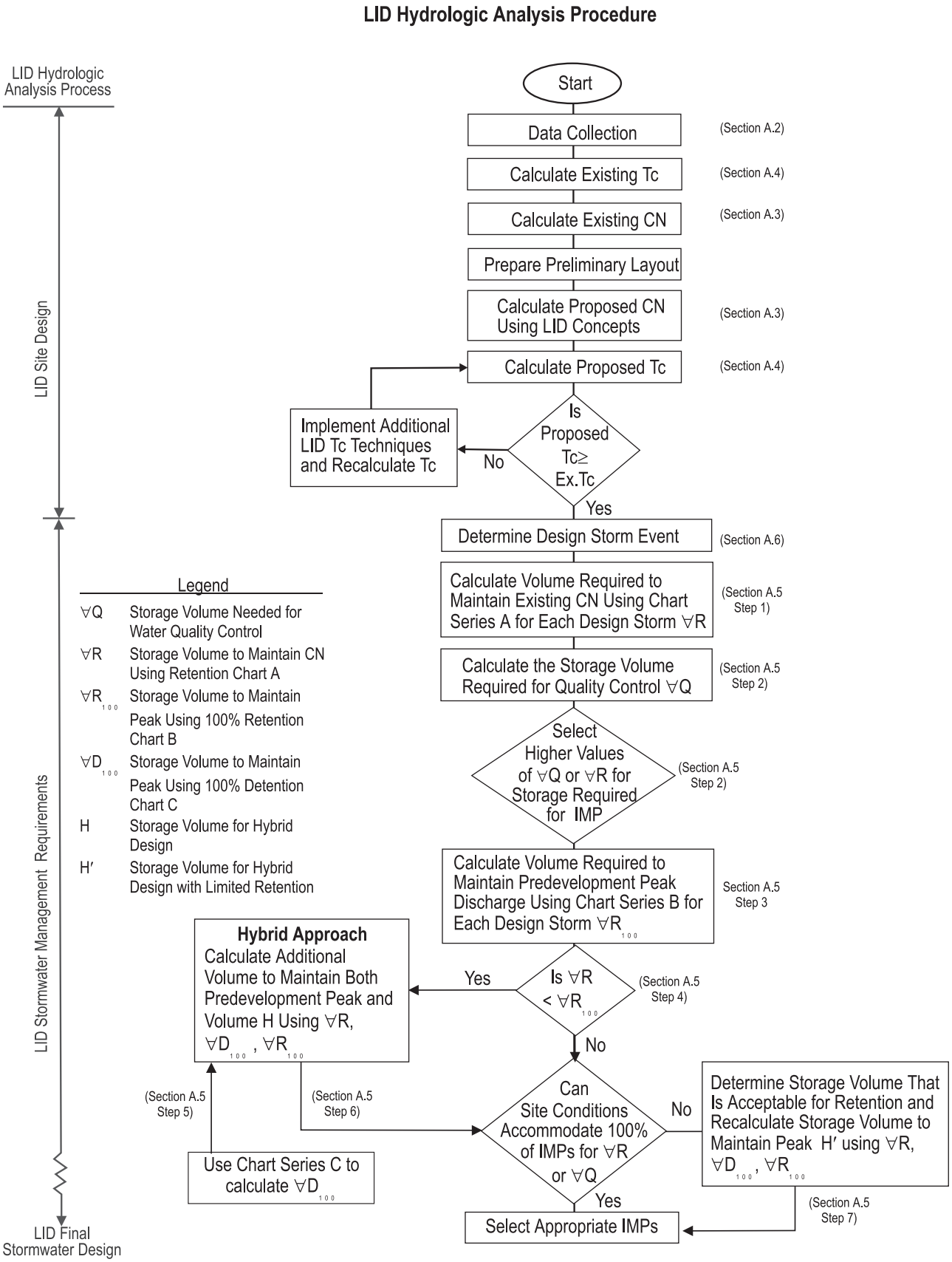

Figure A.4. Procedure to determine percentage of site area required for IMPs to maintain predevelopment runoff volume and peak runoff rate.

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Example A.2

Determining Site Area Required to Maintain Volume (CN) Using Chart Series A: Storage Volume Required to Maintain the Predevelopment Runoff Volume Using Retention Storage

Given:

Site Area is 18 acres

Existing CN is 60

Proposed CN is 65

Design storm is 5 inches

Design depth of IMP is 6 inches

Solution:

Use Chart Series A: Storage Volume Required to Maintain Runoff Volume or CN.

0.35 inch of storage over the site is required to maintain the runoff volume.

Therefore: if 6-inch design depth is used, 1.1 acres (18 acres x 0.35 / 6) of IMPs distributed evenly throughout the site are required to maintain the runoff volume, or CN.

Additional Considerations:

1) Account for depths other than 6 inches:
   Site of IMP Area = 1.1 acres, if 6-inch depth is used
   Depth of IMPs = 4 inches
   Site of IMP Area = 1.1 x 6 in./4 in.
   Site of IMP Area = 1.65 acres

2) Account for infiltration and/or evapotranspiration (using Equation A.4)
   If 10% of the storage volume is infiltrated and/or reduced by evaporation and transpiration.
   Site of IMP Area = (storage volume) x (100 - X) / 100
   Site of IMP Area =1.1 x (100-10)/100

Area for IMP Storage = 1.0 acre

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for quality control is provided in Example A.3. The greater number, or percent, is used as the required storage volume to maintain the CN.

From the results of Example A.3, 0.1" of storage is required for water quality using retention; from Example A.2, 0.35" of storage is required to maintain the runoff volume using retention. Since the volume required to maintain the runoff volume is larger, in this case 0.35" of storage over the site should be reserved for retention IMPs.

Step 3: Determine storage volume required to maintain peak stormwater runoff rate using 100 percent retention.

The percentage of site area or amount of storage required to maintain the predevelopment peak runoff rate is based on *Chart Series B: Percentage of Site Area Required to Maintain Predevelopment Peak Runoff Rate Using 100% Retention (Exhibit B)*. This chart is based on the relationship between storage volume, $\forall_s / \forall_r$, and discharge, Q_o / Q_i, to maintain the predevelopment peak runoff rate.

Where: *Vs* = volume of storage to maintain the predevelopment peak runoff rate using 100% retention;

Vr = postdevelopment peak runoff volume;

Qo = peak outflow discharge rate; and

Qi = peak inflow discharge rate.

Example A.3

Calculation of Volume, or Site Area, for Water Quality Control

Given:

Site area is 18 acres

Impervious area is 3.6 acres (20%)

Depth of IMP is 6 inches

Solution:

The water quality requirement is to control the first ½ inch of runoff from impervious areas *(18 acres x 20%) x 0.5in. / 18 acres* = 0.1 inch storage for water quality 0.1 inch is less than 0.35 inch (from example A.2). Therefore, use storage for runoff volume control to meet the water quality requirement.

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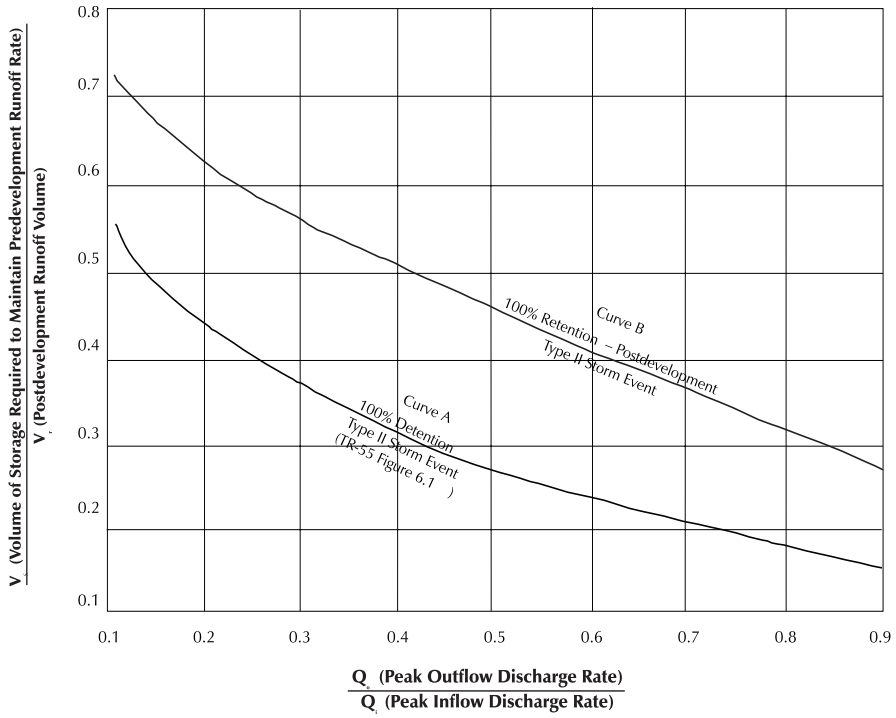

Figure A.5. Comparison of retention of storage volumes required to maintain peak runoff rate using retention and detention.

The relationship for retention storage to control the peak runoff rate is similar to the relationship for detention storage. Figure A.5 is an illustration of the comparison of the storage volume/discharge relationship for retention and detention. Curve A is the relationship of storage volume to discharge to maintain the predevelopment peak runoff rate using the detention relationship from Figure 6-1 (SCS, 1986) for a Type II 24-hour storm event. Curve B is the ratio of storage volume to discharge to maintain the predevelopment peak runoff rate using 100 percent retention. Note that the volume required to maintain the peak runoff rate using detention is less than the requirement for retention. This is graphically demonstrated in Figure A.6.

- Hydrograph 2 represents the response of a postdevelopment condition with no stormwater management IMPs. This hydrograph definition reflects a shorter time of concentration (Tc), and increase in total site imperviousness than that of the predevelopment condition. This resultant hydrograph shows a decrease in the time to reach the peak runoff and discharge rate and volume, and increased duration of the discharge volume.
- Hydrograph 8 illustrates the effect of providing additional detention storage to reduce the postdevelopment peak discharge rate to predevelopment conditions.

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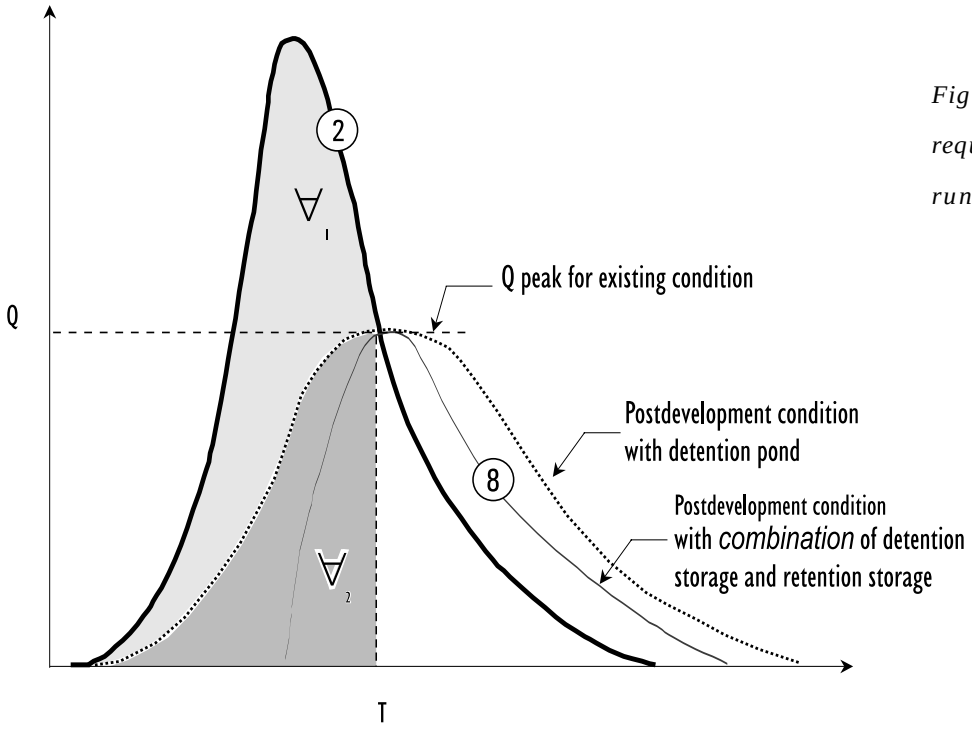

Figure A.6. Storage volume required to maintain peak runoff rate

$\forall_1$ is the storage volume required to maintain the predevelopment peak discharge ratio using 100% detention storage. The combination of $\forall_1$ and $\forall_2$ is the storage volume required to maintain the predevelopment peak discharge rate using 100% retention storage.

The following calculations apply to Design Chart Series B:

- The Tc for the postdevelopment condition is equal to the Tc for the predevelopment condition. This equality can be achieved by techniques such as maintaining sheet flow lengths, increasing surface roughness, decreasing the amount and size of storm drain pipes, and decreasing open channel slopes. Chapter 2 of this manual provides more details on these techniques.
- The depth of storage for the retention structure is 6 inches. For other depths, see Example A.2.

If the Tc is equal for the predevelopment and postdevelopment conditions, the peak runoff rate is independent of Tc for retention and detention practices. The difference in volume required to maintain the predevelopment peak runoff rate is practically the same if the Tcs for the predevelopment and postdevelopment conditions are the same. These concepts are illustrated in Figure A.7. In Figure A.7, the difference in the required IMP area between a Tc of 0.5 and a Tc of 2.0

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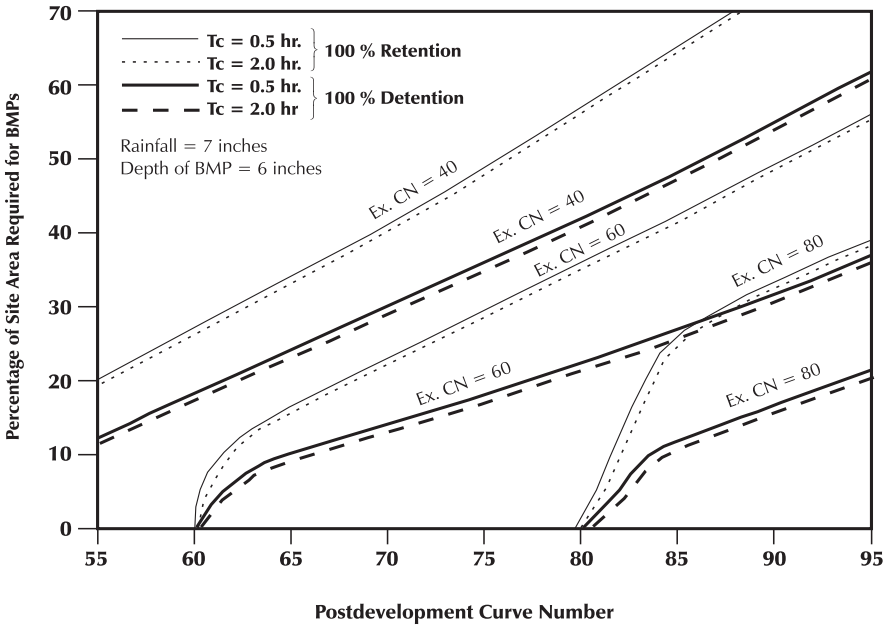

Figure A.7. Comparison of storage volumes for various Tcs.

is minimal if the predevelopment and postdevelopment Tcs are maintained.

Step 4: Determine whether additional detention storage is required to maintain the predevelopment peak runoff rate.

The storage volume required to maintain the predevelopment runoff volume using retention, as calculated in Step 1, might or might not be adequate to maintain both the predevelopment volume and peak runoff rate. As the CNs diverge, the storage requirement to maintain the volume is much greater than the storage volume required to maintain the peak runoff rate. As the CNs converge, however, the storage required to maintain the peak runoff rate is greater than that required to maintain the volume. Additional detention storage will be required if the storage volume required to maintain the runoff volume (determined in Step 1) is less than the storage volume required to maintain the predevelopment peak runoff rate using 100 percent retention (determined in Step 3).

The combination of retention and detention practices is defined as a hybrid IMP. The procedure for determining the storage volume required for the hybrid approach is described in Step 5.

Table A.2 illustrates the percentage of site area required for volume and peak control for representative curve numbers. Using a 5-inch type II 24-hour storm event and 6" design depth, with a predevelopment CN of 60, the following relationships exist:

- For a post-development CN of 65, 5.9 percent of the site area (column 4) is required for retention practices to maintain the

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Table A.2. Representative Percentages of Site Required for Volume and Peak Control

Type of 24-Hour Storm Event (1)	Runoff Curve No.		% of Area Needed for BMP				Percent of Volume Retention for Hybrid Design (Eq. 4.5) (8)
	Existing (2)	Proposed (3)	Volume Control Using 100% Retention Chart Series A (4)	Peak Control Using 100% Retention Chart Series B (5)	Peak Control Using 100% Detention Chart Series C (6)	Hybrid Design (Eq. 4.6) (7)	
3"	50	55	1.7	1.6	0.9	1.7	100
		60	4.0	3.4	2.4	4.0	100
		65	6.9	6.2	4.5	6.9	100
		70	10.4	9.3	7.3	10.4	100
		80	19.3	18.0	15.8	19.3	100
	60	65	2.9	3.9	2.3	3.6	80
		70	6.3	6.7	4.4	6.6	96
		75	10.5	10.0	7.1	10.5	100
		90	27.5	24.9	18.7	27.5	100
	70	75	4.1	5.9	3.4	5.3	77
		80	8.9	9.7	5.8	9.5	94
		85	14.6	13.9	8.8	14.6	100
		90	21.2	18.7	12.6	21.2	100
	75	80	4.8	7.5	4.2	6.6	73
		85	10.5	11.8	7.0	11.4	91
		90	17.1	16.6	10.2	17.1	100
5"	50	55	4.8	6.9	4.0	6.3	77
		60	10.1	11.1	6.9	10.9	93
		65	16.0	15.6	10.4	16.0	100
		70	22.4	20.6	14.5	22.4	100
		80	36.7	32.8	23.9	36.7	100
	60	65	5.9	9.5	5.3	8.3	71
		70	12.3	14.6	8.4	13.9	88
		75	19.1	19.8	12.0	19.6	97
		90	42.9	37.2	25.3	42.9	100
	70	75	6.9	13.2	7.2	10.9	63
		80	14.3	18.9	10.7	17.4	82
		85	22.2	24.5	14.3	23.8	93
		90	30.7	30.5	18.2	30.7	100
	75	80	7.4	15.0	8.1	12.3	60
		85	15.3	20.6	11.6	18.9	81
		90	23.8	26.7	15.2	25.7	92
7"	50	55	7.6	12.3	6.8	10.7	71
		60	15.6	18.6	10.7	17.7	88
		65	23.9	25.0	15.1	24.7	97
		70	32.5	31.4	19.6	32.5	100
		80	50.5	44.5	30.0	50.5	100
	60	65	8.3	16.6	9.0	13.6	61
		70	16.9	23.2	13.2	21.2	80
		75	25.8	29.9	17.3	28.7	90
		90	53.7	49.7	30.7	53.7	100
	70	75	8.9	20.4	10.9	16.1	55
		80	17.9	26.8	14.7	23.8	75
		85	27.2	33.4	18.9	31.5	87
		90	36.7	42.3	23.0	39.2	94
	75	80	9.1	22.1	11.5	17.1	53
		85	18.4	28.6	15.6	25.1	73
		90	27.9	35.3	19.8	32.9	85

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predevelopment volume. To maintain the predevelopment peak runoff rate (column 5), 9.5 percent of the site is required. Therefore, additional detention storage or a hybrid approach (calculated in column 7) is required.

- For a postdevelopment CN of 90, 42.9 percent of the site area (column 4) is required for retention practices to maintain the predevelopment volume. To maintain the predevelopment peak runoff rate (column 5) 37.2 percent of the site is required. Therefore, the storage required to maintain the runoff volume is also adequate to maintain the peak runoff rate. However, 42.9 percent of the site for IMPs may not be a practical and reasonable use of the site. Refer to Step 7, hybrid approach, for a more reasonable combination of retention and detention storage.

Step 5: Determine storage required to maintain predevelopment peak runoff rate using 100 percent detention. (This step is required if additional detention storage is needed.)

Chart Series C: Storage Volume Required to Maintain the Predevelopment Peak Runoff Rate Using 100% Detention is used to determine the amount of site area to maintain the peak runoff rate only. This information is needed to determine the amount of detention storage required for hybrid design, or where site limitations prevent the use of retention storage to maintain runoff volume. This includes sites that have severely limited soils for infiltration or retention practices. The procedure to determine the site area is the same as that of Step 3. Using Chart Series C, the following assumptions apply:

- The Tc for the post-development condition is equal to the Tc for the predevelopment condition.
- The storage volume, expressed as a depth in hundredths of an inch (over the development site), is for peak flow control.

These charts are based on the relationship and calculations from Figure 6.1 (Approximate Detention Basin Routing for Rainfall Types I, IA, II and III) in TR-55 (SCS, 1986).

Step 6: Use hybrid facility design (required for additional detention storage).

When the percentage of site area for peak control exceeds that for volume control as determined in Step 3, a hybrid approach must be used. For example, a dry swale (infiltration and retention) may incorporate additional detention storage. Equation A.5 is used to

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determine the ratio of retention to total storage. Equation A.6 is then used to determine the additional amount of site area, above the percentage of site required for volume control, needed to maintain the predevelopment peak runoff rate.

$$x = \frac{50}{(\forall_{R100} - \forall_{D100})} \times (-\forall_{D100} + \sqrt{\forall^2_{D100} + 4 \times (\forall_{R100} - \forall_{D100}) \times \forall R}\ ) \quad \text{Eq. A.5}$$

where

$\forall R$ = Storage Volume required to maintain predevelopment runoff volume (Chart Series A)

$\forall_{R100}$ = Storage Volume required to maintain predevelopment peak runoff rate using 100% retention (Chart Series B)

$\forall_{D100}$ = Storage Volume required to maintain predevelopment peak runoff rate using 100% detention (Chart Series C)

x = Area ratio of retention storage to total storage

and the hybrid storage can be determined as:

$H = \forall R \times (100 \div x)$ Eq. A.6

Equations A.5 and A.6 are based on the following assumptions:

- x% of the total storage volume is the retention storage required to maintain the predevelopment CN calculated from Chart Series A: Storage Volume Required to Maintain Predevelopment Volume using Retention Storage.
- There is a linear relationship between the storage volume required to maintain the peak predevelopment runoff rate using 100% retention and 100% detention (Chart Series B and C)

The procedure for calculating hybrid facilities size is shown in Example A.4.

Step 7: Determine hybrid amount of IMP site area required to maintain peak runoff rate with partial volume attenuation using hybrid design (required when retention area is limited).

Site conditions, such as high percentage of site needed for retention storage, poor soil infiltration rates, or physical constraints, can limit the amount of site area that can be used for retention practices. For sites with poor soil infiltration rates, bioretention is still an acceptable alternative, but an underdrain system must be installed. In this case, the bioretention basin is considered detention storage.

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Example A.4:

Calculation of Additional Storage Above Volume Required to Maintain CN and Maintain Predevelopment Peak Runoff Rate Using Hybrid Approach

Given:

- 5-inch Storm Event with Rainfall Distribution Type II
- Existing CN = 60
- Proposed CN = 65
- Storage volume required to maintain volume (CN) using retention storage = 0.35 inch (from Chart Series A)
- Storage volume required to maintain peak runoff rate using 100% retention = 0.62 inch (from Chart Series B)
- Storage volume required to maintain peak runoff rate using 100% detention = 0.31 inch (from Chart Series C)

Step 1: Solve for *x* (ratio of retention to total storage) using Equation A.5:

$$\chi = \frac{50}{(.62 - .31)} \times \left(-.31 + \sqrt{.31^2 + 4 \times (.62 - .31) \times .35}\right)$$

$$\chi = 68$$

Therefore: 0.35 inch of storage needed for runoff volume control is 68% of the total volume needed to maintain both the predevelopment volume and peak runoff rates.

Step 2: Solve for the total area to maintain both the peak runoff rate and volume using Equation A.6. Therefore, the difference between 0.35 inch and 0.51 inch is the additional detention area needed to maintain peak discharge.

$$H = 0.35 \times \frac{100}{68}$$

$$H = 0.51 \text{ inch}$$

Therefore , the difference between 0.35 inch and 0.51 inch is the additional detention area needed to maintain peak discharge.

When this occurs, the site area available for retention IMPs is less than that required to maintain the runoff volume, or CN. A variation of the hybrid approach is used to maintain the peak runoff rate while attenuating as much of the increased runoff volume as possible. First, the appropriate storage volume that is available for

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runoff volume control (∀R′) is determined by the designer by analyzing the site constraints. Equation A.7 is used to determine the ratio of retention to total storage. Equation A.8 is then used to determine the total site IMP area in which the storage volume available for retention practices (∀R′) substitutes the storage volume required to maintain the runoff volume.

$$\chi' = \frac{50}{\left(\forall_{R100} - \forall_{D100}\right)} \times \left(-\forall_{D100} + \sqrt{\forall^{2}_{D100} + 4 \times \left(\forall_{R100} - \forall_{D100}\right) \times \forall R'}\right) \quad 8 \text{ Eq. A.7}$$

Where ∀R′ = storage volume acceptable for retention IMPs. The total storage with limited retention storage is:

$$H' = \forall R' \text{ x } (100 \div x') \qquad \text{Eq. A.8}$$

where H′ is hybrid area with a limited storage volume available for retention IMPs.

Example A.5 illustrates this approach.

A.6 Determination of Design Storm Event

Conventional stormwater management runoff quantity control is generally based on not exceeding the predevelopment peak runoff rate for the 2-year and 10-year 24-hour Type II storm events. The amount of rainfall used to determine the runoff for the site is derived from Technical Paper 40 (Department of Commerce, 1963). For Prince George's County, these amounts are 3.3 and 5.3 inches, respectively. The 2-year storm event was selected to protect receiving channels from sedimentation and erosion. The 10-year event was selected for adequate flow conveyance considerations. In situations where there is potential for flooding, the 100-year event is used.

The criteria used to select the design storm for low-impact development are based on the goal of maintaining the predevelopment hydrologic conditions for the site. The determination of the design storm begins with an evaluation of the predevelopment condition. The hydrologic approach of low-impact development is to retain the same amount of rainfall within the development site as that retained by woods (or meadows, if they were the natural historical landscape), in good condition, and then to gradually release the excess runoff as woodlands would release it. By doing so, we can emulate, to the greatest extent practical, the predevelopment hydrologic regime to protect watershed and natural habitats. Therefore, the predevelopment condition of the low-impact development site is required to be *woods in good condition*.

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Example A.5:

Calculation of Percentage of Site Area Required to Maintain the Peak Runoff Rate Using the Hybrid Approach of Retention and Detention

Given:

- 5-inch storm event with rainfall distribution Type II
- Existing CN = 60
- Proposed CN = 65
- Storage volume required to maintain volume (CN) = 0.35 inch (From Chart Series A)
- Storage volume required to maintain peak runoff rate using 100% retention = 0.62 inch (from Chart Series B)
- Storage volume required to maintain peak runoff rate using 100% detention = 0.31 inch (from Chart Series C)
- Only half of the required site area is suitable for retention practices, remainder must incorporate detention.
  ($\forall R' = 0.35 \times 0.50 = 0.18$ inch)

Step 1: Determine appropriate amount of overall IMP area suitable for retention practices. Half of area is appropriate (given above). Use Equation A.7:

$$\chi' = \frac{50}{(.62 - .31)} \times \left(-.31 + \sqrt{.31^2 + 4 \times (.62 - .31) \times .18}\right)$$

$\chi' = 41.2\%$

Therefore, 0.35 inch of site area available for runoff volume control is 41.2% of the total volume needed for maintaining the predevelopment peak runoff rate.

Step 2: Solve for the total area required to maintain the peak runoff rate using Equation A.8.

$$H' = 0.18 \times \frac{100}{41.2}$$

H' = 0.43 inch

Therefore, totally 0.43 inch of the site is required to maintain the predevelopment peak runoff rate but not the runoff volume. Of the 0.43 inch storage, 0.18 inch of the storage is required for retention volume.

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This requirement is identical to the State of Maryland's definition of the predevelopment condition. The CN for the predevelopment condition is to be determined based on the land cover being woods in good condition and the existing HSG. The design storm is to be the greater of the rainfall at which direct runoff begins from a woods in good condition, with a modifying factor, or the 1-year 24-hour storm event. The rainfall at which direct runoff begins is determined using Equation A.9. The initial rainfall amount at which direct runoff begins from a woodland is modified by multiplying this amount by a factor of 1.5 to account for the slower runoff release rate under the wooded predevelopment condition.

$$P = 0.2 \text{ x } \left(\frac{1000}{CN_c} - 10 \right) \qquad \text{Eq. A.9}$$

where P is rainfall at which direct runoff begins.

It should be noted that this assumption will need to be adjusted for communities with different climatic conditions such as the arid southwest or the great plains.

A three-step process, illustrated in Example A.6, is used to determine the design storm event.

Step 1: Determine the predevelopment CN.

Use an existing land cover of woods in good condition overlaid over the hydrologic soils group (HSG) to determine the composite site CN.

Step 2: Determine the amount of rainfall needed to initiate direct runoff.

Use Equation A.9 to determine the amount of rainfall (P) needed to initiate direct runoff.

Step 3: Account for variation in land cover.

Multiply the amount of rainfall (P) determined in Step 2 by a factor of 1.5.

Example A.6 demonstrates this approach.

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Example A.6:

Determination of Design Storm

Step 1: Determine the predevelopment CN based on woods (good condition) and HSG.

Given:

Site condition of 90% HSG soil type B and 10% HSG soil type C,

$CN_c = 0.9\ (55) + 0.1 \times (70)$

$CN_c \geq 56.5 \approx 57$ use 57

Step 2: Determine the amount of rainfall to initiate direct runoff using Equation A.9.

$$P = 0.2 \times \left(\frac{1000}{57} - 10 \right)$$

$P = 1.5$ inches

Step 3: Multiply the amount of rainfall by a factor of 1.5.

Design rainfall = P x 1.5

Design rainfall = 1.5 inches x 1.5

Design rainfall = 2.25 inches

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Exhibit A

Storage Volume Required to Maintain the Predevelopment Runoff Volume Using Retention Storage

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Chart A4: Percentage of Site Required to Maintain Pre-development Runoff Volume Using Retention Storage

5" Rainfall Event - Type II 24-Hour Storm - BMP Depth = 6"

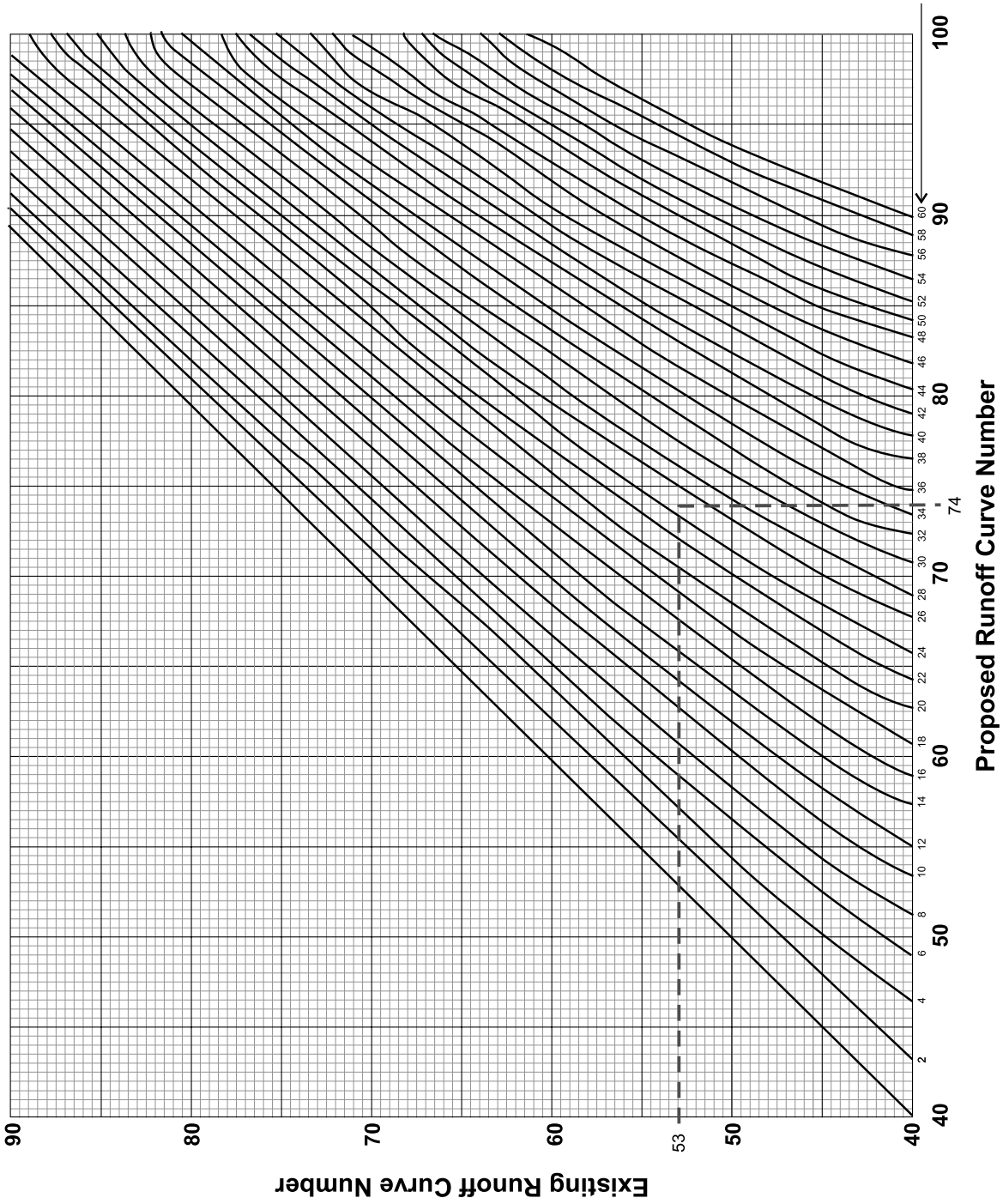

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Exhibit B

Storage Volume Required to Maintain the Predevelopment Peak Runoff Rate Using 100% Retention Storage

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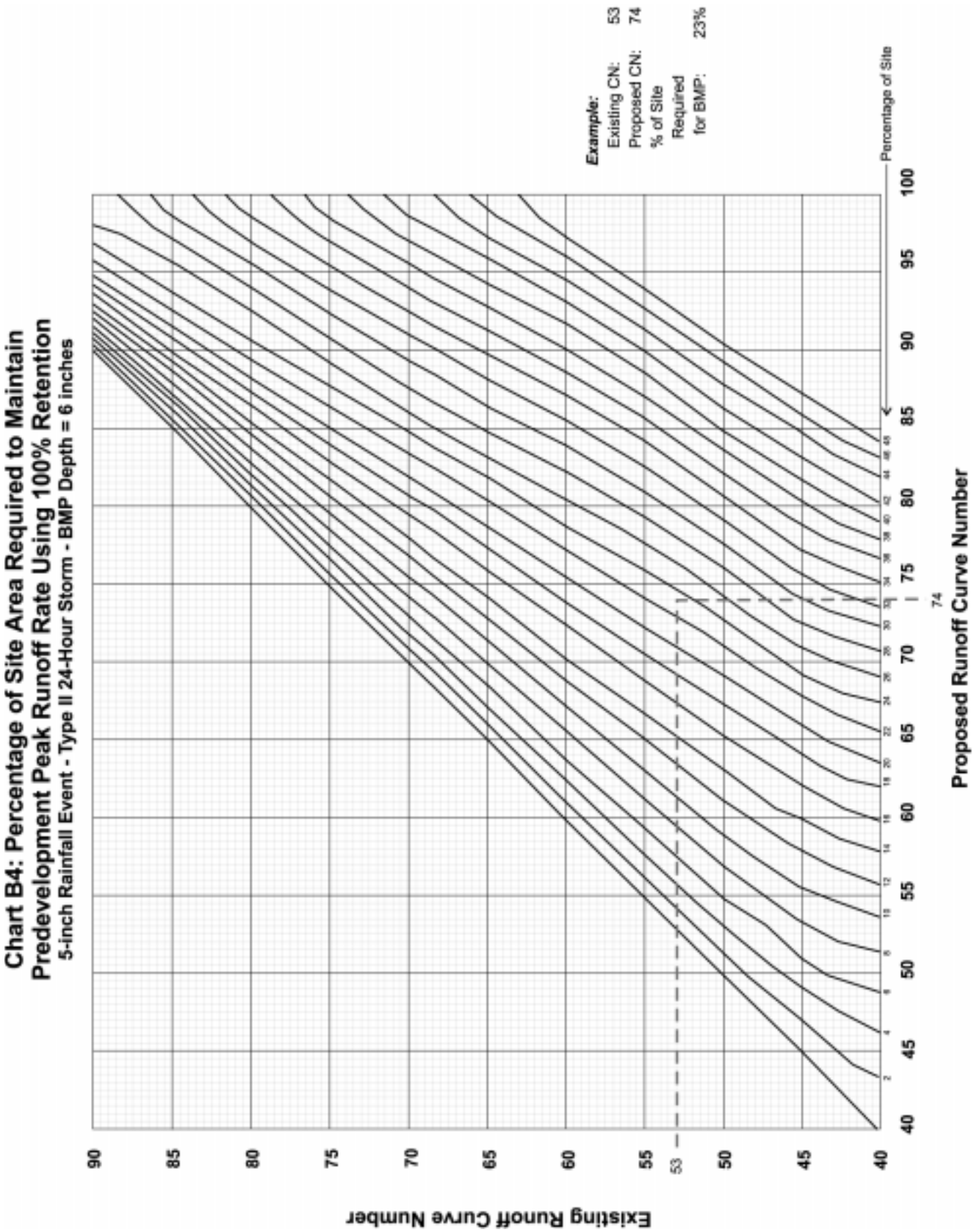
Chart B4: Percentage of Site Area Required to Maintain Predevelopment Peak Runoff Rate Using 100% Retention
5-inch Rainfall Event - Type II 24-Hour Storm - BMP Depth = 6 inches
Example:
Existing CN: 53
Proposed CN: 74
% of Site Required for BMP: 23%
Percentage of Site
Existing Runoff Curve Number
Proposed Runoff Curve Number
90
85
80
75
70
65
60
55
53
50
45
40
40
45
50
55
60
65
70
75
74
80
85
90
95
100

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Exhibit C

Storage Volume Required to Maintain the Predevelopment Peak Runoff Rate Using 100% Detention Storage

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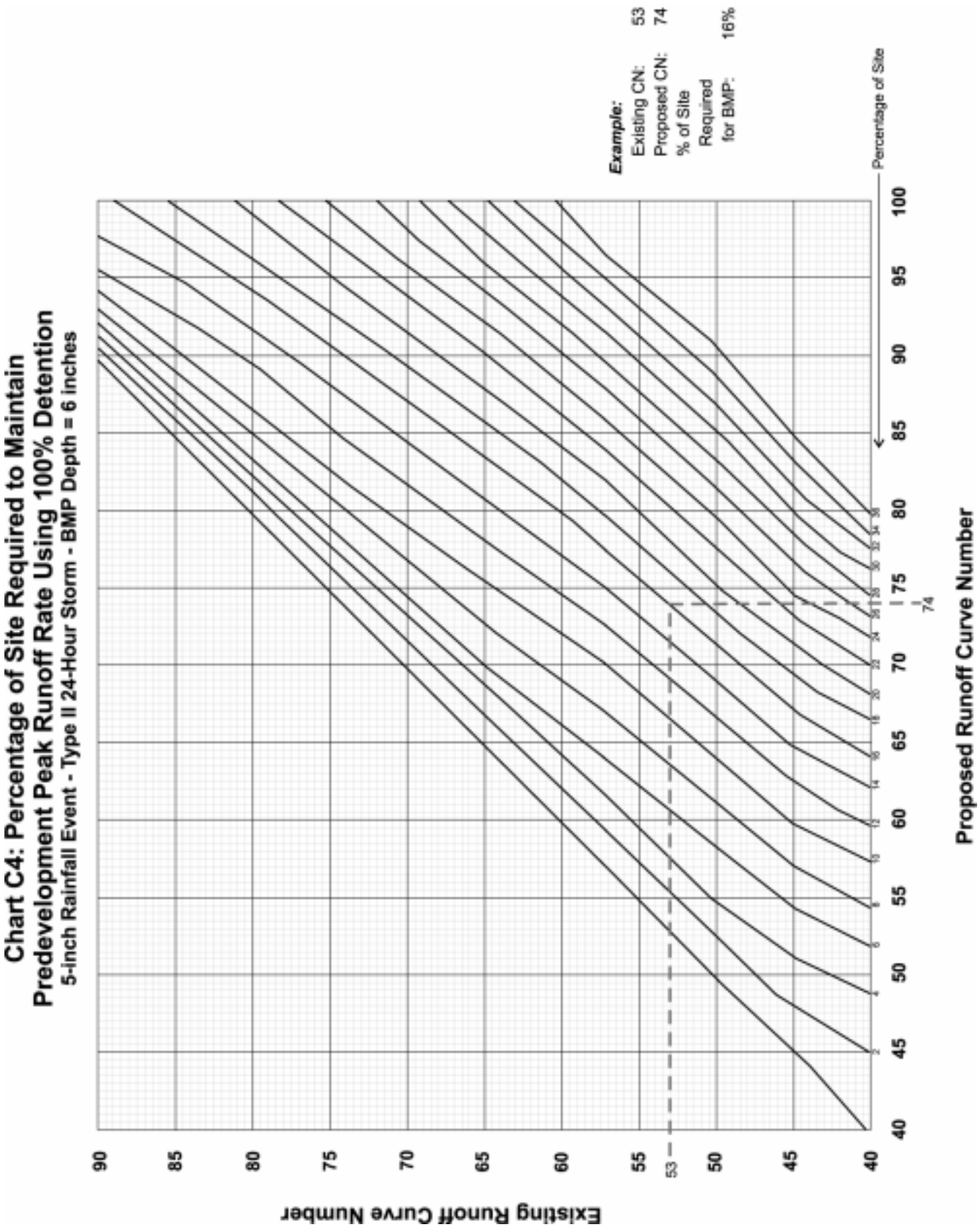
Chart C4: Percentage of Site Required to Maintain Predevelopment Peak Runoff Rate Using 100% Detention
5-inch Rainfall Event - Type II 24-Hour Storm - BMP Depth = 6 inches
Example:
Existing CN: 53
Proposed CN: 74
% of Site Required for BMP: 16%
Percentage of Site
Existing Runoff Curve Number
Proposed Runoff Curve Number
90
85
80
75
70
65
60
55
50
45
40
53
74

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Appendix B - Sample Maintenance Covenant

DECLARATION OF COVENANTS
For Storm and Surface Water Facility, and Integrated Management System Maintenance

THIS DECLARATION OF COVENANTS, made this _____ day of _____, 20___, by _____ hereinafter refered to as the "Covenantor(s)" to and for the benefit of (governing body—state, county, city, etc.) and its successors and assigns hereinafter referred to as the "(State, County, City, etc.)."

WITNESSETH:

WHEREAS, the (State, County, City) is authorized and required to regulate and control the disposition of storm and surface waters within the County's Stormwater Management District set forth in (cite governing laws or regulations): and

WHEREAS, Covenantor(s) is (are) the owner(s) of a certain tract or parcel of land more particularly described as:

_____

_____

being all or part of the land which it acquired by deed dated _____ _____ from _____ _____ grantors, and recorded among the Land Records of (governing body), in Liber _____ at Folio _____ such property being hereinafter referred to as the "the property"; and

WHEREAS, the Covenantor(s) desires to construct certain improvements on its property which will alter the extent of storm and surface water flow conditions on both the property and adjacent lands: and

WHEREAS, in order to accommodate and regulate these anticipated changes in existing storm and surface water flow conditions, the Covenantor(s) desires to build and maintain at its expense, a storm and

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surface water management facility and system more particularly described and shown on plans titled _____

_____

and further identified under approval number _____

_____; and _____.

WHEREAS, the (State, County, City, etc.) has reviewed and approved these plans subject to the execution of this agreement.

NOW THEREFORE, in consideration of the benefits received by the Covenantor(s), as a result of the (State, County, City) approval of his plans. Covenantor(s), with full authority to execute deeds, mortgages, other covenants, and all rights, title and interest in the property described above do hereby covenant with the (State, County, City) as follows:

1. Covenantor(s) shall construct and perpetually maintain, at its sole expense, the above-referenced storm and surface management facility and system in strict accordance with the plan approval granted by the (State, County, City).

2. Covenantor(s) shall, at its sole expense, make such changes or modifications to the storm drainage facility and system as may, in the (State, County, City) discretion, be determined necessary to insure that the facility and system is properly maintained and continues to operate as designed and approved.

3. The (State, County, City), its agents, employees and contractors shall have the perpetual right of ingress and egress over the property of the Covenantor(s) and the right to inspect at reasonable times and in reasonable manner, the storm and surface water facility and system in order to insure that the system is being properly maintained and is continuing to perform in an adequate manner.

4. The Covenantor(s) agrees that should it fail to correct any defects in the above-described facility and system within ten (10) days from the issuance of written notice, or shall fail to maintain the facility in accordance with the approved design standards and with the law and applicable executive regulation or, in the event of an emergency as determined by the (State, County, City) in its sole discretion, the (State, County, City) is authorized to enter the property to make all repairs, and to perform all maintenance, construction and reconstruction as (State, County, City) deems necessary. The (State, County, City) shall then assess the Covenantor(s) and/or all landowners served by the facility for the cost of the work, both direct and indirect, and applicable penalties. Said assessment shall be a lien against all properties served by the facility and may be placed on the property tax bills of said properties and collected as ordinary taxes by the (State, County, City).

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5. Covenantor(s) shall indemnify, save harmless and defend the (State, County City) from and against any and all claims, demands, suits, liabilities, losses, damages and payments including attorney fees claimed or made by persons not parties to this Declaration against the (State, County, City) that are alleged or proven to result or arise from the Covenantor(s) construction, operation, or maintenance of the storm and surface water facility and system that is the subject of this Covenant.

6. The covenants contained herein shall run with the land and the Covenantor(s) further agrees that whenever the property shall be held, sold and conveyed, it shall be subject to the covenants, stipulations, agreements and provisions of this Declaration, which shall apply to, bind and be obligatory upon the Covenantor(s) hereto, its heirs, successors and assigns and shall bind all present and subsequent owners of the property served by the facility.

7. The Covenantor(s) shall promptly notify the (State, County, City) when the Covenantor(s) legally transfers any of the Covenantor(s) responsibilities for the facility. The Covenantor(s) shall supply the (State, County, City) with a copy of any document of transfer, executed by both parties.

8. The provisions of this Declaration shall be severable and if any phrase, clause, sentence or provisions is declared unconstitutional, or the applicability thereof to the Covenantor is held invalid, the remainder of this Covenant shall not be affected thereby.

9. The Declaration shall be recorded among the Land Records of (Governing Body) at the Covenantor(s) expense.

10. In the event that the (State, County, City) shall determine at its sole discretion at future time that the facility is no longer required, then the (State, County, City) shall at the request of the Covenantor(s) execute a release of this Declaration of Covenants which the Covenantor(s) shall record at its expenses

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IN WITNESS WHEREOF, the Covenantor(s) have executed this Declaration of Covenants as of this_____day of_____, 20_____.

ATTEST: FOR THE COVENANTOR(S)

_____ _____
(Signature) (Signature)

_____ _____
(Printed Name) (Printed Name and Title)

STATE OF_____ :

COUNTY OF _____ :

On this_____day of_____, 20___, before me, the undersigned officer, a Notary Public in and for the State and County aforesaid, personally appeared _____, who acknowledged himself to be_____, of_____, and he as such authorized to do so, executed the foregoing instrument for the purposes therein contained by signing his name as_____for said_____.

WITNESS my hand and Notarial Seal

My commission expires_____ _____
Notary Public

Seen and approved

_____
(Governing Body)

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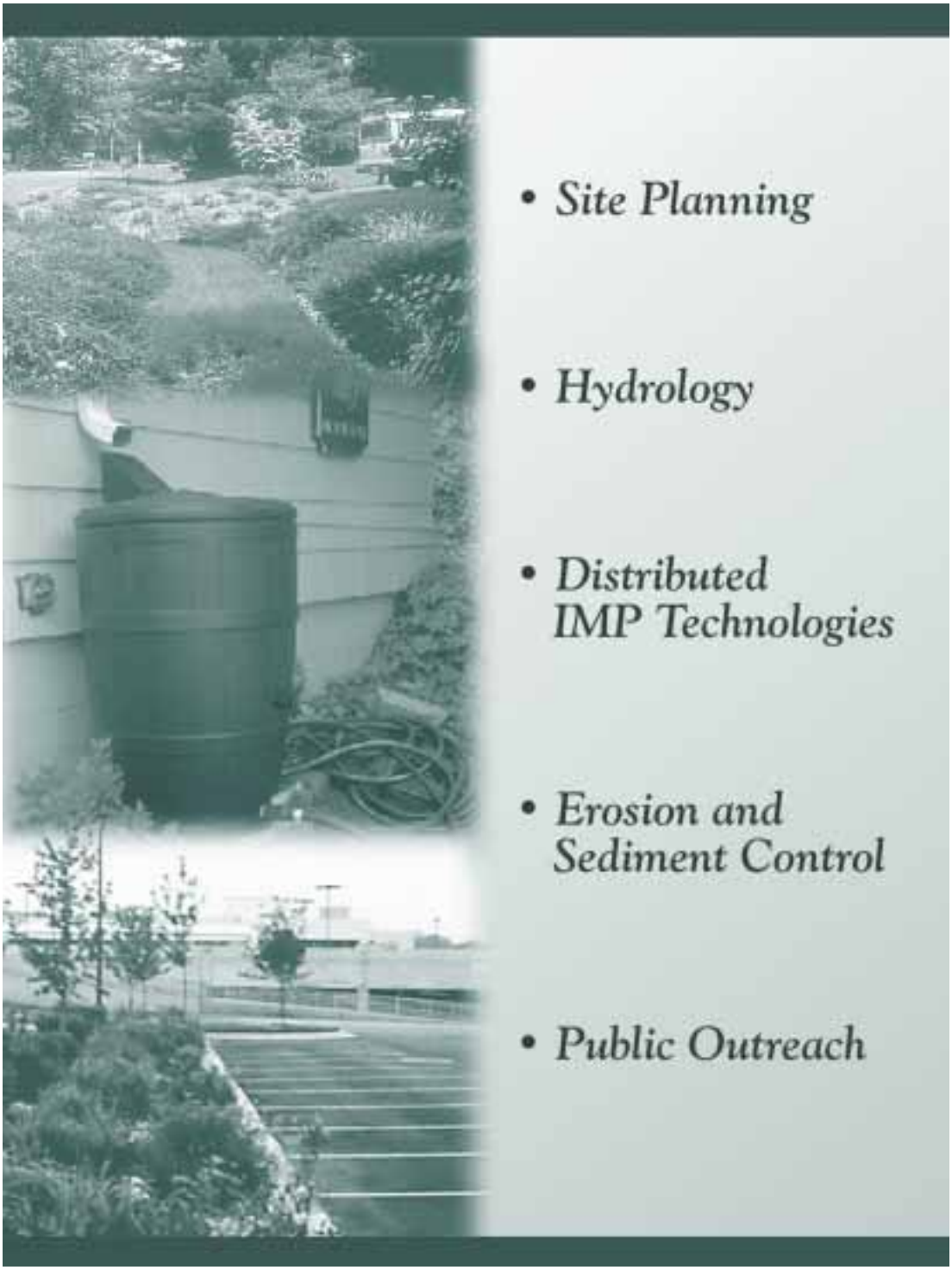
Glossary


• Site Planning
• Hydrology
• Distributed IMP Technologies
• Erosion and Sediment Control
• Public Outreach

Glossary

Bioretention: On-lot retention of stormwater through the use of vegetated depressions engineered to collect, store, and infiltrate runoff.

IMP: Best Management Practice; a practice or combination of practices that are the most effective and practicable (including technological, economic, and institutional considerations) means of controlling point or nonpoint source pollutants at levels compatible with environmental quality goals.

Buffer: A vegetated zone adjacent to a stream, wetland, or shoreline where development is restricted or controlled to minimize the effects of development.

Cluster Development: Buildings concentrated in specific areas to minimize infrastructure and development costs while achieving the allowable density. This approach allows the preservation of natural open space for recreation, common open space, and preservation of environmentally sensitive features.

Curbs: Concrete barriers on the edges of streets used to direct stormwater runoff to an inlet or storm drain and to protect lawns and sidewalks from vehicles.

Design storm: A rainfall event of specific size, intensity, and return frequency (e.g.,. the 1-year storm) that is used to calculate runoff volume and peak discharge rate.

Detention: The temporary storage of stormwater to control discharge rates, allow for infiltration, and improve water quality.

Dry Well: Small excavated trenches filled with stone to control and infiltrate rooftop runoff.

EPA: Environmental Protection Agency.

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Erosion: The process of soil detachment and movement by the forces of water.

Filter Strips: Bands of closely-growing vegetation, usually grass, planted between pollution sources and downstream receiving waterbodies.

Greenway: A linear open space; a corridor composed of natural vegetation. Greenways can be used to create connected networks of open space that include traditional parks and natural areas.

Groundwater: Water stored underground in the pore spaces between soil particles or rock fractures.

Habitat: An area or type of area that supports plant or animal life.

Hydrology: The science dealing with the waters of the earth, their distribution on the surface and underground, and the cycle involving evaporation, precipitation, flow to the seas, etc.

IMP: Intregrated management practice. A LID practice or combination of practices that are the most effective and practicable (including technological, economic, and institutional considerations) means of controlling the predevelopment site hydrology.

Impervious Area: A hard surface area (e.g., parking lot or rooftop) that prevents or retards the entry of water into the soil, thus causing water to run off the surface in greater quantities and at an increased rate of flow.

Imperviousness Overlay Zoning: One form of the overlay zoning process. Environmental aspects of future imperviousness are estimated based on the future zoning build-out conditions. Estimated impacts are compared with watershed protection goals to determine the limit for total impervious surfaces in the watershed. Imperviousness overlay zoning areas are then used to define subdivision layout options that conform to the total imperviousness limit.

Incentive Zoning: Zoning that provides for give-and-take compromise on zoning restrictions, allowing for more flexibility to provide environmental protection. Incentive zoning allows a developer to exceed a zoning ordinance's limitations if the developer agrees to fulfill conditions specified in the ordinance. The developer may be allowed greater lot yields by a specified amount in exchange for providing open spaces within the development.

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Infiltration: The downward movement of water from the land surface into the soil.

Level Spreader: An outlet designed to convert concentrated runoff to sheet flow and disperse it uniformly across a slope to prevent erosion.

Low-Impact Development: The integration of site ecological and environmental goal and requirements into all phases of urban planning and design from the individual residential lot level to the entire watershed.

Nonpoint Source Pollution: Water pollution caused by rainfall or snowmelt moving both over and through the ground and carrying with it a variety of pollutants associated with human land uses. A nonpoint source is any source of water pollution that does not meet the legal definition of point source in section 502(14) of the Federal Clean Water Act.

NPDES: National Pollutant Discharge Elimination System; a regulatory program in the Federal Clean Water Act that prohibits the discharge of pollutants into surface waters of the United States without a permit.

Open Space: Land set aside for public or private use within a development that is not built upon.

Overlay Districts: Zoning districts in which additional regulatory standards are superimposed on existing zoning. Overlay districts provide a method of placing special restrictions in addition to those required by basic zoning ordinances.

Performance Zoning: Establishes minimum criteria to be used when assessing whether a particular project is appropriate for a certain area; ensures that the end result adheres to an acceptable level of performance or compatibility. This type of zoning provides flexibility with the well-defined goals and rules found in conventional zoning.

Permeable: Soil or other material that allows the infiltration or passage of water or other liquids.

Planned Unit Development (PUD) Zoning: Planned unit development provisions allow land to be developed in a manner that does not conform with existing requirements of any of the standard zoning districts. The PUD allows greater flexibility and innovation

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than conventional standards because a planned unit is regulated as one unit instead of each lot being regulated separately.

Rain Barrels: Barrels designed to collect and store rooftop runoff.

Recharge Area: A land area in which surface water infiltrates the soil and reaches the zone of saturation or groundwater table.

Riparian Area: Vegetated ecosystems along a waterbody through which energy, materials, and water pass. Riparian areas characteristically have a high water table and are subject to periodic flooding.

Runoff: Water from rain, melted snow, or irrigation that flows over the land surface.

SCS: U.S. Department of Agriculture Soil Conservation Service; renamed the Natural Resources Conservation Service (NRCS).

Site Fingerprinting: Development approach that places development away from environmentally sensitive areas (wetlands, steep slopes, etc.), future open spaces, tree save areas, future restoration areas, and temporary and permanent vegetative forest buffer zones. Ground disturbance is confined to areas where structures, roads, and rights-of-way will exist after construction is complete.

Subdivision: The process of dividing parcels of land into smaller building units, roads, open spaces, and utilities.

Swale: An open drainage channel designed to detain or infiltrate stormwater runoff.

Urbanization: Changing land use from rural characteristics to urban (city-like) characteristics.

Urban Sprawl: Development patterns, where rural land is converted to urban uses more quickly than needed to house new residents and support new businesses. As a result people become more dependent on automobiles and have to commute farther. Sprawl defines patterns of urban growth that include large acreage of low-density residential development, rigid separation between residential and commercial uses, residential and commercial development in rural areas away from urban centers, minimal support for nonmotorized transportation methods, and a lack of integrated transportation and land use planning.

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USGS: United States Geological Survey, an agency within the Department of the Interior.

Watershed: The topographic boundary within which water drains into a particular river, stream, wetland, or body of water.

Watershed-based Zoning: Zoning that achieves watershed protection goals by creating a watershed development plan, using zoning as the basis (flexible density and subdivision layout specifications), that falls within the range of density and imperviousness allowable for the watershed to prevent environmental impacts. Watershed-based zoning usually employs a mixture of zoning practices.

Wet pond: A stormwater management pond designed to detain urban runoff and always contain water.

Zero-lot-line Development: A development option in which side yard restrictions are reduced and the building abuts a side lot line. Overall unit-lot densities are therefore increased. Zero-lot-line development can result in increased protection of natural resources, as well as reduction in requirements for road and sidewalk.

Zoning: Regulations or requirements that govern the use, placement, spacing, and size of land and buildings within a specific area.

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